KANSAS
River Reservoirs Flood and Sediment
STUDY

Draft Watershed Study Report

October 2023







US Army Corps
of Engineers.
Kansas
Water Office
Kansas
Department of
Wildlife and Parks

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DISCLAIMER: The information presented in this report is to provide a strategic framework of potential options to address problems within the Kansas River Basin watershed. Options identified will follow normal authorization and budgetary processes of the appropriate agencies. Any costs presented in this document are rough order magnitude estimates used for screening purposes only.

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EXECUTIVE SUMMARY

EX.1 Authority

The Kansas River Reservoirs Flood and Sediment Study (watershed study, KRRFSS) is authorized by Resolution of the Senate Committee on Environment and Public Works, Kansas River and Tributaries, May 23, 2006, and Section 729 of the Water Resources Development Act (WRDA) of 1986, as amended (33 U.S.C. § 2267a). Section 729 allows the U.S. Army Corps of Engineers (USACE) to study the water resources needs of river basins and regions of the United States. In carrying out these studies, USACE is authorized to consult with and accept contributions from federal, state, tribal, interstate, and local government entities.

EX.2 Interest

There is a federal interest in conducting a watershed study to investigate strategies to integrate water and related land resource management considerations, seeking sustainable water resource management and making additional considerations. Ultimately, the watershed study will inform multiple stakeholders and decision makers at all levels of government and provide a strategic roadmap toward future investment decisions by multiple agencies. Significant need and opportunities exist in the areas of sediment management, flood risk management, water supply availability and sustainment, and related purposes, such as ecosystem restoration, and recreation.

EX.3 Purpose and Scope

Significant near- and long-term water resource challenges need to be met in the basin. The 18 federal reservoirs operated by USACE and the U.S. Bureau of Reclamation (USBR) and levees in the Kansas River Basin, originally authorized from 1938 to 1962, are now being asked to meet the multipurpose needs and values of today's modern society, including an increasing demand for flood risk management benefits to large and small communities, recreation facilities, and agricultural areas; an increasing demand on water supply; a changing climate; and an increasing societal value on protecting and restoring the ecosystem. The existing system needs reinvestigation to optimize operation and functionality where possible, and to remove, repair, rehabilitate, or upgrade current facilities to reduce risk and improve benefits to society. The system also needs review to account for the demand and need for integrated water resources management to provide flood risk management, water availability and sustainment, and ecosystem restoration benefits.

The scope of the study includes a comprehensive and strategic evaluation of the Kansas River Basin system operating plan, reservoir operations and manuals, reservoir facilities and features, conditions upstream and downstream of reservoirs, infrastructure, and other related needs in the system. This includes a comprehensive existing and future conditions update of flood risk, drought risk and preparedness, ecosystem degradation, water supply availability and sustainment, water quality, and recreation.

The watershed study team investigated water resource issues and opportunities in the basin and are recommending comprehensive, long-term solutions based on a shared

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vision for the basin. Herein, the study makes long-term recommendations for potential involvement by USACE, other federal agencies, and non-federal interests. The watershed study integrates water and related land resource management considerations, seeking sustainable water resource management and making additional considerations. Ultimately, the watershed study informs multiple stakeholders and decision makers at all levels of government and provides a strategic roadmap toward future investment decisions by multiple agencies. Significant need and opportunities exist in the areas of sediment management, flood risk management, water supply availability and sustainment, and related purposes, such as ecosystem restoration, navigation, and recreation. This integrated watershed study focuses attention on significant objectives and tradeoffs, accounts for uncertainty, and promotes adaptive management, stakeholder collaboration, and systems analysis for watershed-scale planning and evaluation.

This report presents current findings and recommendations for future efforts, including potential future projects and studies in which USACE could partner with the State of Kansas (State), sister Federal agencies, and non-federal entities.

This report is not a project implementation document. The level of detail is at a scale adequate to make watershed-level resource assessments and recommendations. If specific projects are identified for potential implementation under existing authorities of USACE (e.g., review of existing projects for sediment management), separate decision documents or interim reports are required to specify project features, include detailed engineering information, and provide appropriate National Environmental Policy Act (NEPA) documentation.

EX.4 Shared Vision Statement

Within the Kansas River Basin, significant water resource challenges exist including increased flood risk, reduced water availability, reservoir sedimentation, water quality concerns, streambank erosion, increased demand for recreational opportunities, and loss of wetlands and riparian habitat. Sustainable measures must be identified and developed to reduce flood risk, improve sediment management, and mitigate drought, and to address additional existing water resource problems within the watershed. Measures include those necessary to increase the resiliency and sustainability of the system, and identification of viable opportunities for investment in critical infrastructure throughout the basin, including existing reservoirs, to increase their resiliency and maintain capacity for water availability and sustainment, ecosystem restoration, water quality, and recreational amenities.

EX.5 Study Collaboration

The watershed study is a collaborative effort between USACE and representatives of the State of Kansas including the Kansas Water Office (KWO) and the Kansas Department of Wildlife and Parks (KDWP). The watershed study incorporates the state's ongoing planning efforts and leverages, as appropriate, state agencies' planning and investigation capabilities where state program efforts become part of the cost share match and state agency capabilities and resources can meet specific scoped elements for the watershed study in a cost-effective and timely manner.

The study process involved broad stakeholder engagement with representation from federal, state, and local agencies, and organizations. This collaboration between partners and stakeholders is a critical aspect of the study and plays a crucial role in shaping the outcomes.

USACE worked in collaboration with federal and state agencies, community/local governments and groups, and stakeholders to develop the watershed study. In accordance with Section 202 of the Water Resources Development Act (WRDA) of 2000 (P.L. 106-541, as amended), cooperation letters were sent to the:

- United States Bureau of Reclamation, Nebraska-Kansas Area Office
- United States Environmental Protection Agency (USEPA), Region 7
- United Stated Fish and Wildlife Service (USFWS) Kansas, Nebraska, and Colorado Field Offices
- United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)
- National Park Service (NPS), Department of Interior Regions 3, 4, and 5
- United States Geological Survey (USGS), Kansas Water Science Center
- United States Department of Commerce
    - National Oceanic and Atmospheric Administration (NOAA), Central Region Climate Services
    - National Weather Service (NWS).

Additionally, coordination letters were sent to:

- Kansas, Nebraska, and Colorado State Historic Preservation Officers
- Kansas Department of Health and Environment (KDHE)
- Nebraska Game and Parks Commission (NGPC)
- Affiliated Tribes.

Partner and stakeholder involvement was a cornerstone for the development of the watershed study, and many participants were invited and encouraged to participate throughout all stages of the planning process and report development. Other agencies and stakeholders participating in various pieces include:

- State Agencies/Organizations: Kansas Water Authority (KWA), Kansas Department of Agriculture (KDA), Kansas Forestry Service, Kansas Department of Emergency Management, Kansas Hazard Mitigation Team (KHMT)
- Community/Local: City of Manhattan, Kansas; City of Lawrence, Kansas; City of Topeka, Kansas; City of Olathe, Kansas; City of Phillipsburg, Kansas; Wilson Lake Association; Kansas Rural Water District Number 1; Kansas Rural Water Association; Kansas Farm Bureau; Smoky Hill Access District; Post Rock Rural Water District
- Other: Kansas State University (KSU), Kansas University, Kansas Watershed Restoration Protection Strategy (WRAPS), Friends of the Kaw, Kansas Alliance for Wetlands and Streams (KAWS), State Association of Kansas Watersheds,

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Water One, Regional Advisory Committees (Kansas, Smoky Hill-Saline, Solomon-Republican), Ducks Unlimited, The Nature Conservancy, Kansas Biological Survey, Bowersock Mills and Power Company, Thunderbird Marina.

Meetings with project partners were held throughout the duration of the watershed study including small group workshops, public meetings, special interest group meetings, and collaboration with Watershed Study Advisory Committee. Appendix I, Agency Coordination and Public Involvement, and Section 1.6, Study Collaboration, provide documentation of study collaboration. Partner meetings were used to achieve the following:

- Determine study scope
- Develop shared vision statement
- Determine and validate problems and opportunities in the Kansas River Basin
- Develop an initial array of measures, strategies, and recommendations
- Refine, validate, and prioritize measures, strategies, and recommendations
- Assess risk associated with focus areas and problems and stressors and evaluate uncertainty related to solutions to address risk
- Seek input from subject matter experts (SMEs)
- Provide opportunities for stakeholder input.

EX.6 Study Area and Background

The basin (study area) occupies almost the entire northern half of Kansas, as well as parts of Nebraska and Colorado and encompasses more than 60,000 square miles (38,400,000 acres) (Figure EX-1). The Kansas River is an important resource for the State of Kansas. There are roughly 640 freshwater stream miles below all major dams, and approximately 100,000 acres of federally-owned freshwater impoundments, including USACE and USBR reservoirs, in the basin.

The Kansas River Basin supplies drinking water to more than 600,000 people and is used for irrigation, municipal wastewater and industrial discharges, power generation, and as a source of commercial sand and gravel. In addition to flood risk reduction benefits from the reservoirs (more than $35B in flood damages prevented by USACE and USBR projects in the basin since construction through 2022), federal levee projects located on the banks of the Kansas River provide flood risk reduction benefits ($1B in flood damages prevented in the basin since construction through 2022), mainly to larger urban areas such as Manhattan, Topeka, and Kansas City, Kansas. Recreation in the basin (boating, kayaking, camping, picnicking, fishing, swimming, hunting, wildlife viewing, etc.) substantially benefits the local, regional, and national economy. Kansas River fish populations provide quality, unique, and diverse fishing opportunities throughout the study area. Decades of sportfish management, monitoring, and research led to fisheries that are highly sought after by anglers, not only locally and statewide, but regionally and nationally too. The Kansas River, its tributaries, and their floodplains consist of terrestrial and aquatic habitats sustaining wide assemblages of fish and wildlife species. These assemblages include species living year-round in waters and on

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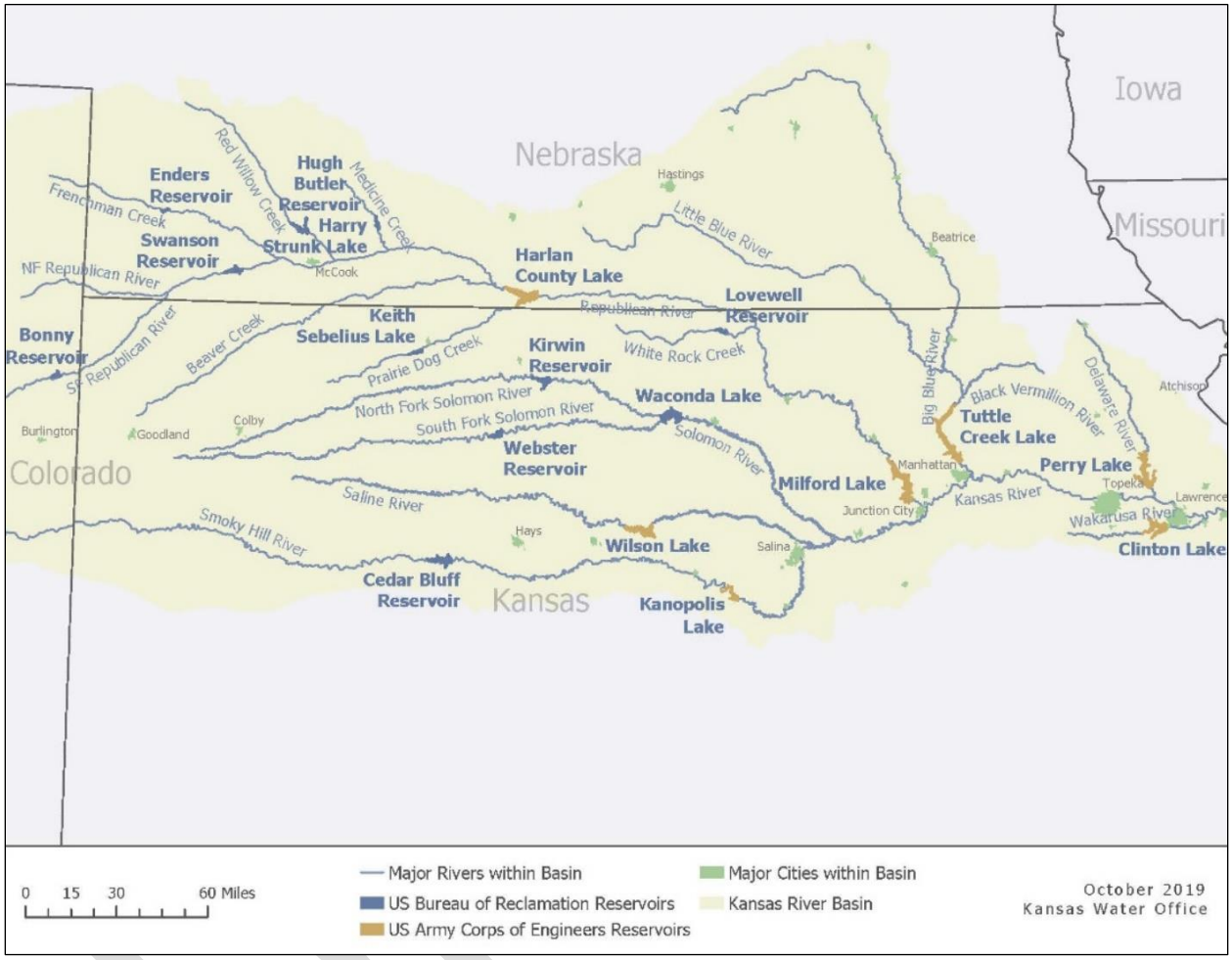
the floodplain and migratory species for which the ecosystem provides vital seasonal habitat (e.g., wintering and breeding), movement corridors, and stopover habitats.

Figure EX-1. Kansas River Basin



Currently, the basin land use is a mixture of agricultural (e.g., cropland and pasture/hay), urban developed areas (high, medium, and low density including Junction City, Manhattan, Topeka, Lawrence, and Kansas City, Kansas), grasslands, forested lands, transportation corridors, and extensive water bodies (lakes, rivers, ponds, and wetlands). The basin is about 85 percent privately owned (USGS 2018). The States of Kansas, Nebraska, and Colorado own 1 percent of the land, the Federal government owns 12 percent of the land, local governments own less than 1 percent of the land, and other entities (e.g., non-governmental agencies) own less than 1 percent of the land (USGS 2018).

The basin includes 18 federal reservoirs, 12 of which reside in the state of Kansas, 5 in Nebraska, and 1 in Colorado (Table EX-1, Table EX-2, Table EX-3). The dams at these reservoirs regulate 85 percent of the drainage area in the basin, and the reservoirs supply flood damage risk reduction to major population centers such as Manhattan, Topeka, Lawrence, and Kansas City along the Kansas River, and flood damage risk reduction and navigation flow support to communities along the Missouri River.

Table EX-1. Republican River Basin Water Management Projects

Water Management Project	Basin or Stream	Operating Agency
Bonny Dam, Colorado	South Fork Republican River	USBR
Trenton Dam (Swanson Lake), Nebraska	Republican River	USBR
Enders Dam, Nebraska	Frenchman Creek	USBR
Red Willow Dam (Hugh Butler Lake), Nebraska	Red Willow Creek	USBR
Medicine Creek Dam (Harry Strunk Lake), Nebraska	Medicine Creek	USBR
Norton Dam (Keith Sebelius Lake), Kansas	Prairie Dog Creek	USBR
Harlan County Dam, Nebraska	Republican River	USACE, Kansas City District
Lovewell Dam, Kansas	White Rock Creek	USBR
Milford Dam, Kansas	Republican River	USACE, Kansas City District

Table EX-2. Smoky Hill River Water Management Projects

Water Management Project	Basin or Stream	Operating Agency
Kanopolis Dam, Kansas	Smoky Hill River	USACE, Kansas City District
Glen Elder Dam (Waconda Lake), Kansas	Solomon River	USBR
Wilson Dam, Kansas	Saline River	USACE, Kansas City District
Cedar Bluff Dam, Kansas	Smoky Hill River	USBR
Webster Dam, Kansas	South Fork Solomon River	USBR
Kirwin Dam, Kansas	North Fork Solomon River	USBR

Table EX-3. Lower Kansas River Water Management Projects

Water Management Project	Basin or Stream	Operating Agency
Clinton Dam, Kansas	Wakarusa River	USACE, Kansas City District
Perry Dam, Kansas	Delaware River	USACE, Kansas City District
Tuttle Creek Dam, Kansas	Big Blue River	USACE, Kansas City District

EX.7 Planning Process

Watershed studies use specific, measurable, attainable, risk-informed, and timely planning principles. Project delivery teams (PDTs) incorporate critical thinking, risk-informed decision-making, and early and frequent team engagement throughout the watershed study process.

The following elements key components of an effective watershed planning process are consistent with the interactive six-step USACE planning process:

1. Identifying problems and opportunities
2. Inventorying and forecasting
3. Identifying and screening measures

4. Formulating an initial array of strategies
5. Refining an initial array of strategies and evaluating a focused array of strategies
6. Comparing strategies and selecting.

The watershed study develops a comprehensive and holistic long-term (50–100 year) plan for identifying and addressing multiple water resource problems within the basin, including flood risk management, stream erosion, sediment loading of reservoirs, reductions of flood storage and water supply availability, water quality issues, and drought. The study process fully defines and describes the problems, needs, and opportunities in the watershed by involving study partners, water resources and related stakeholders, resource agencies, and the public to collect a broad view of problems, needs, and opportunities and reaffirm the purpose of the watershed study. The watershed study builds on previous outreach, communication, and coordination by the KWO and other partnering state agencies during vision development.

EX.7.1 Issues and Opportunities

In the watershed study, identified problems focus on flood risk, sedimentation and erosion, reduction in the ability to meet water supply demands, degraded/poor water quality, ecosystem degradation and species impacts, and loss of recreational opportunities. Most critically, the study effort identifies problems and opportunities reflecting the priorities and preferences of the federal government, the non-federal sponsors, and other participating groups.

Risk conditions currently exist within the study area, with the potential for increased probability of risk event occurrence and associated consequences under future conditions. These risks, identified and evaluated through review of existing documentation, new assessments, and a series of partner and stakeholder engagement meetings, largely fall within three categories: economic, social, and environmental.

The study team, in conjunction with input from partners and stakeholders identified a set of stressors for each problem category. For the purposes of this watershed study, stressors are conditions or events occurring because of the driving problem category. Tables EX-4 through EX-8 outline identified problem statements and associated stressors.

Table EX-4. Flood Risk Problem Statement and Stressors

Flood Risk: Flooding is a reoccurring challenge in the Kansas River Basin that can be costly, both in property loss, and, more significantly, in life loss. Flooding events in the Kansas River Basin cause riverine and overland flooding and high reservoir water levels that threaten life safety, and damages homes, businesses, public facilities, agricultural lands, and critical infrastructure (roads, railroads, utilities). Flooding displaces individuals and businesses, damages cultural resources, increases environmental degradation, and causes public health issues.
Stressors
Riverine Flooding: The entire Kansas River Basin is subject to severe riverine flooding at infrequent intervals erratically interspersed by less severe floods of varying magnitudes. Flooding is a reoccurring challenge in the basin that can be costly, both in property loss and, more significantly, in life loss. Floods in the basin damage millions of dollars of private property and crop land as well as critical infrastructure, such as interstate highways, railroads, and state highways. Flooding displaces individuals, impacts delivery of services, and causes repetitive losses in many areas in the basin. Additionally, floods cause damages and lost revenue at recreational facilities managed by federal and

state agencies, private entities, and non-profit organizations. The most obvious threat to health and safety is the danger of drowning in flood waters. Swiftly flowing flood waters can easily overcome even good swimmers. If flooding occurs suddenly, people may become trapped in their homes and drown. Additionally, when people attempt to drive through flood waters, their vehicles can be swept away in as little as two feet of water.

High Reservoir Water Levels: The lower Kansas River reservoir system (Milford, Tuttle Creek, Perry, and Clinton) operates to provide flood protection for the Kansas and Missouri rivers. High rainfall events leading to extended periods of inflow storage in the reservoirs causes extended periods of elevated pool elevations and adds to the risk of large surcharge releases from these projects. Extensive impacts can occur when high reservoir water levels happen, causing damages and lost revenue at facilities managed by federal and state agencies, private entities, and non-profit organizations. High water levels damage roadways and utility services surrounding the reservoirs. Additionally, agricultural lands in the upper regions of the reservoirs flood during high reservoir water levels, causing damages and loss of revenue to producers on these lands.

Missouri River flood criteria exists for the Kansas City and Waverly gages. Sometimes, elevated Missouri River flows keep the lower Kansas tributary project releases at low-flow levels for weeks or months on end. That extended period of inflow storage causes extended periods of higher pool elevations and adds to the risk of large surcharge releases from these projects.

Climate Change Implications—Increasing Risk to Urban Areas and Agricultural Lands: Climate change in the basin will show increasing temperatures and precipitation, resulting in increased frequency of extreme storm events. These extremes in climate will result in larger, more extensive storms and increases in streamflow in the basin, particularly for the Republican River and the lower Kansas River. Larger flood volumes in the future could cause higher pool elevations at reservoirs and an inability to contain flood events, with more frequent occurrence of surcharge releases and uncontrolled flows.

The hundreds of levees within the basin range in size from small agricultural levees to protect farmland to large urban levees constructed to protect people and property. Damages to levees have occurred during past flood events, causing life safety risks and property damages in the areas where water flowed behind leveed areas. With larger flood events caused by climate change, higher water surface elevations have a greater probability of overtopping and will cause longer loading durations on existing levee systems, increasing the likelihood of levee breach. Due to climate change, experts expect greater flood extents will occur in non-leveed areas, causing more damages to unprotected areas.

Flood Response Communications Issues: To better communicate risks to the public, improved communication, coordination, and planning between flood risk management entities and the public in the basin is needed. This includes improved flood forecasting, flood warning systems, and emergency action plans. Many communities do not have adequate warning and response tools.

Due to climate change, the need for improved communications will increase. The likelihood of more frequent activation of flood forecasting and warning systems and more frequent updates to emergency operations plans will also increase.

Sedimentation in Reservoirs and Downstream Erosion: To realize benefits provided by the reservoirs for flood risk management, in-basin reservoir sedimentation needs addressed. Sedimentation in the reservoirs threatens crucial flood risk management infrastructure. Sediment accumulation impedes maintenance of flood control gates and other appurtenances seriously impacting the flood risk mission of USACE. Without deliberate restorative action, sedimentation issues will increase operation and maintenance costs at reservoirs and in downstream river channels. Historical data and projected estimates indicate that the flood control pools in reservoirs will experience sedimentation, with some filling by as much as 17 percent over the next 100 years and experiencing greater frequency of higher water levels compared to existing conditions.

Channels downstream of most federal reservoirs in the basin experience bed degradation and bank erosion because of the sediment trapping in the reservoirs, with varying degrees of downstream bed and bank loss in different reaches. Degradation will continue, increasing risk to downstream infrastructure and uses. Downstream riverbed degradation can impact the long-term sustainability of flood risk reduction levees.

Table EX-5. Reduction in Ability to Meet Water Supply Demands Problem Statement and Stressors

Reduction in Ability to Meet Water Supply Demands: The water supply system throughout the Kansas River Basin is vulnerable to naturally occurring and anthropogenic stressors including reservoir sedimentation, drought, groundwater depletions, the risk of reduced water supply from navigation releases, and climate change implications. Lack of reliable water supply and shortages of water could have a devastating effect on the economy in the basin and the health and welfare of its citizens.
Stressors
Sedimentation: *Loss of Water-Supply Storage in Federal Reservoirs.* Every year, federal reservoirs lose thousands of acre-feet of water storage, as millions of cubic yards of sediment accumulates. All federal reservoirs in the basin have experienced loss of water supply storage and will continue to lose water supply storage in the future. The most extreme case being Tuttle Creek Reservoir, a vital source of water supply, will have only 25 percent of the multipurpose pool remaining in 50 years. In the future, increased sedimentation in reservoirs may not be able to meet water supply targets downstream for intake or reservoir levels in the multipurpose pools. Water storage may be depleted, causing impacts within the reservoirs to water quality, fisheries, and recreation. Lack of reliable water supply and shortages of water could have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Sediment management on the mainstem of the Kansas River is important for maintaining infrastructure, including water supply intakes, irrigation diversion structures, and for other uses such as recreation and ecological resources. An increase in more extreme flood events due to climate change would lead to an increase in sediment loading in reservoirs already impacted by current inflows of sediment. This will cause loss of additional storage.
Drought: *Societal Consequences and Economic Impacts Associated with Drought Risk*. Periods of drought are normal occurrences in all parts of the basin. Drought can adversely affect surface and groundwater supplies, farming and ranching, and uses of surface water for other purposes, like recreation. Many economic impacts have already occurred in agriculture and related sectors including losses in yields of crop and livestock production, leading to loss of income and increased food costs. Drought can severely impact public water supply through depletion of the raw water availability and increased customer water demand. Other associated problems that may increase water supply costs include limited treatment capacity or limited distribution system capacity. Planning for extreme events, like water conservation management planning that can secure and improve the reliability of water supply, is essential for the future prosperity of Kansas communities and the health of citizens.
Reduced Water Supply from Navigation Releases: Releases for navigation on the Missouri River can be made from Milford, Tuttle Creek, and Perry reservoirs. Currently, approximately 230,000 acre-feet is subject to these releases. If releases are made, the potential reduction in storage at the three reservoirs could lead to inadequate water supply for in-reservoir purposes like recreation and fisheries, and the ability of downstream releases to support water supply, water quality, fish and wildlife, and recreation. These effects are especially significant during drought periods when excessive drawdowns would decrease capability of meeting flow targets and reduce water supply resiliency for multiple communities.
Groundwater Depletion: Groundwater is the predominant public water supply source in many areas within the basin. Groundwater depletions in the basin have led to reductions in available water supply. Groundwater in the basin, primarily from the High Plains Aquifer, provides domestic, municipal, industrial, and agricultural purposes. In western Kansas, the primary source of water is groundwater drawn from wells that reach into the water-bearing aquifers, such as the Ogallala portion. Alluvial aquifers also supply water to many citizens in the basin where, in many parts, it is the only source of drinkable water for public water suppliers and individual domestic wells. Alluvial aquifers are recharged by flow in associated rivers and streams. Groundwater irrigation for crop production and land practices, particularly in western Kansas, caused groundwater depletion leading to the loss of base stream flows. In recent years, drought affected certain communities and regions of the basin on a recurring basis. With a recent drought event (2012–2013), there was a significant reduction in baseflow gain as irrigation demands increased, requiring significant sustained releases from federal reservoirs to

maintain low-flow targets and ensure adequate supply to downstream municipal and industrial diversion points. With climate change, this may affect more regions of the state more often.
Climate Change Implications: Lack of reliable water supply and shortages of water could have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Every industry from agriculture, electric power generation, and manufacturing to tourism relies on water to grow and sustain business. Under climate change there would be an increase in the occurrence of drought periods with longer more severe droughts expected. This will cause lower inflows in reservoirs and potentially a lack of water available to support reservoir releases and withdrawals, causing inadequate water supply for users in the basin.

Table EX-6. Degraded and Poor Water Quality Problem Statement and Stressors

Degraded and Poor Water Quality: Water quality throughout the Kansas River Basin is vulnerable to naturally occurring and anthropogenic stressors including harmful algal blooms (HABs), impaired waters, risk to high quality water, stormwater management, and sedimentation. There is a risk, with loss of reservoir storage and future water shortages, of a reduced ability to meet water quality needs within the basin during times of extended drought and to maintain a base level of streamflow. Currently 17 of the 18 federal reservoirs in the basin are considered as impaired and, with expected sedimentation in reservoirs, there could be a reduction in their ability to provide current benefits of chemical buffering
Stressors
Harmful Algal Blooms: HABs continue to plague the region, with many reservoirs experiencing blooms. If conditions lead to a decrease in reservoir volumes and streamflow during drought or low inflow periods, this could lead to an increase in nutrient concentrations and an increased frequency and intensity of HABs.
Impaired Waters: Negative impacts from degrading and poor water quality conditions can increase costs to treat water for public water supply needs, decrease yields for agricultural producers, decrease recreational opportunities, increase fish consumption advisories, and diminish biological diversity in streams and reservoirs.
Water Shortages (Causing Reduced Availability of High-Water Quality for Residential, Commercial, Industrial, and Recreation Uses): Water quality storage maintains minimum flow targets on the Kansas River downstream of the reservoirs. As water quality conditions degrade in reservoirs use of water from that source, as well as uses downstream, negatively impacts water quality conditions. A decrease in water volumes in reservoirs and streams could lead to increased nutrient concentrations with an increase in water quality degradation. Lower reservoir storage volumes would decrease the ability to maintain water quality reservoir releases.
Inadequate Stormwater Management: Absence of appropriate stormwater management in some areas contributes to degradation in water quality and supply. Pollutants from housing and urban areas, industrial sources, and agricultural activities can end up in water sources, changing water chemistry and thereby impacting aquatic vegetation, invertebrate communities, amphibians, and fish. Pollution can be from direct and indirect sources, which can make it difficult to identify, quantify, and remediate.
Sedimentation: Water quality storage maintains minimum flow targets on the Kansas River downstream of the reservoirs. As accumulation of sediment reduces storage capacity of reservoirs, water quality problems intensify as reservoir temperatures increase. Currently, only Tuttle Creek Reservoir has a portion of the multipurpose pool allocated for water quality. This water quality allocation is too small to support low-flow targets on the lower Kansas River through a drought. Milford and Perry reservoirs' water supply storage volumes provide water quality releases to support minimum flow criteria on the Kansas River. With current sedimentation at Tuttle Creek Reservoir, the water quality allocation will be further reduced, and less water will be available to support downstream uses. Additionally, in the future, the remaining water supply storage may be used for water supply further reducing the availability of water for water quality purposes.

Table EX-7. Ecosystem Degradation and Species Impact Problem Statement and Stressors

Ecosystem Degradation and Species Impact: Change, loss, and fragmentation of terrestrial and aquatic habitats in the basin led to habitat degradation, loss of heterogeneity, and loss of connectivity of these habitats, leading to declines in species populations in the Kansas River Basin. Invasive and non-native species caused declines in native species and degradation of terrestrial and aquatic habitat.
Stressors
Loss of Riverine and Floodplain Habitat Leading to Species Declines: Historically, there has been a substantial loss and fragmentation of terrestrial and aquatic habitats in the basin from agricultural conversion, urban development, and construction of dams and levees. This led to a reduction in native plant and animal populations. Dams and the use and management of water in the basin replaced stream and floodplain habitats which affects the timing and volume of downstream flows, as well as timing the volume of water within the reservoirs, affecting fish and wildlife and their habitats. Many streams in the basin experience areas of streambank erosion and head-cuts. Excessive erosion caused stream reaches to become incised, reducing floodplain connectivity and the quality and quantity of riparian habitat. Currently five federally-threatened and seven federally-endangered species inhabit the basin. Designated critical habitats are in a variety of locations in the basin, including the Kansas River and other streams in the watershed affected by reservoir management. Numerous state-listed species also live in the basin. Many of the listed species rely upon surface waters associated with basin streams and impoundments, adjacent riparian habitats, or wetlands for some portion of their life cycles. Sediment trapped behind reservoirs reduced the turbidity in downstream reaches, causing a reduction in species that were present in more turbid environments pre-impoundment. Lack of floodplain connectivity in river reaches below reservoirs led to loss of habitat and species that once thrived in these areas. Streambank erosion is a significant cause of reservoir sedimentation in the basin. Agricultural development and activity and urban development in the watersheds above the reservoirs led to streambank erosion that contributes to sedimentation. Numerous head-cuts also occurred within in the basin on various streams above and below reservoirs, leading to loss of habitat. Sedimentation in reservoirs led to loss or changes of habitat for species and reductions in species requiring certain habitats for their life history needs, like cove habitats. As sedimentation continues under extreme conditions, as in Tuttle Creek Reservoir, the majority of the reservoir fisheries will disappear due to the highly reduced lake volumes and only areas of shallow water remaining. There are also barriers to aquatic species movement in rivers and streams in the basin, which fragment populations, prevent individuals from moving up and down river systems, and cut off movement during droughts. Under climate change and during times of increased drought frequency, streamflow and reservoir levels are expected to decrease. This will lead to a decrease in suitable habitat for aquatic species and a decline of species. Drought conditions caused damages to plant and animal species, wildlife habitat, degradation of landscape quality, loss of biodiversity, and soil erosion. A drought period can last for months, years, or decades. The cost of drought locally and nationally is high, and, with climate change, the economic Impacts could dramatically increase in the future.
Invasive and Non-native Species: Invasive and non-native species can degrade and impact natural ecosystem functions. Invasive species impact riparian areas by reducing streamflow, outcompeting native species, creating monocultural stands with little diversity, and reducing habitat richness that fish and wildlife species require. Aquatic nuisance species (ANS) in the basin threaten the diversity and abundance of native species, the ecological stability of infested waters, and recreational activities dependent on such waters. Several ANS have been introduced and dispersed in the basin. These species have few natural controls and spread rapidly, causing alterations to food webs, nutrient dynamics, and biodiversity. Invasive, non-indigenous plant species infest multiple impoundments within the basin. These species are known to reduce or clog water intakes, reduce property values, cause declines in native species, decrease spawning habitat, and reduce useable recreational areas on reservoirs. Currently, there is not enough funding or capacity of resources to manage, monitor, and enforce best management practices, like watercraft decontamination and inspection stations, to prevent the spread of invasive species such as zebra mussels. Under climate change, conditions could lead to changes in habitat and a potential for the increased

spread of invasive species.
Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains: Seasonal patterns of high and low river flows support animal and plant lifecycles, preserve water quality, and maintain diverse habitats. Dams and the use and management of water in the basin replaced stream and floodplain habitats and affect the timing and volume of downstream flows, as well as timing the volume of water within the reservoirs, which affects fish and wildlife and their habitats.
Loss of Reservoir Fisheries Habitat Leading to Declines: Maintaining habitat for fish is important for reservoir sport fishery. Sedimentation in reservoirs impacts fish populations. As shorelines erode, habitats such as coves, spawning habitats, and nursery habitats become inaccessible and cause the loss of fish habitat structure and vegetation. High-water events also impact the fisheries, with flooding of habitat leading to reduced aquatic vegetation and entrainment of fish through the dam during high water releases. Low water conditions in reservoirs often leave areas dewatered for long periods of time and reduce primary productivity needed by the fisheries, thereby reducing habitat quality and diversity, limiting fish species abundance and welfare.
Groundwater Depletion: In western Kansas, the primary source of water is groundwater drawn from wells that reach into the water bearing aquifers. Many domestic, municipal, industrial, and agricultural purposes use groundwater. Groundwater depletion led to loss of base stream flows, particularly in western Kansas, from groundwater irrigation for crop production and land practices.

Table EX-8. Loss of Recreation Opportunities Problem Statement and Stressors

Loss of Recreation Opportunities: Flooding, low water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species threaten water-based recreational opportunities. These impacts cause a loss of visitation leading to lost revenue and high costs to repair damages to recreation facilities. Public lands providing recreation opportunities are rare in Kansas, with privately-owned lands accounting for most of the recreational opportunities. State-owned-and-controlled lands for recreation account for only 0.7 percent of the lands in the State of Kansas. Protection of federal and state public lands for recreation is imperative due to their scarcity. These lands must be managed in a way that promotes sufficient recreational opportunities to meet the needs of residents and visitors.
Stressors
Limited Public Lands: Currently, only a small amount of land is publicly owned and used for recreation (0.7 percent), limiting the opportunities to expand or replace any lost facilities when they are damaged from sedimentation or flood waters. Protection of federal and state public lands for recreation is imperative due to their scarcity. These lands must be managed in a way that promotes sufficient recreational opportunities to meet the needs of residents and visitors.
Reservoir Sedimentation: To realize benefits provided by the reservoirs for recreation and fish and wildlife, sedimentation in reservoirs within the basin needs to be addressed. Sedimentation in reservoirs causes parks and private recreation facilities to close. Boating safety is also a concern with sedimentation. As sedimentation continues, these impacts will increase, and recreational opportunities will decrease in the basin.
Water Quality HABs: HABs can impact use of recreation areas in reservoirs, closing swim beaches, reducing boating activities, decreasing visitation, and causing lost revenue. HABs also cause health and safety concerns for those exposed causing illness and even death. The causes and treatment of HABs need further study and research.
Increased Operational Costs and Lost Revenues from Flooding and Drought: Floods cause damages to recreational infrastructure and facilities, increase operating costs, require closures, and create lost revenue at recreational facilities managed by federal and state agencies, private entities, and non-profit organizations. There are limited opportunities to expand or replace lost facilities due to the very small portion of publicly-owned land in the basin. Droughts also cause impacts to recreation by reducing access to areas like coves and reducing the use of infrastructure like boat ramps. Droughts reduce fishing opportunities, cause hazards for boaters, impact beaches, expose shorelines, increase erosion

potential, and reduce the aesthetic value of the reservoirs. During drought conditions, lakes with substantial sediment depositions—Tuttle Creek, Perry, and Kanopolis—are shallower, exacerbating adverse effects to lake access, boater safety, fish habitat, and recreation.

Both drought and flooding adversely affect riverine recreational opportunities on the lower Kansas River, from either decreased streamflow or water levels that are too high to allow safe recreational activities. During drought conditions, when flows are low, water quality impacts cause unpleasant odors, impacting the recreation experience for boaters and paddlers. Flooding and high river flows cause unsafe conditions for people on the Kansas River and limit access for various activities including riverine access points, angling, hunting, and camping.

EX.7.2 Goals and Objectives

Planning goals include:

- Reduce the risk to public safety from flooding in the basin
- Reduce the risk of damages from flooding to residential, agricultural, commercial/industrial areas, utilities, and to roads and other critical infrastructure
- Reduce the risk of damages from drought/low water levels
- Extend the useful life of Kansas reservoirs, with focus on those reservoirs most impacted by sediment and nutrient loading, and those that provide drought critical water supply
- Improve and protect the Kansas River ecosystem.

Using an integrated approach, the watershed study evaluates system functions from water supply to flood risk management to ecosystem restoration and protection and climate change adaptation. The specific goal of this study is to assist in developing a comprehensive basin-wide management plan that will:

- Incorporate public input and involvement
- Assess existing and future watershed characteristics and conditions
- Identify watershed issues and concerns
- Develop, evaluate, and prioritize conceptual plans including both structural and non-structural measures, in support of identified goals and objectives
- Identify potential “spin-off” and “off-shoot” projects that may fall under appropriate Federal, State, and/or local authorities
- Identify potential regional or locally funded projects.

The primary objective of the watershed study is to develop a comprehensive plan to support the shared vision to identify actions within the Kansas River Watershed necessary to address significant water resource challenges.

Planning objectives for the study include those for the near-term (i.e., the next 10 years) and those for the long-term (greater than 10 years) and cover the planning timeframes of 25, 50, and 100 years (considered under FWOP scenarios) and include:

- Reduce risks to life safety in the Kansas River Watershed with a focus on improved flood risk system flexibility under a variety of climate change and land use development patterns

- Reduce both societal consequences and economic damages associated with flood risk in the study area, with an emphasis on improving system resiliency and increasing the long-term integrity of the flood system
- Increase the reliability, quality, and availability of water in the basin
- Reduce both societal consequences and economic impacts associated with drought risk in the study area, with an emphasis on improving system resiliency and increasing the long-term integrity of water availability
- Address adverse effects of sedimentation in the watershed including at existing reservoirs and in river reaches
- Identify watershed practices to address existing water resource problems within the watershed and increase the resiliency and sustainability of the system implemented by local, regional, state, or federal entities
- Protect critical water resource infrastructure and investments (e.g., reservoirs, lakes, levees, public water supply infrastructure)
- Protect and improve biological resources
- Protect, promote, and expand recreational opportunities and amenities
- Increase the adaptability and resiliency of the water supply, flood risk management, and ecological systems of the Kansas River Watershed in relation to climate change, including planning for extreme events (i.e., flooding and drought).

EX.7.3 Existing Conditions and Future Without Project

The study includes an inventory of baseline or existing conditions for each of the resource topics and forecasts future conditions. Understanding the existing conditions, and the stressors related to them, is critical to identification of measures and strategies to formulate recommendations to reduce risks and increase resiliency. Resource topics were also included if watershed strategies and recommendations would adversely or beneficially affect the conditions. Sufficient descriptions were developed to document existing and future without project (FWOP) conditions.

The FWOP is the most likely condition expected to occur in the future in the absence of proposed actions included in the watershed study. Where possible, forecasting and modeling over 25-year, 50-year, and 100-year time periods were conducted and used to describe the FWOP. The FWOP defines the benchmark against which the risk assessment was conducted, and strategies and recommendations were evaluated.

The evaluation includes identification of data, models, and tools needed to evaluate and forecast the effects of possible management strategies or recommendations for the FWOP. At the very least, a qualitative description of the FWOP was provided, given the current conditions, trends, and possible factors that could affect the resources. Focus areas and resource topics considered in the existing conditions and FWOP include:

- Climate and Precipitation
- Reservoirs and River Infrastructure, Operations, Hydrology/Hydraulics, and Flood Risk

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- Reservoir Sedimentation
- Watershed Geology, Soils, Upstream Sediment, and Kansas River Geomorphology
- Water Supply
- Recreation
- Water Quality
- Environmental Justice
- Land Use
- Biological Resources
- Cultural Resources.

EX.7.4 Risk Assessment and Uncertainty Evaluation

In collaboration with partners and stakeholders, this study qualitatively assessed stressors on risks relating to economic damage, social vulnerability, and environmental degradation. The risk assessment accounted for both probability or likelihood and consequence of the stressor's contributions to risk indices. Risk ratings were evaluated based on current circumstances and included flexibility for risks expected to worsen with exacerbated environmental stressors like climate change, population growth, and reservoir sedimentation. Three risk metrics—economic, social, and environmental—were evaluated based on the criteria in Sections 4.2.1 through 4.2.3. This aligns with benefit categories defined in the USACE Policy Memorandum, "Policy Directive–Comprehensive Documentation of Benefits in Decision Documents", dated January 5, 2021, which calls for, "equal consideration of economic, environmental, and social categories." The principles of this policy directive were applied to inform the risk-based prioritization of identified problems.

A series of six scoping charettes and numerous special interest group meetings were held with partners and stakeholders to gain input and understanding of the problem categories, prioritize areas of risk, and develop an array of recommendations. The qualitative risk assessment, conducted in collaboration with partners and stakeholders, identified the risk metrics for the detailed problem/stressor economic, social, and environmental categories.

Section 4, Risk Assessment and Uncertainty Evaluation, summarizes the risk assessment results. Economic, social, and environmental risks received equal consideration; therefore, the problems and stressors ranked as the highest relative risk from any metric were categorized as high. Moderate or low problems and stressors are those for which no relative risk ranking fell among the highest risks. The categories help prioritize strategy implementation that USACE and partners agree are imminent. While still important to address, any risk considered lower risk and not a near-term priority (one to ten years), fell below the thresholds of likely to occur and high impact.

The risk assessment used smaller geographic areas within the study area. The geographic areas used include the regional planning areas (RPAs) in the state of Kansas. Five RPAs occur within the Kansas River Basin. East to west and north to south, these include the Kansas RPA, Solomon-Republican RPA, Smoky Hill-Saline

RPA, Upper Republican RPA, and the Upper Smoky Hill RPA. A Regional Advisory Committee (RAC) made up of groups of local stakeholders representing the varied local water-related issues represents each RPA. The RACs identify and prioritize goals to address water needs in their respective areas and develop regional action plans to meet those goals. One geographic area represented the Upper Republican and the Upper Smoky Hill RPAs for the risk assessment, as they are highly similar in the risks identified.

In addition to risk, a qualitative assessment of uncertainty was performed to identify the level of consensus among stakeholders to implement potential risk reduction measures for each problem or stressor. The uncertainty assessment evaluated how much is known about the problem, stressors, and potential solutions. The results of the uncertainty assessment were used to determine the most suitable types of recommendations. If a solution exists and is supported by stakeholders with strong consensus, the recommendations were classified as actions. If potential solutions were identified but did not have a strong consensus or more data was needed to create potential solutions, the recommendations were classified as evaluate options or fill data gaps. The following categories of consensus were developed to frame risk reduction recommendations and actions and to evaluate and fill data gaps.

- Action—Implementable solutions with a high level of consensus to address the risks resulting from a given stressor.
- Evaluate Options/Fill Data Gaps—Potential solutions are defined with existing information (evaluate options) or additional data is required to better define the extent and consequence of the problem and or identify potential solutions (fill data gaps).

This qualitative uncertainty assessment was conducted through a review of existing information and with input from partners and stakeholders through a series of collaborative workshops and was based on research and knowledge of possible solutions. Similar to the risk assessment the uncertainty evaluation was conducted for each RPA. Risk and uncertainty results were used to develop a framework for the appropriate types (uncertainty based) and timing for (risk based) recommendations. For problems or stressors categorized with a high level of risk (high probability and high consequence), immediate or near-term steps should be taken to reduce risks through direct actions or evaluation of potential options for reducing risks, or filling data gaps. Immediate or near-term was defined as the next one to ten years. Immediate actions were identified to reduce high risks for which implementable solutions were identified with a high level of consensus among agencies and stakeholders. Immediate evaluations or fill data gaps were identified to reduce high risks where a strong consensus does not occur or more data is needed. For problems or stressors categorized as moderate or low, incremental, or long-term steps should be taken (or continued) to reduce these risks or may be considered lower priorities that do not require immediate steps. Incremental or long-term was defined as ten years or longer. Incremental actions were identified to reduce major risks with similar uncertainty. Incremental evaluations or fill data gaps were identified to reduce moderate to low risks where a strong consensus does not occur or more data is needed. The risk and uncertainty analyses framed recommendations and helped prioritize actions for near-

term verses long-term. The results from the risk and uncertainty analyses placed the stressors into these broad recommendation categories. The results of the risk and uncertainty analyses were used to develop summaries for each assessed RPA (Figures EX-2 through EX-5).

EX.8 Recommendations and Implementation Strategy

Recommendations were developed based on risk and uncertainty prioritization frameworks to help achieve a shared vision. The risk and uncertainty analyses framed the recommendations and helped prioritize actions for the near- verses long-term. The results from the risk and uncertainty analyses placed the stressors into these broad recommendation categories.

To reduce potential high risks for which implementable solutions were identified, immediate (near-term) actions were identified and consensus among agencies and stakeholders was achieved. To reduce moderate to low risks with temporary impacts or consequence. incremental (long-term) actions were identified. For problems or stressors categorized as moderate or low, incremental, or long-term steps should be taken to reduce the risks. Risks that do not require immediate steps are considered a lower priority. Immediate or near-term is defined as needing attention within the next one to ten years while incremental or long-term is defined as ten years or longer. Options for immediate evaluations were identified for high risks where sufficient data and information exists to define potential solutions. Options for incremental steps toward evaluation were identified to reduce the moderate to low risks. Data gaps that should be addressed in the near-term were identified for potentially high risks, where warranted; incremental steps to fill-data gaps were identified for moderate to low risks. The risk and uncertainty assessment recommendations are appropriate for the known level of risk, existing knowledge, and resources. Recommendations follow the broad outline set forth from the risk and uncertainty results.

The recommendations were developed by combining management measures (Section 5, Recommendations and Implementation Strategy) through partner input, USACE expertise, and recommendations from existing reports and project requests. Management measures are the building blocks for recommendations. There are many ongoing efforts undertaken by partners, stakeholders, and USACE to address problems across the Kansas River Basin. An array of planning measures to address problems and achieve planning objectives were developed using on-going and forecasted efforts (found in reports or identified during study workshops) and by gathering additional input from stakeholders and SMEs on the team.

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Figure EX-2. Kansas Regional Planning Area Risk and Uncertainty Summary

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

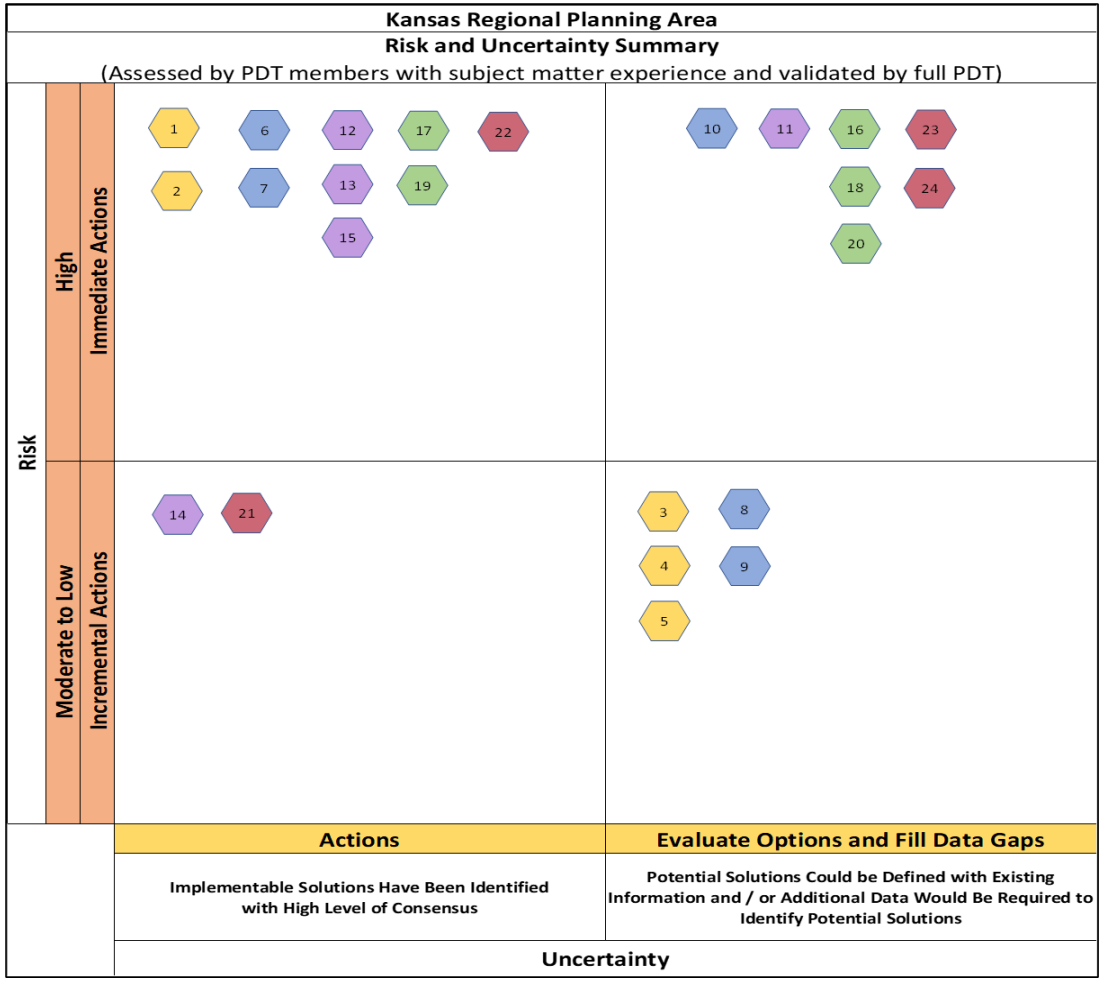


Figure EX-2. Solomon-Republican Regional Planning Area Risk and Uncertainty Summary

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



Figure EX-3. Smoky Hill-Saline Regional Planning Area Risk and Uncertainty Summary

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

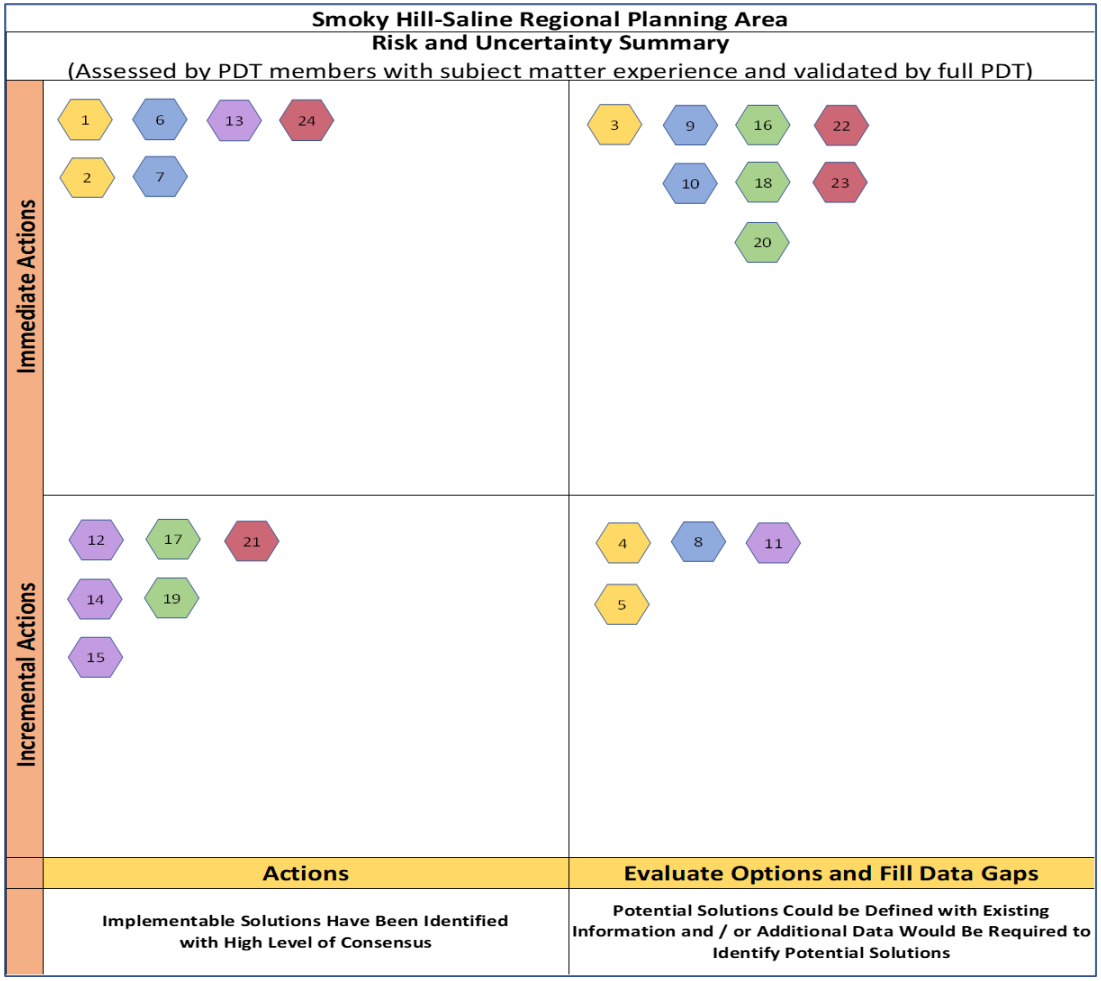
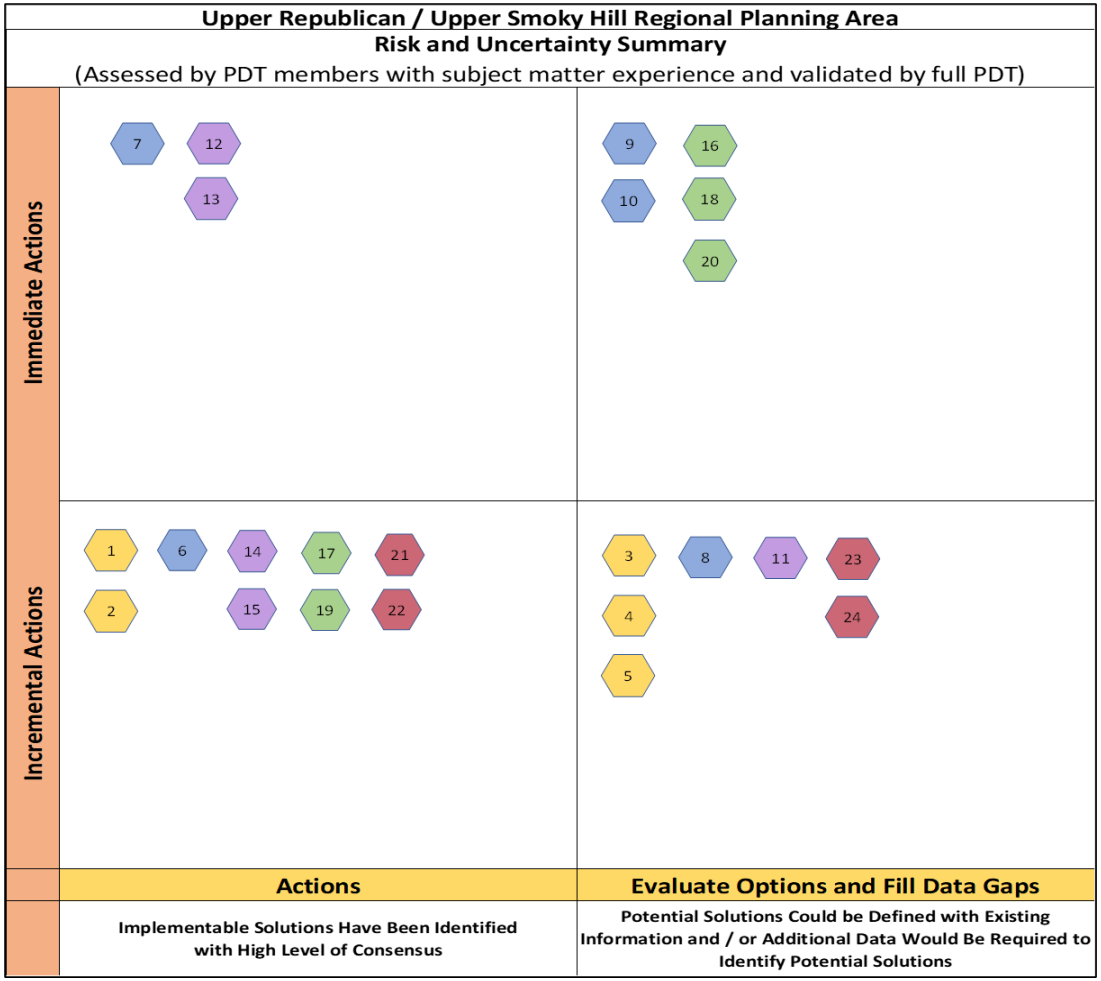


Figure EX-4. Upper Republican/Upper Smoky Hill Regional Planning Areas Risk and Uncertainty Summary

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



Measures contributing to identified planning objectives were retained and compiled into recommendations. ***No measures were screened from further consideration, as all identified measures contributed to the identified planning objectives.*** Recommendations were developed through risk assessment, uncertainty of problem categories, and addressing the most critical needs. Although not all measures are used in recommendations, the comprehensive list of measures is retained for future consideration by interested agencies.

After the measures were screened, they were grouped into strategy types and recommendations. Using the list of measures, the study partners (USACE, KWO, and KDWP) formulated strategies to address identified issues and opportunities, emphasizing the alignment of actions of federal, state, interstate, and local government entities, and expected outcomes resulting from the combination of measures. Strategies and recommendations were developed in the context of options or choices and their projected outcomes and were developed based upon reputable and readily available science and technical analyses. A range of strategies and recommendations were formulated for each focus area (flood risk management, ecosystem restoration and management, water availability and sustainment, water quality, and recreation). Figure EX-6 shows the broad types of strategies and recommendations the team and partners evaluated as part of this watershed study.

Figure EX-5. Types of Recommendations

Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded / Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
Operational Measures / Dams and Reservoir Upgrades	Operational Measures	Nutrient and Sediment Reduction	Reservoir Habitat Improvements	Reservoir Recreation
Levee Upgrades	Resiliency Planning	Water Management	Off Channel / Watershed Improvements	Riverine Recreation
Flow Improvements	Sediment Reduction	Harmful Algal Blooms	Invasive Species Management	Other Recreation Needs
Floodplain Improvements	Sediment Removal		Research / Monitoring / Surveys / Stocking	
Non-Structural Measures	New Water Storage			

In the recommendations milestone phase of the study, and in consultation with the watershed study partners and experts, the strategies and recommendations were evaluated and further refined in terms of meeting the identified problems, while focusing on the collective values, missions, and shared vision. There may be several ways to address the needs within a watershed, so a structured assessment of the pros and cons of each strategy or alternative was used to inform a trade-off analysis.

The strategies and recommendations describe the overall benefits toward advancing the shared vision. The document provides a general assessment of rough order of

magnitude costs, sequencing, priority of actionable items, and associated needs. The primary responsible federal and non-federal partners and their associated missions, authorities, programs, and sources for potential future appropriations were also identified to inform a strategic roadmap that guiding implementation and providing measurable value to the nation. The four principles and guideline evaluation criteria were used to evaluate strategies or recommendations.

EX.8.1 Immediate Actions

Immediate and near-term actions address stressors with high risk and low implementation uncertainty. These should be pursued as soon as possible and within ten years. Immediate actions may require some level of analysis to appropriately implement the measure in the basin. Figure EX-7 shows immediate actions for reducing risks related to floods, decreasing reduction in the ability to meet water supply demands, preventing degraded and poor water quality, improving degraded ecosystems, and reducing species declines.

Tables EX-9 through EX-12 include immediate (near-term) actions shown as flood risk, reduced ability to meet water supply demands, degraded and poor water quality, and ecosystem degradation and species impacts recommendations.

Table EX-9. Flood Risk Recommendations-Immediate Actions

Focus	Recommendation	Potential Partners and Funding
Lower Kansas River Basin Master Manual and/or Individual Reservoir Project WCM Update	Initiate spin-off studies to update the Lower Kansas River Basin Master Manual or individual reservoir project WCMs within the Kansas River Basin for Tuttle Creek, Perry, Clinton, and Milford.	Estimated Cost: $–$$ Potential Funding: USACE WCM Updates Other Potential Partners/Stakeholders: USACE, KWO, KDWP, KDA, KDHE NDNR, NGPC, USBR Priority Area(s): USACE Reservoirs
Flood Risk Feasibility Studies	Support existing proposals and new requests for flood risk management projects.	Estimated Cost: $$ Potential Funding: USACE, City of Topeka, Kansas Other Potential Partners/Stakeholders: USACE, City of Topeka, Kansas Priority Area(s): Shungununga Creek, Topeka, Lawrence, Junction City, Manhattan, Shawnee, Edwardsville, and Muncie, Kansas

Figure EX-6. Basin-wide Immediate Actions

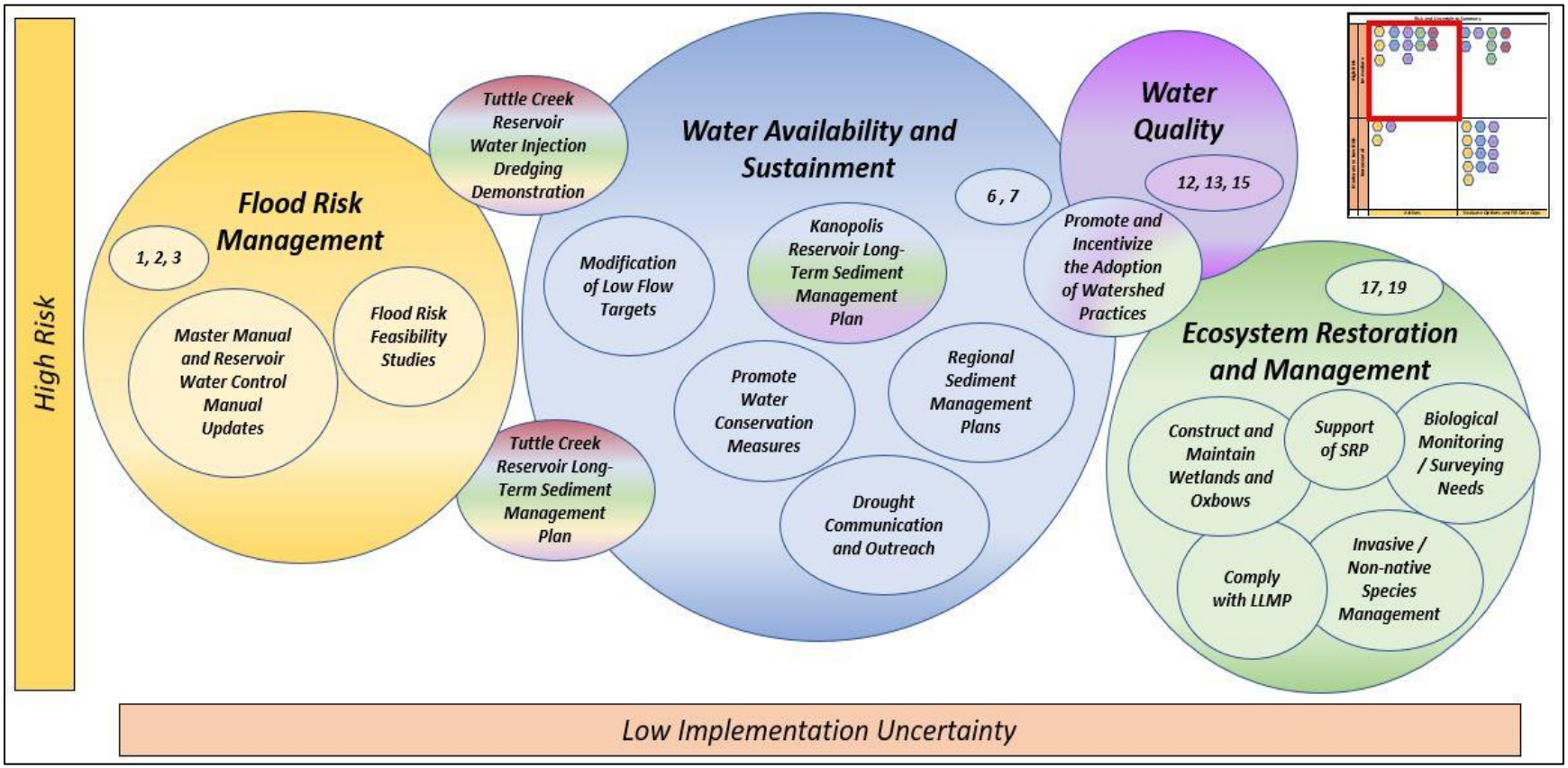


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Table EX-10. Reduction in Ability to Meet Water Supply Demands Recommendations-Immediate Actions (sheet 1 of 2)

Focus	Recommendation	Potential Partners and Funding
Modification of Low Flow Target Values to Extend Periods of Low Flow Support	Initiate spin-off studies to update the Lower Kansas River Basin Master Manual or individual reservoir project WCMs within the Kansas River Basin (Tuttle Creek, Perry, Clinton, and Milford) Include modification of the low flow target values to extend the period of low flow support during extended drought periods.	Estimated Cost: $–$$ Potential Funding: USACE WCM Updates Other Potential Partners/Stakeholders: USACE, KWO, KDWP, KDA, KDHE NDNR, NGPC, USBR Priority Area(s): USACE Reservoirs
Tuttle Creek Water Injection Dredging Demonstration	Initiate a spin-off study to perform a WID Demonstration at Tuttle Creek Reservoir to assess the effectiveness of WID technology at a range of downstream discharges, pool elevations, and in-reservoir locations for potential long-term implementation. Monitor and evaluate both operational effectiveness and environmental results.	Estimated Cost: $$ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: USACE. KWO Priority Area(s): Tuttle Creek Reservoir
Tuttle Creek Reservoir Long-Term Sediment Management Plan	Initiate a spin-off study to investigate sediment management alternatives for the perpetual sustainment of Tuttle Creek Reservoir's authorized purposes and benefits. Lessen negative impacts on the upstream and downstream reaches. Include analysis of technologies to create a long-term recommended plan that supports sustainability of reservoir storage.	Estimated Cost: $$ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: KDWP, KDHE Priority Area(s): Tuttle Creek Reservoir, Lower Big Blue HUC 8 watershed
Kanopolis Dam Reservoir Long-Term Sediment Management Plan	Initiate a spin-off study to investigate sediment management alternatives for the perpetual sustainment of Kanopolis Dam reservoir's authorized purposes and benefits. Lessen negative impacts on the upstream and downstream reaches. Include analysis of technologies to create a long-term recommended plan that supports sustainability of reservoir storage.	Estimated Cost: $$ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: KDWP, KDHE Priority Area(s): Kanopolis Dam reservoir, Middle Smoky Hill HUC 8 watershed
Regional Sediment Management Plans	Conduct a USACE PAS Study to prepare sediment management plans for multiple watersheds in the basin.	Estimated Cost: $ Potential Funding: USACE PAS, USACE R&D, USACE RSM, KWO Other Potential Partners/Stakeholders: WRAPS, Watershed Districts, Conservation Districts Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds

Table EX-11. Reduction in Ability to Meet Water Supply Demands Recommendations-Immediate Actions (sheet 2 of 2)

Focus	Recommendation	Potential Partners and Funding
Promote Water Conservation Measures	The State of Kansas currently has Water Conservation Plans for each RWD. Updates to water conservation plan guidelines are necessary to ensure all communities and rural water districts have current water conservation and drought management plans.	Estimated Cost: $ Potential Funding: KWO, KDA Other Potential Partners/Stakeholders: RWDs Priority Area(s): Basin-wide
Promote and Incentivize the Adoption of Watershed Practices	Continue to promote and support adoption of watershed practices to support water quantity and quality (streambank stabilization, improved soil health, increased riparian vegetation and forest wetlands, cover crops, not till farming practices). Success measures should be developed for practices to determine effectiveness. Many good examples of programs in the watershed already exist (WRAPS, RCPP).	Estimated Cost: $–$$ Potential Funding: Other Potential Partners/Stakeholders: WRAPS, KDHE, NRCS, KWO, KDWP, KDA, Tribes, private companies Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds
Drought Communication and Outreach	Conduct drought simulation exercises to educate the public and identify gaps in conservation efforts. Incorporate drought simulation efforts into state hazard planning. Seek funding and support for efforts from federal partners.	Estimated Cost: $ Potential Funding: KWO Other Potential Partners/Stakeholders: KDEM Priority Area(s): Basin-wide

Table EX-12. Degraded and Poor Water Quality Recommendations-Immediate Actions

Focus	Recommendation	Potential Partners and Funding
Promote and Incentivize the Adoption of Watershed Practices	Continue to promote and support adoption of watershed practices to support water quantity and quality (streambank stabilization, improved soil health, increased riparian vegetation and forest wetlands, cover crops, no till farming practices). Develop success measures for practices to determine effectiveness. Many good examples of programs in the watershed already exist (WRAPS, RCPP).	Estimated Cost: $–$$ Potential Funding: Other Potential Partners/Stakeholders: WRAPS, KDHE, NRCS, KWO, KDWP, KDA, Tribes, private companies Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds

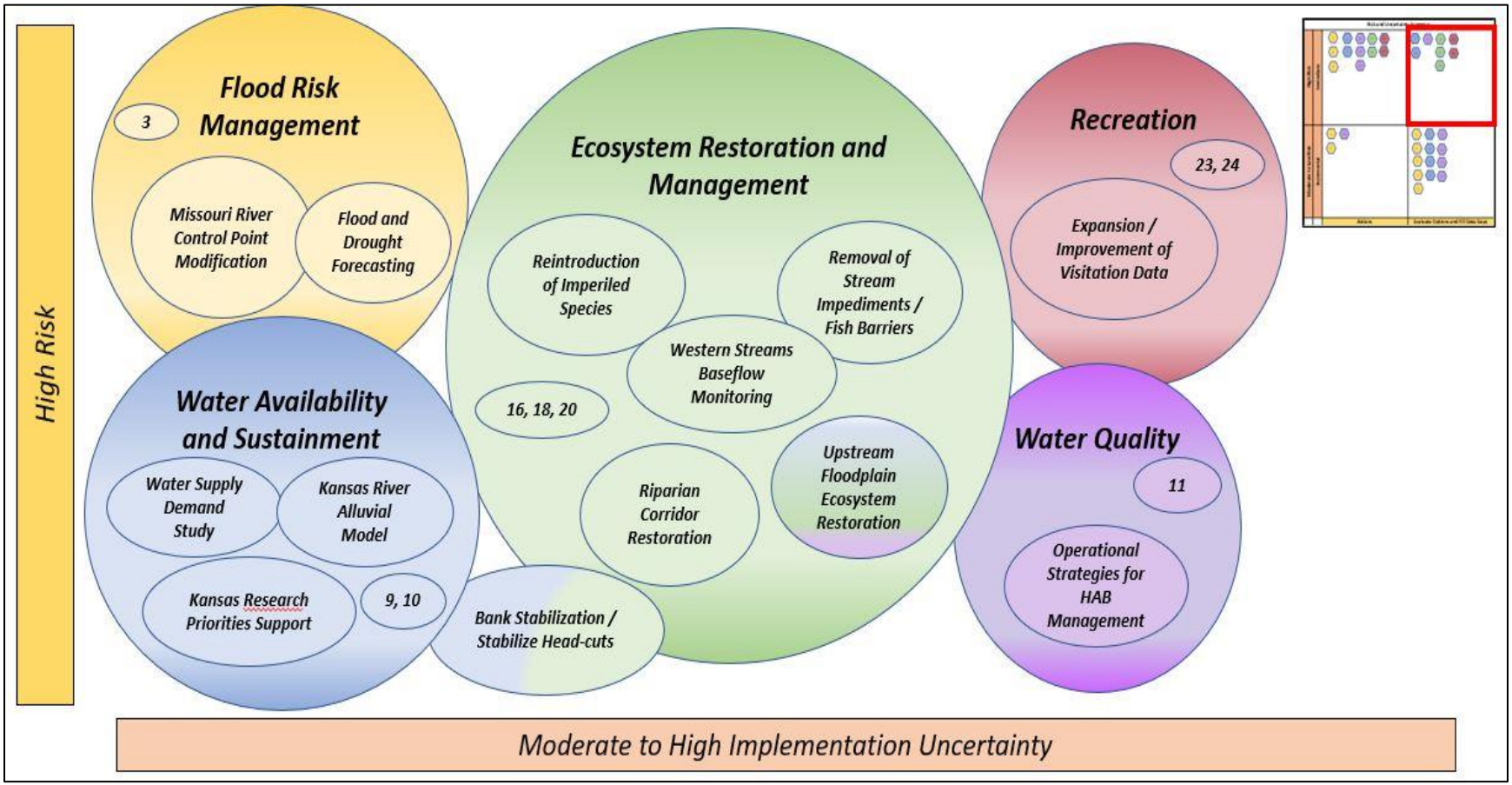
Table EX-13. Ecosystem Degradation and Species Impacts-Immediate Actions

Focus	Recommendation	Potential Partners and Funding
Support existing plans to Construct and Maintain Wetlands and Rehabilitate Old Oxbows	Support existing proposals and requests for ecosystem restoration projects. Current projects listed on USACE's new start list for GI, CAP, or conversion include Smoky Hill River GI, Jersey Creek GI, Rocky Ford GI, and Harlan County CAP Section 1135.	Estimated Cost: $–$$ Potential Funding: USACE, City of Salina, Kansas, KDWP, Unified Government of Wyandotte County, Kansas, NGPC Other Potential Partners/Stakeholders: Priority Area(s): Smoky Hill River, Salina, Kansas; Jersey Creek, Wyandotte County, Kansas; Rock Ford; Harlan County Reservoir
Consideration and Evaluation of the Kansas River Sustainable Rivers Project	Implement ecological flow proposals to better mimic natural hydrologic regimes and habitat formation developed from the Kansas River Sustainable Rivers Project and continue to refine and adjust these releases as appropriate (adjustments for wet and dry cycles). Monitor the effectiveness of SRP implementation on riverine species reproduction. Recruitment is needed to determine success. Develop adaptive management measures for further implementation.	Estimated Cost: $ Potential Funding: USACE Other Potential Partners/Stakeholders: USACE, KDWP, KWO, Kansas River Sustainable Rivers Team Priority Area(s): Kansas River mainstem
Biological Monitoring/ Surveying Needs	Monitor reintroduced populations to determine success and inform adaptive management for future efforts.	Estimated Cost: $$ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: NGPC Priority Area(s): Basin-wide
Invasive/Non-native Species Management (Kansas RPA)	Install watercraft inspection and decontamination stations near federal reservoirs. Continue to request funding through the Kansas State Water Plan Fund for the KDWP ANS management and control.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USBR Priority Area(s): Federal Reservoirs
Lake Level Management Plans	Conduct a comprehensive review of LLMPs and the review process and implementation. Greater flexibility and local control are desired to utilize LLMPs more effectively. The SRP E-pools work is currently supporting these efforts.	Estimated Cost: $ Potential Funding: USACE, KWO, KDWP Other Potential Partners/Stakeholders: USACE, KWO, KDWP Priority Area(s): USACE Reservoirs in the Kansas River Basin

EX.8.2 Immediate Evaluation Options/Fill Data Gaps

Problems and stressors deemed appropriate for evaluating options in the near-term are those with high risk and moderate levels of implementation uncertainty. Additional studies are needed to better understand the problem and identify recommended plans. Studies should be initiated in the near-term, ideally within five years, and target implementation should happen between five to ten years. To address problems and stressors requiring a more detailed understanding of the problem, recommendations should be categorized as filling data gaps before initiating a study or project. These data gaps should be resolved in the near-term (0 to 5 years) with initiation of a study or implementation of a program taken in incremental steps (five to ten years or sooner, if possible). Figure EX-8 shows near-term evaluations and fill-data gaps for reducing risks related to floods, decreasing reduction in the ability to meet water supply demands, preventing degraded and poor water quality, improving degraded ecosystems reducing species declines, and preserving recreation.

Figure EX-8. Basin-wide Immediate Evaluate Options and Fill Data Gaps



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Tables EX-13 through EX-17 include immediate (near-term) evaluation options and fill data gaps shown as flood risk, reduced ability to meet water supply demands, degraded and poor water quality, ecosystem degradation and species impacts, and loss of recreational opportunities recommendations.

Table EX-14. Flood Risk Recommendations-Immediate Evaluations and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Missouri River Control Point Modification	Initiate a spin-off study to evaluate modification to control point (Waverly gage) operations for the Kansas River Basin. Recommend a spin-off USACE project to update the WCMs. It would allow for greater flexibility during extreme and high events and quicker evacuation of flood storage at the reservoirs. It would decrease the risk of surcharge releases, and possible downstream flooding along the Kansas River and tributaries caused by surcharge releases.	Estimated Cost: $ Potential Funding: USACE WCM Updates Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE Priority Area(s): Milford, Tuttle Creek, Perry, and Clinton Reservoirs

Table EX-15. Reduction in Ability to Meet Water Supply Demands Recommendations-Immediate Evaluations and Fill Data Gaps (sheet 1 of 2)

Focus	Recommendation	Potential Partners and Funding
Water Supply Demand Study	Determine future water supply demands in the Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.	Estimated Cost: $ Potential Funding: USACE PAS, KWO Other Potential Partners/Stakeholders: Priority Area(s): Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.
Bank Stabilization/ Stabilize Head-cuts	Identify bank stabilization sites, expansion of head-cut assessments, and potential project sites Include hydraulic modeling to determine appropriate design features for maximum performance and cost effectiveness.	Estimated Cost: $ Potential Funding: USACE, KDWP, KWO, WRAPS SLT Other Potential Partners/Stakeholders: Priority Area(s): WRAPS Priority Areas, Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds
Kansas River Alluvial Model	Develop a stream aquifer model of the Kansas River Alluvial Aquifer for Junction City, Kansas, to the junction with the Missouri River to examine the effect of scenarios of future development and management of groundwater and river water levels.	Estimated Cost: $ Potential Funding: KWO, Kansas Geological Survey (KGS) Other Potential Partners/Stakeholders: USGS Priority Area(s): Kansas River mainstem

Table EX-16. Reduction in Ability to Meet Water Supply Demands Recommendations-Immediate Evaluations and Fill Data Gaps (sheet 2 of 2)

Focus	Recommendation	Potential Partners and Funding
Kansas Research Priorities Support	Support reservoir research priorities developed by the Kansas Water Research Coordination Group. USACE Kansas City District (NWK) and KWO recently entered into a PAS Study that provides an opportunity to work together on Kansas reservoir research priorities, utilizing expertise from state agencies, universities, and USACE. Pooled funding is used to support these efforts. Kansas will continue to look for opportunities to work with USACE on similar efforts.	Estimated Cost: $ Potential Funding: USACE PAS, USACE R&D, USACE RSM, KWO Other Potential Partners/Stakeholders: KDHE, KGS, KBS Priority Area(s): Basin-wide

Table EX-17. Degraded and Poor Water Quality Recommendations-Immediate Evaluations and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Operational Strategies for HAB Management in Inland Reservoirs	Conduct systematic study of the influence of USACE reservoir control options on HABs. Investigate the effectiveness of water level management and releases to address HABs in reservoirs.	Estimated Cost: $ Potential Funding: USACE PAS, USACE research and development (R&D), State of Kansas Programs Other Potential Partners/Stakeholders: USACE, KDHE, KWO Priority Area(s): Milford Reservoir

Table EX-18. Ecosystem Degradation and Species Impacts Recommendations-Immediate Evaluations and Fill Data Gaps (sheet 1 of 2)

Focus	Recommendation	Potential Partners and Funding
Removal of Stream Impediments and Fish Barriers	Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects. Remove existing man-made or natural stream impediments and fish barriers.	Estimated Cost: $$ Potential Funding: USACE CAP Section 206 Other Potential Partners/Stakeholders: KDWP, Ducks Unlimited, TNC Priority Area(s): Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 Watersheds

Table EX-19. Ecosystem Degradation and Species Impacts Recommendations-Immediate Evaluations and Fill Data Gaps (sheet 2 of 2)

Focus	Recommendation	Potential Partners and Funding
Upstream Floodplain Ecosystem Restoration	Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects that induce deposition on upstream floodplains in composition with grade control (stage zero projects). These would be multipurpose projects providing ecological habitat benefits, sediment reduction to downstream waters, reduction of water quantity and water quality concerns, and reduction of ongoing streambank erosion and head-cuts.	Estimated Cost: $$ Potential Funding: USACE, KWO, KDWP, Ducks Unlimited, TNC, WRAPS Other Potential Partners/Stakeholders: Conservation Districts Priority Area(s): Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds
Reintroduction of Imperiled Species	Develop habitat suitability requirements and site evaluation methods to identify sites and segments for potential reintroduction of imperiled species. Include establishment of safe harbor agreements and candidate conservation agreements with willing landowners to reintroduce imperiled species on their property.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USFWS Priority Area(s):
Riparian Corridor Restoration	Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects that focus on riparian habitat restoration. These would be multipurpose projects that provide ecological habitat benefits, sediment reduction to downstream waters (reservoirs), reduction of water quantity and water quality concerns, and reduction of ongoing streambank erosion and head-cuts.	Estimated Cost: $$ Potential Funding: USACE, KDWP, Ducks Unlimited Other Potential Partners/Stakeholders: KWO, TNC, WRAPS, Conservation Districts Priority Area(s): Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds
Western Streams Baseflow Monitoring	Initiate a spin-off study to monitor baseflow in streams in western Kansas. This would provide a baseline to monitor future reductions in stream baseflow in the future.	Estimated Cost: $ Potential Funding: KWO, KDWP, KDHE Other Potential Partners/Stakeholders: USACE, USGS Priority Area(s): western Kansas streams

Table EX-20. Loss of Recreational Opportunities Recommendations-Immediate Evaluations and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Expansion and Improvement of Visitation Data	Collaboration between USACE and KDWP to develop a central storage location for visitor and visitation data, allowing for better sharing between state and federal agencies.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USBR Priority Area(s): Basin-wide

EX.8.3 Incremental Actions

Recommendations categorized as incremental actions have a low level of implementation uncertainty and pose a moderate risk to life and property loss. The watershed study focused on gaining partner insight and collaboration for high-risk recommendations. As such, recommendations for incremental actions and studies and filling data gaps do not have potential partners listed.

These recommendations should initiate implementation as soon as possible but could be done long-term, within the next 10 to 25 years. These problems are important to address and pose risks, however, with limited resources, these recommendations may require incremental steps to make continuous progress toward enhancing resiliency. Figure EX-9 shows incremental actions for reducing risks related to flood risk, preventing degraded/poor water quality, improving degraded ecosystems, preventing species declines, and preserving recreation.

Tables EX-18 through EX-21 include incremental actions shown as flood risk, degraded and poor water quality, ecosystem degradation and species impacts, and loss of recreational opportunities recommendations.

Table EX-21. Flood Risk Recommendations-Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Kansas Flood Center/Flood Information System	Establish a flood center and flood information system. The flood center would give Kansans access to the latest technology and resources to help prepare for floods and become more resilient. Providing direct services and engagement in flood-related projects that help Kansans understand their flood risks and make better flood-related decisions.	Estimated Cost: $–$$ Potential Funding: USACE FPMS/PAS, State of Kansas Programs Potential Partners: USACE, NOAA, NWS, KDEM, KWO, KDWP, KDA, KGS, KDHE, KHMT, Kansas Regional HMTs, Tribes Priority Areas: Basin-wide
Silver Jackets Projects Related to Healthy Watersheds	Initiate additional work related to the ongoing Silver Jacket Healthy Watershed projects.	Estimated Cost: $ Potential Funding: USACE Silver Jackets, KDEM, KDHE, KWO Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Basin-wide

Figure EX-7. Basin-wide Incremental Actions

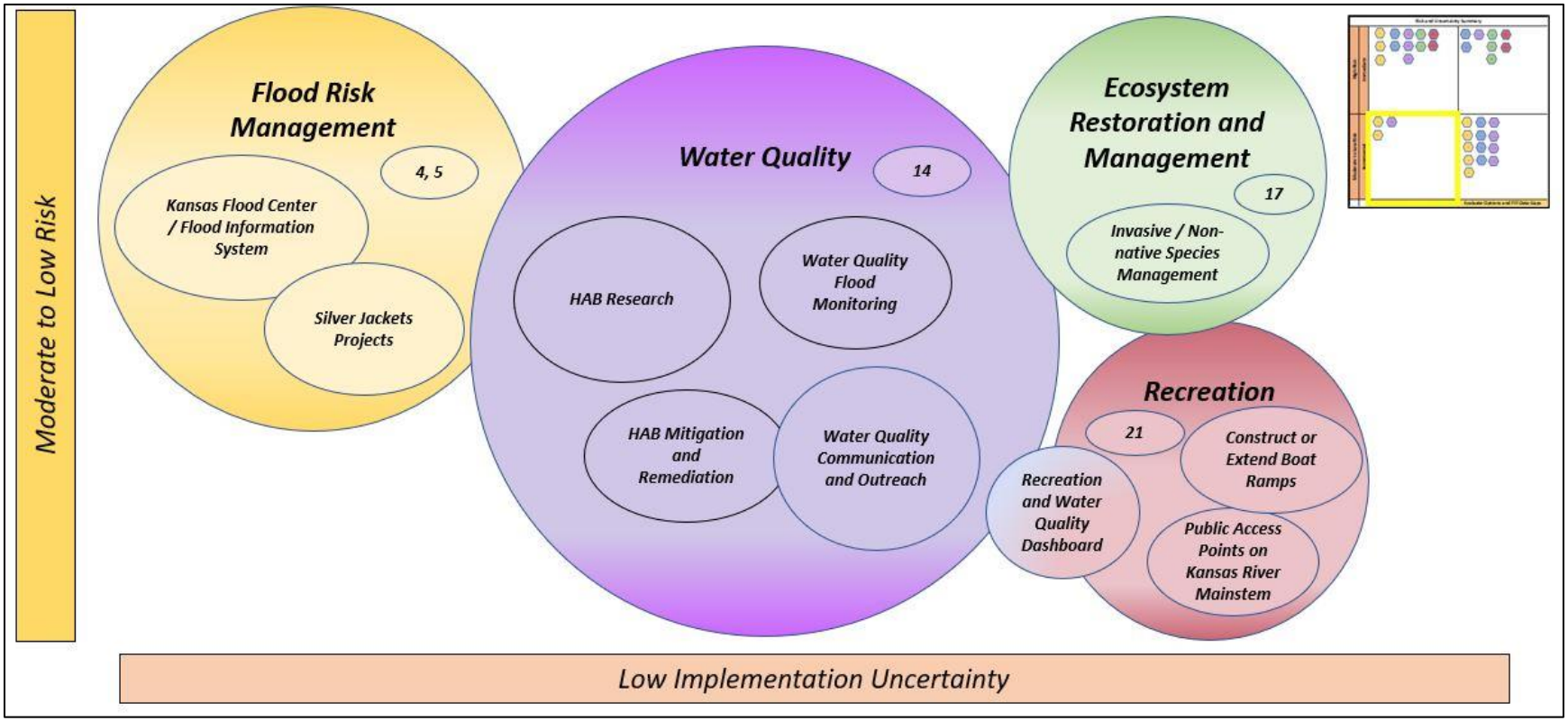

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Table EX-22. Degraded and Poor Water Quality Recommendations-Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Water Quality Flooding Monitoring	Monitor the impact of flood conditions, such as debris, nutrient runoff, and sedimentation on water quality. Incorporate concerns into flood management strategies.	Estimated Cost: $ Potential Funding: Other Potential Partners/Stakeholders: USACE, KWO, KDHE Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds
Water Quality Communication and Outreach	Continue to support and provide educational outreach encouraging the implementation of watershed conservation practices, in particular soil health initiatives, streambank stabilization, and riparian corridor restoration.	Estimated Cost: $–$$ Potential Funding: KWO Other Potential Partners/Stakeholders: WRAPS, KDHE, NRCS, KWO, KDWP, KDA, Tribes Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds
HAB Research (Kansas RPA)	Identify and remediate causes, prevention, and treatment of HABs, including potential in-lake technologies.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin
HAB Mitigation and Remediation (Kansas RPA)	A variety of HAB control treatments have been proposed and some have been tested in Kansas, including hydrogen peroxide treatment, ultrasonic cavitation, and barley straw additions. There are other treatment options that are cost prohibitive for our current situation but can provide short-term benefits. Other mitigation actions also include warnings and closures and data collection and outreach. These actions should continue and improve as information becomes available.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin

Table EX-23. Ecosystem Degradation and Species Impacts-Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Invasive/Non-native Species Management (Solomon-Republican, Smoky Hill-Saline, and Upper Republican/Upper Smoky Hill RPA)	Install watercraft inspection and decontamination stations near federal reservoirs. Continue to request funding through the Kansas State Water Plan Fund for the KDWP ANS management and control.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USBR Priority Area(s): Federal Reservoirs

Table EX-24. Loss of Recreational Opportunities Recommendations-Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Develop a Plan for New Low-Water Boat Ramps or Extending Existing Boat Ramps	Develop a plan for new lower-water boat ramps or extending boat ramps to mitigate boating access restrictions during low water conditions at USACE reservoirs in the basin and on the Kansas River mainstem.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: Friends of the Kaw Priority Area(s): USACE reservoirs in the Kansas River Basin and Kansas River mainstem
Public Access Point Along the Kansas River Mainstem	Develop Kansas River mainstem public access points to meet increasing use of the river for canoeing, kayaking, camping, fishing, hunting, and wildlife viewing. Provide access points for search and rescue efforts. Develop a plan for parking lots, lighting, boat ramps, lifejacket stations, camping areas, potable water, and safety signage.	Estimated Cost: $ Potential Funding: KDWP, Friends of the KAW Other Potential Partners/Stakeholders: Priority Area(s): Kansas River mainstem
Dashboard to Serve Recreation and Water Quality	Develop an online dashboard or application for users to access information on river flows, safety hazards, forecast river or reservoir conditions with multi-lingual access.	Estimated Cost: $ Potential Funding: USACE, USGS, KDWP, KWO Other Potential Partners/Stakeholders: Priority Area(s): Basin-wide

EX.8.4 Incremental Evaluate Options/Fill Data Gaps

Incremental studies and evaluation options should be initiated as soon as possible but could be done long-term, such as within the next 10 to 25 years. Studies should further investigate the stressor, determine the most effective solution, and implement strategy to achieve resiliency. Incremental recommendations for filling data gaps and stressors requiring a more detailed understanding of the problems should be addressed in the next ten years. Figure EX-10 shows incremental evaluations and fill data gaps.

Tables EX-22 through EX-24 include incremental evaluate options and fill data gaps shown as flood risk, reduction in ability to meet water supply demands, and degraded and poor water quality recommendations.

Figure EX-8. Basin-wide Incremental Evaluate Options and Fill Data Gaps

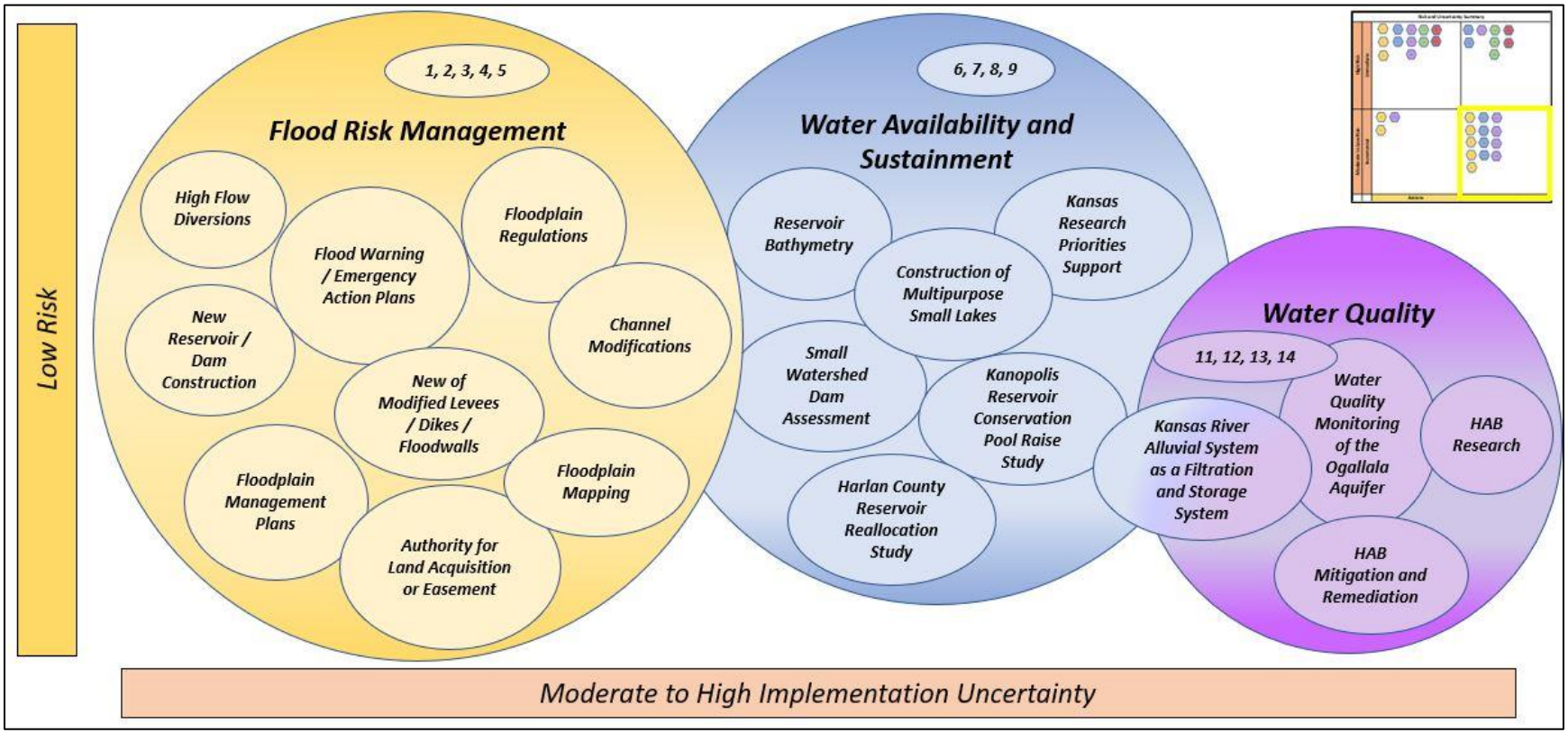

Table EX-25. Flood Risk Recommendations-Incremental Evaluations and Fill Data Gaps (sheet 1 of 4)

Focus	Recommendation	Potential Partners and Funding
New or Modified Levees/Dikes/ Floodwalls	Coordination with communities identified as high-risk for potential life loss or damages that would benefit from new or modified levees/dikes/floodwalls. Determine the need for support from the federal or state government agencies (USACE, FEMA, KDEM). The Watershed Study Flood Risk Assessment and the Regional Hazard Mitigation Plans identify potential communities to determine needs and cost benefits of levee, dike, and floodwall construction.	Estimated Cost: $$–$$$ Potential Funding: USACE FPMS/PAS, USACE GI, NRCS, State of Kansas Programs Other Potential Partners/Stakeholders: City Governments, County Governments Priority Area(s): Cities of: Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, and Muncie, Kansas
High Flow Diversions	Identify specific sites for diversion and redirection of excess flows away from developed areas using naturally or artificially constructed bypass channels or conduits. Prioritize site list based on problem areas, flood risk, and where benefits could be realized. The Watershed Study Flood Risk Assessment and the Regional Hazard Mitigation Plans identified areas with potential need and high life safety risk or economic damages.	Estimated Cost: $$ Potential Funding: USACE FPMS/PAS, USACE GI, NRCS, State of Kansas Programs Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, Tribes, WRAPS, Conservation Districts, Watershed Districts Priority Area(s): Upper Kansas HUC 8 watershed, Middle Kansas HUC 8 watershed, Lower Kansas HUC 8 watershed; cities of Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, and Muncie, Kansas
Channel Modifications	Identify specific sites to widen or deepen the channel to increase flood conveyance. Prioritize site list based on problem areas, flood risk, and where highest benefits could be realized. The Watershed Study Flood Risk Assessment identified areas with potential high life safety risk or economic damages. The Regional Hazard Mitigation Plans identified areas with potential need.	Estimated Cost: $$ Potential Funding: USACE PAS, USACE GI, NRCS, State of Kansas Programs Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, Tribes Priority Area(s): Upper Kansas HUC 8 watershed, Middle Kansas HUC 8 watershed, Lower Kansas HUC 8 watershed (Wyandotte County); cities of: Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, and Muncie, Kansas

Table EX-26. Flood Risk Recommendations-Incremental Evaluations and Fill Data Gaps (sheet 2 of 4)

Focus	Recommendation	Potential Partners and Funding
Identification of New Reservoir/Dam or Detention Basins	Identify specific sites to construct new reservoirs and dams or detention basins to provide additional temporary storage of runoff waters, extending the period of runoff with the intent of reducing flood peaks. Include smaller reservoirs constructed by state agencies and county or local government. Prioritize sites based on problems, flood risk, and where the highest benefits could be realized. The Watershed Study Flood Risk Assessment identified areas with potential high life safety risk or economic damages. The Regional Hazard Mitigation Plans identified areas with potential need.	Estimated Cost: $$–$$$ Potential Funding: USACE PAS, USACE GI, NRCS, State of Kansas Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, Tribes Priority Area(s): Upper Kansas HUC 8, Middle Kansas HUC 8, Lower Kansas HUC 8 watersheds; cities of: Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, and Muncie, Kansas
Authority for Land Acquisition or Easement Purchase for Flood Control	USACE currently does not have authority to acquire lands or easements for flood control. This would require a new authority and would consist of USACE acquisitioning lands and reconnecting old oxbows or easements along the Kansas River mainstem and major tributaries for flood control measures (including levee setbacks, floodplain expansion, restoration of oxbows). The state may have some instruments for this.	Estimated Cost: $–$$$ Potential Funding: USACE Other Potential Partners/Stakeholders: Priority Area(s): Upper Kansas HUC 8, Middle Kansas HUC 8, and Lower Kansas HUC 8 watersheds
Floodplain Management Plans	Identify regional and local areas with a need for FMPs. Incorporate risk evaluation. Recommend concrete steps to address risks using a variety of structural and non-structural solutions. Develop an FMP to increase public awareness of flood risk. The Regional Hazard Mitigation Plans identified areas with potential need. Collaborate with Silver Jackets Program to develop proposals and plans in high-risk communities.	Estimated Cost: $ Potential Funding: USACE FPMS/PAS, NOAA, FEMA, USGS, KDEM, State of Kansas Programs, State of Nebraska programs Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Middle Kansas HUC 8 (Willard County); Upper Kansas HUC 8 (Riley County); Lower Big Blue HUC 8 (Riley County) watersheds

Table EX-27. Flood Risk Recommendations-Incremental Evaluations and Fill Data Gaps (sheet 3 of 4)

Focus	Recommendation	Potential Partners and Funding
Floodplain Mapping	Assess flood-prone areas to implement future flood reduction measures in Belvue, Havensville, Louisville, Onaga, St. George, St. Mar''s, Wamego, Alma, McFarland, and Paxico, Kansas. Increase availability of floodplain maps beyond standard FEMA products to increase understanding of flood risk.	Estimated Cost: $ Potential Funding: USACE FPMS/PAS, NOAA, FEMA, USGS, KDEM, State of Kansas Programs, State of Nebraska Programs Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Lower Kansas HUC 8 watershed (Shawnee, Johnson, Leavenworth, Wyandotte, Jefferson, Atchison, Jackson, Douglas Counties; cities of Lawrence and Bonner Springs); Delaware HUC 8 watershed (Atchison, Brown, Jackson, Jefferson, Jefferson Counties; city of Horton); Middle Kansas HUC 8 watershed (Shawnee and Jackson Counties; cities of: Rossville, Silver Lake, Topeka, Willard, Belvue, Havensville, Louisville, Onaga, St. George, St. Mar's, Wamego, Alma, McFarland, Paxico); Fillmore County Nebraska; Marshall and Geary Counties in Kansas; city of Manhattan; Lower Big Blue HUC 8 watershed (Riley, Pottawatomie, Marshall Counties; cities of Frankfort, Marysville); Lower Little Blue HUC 8 watershed (Washington and Marshall Counties)
Flood Warning/Emergency Plans	Develop flood warning and emergency plans for high-risk communities. Include flood emergency measures (flood-fighting plans, contingency and emergency floodproofing, emergency evacuation plans).	Estimated Cost: $-$$ Potential Funding: USACE FPMS/PAS, NOAA, FEMA, KDEM, State of Kansas Programs, State of Nebraska Programs Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Lower Kansas HUC 8 watershed (Johnson, Wyandotte Counties)

Table EX-28. Flood Risk Recommendations-Incremental Evaluations and Fill Data Gaps (sheet 4 of 4)

Focus	Recommendation	Potential Partners and Funding
Floodplain Regulations	Establish ordinances, zoning, subdivision regulations, building and housing codes, and sanitary codes with specific flood hazard provisions by working with local communities, counties, and regional floodplain managers.	Estimated Cost: $ Potential Funding: USACE FPMS/PAS, NRCS, State of Kansas Programs, State of Nebraska Programs Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, KHMT, Kansas Regional HMTs, Tribes Priority Area(s): Lower Kansas HUC 8 watershed (Shawnee, Leavenworth, Jackson, Atchison, Jefferson Counties); cities of Rossville, Bonner Springs, Eudora); Delaware HUC 8 watershed (Atchison, Brown Jackson, Jefferson, Nehama Counties); Middle Kansas HUC 8 watershed(Pottawatomie, Nemaha, Shawnee, Jackson Counties; cities of Rossville; Upper Kansas HUC 8 watershed (Thayer County Nebraska, Marshall, Geary Counties, Kansas); Lower Big Blue HUC 8 watershed (Riley, Pottawatomie, Washington, Marshall Counties); Lower Little Blue HUC 8 watershed (Marshall, Washington Counties)

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Table EX-29. Reduction in Ability to Meet Water Supply Demands Recommendations-Incremental Evaluations and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Develop a plan for Multipurpose Small Lakes	Develop a plan for multipurpose, small lakes to alleviate regional water supply issues. This would be done in regions where it is not feasible to restore water supply storage in reservoirs.	Estimated Cost: $-$$ Potential Funding: Other Potential Partners/Stakeholders: Priority Area(s):
Kansas River Alluvial System Utilized as a Filtration and Storage System	Determine areas of potential artificial recharge in the Kansas River Alluvial Aquifer. Utilize the Kansas River Alluvial Model currently in development by the Kansas Geologic Survey.	Estimated Cost: $ Potential Funding: KWO Other Potential Partners/Stakeholders: Priority Area(s): Kansas River mainstem
Kanopolis Reservoir Multipurpose Pool Raise Study	Initiate a spin-off study to evaluate the possibility of a permanent multipurpose pool raise at Kanopolis Reservoir.	Estimated Cost: $ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: RWD Priority Area(s): Kanopolis Reservoir
Small Watershed Dam Assessment	Identify existing watershed structures that need restoration and have the potential to be made larger. Provide supplemental water supply in the Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.	Estimated Cost: $ Potential Funding: KDA, KWO Other Potential Partners/Stakeholders: NRCS Priority Area(s):
Kansas Research Priorities Support	Support reservoir research priorities developed by the Kansas Water Research Coordination Group. USACE NWK and KWO recently entered into a PAS Study that provides an opportunity to work together on Kansas reservoir research priorities, utilizing expertise from state agencies, universities, and USACE. Pooled funding is used to support these efforts. Kansas will continue to look for opportunities to work with USACE on similar efforts.	Estimated Cost: $ Potential Funding: USACE PAS, USACE R&D, USACE RSM, KWO Other Potential Partners/Stakeholders: KDHE, KGS, KBS Priority Area(s): Basin-wide
Reservoir Bathymetry	Increase the frequency of reservoir bathymetry to monitor progress on sedimentation trends, reservoir storage loss, and future water supply planning projections	Estimated Cost: $ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: USBR Priority Area(s): USACE reservoirs

Table EX-30. Degraded and Poor Water Quality Recommendations-Incremental Evaluations and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
HAB Research (Solomon-Republican, Smoky Hill-Saline, Upper Republican, Upper Smoky Hill RPAs)	Identify and remediate causes, prevention, and treatment of HABs, including potential in-lake technologies.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin
HAB Mitigation and Remediation (Solomon-Republican, Smoky Hill-Saline, Upper Republican, Upper Smoky Hill RPAs)	A variety of HAB control treatments have been proposed and some have been tested in Kansas, including hydrogen peroxide treatment, ultrasonic cavitation, and barley straw additions. Other treatment options that are cost prohibitive for our current situation but can provide short-term benefits. Other mitigation actions also include warnings, closures, data collection, and outreach. These actions should continue and improve as information becomes available.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin

To help prioritize time and resources, Section 5, Recommendations and Implementation Strategy, provides a general timeline for recommendation implementation. Recommendations reflect the level of readiness to implement, with a greater emphasis on accelerating implementation for high risks. The timeline is an estimate based on the urgency of the stressor and possible implementation roadblocks, such as knowledge gaps, local approval, and funding (determined through the uncertainty analysis). Generally, near-term actions should be implemented within ten years. Near-term options should be evaluated within one to ten years and implemented as soon as possible. Incremental options should be implemented as soon as possible but may have additional time available for implementation, as the stressor assessed at a moderate to low risk. Evaluation of options to address major stressors should occur within one to ten years, with implementation occurring soon thereafter. Some recommendations have less implementation uncertainty and, therefore, may stray from the timeline explained above.

The implementation strategy includes phasing of implementation, evaluation, and filling data gaps recommendations under shorter timeframes then 10 years (0 to 5 years). Immediate recommendations (actions/projects) that are high risk with solutions supported by stakeholders with a strong consensus are proposed for implementation within the next 5 years. Immediate recommendations (evaluations/fill data gaps) that address high risk but did not have potential solutions with a strong consensus are proposed for either evaluation or additional data gathering in the next 5–10 years with implementation to occur later (10+ years). Incremental recommendations (actions/projects and evaluations/fill data gaps) that address moderate to low risk are

proposed for evaluation or additional data gathering in 5–10 years and either implementation or evaluation to occur later (10 or more years). This phasing approach is included in Tables 5-22 through 5-24.

Implementation of recommendations in the future require alignment of actions by federal, state, interstate, and local government entities identifying and using authorities, programs, and sources for potential future appropriations. Potential agencies that could champion the implementation of recommendations are noted in recommendation tables in Section 5. While the priorities in the basin may shift in the future as new circumstances occur, or new information is developed, this watershed study provides a benchmark for the future.

EX.8.5 Potential Funding and Implementation Resources

Existing authorities and programs will be utilized, when possible, to implement recommendations. Following are explanations of identified funding opportunities from USACE and other agencies. Additional information may be found online through coordination with agency representatives.

EX.8.5.1 U.S. Army Corps of Engineers Authorities

Following is a summary of all USACE authorities available for planning, feasibility studies, technical assistance, or construction efforts. Most authorities require a non-federal cost share; however, cost share waivers may be available, per Section 1156 of WRDA 1986, as amended (33 U.S.C. 2310), for the categories of Planning Assistance to States (PAS), General Investigation (GI) Studies, and the Continuing Authorities Program (CAP) described below.

- **Floodplain Management Services (FPMS)**—Authorized under Section 206 of the Flood Control Act of 1960, as amended, FPMS provides communities with technical and planning services to support effective floodplain management. FPMS efforts are often completed by Silver Jackets teams. Under FPMS, USACE supports both riverine and coastal flood challenges and empowers communities to better understand the risks of flooding and develop plans to communicate and manage that risk. Activities provided under this authority include hydrologic and hydraulic technical services, general planning guidance, education and outreach material, and National Flood Insurance Program (NFIP) support. Funding is typically 100 percent federally provided, within limits of the authority. Requests for assistance should be in the form of a letter including the location and nature of the problem to be investigated.
- **Silver Jacket**s—Silver Jackets teams in states and territories across the United States bring together a partnership of multiple state, federal, tribal, territorial, and local agencies to collaborate on reducing flood risk and other natural disasters. By applying their shared knowledge, the teams enhance response and recovery efforts when events occur. The partnership provides an opportunity for mentoring and networking, enables agencies to better respond and prepare for disasters as a team, and helps achieve communities sustainable and resilient to natural disasters, especially flooding. The interagency nature of Silver Jackets teams allows for leveraging of all available resources and authorities, including those

from within USACE such as FPMS, to support local flood risk management needs.

- **Planning Assistance to States (PAS**)—Two types of planning assistance, including preparation of Comprehensive Plans and technical assistance, are offered through the PAS program (authorized by Section 22 of WRDA 1974, as amended). Requests for assistance should be in the form of a letter including the location and nature of the problem to be investigated.
  - Comprehensive Plans include planning for the development, utilization, and conservation of the water and related resources of drainage basins, watersheds, or ecosystems located within the boundaries of that state or territory (or group of states and territories) to comprehensively address water resource challenges.
  - Technical assistance provided through the PAS program includes support of planning efforts related to the management of water resources, including the provision and integration of hydrologic, economic, or environmental data and analysis in support of water resources management and related land resource development plans. This technical assistance does not include the preparation of site-specific designs or construction. Section 22 technical assistance is only available upon request of a government agency or non-federal interest. Technical assistance activities through the PAS program are cost shared 50 percent) with the non-federal sponsor, and voluntarily-contributed funds in excess of cost share may be provided by the non-federal sponsor. The cost share for technical assistance must be provided by funds (not in-kind).
- **General Investigation**—USACE is authorized to conduct investigations related to its core mission areas of navigation, flood risk management, and ecosystem restoration, to determine if congressional authorization and implementation of specific civil works projects are warranted. GIs involve a jointly conducted study with a sponsor and, if shown by the study to be feasible, the construction and implementation of the project. This approach requires Congress to provide an authorization to construct and implement the project. There are several types of planning studies and decision documents, but for the GI process, the most common studies are Feasibility Studies, which include optimizing the plans to be built. They are equally cost-shared and are usually completed in 24 to 36 months. The first $100,000 is federally funded. If the study cost exceeds $100,000, the cost share is 50 percent federal and 50 percent non-federal. Project implementation requires both authorization and appropriation from Congress, and the cost share is typically 65 percent federal and 35 percent non-federal. Requests for assistance should be submitted in the form of a letter of intent from a state or local government agency to USACE.
- **USACE Engineering with Nature (EWN) Initiativ**e—EWN is the USACE initiative enabling more sustainable delivery of economic, social, and environmental benefits associated with infrastructure. Sustainable water resource infrastructure is achieved through the beneficial integration of engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single

collaborative and cost-effective approach for infrastructure development and environmental management. Positive outcomes are achieved through EWN by systematically integrating social, environmental, and economic considerations at every phase of a project. The results are innovative and resilient solutions that are more socially acceptable, viable, equitable, and, ultimately, more sustainable.

- **Regional Sediment Management (RSM) Progra**m—RSM is a research program implementing innovative management strategies to optimize the use of sediment and improve the management of projects. The program supports initiatives developing and demonstrating sustainable practices that systematically increase benefits and reduce lifecycle costs for USACE's navigation, flood risk management, and environmental missions. RSM provides opportunities to collaborate with stakeholders and other agencies to leverage resources, share technology and data, and develop and implement innovative solutions to improve regional utilization and management of sediments. Proposals are typically solicited once per year in June and are submitted by USACE. Projects do not require a non-federal cost share, however, stakeholder and partner engagement and information sharing is strongly encouraged and considered in the proposal selection process.
- **Section 7001 Annual Repor**t—The Section 7001 Annual Report to Congress Process may be used when study authority does not already exist for an area of interest. In Section 7001 of the Water Resources Reform and Development Act of 2014 (P.L. 113-121; 33 U.S.C. §2282d), Congress established an annual process for identifying proposals for site-specific studies and projects within USACE's water resource mission and authorities. The process includes a call for non-federal proposals, which should be submitted to the Planning Division at the regional USACE district and include the area of interest (for Kansas River Basin this is NWK). Inclusion of a proposal in a Section 7001 annual report does not provide congressional authorization or appropriation. Rather, inclusion of a proposal in a report facilitates congressional consideration to authorize the proposal.

Continuing Authorities Program (CAP)—The CAP is a group of nine legislative authorities under which USACE can plan, design, and implement certain types of water resource projects without additional project specific Congressional authorization. The purpose of the CAP is to plan and implement projects of limited size, cost, scope, and complexity. For all sections, except Sections 204 and 111, the feasibility phase may be initially federally funded up to $100,000. Any remaining feasibility phase costs are shared fifty-fifty with the non-federal sponsor after executing a feasibility cost sharing agreement. For Section 204 projects, the feasibility phase is performed at 100 percent of federal cost. For Section 111 projects, the feasibility phase costs above the initial $100,000 are cost-shared in the same proportion as the cost-sharing provisions applicable to the construction of the federal navigation project causing the shore damages. Construction is either cost shared at 65 percent federal and 35 percent non-federal, or 75 percent federal and 25 percent non-federal, depending on the authority. Requests for assistance should be in the form of a letter describing the location and nature of the problem and requesting assistance under the program.

Table EX-25 shows five of the authorities included in the program for use in the Kansas River Basin.

Table EX-31. Continuing Authorities Program Authorities

Authority	Types of Projects	Feasibility Cost Share (Federal—Non-Federal)	Implementation Phase Cost Share (Federal—Non-Federal)	Federal Project Limit
Section 14, Flood Control Act of 1946, as amended. Emergency Streambank and Shoreline Protection.	Develop a plan for bank protection for highways, bridge approaches, municipal water supply systems, sewage disposal plants, churches, hospitals, schools, non-profit public services and known cultural sites endangered by flood-caused bank and shoreline erosion.	100% federal for first $100,000 50%-50% remaining cost	65%—35%	$10M
Section 205, Flood Control Act of 1946, as amended. Small Flood Control Projects.	Projects include levees, floodwalls, impoundments, pumping stations, and channel modifications, as well as non-structural measures, such as flood-proofing, relocation, and flood warning systems.	100% federal for first $100,000 50%—50% remaining cost	65%—35%	$10M
Section 206, Water Resources Development Act of 1996, as amended. Aquatic Ecosystem Restoration	Projects include restoring floodplains, channel modifications, or modification of structures to restore conditions conducive to native aquatic species.	100% federal for first $100,000 50%—50% remaining cost	65%—35%	$10M
Section 1135, Water Resources Development Act of 1986, as amended. Project Modifications for Improvement of Environment.	Modifications to existing USACE structures and operations, or implementation of restoration measures in affected areas.	100% federal for first $100,000 50%—50% remaining cost	75%—25%	$10M

USACE Kansas City District Water Quality Program—The NWK Water Quality Program has maintained a long-term and robust water-quality monitoring and data collection program to meet the needs of all lake projects. Chemical, physical, and biological parameters are measured to evaluate water and lake-bed sediment quality. USACE uses this data to describe conditions and changes from the inflow and outflow streams within the main lake, focusing on eutrophication, nutrients, sediment, herbicides, metals, and contaminants. This data is critical to investigating problems that may arise, such as HABs, bacteria issues, and fish kills, as well as designing and implementing modifications to improve water management procedures.

EX.8.5.2 Funding Opportunities Available from Other Agencies and Organizations

- **FEMA Hazard Mitigation Assistance Grant Programs**
  - The Hazard Mitigation Grant Program (HMGP) provides funding to rebuild in a way that reduces, or mitigates, future natural hazard losses in communities. HMGP funding is authorized with a presidential major disaster declaration. The amount of funding made available to the applicant is generally 15 percent of the total federal assistance amount provided for recovery from the presidentially-declared disaster and is determined by the FEMA-approved Hazard Mitigation Plan.
  - The Building Resilient Infrastructure and Communities (BRIC) is a competitive grant program supporting hazard mitigation projects to reduce the risks from disasters and natural hazards. The BRIC program aims to categorically shift federal focus away from reactive disaster spending and towards proactive investment in community resilience. As a competitive grant program, applicants must apply on a yearly basis and the proposed project must have positive net benefits. BRIC encourages public infrastructure projects, nature-based solutions, and the adoption and enforcement of modern building codes.
  - Emergency Management Performance Grant Program provides funding for emergency management agencies implementing National Preparedness Systems and Goals. The goals of preparedness are prevention, protection, mitigation, response, and recovery from the threat of natural hazards.
- **Housing and Urban Development (HUD) Disaster Resilience Grants**
  - The Office of Community Planning and Development (CPD) provides billions of dollars in flexible funding to help communities, particularly low-and-moderate-income communities especially vulnerable to current and historic discrimination and disinvestment, recover from, and build resilience to, climate hazards and natural disasters. The Community Development Block Grant (CDBG) program is both a flexible and widespread program reaching more than 1,200 local governments in all states and territories. The program's scope and promotion of community-specific solutions makes CDBG a powerful tool for climate resilience. It requires jurisdictions to incorporate resilience to natural hazard risks into their consolidated plan and to discuss how climate change will increase those risks. It also requires verbiage on how jurisdictions will address the impacts of climate change for low-and-moderate-income residents.
  - The Section 108 Loan Guarantee Program (Section 108) provides communities with a source of low-cost, long-term financing for economic and community development projects. Section 108 financing provides an avenue for communities to undertake larger, more costly projects when there are limited resources for upfront investment. Section 108 funds economic development, housing, public facilities, infrastructure, and other physical development projects, including improvements to resilience against natural

disasters. The flexibility of uses makes it one of the most potent and important public investment tools the HUD offers to states and local governments.

- **U.S. Department of Agriculture Natural Resources Conservation Service:**
  - Agricultural Conservation Easement Program, Agricultural Land Easements (ALE), and Wetland Restoration Easements help restore, protect, and enhance wetlands on eligible lands. ALE protects farmlands and grasslands by limiting non-agricultural uses of the land.
  - Environmental Quality Incentive Program Conservation Incentive combines the best of the Conservation Stewardship Program and the Environmental Quality Incentive Program, providing annual payments for the operation's existing level of conservation and providing financial assistance for the installation of conservation practices or enhancements. Unlike the Conservation Stewardship Program, not all acres under the applicants control need to be enrolled or assessed for eligibility for the Environmental Quality Incentive Program Conservation Incentive.
  - Conservation Stewardship Program is the nation's largest conservation program in terms of participating land. It is designed to help farmers have more robust conservation activities. Agricultural producers and forest landowners looking to increase conservation efforts receive annual payments and financial assistance for an operation's existing level of conservation and for a wide variety of conservation activities.
  - Farm Bill 2014 Regional Conservation Partnership Program (RCPP) funds solutions to natural resource challenges. By leveraging collective resources and collaborating on common goals, RCPP demonstrates the power of public-private partnerships in delivering results for agriculture and conservation. There is a current RCPP for Milford Lake implementing best management practices within the Milford Lake watershed to decrease nutrient runoff.
  - Emergency Watershed Protection Program is a program that relieves imminent hazards to life and property caused by floods, fires, windstorms, and other natural hazards. Financial and technical assistance is provided to remove debris from streams, protect destabilized streambanks, establish cover on critically eroded lands, repair conservation practices, and purchase floodplain easements.
- **U.S. Environmental Protection Agency (EPA):**
  - Agency Clean Water State Revolving Funds—The Clean Water State Revolving Fund (CWSRF) program is a federal and state partnership that provides communities with low-cost financing for a wide range of water quality infrastructure projects. Projects eligible to receive assistance are construction of publicly owned treatment works, nonpoint source pollution programs, national estuary programs, decentralized wastewater treatment systems, stormwater systems, water conservation plans, watershed pilots, energy efficiency plans, water reuse plans, security measures at publicly owned treatment works, and technical assistance.
  - Nonpoint Source and the Section 319 Grant Program—Under Section 319 of the Clean Water Act, the EPA provides annual grants to states to control

nonpoint sources of pollution, such as agricultural runoff, mining activities, and malfunctioning onsite septic systems. In states where onsite systems are identified as a significant source of such pollution, these funds may be used to construct, upgrade, or repair onsite systems.

- Water Quality Monitoring Grant Program—Also known as the Section 106 Grant Program funds projects enhancing existing monitoring efforts to help achieve long-term monitoring program goals.

- The following programs and organizations are described in Section 1 and could provide funding opportunities to support study recommendations:
  - Kansas WRAPS Groups
  - Kansas Reservoir Protection Initiative (KRPI)
  - The KAWS
  - Local Enhanced Management Areas (LEMA)
  - Kansas Wetland Program
  - KDWP Stream Survey and Monitoring Program
  - The Playa Lakes Joint Venture (PLJV)
  - KDHE:
    - Stream Chemistry Monitoring Program
    - Stream Biological Monitoring Program
    - Harmful Algal Bloom Response Program
  - KDWP ANS Program
  - KDA Division of Conservation:
    - Water Transition Assistance Program
    - Riparian Quality Enhancement Initiative
    - Sediment and Nutrient Reduction Initiative
    - Streambank Protection Program
    - Riparian and Wetland Program
    - Water Quality Buffer Initiative
    - Water Resources Cost Share Program
    - Watershed Planning Assistance Program
    - Flood Control and Lakes Programs
      - Multipurpose Small Lakes Program
      - Water Supply Restoration Program
      - Watershed Dam Construction Assistance
    - Kansas Forest Service (KFS) Programs
      - Riparian Restoration Initiative
      - Assessment of Riparian Forests to Reduce Sedimentation of Federal Reservoirs.

EX.9 Conclusions

The watershed study team investigated water resource issues and opportunities in the Kansas River Basin and recommend comprehensive, long-term solutions based on a shared vision for the basin. The study presents current findings and recommendations for future efforts, including potential future projects and studies in which USACE could partner with the State of Kansas, sister Federal agencies, and non-Federal entities. The study makes near-term and long-term recommendations. The watershed study integrated water and related land resource management considerations, seeking sustainable water resource management, and making additional considerations. Ultimately, the watershed study informs multiple stakeholders and decision makers at all levels of government and provides a strategic roadmap toward future investment decisions by multiple agencies. Significant need and opportunities exist in the areas of flood risk management, water supply availability and sustainment, and related purposes, such as ecosystem restoration, water quality, sediment management, and recreation. This integrated watershed study focuses attention on significant objectives and tradeoffs, accounts for uncertainty, and promotes adaptive management, stakeholder collaboration, and systems analysis for watershed-scale planning and evaluation.

Developed in collaboration with federal and state agencies, community/local governments and groups, and stakeholders, the watershed study incorporates the best available scientific literature and robust stakeholder engagement across local and federal partners. This collaboration between partners and stakeholders was a critical aspect of the study and played a crucial role in shaping the outcomes.

This watershed study report is not a project implementation document. The level of detail is at a scale adequate for making watershed-level resource assessments and recommendations. Specific projects identified for potential implementation under existing authorities of USACE (e.g., review of existing projects for sediment management) require separate interim reports to specify project features, include detailed engineering information, and appropriate NEPA documentation.

The prioritized list of recommendations addresses the problems, explores the opportunities, and meets the study objectives. This watershed study can be used with other relevant studies and efforts to initiate further studies or projects meeting the priorities and greatest needs in the basin.

EX.9.1 Potential for Federal Interest

The potential for federal interest in risk reduction measures and strategies benefiting multiple areas in the basin is promising with many measures being multipurpose. The problems and issues addressed exist throughout the basin. Recommendations solving the problems and issues related to the reduction in ability to meet water supply demands, degraded or poor water quality, and loss of recreation opportunities also provide benefits for flood risk and ecosystem restoration and support solutions having comprehensive benefits.

Recommendations to address water resource problems and opportunities require intentional action and a substantial investment of time and funding by Federal, State, and local entities. The challenges of studying, planning, and implementing a suite of

projects of the magnitude for the basin requires that projects are implemented in phases, based on where the needs are most urgent and where there is consensus and support for implementation among State, regional, and local groups; Tribes; and the Federal government.

The State of Kansas is committed, in partnership with stakeholders, local and regional groups, Tribes, and the Federal government, to continue making investments in water resources infrastructure, innovation, and research. The most recent state legislative bill passed fully funds the Kansas State Water Plan and represents a significant increase in funding to protect essential water resources. The bill funds technical assistance supporting municipalities and other units (i.e., watershed districts), provides water project grant funds for construction and upgrades to water infrastructure projects, and funding for high priority water projects in the state.

Several of the recommendations for this watershed study including collaboration between the State of Kansas and USACE Kansas City District (NWK) were initiated during the development of recommendations. These projects are considered a high priority and described in Section 6, Conclusions.

These new initiatives are in addition to the many ongoing efforts by State, regional, local, Tribal, and Federal entities discussed in Section 1.7, Plans, Programs, Studies, and Reports. Existing authorities and programs described in Section 1.7 will be utilized, when possible, to implement recommendations.

It is critical that State, regional, local, Tribal, and Federal entities work together to strategically plan and implement the needed projects in order to promote efficiency and effectiveness, and to take advantage of synergies, where possible.

EX.9.2 Additional Considerations

The federal reservoirs and their associated multipurpose storage, owned and operated by USACE in the Kansas River Basin, provide substantial economic benefits to the local, regional, and national economy from water supply, recreation, fish and wildlife, and water quality. The Kansas River Basin USACE reservoirs serve as a critical drinking water supply for more than 600,000 people in addition to being used for irrigation, municipal wastewater and industrial discharges, and power generation. There are significant water resource challenges that must be met over the short- and long-term in the Kansas River Basin. The federal reservoirs operated by USACE have been asked to meet the multi-purpose needs and values of today’s modern society, including an increased demand for flood risk management benefits to large and small communities, recreation facilities, agricultural areas, an increased demand on water supply, a changing climate, and an increased societal value on protecting and restoring the ecosystem.

Recommendations of this watershed study include those necessary to increase the resiliency and sustainability of the system. The study identifies viable opportunities for investment in critical infrastructure throughout the basin, including the existing reservoirs, to increase their resiliency to provide for water availability and sustainment, ecosystem restoration, water quality, and recreational amenities. With the projected increased demands for the Kansas River basin, potential for more variable future conditions, potential for higher temperatures, winds, higher reservoir evaporation rates,

and uncertainty in future drought frequencies, there is a critical need to implement actions to maintain reservoir storage capacities and increase future water supply security.

The sponsors believe there is shared local and federal interest in improving long-term management of the reservoirs to better sustain the valuable multipurpose storage created with federal authority and funding. Currently, water supply use in USACE reservoirs and sustainment of that storage is a 100 percent local, non-federal partner responsibility. The sustainment of water supply investment that USACE makes available is a matter of Federal interest and could be raised to a level similar to flood risk and navigation. Water supply sources are critical to supporting life and economic activity in the region and the nation, and when considering growing future water supply needs and increasing acute challenges, the sustainment of resources developed under federal authority are strongly in the federal interest. Future water supply in the Kansas River Basin is threatened by loss of multipurpose pool storage in USACE reservoirs and will have high economic, social, and environmental risks. Elevating water supply to a threat level comparable to flood risk is warranted to meet the multipurpose needs and values of today's society.

The State of Kansas established a funding stream and is dedicated to the development of additional funding to support future reservoir sustainability strategies and USACE has an opportunity to partner with the state in evaluating methods to extend the useable lifetimes of USACE projects. The Kansas Legislature invested a substantial amount of state general funds to shore up public water supply programs and the State Water Plan Fund, for investment in water studies and projects. The KWO advises they are ready, willing, and able to pursue cost-shared efforts toward in-lake reservoir sediment management, both for research and development and/or for project implementation.

This consideration could also support creation of a new authority allowing dredging or other measures applied to federal reservoirs through routine operations and maintenance for the purpose of long-term sustainment of the multipurpose pool and its use for water supply and other purposes that are about sustainment of life and economic development affecting the economy regionally and nationally. USACE should take a broader federal interest in reservoir sediment management similar to sediment management currently ongoing to coastal ports and harbors.

EX.9.2.1 Research and Development

The State of Kansas also requests consideration of new GIs or a Continuing Authorities Program that, through the newly established Research and Development account, provides a mechanism for cost sharing with the federal government and non-federal sponsors on research and development (R&D) projects including R&D related to reservoir sustainability and reservoir sediment management. Also, provisions should be made to allow for research and development projects to be components of feasibility studies where that would be useful and viable.

EX.9.2.2 Infrastructure Operations and Maintenance

Water infrastructure in Kansas including dams, levees, reservoirs, treatment plants, distribution lines, etc., were mostly developed 50 to 60 years ago and a large percentage of the facilities need upgrade, repair, or replacement. Reservoirs are filling

with sediment, reducing the ability to store multipurpose pool storage and capture flood waters, and many levees and dams may already be unable to provide the desired or needed level of public safety protection. Significant critical infrastructure including water and wastewater treatment plants, power plants, fire stations, schools, and military installation facilities are located downstream of the reservoirs. Sustaining the ability of federal and state infrastructure projects (or operations) to provide these risk reduction benefits for this infrastructure into the future is crucial as replacement of these facilities with the benefits they provide is for the most part cost prohibitive.

Underfunding of routine operations and maintenance budgets at USACE reservoirs presents significant economic, flood, and environmental risks to areas in the Kansas River Basin. It is anticipated that for flood risk management, future funding of routine operations and maintenance activities at some Kansas River Basin reservoirs will be less than the amount requested to maintain the current level of service which could lead to a reduction in operational capability and performance. The same issue applies to other purposes and sustainment of reservoir multipurpose benefits as a whole.

EX.9.3 Additional Recommendations

Based on the additional considerations the following recommendations are included for consideration in the future.

- Elevate water supply to a priority equivalent to flood risk management and navigation because future water supply needs are growing and challenges in meeting those needs, and the critical nature of water supply in supporting and sustaining life and economic development, continue to mount.
- Establish more flexible and efficient collaboration mechanisms and authorities for USACE to partner with state and other agencies to leverage resources to sustain the water resources benefits provided by USACE reservoirs and other projects where applicable.
- Establish or expand authority or policy to allow for projects at USACE lakes to reduce sediment accumulation for multiple beneficial purposes.

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ACRONYMS AND ABBREVIATIONS

AEP	annual exceedance probability
AICP	American Institute of Certified Planners
ALE	Agricultural Land Easements
ANS	aquatic nuisance species
AOP	annual operating plan
ASA	Assistant Secretary of the Army
ASAP	As Soon as Possible
ATV	all-terrain vehicle
BMPs	best management practices
BRIC	Building Resilient Infrastructure and Communities
CAP	Continuing Authorities Program
CD	conservation districts
CDBG	Community Development Block Grant
CEDBR	U.S. Census and the Center for Economic Development and Business Research
CENWK-EDH-R	U.S. Army Corps of Engineers Kansas City District Engineering Division Hydrology & Hydraulics-River Engineering & Restoration Section
CEQ-CEJST	Council on Environmental Quality's Climate and Economic Justice Screening Tool
CFR	Code of Federal Regulations
CHAT	Climate Hydrology Assessment Tool
CID	Central Industrial District
CL	Clinton Lake
CMIP-5	Coupled Model Intercomparison Project Phase 5
COVID	coronavirus disease
CPE	conservation-pool elevation
CRP	Conservation Reserve Program
CWA	Clean Water Act
CWMS	Corps Water Management System
DOC	Division of Conservation
DOD	Department of Defense
DOI	U.S. Department of the Interior
DSAC	Dam Safety Action Classification
EAP	emergency action plan
EFA	ecological focus area
EGM	Economic Guidance Memorandum
EO	Executive Order
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ER	Engineering Regulation
ERDC	Engineer Research and Development Center
ERP	emergency response plan
ESA	Endangered Species Act
ETL	Engineer Technical Letter
EWN	Engineering with Nature
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FPMS	Floodplain Management Services
FWOP	future without project
FWS	U.S. Fish and Wildlife Service
GAP	GAP Analysis Project
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamics Laboratory
GI	general investigation
GIS	Geographic Information System
GMD	Groundwater Management District
HAB	harmful algal bloom
HAWQS	Hydrologic and Water Quality System
HAZUS	Hazards U.S.
HC	Harlan County Lake
HEC	Hydrologic Engineering Center
HEC-RAS	River Analysis System
HEC-ResSim	Reservoir System Simulation
HMGP	Hazard Mitigation Grant Program
HPMP	Historic Properties Management Plan
HQUSACE	Headquarters, U. S. Army Corps of Engineers
II	habitat suitability index
HUC	Hydrologic Unit Code
HUD	housing and urban development
IEPR	Independent External Peer Review
IG	Inspector General
IGUCA	Intensive Groundwater Use Control Area
IMPLAN	impact analysis for planning

IPAC.....Information, Planning, and Conservation
IWR.....Institute for Water Resources
IWRM.....Integrated Water Resource Management
KA.....Kanopolis Lake
kac-ft.....Million acre-feet
KAWS.....Kansas Alliance for Wetlands and Streams
KDA.....Kansas Department of Agriculture
KDA-DWR...Kansas Department of Agriculture, Division of Water Resources
KDEM.....Kansas Division of Emergency Management
KDHE.....Kansas Department of Health and Environment
KDOT.....Kansas Department of Transportation
KDWP.....Kansas Department of Wildlife and Parks
KFS.....Kansas Forest Service
KGS.....Kansas Geological Survey
KHMT.....Kansas Hazard Mitigation Team
KRPI.....Kansas Reservoir Protection Initiative
KRRFSS.....Kansas River Reservoirs Flood and Sediment Study
KS.....Kansas
KSU.....Kansas State University
KWA.....Kansas Water Authority
KWO.....Kansas Water Office
LAMP.....Levee Analysis Mapping Procedures
LEMA.....local enhanced management area
LiDAR.....light detection and ranging
LLMP.....lake level management planning
LSAC.....Levee Safety Action Classification
LST.....Levee Screening Tool
MASS.....Monitoring, Assessment and Science Section
MBTA.....Migratory Bird Treaty Act of 1918
MDS.....Minimum Desirable Streamflow
MFR.....Memorandum for Record
MI.....Milford Lake
MIROC.....Model for Interdisciplinary Research on Climate
MO.....Missouri
MOA.....Memorandum of Agreement
MOU.....Memorandum of Understanding
MP.....multipurpose
MPP.....multipurpose pool
Map MOD....Flood Map Modernization Initiative
NA.....not applicable
NADA.....Non-detects and Data Analysis
NEDEE.....Nebraska Department of Environmental and Energy
NEPA.....National Environmental Policy Act
NFIP.....National Flood Insurance Program
NFRMP.....National Flood Risk Management Program
NGO.....non-governmental organization
NGPC.....Nebraska Game and Parks Commission
NHPA.....National Historic Preservation Act
NLCD.....National Land Cover Database
NLD.....National Levee Database
NOAA.....National Oceanic and Atmospheric Administration
NRCS.....Natural Resources Conservation Service
NRHP.....National Register of Historic Places
NTU.....nephelometric turbidity unit
NWD.....Northwestern Division (Portland, Oregon)
NWK.....Kansas City District
NWR.....National Wildlife Refuge
NWS.....National Weather Service
OHV.....off-highway vehicle
OK.....Outdoor Kansas
OLS.....Ordinary Least Squares
OMRR&R....operation, maintenance, repair, replacement, and rehabilitation
ORV.....off-road vehicle
OW.....Office of Water
OWPR.....Office of Water Project Review
PAD-US.....Protected Areas Database of the United States
PAH.....polycyclic aromatic hydrocarbons
PAL.....Provisionally Accredited Levee
PAR.....population at risk
PAS.....Planning Assistance to States
PC.....personal computer
PCB.....polychlorinated biphenyls
PCX.....Planning Center of Expertise
PDF.....portable document format
PDM.....Pre-Disaster Mitigation
PDT.....Project Delivery Team
PE.....Perry Lake

PEC	probable effect concentration
PET	potential evapotranspiration
PLJV	Playa Lakes Joint Venture
PM	Project Manager/Management
PMP	Project Management Plan
POR	period of record
PRB	Project Review Board
PWP	project work plan
QA/QC	Quality Assurance/Quality Control
QAPP	quality assurance project plan
QMP	Quality Management Plan
QZAP	Quagga Zebra Mussel Action Plan for Western Waters
RAC	Regional Advisory Committee
RBL	regulatory baseline survey
RCP	representative concentration pathway
RCPP	Regional Conservation Partnership Program
RCR	river complexity ratio
RECONS	Regional Economic System
RFC	Repetitive Flood Claims
RIT	Regional Integration Team
RM	river mile
RPA	Regional Planning Area
RQEI	Riparian Quality Enhancement Initiative
RR	release rate
RSM	Regional Sediment Management
RT	residence time
RV	recreational vehicle
RWD	rural water district
Rec-BEST	Recreation Budget Evaluation System
Risk MAP	Risk Mapping, Assessment, and Planning
SBWG	Sediment Baseline Work Group
SD	standard deviation
SE	standard error
SGCN	Species of Greatest Conservation Need
SHMP	State Hazard Mitigation Plan
SHPO	State Historic Preservation Officers
SINC	Species in Need of Conservation
SK	Seasonal Kendall
SMART	Specific Measurable Attainable Risk
SNRI	Sediment and Nutrient Reduction Initiative
SOP	standard operating procedures
SQC	sediment quality guidelines
SRP	sustainable rivers project
SWAP	Kansas Wildlife Action Plan
SWAT	Soil and Water Assessment Tool
TC	Tuttle Creek Lake
TEC	threshold effect concentration
TEL	threshold effect level
THPO	Tribal Historic Preservation Officers
TKN	Total Kjeldahl
TMDL	Total Maximum Daily Load
TN	total nitrogen
TNC	The Nature Conservancy
TP	total phosphorus
TSI	Trophic State Index
TSS	total suspended solids
TWIP	Topographic Wetland Identification Process
UDV	unit day value
USACE	U. S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USC	United States Code
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
VERS	Visitation Estimation and Reporting System
VT	Vertical Team
Vision	Vision for the Future of Water Supply in Kansas (2015)
WARP	Wetland and Riparian Protection
WCA	water conservation area
WCFMP	Wildcat Creek Floodplain Management Plan
WCM	water control manual
WI	Wilson Lake
WID	water injection dredging
WLMP	Water Level Management Plan
WPDG-11	Wetland Protection and Development 2011
WPP	Wetland Program Plan
WQ	Water Quality
WRAPS	Watershed Restoration and Protection Strategy
WRC	Water Resources Council
WRDA	Water Resources Development Act
WTAP	Water Transition Assistance Program Watershed Study Kansas River Reservoirs Flood and Sediment Study
YOY	young of the year

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1.0 INTRODUCTION AND BACKGROUND

The Kansas River Reservoirs Flood and Sediment Study (watershed study, KRRFSS) is a collaborative effort between the U.S. Army Corps of Engineers (USACE) and the State of Kansas including the Kansas Water Office (KWO) and the Kansas Department of Wildlife and Parks (KDWP).

The Kansas River Basin (the basin) supplies drinking water to more than 600,000 people and is used for irrigation, municipal wastewater and industrial discharges, power generation, and as a source of commercial sand and gravel. In addition to flood risk reduction benefits from the reservoirs (more than $35 billion (B) in flood damages prevented by USACE and U.S. Bureau of Reclamation (USBR) projects in the basin since construction through 2022), federal levee projects located on the banks of the Kansas River provide flood risk reduction benefits ($1B in flood damages prevented in the basin since construction through 2022), mainly to larger urban areas such as Manhattan, Topeka, and Kansas City, Kansas. Recreation in the basin (boating, kayaking, camping, picnicking, fishing, swimming, hunting, wildlife viewing, etc.) substantially benefits the local, regional, and national economy. Kansas River fish populations provide quality, unique, and diverse fishing opportunities throughout the study area. Decades of sportfish management, monitoring, and research led to fisheries that are highly sought after by anglers, not only locally and statewide, but also regionally and nationally. The Kansas River, its tributaries, and their floodplains consist of terrestrial and aquatic habitats sustaining wide assemblages of fish and wildlife species. These assemblages include species living year-round in waters and on the floodplain and migratory species for which the ecosystem provides vital seasonal habitat (e.g., wintering and breeding), movement corridors, and stopover habitats.

Currently the basin land use is a mixture of agricultural (e.g., cropland and pasture/hay), urban developed areas (high, medium, and low density—which includes Junction City, Manhattan, Topeka, Lawrence, and Kansas City, Kansas), grasslands, forested lands, transportation corridors, and extensive water bodies (lakes, rivers, ponds, and wetlands). The basin is about 85 percent privately owned (USGS 2018). The States of Kansas, Nebraska, and Colorado own 1 percent of the land, the Federal government owns 12 percent of the land, local governments own less than 1 percent of the land, and other entities (e.g., non-governmental agencies) own less than 1 percent of the land (USGS 2018).

1.1 Background

The basin includes 18 federal reservoirs, 12 in the State of Kansas, 5 in Nebraska, and 1 in Colorado (Tables 1-1, 1-2, and 1-3). The dams at these reservoirs regulate 85 percent of the drainage area in the basin, and the reservoirs supply flood damage risk reduction to major population centers along the Kansas River such as Manhattan, Topeka, Lawrence, and Kansas City, and flood damage risk reduction and navigation flow support to communities along the Missouri River.

Table 1-1. Republican River Basin Water Management Projects

Water Management Project	Basin or Stream	Operating Agency
Bonny Dam, Colorado	South Fork Republican River	USBR
Trenton Dam (Swanson Lake), Nebraska	Republican River	USBR
Enders Dam, Nebraska	Frenchman Creek	USBR
Red Willow Dam (Hugh Butler Lake), Nebraska	Red Willow Creek	USBR
Medicine Creek Dam (Harry Strunk Lake), Nebraska	Medicine Creek	USBR
Norton Dam (Keith Sebelius Lake), Kansas	Prairie Dog Creek	USBR
Harlan County Dam, Nebraska	Republican River	USACE, NWK
Lovewell Dam, Kansas	White Rock Creek	USBR
Milford Dam, Kansas	Republican River	USACE, NWK

Table 1-2. Smoky Hill River Water Management Projects

Water Management Project	Basin or Stream	Operating Agency
Kanopolis Dam, Kansas	Smoky Hill River	USACE, NWK
Glen Elder Dam (Waconda Lake), Kansas	Solomon River	USBR
Wilson Dam, Kansas	Saline River	USACE, NWK
Cedar Bluff Dam, Kansas	Smoky Hill River	USBR
Webster Dam, Kansas	South Fork Solomon River	USBR
Kirwin Dam, Kansas	North Fork Solomon River	USBR

Table 1-3. Lower Kansas River Water Management Projects

Water Management Project	Basin or Stream	Operating Agency
Clinton Dam, Kansas	Wakarusa River	USACE, NWK
Perry Dam, Kansas	Delaware River	USACE, NWK
Tuttle Creek Dam, Kansas	Big Blue River	USACE, NWK

The watershed study team investigated water resource issues and opportunities in the basin and are recommending comprehensive, long-term solutions based on a shared vision for the basin. Herein, the study makes long-term recommendations for potential involvement by USACE, other federal agencies, and non-federal interests. The watershed study integrates water and related land resource management considerations, seeking sustainable water resource management and making additional considerations. Ultimately, the watershed study informs multiple stakeholders and decisionmakers at all levels of government and provides a strategic roadmap toward future investment decisions by multiple agencies. Significant needs and opportunities exist in the areas of sediment management, flood risk management, water supply availability and sustainment, and related purposes, such as ecosystem restoration, navigation, and recreation. This integrated watershed study focuses attention on significant objectives and tradeoffs, accounts for uncertainty, and promotes adaptive

management, stakeholder collaboration, and systems analysis for watershed-scale planning and evaluation.

The watershed study builds from the extensive research, planning, outreach, and documentation in the Kansas Water Plan (KWO 2022) and Vision for the Future of Water Supply in Kansas (KWO 2015)—hereafter referred to as Vision. The Kansas Water Plan is a primary tool used by the State of Kansas to address current water resource issues for future needs. KWO, in coordination with local, state, federal and interstate partners, updates the Kansas Water Plan as conditions allow. Water resource issues addressed in the Kansas Water Plan extend beyond water supply and include goals and priorities, such as improving the state's water quality and improving recreational opportunities available to citizens. The Vision guides the Kansas Water Plan, which provides five-year milestone events to measure success towards achieving the goals stated in Vision.

This report presents current findings and recommendations for future efforts, including potential future projects and studies in which USACE could partner with the State of Kansas (hereafter referred to as State), sister Federal agencies, and non-Federal entities.

This report is not a project implementation document. The level of detail is at a scale adequate to make watershed-level resource assessments and recommendations. If specific projects are identified for potential implementation under existing USACE authorities (e.g., review of existing projects for sediment management), separate decision documents or interim reports will be required to specify project features, include detailed engineering information, and inform appropriate National Environmental Policy Act (NEPA) documentation.

1.2 Authority

The watershed study is authorized by Resolution of the Senate Committee on Environment and Public Works, Kansas River and Tributaries, May 23, 2006, and Section 729 of the Water Resources Development Act (WRDA) of 1986, as amended (33 U.S.C.§2267a). Section 729 allows USACE to study the water resources needs of river basins and regions of the United States. In carrying out these studies, USACE is authorized to consult with and accept contributions from federal, state, tribal, interstate, and local government entities. The study is authorized at $3 million (M) and requires a 75 percent Federal/25 percent non-Federal cost share agreement.

1.3 Watershed Planning Guidance

USACE Engineering Regulation (ER) 1105-2-102 provides watershed planning guidance and is briefly reviewed in this section. The USACE watershed studies use an Integrated Water Resource Management (IWRM) strategy providing a holistic focus on water resource challenges and opportunities reflecting coordinated management of water resources. The IWRM principles include focused attention on multiple objectives and tradeoffs and better accounting for uncertainty, and requires adaptive management, stakeholder collaboration, and systems analysis for watershed-scale planning and evaluation.

Watershed studies use specific, measurable, attainable, risk-informed, and timely planning principles. Project delivery teams (PDTs) incorporate critical thinking, risk-informed decision-making, and early and frequent team engagement throughout the watershed study process.

Key components of an effective watershed planning process consistent with the interactive six-step USACE planning process include:

1. Identifying problems and opportunities
2. Inventorying and forecasting
3. Identifying and screening measures
4. Formulating an initial array of strategies
5. Refining an initial array of strategies and evaluating a focused array of strategies
6. Comparing strategies and selecting.

Watershed studies recommend actions to solve identified problems. Conclusions and recommendations should have broad implications for decision makers at all levels of government. The recommendations should provide a strategic roadmap identifying the sequencing of priorities, including where federal authorities and appropriations are available, and where new ones may be needed.

Watershed studies are not project implementation documents. The level of detail is adequate for making watershed-level resource assessments and recommendations. If specific projects are identified for potential implementation under existing USACE authorities (e.g., flood damage reduction or ecosystem restoration), separate decision documents describe specific project features and include detailed engineering and NEPA documentation.

This watershed study presents findings and recommendations for future efforts including potential future projects and studies in which USACE could partner with the State, sister agencies, and other non-federal entities. Watershed studies are completed in a single phase and include three milestones: shared vision, recommendations, and final report.

1.4 Non-federal Sponsor Support

The watershed study is a collaborative effort between the USACE and the State (through the KWO and KDWP). The watershed study incorporates the state's ongoing planning efforts and leverages, as appropriate, state agencies' planning and investigation capabilities where state program efforts become part of the cost share match and state agency capabilities and resources meet specific scoped elements for the watershed study in a cost-effective and timely manner.

Appendix L Letters of Support documents non-federal sponsor support of this report's recommendations.

1.5 Partners and Stakeholders

The study process involves broad stakeholder engagement with representation from federal, state, and local agencies, and organizations. This collaboration between partners and stakeholders is a critical aspect of the study and plays a crucial role in shaping the outcomes.

USACE worked in collaboration with federal and state agencies, community/local governments and groups, and stakeholders to develop the watershed study. In accordance with Section 202 of WRDA of 2000 (P.L.106-541), as amended, cooperation letters (Appendix I) were sent to the:

- USBR, Nebraska-Kansas Area Office
- United States Environmental Protection Agency (EPA), Region 7
- U.S. Fish and Wildlife Service (FWS) Kansas, Nebraska, and Colorado Field Offices
- U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS)
- United States Department of the Interior
    - National Park Service (NPS) Regions 3, 4, and 5
    - U.S. Geological Survey (USGS) Kansas Water Science Center
- United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)
    - National Centers for Environmental Information (NCEI), Central Region Climate Services
    - National Weather Service (NWS).

Additionally, coordination letters (Appendix I) were sent to:

- Kansas, Nebraska, and Colorado State Historic Preservation Officers
- Kansas Department of Health and Environment (KDHE)
- Nebraska Game and Parks Commission (NGPC)
- Affiliated Tribes: Apache Tribe of Oklahoma, Cheyenne and Arapaho Tribes of Oklahoma, Cheyenne River Sioux Tribe Preservation Office, Comanche Nation, Crow Creek Sioux Tribe, Delaware Nation, Flandreau Santee Sioux Tribe, Fort Sill Apache Tribe, Iowa Tribe of Kansas, Northern Cheyenne Tribe, Ogalala Sioux Tribe, The Osage Nation, Jicarilla Apache Nation, Kaw Nation, Kickapoo Tribe of Kansas, Kiowa Tribe of Oklahoma, Mescalero Apache Tribe, Miami Tribe of Oklahoma, Otoe-Missouria Tribe, Pawnee Nation of Oklahoma, Ponca Tribe of Oklahoma, Prairie Band Potawatomi Nation, Rosebud Sioux Tribe, Sac and Fox Nation of Missouri in Kansas and Nebraska, Santee Sioux Nation, Wichita and Affiliated Tribes, Wyandotte Nation, and Yankton Sioux Tribe.

Partner and stakeholder involvement was a cornerstone for the development of the watershed study, and many participants were invited and encouraged to participate throughout all stages of the planning process and report development. Other agencies and stakeholders participating in various pieces include:

- State Agencies/Organizations: Kansas Water Authority (KWA), Kansas Department of Agriculture (KDA), Kansas Forestry Service, Kansas Department of Emergency Management, and Kansas Hazard Mitigation Team (KHMT)

- Community/Local: City of Manhattan, Kansas; City of Lawrence, Kansas; City of Topeka, Kansas; City of Olathe, Kansas; City of Phillipsburg, Kansas; Wilson Lake Association; Kansas Rural Water District Number 1; Kansas Rural Water Association; Kansas Farm Bureau; Water One; Smoky Hill Access District; and Post Rock Rural Water District
- Other: Kansas State University (KSU), Kansas University, Kansas Watershed Restoration Protection Strategy (WRAPS), Friends of the Kaw, Kansas Alliance for Wetlands and Streams (KAWS), State Association of Kansas Watersheds, Regional Advisory Committees (Kansas, Smoky Hill-Saline, Solomon-Republican), Ducks Unlimited, The Nature Conservancy, Kansas Biological Survey, Bowersock Mills and Power Company, and Thunderbird Marina.

1.6 Study Collaboration

Meetings with project partners and key stakeholders were held throughout the duration of the watershed study including small group workshops, public meetings, special interest group meetings, and collaboration with Watershed Study Advisory Committee. Partner and stakeholder meetings were used to achieve the following:

- Determine study scope
- Develop shared vision statement
- Determine and validate problems and opportunities in the Kansas River Basin
- Develop an initial array of measures, strategies, and recommendations
- Refine, validate, and prioritize measures, strategies, and recommendations
- Assess risk associated with focus areas and problems and stressors and evaluate uncertainty related to solutions to address risk
- Seek input from subject matter experts
- Provide opportunities for stakeholder input.

During the kickoff and scoping phase of the project, one small group workshop, four public meetings, and many one-on-one conversations were held discussing the scope of the study and drafting the shared vision statement (Appendix I).

A small group workshop was held during scoping in November 2019 with more than 40 participants from different agencies, organizations, and interest/stakeholder groups. The purpose of the workshop was to gather and exchange information and to hear specific ideas, concerns, and opinions from a group of diverse interests and stakeholders across the basin and to ensure the values of stakeholders and the public are incorporated into the watershed study. The desired outcomes included identification of the scope of various goals and objectives of individual stakeholders and issues and problems occurring in the basin. Participants were asked to describe issues in their community or area of interest that exist or could emerge within the next 50 years. They were also asked to describe why the issues are important and how they would prioritize the water-related issues. Ideas were discussed for six different focus areas including flood risk management, sediment management and reservoir sustainability, water supply and drought, water quality, recreation, and ecosystem restoration and management (see Appendix I).

During scoping in December 2019, four public meetings were held within the basin in the Kansas cities of Manhattan, Ellsworth, Junction City, and Perry. The public scoping meetings, as did the previous month's small workshop, provided for an exchange of information and airing of specific ideas, concerns, and opinions from the public across the basin ensuring the values of the public are incorporated into the watershed study. The format of each meeting was open-house, come-and-go style. Presentations were given at each meeting discussing the study background, basin facts, problems in the basin, the shared vision statement, opportunities, study scope, study focus areas, potential strategies/alternatives, outreach and public involvement, study outcomes, and the study timeline. Various information stations with poster boards and banners were available for attendees to view. Poster boards and banners included information related to study background, basin facts, problems in the basin, the shared vision statement, opportunities, study scope, study focus areas, potential strategies/alternatives, outreach and public involvement, study outcomes, and the study timeline. Staff from the study partners were available at the various information stations to answer questions and provide additional information to meeting attendees. Handouts were also available for attendees, including a study brochure and basin maps (see Appendix I).

During the identification of measures, another small group workshop was held in January 2021 with more than 40 participants from different agencies, organizations, and interest/stakeholder groups. This second workshop built on the information obtained during the first small group workshop held in November 2019 related to problems and issues. The purpose of the workshop was to gather and exchange information and to hear specific ideas, concerns, and opinions from a group of diverse interests and stakeholders across the basin and to ensure the values of stakeholders and the public are incorporated into the watershed study. The desired outcomes included:

- Refinement of the working draft measures and strategies and identification of new measures and strategies recommended by individual stakeholders addressing the issues and problems identified and helping meet the study goals and objectives.
- Identification and refinement of measures and strategies related to water supply and drought, sediment management and reservoir sustainability, flood risk management, ecosystem restoration management, and recreation.

Participants were asked to provide ideas for new measures addressing specific problems and issues and to think about locations or opportunity areas for proposed measures in the basin. Ideas were discussed for six different focus areas including flood risk management, sediment management and reservoir sustainability, water supply and drought, water quality, recreation, and ecosystem restoration and management (see Appendix I).

A planning charette was held in March 2021 with members of the USACE Vertical Team (Northwestern Division [NWD], Headquarters USACE Regional Integration Team, Headquarters USACE Office of Water Project Review); USACE Flood Risk Planning Center of Expertise; study non-federal sponsors (KWO, KDWP); and USACE, Kansas City District (NWK) staff. The purpose of the charette was to bring together the watershed study PDT members from NWK, KWO, KDWP, and the USACE Vertical

Team to discuss the working draft measures and strategies and to hear specific concern and opinions ensuring they capture the breadth of interests and support the shared vision statement for the study. The charette was also an opportunity to discuss the screening criteria the study team will use to ensure measures and strategies contribute towards meeting the planning objectives. Major discussion points included problems facing the basin in the next 50 years, the study scope, the shared vision, FWOP, and measures and strategies (Appendix J).

During the screening of measures and evaluation and selection of draft recommendations a series of six charette style workshops were held from January through March 2023 to conduct a risk assessment to support identification and prioritization of recommendations for each problem area (i.e., flood risk, sedimentation, reduction in the ability to meet water supply demands, degraded/poor water quality, ecosystem degradation and species impacts, and loss of recreation) (Appendix J). Participants included PDT members from USACE, KWO, and KDWP and subject matter experts for each problem area. A larger workshop was conducted in June 2023 to review the rollup of the risk assessment and to discuss the uncertainty of solutions to address the risks and stressors evaluated. The workshop provided validation of initial draft recommendations and their prioritization (i.e., near-term/immediate versus long-term/incremental) (Appendix J). Participants from the initial six charette style workshops attended as did members of the Watershed Study Advisory Committee. The results of the risk assessment and uncertainty evaluation are summarized in Section 4, Risk Assessment and Uncertainty Evaluation.

Numerous special interest group and key stakeholder engagements were conducted throughout the shared vision and the recommendations milestone phases of the watershed study. During these engagements participants discussed ongoing efforts in the basin, needs for collaboration and funding, specific issues related to various problem areas, and ideas related to measures to minimize risk. The study team provided regular briefings to decision makers (e.g., KWA, Regional Advisory Committees, KHMT, Rural Water Districts, Advisory Committee) in the basin at key points of the watershed study for sharing and discussion of key information.

Information from the many different meetings including problems and issues, stressors, opportunities, risk and uncertainty, and identification of measures and strategies is incorporated in discussions throughout the report.

1.7 Plans, Programs, Studies, and Projects

Plans, programs, studies, and projects from past and current efforts by various agencies and organizations are summarized in the sections below.

1.7.1 System Operating Plans

USACE operates the three river systems in the basin in accordance with the policies and procedures prescribed in the Lower Kansas River Basin Reservoir Regulation Manual, Master Manual (USACE 1966); the Republican River Basin Reservoir Regulation Manual, Master Manual (USACE 1977); and the Smoky Hill River Basin Lake Regulation Manual, Master Manual (USACE 1974) (hereafter referred to as Master Manuals). These Master Manuals record the basic water control plans and

objectives for the integrated operation of the reservoirs. The reservoir stage and flow releases vary throughout the year because of reservoir operations that follow these Master Manuals and the individual reservoir water control manuals (WCMs). The Master Manuals describe the water control plans, which consists of the water control criteria for the management of the basin for the full spectrum of anticipated runoff conditions that could be expected to occur. Annual Water Management Plans (Annual Operating Plans [AOPs]) are prepared each year, based on the water control criteria contained in the Master Manuals, to detail reservoir regulation of the systems for the current operating year. Because the basin is so large, it can respond to extreme conditions of longer than one-year in duration. AOP documents also provide an outlook for planning purposes in future years.

For a portion of some years, deviations may be made from the specific technical criteria stated in the Master Manuals to achieve the operational objectives of the current water control plan or to comply with other statutory or regulatory obligations such as the Endangered Species Act (ESA). In such circumstances, the AOP explains the deviation from the specific technical criteria and the rationale for that deviation related to the operational objectives or applicable statutory or regulatory requirements. All significant deviations from the current water control plan are coordinated and approved by the NWD commander. All deviations of significance are modeled and presented to the public through the normal coordination procedures involving public press releases and online dissemination. Minor deviations are accomplished by Missouri River Basin Water Management through coordination directly with the affected parties.

Basin interests can anticipate continued public involvement in the water control management process and any significant water control plan or Master Manual revisions in the future will be processed in accordance with ER 1110-2-240 (USACE 2016a). Changed circumstances or unforeseen conditions may necessitate short-term deviations from the current water control plans. As stated, such deviations are reviewed and approved by the NWD commander in accordance with ER 1110-2-1400 (USACE 2016b).

Each USACE and USBR reservoir operates for specific congressionally-authorized purposes and has a WCM detailing the rules and regulations specific to each reservoir. Section 3.2, Reservoirs and River Infrastructure, Operations, and Hydrologic Processes, summarize the main rules used to regulate releases in both flood control and multipurpose pools.

The following list of documents and resources provides data on reservoir properties and operating rules for the federal reservoirs in the basin.

- Tuttle Creek Water Control Manual (USACE 1973a)
- Harlan Water Control Manual (USACE 1973b)
- Clinton Water Control Manual (USACE 1979)
- Kanopolis Water Control Manual (USACE 1984a)
- Wilson Water Control Manual (USACE 1983)
- Milford Water Control Manual (USACE 1984b)

- Perry Water Control Manual (USACE 1984c)
- The Cedar Bluff Unit (USBR 1998)
- Glen Elder Unit (USBR 2001)
- Kirwin and Webster Projects (USBR 1996)
- Bostwick Division (USBR 2009)
- The Webster Unit (USBR 1995).

1.7.2 Kansas Water Plan

The Kansas Water Plan is the long-term strategic plan for sound management and development of water resources in Kansas. With updates every five years, the Kansas Water Plan reaffirms the State's commitment to integrated water management.

The Kansas Water Plan (KWO 2022) considers:

- The management, conservation, and development of the water resources of the State of Kansas for the benefit of the state as a whole
- The benefits to be derived from development of reservoir sites for the combined purposes of flood control, water supply storage, and recreation
- The safeguards to public health, aquatic, and animal life established in Kansas law and the Kansas water quality management plan
- Water development policies, whenever possible, consistent with the beneficial development of other natural resources
- The public health and general welfare of the people of Kansas
- All appropriation and other rights to the use of water pursuant to the Kansas Water Appropriation Act and the State Water Plan Storage Act
- The interrelationship of groundwater and surface water supplies and the effects of evapotranspiration on water supply
- The alternative plans, programs, and projects in the interest of effective water resource management, conservation, and development
- The means and methods for the protection of aquatic and other wildlife
- The use of waters to augment the flow of surface streams for the support of aquatic and other wildlife and to improve the water quality of the stream and to protect the public health
- The inclusion of conservation storage in reservoir development and planning for the regulation of streamflow for the purpose of quality control, such inclusion not to serve as a substitute for methods of controlling wastes at their sources
- The maintenance, preservation, and protection of the sovereignty of the state over all the waters within the state
- Plan, projects, and recommendations of public corporations, the federal government and state agencies prepared pursuant to statutory authority
- Plans, recommendations, and projects of private associations or organizations as they relate to the water resources of the state

- The need of the state to control storage in federal reservoirs by purchase or agreement
- Other matters the KWO deems proper or desirable.

The Kansas Water Plan (KWO 2022) has five guiding principles providing the foundation and framework for addressing water issues in Kansas identifying the overarching challenges and the steps needed to meet those challenges.

7. Conserve and Extend the High Plains Aquifer—The High Plains Aquifer serves as the primary water supply for much of central and most of western Kansas. The Ogallala Aquifer within the High Plain Aquifer is the most severely depleted, with some areas already effectively dry in terms of economic feasibility. All water users need to adopt practices using less groundwater if the populations and economies are to remain viable. A variety of state and federal entities are charged with the duty to help implement water conservation efforts within the region. These entities assist producers through cost-share and incentives programs, conservation and environmental programs, and education and outreach efforts. The Kansas Water Plan (KWO 2022) includes a set of actions and strategies recommended; describes data, research, and study needs; and funding/resource needs to support each of the guiding principle.
8. Secure, Protect, and Restore Our Kansas Reservoirs—Reservoirs in the state and in the basin serve to protect the public interest and facilitate multiple diverse beneficial uses. Water users in the basin are dependent on federal reservoirs to maintain streamflow for downstream diversions, maintaining sufficient water quality for human use, and providing drought resiliency. For many communities in the basin, the reservoirs are the only source of water through periods of prolonged drought. The federal reservoirs in Kansas serve as a critical drinking water supply for more than 600,000 people in addition to being used for irrigation, municipal wastewater and industrial discharges, power generation, and a source of commercial sand and gravel. Sedimentation is a critical issue in these reservoirs, in some cases severely reducing storage capacity. Tuttle Creek Reservoir, one of the largest reservoirs which serves users throughout the basin, is currently at 51 percent of its original capacity due to sedimentation. Future conflicts may arise where the amount of water able to be retained in reservoir storage will be insufficient to meet the demands of multiple user groups and an inability to supply adequate amounts of water for anticipated future uses. Other challenges include harmful algal blooms (HABs) that threaten public health and create the risk of not meeting contractual financial obligations that the State carries for storage and local use of water in the federal reservoirs. HABs that cause restricted use and/or closure of reservoirs negatively impacts municipal, industrial, and recreational activities in and around a reservoir. The Kansas Water Plan (KWO 2022) identifies reservoir data and research support needed to:
    - Identify and implement innovative strategies to reduce flooding and damage reduction

- Utilize new technologies to conduct remote sensing and transfer information more efficiently
- Better quantify the sedimentation issue through updated reservoir bathymetric surveys and surface water monitoring where feasible
- Gauge and identify if the reservoirs are losing storage capacity at rates as initially projected and potential changes to these rates from behavioral changes within the watersheds
- Identify impacts of large-scale climatic events, such as extreme flood events.

9. Improve the State's Water Quality—KDHE is the primary agency in the State of Kansas responsible for assessing and managing water quality, with other agency partners also participating. Water quality issues affect surface waters and groundwater in the watershed. KDHE administers the WRAPS program, a framework engaging citizens and other stakeholders in a teamwork environment aimed at protecting and restoring Kansas watersheds. Innovative water reuse programs are also demonstrating the economic and environmental benefits of repurposing water as compared to sole reliance on single-use supplies. To address some of the water quality concerns in the basin, multiple agencies and non-governmental organizations (NGOs) collaborate to provide viable management tools and to promote best management practices (BMPs). These could include practices such as vegetative riparian buffers, wetlands, nutrient management plans, crop rotation, cover crops and vegetative buffer strips, along with many others that have demonstrated a reduction in surface runoff.
10. Reduce Our Vulnerability to Extreme Events—Extreme events, such as droughts and floods, are expected to become more intense and less predictable under climate change. From 1980 to 2021, 6 flood and 17 drought events resulted in billion-dollar disaster events in Kansas. Flood risk is expected to increase in the future due to climate change and population growth with risk possibility occurring in impoverished communities. Employing state of the art science and technology is imperative to securing a safe, secure water supply. Municipal conservation plans, public water supply emergency response plans (ERPs), and proper reservoir management in partnership with the Federal Government are among the essential tools and strategies to prepare for, and respond to, extreme events. During flood events, not only are life safety and property damages a concern, water utilities can become vulnerable to flood events due to their proximity to surface waters and water treatment plants may be compromised by a blockage or loss of power. Wastewater systems can also be overwhelmed by stormwater entering municipal sewer systems or overtopped by floodwater. Real-time information on weather, streamflow, reservoir storage, levee integrity, and other items is important for informing emergency operations. Communication using well-developed procedures between agencies, emergency responders, government officials, utility providers, and the general public is crucial. Measures supporting adapting to changing conditions and minimizing harm from severe droughts is vital for water resource management and agriculture in the basin. Maximizing conservation practices (e.g., increasing soil health practices) and efficient water use during a drought is critical. Drought puts a strain on

communities, businesses, industries, agriculture, and wildlife which can cause severe economic and social impacts. Vulnerability assessments and adaptive planning are critical to understanding how and when extreme events are likely to occur and to creating policies and plans for preventing as much damage as possible.

11. Increase Awareness of Kansas Water Resources—The importance of increased education and awareness during the water planning process was highlighted during the 2022 update to the Kansas Water Plan (KWO 2022). When the public is aware, concerned, and engaged, there is a greater likelihood of successful outcomes. This guiding principle represents an opportunity to build upon and maximize the many successful education organizations and activities currently in place in Kansas and to fill gaps to improve the knowledge and awareness of water and water-related issues. Outreach and awareness techniques could include providing outreach events and opportunities for public involvement, integrating water conservation in academic curriculum at all levels, and implementing a social marketing campaign statewide. The Kansas Runs on Water marketing campaign was introduced to achieve this goal.

The state of Kansas has 14 regional planning areas (RPAs) (Figure 4-1) represented by Regional Advisory Committees (RACs) made up of groups of local stakeholders from varied local water-related interests. The charge of these committees is to identify and prioritize goals to address water needs in their respective areas and to develop regional action plans to meet these goals. The Kansas Water Plan includes a section for each RPA that presents background (e.g., climate, land use, major rivers and streams, reservoirs, groundwater) and demographic information (e.g., population and economy) for each area and discussions of issues related to the guiding principles affecting each region. The basin includes five RPAs—the Kansas, Solomon-Republican, Smoky Hill-Saline, Upper Republican, and Upper Smoky Hill RPAs.

1.7.3 Kansas Wildlife Action Plan

The Kansas Wildlife Action Plan (SWAP) (Rohweder 2015) is the principal document guiding conservation of Kansas' rich wildlife diversity. The SWAP is an adaptive document that guides KDWP and conservation partners in planning and implementation of conservation measures to address priority issues and actions. The SWAP is a habitat-based plan beginning with the consideration of species. The SWAP develops geographically explicit areas ecological focus areas (EFAs) to address conservation issues representing landscapes where conservation actions can be applied for maximum benefits to all Kansas wildlife. The SWAP also identifies statewide issues. Conservation actions are proposed for each EFA in the SWAP and include actions related to land/water protection (e.g., acquiring riparian corridor); land/water management (e.g., promoting restoration of stream channels through natural stream design); education and awareness (e.g., conducting rigorous, quantifiable wildlife surveys focused on species/habitat relationships, population demography, and community dynamics); external capacity building (e.g., working with neighboring states to gain compliance of interstate compacts in regards to water rights); livelihood, economic, and other incentives (e.g., providing incentives to private landowners to

preserve native habitats); and species management (e.g., propagating imperiled species for reintroduction and population augmentation efforts)(see Rohweder 2015).

1.7.4 Kansas Hazard Mitigation Plan

The state of Kansas made a commitment to develop and implement a statewide mitigation program to eliminate or minimize vulnerabilities from natural, technological, and societal hazards. The statewide program is intended to encompass actions by the State of Kansas as well as local governments. Only through a comprehensive, coordinated effort at all levels can the communities of Kansas become resilient to the effects of future disasters. To head up this effort, the KHMT, a cooperative group of representatives of state agencies and other interested parties involved in mitigation, was established in the 1990s to develop and coordinate implementation of a statewide hazard mitigation program.

The KHMT assesses hazard mitigation needs, develops and implements statewide hazard mitigation policies, promotes coordination of mitigation programs at all levels of government, and pursues alternate mitigation funding strategies. The KHMT has the following responsibilities:

- Develop and maintain an effective statewide Hazard Mitigation Program involving all levels of government, encouraging government officials to continually strive to promote hazard mitigation, and developing disaster cost-reduction activities
- Determine the capabilities of each state and federal agency to address various hazards including the legal authority of each agency and the programs and funding sources available to address mitigation activities
- Participate actively in the development, implementation, and maintenance of a comprehensive State Hazard Mitigation Plan, with the support of the Division of Emergency Management, Adjutant General's Department
- Designate teams to focus on researching, developing, and reviewing specific policies or processes of various hazard mitigation aspects
- Coordinate all hazard reduction programs, objectives, and procedures to carry out these objectives through:
    - Coordinating strategies to further common program objectives
    - Identifying and evaluating common priorities for each program
    - Reviewing and making recommendations on applications for program assistance
    - Coordinating mitigation activities with local and Federal Government programs
    - Proposing statewide mitigation policies to the Governor, the Commission on Emergency Planning and Response, and agency heads
    - Recommending methods to improve mitigation activities of State agencies, local governments, Federal Government, and private industry
    - Reviewing grant applications to make funding recommendations to appropriate agencies

- Seeking innovative means to effect solutions to known hazards.

The KHMT develops the Kansas Hazard Mitigation Plan that guides the hazard mitigation program to better protect people and property of the State. It demonstrates the State's commitment to reducing risks from hazards and serves as a tool to help decision makers direct mitigation activities and resources. The KHMT reviews the plan annually and updates it every five years, or as needed based on changes in regulations, priorities, disaster events, and funding availability. An update was done in 2023. The purpose of the Kansas Hazard Mitigation Plan is to:

- Create a statewide vision for a disaster resilient future and define the State's goals for hazard mitigation planning
- Provide an effective mechanism to promote interagency coordination of Kansas's state agency programs related to hazard mitigation
- Ensure all the hazards threatening Kansas are identified, evaluated, and addressed with a priority reflecting the risk they pose to the State
- Comply with federal requirements as they pertain to mitigation in a coordinated and integrated manner
- Provide an effective mechanism to plan, budget, monitor, and evaluate mitigation efforts
- Educate state and local officials, as well as the public, regarding the hazards threatening Kansas and methods to mitigate them
- Establish and define programs and policies to improve mitigation planning and programming at the local level.

The Kansas statewide mitigation-planning program's design is twofold: coordinate the state agencies and organizations mitigation planning efforts and programming, and actively promote and coordinate mitigation planning and programming by local jurisdictions.

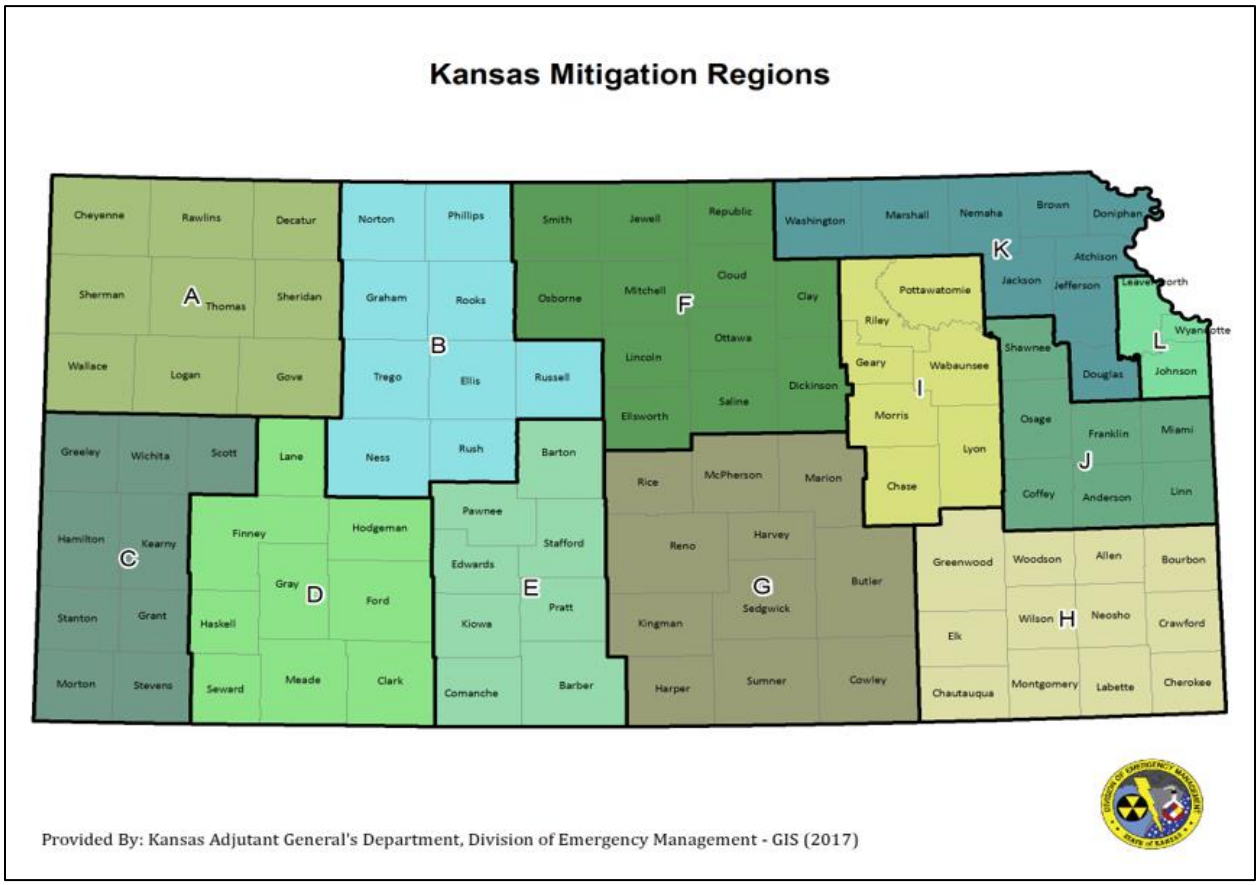
The mitigation plan is linked with KDA Division of Water Resources (KDA-DWR) programs to manage the Federal Emergency Management Agency (FEMA) Floodplain Management Program, which includes the National Flood Insurance Program (NFIP) and the coordination of the statewide floodplain mapping activities. The KDA-DWR provides floodplain management information and technical assistance to help local offices in participating communities. KDA-DWR also administers FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) program in Kansas that created the Flood Insurance Rate Maps (FIRMs) and uses the flood risk data and tools to communicate risk to local citizens and enable communities to enhance their mitigation efforts. To date, the Lower Republican, Lower Little Blue, Lower Big Blue, and the Lower Kansas Hydrologic Unit Code (HUC) 8 watersheds have been completed.

1.7.4.1 Regional Hazard Mitigation Plans

In 2012, the State of Kansas began to regionalize county hazard mitigation plans. This endeavor brought the number of plans from 105 county plans to 12 regional plans. In January of 2016, the last of these regional plans was approved through FEMA. The Kansas Department of Emergency Management is the primary state coordinating

agency for all local emergency operation plans and hazard mitigation plans. The agency has the primary responsibility of working with local governments to develop, review, and update local hazard mitigation plans. As of 2023, all counties in Kansas are included in a Regional Mitigation Plan. The State Hazard Mitigation Plan (SHMP) informs the regional hazard mitigation planning concept, specifically in the way it is written, and the Regional Plans mirrors the SHMP in the 22 identified hazards. Hazard analyses are presented in a regional format, which includes all the counties for each region. Figure 1-1 shows the twelve Kansas Mitigation Planning Regions.

Figure 1-1. Kansas Mitigation Regions



Regional plans direct available community and regional resources toward long-term benefits to the community. Local and regional officials can refer to regional plans when making regulations and ordinances, granting permits, funding capital improvements, and other community initiatives. An approved regional plan ensures future eligibility for federal disaster mitigation funds through the HMGP, Pre-Disaster Mitigation (PDM) grant program, Repetitive Flood Claims (RFC) grant program, and a variety of other state and federal programs.

The statewide risk assessment is the foundation of the SHMP. To define effective mitigation actions to make Kansas more resilient to the impacts of future disasters, it is necessary to understand the hazards threatening the state and how they disrupt Kansas communities. It is also necessary to understand how the communities are vulnerable to the impacts of identified hazards and the scope or extent of vulnerability.

1.7.4.2 State Regulated Dams

Kansas has regulatory jurisdiction over non-federal dams meeting the definition of a jurisdictional dam as defined by K.S.A. 82a-301. Dam classifications describe the level of risk associated with dam failure. These classifications do not reflect the physical condition of the dams, but rather describe areas downstream of dams that could be impacted in the event of failure, which is generally unlikely. The KDA-DWR classifies jurisdictional dams in Kansas as follows:

- Class C (high hazard)—A “hazard class C dam” is located where failure could result in any of the following: extensive loss of life, damage to more than one home, damage to industrial or commercial facilities, interruption of a public utility serving a large number of customers, damage to traffic on high-volume roads that meet the requirements of hazard class C dams or a high-volume railroad line, inundation of a frequently used recreation facility serving a relatively large number of persons, or two or more individual hazards described in hazard class B. Emergency Action Plans (EAPs) are required for all high hazard dams.
- Class B (significant hazard)—A “hazard class B dam” is located where failure could endanger a few lives, damage an isolated home, damage traffic on moderate volume roads that meet the requirements for hazard class B dams, damage low-volume railroad tracks, interrupt the use or service of a utility serving a small number of customers, or inundate recreation facilities, including campground areas intermittently used for sleeping and serving a relatively small number of persons.
- Class A (low hazard)—A “hazard class A dam” is located where failure could damage only farm or other uninhabited buildings, agricultural or undeveloped land including hiking trails, or traffic on low-volume roads that meet the requirements for hazard class A dams.

Within counties located in the basin, there are 131 Class C (high hazard) dams, 78 Class B (significant hazard) dams, and 2,039 Class A (low hazard) dams. Of these dams, five Class C dams do not have an EAP (Kansas Division of Emergency Management 2018).

Kansas has hundreds of levees ranging in size from small agricultural levees constructed primarily to protect farmland from high frequency flooding to large urban levees constructed to protect people and property from larger, less frequent flooding events, such as the 1.0 percent annual exceedance probability (AEP) (i.e., the likelihood of a flood of a given size or larger occurring in a given year) and the 0.2 percent AEP. Levees are usually engineered to withstand a flood with a computed risk of occurrence. Many levees in Kansas were largely constructed to protect agricultural land and are not built to design standards established to protect people and property. Their presence can, in some cases, generate a false sense of security. Levees have been constructed across Kansas by public and private entities with varying levels of protection, inspection oversight, and maintenance.

Levees in the basin may also fall under the FEMA Accredited Levees category. Levees can be in both the USACE Levee Safety Program and the FEMA Accreditation program.

Since 1986, levees have been shown as accredited on FIRMs only when they meet the requirements of 44 C.F.R. § 65.10, Mapping Areas Protected by Levee Systems, including certification by a registered professional engineer or a federal agency with responsibility for levee design. In 2004, as it initiated work under the Flood Map Modernization Initiative (Map MOD), FEMA determined analysis of the role of levees in flood risk reduction would be an important part of the mapping efforts. As a result, FEMA-accredited levees are typically discussed in two main types: those mapped on Digital FIRMs prior to Map Mod and those mapped under Map Mod. As Digital FIRMs are developed, levees fall under one of the three following categories:

- Accredited Levees—With the exception of areas of residual flooding (interior drainage), if the data and documentation specified in 44 C.F.R. § 65.10 is readily available and provided to FEMA, the area behind the levee will be mapped as a moderate-risk area. There is no mandatory flood insurance purchase requirement in moderate-risk areas, but flood insurance is strongly recommended.
- Provisionally Accredited Levee (PAL)—If data and documentation is not readily available, and no known deficiency precludes meeting requirements of 44 C.F.R. § 65.10, FEMA can allow the party seeking recognition up to two years to compile and submit full documentation to show compliance with 44 C.F.R. § 65.10. During this two-year period of provisional accreditation, the area behind the levee is mapped as moderate risk with no mandatory flood insurance purchase requirement.
- De-Accredited Levee—If the information established under 44 C.F.R. § 65.10 is not readily available and provided to FEMA, and the levee is not eligible for the PAL designation, the levee will be de-accredited by FEMA. FEMA evaluates the level of risk associated with each non-accredited levee using the Levee Analysis Mapping Procedures (LAMP) criteria to consider how to map the floodplain and which areas on the dry side of the levee should be shown as high risk. The mapping is then updated to reflect this risk.

The SHMP conducted an analysis of vulnerability of levee failure and the jurisdictions most threatened by levee failure. The assessment included a determination of the number of people and the value of development in identified levee protected areas. The analysis did not attempt to evaluate which levees are more prone to overtopping or failure, but rather provide a general picture of those counties having more people and property protected by levees and, therefore, the potential for more damage if failure or overtopping were to occur. The data is only to be used for general determination of those areas of the State that could suffer the greatest losses in the event of levee failure events. According to the analysis, Saline County was the second highest for the greatest number of people and the highest value of development protected by levees. Wyandotte, Shawnee, Riley, and Ellis counties are in the top ten counties for value of development and populations protected by levees in the basin.

1.7.4.3 Flooding

Major flood impacts occurred in Kansas in 18 of the past 177 years with numerous Presidential Disaster Declarations that included flooding. The SHMP uses HAZUS 4.0

to update the State's risk assessment for riverine flooding. HAZUS can quantify and map risk information such as physical damage to residential and commercial buildings, economic losses including lost jobs, and social impacts (e.g., displaced households). HAZUS provides information on vulnerability in terms of the jurisdictions most threatened by riverine flooding, and most vulnerable to damage and loss associated with flooding events under the 1 percent AEP. Approximately 400 flash flood events occurred in counties within the basin between October 2006 and December 2016 with 3 counties in the basin experiencing 20 or greater (i.e., Shawnee, Leavenworth, and Johnson counties). Most of these counties experienced damage to properties from flash flood events. The assessment found more than 29,000 buildings in the 1 percent AEP floodplain in counties within the basin and more than 60,000 people vulnerable to displacement from flooding. Saline County is ranked in the 3 highest counties with the most vulnerable buildings (9,814) and population (14,607) vulnerable to displacement with Johnson County and Wyandotte County having relatively high numbers for both vulnerable buildings and population vulnerable to displacement from flooding. The assessment included repetitive loss properties in Kansas which includes any, "insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period" (KDEM 2018). Johnson County, Kansas, had the highest number of repetitive loss properties in Kansas with 99 repetitive loss properties having more than $5M in claims paid.

Unless floodplain management is implemented, more people and property will be at risk in flood-prone areas due to land development. Some of the highest risk flood counties are experiencing the greatest development pressures. Shawnee and Johnson counties were in the top ten for at least one of the building loss and displaced population indicators in the SHMP and are also in the top ten counties experiencing significant gains in housing units.

1.7.4.4 Drought

Kansas had recurring periods of drought throughout history, some of them lasting for extended periods. KWO has guidelines for a phased drought response. All regions of the basin are subject to drought of varying levels of severity and duration. Based on historical Kansas Drought Stage Declarations affecting certain counties, the State of Kansas can expect a drought occurrence at a minimum of every three years. In recent years, drought has affected certain counties and regions of the State on a more reoccurring basis. With the possibility of climate change, this hazard may affect more regions of the State even more often. While the entire state is moderately susceptible to drought, some jurisdictions may be more at risk from drought based on such factors as the adequacy of the water supply system, dependence on agriculture, the potential adverse effects to nearby navigation and water-based recreation, and vulnerability to drought-related hazards such as expansive soils, wildfire, and wind erosion. Drought can severely challenge a public water supplier through depletion of the raw water supply and greatly increased customer water demand. Even if the raw water supply remains adequate, problems due to limited treatment capacity or limited distribution system capacity may be encountered. In addition, the water for cropland and livestock can be greatly impacted. Some Regional Advisory Committees set priorities for water supply goals in order to help combat climate change, infrastructure, and drought.

1.7.4.5 State Hazard Mitigation Plan Mitigation Actions

The Kansas SHMP includes a by region summary of rankings for eight commonly rated natural hazards. Drought risk is rated medium for the entire State of Kansas. Flood risk is rated high in regions in the central and eastern portions of the basin and medium for regions in the western portion of the basin.

USACE Civil Works Programs supporting the Kansas Drought and Flood Hazard Mitigation Action Items are considered in Sections 1.7.5 through 1.7.27.

1.7.5 Floodplain Management Plans

Several Kansas River Sub-basin floodplain management plans consider flood hazards while balancing floodplain use benefits and potential losses arising from such uses. Managing flood risks is a shared responsibility of local communities, counties, the State, and federal agencies. The purpose of Floodplain Management Plans (FMPs) is to improve the resiliency of flooding of a specific community or a coalition of communities. Effective floodplain management plans benefit the public by reducing life safety risks and property damages; reducing public expenditures for construction of additional flood damage reduction measures, emergency response actions, and post disaster assistance; and preserving and enhancing natural floodplain values for fish and wildlife habitat along with their benefits for groundwater recharge, moderation of floods, water quality improvement, and reduced erosion and sedimentation.

1.7.5.1 Wildcat Creek Floodplain Management Plan

The Wildcat Creek Floodplain Management Plan (WCFMP), initially developed through the USACE Silver Jackets Program, helps local communities manage Wildcat Creek flood hazards. There are watershed-based flood risks to rural residential areas in the County, and the western and southern sides of Manhattan, both along the stream and in nearby floodplains. The WCFMP lessens the damaging effects of floods, maintains and enhances natural floodplain assets, and makes effective use of water and related land resources within the Wildcat Creek floodplain. The findings and action items in the plan are an important hazard mitigation element for the Wildcat Creek flood hazards in the watershed (Wildcat Creek Watershed Working Group 2013).

1.7.5.2 Big Blue and Kansas Rivers Floodplain Management Plans

The Big Blue and Kansas Rivers Floodplain Management Plans are used by local communities to manage flood hazards along the Big Blue and Kansas Rivers, in and around the City of Manhattan and in Riley and Pottawatomie counties. Within the watershed, there are flood risks to the south and eastern side of the City of Manhattan and residents and business owners in the rural areas of Riley and Pottawatomie counties. The findings and action items in these plans are important hazard mitigation elements for the Big Blue and Kansas river's flood hazards in the watershed (City of Manhattan, Riley County, and Pottawatomie County 2016).

1.7.6 Lake Level Management Plans

NWK water managers and water quality staff have a long history of cooperative management of lake levels using the lake level management planning (LLMP) process

with stakeholders (e.g., state agencies, marina/dock lessees, business owners, recreational users). This process is the equivalent of agencies and user groups formalizing interest and suggestions for environmental actions that can be influenced by water management. Typical suggestions are lake level management for fisheries and waterfowl. Many of the reservoirs in the western region of the basin are used heavily for irrigation. Section 3.10.2, Fish and Wildlife, includes a detailed description of LLMP as of 2024.

1.7.7 Kansas Public Water Supply Emergency Response Plans

KDHE requires development of ERPs to address all threats to a public water supply and provide steps to restore safe delivery of water following a natural or man-made disaster. Drought plans are currently not a requirement, but a suggested action plan of the ERP (KWO 2022).

1.7.8 U.S. Army Corps of Engineers Dam and Levee Safety Programs

1.7.8.1 Dam Safety Program

The USACE Dam Safety Program uses a robust risk-informed approach to manage its portfolio of 694 dams with public safety as the first priority. The Dam Safety Program seeks to ensure that USACE owned and operated dams do not present unacceptable risks to people, property, or the environment. This risk-informed approach is a best practice adopted to develop balanced and informed assessments of the safety of USACE dams and to evaluate, prioritize, and justify dam safety decisions.

Dams reduce the risk of damages and life loss from inundation due to floods but do not eliminate this risk. However, unregulated river flows would be more damaging without the reservoir system.

USACE uses a risk-based approach to evaluate its dams. The results of those relative risk assessments are used to prioritize dam rehabilitation funding.

Critical to an effective dam safety program is the focus on public safety, but it also requires continuous and periodic project inspections and evaluations. USACE completes periodic assessments of their dams, considering potential mechanisms that could result in a breach of the dam and uncontrolled release of the reservoir. USACE implements short- and long-term actions, on a prioritized basis, when unacceptable risks are found at any of its dams.

Dams do not eliminate all inundation risk, so it is important that residents downstream from dams are aware of the potential consequences should a dam breach, not perform as intended, or experience major spillway/outlet works flows. The population centers near rivers downstream of USACE dams warrant increased efforts from USACE, local emergency management officials, and residents to heighten awareness of flood risk management. The primary areas impacted should a dam breach with a full reservoir are identified with the potential for life loss highest near the dam but consequences occurring further downstream as well. Inundation risk must always be managed and information compiled for the population at risk, structures at risk, and land and property at risk.

In collaboration with USBR and the Federal Energy Regulatory Commission, a Dam Safety Action Classification (DSAC) rating scale of 1 to 5 was developed, where DSAC I (1) is high risk and DSAC V (5) is low risk.

1.7.8.2 Levee Safety Program

The USACE Levee Safety Program mission is to assess the integrity and viability of levees and recommend actions to assure levee systems do not present unacceptable risks to the public, property, and the environment. Program objectives include:

- Hold public safety paramount
- Reduce economic impacts
- Maximize cost effectiveness
- Develop reliable and accurate information
- Build public trust and acceptance.

The Levee Safety Program has three main focuses—levee inventory, levee inspections, and levee screening and classification. The levee inventory includes all levees in the USACE program and is a national source of information to facilitate and link activities such as flood risk communication, levee certification, levee inspection, floodplain management, and risk assessments. The National Levee Database (NLD) contains all necessary attributes of levees/floodwalls relevant to design, construction, operations, maintenance, repair, and inspections. Levee inspections include routine inspections on all levee systems that USACE is responsible for inspecting. Inspections include routine inspections, periodic inspections, periodic assessments, and risk assessments listed here in the order of increasing rigor:

- Routine Inspection—Verifies operations and maintenance, enables more rigorous standards, improves communication, and uses system-based approach; occurs yearly.
- Periodic Inspection—Verifies operations and maintenance, evaluates structure stability, compares constructed criteria to current criteria; occurs every 5 years.
- Periodic Assessment—Period inspection plus potential failure mode and consequence analysis; occurs every 5 years.
- Risk Assessments—Data intensive, determine likelihood and consequences of failure; occurs every 10 years.

During inspections, deficiencies such as unsatisfactory culverts, non-compliant vegetation, encroachments, and animal burrows, among others, may be identified. USACE uses inspection findings to rate levee systems, determine compliance with operation and maintenance (O&M) requirements, verify the overall levee condition, and determine eligibility for federal rehabilitation assistance under P.L. 84-99. USACE utilizes the Levee Screening Tool (LST) to assess the risks associated with each levee system and assist with developing risk management solutions. The screening results support the assignment of a Levee Safety Action Classification (LSAC) to denote the level of risk associated with each system.

A primary purpose for assessing and classifying the risk associated with levee systems is to inform responsible parties on appropriate actions to be taken to reduce risk. Risk assessments, including levee screenings, identify risk drivers associated with a particular levee. Risk assessments also identify actions that may be taken to reduce those risks. Actions may be permanent in nature (e.g., replacing defective components or constructing physical improvements to a levee). In many cases Interim Risk Reduction Measures (IRRMs) may be warranted as a means of reducing risk in the interim while permanent measures are planned and implemented. IRRMs for a particular levee system may be developed and implemented by multiple authorities depending on the nature of the risk and the distribution of authorities for that levee system. Parties that could be involved with developing and implementing IRRMs could include individuals (i.e., the public); levee boards; local communities; county, state, and federal emergency management agencies; USACE; and others.

1.7.9 Silver Jackets Program

Silver Jackets is a component of the National Flood Risk Management Program (NFRMP). Silver Jackets coordination funds support NFRMP coordination and outreach activities; technical assistance to address Silver Jackets teams priorities use other funding programs, not limited to but including the USACE Floodplain Management Services (FPMS). The mission of the NFRMP is to, “increase capabilities across all aspects of USACE to improve decisions affecting the Nation’s flood risk that are made internally and collaboratively with our external partners” (personal communication with USACE Kansas City District Silver Jackets Coordinator). Silver Jackets is the state-level implementation of the NFRMP; Flood Risk Management-Silver Jackets coordination funds support USACE district coordination with the state-led interagency flood risk management (or all-hazard) teams and with other partners. The interagency nature of state Silver Jackets teams allows for leveraging of all available resources and authorities, including those from within USACE such as FPMS, to support state-identified flood risk management needs.

Silver Jackets is an innovative program providing an opportunity to consistently bring together multiple state, federal, and sometimes tribal and local agencies to jointly apply resources to reduce flood risk and learn from each other. Silver Jackets teams are state-led interagency teams. Common agency participants include state agencies with mission areas of hazard mitigation, emergency management, floodplain management, natural resources management or conservation, etc. Federal participation typically includes USACE, FEMA, NWS, USGS, USDA NRCS, EPA, and others. This authority provides technical assistance support to communities throughout all phases of the flood risk management cycle (preparation and training, response, recovery, and mitigation). These interagency teams utilize non-structural measures to reduce flood risk, including projects such as education and outreach events, emergency planning and training, non-structural education, and data gathering and dissemination. By applying shared knowledge, the teams enhance preparedness, mitigation, and response and recovery efforts when such events occur. Silver Jackets projects are federally funded with matching in-kind contributions from other federal and local agencies.

The Silver Jackets Program is a USACE civil works program enabling USACE participation in the KHMT. The lead Silver Jackets Coordinator for Kansas directly participates on the KHMT, representing all the USACE districts within the State at the team's regular meetings. The lead Silver Jackets coordinator provides regular status updates upon request. The status updates provide detailed information on active USACE projects and programs, including specific project information that is useful during the FEMA Risk MAP Discovery Phases. The Silver Jackets coordinators may also participate in the FEMA Risk MAP Resiliency Meeting to enhance hazard mitigation efforts. The Kansas Silver Jackets team members have created several FRMPs and FMPs within the basin, including for Manhattan, Kansas. The Manhattan, Kansas, Floodplain Management Plan include a watershed wide plan for Wildcat Creek on their west side, which was adopted by Riley County as well as the city. Silver Jackets coordinated with KDHE on the Kansas Healthy Watershed Study. The project evaluated the benefit of watershed-wide land use incentives supporting the USDA NRCS soil health management systems. The watershed selected for the first study was the Soldier Creek watershed. Watershed planning offers efficiency to federal and state multipurpose objectives, and Silver Jackets is continuing to study soil and land practices in a new study done at the watershed scale. Any community can get assistance with these under the USACE FPMS.

1.7.10 National Flood Insurance Program

NFIP (https://www.fema.gov/flood-insurance) offers flood insurance to homeowners, renters, and business owners if their community participates in the NFIP. Participating communities agree to adopt and enforce ordinances meeting or exceeding FEMA requirements to reduce the risk of flooding. In Kansas, the NFIP is administered by the KDA-DWR.

KDA-DWR reviews and approves floodplain zoning ordinances before their adoption by local governing bodies. It also provides technical assistance to communities to help them develop proper floodplain-related ordinances. The KDA-DWR chief engineer uses data from NFIP studies and mapping for permit and approval decisions. For floodplain management, incorporated cities and unincorporated areas of counties are separate entities that must separately enact and enforce floodplain management regulations.

1.7.11 U. S. Army Corps of Engineers Kansas City District Water Quality Program

The NWK Water Quality Program (https://www.nwk.usace.army.mil/Locations/Water-Quality/) maintains a long-term and robust water quality monitoring and data collection program meeting the needs of all lake projects. Chemical, physical, and biological parameters are measured to evaluate water and lake-bed sediment quality. USACE uses this data to describe conditions and changes from the inflow streams, within the main lake, and outflow focusing on eutrophication, nutrients, sediment, herbicides, metals, and contaminants. This data is critical to investigating problems that may arise, such as HABs, bacteria issues, and fish kills as well as design and implement modifications to improve water management procedures.

Monitoring entails the collection of inflow (i.e., major streams flowing to a lake), in-lake from each major tributary arm of lake, and outflow (i.e., directly below the dam) data for water quality problem identification and to provide a sufficiently robust water quality database for watershed and reservoir environmental modeling. Consequently, lakes with more tributary arms will have more in-lake water quality sites and generally more variation in the results. In-lake data collection includes sampling of both lake waters and sediments in accordance with established NWK standard operating procedures (SOPs) (USACE 2000). Additional details on this program are included in Section 3.8 Water Quality.

1.7.12 Kansas Watershed Restoration and Protection Strategy Groups

The Kansas WRAPS (https://kswraps.org/) initiative is the result of a long history of Kansas' water resource management programs and activities and intends to address priority issues identified in the basin sections of the Kansas Water Plan through the development and implementation of WRAPS in priority watersheds. The Kansas WRAPS process offers a framework engaging citizens and other stakeholders in a teamwork environment aimed at protecting and restoring Kansas watersheds. Participation from stakeholders is essential to the success of the WRAPS program and the future of Kansas' waters. The WRAPS process consists of 4 stages:

- Identifying watershed restoration and protection needs
- Establishing watershed goals
- Creating actions steps/plans to achieve the established goals
- Implementing the plan.

The water resource concerns that WRAPS efforts can address include water quality, water supply protection, flooding, and wetland and riparian habitat protection and restoration. Currently, 36 WRAPS projects completed the first three steps of the WRAPS process and are implementing their plans, of which, 13 are located in the basin (see plans at https://kswraps.org/watershed-plan/approved-plans/). WRAPS watershed plans include costs associated with BMP implementation, technical assistance, additional project coordination, and education. Funding for the WRAPS program is through EPA Section 319 and the Kansas State Water Plan. Projects included under the WRAPS plans extend through each watershed plan's planning timeframe, including funding needs to address water quality impairments greater than $624M.

1.7.13 Kansas Watershed Districts

Watershed districts in Kansas were established by the Watershed District Act of 1953, K.S.A. 24-1201, et seq. The watershed districts construct, operate, and maintain works of improvement needed to provide for water management with designated boundaries. There are 75 organized watershed districts in Kansas encompassing approximately 22 percent of the total area in the State. Each watershed district has a locally elected board of directors responsible for administering the watershed district. The Kansas Legislature appropriated funds, through KDA, Division of Conservation (DOC), for assistance in the construction of flood detention and grade stabilization dams since 1977. The DOC

developed administrative regulations for the implementation of state assistance in watershed dam construction, rehabilitation, and inundation mapping.

1.7.14 Kansas Department of Health and Environment Stream Chemistry Monitoring Program

The KDHE Stream Chemistry Monitoring Program (https://www.kdhe.ks.gov/1219/303d-Methodology-List-of-Impaired-Waters) consists of a sampling network of 327 monitoring sites spanning all the major river basins in Kansas. Annually, 160 permanent sites are visited by staff, with 40 sites visited on a quarterly basis, whereas the remaining 167 sites are monitored using a four-year rotational approach. Sampling stations are chosen to represent water quality conditions in more than 97 percent of the State's contributing drainage area (KWO 2022).

1.7.15 Local Enhanced Management Areas

Local enhanced management areas (LEMAs) provide a mechanism for stakeholders to develop groundwater conservation plans for areas with a Groundwater Management District (GMD).

The Sheridan 6 LEMA economic analysis measures the economic impacts to producers and the regional economy, and hydrologic impacts to the Ogallala Aquifer associated water conservation alternatives intended to extend the economic life of the aquifer and maintain the economic base of the region.

1.7.16 Water Conservation Areas

Water Conservation Areas (https://agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/wca) in Kansas originate from management plans developed by an individual or group of water right holders to address groundwater levels that are declining or have declined excessively, groundwater withdrawal rates that equal or exceed the rate of recharge, the prevention of waste of water, and unreasonable deterioration of water quality. The management plan is the basis for a consent agreement and order from the Chief Engineer designating a Water Conservation Area.

1.7.17 Intensive Groundwater Use Control Areas

The Kansas GMD Act contains specific provisions for initiation of proceedings for and designation of Intensive Groundwater Use Control Areas (IGUCAs) (https://agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/intensive-groundwater-use-control-areas). These provisions recognize that a strict prior-appropriation approach may not be in the public interest and allows water rights to be administered in a method that benefits the most users. The statutes allow the Chief Engineer to implement additional corrective control provisions in areas where it is determined, through a public hearing process, that groundwater levels are declining excessively, the rate of groundwater withdrawal exceeds the rate of groundwater recharge, unreasonable deterioration of groundwater quality has occurred or may occur, or other conditions exist warranting additional regulation to protect public interest. The state of Kansas currently has eight IGUCA orders including four in the Kansas River Basin, the Hays IGUCA, Lower Smoky Hill IGUCA, Upper Smoky Hill IGUCA, and the Walnut Creek IGUCA.

1.7.18 Milford Lake Regional Conservation Partnership Program

The Milford Lake Regional Conservation Partnership Program (RCPP) through NRCS implements BMPs within the Milford Lake watershed to decrease nutrient runoff, thus decreasing the introduction of new nutrient loading contributing to the formation of HABs in Milford Lake. HABs have been an issue dating back to at least 2011 when the KDHE first listed Milford Lake as a public lake with confirmed harmful blue-green algal blooms. HABs have been detected within Milford Lake every year since 2011. The Environmental Quality Incentives Program (EQIP) is the primary USDA NRCS program providing cost share funding to producers within the Milford Lake watershed. The project implements livestock and cropland-related conservation practices within the Milford Lake Watershed to decrease nutrient runoff and sediment. The partnership team consists of state agencies, public water suppliers, farm organizations, local units of government, university and state researchers, county conservation districts (CD), agricultural groups, private businesses, and non-profit organizations. The project also provides improvements such as improving fish and wildlife habitat, increasing soil health, testing of innovative phosphorus reduction technology, and helping ensure future agricultural productivity (KWO 2021b).

1.7.19 High Plains Aquifer Conservation

The High Plains Aquifer is the largest, most economically important groundwater source in Kansas. The Ogallala, which is the largest aquifer region in the High Plains Aquifer, occurs in the western third of Kansas, an area that is semi-arid with limited surface water. In the western portion of the basin, groundwater has historically been the most reliable source of large volumes of water for irrigation, municipal, and industrial use.

When pumping demands exceed the amount of water recharging an aquifer, groundwater declines occur. While some areas of the aquifer are effectively depleted, other areas have substantial volumes of water still in storage. The rate of water level decline typically ranges from only a few inches to several feet per year but can be as much as more than 15 feet per year during drought conditions. Under current pumping demands, many areas of the aquifer already experience significant reduction in well yields or are projected to within the next decade.

A variety of local, state, and federal groups and agencies work together to help implement water conservation efforts within the region with the commitment to make every drop count. Local GMDs, along with state and federal agencies like the KWO, KDA DWR, KDHE, Kansas Geological Survey (KGS), KSU Research and Extension, USDA NRCS, USDA Farm Service Agency, and local conservation district offices provide assistance to producers within the region through cost-share and incentive programs, conservation and environment programs, and education and outreach.

Some current state basin water conservation efforts are included below:

- Cost-Share Incentives—Water Transition Assistance Program (WTAP), Irrigation Technology Initiative, and EQIP
- Conservation and Environment—Regional Advisory Group (RAC), LEMA, Water Conservation Area (WCA)

- Education and Outreach—KSU Research and Extension, Water Technology Farms, High Plains Aquifer Index Well Network.

1.7.20 Kansas Wetland Program

The Kansas Wetland Program increases the knowledge base about Kansas' wetland systems through surveying, monitoring, researching, and assessing establishment of wetland conditions, as well as identifying trends and the causes and sources affecting wetland change. The Kansas Wetland Program Plan (WPP) (2019–2023) was developed by a diverse group of state agencies, interest groups and Kansas citizens with assistance from the EPA to help evaluate Kansas wetlands. The vision of the plan is to, "protect, enhance and restore our wetland resources to be able to support the wealth of services that wetlands provide to the citizens and visitors of Kansas" (KWO 2021f). The four primary areas of focus identified in the current WPP include:

- Topographic Wetland Identification Process (TWIP)—A landscape-level light detection and ranging (LiDAR)-based tool that identifies potential areas for wetland protection, restoration, and enhancement. The continued acquisition of LiDAR statewide and use of the TWIP will enhance and target existing wetland programs on a watershed scale to accomplish broad wetland conservation while restoring and protecting priority watersheds across the state.
- Information and Education—Continued information and education to encourage wetlands conservation including enhancing the availability and quality of information available on a dedicated wetland webpage on the KWO website.
- Understanding—Gain greater understanding of wetland resources through continued monitoring, assessment, and evaluation of function and condition.
- Playa Lake Conservation—Additional attention for conservation and management of playa lake (i.e., round, shallow depressions found at the lowest point of a watershed that collect and hold water from rainfall and runoff creating temporary wetlands) resources in the western part of Kansas.

1.7.21 Kansas Department of Health and Environment Stream Biological Monitoring Program

The program examines the structural attributes of aquatic macroinvertebrate assemblages and utilizes this information to provide a more refined picture of the ecological status of streams in Kansas. Biological monitoring provides an integrated measure of environmental conditions over time frames ranging from weeks to years, depending on the biological assemblage of interest. Stations located in watersheds of major rivers and streams are sampled every year when conditions allow.

1.7.22 Kansas Department of Health and Environment Harmful Algal Bloom Response Program

The program (https://www.kdhe.ks.gov/777/Harmful-Algal-Blooms) was established in 2010 with more than 100 water bodies affected by HABs in the past 10 years. KDHE's complaint-based program addresses blooms on public waters, with no agency sampling or laboratory analysis being conducted on private waters. Managers of private waters are encouraged to perform a jar test and use private labs if they believe they are

experiencing a bloom. Under the KDHE program, there are three levels of advisories: watch, warning, and hazard (KWO 2022).

1.7.23 Kansas Department of Wildlife and Parks Stream Survey and Monitoring Program

The main goal of the KDWP Stream Assessment and Monitoring Program is the assessment of streams and rivers within the 12 river basins in Kansas documenting the current range and distribution of stream species. KDWP has been sampling streams since the 1970s to collect fish data and, more recently, macroinvertebrates used for project reviews for various proposed projects and to assess overall stream conditions. Sampling generally occurs from late spring to summer and each year focuses on a river basin of interest. The goal of the program is to assess biological communities present within Kansas streams.

1.7.24 Kansas Reservoir Protection Initiative

The Kansas Reservoir Protection Initiative (KRPI) protects water supply storage and improves water quality in reservoirs across Kansas providing water to municipal and industrial customers. The KRPI provides financial assistance to landowners in priority watersheds to implement sediment-reducing conservation practices to enhance sediment reduction efforts above federal reservoirs where water supply storage is impacted by sedimentation. Funding is currently available in the basin above the Kanopolis and Tuttle Creek reservoirs to implement BMPs where sedimentation is impacting available water storage. BMPs to reduce sediment and nutrient runoff in watersheds includes terraces, grassed waterways, and buffer strips (KWO 2021g).

1.7.25 Kansas Alliance for Wetlands and Streams

The KAWS (https://kaws.org/) is a non-profit organization working to connect the lands, water, and people of Kansas. KAWS works with landowners and producers across Kansas to improve water quality, reduce sediment and nutrient runoff, and building strong partnerships with natural resource agencies and other organizations. KAWS partners with other organizations on various projects related to wetland restoration, conservation, riparian and streambank stabilization, playas, WRAPS watersheds, and wildlife, and conducts various research projects and public outreach.

1.7.26 Playa Lakes Joint Venture

The Playa Lakes Joint Venture (PLJV) (https://pljv.org/) is a non-profit organization that works to conserve playas through a partnership with state and federal agencies, conservation groups, and private industry. Their purpose is to find solutions to address habitat conservation challenges in the western Great Plains to not only support birds and other wildlife but to also support local communities and agricultural producers thrive in the landscape. Healthy playas are a primary source of aquifer recharge, and also improve the quality of water. The organization collects information on birds and their habitat to inform habitat goals and evaluate conservation strategies and develop tools that guide conservation strategies and develop projects. The organization helps partners and producers do habitat conservation work by providing science-based information, funding, and other resources (PLJV 2022).

1.7.27 Kansas Department of Wildlife and Parks Aquatic Nuisance Species Program

In response to aquatic nuisance species (ANS) threats, in 2005 the Kansas Aquatic Nuisance Species (ANS) Management Plan (https://ksoutdoors.com/Fishing/Aquatic-Nuisance-Species) was completed and received governor endorsement. KDWP was charged with leading implementation of the plan to protect Kansas waterbodies for all Kansans with the goals to:

- Prevent new introductions of ANS to Kansas
- Prevent dispersal of established populations of ANS into waters free from infestation in Kansas
- Eradicate or control to minimize the adverse ecological, economic, social, and public health effects of ANS in an environmentally-sound manner
- Educate all aquatic users of ANS risks and how to reduce the harmful impacts
- Support research on ANS in Kansas and develop systems to disseminate information (KWO 2022).

1.7.28 Kansas Financial Assistance or Incentive Programs

The KDA DOC (https://agriculture.ks.gov/divisions-programs/division-of-conservation) works with CD, watershed districts, other special-purpose districts, as well as state and federal entities to administer programs to improve water quality, reduce soil erosion, conserve water, reduce flood potential, and provide local water supply.

- Water Transition Assistance Program—WTAP is a voluntary, incentive-based program that permanently retires privately held irrigation water rights in exchange for payment by the State of Kansas. It is intended to help restore aquifers and recover stream flows in critically depleted target areas. The target areas in the basin include the Rattlesnake Creek Sub-basin and six high priority areas of northwest Kansas GMD No. 4.
- Riparian Quality Enhancement Initiative—The Riparian Quality Enhancement Initiative (RQEI) seeks to help landowners improve riparian health, land profitability, and wildlife habitat. In partnership with the Kansas Forest Service (KFS), KDA DOC is offering financial and technical service for forestry practices for Kansas landowners. Eligible practices include forest stand improvement, tree/shrub establishment, riparian forest buffer, herbaceous weed control, cover crops for new tree plantings, streambank stabilization, and channel bed stabilization.
- Sediment and Nutrient Reduction Initiative—The Sediment and Nutrient Reduction Initiative (SNRI) is part of an ongoing effort to reduce sedimentation and nutrient runoff offering an incentive payment to producers implementing approved Conservation Reserve Program (CRP) practices. Eligible practices include grassed waterways, shallow water areas for wildlife, filter strips, riparian forest buffers, wetland restoration, improvements to farmable wetlands, farmable wetland buffers, bottomland hardwood timber establishment, and upland bird habitat buffers.

- Streambank Protection Program—This program consists of an inter-agency team with staff from KWO, KDHE, KFS, and the KDA DOC Riparian and Wetlands Program. The program works with private landowners to decrease sediment in federal reservoirs caused by accelerated streambank erosion. The group seeks to target the largest contributing sites first, with some losing more than 20,000 tons of sediment per year. Streambanks are stabilized with riparian buffers installed to help ensure longevity. There is no cost to landowners for the projects. Sites are monitored for several years following installation to help ensure a successful project that protects both agricultural lands and the interest of downstream water users.
- Wetland Development—The KDA DOC Riparian and Wetland Program provides financial assistance to landowners who want to develop or rejuvenate existing wetlands. The program works with partners such as Ducks Unlimited and PLJV promoting playa conservation in western Kansas. These shallow and seasonally dry wetlands provide habitat for many species and serve as a source of recharge for the Ogallala Aquifer.
- Water Quality Buffer Initiative—The program is administered by KDA DOC. This program provides additional incentive for participation in the Continuous Sign-up provision of the USDA CRP. The initiative provides state payments in addition to the CRP annual payments for establishing either grass filter strips or riparian forest buffers in high priority total maximum daily load (TMDL) watersheds, all land draining into the federal reservoirs used for drinking water, and other priority designated watersheds. The program supplements the federal rental payments for the CRP by 30 percent for grass filter strips or 50 percent for riparian forest buffers. Landowners are encouraged to establish filter strips and riparian forest buffers along surface waters. The grass and tree cover improves water quality by filtering sediment, pesticides, nutrients, and other pollutants prior to entering a stream or river.
- Water Resources Cost Share Program—The program, administered by KDA DOC, provides state cost-share assistance to landowners for establishing enduring water conservation practices to protect and improve the quality and quantity of Kansas water resources. This includes targeting water quality funds to address TMDL and other issues in priority areas, continuing base level funding to address water resource problems, funding technical assistance to landowners to implement BMPs and maintain the irrigation efficiency focus on western Kansas.
- Watershed Planning Assistance Program—The program, administered by KDA DOC, provides financial assistance for engineering and environmental services, general plan development, and other flood control and rehabilitation projects in watershed districts.
- Flood Control and Lakes Programs—The KDA DOC flood control and lakes programs address many natural resource and safety related issues such as flood control, public water supply, and recreation. Three KDA DOC programs address these issues:

- Multipurpose Small Lakes Program—This program provides state financial cost-share assistance to a government entity for the construction or renovation of a dam for flood protection, public water supply storage, and water-related recreational facilities. It requires a general plan of works and a local nonpoint source pollution control plan.
- Water Supply Restoration Program—This program is a voluntary, incentive-based water management program providing financial assistance to restore and protect water supply lakes, used directly as a source of water for public water supply systems, where appropriate, and where watershed restoration and protection practices are planned or in place. Eligible sponsors include any entity with taxing authority and the right of eminent domain, rural water districts, and public wholesale water supply districts. Eligible activities include removal of sediment, rehabilitation of structures, watershed protection, and engineering fees.
- Watershed Dam Construction Assistance—The State of Kansas provides cost-share assistance to organized watershed, drainage, or other special districts for implementing structural and non-structural practices that reduce flood damage. These practices provide protection of urban areas, roads, bridges, utilities, agricultural lands, in addition to enhancing wildlife, trapping sediment and pollutants, and providing water for livestock and, in some instances, for rural fire departments. Construction and rehabilitation of flood control and/or grade stabilization dams are the main practices and components of this program. Rehabilitation includes the work necessary to bring a structure to applicable safety and performance standards. Structural practices must be approved by the chief engineer of the DWR.

1.7.29 Projects/Studies

This section provides a brief description of local, regional, state, and federal studies and projects in various stages of completion available in addition to those programs detailed in Section 1.7.32.

1.7.29.1 Streambank Stabilization Projects

Streambank stabilization is key to reducing sediment entering reservoirs. Coordination between KDHE, KDA DOC, and KWO uses the strengths, responsibilities, and resources of each agency to accomplish streambank protection work. KFS, KDWP, local CD, and local WRAPS groups continue to be essential to the success of this process.

Streambank stabilization efforts are currently concentrated in two high priority watersheds within the basin—the Big Blue and Little Blue rivers above Tuttle Creek Reservoir and the Delaware River above Perry Reservoir. Past efforts included implementation projects across the state, including the Smoky Hill-Saline watershed. The streambank stabilization projects implemented to date will likely prevent more than 880,000 tons of sediment from entering the associated downstream reservoirs each year. (KWO 2021e)

1.7.29.2 Stream and River Channel Assessments

KWO is working with multiple state and federal partners on long-term monitoring of the impact of sedimentation to reservoirs and the effectiveness of sediment management strategies. The monitoring program includes a combination of in-stream data collection, bathymetric surveys, and other stream assessment work. The monitoring program has provided valuable information about the volume, rate, quality, and sources of sediment being deposited in the reservoirs.

The Kansas River Basin Regional Sediment Management Section 204—The USACE contracted several stream channel morphology and riparian assessments to identify future sediment control opportunities. These assessments provide information on sediment management potential and contribute to ongoing planning efforts by KWO and other state agencies for long-term reservoir sustainability (KWO 2021d).

1.7.29.3 South Fork Republican River Basin Projects

On August 1, 2018, Colorado and Kansas signed a settlement totaling $4M to resolve any disputes over Colorado's past use of water under the Republican River Compact prior to 2013. Of that total sum, $2M will be spent for the benefit of the South Fork of the Republican River Basin within Kansas and $2M will be spent in Colorado. The money in Kansas is used to implement water conservation projects, water use efficiency upgrades, water management plans by water right holders, and cost-share programs within the South Fork Republican River Basin. Examples include irrigation technologies cost-share programs (e.g., soil moisture probes, mobile-drip irrigation, sub-surface drip irrigation, pivot control systems, electrical conductivity soil field mapping, aerial imagery, variable rate irrigation, and/or weather stations) (KWO 2021c).

1.7.29.4 Lower Republican River Projects

The State of Kansas was awarded $5.5M in *Kansas v. Nebraska*, 574 U.S. 445 (2015), with $3.5M to be credited to the Republican River Water Conservation Projects-Nebraska Moneys Fund for water improvement projects in the Republican River Basin. The projects will improve water supply during dry periods along the Lower Republican River and convert portions of the remaining open irrigation canal systems to buried pipe system within the Kansas Bostwick Irrigation District. Sections of the open irrigation canal system were converted to buried pipe system between 2017 and 2020. Part of the settlement funds also went to contracting with KGS to utilize a model (Lower Republican River Basin Model–OASIS) to simulate the distribution of water resources in the Lower Republican Basin under different management alternatives to optimize beneficial use by water right holders in the basin (KWO 2021a).

1.7.29.5 Lower Republican River Feasibility Study

The feasibility study evaluates new reservoir sites benefiting producers and other users in the basin. Additional reservoirs could also provide a secure water source for water right holders below the Kansas Bostwick Irrigation District, especially those junior to Minimum Desirable Streamflow (MDS) requirements that are part of Kansas Water Appropriation Act, K.S.A. 82a-701 et seq., which ensures base flows in certain streams (KWO 2021a).

1.7.29.6 Delaware River Watershed Streambank Erosion Assessment

In an effort to reduce excessive sedimentation in reservoirs across Kansas, KWO conducted a watershed assessment for the Delaware River watershed to identify areas of streambank erosion providing a better understanding of the Delaware River watershed for streambank restoration purposes and increasing understanding of streambank erosion. A total of 81 streambank erosion sites, covering 55,437 linear feet of unstable streambank, were identified representing sites covering an area of 2,000 square feet or more. These sites have some of the highest rates of erosion and sedimentation in the watershed. The Delaware River WRAPS group used information from the assessment to target streambank stabilization and riparian restoration efforts toward high priority HUC 10s or HUC 12s within the watershed.

1.7.29.7 Small Reservoir Feasibility Study

The feasibility study aimed to determine the suitability or feasibility of construction of four multipurpose small reservoirs (i.e., West Site, East Site, Beaver Creek, Site 4) at pre-determined site locations focused on assisting outside Kansas Bostwick Irrigation District users with decreasing water shortages. Three of the four proposed reservoirs were included in the Lower Republican River Basin Model–OASIS. Preliminary results indicate each reservoir helps to reduce instances of water shortages in the basin, with the West Site and Beaver Creek more so than the East Site. The West Site serves most downstream users in the basin, while the large capacity of Beaver Creek allows for more storage. KWO reconvened the Lower Republican River stakeholder group to review these final reports and deliberate on next steps. Discussions for the stakeholder group include attempting to narrow down the four potential reservoir sites to focus in on one or two. KWO also signed a contract with KGS to, among other items, assess how to operate these potential reservoirs within the basin, such as when to transfer water from the Republican River and the inclusion of an access district for irrigation use (KWO 2021a).

1.7.29.8 Sustainable Rivers Program: Kansas River Project

The Nature Conservancy (TNC) and USACE partnered to form the Sustainable Rivers Program (SRP) (https://www.hec.usace.army.mil/sustainablerivers/) to find opportunities to optimize reservoir releases and river flows benefiting river ecology while maintaining the federal mandates of the reservoir system in the United States. In 2017, NWK and TNC Kansas worked together to add the Kansas River to the SRP. Ultimately, the goal is to identify and integrate understanding of flow needs into real-time decisions about how much and when water is released from the reservoirs to achieve more natural flow regimes, and to adjust operations as needed in response to monitoring and modeled responses. USACE considers impacts caused by reservoir operations and examine possible reservoir management modifications within the range of authorized reservoir releases that would create flows beneficial to the Kansas River ecosystem and its biota.

1.7.29.9 Lincoln Draw Section 205 Flood Damage Reduction Study Feasibility Report with Integrated Environmental Assessment

Urban areas in the overbanks along Lincoln Draw experience flash flooding from heavy rainfall events resulting in damages to property and increasing the risk of life loss. Buildings and streets in downtown Hays, Kansas, are flooded when the existing storm sewer system is overwhelmed from frequent rainfall events. The affected areas have short flood response times due to flash flooding tendency of the basin. The feasibility study aims to determine if there is a feasible flood risk management project in Hays, Kansas, protecting the community against the flood threat presented by Lincoln Draw.

1.7.29.10 Smoky Hill River Ecosystem Restoration Integrated Section 1135 Feasibility Study and Environmental Assessment

The Smoky Hill River Ecosystem Restoration Project restores aquatic and terrestrial habitat functions and features in and adjacent to the portion of the Smoky Hill River previously cut off from the main channel by a past flood risk management project. Aquatic habitat restoration considers opportunities for improving base flow conveyance, stream habitat features, developing aquatic connectivity and backwater habitat functions, as well as supporting wetland and riparian habitats. Restoration of supporting habitats and associated functions can collectively enhance the cut off channel reach's ecosystem form and function and increase habitat value to fish and wildlife, while also providing ancillary benefits to recreational uses and aesthetics.

1.7.29.11 Perry Lake Ecosystem Restoration Project Section 1135 Integrated Feasibility Study and Environmental Assessment

The Integrated Feasibility Study and Environmental Assessment presents alternatives, analyses, and recommendations for the Perry Lake Ecosystem Restoration project located in Jefferson County, Kansas. The project includes restoration of wetlands, streambanks, and riparian corridor habitat within the floodplains of the Delaware River. The wetland, stream, and riparian habitat within the project area and along the Delaware River and tributaries to Perry Lake suffered degradation and loss of floodplain conveyance due to agricultural land use, sedimentation, and flood water attenuation. The non-federal sponsor, KDWP, manages wetland habitat to support native fauna including waterfowl and shorebirds. This study investigates restoration opportunities providing for aquatic ecosystem restoration and further benefiting native flora and fauna.

1.7.29.12 Shunganunga Creek Section 205 Flood Risk Management Integrated Feasibility Report and Environmental Assessment

Residential, commercial, and industrial areas along Shunganunga Creek overbanks experience overbank flooding during short-time durations between peak rainfall and peak floodwater causing high risk to life loss and increased risk to human health factors and frequent inundation causing damages to properties of those areas. The study aims to determine if a feasible flood risk management project exists in Topeka, Kansas, protecting the community against the flood threat presented by Shunganunga Creek.

1.7.29.13 Kansas River Water Quality

Kansas River Water Quality studies provide an advanced real-time notification system to alert managers along the Kansas River of changing water-quality conditions that may affect treatment processes or cause taste-and-odor or algal toxin events. The Public Water Supply workgroup developed a plan to work with USGS to collect real-time water quality data along the river; identify the source, fate, and transport of taste-and-odor compounds; and develop statistical relationships to identify factors that may cause a change in water quality (https://waterdata.usgs.gov/ks/nwis/qw). The workgroup currently establishes one-year contracts with USGS for data collection at sites along the Kansas River (Wamego, Topeka, and De Soto, Kansas). Currently a time of travel study is ongoing at the three locations. Funding for this effort is currently provided through KDHE, KWO, The Nature Conservancy (TNC), public water suppliers, and USGS. Funding levels are adjusted on an annual basis.

1.7.29.14 Stream Gaging Network

The stream gaging network supports continuous monitoring of streamflow on key streams and rivers in Kansas. The State of Kansas and USGS work cooperatively to operate 70 continuous recording stations at locations across the state. Flow data is used to efficiently schedule reservoir releases and to track runoff, for flood forecasting, water right administration, sediment transport, water quality parameters, and interstate compact compliance. Water rights administration relies on accurate streamflow information, as does drought and flood planning. Funding is provided through the State Water Plan Fund. USGS contributes money to the cost of operations of the stream gages and other federal, state, and local agencies contribute cooperative funding along with some private entities (KWO 2021h).

1.7.29.15 Water Research Coordination Workgroup

The Water Research Coordination Workgroup is composed of members throughout Kansas involved with ongoing research activities tied to water supply and water quality issues in Kansas. The purpose of the workgroup is to promote communication; support university studies that, when possible, also benefit Kansas water issue knowledge; and provide opportunities for university researchers and participating agencies to collaborate in research efforts. The top three areas of focus selected for prioritization are the Ogallala-High Plains/groundwater depletion, reservoir sedimentation/loss of storage, and water quality. Ultimately, the objective of workgroup meetings is to provide an opportunity for subject matter experts to work together to identify gaps in the research and existing data, determine what is needed to fill those gaps, foster better collaboration among the state's institutions, and maximize funding opportunities (KWO 2021i).

1.7.29.16 Tuttle Creek Reservoir Water Injection Dredging Study and Demonstration

Working together, KWO, NWK, and the Engineer Research and Development Center (ERDC), are implementing a water injection dredging (WID) demonstration project at Tuttle Creek Reservoir to promote sustainable long-term reservoir sediment management. The project involves constructing and demonstrating the use of the WID at Tuttle Creek Reservoir at different elevations and flow discharges and monitoring and

evaluating both the operational and environmental results. This demonstration is vital in determining the viability of using WID as a permanent solution for addressing sedimentation at Tuttle Creek and potentially other reservoirs.

1.7.29.17 Kansas Municipal Water Conservation Plans

The State of Kansas may require public water suppliers to develop a water conservation plan as a condition of a water right, involvement in a program, or as a condition of a grant. Many suppliers recognize the value of water conservation for communities and voluntarily develop a water conservation plan. The Kansas Rural Water Association provides free technical assistance for developing municipal water conservation plans through the State Water Plan fund. KWO is responsible for reviewing and approving these water conservation plans (KWO 2022).

1.7.29.18 Kansas Water Quality Monitoring

KDHE has primary responsibility for surface water chemical and biological monitoring and assessment and determine impaired water status. KDHE maintains several ongoing programs that collectively fulfill the environmental surveillance and reporting requirements of the Clean Water Act (CWA) and provide the technical data needed to identify and respond to existing and emerging water pollution problems. The 2020 Integrated Water Quality Assessment is a compilation of water quality issues across the State. The KDHE Monitoring, Assessment and Science Section (MASS) monitors water quality conditions in streams and publicly-owned lakes and wetlands throughout Kansas. Programs administered by MASS are designed to meet the environmental surveillance and reporting requirements of the CWA and other applicable federal and state laws. Information obtained through these efforts is applied in the development of the state's biennial Integrated Water Quality Assessment and 303(d) list of water quality-limited surface waters. Water quality data are also applied in the formulation of TMDLs for 303(d)-listed water bodies (https://www.kdhe.ks.gov/1219/303d-Methodology-List-of-Impaired-Waters), used to inform water quality standards development, and used to guide implementation of pollutant and pollution reduction activities. Further details related to water quality in the basin are included in Section 3.8.

1.7.29.19 Kansas Forest Service Programs

KFS (https://www.kansasforests.org/) acts as a technical service provider to more than 15 WRAPS groups throughout Kansas. KFS provides individual WRAPS with streamside forestry technical assistance. Expertise, workshop organization, and assessment functions with the intent on helping each group achieve the water quality goals set out in their watershed plans. Proper management, establishment, and protection of streamside forests results in the reduction of sediment and associated pollutants, such as phosphorous and *E. coli* bacteria in Kansas waterways. KFS receives funding from four major sources: federal funds through the U.S. Forest Service competitive grants, fee generation through technical assistance, conservation plant materials sales, and an allocation from the state general fund.

- Riparian Restoration Initiative—In cooperation with the KDA DOC, KFS is responsible for designing and overseeing the installation and three-year maintenance of streamside forest buffers above (top of bank) rock-engineered

bank stabilization structures along several larger Kansas Rivers. The forest buffers act to further reinforce the rock stabilization structures, as well as provide the vast array of environmental benefits associated with trees. To date, installation of 12 buffers along the Delaware River in Atchison and Jefferson counties and 2 along the Neosho River in Lyon County is complete.

- Assessment of Riparian Forests to Reduce Sedimentation of Federal Reservoirs—KFS and various partners developed a riparian forest assessment methodology using geographic information system (GIS), remote sensing, and on-the-ground mensuration (the measuring of geometric magnitudes, lengths, areas, and volumes) to categorize riparian forests into functioning condition classes. The assessment methodology was piloted and refined within the Delaware River watershed, using a design and scale allowing the technique to be readily transferable to other regional watersheds plagued by sedimentation issues. The product is a GIS database for assisting stakeholders (i.e., Delaware River WRAPS) in strategically targeting riparian forestry practices and programs above Perry Reservoir to minimize impoundment sedimentation. In conjunction with the assessment, creation of riparian forestry demonstration areas, as well as basin-wide educational efforts, increased the acceptance and adoption of riparian forestry practices within targeted areas. In addition, riparian forest stand data collected during on-the-ground mensuration act to fill an immense knowledge gap regarding the extent, composition, and condition of riparian forests within the state of Kansas. The riparian forest assessment methodology piloted and refined within the Delaware River watershed was applied within the Tuttle Creek Reservoir watershed (2011–2014), as well as the Spring River watershed (2011–2013).
- Wetland and Riparian Protection—KFS is a member of the Wetland and Riparian Protection (WARP) Team headed by KWO. KFS was involved in the Wetland Protection and Development 2011 project (WPDG-11) led by WARP. WPDG-11 entails assessing two similar Kansas watersheds to examine the impact wetlands and streamside forests have in overall watershed health and water quality. The role of KFS in WPDG-11 entails assessing streamside forests in each watershed and providing data to WARP regarding the location, extent, and condition of these resources.
- Sediment Baseline Study—KFS is a member of the Sediment Baseline Work Group (SBWG), headed by KWO. The SBWG is currently investigating three northeast Kansas watersheds to determine what watershed characteristics (such as landcover, agricultural practices, and streamside forest conditions) lead to the lowest amount of sediment pollution to waterways. Streamside forest condition data will assist SBWG in determining the role that these areas play in terms of sediment reduction and water quality enhancement. Data will also allow KFS to promote specific streamside forestry practices to the areas where the largest benefit to water quality will result.

1.7.29.20 Weather Stations

Information about precipitation, wind speed, temperature, and other atmospheric conditions is measured at numerous weather stations throughout the State. These stations are operated by several government agencies for a variety of purposes. Agencies involved in this effort include NWS, USDA NRCS, KSU, the Kansas Department of Transportation (KDOT), and local GMDs.

Development of a multi-purpose Kansas Meso-scale Network (Mesonet) (https://mesonet.k-state.edu/) of automated stations was initiated in 2008. Mesonet stations will eventually be deployed in all Kansas counties. KSU will operate and maintain this network which is intended to identify weather conditions on a scale from several to a few dozen miles.

2.0 STUDY INFORMATION AND SCOPE

Significant near- and long-term water resource challenges need to be met in the basin. The 18 federal reservoirs operated by the USACE and the USBR and levees in the Kansas River Basin, originally authorized from 1938 to 1962, are now being asked to meet the multi-purpose needs and values of today's modern society, including an increased demand for flood risk management benefits to large and small communities, recreation facilities, agricultural areas, an increased demand on water supply, a changing climate, and an increased societal value on protecting and restoring the ecosystem. The existing system needs reinvestigation to optimize operation and functionality where possible, and to remove, repair, rehabilitate, or upgrade current facilities to reduce risk and improve benefits to society. The system also needs review to account for the demand and need for integrated water resources management to provide flood risk management, water availability and sustainment, and ecosystem restoration benefits.

The scope of the study includes a comprehensive and strategic evaluation of the Kansas River Basin system operating plan, reservoir operations and manuals, reservoir facilities and features, conditions upstream and downstream of reservoirs, infrastructure, and other related needs in the system. This includes a comprehensive existing and future conditions update of flood risk, drought risk and preparedness, ecosystem degradation, water supply availability and sustainment, water quality, and recreation. The watershed study is not an implementation document and any changes to the Lower Kansas River Basin Reservoir Regulation Master Manual and the associated reservoir water control plans would occur outside of the watershed study.

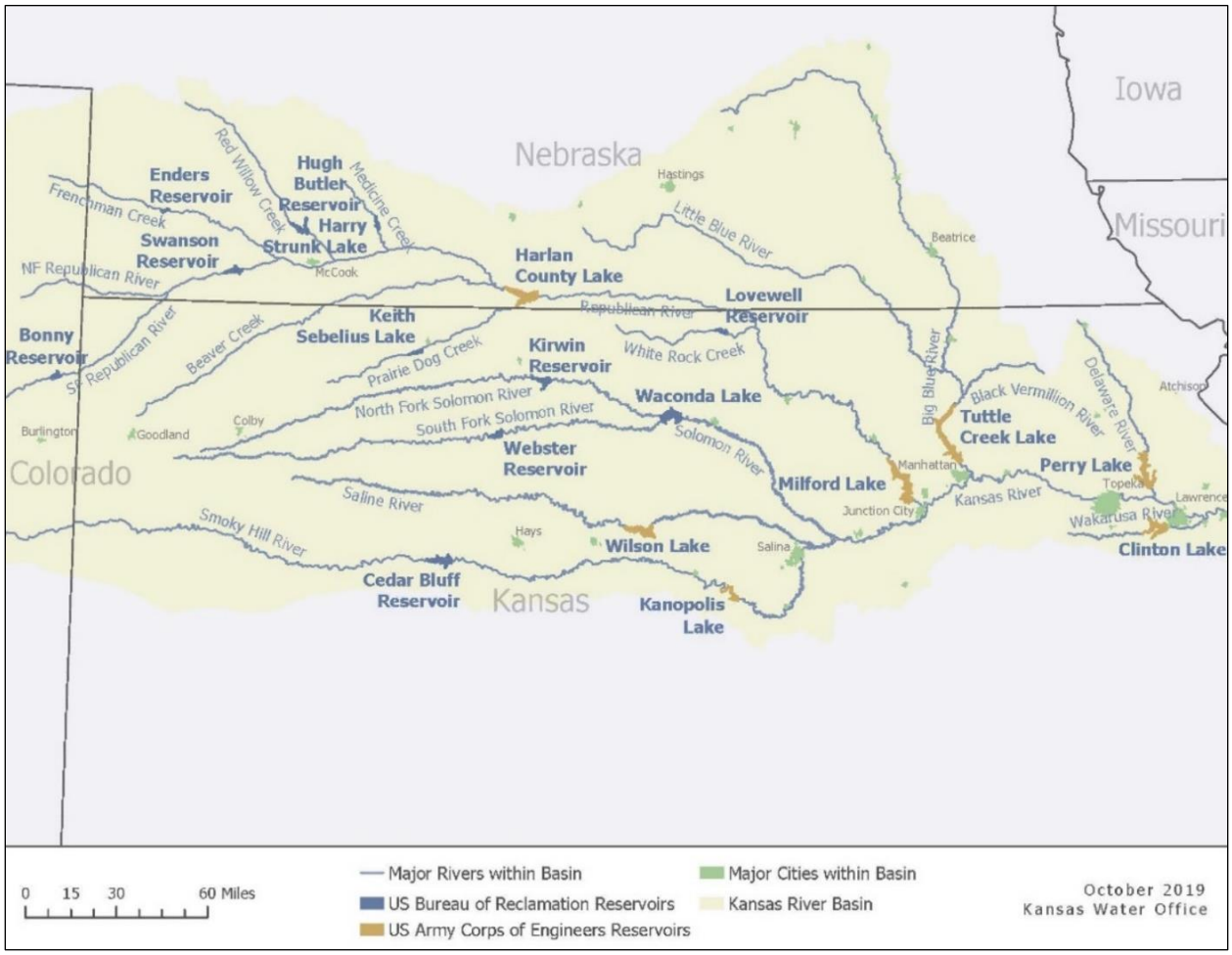
2.1 Study Area

The basin (study area) occupies almost the entire northern half of Kansas, as well as part of Nebraska and Colorado and encompasses more than 60,000 square miles (38,400,000 acres) (Figure 2-1). The Kansas River is an important resource for the State of Kansas.

The Kansas River begins at the confluence of the Republican and Smoky Hill Rivers near Junction City and flows 173 miles to Kansas City, where it joins the Missouri River. The Smoky Hill River begins approximately 40 miles west of the Colorado-Kansas state line. From its source the Smoky Hill flows in an easterly direction to Cedar Bluff Dam, to Kanopolis Dam, and then east-northeast for approximately 184 river miles to its confluence with the Republican, forming the Kansas River. The Saline River begins in western Kansas near Mingo, Kansas. From its source, the Saline River flows eastward 263 miles to Wilson Dam, then 154 miles east to its confluence with the Smoky Hill River. The Solomon River begins at the confluence of the South Fork and North Fork Solomon Rivers below Glen Elder Dam. Waconda Reservoir, at the confluence of the North Fork Solomon and South Fork Solomon rivers, was completed in 1967. From Glen Elder Dam, the Solomon River flows into the Smoky Hill River. The Republican River flows approximately 420 river miles generally easterly and southeasterly, joining with the Smoky Hill River immediately below Junction City, Kansas, to form the Kansas River. There are roughly 640 freshwater stream miles below all major dams, and

approximately 100,000 acres of federally-owned freshwater impoundments, including USACE and USBR reservoirs, in the basin.

Figure 2-1. Kansas River Basin



2.2 Population and Land Use

The basin is diverse, with a variety of land cover types and uses, as inhabitants have taken advantage of productive, largely free-draining soils and flat to moderate to gently sloping terrain. Today, all suitable land in the Kansas River valley is devoted to agriculture (USACE 1966). The western portion of the Basin is primarily in dryland farming with sorghum and wheat the primary crops with areas of irrigated cropland (Rohweder 2015). The eastern two-thirds of the Basin are in various agricultural uses with much of the floodplain area and many areas in the uplands in crops such as corn, wheat, soybeans, and milo. Lands with steeper topography are mostly in pasture and hay. Expected land use changes show a relatively stable land use pattern over a 16-year period. Changes in various land types over the 16-year period include increases in land cover categorized as developed, medium intensity; developed, high intensity; barren land; and emergent herbaceous wetlands; each showing changes over this period. Land types that decreased include open water, deciduous forest, evergreen forest, shrub/scrub, herbaceous, hay/pasture, and woody wetlands.

Population projection data indicates net future population in the Basin will rise by approximately 44 percent (or 801,193) persons by the year 2070. The 6 counties in the Basin most likely to realize land use/land cover changes due to this additional population growth are Johnson County (77 percent, 533,026 persons); Geary County (189 percent, 86,017 persons); Douglas County (47 percent, 68,124 persons); Riley County (48 percent, 44,451 persons); Pottawatomie County (121 percent, 33,056 persons); and Leavenworth County (34 percent, 32,765 persons), with Johnson County expected to increase the most. All of these counties are located in the eastern portion of the basin.

Land use overall within the Basin is not expected to change appreciably within the short-term. The far eastern portion of the Basin is already urban in large areas. Small areas of forests, scrub-shrub, wetland, herbaceous vegetation, and agricultural lands (hay/pasture) within the Basin would be expected to convert to urban land uses in the long-term, as this seems to be the trend.

2.3 Shared Vision Statement

USACE, KWO and KDWP collaborated to develop and define a Shared Vision Statement for the watershed, water, and related resources as developed by partners involved in the watershed study. The statement presents the coordinated study framework and associated activities that clearly support the Shared Vision. The Shared Vision Statement (quoted below) is broad enough to encompass various goals and objectives of individual partners and stakeholders, and sufficiently detailed to allow for subsequent development of planning goals and objectives.

> *Within the Kansas River Watershed there are significant water resource challenges including increased flood risk, reduced water availability, reservoir sedimentation, water quality concerns, streambank erosion, increased demand for recreational opportunities, and loss of wetlands and riparian habitat. Sustainable measures must be identified and developed to reduce flood risk, improve sediment management, and mitigate drought, and to address additional existing water resource problems within the watershed. Measures include those necessary to increase the resiliency and sustainability of the system, and identification of viable opportunities for investment in critical infrastructure throughout the basin, including existing reservoirs, to increase their resiliency and maintain capacity for water availability and sustainment, ecosystem restoration, water quality, and recreational amenities.*

2.4 Issues and Opportunities

The watershed study develops a comprehensive and holistic long-term (50–100 year) plan for identifying and addressing multiple water resource problems within the basin, including flood risk management, stream erosion, sediment loading of reservoirs, reductions of flood storage and water supply availability, water quality issues, and drought. The study process fully defines and describes the problems, needs and opportunities in the watershed by involving study partners, water resources and related

stakeholders, resource agencies, and the public to collect a broad view of problems, needs, and opportunities and reaffirm the purpose of the watershed study. The watershed study builds on previous outreach, communication, and coordination by the KWO and other partnering state agencies during *Vision* development.

In the watershed study, identified problems focus on flood risk, sedimentation and erosion, reduction in the ability to meet water supply demands, degraded/poor water quality, ecosystem degradation and species impacts, and loss of recreational opportunities. Most critically, the study effort identifies problems and opportunities that reflect the priorities and preferences of the federal government, the non-federal sponsors, and other participating groups.

The problems identified in the basin are summarized below and described in greater detail in the following sections.

Problem 1: Flood Risk—Flooding is a reoccurring challenge in the basin that can be costly, both in property lost and more significantly in loss of lives. Flooding events in the basin has caused riverine and overland flooding and high reservoir water levels that threatens life safety; damages homes, businesses, public facilities, agricultural lands, and critical infrastructure (e.g., roads, railroads, utilities); displaces individuals and businesses; damages cultural resources; increases environmental degradation; and causes public health issues.

Problem 2: Sedimentation and Erosion—Reservoir sedimentation is a major threat to crucial flood risk management infrastructure, critical water drinking water supply, irrigation, recreation, and power generation in the basin. Every year, millions of cubic yards of sediment accumulate in the federal reservoirs. Streambank erosion is a significant cause of reservoir sedimentation in the basin with most reservoir sedimentation occurring during high flow events. River channels downstream of dams suffer bed degradation and habitat impairment due to a lack of sediment. Riverbed degradation is impacting river and stream banks, public infrastructure, and levees.

Problem 3: Reduction in Ability to Meet Water Supply Demands—The basin water supply system is vulnerable to naturally occurring and anthropogenic stressors including reservoir sedimentation, drought, groundwater depletions, the risk of reduced water supply from navigation releases, and climate change implications. Lack of reliable water supply and shortages of water could have a devastating effect on the economy in the basin and the health and welfare of basin residents.

Problem 4: Degraded/Poor Water Quality—Water quality throughout the basin is vulnerable to naturally occurring and anthropogenic stressors including HABs, impaired waters, risk to high quality water, stormwater management, and sedimentation. There is a risk with loss of reservoir storage and future water shortages that there could be reduced ability to meet water quality demands within the basin during times of extended drought or maintain a base level of streamflow. Currently 17 of the 18 federal reservoirs in the basin are listed as “impaired” and with expected sedimentation in reservoirs there could be a reduction in their ability to provide current benefits of chemical buffering.

Problem 5: Ecosystem Degradation and Species Impacts—Changes, loss, and fragmentation of terrestrial and aquatic habitats in the basin has led to habitat degradation, loss of heterogeneity, and loss of connectivity of these habitats, leading to declines in species populations in the basin. Invasive and non-native species have caused declines in native species and degradation of terrestrial and aquatic habitat.

Problem 6: Loss of Recreation Opportunities—Water-based recreational opportunities are threatened by flooding, low water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species. These impacts cause a loss of visitation leading to lost revenue and high costs to repair damages to recreation facilities. Public lands that provide recreation opportunities are rare in Kansas, with privately-owned lands accounting for most of the land. State-owned and controlled lands for recreation account for only 0.7 percent of the lands in the state of Kansas. Because of the scarcity of federal and state public lands for recreation, these lands must be protected and managed to promote sufficient recreational opportunities to meet the needs of residents and visitors.

2.4.1 Flood Risk

Flooding is a reoccurring challenge in Kansas that can be costly, both in property lost and more significantly in loss of lives. Due to the high cost of flood damage and the even more significant potential loss of life, flood control measures such as reservoirs, dams, and levees are necessary. Flooding in the basin has historically caused damage to structures, critical infrastructure, and public facilities, and significant flood events continue to occur. In the 20th and 21st centuries, notable flooding occurred on the Kansas River in 1903, 1951, 1993, and 2019. These floods damaged millions of dollars of private property and crop land, as well as critical infrastructure such as interstate highways, railroads, and state highways. Additionally, floods have caused damages and lost revenue at recreational facilities managed by federal and state agencies, private entities, and non-profit organizations.

Structural flood control projects seek to control the flow of water and are intended to prevent flood waters from reaching land, structures, or other property at risk of damage. There are generally three types of structures: levees and floodwalls, dams and diversions, and channel and drainage modifications. Large federal reservoirs have been constructed in Kansas by the USACE and the USBR. Additional funding for watershed dams has come from the U.S. Department of Agriculture (USDA) and the NRCS. The primary purpose of these reservoirs is flood control. Federally funded levees also provide a measure of structural flood protection. Multiple communities are located along the Kansas River and its tributaries downstream of USACE dams. The system of dams and reservoirs in the basin is designed to manage flood risk for these communities.

Aging infrastructure is a national problem and increases the risk that dams and levees could fail during a flooding event. Failures could be disastrous due to destruction of vulnerable development below dams and behind levees. Federal, state, and local action is needed to ensure the safety of communities that benefit from reduced flood risk of flooding through dams and levees. The ongoing infrastructure assessment and

inspection system provides valuable information for the watershed study of existing conditions and future needs related to infrastructure investment needs.

2.4.1.1 History of Flooding

The entire basin is subject to severe flooding at infrequent intervals, erratically interspersed by less severe floods of varying magnitudes. At no time since settlement by man has the entire basin experienced severe damage from a single flood or closely related series of floods. The nearest approach to this was by the May, June, and July floods of 1951, which covered most of the basin except the Republican River and tributaries above Harlan County Dam. As would be expected from the average annual rainfall pattern previously described, the more frequent floods occur in the lower part of the basin. Following are summaries of the major flooding events in the basin since 1950. All estimates of monetary damages remain in flood year dollars (i.e., estimates made in same or following year as that flood event) and have not been inflated to 2023 values.

Generally, flooding in the basin are of two classifications. The first, less frequent but severe, is flood flows due to prolonged periods of rainfall which saturate the soils, raise the water table, and bring the streams to bank full stage. These are climaxed by a period of intense rainfall producing considerable and extensive damage to both rural and urban developments, with major losses occurring at urban and industrial centers. The second, which is more frequent, is the overflow produced by storms of cloudburst type over small areas and result in considerable local damage to crops, lands, transportation facilities, and other properties in rural areas, with possibly some urban damage. These flash floods are seldom of sufficient volume or duration to cause general flooding of the mainstream valleys. Floods and damage caused by melting snow are of infrequent occurrence. The shape of the drainage is conducive to concentration of floodwaters and the production of excessive flood discharges in the downstream areas, even though storms of sufficient magnitude to cause extensive flooding in the mainstream valley are of infrequent occurrence.

2.4.1.1.1 Early Floods

Several of the earliest floods are not well documented in the historical record and are more known through anecdotal reports. Anecdotal sources, report floods affecting the lower basin occurred in 1785, 1826, 1844, 1845, 1851, 1858, 1870, 1881, and 1886. The 1844 flood appears to have produced the maximum stages of record, at Topeka, Kansas. High-water marks of the 1844 flood indicate that it was probably comparable to the July 1951 flood. The large flood of May-June 1903 had an estimated discharge of 337,000 cubic feet per second (cfs) at the mouth of the Kansas River. Very little information is available relative to actual damages caused by floods prior to 1900. Extensive investigations were made during 1929 and 1930 of flood losses subsequent to 1902. The research showed that there were approximately 500,000 acres, or about 2 percent of agricultural lands in the basin subject to overflow. Total flood damages on agricultural lands for the 29-year period, 1902-1930, at 1959 prices, were $41,170,000, of which $18,691,000 occurred in the lower basin. Four municipalities: Manhattan, Topeka, Lawrence, and Kansas City sustained a total flood damage of $33,472,000 during the 28-year period, 1903-1930 inclusive.

2.4.1.1.2 Flood of 1903

The flood of 1903 affected the Missouri, Kansas, and lower Republican River basins. Flooding along the Kansas River during May 1903 was the greatest since 1844. A total of 57 people died; 38 of those were in Topeka. The Topeka Daily Capital also reported that 4,000 people were driven from their homes. Rainfall was above normal during the first half of May 1903 in northeast and north-central Kansas. As a result, soils in the Kansas and lower Republican River basins were already saturated when excessive rains began in late May. Salina had more than 17 inches of rain during the month, and most of northeast and north-central Kansas had more than 10 inches of rain. The lack of surface storage in river basins and already saturated soils made the flood of 1903 of exceptional magnitude. The maximum daily gage height of the USGS Lecompton gage for this date was 27.9 feet, which was 6 feet higher than the highest reading during the previous 22 years of record. The Missouri River gage at Kansas City recorded its highest reading during the 1903 flood, nearly 35 feet, on June 2, which was only 2 feet below the highest mark of the great flood of June 20, 1844. For a period of 11 days (May 28 through June 7), the Kansas River was higher than it had been in the previous 22 years of record. Hundreds of homes were swept away by floodwaters and property damage was great totaling $22M in Kansas and Kansas City, Missouri. Of the 16 bridges spanning the Kansas River from the Armourdale District in Kansas City, Kansas, to its joining with the Missouri River, all except one were in part or wholly destroyed. One of the bridges carried a 36-inch water pipe that supplied Kansas City, Missouri, and a part of Kansas City, Kansas. As a result of the pipe loss, the whole city was without water for 12 days, and electric and gas companies, and street railways were forced to shut down. In Lawrence, the north span of the Massachusetts Street Bridge over the Kansas River was swept off its piers by a house that was carried along by the raging torrent. Had it not been for the forethought of authorities in uncoupling this bridge span from the others, the entire bridge might have been lost. Bowersock Mill was swept away, and during the day of May 30, 50 houses were counted as they were swept over the mill dam (USGS 2003).

2.4.1.1.3 Floods of 1930 to 1940 Period

Only one flood of any consequence occurred during this period. The flood of 1935 was probably the most unusual and was the most damaging flood in the Republican River Basin. It occurred as a result of severe thunderstorm type rainfall in a period that was otherwise noted, from the hydrologic viewpoint, as the most critical sustained drought period on record for the basin. The runoff originated in the headwaters of the Republican River and reached its maximum discharge of 280,000 cfs near Cambridge, Nebraska. Peak travel time was unusually fast-traveling at approximately 10 miles per hour upstream from Trenton, Nebraska, and 5 miles per hour in the vicinity of Oxford, Nebraska. The flood peak had reduced to 179,000 cfs at the upper end of the Kansas River and passed Bonner Springs at a peak flow of 122,000 cfs. Flood damage, based on 1935 price levels, amounted to $10,665,000 in the basin of which $9,029,600 was experienced on the Republican River. Due to the lack of time to warn the people in the upper Republican basin and the disbelief of the impending danger to residents below Trenton, Nebraska, there were 10 lives lost on the Republican River.

2.4.1.1.4 Floods Since 1940

Beginning in 1941, floods of varying degrees of magnitude have occurred on all or part of the major Kansas River tributaries each year through 1960 and on the mainstem of the Kansas River except during the period of 1952 and 1959. The largest of these floods occurred in 1943, 1945, 1947, 1949, 1951, 1957, and 1960. The period 1952 through 1956 included a severe drought period accompanied by extremely low flows in the lower basin notwithstanding one or more relatively small tributary floods in each year. The 1957 flood was of a minor nature on the Kansas River but marked the end of the 1950's drought period.

2.4.1.1.5 Flood of 1943

Frequent heavy rains over the basin beginning in early June and continuing to mid-June resulted in damaging floods in much of the basin. Portions of 27 counties were inundated along the main stem of the Kansas River and its tributaries with extensive damage to land and loss of livestock, in addition to crop losses. Railroads, state highways, county roads, and bridges were damaged extensively. The Sunflower Ordinance Works near De Soto, Kansas sustained severe damage to its water supply facilities and structures. Levees along the Kansas River sustained severe damage and major municipal losses occurred at Paxico, Lawrence, and Topeka. One drowning occurred in Mill Creek. The total damage resulting from the June flood for the entire basin was estimated to be $10,172,000 of which $7,303,000 or 72 percent, occurred along its principal tributaries. A total of 246,000 acres of land was inundated of which 142,000 acres, or 58 percent, occurred in the main stem basin.

2.4.1.1.6 Flood of 1951

In July 1951, following a 2-month period of above-normal precipitation, rains of unprecedented intensity occurred over the Kansas River, Marais des Cygnes, and Neosho basins in Kansas, causing the most devasting floods in the history of the Kansas and lower Missouri River basins for which hydrologic records are available. Volumetrically, the runoff during May, June, and July amounted to three times the average annual discharge in the basin.

Figure 2-2. Flooding at the confluence of the Kansas and Missouri Rivers during the 1951 flood



The flooding that occurred during July 1951 was the most damaging in the history of the Kansas and lower Missouri Rivers. The entire lower basin was paralyzed, as all transportation was brought to a standstill, communication lines were down, radio stations were inundated, and electric-power and water facilities were disrupted. In all cities and towns throughout the flooded area, the normal economic activity was replaced by rescue and relief operations, and after the flood by rehabilitation efforts. A total of approximately 892,000 acres of floodplain were inundated in the basin. Twenty lives were lost and there were unverified reports of four additional deaths. The 1951 floods directly affected 116 cities and towns in the basin and caused evacuation of about 85,000 persons. Approximately 22,370 residences in the basin were inundated, about 2,480 being demolished. About 200 schools and churches were damaged. Nearly 3,270 business concerns—including factories, warehouses, and wholesale and retail outlets—were flooded and 336 were destroyed. The damage to buildings was aggravated by the battering force of the turbulent debris-laden waters. Many buildings collapsed under the weight of sediment deposited on floors and roofs. Over 10,000 farms suffered flood damage. The swift current of the floodwaters scoured many fields and deposited heavy blankets of sediment or sterile sand over others. In many areas, costly deep plowing was employed in an attempt to restore damaged lands to production.

Total losses in the basin and at the Kansas City's exceeded $725,000,000. The predominant part of this tremendous loss occurred in mid-July, for it was then that large sections of Topeka, Manhattan, Salina, and Lawrence, and the Argentine, Armourdale, and Fairfax Districts of Kansas City in Kansas. The Kansas and Missouri sections of the Kansas City Central Industrial District, and other communities were flooded to great depths. Losses were largest in the urban areas, but rural losses amounted to about $122,500,000. The evaluated losses do not include secondary losses which occur after a flood of such magnitude.

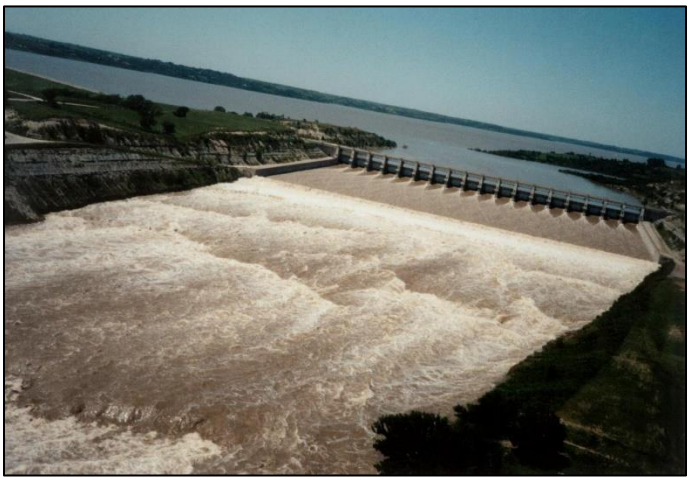
2.4.1.1.7 Flood of 1960

Recurring heavy snows from February into March culminated in the heaviest widespread snowfall of record for Kansas. Mild weather and intermittent warming in the western part of Kansas and Nebraska in late March soon reduced the snow cover, resulting in general flood conditions in the upper and middle portions of the Solomon, Saline, and Republican River basins. Along the mid-Republican River some flooding was aggravated by ice jams. By the end of March general flooding prevailed in the basin with moderate to heavy flooding in the lower reaches of the Big Blue, Black Vermillion, Republican, Smoky Hill, Saline, and Solomon Rivers. Some flooding in isolated localities occurred on the Delaware and Wakarusa Rivers, and Stranger Creek, minor tributaries of the Kansas River. Along the Kansas River there was some flooding in the vicinity of Fort Riley and Manhattan, and from Lecompton to below Bonner Springs. Numerous state highways and two federal highways were flooded and closed in the vicinity of stream crossings in the Blue River and Stranger Creek basins. Additional roads and section of railroad were also closed. Almost 200,000 acres of cropland were flooded principally in the lower reaches of Kansas River tributaries. Monetary damages due to the flood were estimated at about a half million dollars.

2.4.1.1.8 Flood of 1993

The historic flood of 1993 affected more than just Kansas and spanned nearly 2 months from mid-June to early August. The area of significant flooding extended into much of the upper Mississippi River Basin and included parts of southern Minnesota, southwestern Wisconsin, Iowa, western Illinois, northern Missouri, southern North Dakota, and eastern parts of South Dakota, Nebraska, and Kansas. Fifty deaths occurred, and damages approached $15B in the nine-state-area. The magnitude and timing of several rainstorms in mid-June and July 1993, combined with wet antecedent conditions, were the principal causes of the severe flooding in the upper Mississippi River Basin in 1993.

Figure 2-3. Releases from Tuttle Creek Dam during the 1993 flood



In Kansas, January through July monthly precipitation total ranged from 64 to 535 percent of normal for the NWS station at Manhattan. From July 22 to 24, 2 to 13 inches of rain fell in parts of Kansas and Nebraska contributing large flows to already filled reservoirs in the basin. Moderate to large flooding occurred in a large part of the basin during July 1993. The Kansas, Big Blue, Black Vermillion, Smoky Hill, and Republican Rivers, along with their tributaries, produced flooding of agricultural fields, numerous secondary roads, and many county, State, and Federal highways. Eighteen of the 163 USGS streamflow-gaging stations in operation during 1993 measured record maximum daily peak flows, and 68 stations measure mean annual stream flows for the 1993 water year that exceeded the greatest mean annual streamflow for their periods of record, which ranged from 6 to 78 years in length.

In the Kansas City metropolitan area, the Missouri and Kansas Rivers reached their highest flows almost simultaneously on July 27, 1993, peaking at 170,000 cfs on the Kansas River. Excessive rainfall upstream, saturated soil conditions, and high river stages combined to create a flood of historic magnitude on the Missouri River. Without the reservoirs in the Missouri and Kansas River basins, the maximum daily flow at the USGS gaging station on the Missouri River at Kansas City, Missouri could have been as high as 713,000 cfs, overtopping the Federal levee system. With the reservoirs, streamflow was contained within the levees. Observed flows on July 27 were less than 2 feet from the top of the Federal levees, and despite upstream regulation of flows, the

Missouri River at Kansas City, Missouri gaging station was above flood stage (32 feet) from July 6 through August 6. No lives were lost in Kansas as a result of the flooding.

Figure 2-4. Spillway and Kansas Highway 244 Spur Blowout at Milford Reservoir During the 1993 Flood



Record rains fell in Geary County where Milford Reservoir is located and on July 19 the reservoir reach the top of flood pool resulting in maximum releases from the dam gates. Water levels crested at roughly 5.7 feet over the top of the grassed spillway south of the dam and water flowed unrestricted until the river levels subsided. Flood waters broke through the Kansas 244 Spur and in an effort to direct floodwaters, a cut was made through Highway 57 to allow spillway water to flow back into the Republican River. Republican River water levels caused flooding downstream, including in the Smoky Hill River. More than 3,000 people evacuated and sought temporary shelter. Hundreds of citizens filled more than 10,000 sandbags in parking lots for delivery to flooding areas.

2.4.1.1.9 Flood of 2019

In 2019, saturated conditions in the Great Plains early in the year were amplified by the wettest spring on record and additional summer rains. Thanks to the system of federal reservoirs, levees, and other watershed dams, most of the flood damage waters were held in federal reservoirs and contained within unoccupied floodplains and riparian corridors. The localized damage, however, came at a cost within the basin. Low-lying areas, often accompanied by productive agricultural lands, public infrastructure, and other assets, endured long periods of inundation and the erosive forces of flood waters.

Figure 2-5. High Water at Perry Reservoir During the 2019 Flood

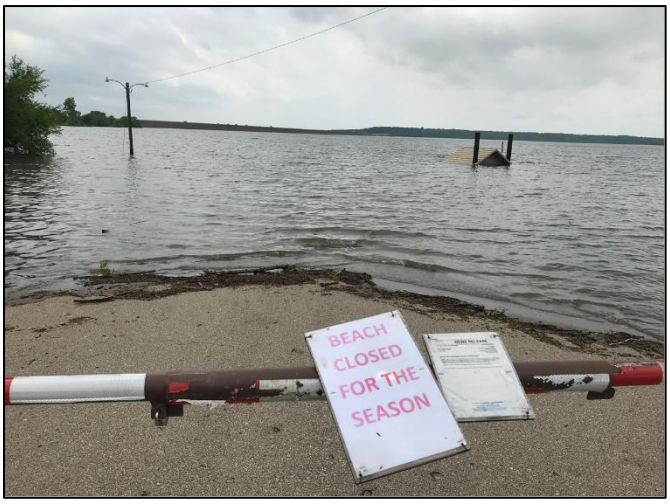


Figure 2-6. High Water at Clinton Reservoir During the 2019 Flood



Prolonged wet weather throughout the Missouri River Basin with the inability to release flows from the dams in the basin drove two of the seven lower basin dams to record pools (Perry and Clinton reservoirs), eclipsing 1993, two other reservoirs to their second highest pools (Tuttle and Milford reservoirs) behind 1993, and one reservoir to its third highest (Kanopolis Reservoir) behind 1951 and 1993. Upstream of Milford Dam, Harlan County Dam, completed in 1959, also set a record pool on the Republican River Basin. Fortunately, rains slowed when Perry and Tuttle Creek Dams were beginning to initiate surcharge operations. Based on the NWS gage at the Turner Bridge at mile 9.3, maximum 2019 water surface elevations were approximately 751 feet, over 15 feet lower than 1993 on June 24, 2019, at a Kansas River flow of 102,000 cfs with 258,000 cfs below the confluence. Storage peaked on June 1, 2019, in the lower seven basin dams at 5.1 million acre-feet, representing 75 percent of the multipurpose and flood pools. Reservoir storage dropped to 4.6 million acre-feet before reaching a second peak of five million acre-feet on June 24, 2019. The ability to draw down pools levels has been limited by the downstream flow target on the Missouri River at Waverly, Missouri throughout much of the year, representing a long duration of heightened flood risk for the Kansas River. The extended wet period was similar to 1951 and 1993, but without

additional extreme precipitation in the northeastern Kansas area that would create a major flood on the Kansas River.

2.4.2 Sedimentation and Erosion

Sedimentation in reservoirs within the basin is a looming problem to be addressed so that benefits provided by the reservoirs for water availability and sustainment, flood risk management, water quality, recreation, and fish and wildlife can be realized into the future. Sediment management on the mainstem of the Kansas River is important to infrastructure, such as water supply intakes, irrigation diversion structures, and other uses such as recreation and ecological resources.

Sedimentation in the reservoirs threatens crucial flood risk management infrastructure, critical drinking water supply for more than 800,000 people, irrigation, and power generation. Historical data and projected estimates indicate that the multi-purpose pools of the reservoirs will continue to fill with sediment, some nearly half full and losing at rates of one to two percent a year. Additionally, sediment accumulation could impede the ability to maintain the function of flood control gates and other appurtenances, which could seriously impact the flood risk mission of the USACE.

Meanwhile, river channels, including the Kansas River, downstream from the dams are suffering bed degradation and habitat impairment due to a lack of sediment. Riverbed degradation can impact both main stem and tributary riverbanks, public infrastructure, and the long-term sustainability of flood risk reduction levees. Sedimentation induced expanding shallow zones in reservoirs reduces water quality and operational storage capacity for public water supply and recreation.

Targeted investments have included implementation of BMPs such as streambank stabilization projects, watershed dam construction, and increased support of soil health initiatives. However, acres of agricultural lands that have had conservation practices implemented and the number of streambank stabilization sites completed, with past and current levels of funding, have not remediated reservoir sedimentation issues. Barring deliberate restorative action, sedimentation issues will significantly reduce project benefits, increase O&M costs, and increase safety risks over the next 50 years, and these crucial benefits will continue to diminish.

Streambank erosion is a significant cause of reservoir sedimentation in the basin. To combat this problem over 250 streambank stabilization projects have been completed along rivers draining into major federal reservoirs. The effectiveness of streambank stabilization projects needs to be studied to determine whether or not streambank stabilization projects accomplish the goal of reducing total sediment loads entering Kansas reservoirs, and whether or not it resolves the underlying causes of streambank erosion, a stream out of equilibrium, and does not shift erosion upstream or downstream of the streambank stabilization site. Baseline data and post-construction monitoring are essential to assess the long-term effectiveness of streambank stabilization projects.

2.4.3 Water Supply Availability and Sustainment

Lack of reliable water supply and shortages of water could have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Every industry from agriculture, electric power generation and manufacturing to tourism relies on water to

grow and ultimately sustain its business. Developing and implementing plans and tools that secure and improve the reliability of state water supplies is essential for the future prosperity of Kansas communities and health of citizens. Water supplies can be affected by competing and multiple uses, including the USACE releases of water from Kansas River Reservoirs to support navigation on the Missouri River. In addition, planning for extreme events, such as drought, is necessary to reduce vulnerability and create resiliency to ensure clean water delivery to Kansas citizens.

2.4.3.1 Reservoirs and Surface Water

Within the basin, there are 18 federal reservoirs operated by the USACE and the USBR for multiple purposes, with the USACE managing flood risk management operations. Significant critical infrastructure is located downstream of the federal projects, including water and wastewater treatment plants, power plants, fire stations, schools, and military installation facilities. Surface water resources in Kansas serve as the source of municipal and industrial water supply for more than two-thirds of the state's population. Nearly 60 percent of the energy produced in Kansas relies on the storage in the state's reservoirs. Irrigation is also an authorized use for some reservoirs in the watershed and in areas below reservoirs. All of these uses require a reliable quantity and quality of water supply to continue providing economic benefits to the basin.

A major threat to water supply availability in the basin is reservoir sedimentation. Every year, thousands of acre-feet of water storage are lost, as millions of cubic yards of sediment accumulate in the federal reservoirs. Other challenges to managing reservoir supplies include regaining lost and preserving current water supply storage; identifying additional storage opportunities and reallocations of existing storage; and funding sources and responsibilities for O&M costs. As part of the *Reservoir Roadmap* completed by the KWO in 2010, the 2014 *Kansas Water Plan*, as well as the *Vision*, the development of long-term plans for securing, protecting, and restoring Kansas water supplies into the future was highlighted as a major need in Kansas. Loss of reservoir water supply will inhibit future urban and rural development efforts and create a regressive expense burden for small-town residents, as water suppliers incur elevated costs for water sourcing (KWO 2022).

2.4.3.2 Groundwater

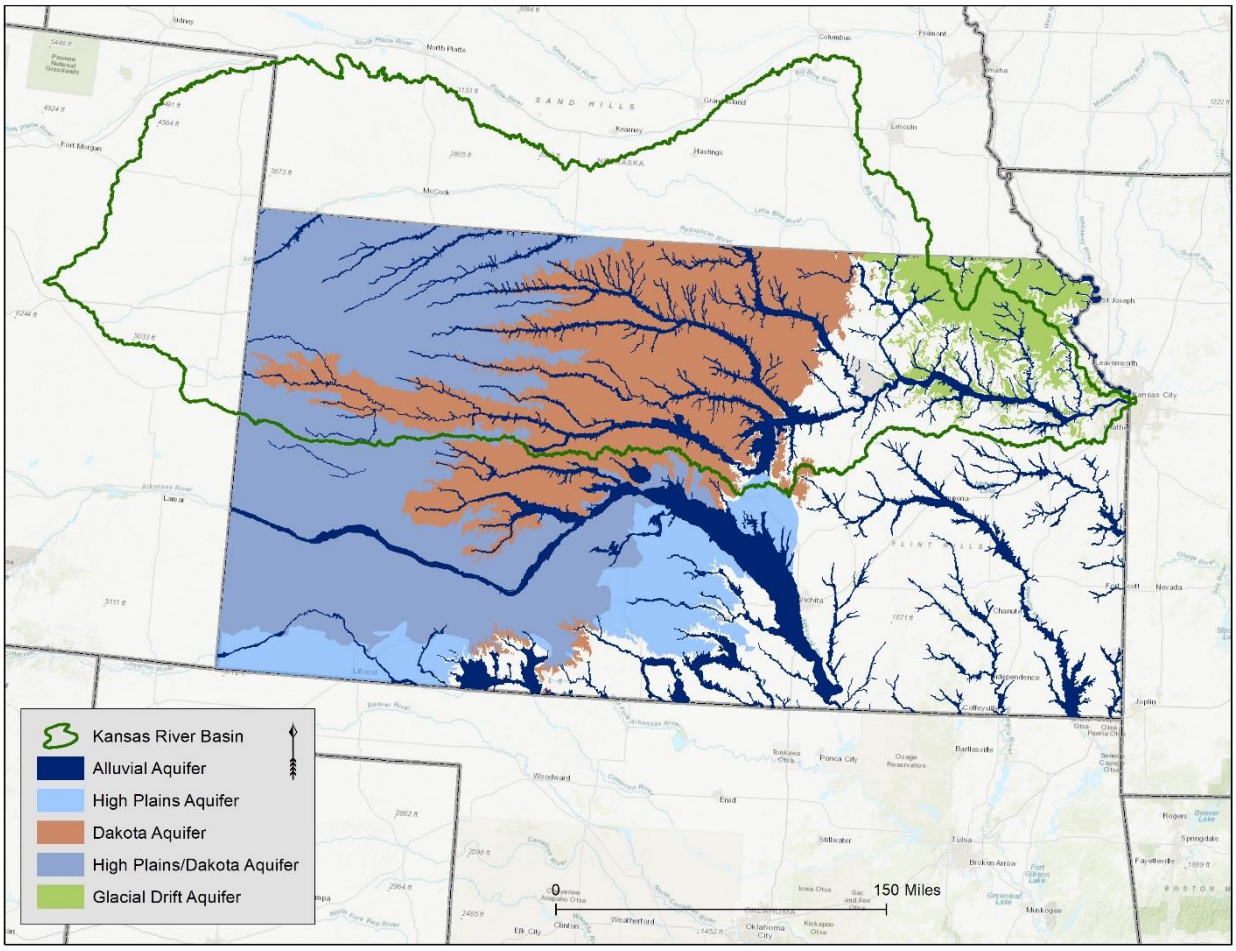
Western Kansas aquifers are generally deep and saturated while the eastern Kansas aquifers are generally shallower and alluvial (Figure 2-7). A Master Groundwater Well Inventory was established and is maintained by the KGS (https://geohydro.kgs.ku.edu/geohydro/master_well/index.cfm). Water right and annual water use information is collected and available through the KDA-DWR.

The High Plains aquifer underlies the western and south-central portions of Kansas. The High Plains aquifer is heavily developed, particularly for irrigation, with most of the Ogallala portion in long term, serious decline (Fross et al. 2012).

Alluvial aquifers are the predominant source of groundwater for central and eastern portions of the study area. Water rights development within these alluvial aquifers has been limited to average annual recharge (safe yield). Generally, alluviums of the Lower Smoky, Republican, and Kansas Rivers still contribute baseflow to the surface water

system. Some unconfined Dakota aquifer is present between the High Plains aquifer of the west and the alluvial dominated east. Its use is relatively small, but water level declines have impacted surface water flows in some areas near outcrops. Outside the alluvial corridors of northeast Kansas, pockets of glacial drift are used as water supply, but they are not extensive.

Figure 2-7. Kansas Aquifers



The Kansas River corridor is projected to continue to be a major area of population and economic expansion in the coming decades, and the Kansas River alluvial aquifer will be utilized to help support that expansion. The aquifer provides groundwater from the Kansas River alluvium. Currently there is insufficient information to reliably assess how water levels in the aquifer and the Kansas River will respond to an increase in pumping. Management of groundwater storage in the aquifer in conjunction with management of reservoir system storage requires this information. The KGS is carrying out a two-phase program to improve the understanding of the aquifer and its relationship to the Kansas River.

2.4.4 Drought Risk

The history of drought major drought events in the Basin and included in this section from the early droughts to more recent ones. The current drought (2023) is not

discussed but it is acknowledged and will be considered in the drought record for future assessments.

2.4.4.1 History of Drought

Kansas has repeatedly experienced droughts, with some of the most severe occurring in the 1930s and 1950s. These events are typically used as standards for severe droughts in Kansas in the past hundred years. Kansas is one of the states with a history of significant impacts from drought. In recent years, drought-related losses in Kansas have been particularly significant in agriculture. In 2011, the KDA estimated that drought caused roughly $1.8B in crop losses in Kansas including the price farmers would have received for the lost production and nearly $366M in drought-related herd liquidation to overfilled cattle livestock auction houses. Even more destructive, the 2012 drought caused more than $3B in drought-related crop losses in Kansas. Intense flash drought can also rapidly impact water supplies. With approximately two-thirds of the Kansas population relying on surface water for municipal and industrial needs, depletion of these resources creates a significant strain on communities and businesses (KWO 2022) Ultimately, drought mitigation planning is needed by all sectors that use water. Additional storage of water in reservoirs or aquifers would give Kansans greater ability to manage for potential changes in precipitation timing, duration, and frequency, such as extended dry spells. This can be accomplished through conservation practices to extend and conserve groundwater resources, building or purchasing additional storage, or the recovery of existing surface storage lost to sedimentation. All options for drought mitigation should be pursued to protect Kansans and the future economic health of the State. Kansas relies heavily on access to surface and subsurface water resources for everyday use. When managing through extreme events, these storage resources play a critical public safety role in fighting drought or holding back flood water.

Climatologists have warned that Kansas is facing a warming trend in the future, causing a potential increase in the frequency, duration, and intensity of extreme events. Recent decades support this trend, with temperature increases particularly notable in the spring.

What has historically allowed the State of Kansas to grow and prosper is the utilization of water resources to combat extreme events. In western Kansas, groundwater resources play a critical role. In eastern Kansas, surface water resources have a more significant impact. However, these vital resources have a threshold. The State supports extensive monitoring, such as stream gaging partnerships with the USGS, to evaluate historical events and assess when current conditions are approaching a critical point. These efforts help the State to understand how extreme events have impacted Kansas in the past and project how they may continue to do so in the future.

During drought, the majority of flow in a river is actively managed with prescribed releases from USACE reservoirs, often providing the majority of water to the tap.

The State manages a Drought Response Team that is charged with monitoring conditions, coordinating resources, and supplying the Governor’s Office with updates or recommendations to deploy additional resources as needed.

2.4.5 Reservoir Operations

USACE dams manage water flow from a majority of the Kansas River watershed with a total of approximately 45,800 square miles of drainage area upstream of USACE dams. Approximately 9,730 square miles of unregulated areas remain below major dams and the mouth of the Kansas River. The map at Figure 2-1 details the predominant streams in the Kansas River watershed.

Significant critical infrastructure including water and wastewater treatment plants, power plants, fire stations, schools, and military installation facilities is located downstream of the reservoirs. Sustaining the ability of reservoir projects (or operations) to continue to provide these risk reduction benefits for this infrastructure into the future is crucial, as there is no feasible way to replace these benefits.

An assessment of system management to identify areas of concern and to evaluate alternative improvements to the system is needed. The assessment evaluates the potential for water supply shortages, flood risk management, minimum stream flow deficiencies, recreation impacts, in-stream water quality, drought related issues, and flood related issues. Conditions that influence storage in the various pools within a reservoir affect the ability to meet releases for uses downstream (e.g., water marketing and assurance customer shortages, downstream water quality minimum release targets not met). Strategies and alternatives that could improve reliability include sediment removal, water supply reallocation, structural restoration, demand management, reservoir operational changes, new reservoirs, off-stream storage, and watershed management.

Operational limits on the amount of allowable Missouri River flow during various flood stages can require large amount of water to be stored in reservoirs in the basin. This increased risk of limited available flood control storage for additional precipitation events, such as during the 2019 flood event, has severely impacted user groups (e.g., recreation, agriculture). Consideration of changes to these criteria for releases that would allow for earlier releases of water stored in the flood control pools in basin reservoirs could reduce potential impacts to users.

2.4.6 Water Quality

The availability of high-quality water for commercial, industrial, and residential uses is vitally important for the water users of Kansas. Activities to further protect and improve the water quality of Kansas to avoid degradation of the State’s water resources are imperative for current and future water users. State natural resource agencies have designated 17 of the 18 lakes in the basin as “impaired” from nutrient related impacts (e.g., excess nitrogen and/or phosphorus, general eutrophication, excess chlorophyll/algae measures, dissolved oxygen sags resulting from algae blooms) due in part to agricultural runoff.

Figure 2-8. Harmful Algal Blooms at Clinton Reservoir



Inflow streams flowing into Basin lakes are frequently impaired from a range of pollutants including, but not limited to, fecal bacteria, herbicides like atrazine, and chemical contamination from naturally occurring compounds found in geological deposits (e.g., chloride and sulfate salts, selenium, and arsenic). Approximately 86 percent of the state's assessed stream miles are impaired for one of their uses and less than 5 percent of the state's assessed wetlands able to support aquatic life and recreational uses (KWO 2021f). Excess nutrients can promote HABs under ideal growing conditions. HABs have impacted six lakes in the basin since 2011. Milford Lake has been the hardest hit, with HAB warnings impacting recreation 7 of the last 10 years. As accumulation of sediment reduces storage capacity of reservoirs, and internal nutrient loading increases, water quality problems are expected to intensify.

As water quality conditions degrade within a water body, use of water from that source as well as downstream uses can be negatively impacted. Negative impacts from degrading/poor water quality conditions can include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, decreased recreational opportunities, fish consumption advisories, and diminished biological diversity in streams and lakes.

Reservoirs play a key role in providing sufficient quantity of water to meet demands and by being a source of water to maintain water quality for drinking water, industrial, or environmental standards during times of degraded natural flow conditions. Reservoir stored water supply is needed to provide dilution for naturally occurring water quality concerns, and the water quality fluctuations in response to periods of high or low streamflow events experienced in the variable Kansas climate (KWO 2022). It is necessary to maintain adequate quantities of higher quality water in storage within water quality pools secured within federal reservoirs to respond to these events and maintain supply security to water users.

2.4.7 Ecosystem Preservation and Restoration

Water management in the form of dams, levees, and floodplain development has disrupted the natural flow patterns that are critical to river health. As an example, sediment trapping by reservoirs results in artificially clear releases, and some native

aquatic species in the Kansas River are in decline due to lack of turbidity. Seasonal patterns of high and low river flows support animal and plant lifecycles, preserve water quality, and maintain diverse habitats. Therefore, the Kansas River is part of the Sustainable River Program (SRP) which promotes seasonal flows to mimic natural river flow patterns that yield diverse benefits for ecosystems and people while causing minimal impacts to current uses.

Invasive and non-native species can degrade and impact natural ecosystem functions. For example, the infestation of zebra mussels, an invasive species of mussel, were discovered in numerous Kansas reservoirs (e.g., Perry, Milford, Wilson, Kanopolis, Clinton, Glen Elder, Cedar Bluff, Tuttle Creek).

Dams also serve as important barriers that prevent the upstream spread of invasive species, such as invasive Carp. However, timing and volume of releases from reservoirs may enable the passage and spread of invasive species over smaller downstream barriers, such as the Bowersock Dam in Lawrence.

2.4.8 Recreation

Recreational opportunities (e.g., boating, fishing, hunting, camping, and kayaking) improve the quality of life for the citizens of Kansas and contribute to the state's economy. The availability of recreational destinations and activities provides Kansas the opportunity to prosper economically and increases the value of natural resources in the state. While recreational opportunities are currently available in the State, more focus on promoting, expanding, and protecting recreational activities is needed. Water-based recreational opportunities are threatened by low water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species. A 2018 study of Keith Sebelius Reservoir documented the value of the reservoir to Norton County, Kansas at $4.8M. Eastern reservoirs would likely have a much higher value. Water related recreation provides millions of dollars in economic benefits from visitor expenditures within the state.

2.4.9 Infrastructure Investment

Water infrastructure in Kansas–dams, levees, reservoirs, treatment plants, distribution lines–was mostly developed 50 to 60 years ago and needs upgrade, repair, or replacement. Reservoirs are filling with sediment, reducing the ability to capture flood waters, and many levees and dams may already be unable to provide the desired or needed level of public safety protection. A report completed in 2010 estimates that the financial needs to secure, protect and restore storage is over $483M in the next 10 years, increasing to $3.9B over the next 40 years. This estimate includes rehabilitation of dams to assure safety but does not include the needed costs associated with levee rehabilitation which is important to protect life and property from catastrophic failure during floods (Kansas Water Plan 2014). The *Kansas Water Plan* estimate does not include costs to remove accumulated sediments.

2.5 Goals, Objectives, and Constraints

Based on the issues and opportunities described in Section 3.3, the next step in the process is to establish plan goals and objectives, as well as specify the watershed study constraints and assumptions.

2.5.1 Goals and Objectives

The PDT reviewed the *Kansas Water Plan*, *Vision for the Future Water Supply in Kansas,* and *State of the Resource Reports* for the relevant regional planning areas in the basin to refine the initial set of goals and objectives. The PDT worked to collect additional information and studies relevant for developing the list of goals and objectives. The goals are grouped by the topics developed in Section 2.4 Issues and Opportunities. For example, there are goals and objectives developed for Water Supply Availability and Sustainment.

Planning goals include:

- Reduce the risk to public safety from flooding in the basin
- Reduce the risk of damages from flooding to residential, agricultural, commercial/industrial areas, utilities, and to roads and other critical infrastructure
- Reduce the risk of damages from drought/low water levels
- Extending the useful life of Kansas reservoirs, with focus on those reservoirs most impacted by sediment and nutrient loading, and those that provide drought critical water supply
- Improve and protect the Kansas River ecosystem.

The watershed study uses an integrated approach to evaluate system functions from water supply to flood risk management to ecosystem restoration and protection and climate change adaptation. The specific goal of this study is to assist in developing a comprehensive basin-wide management plan that will:

- Incorporate public input and involvement
- Assess existing and future watershed characteristics and conditions
- Identify watershed issues and concerns
- Develop, evaluate, and prioritize conceptual plans including both structural and non-structural measures, in support of identified goals and objectives
- Identify potential “spin-off” and “off-shoot” projects that may fall under appropriate Federal, State, and/or local authorities
- Identify potential regional or locally funded projects.

The primary objective of the watershed study is to develop a comprehensive plan to support the shared vision from Section 2.3 to identify actions within the Kansas River Watershed necessary to address significant water resource challenges.

Planning objectives for the study include those for the near-term (i.e., the next 10 years) and those for the long-term (greater than 10 years) and cover the planning timeframes of 25, 50, and 100 years (considered under FWOP scenarios) and include:

- Reduce risks to life safety in the Kansas River Watershed with a focus on improved flood risk system flexibility under a variety of climate change and land use development patterns
- Reduce both societal consequences and economic damages associated with flood risk in the study area, with an emphasis on improving system resiliency and increasing the long-term integrity of the flood system
- Increase the reliability, quality, and availability of water in the basin
- Reduce both societal consequences and economic impacts associated with drought risk in the study area, with an emphasis on improving system resiliency and increasing the long-term integrity of water availability
- Address adverse effects of sedimentation in the watershed including at existing reservoirs and in river reaches
- Identify watershed practices to address existing water resource problems within the watershed and increase the resiliency and sustainability of the system that would be implemented by local, regional, state, or federal entities
- Protect critical water resource infrastructure and investments (e.g., reservoirs, lakes, levees, public water supply infrastructure)
- Protect and improve biological resources
- Protect, promote, and expand recreational opportunities and amenities
- Increase the adaptability and resiliency of the water supply, flood risk management, and ecological systems of the Kansas River Watershed in relation to climate change, including planning for extreme events (i.e., flooding and drought).

2.5.2 Constraints and Considerations

An important part of specifying the purpose, goals, and objectives of the watershed study is to understand and document the items and issues that will *not* be addressed or considered in the watershed study. For example, examining the efficacy of conservation measures for groundwater consumption for irrigation may not be a focus for this watershed study. Other actions may require more detailed follow-on study. For example, detailed examination of constructing new reservoirs may be a follow-on study that the watershed study recommends.

Related to the development of the multipurpose recommendations, the following constraints were identified to direct plan formulation efforts so that beneficial effects would be maximized, and adverse effects would be minimized:

- Strategies and recommendations will comply with all applicable Federal and State laws, regulations, and policies.

Planning considerations represent key elements for the project team to keep in mind as the watershed study evolves; however, these elements will not necessarily limit the recommendations formulation process.

Consideration 1: Strategies and recommendations related to changes to the Lower Kansas River Basin Reservoir Regulation Manual Master Manual or the

associated reservoir WCMs will be coordinated with all interests, including those in Kansas and Missouri.

Consideration 2: Climate change is predicted to result on increased frequency in the occurrence of extreme storm events and more severe droughts and larger more extensive storms. Climate change will be considered and integrated in all stages of the planning process.

Consideration 3: Real Estate and Land Use Considerations—The watershed study is not required to follow a regular Real Estate Plan format and will not include an assessment of the twenty sections required to be within a Real Estate Plan as according to ER405-1-12, Chapter 12. Once a project is identified as a spinoff from this watershed study, a Realty Specialist will then be involved and will perform the necessary work to create a Real Estate Plan.

Consideration 4: Cost Estimates—The watershed study is not required to develop a scope of work to support a class 3 cost estimate as defined in Engineer Regulation 1110-2-1302. Once a project is identified as a spinoff from this watershed study, the PDT will develop scopes of work and the cost engineer will develop cost estimates for purposes of evaluating alternatives, likely a class 4 or 5 estimate. A recommended plan will have a scope of work with design maturity that supports a class 3 cost estimate. Cost estimate certification will be sought for each spinoff study.

Consideration 5: For any future pool raise considerations, proper coordination with the USACE Risk Management Center and Dam Safety Program Managers will be followed.

Consideration 6: USACE will ensure collaboration and concurrence with partners on the recommendations set forth in the watershed study. However, recommendations do not affect the administrative priorities of the Kansas Government or federal and local agencies and carry no obligation to be implemented.

3.0 EXISTING AND FUTURE WITHOUT PROJECT CONDITIONS

The study includes an inventory of baseline or existing conditions for each of the resource topics and forecasts future conditions. Understanding the existing conditions, and the stressors related to them, is critical to identification of measures and strategies to formulate recommendations to reduce risks and increase resiliency. Resource topics were also included if watershed strategies and recommendations would adversely or beneficially affect the conditions. Sufficient descriptions were developed to document existing and FWOP conditions.

The study area was defined for each of the resource topics. For example, some of the data collected for socioeconomic resources requires a county-based study area, whereas a broader study area is required for information on Missouri River navigation requirements for water supply and storage. In addition, description of the existing conditions for some resources necessitated further organization of the watershed study into sub-regions, such as by regional planning areas (RPAs), as established in 2014 by the KWA. The relevant RPAs in the Kansas River Basin are the Kansas, Solomon-Republican, Smoky Hill-Saline, Upper Republican, and Upper Smoky Hill RPAs. As part of the existing conditions, policy or regulatory considerations, or federal guidance are described as warranted in the resource sections.

Once the existing conditions are described, the FWOP evaluation is conducted and described. The FWOP is the most likely condition expected to occur in the future in the absence of proposed actions included in the watershed study. Where possible, forecasting and modeling over 25-year, 50-year, and 100-year time periods were conducted and used to describe the FWOP. The FWOP defines the benchmark against which the risk assessment was conducted, and strategies and recommendations were evaluated.

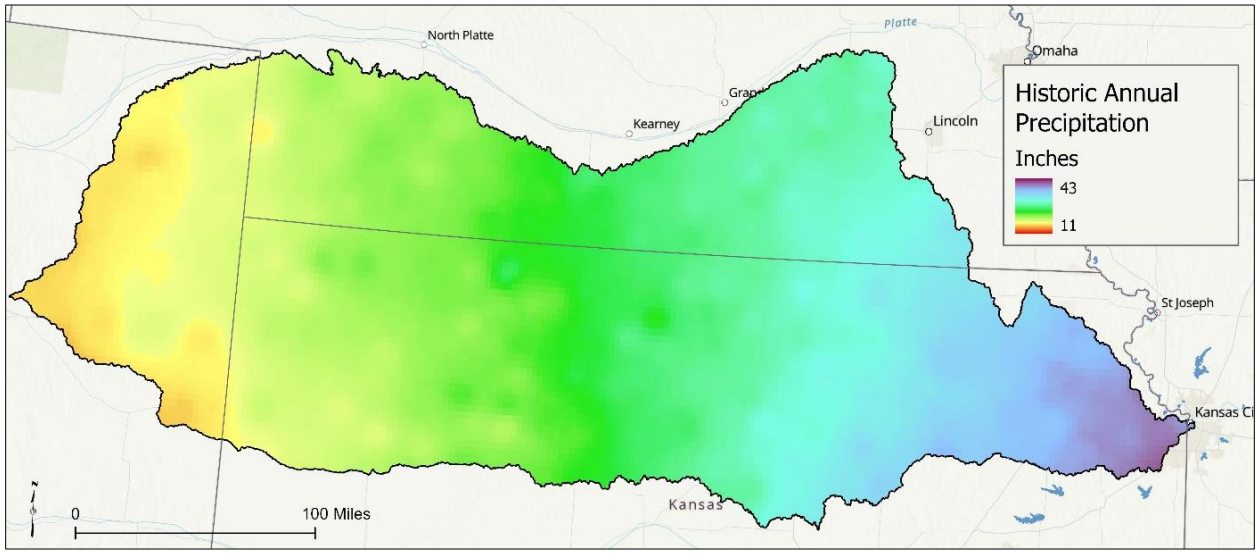
The evaluation includes identification of data, models, and tools needed to evaluate and forecast the effects of possible management strategies or recommendations for the FWOP. At the very least, a qualitative description of the FWOP was provided, given the current conditions, trends, and possible factors that could affect the resources. Individual subsections describe the scope of work for resources considered.

3.1 Climate and Precipitation

The Kansas River Basin has a continental climate with cold winters and hot summers. The climate varies from humid in the eastern part of the basin to semi-arid in the west, with average annual precipitation ranging from 43 inches over the eastern portion of the basin to 11 inches in western portions (Figure 3-1) (USDA 2023). Rainfall is concentrated in the summer months when convective storms often cause intense downpours. In the eastern part of the basin, May and June are typically the wettest months. In western portions of the basin, the maxima shifts to June and July. The climatic record of the basin includes intense and prolonged rainfall during some years and severe droughts in others, without a fixed cyclic pattern. The varied weather displayed in the basin is due, in part, to its diverse topography. Moisture from the Gulf of Mexico (Gulf) is blown into the basin by strong surface winds. The eastern portion of the

basin receives warm moist air from the Gulf more often since normal surface winds blow from a southerly direction (Rohweder 2015). Summer thunderstorms account for much of the annual rainfall, with 75 percent of the precipitation occurring during the growing season of April through September. Much of the basin receives significant snowfall, but snow melts before the summer months, at which time rainfall is the primary source of hydrology in the basin. The average annual snowfall varies from 20 inches along the eastward and southern perimeter of the basin to 33 inches in north-central Kansas and in southeastern Nebraska. Kansas air temperatures can reach over 100 °Fahrenheit (F) with a record high of 121 °F and a record low of -40 °F. Although the basin displays a great variation of temperature regimes, the annual mean temperature is about 55 °F.

Figure 3-1. Kansas River Basin Annual Precipitation



3.1.1 Climate Change Assessment

Climate change impacts on the hydrology of the Kansas River Basin were considered in accordance with USACE Engineering Construction Bulletin (ECB) 2018-14, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs and Projects (USACE 2018), as well as USACE Engineer Technical Letter (ETL) 1100-2-3, Guidance for Detection of Nonstationarities in Annual Maximum Discharges (USACE 2017). ECB 2018-14 was renewed on 10 September 2020 and the expiration date was extended to 10 September 2022.

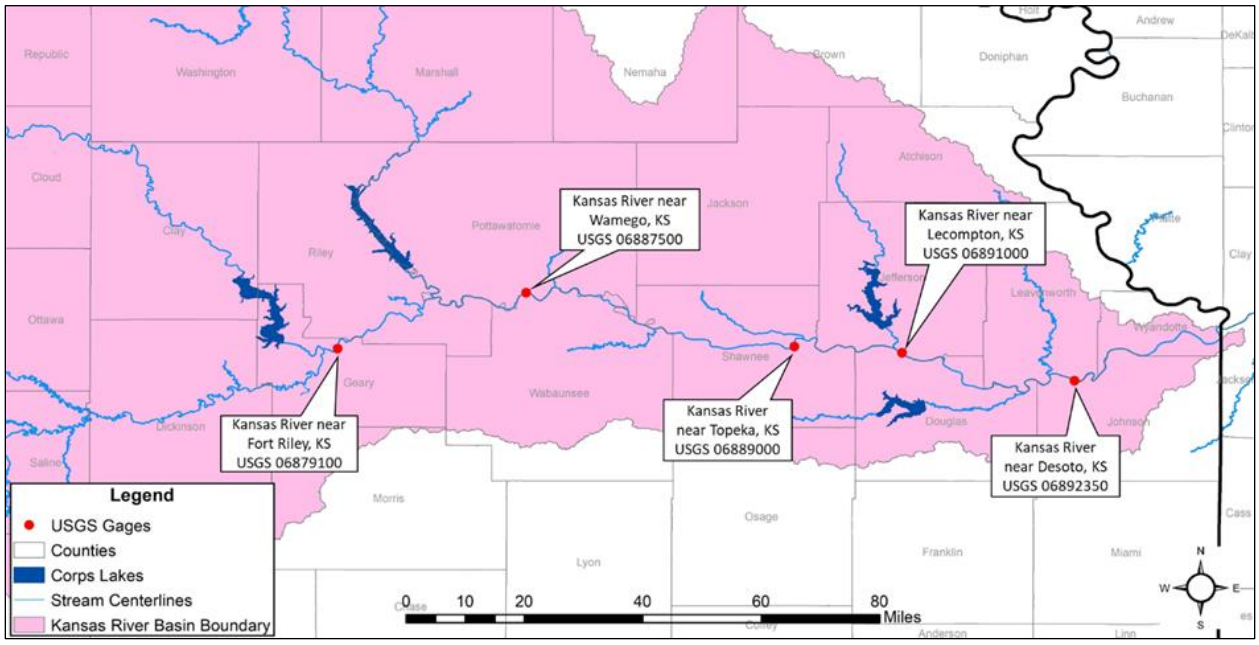
Changes in the hydrology of the Kansas River Basin due to climate change may significantly affect most, if not all, of the study objectives. For example, increased intense rainfall events would likely lead to greater flood risk, and greater sediment transport, causing increased sedimentation at reservoirs. Results from this qualitative assessment were used to inform evaluation of the existing conditions, FWOP conditions, and proposed conditions based on implementation of recommendations. Additionally, the information in the assessment was considered in the screening of measures. Only qualitative impacts of climate change were assessed for the study.

The Climate Change Assessment, documented in Appendix A, includes a literature review of existing and future climate projections, non-stationarity, and trend analyses for

five mainstem Kansas River gages (Figure 3-2) and Kansas River Basin reservoirs, a regional scale trend analysis, and a screening level vulnerability assessment to climate change impacts.

Overall, significant trends in several relevant climate variables are expected based on this qualitative analysis, but direct impacts to streamflow remain uncertain.

Figure 3-2. Climate Change Assessment Kansas River Mainstem Gages

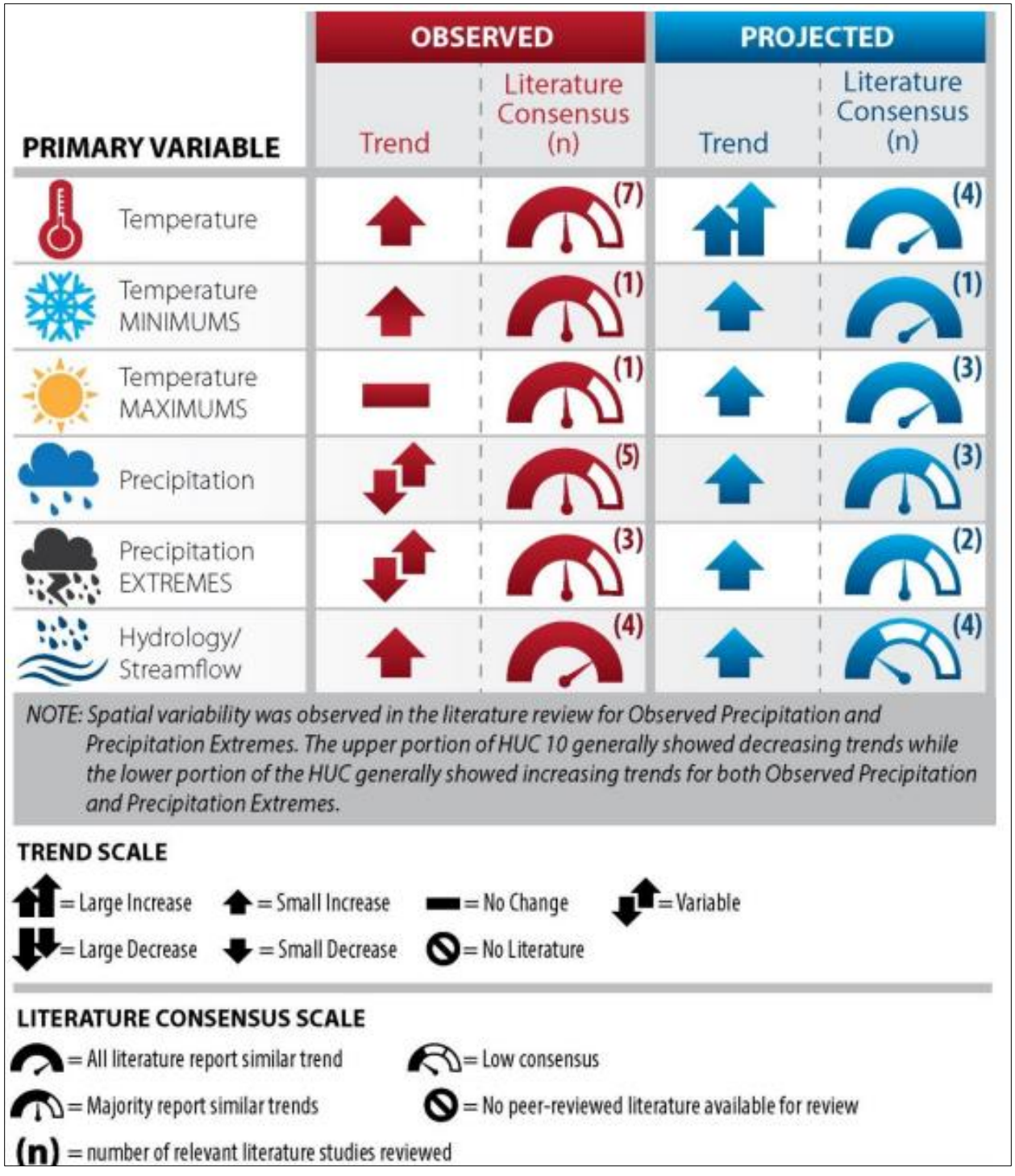


The strongest consensus amongst the literature supports a trend of increasing temperatures and precipitation in the region resulting in increased frequency in the occurrence of extreme storm events (Figure 3-3). Extremes in climate will also magnify periods of wet and dry weather, resulting in longer, more severe droughts and larger, more extensive storms. The literature is conflicted as to projected streamflow peak magnitude, duration, and volume of extreme events with the uncertainty largely attributed to the uncertainty of the climate models themselves.

Multiple gage sites on the Kansas River detected non-stationarities with a strong consensus and agreement around 1940, likely due to the 1930s drought. Based on this assessment, the recommendation is to constrain periods of analysis for flow frequency based on the results of non-stationarity detection and trend analysis. The mainstem Kansas River gaging stations analyzed indicate that the period of 1941 to 2019 may be considered stationary. For the reservoir inflow data analyzed, all reservoirs, except the Harlan County reservoir, may be considered stationary, as no strong non-stationarities or statistically significant trends were found. There may be other indicators of climate change, such as changes in biotic communities, but this analysis is focused on climate changes as they relate to hydrology and hydraulics. Methods of translating qualitative climate change impact uncertainty for an engineering-based analysis do not currently exist.

Results of the regional scale analysis using the Climate Hydrology Assessment Tool (CHAT) indicate that increases in streamflow in the Kansas River Basin are likely and projections contain significant trends for the Republican River Basin and the Lower Kansas Basin. These trends, while indicative of increasing flows over time, are relatively small in magnitude. Four business lines pertinent to the watershed study were analyzed using the USACE Screening Level Vulnerability Assessment Tool. The analyzed business lines included ecosystem restoration, flood risk reduction, recreation, and water supply. The tool indicates that for all four business lines, the three HUC 4 basins analyzed (1025, 1026, 1027) are in the top 20 percent of most vulnerable basins in the continental United States, excepting the Republican River Basin for recreation in the 2085 dry scenario. Primary vulnerability indicators for ecosystem restoration include at risk freshwater plants, runoff elasticity, and short-term variability in hydrology for all three basins. For flood risk reduction, long-term variability of the hydrology and runoff elasticity drive the vulnerability for the dry scenarios, while cumulative and local flood magnification drive the vulnerability for the wet scenarios. Recreation vulnerability in the Kansas River Basin is driven by both increases in flooding or changes in low flow conditions and drought effects. For the water supply business line, sediment, runoff elasticity, and long-term variability in flows drive the vulnerability in the Kansas River Basin.

Figure 3-3. Summary Matrix of Observed and Projected Climate Trends Literary Consensus for the Kansas River Basin



Several resiliency measures were identified for the watershed study, and any future brainstorming effort to conceptualize measures will consider results from this assessment. Some examples of potential impacts of the projected changes on proposed measures were considered, such as increased or decreased sedimentation at

reservoirs under wetter or drier conditions, potential for higher or lower water levels at recreation facilities, impacts of potentially greater flood flows on flood risk management infrastructure, and potential for increased hydrologic variability on ecosystem restoration projects. Table 3-1 summarizes potential impacts of the expected or possible results of climate change on the currently-proposed measures.

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Table 3-1. Climate Risks for Proposed Measures (sheet 1 of 3)

Measurement Type	Measure	Trigger	Hazard	Harm/Benefit	Qualitative Likelihood
Flood Risk Management	Operational Measures/Dam and Reservoir Upgrades (WCM Updates, New Reservoir/Dam or Detention Basins Construction)	Larger flood volumes in future years	Higher pool elevations at existing and proposed reservoirs.	Inability to contain flood events, more frequent occurrence of surcharge releases, and uncontrolled flows.	Likely
Flood Risk Management	Levee Upgrades (New or Modified Levees/Dikes/Floodwalls)	Larger flood peaks in future years; increased flood durations	Higher water surface elevations; Longer loading duration	Higher probability of overtopping; Greater likelihood of levee breach	Likely
Flood Risk Management	Flow Improvements (Channel Modifications, High Flow Diversions)	Larger flood peaks in future years; increased flood durations	Higher water surface elevations; Longer loading duration	Higher probability of exceeding capacity; Greater likelihood of erosion	Likely
Flood Risk Management	Floodplain Improvements (Authority for Land Acquisition or Easement Purchase for Flood Control, Floodplain Management Plans)	Larger flood peaks in future years; increased flood durations	Greater flood extents in non-leveed areas	Larger floodplain areas that require management or purchase	Likely
Flood Risk Management	Non-Structural Measures*	Larger flood peaks and volumes in future years; increased flood durations	More frequent and larger floods	More frequent activation of flood forecasting and warning systems; frequent updates of plans.	Likely

136 *Table 3-2. Climate Risks for Proposed Measures (sheet 2 of 3)*

Measurement Type	Measure	Trigger	Hazard	Harm/Benefit	Qualitative Likelihood
Water Availability and Sustainment	Operational Measures, New Water Storage, Resiliency Planning	Increased Drought and decreased low inflows to reservoirs	Lack of available water to support reservoir releases and withdrawals	Water users in basin will not have adequate supply	Likely
Water Availability and Sustainment	Incoming Sediment Reduction, Sediment Removal from Reservoirs	Increased frequency of extreme precipitation and stream flow events	Increased sediment loading from watershed	Loss of additional storage from increased sediment load	Likely
Ecosystem Restoration and Management	Reservoir Habitat Improvements	Decreased stream flows and increased drought frequency	Not enough water in streams and reservoirs to allow use of habitat	Decreased fish and wildlife populations	Likely
Ecosystem Restoration and Management	In-channel Habitat Improvements	Increased flood flows	Damage to habitat improvements; reduction to habitat	Decreased fish and wildlife populations	Likely (Low Confidence)
Ecosystem Restoration and Management	Off-channel/Upper Watershed Improvements	Increased floodplain inundation	Improved habitat conditions and availability	Increased fish and wildlife populations	Likely (Low Confidence)
Ecosystem Restoration and Management	Invasive Species Management	Decreased stream flows or increased drought frequency	Changed habitat conditions	Better conditions for invasive species	Likely
Ecosystem Restoration and Management	Invasive Species Management	Increased stream flooding and longer duration flooding	Increased likelihood of invasive species spread	Decrease in suitable conditions for native species	Likely (Low Confidence)
Water Quality	Nutrient and Sediment Reduction	Decreased stream flows or increased drought frequency	Decreased water volume could lead to increased nutrient concentrations	Increased water quality problems	Likely

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138 *T*able 3-3. **Climate Risks for Proposed Measures (sheet 3** of *3)*

Measurement Type	Measure	Trigger	Hazard	Harm/Benefit	Qualitative Likelihood
Water Quality	Water Management	Decreased stream flows or increased drought frequency	Lower reservoir storage volumes	Decreased ability to maintain water quality reservoir releases	Likely
Water Quality	HABs	Decreased stream flows or increased drought frequency	Increased reservoir nutrient concentrations	Increased frequency and intensity of HABs	Likely
Recreation	Reservoir Recreation	Decreased reservoir inflows due to increased drought	Lower reservoir levels	Inadequate reservoir depths to support traditional recreation	Likely
Recreation	Riverine Recreation	Decreased stream flows or increased drought frequency	Lower stream water levels	Decreased recreational opportunities	Likely
Recreation	Riverine Recreation	Increased stream flooding and longer duration flooding	High stream water levels make recreation too dangerous	Decreased recreational opportunities	Likely (Low Confidence)

139 Note: Nonstructural measures include climate plan/extreme event planning, Kansas flood center/flood information system, floodplain regulations, flood forecasting, flood
140 warning/emergency plans, and floodplain mapping.

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3.2 Reservoirs and River Infrastructure, Operations, Hydrology/ Hydraulics, and Flood Risk

3.2.1 Basin Overview

The flow of the mainstem Kansas River and its main tributaries (i.e., Republican River, Solomon River, Smoky Hill River) is influenced by precipitation and seasonal snowmelt occurring throughout the basin, as well as flow regulation from dams within the basin. Base and peak flows make up river flows. Base flow consists of groundwater discharge and the drainage of soil moisture from the surrounding watershed of the Kansas River and its tributaries. Unregulated peak flow consists of distinct pulses of higher discharge as a result of large rainstorms throughout the year and snow melting periods in the winter and spring. The magnitude, frequency, timing, duration, and rates of change of river flows affect geomorphology, chemistry, human uses, and biological processes in the Kansas River and its main tributaries.

The assessment of existing conditions for reservoirs and river infrastructure, operations, hydrology/hydraulics, and flood risk includes information for each reservoir and the river system in the Kansas River Watershed, including the summaries of the current operating plans of the reservoirs, guiding policies and operations, multipurpose pool and flood pool elevations, reservoir level management and storage, and others. This section describes precipitation and hydrologic cycles of droughts and flooding events and the impacts of flooding and drought. An assessment of reservoirs planned for construction, but were subsequently deauthorized, was completed. Some of the originally selected sites for reservoirs are in close proximity to urban areas and would have provided enhanced benefits not realized.

The Kansas River Basin (Figure 2-1) drains almost the entire northern half of Kansas, much of the southern third of Nebraska, as well as part of Colorado (60,580 square miles in all) and is the longest prairie-based river in the world. The basin is approximately 490-miles long (west to east), with a maximum width of approximately 200 miles—north to south from Polk County, Nebraska, to McPherson County, Kansas. USACE and many other federal, state, and local agencies constructed numerous water resource development projects within the Kansas River Basin. There are approximately 100,000 acres of federally-owned freshwater impoundments, including USACE and USBR reservoirs, in the Kansas River Basin.

Major tributaries of the Kansas River mainstem include the Big Blue River (9,681 square miles), Vermillion Creek (520 square miles), Mill Creek (421 square miles), Soldier Creek (345 square miles), Delaware River (1,144 square miles), Wakarusa River (523 square miles), and Stranger Creek (533 square miles). The Kansas River joins the Missouri River at Kansas City, Kansas, which then flows generally east 367 miles to the Mississippi River near St. Louis, Missouri. The Mississippi River carries the discharges of the Kansas and Missouri Rivers south to the Gulf of Mexico. There are approximately 640 freshwater stream miles below all major dams in the Kansas River Basin. Figure 2-1 provides a detailed map showing the predominant streams in the Kansas River Basin and the downstream reach of the Missouri River.

The Kansas River begins at the confluence of the Republican and Smoky Hill Rivers near Junction City, Kansas, and flows 148 miles eastward to Kansas City, where it joins the Missouri River. The Kansas River Basin includes 18 federal reservoirs (7 USACE and 11 USBR), 12 within Kansas, 5 in Nebraska, and 1 in Colorado (Tables 3-2 to 3-4). USACE dams manage water flowing from most of the Kansas River Basin with a total of approximately 45,800 square miles upstream of USACE dams. Approximately 9,730 square miles of unregulated areas remain below major dams to the mouth of the Kansas River. Tables 3-2 to 3-4 list federal dam projects in the Kansas River Basin. Figure 2-1 shows the major impoundments in the Kansas River Basin. The Bowersock Dam, a low head hydropower dam serving Lawrence, Kansas, also stores water within the Kansas River for release through its hydropower turbines.

Table 3-4. Republican River Basin Water Management Projects

Water Management Project	Basin or Stream	State	Date of Closure	Operating Agency
Bonny Dam	South Fork Republican River	Colorado	1950	USBR
Trenton Dam (Swanson Lake)	Republican River	Nebraska	1953	USBR
Enders -Dam	Frenchman Creek	Nebraska	1950	USBR
Red Willow Dam (Hugh Butler Lake)	Red Willow Creek	Nebraska	1961	USBR
Medicine Creek Dam (Harry Strunk Lake)	Medicine Creek	Nebraska	1949	USBR
Norton Dam (Keith Sebelius Lake)	Prairie Dog Creek	Kansas	1964	USBR
Harlan County Dam	Republican River	Nebraska	1951	USACE, Kansas City District
Lovewell Dam	White Rock Creek	Kansas	1957	USBR
Milford Dam	Republican River	Kansas	1964	USACE, Kansas City District

Table 3-5. Smoky Hill River Basin Water Management Projects

Water Management Project	Basin or Stream	State	Date of Closure	Operating Agency
Kanopolis Dam	Smoky Hill River	Kansas	1946	USACE, Kansas City District
Glen Elder Dam (Waconda Lake)	Solomon River	Kansas	1967	USBR
Wilson Dam	Saline River	Kansas	1963	USACE, Kansas City District
Cedar Bluff Dam	Smoky Hill River	Kansas	1950	USBR
Webster Dam	South Fork Solomon River	Kansas	1956	USBR
Kirwin Dam	North Fork Solomon River	Kansas	1955	USBR

Table 3-6. Lower Kansas River Basin Water Management Projects

Water Management Project	Basin or Stream	State	Date of Closure	Operating Agency
Clinton Dam	Wakarusa River	Kansas	1975	USACE, Kansas City District
Perry Dam	Delaware River	Kansas	1966	USACE, Kansas City District
Tuttle Creek Dam	Big Blue River	Kansas	1959	USACE, Kansas City District

The Smoky Hill and Republican Rivers both rise in eastern Colorado in the High Plains region, and flow eastward into Kansas and Nebraska respectively. Major tributaries of the Smoky Hill River upstream of Junction City include the Saline and Solomon Rivers. The Smoky Hill River Basin encompasses 19,951 square miles, including 3,425 square miles in the Saline River Basin and 6,846 square miles in the Solomon River Basin. The Smoky Hill River begins approximately 40 miles west of the Colorado-Kansas state line. From its source, the Smoky Hill flows in an easterly direction to Cedar Bluff Dam, to Kanopolis Dam, and then east-northeast for approximately 184 river miles to its confluence with the Republican, forming the Kansas River. The Saline River begins in western Kansas near Mingo, Kansas. From its source, the Saline River flows eastward 263 miles to Wilson Dam, then 154 miles east to its confluence with the Smoky Hill River. The Solomon River begins at the confluence of the South Fork and North Fork Solomon Rivers below Glen Elder Dam and Waconda Reservoir. Waconda Reservoir, at the confluence of the North Fork Solomon and South Fork Solomon rivers, was completed in 1967. From Glen Elder Dam, the Solomon River flows into the Smoky Hill River. The Republican River Basin drainage area is 24,955 square miles, including non-contributing areas. Approximately 70 percent of the drainage area is contributing. The Republican River flows approximately 420 river miles generally easterly and southeasterly, joining with the Smoky Hill River immediately below Junction City, Kansas, to form the Kansas River.

Numerous projects, constructed as early as the 1940s, altered the flows of the Kansas River and its main tributaries. Primary alterations include dams and reservoirs, flow regulation, channelization, and bank stabilization. Channelization altered the river cross section and increased depth and flow velocity within river channels on average compared to pre-channelization conditions. The stabilized channel, levees, and riverbed degradation (lowering) reduced both the connection of the rivers with the floodplains and the amount of groundwater recharge in the remaining floodplain.

3.2.2 Kansas River Basin Reservoir System

3.2.2.1 Operations Overview

The USACE Kansas City District includes the Missouri River watershed from Rulo, Nebraska, (river mile 498.0 above the mouth) to the junction of the Missouri and Mississippi Rivers near St. Louis, Missouri. The Kansas City District fully operates 18 storage projects and manages flood control releases from 11 Section 7 USBR reservoirs.

The Kansas River Basin encompasses 7 USACE reservoirs and 11 USBR lakes, 12 of which reside in the state of Kansas, 5 in Nebraska, and 1 in Colorado (Tables 3-2 to 3-4). The dams at these reservoirs regulate 85 percent of the drainage area in the basin, and the reservoirs supply flood damage risk reduction to major population centers along the Kansas River such as the Kansas cities of Manhattan, Topeka, Lawrence, and Kansas City, as well as flood damage risk reduction and navigation flow support to communities along the Missouri River. Figure 2-1 shows the location of each lake and reservoir in the Kansas City District. Figure 3-4 shows the reservoirs and the Kansas River basin with additional detail.

Kansas River mainstem flows serve as a critical drinking water supply for more than 600,000 people in addition to being used for irrigation, municipal wastewater and industrial discharges, power generation, an- a source of commercial sand and gravel. Additionally, recreation use in the Kansas River Basin (boating, kayaking, camping, picnicking, fishing, swimming, hunting, wildlife viewing, etc.) provides substantial benefits to the local, regional, and national economy.

Each USACE and USBR reservoir operates for specific congressionally-authorized purposes and has a WCM detailing the rules and regulations specific to the reservoir (Table 3-5). The reservoirs vary widely in storage and release capacity. Generally, the size of the flood storage and the discharge capacity is indicative of how much the reservoir impacts downstream flows. The larger reservoirs tend to be authorized for more release capacity. The following sections summarize the primary rules used to regulate releases in both flood control and multipurpose pools. For projects within the Kansas River Basin, the congressionally-authorized purposes include flood control, water supply, water quality, fish and wildlife, recreation, navigation support, and irrigation. To achieve these multipurpose benefits, the system of projects is operated in a hydrologically integrated manner. Table 3-5 summarizes the authorized purposes for each USACE reservoir and each USBR owned and operated reservoir included in the inventory of existing conditions and the assessment of FWOP for Reservoirs and River Infrastructure, Operations, Hydrology/Hydraulics, and Flood Risk. The USBR reservoirs

located in the upper reaches of the basin in Nebraska above Harlan County Reservoir (Hugh Butler Reservoir/Red Willow Dam, Harry Strunk/Medicine Creek Dam, Enders Reservoir, Swanson Reservoir/Trenton Dam) and Bonny Reservoir in Colorado are not included as the reservoirs located in Kansas are the focus of this watershed study. USBR is responsible for irrigation operations, O&M, structure safety, and reservoir operations not specifically associated with regulation of the flood control storage at their reservoirs. USACE is responsible for regulation of the flood control storage at the USBR reservoirs.

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Figure 3-4. Kansas River Major Tributaries and Water Management Projects and Downstream Reach of the Missouri River

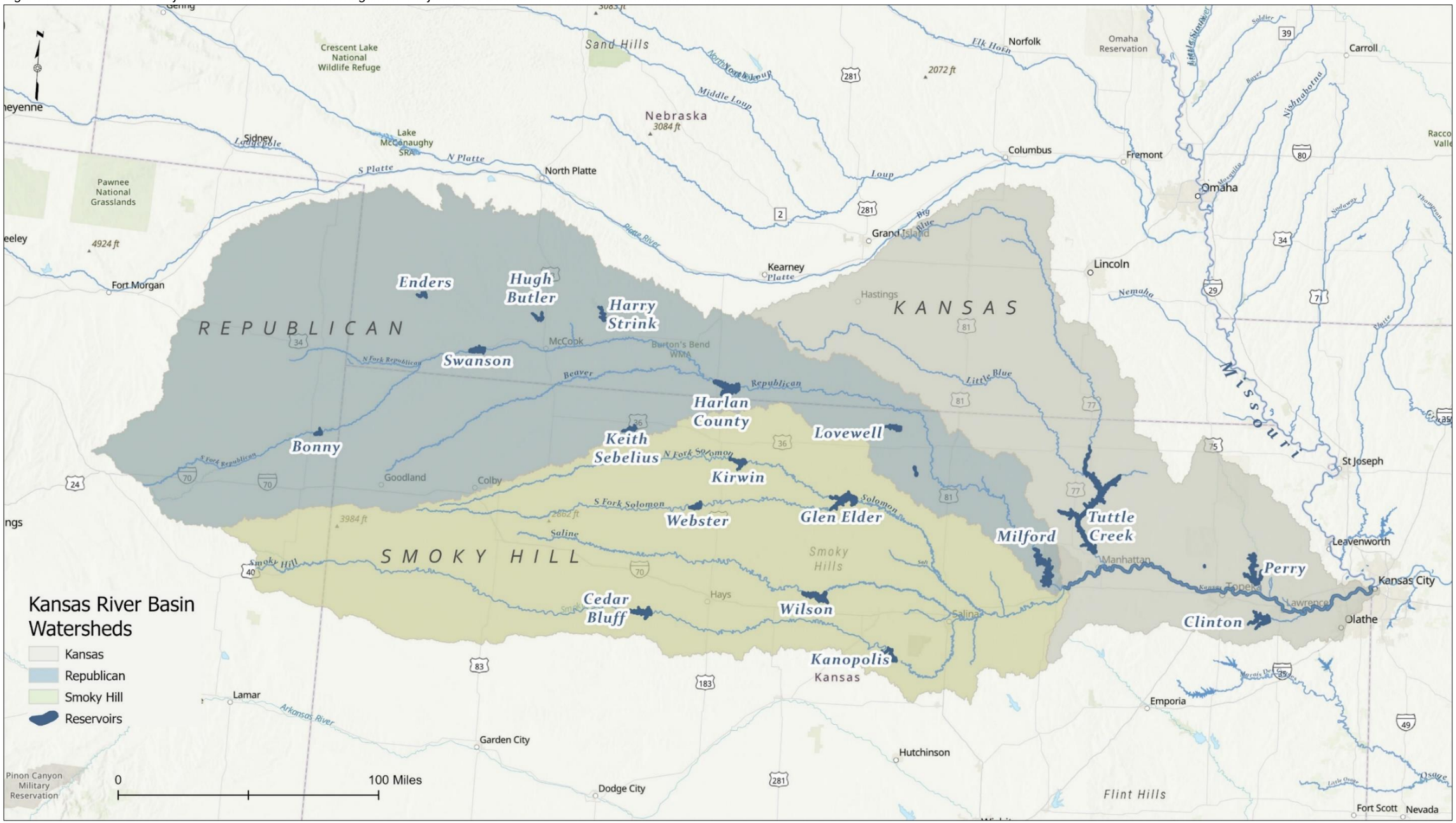


Table 3-7. Kansas River Basin Reservoirs Authorized Purposes

Reservoir	Flood Control	Water Supply	Water Quality	Fish and Wildlife	Recreation	Navigation	Hydropower	Irrigation
Kanopolis	X	X	X	X	X	*	*	*
Wilson	X		X	X	X	*		*
Harlan County	X			X	X			X
Milford	X	X	X	X	X	X		
Tuttle Creek	X	X	X	X	X	X		
Perry	X	X	X	X	X	X		
Clinton	X	X	X	X	X			
Keith Sebelius[1]	X	X		X	X			X
Kirwin[1]	X			X	X			X
Webster[1]	X			X	X			X
Cedar Bluff[1]	X	X		X	X			
Lovewell[1]	X			X	X			X
Waconda[1]	X			X	X			X

* Authorized purpose, not operating purpose based on PR-19, Authorized and Operating Purposes of Corps of Engineers Reservoirs July 1992, revised 1994
[1] USBR Reservoir

Separate rules govern the two major operations categories—flood control and multipurpose. Releases made from USACE and USBR reservoirs serve to fulfill one or more authorized purpose. The following sections explain flood control and the various multipurpose operations of the seven USACE reservoirs in the basin and the six USBR reservoirs in Kansas.

3.2.2.1.1 U.S. Army Corps of Engineers Reservoirs

Kanopolis Reservoir—Kanopolis Reservoir (Figure 3-5) is an impoundment of the Smoky Hill River located in southeastern Ellsworth County, Kansas. Construction, operation, and maintenance of the reservoir for flood control was authorized by the Flood Control Act of 1938, Public Law 75-761, as modified by the Flood Control Act of 1941, Public Law 77-228, and modified by the Flood Control Act of 1944 Public Law 78-534. Other purposes (i.e., irrigation, water supply, low flow supplementation for water quality, recreation, and fish and wildlife) were authorized by the Flood Control Act of 1946 Public Law 79-536 and Title I by Public Law 94-423. Since the Kanopolis Reservoir and dam began operations in 1949, it has prevented an estimated $4.2B in flood damages (Appendix H).

Figure 3-5. Kanopolis Reservoir (Source: USACE)

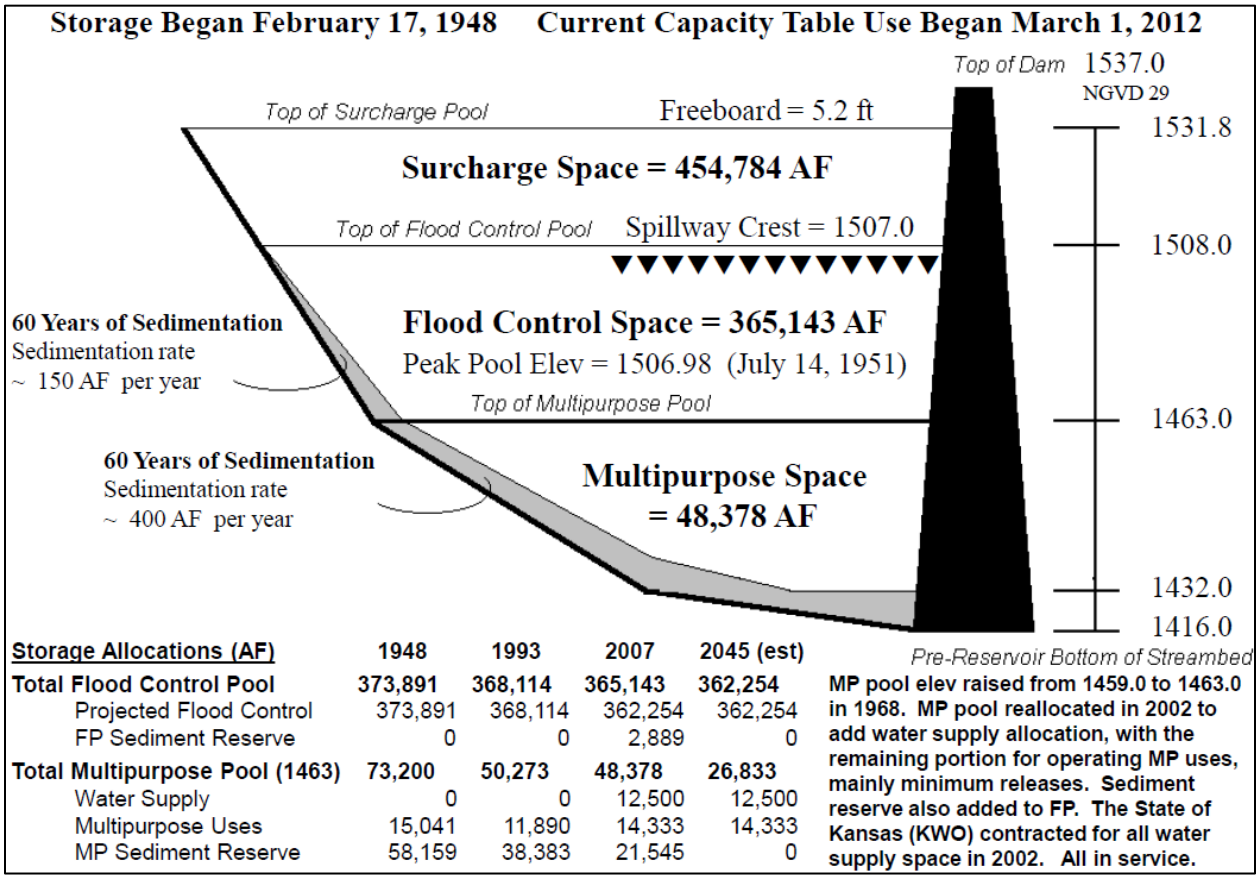


Construction of Kanopolis Dam began in 1940 and was completed in 1948 (USACE 1984). It is the oldest reservoir in Kansas and is operated in tandem with upstream Cedar Bluff Reservoir, a USBR project regulating flows in the Smoky Hill River Basin. The relatively long and narrow drainage basin above the dam consists of approximately 7,857 square miles. Of this, an area of 5,365 square miles is above Cedar Bluff Dam, and, since 1950, is regulated by that project. The 2,330 square miles of drainage area between Cedar Bluff Dam and Kanopolis Dam is about 80-miles long and varies in width from 32 miles at Ellis to 17 miles at Ellsworth, Kansas. The majority of the Kanopolis Reservoir inflow comes from the drainage area below Cedar Bluff Reservoir. Kanopolis Dam is located approximately 184 river miles above the mouth of the Smoky Hill River.

USACE constructed Kanopolis Reservoir as a multipurpose facility for flood control, irrigation, water supply, low flow supplementation, recreation, as well as fish and wildlife purposes. The original reservoir storage capacity included 373,891 acre-feet of storage for flood control, 73,200 acre-feet for multipurpose use, which includes a sediment

reserve of 58,159 acre-feet (Figure 3-5). Following sediment surveys in 1993 and 2007 reservoir storage capacity was reduced to approximately 365,143 acre-feet of storage for flood control and 48,378 acre-feet for multipurpose use (Figure 3-6; Table 3-6).

Figure 3-6. Kanopolis Reservoir Storage Allocations



Storage Allocations (AF)	1948	1993	2007	2045 (est)
Total Flood Control Pool	**373,891**	**368,114**	**365,143**	**362,254**
Projected Flood Control	373,891	368,114	362,254	362,254
FP Sediment Reserve	0	0	2,889	0
Total Multipurpose Pool (1463)	**73,200**	**50,273**	**48,378**	**26,833**
Water Supply	0	0	12,500	12,500
Multipurpose Uses	15,041	11,890	14,333	14,333
MP Sediment Reserve	58,159	38,383	21,545	0

MP pool elev raised from 1459.0 to 1463.0 in 1968. MP pool reallocated in 2002 to add water supply allocation, with the remaining portion for operating MP uses, mainly minimum releases. Sediment reserve also added to FP. The State of Kansas (KWO) contracted for all water supply space in 2002. All in service.

*Source: USACE

The State of Kansas entered into an agreement for municipal and industrial water supply with USACE in 2002. The agreement allows the State of Kansas to use storage space in the multipurpose pool between elevations 1432.0 and 1463.0 feet mean sea level (msl), for 12,500 acre-feet of storage. Table 3-6 shows the original pool storage capacity, the pool storage capacity in 1993 following sediment surveys, and the pool storage capacity with the 2002 reallocation agreement.

To project a baseline and future storage capacity for USACE reservoirs within the basin, sediment modeling was completed for the watershed study. Sediment accumulation in Kanopolis Reservoir is expected to be substantial over the next 50 years with a major loss of storage capacity from sedimentation. A 2017 survey estimates sediment fills approximately 36 percent of the multipurpose pool leaving approximately 46,916 acre-feet of capacity. Approximately 378 acre-feet of sediment accumulates on average annually in Kanopolis Reservoir. Sediment continues to accumulate in Kanopolis Reservoir with an expected additional 20 percent loss of the multipurpose pool over the next 25 years (2049) and 28 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 26,263 acre-feet in 2074. Table 3-6 shows the original pool storage capacity and pool storage capacity under baseline conditions for the watershed study (i.e., 2024) as well as a few other selected surveys.

Table 3-8. Kanopolis Reservoir Storage Capacity and Ownership

Pool Owner	Purpose	Quantity (acre-feet)
1948		
USACE	Flood Control	373,891
USACE	Multipurpose	73,200
1993[1]		
USACE	Flood Control	368,114
USACE	Multipurpose	50,273
2002[2]		
USACE	Flood Control	365,143
KWO	Municipal and Industrial Water Supply	12,500
USACE	Multipurpose Uses	14,333
2024[4]		
USACE	Flood Control	363,130
USACE/KWO	Multipurpose Uses	42,858[3]

[1]August 1993 Surveys
[2]Reallocation Agreement
[3]Reflects additional sediment storage loss (1993–2024) of 7,415 acre-feet from multipurpose pool
[4]Storage capacity projected for 2024 with loss to sedimentation as modeled.

Wilson Reservoir—Wilson Reservoir (Figure 3-7) is a 9,000-acre impoundment of the Saline River located on the eastern border of Russell County, Kansas, with a small portion extending into western Lincoln County, Kansas. Construction, operation, and maintenance of the reservoir was authorized as part of the comprehensive plan for the Missouri River Basin by the Flood Control Act of 1944 Public Law 78-534 with jurisdiction for construction transferred from the USBR to the USACE in May 1956 by Public Law 84-505. Secondary purposes (i.e., recreation and fish and wildlife) were authorized by the Flood Control Act of 1946 Public Law 79-526. The reservoir is not used for public water supply (drinking water, irrigation). A multitude of recreational activities draw people to the reservoir and its beautiful scenery, clear water, and bountiful sportfish populations. Since the Wilson Reservoir and dam began operations in 1964, it has prevented an estimated $3.3B in flood damages (Appendix H).

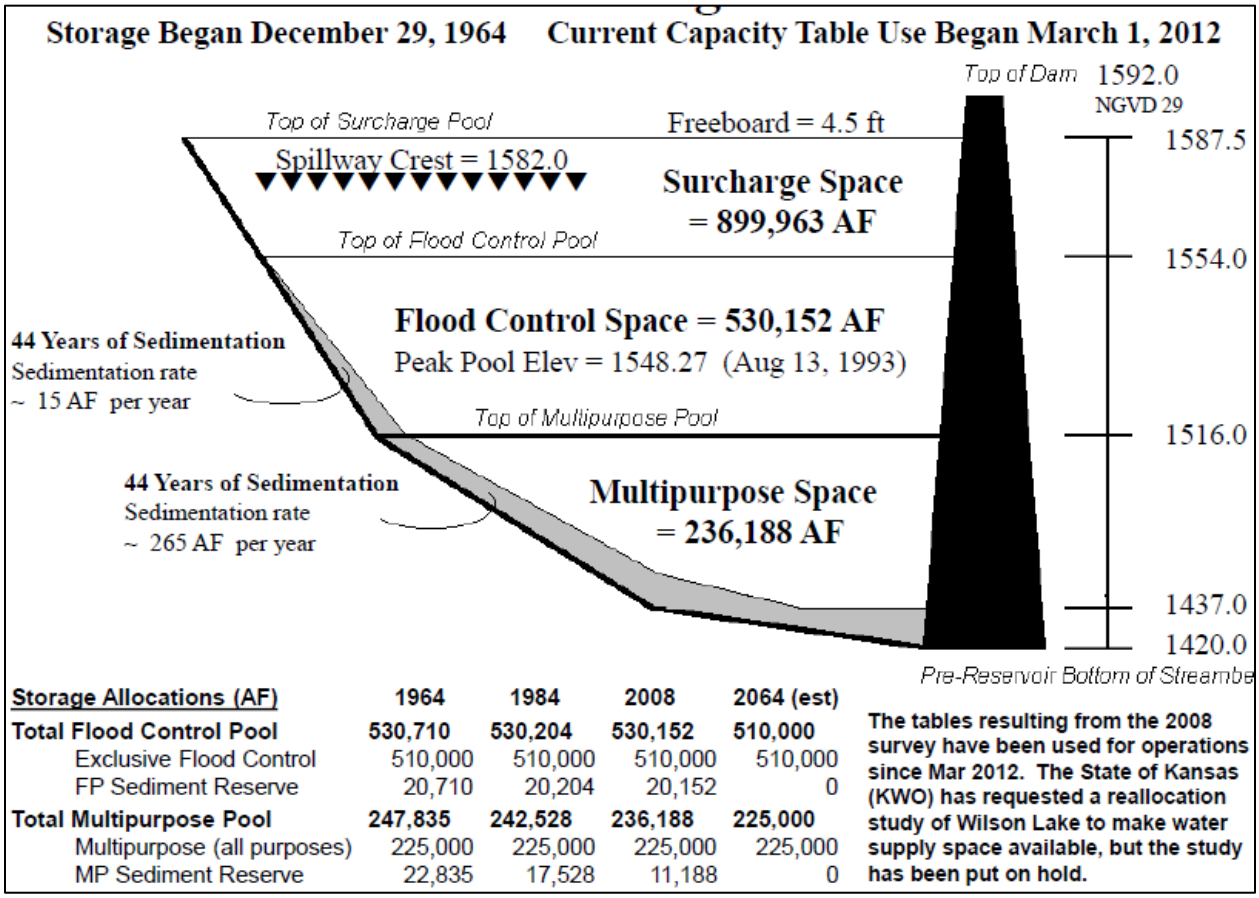
Figure 3-7. Wilson Reservoir (Source: USACE)



Construction of Wilson Dam began in 1961 and was completed in 1964 (USACE 1983). The drainage basin above the dam consists of approximately 1,917 square miles. The 1,917 square miles of drainage area is long and narrow and is about 215 miles long with an average width of only 16 miles. Wilson Dam is located approximately 153 river miles above the mouth of the Saline River.

USACE constructed Wilson Reservoir as a multipurpose facility for flood control, silt control, irrigation, recreation, as well as fish and wildlife purposes. The original reservoir storage capacity included 530,710 acre-feet of storage for flood control and 247,835 acre-feet for multipurpose use, which includes a sediment reserve of 22,835 acre-feet (Figure 3-8). Wilson Reservoir is currently not a source of water supply due to salinity and lack of infrastructure and it is not expected to be a source in the future.

Figure 3-8. Wilson Reservoir Storage Allocations



Storage Allocations (AF)	1964	1984	2008	2064 (est)
Total Flood Control Pool	**530,710**	**530,204**	**530,152**	**510,000**
Exclusive Flood Control	510,000	510,000	510,000	510,000
FP Sediment Reserve	20,710	20,204	20,152	0
Total Multipurpose Pool	**247,835**	**242,528**	**236,188**	**225,000**
Multipurpose (all purposes)	225,000	225,000	225,000	225,000
MP Sediment Reserve	22,835	17,528	11,188	0

The tables resulting from the 2008 survey have been used for operations since Mar 2012. The State of Kansas (KWO) has requested a reallocation study of Wilson Lake to make water supply space available, but the study has been put on hold.

*Source: USACE

Sediment accumulation in Wilson Reservoir is expected to be low to moderate over the next 50 years with a minor loss of storage capacity from sedimentation. Sediment filled approximately 4 percent of the multipurpose pool leaving approximately 236,188 acre-feet of capacity (based on 2008 survey results). Approximately 459 acre-feet of sediment accumulates on average annually in Wilson Reservoir. Sediment continues to accumulate in Wilson Reservoir with an expected additional 8 percent loss of the multipurpose pool over the next 25 years (2049) and 13 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 203,404 acre-feet in 2074. Table 3-7 shows the original pool storage capacity and pool storage capacity under baseline conditions for the watershed study (i.e., 2024).

Table 3-9. Wilson Reservoir Storage Capacity and Ownership

Pool Owner	Purpose	Quantity (acre-feet)
1965		
USACE	Flood Control	530,710
USACE	Multipurpose	247,835
2024[1]		

USACE	Flood Control	528,683
USACE	Multipurpose Uses	227,372

[1]Storage capacity projected for 2024 with loss to sedimentation as modeled.

Milford Reservoir—Milford Reservoir (Figure 3-9) is located downstream of Harlan County and Lovewell reservoirs on the Republican River near its confluence with the Kansas River. Milford Reservoir is the largest lake in Kansas (over 15,000 acres) and is located in the Republican River Basin (Dickinson, Clay, and Geary counties) of north-central Kansas. This impoundment drains 24,880 square miles. The total contributing watershed area to Milford Reservoir is 17,388 square miles, with 3,507 square miles of this below Harlan County and Lovewell reservoirs. Authorized by the Flood Control Act of 1954, Milford Reservoir went under construction in 1962 and began operation in 1967 by the USACE. Since the Milford Reservoir and dam began operations in 1967, it has prevented an estimated $3.9B in flood damages (Appendix H).

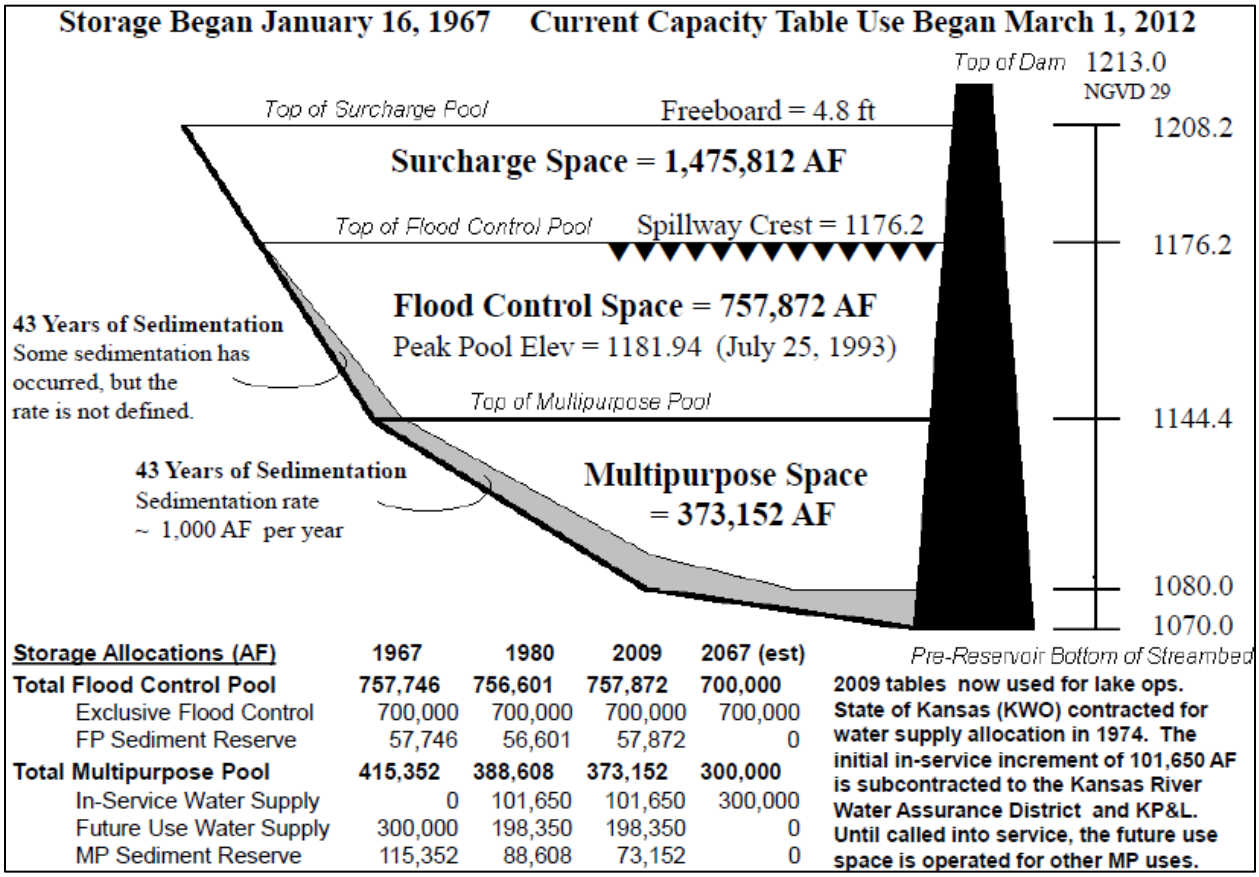
Figure 3-9. Milford Reservoir (Source: USACE)



USACE constructed Milford Reservoir as a multipurpose facility for flood control, silt control, water supply, recreation, fish and wildlife, and support of navigation on the Missouri River. The original reservoir storage capacity included 757,746 acre-feet of storage for flood control, 415,352 acre-feet for multipurpose use, which includes a sediment reserve of 115,352 acre-feet (Table 3-8; Figure 3-10).

The State of Kansas entered into an agreement for municipal and industrial water supply with the USACE in 1974. The agreement allows the State of Kansas to use storage space in the multipurpose pool between elevations 1,080 and 1,144.4 feet mean sea level (msl), for 300,000 acre-feet of storage. Of the 300,000 acre-feet of storage allocated for water supply currently 101,650 acre-feet is in service and 198,350 is designated as future use water supply (Table 3-8). Remaining storage was estimated using a 2009 survey performed of Milford Reservoir. The 2009 survey shows Milford flood control pool has all of its original flood control storage (Table 3-8). Some sedimentation has likely occurred, but new survey methods have captured a more accurate assessment of current storage with the volume being near the original design.

Figure 3-10. Milford Reservoir Storage Allocations



Storage Allocations (AF)	1967	1980	2009	2067 (est)
Total Flood Control Pool	**757,746**	**756,601**	**757,872**	**700,000**
Exclusive Flood Control	700,000	700,000	700,000	700,000
FP Sediment Reserve	57,746	56,601	57,872	0
Total Multipurpose Pool	**415,352**	**388,608**	**373,152**	**300,000**
In-Service Water Supply	0	101,650	101,650	300,000
Future Use Water Supply	300,000	198,350	198,350	0
MP Sediment Reserve	115,352	88,608	73,152	0

2009 tables now used for lake ops. State of Kansas (KWO) contracted for water supply allocation in 1974. The initial in-service increment of 101,650 AF is subcontracted to the Kansas River Water Assurance District and KP&L. Until called into service, the future use space is operated for other MP uses.

Source: USACE

Sediment accumulation in Milford Reservoir is expected to be moderate over the next 50 years with a minor loss of capacity from sedimentation. Approximately 10 percent of the multipurpose pool is filled in with sediment leaving approximately 373,152 acre-feet of capacity (based on 2009 survey results). Approximately 938 acre-feet of sediment accumulates on average annually in Milford Reservoir. Sediment continues to accumulate in Milford Reservoir with an expected additional 5 percent loss of the multipurpose pool over the next 25 years (2049) and 6 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 347,772 acre-feet in 2074. Table 3-8 shows the original pool storage capacity and pool storage capacity under baseline conditions for the watershed study (i.e., 2024) as well as the 2009 survey (for reference).

Table 3-10. Storage Capacity and Ownership

Pool Owner	Purpose/Use	Quantity (acre-feet)
1967		
USACE	Flood Control	757,746
USACE	Multipurpose	415,352
USACE	Sediment Reserve	115,352
2009		
USACE	Flood Control	757,872
KWO	Municipal and Industrial Water Supply	373,152
USACE	Sediment Reserve	73,152
20241		
USACE	Flood Control	756,929
KWO	Municipal and Industrial Water Supply	366,220

[1]Storage capacity projected for 2024 with loss to sedimentation as modeled.

Tuttle Creek Reservoir—The Flood Control Act of 1938 authorized construction of Tuttle Creek Reservoir (Figure 3-11). Funds were appropriated for initial planning in 1944. The Flood Control Act of 1944, known as the Pick-Sloan Plan, coordinated plans by the USACE and the USBR for the entire Missouri River Basin. The first exploratory core hole was drilled in the spillway area on June 6, 1944. A 1950 study looked at the possibility of a series of reservoirs in the upper Blue River Basin as an alternative to Tuttle Creek Reservoir. It found that the single reservoir was the most feasible for controlling floods on the Big Blue River. A series of historic flood events occurred in 1951 causing more than $725,000,000 in damages. In light of these damages, the 1952 Definite Project Report served as the basis for design of Tuttle Creek Dam and Reservoir. Due to various economic and environmental factors actual construction of the dam occurred off and on between early 1950s and early 1960s. Construction was completed, and operation began July 1, 1962. Since the Tuttle Creek Reservoir and dam began operations in 1962, it has prevented an estimated $15.1B in flood damages (Appendix H).

Figure 3-11. Tuttle Creek Reservoir (Source: USACE)



Tuttle Creek Reservoir, constructed by USACE, is an impoundment of the Big Blue River and controls approximately 9,628 square miles of drainage area. The original reservoir storage capacity includes 1,941,705 acre-feet of storage for flood control and 425,312 acre-feet for multipurpose use, which includes a sediment reserve of 240,312 acre-feet. Following sediment surveys in 2009, reservoir storage capacity was reduced and included approximately 1,884,312 acre-feet of storage for flood control and 257,014 acre-feet for multipurpose use (which includes allocations for water supply, water quality, navigation, and other purposes) (Figure 3-12; Table 3-9). The dam and the reservoir currently provides substantial municipal water supply, flood control, navigation, recreation, fish and wildlife conservation, and water benefits. Figure 3-12 and Table 3-9 illustrate the original and current (i.e., 2009) storage capacity.

Table 3-11. Tuttle Creek Reservoir Storage Capacity and Ownership

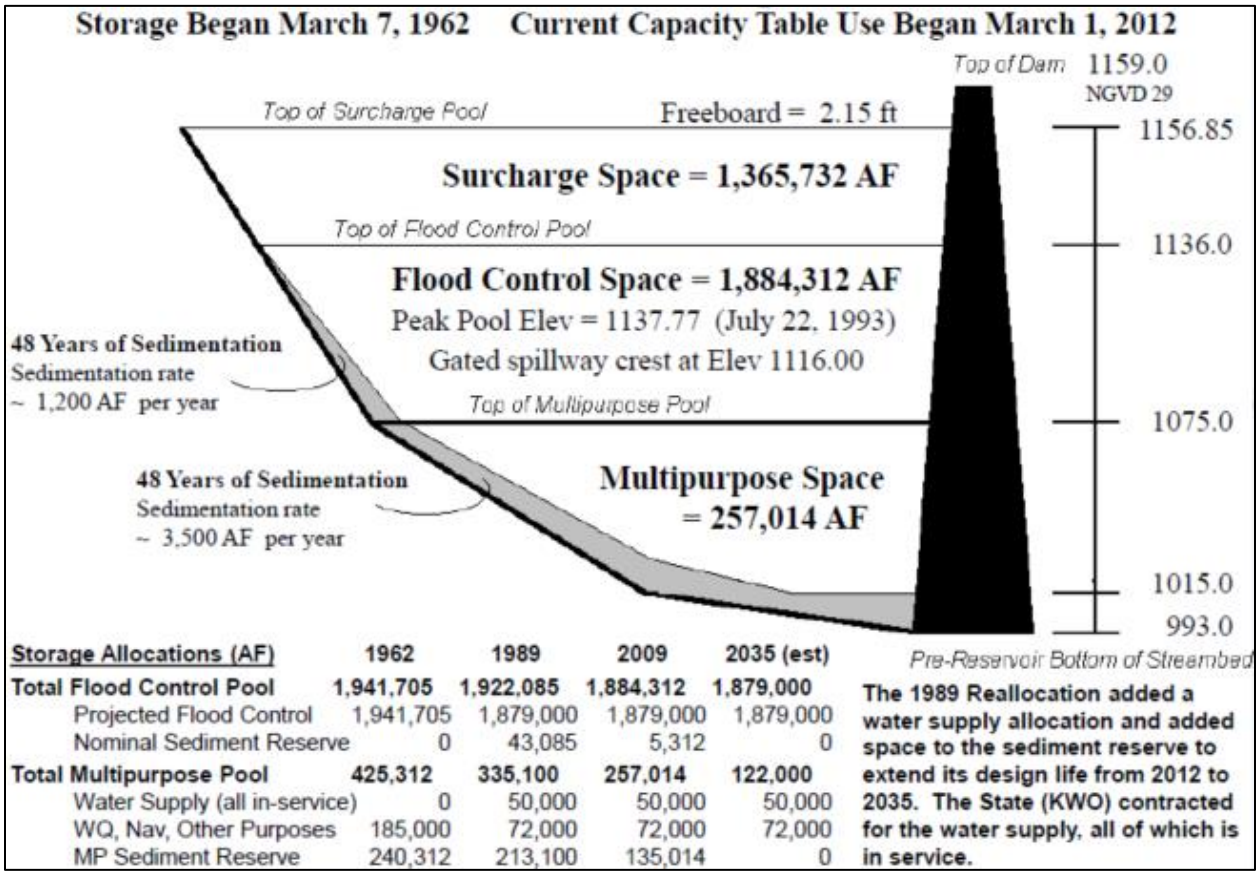
Pool Owner/Contracted Storage	Purpose	Quantity (acre-feet)*
USACE	Flood Control	1,884,312
USACE	Multipurpose	257,014
USACE	Water Quality/Navigation/Other Purposes	72,000
State of Kansas	Water Supply	50,000
USACE	Sediment Reserve	135,014
USACE	Surcharge	1,365,732

* Based on current capacity table and latest survey in 2009.

Water quality storage is used to maintain minimum flow targets downstream of the reservoirs. In the mainstem Kansas River Basin, only Tuttle Creek Lake has a water quality pool that is to be used to maintain flow targets on the Kansas River. The Kansas River flow criteria includes minimum flows at Topeka and De Soto in support of both water quality and water supply; the flow targets and their relationship to Tuttle Creek Reservoir. Table 3-10 summarizes reservoir pool levels. Milford, Perry, and Tuttle Creek lakes are operated as a system to support minimum flow criteria on the Kansas River, with the current practice being to make releases from Tuttle Creek water quality storage

and water supply storage volumes within Milford and Perry multipurpose pools not called into service by the State. This water is also used to provide supplemental releases for support of navigation flow targets on the Missouri River when a navigation call is made.

Figure 3-12. Tuttle Creek Reservoir Storage Allocations



*Source: USACE

Typically, the three reservoirs (Perry, Tuttle Creek, and Milford) are operated to maintain a 1,000 cfs minimum flow at the De Soto gage for water quality purposes, as shown in Table 3-10 (USACE Final Draft Navigation Study: Milford, Tuttle Creek, Perry Lakes. 2009). The Tuttle Creek pool elevation determines drought status of the basin and sets the downstream water quality targets.

Table 3-12. Low Flow Operational Target for the Kansas River

	Topeka (cfs)		De Soto (cfs)	
Tuttle Creek Pool Elevation	**Summer**	**Winter**	**Summer**	**Winter**
1075–1070	750	750	1,000	1,000
1070–1065	750	600	1,000	800
1065–1048	600	600	750	700

Summer: May 1 to October 31; Winter: November 1 to April 30.

Navigation releases from Tuttle Creek Reservoir are made from the water quality storage volume and the flood control storage. Navigation releases are possible when the lake level is less than three feet below multi-purpose pool level (above 1,072.0 feet) during the recreational season and less than six feet below multi-purpose pool level (above 1,069.0 feet) after 1 October.

Sedimentation impacts O&M and infrastructure surrounding the lake mainly through the closure of boat ramps and other recreational facilities. Impacts mostly occur in the upper portions of the lake as the delta has migrated downstream. So far, sedimentation has not caused impacts to the operation of the service gates; likely because there is sufficient flushing from operations to prevent the buildup of sediment near the gates.

Sediment accumulation in Tuttle Creek Reservoir is expected to be substantial over the next 50 years with a major loss of storage capacity from sedimentation. Approximately 39 percent of the multipurpose pool is filled with sediment leaving approximately 257,014 acre-feet of capacity (based on 2009 survey results). Approximately 3,560 acre-feet of sediment accumulates on average annually in Tuttle Creek Reservoir. Sediment continues to accumulate in Tuttle Creek Reservoir with an expected additional 25 percent loss of the multipurpose pool over the next 25 years (2049) and 36 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 106,499 acre-feet in 2074. Table 3-11 shows the pool storage capacity under baseline conditions for the watershed study (i.e., 2024).

Table 3-13. 2024 Tuttle Creek Reservoir Storage

Purpose	**Quantity** (acre-feet)[1]
Flood Control	1,851,668
Multipurpose Uses	216,570

[1]Storage capacity projected for 2024 with loss to sedimentation as modeled.

Perry Reservoir—The Delaware River watershed covers approximately 1,117 square miles of land in northeast Kansas. Construction began on the roughly 7,750-foot long and 95-foot-tall earthen embankment in March of 1964 and was completed and put into operation in January of 1969. At its multipurpose pool elevation of 891.5 feet (msl), the surface area of the impoundment at Perry Reservoir (Figure 3-13) is 10,227 acres. At the top of the flood control pool elevation, surface acreage is in the area of 25,000 acres. Since the Perry Reservoir and dam began operations in 1969, it has prevented an estimated $12.4B in flood damages (Appendix H).

Figure 3-13. Perry Reservoir (Source: USACE)



Constructed by USACE, Perry Reservoir is an impoundment of the Delaware River and controls approximately 1,117 square miles of drainage area. The original reservoir storage capacity includes 521,880 acre-feet of storage for flood control and 243,220 acre-feet for multipurpose use, which includes a sediment reserve of 93,220 acre-feet. Following sediment surveys in 2009 reservoir storage capacity was reduced and included approximately 515,519 acre-feet of storage for flood control and 200,004 acre-feet for multipurpose use (Figure 3-14; Table 3-12). The dam and the reservoir currently provide substantial municipal water supply, flood control, navigation, recreation, fish and wildlife conservation, and water quality benefits. The entire multipurpose pool is allocated to water supply purposes. Only a portion is currently in service with the remainder being held as future use storage for water supply. Until all the storage is called into service by the State of Kansas, multipurpose objectives of the remaining storage are to supplement Missouri River flows for navigation within operating limits selected, to provide a relatively stable pool in the interest of recreation, to augment low flows and improve water quality in the Kansas River, and to enhance fish and wildlife habitat. Table 3-12 and Figure 3-14 show the original storage capacity and storage allocations and storage capacity and allocations based on current capacity and the latest survey (i.e., 2009).

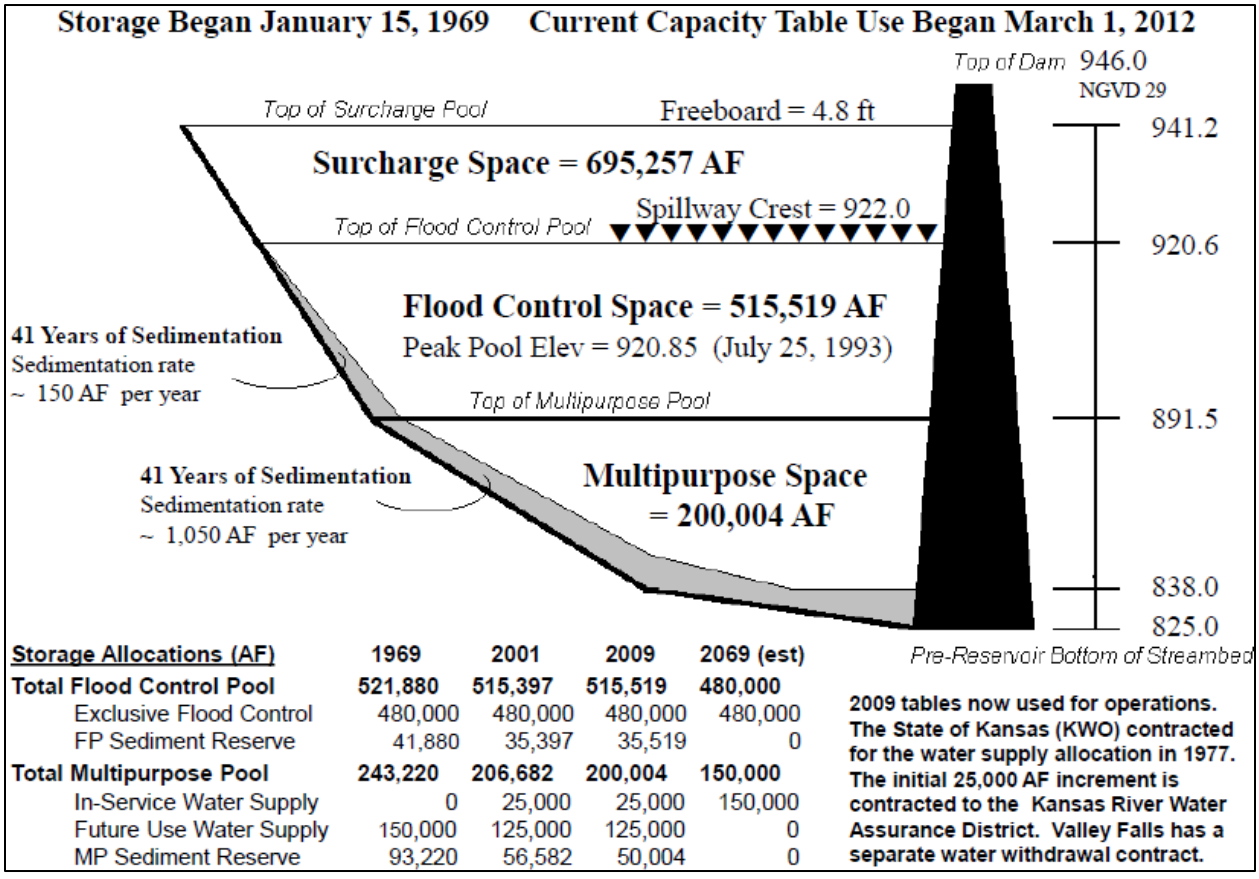
Table 3-14. Perry Reservoir Storage Capacity and Ownership

Pool Owner/Contracted Storage	Purpose	Quantity (acre-feet)1
USACE	Flood Control Pool	515,519
USACE	Sediment Reserve in FP	35,519
USACE	Multipurpose Pool	200,004
State of Kansas	Water Supply	150,000[2]-
USACE	Sediment Reserve in Multipurpose Pool (MPP)	50,004
USACE	Surcharge	695,257

[1]Based on current capacity table and latest survey in 2009
[2]25,000 acre-feet – In-service water supply; 125,000 acre-feet—future use water supply

The Milford, Perry, and Tuttle Creek reservoirs are operated as a system to support minimum flow criteria on the Kansas River, with the current practice being to make releases from water supply storage volumes within Milford and Perry multipurpose pools that have not been called into service by the State, and to provide supplemental releases for support of navigation flow targets on the Missouri River. Typically, the three reservoirs (Perry, Tuttle Creek, and Milford) are operated to maintain 1,000 cfs minimum flow at the De Soto gage for water quality purposes, as shown in Table 3-26 (USACE 2009).

Figure 3-14. Perry Reservoir Storage Allocations



Storage Allocations (AF)	1969	2001	2009	2069 (est)
Total Flood Control Pool	**521,880**	**515,397**	**515,519**	**480,000**
Exclusive Flood Control	480,000	480,000	480,000	480,000
FP Sediment Reserve	41,880	35,397	35,519	0
Total Multipurpose Pool	**243,220**	**206,682**	**200,004**	**150,000**
In-Service Water Supply	0	25,000	25,000	150,000
Future Use Water Supply	150,000	125,000	125,000	0
MP Sediment Reserve	93,220	56,582	50,004	0

2009 tables now used for operations. The State of Kansas (KWO) contracted for the water supply allocation in 1977. The initial 25,000 AF increment is contracted to the Kansas River Water Assurance District. Valley Falls has a separate water withdrawal contract.

*Source: USACE

Navigation releases from Perry Reservoir are from the water supply storage volume not called into service and the flood control storage. With navigation releases possible when the reservoir level is less than 3 feet below multi-purpose pool level (above 1,072.0 feet) during the recreational season and less than 6 feet below multi-purpose pool level (above 1,069.0 feet) after October 1.

Sediment accumulation in Perry Reservoir is expected to be substantial over the next 50 years with a major loss of storage capacity from sedimentation. Approximately 18 percent of the multipurpose pool is filled in with sediment leaving approximately 200,004 acre-feet of capacity (based on 2009 survey results). Approximately 1,080 acre-feet of sediment accumulates on average annually in Perry Reservoir. Sediment continues to accumulate in Perry Reservoir with an expected additional 19 percent loss of the

multipurpose pool over the next 25 years (2049) and 31 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 120,752 acre-feet in 2074. Table 3-13 shows the pool storage capacity under baseline conditions for the watershed study (i.e., 2024).

Table 3-15. 2024 Perry Reservoir Storage

Purpose	Quantity (acre-feet)1
Flood Control	511,851
Multipurpose Uses	180,366

[1]Storage capacity projected for 2024 with loss to sedimentation as modeled.

Clinton Reservoir—Clinton Reservoir (Figure 3-15) is an impoundment on the Wakarusa River located in northwestern Douglas County, Kansas, 22 miles above the confluence with the Kansas River. As a result of numerous flooding events within the Wakarusa valley, construction of the Clinton dam and reservoir was authorized in the Flood Control Act of 1962. Construction began in 1972, and the dam was completed in 1975. Impoundment began on November 30, 1977, and the top of multipurpose pool was reached in 1980. In April 1981, the lake began multipurpose operations including flood control, water supply, water quality, and recreation. Since the Clinton Reservoir and dam began operations in 1981, it has prevented an estimated $2.8B in flood damages (Appendix H).

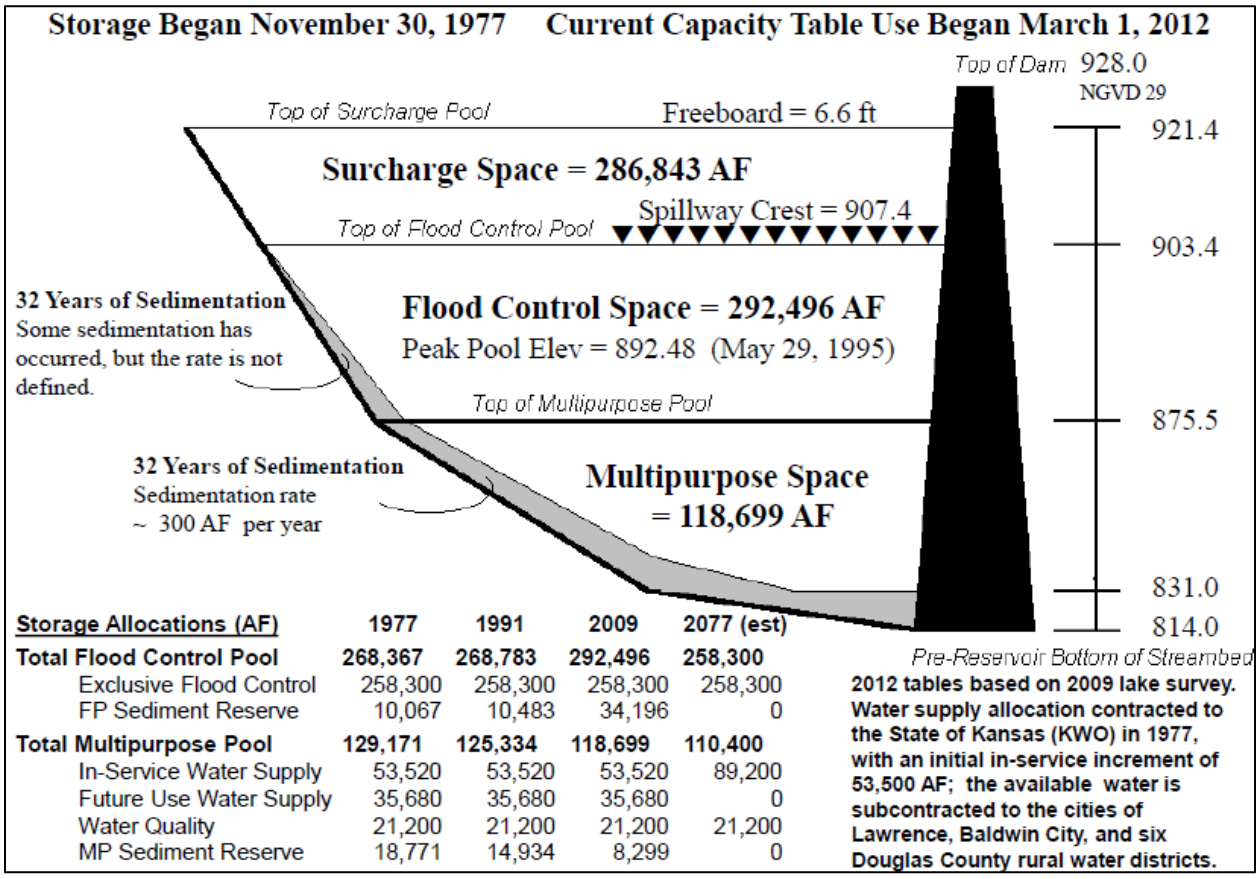
Figure 3-15. Clinton Reservoir (Source: USACE)



Constructed by USACE, Clinton Reservoir is an impoundment of the Wakarusa River and controls approximately 367 square miles of drainage area. The original reservoir storage capacity includes 268,367acre-feet of storage for flood control and 129,171 acre-feet for multipurpose use, which includes a sediment reserve of 18,771 acre-feet. Following sediment surveys in 2009 using different survey methods, there was a gain in volume of the flood pool increasing the storage capacity to 292,496 acre-feet. The reservoir multipurpose pool storage capacity was reduced and included approximately 118,699 acre-feet for multipurpose use (Figure 3-16; Table 3-14). The dam and the reservoir currently provide substantial municipal water supply, flood control, recreation, fish and wildlife conservation, and water quality benefits. A portion of the multipurpose pool is allocated to water supply purposes with a portion of that currently in service with the remainder held as future use storage for water supply. Until all the storage is called into service by the State of Kansas, multipurpose objectives of the remaining storage provide a relatively stable pool in the interest of recreation, to augment low flows and improve water quality in the Kansas River, and to enhance fish and wildlife habitat.

Table 3-14 and Figure 3-16 show the original and current (i.e., 2009) storage capacity and storage allocations and storage capacity.

Figure 3-16. Clinton Reservoir Storage Allocations



Storage Allocations (AF)	1977	1991	2009	2077 (est)
Total Flood Control Pool	**268,367**	**268,783**	**292,496**	**258,300**
Exclusive Flood Control	258,300	258,300	258,300	258,300
FP Sediment Reserve	10,067	10,483	34,196	0
Total Multipurpose Pool	**129,171**	**125,334**	**118,699**	**110,400**
In-Service Water Supply	53,520	53,520	53,520	89,200
Future Use Water Supply	35,680	35,680	35,680	0
Water Quality	21,200	21,200	21,200	21,200
MP Sediment Reserve	18,771	14,934	8,299	0

2012 tables based on 2009 lake survey. Water supply allocation contracted to the State of Kansas (KWO) in 1977, with an initial in-service increment of 53,500 AF; the available water is subcontracted to the cities of Lawrence, Baldwin City, and six Douglas County rural water districts.

*Source: USACE

Sediment accumulation in Clinton Reservoir is expected to be low over the next 50 years with a minor loss of capacity from sedimentation. Approximately 12 percent of the multipurpose pool is filled in with sediment leaving approximately 118,699 acre-feet of capacity (based on 2009 survey results). Approximately 384 acre-feet of sediment accumulates on average annually in Clinton Reservoir. Sediment continues to accumulate in Clinton Reservoir with an expected additional 8 percent loss of the multipurpose pool over the next 25 years (2049) and 14 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 94,870 acre-feet in 2074. Table 3-14 shows the original pool storage capacity and pool storage capacity under baseline conditions for the watershed study (i.e., 2024).

Table 3-16. Clinton Reservoir Storage Capacity and Ownership

Pool Owner/Contracted Storage	Purpose	Quantity (acre-feet)
2009		
USACE	Flood Control	292,496
USACE	Multipurpose	118,699
USACE	Water Quality/Other Purposes	21,200
State of Kansas	Water Supply	89,200
USACE	Sediment Reserve	8,299
USACE	Surcharge	286,843
2024		
USACE	Flood Control	291,404
USACE/KWO	Multipurpose Uses	112,142

[1]Storage capacity projected for 2024 with loss to sedimentation as modeled.

Harlan County Reservoir—Harlan County Reservoir (Figure 3-17) is a USACE project covering 31,000 acres, including a reservoir with 13,500 surface acres at multipurpose pool. The reservoir is about 7 miles long with 75 miles of shoreline. Located on the Republican River in the south-central part of the Nebraska (7 miles from the Nebraska-Kansas state line), the reservoir drains into the Kansas River. The massive flood of 1935 prompted state and federal officials to investigate flood control measures in the Republican River Basin. On May 31, 1935, a storm dumped 24 inches of rain on the Republican River watershed wiping out Republican City, Nebraska, and resulting in the deaths of more than 100 people. Nearly 10,000 cattle were reportedly lost along the Republican River Valley along with 300 county bridges and more than 300 miles of roads and railway. The flood was responsible for more than $26 million in damages.

Figure 3-17. Harlan County Reservoir (Source: USACE)



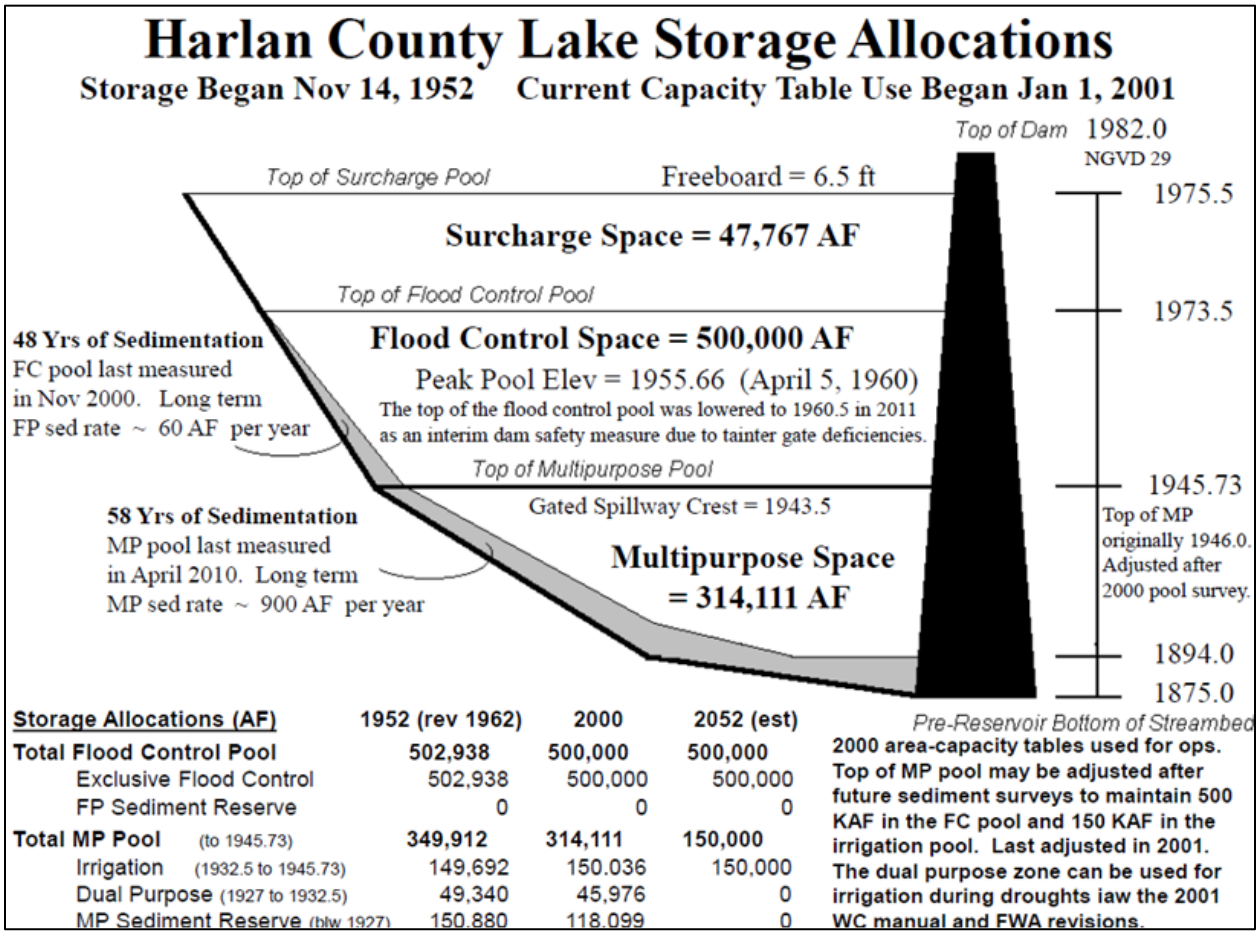
USACE researched a potential location for a dam to prevent such flood loss and selected a site located between the towns of Republican City and Naponee, Nebraska. The USACE Kansas City District began construction of the Harlan County Dam and

Reservoir in 1946. Republican City, Nebraska, was eventually moved and rebuilt 2 miles north on higher ground. The dam, completed in 1953, extends for 2 miles across the Republican River valley and is about 100 feet high. USACE and USBR jointly developed the project and the reservoir is owned and operated by USACE for flood control, irrigation, recreation, and fish and wildlife purposes. The reservoir provides a valuable recreation area and popular fishing spot in Nebraska. The NGPC is the administering agency for fish and wildlife management activities for both the land and water resources at Harlan County Reservoir. Since the Harlan County Reservoir and dam began operations in 1953, it has prevented an estimated $703M in flood damages (Appendix H).

USACE constructed Harlan County Reservoir as a multipurpose facility for flood control and irrigation. The original reservoir storage capacity included 502,938 acre-feet of storage for flood control, 349,912 acre-feet for multipurpose use, and a sediment reserve of 150,880 acre-feet. Table 3-15 and Figure 3-18 show the storage capacity and allocations.

Approximately 150,000 acre-feet of multipurpose pool storage is allocated exclusively for irrigation. An additional 46,000 acre-feet of multipurpose pool was allocated as dual purpose in 2001. Through a USBR and USACE Consensus Plan, the dual-purpose zone is used for irrigation during drought conditions. Harlan County Reservoir provides irrigation water to approximately 100,000 acres of cropland in south-central Nebraska and north-central Kansas under the authority of the Bostwick Division, part of the Pick-Sloan Missouri Basin Water Program.

Figure 3-18. Harlan County Reservoir Storage Allocations



Sediment accumulation in Harlan County Reservoir is expected to be low over the next 50 years with a minor loss of storage capacity from sedimentation. Approximately 11 percent of the multipurpose pool is filled in with sediment leaving approximately 314,111 acre-feet of capacity (based on 2000 survey results). Approximately 756 acre-feet of sediment accumulates on average annually in Harlan County Reservoir. Sediment continues to accumulate in Harlan County Reservoir with an expected additional 1 percent loss of the multipurpose pool over the next 25 years (2049) and 1 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 298,227 acre-feet in 2074. Table 3-15 shows the pool storage capacity under baseline conditions (i.e., 2024).

Table 3-17. Storage Capacity and Ownership

Pool Owner	Purpose	Quantity (acre-feet)
1952		
USACE	Flood Control	502,938
USACE	Multipurpose	349,912
2024[1]		

USACE	Flood Control	499,840
USACE	Multipurpose Uses	158,593
Irrigation Districts	Irrigation	150,000

[1]Storage capacity projected for 2024 with loss to sedimentation as modeled.

3.2.2.1.2 U.S. Bureau of Reclamation Reservoirs in Kansas

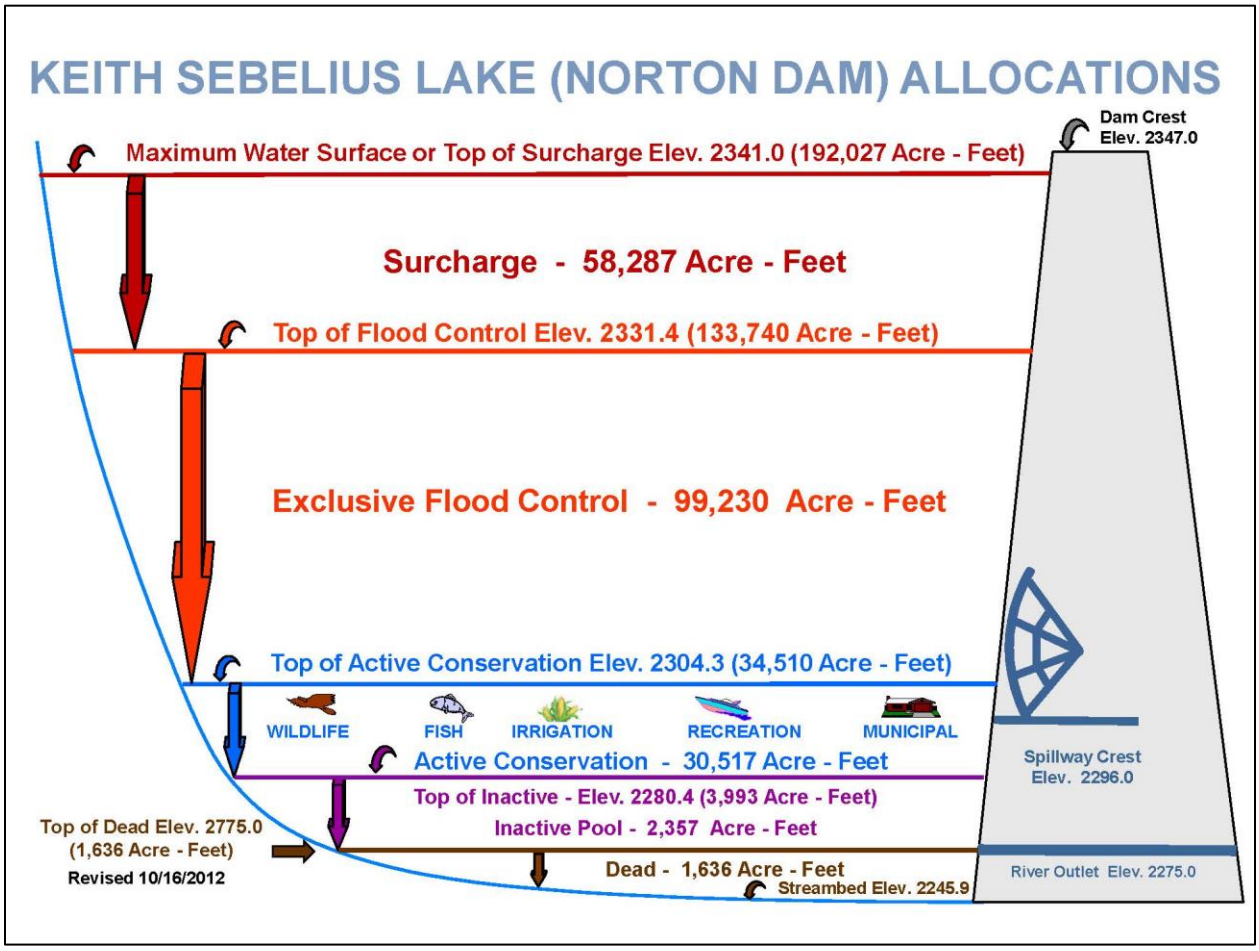
Keith Sebelius Reservoir—Keith Sebelius Reservoir (Figure 3-19) is located on Prairie Dog Creek, three miles west and one mile south of Norton, Kansas. The reservoir is formed by a rolled earth filled dam, in which water storage began on December 1, 1964. The drainage area consists of 683 square miles of cultivated and pastureland. The reservoir was constructed by the USBR for flood control, municipal water for the City of Norton, and irrigation. At normal pool (elevation 2,304.30 feet National Geodetic Vertical Datum of 1929 [NGVD 29]), the reservoir consists of 2,181 surface acres and contains 34,510 acre-feet of water. At maximum capacity, elevation 2,341.00 feet, the reservoir can impound 6,713 surface acres and 192,027 acre-feet of water. Since the Keith Sebelius Reservoir and dam began operations in 1964, it has prevented an estimated $26M in flood damages (Appendix H).

Figure 3-19. Keith Sebelius Reservoir (Source: USBR)



USBR constructed the Norton Dam and Keith Sebelius Reservoir. The reservoir storage capacity includes 99,230 acre-feet storage for flood control and 30,517 acre-feet for multipurpose use (based on 2000 survey results) (Table 3-16 and Figure 3-20). Keith Sebelius Reservoir currently provides flood control, municipal water supply, irrigation, recreation, and fish and wildlife conservation benefits.

406 *Figure 3-20. Keith Sebelius Reservoir Storage Allocations*



407

408 Source: USBR

409 USBR operates and maintains Keith Sebelius Reservoir. USACE furnishes regulating
410 instructions for water within the flood control capacity. Keith Sebelius Reservoir stores
411 water for irrigation of the Almena Unit, water for use in the city of Norton, Kansas, and
412 for flood control, along with the secondary benefits of recreation and fish and wildlife.
413 The Almena Irrigation District Number 5 holds the water rights. Current irrigation
414 infrastructure includes Norton Dam and Keith Sebelius Reservoir, the Almena Diversion
415 Dam, Almena Main and South Canals, and a system of laterals and drains.

416

Table 3-18. Keith Sebelius Reservoir Storage Capacity and Ownership

Pool Owner/Water Rights	Purpose	Quantity (acre-feet)*
USBR	Flood Control	99,230
USBR	Multipurpose	30,517
Almena Irrigation District	Irrigation	27,800
City of Norton	Municipal Water Supply	1,600

*Source: USBR.

The multipurpose pool at Keith Sebelius Reservoir originally included 36,700 acre-feet of capacity (including the active pool and the inactive or dead pool). Approximately 4.5 percent of the multipurpose pool is filled in with sediment leaving approximately 34,510 acre-feet of capacity (based on 2000 survey results). Approximately 45 acre-feet of sediment accumulates on average annually in Keith Sebelius Reservoir. Sediment continues to accumulate in Keith Sebelius Reservoir with an expected additional 6.1 percent loss of the multipurpose pool over the next 25 years (2049) and 9.2 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 31,164 acre-feet in 2074.

Kirwin Reservoir—Kirwin Reservoir (Figure 3-21) is located on the North Fork of the Solomon River and Bow Creek, one-half mile south of the town of Kirwin, Kansas. The reservoir is formed by a compacted earthen-fill dam into which water storage began on September 19, 1955. USBR constructed Kirwin reservoir, for flood control and irrigation. The drainage area consists of 1,367 square miles of cultivated and pastureland. At normal pool (elevation 1,729.25 feet above msl) the reservoir consists of 5,071 surface acres and contains 98,154 acre-feet of water. At maximum capacity (top of surcharge, elevation 1,773 feet) the reservoir impounds 14,660 surface acres and 511,757 acre-feet of water. Since the Kirwin Reservoir and dam began operations in 1955, it has prevented an estimated $317M in flood damages (Appendix H).

Figure 3-21. Kirwin Reservoir (Source: USBR)



Kirwin Reservoir was specified as one of three projects (i.e., Kirwin Reservoir, Webster Reservoir, and Waconda Reservoir) in the Solomon River Basin required to meet flood control and irrigation needs of the basin as part of the Pick-Sloan plan and the Flood

Control Act of 1946. The reservoir storage capacity includes 215,136 acre-feet storage for flood control and 89,639 acre-feet for multipurpose use (based on 1996 survey results). Kirwin Reservoir currently provides flood control, irrigation, recreation, and fish and wildlife conservation benefits.

USBR operates and maintains Kirwin Reservoir. USACE furnished instructions for regulating water in the flood control capacity. The Kirwin Irrigation District holds the water rights. Three canals for irrigation were constructed in 1958 to distribute water to serve 11,435 irrigable acres. Kirwin Irrigation District is responsible for the O&M of canals, laterals, and drains associated with the reservoir. A petition of organization and an application for water rights were filed with the KDA-DWR, by the Kirwin Irrigation District on April 22, 1948, and approved on September 25, 1948. The application is for the maximum use of 35,600 acre-feet of water annually and the storage of all flows of the North Fork Solomon River to a maximum quantity of 80,000 acre-feet. During the last two decades, less water was available for delivery to the Kirwin Irrigation District due to reduced reservoir elevations from drought conditions, with no deliveries of irrigation waters for a five-year period in the 1980s and early 1990s (USFWS 2006).

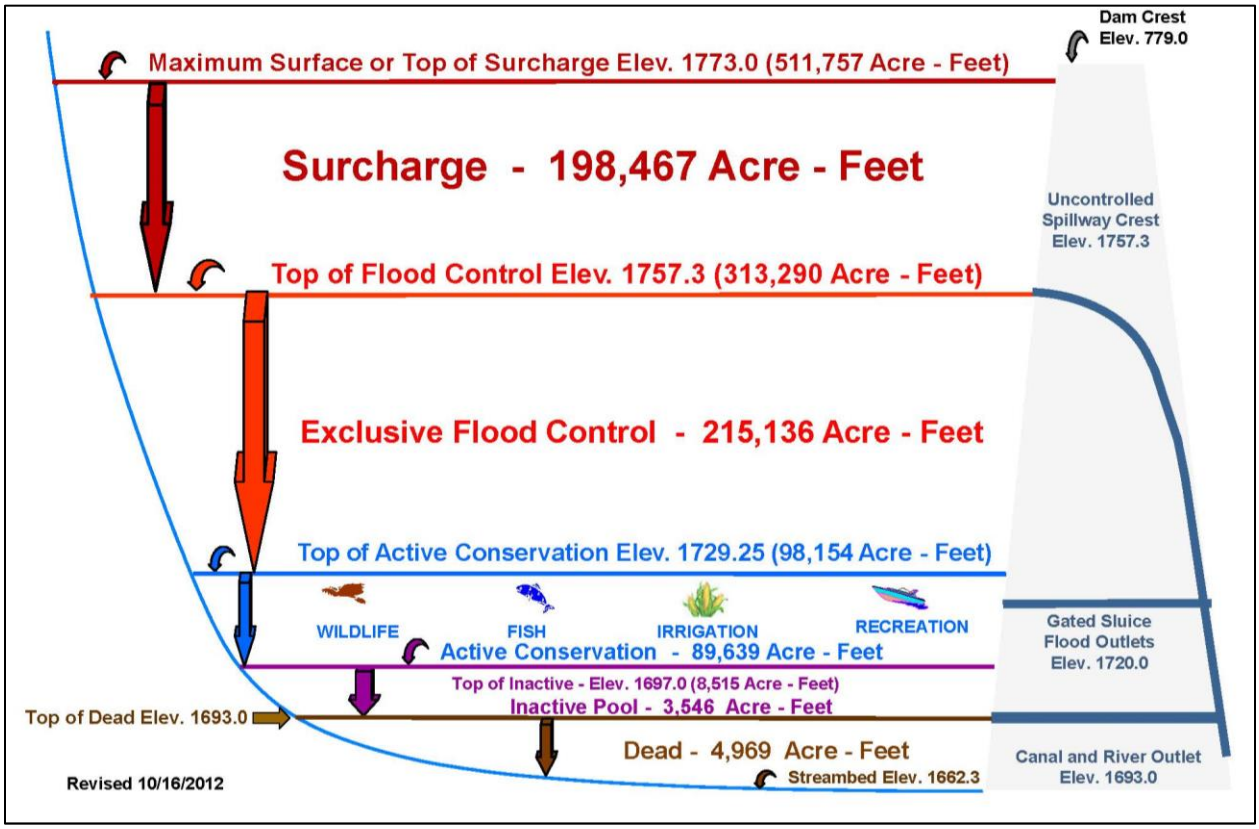
The Kirwin National Wildlife Refuge (NWR) was established in 1954 as an overlay project on the irrigation and flood control reservoir. U.S. Fish and Wildlife refuge staff manage all activities on the reservoir and its surrounding lands, with the exception of irrigation and flood control. The primary purpose of the Kirwin NWR is to provide nesting cover, food, and shelter for songbirds, waterfowl, upland game birds, and mammals.

Table 3-17 and Figure 3-22 show the storage capacity and water rights.

Table 3-19. Kirwin Reservoir Storage Capacity and Ownership

Pool Owner/Water Rights	Purpose	Quantity (acre-feet)
USBR	Flood Control	215,136
USBR	Multipurpose	89,639
Kirwin Irrigation District	Irrigation	35,600

Figure 3-22. Kirwin Reservoir Storage Allocations



Source: USBR

The multipurpose pool at Kirwin Reservoir originally included 99,432 acre-feet of capacity (including the active pool and the inactive or dead pool). Approximately 1.3 percent of the multipurpose pool is filled in with sediment leaving approximately 98,154 acre-feet of capacity (based on 1996 survey results). Sediment continues to accumulate in Kirwin Reservoir with an expected additional 1.7 percent loss of the multipurpose pool over the next 25 years (2049) and 2.4 percent loss over the next 50 years (2074) (Appendix D).

Webster Reservoir—Webster Reservoir (Figure 3-23) is located on the South Fork of the Solomon River, eleven miles west and one-half mile south of Stockton, Kansas. The reservoir is formed by a compacted earthen-fill dam, into which water storage began on May 3, 1956. The drainage area consists of 1,150 square miles of pasture and cultivated land. USBR constructed the reservoir for flood control and irrigation. At normal pool (elevation 1,892.45 feet [NGVD 29]), the reservoir consists of 3,766 surface acres and contains 76,157 acre-feet of water, with many rocky ledges making up its shoreline. At maximum capacity, elevation 1,938.00 feet, the reservoir impounds 11,270 surface acres and 400,422 acre-feet of water. Since the Webster Reservoir and dam began operations in 1956, it has prevented an estimated $303M in flood damages (Appendix H).

Figure 3-23. Webster Reservoir (Source: USBR)



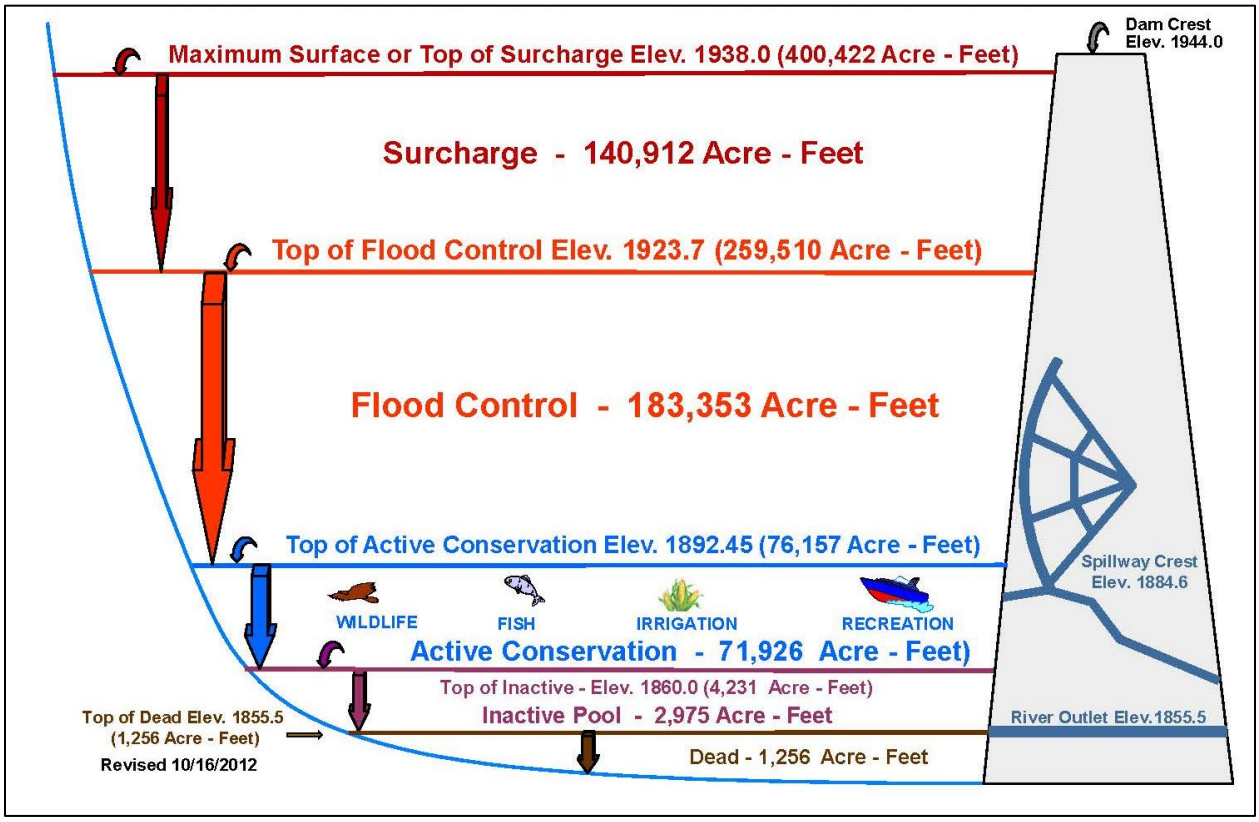
Webster Reservoir was specified as one of three projects (i.e., Kirwin Reservoir, Webster Reservoir, and Waconda Reservoir) in the Solomon River Basin required to meet flood control and irrigation needs of the basin as part of the Pick-Sloan plan and the Flood Control Act of 1946. The reservoir storage capacity includes 183,353 acre-feet storage for flood control and 71,926 acre-feet for multipurpose use (based on 1996 survey results). Webster Reservoir currently provides flood control, irrigation, recreation, and fish and wildlife conservation benefits (Table 3-18 and Figure 3-24).

Table 3-20. Webster Reservoir Storage Capacity and Ownership

Pool Owner/Water Rights	Purpose	Quantity (acre-feet)
USBR	Flood Control	183,353
USBR	Multipurpose	71,926
Webster Irrigation District	Irrigation	71,700

Source: USBR 2012.

Figure 3-24. Webster Reservoir Storage Allocations



Source: USBR

USBR operates and maintains Webster Reservoir. USACE furnished instructions for regulating the water in the flood control capacity. The primary purpose of Webster Dam is to store water for irrigation of the Webster Unit and for flood control, along with the secondary benefits of recreation and fish and wildlife. The 71,926 acre-feet for multipurpose use is primarily for irrigation. The Webster Irrigation District Number 4, formed in 1956, holds the water rights. Current irrigation infrastructure downstream of Webster Dam includes the Woodson Diversion Dam, four pumping plants, Osborne Irrigation Canal, and a system of laterals and drains. Irrigation water released from Webster Reservoir into the South Fork of the Solomon River is diverted into the Osborne Irrigation Canal at the Woodson Diversion Dam. The Webster Irrigation District has an irrigation water right (approved in June 1956) with the KDA-DWR, for 71,700 acre-feet of storage in Webster Reservoir.

The KDWP manages Webster State Park, located on the shore of the reservoir, and the Webster Wildlife Area.

The multipurpose pool at Webster Reservoir originally included 77,370 acre-feet of capacity (including the active pool and the inactive or dead pool). Approximately 1.6 percent of the multipurpose pool is filled in with sediment leaving approximately 76,157 acre-feet of capacity (based on 1996 survey results). Approximately 32 acre-feet of sediment accumulates on average annually in Keith Sebelius Reservoir. Sediment continues to accumulate in Keith Sebelius Reservoir with an expected additional 2 percent loss of the multipurpose pool over the next 25 years (2049) and 3 percent loss

over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 73,616 acre-feet in 2074.

Cedar Bluff Reservoir—Cedar Bluff Reservoir (Figure 3-25) is an impoundment on the Smoky Hill River located in southeastern Trego County, Kansas. As a result of severe droughts in the 1930s, USBR initiated investigations in 1939 for potential construction of the new reservoir. These and subsequent investigations led to authorization to construct the reservoir as part of the Missouri River Basin Project, a subsidiary of the Pick-Sloan plan, by the Flood Control Act of 1944. Construction of Cedar Bluff Dam began in 1949 and was completed in 1951 (USBR 1949). Since the Cedar Bluff Reservoir and dam began operations in 1951, it has prevented an estimated $404M in flood damages (Appendix H).

Figure 3-25. Cedar Bluff Reservoir (Source: USBR)



USBR constructed Cedar Bluff Reservoir as a multipurpose facility for flood control, irrigation, recreation, municipal water supply, as well as fish and wildlife purposes.

The City of Russell, Kansas entered into contract 14-06-700-3930 (later renumbered 3-07-70-W0079) for municipal water supply with USBR in 1963. The City obtained Water Right File Number (No.) 7,628 from the Chief Engineer of the KDA-DWR in 1957 to authorize the proposed use. Cedar Bluff Reservoir and associated works operated for each of the originally authorized purposes until 1978 when the last delivery of irrigation water was made because of a lack of dependable water supply available (USBR 2003).

In 1987, the U.S. Department of the Interior (DOI), the State of Kansas, and the Cedar Bluff Irrigation District No. 6 entered into a Memorandum of Understanding (MOU) (1987 MOU; USBR 1987) establishing an intent for reformulation and operation of the Cedar Bluff Unit (i.e., unit includes the watershed, reservoir, and irrigation infrastructure) contingent upon Congressional legislation.

The State of Kansas and USBR entered into Contract 9-07-60-W0387 in 1989, transferring ownership of the water rights held by the Cedar Bluff Irrigation District No. 6 (Water Right File No. 7,684) and DOI, FWS (Water Right File No. 7,627) to the State of Kansas in accordance with the 1987 MOU.

As shown in Table 3-19, Contract 9-07-60-W0387 established four distinct operation pools within the multipurpose pool of Cedar Bluff Reservoir.

Table 3-21. Cedar Bluff Original Pool Ownership

Pool Owner	Purpose	Pool Size (acre-feet)
City of Russell	Municipal Water Supply	2,700
KWO	Artificial Recharge	5,400
KDWP	Fish, Wildlife and Recreation	21,639
KWO and KDWP	Joint Use	147,090
Total		176,829

The United States Congress passed Public Law 102-575, Title IX, Section 901 in 1992 authorizing the reformulation of the Cedar Bluff Unit, including Cedar Bluff Reservoir.

The KWO and the KDWP entered into an Operations Agreement for Cedar Bluff Reservoir February 4, 1994, concerning the management of the designated operating pool and the joint use pool of Cedar Bluff Reservoir.

In furtherance of Contract 9-07-60-W0387, the State of Kansas sought changes to water right Nos. 7,627 (FWS, reallocation of storage for the former federal fish hatchery) and 7,684 (Cedar Bluff Irrigation District No. 6) in 1995 to reflect the reformulated uses. The reformulated uses include moving 10,739 acre-feet from Water Right File No. 7,627, and 5,400 acre-feet from the Cedar Bluff Irrigation District No. 6 to Water Right File No. 7,684. Table 3-20 includes the reformulated pool ownership. The changes were approved by the Chief Engineer of the DWR in 1996.

Table 3-22. Cedar Bluff Reformulated Water Right Pools

Priority of Fill	Water Right File No.	Pool	Holder	Quantity (acre-feet)
1	7,627	Fish, Wildlife and Recreation	KDWP	10,900
2	7,628	Municipal Water Supply	City of Russell, Kansas	2,700
3	7,684	Artificial Recharge Fish, Wildlife and Recreation Joint Use	KWO and KDWP	163,229
Total				176,829

In 2003, an MOU further defined accounting procedures for storage at Cedar Bluff Reservoir. The allocations of available storage were finalized, and a monthly accounting is provided by the KWO. The current reservoir storage capacity includes 191,890 acre-feet of storage for flood control and 143,878 acre-feet for multipurpose use.

Periodically, USBR conducts sediment surveys of Cedar Bluff Reservoir to determine the amount of storage available in the multipurpose pool. A 2000 sediment survey indicated a total of 12,608 acre-feet of sediment is deposited in Cedar Bluff Reservoir. Of this total, 8,779 acre-feet of sediment is deposited in Cedar Bluff Reservoir between the elevations of 2,090.0 and 2,144.0. According to the data, the flood pool gained 30 acre-feet of space and the pool below elevation 2,090.00 lost 3,859 acre-feet of space.

Storage lost to sediment deposition is not deducted from the KDWP pool, Water Right File No. 7,627 or the City of Russell's pool, Water Right File No. 7,628. The pools associated with these remain at 10,900 acre-feet and 2,700 acre-feet, respectively. As shown in Table 3-21, storage lost to sediment deposition is deducted from the pools with storage covered by Water Right File No. 7,864 (KWO, KDWP, Joint Use), based on the percentages.

Table 3-23. Cedar Bluff Pools for Water Right File No. 7,684

Water Right No.	Pool	Holder	Percentage Inflow (percent)	Quantity (acre-feet)	
7,684		Artificial Recharge	KWO	3.31	5,110
		Fish, Wildlife and Recreation	KDWP	6.58	10,161
		Joint Use	KWO and KDWP	90.11	139,179
		Total			154,450

Source: USBR 2003.

Table 3-22 shows the incorporation of the 2000 sediment data according to water right.

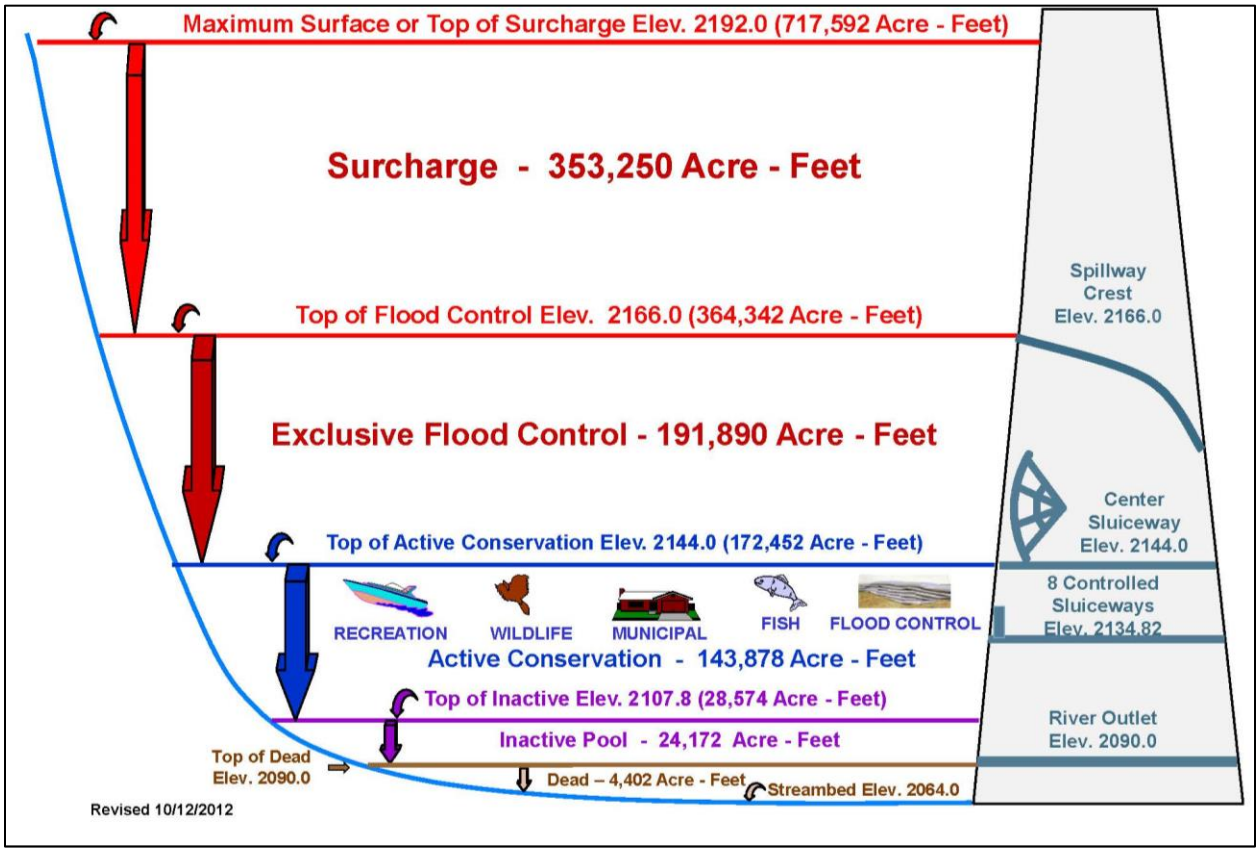
Table 3-24. Cedar Bluff Water Rights Pools (including 2000 Sediment Survey)

Priority of Fill	Water Right File No.	Pool	Holder	Quantity (acre-feet)
1	7,627	Fish, Wildlife and Recreation	KDWP	10,900
2	7,628	Municipal Water Supply	Russell	2,700
3	7,684	Artificial Recharge Fish, Wildlife and Recreation Joint Use	KWO and KDWP	154,450
Total				168,050

Table 3-25. Cedar Bluff Storage Capacity and Ownership

Pool Owner/Water Rights	Purpose	Quantity (acre-feet)
USBR	Flood Control	191,890
KDWP, KWO, City of Russell, Kansas	Multipurpose	143,878

Figure 3-26. Cedar Bluff Reservoir Storage Allocations



Source: USBR.

Approximately 7 percent of the multipurpose pool is filled in with sediment leaving approximately 172,452 acre-feet of capacity (based on 2000 survey results). Approximately 262 acre-feet of sediment accumulates on average annually in Cedar Bluff Reservoir. Sediment continues to accumulate in Cedar Bluff Reservoir with an expected additional 1 percent loss of the multipurpose pool over the next 25 years (2049) and 2 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 169,008 acre-feet in 2074.

Lovewell Reservoir—Lovewell Reservoir (Figure 3-27) is an impoundment on White Rock Creek located in northeastern Jewell County, Kansas, just six miles south of the Kansas-Nebraska border. Lovewell Reservoir is part of the Bostwick Division and Irrigation District, formed by the Flood Control Act of 1944 as part of the Pick-Sloan Missouri Basin Program following a catastrophic flood of the Republican River in 1935 (USBR 2009b). The Bostwick Division and Irrigation District located in south-central Nebraska and north-central Kansas includes lands on both sides of the Republican River. the construction of Lovewell Dam and Reservoir on White Rock Creek, a tributary of the Republican River, was part of the development of the Bostwick Division and Irrigation District. Construction began in January 1955 and finished in 1957 with the reservoir beginning to fill on October 1. The reservoir began operation on October 15, 1957 (Rucker 2009). Since the Lovewell Reservoir and dam began operations in 1957, it has prevented an estimated $419M in flood damages (Appendix H).

Figure 3-27. Lovewell Reservoir (Source: KDWP)



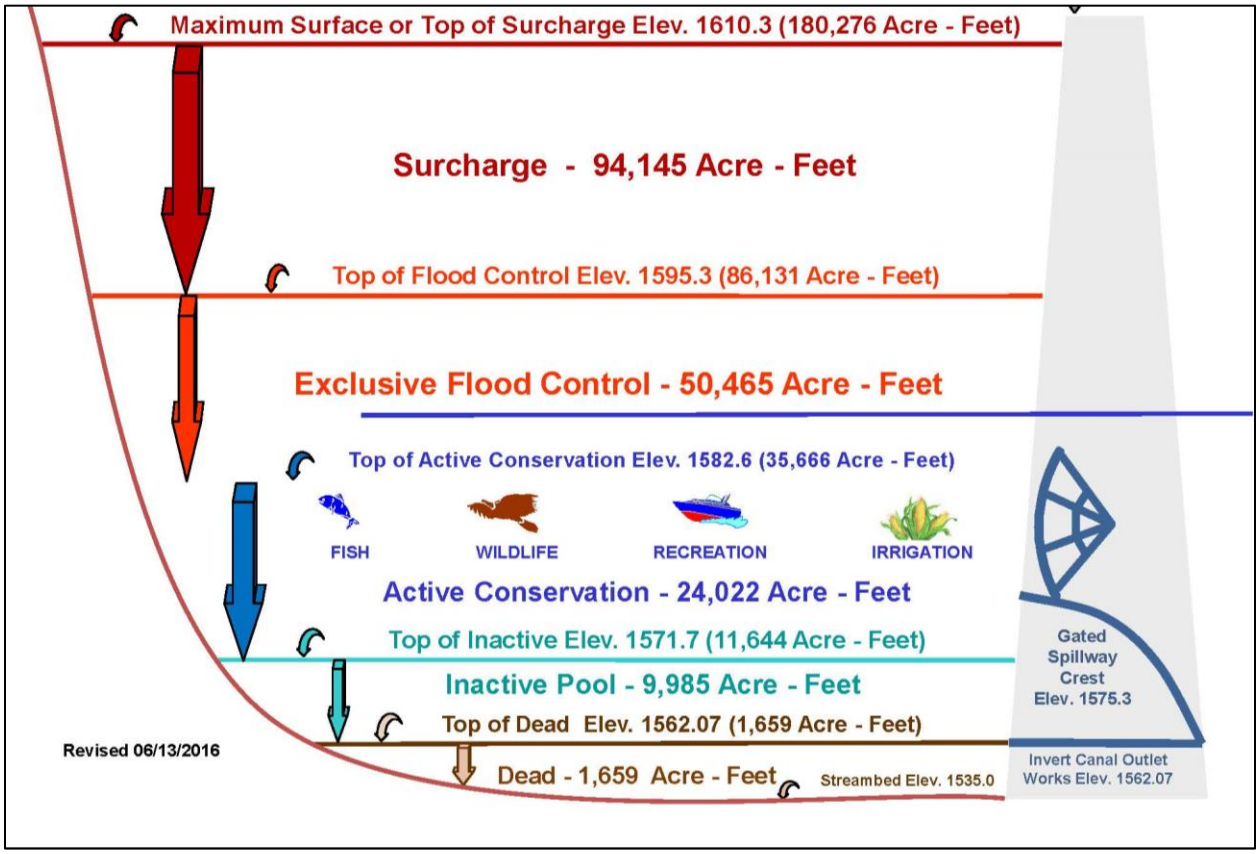
USBR constructed the Lovewell Dam and Reservoir project to function as an irrigation reservoir diverting water to serve 12,508 acres above Lovewell Dam and 27,014 acres below Lovewell Dam by diverting water from the Republican River via the Courtland Canal. Lovewell Reservoir also provides flood control to the valley immediately downstream of the impoundment as well as to cities, towns, farms, and lands located far downstream. The reservoir storage capacity includes 50,465 acre-feet of storage for flood control and 24,022 acre-feet for multipurpose use. Lovewell Reservoir also provides recreation and fish and wildlife conservation benefits.

The Lovewell Reservoir water surface and major portions of surrounding reservoir lands are administered by the KDWP in accordance with an MOU. KDWP requested that the Kansas Bostwick Irrigation District and USBR maintain, when possible, a flow of 20 cfs into Lovewell Reservoir when the Courtland Canal is in operation and the multipurpose pool is below capacity. This recommended inflow provides excellent fishing around the canal inlet to the reservoir. Table 3-24 and Figure 3-28 show the storage capacity and ownership. The multipurpose pool at Lovewell Reservoir originally included 41,690 acre-feet of capacity (including the active pool and the inactive or dead pool).

Table 3-26. Lovewell Storage Capacity and Ownership

Pool Owner/Water Rights	Purpose	Quantity (acre-feet)
USBR	Flood Control	50,465
USBR	Multipurpose	24,022

Figure 3-28. Lovewell Reservoir Storage Allocations



Source: USBR

Approximately 16.3 percent of the multipurpose pool is filled in with sediment leaving approximately 34,888 acre-feet of capacity (based on 2020 survey results). Approximately 31 acre-feet of sediment accumulates on average annually in Lovewell Reservoir. Sediment continues to accumulate in Lovewell Reservoir with an expected additional 2.2 percent loss of the multipurpose pool over the next 25 years (2049) and 4.1 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 33,189 acre-feet in 2074.

Waconda Lake—Glen Elder Dam and its reservoir, Waconda Lake, (Figure 3-29) is an impoundment on the Solomon River located in western Mitchell and eastern Osborne counties Kansas, approximately 7 miles below the confluence of the North and South Forks of the Solomon River, just west of Glen Elder, Kansas. The dam was authorized and constructed primarily as a flood control structure for the lower Solomon River Valley including the towns of Glen Elder, Beloit, and Simpson, Kansas, by the Flood Control Act of 1946. In addition, when working in conjunction with other flood control reservoirs, the reservoir assists in reducing flooding of the Smoky Hill and Kansas rivers. The dam was completed in December 1968 at a cost of $13.7M and the reservoir began to fill immediately. The reservoir has a shoreline of more than 100 miles and covers 12,586 surface acres at conservation. Since the Waconda Reservoir and dam began operations in 1968, it has prevented an estimated $3.1B in flood damages (Appendix H).

Figure 3-29. Waconda Reservoir (Source: USBR)



Glen Elder controls about 2,559 square miles drainage area below the upstream dams of Kirwin and Webster Reservoirs. The total drainage area including Kirwin (1,367 square miles) and Webster (1,150 square miles) is 5,076 square miles. The date of Glen Elder dam closure was October 18, 1967. The reservoir did not fill to the top of the multipurpose pool until May 16, 1973.

USBR constructed Glen Elder Dam and Waconda Lake. It was specified as one of six units in the Smoky Hill River Basin required to meet flood control and irrigation needs of the basin. The reservoir storage capacity includes 722,988 acre-feet of storage for flood control and 193,183 acre-feet for multipurpose use. The Glen Elder Dam and Waconda Lake project currently provides substantial municipal water supply, flood control, irrigation, recreation, fish and wildlife conservation, and pollution abatement benefits.

Releases from Waconda Lake are regulated as outlined in two MOUs between the State of Kansas and USBR. Releases are made for the City of Beloit, Kansas, the Mitchell County Rural Water District, the long-term water service contract with Glen Elder Irrigation District, and water right administration. The City of Beloit, Kansas, has a 2,000 acre-feet water right; the Mitchell County Rural Water District has a 1,009 acre-feet water right; and the Glen Elder Irrigation District utilizes water to irrigate 21,000 acres of farmland and can request up to 15,170 acre-feet of storage. Table 3-25 and Figure 3-30 show the storage capacity and water rights.

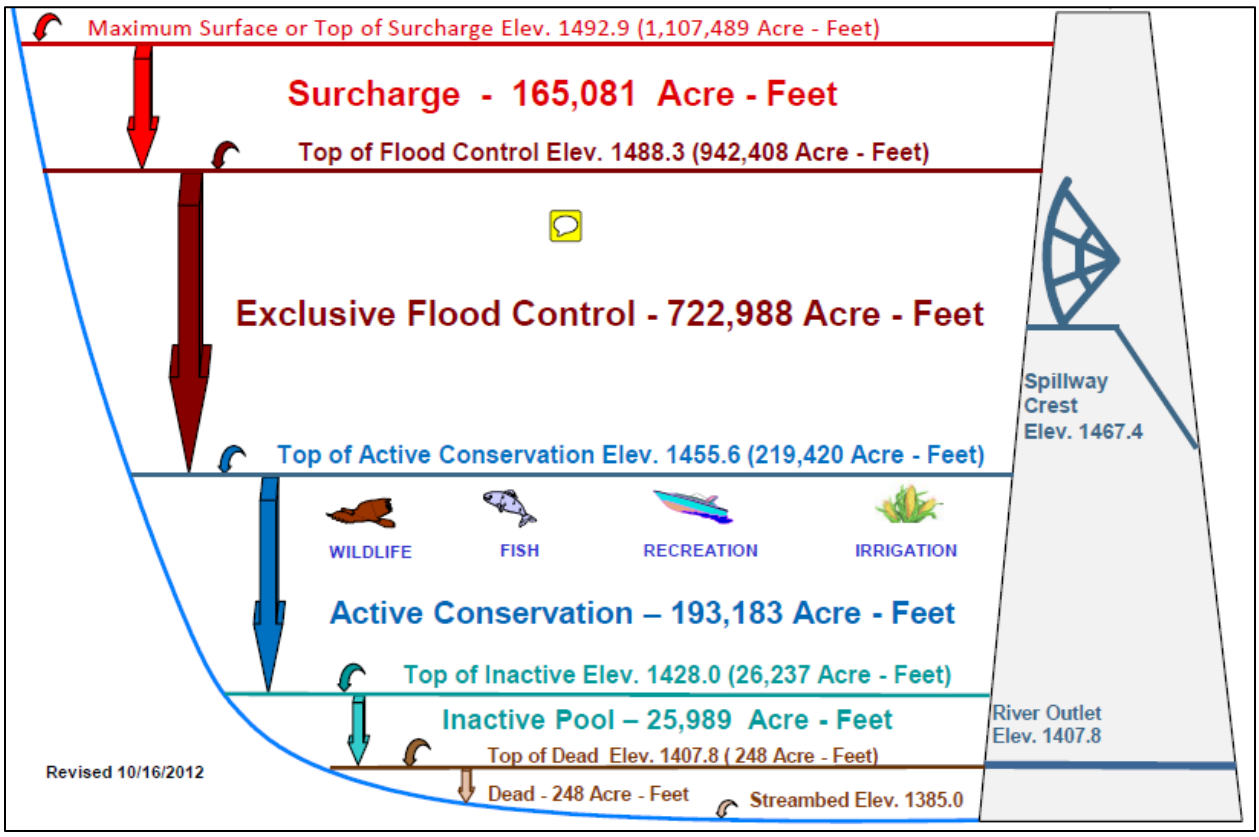
Table 3-27. Waconda Reservoir Storage Capacity and Ownership

Pool Owner/Water Rights	Purpose	Quantity (acre-feet)
USBR	Flood Control	722,988
USBR	Multipurpose	193,183
City of Beloit, Kansas	Municipal Water Supply	2,000
Mitchell County Rural Water District	Municipal Water Supply	1,009
Glen Elder Irrigation District	Irrigation	15,170

The multipurpose pool at Waconda Lake originally included 241,460 acre-feet of capacity (including the active pool and the inactive or dead pool). Approximately 9.3

685 percent of the multipurpose pool isn't filled in with sediment leaving approximately
686 219,420 acre-feet of capacity (based on 2001 survey results). Approximately 670 acre-
687 feet of sediment accumulates on average annually in Waconda Lake. Sediment
688 continues to accumulate in Waconda Lake with an expected additional 13.4 percent
689 loss of the multipurpose pool over the next 25 years (2049) and 20.4 percent loss over
690 the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to
691 164,307 acre-feet in 2074.

692 *Figure 3-30. Waconda Reservoir Storage Allocations*



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694 Source: USBR

3.2.2.2 System Operations—Reservoir Storage

Typically, reservoir flood control pools are designed to store runoff from major floods up to about the 1 percent annual chance inflow event. Stored flood flows are then evacuated as rapidly as the downstream channel capacities allow.

When flooding is not occurring, USACE works to seasonally fluctuate reservoir elevations near the multipurpose pool level in order to principally benefit on-reservoir fish and wildlife purposes. Minimum releases are maintained at all projects for the purpose of sustaining water quality control in the first reach downstream. The State of Kansas for downstream water supply (both municipal and industrial) in cooperation with the Kansas River Water Assurance District No. 1 purchased or reserved large portions of the multipurpose pools at Milford, Tuttle Creek, Perry, and Clinton reservoirs. The KWO tracks and accounts for releases from this contracted storage consistent with USACE monthly reservoir accounting for each project. Storage in the multipurpose pools at USACE projects that support irrigation are contracted to irrigation districts. Generally, a portion of each multipurpose pool is reserved for sediment storage. On an interim basis, a portion of the multipurpose pools at Milford, Tuttle Creek, and Perry are available for supplementation of navigation flows on the Missouri River with Tuttle Creek having provision for some permanent support to Missouri River navigation.

The operation of the Kansas River Basin is guided by the Lower Kansas River Basin Reservoir Regulation Manual, Master Manual (USACE 1966); the Smoky Hill River Basin Lake Regulation Manual, Master Manual (USACE 1974); and the Republican River Basin Reservoir Regulation Manual, Master Manual (USACE 1977). These master manuals record the basic water control plans and objectives for the integrated operation of the reservoirs in each subbasin. The reservoir elevations and flow releases vary throughout the year as a result of reservoir operations following the master manuals.

The master manuals describe the water control plan for the system, which consists of the water control criteria for the management of the Kansas River Basin for the full spectrum of anticipated runoff conditions expected to occur. Individual reservoir WCMs give lake specific information and reservoir release requirements in accordance with the system master plan.

For a portion of some years, deviations may be made from the specific technical criteria stated in the master manuals and individual reservoir WCMs to address specific concerns not adequately covered in the manuals. Typically, deviations have been requested to support project needs during construction or for extreme events such as floods or droughts. All significant deviations from the current water control plan are coordinated and approved by the NWD Commander. All deviations of significance are analyzed to assess impacts and presented to the public through the normal coordination procedures involving public press releases and web dissemination. Minor deviations are accomplished by the Missouri River Basin Water Management through coordination directly with the affected parties.

Basin interests can anticipate continued public involvement in the water control management process and any significant water control plan or master manual revisions in the future will be processed in accordance with ER 1110-2-240 and ER 1110-2-8156.

Changed circumstances or unforeseen conditions may necessitate short-term deviations from the current water control plans. As stated above, such deviations are reviewed and approved by the Commander, NWD, in accordance with ER-1110-2-1400.

The following list the documents and resources to obtain data on reservoir properties and operating rules for the federal reservoirs in the Kanas River Basin.

- Lower Kansas River Basin Reservoir Regulation Manual, Master Manual (USACE 1966)
- Smoky Hill River Basin Lake Regulation Manual, Master Manual (USACE 1974)
- Republican River Basin Reservoir Regulation Manual, Master Manual (USACE 1977)
- Kanopolis Water Control Manual (USACE 1984a)
- Wilson Water Control Manual (USACE 1983)
- Waconda Water Control Manual (USACE 1972)
- Milford Water Control Manual (USACE 1984b)
- Tuttle Creek Water Control Manual (USACE 1973a)
- Perry Water Control Manual (USACE 1984c)
- Clinton Water Control Manual (USACE 1979)
- Harlan County Water Control Manual (USACE 1973b)
- Almena Unit (USBR 2009a)
- The Cedar Bluff Unit, Smoky Hill Division (USBR 1998)
- Glen Elder Unit, Solomon Division (USBR 2001)
- Kirwin and Webster Projects, Solomon Division (USBR 1996)
- Bostwick Division (USBR 2009b)
- The Webster Unit, Solomon Division (USBR 1995).

3.2.2.2.1 Flood Control

The lower Kansas River Basin reservoirs, augmented with the upstream reservoir system and the local protection works, are intended to provide flood protection for the urban population centers along the Kansas River, including the Kansas City population, when operated as a system. The severity of floods over rural areas is also greatly reduced, but without agricultural levees this type of impact continues to be substantial during major floods. The four lower basin reservoirs have a combined capacity of 3.45 million-acre-feet specifically allocated to flood control which is supplemented by an additional 3.25 million-acre-feet of upstream flood storage capacity in the 14 reservoirs in the Smoky Hill and Republican River basins. The flood control benefits of the Kansas River system of reservoirs extends downstream along the Missouri River. During major floods, releases from the Kansas River system flood storage capacity is coordinated with the Missouri River mainstem reservoirs upstream of Omaha, Nebraska, providing flood control benefits along the lower Missouri River.

General flood control storage and release criteria are as follows:

1. Flood control storage space is reserved for the reduction of damages caused by floods.
2. Releases of accumulated flood control waters only occur when the channel downstream can accommodate the releases without resulting in further flooding, accounting for local inflows and travel time.
3. In determining priority of releases from individual projects, consideration is given to the occupied flood control storage space in each reservoir and the potential that future basin runoff upstream of a dam will fill the flood control pool behind that dam. The process also accounts for travel times to downstream flood damage centers in such a manner that flood control benefits are maximized.
4. The seasonal hydrologic characteristics of each inflow basin are recognized in developing the plan for evacuating accumulated flood storage. When the top of the flood control pool is exceeded, water begins accumulating in the surcharge pool and mandatory releases become necessary irrespective of downstream channel space. Surcharge storage is used only in conjunction with the respective spillways to control floods in excess of project capacity and to preserve the safety of the dam and embankment from overtopping.

The flood control pool at each reservoir is divided into three zones that vary seasonally. Each reservoir has a separate designation of zones termed the Seasonal Guidelines which are referenced in Figures 3-30 to 3-32. The portions of the flood pool assigned to each zone varies seasonally to reflect the higher probability of major rainstorms in the spring. The zones are designated in order from lowest to highest as Phase I, II, and III. Phase I storage occupies the lowest portion of the flood pool and occurs most frequently. Releases made to evacuate stored water from this zone should not exceed about 60 percent of the historic downstream channel capacity. This provides a margin of safety if an unexpected storm arrives, increasing local inflows below the dam. As the reservoir fills, the chance that a future storm will fill the remaining flood control pool storage space increases, as does the dam safety risk and concerns at downstream damage centers. Therefore, it becomes more urgent to evacuate the accumulated flood storage as the pool elevation increases. As the reservoir rises into the Phase II zone, releases are made to essentially fill the downstream historic channel capacity. This means an unexpected storm will likely result in out-of-bank flows at the damage center. The Phase III zone is the upper portion of the flood pool, usually the last 10 percent of the flood pool. Phase III releases typically fill the downstream channels and have out of bank flooding. This can result in impacts to agriculture and outbuildings, but the releases are sized to not impact houses, businesses, and major infrastructure. However, new development near the river may be subject to damage. Phase I, II, and III zones are associated with maximum reservoir releases as well as maximum flows at specific downstream gages called control points. Figures 3-31 and 3-32 show these control points and associated releases.

Above Phase III, flood control operations transition to surcharge operation and the preservation of the dam and embankment is prioritized over downstream flood control. Surcharge releases are sized to be less than the maximum inflow for a given event, but releases are large and sized to pass a majority of the inflows without regard to downstream flooding.

823 *Figure 3-30. Flood Control Pool Seasonal Guidelines*

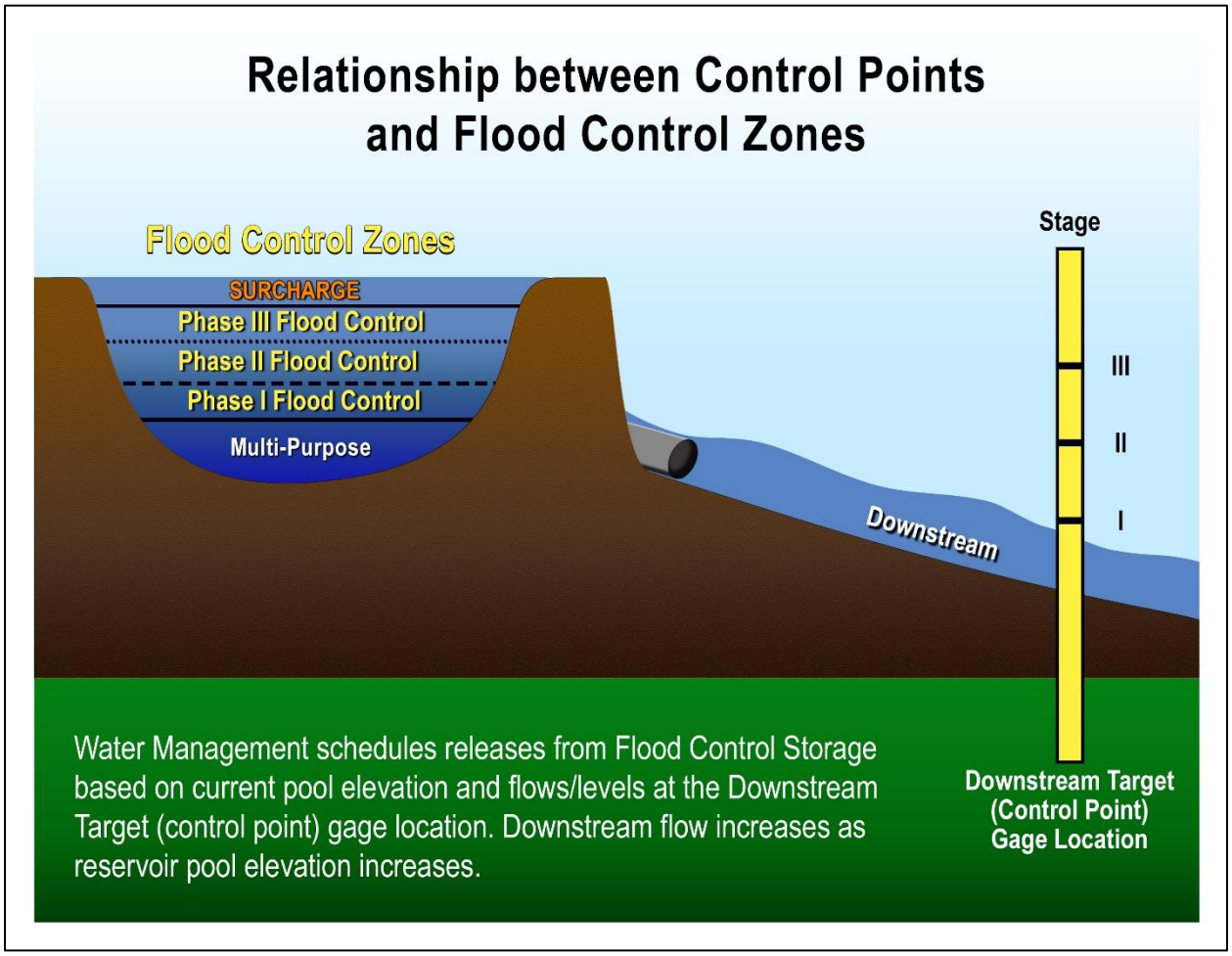

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Figure 3-31. Kansas River Basin Reservoir Flood Control Releases and Control Point Gages *(flows in cfs)*

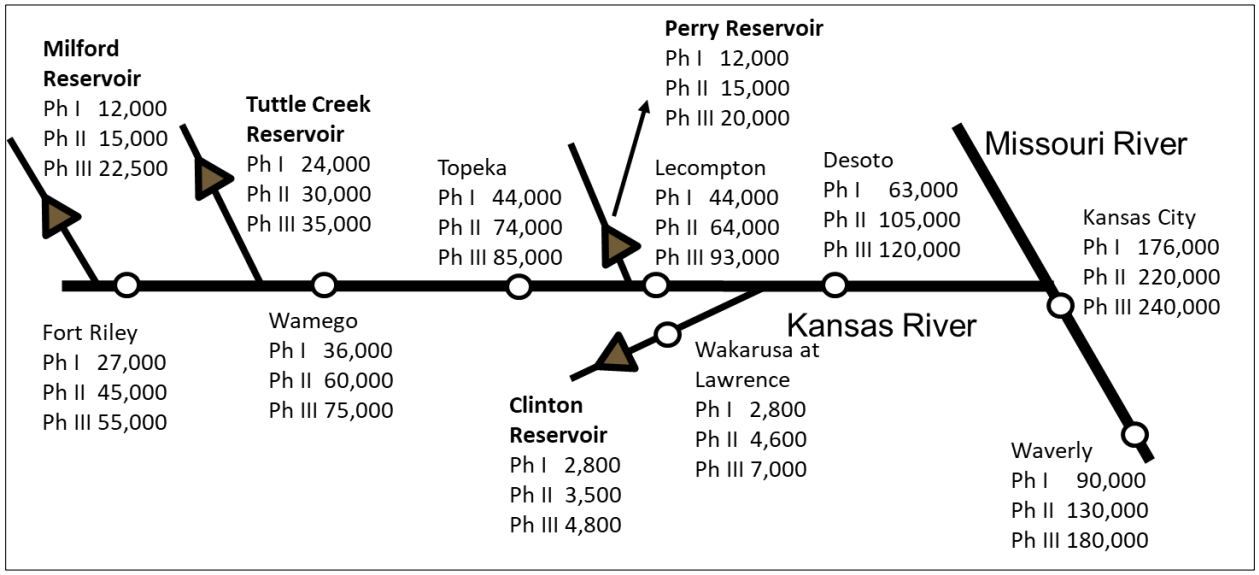
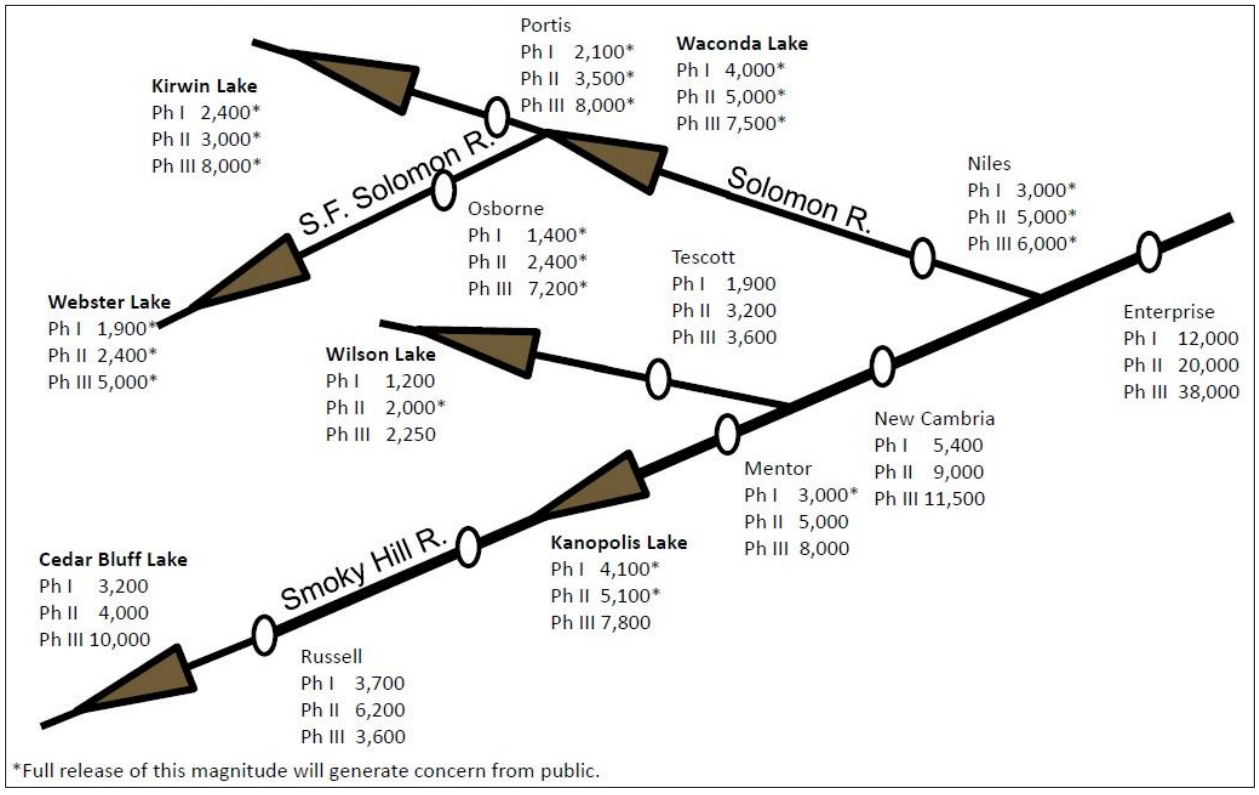


Figure 3-32. Upper Kansas River Basin Reservoir Flood Control Releases and Control Point Gages (flows in cfs)



3.2.2.2.2 Municipal, Industrial, and Rural Water Supply and Water Quality

Minimum releases from each of the USACE reservoirs in the Kansas River Basin were established during the original design and authorization process using U.S. Public Health Service guidelines for downstream water quality needs along the tributary

before it reaches the Kansas River. Minimum releases range from 7 to 100 cfs (Figures 3-33 and 3-34). Authorizations were also included at Milford, Tuttle Creek, and Perry reservoirs for low flow supplementation for water quality on the lower Kansas River at Topeka and De Soto. Table 3-26 shows the Topeka and De Soto target flows depending on drought conditions in the basin. Target flows decrease with drought which is based on the Tuttle Creek pool elevation. The seepage through the USBR dams is considered enough for water quality purposes in the upper Kansas River Basin.

Figure 3-33. Kansas River Basin Low Flow Releases and Flow Targets

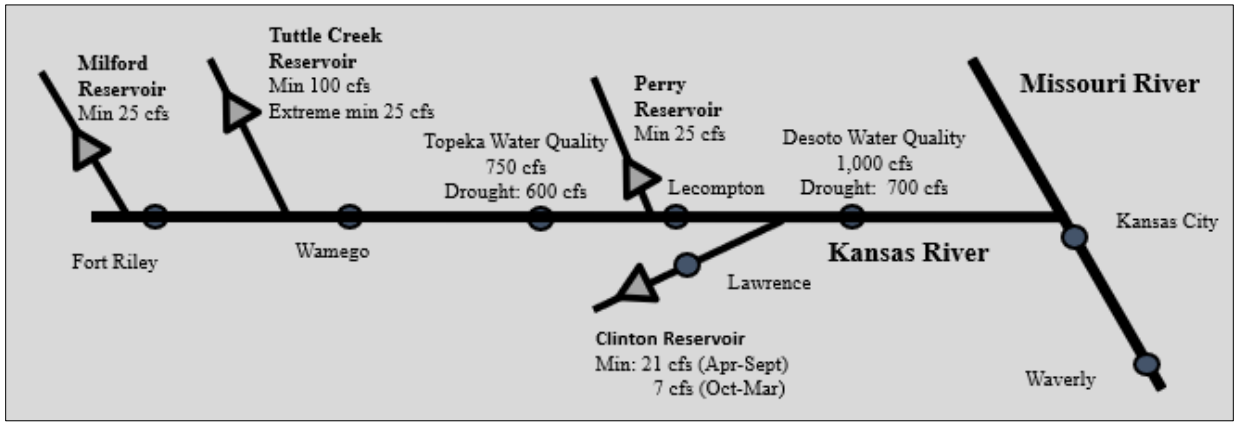
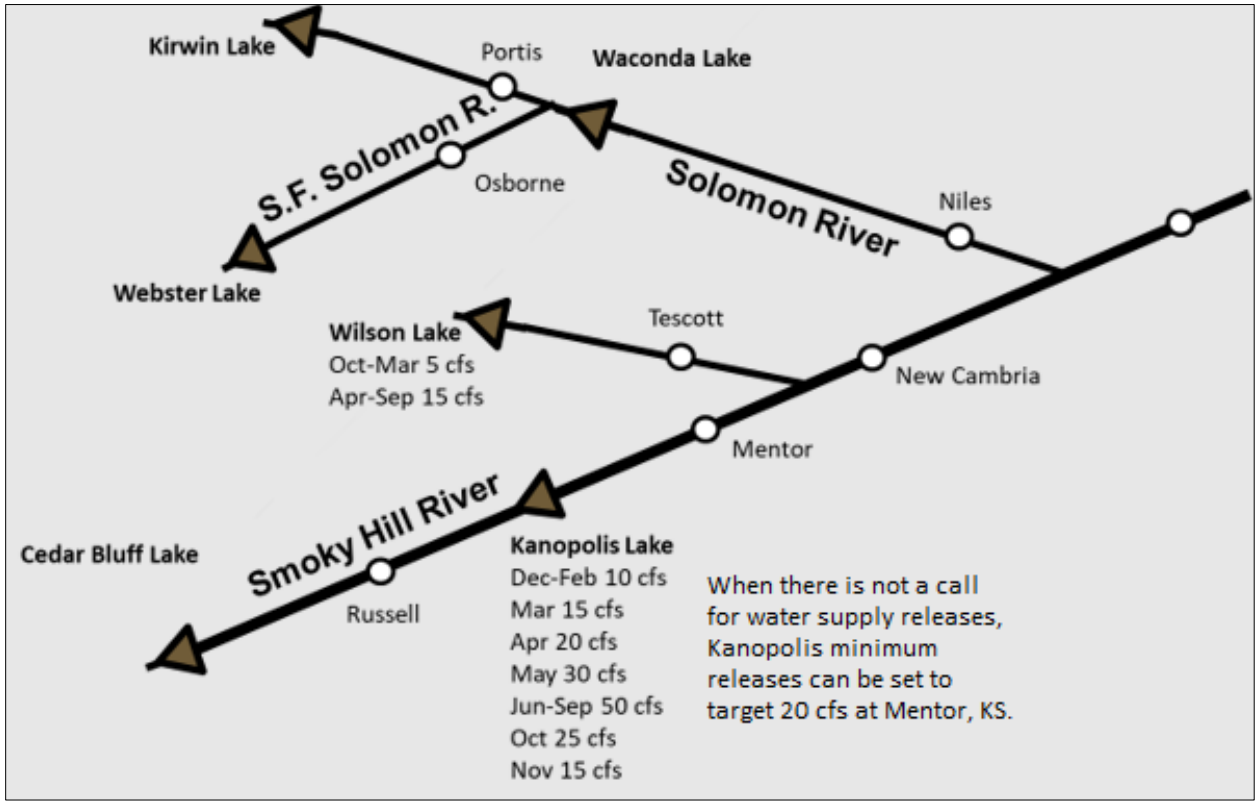


Figure 3-34. Upper Kansas River Basin Low Flow Reservoir Releases



Under the Water Supply Act of 1958 (P.L. 85-500) and amended by the Federal Water Pollution Control Act amendments of 1961 (P.L. 87-88), state and local interests were

authorized to purchase storage rights in the multipurpose pools of most Federal reservoirs. The Act also set the policy of recognizing the primary responsibility of states and local interests to develop water supplies for domestic, municipal, industrial, and other purposes. Since then, the State of Kansas has reserved or purchased most of the multipurpose storage in Milford, Tuttle Creek, Perry, and Clinton allocated for water supply purposes.

The State of Kansas initially reserved storage in Milford and Perry Reservoirs under the terms of the Federal Water Supply Act of 1958 and the State Water Resource Planning Act (K.S.A. 82a-907) passed by the 1963 Kansas Legislature. The State Water Plan was supplemented and enacted in 1965. In 1986, the Kansas legislature enacted the Water Assurance Program Act (K.S.A. 82a-1330) which assigned the KWO the authority to negotiate with the Federal government to contract for multipurpose storage in each reservoir for water supply and quality, which, in turn, would be contracted to local users. Water right holders are, thereby, provided with water during times of low flow.

The KWO assisted in the formation of the Kansas River Water Assurance District No. 1 (Assurance District) and entered into an MOU with the Department of the Army to give the state the first purchase option for multipurpose storage in Tuttle Creek and a number of other reservoirs in Kansas. The Assurance District includes municipal and industrial water rights holders along the Kansas River from Junction City, Kansas, in the west to the Kansas-Missouri border in the east. Reserve capacity in Milford and Perry previously purchased under the State Water Plan Act was then transferred to the Assurance program. Separate contracts for municipal water supplies from Clinton Reservoir are not affected by the Assurance program. The State of Kansas has now contracted for use of 101,650 acre-feet of the total 373,152 acre-feet of multipurpose storage at Milford; 50,000 acre-feet of the total 257,014 acre-feet at Tuttle Creek; 25,000 acre-feet of the total 200,004 acre-feet at Perry; and 53,520 acre-feet of the total 118,699 acre-feet available at Clinton. Portions of the remaining storage in each reservoir are reserved for sediment. Releases for low flow supplementation on the Kansas River beyond the specified minimum reservoir releases are coordinated with the KWO and through them with the Assurance District and other state offices.

3.2.2.2.3 Irrigation

Of all the USACE reservoirs in the Kansas River Basin, irrigation is an authorized use only of the Harlan County multipurpose pool. All authorized irrigation storage space in Federal reservoirs in the Kansas City District has been contracted out to irrigation districts. The USBR regulates the release of water from the contracted storage at the Harlan County multipurpose pool. Irrigation releases are not a factor in controlling flows on the mainstem Kansas River.

3.2.2.2.4 Navigation

Authorizations for Milford, Tuttle Creek, and Perry Reservoirs on Kansas River tributaries include supplemental flows for maintenance of navigation on the mainstem of the Missouri River (PL 83-780). Water from lower Kansas River Basin reservoirs of Milford, Tuttle Creek, and Perry may be used effectively to replace releases from the

mainstem reservoirs when natural gains in flow between Nebraska City and Kansas City are less than the increase in requirements for navigation, up to a maximum of 4,000 cfs.

USACE established guidelines in the WCMs for the release of water from the joint use or water quality storage space available in each of these three reservoirs. The guidelines are intended to balance the needs of the multiple purposes authorized at each reservoir. The joint use space is used for navigation and water quality supplemental flows, recreation, fish and wildlife, and sediment storage.

Tuttle Creek is the only Kansas River Basin reservoir allocated with specific navigation storage. It has 72,000 acre-feet allocated for navigation, water quality, and other purposes. Future use water supply storage at Milford and Perry reservoirs can also be utilized for navigation until all this storage is called into service by the State of Kansas. This storage is 198,350 acre-feet at Milford and 125,000 acre-feet at Perry. These storage amounts are limited and 4,000 cfs can deplete available storage in a few weeks.

Supplemental releases for navigation from Tuttle Creek, Milford, and Perry are limited each year prior to October 1 to the volume available through the first 3 feet (0.9 meters) below multipurpose. After October 1 the allowable volume increases to the first 6 feet (1.8 meters) below multipurpose. Releases for navigation supplementation originate with a requirement for water from Missouri River Basin Water Management Office and are coordinated by Kansas City District Water Management Office with the state of KWO.

3.2.2.2.5 Hydropower

There are no hydropower facilities associated with USACE projects within the Kansas River Basin and tributaries. However, the Bowersock Mill run of river hydropower facility at Lawrence, under private ownership, is kept informed of changes in Kansas City District Reservoir Project releases and forecasts of flows above and below the plant.

3.2.2.2.6 Recreation

A comprehensive master plan for recreational purposes and land management for each project in the basin has been prepared in coordination with the National Park Service, FWS, U.S. Public Health Service, KDWP, and Kansas Board of Health. Provisions have been made at each project for interior roads, parking areas, boat launching ramps, group shelters, comfort stations, drinking water supplies, and other facilities for picnicking or camping.

Optimum recreational use of the projects depends on maintaining the reservoir elevations near the multipurpose pool level, particularly for the boat ramps, marina facilities, and swim beaches. Moderate rises in the pools do not have a large impact on recreation. Some boat ramps and beaches become unusable when water levels are at 75 percent of the multipurpose pool or less. Sediment accumulation also leads to loss of access to recreational facilities in the upper portions of the multipurpose pool. Most of the recreational use occurs in the summer, but fishing and hunting access is important throughout the year.

3.2.2.2.7 Fish and Wildlife

A wide variety of fish and game species occur within the Kansas River Basin, but aquatic resources can be limited in the western parts of the basin due to long periods of little or no stream flow. In the more humid eastern parts of the basin, natural stream flows are enough to support significant populations of fish and other aquatic organisms. Some mammal, bird, and fish species provide significant recreational opportunities for anglers, hunters, and non-consumptive recreationists.

Close cooperation between the USACE Kansas City District office, project operating personnel, and KDWP has resulted in operation plans recognizing reservoir fish and wildlife management objectives. One significant feature of this cooperation is the annual development of lake level management plans (https://www.kwo.ks.gov/docs/default-source/reservoirs/rpt_llmp_wy2023_092822.pdf?sfvrsn=c62c8e14_2) for each reservoir. These plans modify the effective multipurpose pool elevation for water release guidance to principally benefit fish and wildlife on the reservoir. Those plans are reviewed and modified annually in cooperation with the state with the restriction not to exceed the lowest 5 percent of the respective flood control storage and to include some period of time at or below the multipurpose pool throughout the year.

The typical water level management plan for Kansas River reservoirs calls for a low winter level for ice control and provides additional buffer storage for large winter and spring flows. In the spring, a slow pool rise is preferred to enhance fish spawning. For the same reason, large releases are minimized to prevent fish entrainment through dams. Later in the spring and summer, the pool is usually maintained close to the multipurpose level to enhance recreation and maximize flood control benefits during the wet season. In the late summer or early fall, the pool may be lowered to enhance shoreline vegetation growth. Then, later in the fall, the pool is allowed to rise when water is available to inundate the vegetation growth and maximize waterfowl habitat and hunting access. In late December, the pool is lowered to its winter level. The individual lake level management plans are described in more detail in Section 3.10.2 Aquatic Habitat and Species.

3.2.2.3 System Limitations

Generally, long travel times from the controlling dams and the opportunities for large uncontrolled local inflows are limitations in the Kansas River Basin (https://www.usgs.gov/centers/kansas-water-science-center/science/kansas-river-time-travel-study). In general, the water travel time with bank full flows is approximately 40 to 50 miles per day. The travel time from Kanopolis, Wilson, and Waconda reservoirs to Enterprise, Kansas (Figure 3-32) is about 4 days, and, therefore, those projects are typically not operated for points below this gage. Wamego (Figure 3-31) tends to be the index gauge in the Upper Kansas River reach and only Milford and Tuttle Creek can reduce flood flows at Wamego. During moderate and high flood flows, the controlling damage point for reservoir regulation often becomes the Missouri River at Waverly (Figure 3-31), because of the restricted channel capacity on the Missouri River at that point.

The longer the travel time for flows from a reservoir to a downstream target flow point, the less chance the reservoir will be able to provide effective stage control because of

the incidence of local inflows and lengthy reaction/travel time. From Milford Reservoir to Wamego travel time is about 2 days, and from Tuttle Creek to Wamego it is about 1 day. For points within one day travel time downstream, the reservoir releases could be reduced soon enough to have a large impact on potential flood flows, although sometimes the flood flows could not be entirely eliminated. Peak local flows generally occur in the intervening local reach within one day after a storm, and the effectiveness of the reservoir decreases rapidly after one day and with the magnitude of the storm.

3.2.2.4 System Flexibility

Much of the flood control flexibility of the reservoir project system is derived from the ability to regulate each reservoir within broad bands defined by the seasonal phase diagrams (Figure 3-30). Flexibility increases when normal basin runoff occurs. The flexibility of the system becomes much more restricted as the flood control pools fill and the urgency to evacuate accumulated flood control storage increases. The flood control system flexibility is gone when the reservoir is in surcharge operations. Because the Kansas River Basin is subject to prolonged droughts, it is desired to maintain the reservoirs at multipurpose pool. This also enhances recreation opportunities and fish and wildlife habitat. While a routine operational pattern is followed, detailed plans for specific floods are not a part of the normal operating plans.

3.2.2.5 Reservoir Operations Assessment

Significant critical infrastructure including water and wastewater treatment plants, power plants, fire stations, schools, and military installation facilities are located downstream of the reservoirs. Sustaining the ability of reservoir projects (or operations) to continue to provide these risk reduction benefits for this infrastructure into the future is crucial, as there is no feasible way to replace these benefits.

An assessment of system management to identify areas of concern and to evaluate alternative improvements to the system is needed. The assessment evaluates the potential for water supply shortages, flood risk management, and minimum stream flow deficiencies, and supports additional assessments including, but not limited to, recreation impacts, in-stream water quality, and drought- and flood-related issues. Conditions that influence storage in the various pools within a reservoir affect the ability to meet releases for uses downstream (e.g., water marketing and assurance customer shortages, downstream water quality minimum release targets not met).

The existing Hydrologic Engineering Center Reservoir System Simulation (HEC-ResSim) model was updated for the study to evaluate the impacts of current operation of the lower seven flood control reservoirs in the Kansas River Basin. These seven reservoirs include Kanopolis, Wilson, Waconda, Milford, Tuttle Creek, Perry, and Clinton reservoirs. The assessment includes with navigation and without navigation release scenarios for the existing conditions and FWOP scenarios. The existing data sets were extended to cover the period of January 1, 1920, to December 31, 2019 (hereinafter described as the period of record (POR)). Updated local flows were created using the extended data set for use in the updated model simulation. The outputs of the model include a complete regulated set of flows at several key stream gage locations on the Kansas River and the pool elevations and releases for each reservoir. The existing condition simulations were used as a baseline for FWOP simulations that evaluate

changes as sediment accumulates over the next 100 years—2024 (base condition), 2049 (25-year), 2074 (50-year), 2124 (100-year). The existing condition flows were used to evaluate flood reduction measures and to develop the updated flow frequency relationships for unregulated and regulated basin conditions described in this subsection of Section 3. Simulated reservoir pool elevations and outflows were utilized for evaluation of other resources (e.g., recreation, water supply, water quality) within the basin. The model rules were set in accordance with the approved WCMs at each reservoir. Further details for the HEC-ResSim model are included in Appendix B.

To utilize the model, a complete period of analysis data set for a number of inputs was required. Data sets were collected from observed records (period of record data) and extended, filling in missing and historical data by a variety of methods. Observed records were obtained from the U.S. Geological Survey (USGS), comprising official daily streamflow records, as well as record inflow, release, and elevation data from the Corps Water Management System (CWMS) database. For the timeframe that precedes the POR database entries, the lake inflow was determined by evaluating the upstream gages using standard hydrologic methods and statistical analysis. All gage data was obtained from the USGS website; daily, period-average flow records were obtained in all cases. A ratio of flow based on a direct comparison of the drainage basin area ratios was used only occasionally due to the very large areas involved and the high variability in the amount of contribution.

There are many reasons why modeled results may not match observed. Before the dams were in place, the observed flow at the gages downstream of the dams was unregulated. After the dams were constructed, reservoir operations at times formally deviated from the water control plan (modeled rules) for specific flood control purposes approved by Missouri River Basin Water Management or for significant dam maintenance activities. Also, reservoir release decisions are made with a certain amount of forecast uncertainty relating to the flow at downstream control points when reservoir releases reach that location. As much as possible decisions are based on water on the ground forecasts, but there is uncertainty about future conditions especially where long travel time from reservoir to gage location exists (such as from Milford Reservoir to the Missouri River at Waverly, Missouri). The model downstream control point rules used incorporate elements of forecast uncertainty, but these decisions are different than in real-time operations. Additional details are included in Appendix B describing the reason why differences in observed versus modeled results may exist. Hydrologic conditions in the basin tend to result in a much lower runoff contribution from the western drainage areas. The modeling also accounted for reservoir evaporation and depletions. River depletions can have a large impact on the hydrology of the Kansas River Basin especially for low flow conditions. Additional information related to the assumptions used for reservoir evaporation and depletions is included in Appendix B.

Simulations were set up with and without navigation to help quantify the impact that navigation releases may or may not have on the water levels in the basin. The model was set up with rules to provide navigation flows from Milford, Tuttle Creek, and Perry reservoirs supporting navigation on the Missouri River. Navigation releases can target a flow of 4,000 cfs or less at the Kansas River at De Soto, Kansas. The Missouri River Master Manual specifies flow for several navigation targets including the Missouri River

at Kansas City, Missouri, which is the only target impacted by the Kansas River flows. The Kansas City navigation season is officially from March 28 to November 27 during a typical year and flows can range from the full service 41,000 cfs to the minimum service 35,000 cfs. The navigation season can be shortened by one or two months based on the July 1 system storage check for the Missouri River reservoir system storage. The Missouri River Basin Water Management can call for Kansas River navigation flow support whenever necessary. However, the main use of the Kansas River navigation storage is in dry years to balance overall regional system storage. Other times, it becomes necessary during the nesting season of endangered species of birds that take up residence either on the shores of the mainstem reservoirs above Gavins Point, South Dakota, or on the banks of the Missouri River below Gavins Point. Either circumstance prevents necessary release increases from Gavins Point Dam on the Missouri River. Navigation support is provided in a stepped approach where storage above one threshold can be utilized before October 1 and more storage can be utilized from October 1 until the end of the navigation season. Table 3-26 shows these thresholds.

Table 3-28. Navigation Release Pool Elevation Thresholds.

Navigation Releases Can Utilize Storage to a Given Elevation (feet [NGVD 29])			
Reservoir	**Milford**	**Tuttle Creek**	**Perry**
Before Oct 1	1141.4	1072	888.5
After Oct 1	1138.4	1069	885.5

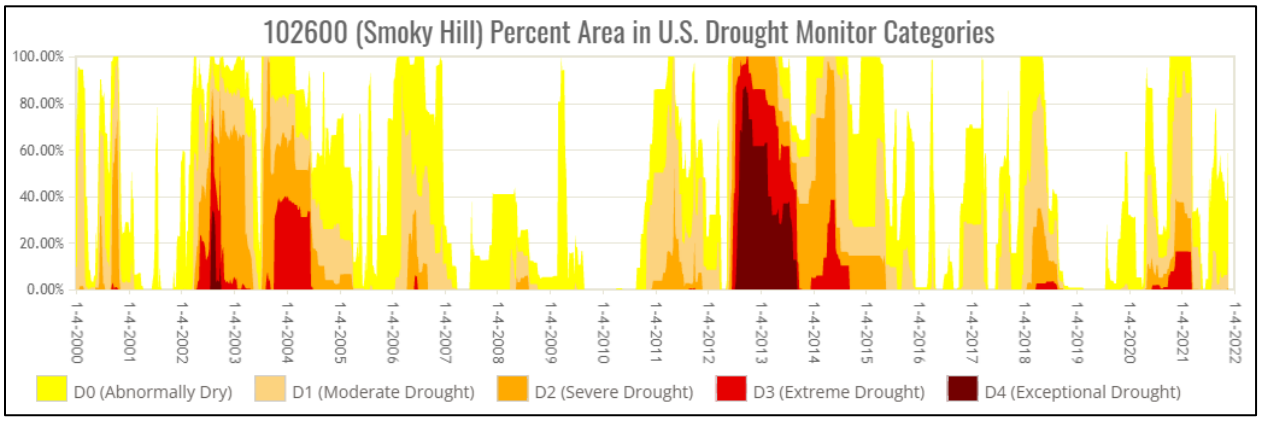
The navigation flow support scenarios resulted in navigation releases being made in approximately half of the years; however, four main time periods had multi-year reservoir drawdowns as a result of navigation releases. These time periods were 1932 to 1941, 1953 to 1957, 1988 to 1992, and 2002 to 2007. These were some of the dry periods when the Missouri River at Kansas City, Missouri, dropped below the minimum service level during the navigation season. Navigation flow support can result in significant reductions in pool elevations particularly during drought periods, but there is minimal change in the peak flows even for years when navigation releases are made. The assumptions used in the model and model results comparing with and without navigation releases are included in Appendix B.

The assessment included evaluating a recent drought that occurred in each of the sub-basins (i.e., Smoky Hill River Basin, Republican River Basin, Big Blue River Basin, and the Kansas River Basin) and annual flow volumes.

3.2.2.5.1 Smoky Hill River Basin

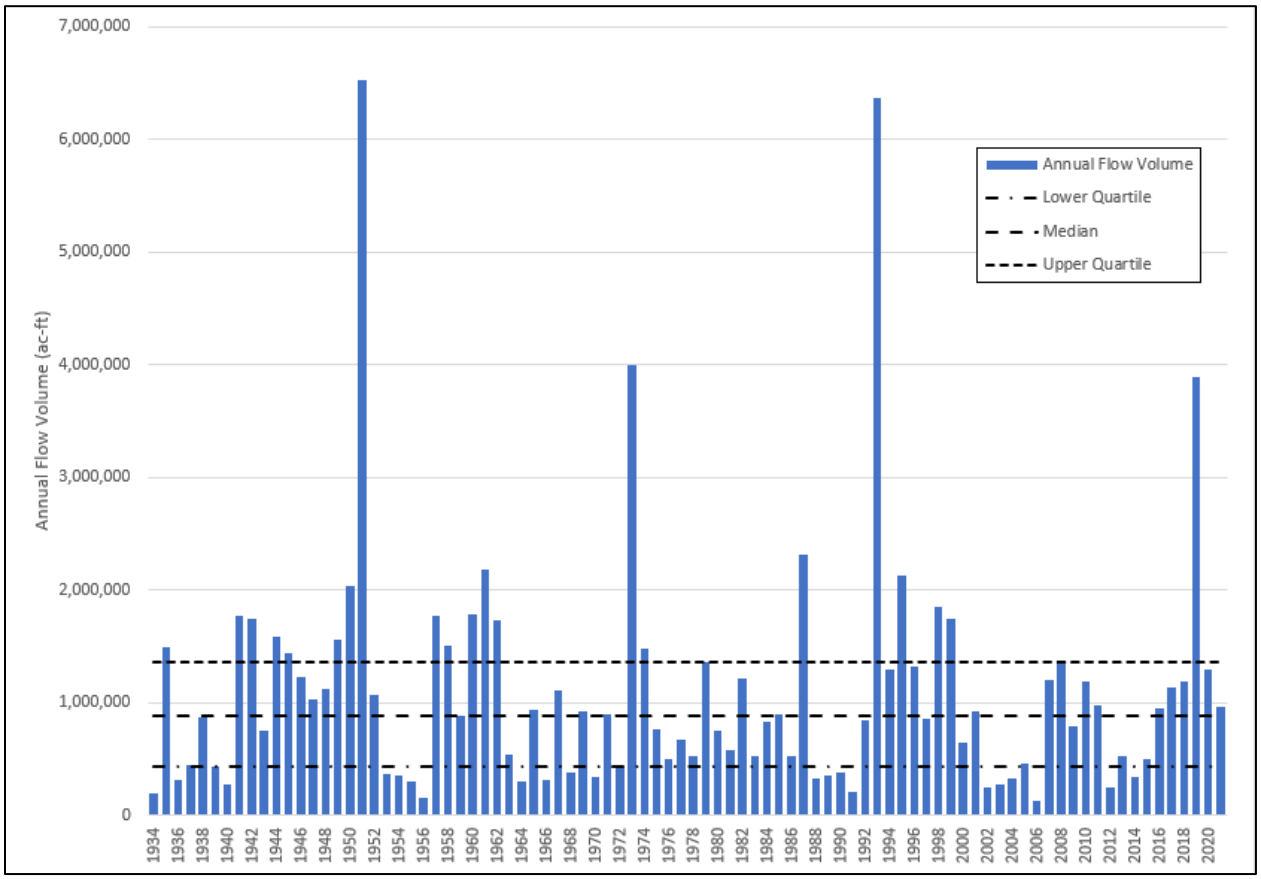
The Smoky Hill River Basin had several periods of droughts and floods. In the past 20 years, the U.S. Drought Monitor shows periods where none of the basin had any drought characterization and one period in 2012 and 2013 where much of the basin was listed as in exceptional drought (Figure 3-35).

Figure 3-35. Percent of the Smoky Hill River Basin in U.S. Drought Monitor Categories from 2000 through 2021



At the furthest downstream gage on the Smoky Hill River (Enterprise, Kansas), the long-term average flow was 1,535 cfs and the maximum flow of record was 207,000 cfs in July 1951. Drought condition flows often dropped below 100 cfs. Figure 3-36 shows annual flow volume.

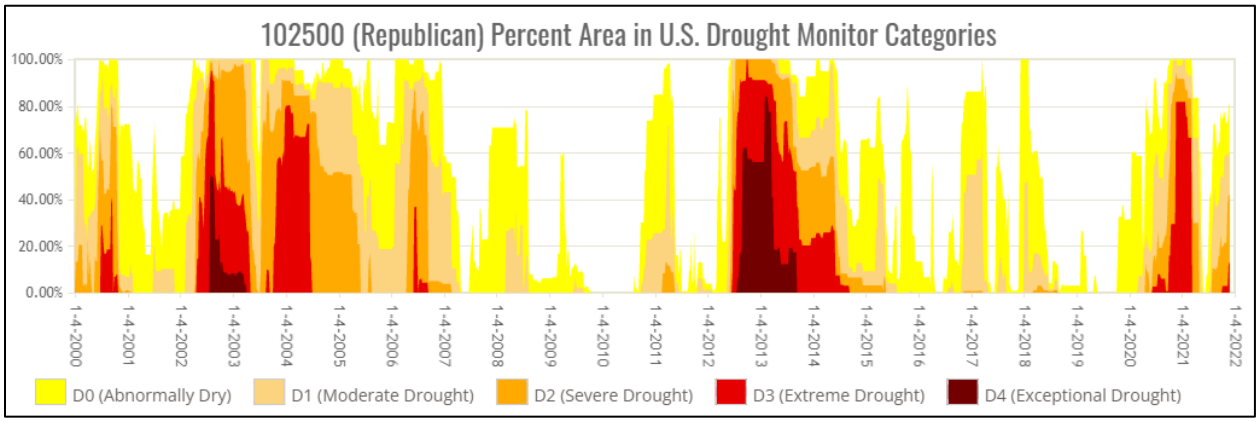
Figure 3-36 Smoky Hill River at Enterprise–Annual Flow Volume



3.2.2.5.2 Republican River Basin

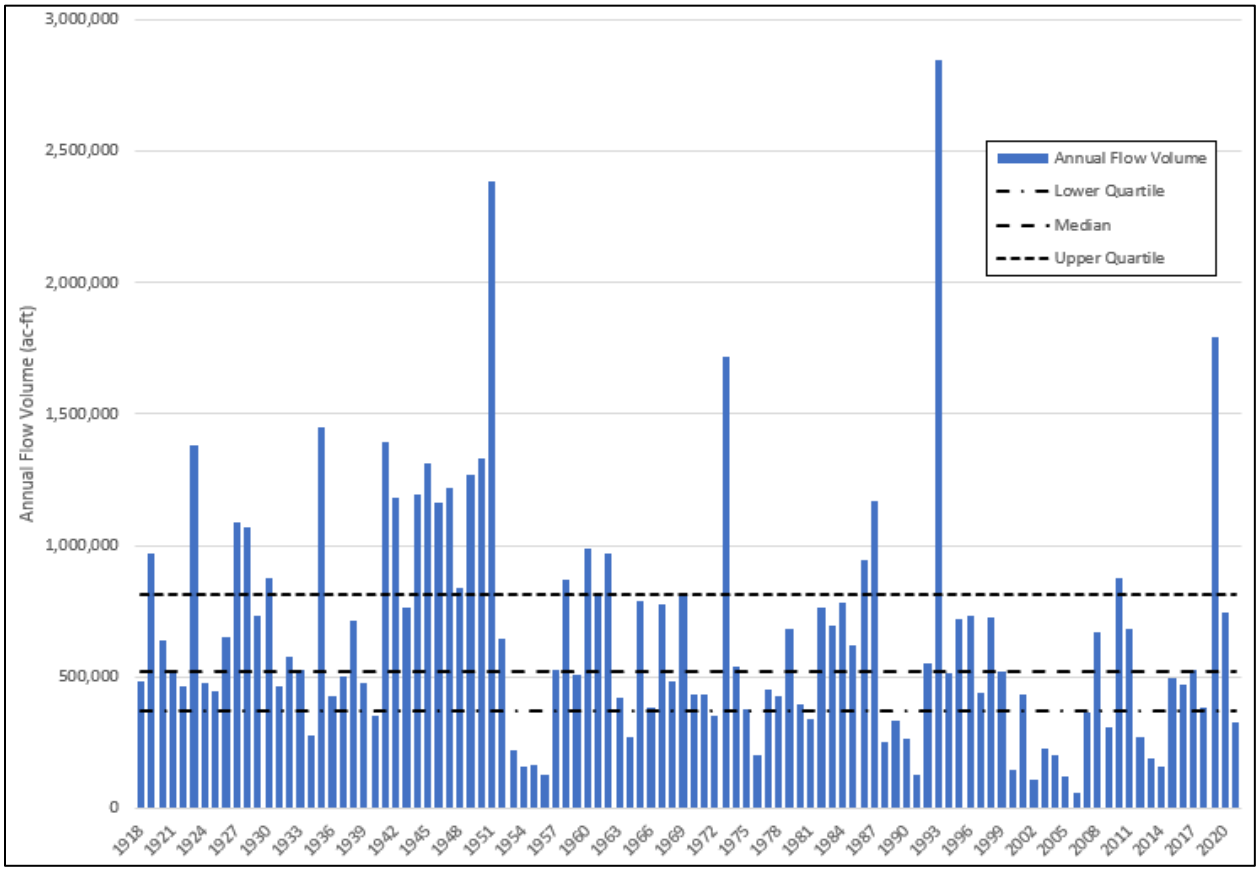
The Republican River Basin had several periods of drought and flood. In the past 20 years, the U.S. Drought Monitor shows periods where none of the basin had any drought characterization and periods in 2002 and 2012 where much of the basin was listed as in extreme or exceptional drought (Figure 3-37).

Figure 3-37. Percent of the Republican River Basin in U.S. Drought Categories from 2000 through 2021



At the furthest downstream gage on the Republican River (Clay Center, Kansas), the long-term average flow was 913 cfs and the maximum flow of record was 195,000 cfs in June 1951. Drought condition flows often dropped below 100 cfs. Figure 3-38 shows the annual flow.

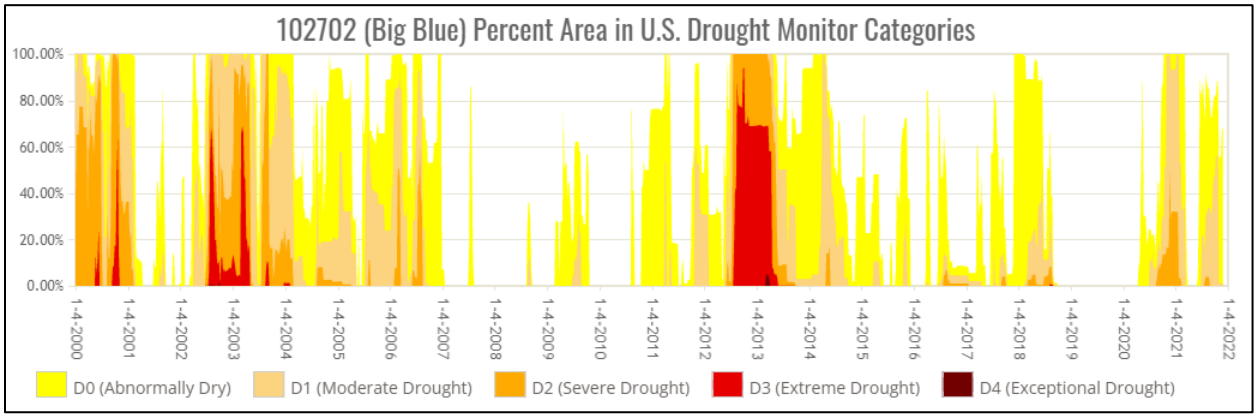
Figure 3-38. Republican River at Clay Center–Annual Flow Volume



3.2.2.5.3 Big Blue River Basin

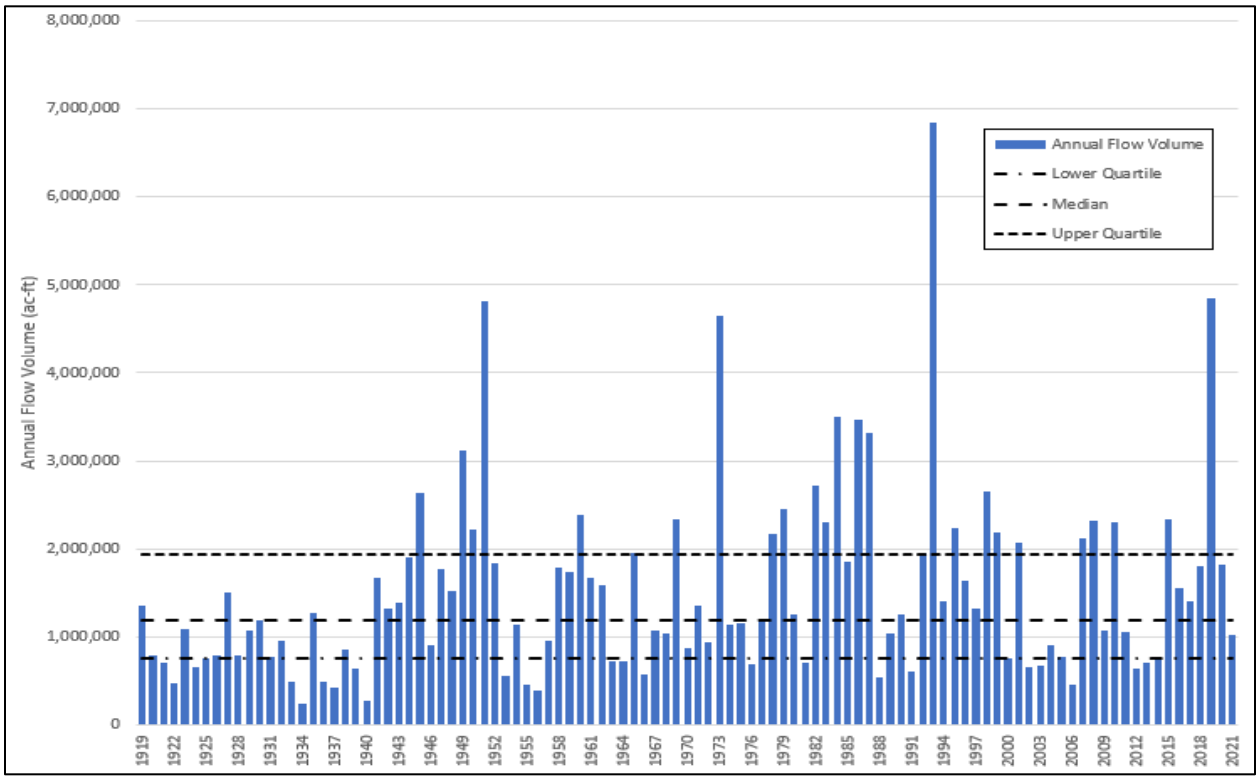
The Big Blue River Basin had several periods of drought and flood. However, it is less prone to drought than the Republican and Smoky Hill Rivers. In the past 20 years, the U.S. Drought Monitor shows periods where none of the basin had any drought characterization and some periods of extreme drought especially in the 2012 and 2013 timeframe (Figure 3-39).

Figure 3-39. Percent of the Big Blue River Basin in U.S. Drought Monitor Categories from 2000 through 2021



Using a combined record for the Big Blue River at Randolph, Kansas, which has data from 1918 to 1960 and was inundated when the Tuttle Creek pool began to fill, and the nearby Big Blue River near Manhattan, Kansas, which has data from 1950 to the present, the long-term average flow was 2,076 cfs and the maximum flow of record was 86,400 cfs in July 1951. Drought condition flows often dropped to around 200 cfs, with a minimum flow requirement of 100 cfs when possible from Tuttle Creek Reservoir. Figure 3-40 shows the annual flow volume.

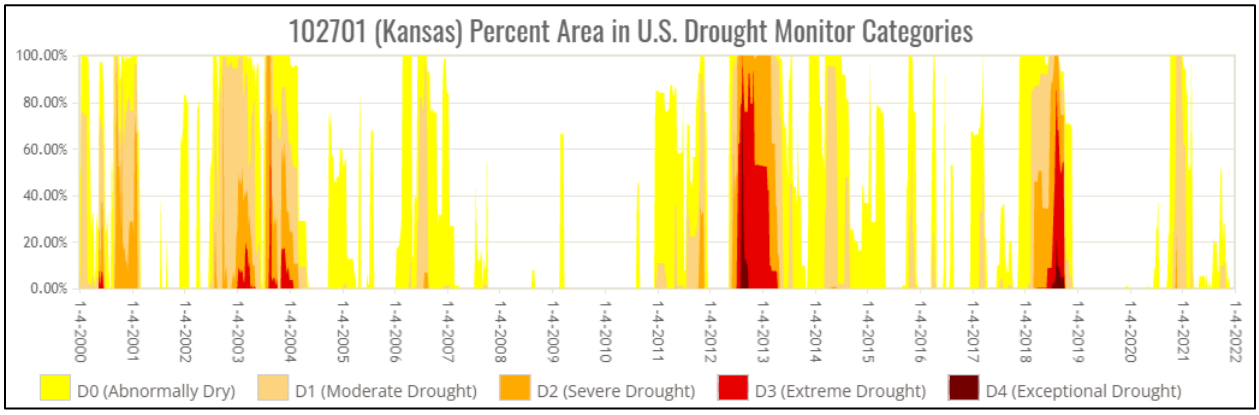
Figure 3-40. Big Blue River at Randolph (1919–1950) and Manhattan (1951 to present)–Annual Flow Volume



3.2.2.5.4 Kansas River Basin

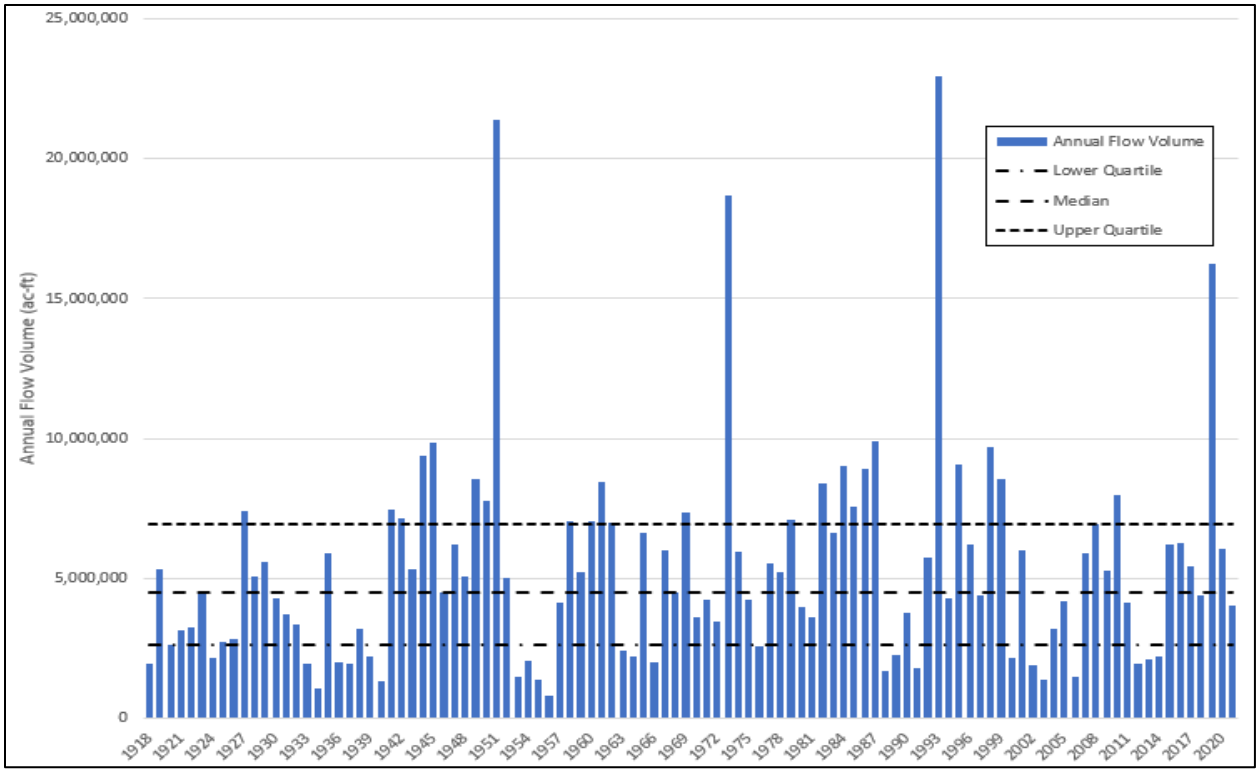
The Kansas River Basin (from the confluence of the Republican and Smoky Hill Rivers to the Missouri River) had several periods of drought and flood. However, it is less prone to drought than the Republican and Smoky Hill Rivers. In the past 20 years, the U.S. Drought Monitor shows periods where none of the basin had any drought characterization and some periods of drought especially in the 2012 and 2013 timeframe (Figure 3-41).

Figure 3-41. Percent of the Kansas River Basin in U.S. Drought Monitor Categories from 2000 through 2021



At the furthest downstream gage on the Kansas River (De Soto, Kansas), the long-term average flow was 7,351 cfs and the maximum flow of record was 486,000 cfs in July 1951. Drought condition flows often drop near the water quality target of 1,000 cfs but natural flows could drop more into the 500 cfs range. Figure 3-42 shows the annual flow volume.

Figure 3-42. Kansas River at De Soto–Annual Flow Volume



3.2.3 River Infrastructure—Levees

The existing levee system in the basin includes USACE federally constructed levees that were turned over to a local sponsor for operation and maintenance; locally constructed levees that are locally operated and maintained; and levees constructed by other federal agencies (https://levees.sec.usace.army.mil/#/levees/system/3605000127/summary). The majority of the levees in the basin are ones constructed by the USACE or those that were locally constructed.

The larger USACE federally and locally constructed levee units in the basin are described herein. Additional levees are described in Appendix H.

3.2.3.1 Armourdale Unit

The Armourdale Unit levee system (Figure 3-43) reduces the occurrence of flooding to areas of Kansas City, Kansas. The levee system includes 1.3 miles of floodwall and 5.5 miles of earthen levee along the Kansas River. The existing local levee was re-designed and reconstructed by the USACE. Shortly after construction was completed in 1951, the levee was overtopped and damaged by the 1951 flood. The USACE repaired the damage after the flood and then constructed major improvements that included raising the levee and floodwall in 1974. After construction was completed, the project was turned over to the local sponsor, the Kaw Valley Drainage District, for operation and maintenance. The USACE is currently working on raising the levee and floodwall again.

Figure 3-43. Armourdale Unit, Kansas City, Kansas



The screening level risk assessment completed for this levee in 2017 estimates the likelihood of a Kansas River flood overtopping this levee in any given year at approximately 0.2 percent, or a one chance in 500. Overtopping was identified as the primary flooding risk; however, all levees have the potential to breach prior to water flowing over the top. The USACE anticipates there being sufficient warning time to evacuate the area prior to water reaching the top of this levee. However, levee breaches prior to water reaching the top often have very short warning times.

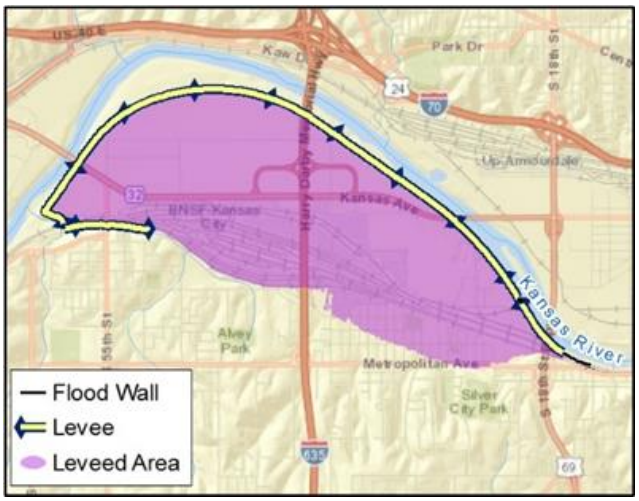
The risk assessment identified some performance concerns prior to water overtopping the levee under large flooding events. With the 2019 Kansas City Levees Project, USACE is further evaluating these issues and will be constructing improvements as needed, as well as raising the entire project. In 1993, the project was loaded to within a few feet of the top and performed as designed.

The area behind the levee features significant residential and commercial development. The 2017 screening estimates a leveed area daytime population of approximately 6,700 people and a property value of approximately $1.9B.

3.2.3.2 Argentine Unit

The Argentine Unit levee system (Figure 3-43) reduces the occurrence of flooding in Kansas City, Kansas. The levee system includes five- and one-half miles of earthen levee and a quarter of a mile of concrete floodwall along the Kansas River. The levee was designed and constructed by USACE in 1955. After construction the levee was turned over to the local sponsor, the Kaw Valley Drainage District, for operation and maintenance. USACE raised the levee and floodwall in 1978 and is currently working on another raise.

Figure 3-43. Argentine Unit, Kansas City, Kansas



The Argentine Unit-Kansas City, Kansas protects structures, people, and various critical infrastructure (e.g., school, fire station, industrial facilities). A 2017 screening level risk assessment completed on this levee estimates the likelihood of a Kansas River flood overtopping this levee in any given year at approximately 0.2 percent, or a one chance in 500. Overtopping was identified as the primary flooding risk; however, all levees have the potential to breach prior to water flowing over the top. USACE anticipates there being sufficient warning time to evacuate the area prior to water reaching the top of this levee. However, levee breaches prior to water reaching the top often have very short warning times.

The risk assessment identified some performance concerns prior to water overtopping the levee under large flooding events. With the 2019 Kansas City Levees Project, USACE is further evaluating these issues and will be constructing improvements as needed, as well as raising the entire project. The levee was loaded to about half its height in 1993 and performed as designed.

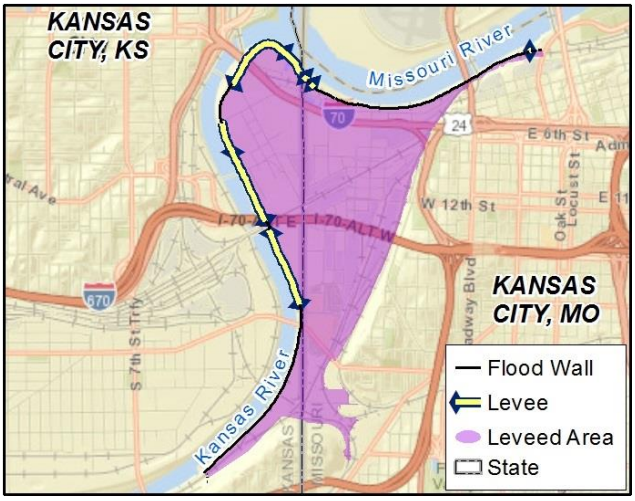
The area behind the levee includes residential, commercial, and industrial development. The 2017 screening estimates a leveed area daytime population of approximately 10,700 and the property value to be approximately $3.5B. Flooding of the leveed area could lead to flood depths of 6 to 15 feet resulting in high consequences due to the high population at risk and property values behind the levee.

3.2.3.3 CID, Central Industrial District

The Central Industrial District (CID), levee system (Figure 3-44) reduces the occurrence of flooding in Kansas City, Kansas and Kansas City, Missouri. This system includes 3 miles of concrete floodwall and 1.9 miles of earthen levee along the Kansas and Missouri Rivers. USACE designed and constructed the levee in 1950. After construction was completed, it was turned over to the local sponsors for operation and maintenance. Because this levee system is owned and operated by two separate sponsors, it contains two segments. Kanas City, Missouri owns and operates the CID-MO segment on the Missouri side and Kaw Valley Drainage District owns and operated the CID-KS segment on the Kansas side. Because the system was overtopped by the 1951 Kansas River flood, USACE raised the levee and floodwall in the 1970s. USACE is currently raising a portion of the system again due to the higher-than-expected loading in 1993.

A 2017 screening level risk assessment completed on this levee identified overtopping as the primary levee risk, however all levees have the potential to breach prior to water flowing over the top and warning times for evacuation are often much shorter when the levee breaches prior to water reaching the top. The screening level risk assessment estimates the likelihood of a Kansas River flood overtopping this levee in any given year at 0.2 percent (one chance in 500). USACE anticipates there being sufficient warning time to evacuate the area prior to water reaching the top of this levee. However, levee breaches prior to water reaching the top often have very short warning times.

Figure 3-44. CID, Central Industrial District, Kansas City, Kansas, and Kansas City, Missouri



The risk assessment identifies some performance concerns prior to water overtopping the levee under large flooding events. With the 2019 Kansas City Levees Project, USACE is further evaluating these issues and will be constructing improvements as needed, which includes raising sections of the project. The levee was loaded nearly to the top in 1993 and it performed as designed.

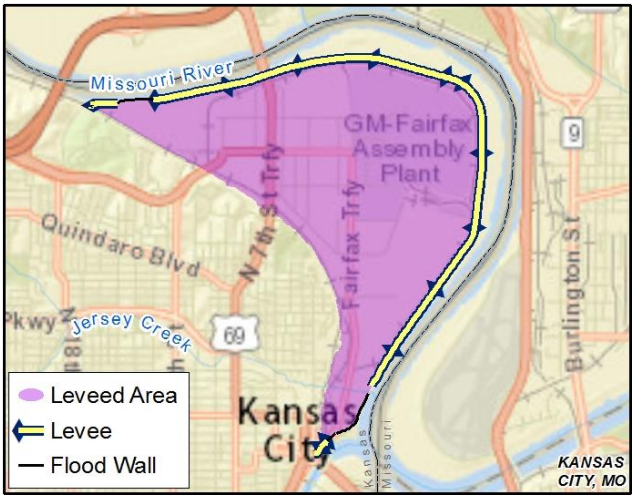
The area behind the levee features significant residential, industrial, and commercial development. The 2017 USACE levee screening risk assessment estimates the leveed area population to be 7,500 and the estimated property value to be almost $1B. More recent information estimates the leveed population to be 15,000 and the estimated property value to be approximately $3.3B. The levee faced major flooding in 1951 when

the levee was overtopped and in 1993 when river levels reached within a few feet of the levee top. Flooding of the leveed area could lead to flood depths of 6 to 15 feet resulting in high consequences due to the high population at risk and property values behind the levee.

3.2.3.4 Fairfax-Jersey Creek

The Fairfax-Jersey Creek levee system (Figure 3-45) reduces the occurrence of flooding for approximately 2,102 acres of both the Missouri River floodplain and Kansas River floodplain in Kansas City, Kansas. The levee system includes 1.2 miles of floodwall and 4.9 miles of earthen levee along the Kansas and Missouri Rivers. In 1940, USACE redesigned and reconstructed an existing levee. It was turned over to the levee sponsors after initial construction but then USACE raised and modified the levee after large flooding events in 1951 and 1952. After those modifications, the project was again turned over to the local sponsors to operate and maintain. Because this levee system is owned and operated by two separate sponsors, it contains two segments. The Upper Fairfax segment (also called Fairfax-Jersey Creek) is owned and operated by the Fairfax Drainage District and Lower Fairfax is owned and operated by the Kaw Valley Drainage District.

Figure 3-45. Fairfax-Jersey Creek, Kansas City, Kansas



A 2019 USACE screening level risk assessment on this levee identifies overtopping as the most likely flooding scenario. The likelihood of a flood overtopping this levee in any given year has been estimated at 0.1 percent, or a one chance in 1,000. However, all levees have the potential to breach prior to water reaching the top. A levee breach prior to overtopping often has short warning times.

This levee is well maintained and is highly monitored during flood events. The levee and floodwall performed as designed in 1993 when river levels reached within a few feet of the top, but the project has not been largely loaded since then. Although the 2019 risk assessment identifies overtopping as the most likely flooding scenario, it also identifies two issues that could affect the levee's performance prior to being overtopped. The levee was constructed with a buried seepage collector system within the levee embankment. The condition of the buried pipe that is now over 70 years old is unknown and there is no access for inspection. The sponsor installed some inspection manholes and is working with USACE on the others needed to fully inspect the entire system. There is also a portion of I-wall on the Lower Fairfax segment. While no issues with this I-wall have ever been reported, I-walls create uncertainty in performance because they

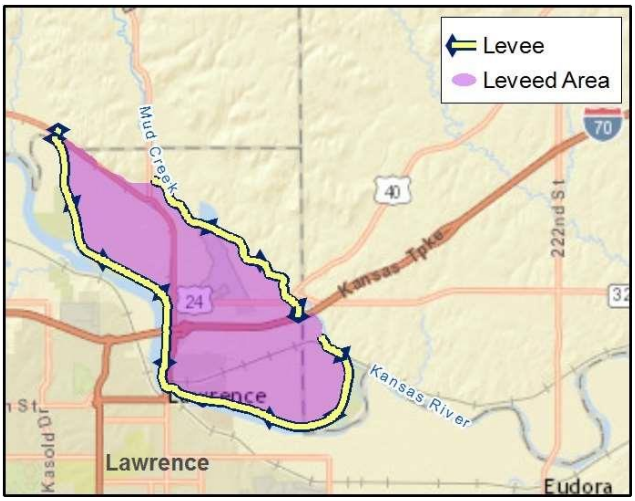
have been linked to problems with levees in other areas of the country. Both of these issues will be closely monitored during large loading events.

The area behind the levee is predominantly industrial and commercial. The 2019 risk assessment estimates a leveed area population of almost 10,000 people and a property value of approximately $3–5B. Flooding of the leveed area could lead to flood depths of 6 to 15 feet deep resulting in life loss and economic consequences. There would be significant warning time prior to water reaching the top of this levee, however levee breaches prior to water reaching the top often have very short warning times.

3.2.3.5 Lawrence Unit

The Lawrence Unit levee system (Figure 3-46) reduces the occurrence of flooding in area of Lawrence, Kansas. The levee system includes 15.8 miles of earthen levee along the Kansas River and Mud Creek. USACE designed and constructed the levee and turned it over to the local sponsor, the City of Lawrence, Kansas. Construction was fully completed in 1979. The local sponsor now owns, operates, and maintains the levee system.

Figure 3-46. Lawrence Unit, Lawrence, Kansas



The 2012 USACE levee screening risk assessment estimates the likelihood of a Kansas River flood overtopping this levee in any given year at approximately 0.5 percent, or a 1 chance in 200. The screening identified overtopping as the most likely risk driver, but also noted that a small depression landward of the levee and uninspected pipes can increase the likelihood of soil movement under the levee when the water is high. This could lead to poor performance before the levee is overtopped. The levee sponsor has an active O&M program. The levee is regularly inspected and is closely monitored during flood events, and material movement is often seen early and can be managed with effective flood fighting techniques. Both the City of Lawrence and USACE have available flood fighting supplies.

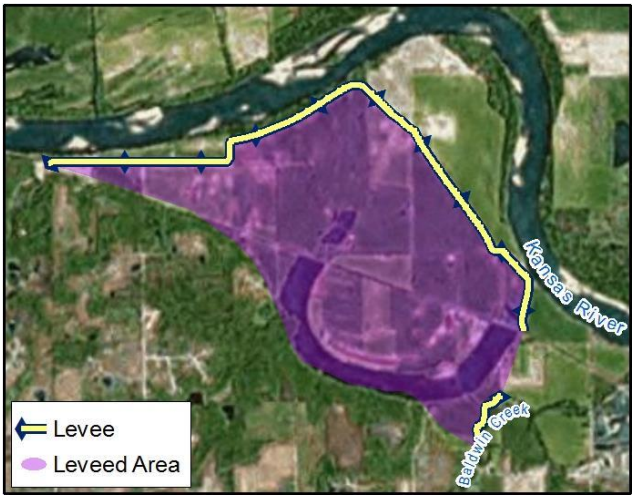
The levee faced record flooding in 1993 when Kansas River levels reached approximately half of the levee height. The levee performed as designed in 1993 with no major concerns, however it has never been fully loaded.

The area behind the levee features significant residential, commercial, and high production agricultural development. The 2012 risk assessment estimates a leveed area population of approximately 2,215, a property value of approximately $336M, and an agricultural product value of approximately $27M. Flooding of the leveed area from overtopping or from a breach prior to overtopping could lead to flood depths up to 6 feet in populated areas and deeper than 6 feet in undeveloped areas. These depths could result in life loss and economic consequences. It is expected that there would be significant warning time before water would overtop the levee, however warning times for a levee breach prior to overtopping are often short.

3.2.3.6 Douglas County Drainage District

The Douglas County Drainage District levee system (Figure 3-47) reduces flood risk to approximately 1,400 acres of Kansas River floodplain in Douglas County, County. The levee system includes four miles of earthen levee along the Kansas River. USACE did not design or construct this levee. The levee is owned, operated, and maintained by the Douglas County Drainage District.

Figure 3-47. Douglas County Drainage District, Douglas County, Kansas



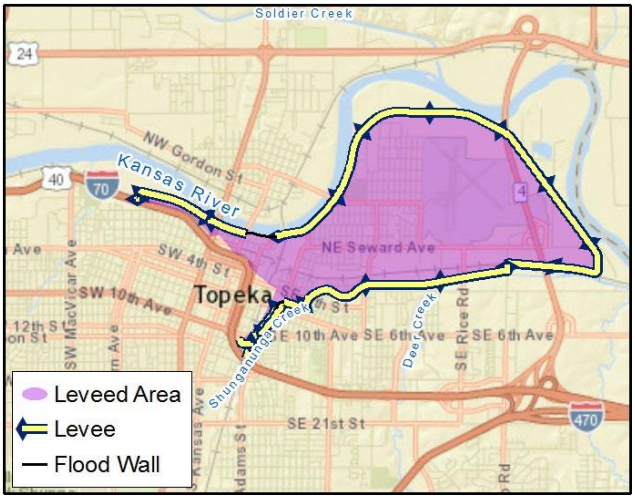
The 2015 USACE screening level risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 2 percent, or a 1 chance in 50. This levee was overtopped in 1993. In this flood, water flowing over the top of the levee eroded the slope and led to a breach of the levee. Although the screening finds overtopping to be the highest risk driver, it also notes that the condition of the drainage pipes in the levee is unknown because they have not been video inspected. Aging or damaged pipes increase the chance of a levee breach prior to water reaching the top. Warning times for breaches that happen prior to the water reaching the top of the levee are often shorter than for water overtopping the levee. Flooding of the levee could lead to flood depths of 6 to 15 feet resulting in life loss and economic consequences.

The area behind the levee is predominantly agricultural with some residential and farm structures. The 2015 USACE screening level risk assessment estimated a leveed area population of less than 10, a property value of approximately $4.9M, and an agricultural product value of approximately $555,000.

3.2.3.7 South Topeka Oakland Unit

The South Topeka Oakland levee system (Figure 3-48) reduces the occurrence of flooding for approximately 3,581 acres of Kansas River floodplain in Topeka, Kansas. The levee system includes 0.4 miles of floodwall and 11.8 miles of earthen levee along the Kansas River and Shunganunga Creek. USACE designed and constructed the levee. Construction on the levee began in 1938 and was completed after several modifications in 1971. After construction, USACE turned over the operation and maintenance to the local sponsor, the City of Topeka, Kansas.

Figure 3-48. South Topeka Oakland Unit, Topeka, Kansas



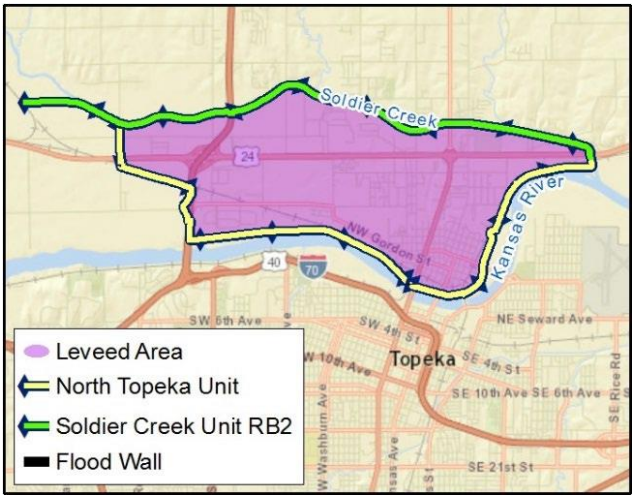
A 2013 USACE screening level risk assessment on this levee system identifies overtopping as the main risk driver. The likelihood of a flood overtopping this levee in any given year has been estimated as 0.5 percent, or a one chance in 200. Flooding of the levee could lead to flood depths of at least 16 feet resulting in life loss and economic consequences. It is expected that there would be significant warning time before the Kansas River would overtop the levee, however warning times for a levee breach prior to overtopping are often short. The levee faced record flooding in 1951 and 1993 when river levels reached over half the levee height.

The area behind the levee features significant residential, commercial, and local governmental development. The 2013 risk assessment estimates a leveed area population of approximately 12,275 people and property values of approximately $1B.

3.2.3.8 North Topeka Unit—Soldier Creek RB2

The North Topeka-Soldier Creek RB2 levee system (Figure 3-49) reduces the occurrence of flooding for approximately 6,061 acres of Kansas River floodplain in Topeka, Kansas. USACE designed and constructed the levee projects in 1957 (Soldier Creek RB2) and 1965 (North Topeka). USACE then turned over the operation and maintenance of the levees to local sponsors: the City of Topeka and the North Topeka Drainage District. The City of Topeka owns and operated the North Topeka levee segment, which consists of 10.2 miles of earthen levee along the Kansas River. The North Topeka Drainage District owns and operates the Soldier Creek Right Bank 2 segment, which consists of 8.3 miles of earthen levee along Soldier Creek.

Figure 3-49. North Topeka Unit-Soldier Creek RB2, Topeka, Kansas



A 2015 USACE screening level risk assessment completed on this levee system identifies overtopping as the main risk driver. The likelihood of flood waters from the Kansas River or from Soldier Creek overtopping this levee in any given year are estimated at 0.5 percent (one chance in 200). Flooding of the levee from the Kansas River is expected to flood depths of at least 14 feet, which could result in life loss and significant economic consequences. It is expected that there would be significant warning time before the Kansas River would overtop the levee, however, warning times for a levee breach prior to overtopping or for a Soldier Creek overtopping event are often short.

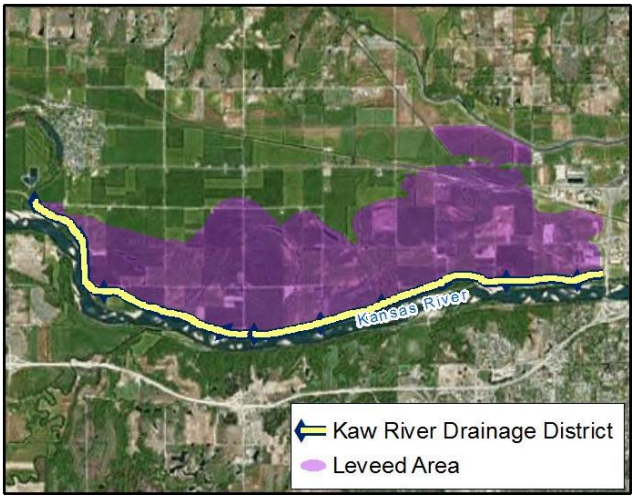
The levee faced record flooding in 1993 on the North Topeka section when river levels reached nearly half the levee height. In 2005, water from Soldier Creek overtopped the Soldier Creek RE2 levee segment upstream of Highway 75. The levee performed as designed until it was overtopped and once overtopped it did not breach. Only a portion of the leveed area was flooded and depths were relatively shallow.

The area behind the levee features residential, commercial, and local government development. The 2015 risk assessment estimates the leveed area population at approximately 6,687 people and the property value at approximately $1.65B.

3.2.3.9 Kaw River Drainage District

The Kaw River Drainage District levee system (Figure 3-50) reduces flood risk to approximately 5,500 acres of Kansas River floodplain in Shawnee County, Kansas. The levee system includes 8.3 miles of earthen levee along the Kansas River. This levee was not designed or constructed by USACE. The levee is operated and maintained by the Douglas County Kaw Drainage District.

Figure 3-50. Kaw Valley Drainage District, Shawnee County, Kansas



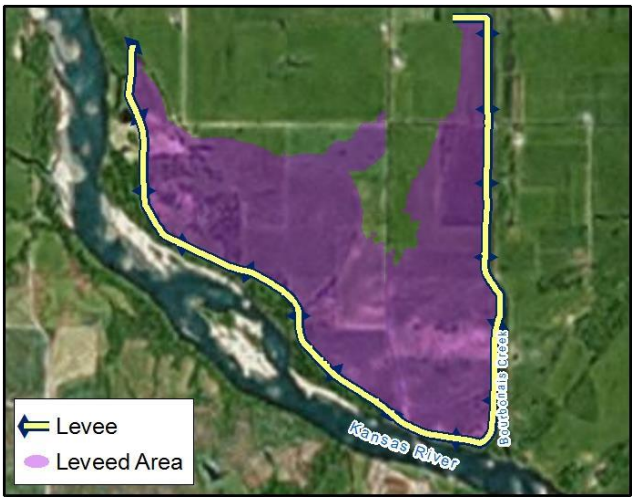
The 2015 USACE screening level risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 1 percent, or a 1 chance in 100. The highest loading this levee has experienced was in 1993 when the levee was loaded up to 75 percent of its height. The screening found overtopping to be the highest risk driver, however, warning times for breaches that happen prior to water reaching the top of the levee are often shorter than for water overtopping the levee. Flooding depths are expected to be mainly shallow on the western side of the leveed area, but some areas on the eastern side, including much of the residential area, could see water depths of at least 15 feet.

The area behind the levee is predominantly agricultural with a small residential area of the eastern side. The 2015 USACE screening level risk assessment estimates the leveed area population to be approximately 158 people, the property value to be approximately $31.4M, and the crop value to be approximately $2.1M.

3.2.3.10 Tri-County Drainage District No. 1 Section 1

The Tri-County Drainage District No. 1, Section 1 levee system (Figure 3-51) reduces flood risk to approximately 1,700 acres of predominantly farmland in the Kansas counties of Shawnee, Pottawatomie, and Wabaunsee. The levee system includes 5 miles of earthen levee along the Kansas River. USACE did not design or construct this levee. The levee is owned, operated, and maintained by the Tri-County Drainage District.

Figure 3-51. Tri-County Drainage District No.1, Section 1, Shawnee, Pottawatomie, and Wabaunsee counties, Kansas



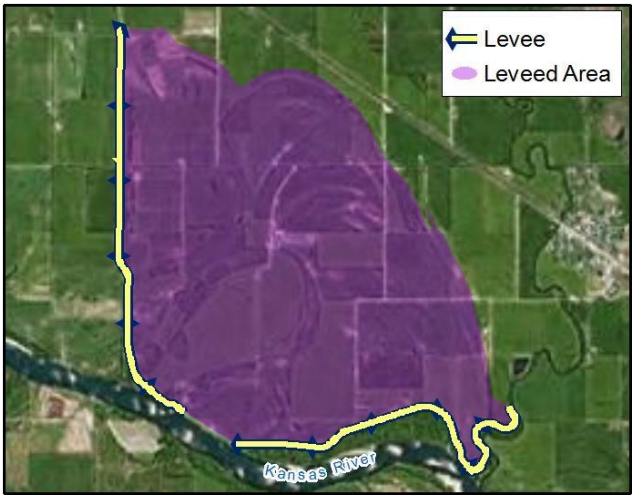
The 2015 USACE screening level risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 2 percent, or a 1 chance in 50. This levee was overtopped in 1993. In this flood, water flowing over the top of the levee eroded the slope and led to a breach of the levee. Although the screening found overtopping to be the highest risk driver, it also notes that the condition of drainage pipes in the levee is unknown because they have not been video inspected. Aging or damaged pipes increase the chance of a levee breaching prior to water reaching the top. Warning times for breaches that happen prior to water reaching the top of the levee are often shorter than for water overtopping the levee. Flooding of the levee could lead to flood depths of 6 to 15 feet resulting in life loss and economic consequences.

The area behind the levee is predominantly agriculture. As of 2015, there were no structures or population in the leveed area. In the 2015 screening, USACE estimates approximately $811,000 in agricultural product grown in the leveed area.

3.2.3.11 Tri-County Drainage District No. 1 Section 2

The Tri-County Drainage District No. 1, Section 2 levee system (Figure 3-52) reduces flood risk to approximately 4,000 acres of predominantly farmland in the Kansas counties of Shawnee and Wabaunsee. The levee system includes 9.7 miles of earthen levee along the Kansas River. USACE did not design or construct this levee. The levee is owned, operated, and maintained by the Tri-County Drainage District.

Figure 3-52. Tri-County Drainage District No. 1, Section 2,Shawnee and Wabaunsee counties, Kansas



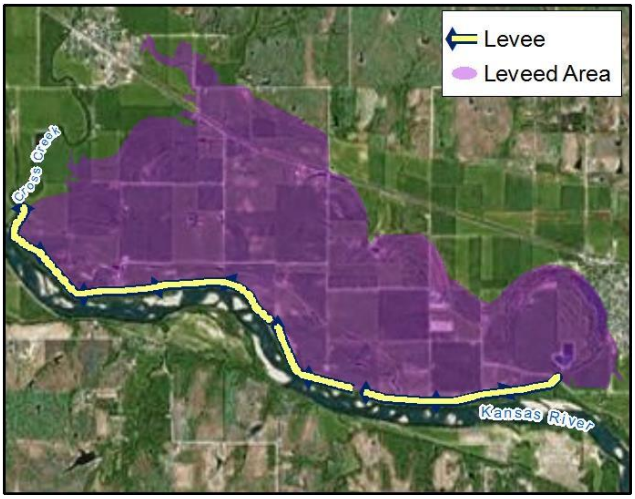
The 2015 USACE screening level risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 1 percent or a 1 chance in 100. This levee was loaded up to 75 percent of its height in the flood of 1993 and has not been loaded greater than that since then. Although the screening found overtopping to be the highest risk driver, it also notes that the condition of drainage pipes in the levee is unknown because they have not been video inspected. Aging or damaged pipes increase the chance of a levee breaching prior to water reaching the top. Warning times for breaches that happen prior to water reaching the top of the levee are often shorter than for water overtopping the levee. Flooding of the levee could lead to flood depths of 6 to 15 feet resulting in life loss and economic consequences.

The area behind the levee is predominantly agriculture with some residential and farm structures. The 2015 USACE screening level risk assessment estimates the leveed area population at approximately 49 people, the property value at approximately $5.3M, and the agricultural product value at approximately $2.0M.

3.2.3.12 Tri-County Drainage District No. 1 Section 3

The Tri-County Drainage District No. 1, Section 3 levee system (Figure 3-53) reduces flood risk to approximately 5,400 acres of predominantly farmland in Shawnee County, Kansas. The levee system includes approximately 7 miles of earthen levee along the Kansas River. USACE did not design or construct the levee. The levee is owned, operated, and maintained by the Tri-County Drainage District.

Figure 3-53. Tri-County Drainage District No. 1, Section 3, Shawnee County, Kansas



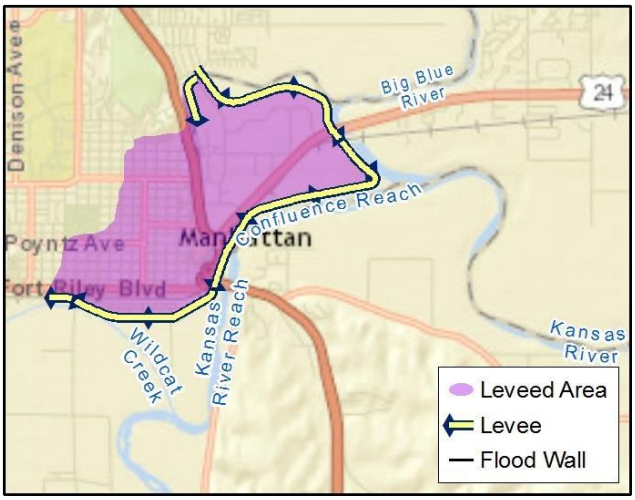
The 2015 USACE screening level risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 2 percent, or a 1 chance in 50. This levee was loaded up to 75 percent of its height in the flood of 1993 and has not been loaded greater than that since then. Although the screening found overtopping to be the highest risk driver, it also noted that the condition of drainage pipes in the levee is unknown because they have not been video inspected. Aging or damaged pipes increase the chance of a levee breaching prior to water reaching the top. Warning times for breaches that happen prior to water reaching the top of the levee are often shorter than for water overtopping the levee. Flooding of the levee could lead to flood depths up to 15 feet resulting in life loss and economic consequences.

The area behind the levee is predominantly agriculture with some residential and farm structures. The 2015 USACE screening estimates the leveed area population to be approximately 59 people, the property value to be approximately $11.1M, and the agricultural product value to be approximately $3.1M.

3.2.3.13 Manhattan Unit

The Manhattan Levee Unit levee system (Figure 3-54) reduces the occurrence of flooding in Manhattan, Kansas. The levee system includes approximately 5.4 miles of earthen levee along the Kansas River, Big Blue River, and Wildcat Creek. USACE designed and constructed the levee in 1963 and then turned it over to the local sponsor, the City of Manhattan, for operations and maintenance. The local sponsor now owns, operates, and maintains the levee system.

Figure 3-54. Manhattan Unit, Manhattan, Kansas



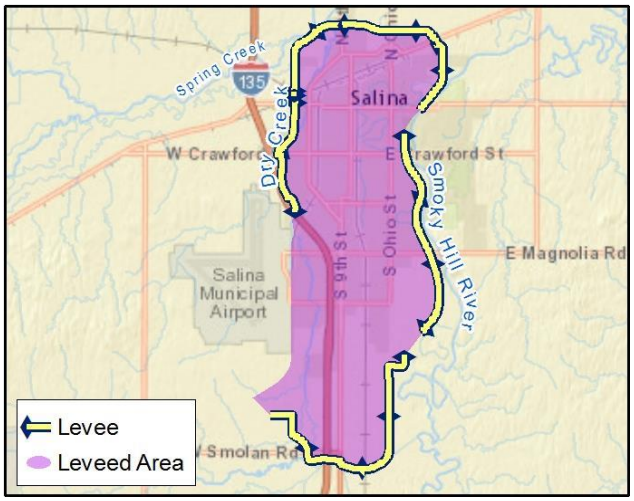
The 2017 USACE levee screening risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 0.5 percent, or a 1 chance in 200. Although it found water overtopping the levee to be the most likely scenario, the risk assessment also identifies a performance concern with levee under-seepage due to the foundation conditions beneath the levee and observed seepage during the 1993 flood. The levee faced record flood levels in 1993 when Big Blue River levels loaded over 75 percent of the levee height. A study done after the 1993 flood found that seepage of water under the levee is a concern when the river is almost at the top of the levee. Seepage of water under the levee can move foundation material that can lead to a breach of the levee before water reaches the top. A USACE project was authorized and funded in 2018 to raise portions of the levee and address the seepage concern. This project is currently under construction. The levee is regularly inspected and is closely monitored during flood events. Material movement is often seen early and can be managed with effective flood fighting techniques. Both the City of Manhattan, Kansas, and USACE have available flood fighting supplies.

The area behind the levee features significant residential, commercial, and local government development. The 2017 risk assessment estimates the leveed area population at just over 10,000 and the property values at $1.3B. Flooding of the leveed area could lead to flood depths up to 15 feet resulting in large consequences due to the high population at risk and property values behind the levee. It is expected that there would be sufficient warning time before water would overtop the levee, however warning times for a levee breach prior to overtopping are often short.

3.2.3.14 Salina, KS FPP

The Salina, KS FPP levee system (Figure 3-55) reduces the risk of flood damage in Salina, Kansas. Before 1930, 4.7 miles of levee had been constructed with local funds along the east side of Dry Creek, southwest of Crawford Street. Approximately 3.6 miles of this levee were incorporated in the Federal Project in 1961, the USACE designed and constructed more than 18 miles of levee along the Smoky Hill River, Mulberry Creek, Saline River, and Dry Creek. USACE turned over the levee to the local sponsor, the City of Salina, Kansas, for operations and maintenance, bringing the total levee maintained by the city to approximately 21 miles. The local sponsor now owns, operates, and maintains the levee system.

Figure 3-55. Salina, KS FPP, Salina, Kansas



The 2017 USACE levee screening risk assessment estimates the likelihood of a flood overtopping this levee in any given year at approximately 0.2 percent, or a 1 in 500 chance. The 2017 risk assessment identifies overtopping, either from Mulberry Creek or the Smoky Hill River, as the most likely flooding scenario.

Flooding of the leveed area from overtopping or from a breach prior to overtopping could lead to flood depths of at least 8 feet in some populated areas. Because there are many rivers surrounding the city, water depths and flooded areas will vary depending on the source of the flooding. Floods on Mulberry Creek are flashier and would have a limited impacted area. Floods on the Smoky Hill River would have the largest impacts due to the large volumes of water possible. In 2018, officials from the city, county, and USACE held a tabletop exercise with numerous other participants to improve emergency preparedness, evacuation planning, and community awareness.

This levee system almost surrounds the city of Salina. The area behind the levee features significant residential, commercial, and local government development. The 2017 risk assessment estimates the leveed area population to be approximately 44,676 people and the property value at approximately $10B. The levee faced record flooding in 2007 when river levels on Mulberry Creek were less than 2 feet from the top of the levee. In 2019, river levels on Mulberry Creek were less than 3 feet from the top of the levee.

3.2.4 Hydrological Processes

There are many tributaries contributing to the Kansas River mainstem. Table 3-27 summarizes the origin, length, and basin area of the various tributaries. Figure 2-1 is a detailed map showing the predominant streams in the Kansas River Basin.

Table 3-29. Kansas River Tributaries

Tributary	Origin	Length	Basin Area
Kansas River	KS	148 mi (238 km)	60,114 mi^2 (155,695 km^2)
Republican River	NE	453 mi (729 km)	24,900 mi^2 (64,491 km^2)
White Rock Creek	KS	74 mi (119 km)	358 mi^2 (930 km^2)
Smoky Hill River	CO	575 mi (925 km)	19,260 mi^2 (49,883 km^2)
Big Blue River	NE	575 mi (925 km)	2,330 mi^2 (6,000 km^2)
Delaware River	KS	359 mi (578 km)	9,600 mi^2 (25,000 km^2)
Wakarusa River	KS	94 mi (151 km)	1,117 mi^2 (2,890 km^2)
Solomon River	KS	80.5 mi (130 km)	367 mi^2 (950 km^2)
North Fork Solomon	KS	184 mi (296 km)	6,835 mi^2 (17,703 km^2)
South Fork Solomon	KS	287 mi (462 km)	1,367 mi^2 (3,540 km^2)
Saline River	KS	292 mi (470 km)	1,150 mi^2 (3,000 km^2)
Prairie Dog Creek	KS	397 mi (639 km)	3,419 mi^2 (8,855 km^2)

The Kansas River Basin exhibits great variation in natural stream flows. Annual and daily discharges for any given location vary through a wide range, and considerably different discharges result from similar conditions at different locations. Severe drought periods frequently follow a flood. The entire Kansas River Basin is subject to severe flooding at infrequent intervals, erratically interspersed by less severe floods of varying magnitudes.

Channel capacities vary from 4,000 cfs immediately below Wilson Lake Dam to 16,700 cfs at Enterprise, Kansas, on the Smoky Hill River. Channel capacities of the Kansas River mainstem become progressively larger from Junction City, Kansas, to the mouth, varying from 40,000 cfs to 119,000 cfs. Relatively large areas exist in the western portion of the basin that contribute little to no surface runoff to the Kansas River mainstem flows, while most of the runoff in the eastern portion of the basin contributes surface runoff to the Kansas River mainstem flows (USACE 1966). Wide river valleys with relatively small sinuous channels are predominant, and these characteristics are more exaggerated in some areas such as on the main stems of the Solomon, Smoky Hill, and Saline rivers.

Old oxbows are present in various stages of reclamation along the Kansas River and provide potential opportunities to create wetland and aquatic habitat that is currently lacking.

The Republican River is a meandering sand bed stream with a typically wide and shallow channel. The floodplain varies from 1 to 3 miles in width and is generally composed of level to gently sloping benches. Along the mainstem of the Republican

River below Harlan County Dam, there are numerous diversions and canals which divert water for irrigation and other uses. There are two diversion sites in Nebraska, which are overseen by the USBR, including the Franklin Pump Canal and the Superior-Courtland Diversion Dam. The Superior-Courtland Diversion Dam diverts water into the Superior Canal on the north and the Courtland Canal on the south. The Franklin Pump Canal and the Superior Canal are operated by the Nebraska Division of the Bostwick Irrigation District and typically divert water June through September, with peak diversion occurring in July.

The Smoky Hill River below Kanopolis Lake Dam is a meandering channel through a wide valley of moderately deep soils. The river ranges from 120 to 250 feet wide near Salina, Kansas. Old oxbows are in various stages of reclamation, but active bank erosion is evident on nearly every bend of the river.

The Solomon River below Glen Elder Dam varies in width from 100 to 200 feet. The river flows 184 miles from Glen Elder Dam before joining the Smoky Hill River immediately south of Solomon, Kansas. The Solomon River is a meandering channel with an abundance of sand bars, formed by the confluence of the North Fork Solomon River and the South Fork Solomon River at Waconda Lake (Glen Elder Reservoir), which was impounded in January 1969.

The Saline River below Wilson Reservoir Dam is a meandering channel that varies in width from 75 to 200 feet. The Saline River is sluggish and unnavigable with no major tributaries and has a riverbed of sand and mud. The Saline River joins the Smoky Hill River just east of Salina, Kansas.

The Big Blue River downstream from Tuttle Creek Lake Dam varies in width from 200 to 300 feet. The channel is generally well armored with sand, gravel, and stones for several miles below the Rocky Ford Dam, an abandoned privately-owned run-of-the-river hydroelectric plant which is now owned by KDWP. The channel has a long history of caving banks due to the erosion of sand strata which are found near the bottom at numerous locations.

The Delaware River below Perry Lake Dam ranges from 50 to 100 feet in width, except in the Kansas River floodplain where it has widened to approximately 300 feet. Channel depths vary greatly. Channelization of the Delaware River above Highway 24 occurred in 1960.

Seven smaller tributaries enter the Kansas River downstream of Junction City, Kansas. These tributary channels are generally steeper and proportionately smaller, but otherwise have many of the characteristics of the Kansas River channel.

3.2.5 Hydrology/Hydraulics/Flood Risk-Life Safety Assessment

This section describes that assessments conducted to assess hydrology, hydraulics, and flood risk including an assessment of life safety in the Basin.

3.2.5.1 Hydrology

With recent extreme hydrologic events, a flow frequency analysis of the Kansas River and its tributaries was conducted to provide a better understanding of current flood risk and allow for better informed floodplain and flood risk management decisions. The

results of the flow frequency study help to improve understanding of potential changes in the Kansas River floodplain including current risk and help facilitate better floodplain management by local, state, and Federal agencies. The information can also be used by USACE, FEMA, the NRCS, state and local communities, and others to assess changes in risk from previous flow frequency and duration values, and can be used to inform new flood studies, floodway/floodplain analyses, levee system adequacy, and stage frequency updates along the Kansas River.

The flow frequency analysis provides an update using the most recent period of record for all gages establishing a new baseline for future assessments. Systematic streamflow records for the flow frequency analysis were available from the USGS for the Kansas River and tributary gages listed in Table 3-28. The USACE Kansas City District Water Management Section produced the unregulated daily flow data for the five mainstem Kansas River gages (Fort Riley, Wamego, Topeka, Lecompton, and De Soto) and the four tributary gages downstream of USACE dams (Republican River at Junction City, Big Blue River at Manhattan, Delaware River at Perry, and Wakarusa River at Lawrence) for the regulation period. USACE Kansas City District Water Management Section produced the regulated data for the five mainstem Kansas River gages and the four tributary gages using ResSim software. Development of the regulated period of record flows is documented in Appendix B. USGS records list several historic floods for the stream gages of interest. Figure 3-56 provides a map of the flow frequency analysis study area.

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Table 3-30. U.S. Geological Survey Streamflow Data

USGS Gage ID	Stream	Location	Drainage Area (square miles)	USGS Peak Streamflow Record	Historic Floods (USGS Water Year)	Regulation Start Year (USGS)
Mainstem Kansas River						
06879100	Kansas River	Fort Riley	44,870	1918–1951[a], 1964–2019	1903, 1915	1948
06887500	Kansas River	Wamego	55,280	1902–1903, 1914–2019	1908	1948
06889000	Kansas River	Topeka	56,720	1902–2019	1869, 1877, 1885, 1889, 1897	1948
06891000	Kansas River	Lecompton	58,400	1891–1904, 1929–2019	1908, 1915, 1919	1948
06892350	Kansas River	De Soto	59,756	1917-2019[b]	1903	1948
Kansas River Tributaries below Dams						
06857100	Republican River	Junction City	24,900	1895–1905[c], 1951–2019	1915, 1935	1953, 1957
06887000	Big Blue River	Manhattan	9,640	1918–1960[d], 1955–2019	1903 (stage only), 1951	1960
06890900	Delaware River	Perry	1,141	1922–1968[e], 1969–2019	1865, 1903, 1904, 1908, 1915	1970
06891500	Wakarusa River	Lawrence	425	1930–1972, 1981–2019	1921, 1929	1981

[a]Data 1918–1951 obtained from Ogden USGS gage (06879500)
[b]Data 1917–1973 obtained from Bonner Springs USGS gage (06892500)
[c]Data for 1895–1905, 1951–1963, and 1915, 1935 historic floods taken from Milford, Kansas, USGS gage (06857000).
[d]Data for 1918–1954 (except 1951 flood) taken from Randolph, Kansas, USGS gage (06886000).
eData for 1922–1967 taken from Valley Falls, Kansas, USGS gage (06890500). Peak flow for 1968 taken from Arrington, Kansas (USGS 06890400).

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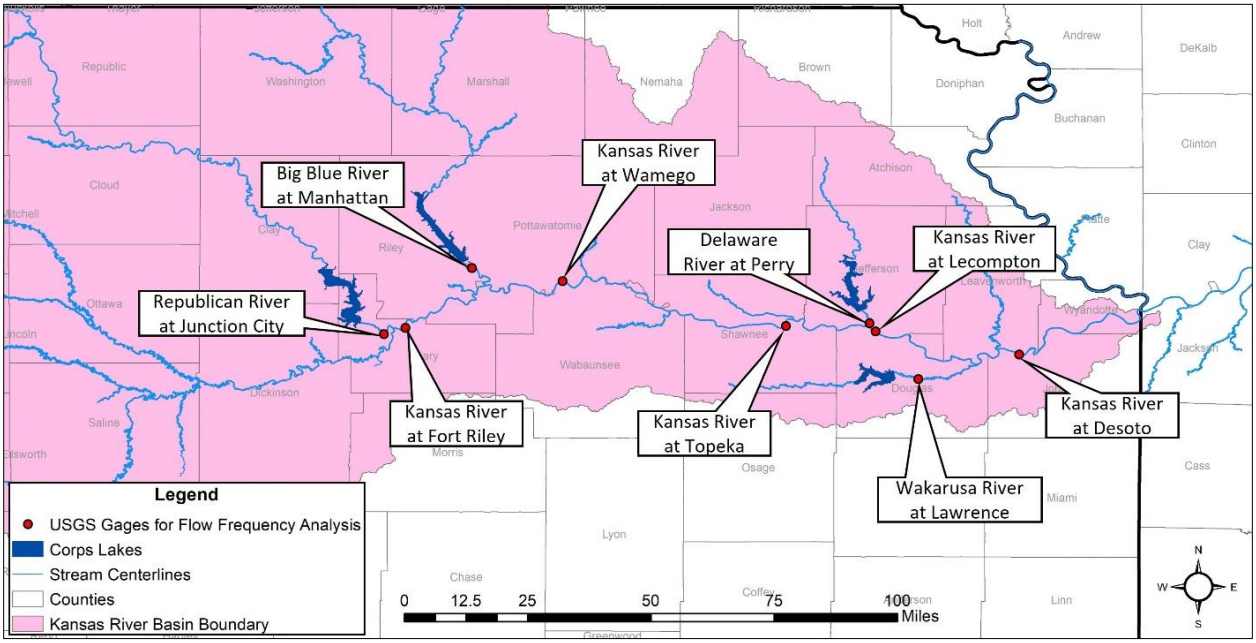
Figure 3-56. Map of Flow Frequency Analysis Study Area



Tables 3-29 and 3-30 show the regulated frequency flows for each of the five mainstem Kansas River gages (Fort Riley, Wamego, Topeka, Lecompton, and De Soto) and the four tributary gages downstream of USACE dams (Republican River at Junction City, Big Blue River at Manhattan, Delaware River at Perry, and Wakarusa River at Lawrence). Further details are provided in Appendix C.

Table 3-31. Existing Conditions Regulated Frequency Flows for the Mainstem Gages

Annual Exceedance Probability (percent)	De Soto	Lecompton	Topeka	Wamego	Fort Riley
0.2	359,000	363,000	394,000	376,000	282,000
0.5	275,000	274,000	275,000	239,000	182,000
1	224,000	219,000	209,000	170,000	129,000
2	181,000	172,000	159,000	121,000	91,300
5	134,000	123,000	109,000	77,200	57,400
10	104,000	92,500	80,400	54,400	40,100
20	78,500	67,600	57,700	37,800	27,800
50	47,800	40,600	33,400	22,000	16,500

Table 3-32. Existing Conditions Regulated Frequency Flows for the Tributary Gages

Annual Exceedance Probability (percent)	Lawrence	Perry	Manhattan	Junction City
0.2	12,700	34,100	102,000	66,100
0.5	10,700	27,700	77,400	43,800
1	9,330	23,600	62,400	32,700
2	8,110	19,900	50,100	24,600
5	6,640	15,600	36,800	16,800
10	5,590	12,700	28,600	12,500
20	4,580	10,000	21,700	9,090
50	3,130	6,680	14,000	5,540

The new hydrology flow frequency curves developed as part of the study support other floodplain evaluation and delineation programs. The data could be used to improve the quality and accuracy of flood hazard data and mapping available to local communities.

This data could accomplish:

- Providing updated technical information about flood risks that can help communities comply with state and local code requirements.
- Providing detailed aerial photographs and topographical data for many Kansas River Basin communities for use by local governments.
- Updating hydrologic and hydraulic (H&H) models (acceptable to FEMA and USACE) that can be made available for use by state and local governments.
- Providing more detailed and current flood risk information to inform the development of local land use plans and emergency preparedness plans.

In general, continued urban expansion can be expected to increase both peak flows and runoff volumes; these factors will have the largest effect on occurrences of storm events with a greater than the four percent annual chance exceedance events.

As previously described in Section 3.1, Climate and Precipitation, increased temperatures due to climate change may also alter precipitation and runoff patterns. The combination of earlier snowmelt and shifts from snowfall to rainfall seem likely to increase flood peak flows and flood volumes, which is likely to affect associated flood risk.

3.2.5.2 Hydraulics

An existing CWMS hydraulic model was modified to estimate flood inundation resulting from the flow frequency results. Three probability events were selected for modeling: the 0.2 percent AEP flood event, the 1 percent AEP flood event, and the 10 percent AEP flood event. These events were chosen because historical flood events occurred along the Kansas River that approximately reflect these probability flows (1951 event=0.2 percent AEP flood event; 1993 event=1 percent AEP flood event; and 2019 event=10 percent AEP flood event). Model plans were created to produce flood

inundations for the new frequency flows. The model plans created to run target flows from the flow frequency analysis and produce inundation maps include:

- 0.2 percent Mainstem Kansas River (Top of Reach to Topeka)
- 0.2 percent Mainstem Kansas River (Lecompton to Missouri River Confluence)
- 0.2 percent Big Blue River
- 0.2 percent Delaware River
- 0.2 percent Wakarusa River
- 1 percent Mainstem Kansas River
- 1 percent Big Blue River
- 1 percent Delaware River
- 1 percent Wakarusa River
- 10 percent Mainstem Kansas River
- 10 percent Big Blue River
- 10 percent Delaware River
- 10 percent Wakarusa River.

The inundation mapping for each plan is based on the target flow for the reach of interest and the base observed flows for all other reaches. Documentation of the hydraulic analysis is included Appendix C.

3.2.5.3 Flood Risk/Life Safety

Flooding in urban areas can cause serious health and safety problems for the affected population. The most obvious threat to health and safety is the danger of drowning in flood waters. Swiftly flowing flood waters can easily overcome even good swimmers. If flooding occurs suddenly, people may become trapped in their homes and drown. Additionally, when people attempt to drive through flood waters, their vehicles can be swept away in as little as two feet of water.

In the Kansas River Basin, the risk of a large flood is seasonal. The majority of rainfall occurs in the March through August rainy season, making the area most vulnerable to spring and summer floods.

Another risk during a flood is local water systems becoming contaminated, either through the loss of power to a public water supply or if private wells are flooded. Sources of contamination could include animal and human waste, dead and decaying animals, or chemicals accidentally released during flooding. Liquified petroleum gas tanks and underground storage tanks can break away from their supports and float in flood waters, causing hazards from their released contents. Resulting water supply contamination can lead to a number of waterborne illnesses.

Buildings damaged by flooding can also become contaminated with mold and fungi if they do not dry out quickly enough. These molds and fungi can pose serious health risks. Additionally, food exposed to floodwaters or stored without refrigeration during extended losses of power during flooding could also lead to food-borne illnesses.

Floods can damage fire protection systems, delay response times of emergency responders, and disrupt water distribution systems. All of these factors, in turn, can lead to increased danger from fires.

Workers who respond to flooded areas are at the most risk of illness, injury, or death. These workers include utility workers, law enforcement, emergency medical personnel, firefighters, and military and government personnel. According to the Occupational Safety and Health Administration, some of the hazards associated with working in flooded or recently flooded areas include electrical hazards, hypothermia, structural instability, exhaustion, hazards associated with heavy equipment operation, drowning, biohazards, fire, burns from fires caused by energized line contact or equipment failure, carbon monoxide, falls from heights, hazardous materials, and dehydration.

Water utilities tend to be vulnerable to flood events due to their proximity to surface water resources. Water treatment intakes may be compromised by a blockage or loss of power. Wastewater systems can be overwhelmed by stormwater entering municipal sewer systems and may also be over-topped by adjacent floodwater. The development of vulnerability assessments and emergency plans is key to minimizing these disruptions of safe water.

During and after a flood event, the public costs for emergency services, evacuation, securing infrastructure, and clean-up can be substantial. For example, considering the costs associated with evacuation, there are significant costs (and, therefore, economic losses) related to temporary movement of a population away from a flood-impacted area. Evacuation and its associated costs can take place before, during, or after a flood event.

Managing a flood event requires well-developed procedures for communication between forecasting agencies, emergency responders, government officials, utility providers, and the general public. Real-time information on weather, stream flow, reservoir storage, levee integrity and others are used to inform the State's emergency operations. The Kansas Division of Emergency Management (KDEM) provides guidance for hazard response in the 2017 Kansas Response Plan and information on mitigation in the 2018 State Hazard Mitigation Plan. The state is currently working to update the State Hazard Mitigation Plan.

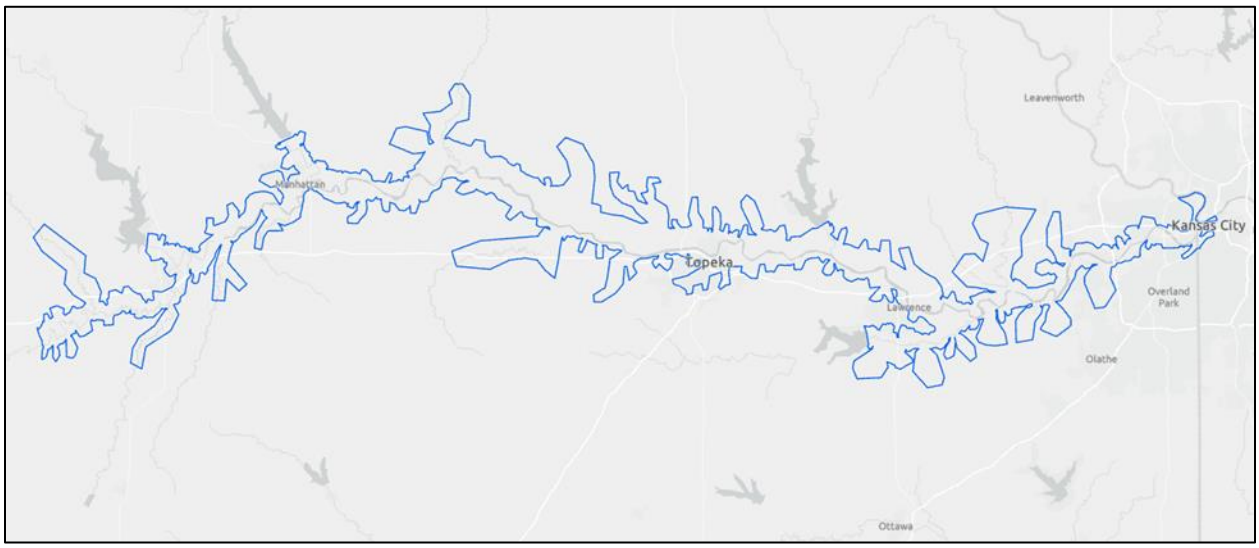
3.2.5.3.1 Flood Risk Assessment

The flood risk management infrastructure in the Kansas River Watershed consists of reservoirs and levees as described in Section 3.2.2, Kansas River Basin Reservoir System, and Section 3.2.3, River Infrastructure—Levees, and are further described in Appendix H. An assessment was conducted to determine the population, structure values, and content values for the different structure types in the basin. Population numbers were calculated for both nighttime and daytime populations within residential, commercial/industrial, education/government/religious, and agriculture categories. The total population in the Kansas River Basin for nighttime is 1,322,400 and for daytime is 1,303,000. Structure values for the basin were estimated at $188,092,617,000 (residential: $112B; commercial/industrial: $56M; education/government/religious: $18M; agriculture: $1M) and content value at $165,848,330,000 (Appendix H).

House Report No. 98-217, which is a part of Congressional documents for the Energy and Water Development Appropriation Bill of 1984, directs USACE to issue an annual report to Congress on floods, flood damage, hurricanes, and other natural disasters requiring USACE intervention. Every year, USACE Districts calculate flood damages prevented for each project, categorized by USACE and USACE-controlled reservoir projects, levees, and emergency operations. The flood damages prevented are an estimate of the monetary value of damages that floods would have caused in the absence of these projects and their flood risk reduction capabilities. These economic damages are used as the damages prevented estimates. Damages prevented are calculated for each project since the project's inception. Each fiscal year, damages prevented calculated for projects are added to the previous damages prevented for that project to get the cumulative damages prevented. The methodology for computing damages prevented and the damages prevented are included in Appendix H. As of 2022, USACE reservoirs in the basin have prevented more than $42B in damages and USBR reservoirs have prevented more than $4B in damages. Federal levees in the basin have prevented more than $1B in damages.

Portions of the study area were modeled using Life Loss Estimation (LifeSim) to produce rough order of magnitude estimates of existing areas with population at risk (PAR) and structure damages for the 0.2 percent AEP, 1 percent AEP, and the 10 percent AEP flood events. LifeSim provides a snapshot of areas vulnerable to existing and future conditions and aids in prioritization of measures to reduce flood risk. LifeSim is an agent-based system for estimating life loss with the fundamental intent to simulate population redistribution during an evacuation. Life loss and economic damages are then determined by the hazard (e.g., flooding). LifeSim is designed to simulate the entire warning and evacuation process for estimating potential life loss and direct economic damages resulting from catastrophic floods. The study area for LifeSim modeling includes the lower Kansas River in eastern Kansas and extends from just east of Chapman, Kansas, and following the Kansas River to the confluence with the Missouri River at Kansas City, Kansas/Kansas City, Missouri (Figure 3-57).

Figure 3-57. LifeSim Modeling Study Area



The study areas was broken into reaches to facilitate reporting for the LifeSim model results. The reaches generally contain a single city along the river and are named after that city. Rather than make the reaches contain cities overly large, the rural areas between cities are created as separate reaches and are named for the cities they fall between. Table 3-31 lists the modeled reaches.

Table 3-33. LifeSim Modeled Reaches

Start of River	Between Eudora and De Soto
Junction City	De Soto
Fort Riley	Between De Soto and Bonner Springs
Manhattan	Bonner Springs
Between Manhattan and Wamego	Shawnee
Wamego	Edwardsville
Between Wamego and Topeka	Muncie*
Topeka	Argentine Leveed Area*
Between Topeka and Lawrence	Armourdale Leveed Area*
Lawrence	CID Leveed Area*
Eudora	Fairfax Leveed Area*

*These five areas are neighborhoods of Kansas City, Kansas with Muncie being the only one of the five that is not located behind a levee.

The population of the cities included in the LifeSim modeling and economic data for these cities is included in Appendix H.

3.2.5.3.2 Population at Risk

If flooding should occur in the study area, the consequences would be catastrophic, even with existing projects and ongoing studies assumed to be in place. The system of dams and reservoirs in the Kansas River Basin is designed to manage flood risk for these communities.

PAR is defined as the number of people subject to inundation during a flood hazard event. To determine the percentage of PAR within a structure that is warned and mobilized over time, several parameters are used within LifeSim to estimate the probable values of warning and mobilization percentages at each time step. These include when hazards are identified and warnings will be issued (hazard identification and delays), how long they will take to become effective (warning diffusion), and the rate at which PAR will mobilize in response (mobilization). The PAR for the three flood events modeled are included in Tables 3-32 through 3-34 and in Appendix H.

1846 *Table 3-34. Population at Risk for the 10 Percent Annual Exceedance Probability Scenario*

Reach	Structures Inundated	Max Structure Depth (feet)	PAR Nighttime	PAR Daytime
Start of Modeled Area	0	0	0	0
Junction City	0	0	0	0
Fort Riley	0	0	0	0
Manhattan	0	0	0	0
Between Manhattan and Wamego	0	0	0	0
Wamego	0	0	0	0
Between Wamego and Topeka	0	0	0	0
Topeka	0	0	0	0
Between Topeka and Lawrence	6	2	6	0
Lawrence	2	6	0	0
Eudora	0	0	0	0
Between Eudora and De Soto	0	0	0	0
De Soto	0	0	0	0
Between De Soto and Bonner Springs	0	0	0	0
Bonner Springs	0	0	0	0
Shawnee	0	0	0	0
Edwardsville	0	0	0	0
Muncie	0	0	0	0
Argentine	0	0	0	0
Armourdale	0	0	0	0
CID	0	0	0	0
Fairfax	0	0	0	0
Total	8	6	6	0

1847

Table 3-35. Population at Risk for the One Percent Annual Exceedance Probability Scenario

Reach	Structures Inundated	Max Structure Depth (feet)	PAR Nighttime	PAR Daytime
Start of Modeled Area	3	3	3	0
Junction City	58	7	99	245
Fort Riley	364	11	672	322
Manhattan	21	5	37	19
Between Manhattan and Wamego	15	4	28	20
Wamego	5	3	10	7
Between Wamego and Topeka	41	7	93	132
Topeka	10	10	8	63
Between Topeka and Lawrence	284	12	582	266
Lawrence	148	15	762	403
Eudora	12	3	32	10
Between Eudora and De Soto	6	6	12	3
De Soto	14	7	32	56
Between De Soto and Bonner Springs	1	3	2	0
Bonner Springs	31	4	90	31
Shawnee	37	7	138	379
Edwardsville	79	9	342	2,486
Muncie	296	11	292	388
Argentine	0	0	0	0
Armourdale	0	0	0	0
CID	0	0	0	0
Fairfax	0	0	0	0
Total	1,426	15	3,234	4,830

Table 3-36. Population at Risk for the 0.2 Percent Annual Exceedance Probability Scenario

Reach	Structures Inundated	Max Structure Depth (feet)	PAR Nighttime	PAR Daytime
Start of Modeled Area	353	10	868	460
Junction City	255	17	642	1,211
Fort Riley	1,047	20	3,356	2,024
Manhattan	1,516	16	4,596	5,804
Between Manhattan and Wamego	64	10	122	84
Wamego	20	9	39	20
Between Wamego and Topeka	537	17	1,018	726
Topeka	2,423	19	10,536	8,117
Between Topeka and Lawrence	945	18	2,129	3,300
Lawrence	1,134	20	2,843	3,176
Eudora	34	8	95	50
Between Eudora and De Soto	24	12	42	15
De Soto	47	13	86	83
Between De Soto and Bonner Springs	13	9	14	49
Bonner Springs	153	13	436	155
Shawnee	87	16	180	627
Edwardsville	907	18	3,767	5,308
Muncie	345	21	420	1,585
Argentine	7	6	28	14
Armourdale	0	0	0	0
CID	0	0	0	0
Fairfax	0	0	0	0
Total	9,911	21	31,217	32,808

3.2.5.3.3 Life Loss and Economic Damages

LifeSim was used to estimate direct life loss and economic damages that could occur for the three flood events modeled. Economic damages are defined as property damages that include structure, content, and vehicle damage. The economic damages were estimated for each structure occupancy type and the structure stability.

There was no life loss under the 10 percent AEP flood event. Tables 3-35 through 3-36 include the life loss of the PAR nighttime and the risk to structures under the 1 percent AEP and 0.2 percent AEP flood events.

Table 3-37. Life Loss for the One Percent Annual Exceedance Probability Flood Event

Reach	Life Loss
Start of Modeled Area	0
Junction City	0
Fort Riley	0
Manhattan	0
Between Manhattan and Wamego	0
Wamego	0
Between Wamego and Topeka	0
Topeka	0
Between Topeka and Lawrence	0
Lawrence	0
Eudora	0
Between Eudora and De Soto	0
De Soto	0
Between De Soto and Bonner Springs	0
Bonner Springs	0
Shawnee	0
Edwardsville	0
Muncie	5
Argentine	0
Armourdale	0
CID	0
Fairfax	0
Total	5

Table 3-38. Life Loss for the 0.2 Percent Annual Exceedance Probability Flood Event

Reach	Life Loss
Start of Modeled Area	0
Junction City	2
Fort Riley	41
Manhattan	0
Between Manhattan and Wamego	0
Wamego	0
Between Wamego and Topeka	0
Topeka	7
Between Topeka and Lawrence	1
Lawrence	0
Eudora	0
Between Eudora and De Soto	0
De Soto	0
Between De Soto and Bonner Springs	0
Bonner Springs	4
Shawnee	0
Edwardsville	24
Muncie	14
Argentine	0
Armourdale	0
CID	0
Fairfax	0
Total	93

Figures 3-58 and 3-59 show the spatial distribution of the life loss (direct mean) for the 1 percent AEP and 0.2 percent AEP flood events at night under a minimal warning scenario. The highest risk for the 1 percent AEP flood event is in the Muncie reach. The highest risk for the 0.2 percent AEP flood event is in the Edwardsville, Topeka, and Fort Riley reaches.

Figure 3-58. Direct Mean Life Loss for the One Percent Annual Exceedance Probability Flood Event

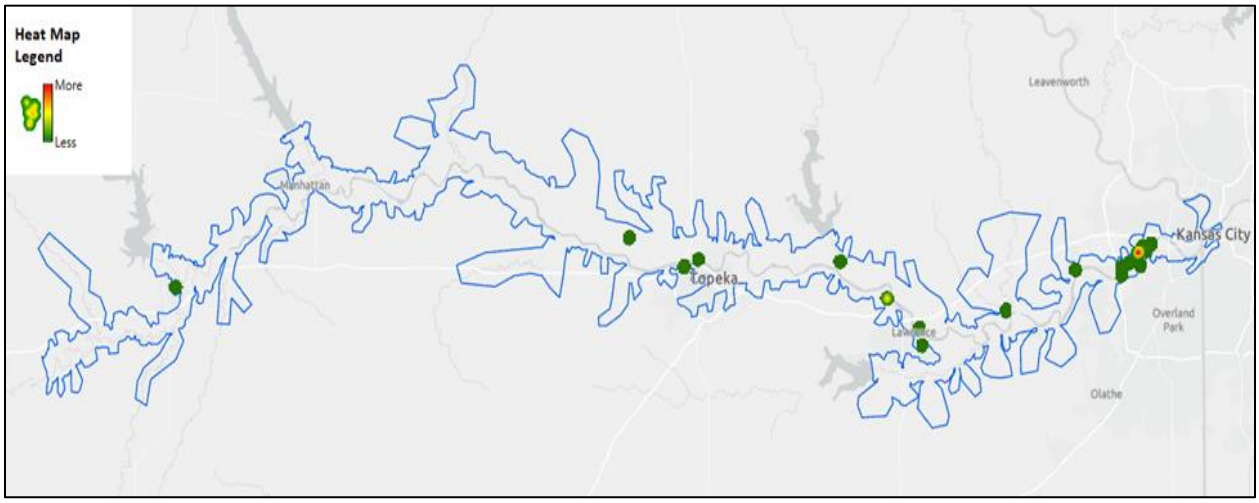
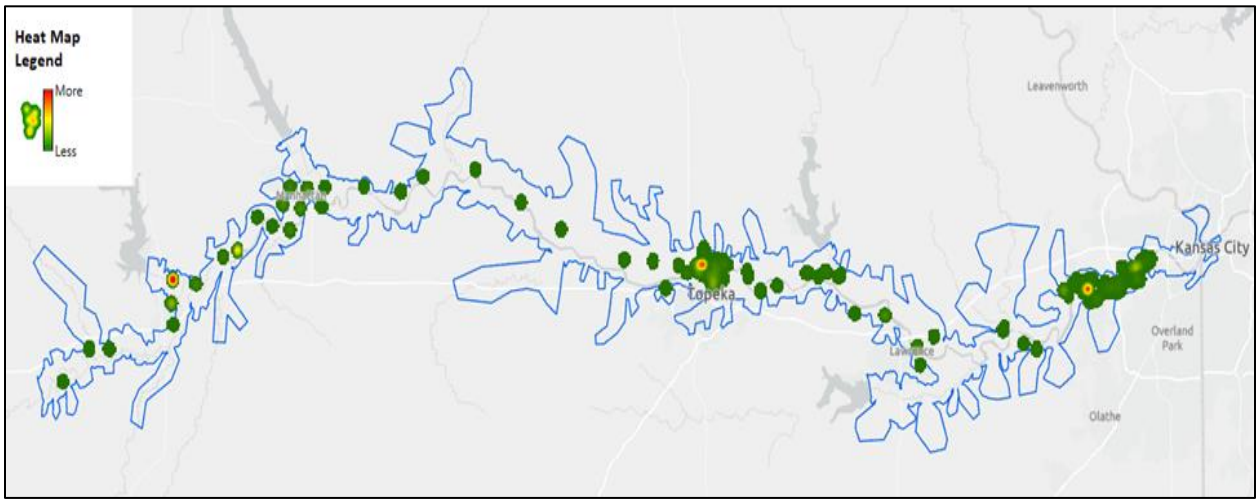


Figure 3-59. Direct Mean Life Loss for the 0.2 Percent Annual Exceedance Probability Flood Event



Tables 3-37 through 3-39 include the risk to structures under the 10 percent AEP, 1 percent AEP, and 0.2 percent AEP flood events.

1876 *Table 3-39. Economic Damages for the Ten Percent Annual Exceedance Probability Flood Event*

Reach	Total Damages
Start	$0
Junction City	$0
Fort Riley	$0
Manhattan	$0
Between Manhattan and Wamego	$0
Wamego	$0
Between Wamego and Topeka	$0
Topeka	$0
Between Topeka and Lawrence	$111,381
Lawrence	$391,064
Eudora	$0
Between Eudora and De Soto	$0
De Soto	$0
Between De Soto and Bonner Springs	$0
Bonner Springs	$0
Shawnee	$0
Edwardsville	$0
Muncie	$0
Argentine	$0
Armourdale	$0
CID	$0
Fairfax	$0
Total Reaches	$502,445

1877

1878 *Table 3-40. Economic Damages for the One Percent Annual Exceedance Probability Flood Event*

Reach	Total Damages
Start	$21,999
Junction City	$3,757,469
Fort Riley	$11,583,022
Manhattan	$2,375,427
Between Manhattan and Wamego	$1,081,736
Wamego	$348,467
Between Wamego and Topeka	$3,811,488
Topeka	$3,189,013
Between Topeka and Lawrence	$16,357,495
Lawrence	$18,190,481
Eudora	$625,566
Between Eudora and De Soto	$467,769
De Soto	$3,310,963
Between De Soto and Bonner Springs	$99,949
Bonner Springs	$222,070
Shawnee	$5,397,154
Edwardsville	$125,753,926
Muncie	$103,512,222
Argentine	$0
Armourdale	$0
CID	$0
Fairfax	$0
Total Reaches	$300,106,216

1879

Table 3-41. Economic Damages for the 0.2 Percent Annual Exceedance Probability Flood Event

Reach	Total Damages
Start	$359,10,729
Junction City	$172,873,980
Fort Riley	$291,247,122
Manhattan	$572,964,927
Between Manhattan and Wamego	$7,247,535
Wamego	$1,025,411
Between Wamego and Topeka	$46,018,129
Topeka	$908,485,556
Between Topeka and Lawrence	$113,301,238
Lawrence	$189,735,313
Eudora	$3,167,693
Between Eudora and De Soto	$1,872,484
De Soto	$13,579,460
Between De Soto and Bonner Springs	$4,733,248
Bonner Springs	$21,037,344
Shawnee	$59,618,628
Edwardsville	$558,876,073
Muncie	$275,236,751
Argentine	$350,898
Armourdale	$0
CID	$0
Fairfax	$0
Total Reaches	$3,241,371,790

Kansas is a state with a considerable amount of agriculture. In the study area for the model, there are approximately 216,500 acres of land devoted to agriculture. The primary crops in this area of the state are corn, soybeans, oats, and alfalfa. Tables 3-40 and 3-41 show crop damages for the 1 percent AEP and the 0.2 percent AEP flood events using crop budgets of FY 16.

Table 3-42. Crop Damages for the One Percent Annual Exceedance Probability Flood Event

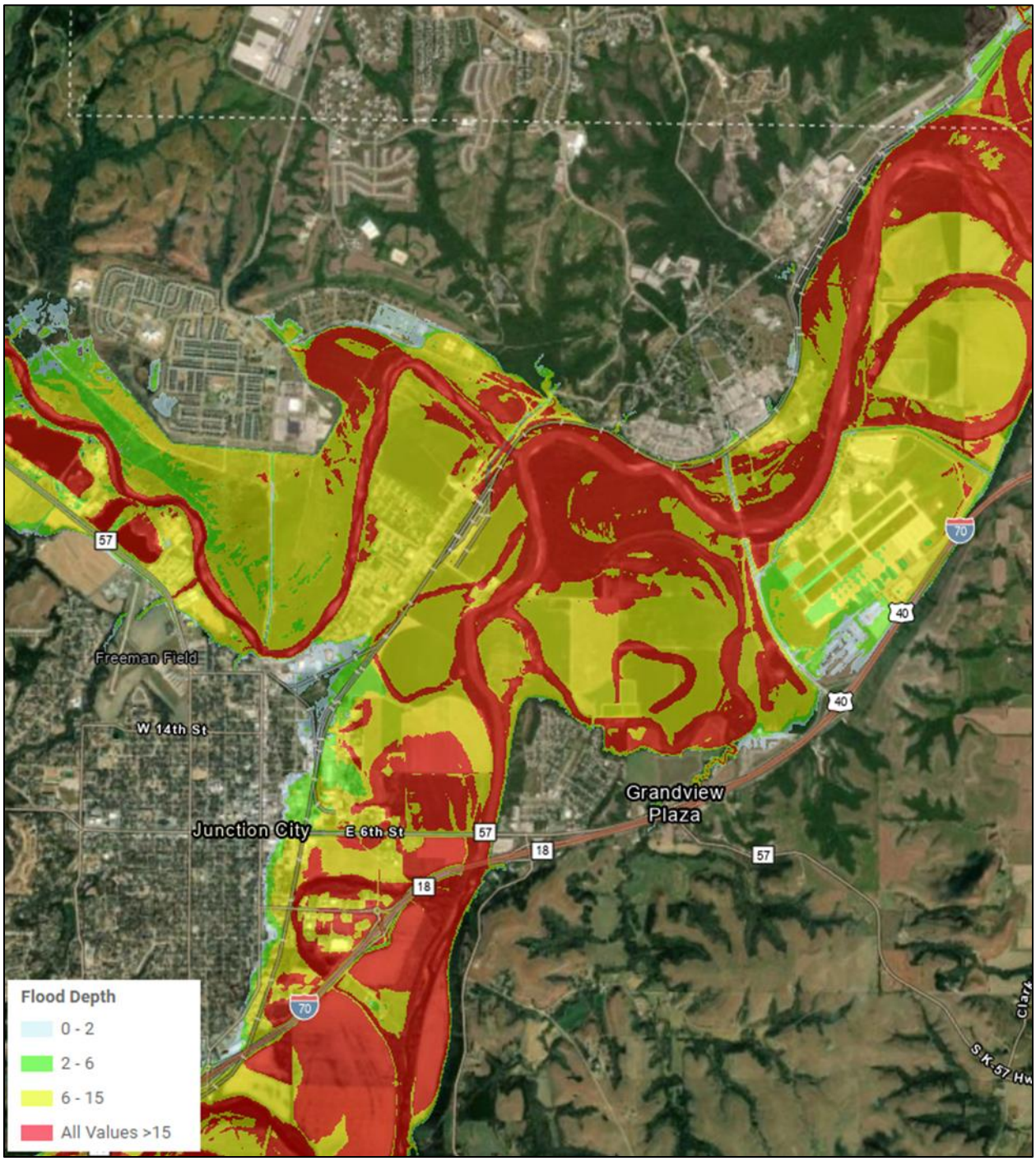
Category	Damages (FY16)
Corn	$6,257,350
Soybeans	$3,586,001
Alfalfa	$88,223
Oats	$5,706
Barley	$67
Sunflowers	$26
Total	$9,937,374

Table 3-43. Crop Damages for the 0.2 Percent Annual Exceedance Probability Flood

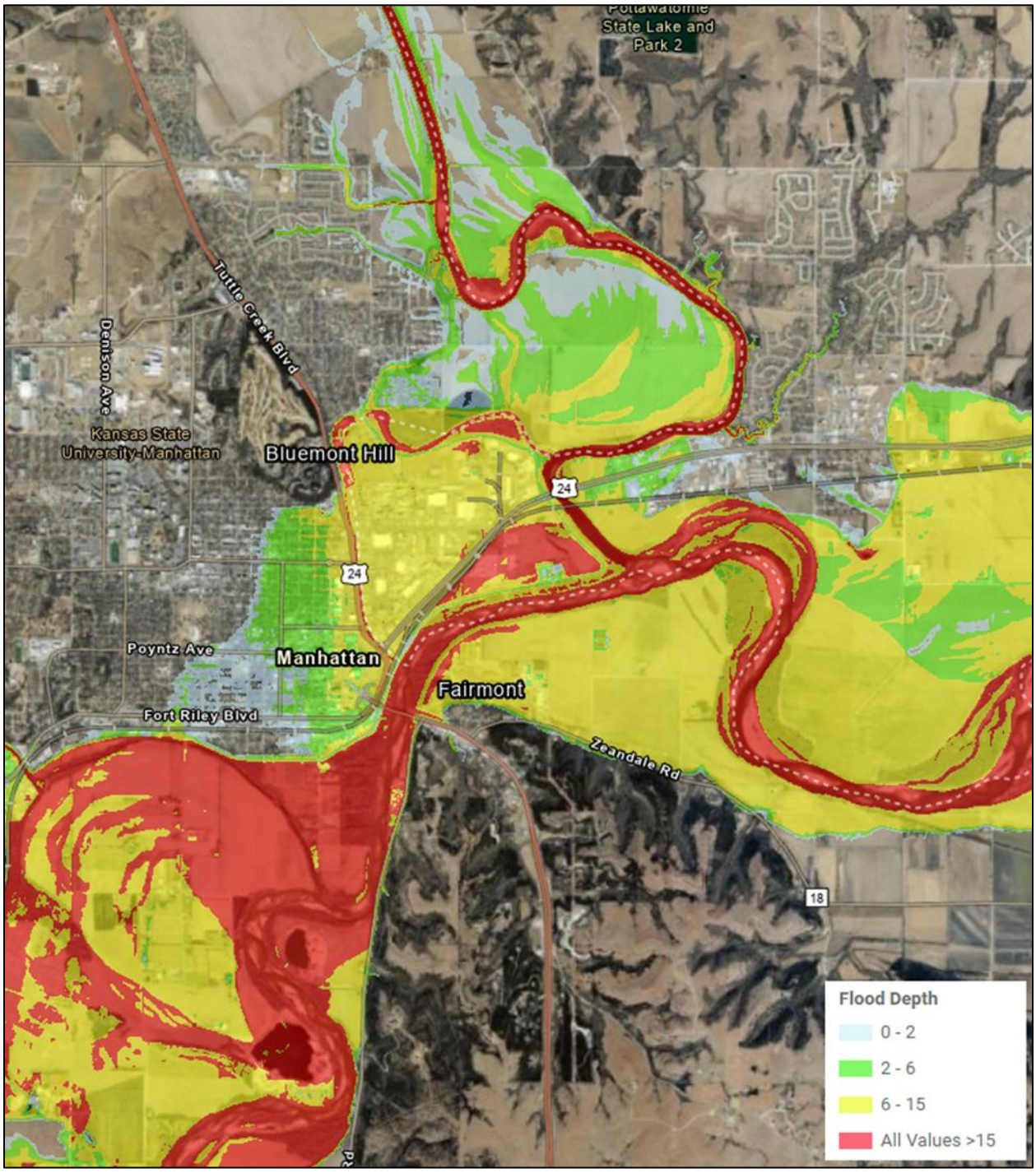
Category	Damages (FY16)
Corn	$16,679,862
Soybeans	$9,159,241
Alfalfa	$203,519
Oats	$16,555
Barley	$289
Sunflowers	$26
Total	$25,503,022

Inundation mapping was also developed showing the extent and depth of inundation in areas along the Kansas River for the 0.2 percent AEP flood event (Figures 3-60 through 3-65). The extent and depths of inundation could be a guide for future actions (e.g., emergency personnel in development of communications plans and developing evacuation routes).

Figure 3-60. Flood Inundation for the 0.2 Percent Annual Exceedance Probability Flood Event at Junction City and Fort Riley, Kansas

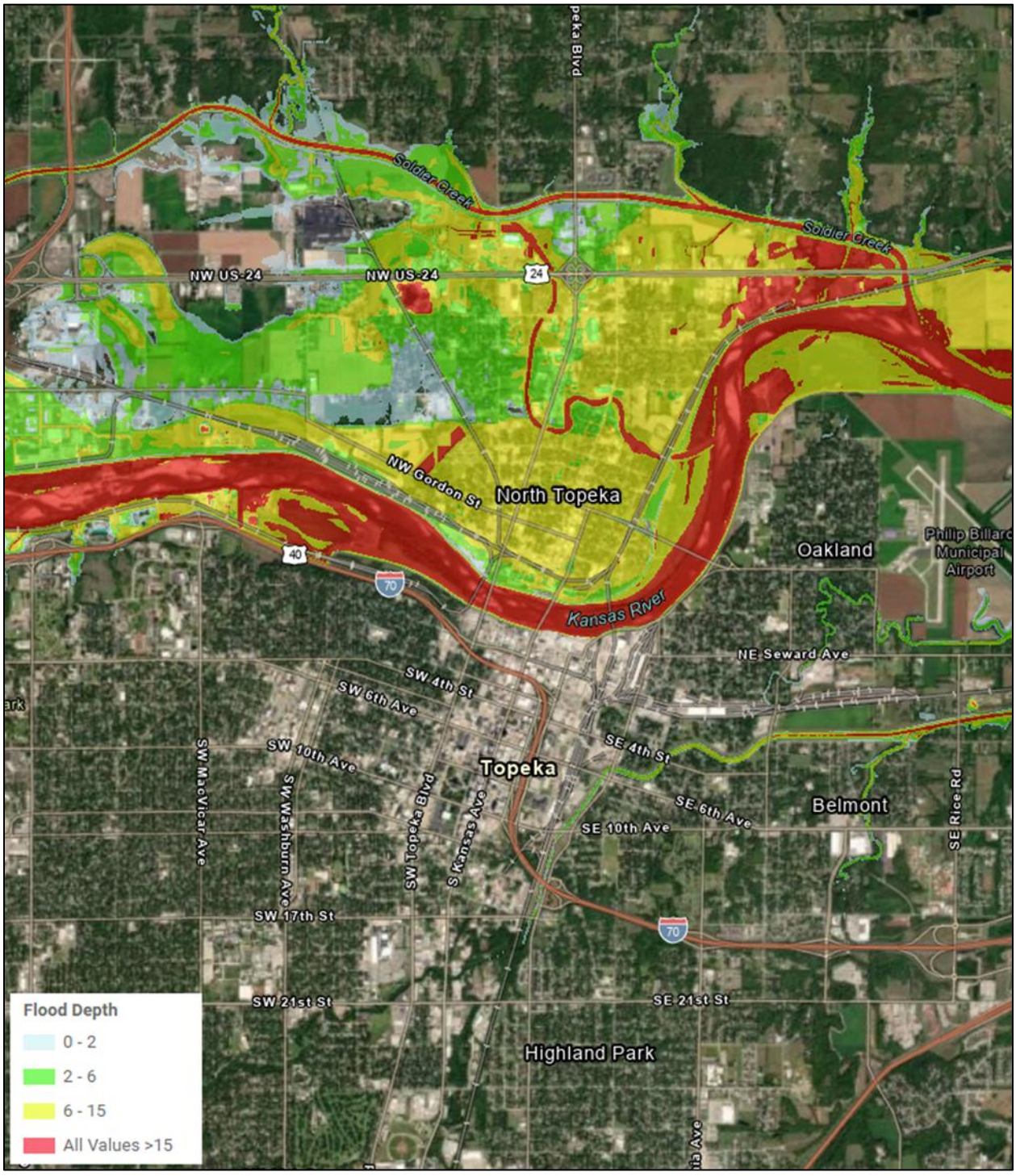


1899 *Figure 3-61. Flood Inundation for the 0.2 Percent Annual Exceedance Probability Flood Event at*
1900 *Manhattan, Kansas*



1901
1902

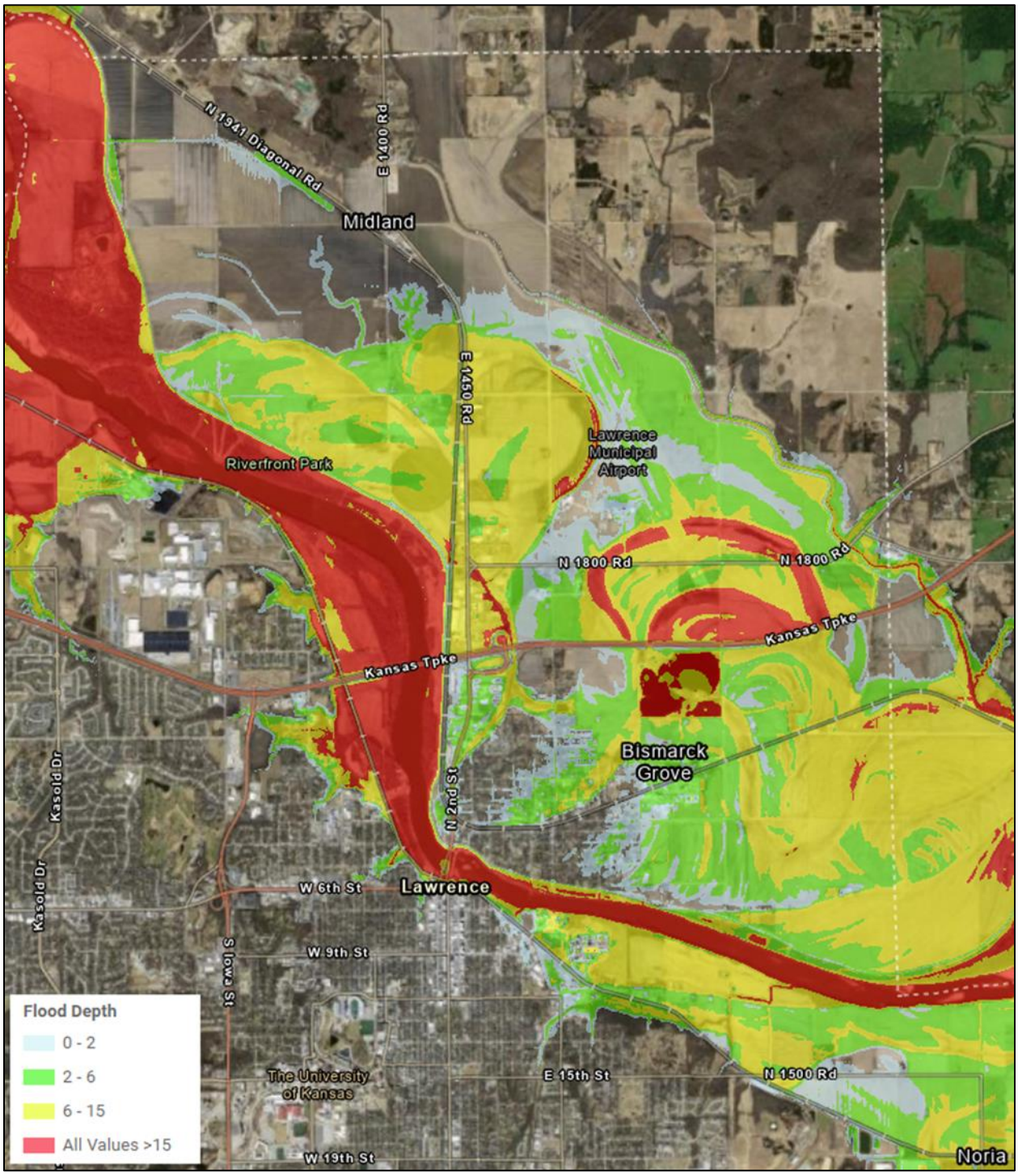
1903 *Figure 3-62. Flood Inundation for the 0.2 Percent Annual Exceedance Probability Flood Event at Topeka,*
1904 *Kansas*



1905

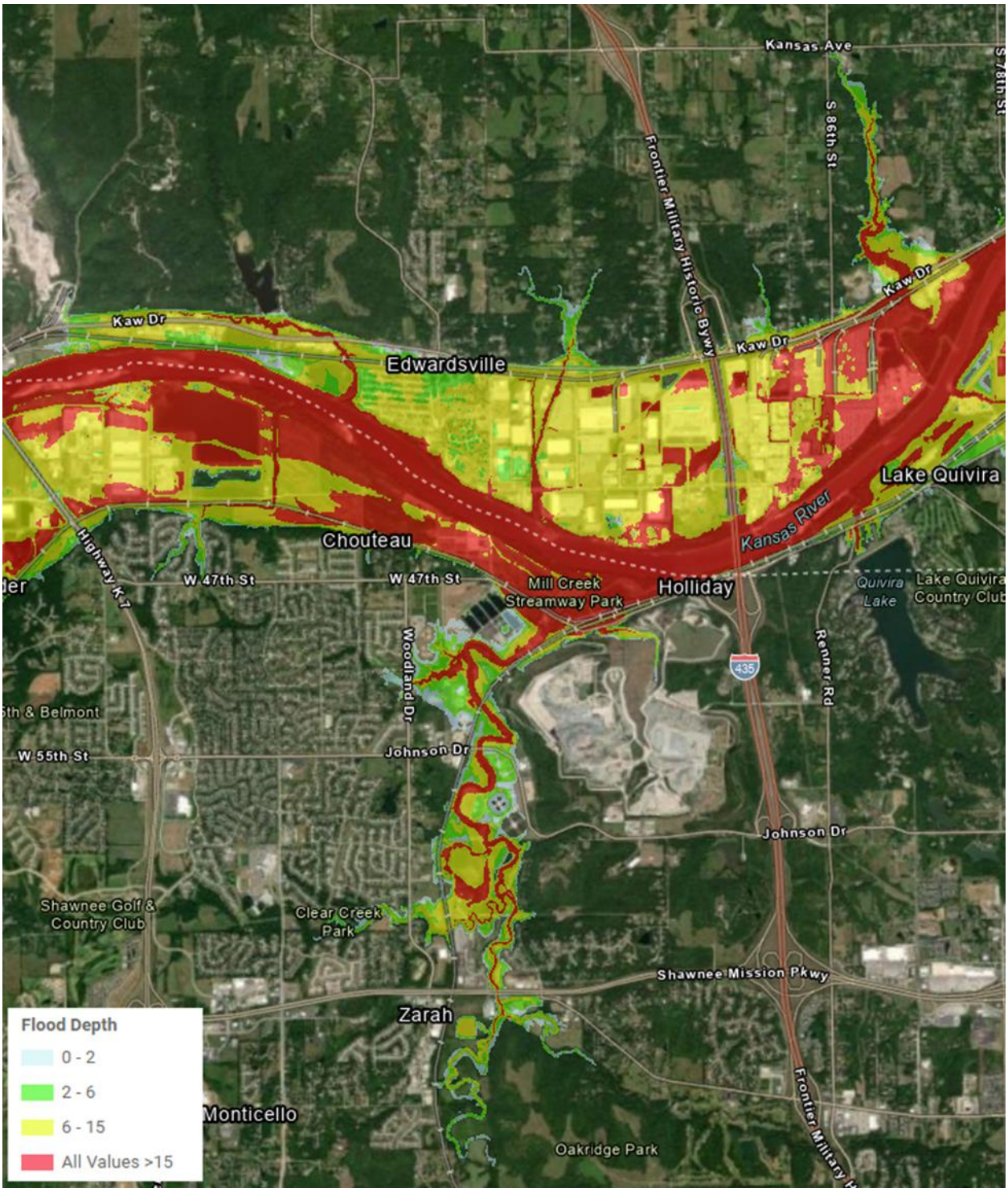
1906

1907 *Figure 3-63. Flood Inundation for the 0.2 Percent Annual Exceedance Probability Flood Event at*
1908 *Lawrence, Kansas*

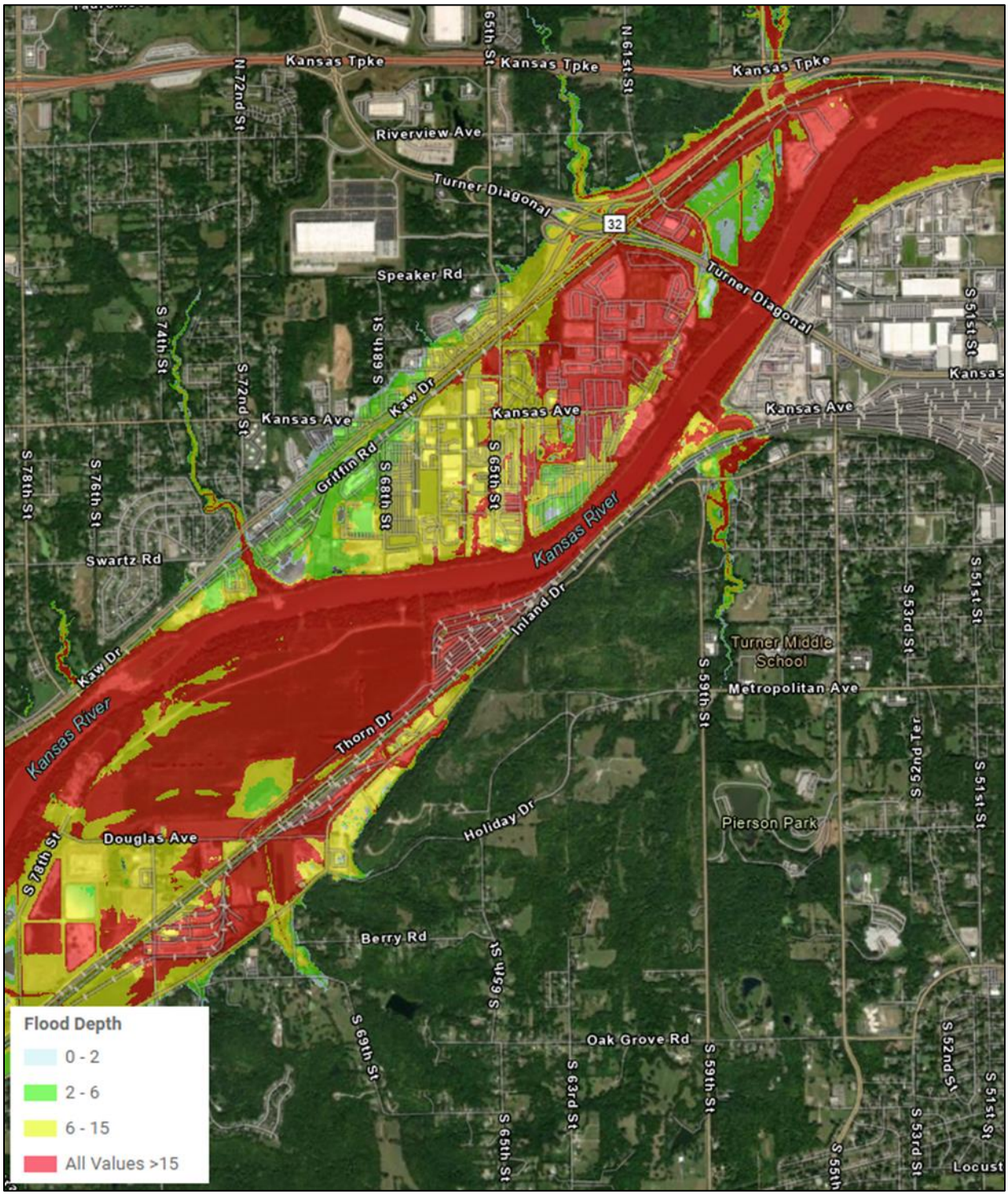


1909
1910

Figure 3-64. Flood Inundation for the 0.2 Percent Annual Exceedance Probabiltiy Flood Event at Edwardsville, Kansas



1915 *Figure 3-65. Flood Inundation for the 0.2 Percent Annual Exceedance Probability Flood Event at Muncie,*
1916 *Kansas*



1917
1918

3.2.6 Future Without Project Conditions

Expected changes, if any, in the conditions of hydrology/hydraulics, reservoir operations, and flood risk/life safety in the Kansas River Watershed are described in the following paragraphs. Future conditions on reservoir and river infrastructure will likely be affected by drivers related to climate change, increased urbanization, regulations addressing environmental degradation and water quality, and availability of public funding. Many of the reservoir and river infrastructure projects are old and will reach the end of their useful design lives within a 50-year planning timeframe. Expected increases in urbanization and climate change effects that could alter runoff characteristics potentially increasing the depth and extent of flooding in the region could impact the capacity and performance of some flood protection structures.

3.2.6.1 Reservoir Operations

As described in Section 3.2.2, Reservoir Operations Assessment, the existing conditions 100 years of inflow were used as a baseline for FWOP simulations evaluating changes and impacts to reservoirs and stream flows as sediment accumulates in the reservoirs over the next 100 years—2024 (base condition), 2049 (25-year), 2074 (50-year), 2124 (100-year). All data inputs used for the existing condition assessment of reservoir operations were shifted forward in time 104 years to have the FWOP simulations start on January 2024 and end January 2124 (hereinafter referred to as the FWOP POR). The start date is considered the base condition and corresponds to the completion of the watershed study. The FWOP assessment was conducted on the same seven reservoirs assessed for existing conditions (i.e., Kanopolis, Wilson, Waconda, Milford, Tuttle Creek, Perry, and Clinton reservoirs). The FWOP simulations were used to quantify impacts to flood risk management, reservoir operations, infrastructure investment, water supply availability and sustainment, water quality, recreation, and ecosystem preservation and restoration.

Future sedimentation for each reservoir in the basin was estimated by engineers in the USACE Kansas City District River Engineering and Restoration Section (Appendix D). These calculations resulted in elevation/storage and elevation/area curves for four future conditions—2024 (base condition), 2049 (25-year), 2074 (50-year), and 2124 (100-year). Calculated storage and area were from zero storage to the top of the flood control pool; beyond this level, it was assumed that the incremental storage and area did not change, and the curves extended through the surcharge zone to the top of the dam. Storage and area curves used in the HEC-ResSim model for each of the seven reservoirs are included in Appendix B.

Each reservoir pool elevation and outflow were evaluated for the four sedimentation future conditions both with and without navigation releases. Observed and modeled existing condition data were also included in the analysis of the FWOP to provide a reference of change in the future condition. The reasons why observed versus modeled results may differ is discussed in Section 3.2.2, Reservoir Operations Assessment, and in Appendix B.

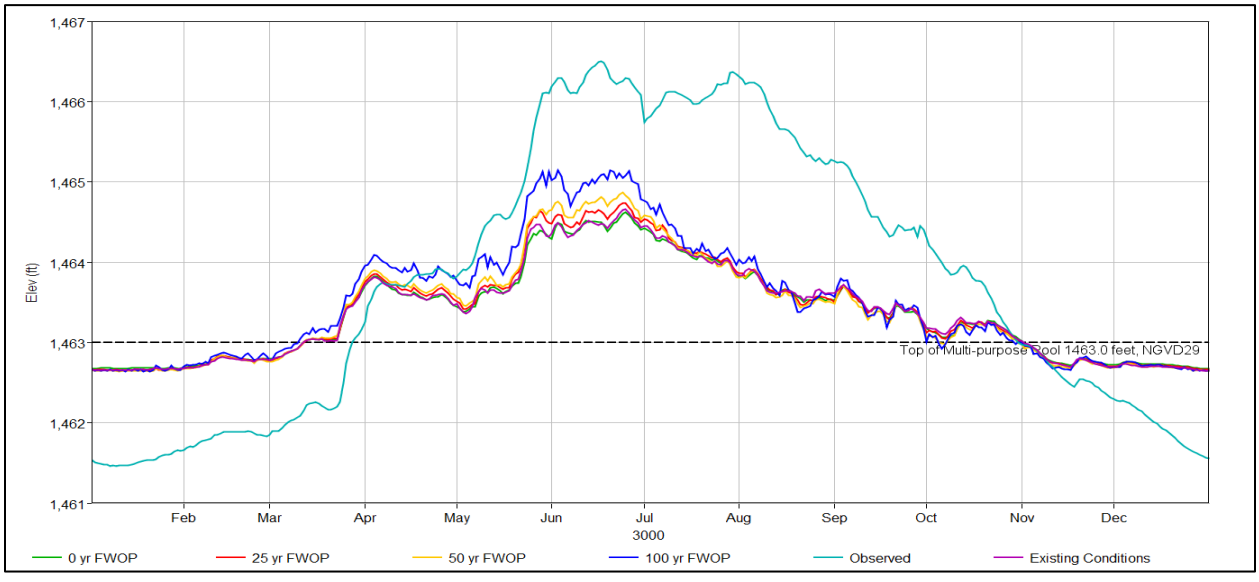
Generally, the assessment of reservoir operations evaluated the changes under the eight FWOP scenarios for the FWOP POR (i.e., January 2024 through January 2124). During extreme low water years during drought events the FWOP modeling results

show periods where there are substantial changes in reservoir multipurpose pool storage (e.g., minimal storage or complete depletion for extended periods) at select reservoirs as storage diminishes due to sedimentation. Based on the floods of record in the Kansas River Basin during high water years, during flood events in the future there is an increased frequency in the lower portions of the flood control pool as the storage diminishes due to sedimentation for select reservoirs. Specific examples are included in the discussion under these reservoirs to set the benchmark for future conditions if no action is taken to reduce the risks related to reservoir sedimentation and to drought and flooding. The effects of navigation releases are described with the discussion focusing on the non-navigation FWOP scenarios with references to the additional effects from navigation FWOP scenarios if any. The FWOP modeling results for each of the reservoirs follow.

3.2.6.1.1 Kanopolis Reservoir

In the results of the reservoir operations FWOP assessment, navigation did not impact Kanopolis Reservoir since Kanopolis does not support navigation flows. The existing conditions and 2024 FWOP scenarios are very similar as the sediment conditions do not change dramatically between these two scenarios for Kanopolis Reservoir. However, as more sediment accumulates with each additional FWOP scenario (e.g., 2049 (25-year), 2074 (50-year)) the average pool elevation also increases. The 2124 FWOP has slightly higher pool elevations because of reduced storage in the multi-purpose pool (Figure 3-66).

Figure 3-66. Kanopolis Daily Average Pool Elevation for Observed and Existing Conditions and FWOP Scenarios (Period of Record 2024 through 2124)



Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

The Kanopolis Reservoir duration shows increased frequency in the lower portions of the flood control pool and deeper drops into the multi-purpose pool as the storage diminishes due to sedimentation (Figure 3-67).

Figure 3-67. Kanopolis Reservoir Pool Elevation Duration for the Non-navigation FWOP Scenarios (Period of Record 2024 through 2124)

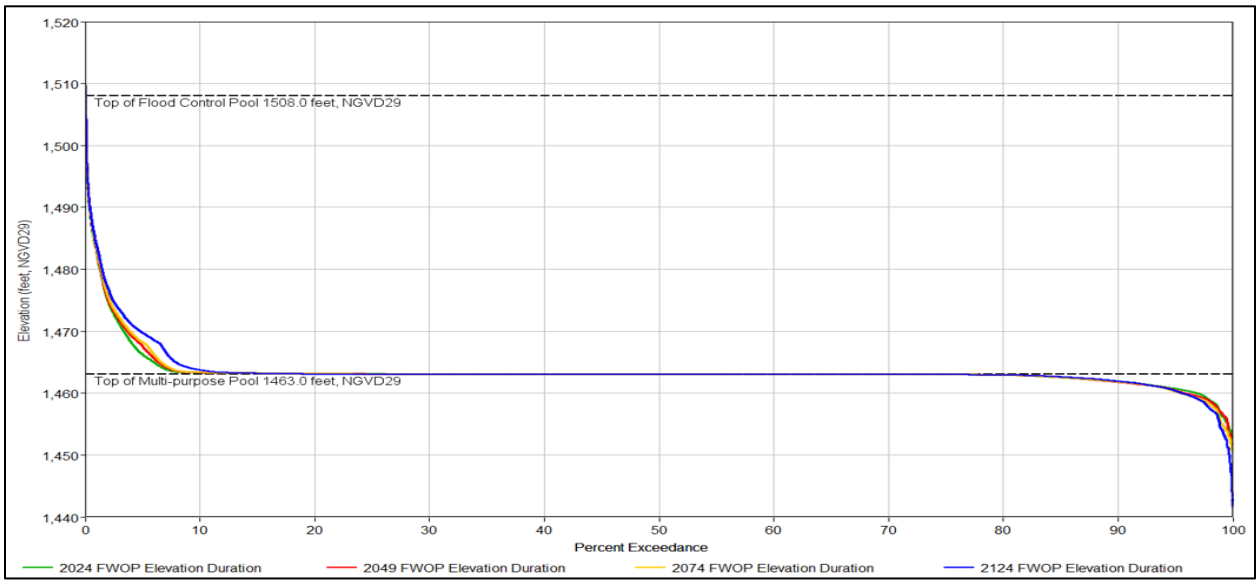
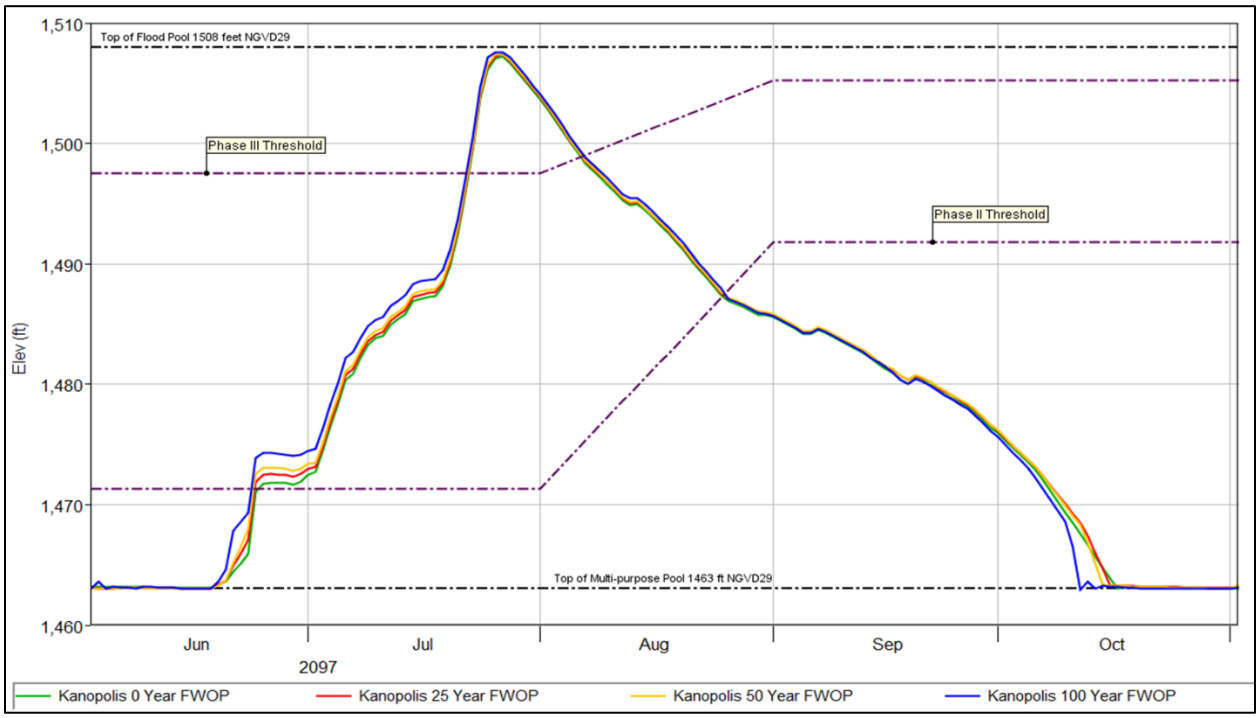


Figure 3-68 shows one of the floods of record in the Kansas River Basin, 1993, projected into the future under the FWOP scenarios to further exhibit a specific example of the increased frequency in the lower portions of the flood control pool as the storage diminishes due to sedimentation.

Figure 3-68. Kanopolis Reservoir Non-navigation FWOP Scenarios–Flood Example



During extreme low water years during drought conditions, all FWOP scenarios show periods of reservoir elevations below the top of the multipurpose pool with sharper decreases under each additional FWOP scenario (Figure 3-69). The 2124 FWOP

scenario shows two events where multipurpose storage is less than 1,000 acre-feet or completely depleted for extended periods (Figure 3-70). These conditions occur under periods when extreme drought conditions occur and all storage is used to meet downstream target flows on the Smoky Hill River. The graphic represents the drought occurring in the 1920s in the Kansas River Basin projected into the future under the FWOP scenarios, which include increased sedimentation in the reservoir. Kanopolis is expected to experience substantial sedimentation over the next 100 years with approximately 25 percent of the multipurpose pool remaining in 2124.

Figure 3-69. Kanopolis Reservoir Elevation Under Non-navigation FWOP Scenarios (2023 through 2060)

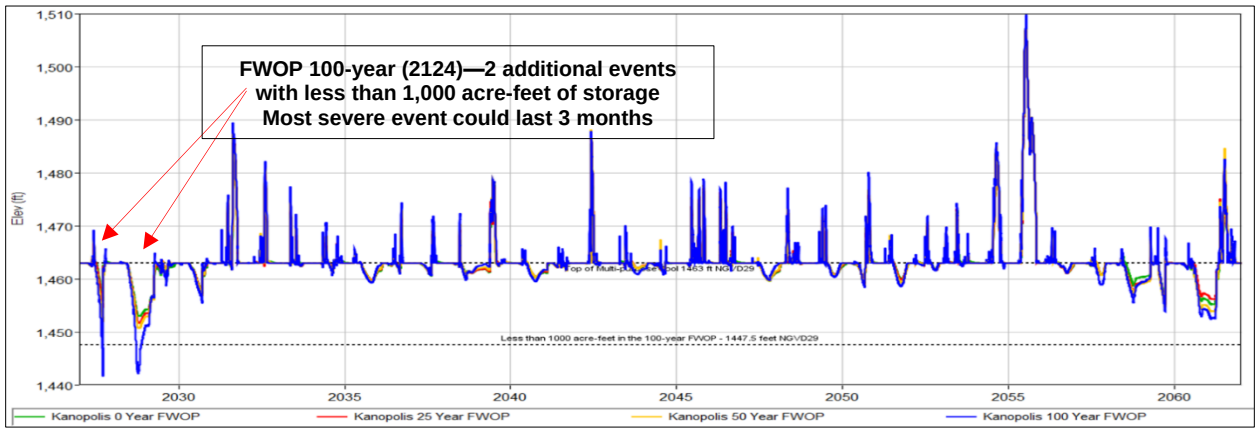
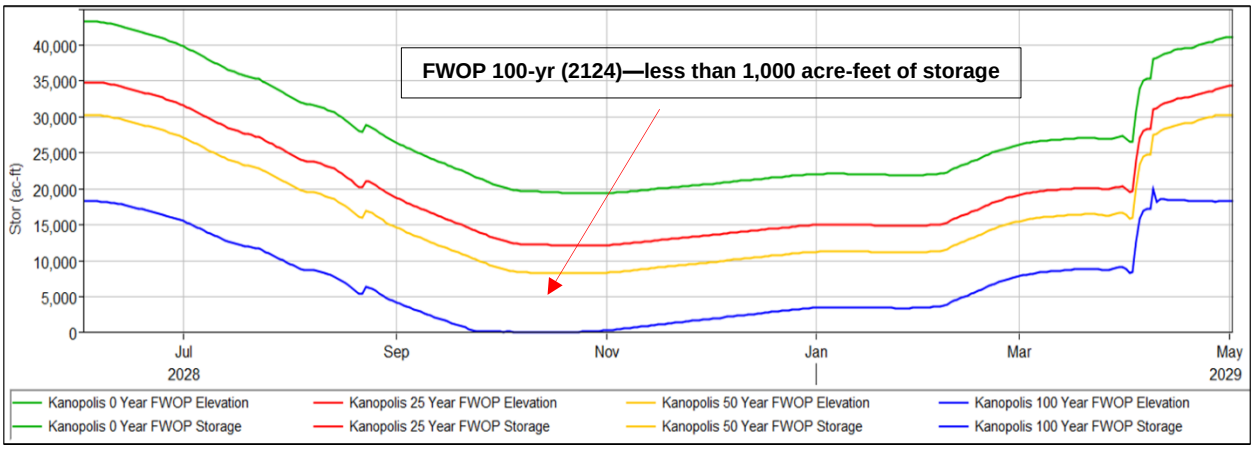


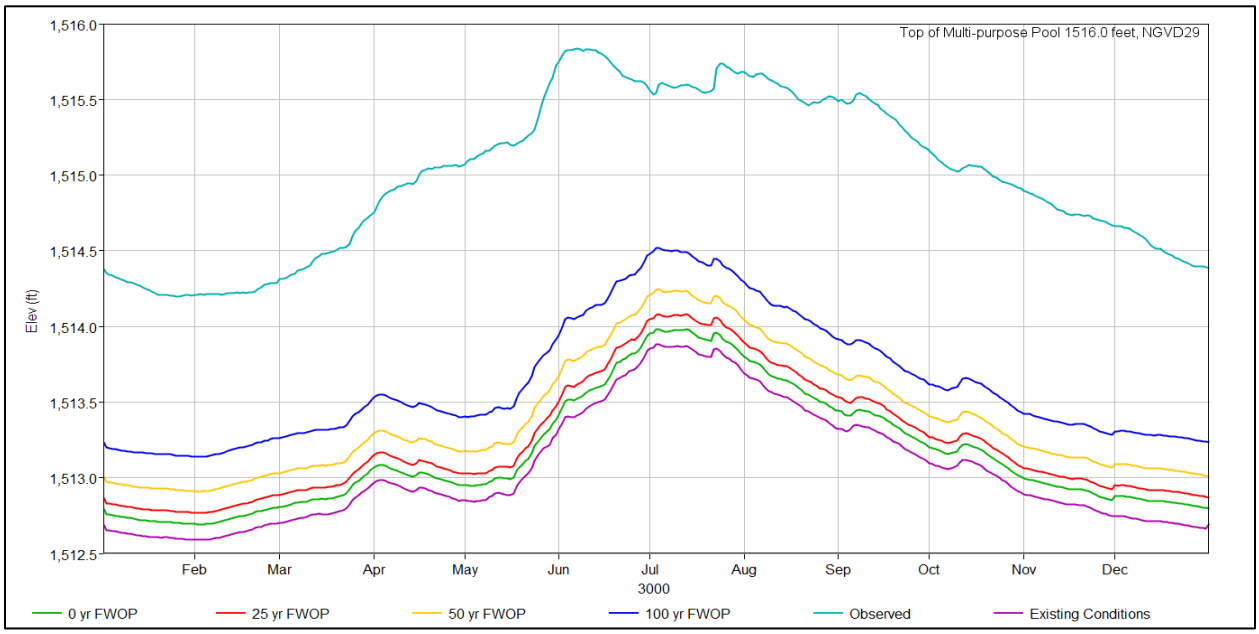
Figure 3-70. Kanopolis Reservoir Storage Under FWOP Non-navigation Scenarios–Drought Example



3.2.6.1.2 Wilson Reservoir

The reservoir operations assessment shows that navigation did not impact Wilson Reservoir since it does not support navigation flows. The average and median modeled FWOP elevations are all below the top of multipurpose pool which is reflective of the frequent drought conditions observed there. The 2024 FWOP and 2049 FWOP scenarios are very similar as the sediment conditions do not change dramatically in this timeframe for Wilson Reservoir. However, as more sediment accumulates with each additional FWOP scenario the average pool elevation also increases (Figure 3-71).

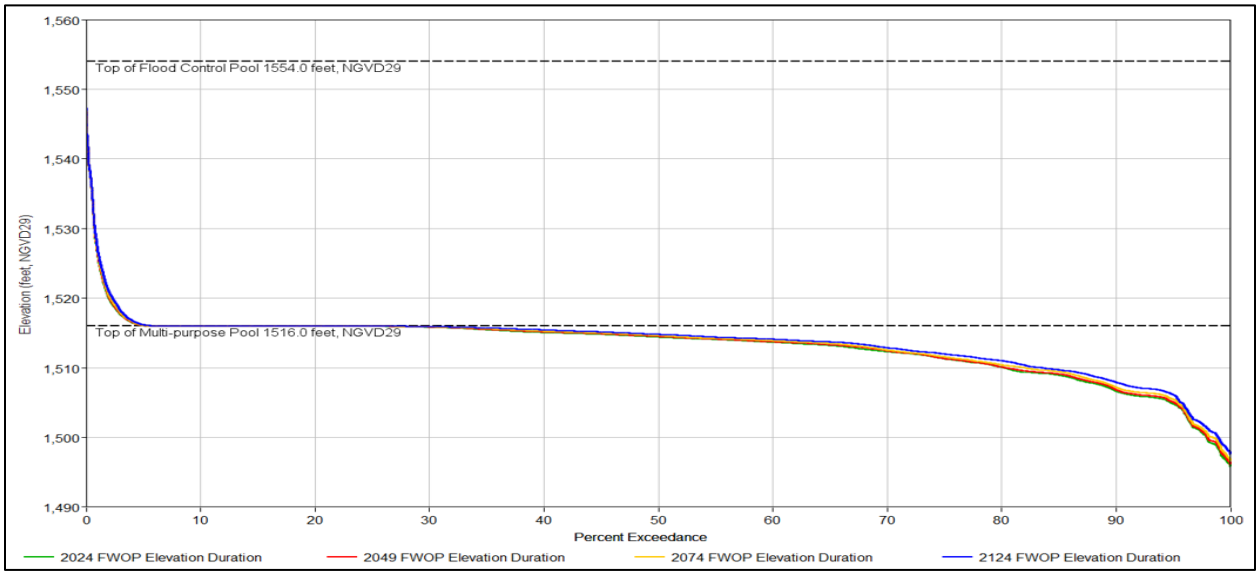
Figure 3-71. Wilson Reservoir Daily Average Pool Elevations for the Observed and Existing Conditions and the FWOP Scenarios (Period of Record 2024 through 2124)



Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

The Wilson Reservoir model shows that the pool elevation does not drop as far into the multi-purpose pool in the later FWOP scenarios. This is likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at Wilson Reservoir (Figure 3-72).

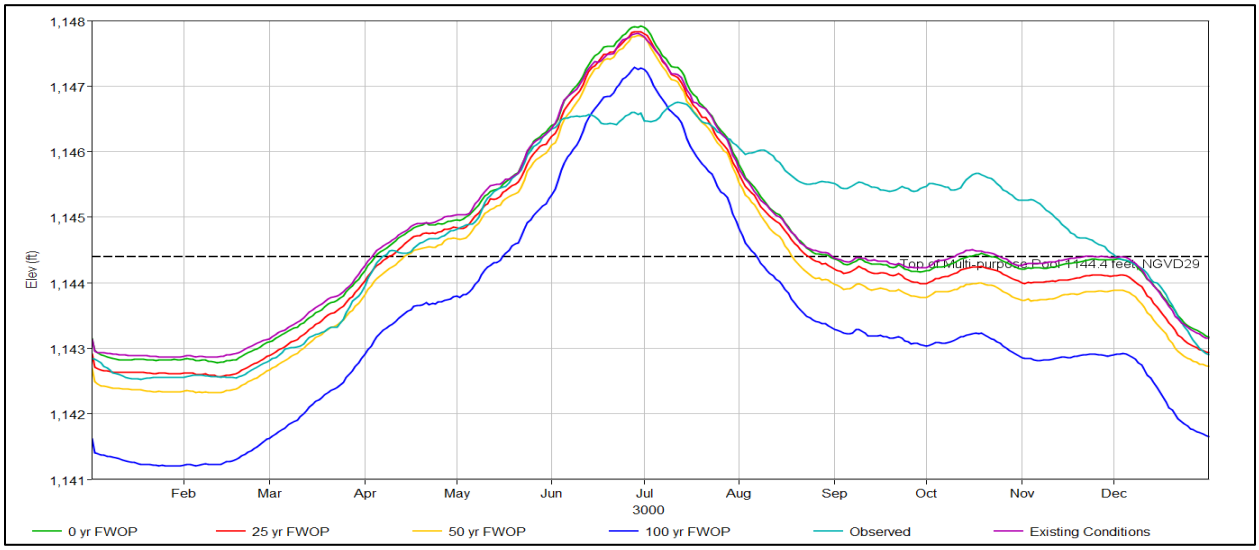
Figure 3-72. Wilson Reservoir Pool Elevation Duration for the Non-navigation FWOP Scenarios (Period of Record 2024 through 2124)



3.2.6.1.3 Milford Reservoir

Milford Reservoir does not lose significant storage over the 100-years of the FWOP. However, with each subsequent FWOP scenario, the average pool elevation decreases as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., De Soto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets (Figure 3-73).

Figure 3-73. Milford Reservoir Daily Average Pool Elevations for the Observed and Existing Conditions and the FWOP Scenarios (Period of Record 2024 through 2124)



Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

Navigation releases from Milford and Perry reservoirs can be made from the water supply storage volume not called into service by the State of Kansas. All of the multipurpose pool storage is under contract for water supply to the State of Kansas in the two reservoirs. Until all storage is called into service, multipurpose objectives of the remaining storage can be used to supplement Missouri River flows for navigation within operating limits. If 100 percent of the water supply volume is called into service for Milford and Perry reservoirs, navigation releases from the water supply volume would not occur at these reservoirs. Navigation flow support is provided by Milford Reservoir in the FWOP scenario for 2024 but not for 2049, 2074, and 2124 as it is anticipated that the remaining storage will be called into service by the State of Kansas before these three timeframes. Navigation releases under the 2024 FWOP results in increased frequency of pool elevations below the top of the multipurpose pool elevation. Higher pool elevations in the navigation 2024 FWOP scenario are the same as those under the non-navigation 2024 FWOP scenario. The 2049, 2074, and 2124 FWOP scenarios did not provide navigation support flows, but some small impacts are assessed because of Tuttle Creek Reservoir providing the navigation support flows which then requires Milford Reservoir to make additional releases to support water quality targets. Under the 2124 FWOP scenario Milford Reservoir is already supporting most of the water quality releases as the multipurpose pool as Tuttle Creek Reservoir is almost full of sediment with little remaining storage volume (see Appendix B).

The Milford Reservoir model shows little change in the flood control operation and deeper drops into the multipurpose pool as the storage diminishes due to sedimentation (Figure 3-74).

Figure 3-74. Milford Reservoir Pool Elevation Duration for the Four Non-navigation FWOP Scenarios (Period of Record 2024 through 2124)

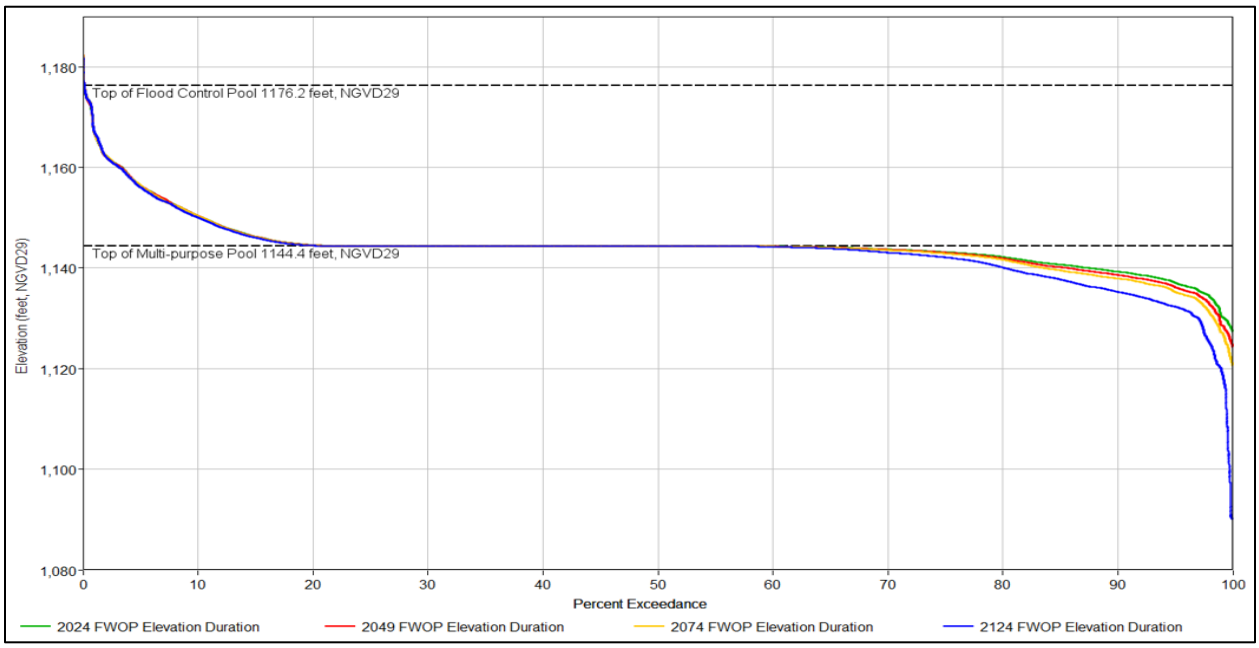
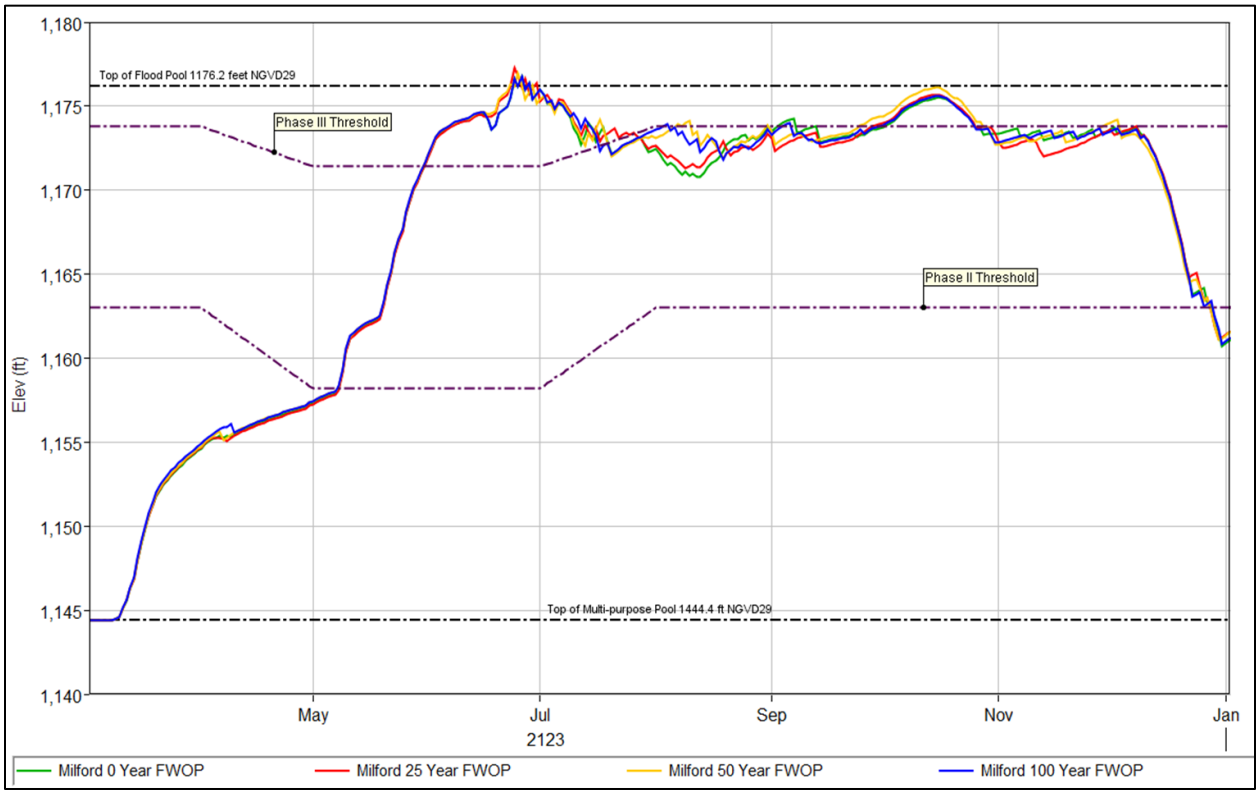


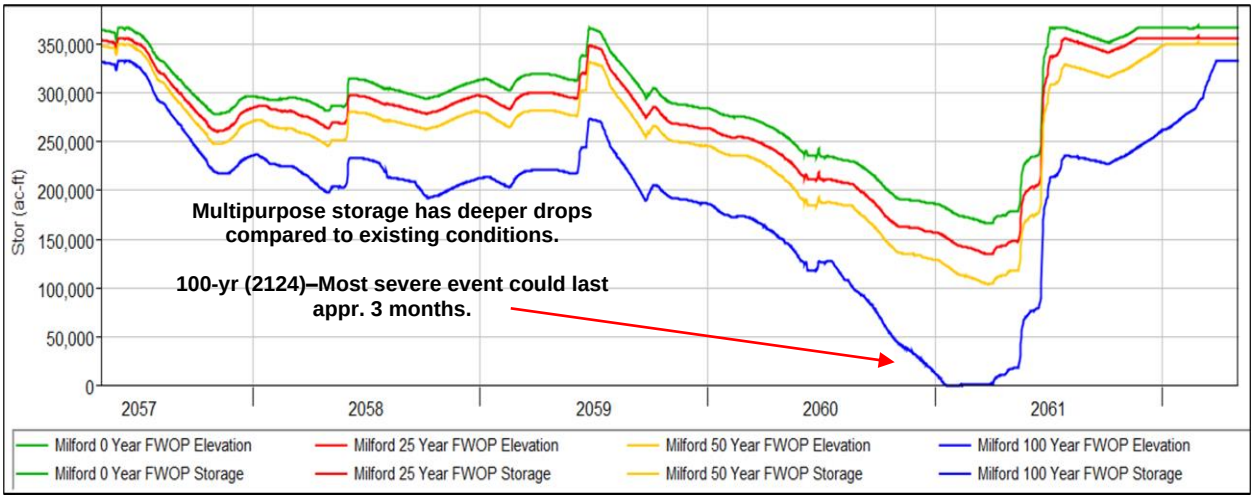
Figure 3-75 shows one of the floods of record in the Kansas River Basin, 2019, projected into the future under the FWOP scenarios to further exhibit a specific example of the small increases in frequency in the lower portions of the flood control pool as the storage diminishes due to sedimentation. For Milford Reservoir these are small differences compared to existing conditions.

Figure 3-75. Milford Reservoir Non-navigation FWOP Scenarios–Flood Example



During extreme low water years during drought conditions all FWOP scenarios show periods of reservoir elevations below the top of the multipurpose pool with sharper decreases under each additional FWOP scenario. The 2124 FWOP scenario shows one event where multipurpose storage is at minimum storage or completely depleted for an extended period (Figure 3-76). These conditions occur under periods when extreme drought conditions occur and all storage is used to meet downstream target flows on the Kansas River. The graphic represents the drought occurring in the 1950–1960s in the Kansas River Basin projected into the future under the FWOP scenarios, which include increased sedimentation in the reservoir. Milford is expected to experience substantial sedimentation over the next 100 years with approximately 80 percent of the multipurpose pool remaining in 2124.

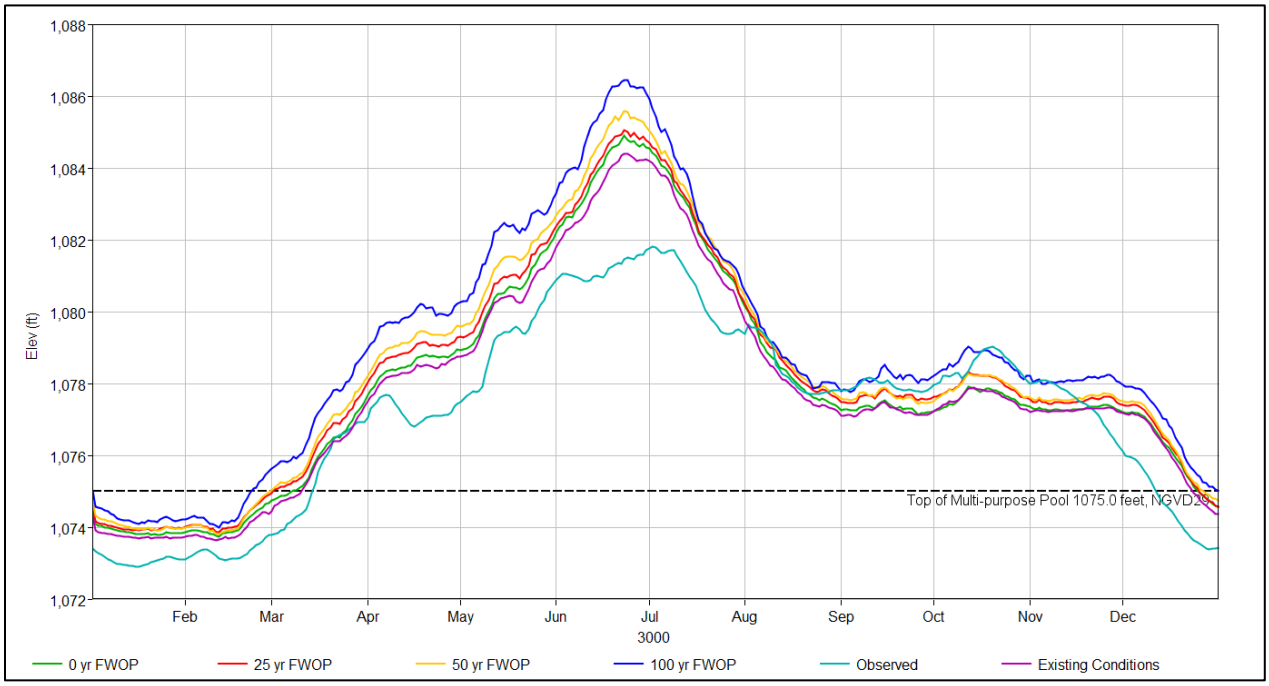
Figure 3-76. Milford Reservoir Storage Under FWOP Non-navigation Scenarios–Drought Example



3.2.6.1.4 Tuttle Creek Reservoir

Tuttle Creek Reservoir is projected to lose significant storage over the 100-years of the FWOP. As more sediment accumulates the average pool elevation increases. The 2124 FWOP has more variability because of the multipurpose pool being near full of sediment. This results in quick drops in the pool when low-flow water quality releases need to be made and quick rises in the pool as inflows are received (Figure 3-77). The 2124 FWOP also has lower pool elevations over the winter because the multipurpose pool storage available is often used for water quality releases.

Figure 3-77. Tuttle Creek Reservoir Daily Average Pool Elevations for the Observed and existing Conditions and the FWOP Scenarios (POR 2024 through 2124)



Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

Navigation flow support is provided by Tuttle Creek Reservoir in all of the FWOP scenarios. This results in increased frequency of pool elevations below the multipurpose pool. Higher pool elevations in the navigation FWOP scenarios are the same as those under the non-navigation FWOP scenarios. As the sediment increases the pool does not drop as far into the multipurpose pool because there is simply not as much depth. The decreasing storage results in the pool rising into the lower portions of the flood control pool more often (Figure 3-78 and Appendix B).

The Tuttle Creek Reservoir model shows increased frequency in the flood control pool and lessening drops into the multipurpose pool as the storage diminishes due to sedimentation (Figure 3-79).

Figure 3-78. Tuttle Creek Reservoir Pool Elevation Duration for the Four Non-navigation FWOP Scenarios (Period of Record 2024 through 2124)

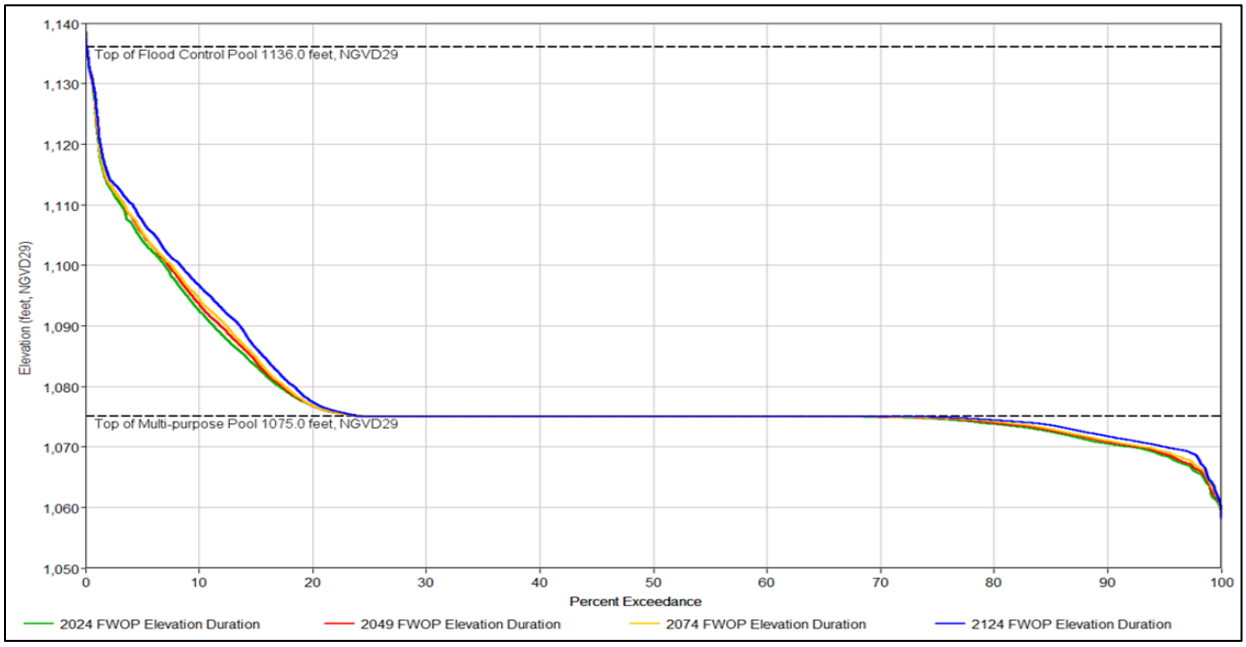
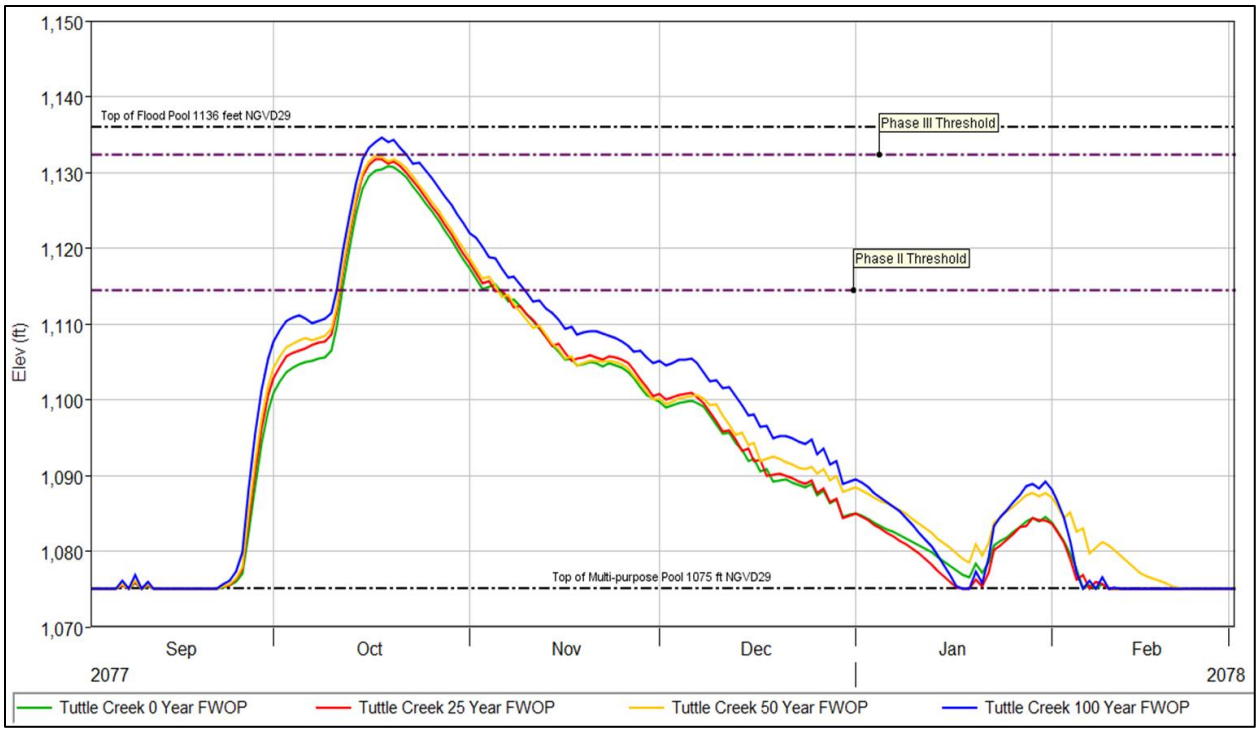


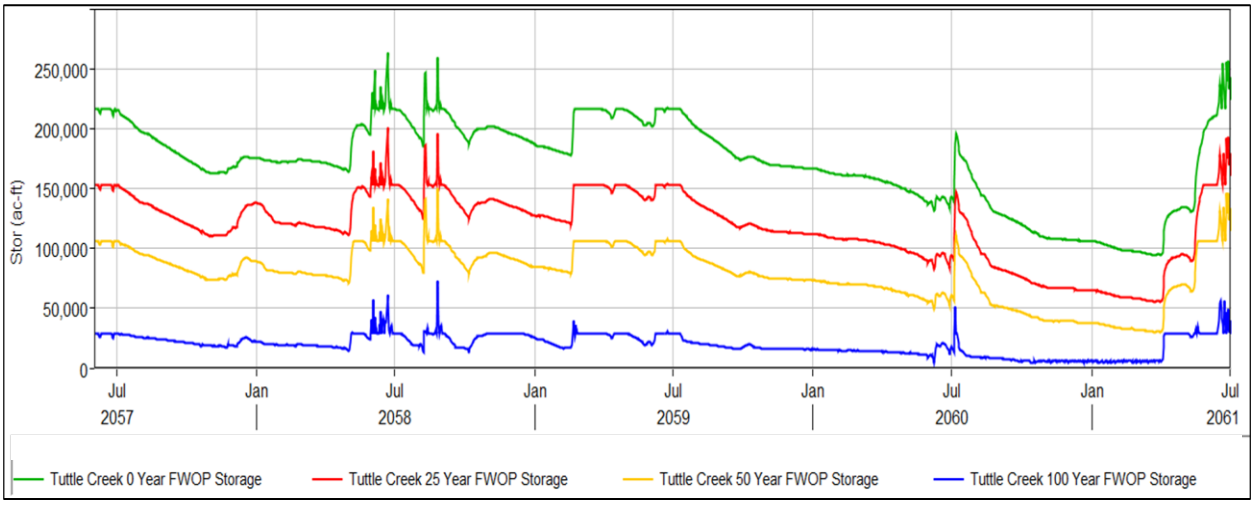
Figure 3-79 illustrates one of the floods of record in the Kansas River Basin, 1973, projected into the future under the FWOP scenarios to further exhibit a specific example of the increased frequency in the lower portions of the flood control pool as the storage diminishes due to sedimentation.

Figure 3-79. Tuttle Creek Reservoir Non-navigation Futures without Project Scenarios–Flood Example



During extreme low water years in drought conditions all FWOP scenarios show periods of reservoir elevations below the top of the multipurpose pool with sharper decreases under each additional FWOP scenario (Figure 3-80). These conditions occur under periods when extreme drought conditions occur and all storage is used to meet downstream target flows on the Kansas River. The graphic represents the drought occurring in the 1950s in the Kansas River Basin projected into the future under the FWOP scenarios, which include increased sedimentation in the reservoir. Tuttle Creek Reservoir is expected to experience substantial sedimentation over the next 100 years with approximately 7 percent of the multipurpose pool remaining in 2124. In the 2124 FWOP scenario, no meaningful storage remains in the Tuttle Creek Reservoir multipurpose pool to support downstream water targets.

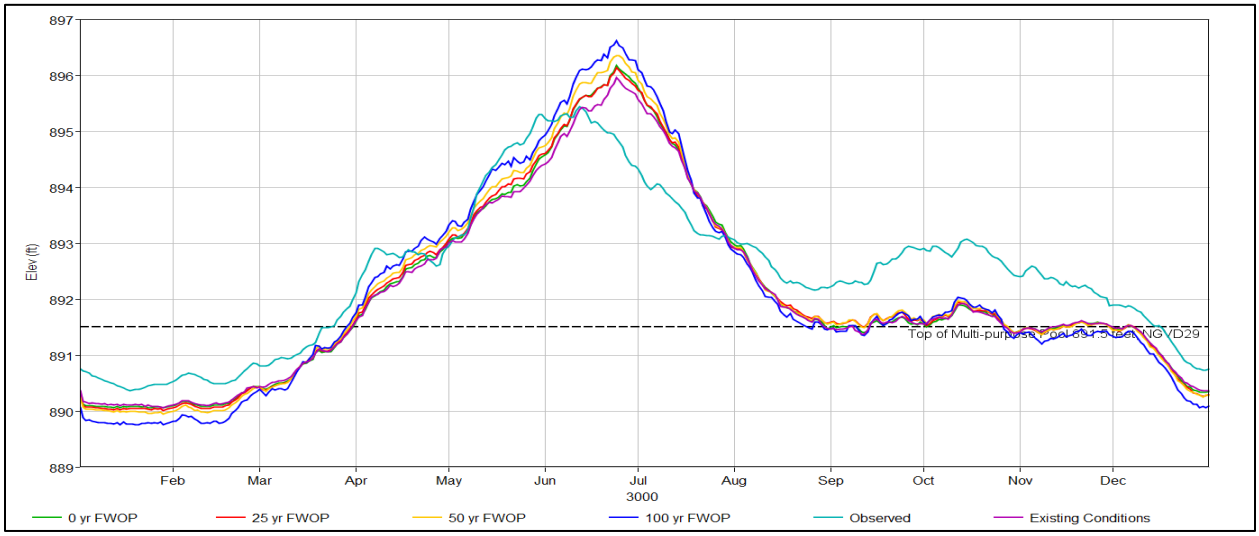
Figure 3-80. Tuttle Creek Reservoir Storage Under FWOP Non-navigation Scenarios–Drought Example



3.2.6.1.5 Perry Reservoir

There are not substantial differences between the FWOP scenarios for Perry Reservoir, but, as sediment increases, the pool elevations tend higher during flood season because of reduced storage in the multipurpose pool. As sediment increases, slightly lower pool elevations are seen in the drier months because the multipurpose pool drops quicker when making releases for water quality targets (Figure 3-81).

Figure 3-81. Perry Reservoir Daily Average Pool Elevations for the Observed and Existing Conditions and the FWOP Scenarios (Period of Record 2024 through 2124)



Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

Since navigation flow support is only provided from the future use water supply storage at Perry, navigation flow support is provided by Perry Reservoir in the FWOP scenario for 2024 but not for 2049, 2074, and 2124 as it is anticipated that the remaining storage will be called into service by the State of Kansas before these timeframes. Navigation releases under the 2024 FWOP results in increased frequency of dropping below the top of the multipurpose pool elevation. Higher pool elevations in the navigation scenario

are the same as those under the non-navigation 2024 FWOP scenario. The 2049, 2074, and 2124 FWOP scenarios did not provide navigation support flows, but some small impacts are assessed because of Tuttle Creek Reservoir providing the navigation support flows which then requires Perry Reservoir to make additional releases to support water quality targets (see Appendix B).

The Perry Reservoir model shows increased frequency in the flood control pool as the storage diminishes due to sedimentation. The 2124 FWOP initially has similar drops into the multipurpose pool compared to other scenarios and then drops farther than any other scenario due to running out of storage while supporting water quality target releases (Figure 3-82).

Figure 3-82. Perry Reservoir Pool Elevation Duration for the Non-Navigation FWOP Scenarios (POR 2024 through 2124)

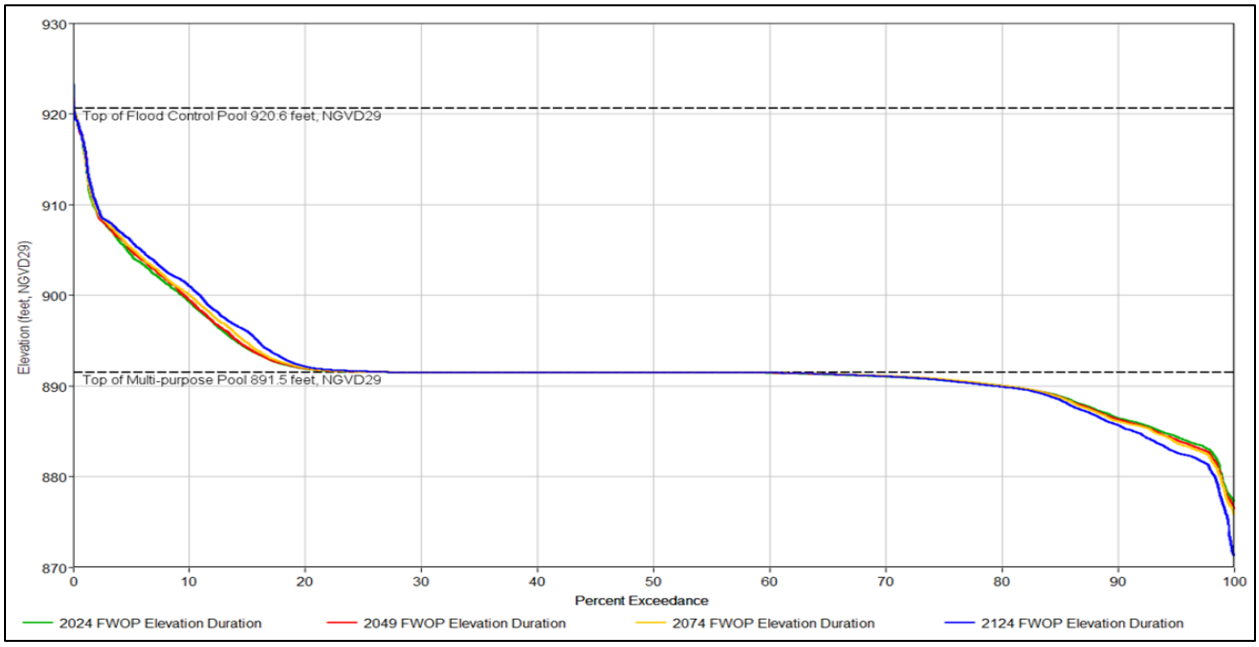
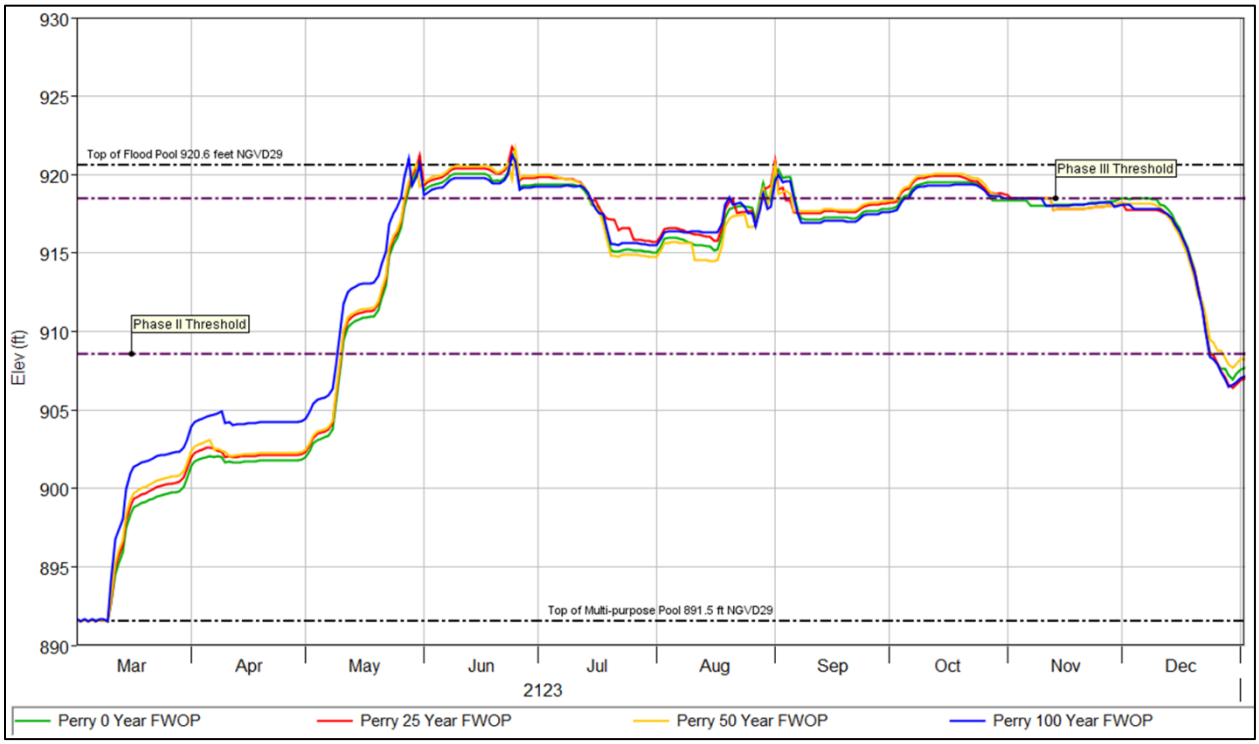


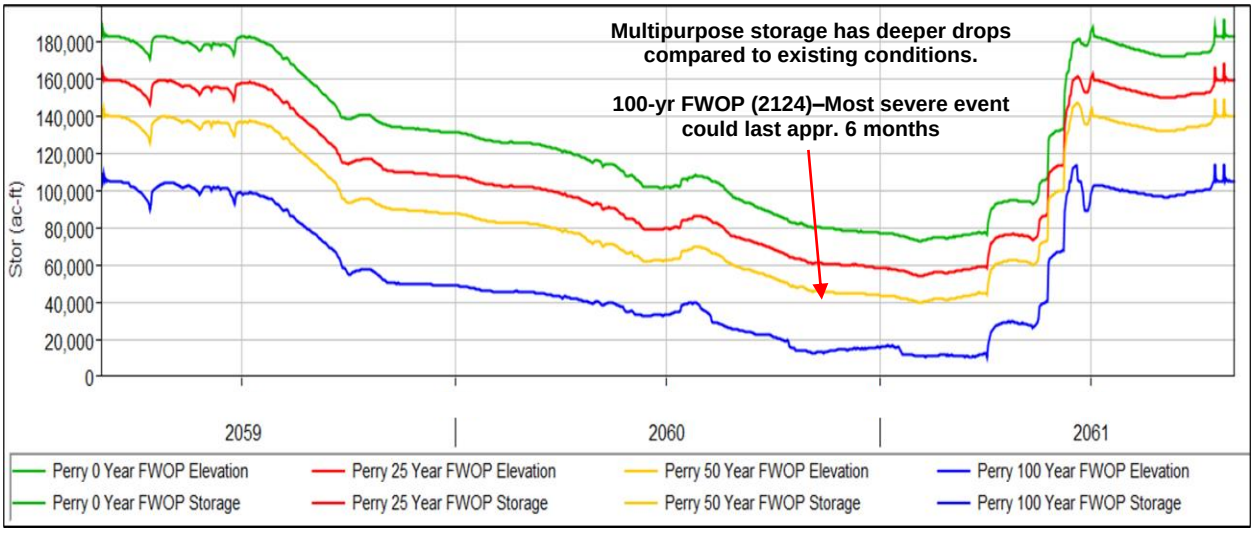
Figure3-83 illustrates one of the floods of record in the Kansas River Basin, 2019, projected into the future under the FWOP scenarios to further exhibit a specific example of the increased frequency in the lower portions of the flood control pool as the storage diminishes due to sedimentation. However, once the pool climbs further into flood control, the differences diminish.

Figure 3-83. Perry Reservoir Non-navigation FWOP Scenarios–Flood Example



During extreme low water years and drought conditions, all FWOP scenarios show periods of reservoir elevations below the top of the multipurpose pool with sharper decreases under each additional FWOP scenario. The 2124 FWOP scenario shows one event where multipurpose storage is functionally at a minimum for an extended period (Figure 3-84). These conditions occur under periods when extreme drought conditions occur and all storage is used to meet downstream target flows on the Kansas River. The graphic represents the drought occurring in the 1950-1960s in the Kansas River Basin projected into the future under the FWOP scenarios, which include increased sedimentation in the reservoir. Perry is expected to experience substantial sedimentation over the next 100 years with approximately 43 percent of the multipurpose pool remaining in 2124.

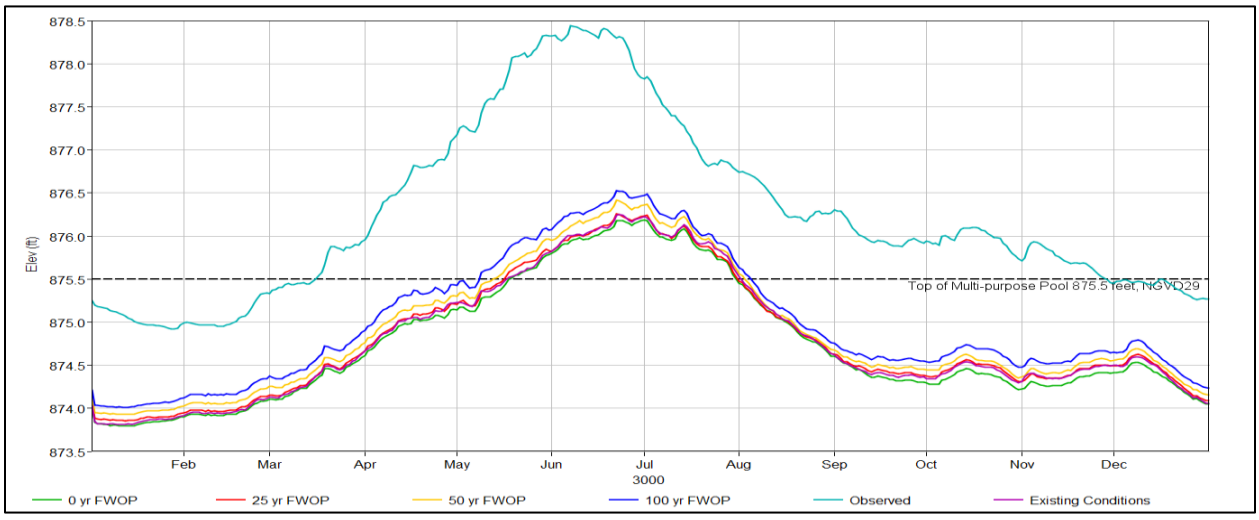
Figure 3-84. Perry Reservoir Storage Under FWOP Non-navigation Scenarios–Drought Examples



3.2.6.1.6 Clinton Reservoir

Navigation did not impact Clinton Reservoir since it does not support navigation flows. The median pool elevation tends to be near the top of the multipurpose pool but is slightly lower from July to March as water quality releases draw the reservoir down in the dry season. The existing conditions and the 2024 FWOP scenario are very similar as the sediment conditions do not change dramatically between these two scenarios for Clinton Reservoir. However, as more sediment accumulates with each additional FWOP scenario the average pool elevation also increases (Figure 3-85).

Figure 3-85. Clinton Reservoir Daily Average Pool Elevations for the Observed and Existing Conditions and the FWOP Scenarios (Period of Record 2024 through 2124)

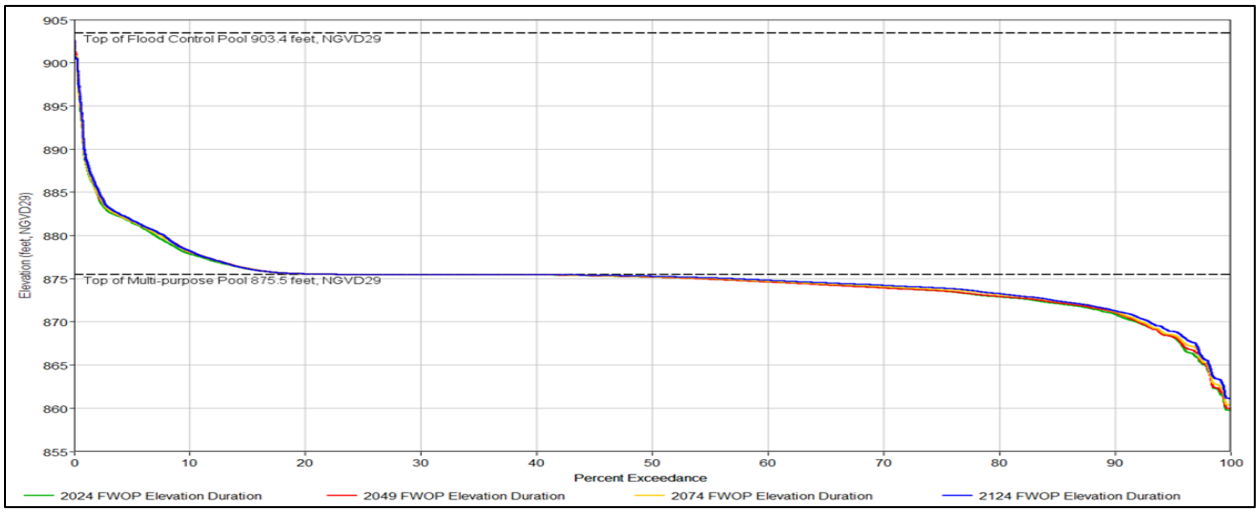


Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

The Clinton Reservoir model shows that the pool elevation does not drop as far into the multipurpose pool in the later FWOP scenarios. This is likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at

Clinton Reservoir. There are also small increased frequencies of higher pool elevations in the flood control pool (Figure 3-86).

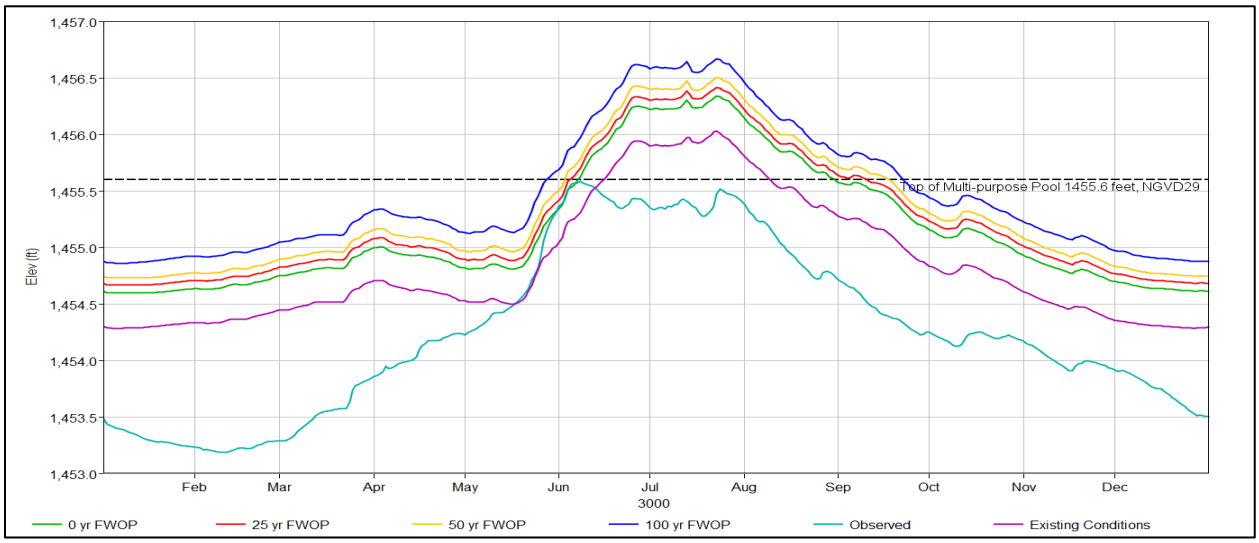
Figure 3-86. Clinton Reservoir Pool Elevation Duration for the Four Non-navigation FWOP Scenarios (Period of Record 2024 through 2124)



3.2.6.1.7 Waconda Reservoir

Navigation did not impact Waconda Reservoir since it does not support navigation flows. The median pool elevation is near or a little below multipurpose pool. As more sediment accumulates with each additional FWOP scenario the average pool elevation slightly increases (Figure 3-87).

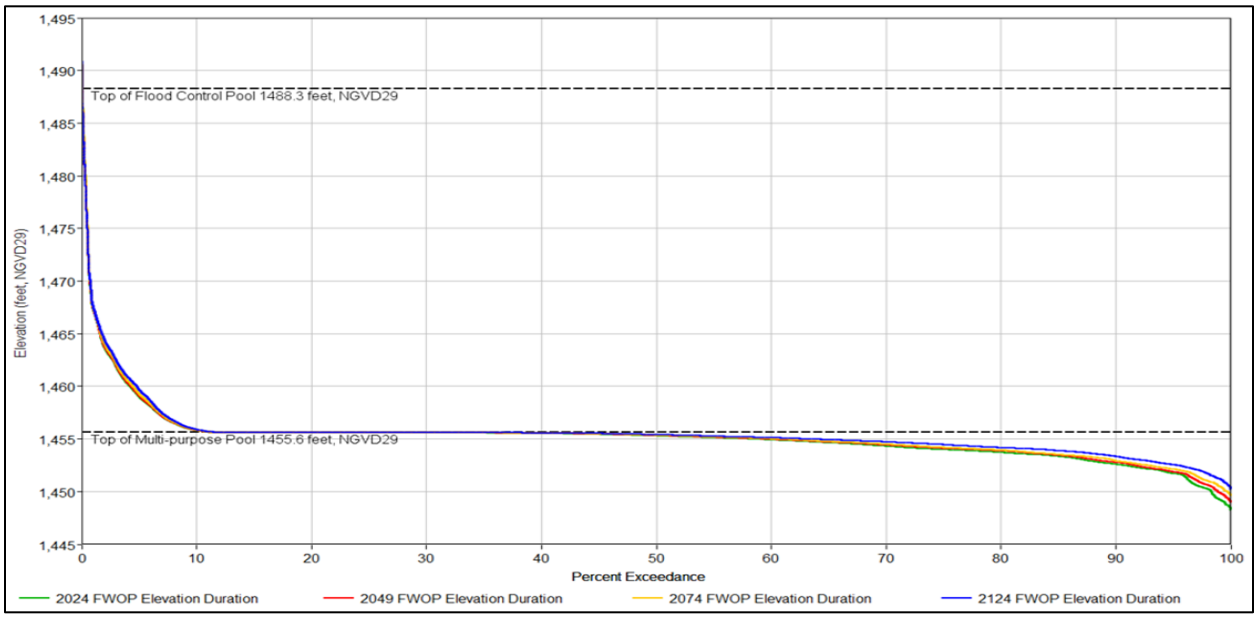
Figure 3-87. Waconda Reservoir Daily Average Pool Elevations for the Observed and Existing Conditions and the FWOP Scenarios (Period of Record 2024 through 2124)



Note: Existing Conditions=Modeled conditions; 0 yr FWOP=2024; 25 yr FWOP=2049; 50 yr FWOP=2074; 100 yr FWOP=2124

The Waconda Reservoir model shows that the pool elevation does not drop as far into the multipurpose pool in the later FWOP scenarios. This is likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at Waconda Reservoir (Figure 3-88).

Figure 3-88. Waconda Reservoir Pool Elevation Duration for the Four Non-navigation FWOP Scenarios (Period of Record 2024 through 2124)



3.2.6.1.8 Summary of Trends

Some clear trends were established between the four FWOP non-navigation scenarios. Reservoir storage decreased with each successive FWOP scenario. Multipurpose storage loss was largest at Kanopolis, Tuttle Creek, and Perry reservoirs. Small losses in the flood control pool area are also experienced in all the reservoirs. Clear trends and the main takeaways include:

- As sediment accumulates in the multipurpose pool, the average pool elevation increases. Some small increases are also seen in the higher 95th percentile pool elevations, but the trend is not as clear. The exception to this trend is Milford Reservoir as pool elevations are lower due to increased water quality releases.
- As sediment accumulates in the multipurpose pool, the reservoir outflows remain virtually unchanged. Average releases are slightly increased for some reservoirs. Milford and Perry have slightly increased releases in the 100-year FWOP for the low-flow releases. The is no difference in the 95th percentile outflows for each FWOP scenario.
- As the Tuttle Creek Reservoir multipurpose storage decreases, more of the Topeka and De Soto, Kansas, water quality releases are shifted to Milford and Perry reservoirs. This results in lower pool elevations at Milford Reservoir overall and at Milford and Perry reservoirs during extreme drought conditions. There are some trends where the river flows drop below the water quality targets more often in the future. Water supply storage at Milford and Perry reservoirs is, at times, needed to meet the water quality flow targets.
- River high flows are very similar across the FWOP scenarios. Average flows are slightly increased.

- More stress is placed on the water supply storage due to loss of storage while there is expected increased future usage to satisfy demands of growing populations.
- Future shortages to meet all the water quality and supply demands within the basin during times of extended drought.
- Future shortages to maintain a base level of streamflow.
- Increases in the above due to climate change (extreme storm events, more extreme droughts, more extensive storms).

Of the four navigation FWOP scenarios navigation flow support leads to lower multipurpose pool elevations at Milford, Tuttle Creek, and Perry reservoirs.

3.2.6.2 Hydrology and Hydraulics

A statistical analysis was conducted for selected downstream gages at Enterprise, Topeka, and De Soto, Kansas and there appears to be small increases in average flow (Figure 3-89 through Figure 3-91). This may be due to more water being passed through the reservoirs since there is diminished storage throughout the FWOP.

Generally, the assessment of the downstream gages evaluated the changes under the eight FWOP scenarios for the FWOP POR (i.e., January 2024 through January 2124). During extreme low water years during drought conditions, the FWOP modeling results at the downstream gages show periods where flows are well below the targets at the Topeka and De Soto, Kansas, gages. Specific examples are included in the discussion to set the benchmark for future conditions if no action is taken to reduce the risks related to reservoir sedimentation and drought.

Figure 3-89. Smoky Hill River at Enterprise Average Flow Compared for each Future without Project Scenario (Period of Record 2024 through 2124)

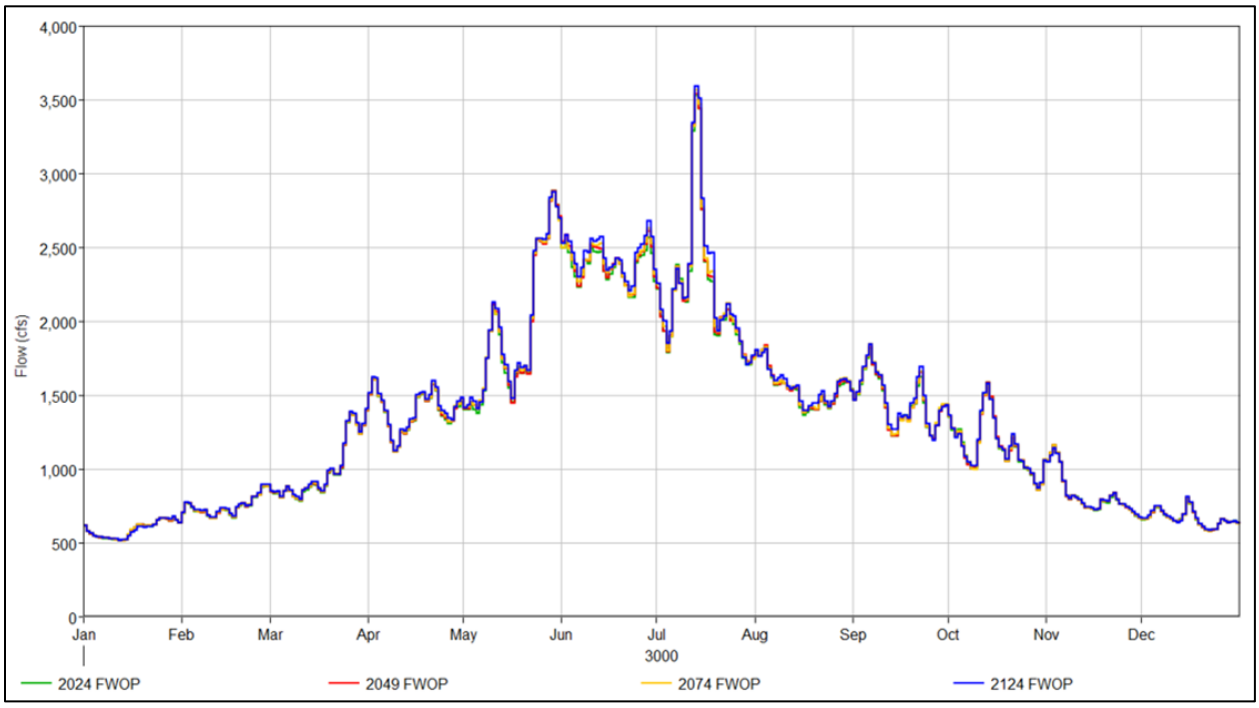


Figure 3-90. Kansas River at Topeka Average Flow Compared for each Future without Project Scenario (Period of Record 2024 through 2124)

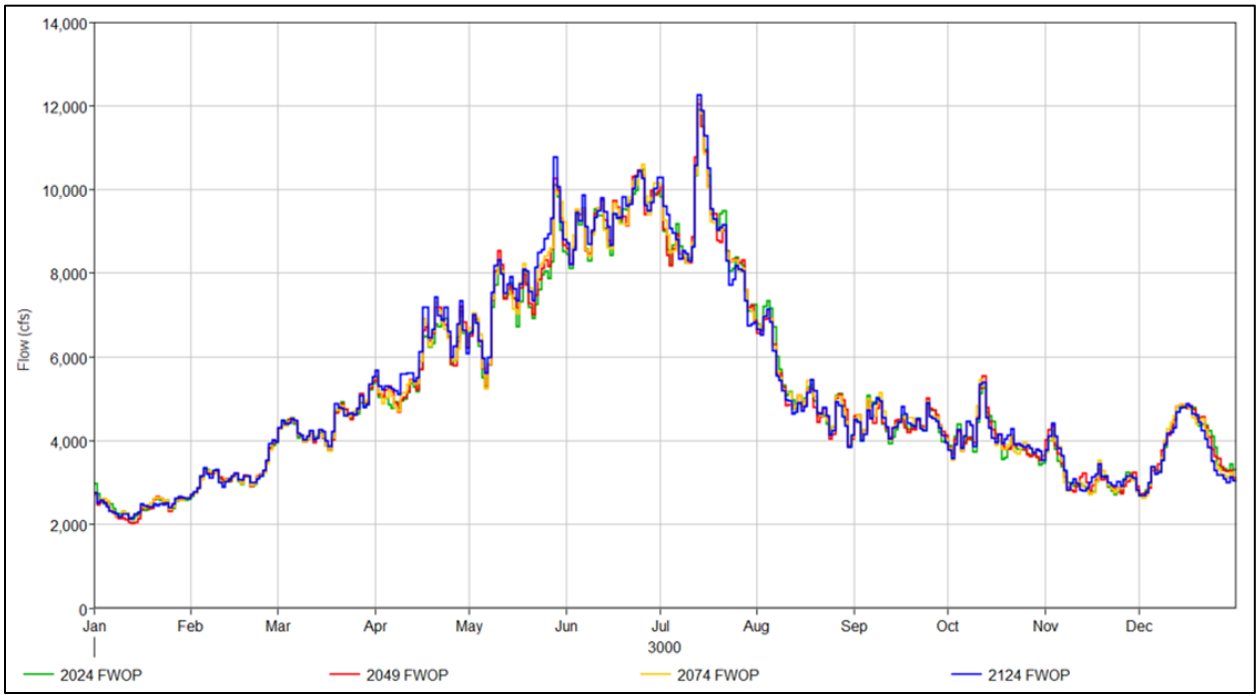
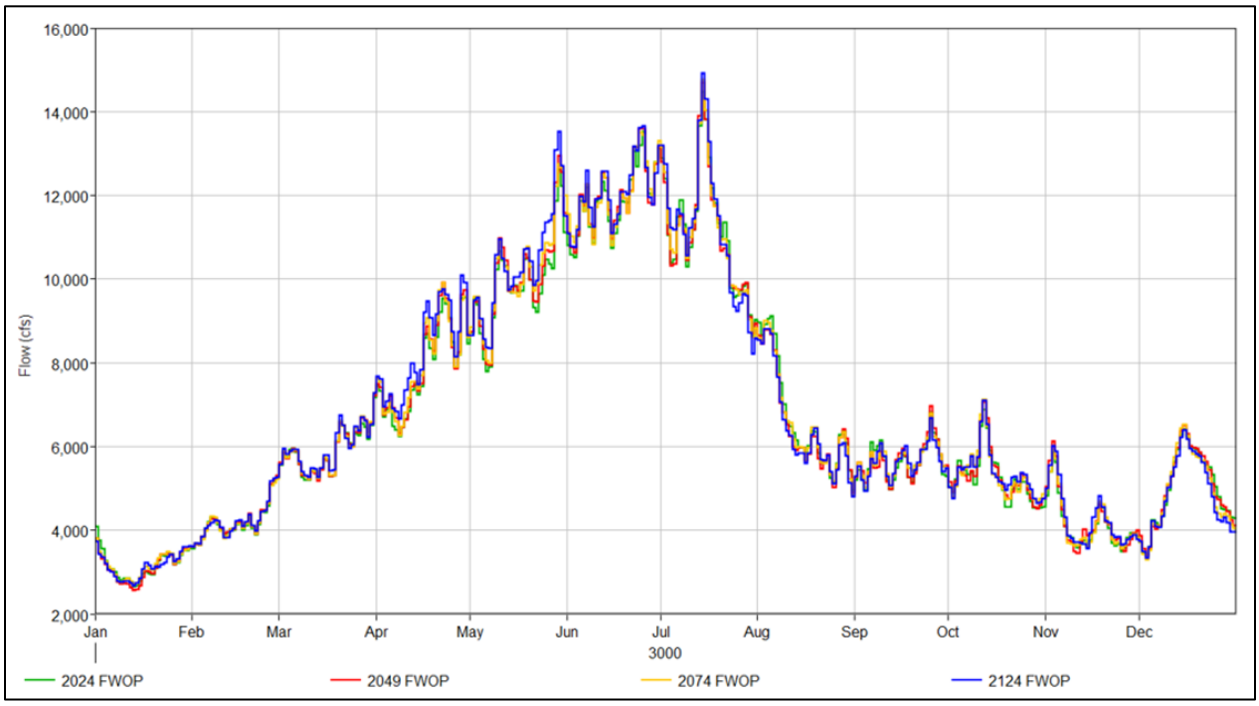


Figure 3-91. Kansas River at De Soto Average Flow Compared for each Future without Project Scenario (Period of Record 2024 through 2124)



The graphic for average daily flows at the three gages under the four FWOP scenarios indicates very little impact on the downstream gages from the increased reservoir sedimentation projected. However, there are some subtle impacts and changes. The water quality targets established on the Kansas River at Topeka and De Soto, Kansas, were evaluated to determine how often the target flows were not met over the POR (2024 through 2124). Of the 36,526 days in the 100-year modeling period, a few days dropped below target as shown in Table 3-42. Some natural variation in releases is observed in the model output. However, between the FWOP scenarios, there is a clear trend that the Topeka water quality target is not met as consistently in the 2124 scenarios for non-navigation and navigation and the drought of record shows systematic loss of water to meet downstream water quality targets in the 2124 scenarios. The 2124 scenario is shown in Appendix B. As described in Appendix B, the 2124 scenario has fewer days below the minimum targets than the 2024, 2049, and 2074 scenarios. This is because the Res-Sim model rules smooth multipurpose releases near the lower portion of the multipurpose pool and gives the appearance of smoother flows downstream when averaged over the POR. As discussed below, there are periods within the overall POR in the 2124 scenario when flows are extremely low for extended periods. The navigation FWOP scenarios also show more days below target than their non-navigation counterparts.

Table 3-44. Days Below the Water Quality Minimum Flow Targets at Topeka and De Soto

	Kansas River at Topeka		Kansas River at De Soto	
Scenario	Days below the Minimum Target	Days more than 50 cfs below Minimum Target	Days below the Minimum Target	Days more than 50 cfs below Minimum Target
2024 FWOP Non-Navigation	672	38	1,395	326
2024 FWOP Navigation	739	40	1,399	383
2049 FWOP Non-Navigation	638	33	1,382	362
2049 FWOP Navigation	726	33	1,465	431
2074 FWOP Non-Navigation	616	37	1,347	354
2074 FWOP Navigation	673	45	1,503	479

During extreme low water years during drought conditions the FWOP modeling results at the downstream gages show periods where flows are well below the targets at the Topeka and De Soto, Kansas, gages. Flows under the 2124 FWOP scenario at Topeka, Kansas are as low as 100 cfs for an extended period compared to the existing condition and not able to meet the target flow at that location of 600 to 750 cfs depending on the time of year (Figure 3-92). At the De Soto, Kansas, gage, flows are as low as 200 cfs for an extended period compared to existing conditions and at that location are not able to meet the target flow of 700 to 1,000 cfs depending on the time of year (Figure 3-93). These are examples that could occur in the future with no project under extreme drought conditions similar to those experienced in the Kansas River Basin in the 1950s.

Figure 3-93. Kansas River Average Flow at Topeka for Non-navigation Future without Project Scenarios–Drought Example

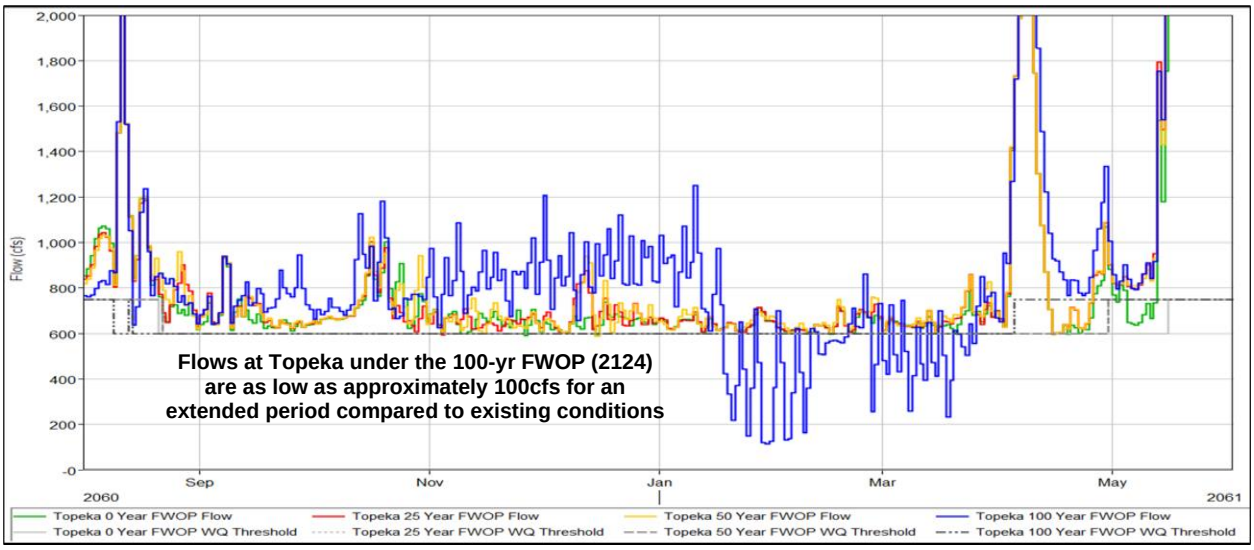
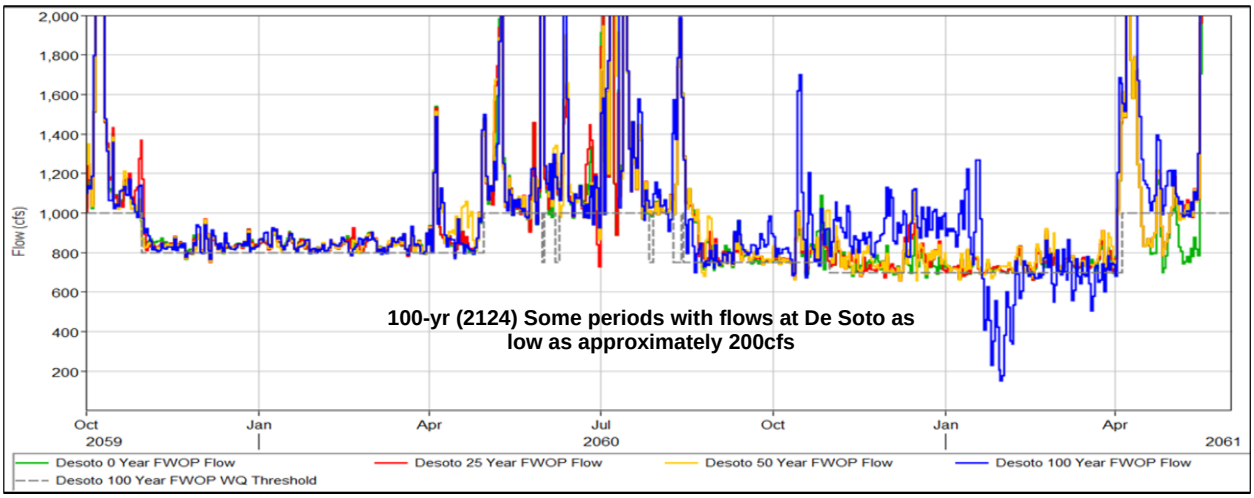


Figure 3-93. Kansas River Average Flow at De Soto for Non-Navigation Future without Project Scenarios–Drought Example



Frequency flows were developed for the FWOP using the same methodology as the existing conditions frequency flows for the mainstem Kansas River gages described in Section 3.2.5, Hydrology/Hydraulics/Flood Risk-Life Safety Assessment. FWOP daily flows were developed for the POR with projected sedimentation in the reservoirs for 25, 50, and 100 years into the future. The 100-year FWOP scenario used for reservoir operations was used in the FWOP flow frequency analysis because it was expected to have the largest impact compared to existing conditions. The average percent differences in peak annual daily flows for existing conditions and FWOP 100-year were less than 7 percent for all of the mainstem gages except Wamego, Kansas which was approximately 11 percent. The 100-year FWOP frequency flows are included in Table 3-43.

Table 3-45. FWOP 100-Year Regulated Frequency Flows for the Mainstem Gages

Annual Exceedance Probability (percent)	De Soto	Lecompton	Topeka	Wamego	Fort Riley
0.2	361,000	365,000	396,000	378,000	283,000
0.5	277,000	276,000	276,000	241,000	183,000
1	225,000	220,000	211,000	172,000	130,000
2	182,000	173,000	160,000	123,000	91,900
5	135,000	123,000	110,000	78,300	57,800
10	105,000	92,200	80,900	55,300	40,600
20	78,900	67,400	57,900	38,400	28,200
50	47,900	40,600	33,300	22,300	16,800

Based on the small differences in peak annual daily flows for the FWOP 100-year (less than 7 percent for all of the mainstem gages except Wamego, Kansas which was approximately 11 percent), the hydraulic models were used to determine if there were notable impacts to the hydraulics compared to existing conditions. The 100-year FWOP

peak flows vary less than 2 percent at every mainstem Kansas River gage for the three events modeled (0.2 AEP flood event, 1 percent AEP flood event, and 10 percent AEP flood event). This margin is well within the bounds of assumed model accuracy for producing depth grids and inundation boundaries (Appendix C). To verify that the flow differences would have a negligible impact, the maximum stage change at all mainstem gages except Topeka, Kansas, were estimated for the 0.2 percent AEP flood event. Topeka, Kansas, was not included as the levees in the area overtop from the 0.2 percent AEP flood event and information was difficult to develop for this location. Based on model results, the average stage increase for a 2 percent flow increase is approximately 0.21 feet. Since this difference is within the range of model accuracy, future conditions were not conducted in the hydraulic analysis of the watershed study (Appendix C). Additionally, the incipient overtopping flows for two of the Kansas River levee systems (Topeka Levee Units and Kansas City Levee Units) was checked to determine if changes in flows could show changes to flood inundation mapping due to levee overtopping. With very small changes to FWOP peak flows, levee overtopping status is not expected to change and flood inundation map differences would likely be negligible.

3.2.6.3 Flood Risk/Life Safety

The flood risk and life safety described for the existing conditions in Section 3.2.5.3, Flood Risk/Life Safety, will continue in the future with risk to the PAR related to life loss and economic damages that could occur. Under the FWOP the peak flows are expected to vary less than 2 percent at every mainstem Kansas River gage and, therefore, there was no LifeSim modeling conducted for the FWOP. The results of the LifeSim modeling for existing conditions if any of the three modeled flood events occur could be realized in the future.

3.3 Reservoir Sedimentation

The construction of dams on major Kansas River tributaries created significant discontinuities in the natural sediment transport regime of the Kansas River Basin, i.e., the slack water of the lakes induces sediment deposition while the release sediment-poor water (also known as hungry water) induces degradation and bank erosion downstream.

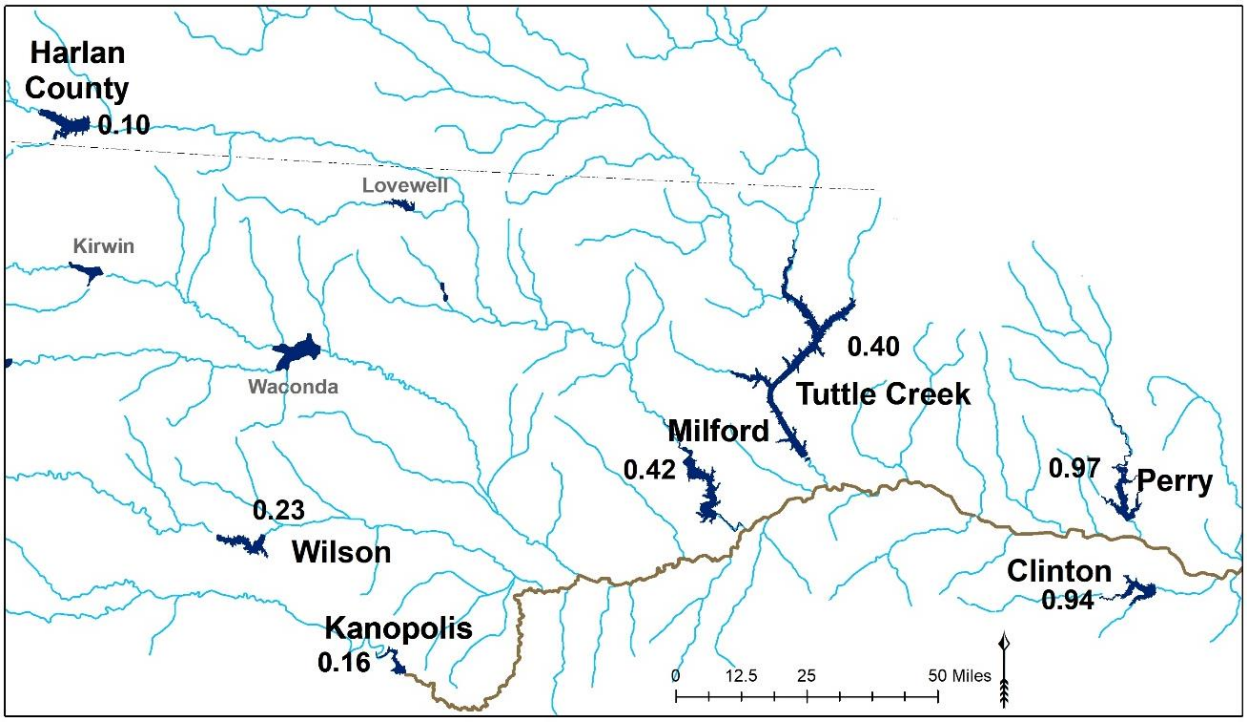
USACE, USGS, and the State of Kansas measured various aspects of sedimentation since before the construction of the dams to the present. These include elevation change, incoming and outgoing sediment concentrations, trapping efficiencies, sediment properties like bulk density and size gradation, and other parameters. This rich data allowed the computation of the current and future status for lake sedimentation and downstream degradation. See the technical appendices for detail on the methodologies, data availability, quality, and gaps, and for descriptions of the availability of infrastructure (gates, etc.) that could be used in sediment management measures. The following sections summarize the findings.

3.3.1 Reservoir Sediment Deposition

Figure 3-94 maps the average annual sediment deposition per square mile of unregulated drainage area at USACE lakes. As seen, the eastern watersheds produce

much more sediment per square mile than the western watersheds. This is due to the difference in mean annual precipitation, which quadruples from Western Kansas to Eastern Kansas.

Figure 3-94. Average annual deposition per square mile of unregulated drainage area at U.S. Army Corps of Engineers' lakes (acre-feet/years/miles$^{2)}$. Smaller labels indicate USBR lakes.



Tables 3-44 and 3-45 list the total sedimentation in each of the USACE and USBR lakes, respectively. As seen in Table 3-44, the multipurpose pools are much more affected than the flood pools. Some of the flood pool measurements report an increase in available volume rather than the decrease expected due to sedimentation. This occurs due to the shift in measurement methods from sediment rangelines to LiDAR; the older rangelines erroneously missed storage volume that the newer LiDAR detected. The annual flood control pool deposition amounts were corrected to account for this shift as much as possible. However, Clinton Dam reservoir still indicates a negative flood control pool deposition rate due to insufficient data to perform the correction. Future LiDAR surveys will allow a more accurate computation for flood pool deposition.

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Table 3-46. Total Sediment Accumulation in USACE Lakes (Lakes listed East to West)

Lake	MPP Initial Volume, acre-feet (Survey Year)	MPP Recent Volume, acre-feet (Survey Year)	Percent of MPP Lost to Sediment	MPP Deposition (acre-feet/year)	FCP Initial Volume, acre-feet (Survey Year)	FCP Recent Volume, acre-feet (Survey Year)	Percent of FCP Lost to Sediment	FCP Deposition (acre-feet/year)**
Clinton	129,171 (1977)	113,032 (2019)	12	384	268,367 (1977)	291,570 (2019)	-8.6*	-552
Perry	243,220 (1969)	200,004 (2009)	18	1,080	521,880 (1969)	515,519 (2009)	1.2	159
Tuttle Creek	424,312 (1962)	257,014 (2009)	39	3,794	1,942,705 (1962)	1,870,735 (2000)	3.7	1,242
Milford	415,352 (1967)	373,152 (2009)	10	1,558	757,746 (1967)	757,872 (2009)	-0.02*	178
Kanopolis	73,200 (1948)	47,170 (2017)	36	374	447,091 (1948)	413,521 (2007)	2.3	147
Wilson	247,835 (1964)	236,188 (2008)	4.7	459	530,710 (1964)	529,289 (2008)	0.5	28
Harlan County	346,512 (1951)	314,111 (2000)	9.4	756	503,488 (1951)	500,000 (2000)	0.7	69

*Negative deposition is a numerical artifact caused by the shift in survey methods.
**FCP deposition rates have been corrected where possible to account for the shift in survey methods from rangelines to LIDAR. At Clinton Lake, the data were insufficient to make the adjustment.

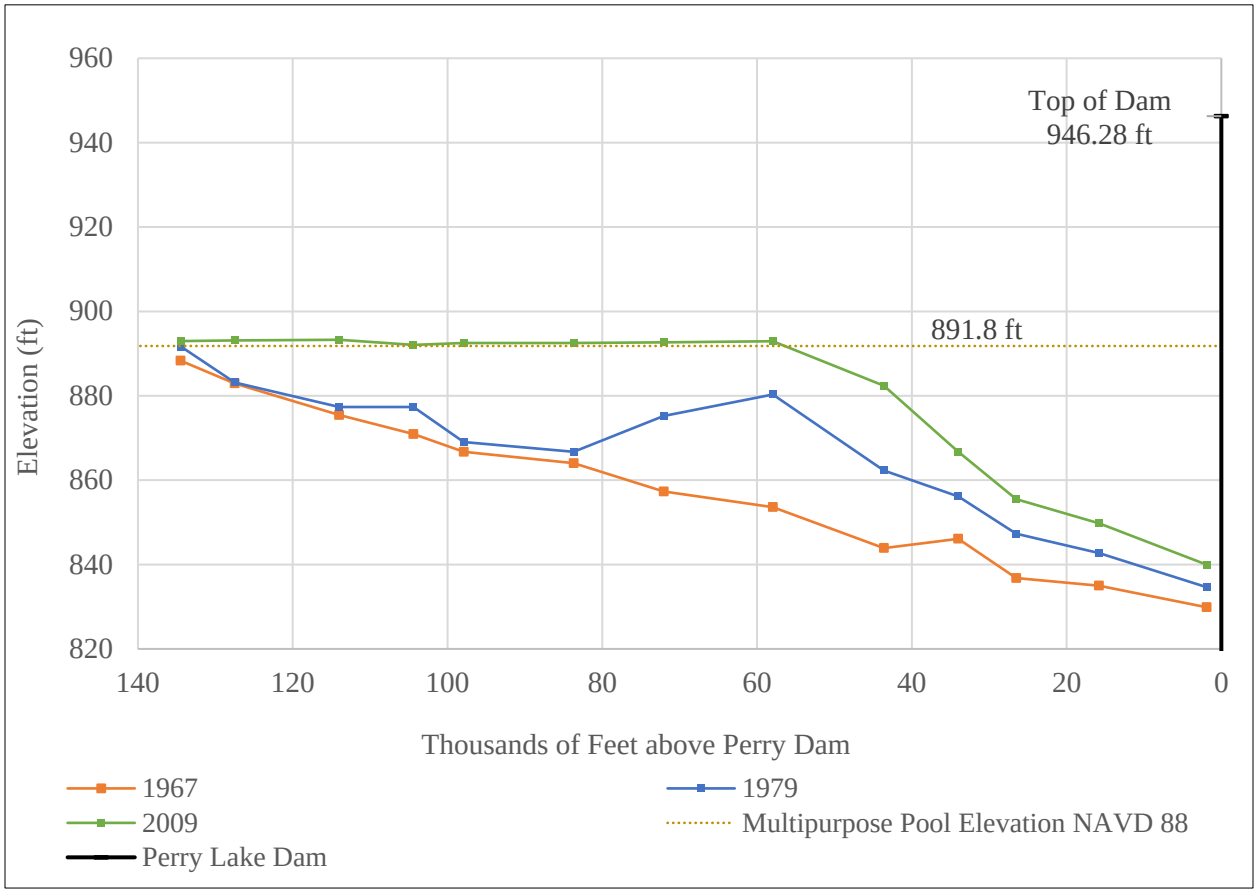
Table 3-45 provides the sedimentation values for the USBR lakes. Flood pool measurements were not available for these lakes.

Table 3-47. Total Sediment Accumulation in USBR Lakes

Lake	MPP Initial Volume, acre-feet (Survey Year)	MPP Recent Volume, acre-feet (Survey Year)	Volume Lost from MPP (acre-feet)	Percent of MPP Lost to Sediment	MPP Deposition (acre-feet/year)
Lovewell	41,687 (1957)	35,666 (1995)	6,021	14.4	158
Waconda	242,017 (1967)	219,420 (2001)	22,597	9.3	670
Kirwin	99,432 (1955)	98,154 (1996)	1,278	1.3	31
Webster	77,370 (1956)	76,103 (1996)	1,267	1.6	32
Cedar Bluff	185,496 (1950)	172,452 (2000)	13,044	7.0	262
Keith Sebelius	36,127 (1964)	34,510 (2000)	1,617	4.5	45
Harry Strunk	41,120 (1951)	34,647 (2006)	6,473	15.7	118
Hugh Butler	37,840 (1997)	36,224 (1997)	1,616	4.3	45
Swanson	120,366 (1953)	110,175 (2011)	10,191	8.5	176
Enders	44,482 (1950)	42,910 (1997)	1,572	3.5	34

Sediment deposited both as a delta at the upstream end of the lake and as a veneer throughout the multipurpose pool. Figure 3-95 shows the delta progression for Perry Reservoir. See technical Appendices D1–D4 for similar figures for all USACE reservoirs.

Figure 3-95. Delta Progression at Perry Reservoir



3.3.2 Sediment Effects on Operation and Maintenance Costs

Sedimentation impacts O&M costs at Kansas River basin reservoirs. At Kanopolis Reservoir, two targeted dredging actions occurred to remove sediment interfering with the deployment and operation of the emergency bulkheads. At Harlan County Lake, sediment blocking marina and boat ramp access is periodically removed.

3.3.3 Sediment Trapping During Flood Control Operations

As seen in Table 3-44, the multipurpose pools of each of the lakes accumulated much more sediment than the flood control pools, both in absolute volumes and as a percentage of the original pool volume. Daily flows, daily recorded pool elevations, and calibrated rating curves from each lake were used to determine whether the sediment enters the lake during multipurpose or during flood control operations. This was defined in two ways: as the daily pool elevation being at or below versus above the multipurpose pool elevation and as the daily pool elevation being at or below versus above the Water Level Management Plan (WLMP) elevation. The WLMP reflects the seasonal target water surface elevations, which may be higher or lower than the top of

the multipurpose pool. Table 3-46 provides these percentages for each lake. The sediment is classified according to when it enters the lake, but the quantity indicates the volume that eventually deposits rather than the incoming volume (i.e., it subtracts the small percentage that passes through the dam).

Table 3-48. Incoming Sediment during Flood Control and Multipurpose Operations (Lakes listed East to West)

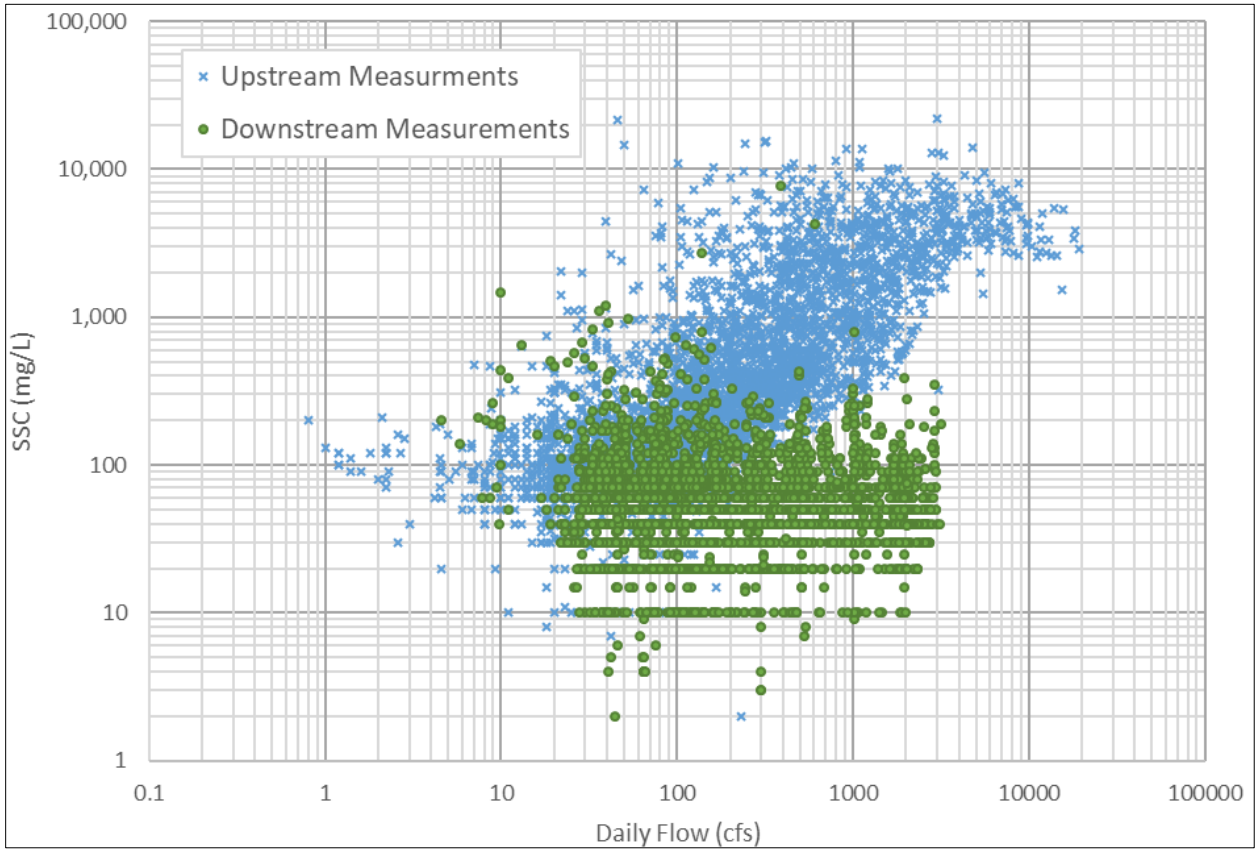
Lake	Deposition Years	Total Deposition (acre-feet)	Percent at/below Multipurpose Pool	Percent above Multipurpose Pool	Percent at/below WLMP	Percent above WLMP
Clinton	1977–2019	23,812	9	91	17	83
Perry	1969–2009	100,864	7	93	24	76
Tuttle Creek	1965–2019	302,110	5	95	5	95
Milford	1967–2019	62,517	10	90	5	95
Kanopolis	1969–2019	21,598	3	97	23	77
Wilson	1973–2019	23,235	18	82	33	67
Harlan County	1957–2019	20,006	30	70	No WLMP	

As seen in Table 3-46, nearly all of the sediment that eventually deposits in the lake enters during flood control operations. This is true whether the definition for flood control operations is that the lake level is above the multipurpose pool or that the lake level is above the WLMP. If all the flood water were passed around or through the dam, there would be very little sedimentation in the lakes. Thus, impounding water for the flood control authorized purpose induces the sedimentation that impacts other authorized purposes.

3.3.4 Downstream Sediment Concentrations and Degradation

The lakes trap virtually all incoming sediments and release clear water downstream. This results in clear water releases with deleterious ecological effects as well as degradation of the bed and banks in the downstream channel. Figure 3-96 provides an example of the change in sediment concentration for the inflow versus the outflow to Kanopolis Lake. As seen, sediment concentrations at moderate and high flows are up to two orders of magnitude higher than the outgoing sediment. See Appendix A1-7 for similar graphs for the remaining lakes.

Figure 3-96. Sediment Concentrations in Inflows versus Outflows from Kanopolis Lake



The incoming sediment concentrations reflect the natural (i.e., no dam) sediment concentrations. Sediment management strategies increasing downstream concentrations to within the range of variability of the incoming sediment concentrations could be considered restorative in nature, while sediment releases exceeding the upstream concentrations could induce negative impacts downstream. Thus, the demarcation of the incoming sediment concentrations is especially important for describing the existing conditions and for correctly characterizing potential management options. Figure 3-97 provides the sediment concentration in the incoming flows to each of the USACE lakes. The lines represent the conditional distribution of suspended sediment concentration, given an amount of flow, with the solid line representing the best fit and the dotted lines excluding the highest and lowest 10 percent in order to show the typical range of concentration.

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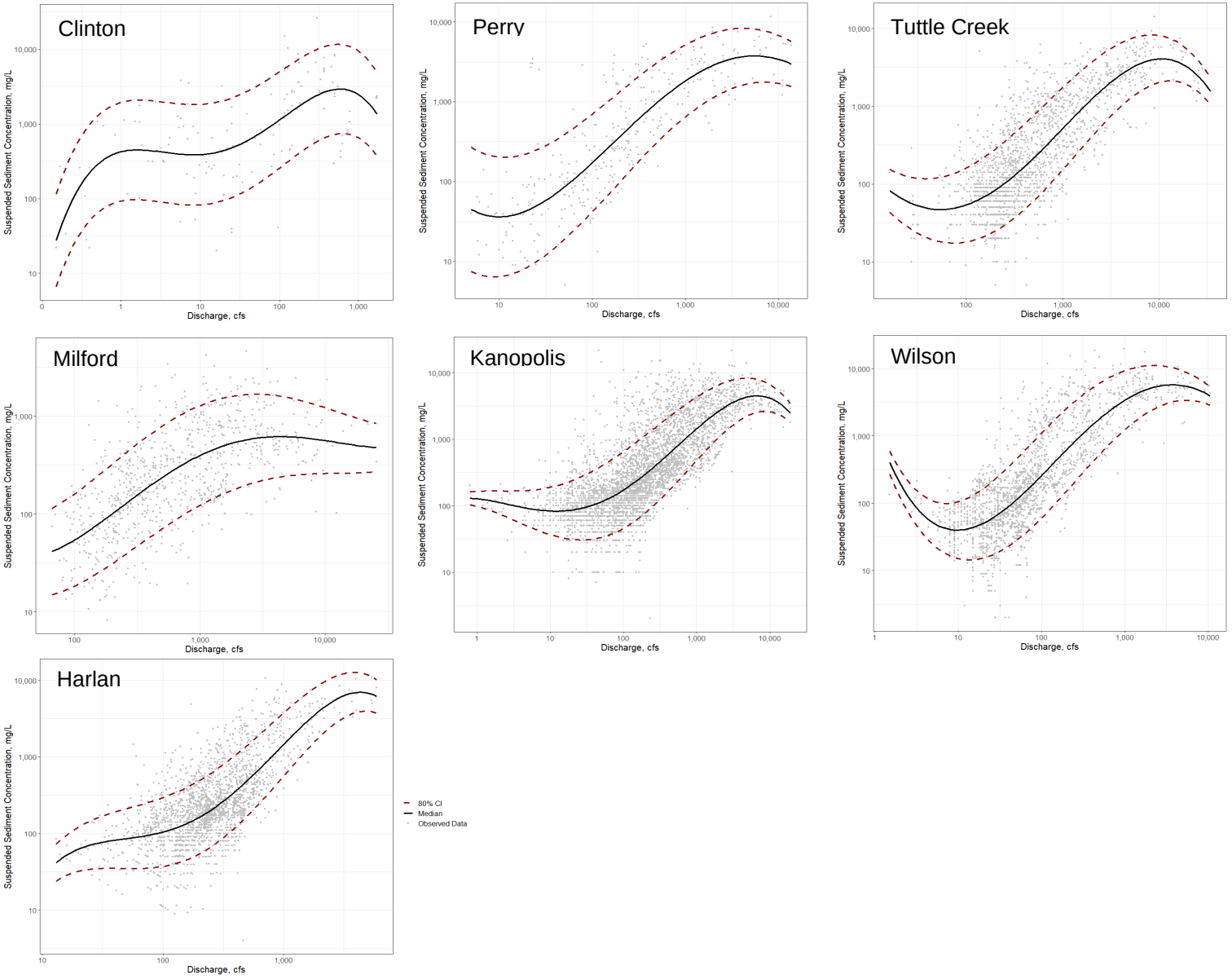
Figure 3-97. Sediment Concentration in Lake Inflows with 80 Percent Confidence Intervals



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Degradation rangelines downstream from each dam indicate that the trapping of sands and gravel by the dams induced bed degradation and bank erosion in the channels downstream. Figure 3-98 shows degradation downstream from Tuttle Creek Lake. Figures for the rest of the lakes are provided in the technical appendices (Appendix D).

Figure 3-98. Degradation Downstream from Tuttle Creek Lake

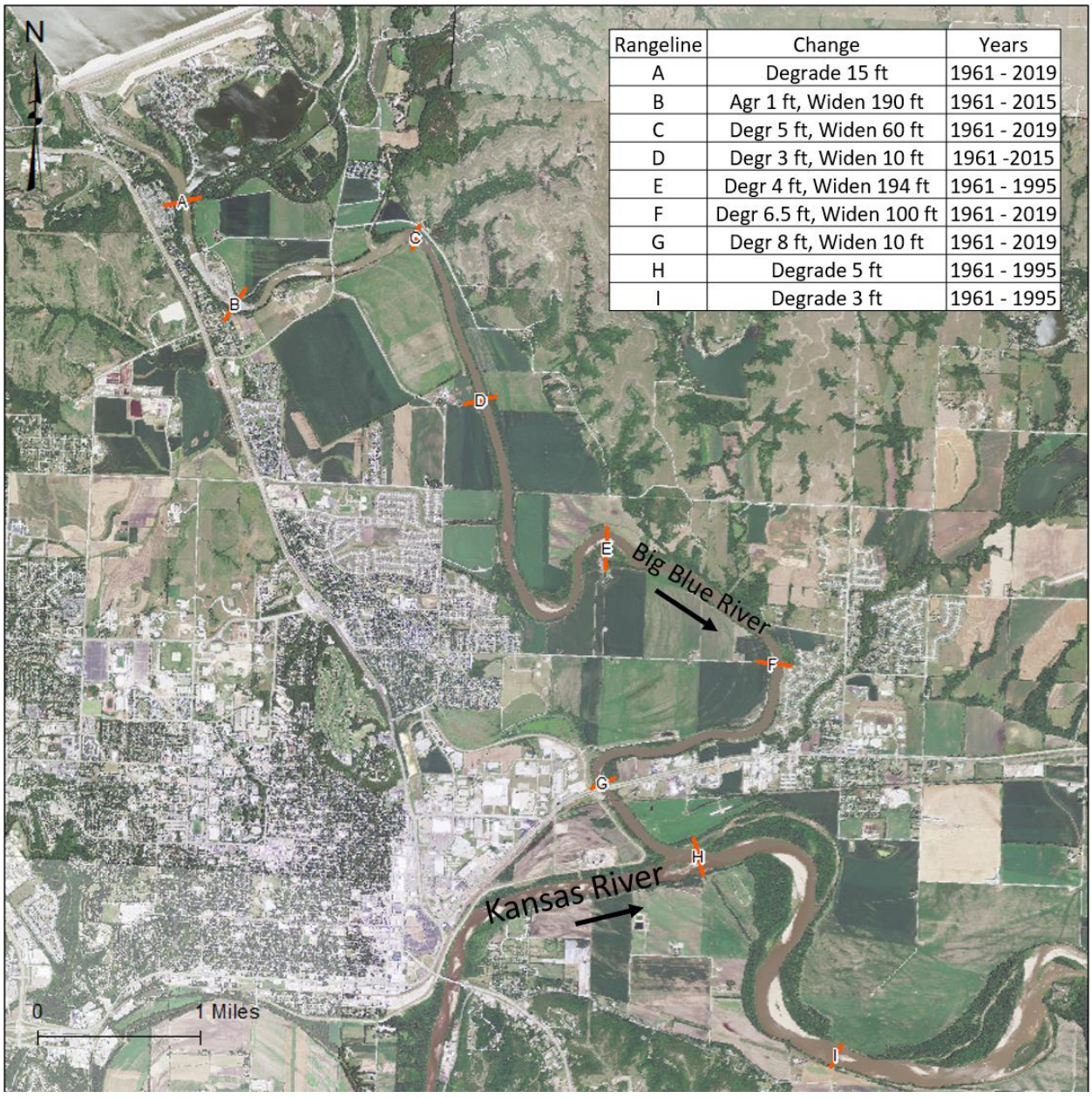


Table 3-47 summarizes the volume of bed degradation and bank erosion in the channels downstream from each dam. Wilson Lake did not experience degradation and is not included in the table.

Table 3-49. Downstream Channel Degradation

Lake	Survey Years	Miles Downstream of the Dam Included	Degradation Rate (acre-feet/year)
Clinton	1977–2018	19.74	14.5
Perry	1967–2012	4.38	14.7
Tuttle Creek	1961–2019	9.24	93.1
Milford	1967–2016	6.3	48.7
Kanopolis	1948–2015	16	4.0
Harlan County	1988–2015	12	7.2

3.3.5 Reservoir Shoreline Erosion

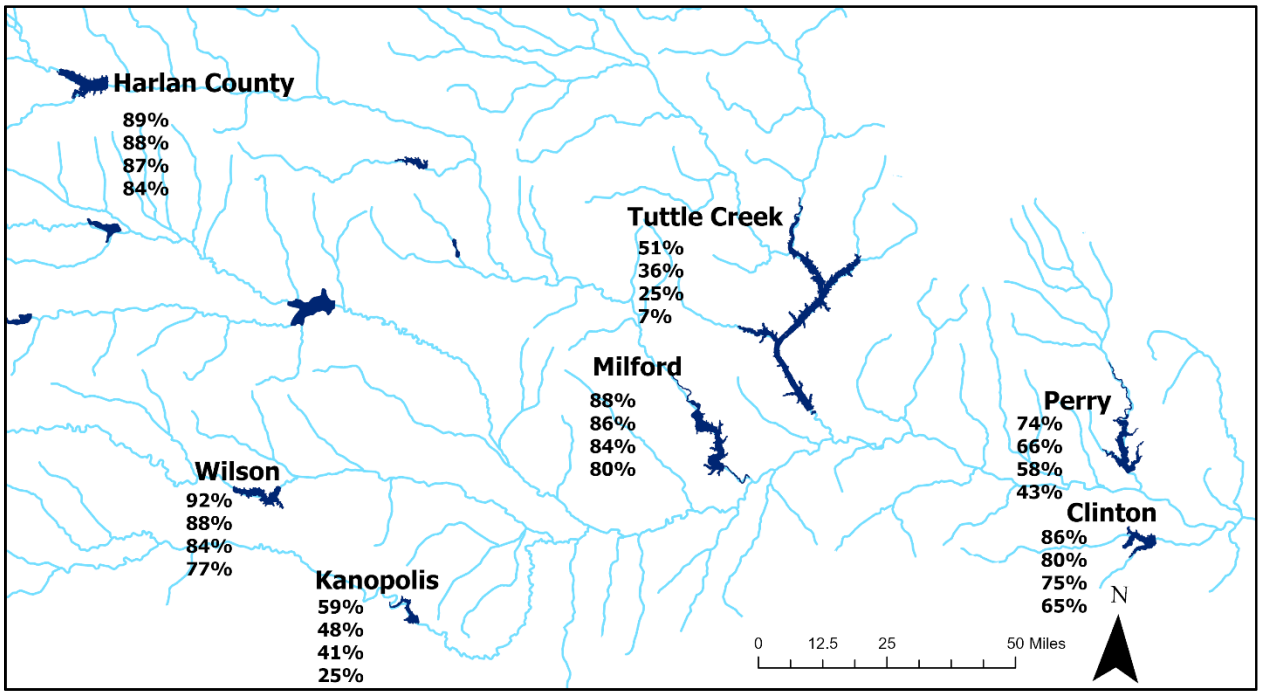
Shoreline erosion represents an additional sedimentation process occurring at lakes in the Kansas River basin. Shoreline erosion occurs due to the frequent filling and draining of the flood control pool and due to wave and wind action at various pool elevations. The result of shoreline erosion is to erode sediment from the flood control pool and deposit it into the multipurpose pool. Shoreline erosion can induce very localized impacts as the eroded sediment buries infrastructure or habitat features. For example, erosion of an eroding bank near the Kanopolis Dam control tower caused problems with gate operations and required targeted dredging in 2010 and 2019. Sediment from shoreline erosion at Harlan County Lake deposited at cove openings, which reduced accessibility of important fish habitats for which a restoration project is being designed.

3.3.6 Future Without Project Conditions

3.3.6.1 U.S. Army Corps of Engineers Lake Volume Estimates

Existing flow data, bathymetric surveys, sedimentation and degradation range lines, sediment characterization data, and sediment concentration/load data was used to estimate the FWOP condition for each lake. In this context, the FWOP assumes sediment continues to accumulate with no intentional action at removal, except localized removal for gate operability. Figure 3-99 indicates the percent of original multipurpose pool left at the end of 25, 50, and 100 years for the USACE lakes. Table 3-48 lists the values. As seen in Figure 3-99 and Table 3-48, Tuttle Creek, Kanopolis, and Perry are the most affected.

2508 *Figure 3-99. Percent remaining of the original multipurpose pool at the end of 25, 50, and 100 years for*
2509 *U.S. Army Corps of Engineers' lakes.*



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2511 *Table 3-50. Future without Project Multipurpose Pool Volumes in U.S. Army Corps of Engineers' Lakes*

Lake	Original Volume kac-ft	Year 0 (2024)		Year 25 (2049)		Year 50 (2074)		Year 100 (2124)	
		kac-ft	%	kac-ft	%	kac-ft	%	kac-ft	%
Clinton	129.2	112.2	87	103.9	80	96.7	75	83.9	65
Perry	243.2	182.9	75	159.4	66	140.0	58	105.2	43
Tuttle Creek	424.3	216.6	51.0	153.0	36.1	106.5	25.1	29.2	6.9
Milford	415.4	366.5	88.2	355.8	85.7	349.9	84.2	333.0	80.2
Kanopolis	73.2	43.3	59.1	34.8	47.5	30.2	41.3	18.2	24.9
Wilson	247.8	228.1	92.0	218.0	87.9	209.0	84.3	190.1	76.7
Harlan County	346.5	309.4	89.3	304.0	87.7	300.7	86.8	291.0	84

2512

Table 3-49 lists the remaining flood control pool volumes. Note that at Clinton, while the volume does decrease over time, the 100-year estimate is still greater than the original volume. This is because the recent LiDAR surveys indicate the flood pool is much larger than original estimates. Tuttle Creek Lake shows the most decline, with a 13.6 percent decrease in flood control pool volume. Section 3.2.6 presents the implications of these decreases.

Table 3-51. Future without Project Flood Control Pool Volumes in U.S. Army Corps of Engineers' Lakes

Lake	Original Volume kac-ft	Year 0 (2024)		Year 25 (2049)		Year 50 (2074)		Year 100 (2124)	
		kac-ft	%	kac-ft	%	kac-ft	%	kac-ft	%
Clinton	268.4	291.4	109	289.4	108	287.0	107	281.0	105
Perry	521.9	510.1	98	499.3	96	487.3	93	458.8	88
Tuttle Creek	1942.7	1851.7	95.3	1780.9	91.7	1738.3	89.5	1612.3	83.0
Milford	757.7	756.9	99.9	755.0	99.6	753.9	99.5	749.9	99.0
Kanopolis	373.9	362.9	97.1	358.0	95.7	354.7	94.9	344.8	92.2
Wilson	530.7	528.5	99.6	527.3	99.4	525.8	99.1	521.2	98.2
Harlan County	503.5	499.3	99.2	498.4	99.0	497.8	98.9	495.7	98.5

Due to increased backwater and more frequent high pools, over time the proportion of sediment depositing in the flood pool increases.

3.3.6.2 Lake Depths and Surface Areas

As seen in Figure 3-100, sediment deposits throughout the multipurpose pool, including in a downward-migrating delta. The FWOP volumes of sediment accumulation were added to existing bathymetric surfaces in order to estimate future delta migration and surface area loss. See Section 3.7, Recreation, for implications of the delta migration on recreational features. Figure 3-100 shows the multipurpose pool depths over time at the three most affected reservoirs: Perry, Tuttle Creek, and Kanopolis.

Figure 3-100 Future without Project Multipurpose Depths in Perry, Tuttle Creek, and Kanopolis Lakes

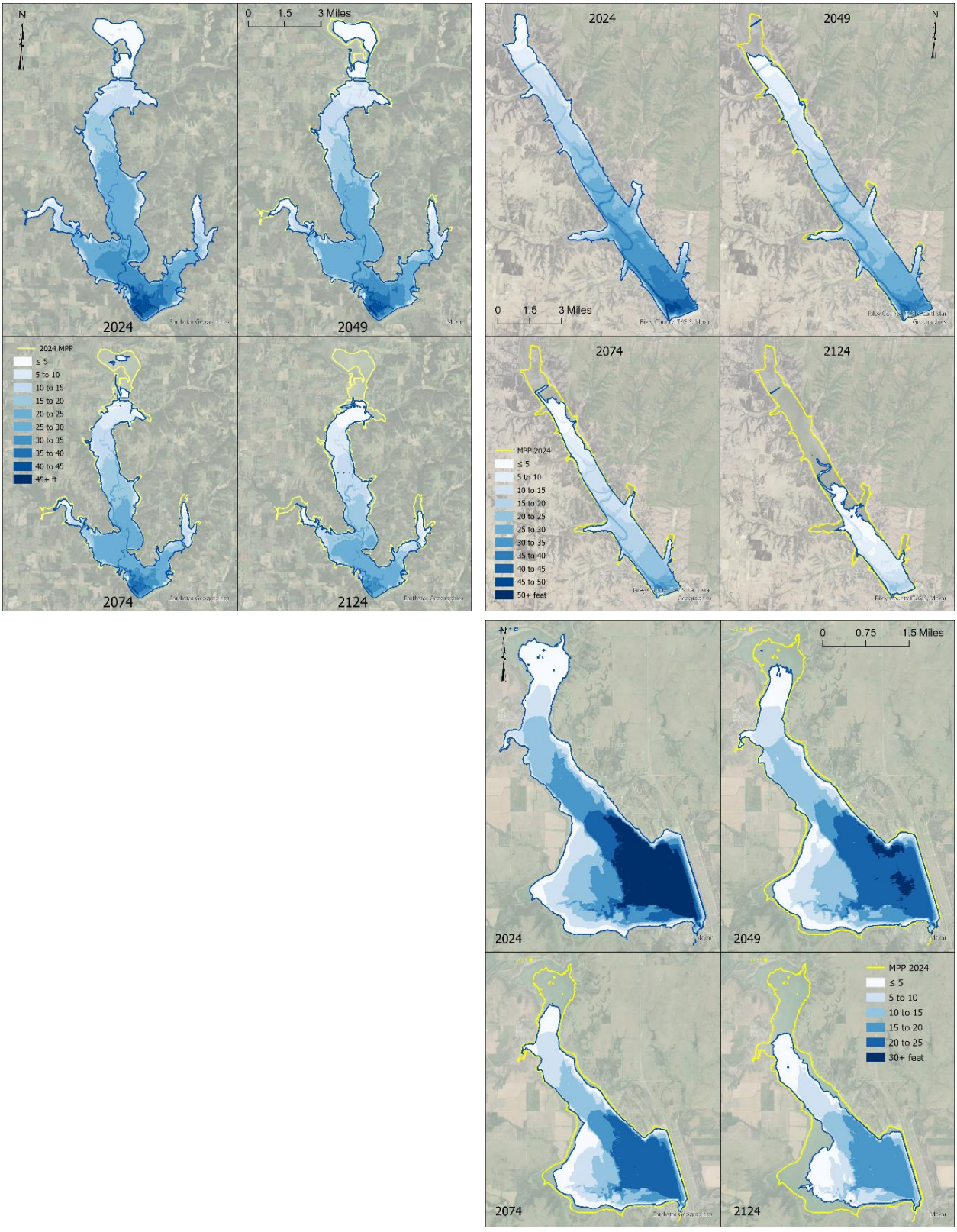

Table 3-50 presents the multipurpose pool surface areas over time. Note that this represents the acreage with any depth at all. Much of the remaining surface area will be too shallow for recreational use.

Table 3-52. Multipurpose Pool Surface Area (Thousands of Acres)

Lake	Original	Year 0 (2024)	Year 25 (2049)	Year 50 (2074)	Year 100 (2124)
Clinton	7.0	7.5	7.2	6.8	6.3
Perry	12.2	9.8	9.0	8.1	7.2
Tuttle Creek	15.8	9.4	7.5	6.4	3.2
Milford	16.6	15.3	14.9	14.7	14.2
Kanopolis	4.1	2.9	2.6	2.4	1.9
Wilson	9.0	8.4	8.3	8.2	7.9
Harlan County	13.8	12.9	12.7	12.6	12.4

3.3.6.3 U.S. Bureau of Recreation Lake Volume Estimates

Volume estimates from the USBR were used to compute the annual rate of sediment accumulation in USBR lakes in the Kansas River Basin. The FWOP starts with the same annual rate but adjusts for decreased inflows since the construction of the dams and decreased trapping efficiency over time as reservoirs fill. See Appendix D for full explanation of the technical methods. Table 3-51 presents the FWOP volume estimates for the multipurpose pool.

Table 3-53. Future without Project Volume Estimate for U.S. Bureau of Recreation Lakes

Name	Original Volume	2024		2049		2074		2124	
	Acre-feet	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent	Acre-feet	Percent
Lovewell	41,687	34,746	83.3	33,967	81.5	33,189	79.6	31,633	75.9
Waconda	242,017	197,740	84.2	181,016	77.3	164,307	70.3	130,949	56.6
Kirwin	99,432	97,267	97.8	96,492	97.0	95,716	96.3	94,166	94.7
Webster	77,370	75,197	97.2	74,407	96.2	73,616	95.1	72,034	93.1
Cedar Bluff	185,496	171,590	92.5	170,299	91.8	169,008	91.1	166,426	89.7
Keith Sebelius	36,127	33,415	92.5	32,289	89.4	31,164	86.3	28,913	80.0
Harry Strunk	41,120	33,270	80.9	32,061	78.0	30,853	75.0	28,439	69.2
Hugh Butler	37,840	35,363	93.5	34,959	92.4	34,176	90.3	32,989	87.2
Swanson	120,366	110,040	91.4	109,819	91.2	109,598	91.1	109,157	90.7
Enders	44,482	42,801	96.2	42,795	96.2	42,691	96.0	42,582	95.7

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The decline in flood control pool storage for the USBR lakes in the Kansas River basin was estimated differently because the bathymetric surveys did not reach high enough into the flood pool. The flood pool deposition at Waconda was estimated based on a correlation between the percentage of time the lake elevation is in the flood pool and the cumulative flood pool deposition observed at nearby lakes (see Appendix D for more information). Table 3-52 presents the FWOP projected flood pool volume for Waconda. The flood pool storage at Waconda is not appreciably affected over the next 100 years. The other USBR lakes were not analyzed.

Table 3-54. Flood Pool Storage at Waconda

Year	Flood Pool Volume (acre-feet)	Percent of Original
1967 (surveyed)	722,988	100.0
2001	720,592	99.7
2024	718,462	99.4
2049	715,297	98.9
2074	711,429	98.4
2124	702,030	97.1

3.3.6.4 Downstream Channel Impacts

Sediment trapping in the lakes will induce additional degradation in the downstream channels. For the FWOP, the ratio of downstream degradation to in-lake sand trapping was assumed to remain constant. This yields the downstream degradation rates seen in Table 3-53 for USACE lakes. This level of analysis is not sufficient to indicate specifically affected infrastructure and was not completed for USBR lakes. The river downstream from Wilson did not experience degradation and was, therefore, not included.

Table 3-55. Future without Project Downstream Channel

Lake	Downstream Loss/Lake Trapping	Lake Sand and Gravel Trapping (Thousand CY)			Bed/Bank Loss (Thousand CY)		
		Year 25	Year 50	Year 100	Year 25	Year 50	Year 100
Clinton	0.78	765	1,495	2,967	597	1,166	2,315
Perry	0.2	2,771	5,383	10,777	551	1,071	2,144
Tuttle Creek	0.30	14,310	23,764	49,404	4,338	7,203	14,975
Milford	0.35	2,741	4,133	8,620	965	1,455	3,035
Kanopolis	0.05	2,910	4,596	9,641	150	237	498
Wilson	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Harlan County	0.42	1,053	1,689	3,656	441	707	1,530

As the lake multipurpose pools fill with sediment, the flood pools trap additional sediment due to more frequent high pools and backwater effects, but the multipurpose pools trap less sediment due to a shorter travel distance and residence time. The net effect is that at most lakes, the downstream sediment concentrations do not change appreciably. However, at Kanopolis and Tuttle Creek reservoirs, respectively, the sediment concentrations in the releases in the hundredth year are 1.8 and 4.0 times what they are in Year 0. Even at these two lakes, the majority of incoming sediment will continue to deposit in the pools rather than passing downstream. The sediment that does pass will be predominantly fine sediment (silts and clays) rather than sands or gravels.

3.3.6.5 Reservoir Sedimentation Conclusion

Reservoir sedimentation is and continues to be a significant problem at Kansas River basin lakes, particularly at Tuttle Creek, Kanopolis, Lovewell, and Perry dams. Without intentional sediment management, the multipurpose pool and flood pool volumes will shrink, the multipurpose pool surface area and depths will decrease, and the bed and banks of the downstream channels will degrade.

3.4 Watershed Geology, Soils, Upstream Sediment, and Kansas River Geomorphology

The existing conditions for geology, soils, sediment, and geomorphology describe the various soil types in the region, locations and effectiveness of stream restoration and bank/shoreline stabilization status, and other projects to reduce sedimentation inflow to reservoirs. This section also includes summaries of recent studies in Kansas River geomorphology and other sediment modeling studies. Maps showing generalized soil types, geology, and geomorphic provinces are included to aid the discussion.

3.4.1 Geology and Soils

Geologically, Kansas is in the county’s stable midcontinent. Kansas is underlain by metamorphic and igneous rocks that are several thousand feet below the surface. Draped over the top of those crystalline rocks are layer upon layer of sediments. Geologically, the sedimentary layers in the basin are relatively young, of Mississippian age and younger (Wilson and Bennett 1985, as cited in KDWP 2016) with the oldest strata exposed in eastern Kansas and most recent near the Colorado border. The geology visible at the surface today is generally the result of two forces: deposition and erosion. Shallow oceans, streams, glaciers, and windstorms left behind sediments that were eventually consolidated into sedimentary rocks, by far the most common type of rock at the state’s surface. These surficial rocks, which range from 330 million years to a few hundred thousand years old, have since been dissected and rearranged by erosive forces, especially water.

The Osage Cuestas in the eastern portion of the basin are formed mostly on limestones and shales of Pennsylvanian age, about 300 million years old. These Pennsylvanian deposits include coal which was mined extensively at the surface and underground for much of the twentieth century. Slightly younger rocks of Cretaceous age, about 100 million years old, form the Smoky Hills that cover much of central and west-central portion of the basin. Sandstone (deposited originally as sand by rivers at the ocean’s

edge), limestone, shale, and chalk are found here. Rocks in the other physiographic regions are much younger, generally deposited in the past 10 million years or less. The High Plains of western Kansas are covered by sand, silt, and other debris that washed off the face of the Rocky Mountains and onto the plains by sluggish braided streams. Although this is a land of little rain, vast amounts of water accumulated underground in pore spaces of the sand, gravel, and other material that make up the Ogallala aquifer. That groundwater supports a massive irrigation-based agriculture in the region. Declining water levels in the Ogallala have led to widespread concerns about the resource's sustainability and the industries the water supports. The Glaciated Region in the northeastern portion of the basin includes Pennsylvanian and Permian bedrock covered by glacial debris, brought into the state about six hundred thousand years ago. This glacial material includes large red boulders of quartzite, a metamorphic rock originally in place in the area around Sioux Falls, South Dakota.

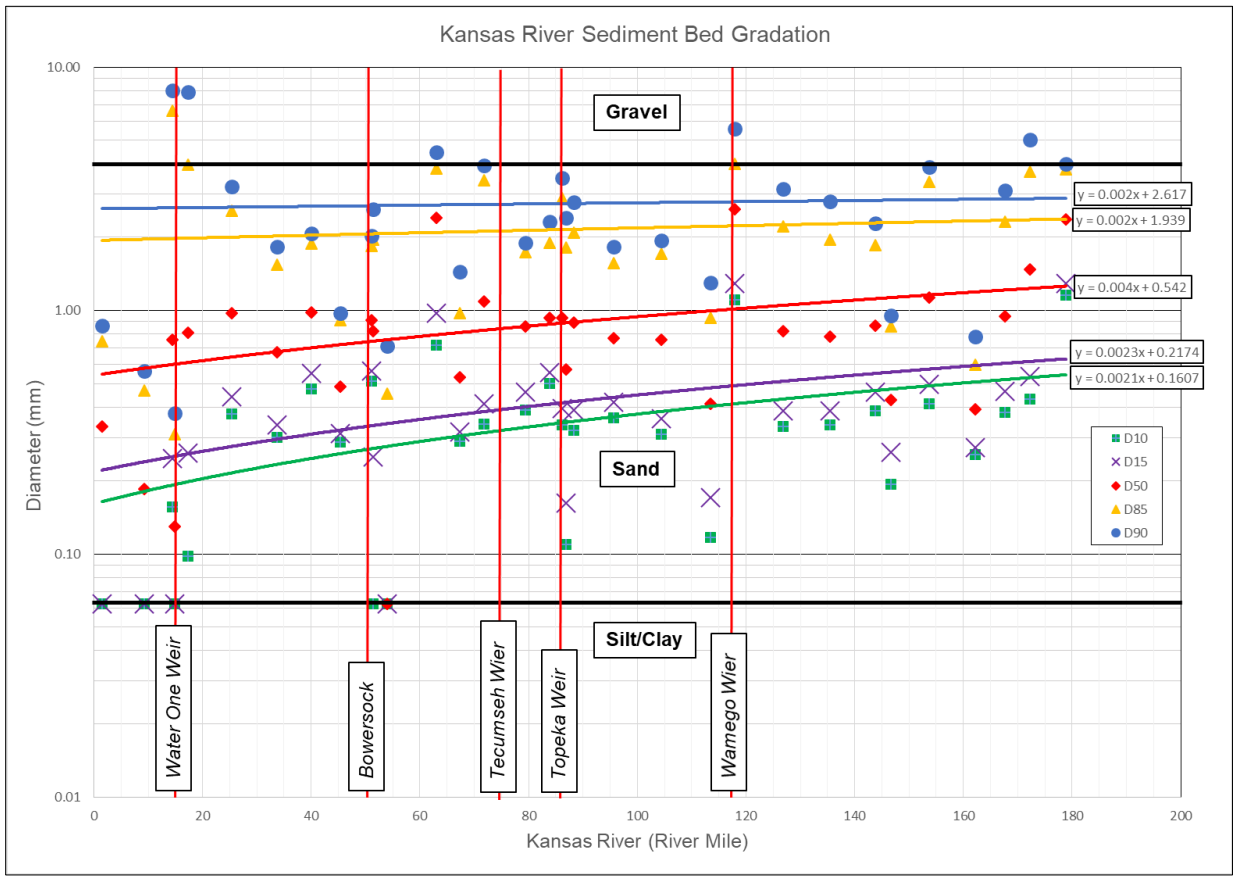
3.4.2 Geomorphology

3.4.2.1 Kansas River Geomorphology

The Kansas River is a large, sand-bed river. Its shifting low-flow channels, frequent islands, and sandbars reside within an overall incised single-thread meandering channel. Previous decades show dramatic planform shifts including cutoffs, the formation of oxbows, and avulsions. Since the late 70s, the planform has been mostly stable with a few exceptions (Dort 2009).

Sand dominates the active channel, with sizes fining slightly in the downstream direction, as shown in Figure 3-101.

Figure 3-101. Sediment Sizes on the Kansas River. Data from 2017

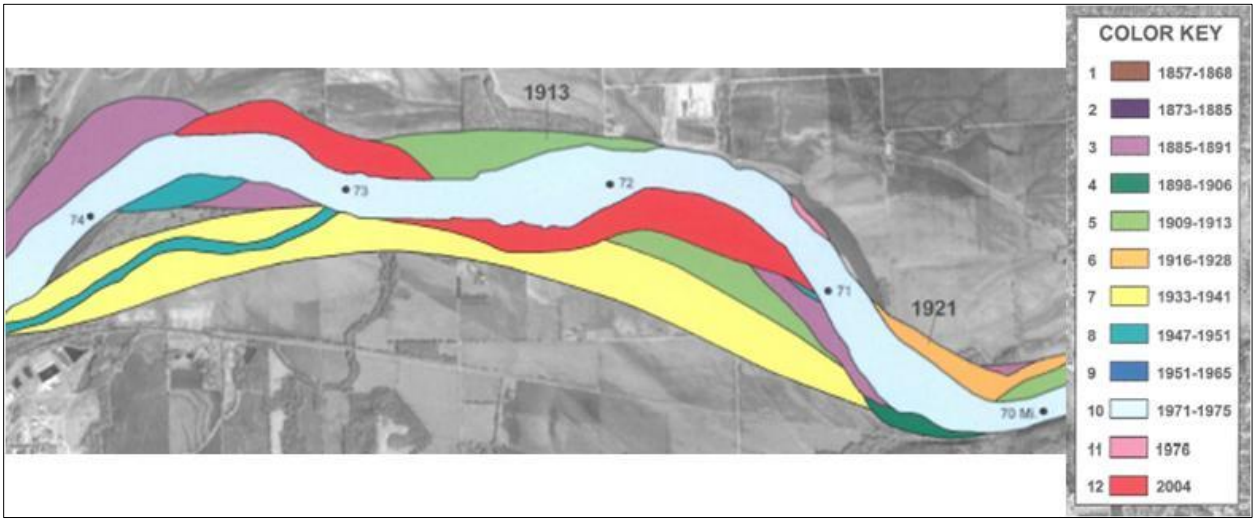


Bank erosion is common on the Kansas River, particularly in the more upstream reaches. Most often, bank erosion occurs on outside bends (Figure 3-102), concurrent with bar growth and land accretion on the inside bends. In some reaches, this has resulted in increased sinuosity over time.

Figure 3-102. Cutting outside bank (A) and accreting inside bank (B). River Mile 74.1. Photos from 2010



Figure 3-103. Planform Changes. River Miles 70–74, from Dort (2009).



Where the dark red is obscured by the light blue, the 2004 channel follows the 1975 channel.

Bank stabilization of many types is employed with success on the Kansas River. Some older rock revetment projects are completely overgrown with vegetation, as shown in Figure 3-104. Figure 3-105 shows an L-head revetment, constructed in 2003, which induced deposition, accreted land, and established riparian vegetation.

Figure 3-104. Rock Revetment Has Allowed the Growth of Stable Vegetation at River Mile 102.2. Photo from 2010



Figure 3-105. L-head revetments halt bank erosion at allow land accretion and stable revegetation near Eudora, Kansas. Trace of 1991 bankline is retained throughout.



Image source: GoogleEarth

Multiple channel mining operations remove sand from the active channel in the Kansas River and from floodplain pits along the Kansas River. In-channel sand and gravel mining occurs near Topeka, Kansas, and at various locations from Lawrence, Kansas, to Kansas City, Kansas.

3.4.2.2 Tributary Geomorphology

Rivers and streams in the Kansas River basin exhibit a variety of geomorphic features, stream types, substrates, anthropogenic stressors, and bank stabilization efforts. Stream straightening and the removal of riparian vegetation are ubiquitous across the whole basin, which has induced channel incision and bank erosion. Common channel substrates in the basin include sand, gravel, bedrock, and clay.

The few relatively natural reference reaches in the basin are predominantly Rosgen Type C and E meandering channels (Shelley 2012). Reference reaches with sand and gravel beds feature regular, repeating patterns of riffles and pools. Reference reaches with clay beds do not.

Bank erosion on major tributaries to the USACE reservoirs is identified as a source of sediment to the lakes. This erosion is most common on outside bends where riparian vegetation is lacking (Figure 3-106). The State of Kansas has stabilized dozens of eroding bends using river training structures (bendway weirs and rock vanes). These projects typically, but not always, include longitudinal stone toe protection and may or may not also include bank sloping and planting. Many more banks remain unstable.

Figure 3-106. Eroding banks on the Big Blue River with Bendway Weirs (top meander) and without Bendway Weirs (bottom meander).



Photo from 2014 (GoogleEarth)

Two run-of-river dams on the Big Blue River (upstream of Tuttle Creek Lake) have breached in recent years. In May of 2004, a dam breached near Blue Springs, Nebraska (Figure 3-107).

Figure 3-107. Breached Dam on the Big Blue River near Blue Springs, Nebraska



A second dam breached on the Big Blue River in May of 2018 near Marysville, Kansas. The breach of this dam has caused upstream-progressing bed degradation, bank erosion, and a lowering of the ground water (Figure 3-108).

Figure 3-108. Breached Dam on the Big Blue River near Marysville, Kansas



The presence and condition of other small dams in the Kansas River Basin has not been documented.

3.4.3 Sedimentation and Erosion

3.4.3.1 Sediment Sources

Sediment fingerprinting in the Kansas River basin has indicated both channel and overland sources of sediment are significant contributors to downstream sedimentation (Juracek and Ziegler 2009). Channel sources include bank erosion and headcutting, including headcutting induced by dam breaches, channel cutoffs, and channelization. KWO has identified 176 erosion hotspots in the watershed upstream from Tuttle Creek Lake and 85 upstream from Perry Lake (KWO 2017) (https://ksdot.maps.arcgis.com/apps/Cascade/index.html?appid=35023fa276e446a594f07ff99a8bc0ba). If left unstable, the 176 erosion hotspots upstream from Tuttle Creek Lake are expected to contribute 4.6 million cubic yards of fine sediment over the next 30 years (see Appendix D).

Headcutting induced by numerous channelizations throughout the basin could potentially contribute even more sediment than the hotspot bank erosion (see Figure 3-109). Headcuts move upstream, degrading the bed and causing bank erosion over many miles.

Figure 3-109. Headcut in the Tuttle Creek Dam Lake Watershed



The headcut upstream from the breached Marysville Dam (Figure 3-84) contributed 1.1 million cubic yards of sediment from 2018 to 2022 and is expected to erode an additional 230,000 cubic yards of sediment before headcutting up to a resistant bedrock outcrop.

3.4.3.2 Kansas River Sedimentation

USACE reservoirs trap 95 to 98 percent of all sediment they receive which significantly reduces the sand contribution to the Kansas River. Major remaining sources of sediment to the Kansas River include bank erosion on the Kansas River itself, undammed tributaries, and degradation on tributaries downstream from USACE lakes. Degradation on the tributaries downstream from the dams partially offsets the quantity of trapped sand and gravel, with amounts ranging from no degradation (downstream from Wilson) to degradation equating to 78 percent of the trapped sands and gravels (at Clinton). See Appendix D1.

Comparisons of historic cross sections on the lower Kansas River indicate 4 feet to 20 feet of degradation occurred from the 1960s to 1983 from RM 9.5 to 26 (SLA 1984).

Channel mining, known locally as commercial dredging, has occurred on the Kansas River since the early 1900s. Commercial dredging removed 112,157,446 tons of sand and gravel from the Kansas River from 1960 to 2015 (USACE 2017a). Every two years, cross sections are surveyed to monitor the bed elevations in reaches where dredging operations are proposed for the following two years. As per the regulatory plan, dredging activities are suspended in reaches where the bed degraded two additional feet compared to a regulatory baseline survey (RBL). The RBL is principally the 1992

survey with a few gaps filled in with data from 2007. Figures 3-110 and 3-111 provide the most recent two years of this monitoring data (USACE 2022), which indicate from 5 feet of continued degradation to 9 feet of recovery compared to the RBL.

Figure 3-110. Change in Average Bed Elevation at Individual Cross-Sections from the Regulatory Baseline Survey to the 2022 survey (Kansas City, Kansas to De Soto, Kansas)

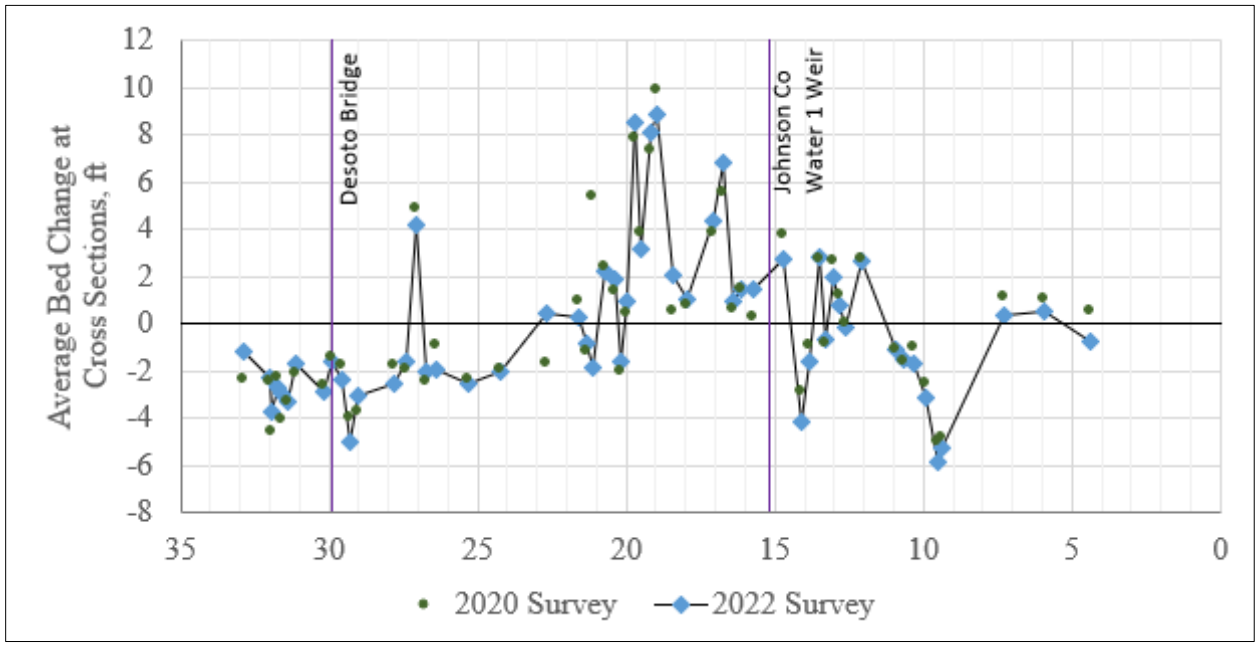
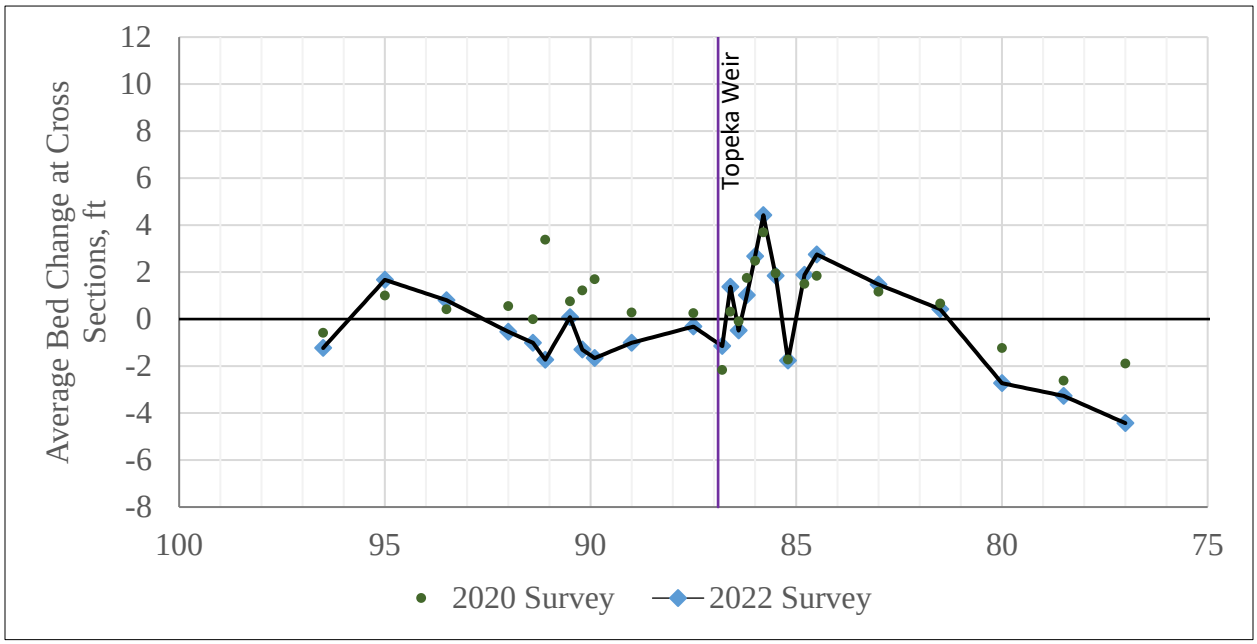


Figure 3-111. Change in Average Bed Elevation at Individual Cross-Sections from the Regulatory Baseline Survey to the 2022 survey (Topeka, Kansas)



3.4.4 Future Without Project Conditions

Over the next 100 years, the Kansas River watershed is expected to continue to yield high levels of sediment. Channelized streams will slowly regain sinuosity through

channel incision and bank erosion. Many rivers upstream from the reservoirs have recent or impending cutoffs which are expected to induce additional headcutting and bank erosion upstream (Figure 3-112).

Figure 3-112. Impending channel cutoff on Crooked Creek, Tributary to Tuttle Creek Lake. This cutoff induces channel degradation and bank erosion upstream.



(Photo date: 2012. Photo source: GoogleEarth).

Sands and gravels continue to be trapped by all the lakes. Degradation in the downstream channels continues, though will likely slow near the dam and extend downstream. The releases of fine (silt and clay) sediments will increase from Tuttle Creek Lake and Kanopolis Lake.

The Kansas River is expected to degrade overall as sediment is continuously trapped in the major reservoirs and removed via channel mining. In addition, large floods will continue to deposit tremendous volumes of sediment on the floodplain which the river is not able to recapture.

3.5 Water Supply

Within the Kansas River Basin, there are 18 federal reservoirs, 7 of which are operated by the USACE, and 11 are operated by USBR. The reservoirs are operated for multiple

purposes, including water supply. Surface water resources in Kansas serve as the source of municipal and industrial (M&I) water supply for more than two-thirds of the state's population. Irrigation is an authorized use that has a significant presence throughout the watershed, in areas below reservoirs, and some direct reservoir diversions. A major threat to water supply availability in the Kansas River basin is reservoir sedimentation. Every year, thousands of acre-feet of water storage are lost, as millions of cubic yards of sediment accumulate in the federal reservoirs. Other challenges to managing reservoir supplies include regaining lost and preserving current water supply storage; identifying additional storage opportunities and reallocations of existing storage; and funding sources and responsibilities for O&M costs.

Lack of reliable water supply and shortages of water could have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Developing and implementing plans and tools that secure and improve the reliability of state water supplies is essential for the future prosperity of Kansas communities and public health of citizens. Water supplies can be affected by competing and multiple uses, including the USACE releases of water from Kansas River reservoirs to support navigation on the Missouri River. In addition, planning for extreme events, such as drought, is necessary to reduce vulnerability and create resiliency to ensure clean water delivery to Kansas citizens.

3.5.1 Existing Conditions

The existing conditions for water supply for M&I and irrigation uses are described in this section, including a description of M&I water supply storage allocations, customers, and contracts associated with the Kansas River basin reservoirs and account and depiction of water use trends for these customers. In addition, this section describes the current process for obtaining and paying for current and future use storage in USACE reservoirs.

3.5.1.1 Overview of Kansas Water Appropriations and Rights

Kansas' water management laws are based on a prior appropriation doctrine (first in time, first in right) which generally affords those entities with senior water rights priority to use water over junior water rights during periods of water-shortage, such as during drought. Kansas laws pertain equally to both surface water and groundwater. Priority of a water right is based on the date which an acceptable application was filed with the state's DWR Chief Engineer. Essentially all water users (irrigation, stock watering, public water supply, recreation, etc.) must obtain prior approval from the state's chief engineer through a permit to appropriate water for beneficial use. The only exception is domestic water uses, such as water used for household purposes, domestic livestock on pasture, and irrigation of less than two acres of lawns, gardens, and orchards.

While the Kansas Water Appropriation Act (https://agriculture.ks.gov/docs/default-source/statues-water/kswaterappropriationact82a_701.pdf?sfvrsn=4) became law in 1945, it was not compulsory until the mid-1970s. Applications are currently evaluated based on reasonable use, well spacing, and safe yield criteria. Safe yield and well spacing requirements, however, were not implemented until the late 1980s, after a majority of Kansas water rights were already developed. Significant declines have been noted in western Kansas counties where annual water use exceeds natural recharge.

This is most notable along western alluvial aquifers and in the Ogallala Aquifer. The more severely impacted areas have been closed to new appropriation. While no new water rights are allowed to be developed in those areas, Kansas law does allow existing water rights to be sold and allows the authorized points of diversion (well locations), places of use, and use made of water to be changed to accommodate new uses, new industry, and increased public water supply. There are also provisions for small-use exemptions in most closed areas (https://agriculture.ks.gov/docs/default-source/dwr-water-appropriation-documents/ClosedAreas.pdf).

Kansas has a robust water flow metering and water use reporting program, which helps state planners and others to continually evaluate the condition of their water resources. For surface water, the state implemented MDS requirements on 23 major streams and rivers, at 33 locations, to protect senior water rights and to meet in-stream water uses related to water quality, fish and wildlife conservation, and recreation. Groundwater wells in western Kansas are measured annually during January to determine any changes in the aquifers.

To allow for local input into the water appropriation process, the Kansas Legislature enacted the Kansas Groundwater Management District Act, K.S.A. 82a-1020 et seq (https://agriculture.ks.gov/divisions-programs/dwr/managing-kansas-water-resources/groundwater-management-districts). There are currently five GMDs in Kansas, primarily covering major regions of the High Plains Aquifer. The districts are governed by a local board of directors composed of water users in their respective areas. Those boards develop management plans and promulgate rules and regulations tailored for their districts, subject to review and approval by the Kansas Chief Engineer. In districts still open to new appropriation, applications for new permits and water rights are reviewed by district staff for compliance with Kansas law with recommendations to the Chief Engineer as to whether they should be approved or denied.

The Kansas GMD Act contains specific provisions for initiation of proceedings for and designation of IGUCAs. These provisions recognize that a strict prior-appropriation approach may not be in the public interest and allows water rights to be administered in a method that benefits the most users. The statutes allow the Chief Engineer to implement additional corrective control provisions in areas where it is determined, through a public hearing process, that groundwater levels are declining excessively, the rate of groundwater withdrawal exceeds the rate of groundwater recharge, unreasonable deterioration of groundwater quality has occurred or may occur, or other conditions exist warranting additional regulation to protect public interest. Similar provisions were added to Kansas law in 2012 allowing the formation of LEMAs. Similar to an IGUCA, but driven by local stakeholders, a LEMA allows GMDs to develop their own plan and corrective control measures to aid in water conservation, with the approval of the Chief Engineer through a public hearing process.

Figure 3-113 illustrates the diverse nature of water resources and institutional framework managing the water right development within the watershed. Generally, policies in the western part of the State resulted in groundwater declines, and implementation of conservation measures are being encouraged. Outside the GMDs, the Chief Engineer closed and restricted further development of groundwater and surface water sources through much of the western half of the study area.

Groundwater through the majority of the central to eastern parts of the watershed is open to further development and is restricted to safe yield criteria. Additional surface water development is highly restricted in most of the watershed. With new surface water right developments requiring an alternate source of supply for July to September annually, essentially restricting further irrigation developments that have not secured an alternative source of water supply through off stream storage, groundwater sources, or access district membership (see Section 3.5.1.2, Surface Water Programs and Allocations, Lower Smoky Hill Water Supply Access District, for additional details on access districts). Restrictions on future surface water right developments should reduce the demands on the system during extended times of low flows. The Kansas and Big Blue rivers are open to new applications without this restriction.

The Kansas River basin has varied climate patterns and hydrology from the western upper basin in Kansas and Nebraska which overlies the High Plains Aquifer, to the eastern lower basin which generally aligns with historical glaciation extent. Figure 3-114 illustrates that the western portion of the basin receives less precipitation than the potential evapotranspiration (PET). This upper basin has less prevalent surface water flows and water use is more dependent on groundwater diversions from the high plains and less extensive alluvial aquifer deposits. Water use records show higher irrigation water use per acre in the western part of the basin, with all the alluvial aquifers being restricted to additional water right development to prevent further baseflow depletions.

The lower basin has significantly more surface water flows and is the home to many of the reservoirs discussed in this document, where they serve flood control, water supply, and recreation functions for this higher population area of the State. The lower basin receives significantly more precipitation than the more arid upper basin, which is reflected in reduced irrigation water use per acre than the west and, in many years, irrigation can be more supplemental to received precipitation. Much of the Kansas River alluvial corridor in the lower basin is still open to new water right development and through most climate scenarios the lower Kansas River is a gaining stream. With the drought event of 2012–2013, a significant reduction in baseflow gain was observed as irrigation demands increased, requiring significant sustained releases from federal reservoirs to maintain low flow targets and ensure adequate supply to downstream municipal and industrial diversion points.

Figure 3-113. Gridded Values of 1971–2000 Average Precipitation Minus Average Potential Evapotranspiration (USGS.gov)

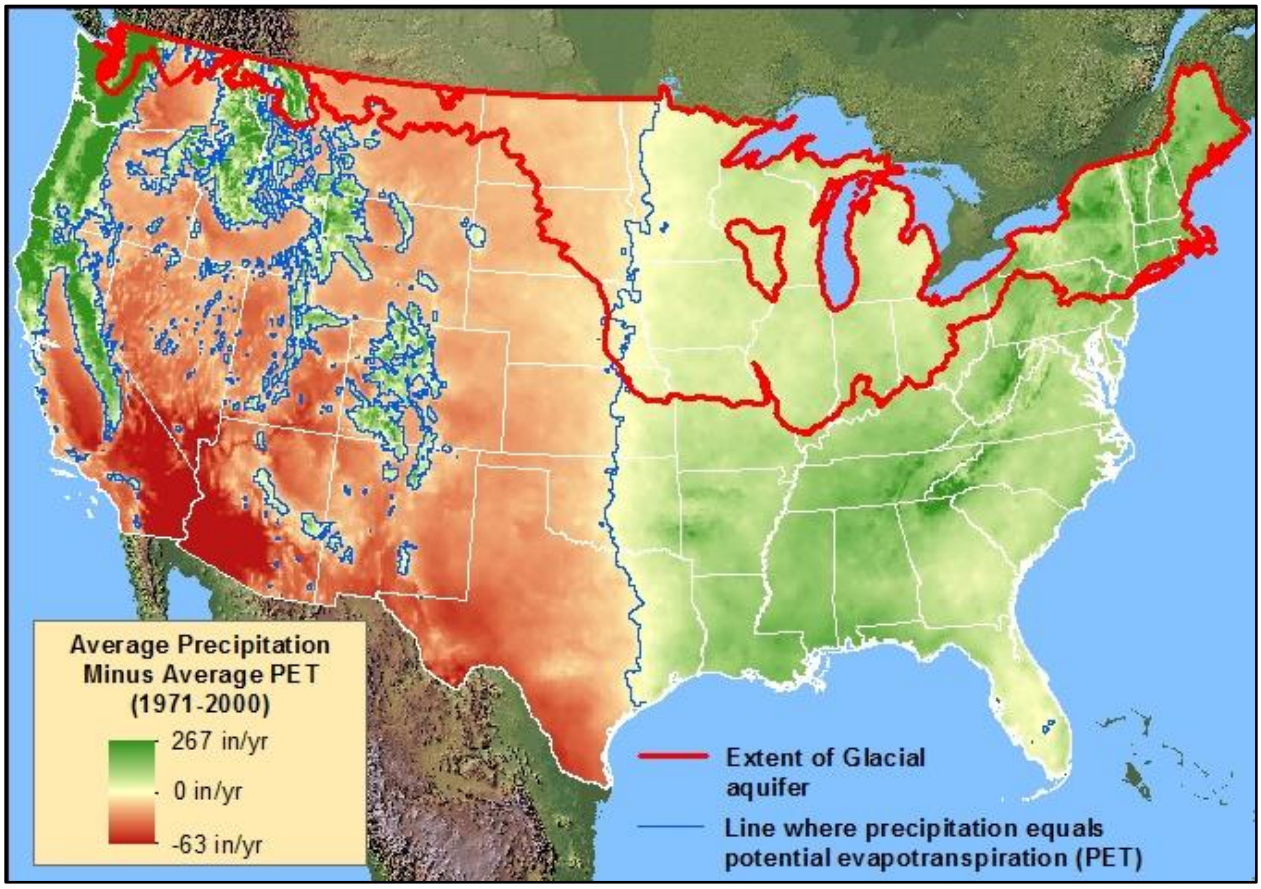


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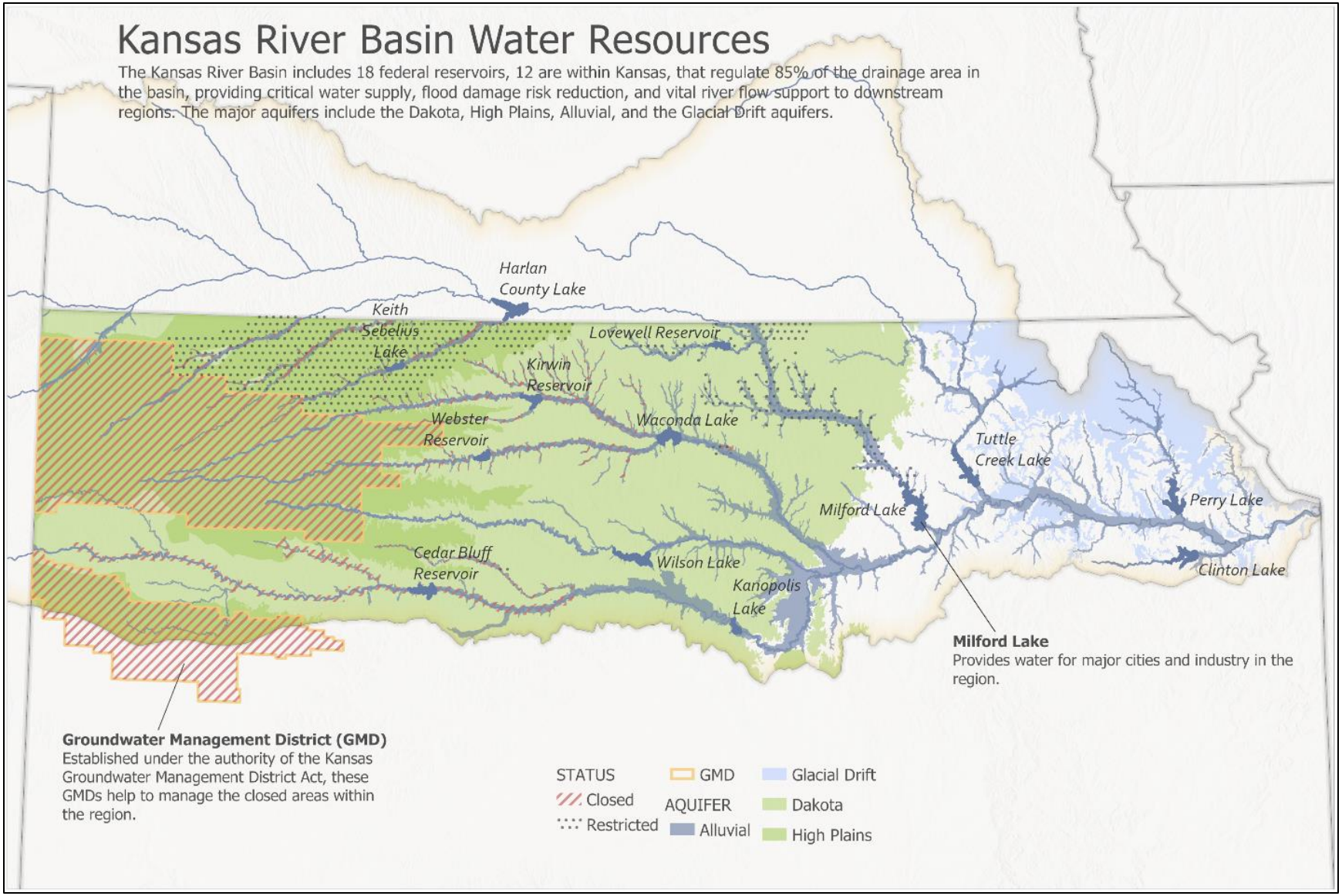
Figure 3-114. Kansas River Basin Water Resources



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Separate from the Water Appropriation Act, the State Water Plan Storage Act, K.S.A. 82a-1301 et seq., authorizes the KWO director to acquire the right to store waters flowing into conservation storage of federal reservoirs, with conservation storage aligning to the multi-purpose pool allocations as defined by USACE. These are called Water Reservation Rights and allow for water to be legally stored in both water supply and water quality storage space in federal reservoirs. Despite being separate from the Appropriation Act, reservation rights are still subject to the priority system and reservoir operations within conservation storage must allow for fulfilling the demands of senior water rights. In a water right administration event, senior water rights downstream of a water storage reservoir have priority to the natural flows of the river system and natural inflows shall be bypassed to satisfy the demands; water already in storage at the time of water right administration is not subject to forfeiture to satisfy a senior downstream water right. Water Reservation Rights are a key component to Kansas' water management framework, as the releases from storage stored under the authority of a Water Reservation Right are required to be protected from unauthorized diversion. Water supply releases are diverted by the intended customer (i.e., the assurance district member) and water quality releases are protected to maintain streamflow.

3.5.1.2 Surface Water Programs and Allocations

This section describes the state programs to manage water supply storage in the federal reservoirs, including the various types of reservoir storage pools and the current surface water storage allocations in the federal reservoirs in the Kansas River Basin.

- **Programs to Manage Water Supply Storage in Federal Reservoirs**

  KWO oversees the Water Marketing, Water Assurance, and Lower Smoky Hill Water Access District programs (https://kwo.ks.gov/reservoirs). The purpose of the Water Marketing program is managing water supply storage in federal reservoirs as a wholesale raw water utility to meet present and anticipated (future) M&I water supply needs. The purpose of the Water Assurance program is assuring adequate supply from that water supply storage to meet downstream M&I needs during times of drought. Finally, the purpose of the Lower Smoky Hill Water Access District is providing access and reliable water supply to M&I, recreation, and irrigation users during drought.

- **Water Marketing Program**

  The 1974 legislature enacted the State Water Plan Storage Act authorizing KWO to contract with water purchasers for sale of water from any reservoir included in the Kansas Water Marketing Program. Water sold from these reservoirs must be used for M&I purposes.

  To begin the process of obtaining a water supply contract under the marketing program, a prospective purchaser files an application with KWO. The application includes the desired amount of water and identifies the specific reservoir. The application may remain on file for 10 years. Contract negotiations begin at the applicant's request.

  A successful negotiation between KWO and the applicant produces a contract stating the conditions of the purchase. Common contract provisions include the

length of time the contract will remain in force, the amount of water to be withdrawn, the place of use, billing and payment procedures, conservation measures, and metering of water. These contracts are limited to the quantity of water State-owned reservoir storage is projected to provide through a 2 percent drought event, which is the 1952–1957 drought event within this watershed.

All contracts since 1983 include a price for water which is set annually by the KWA. The rate is set to ensure the revenue into the program is adequate to meet the expected expenses of the program, which include principal and interest on storage under federal contract, O&M costs for storage, and the state's administration and enforcement costs associated with operating the program. The 2023 variable rate is $0.473 per thousand gallons.

Water purchase contracts are issued through the Water Marketing Program and authorize the withdrawal of water from Water Marketing storage allocations within federal reservoirs. The Water Marketing customer may either withdraw the water directly from the reservoir or water may be released to the river for downstream delivery at a re-diversion point. Neither option requires a water right acquired through the appropriation act.

- **Water Assurance Program**

The Water Assurance Program allows for coordinated operation of state-owned or controlled water storage space in federal reservoirs in a designated basin to satisfy downstream M&I water rights during drought conditions. Water right holders are, therefore, assured to receive enhanced flow during times of drought while the State operates the reservoirs in a basin as a system for increased water delivery efficiency.

The Water Assurance Program Act, K.S.A. 82a-1330 et seq., provides that water assurance districts can be organized by eligible water right holders. The process for organization of a district includes identification of eligible water right holders by the Chief Engineer; filing a petition with the Secretary of State for organization of the proposed district; review and approval of the petition by the Chief Engineer; and an election by persons holding the eligible water rights to form a district. Upon organization and formation of a district, participation is mandatory for all eligible water right holders.

Among the powers granted to a water assurance district is the authority to levy an annual charge against district members to cover costs to the State in acquiring, operating, and maintaining water supply storage needed to satisfy the district's needs. A contract, specifying arrangements for payment of these costs to the State, must be negotiated between KWO and the assurance district. A key element of the contract and the negotiation process is an operations agreement between KWO, the Chief Engineer, and the assurance district describing the manner in which the reservoirs will be operated to increase their efficiency and enhance the benefits to members of the assurance district.

To date, three water assurance districts have been formed in the state of Kansas and are operational—Kansas River Water Assurance District No. 1, Marais des Cygnes River Water Assurance District No. 2, and Cottonwood/Neosho River Basins Assurance District No. 3.

- **Lower Smoky Hill Water Supply Access District**

  Legislation enacted in 2011 led to the access district program and the district formed in 2016. The access district differs from the assurance district in two key ways: Membership is voluntary for water right holders rather than mandatory and eligible water rights include municipal, recreational, and irrigation uses of water.

  Similar to under the Water Assurance Program, the access district is able to contract for water supply storage in Kanopolis Reservoir. This storage can then provide supplemental releases to downstream water right holders when natural flows are insufficient to meet downstream demands. This increases drought resiliency for the member water rights and allows continued water right development along the Lower Smoky Hill River. The DWR protects releases made from access district storage used to meet downstream flow targets allowing for continued water use by access district members.

Table 3-56. Current Water Supply Storage Allocations

Access Purpose	Water Right Required	Voluntary	Customer Uses	Current Storage Allocations (percent)
Assurance	Yes	No	Municipal Industrial	Milford 18.33 Tuttle 33.89 Perry 16.67
Access District	Yes	Yes	Municipal Irrigation	Kanopolis 24.23
Marketing		Yes	Municipal Industrial	Kanopolis 22.37 Milford 15.55

3.5.1.3 Reservoir Storage Pools

Each of the water supply reservoirs are separated into different components, or pools, based on the designated use of the storage. This section includes definitions of each of the storage pool designations.

Water Quality. The water quality pool is utilized to make established minimum releases and intended to maintain flow in the stream downstream of the reservoirs, including navigation demands.

Water Marketing. This storage pool is owned by the State through contracts with the USACE and is utilized to serve the long-term needs of municipal and industrial users who have marketing contracts with KWO.

Water Assurance. This storage pool was purchased from the State by a Water Assurance District to provide district members (municipal and industrial water right holders on mainstem rivers below federal reservoirs) with an assurance of a water supply during times of low natural river flow.

Access District. This storage pool was purchased by the Water Supply Access District in accordance with the purchase contract between the KWO and the access district. The access district releases support downstream member demands during times of low natural river flow.

Reserve Capacity. The reserve capacity pool is storage within the water supply pool purchased and called into service by the State but is not yet contracted to marketing or assurance customers.

Future Use. Future use storage is considered storage not currently in service by the State. Some of the water supply contracts between USACE and KWO allow the State to defer payments on the storage until the storage is needed. The USACE retains ownership of future use storage until the State calls it into service. Future use storage in Milford and Perry reservoirs has historically been released to support water quality targets on the Kansas River and for Missouri River navigation.

3.5.1.4 Current Surface Water Allocations

Table 3-55 includes the water supply and water quality storage allocations where KWO has water supply contracts in USACE reservoirs. The contracted storage space is based on percent of conservation storage (i.e., multi-purpose pool). Table 3-56 shows the contracted water supply and water quality storage by the current storage pools area, which are based on the estimated multipurpose pool capacity in 2024 (see sediment section). It is important to note that the storage space in the water supply contracts, as provided in the original contracts with USACE or reallocation studies, are based on a percent of conservation (multipurpose) storage through the useful life of the reservoir. Table 3-57 summarizes the flood and conservation storage, as well as storage allocations within the multipurpose pool for the remaining reservoirs, both managed by USBR and USACE.

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Table 3-57. Contracted Storage for Water Supply and Water Quality in Corps Reservoirs

Reservoir	MPP Design Storage (Future) Contracted Water Storage (acre-feet)	Contracted Water Supply Percentage of Design Storage (percent)	Total Contracted Water Supply Storage (acre-feet)	Percentage of MPP Design Contracted Water Storage for Quality (percent)	Contracted Water Storage for Quality (acre-feet)	Percentage Water Supply In Use (percent)	Percentage Water Supply Future Use (percent)	Water Supply Storage In Use (acre-feet)	Water Supply Storage Future Use (acre-feet)
Milford Lake	300,000 (2067)	100.00	300,000	0.00	0	33.88	66.12	101,640	198,360
Clinton Lake	110,400 (2077)	80.80	89,200	19.20	21,200	60.00	40.00	53,520	35,680
Perry Lake	150,000 (2069)	100.00	150,000	0.0	0	16.67	83.33	25,005	124,995
Tuttle Creek Lake	122,000 (2035)	40.98	50,000	59.02*	72,000	100.00	0.00	50,000	0
Kanopolis Lake	26,833 (2045)	46.60	12,500	53.40	14,333	100.00	0.00	12,500	0

Notes: MPP=multi-purpose pool; *Includes Navigation release.

Table 3-58. Contracted Reservoir Water Storage by Storage Pools for U.S. Army Corps of Engineers' Reservoirs

Reservoir	Current MPP/ Capacity (2024) (acre-feet)	Water Quality Percent of MPP (2024)	Water Quality Current Storage (2024) (acre-feet)	Marketing Water Supply Percent of MPP (2024)	Water Marketing Current Storage (2024) (acre-feet)	Water Assurance Supply Percent of MPP (2024)	Assurance Water Supply Current Storage (2024) (acre-feet)	Access District Water Supply Percent of MPP (2024)	Access District Water Supply Current Storage (2024) (acre-feet)	Reserve Capacity Water Supply Percent of MPP (2024)	Reserve Capacity Water Supply Current Storage (2024) (acre-feet)	Future Use Water Supply Percent of MPP (2024)	Future Use Water Supply Current Storage (2024) (acre-feet)
Milford Lake	366,500	0.00	0	15.55	56,991	18.33	67,179	0.00	0	0.00	0	66.12	242,330
Clinton Lake	112,200	19.20	21,542	48.50	54,417	0.00	0	0.00	0	0.00	0	32.30	36,241
Perry Lake	182,900	0.00	0	0.00	0	16.67	30,489	0.00	0	0.00	0	83.33	152,411
Tuttle Creek Lake	216,600	59.02	127,837	0.00	0	33.89	73,406	0.00	0	7.09	15,357	0.00	0
Kanopolis Lake	43,300	53.40	23,122	22.37	9,686	0.00	0	24.23	10,492	0.00	0	0.00	0

Note: MPP=multi-purpose pool.

Table 3-59. Reservoir Pool Storage for Remaining Reservoirs, acre-feet

Lake/Reservoir	Flood Pool	Active Multipurpose pool*	Municipal	Irrigation	Water Quality	Other Uses
Harlan County NE (USACE)	500,000	309,400	NA	150,000	NA	46,000[a]
Cedar Bluff Reservoir (USBR)	191,890	172,452 (2000)	2,700 AF for City of Russell		154,450 (State of Kansas)	10,900 (Fish Hatchery)
Keith Sebelius Lake (Norton Dam) (USBR)	133,740	34,510 (2000)	1,600 AF for City of Norton	27,800 AF for Almena Irrigation District		
Kirwin Reservoir (USBR)	215,136	98,154 (1996)		35,600 AF for Kirwin Irrigation District		
Lovewell Reservoir (USBR)	50,465	34,888 (2020)		Kansas Bostwick Irrigation District via diversions		
Waconda Lake (Glen Elder) (USBR)	722,988	219,420 (2001)	2,000 AF for Beloit (downstream use); 1,009 AF for Mitchell County RWD #1, #2, #3	15,170 AF for Glen Elder Irrigation Districts		
Webster Reservoir (USBR)	183,353	76,103 (1996)		71,700 AF for Webster Irrigation District #4		
Wilson Lake (USACE)	529,289	228,100	NA	NA	NA	NA

Notes: [a] The dual-purpose zone can be used for irrigation during droughts.
*Source Kansas River Basin Existing Conditions and FWOP for USBR Lakes Draft 1/13/2022

3.5.1.5 Water Use and Water Supply Storage Availability

For water supply planning purposes, the state of Kansas is categorized into 14 regional planning areas (RPAs) (https://kwo.ks.gov/about-the-kwo/regional-advisory-committees/regional-advisory-committee-notification), of which the Kansas River Basin downstream of federal reservoirs encompasses 3 RPAs: the Kansas RPA, Smoky Hill-Saline RPA, and the Solomon-Republican Regional RPA. Descriptions of the water use, precipitation, municipal and industrial customers, and water supply storage is provided in this section for the three RPAs.

Water use patterns vary between the regions, with Kansas RPA having an even balance of direct surface water and alluvial groundwater sourcing for water supply. The Solomon-Republican RPA is surface water-dominated, while the Smoky Hill-Saline RPA water use is primarily groundwater usage from the alluvial aquifer. Within each RPA there are differing levels of water right development and water use restrictions in place to reduce the risk of water right impairments to downstream water users. Specifically, many areas of the Kansas River Basin have been closed to new water right development, and some areas are required to obtain alternate supplies of water through storage agreements in order to receive water right approval.

Water use is highly variable depending on short term precipitation patterns, with fluctuations in the amount of water that is used being most apparent in the fluctuations of reported irrigation water use. This can be seen in Figure 3-115 (measured on the Kansas River at the Wamego gate), where in response to below normal precipitation in 2002 and 2012, there are distinct increases in irrigation water usage. These increases in irrigation demand coincide with times of reduced river flow, as seen in Figure 3-116, which increases the reliance on stored water supplies to maintain streamflow and satisfy the demands of industrial and municipal customers located below the reservoirs.

The increases in irrigation use are accomplished by water right holders using a higher percentage of their authorized water right allocations, with the general water right allocation usage being under 60 percent on average. This response pattern can be seen in the reported acre-inches used per acre irrigated, as shown in Figure 3-117. The climatic differences of the RPAs can also be identified, with increased irrigation use per acre in the more western RPAs. The response to below average precipitation in 2002 and 2012 is an increase in the reported irrigation use per acre.

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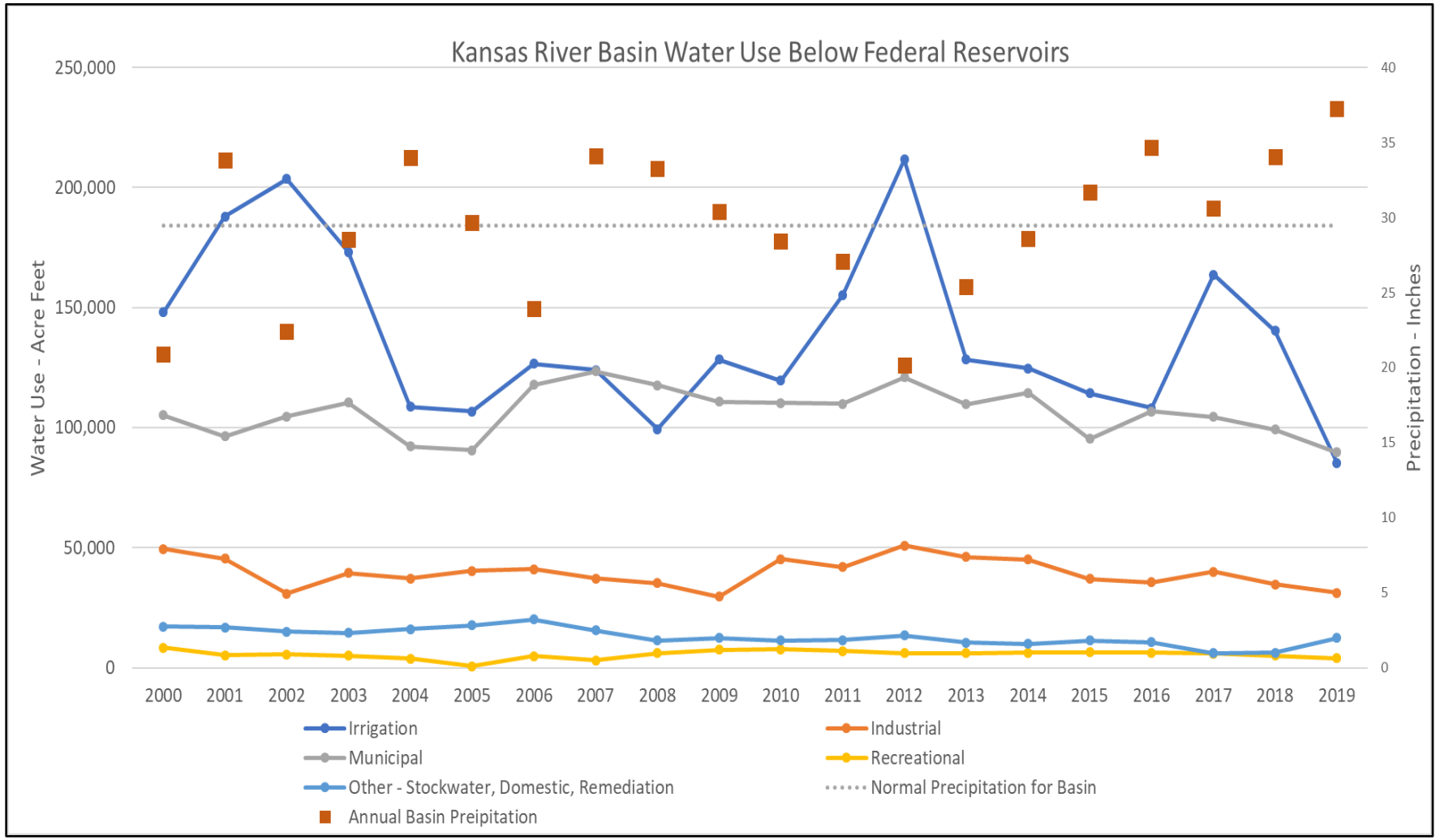
3096 *Figure 3-115. Kansas River Basin Water Use Below Federal Reservoirs*



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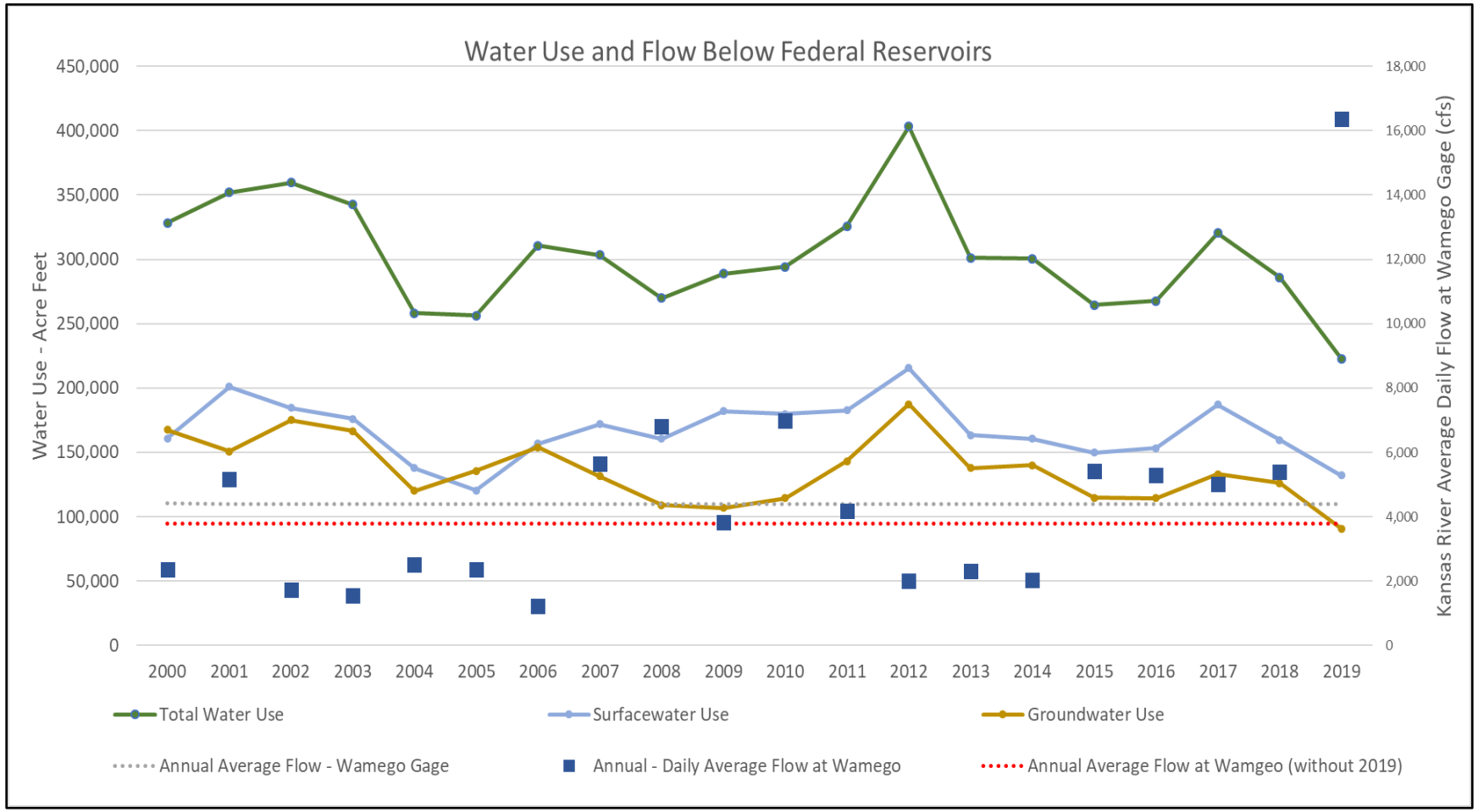
3099 *Figure 3-116. Water Use and Flow Below Federal Reservoirs*



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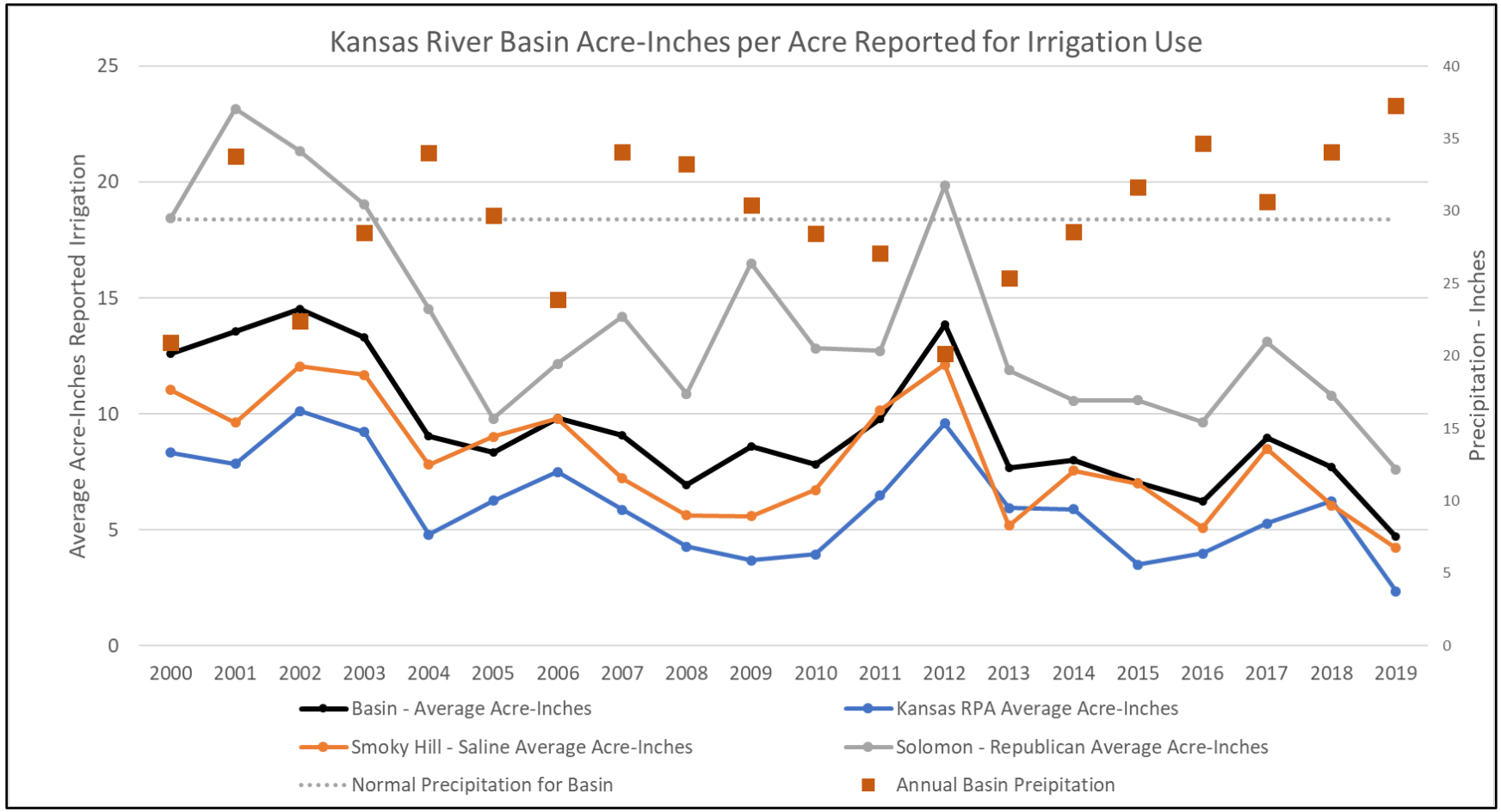
3102 *Figure 3-117. Kansas River Basin Acre-Inches per Acre Reported for Irrigation Use*



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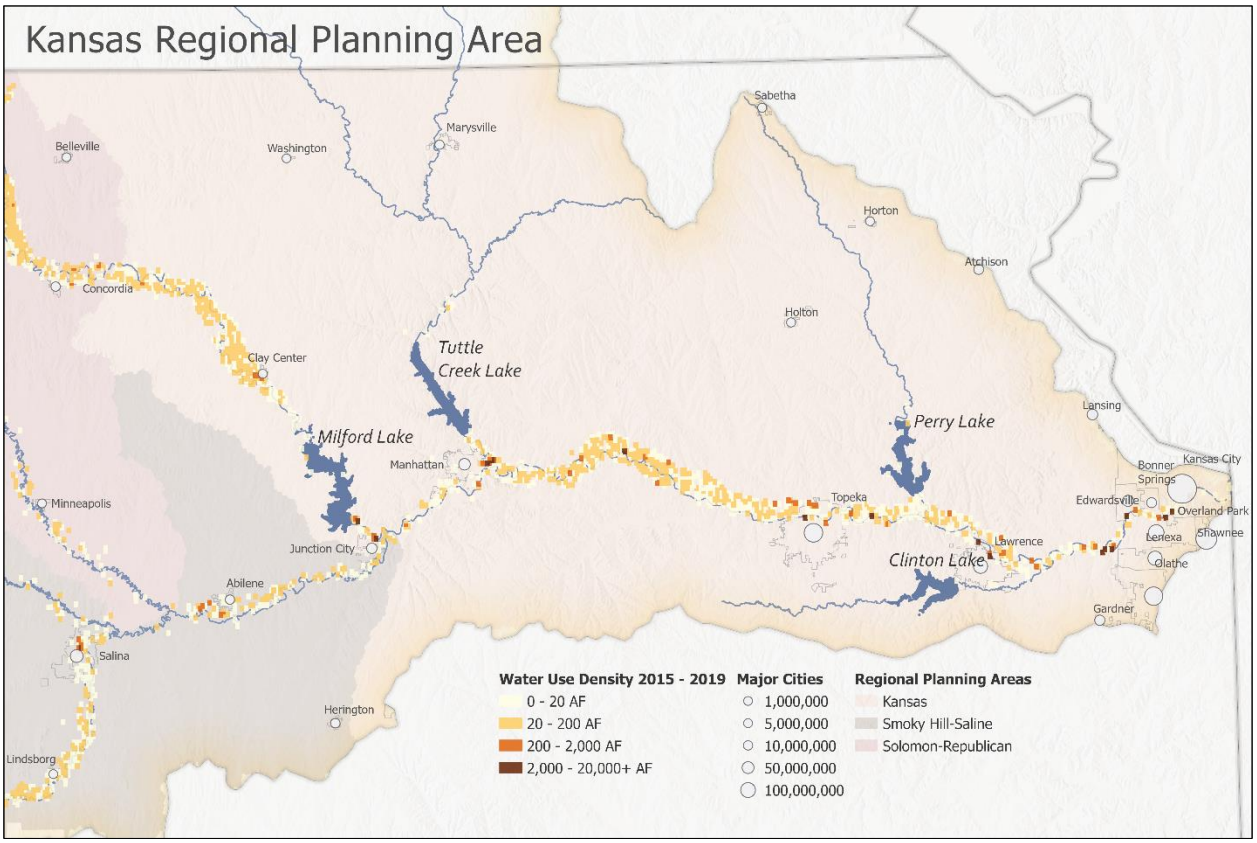
3.5.1.5.1 Kansas Regional Planning Area

The Kansas RPA is located to the east and downstream of the Smoky Hill-Saline and Solomon-Republican RPAs and includes four USACE-managed reservoirs: Tuttle Creek, Perry, Milford, and Clinton. As shown below, Kansas RPA has water use distributed throughout the alluvial corridor below federal reservoirs, with variable use patterns dependent on reservoir releases to meet demands through low precipitation and low flow conditions. With continued sedimentation at Tuttle Creek reservoir, the ability of its water quality pool to sustain flows through an extending drought is reduced, requiring increased usage of storage in Milford and Perry reservoirs to maintain low flow targets, as evidenced during the 2012–2013 drought. The trend of increasing irrigated acres will add additional demand on the system during low precipitation and low flow conditions, with some municipal demands having the ability to be met from pump sites on the Missouri River.

Figure 3-118. Water Use Trends and Precipitation



Surface and groundwater sources are both used in the Kansas RPA, with surface water diversions accounting for 56 percent of 2015–2019 usage and groundwater accounting for 44 percent. Municipal is the largest water user in the region (53 percent), followed by industrial (21 percent), and irrigation (19 percent). Surface and groundwater use is highly correlated with annual precipitation and climate variations, with relatively drier and drought periods contributing to higher usage (Figures 3-119 and 3-120).

Municipal water use shows a recent downward trend, which is reflective of the balancing of pumping from the Kansas River and alternative Missouri River sources for several municipalities within the Kansas City metropolitan area. WaterOne specifically, which services many of the growing Kansas City metropolitan areas, is developing water rights and pumping capabilities on the Missouri River. The Missouri River can also serve as an alternative source of supply during periods of poor water quality on the Kansas River, such as times with elevated chloride or bromide levels and taste and odor events related to HABs.

Figure 3-119. Annual Surface and Groundwater Use and Precipitation, Kansas RPA

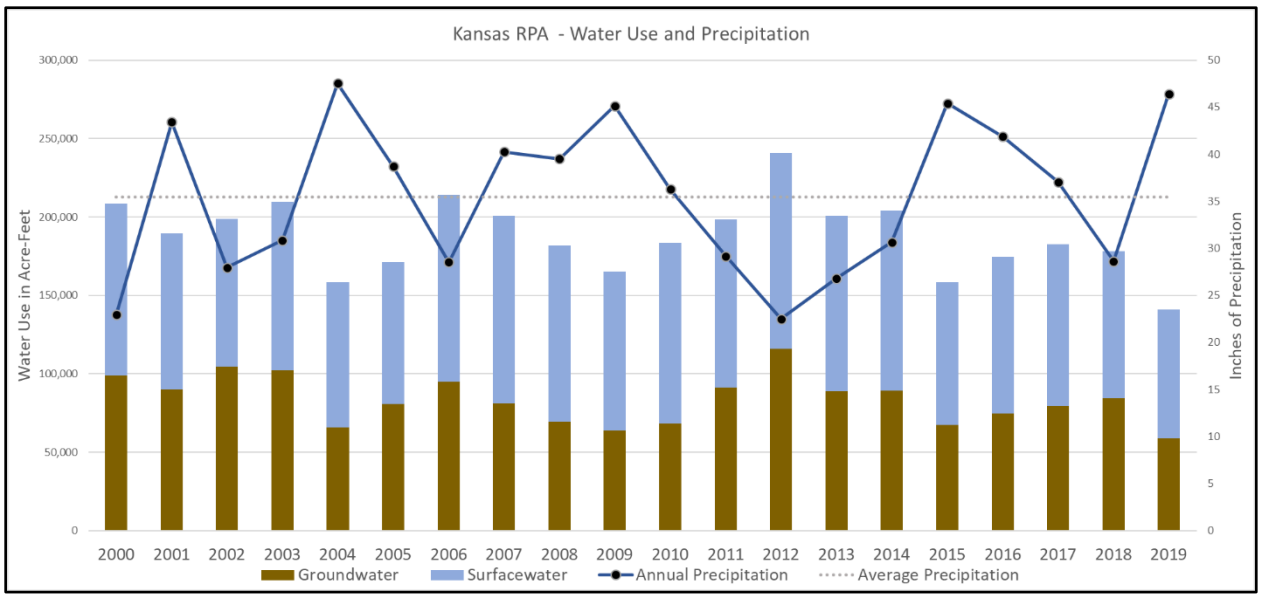
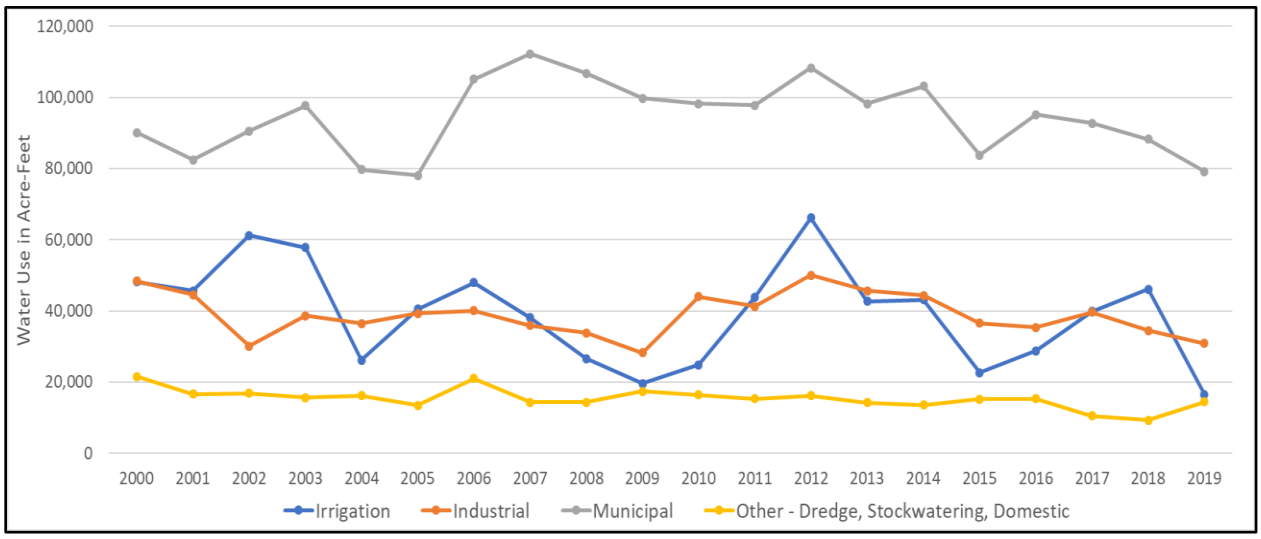


Figure 3-120. Water Use by Type in the Kansas RPA, 2000 to 2019

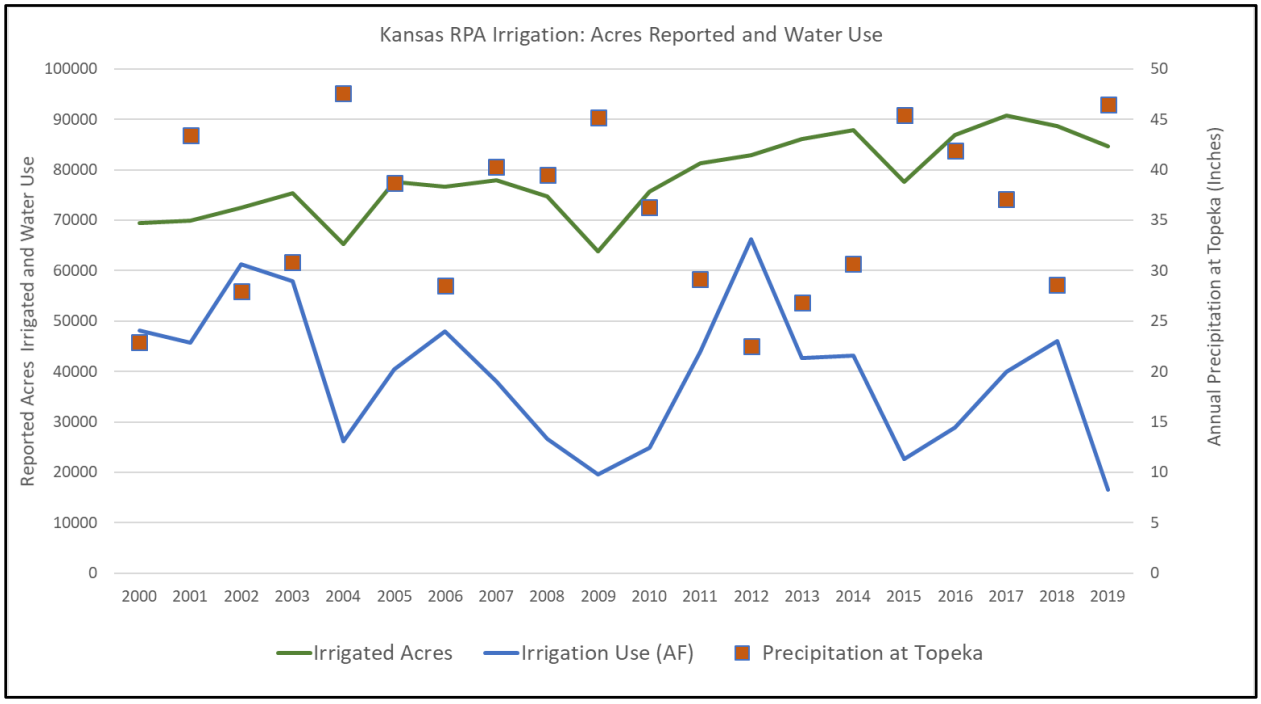


In the Kansas RPA below federal reservoirs, there has been ongoing development of water rights to support demands driven primarily for irrigation, municipal, and industrial uses. Recent water use patterns (2000–2019) are reflective of the variable Kansas climate, twenty-year average annual water use (2000–2019) was 294,414 acre-feet per

year. The 2015–2019 time period average use was less, at 272,800 acre-feet per year, and the 2010–2014 period average use was higher, at 324,900 acre-feet per year. These two periods, within the same decade, have a significant variation in water use related to short term climate variability. With increased water use in response to the 2011–2012 drought, the 2010-2014 period is 110 percent of the 20-year average water use. The 2015–2019 period in contrast had 92 percent of the 20-year average water use, with several years of above average precipitation and the 2019 flood impact (35 percent reduction in 2019 use) evident in irrigation water use.

There is an increasing trend in the acres reported as irrigated annually. With much of the Kansas RPA still open to further water right development, subject to local safe yield water availability calculations, there are additional water rights being issued that meet regulatory requirements. Additionally, some previously authorized acres that were not being irrigated may come back into irrigated production dependent on crop commodity cycles.

Figure 3-121. Annual Irrigation Use, Irrigated Acres, and Precipitation, Kansas RPA



There is widespread water use throughout the river corridor, with more concentrated usage near urban areas where municipal use is greatest. Figure 3-121 Illustrates the density of reported water use through the Kansas RPA per square mile for 2015–2019. The hot spots (dark red areas) can be identified that generally correspond to municipal water right diversion locations, with the lower basin having a higher concentration of hotspots correlating to usage of 2,000–20,000 acre-feet per year.

Water Supply Storage Customers

The Assurance District customers and allocations for water supply associated with storage in the Kansas RPA federal reservoirs are described in Figure 3-122. The max authorized use as well as the maximum historical use to 2019 are provided in the figure.

Additional water right developments throughout the Kansas River alluvium and river corridor place additional demand on base flows during periods of drought. With the Kansas River reach within the Kansas RPA generally a gaining stream, the extensive amount of water right development has reduced the base flow contribution to the river in recent droughts. A Kansas River groundwater model is in development and alluvial index monitoring wells were installed to provide more data on this interaction and allow improved future resource planning.

As shown in Figure 3-122, there has been an extensive amount of water right development within the Kansas RPA since the drought of record in the 1950s. The reduction to baseflow contributions from this additional demand will need to be offset during periods of prolonged drought in order to maintain low flow operational targets.

Figure 3-122. Water Rights Developed Since 1952–1957 Drought Event

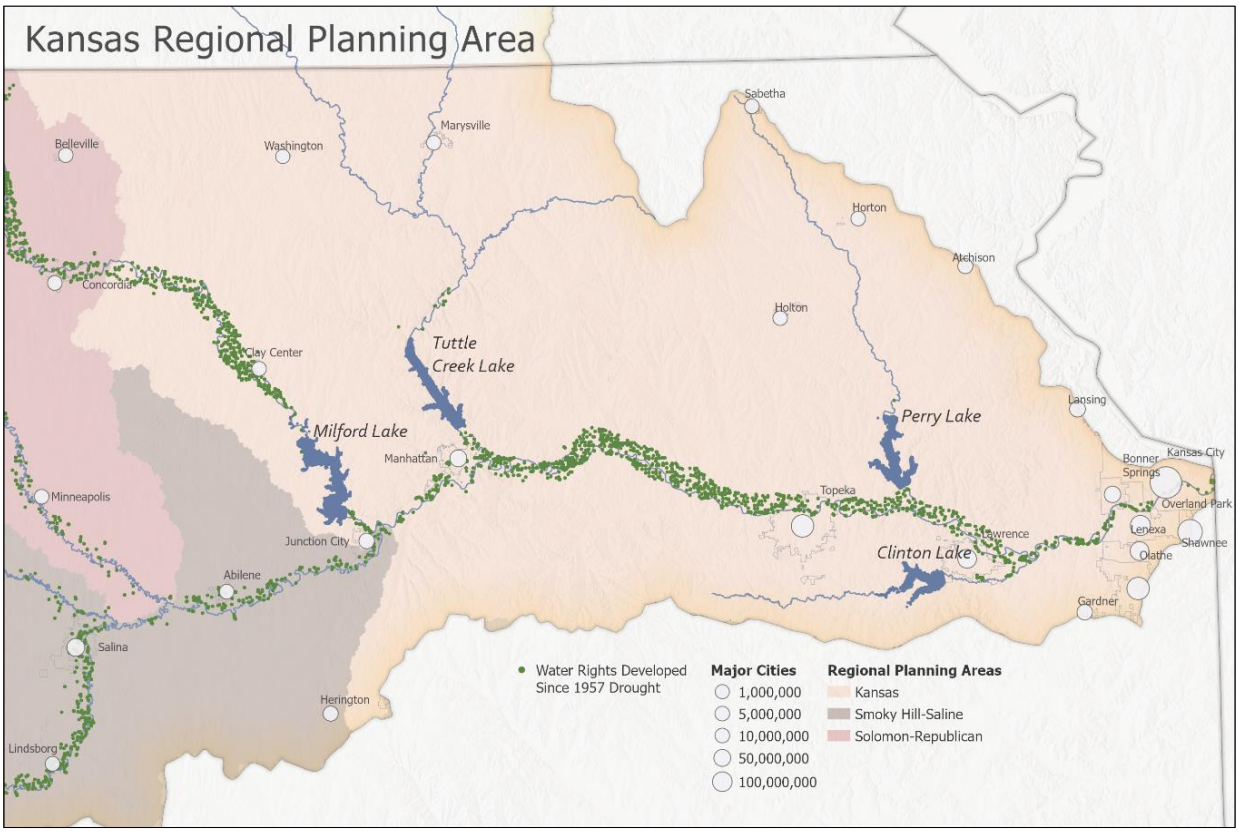


Figure 3-123. Water Supply Storage Customers and Authorized Use by Current Water Rights



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Water Supply Storage Allocations and Sedimentation

The Kansas RPA incorporates portions of the drainage basins for four major federal reservoirs: Clinton Lake, Milford Lake, Perry Lake, and Tuttle Creek Lake. All 4 reservoirs store water for water users downstream and Tuttle Creek and Clinton have water quality storage allocations that support river flow to support Kansas River flow targets (see following subsection describing water supply for Water Quality and Navigation). Table 3-54 provides current water supply allocations.

As described in this section, sedimentation in lakes is a major problem in eastern Kansas, reducing storage of the multipurpose pools in the reservoirs and in some cases reducing the flood pool storage. Soil type, land practices and extreme rainfall events are the main causes that lead to reservoir sedimentation. High flow events following heavy rainfall account for a large portion of the siltation that takes place in reservoirs. Periodic bathymetric surveys are necessary to monitor this loss of capacity. In 2009, bathymetric surveys were completed in all four of the region's reservoirs (Kansas River State of the Resource and Regional Goal Action Plan Implementation Report, 2018). More recently, bathymetric surveys were completed at Clinton Lake in 2019, Tuttle Creek and Milford in 2020, and Perry in 2021.

Tuttle Creek Lake has experienced a significant amount of sedimentation, it is estimated that Tuttle Creek Lake has lost 51 percent of its initial multipurpose pool storage capacity from sedimentation (Figure 3-124), which has substantially reduced the supply available to maintain operational Kansas river flow targets through prolonged drought. This was recently observed during the July 2012–April 2013 drought period, where Tuttle Creek Lake was drawn down over 15 feet to maintain Kansas River flow targets, and Milford Lake providing support was drawn down over 6 feet to maintain flow targets. During this relatively short nine-month period, there were times when the combined operation of Tuttle Creek, Milford, and Perry lakes for water quality missed some low flow targets. Target flows were established along the Kansas River, representing the amount of flow necessary to meet the water supply needs of major metropolitan population centers and three electrical generating stations in Northeast Kansas. Not only has the intake infrastructure been built with these expected flows but the quality of the water is also an important aspect, as dilution of highly mineralized water from the upstream Smoky Hill River is essential. Maintaining established target flows is critical to meeting the municipal and industrial water demands from the Kansas River. Without flow augmentation from Milford, Tuttle Creek, and Perry reservoirs, citizens of Northeast Kansas could experience electrical power generation interruptions, poor quality water, and potential shortages of drinking water availability.

Forty-one percent of Tuttle Creek Lake multipurpose pool is currently allocated for Water Supply purposes and is utilized to meet the needs of Kansas River Water Assurance District Customers. The Kansas River Water Assurance District has multiple growing cities as members and several industrial water users.

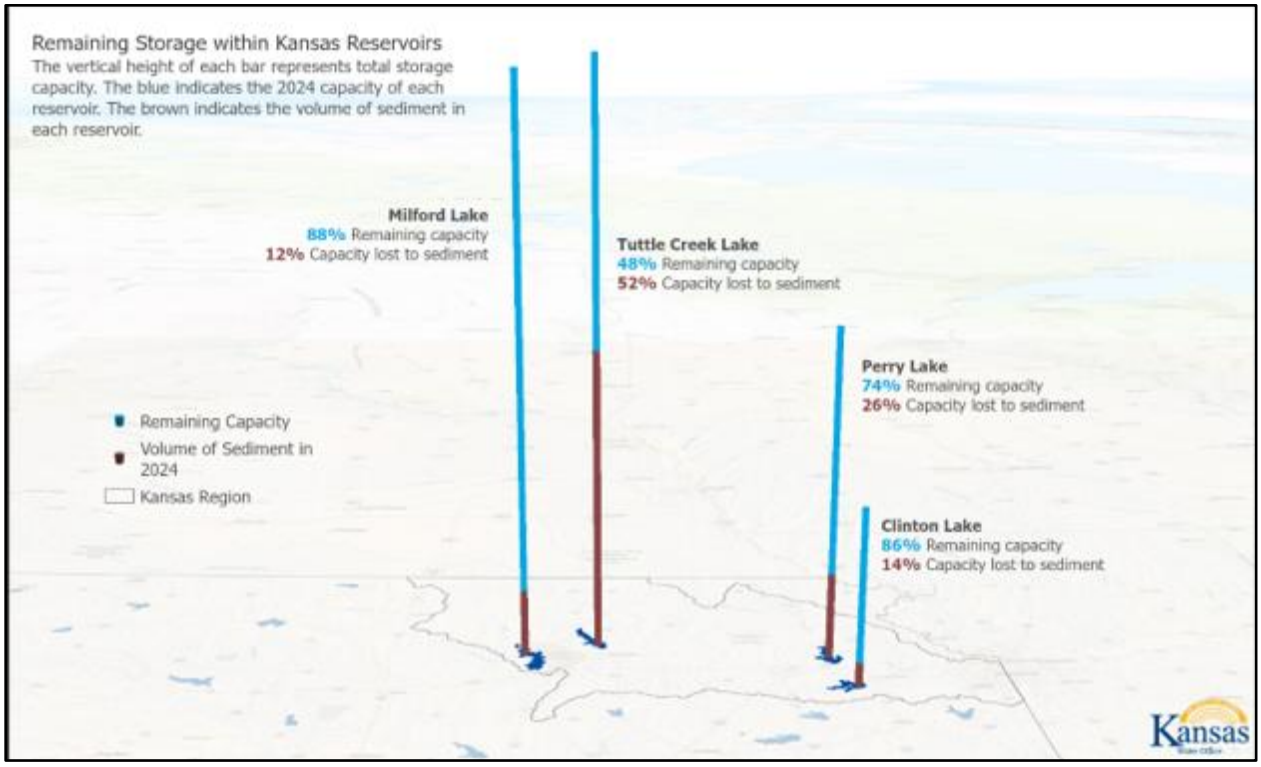
Clinton Lake, located on the Wakarusa River a tributary to the Kansas River, also has a Water Quality pool as part of its reservoir allocation. However, the Kansas Water Assurance District operational agreement prohibits it to be operated to fulfill downstream flow targets on the Kansas River. Clinton Lake's storage is allocated to

Water Supply purposes (80.8 percent of MPP storage) through contracts with the Kansas Water Marketing program to several Rural Water Districts and the City of Lawrence, Kansas. It is estimated that Clinton Lake has lost 13 percent of its initial storage capacity from sedimentation (Figure 3-124).

Perry Lake, located on the Delaware River a tributary to the Kansas River, is currently allocated 100 percent to Water Supply purposes. 16.67 percent of the storage is currently in service and is utilized to meet the need of Kansas River Water Assurance District Customers. Future Use storage accounts for 83.33 percent of total MPP storage, and the State of Kansas has until 2041 to call this storage into use. It is estimated that Perry Lake has lost 22 percent of its initial storage capacity from sedimentation (Figure 3-124).

Milford Lake, located on the Republican River a tributary to the Kansas River, is currently allocated 100 percent to Water Supply purposes. Water supply storage that is currently in use accounts or 33.88 percent of the total MPP storage and is utilized for the Kansas Water Marketing program and the Kansas River Water Assurance District. Future Use storage accounts for 66.12 percent of MPP storage, and the State of Kansas has until 2034 to call this storage into use. There has been significant water right development along the Republican River alluvium upstream of Milford Lake and reduced river flows have been experienced, which will impact future water supply yield from the reservoir. Many surface-water and groundwater rights along the Republican River alluvium are subject to water use administration to satisfy MDS requirements in Kansas, with MDS requirements being established for the Clay Center, Kansas gage. It is estimated that Milford Lake has lost 12 percent of its initial multipurpose pool storage capacity from sedimentation.

Figure 3-124. Total Sediment Accumulation in the Multipurpose pool in Kansas RPA Lakes



Water Quality and Navigation

Water quality storage is used to maintain minimum flow targets downstream of the reservoirs. In the mainstem Kansas River basin, only Tuttle Creek Lake has a water quality pool that is to be used to maintain flow targets on the Kansas River. The Kansas River flow criteria include minimum flows at Topeka and De Soto in support of both water quality and water supply; the flow targets and their relationship to the Tuttle Creek Lake pool level are summarized in Table 3-58. Milford, Perry, and Tuttle Creek lakes are operated as a system to support minimum flow criteria on the Kansas River, with the current practice being to make releases from water supply storage volumes within Milford and Perry multipurpose pools that have not been called into service by the State, and to provide supplemental releases for support of navigation flow targets on the Missouri River.

Table 3-60. Tuttle Creek Lake Low Flow Operational Target Flows by Elevation (cfs)

Tuttle Creek Lake Pool Elevation	Topeka Summer* Flows	Topeka Winter** Flows	De Soto Summer* Flows	De Soto Winter** Flows
1075–1070	750	750	1,000	1,000
1070–1065	750	600	1,000	800
1065–1048	600	600	750	700

*Summer: May 1–October 31;** Winter: November 1 through April 30.

Typically, the three reservoirs (Perry, Tuttle Creek, and Milford) are operated to maintain 1,000 cubic feet per second (cfs) minimum flow at the De Soto gage for water

quality purposes, as shown in the table above (USACE Final Draft Navigation Study: Milford, Tuttle Creek, Perry Lakes 2009). The additional 3,000 cfs flow for Missouri River navigation support translates to between six and seven tenths of a foot when the Missouri River is near the 41,000 cfs Kansas City navigation target (CDM 2011). The Missouri River navigation flow targets are only supported by Kansas lake releases when requested by the Missouri River Reservoir Control Center, in accordance with criteria in the lake regulation manuals, the Kansas River Master Manual (USACE 1966), and the Missouri River Master Manual.

Navigation releases from Tuttle Creek Lake are made from the water quality storage volume and the flood control storage. With navigation releases possible when the lake level is less than 3 feet below multi-purpose pool level (above 1,072.0 feet) during the recreational season and less than 6 feet below multi-purpose pool level (above 1069.0 feet) after October 1. Navigation releases from Perry Lake and Milford Lake can be made from the water supply storage volume that has not been called into service by the State, and allowable drawdowns could potentially be greater than 6 feet below multi-purpose pool level, though neither pool has been lowered more than 6 feet for navigation purposes since construction. Excessive drawdowns during a drought condition would decrease capabilities of meeting flow targets later in a drought event and impact recreational activities.

As shown in Table 3-59, USACE modeling shows that a significant amount of reservoir storage will be needed to meet the current water quality and low flow targets on the Kansas River through a recurrence of the 1950's drought of record.

Table 3-61. Future Reservoir Storage Conditions Used in USACE ResSim Model to Show Days Reservoir Storage Needed to Maintain Low Flow Targets Through a Recurrence of the 1950s Drought of Record Without Navigation Releases

	Year 0 (2024)		Year 25 (2049)		Year 50 (2074)		Year 100 (2124)	
Historical Drought Year Modeled	**Days**	**Acre-Feet Released**	**Days**	**Acre-Feet Released**	**Days**	**Acre-Feet Released**	**Days**	**Acre-Feet Released**
1953	137	203,656	134	191,491	137	185,579	155	174,884
1954	221	185,703	247	199,070	252	195,274	246	207,423
1955	227	262,109	222	257,419	218	246,885	220	242,057
1956	291	293,163	292	291,772	288	277,733	312	310,999
1957	87	45,789	89	49,416	88	51,325	63	60,490

Until all the storage is called into service by the State, multipurpose objectives of the remaining storage can be used to supplement Missouri River flows for navigation within operating limits selected, to provide a relatively stable pool in the interest of recreation, to augment low flows and improve water quality in the Kansas River, and to enhance fish and wildlife habitat. If 100 percent of the water supply volume is called into service for Perry and Milford lakes, navigation releases from the water supply volume would not occur at these lakes; however, navigation support from the flood control zone could still be possible.

As shown in Table 3-59, recurrence of the 1950's drought of record with future reservoir conditions will require significant amounts of the future use reservoir storage to be utilized to maintain the low flow and water quality targets. For the 2074 scenario, the modeled simulation shows reservoir storage needed to support river flow for 288 days in a recurrence of the conditions of the 1956 drought. Releases from reservoir storage early in a multi-year drought scenario for navigation support will reduce the potential capabilities of maintaining river flows and reduce water supply resiliency for multiple communities identified as disadvantaged in the Justice 40 Environmental Justice screening tool. Further described within Section 3.8 Environmental Justice.

3.5.1.5.2 Smoky Hill-Saline Regional Planning Area

The Smoky Hill-Saline RPA has water use concentrated in the alluvial corridor below Kanopolis Lake and the confluence of the Smoky Hill and Saline Rivers. With on average 56 percent of the region's water use associated with irrigation, there are variable water use patterns in relation to precipitation and flow conditions.

In the Smoky Hill-Saline RPA, there are three federal reservoirs: Kanopolis, Cedar Bluff, and Wilson Lake. With the restrictions on additional water right development, Kanopolis Lake will serve an increasing role as an alternative source of supply for further development within the region through the Lower Smoky Hill Water Access District. With continued sedimentation at Kanopolis Lake, the ability of its water quality pool to sustain flows through an extended drought is reduced. Additional description of water use, water supply storage customers, and current impacts of sedimentation in the lakes are described in this section.

Figure 3-125 shows historical water use within the area below federal reservoir projects and the extent of the Lower Smoky Hill Access District. Municipal and irrigation water users have developed water rights that are dependent on releases from reservoir storage to operate through prolonged drought conditions.

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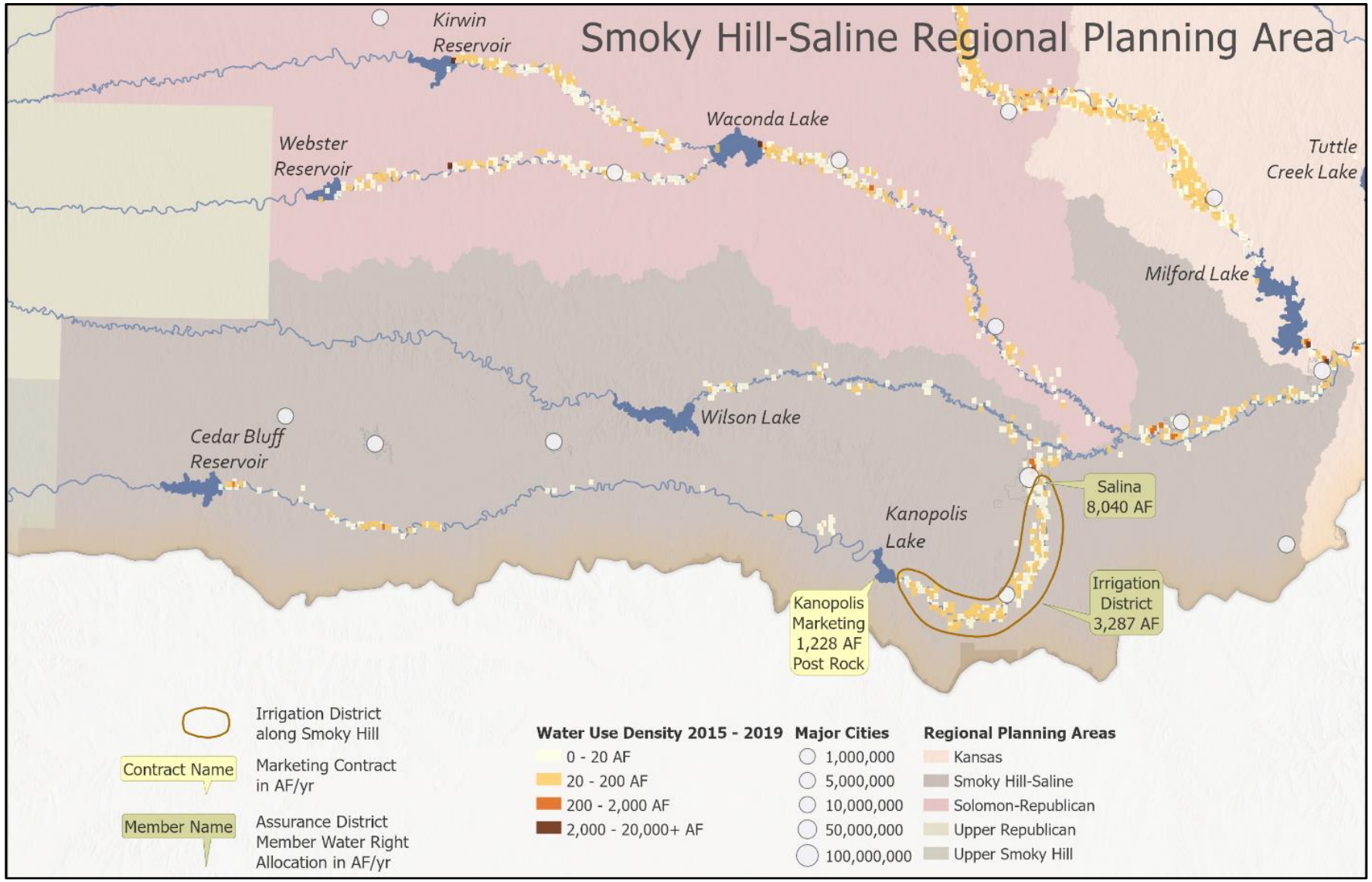
Figure 3-5. Recent Water Use Within the Smoky Hill-Saline Regional Planning Area



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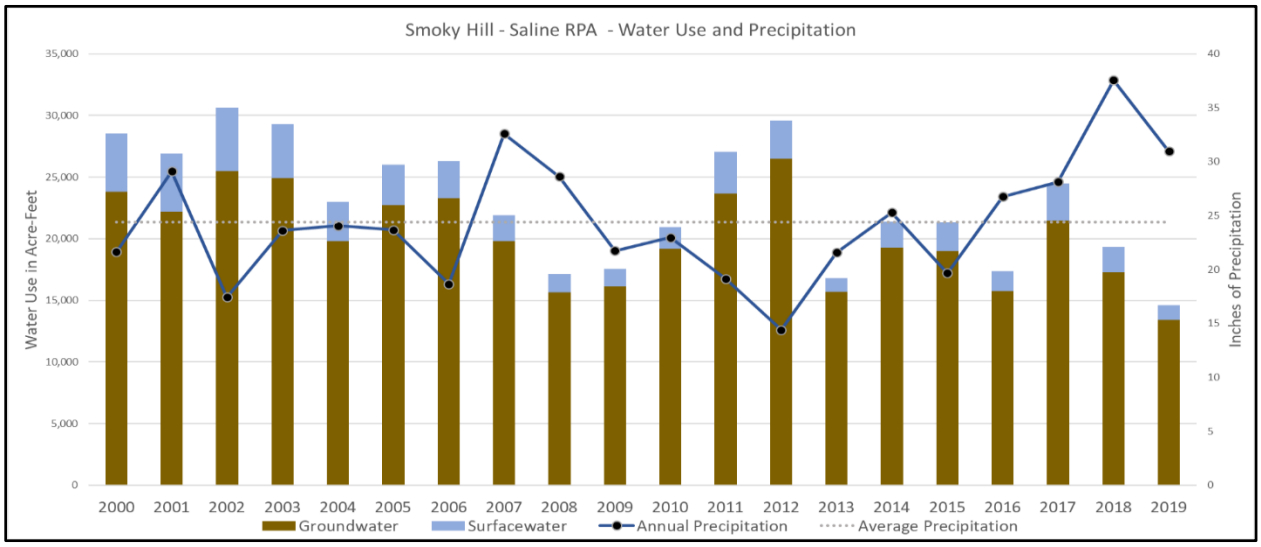
Water Use Trends and Precipitation

Kanopolis Lake (USACE) provides a primary water source for many in the Smoky Hill-Saline Region as well as irrigation water, while Cedar Bluff (USBR) supports a small municipal water right as well as a state water right to support fish, wildlife, and recreation. Wilson Lake (USACE) is currently not a source of water supply due to salinity and lack of infrastructure (KWO Smoky Hill-Saline State of the Resource, 2018).

Groundwater is the primary source of water used in the region (Figure 3-126), accounting for approximately 88 percent of the total use over the last 20 years. Water rights have been developed throughout the alluvial aquifer of the Smoky Hill River below Kanopolis Reservoir and in areas of the Saline River alluvium below Wilson Reservoir.

Figure 3-126. Annual Surface and Groundwater Use and Precipitation, Smoky Hill-Saline RPA



Irrigation accounts for 56 percent of water use within this RPA and municipal use 33 percent. Irrigation water demand is highly variable as indicated in Figure 3-127, with increases in water use in response to prolonged periods of reduced rainfall. In the recent 2012 drought, irrigation water use increased to 66 percent of the basin's total use, while streamflow in the Smoky Hill and Saline Rivers was reduced. In 2019 with flood conditions, irrigation use was only 57 percent of the historical average.

Figure 3-128 illustrates a slight increasing trend in irrigated acres over the last 20 years, with most of the region having restrictions in place for continued water right development. New surface water diversions require an alternative source of supply to be secured before a new water right can be authorized. The recently formed Lower Smoky Hill Water Access District has purchased storage in Kanopolis Reservoir, which provides an alternative source of supply for new water right developments and water security for 10,500 acre-feet of water rights, covering 2,100 irrigated acres and the City of Salina's municipal demands.

Figure 3-127. Water Use by Type in the Smoky Hill-Saline RPA, 2000 to 2019

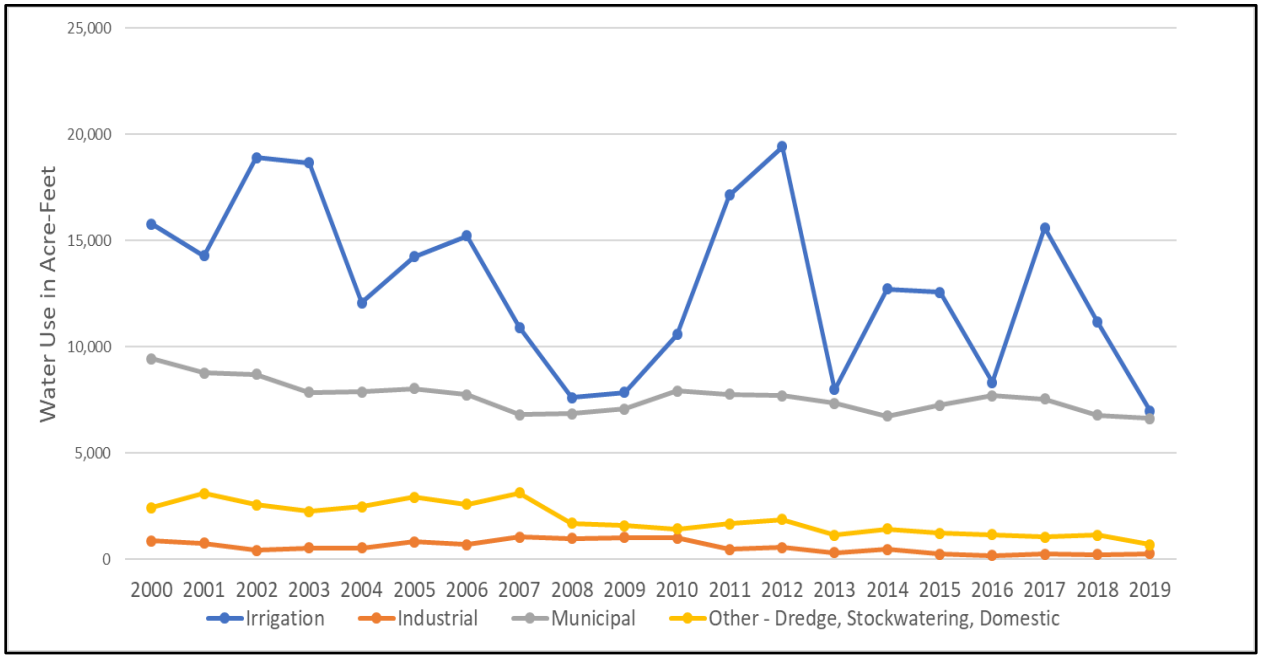
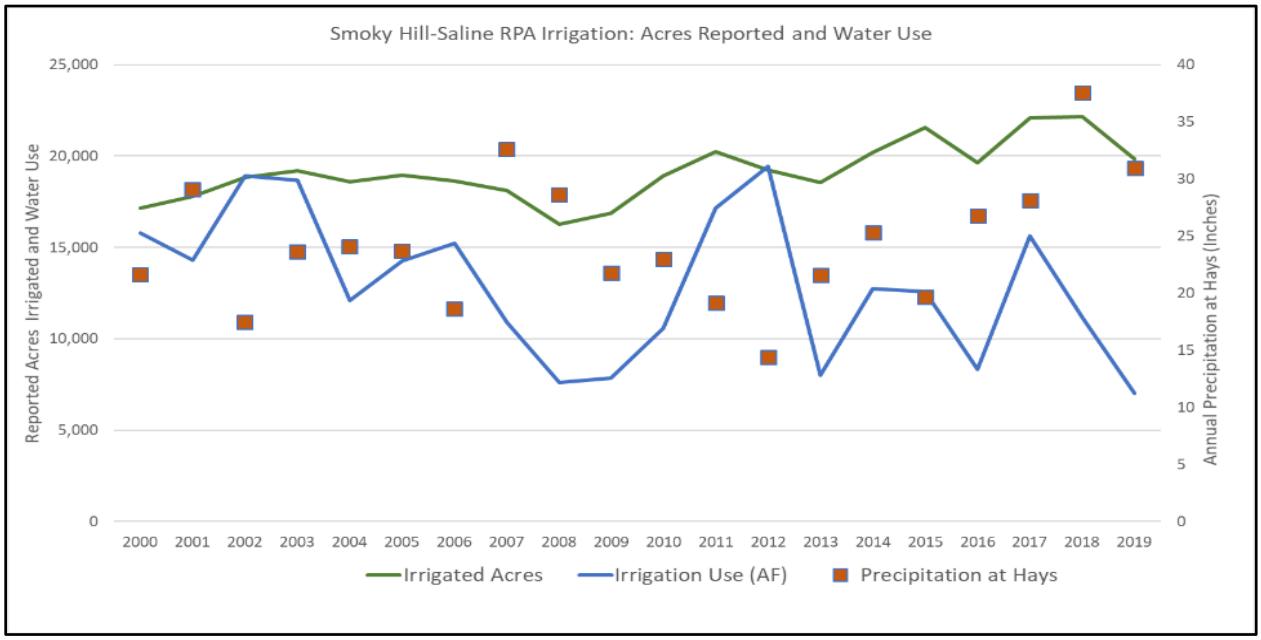


Figure 3-128. Annual Irrigation Use, Irrigated Acres, and Precipitation, Smoky Hill-Saline RPA



Recent water use density can be seen in Figure 3-128, with a high concentration of the region's use taking place below Kanopolis Lake along the Smoky Hill River alluvium. There is increased municipal demands in the eastern part of the region. It should be noted that the City of Hays, Kansas is currently working to develop a water source outside of the basin and will be importing their water supply. There are localized irrigation developments below Cedar Bluff Lake and Wilson Lake. USBR (Cedar Bluff Lake) lakes while not considered in detail in this study, do provide water supply benefits

to many downstream water users through moderation of streamflow and additional water supply agreements.

Water Supply Storage Customers

The Kanopolis water supply customers are described in Figure 3-129, including the Lower Smoky Hill Water Access District, the City of Salina, Kansas, and the Kanopolis Marketing customer Post Rock Rural Water District. Wilson Lake does not have any water supply contracts or rights.

In 1963, the City of Russell, Kansas entered contract negotiations for municipal water supply with USBR associated with Cedar Bluff Reservoir. The City obtained water rights to authorize the proposed use. The reservoir and associated works operated for each of the originally authorized purposes until 1978 when the last delivery of irrigation water was made. In 1987, the DOI, the State of Kansas, and the Cedar Bluff Irrigation District No. 6 entered into a MOU (1987) establishing an intent for reformulation and operation of the Cedar Bluff Unit contingent upon Congressional legislation.

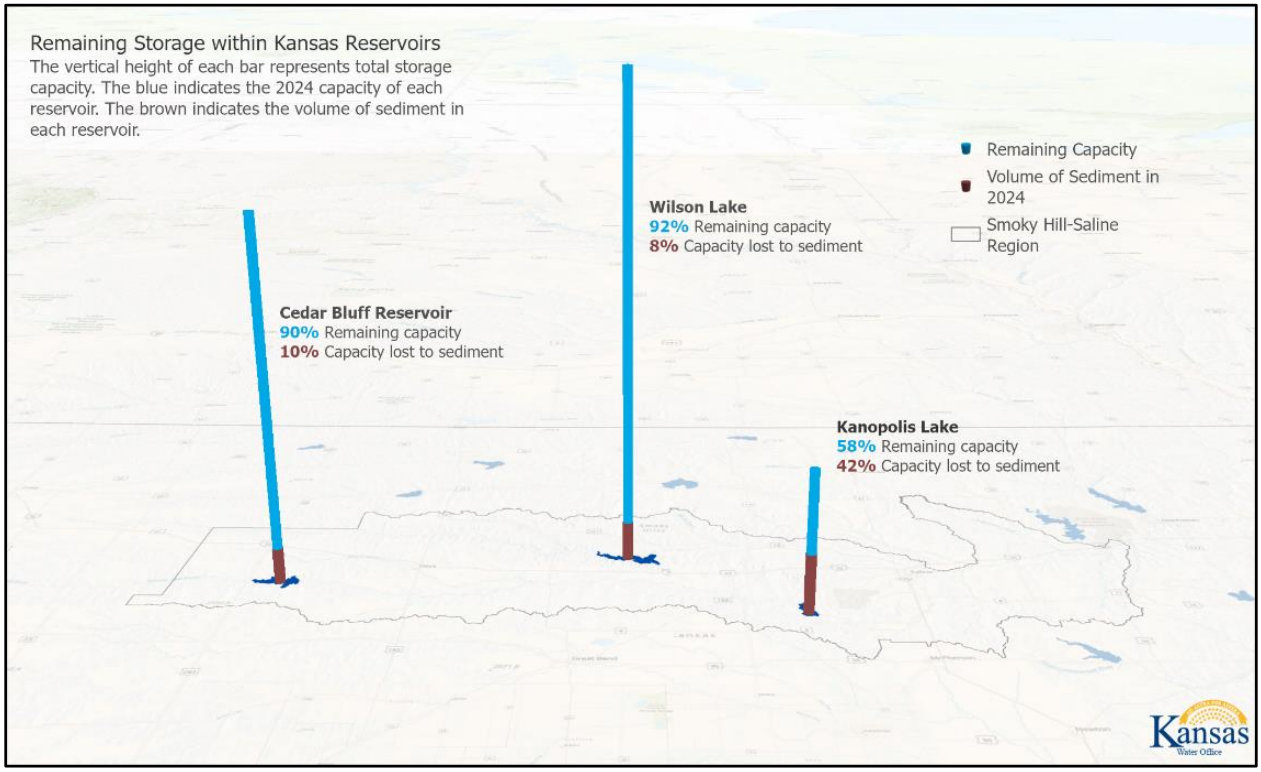
The United States Congress passed Public Law 102-575, Title IX, Section 901 in 1992 authorizing the reformulation of the Cedar Bluff Unit, including Cedar Bluff Reservoir. In 1989, a contract between the State and USBR, transferring ownership of the water rights held by the Cedar Bluff Irrigation District No. 6 (Water Right File No. 7,684) and DOI, Fish and Wildlife Service (Water Right File No. 7,627) to the State of Kansas in accordance with the 1987 MOU. The contract established four distinct operation pools within the multipurpose pool of Cedar Bluff Reservoir as shown in the Table 3-60.

Table 3-62. Water Rights in Cedar Bluff Reservoir

Pool Owner	Purpose	Pool Size (acre-feet)
City of Russell	Municipal Water Supply	2,700
KWO	Artificial Recharge	5,400
KDWP	Fish, Wildlife and Recreation	21,639
KWO and KDWP	Joint Use	147,090

Water Supply Storage Allocations and Sedimentation

Figure 3-129. Total Multipurpose pool Sediment Accumulation in the Smoky Hill-Saline Region



Kanopolis Lake, located on the Smoky Hill River a tributary to the Kansas River, is currently 100 percent allocated, with 53.40 percent for Water Quality and 46.60 percent for Water Supply purposes. Approximately 22 percent is utilized to meet the needs of Kansas Water Marketing Program Customers and 24 percent is for the Lower Smoky Hill Water Access District. It is estimated that Kanopolis Lake has lost 34 percent of its initial multipurpose pool storage capacity in 2007 and will have lost 41 percent in 2024 from sedimentation. Table 3-61 incorporates the 2000 sediment data according to water right.

Table 3-63. Cedar Bluff Water Right Pools (including 2000 Sediment Survey)

Priority of Fill	**Water Right** File No.	Purpose of the Pool	Holder	Quantity (acre-feet)
1	7,627	Fish, Wildlife and Recreation	KDWP	10,900
2	7,628	Municipal Water Supply	Russell	2,700
3	7,684	Artificial Recharge (3.31%;5,110 acre-feet) Fish, Wildlife and Recreation (6.58%; 10,161 acre-feet) Joint Use (90.1%; 139,179 acre-feet)	KWO, KDWP, KWO and KDWP	154,450

Note: Storage lost to sediment deposition will be deducted from the pools with storage covered by Water Right File No. 7,864, based on the percentages shown.

Periodically, USBR conducts sediment surveys of Cedar Bluff Reservoir to determine the amount of storage that is available in the multipurpose pool. Storage lost to sediment deposition will not be deducted from the KDWP pool. A sediment survey was completed in 2000 which indicated that a total of 12,608 acre-feet of sediment had been deposited in Cedar Bluff Reservoir. Of this total, 8,779 acre-feet of sediment was deposited in Cedar Bluff Reservoir between the elevations of 2090.00 and 2144.00.According to the data the flood pool gained 30 acre-feet of space and the pool below elevation 2090.00 lost 3,859 acre-feet of space.

Water Quality

The 2002 Kanopolis Reallocation Report established a multipurpose space allocation for general multipurpose uses, including water quality (minimum releases), recreation, and fish and wildlife. Unused sediment reserve space is also available for those purposes. The water supply contract states that for accounting purposes the remaining sediment space is split proportionately between the allocations.

Authorized irrigation, navigation, and hydropower have never been part of the operating purposes of the lake and no space has been allocated for their use. The travel time for supplemental navigation releases from Kanopolis to the Missouri River is considered too long for effective regulation. The outlet tunnel is designed to accommodate the (currently unplanned) installation of a steel penstock for power.

3.5.1.5.3 Solomon-Republican Regional Planning Area

In the Solomon-Republican RPA, there are 5 federal reservoirs managed by USBR in Kansas: Keith Sebelius Lake; Kirwin Reservoir; Lovewell Reservoir; Waconda Lake; and Webster Reservoir. With the exception of municipal water rights for the cities of Norton at Keith Sebelius Reservoir, Cawker City and Mitchell Rural Water District No. 2 at Waconda Reservoir, these reservoirs are not managed for M&I water supply.

Figure 3-130 shows historical water use within the area below federal reservoir projects.

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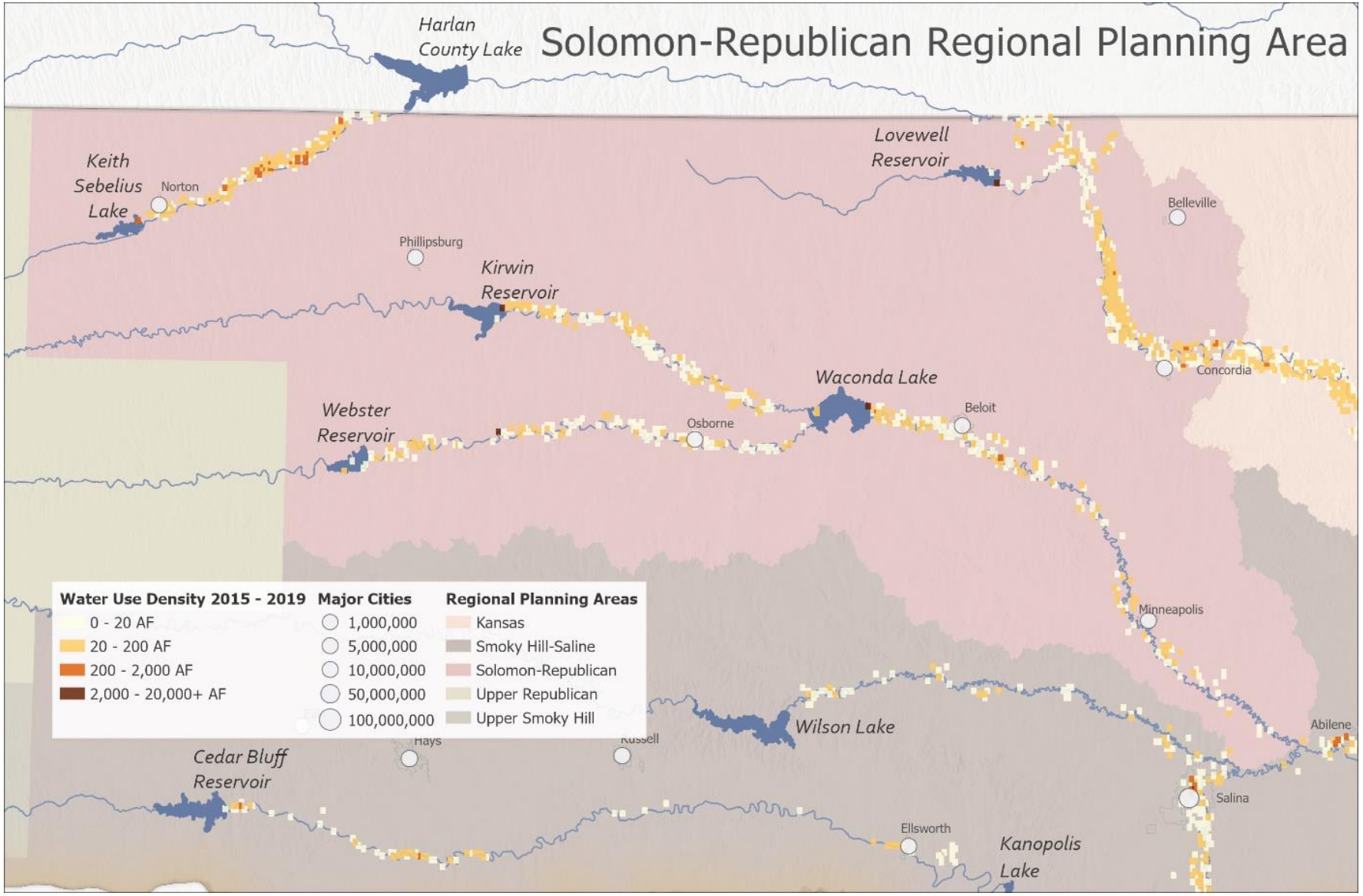
3452 *Figure 3-130. Recent Water Use within the Solomon-Republican Regional Planning Area.*



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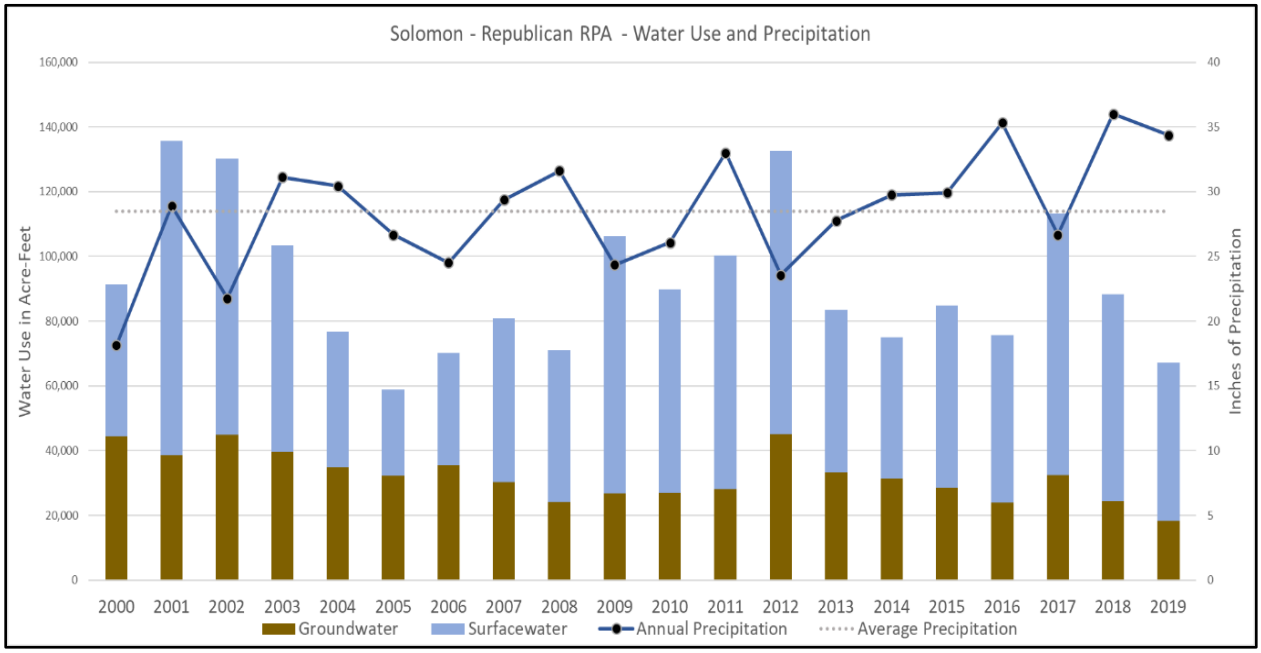
The Solomon-Republican RPA has water use concentrated in the alluvial corridors of the North Fork Solomon, South Fork Solomon, Solomon River, and Republican River below USBR lakes. With on average 93 percent of the region's water use being for irrigation and 97 percent of the region's surface water use, the water use patterns in relation to precipitation and flow conditions are highly variable. Additional water right development is closed in much of the RPA and substantially restricted through regulation in the rest of the region. Many of the irrigation water rights operating are subject to being shut off for MDS administration in times of low flow.

Water Use Trends and Precipitation

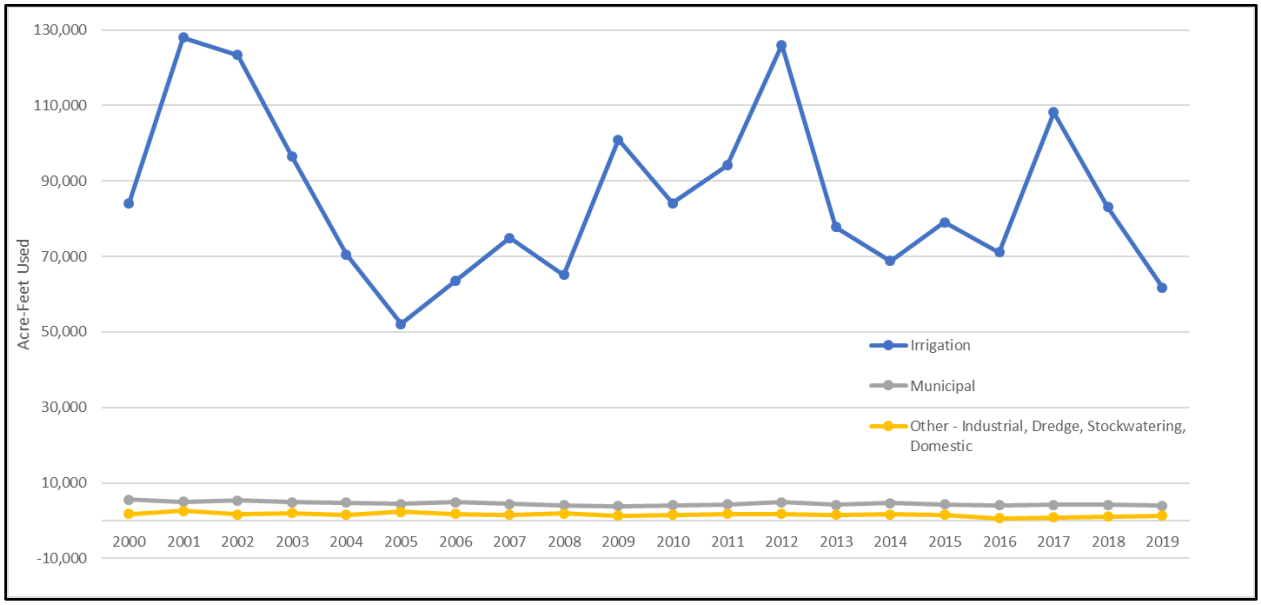
Surface water is the primary source of water within the RPA, providing for 65 percent of the historical water usage. As indicated in Figure 3-131 the amount of surface water pumped annually can be highly variable, in response to water availability and climate patterns. Many surface water and groundwater rights along the Republican River alluvium are subject to water use administration to satisfy MDS requirements set at the Concordia gage.

Figure 3-131. Annual Surface and Groundwater Use and Precipitation, Solomon-Republican RPA



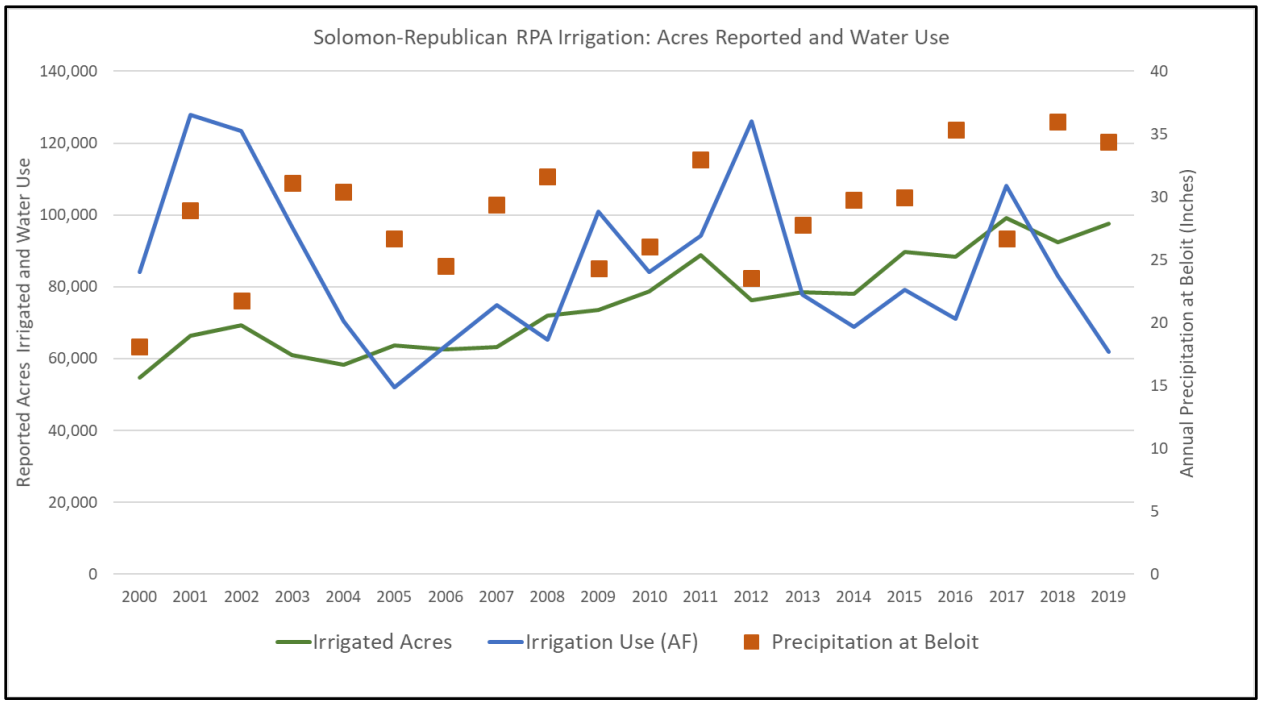
Irrigation accounts for 93 percent of the overall water use within the Solomon-Republican RPA and 97 percent of the surface water use over the historical period. Figure 3-132 indicates an increasing trend in the number of acres reported as irrigated.

Figure 3-132. Water Use by Type in the Solomon-Republican RPA, 2000 to 2019



Much of the RPA is closed to additional water right development within the North Fork Solomon River, South Fork Solomon River, and Prairie Dog Creek reaches. Solomon River alluvial areas below Waconda Lake are still open to further development, subject to additional restrictions that limit the extent that new demands can created. The Republican River alluvial area is still open to further development but is highly restricted on the amount of additional water rights that can be issued.

Figure 3-133. Annual Irrigation Use, Irrigated Acres, and Precipitation, Solomon-Republican RPA



Density of water use is high through the river reaches downstream of Keith Sebelius Lake, where relatively drier conditions in the western part of the RPA drive higher use per irrigated acre (Figure 3-133). There are also high use densities through the Republican River corridor in the eastern part of the region and some concentrated use in the reaches directly below USBR Lakes. These USBR lakes while not considered in detail in this study, do provide water supply benefits to many downstream water users through moderation of streamflow and additional water supply agreements.

Water Supply Storage Customers

The City of Norton is the only municipality with a water supply storage right in the RPA. The City has a storage allocation in Keith Sebelius Reservoir (Norton Dam). Mitchell RWD No.2 has a water right for direct water diversion from Waconda Reservoir. Many of the reservoirs in this RPA, including Webster, Keith Sebelius, and Kirwin, have struggled to keep lake elevations close to multipurpose pool levels due to relatively drier conditions. Many cities within this region are supplied with groundwater wells located within the alluvial corridor or direct surface water intakes with senior water rights. Keith Sebelius Lake also serves as irrigation storage for the Almena Irrigation District and Lovewell provides irrigation storage to the Bostwick Irrigation District.

Water Supply Storage Allocations and Sedimentation

Table 3-64. Multipurpose Pool Volumes

Lake	Original Volume (acre-feet)	Year 0 (2024) acre-feet Existing Condition	Year 0 (2024) Percent Existing Condition
Cedar Bluff	185,496	171,590	92.5
Keith Sebelius	36,127	33,415	92.5
Kirwin	99,432	97,267	97.8
Lovewell	41,687	34,746	83.3
Waconda	242,017	197,740	84.2
Webster	77,370	75,197	97.2

3.5.1.5.4 Harlan County

Harlan County Lake (USACE) is on the Republican River in Nebraska, and it provides irrigation storage that is managed by the USBR.

Water Supply Storage Customers

The total storage capacity of 850,000 acre-feet in the Harlan County Reservoir provides 500,000 acre-feet of storage space reserved for flood control, 150,000 acre-feet exclusively for irrigation, and 200,000 acre-feet for sediment reservoir. The sediment reserve can be used for irrigation and other conservation purposes until depleted (USACE Harlan County Reallocation Report, 1959). An additional 46,000 acre-feet of the multi-purpose pool was allocated as Dual Purpose in 2001. The dual-purpose zone can be used for irrigation during drought conditions through a Consensus Plan between USBR and the USACE.

Harlan County Lake provides irrigation water to approximately 100,000 acres of cropland in south-central Nebraska and north-central Kansas under authority of the Bostwick Division, part of the Pick-Sloan Missouri Basin Water Program. The reservoir provides an average mixed-use annual water supply of 150,000 acre-feet, producing approximately $2.8M in annual water supply benefits (USACE Harlan County Consequence Assessment Report, 2011).

Harlan County Lake supplies water for 22,787 acres in the Nebraska-Bostwick Irrigation District, 13,550 acres in the Kansas Courtland Unit-Bostwick Irrigation District (above Lovewell Reservoir), and 28,338 acres in the Kansas-Bostwick Irrigation Districts below Lovewell Reservoir (USACE Harlan County Dam Safety Assurance Program Report, 2009).

The original project design and Field Working Agreement with the USBR specified a flood control pool of 500,000 acre-feet and an irrigation pool of 150,000 acre-feet, with the multipurpose pool elevation at 1946.0 feet (https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/republican/RRCA/2017/10_CurrentResolutions.pdf). The Field Working Agreement specified that when sedimentation reduced either of these capacities by more than 10 percent then the pool elevations would be adjusted (basically the pool would be reallocated) to restore the design capacities.

Discussions continued between USACE and USBR regarding the availability of the dual use zone for irrigation. USBR had always contended that the sediment pool was intended to be used for irrigation in addition to other authorized purposes until filled with sediment. But the Corp's Lake Regulation Manual (USACE 1973b) and USACE interpretation of the Field Working Agreement and design documents did not provide such use. In 2000 the agencies agreed to a Consensus Plan which set a procedure to allow the space down to elevation 1927 feet to be used for irrigation during drought years, with the allowable drawdown keyed to quantifiable drought conditions.

In early 2001, a lake regulation manual revision was approved by the USACE NWD incorporating the Consensus Plan. The final revisions to the manual's multipurpose plan revised the key pool elevations with reference to the 2000 sediment survey. The top of multipurpose pool was set to elevation 1945.73 feet (providing exactly 500,000 acre-feet in the flood pool per the 2000 area-capacity tables), and the bottom of the irrigation pool was set to elevation 1932.50 feet (providing exactly 150,000 acre-feet in the irrigation pool). Later in 2001, the revised Field Working Agreement was approved by both agencies, also incorporating the elevations derived from the 2000 sediment survey.

Low flow release criteria had also long been an issue between both agencies. The current 1973 Lake Regulation Manual (USACE 1973b) stated that non-irrigation season releases would be supplied to attempt to maintain a minimum of 10 cfs below the dam for fish and wildlife. The Field Working Agreement in effect at the time was more specific in that it also required higher mean weekly and mean monthly flows at the downstream gages, in addition to the 10 cfs mean daily flow. But USBR has always contended that it had control over the entire multipurpose pool, and when the pool is in that zone it is primarily responsible for regulating minimum releases. In response to the declining average annual inflows, USBR prepared an environmental assessment in

1983 and a revised schedule of minimum releases, specifying that such releases would only be made in November, December, and January, with the magnitude dependent on pool levels. The USACE implemented this schedule without formal approval, although a 1984 office of counsel legal opinion questioned our authority to do so.

The minimum release wording in the 1973 Lake Regulation Manual was retained in the initial 2001 manual revision. But the 1983 USBR schedule minimum release was attached to the revised Field Working Agreement, to which both parties also agreed. In 2002, USBR requested that a somewhat modified schedule of minimum releases be adopted. This was approved by the District in 2003, and the revised schedule was incorporated into the manual revision and also replaced the original Appendix B in the revised Field Working Agreement.

Water Supply Storage Allocations and Sedimentation

Sedimentation has had a moderate impact on Harlan County Lake through loss of storage capacity and moderate impacts to infrastructure surrounding the lake. Approximately 70 percent of the incoming sediment enters Harlan County Lake during flood control operations.

Table 3-65. Total Sediment Accumulation in the Multipurpose pool in Harlan County Lake

Lake	MPP Initial Volume (acre-feet)	MPP Recent Volume (survey year)	Percent of Initial MPP Volume Lost to Sediment in Recent Survey Year	Estimate 2024 Remaining MPP Volume (acre-feet)	Percent of MPP Lost to Sediment 2024
Harlan County	346,500	310,200 (2000)	10.5	309,400	11.0

3.5.1.6 Cost of Storage

The multipurpose pools at Milford Lake and Perry Lake are similar in that the entire pools are allocated to water supply and contracted to the State of Kansas. Like Perry Lake, only a portion of the water supply space in Milford has been called into service. At Tuttle Creek Lake, all of the water supply storage space is in service, but it also has a separate allocation specifically reserved for multipurpose uses.

For USACE project, the cost of water supply storage varies depending on how and when the storage was acquired. For storage that was originally authorized as part of the project (Clinton, Harlan, Milford, Perry) the State paid a portion of the joint-use construction costs and the entire amount of any water supply specific infrastructure. If the storage was obtained through a reallocation study (Tuttle Creek and Kanopolis), the storage was priced according to a 1985 Memorandum of Agreement (MOA) which limited the cost of storage as a percent (proportion of usable storage which is multipurpose pool and flood control pool, associated with the water supply allocation) of the joint-use construction costs at the time of construction.

The nonfederal entity shall also be responsible for an appropriate share of the annual costs that include specific and joint-use operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs.

3.5.2 Future Without Project Conditions

The methods and assumptions for assessing the FWOP for water supply in the Basin are described in the following section. The FWOP includes assessment of future water supply demands, a demand gap analysis, and the value of water supply along with the impacts from sedimentation to surface water supply.

3.5.2.1 Methodology and Assumptions

Information and model results from the sedimentation analysis were used to calculate remaining storage at reservoirs in the Basin. Detailed information regarding the sedimentation analysis can be found in Appendix D.

3.5.2.1.1 Water Supply/Demand Gap Analysis

The water supply/demand gap analysis was conducted for future water supply demands and future water supply storage with projected future sedimentation in reservoirs.

Future Surface Water Demands

Current demands in the Kansas River basin were determined for each water user; this was done using water rights and their annual reported use. Water use, including water rights and marketing contracts, for each user were summed to obtain a total water use for the years 1990 to 2014. Since the highest water use generally occurs during drought because of the need for irrigation and high evaporation from industrial storage impoundments, the current demand is estimated by taking the maximum of the historic water use because it offers a realistic estimate of the current water use in severe drought. In some cases, the estimate of current water use is increased or decreased from the maximum historic use based on the available trends. Because of this assumption, this model is most accurate in drought periods and generally less accurate during wet years.

The Smoky Hill Access District stores water for irrigators as well as the city of Salina. To estimate irrigation water use, crop net irrigation requirement as well as the observed precipitation are used to estimate field applied water, which is multiplied by the number of acres.

When available, projected water use is obtained from municipalities and industry themselves, such is the case with 2040 demand projections from the Kansas Water Assurance District and the city of Salina. Other demand projections are based on best judgement, use trends, and population projections, using 2015 to 2070 data from the Center of Economic Development and Business Research (2020) and assuming constant per capita consumption.

Future Water Supply Storage

In order to evaluate what changes may occur in the future, four different time intervals were measured in the future. Table 3-64 provides the remaining multipurpose pool volumes in year 0 (2024), as well as years 25 (2049), 50 (2074), and 100 (2124), as described in the sediment evaluation for USACE reservoirs (Appendix D). Table 3-65 provides the remaining multipurpose pool volumes in year 0 (2024), as well as years 25, 50, and 100 for USBR reservoirs. Figure 3-109 shows the reservoir capacity projected

to be lost to sedimentation by 2074 for each reservoir. These future sedimentation results were used to estimate the loss in water supply and water quality storage as shown in Table 3-66.

Table 3-66. Remaining Multipurpose Pool Volumes for U.S. Army Corps of Engineers' Reservoirs

		Existing Condition		Future Without Project Condition					
Lake	Original Volume acre-feet	Year 0 (2024) acre-feet	Year 0 (2024)%	Year 25 (2049) acre-feet	Year 25 (2049) %	Year 50 (2074) acre-feet	Year 50 (2074) %	Year 100 (2124) acre-feet	Year 100 (2124) %
Clinton	129,200	112,200	87	103,900	80	96,700	75	83,900	65
Perry	243,200	182,900	75	159,400	66	140,000	59	105,200	43
Tuttle Creek	424,300	216,600	51	153,000	36.1	106,500	25.1	29,200	6.9
Milford	415,400	366,500	88.2	355,800	85.7	349,900	84.2	333,000	80.2
Kanopolis	73,200	43,300	59.1	34,800	47.5	30,200	41.3	18,200	24.9
Wilson	247,800	228,100	92	218,000	87.9	209,000	84.3	190,100	76.7
Harlan County	346,500	309,400	89.3	304,000	87.7	300,700	86.8	291,000	84

Table 3-67. Remaining Multipurpose Pool Volumes for USBR Reservoirs

		Existing Conditions		Future Without Project Condition					
Lake	Original Volume acre-feet	Year 0 (2024) acre-feet	Year 0 (2024) %	Year 25 (2049) acre-feet	Year 25 (2049) %	Year 50 (2074) acre-feet	Year 50 (2074) %	Year 100 (2124) acre-feet	Year 100 (2124) %
Cedar Bluff	185,496	171,590	92.5	170,299	91.8	169,008	91.1	166,426	89.7
Keith Sebelius	36,127	33,415	92.5	32,289	89.4	31,164	86.3	28,913	80.0
Kirwin	99,432	97,267	97.8	96,492	97.0	95,716	96.3	94,166	94.7
Lovewell	41,687	34,746	83.3	33,967	81.5	33,189	79.6	31,633	75.9
Waconda	242,017	197,740	84.2	181,016	77.3	164,307	70.3	130,949	56.6
Webster	77,370	75,197	97.2	74,407	96.2	73,616	95.1	72,034	93.1

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Table 3-68. Future Days Per Year Reservoir Storage Below Storage Threshold—1950s Drought Scenario

Historical Drought Year	Model Year	Year 0 (2024)-Below 10% Remaining			Year 0 (2024)-Below 25% Remaining			Year 0 (2024)-Below 50%		
		Milford	Tuttle	Perry	Milford	Tuttle	Perry	Milford	Tuttle	Perry
1953	2057	0	0	0	0	0	0	0	0	0
1954	2058	0	0	0	0	0	0	0	0	0
1955	2059	0	0	0	0	0	0	0	0	0
1956	2060	0	0	0	0	0	0	0	58	108
1957	2061	0	0	0	0	0	0	115	94	97
		Year 25 (2049)-Below 10%			Year 25 (2049)-Below 25%			Year 25 (2049)-Below 50%		
		Milford	Tuttle	Perry	Milford	Tuttle	Perry	Milford	Tuttle	Perry
1953	2057	0	0	0	0	0	0	0	0	0
1954	2058	0	0	0	0	0	0	0	0	0
1955	2059	0	0	0	0	0	0	0	0	0
1956	2060	0	0	0	0	0	0	85	95	158
1957	2061	0	0	0	0	0	0	137	95	136
		Year 50 (2074)-Below 10%			Year 50 (2074)-Below 25%			Year 50 (2074)-Below 50%		
		Milford	Tuttle	Perry	Milford	Tuttle	Perry	Milford	Tuttle	Perry
1953	2057	0	0	0	0	0	0	0	0	0
1954	2058	0	0	0	0	0	0	0	0	0
1955	2059	0	0	0	0	0	0	0	0	0
1956	2060	0	0	0	0	0	0	120	137	227
1957	2061	0	0	0	0	0	0	159	95	136
		Year 100 (2124)-Below 10%			Year 100 (2124)-Below 25%			Year 100 (2124)-Below 50%		
		Milford	Tuttle (5,000AF)	Perry (11,000AF)	Milford	Tuttle	Perry	Milford	Tuttle	Perry
1953	2057	0	0	0	0	0	0	0	0	0
1954	2058	0	0	0	0	0	0	0	6	0
1955	2059	0	0	0	0	0	0	0	0	64
1956	2060	34	10	0	103	111	131	282	289	366
1957	2061	136	16	23	167	92	98	172	93	144

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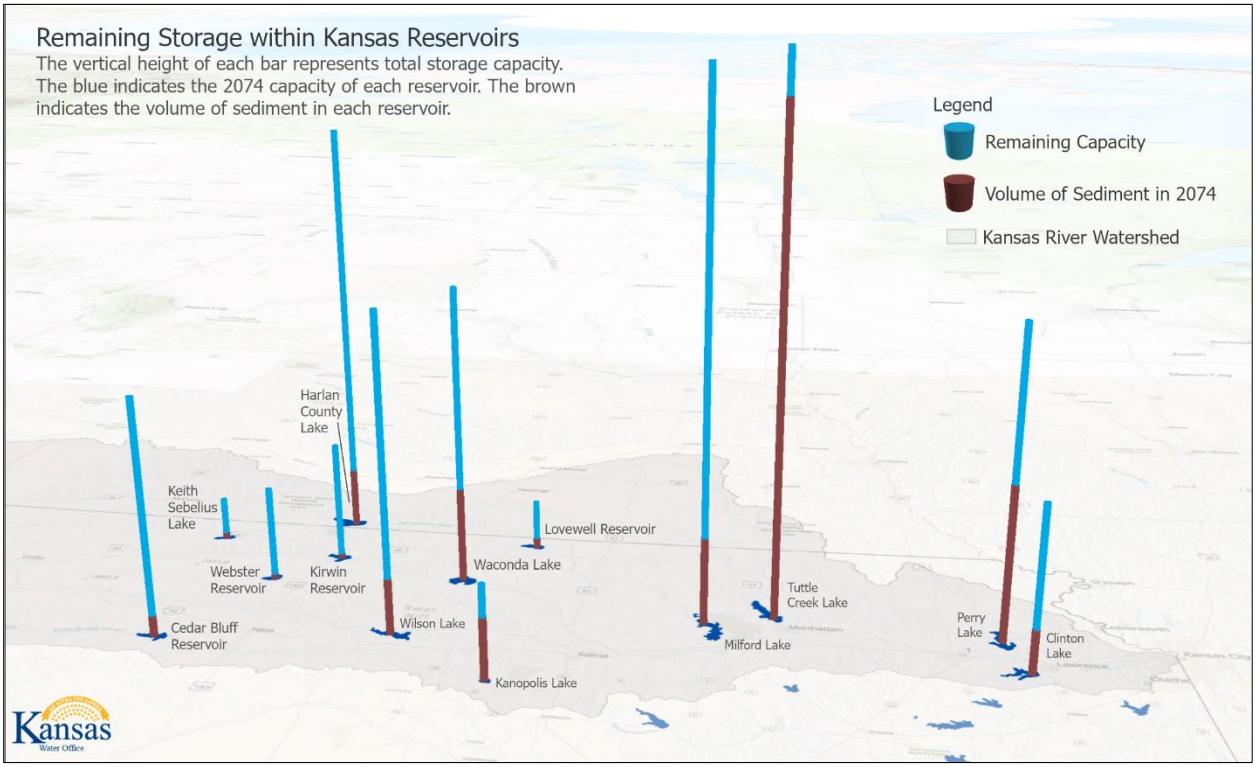
Figure 3-134. Kansas River Reservoirs 2074 Remaining Storage Capacity



Surface Water Supply Gaps

Figure 3-135 shows projections of when there will be a surface water supply gap are completed for each of the Regional Planning Areas of the Kansas River basin with storage contracted by KWO. This water supply gap analysis process is done by calculating the future reservoir yield that will be available with projected reservoir volumes, future water supply demands, and yield required to maintain low flow water quality targets through a recurrence of a 1950's drought of record event.

With potential for land use change, more frequent drought events, and climate variability reducing reservoir yields, water supply shortages may occur sooner with the continued loss of reservoir storage volume to sedimentation.

Projected shortage dates were estimated by KWO. An OASIS mass balance water supply model projects the future reservoir yields through the historic 2 percent drought event, with anticipated future water supply demands and reservoir volumes. The ResSim future water supply modelling conducted by USACE (Appendix B) shows shortages in the 2074 simulation, with 26 days being unable to maintain water supply demands as shown in Table 3-42 through a repeat of the drought of record. With potential for future higher intensity drought events, the projected loss of reservoir volume will lead to water supply shortages for the Kansas River.

3.5.2.1.2 Value of Water Supply

The value of water supply in the future and the benefits that USACE reservoirs provide is described below for municipal and industrial water supply and irrigation.

Municipal and Industrial Water Supply

USACE's primary role in the water supply industry is to provide water supply storage in partnership with state and local interests. The value of USACE's contribution to the nation's M&I water supply or the water supply benefits are generally measured through consumer surplus willingness to pay, in accordance with the Principles and Guidelines (P&G). The willingness to pay can be estimated using avoided costs for alternative water supplies. In general, the least cost alternative for water supply reflects the water supply benefit (it is not in the form of finished water at the tap ready to be consumed as the USACE's partners provide finished water). According to the P&G:

> *The conceptual basis for evaluating the benefits from M&I water supply is society's willingness to pay for the increase in the value of goods and services attributable to the water supply. Where the price of water reflects its marginal cost, use that price to calculate willingness to pay for additional water supply. In the absence of such direct measures of willingness to pay, the benefits from a water supply plan are measured instead by the resource cost of the alternative most likely to be implemented in the absence of a plan.*

Test of Financial Feasibility approach compares the annual cost of USACE storage to the annual cost of the next most likely, least costly water supply alternative. The purpose of the test of financial feasibility is to demonstrate that the provision of M&I water from the federal project is the most efficient water supply alternative.

One approach to estimate the value of the least cost alternative is to use the original construction costs of the reservoirs and escalate the costs with a construction cost index to current price levels. The reservoir construction costs are obtained from the cost allocation reports, which are available for all reservoirs built by the USACE. They can also be obtained in more recent reallocation studies if evaluations were conducted on constructing substitute/alternative reservoirs for water supply. The portion of the reservoir storage allocated for water supply is applied to the costs to obtain the next least cost alternative for water supply.

Irrigation

The value of irrigation water can be valued with a number of approaches. One approach is based on the value of irrigation water on a land's income-producing capability from farming production, often termed the land value methods, which compares the land values with and without irrigation. To derive a price per acre feet of water, it would be necessary to estimate the amount of water used annually for each unit of land. In 2019, irrigated croplands in Kansas and Nebraska were $3,320 and $5,850 per acre, respectively, while non-irrigated croplands were $2,050 and $3,490 per acre.

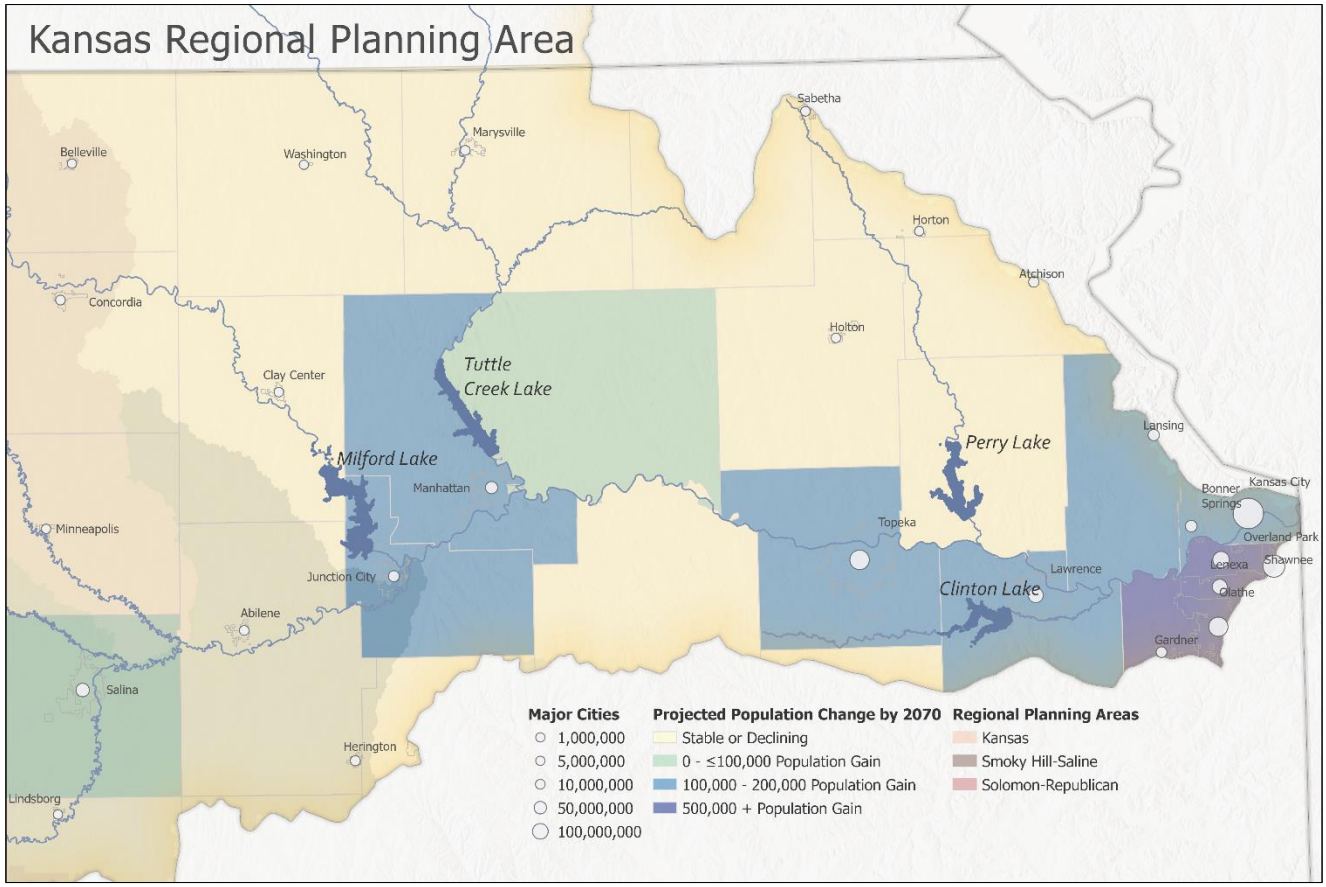
3.5.2.2 Kansas RPA

The following sections focus on the water supply FWOP for the Kansas RPA.

3.5.2.2.1 Future Surface Water Demands

Multiple municipal water suppliers within the basin are projecting increased future usage to satisfy the demands of growing populations. The highest concentrations of the Kansas population are located downstream of Federal reservoirs, sourcing water from surface water intakes and alluvial wells. Population projections forecast an increase of 819,000 within the counties encompassed by the Kansas RPA by the year 2070. With projections of continued growth around the Kansas City metro area, city of Lawrence, and the Manhattan area, which encompasses the U.S. Army's Fort Riley and the National Bio and Agro-Defense Facility development.

Figure 3-135. Projected Population Change by 2070



Water supply modeling shows that with current reservoir sedimentation trends and pool allocations, there will be future water shortages to meet all of the water quality and supply demands within the basin during times of extended drought. Not only is it important to have an adequate water supply to meet the needs of municipal and industrial water users but it is also crucial to maintain a base level of streamflow, provided for by releases from storage allocated for the authorized purpose of Water Quality.

3.5.2.2.2 Future Water Supply Storage: Sedimentation Impacts on Water Supply Storage Availability

The estimates of the multipurpose pool in future years (2049, 2074, and 2124) from the sedimentation evaluations were used to estimate the water quality and water supply storage in the federal reservoirs. Because all water supply storage is anticipated to be called into service between 2024 and 2049, the water supply storage compares the change in only in-use storage in these three future years.

Figure 3-136. Losses in Water Supply Storage

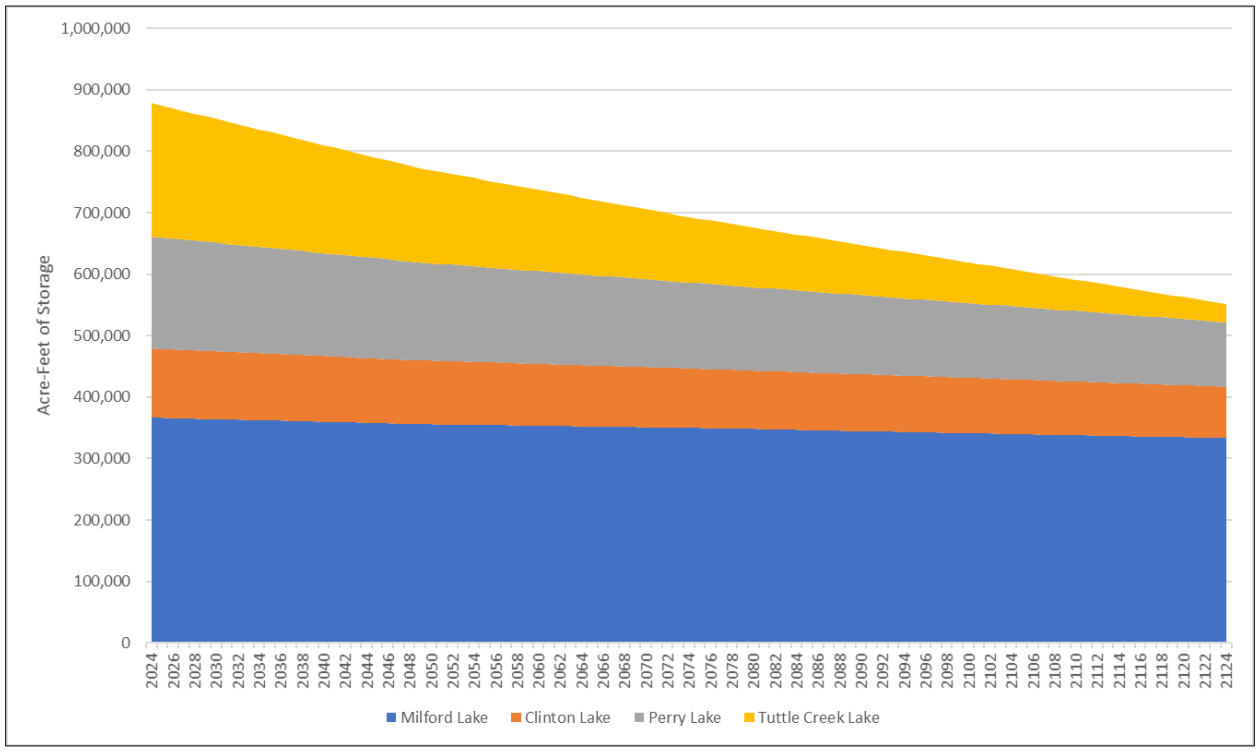


Table 3-69. Water Quality and Water Supply Storage in 2049 and Change in Storage Compared to 2024

Lake	**MPP/Capacity (2049)** (acre-feet)	Water Quality Percentage of MPP (2049) Percent	Water Quality Storage (2049)	Water Supply (in Use) Percentage of MPP (2049) Percent	**Water Supply (in Use) Storage (2049)** (acre-feet)	Future Use Storage (2049)	Change in Water Quality Storage from 2024	Change in Water Supply Storage from 2024 (Total)
Milford Lake	355,800	0.00	0	100.00	355,800	0	0	-10,700
Clinton Lake	103,900	19.20	19,949	80.80	83,951	0	-1,594	-6,706
Perry Lake	159,400	0.00	0	100.00	159,400	0	0	-23,500
Tuttle Creek Lake	153,000	59.02	90,301	40.98	62,699	0	-37,537	-26,063
Kanopolis Lake	34,800	53.40	18,583	46.60	16,217	0	-4,539	-3,961

Table 3-70. Water Quality and Water Supply Storage in 2074 and Change in Storage Compared to 2074

Lake	MPP/Capacity (2074) acre-feet	Water Quality Percentage of MPP (2074) %	Water Quality Storage (2074)	Water Supply (in Use) Percentage of MPP (2074) %	Water Supply (in Use) Storage (2074) acre-feet	Future Use Storage (2074)	Change in Water Quality Storage from 2024	Change in Water Supply Storage from 2024 (Total)
Milford Lake	349,900	0.00	0	100.00	349,900	0	0	-16,600
Clinton Lake	96,700	19.20	18,566	80.80	78,134	0	-2,976	-12,524
Perry Lake	140,000	0.00	0	100.00	140,000	0	0	-42,900
Tuttle Creek Lake	106,500	59.02	62,856	40.98	43,644	0	-64,981	-45,119
Kanopolis Lake	30,200	53.40	16,127	46.60	14,073	0	-6,995	-6,105

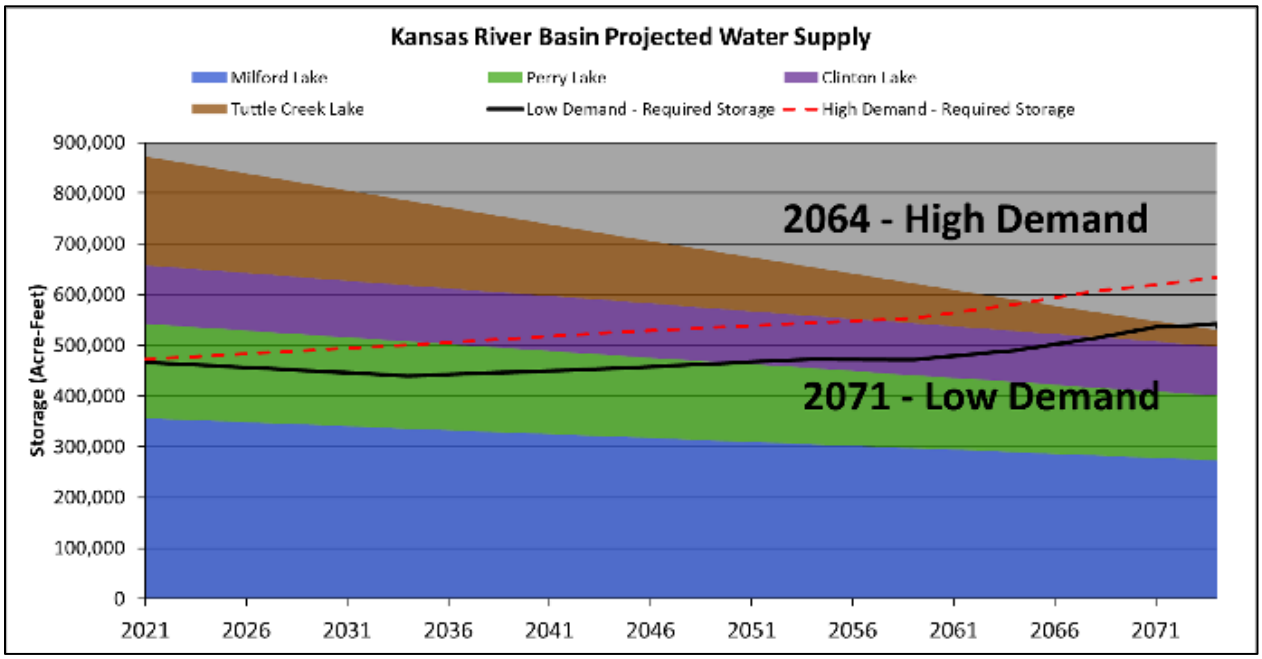
Table 3-71. Water Quality and Water Supply Storage in 2124 and Change in Storage Compared to 2124

Lake	MPP/ Capacity (2124) acre-feet	Water Quality Percentage of MPP (2124) %	Water Quality Storage (2124)	Water Supply (in Use) Percentage of MPP (2124) %	Water Supply (in Use) Storage (2124) acre-feet	Future Use Storage (2124)	Change in Water Quality Storage from 2024	Change in Water Supply Storage from 2024 (Total)
Milford Lake	333,000	0.00	0	100.00	333,000	0	0	-33,500
Clinton Lake	83,900	19.20	16,109	80.80	67,791	0	-5,434	-22,866
Perry Lake	105,200	0.00	0	100.00	105,200	0	0	-77,700
Tuttle Creek Lake	29,200	59.02	17,234	40.98	11,966	0	-110,603	-76,797
Kanopolis Lake	18,200	53.40	9,719	46.60	8,481	0	-13,403	-11,697

3.5.2.2.3 Surface Water Supply Gaps

Figure 3-137 shows how sedimentation in the reservoirs decreases storage for water supply, while a trend of increasing requirements for storage to meet the "system's demands and targets (includes all 4 federal reservoirs in the Kansas River RPA)." "Given the projected sedimentation and demands, results indicate the basin supply will be insufficient to fully meet projected demands through a 1950's type drought by the year 2064 (KWO, 2020)."

Figure 3-137. Kansas River Basin Projected Water Supply



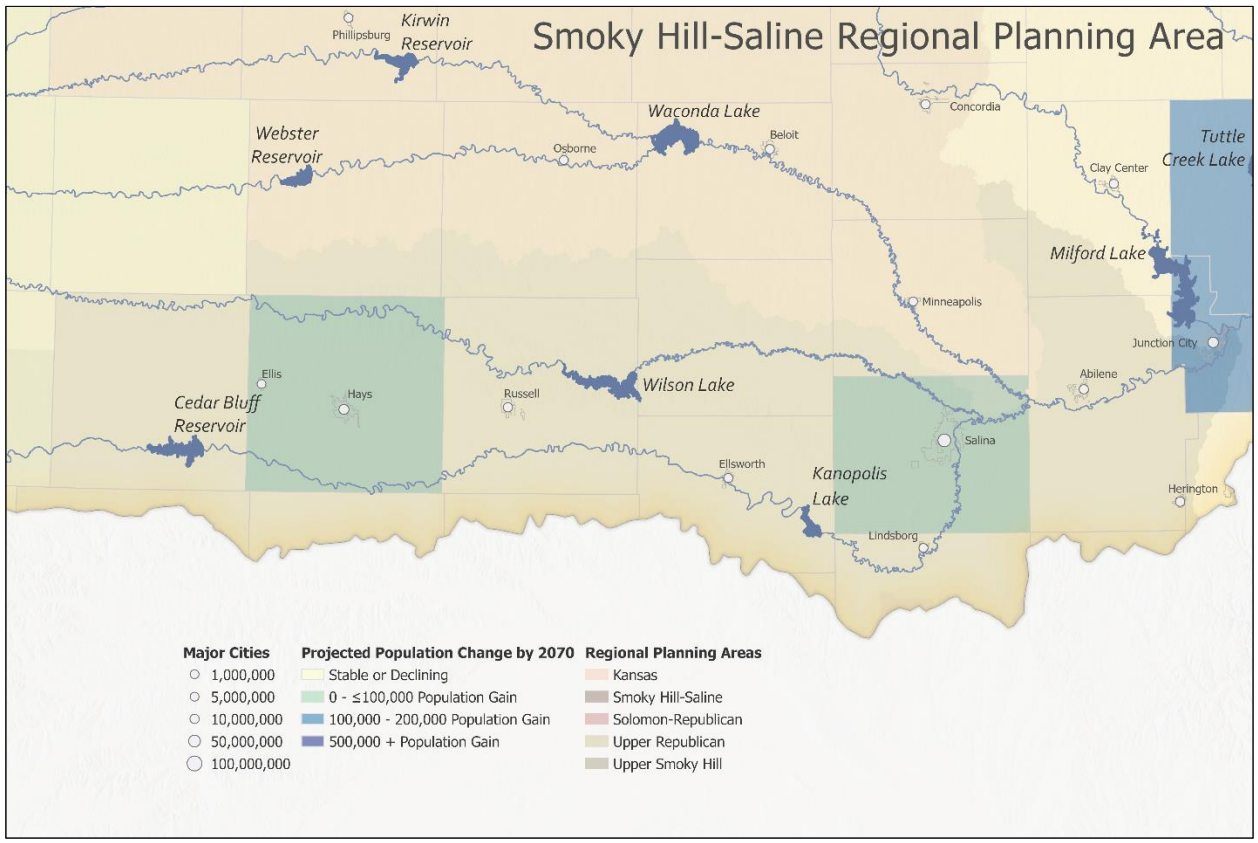
3.5.2.3 Lower Smoky-Saline RPA

The following sections focus on the water supply FWOP for the Lower Smoky-Saline RPA.

3.5.2.3.1 Future Surface Water Demands

The recently formed Lower Smoky Hill Access District has purchased storage in Kanopolis Reservoir and provides water security for 10,500 acre-feet of water rights, covering 2,100 irrigated acres and the City of Salina's municipal demands. Population projections forecast an increase of 87,000 within the counties encompassed by the Smoky Hill-Saline RPA by the year 2070. With projections of continued growth around the Junction City and City of Hays areas.

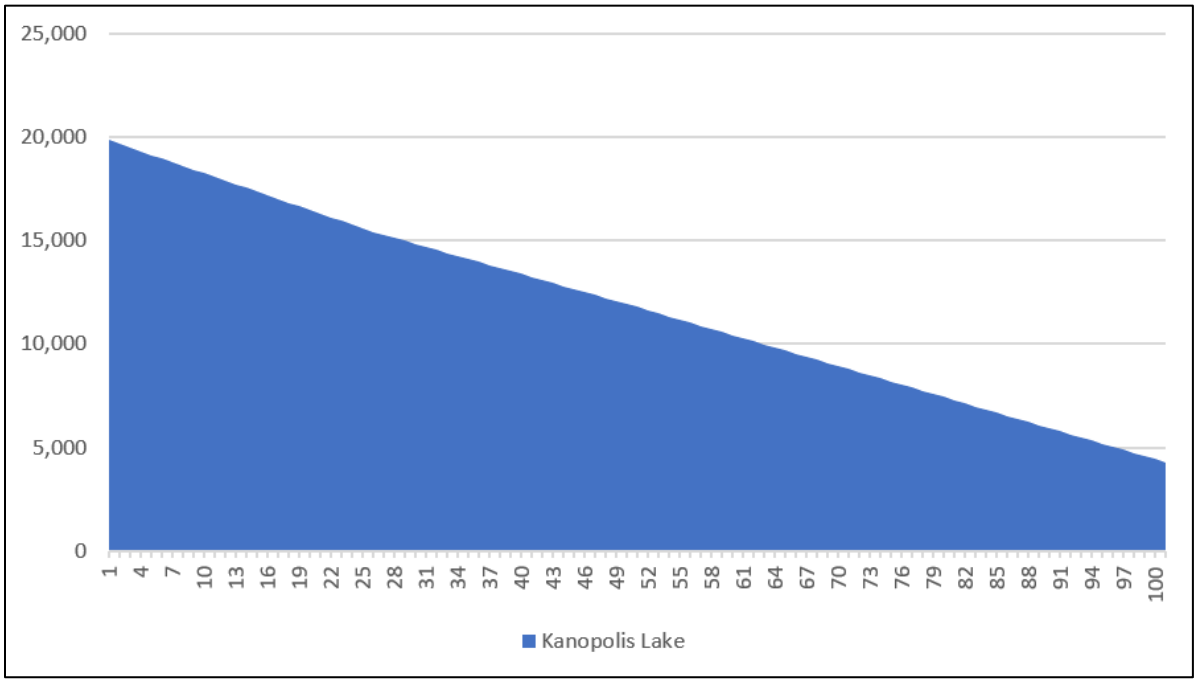
Figure 3-138. Projected Population Change by 2070 Within the Smoky Hill-Saline RPA



3.5.2.3.2 Future Water Supply Storage

There is no future storage to call into service at Kanopolis Reservoir. Figure 3-139 shows the estimated reductions in storage (acre-feet) over the 100-year period, 2024-2124.

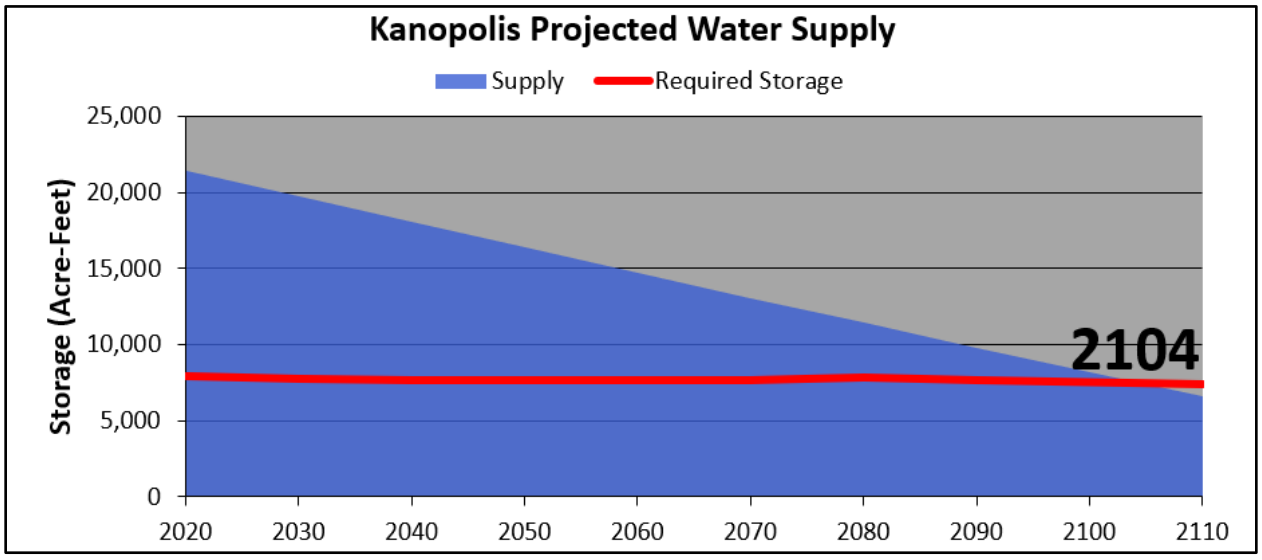
Figure3-139. Estimated Reductions in Water Supply Storage from Sedimentation at Kanopolis



3.5.2.3.3 Sediment Impacts on Storage for Water Supply

Figure 3-140 shows impacts to the MPP and the decreased availability over time (four scenarios–current, 25, 50, and 100 years out) for water supply storage.

Figure3-140. Future Basin Storage Versus Required Storage for the Lower Smoky Hill River Basin



3.5.2.4 Solomon-Republican RPA

Population projections forecast a decreasing population trend within the counties encompassed by the Solomon-Republican RPA by the year 2070.

3.5.2.5 Conclusion and Recommendations

Kansas River low flow management is highly dependent on the future available storage of the USACE reservoirs to provide target flow maintenance and sufficient water quality benefits through dilution of chloride and sulfate loading. The municipal and industrial users along the river have made modifications to their intake and diversion systems to be able to operate at lower river flow levels. The future scenarios where reservoir storage is depleted and flow is unable to be maintained in the river will put a significant part of the state's population at risk of water supply shortages or unusable water quality.

With the projected increased demands for the Kansas River basin, potential for more variable future conditions, potential for higher temperatures, winds, higher reservoir evaporation rates, and uncertainty in future drought frequencies, there is a critical need to implement actions to maintain reservoir storage capacities and increase future water supply security. Such actions are to develop and implement sediment management strategies for each USACE reservoir, look at reducing the low flow and water quality targets for Topeka and De Soto in the Water Control Manual updates, evaluate the reallocation of storage from flood pool to multipurpose storage if sediment management is infeasible.

The State of Kansas has established a funding stream and is dedicated to the development of additional funding to support future reservoir sustainability strategies and the USACE has an opportunity to partner with the state in evaluating methods to extend the useable lifetimes of the USACE projects. The Kansas Legislature invested a substantial amount of state general funds to shore up public water supply programs and the State Water Plan Fund, for investment in water studies and projects. The KWO is ready, willing, and able to pursue cost-shared efforts toward in-lake reservoir sediment management, both for research and development and/or project implementation.

There should also be an evaluation and support of other methods for water supply into the future, such as looking at enhanced recharge opportunities along alluvial corridors, reevaluating previously authorized USACE reservoir locations that were not constructed, and the potential for the interconnection of river basins.

3.6 Recreation

3.6.1 Introduction

Recreational opportunities are currently available in the Kansas River Basin, and a detailed evaluation and analysis of projected changes in the basin is necessary to document the value of recreation to Kansas. Water-based recreational opportunities are threatened by low and high-water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species.

The watershed study focuses on USACE and USBR reservoirs and river reaches in the watershed including the USACE/USBR areas in Kansas, the Kansas River mainstem,

and Harlan County Reservoir in Nebraska. The basin includes seven USACE reservoirs and ten USBR reservoirs.

Public lands providing recreation opportunities relatively rare in Kansas, with privately-owned lands accounting for 98.4 percent of the land in Kansas. State and federal lands account for approximately 1.3 percent of total lands in the state, and only a portion of these state and federal lands are associated with recreational parks and areas (Headwaters Economics, 2020). State-owned and controlled lands for recreation account for only 0.7 percent of lands in the state (KDWP 2023). Because of the scarcity of federal and state public lands for recreation in Kansas, it is imperative that these lands are protected and managed to promote sufficient recreational opportunities to meet the needs of residents and visitors to the state.

The assessment of recreation focuses on how future conditions, including sediment, water quality, and drought within the basin affect recreation, and, where possible, quantifies these economic impacts. Recreational activities in the basin improve the quality of life for the citizens of Kansas and neighboring states, increase the value of natural resources, draw visitors to the area, and contribute to the regional economy.

Recreation areas are grouped by RPAs in Kansas and one Nebraska reservoir—Harlan County Lake—with existing conditions and FWOP conditions described for each reservoir and the Kansas River mainstem. The existing conditions sections include an overview of the recreation areas of the 13 reservoirs (USACE/USBR) and the Kansas River mainstem.

Table 3-72. Regional Planning Areas, Reservoirs, and Kansas River Mainstem

Kansas Regional Planning Area	Smoky Hill Saline Regional Planning Area	Solomon-Republican Regional Planning Area	Nebraska Reservoirs
Clinton	Cedar Bluff*	Keith Sebelius Lake (Prairie Dog State Park)*	Harlan County
Milford	Kanopolis	Kirwin*	
Perry	Wilson	Lovewell*	
Tuttle Creek		Waconda Lake/Glen Elder Dam*	
Kansas River Mainstem		Webster*	

*Denotes USBR Reservoirs
**Throughout the document lake and reservoir are used interchangeably.

3.6.2 Methodology

The assessment of recreation includes both qualitative and quantitative methods. Sections 3.6.2.1 and 3.6.2.2 describe the methods used.

3.6.2.1 Qualitative Assessments

Qualitative methods were used to assess the effects of HABs, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at all of the reservoirs. The information used to qualitatively assess recreation was based on

research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries). FWOP impacts related to flooding repair and clean-up costs are discussed qualitatively, based on past impacts associated with the 2019 flood.

Because USACE sediment modeling indicates very few impacts to future sediment conditions and because no H&H modeling was conducted for Cedar Bluff, Keith Sebelius (Prairie Dog State Park), Kirwin, Webster, and Lovewell reservoirs, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for these reservoirs. In addition, Harlan County Reservoir in Nebraska is affected by sediment deposition in the coves of the reservoir, although the impacts to visitation and economic benefits are described qualitatively. These recreation evaluations were based on resource conditions, such as available information and resource reports on sediment, hydrology, and other conditions. Many of the western reservoirs do not have sufficient inflows for there to be notable sediment impacts.

All reservoirs in the basin will likely experience increasing effects of aging. Future water quality within basin lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40 percent of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The KDA (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals requiring feed and producing increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication—too much phosphorus causing increased growth of algae and aquatic plants resulting in decreased levels of dissolved oxygen. Continued and enhanced water quality impairment may be expected at all of the reservoirs in the basin. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoirs. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the watershed. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at watershed reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal HAB–algal blooms producing toxins detrimental to human and animal health–

issues as some flourish under conditions with elevated phosphorus availability and water temperature (Appendix G).

3.6.2.2 Quantitative Assessments

Quantitative approaches were developed to evaluate economic effects to recreation associated with changes in water surface elevations and sediment deposition under the FWOP. Specifically, quantitative approaches include an assessment of how water surface elevations, river flows, and sediment deposition affect visitation, and, subsequently, consumer surplus and regional economic benefits at six USACE reservoirs (Clinton, Perry, Tuttle Creek, Milford, Wilson, and Kanopolis reservoirs), one USBR reservoir (Waconda), and the Kansas River mainstem. These quantitative approaches are described in this section.

The quantitative models were developed to help answer questions, such as:

- Are there reservoirs more at risk from variations in water surface elevations affecting recreation relative to others?
- What kinds of visitors will be impacted at specific reservoirs?
- Where could future efforts prioritize work to maintain recreation access (e.g., extend boat ramps at a specific reservoir; sediment management; improved flood management)?

Flooding, drought, and reservoir sedimentation are the stressors with the highest risks to recreation economically from losses in recreational opportunities, damage, repair costs, lost revenues, or lost jobs. With changes in water surface elevations, the quantitative models can estimate how visitation, consumer surplus and economic benefits in adjacent communities and the state would be impacted, providing useful and vital information for state resource agencies (e.g., KDWP and KWO).

3.6.2.2.1 Sediment and Water Surface Elevation Modeling

An initial step in the evaluation process was identifying the reservoirs to be further analyzed with regard to recreation impacts in the watershed study. This is often based on the availability of certain types of information. The sedimentation modeling conducted by USACE sediment engineers provides an indication of the potential future impacts to recreation (Appendix D). USACE sediment engineers provided digital mapping of the surface area or contour of the multipurpose pool of the reservoirs as well as digital elevation maps under the FWOP conditions. These digital elevation maps were overlaid with maps of the recreation infrastructure at each of the USACE reservoirs and the USBR reservoir for each of the FWOP sedimentation scenarios. The reservoir depth maps (Appendix F) were used to assess how water-based access at recreation areas would be affected at the lakes impacted by sediment deposition.

Based on input from the project staff and a review of the H&H sediment modeling, it is likely that future impacts to visitation could potentially occur from increased sediment deposition at Tuttle Creek, Perry, Kanopolis, and Waconda. These lakes are assessed in terms of how sediment conditions could affect visitation in the FWOP and subsequently consumer surplus and regional economic benefits.

Future sediment conditions affect reservoir operations and water surface elevations in the affected lake and in other lakes as releases are needed to meet downstream targets. For example, Tuttle Creek Reservoir loses a considerable amount of its multipurpose pool capacity in the future, and releases from Milford and Perry reservoirs are needed to meet water supply and water quality targets. Future sedimentation in reservoirs can affect future reservoir depths, boating accessibility, and other conditions affecting recreation. In severe situations, boat ramps and marinas may be silted in and may not be accessed for water-based recreation. This may especially be the case during drought and relatively drier conditions when lower lake elevations combined with shallower lakes render boat ramps inaccessible, as well as decrease nutrients and fish habitat in the reservoirs, decreasing recreation opportunities.

H&H data, notably reservoir elevations and river flows, are available for most of the USACE reservoirs, Waconda Reservoir, and the Kansas River mainstem. The future H&H projections (FWOP) evaluated four timeframes, both with and without navigation releases: 2024 (Year 0–Year when the watershed study is complete), 2049 (Year 25), 2074 (Year 50), and 2124 (Year 100). Water surface elevation models were developed to link the H&H data and critical lake elevations and river flows for recreation to estimate potential changes in visitation, consumer surplus values, and jobs and income in local communities.

The HEC-ResSim models simulated daily reservoir water surface elevations, storage, and releases (flows) for the period or record from 1919 to 2020 for existing conditions. The HEC-ResSim also modeled 8 FWOP scenarios modeled over the period between 2023 and 2124 (see Appendix B). The 8 FWOP scenarios include 4 with navigation releases at the 4 timeframes used for the sediment assessment (2024, 2049, 2074, and 2124) and 4 without navigation releases at the timeframes used for the sediment assessment (2024, 2049, 2074, and 2124). These four timeframes represent points in time in the future and the expected reservoir sedimentation at those years expanded out over the period of analysis (see Appendix D). These FWOP scenarios consider reservoir releases to meet target flows, water use assumptions, future water withdrawals, projected inflows, and sedimentation accumulation within the reservoirs in the future.

For lakes impacted by future sediment deposition (Tuttle Creek, Perry, Kanopolis, Harlan County, and Waconda lakes), drought and relatively drier conditions would likely result in shallower pools during lower water levels. Because both water surface elevations and sediment deposition and depths are available for these lakes, the evaluation considers both sediment depths and water surface elevations in the impacts to visitation at these lakes. H&H data on reservoir elevations is available for Tuttle Creek, Clinton, Perry, Kanopolis, Milford, Wilson, and Waconda reservoirs, and water surface elevation models were developed for these reservoirs and the Kansas River mainstem. Recreation on the Kansas River mainstem is evaluated through critical river flows needed to support boating during the spring, summer, and fall months with the River Analysis System (HEC-RAS) river flow data. Kansas River boating organization representatives provided elevation thresholds. Recreation on the Kansas River is not notably affected by sediment (Buehler 2020).

3.6.2.2.2 Visitation

The quantitative recreation evaluation and models use 2018 as a base year for visitation. When the models were developed, 2018 was the most recent year of visitation data available for an average water year. While 2019 visitation data was available, the region experienced a considerable flood during that timeframe and the visitation data was not a good representation of typical conditions. The study team used the USACE Visitation Estimation and Reporting system (VERS) visitation data for the USACE reservoirs, and the KDWP state park visitation estimates for the USBR reservoirs. For state parks that are within the USACE projects, the USACE VERS estimates were replaced and the state park visitation estimates were used. Information from an electronic permit system, iSportsman, is in place in Kansas requiring hunters to electronically register for 24 of the wildlife areas in Kansas. iSportsman data was used to estimate hunting visitation and was adjusted to reflect hunting visits for people that do not necessarily register with the system. Wildlife viewing also occurs in the wildlife areas; the FWS 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation report was used, which indicates that wildlife viewing visits across the state is generally about 20 percent of the hunting visits. This percentage was applied to the hunting visit estimates to obtain an estimate of wildlife viewing visitation at each reservoir.

In order to understand visitor trends over time to assess whether visitation would increase in the future, visitation data compiled for state parks from 2003 to 2022 (excluding 2019–2021 due to flooding and coronavirus disease [COVID] conditions) was evaluated (VERS data is not available prior to 2014). For most of the reservoirs, there were stable or decreases in visitation trends at state parks over time. State parks at Wilson, Tuttle Creek, and Cedar Bluff reservoirs experienced decreasing visitation. It is likely that decreasing visitation at these reservoirs is tied to previous and low inflows and water surface elevations rendering boat ramps inaccessible. For this reason, it is assumed that the recreation modeling is capturing these decreasing visitation trends in the future.

Visitation at the state parks at Waconda and Kanopolis reservoirs shows increases of 24 percent and 11 percent, respectively, over the 16-year time period, with implications for consumer surplus and regional economic effects. See Appendix F for additional discussion of future visitation at Waconda and Kanopolis reservoirs.

For the lakes impacted by sediment in the future, the reservoir depth maps identify the recreation areas and infrastructure (i.e., marinas and boat ramps) adjacent to the lake that would no longer be accessible for water-based visitors. 2018 visitation estimates were used at impacted recreation areas to identify water- and shore-based visitation potentially affected by sediment deposition. Activity distributions from VERS were used to identify shore- and water-based visitors at the recreation areas at each lake; these two groups of visitors (water- and shore-based visitors) are affected differently by changes in lake-elevations. Boating, angling, water contact, and other activities were assumed to be “water-based activities,” while the remaining activities were assumed to be shore-based. USACE lake staff and KDWP public lands, recreation, and fisheries staff provided input for these assumptions.

An important piece of the evaluation using the quantitative models for recreation is understanding how reservoir elevations and river flows impact recreation at the reservoir and in river reaches. Project managers at USACE operations, additional reservoir staff, and KDWP staff were consulted to obtain critical lake elevations important to recreation on the six USACE reservoirs and the one USBR reservoir modeled. Additionally, boating organizations on the Kansas River provided information on river flows important to boating on the Kansas River mainstem. Critical lake elevations were also developed for reservoirs that were not quantitatively modeled.

These critical elevations are provided for each reservoir assessed and the Kansas River mainstem in the following sections. The models assume that if the reservoir elevations fall within various key thresholds identified by USACE and KDWP reservoir staff, water-based visitation and shore-based visitation would be impacted.

Not all recreation areas are likely to be directly impacted by changes in lake elevations. Based on a review of the project and lake maps, a judgment was made regarding whether the recreation areas at each of the reservoirs would be affected by changes in lake elevations. Often, these are recreation areas or state parks located on or adjacent to the lake (not below the dam) and generally include those with boat ramps and/or marinas. Wildlife areas are assumed not to be affected by level elevations because most of the uses are upstream of the lakes and not affected by lake elevations. Dispersed recreation was assumed to be impacted by lake elevations, as some of dispersed recreation includes boating.

The water surface elevations recreation models assume that a percent of water-based visitors and shore-based visitors would be impacted at recreation areas potentially affected by lake elevations. In reality, some of the visitation may shift to other areas within the lake, shift from water-based activities to shore-based activities near a lake, or move to another lake within the area. The modeling results will focus on the dramatic or extreme changes in water surface elevations in the future compared to current conditions (i.e., usually occurring during drought or flooding events), where there may be limited options for visitors at the affected lake.

3.6.2.2.3 Consumer Surplus Values

The approach to estimating the value of recreation is to use consumer surplus values or willingness to pay, which is the value a person realizes from engaging in outdoor recreation above and beyond the expenditures incurred for the visit. Consumer surplus values are generally higher with more specialized recreational activities; that is, fishing and hunting activities would have a higher unit day value (UDV) than site-seeing activities. The UDV approach is USACE-certified, providing estimates of the value of recreation through recreation-area specific ratings for criteria at each recreation site. The UDV method of estimating willingness to pay relies on expert and informed opinion to assign relative values to recreation days based on the quality of recreational opportunities supported by individual recreation areas. The USACE Economic Guidance Memorandum (EGM), EGM 22-03 (Unit Day Values for Recreation, Fiscal Year 2022), provides guidelines for assigning points on a 100-point scale based on five recreation criteria. The consumer surplus values are provided in 2022 dollars. Recreation managers rate the recreation areas based on these five criteria. Point ratings are then

converted into a monetary value based on values published in EGM 20-03 for each of the four categories of recreation (general recreation, general hunting and fishing, specialized hunting and fishing, and other specialized activities).

The point ratings for each USACE recreation area were obtained from the USACE Recreation Budget Evaluation System (Rec-BEST) database for 2018 to 2020. The UDV points were weighted by visitation over a two-year period (2018 and 2020) to estimate the lake-wide UDV for the 4 categories; 2019 was omitted due to the 2019 flood. The USBR lake UDV points were estimated based on an evaluation of the five UDV criteria. Information from lake managers and staff was used to estimate the prevalence of specialized visitation (i.e., all-terrain vehicle [ATV] use, specialized fishing, equestrian use, and others) at each of the lakes that would fall into the relatively higher-valued categories. The VERS activity distributions were used to estimate visitation associated with the general and hunting and fishing categories.

3.6.2.2.4 Regional Economic Benefits

The USACE Regional Economic System 2 (RECONS), developed by the Institute for Water Resources (IWR), estimates the regional economic impacts of USACE investment spending and project activities in the USACE's business lines. RECONS is a USACE-certified model that estimates economic output, jobs, earnings, and value added associated with visitation at USACE projects. Labor income, value added, and economic output are provided in 2022 dollars. RECONS uses Economic Impact Analysis for Planning's (IMPLAN©'s) software and data system to estimate the economic effects of visitation, including direct effects (visitor spending) and multiplier effects (indirect and induced effects). The RECONS model, by default, estimates the economic impacts of visitor spending for three study areas: local, state, and the nation. The local study area is specified by default based on USACE project areas. The local study area usually includes the counties within and surrounding a project's boundary, including counties within 30 to 50 miles of the project area. The state study area includes the state or states in which the local study area is located.

There are six visitor segments in the RECONS model:

1. Local day use visitor and non-boater
2. Local day use visitor and boater
3. Overnight camper or other overnight project visitor within project and boater
4. Overnight camper or other overnight project visitor within project and non-boater
5. Non-local visitor (coming from more than 50 miles from project to stay in local communities) and boater
6. Non-local visitor (coming from more than 50 miles from project to stay in local communities) and non-boater.

The USACE VERS activity distributions were used to identify visits at the reservoirs associated with the above visitor segments; for USBR reservoirs, lake staff provided input on these visitor categories.

3.6.3 Assumptions, Considerations, and Uncertainty

There is uncertainty associated with the assumptions described in the following sections. Where possible, the project team has obtained information from experts or lake staff to attempt to support these assumptions. However, there is uncertainty regarding a number of the visitation parameters, including the response of visitors to changes in water surface elevations (critical lake elevations) and sediment conditions and their ability to adapt overtime.

The visitation and economic evaluations use data from the H&H and sediment modeling of the river and reservoir system (Appendix B, Appendix C, and Appendix D). Recreation models estimating changes in visitation and economic impacts from changes in water surface elevations rely on critical lake elevation thresholds for recreation obtained from USACE lake staff and KDWP public lands, recreation, and fisheries staff on lake-wide impacts to visitation. It is assumed that if the reservoir elevations fall within various key thresholds identified by USACE or KDWP lake staff, visitation would be impacted, as described by the USACE lake and KDWP staff. In reality, some of the visitation may shift to other areas within the lake, shift from water-based activities to shore-based activities near a lake, or move to another lake within the area. The modeling results will focus on the dramatic or extreme changes in water surface elevations in the future compared to current conditions (i.e., during drought or flooding events), where there may be limited options for visitors at the affected lake.

Consistent with the UDV approach, recreation water surface elevation modeling assumes the lake-wide UDV points and UDV per visitor day would remain the same under all water surface elevations. However, physical conditions at the lakes and reservoirs can affect the quality of recreational experience to the lake for water- and shore-based visitors, especially for visitors impacted by the severe sediment conditions, such as those at Tuttle Creek Reservoir in the future. As described in Appendix F, the UDV measures the quality of the recreational experience and is based on lake staff ratings of five criteria, which are then aggregated into points (out of 100 total). UDV (consumer surplus) is estimated by natural resource managers at the lake, based on ratings of a number of criteria. In the FWOP, four of the five UDV criteria could potentially be impacted, including:

- Recreation experience
- Carrying capacity
- Accessibility
- Environmental quality.

A potential change in the UDV and consumer surplus values was analyzed outside of the modeling effort with a sensitivity analysis in Appendix F, Consumer Surplus.

Severe impacts to recreation conditions from sedimentation will likely contribute to lower quality of the recreation experience at Tuttle Creek Reservoir under the 2074 and 2124 FWOP scenario. Currently, the visitation-weighted UDV at Tuttle Creek Reservoir is 44, which translates to a general UDV of $8.89 and a general hunting and fishing UDV of $9.91 (FY2022 dollars).

The considerable sedimentation impacts at Tuttle Creek Reservoir could result in notable decreases in the UDV points ratings for recreation experience, carrying capacity, accessibility, and environmental quality. With a decrease of 25 to 50 percent of the UDV points, the UDV points would be 33 and 22, respectively, and the UDV would change from $8.98 (general) and $9.91 (general hunting and fishing) to:

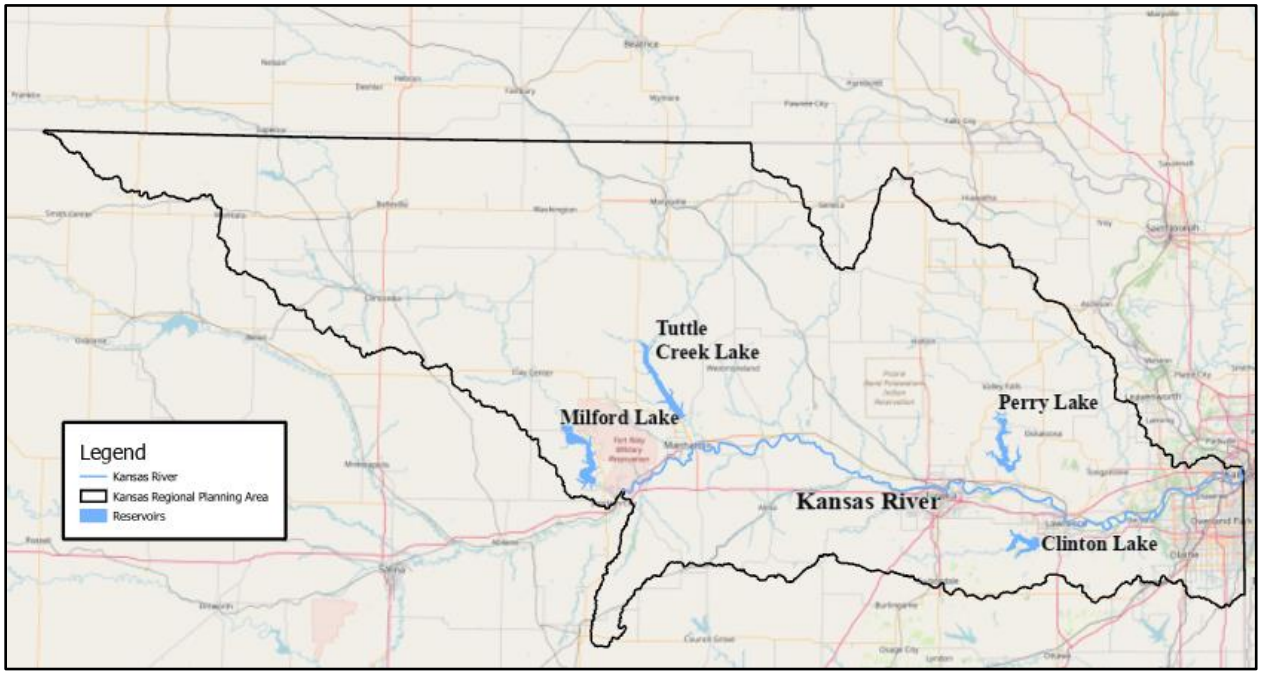
- General: $6.08 (UDV points of 22) to $7.26 (UDV points of 33)
- General hunting and fishing: $8.05 (UDV points of 22) to $8.98 (UDV points of 33).

Based on these changes in the UDV, impacts to consumer surplus could be less than estimated above under FWOP 2074 and 2124. For example, in 2074 and 2124, there would be 367,000 recreation visitor days potentially impacted with an associated impact of $3.3M in consumer surplus (both land- and shore-based visitors); those visitors with a relatively lower UDV would receive between $2.3 to $2.7M in consumer surplus value, reducing impacts under future conditions because of the relatively lower quality of recreational experience at Tuttle Creek Reservoir in the future.

3.6.4 Kansas Regional Planning Area

The Kansas RPA is composed of 21 different counties and encompasses 9,114 square miles in Northeast Kansas. Four USACE reservoirs—Clinton, Milford, Perry, and Tuttle Creek—along with the Kansas River mainstem are in the Kansas Regional Planning Area. Figure 3-143 shows the reservoirs and the Kansas River mainstem located in the Kansas Regional Planning area.

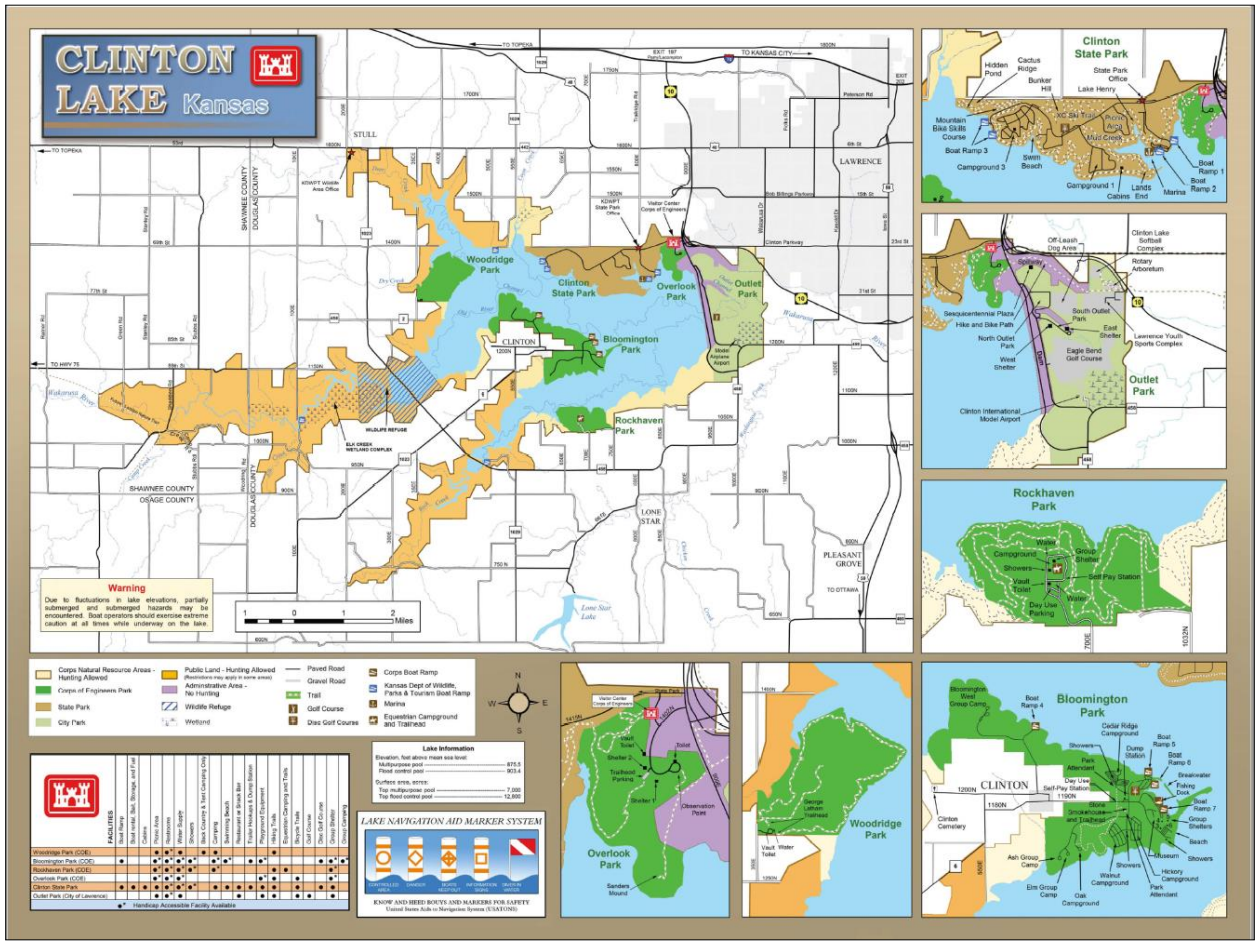
Figure 3-143. The Kansas Regional Planning Area



3.6.4.1 Clinton Reservoir

Clinton Reservoir is located approximately 1 mile west of Lawrence, Kansas on the Wakarusa River and stretches into both Douglas and Shawnee counties (Figure 3-144). The reservoir was constructed by USACE for the purposes of flood control, municipal and industrial water supply, recreation, and to maintenance of stream flow on the Wakarusa and Kansas Rivers.

Figure 3-144. Clinton Reservoir Recreation Areas



3.6.4.1.1 Existing Conditions

Recreation Facilities and Visitation

Clinton Reservoir includes six parks, three managed by the USACE, two managed by KDWP, and one managed by the City of Lawrence. The numerous recreational opportunities available at Clinton Reservoir:

- Boat Ramps
- Picnic Areas
- Hiking Trails
- Bike Trails
- Campsites

- Disc Golf Courses
- Golf Course
- Cross Country Ski Trail
- Softball Complex
- Equestrian Trail
- Swimming Beach..

According to combined USACE and KDWP data, total visitation in 2018 was 1,801,100 (USACE and KDWP 2018–2019). In 2018, the most popular areas at the reservoir were the City of Lawrence outlet park (accounting for approximately 44 percent of total visitation), followed by Clinton State Park (25 percent), and Bloomington East Park (12 percent). Sightseeing activities account for the largest share of visitation activities at Clinton Reservoir at 21 percent, followed by hiking/jogging/walking at 16 percent, and picnickers at approximately 14 percent. Water-based activities and camping account for 11 percent and 8 percent of total visitation activities at Clinton Reservoir, respectively. Special events accounted for 5 percent of visitation in 2018 (USACE and KDWP 2018a). According to 2018 iSportsman data (KDWP 2021), there were 4,269 hunting visits within wildlife areas managed by KDWP associated with the reservoir, comprising 0.2 percent of total activities, and 854 wildlife viewing visits (KDWP iSportsman data). In 2019, there were 48 special events at Clinton Reservoir, including fishing tournaments and derbies, bike races, hikes, and more (USACE and KDWP 2020).

Rockhaven is a specialized campground for equestrian users. It is also the main trailhead for 60 miles of horse and hiking trails along the south side of Clinton Reservoir. Users come from Kansas and the surrounding states to utilize the campground and trails. Woodridge Park is a 900-acre primitive backpacking area. Users can camp in a primitive setting throughout the 900-acre park.

Sport Fisheries

This section provides a summary of sport fishing at Clinton Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (Appendix E). Fish species occurring at Clinton Reservoir include 14 sportfish species like black crappie, blue catfish, and wiper, and 13 non-sport fish species like creek chub, freshwater drum, and sand shiner. The top four most preferred species of fish by anglers includes crappie, catfish species, and walleye.

Factors affecting the fishery at Clinton Reservoir include general limnology, water quality, water level fluctuations, sedimentation, vegetated fishery habitats, and invasive and exotic species. Many limnological characteristics of Clinton Reservoir are resultant from its large watershed, large surface area (7,000 acres), and relatively shallow depths (mean depth=17.0 feet, maximum depth=36.1 feet). The reservoirs large watershed contains a variety of land use practices including grasslands (61.7 percent), forest (14.9 percent), agriculture (12 percent), and urban (6.2 percent). Sedimentation can affect the natural resources in the lake. Suspended sediments carry nutrients and metals which accelerate eutrophication and can limit fishery production for native and game fish species. As the lake fills with sediments from upstream, it reduces the water volume available to fish. In addition, the sediment covers the habitat that many fish species use

for foraging or spawning. Furthermore, the mudflats created in the upper reaches of the lake serves as a disconnect between the lake and the upstream river system that some fish species use for annual migrations or spawning runs. High turbidity from suspended sediments also has impacts on the ability for sight feeders to be able to adequately capture food. During periods of extended high turbidity, the sampling data records lower abundance of forage species and lower body condition of sportfish.

The objective of fisheries management at Clinton Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

Appendix E contains further details related to mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Like other lakes in the region, the 2019 flood impacted recreation at Clinton Reservoir. Due to the spring flood event, the lake was above normal pool for more than 60 days, with a max crest of 21 feet above top of multipurpose pool (USACE 2020). In USACE areas, three miles of roads, parking, and trails were submerged and required restoration and repair.

At the USACE areas and Clinton State Park, there were considerable damages to recreation facilities from the 2019 flood. During a meeting in December 2020, USACE and KDWP Clinton Reservoir staff described the impacts of the 2019 flood. There were numerous closures, including the entire beach area and campgrounds. According to lake staff, there were more impacts and closures at the USACE sites leading to higher visitor use at the state park. Additionally, people were coming to Clinton Reservoir to observe some of the high-water areas which contributed to a 4 percent increase in overall visitation in 2019 (1,801,100 visitors) compared to 2018 (1,870,815 visitors) (USACE and KDWP 2018–2019).

Drought events, especially during the late 1980s, 1990s, early to mid-2000s, and 2012, have affected recreation at Clinton Reservoir (USGS, Kansas Droughts 2020; NOAA 2012). However, Clinton Reservoir staff indicated that the effect of these modest drought periods on recreation was not a particularly large effect. Fishing and boating access was limited, but most day use including camping continued. During low water/drought conditions when the pool drops more than three feet below the multipurpose pool (872 feet), submerged rocks and obstacles start to impact boating at the lake. Below 865 feet, no boating and water-based access can occur, and exposed shorelines, rocks, and steep banks provide obstacles and reduce the aesthetic qualities for visitors. During low water/drought conditions the wildlife areas are impacted because there is less water for the adjacent wetlands. This impacts duck and waterfowl habitat, and hunters may not choose to come if ducks and waterfowl are low in numbers.

There are no current issues with sediment affecting recreational opportunities at Clinton Reservoir. Clinton Reservoir has not experienced recreation impacts from HABs.

Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Clinton Reservoir. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Clinton Reservoir as well as the corresponding impacts to visitation (Tables 3-71 and 3-72). These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. This approach is used for all reservoirs discussed. It is important to note that water surface elevations and depths of water are not equivalent. For example, the water surface elevation may rise five feet above the multipurpose pool, but if ten feet of sediment were to accrue at the bottom of the lake, the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. Appendix F describes future reservoir sedimentation for Clinton Reservoir and any impacts to recreation.

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Table 3-73. Critical Lake Elevations for Recreation at Clinton[1]

Lake Elevations	<865 feet	865–872 feet	872–878 multi-purpose pool is 875.5 feet	878–882 feet	>882 feet	>884 feet
Visitation Impacts	No boating access, all boat ramps are unusable except Ramp 4. Camping is largely unaffected.	Boat ramps usable starting at elevation 865, Ramp 4 is useable above 866.	No Issues	Lower elevation campsites affected at this elevation, closing approximately 25% of campsites. Boat Ramp 4 unusable above 881.5.	Boating access is mostly not available, limiting fishing and recreational boating. The beach is not usable above elevation 879. Most boat ramps unavailable.	Trails at Clinton State Park begin to be affected by high water. Most campsites closed by high water.
Quality of Recreation Effects	Exposed shorelines with debris, rocks, steep banks. Underwater hazards exposed.	Boat ramps usable with caution, potential underwater hazards.	No Impacts	Some campsite impacts due to flooding.	Debris from flooding can become a safety concern.	

[1] The information in this table was developed with input from USACE and KDWP staff familiar with Clinton Reservoir. Lake elevations are in NGVD 1929.

Table 3-74. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<865 feet	865–872 feet	872–878 feet multi-purpose pool is 875.5 feet	878–882 feet	>882 feet	>884 feet
Water-based Visitor Impacts	100%	25%	0%	5%	100%	100%
Shore-based Visitor Impacts	50%	0%	0%	25%	75%	100%

[1] The information in this table was developed with input from USACE and KDWP staff familiar with Clinton Reservoir. Lake elevations are in NVGD 1929.

3.6.4.1.2 Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality, and fishery conditions. The first few sections describe how sediment and water surface elevations change under the four FWOP scenarios, and how these changes impact visitation and economic benefits. As navigation releases are not made from Clinton Reservoir, the impacts of navigation releases were not considered. Appendix F provides a qualitative evaluation of how changes in water quality affect recreation in the future. These discussions are included for all areas considered under recreation.

Changes in Sediment and Water Surface Elevations

Three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods were considered. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Four years were chosen to evaluate flood conditions, with average annual elevations at Clinton Reservoir above 880 feet (NGVD 29), while two years were chosen to evaluate drought conditions, with average annual elevations below 865 feet (NVGD 29). Appendix F describes the impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2059 (1955)
- 2060 (1956).

Flood years include:

- 2031 (1927)
- 2097 (1993)
- 2099 (1995)
- 2123 (2019).

Typical years include all other years.

Approximately 384 acre-feet of sediment accumulates on average annually in Clinton Reservoir. Sediment continues to accumulate in Clinton Reservoir with an expected additional 7 percent loss of the multipurpose pool over the next 25 years (2049) and 12 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 96,669 acre-feet in 2074. Sedimentation has not generally impacted recreation at Clinton Reservoir. While sediment continues to accumulate (7 percent loss of the multipurpose pool over the next 25 years and 12 percent loss over the next 50 years) and the delta could extend, the size of the multipurpose pool and the lake's recreational opportunities are expected to be impacted very minimally. Appendix F shows the depths of Clinton Reservoir at the multipurpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years).

During typical precipitation conditions (at multipurpose pool), the USACE sediment modeling indicates that, with the exception of Coon Creek boat ramp on the north side

of the reservoir, boat ramps at Clinton Reservoir would continue to provide boating access to the lake under all FWOP scenarios.

During drought or flood conditions, the effects of sediment deposition in the future on recreational access remain generally the same as current conditions as the change in depths of the lake to an extent that would cause impacts are generally minor overall but there could be some localized impacts from sedimentation on shorelines or coves or in the delta area of Clinton Reservoir.

Clinton Reservoir does not lose significant storage over the 100-years of the FWOP. However, with each subsequent FWOP scenario, the average pool elevation increases as more sediment accumulates (Appendix B).

Clinton Reservoir modeling shows that median pool elevations tend to be near the top of multipurpose pool but slightly lower from July to March as water quality releases draw the reservoir down in the dry season. The pool elevation does not drop as far into the multipurpose pool in the later FWOP scenarios (FWOP 2074 and FWOP 2124) likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at Clinton Reservoir. There are also small increased frequencies of higher pool elevations in the flood control pool under FWOP scenarios compared to FWOP 2024. Appendix B provides additional information.

Table 3-75. Average Water Surface Elevations at Clinton Reservoir

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	874.65	
2049	874.69	0.04
2074	874.79	0.14
2124	874.88	0.23

Note: The top of the multi-purpose pool is 875.5 feet. Elevations are in NGVD 1929. Represents average across the period of record.

There are two notable drought years over the 100-period of analysis: 2059 (translates to past year of 1955), and 2060 (translates to past year of 1956). There are four notable high water or flood years over the 100-year period of analysis: 2031 (translates to past year of 1927), 2097 (translates to past year of 1993), 2099 (translates to past year of 1995), and 2123 (translates to past year of 2019).

Under both flooding and drought conditions, on average, pool levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions, with the exception of flooding under the FWOP 2074 (Table 3-74). During drought conditions, on average, in 2059 and 2060 pool levels in 25 years (2049) are approximately less than 0.2 feet higher, while in 50 and 100 years, pool levels are approximately 0.5 foot higher on average in 50 years and slightly over a foot higher under 2124 FWOP conditions.

Table 3-76. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years (feet)	Change in Average Water Surface Elevations from 2024 During Flood Years (feet)
2049	0.16	0.64
2074	0.49	-0.12
2124	1.09	0.17

Note: The top of the multi-purpose pool is 875.5 feet (NGVD 29).

During the 2059 and 2060 drought years, under the FWOP 2024 scenarios, the pool is between 861 and 864 feet (from one to four feet lower than the multipurpose pool).

Drought conditions, similar to those experienced in the mid-1950s, result in relatively lower water surface elevations for almost two years between 2059 and 2060, which could result in major implications for recreation with impacts to visitation and revenues over a prolonged period.

During drought or flood conditions, water surface elevations do not reduce the depths of the lake to an extent that would cause impacts (see description on water surface elevations).

Under three notable high water or flood years over the 100-year period of analysis, as shown in Appendix F, on average, water surface elevations are higher under the FWOP 2049 and 2124 conditions and slightly higher under the FWOP 2074 conditions compared to FWOP 2024. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (-0.17 to +0.64 feet).

Changes in Visitation

This section describes how changes and lake elevations can potentially impact visitation at Clinton Reservoir. Impacts from sediment are not discussed as Clinton Reservoir does not lose substantial storage over the 100 years of the FWOP. The following sections describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 910,000 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The study team compared the impacted visitation to 2018 baseline visitation at all locations at Clinton Reservoir. In 2018, visitation across Clinton Reservoir was estimated to be 1,801,100.

Drought and flood conditions are the main driver of recreation impacts across the reservoir, although HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

During drought conditions, consistent with the historic drought of the mid-1950s, water surface elevations are moderately lower than the top of the multipurpose pool across all FWOP scenarios (from one to four feet lower than multipurpose pool during this period) and below thresholds important for recreation. In drought conditions, consistent with mid-1950s water conditions, all water-based access at recreation areas at the lake

would be impacted under all FWOP scenarios with no boating access and exposed shorelines with debris, rocks, steep banks, and under hazards exposed. This would have multi-year impacts as the fishery could also be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be impacted, and revenue sources to maintain the lakes would decrease.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions) visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 320,500, a reduction of approximately 589,500 visitors from 2018 baseline conditions at lake-elevation affected recreation areas.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2031 (modeled after 1927 conditions), 2097 (1993), 2099 (1995), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years. A reduction in visitation at recreation areas impacted by changes in water surface elevations at Clinton Reservoir in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 76 percent compared to baseline conditions at Clinton Reservoir (2018).

With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenario. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 910,000 visitors would be affected, representing 51 percent of visitation under baseline conditions at Clinton Reservoir (2018).

Impacts on visitation under the three flood events could be high similar to past flood events. However, comparing water surface elevation impacts on visitation under the 2049, 2074, and 2124 FWOP scenarios during the four flood events, water surface elevations are minimally impacted (2049–1.9-foot increase to 0.9 foot decrease; 2074–0.3 decrease to 0.4 foot increase; and 2124–0.4 feet increase to 0.4 feet decrease) compared to FWOP 2024. These minimal changes in water surface elevations under the three FWOP scenarios compared to FWOP 2024 during the four flood events has minimal effect on visitation compared to baseline visitation (2018) and shows some increase in impacts as shown in Appendix F.

Changes in Economic Benefits

Consumer surplus values are measured through the USACE UDV approach further described in Appendix F. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). The following sections describe the potential impacts to consumer surplus values compared to all recreation values during typical

conditions at the lake-elevation affected recreation areas under the baseline year, 2018. These discussions are included for all reservoirs that were assessed quantitatively.

Regional economic impacts are estimated through the USACE's RECONS model and further described in Appendix F. This section describes how changes and lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, the study team describes the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. These discussions are included for all reservoirs that were assessed quantitatively.

Consistent with visitation in 2018, 1,801,100 visitors support 480 jobs and $18.1M in labor income in the local economy under baseline conditions at Clinton Reservoir. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 909,958 visitors support 255 jobs and $9.7M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated $9.8M in consumer surplus value. The study team also compared the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Clinton Reservoir. In 2018, visitation across Clinton Reservoir supported approximately $19.3M in consumer surplus values.[1]
  - Regional Economic Benefits

    Drought and flood conditions are the main driver of recreation impacts across the reservoir, although HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation, under the 100 years of the FWOP is assumed to remain similar to past visitation.
- Drought Conditions
  - Consumer Surplus

    The impacts to visitation during an extreme drought (below 865 feet [NVGD 29]) would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and

[1] Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

picnic areas, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). With elevations below 865 feet (NVGD 29), an estimated 50 percent of shore-based visitors could be impacted (see Appendix F).

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2059 and 2060 (modeled after 1955 and 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately $5.6 to $6.4M annually (Appendix F). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 57 percent to 65 percent compared to 2018 baseline conditions.

Under FWOP 2049, 2074, and 2124 conditions, water surface elevations are slightly higher on average compared to FWOP 2024 conditions during modeled years of 2031, 2097, 2099, and 2123 (Appendix F). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal with the highest reductions in consumer surplus in the FWOP 2124 (Appendix F).

- Regional Economic Benefits

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2059 (translates to past year of 1955) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 171 to 188 jobs and $6.6 to $7.3M during drought conditions under 2024 FWOP compared to baseline conditions (Appendix F). These reductions in economic benefits represent a 28 percent to 36 percent decrease in jobs from total jobs supported from all visitor spending at Clinton Reservoir under baseline conditions (480 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049, FWOP 2074, and FWOP 2124 conditions show that in modeled drought years of 2059 (translates to past year of 1955) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 104 to 188 jobs and $4.1 to $7.3M during drought conditions under 2024 FWOP compared to baseline conditions (Appendix F). These reductions in economic benefits represent a 23 to 40 percent decrease in jobs from total jobs supported from all visitor spending at Clinton Reservoir under baseline conditions (480 annual jobs).

- Flood Conditions
  - Consumer Surplus

Within the 100-year period of analysis, considerable flood events would occur in 2031 (modeled after 1927 conditions), 2097 (1993), 2099 (1995), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for

recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $4.4 and $7.5M in consumer surplus values, representing a decrease between 23 percent and 39 percent of total consumer surplus at all locations at Clinton Reservoir under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Under FWOP 2049, 2074, and 2124 conditions, water surface elevations are slightly higher on average compared to FWOP 2024 conditions during modeled years of 2031, 2097, 2099, and 2123 (Appendix F). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal with the highest reductions in consumer surplus in the FWOP 2124.

- Regional Economic Benefits

Within the 100-year period of analysis, considerable flood events would occur in 2031 (modeled after 1927 conditions), 2097 (1993), 2099 (1995), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 119 to 204 jobs and $4.5 to $7.8M in labor income, representing a decrease between 25 percent to 43 percent of total jobs supported by visitor spending at Clinton Reservoir under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Under the FWOP 2049, 2074, and 2124 scenarios, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2031, 2097, 2099, and 2123. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal and the impacts to the regional economic benefits (i.e., jobs and labor income) remain fairly consistent compared to FWOP 2024 for the modeled years of 2031, 2097, 2099, and 2123.

- Damages, Revenues, and Fees to States

Visitation to Clinton Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting, and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Clinton Reservoir were $904,000, the highest lake revenue in the State of Kansas.[2] At Clinton Reservoir in 2019, these revenues

[2]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

were $829,000, a reduction of 8 percent from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and, therefore, revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 31 percent of baseline conditions (2018), while flooding impacts would have larger impact, impacting up to 39 percent of visitation under baseline conditions. These impacts would continue to occur over time when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Clinton Reservoir were $355,000. The impacts at the KDWP state parks at Clinton Reservoir include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris are at $264,000. These damages are likely to continue to occur in the future with extreme events.

Water Quality

Clinton Reservoir has not experienced recreation impacts from HABs. Deteriorating water quality could eventually lead to new occurrence of HABs in Clinton Reservoir with adverse impacts to visitors in the future. Impacts from HABs are implicated in local economic impact based on decreases in tourism/recreational visitation and are expected to continue in the future (Appendix G).

As described, it is estimated that approximately 384 acre-feet of sediment accumulates on average annually at Clinton Reservoir. Sediment continues to accumulate with an expected additional 7 percent loss of the multipurpose pool over the next 25 years and a 12 percent loss over the next 50 years (Appendix D). Reduced volume means less dilution and can equate to higher concentration of nutrients stored in the lake system. With the expected low amount of sediment expected to accumulate in Clinton Reservoir issues related to reduced dilution will not likely impact water quality or recreation at Clinton Reservoir.

Excess nutrients and fecal bacteria are the main impairments to Clinton Reservoir and the inflow TMDLs defined in the 303(d) list provided by KDHE (https://www.kdhe.ks.gov/1219/303d-Methodology-List-of-Impaired-Waters). Cyanobacteria blooms occur at a low to moderate levels and frequently result in taste and odor issues for drinking water supply. These impairments impact support of aquatic life, primary contact recreation, and all other designated use of affected areas with swim beaches frequently closed from bacteria. These impacts are expected to continue and

potentially increase (see Appendix H) in the future causing reduced visitation and reduced visitor experience during periods when there are restrictions, warnings, or closure of favored recreation areas at Clinton Reservoir.

All reservoirs in the watershed, including Clinton Reservoir, will likely experience increasing effects of aging. Future water quality within watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Continued and enhanced water quality impairment may be expected at Clinton Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoir. Based on an assessment of runoff/streamflow, sediment yield, and total nitrogen (TN) and total phosphorous (TP) yield under climate change runoff to Clinton Reservoir is expected to have a high increase in runoff/streamflow and TN yield leading to a medium increase in sediment yield and TP yield and a medium increase in TN yield that could lead to increased levels of eutrophication.

Water residence times were estimated for Clinton Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Clinton Reservoir does not have a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 22 percent under the FWOP 2124. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Angling and Sport Fishery

Clinton Reservoir is filling in with sediment at the detriment of the fish and the anglers who pursue them as well as other interest groups that use the reservoir. Further degradation of existing fish habitat will be countered with the installation of artificial fish habitat, but natural features are likely more appealing to fishes, and it is unknown if the rate of replacement can match the rate of degradation.

There is no reason to believe that use or visitation of Clinton Reservoir will be decreasing in the future. This reservoir is within close proximity to large population centers. The reservoir is already known for its exceptional crappie fishing and receives a good deal of traffic from tournament bass fishing, which is a growing sport. There is also the possibility that in the next ten years, Clinton Reservoir could develop a high-quality blue catfish fishery. If this population takes hold, it is likely to receive increased pressure from metropolitan catfishermen who would like a closer destination than Milford Reservoir.

While angler use may remain constant or increase, access to the reservoir may decrease. Continued siltation at the upper end of the reservoir may hinder angler access to that portion of the reservoir resulting in crowding at lower reservoir boat access areas. Similarly, more frequent, or more drastic water level fluctuations could result in most, if not all, boat ramps being closed to angler access. Without construction

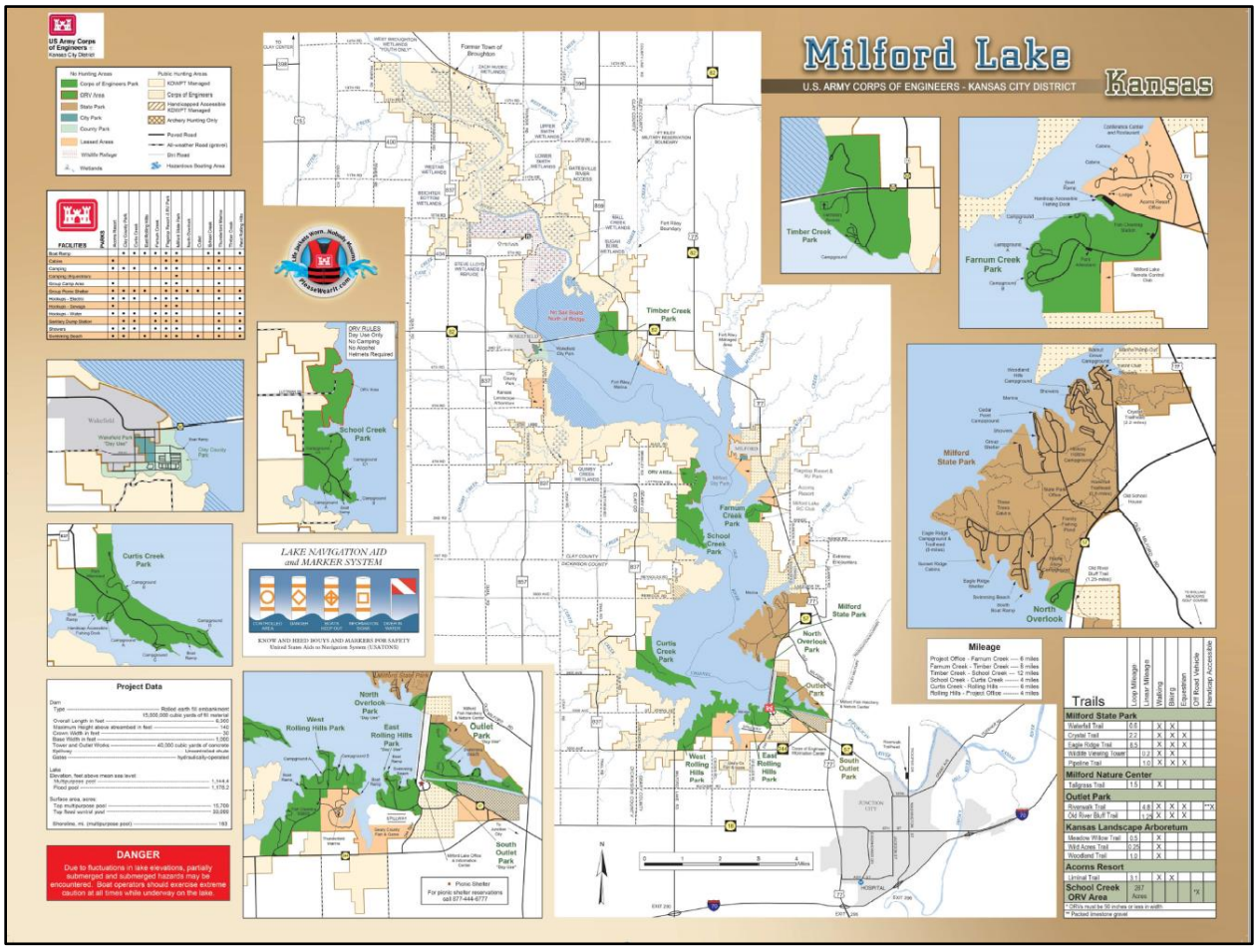
of new, higher elevation boat access points it is possible that anglers may not be able to access the reservoir during times of the year when rains are more frequent.

The loss of bathymetric features and silting in of natural fish attracting features will also negatively affect fish populations. Water level management will also continue to be crucial to sport fisheries and anglers. Available habitats and types, and successful sportfish reproduction and survival, can all be positively or negatively impacted by the timing of water releases and magnitudes thereof. High releases around spawning periods could be detrimental both on the local and statewide scale (Appendix E).

3.6.4.2 Milford Reservoir

Milford Reservoir is located on the Republican River in Geary County, Kansas (see Figure 3-145). It is on Highway 57, four miles northwest of Junction City, and 25 miles southeast of Clay Center. Milford Reservoir was created by USACE for the purposes of flood control, silt control, water quality, water supply, low flow supplementation, recreation, fish and wildlife, and support of navigation on the Missouri River.

Figure 3-145. Milford Lake Recreation Areas



3.6.4.2.1 Existing Conditions

Recreation Facilities and Visitation

Milford Reservoir offers a variety of recreational amenities, including 10 parks managed by KDWP or the USACE (Figure 3-145). A few city and county parks are also located adjacent to Milford Reservoir. Below highlights the numerous recreational opportunities available at Milford Reservoir:

- Boat Ramps
- Beaches
- Campsites
- Picnic Areas
- Hiking Trails
- Off-road Recreational Vehicle Trail
- Wildlife Areas
- Archery Hunting Areas
- Marinas.

According to combined USACE and KDWP data, total visitation for 2018 was 1,579,700. In 2018, the state park, which includes Milford Nature Center and Clay County Park, accounted for 23 percent of total visitation at the lake recreation areas. Another popular destination at Milford Reservoir is Thunderbird Marina, accounting for 13 percent of the total 2018 visitation.

In terms of recreational activities, camping and water-contact activities together accounted for about 40 percent and 15 percent of all activities in 2018, respectively. Walking, hiking, and jogging accounted for a combined 5 percent of visitation while sightseeing and picnicking both accounted for a combined 19 percent of visitation (USACE and KDWP 2018–2019). According to iSportsman data (KDWP), total hunting visits within the wildlife area managed by KDWP at Milford in 2018 were 10,880, accounting for 0.63 percent of all activities in 2018. Wildlife viewing visits totaled 2,176.

The lake holds several activities each year, including several fishing tournaments, bike and cardboard boat races, youth fishing days, and environmental education workshops for kids (Whitworth 2020). Special events at Milford Reservoir account for approximately 2 percent of visitation. During a lake meeting on February 5, 2021, KDWP lake staff indicated that Milford Reservoir has annual fishing tournaments that are very popular, and sometimes bring in people from all over the country.

Sport Fisheries

This section provides a summary of sport fishing at Milford Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The objective of fisheries management at Milford Reservoir is to create quality fishing opportunities for anglers. Milford Reservoir provides a variety of species to appease many angler groups. Fish populations are managed through setting length limit and creel (also referred to as an angler survey) limit regulations, fish stockings to supplement existing populations, deploying artificial habitat, conducting creel surveys of

anglers, and monitoring with sampling activities (Appendix E). Additionally, from February to May, the reservoir level is maintained at 1,141.4 feet (NGVD 29) to eradicate exposed zebra mussels and facilitate spawning areas for walleye.

Milford Reservoir is locally known as the “fishing capital of Kansas”, and is a top destination for anglers, hunters, campers, etc. on a regular basis. Milford Reservoir is one the most popular fishing destinations in Kansas. Several species are sought after which draws anglers from all over Kansas and from out of state. Popularity at Milford Reservoir has drawn attention to many guide services and fishing tournament organizers from all over Kansas and the surrounding areas. Fishing tournaments happen frequently at Milford Reservoir and are hosted by local fishing clubs all the way up to national tournament trails. In recent years, groups such as I-70 bass club, Kansas Bass Nation, etc. hosted several bass tournaments at Milford Reservoir. Local catfish circuits (i.e., Catfish Chasers) also hold tournaments on Milford once or twice a year (Appendix E).

The data presented in Appendix E highlights trends from the past five years excluding 2019 which was not sampled due to flooding. In 2018, an estimated 49,024 anglers fished Milford Reservoir. Anglers preferred “catfish” the most, second was wiper, third was blue catfish specifically, and fourth was “no preference”, or “any” (Appendix E).

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Flood conditions at Milford Reservoir occurred throughout 2019. The flood of 2019 closed approximately 75 percent of all boat ramps, all USACE-managed campgrounds, and closed swimming beaches at USACE recreation areas. Due to the spring flood event, the reservoir was above top multipurpose pool for over 110 days, with a water surface elevation 31 feet above the multipurpose pool (USACE 2020). The high-water levels at Milford Reservoir damaged USACE and state recreation areas.

According to federal and state data, visitation in 2019 decreased by 20 percent in the summer (May–August), decreased by 21 percent in the fall (September–December), and increased in the winter (January–April) by 5 percent. Overall, total annual visitation between 2018 and 2019 decreased by 15 percent (USACE and KDWP 2018–2019). Rising water meant reservoir staff spent a substantial amount of time moving fishing dock cables and removing electrical breakers before the pedestals were flooded. While overall visitation decreased, during the 2019 flood, with just 2 boat ramps open, boating and fishing recreation remained stable. However, boaters experienced longer wait times at boat ramps with the reduction in ramps available (Whitworth 2020).

Drought conditions existed in late 2012 into 2013 (USGS, Kansas Droughts 2020). The drought conditions reduced access to boat ramps, created issues for boaters due to exposed underwater hazards, and reduced fishing access (Whitworth 2020). In a drought, lower lake elevations expose low water boat ramps, and people shift boat ramp use to deeper ramps. The USACE and out grantees often extend the shallower ramps further out to follow the water during drought conditions. If water level drops too low, people shift from fishing off of boats to fishing from the shore (Whitworth 2020).

High water increases duck habitat and spreads ducks out into areas where they normally would not go. Hunters must adjust to this but can still enjoy the same success

as a normal lake level. High water pushes some deer further inland, again forcing hunters to adjust their tactics. Drought also impacts deer movement but creates quail/pheasant habitat from vegetation that grows on the now-exposed mudflats (Whitworth 2020). Overall, some types of hunting may decrease while other types may increase, still offering hunters opportunities to recreate.

Sedimentation is an issue in the upper reaches of the lake, making the water shallower over time and increasing the need for the cleaning or dredging of boat ramps often causing these features to become temporarily inaccessible until maintenance is completed (Whitworth 2020). The multipurpose pool at Milford Reservoir originally included 415,352 acre-feet of capacity (including the active pool and the inactive or dead pool). Approximately 11.8 percent of the multipurpose pool has been filled in with sediment leaving approximately 366,476 acre-ft of capacity (based on 2009 survey results) (Appendix D).

The impacts to visitation associated with HAB activity can depend on not only the presence of the HABs and their duration, but also on other variables or issues specific to each lake, including the prevalence of water-based visitors in the affected area, the locations of the HABs, and the availability of nearby parks or recreation areas and/or other lakes that recreators could use. HABs are prevalent at Milford Reservoir where highly variable algae blooms have led to HAB warnings five of seven years from 2011 to 2017, usually occurring between May and October (Appendix F). Since Milford Reservoir is a large, zoned lake, some zones may have a HAB warning, while others are unaffected.

During the worst HAB year in 2016, Milford Lake experienced 19 weeks of HAB warning impacts (e.g., closed swim beaches and reduced boating activities) which included two weeks of “closure” or what is currently defined as “Public Health Hazard” conditions from extremely toxic HAB conditions that resulted in zones of the lake closed to all public access including boat ramps. In September of 2014, there were HAB hazards and closures in Zone C (upper part of the reservoir) from high algal cell count samples in the lake; warnings occurred at Milford Reservoir in 2014 in June, July, August, and September in all three zones in Milford Lake (see Appendix F). In years with no HAB warnings (2012 and 2013), limited inflows from drought low water years led to HAB minor blooms which never exceeded “watch” status.

Persistent warnings can decrease visitation at a lake, which can adversely affect economic activity in adjacent communities to the lakes. Although difficult to correlate warnings directly with decreased visitation, closures from HAB hazards seem to reduce visitation in affected months.

Although all three zones in Milford Reservoir have been affected by HAB warnings, Zone C (https://www.kdhe.ks.gov/777/Harmful-Algal-Blooms) has experienced more warnings than the other zones and is the only zone that has experienced closures (in 2014, 2015, and 2016) since 2014. Zone C encompasses Fort Riley Recreation area, Timber Creek Park, and Clay County Park, with Clay County Park having the vast majority of visitation. In 2014, 2015, and 2016, these three recreation areas supported less visitation overall in May through September than in 2017 and 2018 (2019 experienced flooding conditions that affected visitation at the lake).

Critical Lake Elevations for Recreation

Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Milford Reservoir as well as the corresponding impacts to visitation (and 1The information in this table was developed with input from USACE and KDWP staff familiar with Milford Reservoir. Lake elevations are in NVGD 29.

Table 3-78). Future reservoir sedimentation for Milford Reservoir and any impacts to recreation are described in Appendix F.

4828 *Table 3-77. Critical Lake Elevations for Recreation at Milford Reservoir[1]*

Lake Elevations	<1,118 feet	1,118–1,130 feet	1,030–1141.4 feet	1,141.5–1148.5 feet; multipurpose pool is 1,144.4 feet	1,148.5–1,160 feet	>1,160 feet
Visitation Impacts	All boat ramps and marinas are closed below 1,118; shoreline and boat angling are compromised with reduced fishing opportunities.	Most boat ramps are not accessible; 11 of 13 of the boat ramps are not accessible. Milford State Park Marina and East Rolling Hills boat ramps remain accessible. Water-based visitation decreases.	Water access is maintained for some visitors; boating access is reduced at elevations below 1,137; overcrowding at usable boat ramps becomes a major issue.	Normal conditions	All boat ramps and marina are inaccessible above 1,148.5; shoreline access for anglers becomes difficult. Approximately half of campground sites are closed; water and electric are shut-off. Water-based visitation decreases.	Maneuver zones no longer accessible; additional camping areas, roads, and trails are inaccessible. Timberlane Cabins are inaccessible.
Quality of Recreation Effects	Extreme safety hazards for boaters and beach impacts. Reduced fishing success.	Overcrowding at usable boat ramps becomes a major issue. Shoreline fishing access is reduced. Safety hazards exist for boaters; silt and rocks on beach limits access and reduces aesthetics. Recreational "frustration" increases as boaters lose access and face ramp congestion.	Visitors start to complain about low water levels; safety hazards start to emerge for boaters.	No Impacts	Visitors start to complain about high water levels. Shoreline erosion begins to occur. Waterfowl hunting may expand into wetted areas, while areas for deer hunting may recede. Continued fishing success. Recreational "frustration" increases as boaters lose access and face ramp congestion.	Safety issues with debris with extreme high water; shoreline erosion.

4829 [1]The information in this table was developed with input from USACE and KDWP staff familiar with Milford Reservoir. Lake elevations are in NVGD 29.

Table 3-78. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds[1]

Lake Elevations	<1,118 feet	1,118–1,130 feet	1,030–1141.4 feet	1,141.5–1148.5 feet; multi-purpose pool is 1,144.4 feet	1,148.5–1,160 feet	>1,160 feet
Water-based Visitor Impacts	100%	70%	40%	0%	100%	100%
Shore-based Visitor Impacts	75%	25%	25%	0%	50%	100%

[1]The information in this table was developed with input from USACE and KDWP staff familiar with Milford Reservoir. Lake elevations are in NVGD 29.

3.6.4.2.2 Future Without Project Conditions

Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Three years were chosen to evaluate flood conditions, with average annual elevations at Milford Reservoir above 1,148 feet, while two years were chosen to evaluate drought conditions, with average annual elevations below 1,130 feet. See Tables 3-75 and 3-76 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2044 (1940)
- 2060 (1956).

Flood years include:

- 2055 (1951)
- 2097 (1993)
- 2123 (2019).

Typical years include all other years.

It is estimated that approximately 468 acre-feet of sediment accumulates on average annually in Milford Reservoir. Sediment will continue to accumulate in Milford Reservoir with an expected additional 2.5 percent loss of the multipurpose pool over the next 25 years (2049) and 4.0 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 349,881 acre-feet in 2074. Sedimentation has not generally impacted recreation at Milford Reservoir.

While sediment will continue to accumulate (2.5 percent loss of the multipurpose pool over the next 25 years and 4.0 percent loss over the next 50 years) and the delta could extend, the size of the multipurpose pool and the lake's recreational opportunities are expected to be impacted very minimally, if at all. Appendix F show the depths of Milford Reservoir at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years).

During typical precipitation conditions (at multi-purpose pool), the USACE sediment modeling indicates that boat ramps at Milford Reservoir would continue to provide boating access to the lake in under all FWOP scenarios.

During drought or flood conditions, the effects of sediment deposition in the future on recreational access remain generally the same. Milford Reservoir does not lose significant storage over the 100-years of the FWOP. However, with each subsequent FWOP scenario, the average pool elevation decreases as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., De Soto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets (Appendix B).

Milford Reservoir modeling shows small increases in frequency in the lower portions of the flood pool and deeper drops into the multipurpose pool as the storage diminishes due to sedimentation. Additional information is provided in Appendix B.

Table 3-79. Average Water Surface Elevations at Milford Reservoir

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	1,144.63	-
2049	1,144.46	-0.17
2074	1,144.25	-0.38
2124	1,143.41	-1.22

Note: The top of the multi-purpose pool is 1,144.4 feet. Elevations are in NVGD 1929. Represents average across the period of record.

There are two notable drought periods over the 100-period of analysis: 2044 (translates to past year of 1940), 2060 and 2061 (translates to past years of 1956 and 1957). There are three notable high water or flood years over the 100-year period of analysis: 2055 (translates to past year of 1951), 2097 (translates to past year of 1993), and 2123 (translates to past year of 2019).

Under both flooding and drought conditions, on average, pools levels are lower in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions. During drought conditions, on average in 2044, 2060, and 2061, pool levels in 25 years (2049) are approximately over a foot lower, while in 50 and 100 years, pool levels are approximately three feet lower on average in 50 years and almost 13 feet lower than under 2124 FWOP conditions.

Table 3-80. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years (feet)	Change in Average Water Surface Elevations from 2024 During Flood Years (feet)
2049	-1.37	-0.04
2074	-3.13	-0.16
2124	-12.71	-0.34

Note: The top of the multi-purpose pool is 1,144.4 feet NVGD 29.

During the 2060-2061 drought period, under the FWOP 2024 scenarios, the pool is between 1,119 and 1,137 feet (NVGD 29) (from seven to 25 feet lower than multi-purpose pool) between July 2060 and until June 2061 when it rises back to multi-purpose pool level.

Drought conditions, similar to those experienced in the mid-1950s, result in relatively lower water surface elevations (between five and 17 feet below multi-purpose pool) for almost two years between 2059 and 2061, which could result in severe implications for recreation as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., De Soto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets. See Section 3.2.2.2.2 for more detail on drought impacts to recreation.

During drought or flood conditions, water surface elevations are not so low that the depth of the lake would cause impacts from water levels that are too low to recreate (see description on water surface elevations).

Under three notable high water or flood years over the 100-year period of analysis, on average, water surface elevations are lower on average under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal.

The worst modeled future flood year in terms of visitation was in 2123 (compared to 2019) when, during the year, water surface elevations were above elevation 1,160 feet (see threshold table in existing conditions section) under all of the FWOP scenarios. In general, Milford Reservoir is closed to visitation when water surface elevations are 1,160 feet (NVGD 29).

Changes in Visitation

In 2018, 1,498,700 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Milford Reservoir. In 2018, visitation across Milford Reservoir was estimated to be 1,579,700.

Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions and HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

During drought conditions consistent with the historic drought of the mid-1950s, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from seven to 25 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation. In drought conditions, consistent with mid-1950s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. In addition, modeling shows periods of low to no storage at Milford Reservoir during extreme drought conditions. This would have multi-year impacts as the fishery would be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be severely impacted, and revenue sources to maintain the lakes would decrease.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 1,080,300, a reduction of approximately 499,400 visitors from 2018 baseline conditions at lake-elevation affected recreation areas. The year 2044 (modeled after 1940 conditions) would have similar impacts to visitation.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP

2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Appendix F). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Milford Reservoir in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 81 percent compared to baseline conditions at Milford Reservoir (2018).

With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenario. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 1,498,700 visitors would be affected, representing 95 percent of visitation under baseline conditions at Milford Reservoir (2018). Appendix F shows how flood conditions under the 2049, 2074, and 2124 FWOP scenarios affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled “flood years” (2055, 2097, and 2123) to baseline conditions (2018).

Impacts on visitation under the three flood events could be high similar to past flood events. However, comparing water surface elevation impacts on visitation under the 2049, 2074, and 2124 FWOP scenarios during the three flood events, water surface elevations are minimally impacted (2049: 0.1-foot increase to 0.1-foot decrease; 2074: 0.0- to 0.3-foot decrease; and 2124: 0.3- to 0.5-foot decrease) compared to FWOP 2024. These minimal changes in water surface elevations under the three FWOP scenarios compared to FWOP 2024 during the three flood events has minimal effect on visitation compared to baseline visitation (2018) and shows some reduction in impacts as shown in Appendix F.

Changes in Economic Benefits

Consistent with visitation in 2018, 1,579,700 visitors support 411 jobs and $12.7M in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 1,498,700 visitors support 387 jobs and $12.0M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated $16.4M in consumer surplus value. The study team also compared the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Milford Reservoir. In 2018, visitation across Milford Reservoir supported approximately $17.2M in consumer surplus values.[3]

[3] Consumer surplus values are estimated with recreation visitor day and the Corps’ UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

- Regional Economic Benefits

  Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions and HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

- Drought Conditions
  - Consumer Surplus
  - The impacts to visitation during an extreme drought (below 1,118 feet [NVGD 29]) would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). With elevations below 1,118 feet [NVGD 29], an estimated 75 percent of shore-based visitors could be impacted (see Appendix F).

    Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately $4.6M annually (Appendix F). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 28 percent compared to 2018 baseline conditions.

    Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049, FWOP 2074, and FWOP 2124 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately $4.6 to $7.2M annually (Appendix F). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 28 to 30 percent compared to 2018 baseline conditions. The larger impacts in the 2124 FWOP are from decreases in the average pool elevation as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., De Soto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir under the 2124 FWOP to support water quality targets.
  - Regional Economic Benefits

    Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2044 (translates to past year of 1940) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 116 jobs and $3.7M during drought conditions under 2024 FWOP compared to baseline conditions. These reductions in economic benefits represent a 28 to 29 percent decrease in jobs from total jobs supported from visitor spending at Milford Reservoir under baseline conditions (411 annual jobs). Droughts can also have lasting

impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049, FWOP 2074, and FWOP 2124 conditions show that in modeled drought years of 2044 (translates to past year of 1940) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 117 to 188 jobs and $3.7 to $6.0M during drought conditions under 2024 FWOP compared to baseline conditions (Appendix F). These reductions in economic benefits represent a 29 percent to 47 percent decrease in jobs from total jobs supported from visitor spending at Milford Reservoir under baseline conditions (411 annual jobs). Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., De Soto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets under the 2124 FWOP causing substantial decreases in jobs and income compared to the baseline and the 2024 FWOP.

- Flood Conditions
  - Consumer Surplus

    Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $11.0 and $13.9M in consumer surplus values, representing a decrease between 67 and 85 percent of total consumer surplus at lake-elevation affected areas at Milford Reservoir under baseline conditions (Appendix F) There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

    Under FWOP 2049, 2074, and 2124 conditions, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2055, 2097, and 2123 (Appendix F). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (Appendix F).

  - Regional Economic Benefits

    Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 273-338 jobs and $8.5 to$10.5M in labor income, representing a decrease between 67 percent and 83 percent of total jobs supported by visitor spending at Milford Reservoir

under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Under the FWOP 2049, 2074, and 2124 scenarios, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2055, 2097, and 2123. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal and the impacts to the regional economic benefits (i.e., jobs and labor income) remain fairly consistent compared FWOP 2024 for the modeled years of 2055, 2097, and 2123.

- Damages, Revenues, and Fees to States

Visitation to Milford Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting, and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Milford Reservoir were $505,000, fourth in revenue in the state of Kansas.[4] At Milford Reservoir in 2019, these revenues were $418,000, a reduction of 17 percent from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 33 percent of baseline conditions (2018), while flooding impacts would have larger impact, impacting up to 81 percent of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Milford Reservoir were $740,000. The impacts at the KDWP state parks at Milford Reservoir include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris are at $435,000. These damages are likely to continue to occur in the future with extreme events.

[4]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

Navigation Releases

Navigation releases from Milford and Perry reservoirs can be made from the water supply storage volume that has not been called into service by the State of Kansas. All of the multipurpose pool storage is under contract for water supply to the state of Kansas in the two reservoirs. Until all storage is called into service, multipurpose objectives of the remaining storage can be used to supplement Missouri River flows for navigation within operating limits. If 100 percent of the water supply volume is called into service for Milford and Perry reservoirs, navigation releases from the water supply volume would not occur at these reservoirs. Navigation flow support is provided by Milford Reservoir in the FWOP scenario for 2024 but not for the 2049, 2074, and 2124 as it is anticipated that the remaining storage will be called into service by the state of Kansas before these three timeframes.

Navigation releases under the FWOP 2024 results in increased frequency of pool elevations below the top of multipurpose pool elevation. Higher pool elevations in the navigation FWOP 2024 scenario are the same as those under the non-navigation FWOP 2024 scenario. The 2049, 2074, and 2124 FWOP scenarios did not provide navigation support flows, but some small impacts are assessed because of Tuttle Creek Reservoir providing the navigation support flows which then requires Milford Reservoir to make additional releases to support water quality targets. Under the FWOP 2124 scenario Milford Reservoir is already supporting most of the water quality releases as the multipurpose pool as Tuttle Creek Reservoir is almost full of sediment with little remaining storage volume (see Appendix B).

Due to the lower pool elevations in the multipurpose pool in the FWOP 2024 scenario with navigation releases, modeled visitation is on average three to 3.3 percent lower than the FWOP scenarios without navigation releases across all these typical precipitation years. These changes also have similar implications for consumer surplus values and regional economic effects. Under the FWOP 2024 scenario with navigation releases, lower pool elevations in these typical precipitation years could result in reduced visitation on average of approximately 47,500 visitors, with an associated reduction in consumer surplus values of $465,000 compared to the FWOP 2024 scenario without navigation releases. There would be small decreases in regional economic benefits as well.

In the two modeled drought years (2044 and 2060), average reservoir elevations under FWOP 2024 with navigation releases in these years are approximately 2.0 feet lower than reservoir elevations under FWOP 2024 without navigation releases.

In the three modeled flood years (2055, 2097, and 2123), average reservoir elevations under all FWOP scenarios with navigation releases show very little change compared to the scenarios without navigation releases, resulting in no change in visitation under FWOP scenarios with navigation releases and FWOP scenarios without navigation releases. There would be no effect of navigation releases on consumer surplus values and regional economic benefits during flood conditions.

Water Quality

Excess nutrients can lead to HABs under ideal growing conditions. HABs have impacted Milford Reservoir since 2011 with HAB warnings impacting recreation seven of the last 10 years. Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Milford Reservoir. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. Milford Reservoir has a below average water residence time compared to other USACE reservoirs in the basin, particularly in late summer, leading to an increase in soluble nutrient concentrations that can lead to increased algal growth and the potential for HABs. Deteriorating water quality could eventually lead to increased prevalence of HABs in Milford Reservoir with adverse impacts to visitors in the future. Watershed conservation efforts have increased in priority for state and local rankings to address Milford Reservoir hypereutrophic conditions and chronic HABs. Impacts from HABs has been implicated in local economic impact from decrease in tourism/recreational visitation and are expected to continue in the future (Appendix G).

As described it is estimated that approximately 468 acre-feet of sediment accumulates on average annually at Milford Reservoir. Sediment will continue to accumulate with an expected additional 2.5 percent loss of the multipurpose pool over the next 25 years and a 4 percent loss over the next 50 years (Appendix D). Reduced volume means less dilution and can equate to higher concentration of nutrients stored in the lake system. With the expected low amount of sediment expected to accumulate in Milford Reservoir issues related to reduced dilution will not likely impact water quality or recreation at Milford Reservoir.

The primary water quality threats at Milford Reservoir for eutrophication are nutrients, sediment, toxic cyanobacteria blooms, and dissolved oxygen sags. Milford Reservoir has been listed as impaired by KDHE and is classified as hypereutrophic due to excessive nutrients. A TMDL was developed for Milford Reservoir to prioritize reduction of nutrients in the watershed to address water quality and frequent HAB issues. Measures that are being tested to reduce the frequency of HABs include a plan for adjustments to the lake level management plan for a functional drawdown during the spring and summer months. This measure will continue to be tested to determine if this operational change may be a tool to mitigate HABs. These impacts are expected to continue and potentially increase (see Appendix H) in the future causing reduced visitation and reduced visitor experience during periods when there are restrictions, warnings, or closure of favored recreation areas at Milford Reservoir.

All reservoirs in the watershed, including Milford Reservoir, will likely experience increasing effects of aging. Future water quality within watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Continued and enhanced water quality impairment may be expected at Milford Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoir. Based on a watershed-wide pattern of

increasing in-lake total phosphorus concentrations there is a potential for continued eutrophication (high algal productivity) at Milford Reservoir with the likelihood of increased transport of quantities of sediment and nutrients based on the likelihood of increased frequency of extreme precipitation events under climate change. Based on an assessment of runoff/streamflow, sediment yield, and TN and TP yield under climate change runoff to Milford Reservoir is expected to have a high increase leading to a high increase in sediment yield and TP yield and a medium increase in TN yield that could lead to increased levels of eutrophication.

Water residence times were estimated for Milford Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Milford Reservoir does not have a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 12 percent under the FWOP 2124. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Angling and Sport Fishery

The future of the fishery for Milford Reservoir looks steady for now. However, several factors that fisheries biologists need to continue to monitor in the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can lead to creating the BMPs to be able to maintain these fish populations in a constantly changing environment. These fish populations are very important to all anglers who utilize Milford Reservoir. Therefore, being able to understand how these populations could be impacted in the future can aid in better management of these fish species (Appendix E).

3.6.4.3 Perry Reservoir

Perry Lake is located on the Delaware River 4.5 miles northwest of Perry, Kansas and 17 miles east of Topeka (Figure 3-146). It was built by the USACE for flood control, navigation, water supply/quality, recreation, and fish and wildlife purposes.

3.6.4.3.1 Existing Conditions

Recreation Facilities and Visitation

Perry Lake hosts eight parks, seven of which are managed by USACE, and one state park managed by KDWP. Below highlights the numerous recreational opportunities available at Perry Lake:

- Marinas
- Boat Ramps
- Yacht Club
- Beaches
- Hiking/Biking/Equestrian Trails

- Disk Golf Course
- Off-road Recreational Vehicle Trail
- Archery Area
- Camping Areas
- Wildlife Areas

According to USACE and KDWP data, for the year 2018, visitation to the lake was estimated at 785,900 people. In 2018, Perry State Park accounted for the most visitation at Perry Lake at 32 percent, followed by Rock Creek Marina and Resort at 15 percent, and Perry Marina at 10 percent. Additionally, there is a private camp operated by the Boy Scouts at Perry Lake, that is not included in the visitation estimates.

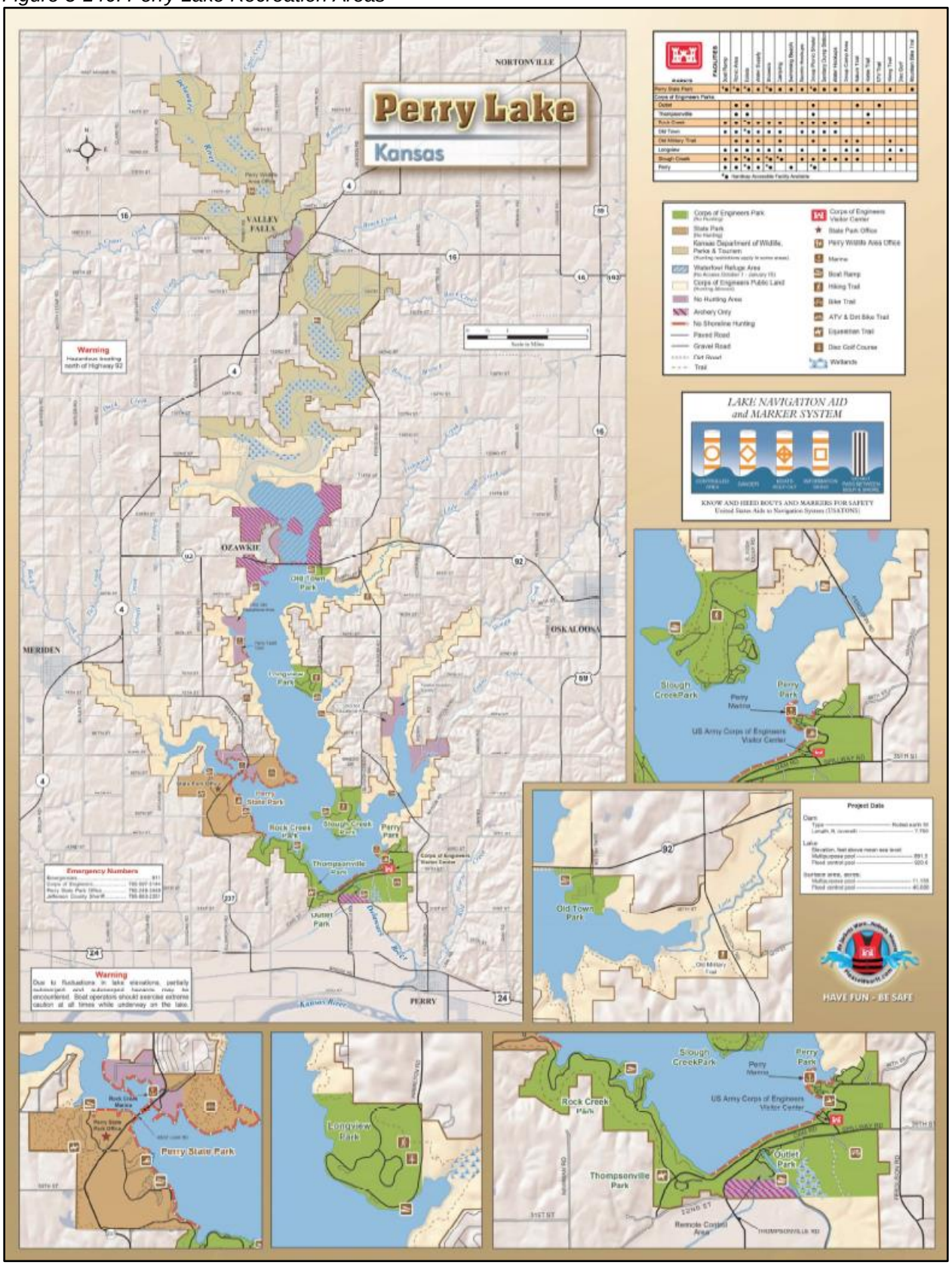
In terms of prevalent activities at Perry Lake, camping was the most popular activity at the lake, accounting for 25 percent of all activities. Other popular activities include water contact activities (19 percent), sightseeing (13 percent), picnicking (12 percent), boating (10 percent), and fishing (5 percent) (USACE and KDWP 2018–2019). Perry Lake hosts many special events including fishing tournaments, Frisbee golf, and bike races. There are also Regattas held every year at Perry Lake. Special event visitation accounted for about 3 percent of total visitation in 2018. According to iSportsman data there were 4,269 hunting visits (with full compliance–meaning that users were reporting as required) in wildlife areas and 854 wildlife viewing visits representing 0.41 percent and 0.08 percent of total activities respectively.

Sport Fisheries

This section provides a summary of sport fishing at Perry Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Perry Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. From March-August the lake elevation can increase to support spawning habitat for bass, crappie, and sauger.

The number of anglers visiting Perry Reservoir is relatively high when compared to other Kansas reservoirs due to its proximity to major metropolitan areas. According to the last creel survey, total angler trips were approximately 57,731. The reservoir sees anglers traveling from not just the population centers of Kansas but from all corners, with 91 communities represented. There were also many anglers visiting Perry Reservoir from neighboring or distant states. Of the eleven states, other than Kansas, which anglers hailed from, the majority came from Missouri (Appendix E).

Figure 3-146. Perry Lake Recreation Areas



Anglers at Perry Reservoir usually harvest at least some fish, with only 12 percent of anglers not harvesting any fish during their trips Harvest is dominated by white crappie and followed by channel catfish, similar to angler preference. White bass comes in third for fish harvested. Largemouth and smallmouth bass anglers on Perry Reservoir tend to be more catch-and-release oriented, choosing to release more of their catch in hopes that they grow to trophy size.

Perry Reservoir is filling in with sediment to the detriment of the fish and the anglers who pursue them, as well as other interest groups that use the reservoir. Sedimentation of the reservoir reduces the storage capacity and also the fishable areas while also filling in any unique, fish attracting bathymetric features (e.g., river channels). Decreased storage capacity will likely result in Perry Reservoir being more responsive to heavy rains, exhibiting more drastic rises than were experienced when the river was impounded over fifty years ago. The more drastic and frequent fluctuations will make the establishment and development of aquatic vegetation even more difficult. Further degradation of existing fish habitat will be countered with the installation of artificial fish habitat, but natural features are likely more appealing to fish and it is unknown if the rate of replacement can match the rate of degradation.

This reservoir is within close proximity to the majority of the large population centers of Kansas; a one-hour drive from the heart of Kansas City. The reservoir is already known for its exceptional crappie fishing and receives a good deal of traffic from tournament bass fishing, which is a growing sport. There is also the possibility that in the next ten years, Perry Reservoir could develop a high-quality blue catfish fishery. If this population takes hold, it is likely to receive increased pressure from metropolitan catfishermen who would like a closer destination than Milford Reservoir. More than 4,000 intermediate paddlefish were stock in 2022. The reintroduction of paddlefish to Perry Reservoir and the Delaware River could also result in an increase of recreational anglers. If this population takes hold and recreational snagging is allowed, there could be a large number of anglers travel to the reservoir’s upper reaches or spillway in the spring when these fish make their spawning runs.

While angler use may remain constant or increase, access to the reservoir may decrease. The upper end of the reservoir north of Highway 92 bridge is closed to access half of the year as a refuge but during periods when this area is accessible anglers utilize this area. Continued siltation at the upper end of the reservoir may hinder angler access to that portion of the reservoir during periods when the area is open to public access resulting in crowding at more southern boat access areas. Similarly, more frequent or more drastic water level fluctuations could result in most, if not all, boat ramps being closed to angler access.

Water level management will also continue to be crucial to sport fisheries and anglers. Available habitats and types, and successful sportfish reproduction and survival, can all be positively or negatively impacted by the timing of water releases and magnitudes thereof. High releases around sauger spawning could be detrimental both on the local and statewide scale, too. KDWP is dependent on this adult sauger population to produce and stock sauger and saugeye across the entire state of Kansas.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

In May of 2019, Perry Lake was severely impacted by flooding, forcing the closure of 6 boat ramps, Slough Creek Park, Rock Creek Park, Old Town Park campground, and Perry Beach. The entire area typically used by recreation visitors was impacted by flooding either from closures of roads or loss of electrical power. During the spring flood event, Perry Reservoir was above multipurpose pool for over 60 days, with a max crest of 30 feet above top of multipurpose pool (USACE 2020).

Annual visitation in 2019 at Perry Lake was 26 percent lower compared to annual visitation in 2018. This decrease was mostly driven by a 39 percent decrease in summer visitation (May-August) and a further 60 percent decrease in fall (September–December) visitation (USACE and KDWP 2018–2019). Perry Lake staff indicated that during the 2019 flood, wellfields were also inundated at Perry Lake at 15 feet over normal elevation. Due to flooding, USACE campgrounds were closed all year, entire roadways were closed, and equestrian trails were too muddy to use. Additionally, the repairs to many recreation areas were slow due to the COVID-19 pandemic, with only 60 percent of recreation areas opened at the start of the 2020 recreation season. Many more “primitive” areas weren’t open until Labor Day weekend of 2020.

In 2012 and 2013 the majority of Kansas suffered a drought. The multi-purpose pool at Perry was 73.9 percent full in January of 2013. In August of 2018, water surface levels were four to six inches below multi-purpose pool levels, exposing hazards which caused safety concerns for boaters (USACE 2018). Wildlife areas tend to be minimally impacted by low water events, and low water sometimes makes it easier for hunting access.

2011 was the last time Perry State Park closed due to HABs impacts. In the summer of 2021, a HAB warning was issued for Perry Lake. However, this is unusual and according to staff, Perry doesn’t tend to have issues with HABS.

Critical Lake Elevations for Recreation

Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Perry Reservoir as well as the corresponding impacts to visitation. Future reservoir sedimentation for Perry Reservoir and any impacts to recreation are described in Section 3.3.1.

5356 *Table 3-81. Critical Lake Elevations for Recreation at Perry Reservoir[1]*

Lake Elevations (feet)	<886 feet	886–888 feet	888–895 feet; multipurpose pool is 891.5 feet	895–897.5 feet	897.5–903.5 feet	>903.5 feet
Visitation Impacts	No boating access, all ramps unusable. Marinas impacted and Yacht Club required to move a majority of boats to deeper water.	Boat ramps usable starting at elevation 886. No pumping of water into wetlands below multipurpose pool, impacting waterfowl hunting.	No Issues	Boating access issues at State Park ramps starting at 895 feet. 25 percent of lower elevation campsites affected. Limited fishing and recreational boating due to closure of approximately 50 percent of boat ramp access.	Water based recreation basically closed due to limited recreational access at boat ramps. Multiple campsites and campground roads affected. Beach areas closed; all water-based recreation affected. Very limited fishing and boating access.	Elevations above 903.5 impacts roadways at the State Park and closes primitive areas. No public water access available. Entire campgrounds closed due to no access from flooded roads. Marina and Yacht Club access is closed.
Quality of Recreation Effects	Exposed shorelines with debris, rocks, steep banks. Underwater hazards exposed.	Boat ramps usable with caution, potential underwater hazards.	No Impacts	Some campsite reductions due to flooding.	Debris from flooding can become a safety concern.	Most areas are closed.

5357 [1]The information in this table was developed with input from USACE and KDWP staff familiar with Perry Reservoir. Lake elevations are in NVGD 1929.

Table 3-82. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations (feet)	<886 feet	886–888 feet	888–895 feet; multipurpose pool is 891.5 feet	895–897.5 feet	897.5–903.5 feet	>903.5 feet
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

[1] The information in this table was developed with input from USACE and KDWP staff familiar with Perry Reservoir. Lake elevations are in NVGD 1929.

3.6.4.3.2 Future Without Project Conditions

Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios. These precipitation conditions are typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Two years were chosen to evaluate flood conditions, with average annual elevations at Perry Reservoir above 903 feet NVGD 29, and two years were chosen to evaluate drought conditions, with average annual elevations below 886 feet NVGD 29. See Table 3-79 and Table 3-80 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2060 (1956)
- 2061 (1957).

Flood years include:

- 2097 (1993)
- 2123 (2019).

Typical years include all other years.

Sedimentation has and will continue to impact recreation at Perry Lake. In terms of USACE managed areas, Rock Creek and Slough Creek is where most visitation currently occurs, and they will likely not be impacted by sediment within the planning timeframe. Old Town Park will likely be lost to sediment accumulation within the next few years. Perry State Park will probably remain open, however there could be changes in the types of uses by visitors. The marinas will be impacted by sediment accumulation in the future, which would greatly impact boating at Perry. By 2124, the entire north end of the lake is projected to be filled with sediment if nothing is done to mitigate the effects of sedimentation. Some boaters could shift to Perry Marina. Rock Creek Park, Outlet Park, and Slough Creek Park would remain accessible.

Dredging boat ramps can potentially mitigate/counter the effects of sedimentation and maintain access for boat ramps. However, the enactment of this temporary measure is uncertain and dependent on funding availability. Without any management actions (e.g., dredging, reallocation), all boating and marina access to Perry Reservoir would no longer be available starting in 2124. Lake managers have indicated that these conditions would result in a severe reduction in visitation if sediment on boat ramps and the marina are not mitigated. Not only would water-based visitors be affected, but also those visitors that come to view or be next to the lake. Boaters, anglers, and other water-contact activities at the recreational areas around the lake accounted for 367,200 visits in 2018, 34 percent of total visitation. Other shore-based visitors could also be affected, including special event attendees, campers, picnickers, and sightseers. Shore-based visitors at the recreation areas around the lake accounted for 418,700 or 66 percent of total visitation in 2018. The impacted visitation and years when access would be lost at the various recreation areas are summarized in Table 3-81.

Table 3-83. Recreation Areas Affected by Sediment and Lake Elevations at Perry Reservoir

	2018 Total Visitation	2018 Water-based Visitation	Percent Water-based Visitors	Approx Year of Loss in Water-based Access
Old Town	13,100	4,600	35	2024
Longview	5,300	1,900	36	2074
Perry Yacht Club	8,800	4,000	45	2124
Perry Park	47,800	20,600	43	2124
Rock Creek Marina	119,500	60,900	51	2124
Recreation Areas Affected by Sediment in the lake*	194,500	92,000	47	-
Rec Areas affected by lake elevation	712,600	242,300	34	-
Project-wide	785,900	367,200	34	-

*Includes Longview, Old Town, Perry Park, Rock Creek Marina, and Perry Yacht Club
**Includes admin/ visitor center, KDWP management area, Perry State Park, Old Military trail, Outlet, Rock Creek, Slough Creek, Thompsonville, and Perry Marina

Table 3-82 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake's average water surface elevation is expected to increase very slightly over time. Additional information is provided in Appendix B.

Table 3-84. Average Water Surface Elevations at Perry Reservoir Across the Period of Record

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	892.08	
2049	892.10	0.02
2074	892.13	0.05
2124	892.11	0.03

Note: The top of the multi-purpose pool is 891.5 feet (NGVD 29).

Table 3-85. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	-0.43	+0.05
2074	-0.79	-0.04
2124	-2.81	+0.18

Note: The top of the multi-purpose pool is 891.5 feet (NVGD 29).

During the 2060-2061 drought period, under the FWOP 2024 scenario, the pool elevation drops from 882 feet NVGD 29 to a low of 876 feet NVGD 29 between Jan 2060 and Feb 2061 before gradually returning to multi-purpose pool level in Jul 2061.

This could result in severe implications for recreation with current and future sediment conditions.

Sediment is already creating problems for water-based access at Old Town Park on the north end of the lake. This problem of sedimentation at the lake will worsen, with USACE sediment modeling indicating that in 100 years, no recreation areas adjacent to the lake will remain boat-ramp accessible. Because water surface elevations would be considerably lower during drought periods than the multi-purpose pool elevation, all recreation areas may not be accessible to boats and may increase safety concerns across the lake compared to typical precipitation water surface elevations.

Under the notable high water or flood years over the 100-year period of analysis, as shown in Table 3-83, on average, water surface elevations will not change by much under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between FWOP 2124 water surface elevations and FWOP water surface elevations can be up to three feet lower.

The worst flood years in terms of surface elevation are 2097 and 2123, when, for most of the year, water surface elevations are above elevation 903.5 feet (NGVD 29) (Table 3-83), even reaching elevations of 920 feet (NGVD 29) for periods of time. In general, Perry Reservoir is closed to visitation when water surface elevations are 903 feet (NGVD 29) or higher.

Changes in Visitation

In 2018, 712,600 people visited recreation areas that are potentially impacted by changing lake elevations in the future. We also compare the impacted visitation to 2018 baseline visitation at all locations at Perry Reservoir. In 2018, visitation across Perry Reservoir was estimated to be 785,900.

Due to the considerable impacts to water-based visitors from sediment deposition impacting access, a sediment map-based assessment was conducted for typical precipitation conditions.

In 2024, there are five recreation areas adjacent to Perry Reservoir with water-based access: Old Town, Longview, Perry Yacht Club, Perry Park, and Rock Creek Marina (Table 3-81). By 2124, water-based access will be considerably reduced at all five of the recreation areas and no boat ramps will be accessible due to the accumulation of sediment (Appendix F). By 2124, an estimated 92,000 water-based recreators would be affected, and if it is assumed that all water- and shore-based visitation at these recreation areas shift to another lake or opt not to recreate, 194,500 visitors would be impacted (Table 3-81). These visitors represent 12 percent and 25 percent, respectively, of visitors under baseline conditions (2018) at Perry Lake. If these recreation areas were converted to accommodate only shore-based activities, perhaps with construction of trails or off-highway vehicle (OHV) areas, a new mix of visitors would be anticipated, although it is difficult to ascertain how visitation would ultimately be impacted.

During drought conditions, notably the period of 2060-2061, water surface elevations are up to 15 feet lower than the top of multipurpose pool across all FWOP scenarios, and considerably below thresholds important for recreation (Appendix F). During these

conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios.

The impacts to visitation during an extreme drought under all FWOP scenarios would be similar, though not as pronounced, to the visitation impacts due to sediment accumulation as described under the FWOP 2049, 2074, and 2124 scenarios above under typical precipitation conditions. An estimated 92,000 (water-based) and 194,500 (both water- and shore-based) visitors could be impacted by reduced lake access during these types of conditions. Additional visitation could also be affected in areas that are not directly impacted by changes in lake elevations, such as in the recreation areas below the dam, although these impacts are not included in the estimates. For example, if lower releases impact fishing conditions on fishing success below the dam, there could be additional impacts to recreation and reductions in visitation not captured in the abovementioned estimates.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), the worst projected drought year, visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 345,500, a reduction of approximately 367,100 visitors from 2018 baseline conditions at lake-elevation affected recreation areas.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2097 (1993) and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Appendix F). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Perry Reservoir in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 92 percent compared to baseline conditions at Perry Reservoir (2018). In comparison, state park data indicated that 2019 visits were 23 percent lower than in 2018, mostly due to flooding conditions.

There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam and safety closures could occur; these impacts are not captured in these figures. Appendix F shows how flood conditions affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled “flood years” (2097 and 2123) to baseline conditions (2018).

During flooding conditions, up to roughly 90 percent of visitors at lake-elevation-affected areas could be impacted, and potentially even more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenarios.

Changes in Economic Benefits

Consistent with visitation in 2018, 785,900 visitors support 249 jobs and $10.5M in labor income in the local economy under baseline conditions. In the recreation areas

potentially affected by changes in lake elevations under baseline conditions, 712,600 visitors support 230 jobs and $9.7M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Reductions in visitation at Perry Reservoir due to sediment deposition would result in lower consumer surplus values as described in this section. By 2124, water-based access will be considerably reduced at Old Town, Longview, Perry Yacht Club, Perry Park, and Rock Creek Marina due to the accumulation of sediment (Appendix F). An estimated 92,000 (water-based) and 194,500 (both water- and shore-based) visitors could be impacted by reduced lake access at the recreation areas affected by sediment. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts are occurring (e.g., odors, reduced fishing success). If all water-based visitors no longer came to Perry Reservoir, there would be an annual loss of $922,600 in consumer surplus values. Shore-based visitors at Perry Reservoir contribute an estimated $1,040,400 in consumer surplus value, and it is likely a portion of these visitors would also be impacted by 2124 sediment conditions by the reduced ability to view and recreate near the lake or by decreased aesthetic qualities (Table 3-84).

Table 3-86. Perry Reservoir Visitation and Consumer Surplus Impacted by Sediment Deposition During Typical Precipitation Conditions under FWOP Scenarios

Perry Lake	Total Visitation and CS Values	Water Based Visitation and CS Values	Shore Based Visitation and CS Values
Baseline Visitation (2018)	785,900	367,200	418,700
Baseline Consumer Surplus Values (2018)	$8,500,000	$3,971,500	$4,528,500
Potential Losses in FWOP 2124			
Potential Losses in Visitation in 2124	194,500	92,000	102,500
Potential Losses in Consumer Surplus in 2124	$1,963,000	$922,600	$1,040,400

  - Regional Economic Benefits

    Reductions in visitation at Perry Reservoir due to sediment deposition would result in lower regional economic benefits to adjacent communities as described in this section. By 2124, water-based access would be considerably reduced at Longview, Old Town, Perry Park, Rock Creek Marina, and Perry Yacht Club due to the accumulation of sediment (Appendix

F). If all visitors no longer came to Perry Reservoir due to these recreation areas being unavailable, there would be an annual loss of 62 jobs and $2.6 million in labor income.

- Drought Conditions
  - Consumer Surplus

    The impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios, a loss of $2.7M in consumer surplus values. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.) With elevations below 886 feet (NVGD 29), an estimate 25 percent of shore-based visitors could also be impacted (Table 3-80), leading to a potential loss of $260,100 in addition to the loss of water-based consumer surplus for a total loss of approximately $3M. In the modeled drought year of 2060, there would be a reduction in visitation of 367,100 and consumer surplus of $4.1 million compared to baseline conditions at the lake-elevation affected areas (Appendix F).
  - Regional Economic Benefits

    The impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. If these visitors did not come to the Lake, there would be a loss in annual regional economic benefits of 77 jobs and $3.2M in labor income compared to baseline conditions. Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.
- Flood Conditions
  - Consumer Surplus

    Within the 100-year period of analysis, considerable flood events would occur in 2097 (1993) and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of approximately $7M in consumer surplus values (Appendix F). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.
  - Regional Economic Benefits

    Within the 100-year period of analysis, considerable flood events would occur in 2097 (1993) and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential

annual loss of 216 jobs and $9.1M in labor income (Appendix F). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

- Damages, Revenues, and Fees to States

Visitation to Perry Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Perry Reservoir were $299,000.[5]

Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that with flooding conditions could result in an annual decrease of visitation up to 83 percent of baseline conditions (2018) at Perry Reservoir (Appendix F).

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Perry Reservoir were $703,500. The impacts at the KDWP state parks at Perry Reservoir for recreational damages were estimated to be $5,200. These damages are likely to continue to occur in the future with extreme events.

Navigation Releases

Navigation releases under the FWOP 2024 results in increased frequency of pool elevations below the top of multipurpose pool elevation. Higher pool elevations in the navigation FWOP 2024 scenario are the same as those under the non-navigation FWOP 2024 scenario.

Due to the lower pool elevations in the multipurpose pool in the FWOP 2024 scenario with navigation releases, modeled visitation is on average three to 3.3 percent lower than the FWOP scenarios without navigation releases across all these typical precipitation years. These changes also have similar implications for consumer surplus values and regional economic effects. Under the FWOP 2024 scenario with navigation releases, lower pool elevations in these typical precipitation years could result in reduced visitation on average of approximately 47,500 visitors, with an associated reduction in consumer surplus values of $465,000 compared to the FWOP 2024 scenario without navigation releases. There would be small decreases in regional economic benefits as well.

[5]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

In the modeled drought period (2060–2061), average reservoir elevations under FWOP 2024 with navigation releases in these years are approximately 1.5 feet lower than reservoir elevations under FWOP 2024 without navigation releases.

In the modeled flood years (2097 and 2123), average reservoir elevations under all FWOP scenarios with navigation releases show very little change compared to the scenarios without navigation releases, resulting in no change in visitation under FWOP scenarios with navigation releases and FWOP scenarios without navigation releases. There would be no effect of navigation releases on consumer surplus values and regional economic benefits during flood conditions.

Water Quality

All reservoirs in the Kansas River Watershed, including Perry Lake, will likely experience increasing effects of aging. Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40 percent of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The KDA (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at Perry Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Perry Lake. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the basin. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at basin reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal HAB issues as some flourish under conditions with elevated phosphorus availability and water temperature. Based on 30 years of annual testing at Perry Reservoir, total phosphorus at the dam has been increasing and can be anticipated to increase in the future as fertilizer use in agriculture increases. With increased levels of phosphorus in the future, storm events could result in algal blooms

in Perry Reservoir, although a number of other factors also impact the development of HABs (e.g., the ability to keep water moving through the reservoir).

Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Perry Reservoir. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. While historically not an issue, deteriorating water quality could eventually lead to increased prevalence of HABs in Perry Reservoir with adverse impacts to visitors in the future.

Water residence times were estimated for Perry Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Perry Reservoir has a moderately high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 40 percent under the FWOP 2124 scenario. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Angling and Sport Fishery

Sediment conditions will continue to have adverse impacts for the fishery at Perry Reservoir. The loss of habitat and water volume due to sedimentation impact the lake's capacity to produce fish. Sedimentation will continue to occur and has the potential to dramatically reduce recreational use of the reservoir, especially for anglers. Dredging can be used to clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat, although these efforts have been minimally effective due to rapid sediment accumulation. The high effort and cost of dredging will also likely limit these projects to select locations. The role of turbidity on the fishery will likely only increase as water volume continues to decrease.

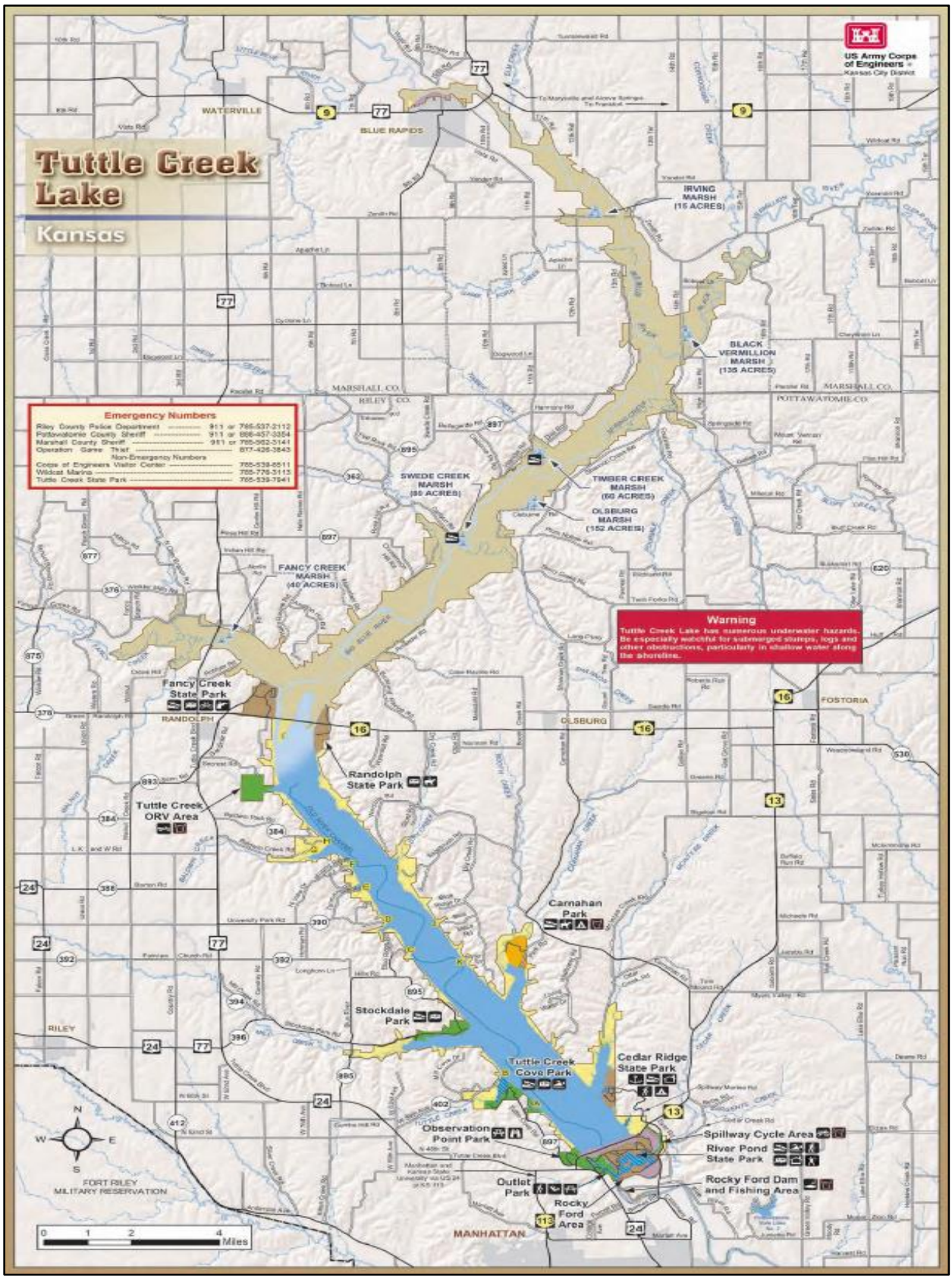
In addition, it is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. Emigration of fish during periods of elevated release rates will likely occur in the future similar to past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Anglers are able to utilize some of the sportfish that regularly emigrate out of the lake. There are several factors that fisheries biologists need to continue to monitor in the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can lead to creating the BMPs to be able to maintain these fish populations in a constantly changing environment.

3.6.4.4 Tuttle Creek Reservoir

Tuttle Creek Dam is located on the Big Blue River, 12.3 miles upstream of the confluence of the Big Blue and Kansas Rivers. Tuttle Creek Lake is located primarily in Riley and Pottawatomie Counties in Kansas with the far upper end of the lake extending

into Marshall County, Kansas. The dam site is situated five miles north of Manhattan, Kansas, 60 miles west of Topeka, 125 miles west of Kansas City, and 130 miles south of Lincoln, Nebraska.

5709 *Figure 3-147. Tuttle Creek Reservoir Recreation Map*



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3.6.4.4.1 Existing Conditions

Recreation Facilities and Visitation

There are four state parks managed by KDWP at Tuttle Creek Reservoir: Fancy Creek State Park, Randolph State Park, Cedar Ridge State Park, and River Pond State Park. There is one county park, and the remainder of the recreation areas are managed by USACE. Below highlights the recreational infrastructure and opportunities available at Tuttle Creek Reservoir (USACE 2019d):

- Recreation Areas
- Boat Ramps
- Marina Slips
- Camping Sites
- Swimming Areas
- Shooting Range
- Archery Range
- Trails
- Off-road Vehicle (ORV) Area
- Spillway Cycle Area.

According to combined USACE and KDWP data, visitation at the lake in 2018 was 1,016,600. This includes hunting and wildlife area visitation. Visitation in 2018 contributed $756,000 in revenue to the state in terms of park fees, entrance fees, camping fees and other revenues.

The state parks at Tuttle Creek Reservoir accounted for 61 percent of visitation in 2018, with most of the use at River Pond State Park, followed by Cedar Ridge State Park. Fancy Creek State Park visitation has recently been affected be sedimentation (see description below). Dispersed recreation, recreation that takes place outside of the established recreation areas, accounted for approximately 3 percent of visitation in 2018 (USACE VERS). In terms of types of recreational activities at Tuttle Creek Reservoir, camping and sightseeing were the most popular activities at the lake in 2018, accounting for 36 percent and 15 percent of total activities, respectively. Boating, angling, and water contact activities accounted for 8 percent, 5 percent, and 13 percent of all activities, respectively (USACE VERS 2018). According to 2018 iSportsman data, hunting visits were 2,983 (with full compliance) and wildlife visits were 597 representing 0.49 percent and 0.10 percent of total activities.

At the start of each new year, Tuttle Creek Reservoir, along with many other Kansas state parks hosts a “First Day Hike” for the public to enjoy the New Year outdoors (KDWP). Special recreation events like this one account for 2 percent of annual activity participation at the lake.

Sport Fisheries

This section provides a summary of sport fishing at Tuttle Creek Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (Appendix E). From

March to September the lake managers allow the elevation to increase to support spawning habitat for crappie.

Reservoir sportfish species accounts and factors affecting their abundance and distribution are included below. It is notable that inherent variability exists in statistics generated from fish population sampling efforts. Changes in reservoir water level, abundance and distribution of flooded terrestrial vegetation, turbidity or lack thereof, etc. can alter fish behavior and feasibility of deploying sampling gear, thus potentially increasing variability of sampling results. As a result, sampling results must be viewed with a degree of skepticism, require interpretation by workers utilizing the data, and often require a series of greater than one year for representative trends to become apparent (Appendix E).

The reservoir has provided some exceptional angling opportunities during these years, but frequent dynamic water level events have restricted the angling potential of the lake due to high fish emigration rates and inconsistent recruitment of many of the popular sportfish species. High water levels in fall of 2018 prevented the completion of the fall standardized annual fish sampling. Exceptional flood conditions in 2019 prevented all forms of fish sampling in the lake that year. Shoreline access available to anglers is quite limited at Tuttle Creek Reservoir when compared to other lakes. This is in part to due to how the purchase of the land for the lake was based on elevation, instead of traditional section lines. This makes many shoreline areas landlocked by private property and inaccessible to the general public by land or road. Bank fishing is further restricted when water levels are elevated as this submerges most of the easily accessible shoreline. High water also limits access by causing road closures, further distancing anglers from the water. Flood debris along the shoreline serves as additional hinderance to shore bound anglers. Many of the historically popular bank fishing locations were in the upper end of the reservoir and have since been loss due to the excessive sedimentation. There are few shoreline areas that have been developed in the lower reaches of the lake that would provide suitable bank fishing access. There is likely resistance to invest in shoreline improvements that could be loss due to the expectation that future high-water events will negate any development efforts (Appendix E).

Boat usage is much lower at Tuttle Creek Reservoir then at other local impoundments and there are multiple factors contributing to this. The lake currently has a low number of boat ramps available to public access. Numerous boat ramps have been loss to sedimentation, road closures, or lack of maintenance. Once the lake is ten feet above multipurpose pool, which is a fairly common occurrence at this lake, there is only one developed boat ramp still accessible to the public. Only two of the existing ramps regularly have a dock available and one of these has been closed since the 2019 flood event. Docks at boat ramps facilitate easier loading/unloading of boats and the absence of docks at ramps likely contributes to lower participation rates, especially for solitary boaters and people with movement limitations or disabilities. Another factor that limits boat usage is high-water events increasing boating hazards in the form of floating debris which probably negatively influences a boat angler’s decision to use this lake. As to the actual fishing experience, it is considered harder to have a successful fishing trip at Tuttle Creek Reservoir than at many other Kansas lakes. Rapid water level fluctuations

and dynamic shifts in water turbidity makes it more difficult to predict fish behavior and reduces angler success per trip (Appendix E).

The lake was stocked an additional eight times from 2007 to 2016 with a total of 145,715 blue catfish fingerlings. The blue catfish population at Tuttle Creek is evaluated with gill nets and with a low pulse electrofishing effort. These sampling efforts through the years indicate that half of the new stocking efforts had limited to poor recruitment. However, the 2013, 2014 and 2015 stockings showed moderate to good survival and the 2011 stocking had excellent recruitment (Appendix E).

Tuttle Creek Reservoir is prone to large and frequent water level fluctuations, which causes difficulty in following a water level management plan. The approved plan for the reservoir has not changed significantly since the late 1990's. This plan calls for water levels to be 3 feet below multipurpose pool in the winter, at multipurpose pool in the spring and through the summer months with a fall rise of 4 feet for waterfowl habitat. This plan is not ideal for the production of a good fishery, but this is mostly irrelevant as water levels at this impoundment rarely adhere to the plan (Appendix E).

Spring waters levels in 2018 were fairly stable and release rates were moderate during the summer. This should have been beneficial to spawning success and limit emigration of many fish species. Unfortunately, evaluation of potential benefits was limited because the traditional netting and fall electrofishing efforts were not conducted due to water levels being approximately 25 feet high during the sampling season. Starting in early September, the drainage saw abundant precipitation which caused water levels to rise 20 feet in five days. Highest water level in 2018 was recorded at 29 feet above multipurpose pool on October 26th. A rainy fall facilitated the reservoir being at least 15 feet high for most of the last four months of the year. This led to outflow rates being well above normal for that time of year with 44 days of release rates at 10,000 to 14,000 cfs. High release rates during October have facilitated emigration of saugeye and young channel catfish in the past (Appendix E).

Much of the Midwest suffered through historic flooding in 2019 and Tuttle Creek Reservoir was no exception. Due to flooding throughout the region, there was a need to retain water in reservoirs to alleviate issues downstream. Therefore, much of the high spring runoff was kept in Tuttle Creek and water levels reached 25 feet above normal multipurpose pool elevations by mid-March. The month of April saw 40-feet above normal multipurpose pool elevations and then flood waters crested at a new record high at the end of May at just over 60 feet above multipurpose pool. At this point, the lake was quadruple the normal surface acres and held over seven times the typical volume. Water levels were elevated through the entire growing season, not dipping below 35 feet high until November, and finally reached plan levels by mid-December. For over 100 days, release rates were at 10,000 cfs or more, with the peak at a record setting 30,000 cfs. The prominent sportfish species at Tuttle Creek were chosen due to their higher flood tolerance, but this was an unprecedented event that may have lingering impacts to the fish populations (Appendix E).

Thankfully, 2020 was a mild year in the Tuttle Creek water level history. The lake did reach 15 feet above normal multipurpose pool in both June and August, but the changes in water elevations were rather slow allowing successful fish spawning for

several species. Release rates were at 10,000 to 14,000 cfs for 27 total days, but fish loss was likely less of a factor due to low densities of the susceptible species from the exceptionally high emigrations the previous year (Appendix E).

White crappie is the most popular sportfish at Tuttle Creek Reservoir, and the species has the ability to draw large numbers of anglers to the reservoir during good fishing conditions. Maintaining a robust crappie fishery for angler harvest is the primary fisheries management objective at Tuttle Creek Reservoir. Compared to other northeastern Kansas reservoirs, Tuttle Creek Reservoir has typically had a lower abundance of crappie. Tuttle Creek Reservoir has supported a productive channel cat fishery. Angler preference for this species is high in the reservoir and in the tail water habitats. Through the history of the lake, white bass have been a popular sportfish drawing anglers that seek this species. However, the white bass population has fluctuated in sample abundance, which is not uncommon for the white bass fish in Kansas impoundments. At Tuttle Creek Reservoir, the rise and fall in white bass density is associated with spring river inflows during the spawning period and with gizzard shad abundance, a prevalent prey species of the white bass. The 2019 flood was devastating to the species as was documented in the 2020 sampling record with only one white bass being collected. Tuttle Creek Reservoir was stocked with a total of 16,263 paddlefish from 1992 to 1995. It was hoped that these fish could establish a self-sustaining population through natural reproduction to create a fishery. This was not the case as there was never any evidence of paddlefish spawning in the drainage.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Sedimentation has had a profound impact on recreation at Tuttle Creek Lake. To date, three parks (Swede Creek, Garrison, and Baldwin) and numerous private/community docks and ramps have been closed as a direct impact of sedimentation, lost lake access, and associated decreased demand. Two state parks (Fancy Creek and Randolph) have been converted to primarily land-based recreation with the loss of boat ramps and a marina, reducing visitation at these areas.

At Tuttle Creek Reservoir, sediment is accumulating and filling in the delta, with the most severe impacts at the northern end of the lake. Mitigation of recreational impacts has included small scale dredging of boat ramps and small coves, park closures, conversion of park areas to land-based recreation, and concentration of recreational development towards the southern recreation areas of the lake (Tuttle Creek Lake Master Plan 2019). With increasing sediment deposition, shallower pools limit boating access to ramps and around the lake, especially during relatively drier periods and associated lower lake elevations.

Sedimentation can also affect the natural resources in the lake. Suspended sediments carry nutrients and metals which accelerate eutrophication and can limit fishery production for native and sportfish species. Sediment deposition can also create land-based recreation opportunities, providing terrestrial and wildlife habitat (especially wetlands), and expanding opportunities for wildlife viewing and hunting (USACE Tuttle Creek Master Plan 2019).

Both flooding and drought have the potential to impact public access to recreation. Like other lakes and reservoirs in the region, Tuttle Creek Reservoir experienced flooding

during the spring and summer of 2019. Although the state park at Tuttle Creek Reservoir did remain open throughout the flooding, most recreation areas around the lake were closed in 2019. River Pond area of Tuttle Creek State Park, located below dam, remained open. State Park data indicated that 2019 visits were 26 percent lower in 2019, compared to 2018, due to flooding conditions, mostly driven by decreases in the summer and fall months. For example, in June 2019, state park visitation was 67 percent lower than visitation in June 2018 (USACE and KDWP 2018–2019). Annual state park fees, including entrance fees, camping fees, and other revenues were $617,000 in 2019, down 18 percent compared to state park fees in 2018.

In 2019, Tuttle Creek Reservoir was above multi-purpose pool for over 160 days, with a max crest of 60 feet above top of multipurpose pool (USACE 2020). Both USACE and KDWP recreation areas at Tuttle Creek Reservoir were closed for the 2019 season and experienced severe damage. In the USACE recreation areas, there were four public use areas impacted, including 12 structures, two campgrounds, one beach, three boat ramps, one lift station, 29 electrical panels, and various other infrastructure was submerged. Three miles of roads, eight parking areas, and 2.5 miles of trails were submerged and required restoration and repair. The USACE flood damages to recreation infrastructure have been estimated to be $1.3M; total USACE damages at Tuttle Creek Reservoir, including damages to roads and parking areas, were estimated to be $4M (FY2019 dollars) (USACE 2020).

The state parks at Tuttle Creek Reservoir incurred damages to docks, fish cleaning stations, and campsites, and required considerable removal of debris. The state flood damages to recreation infrastructure have been estimated to be $242,000; total state damages at Tuttle Creek Reservoir, including damages to roads and parking areas, were estimated to be $551,000 (FY2019 dollars) (KDWP 2020a). After the 2019 flood event, two USACE campgrounds remained closed for the 2020 season, and these repairs are estimated to be completed in 2023. It will take years to recover from the 2019 flood, with some areas permanently closed.

In 2019, the “Country Stampede”, a popular country music festival event, which has historically been held at River Pond below the dam at Tuttle Creek Reservoir, was relocated to Topeka due to flooding threats; subsequently, organizers of the event announced the venue move was to be permanent.

In 2012, drought conditions impacted levels at reservoirs and lakes across Kansas, including at Tuttle Creek Reservoir, impacting access to boating and other recreational activities (NOAA 2012; KWO 2013). However, impacts to recreation at Tuttle Creek Reservoir during the 2012 season were minimal as boat ramps remained accessible through the peak recreation season; the drought didn’t cause ramp closings until after Labor Day weekend.

HABs have not historically been an issue at Tuttle Creek Reservoir, however in 2021 there was a HAB watch in July and a warning in October. Both advisories were lifted within a week and only occurred at River Pond below the reservoir (USACE 2021c).

Critical Lake Elevations for Recreation

Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Tuttle Creek Lake as well as the corresponding impacts to visitation. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multipurpose pool, but if ten feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and reservoir depth to recreation, especially boating and fishing.

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5938 *Table 3-87. Critical Lake Elevations for Recreation at Tuttle Creek Reservoir[1]*

Lake Elevations/	<1,070 feet	1,070–1,072 feet	1,072–1,080 feet; multi-purpose pool is 1,075 feet	1,080–1,086 feet	1,086–1,105 feet	>1,105 feet
Visitation Impacts	There is no boating access; campers and other shore-based visitors are also affected.	25 percent of boating access is available; all other recreation largely unaffected. 1,070 is the minimum elevation for boat ramp access	No issues.	80 percent of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75 percent of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Exposed lakeshores adversely affect aesthetic qualities for visitors.	Safety becomes an issue for remaining boaters; underwater hazards begin to surface (e.g., rocks, debris, and obstacles in shallow water).	No impacts	Increased debris can present a hazard to boaters.	Safety becomes an issue for remaining visitors; flooded roadways present hazard to drivers.	Generally, all recreation is closed at the lake

5939 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Tuttle Creek Lake. Lake elevations are in NVGD 1929.

5940 *Table 3-88. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations/	<1,070 feet	1,070–1,072 feet	1,072–1,080 feet; multi-purpose pool is 1,075 feet	1,080–1,086 feet	1,086–1,105 feet	>1,105 feet
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	50%	0%	0%	0%	75%	100%

5941 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Tuttle Creek Lake. Lake elevations are in NVGD 1929.

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3.6.4.4.2 Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. The FWOP scenarios that include navigation releases are considered in the Navigation Releases Section. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in the Water Quality and Sport Fisheries, respectively.

Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Three years were chosen to evaluate flood conditions, with average annual elevations at Tuttle Creek Lake above 1,098 feet NVGD 29, while two years were chosen to evaluate drought conditions, with average annual elevations below 1,067 feet NVGD 29. See Table 3-85 and Table 3-86 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2044 (1940)
- 2060 (1956).

Flood years include:

- 2055 (1951)
- 2097 (1993)
- 2123 (2019).

Typical years include all other years.

Sedimentation has and will continue to impact recreation at Tuttle Creek Reservoir, more so than any other lake in the basin. To date, three parks (Swede Creek, Garrison, and Baldwin) and numerous private/community docks and ramps have been closed as a direct impact of sedimentation, reducing lake access, and affecting residents and visitors. Two state parks, Fancy Creek and Randolph, have converted to primarily land-based recreation with the loss of boat ramps and a marina. Consistent with these observations, USACE data shows that only 6 percent and 7 percent of activities at Fancy Creek State Park and Randolph State Park, respectively, are water-based activities (i.e., boating, angling, or swimming).

As sediment continues to accumulate and the delta extends southward, the size of the multipurpose pool and the lake's recreational opportunities will continue to decrease (Appendix F). Appendix F shows the depths of Tuttle Creek Lake at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years). Small scale dredging of boat ramps and small coves has occurred along with park closures. Recreation areas

have been converted to land-based recreation, and recreational development has been concentrated towards the southern portion of the lake area.

During typical precipitation conditions (at multi-purpose pool), the USACE sediment modeling indicates that boat ramps at Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park would provide boating access to the lake in 2024. In 2049, the boat ramps and water access at Carnahan Park and Stockdale Park would not be available as these areas would have considerable silt and sediment (or new lands created) or be too shallow for boating access. The recreation areas adjacent to the lake that would remain boat-ramp accessible would be Tuttle Creek Cove Park and Cedar Ridge State Park as well as the areas below the dam. In 2074 (50 years) and 2124, the USACE sediment modeling indicates that the marina and boat ramps would no longer be accessible on Tuttle Creek Reservoir, and the coves at Tuttle Creek Cove Park and Cedar Ridge State Park would largely be silted in. It appears that camp sites would be further from the water at these recreation areas as well.

During drought conditions, the effects of sediment deposition on recreational access become more severe as decreasing water surface elevations reduce the depths of the lake (see description on water surface elevations). In addition, boating safety concerns and obstacles are more pronounced with a shallower lake. During flooding conditions, sediment deposition affects the operations of the reservoir and in general increases water surface elevations as sediment fills the pool over time.

Water surface elevations at Tuttle Creek Lake are generally higher in the future with increasing sediment deposition in the lake. Table 3-87 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake is slightly less than a foot higher in 2049 and 2074 compared to 2024 conditions. In 2124, Tuttle Creek Lake is just under one foot higher than under the FWOP 2024 scenarios without navigation releases. Additional information is provided in Appendix B.

Table 3-89. Average Water Surface Elevations at Tuttle Creek Reservoir

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024
2024	1,078.0	
2049	1,078.2	0.23 (0.02%)
2074	1,078.4	0.38 (0.04%)
2124	1,078.9	0.88 (0.08%)

Note: The top of the multi-purpose pool is 1,075 feet. Elevations are in NVGD 1929.
Represents average across the period of record.

As previously described, drought conditions with lower water surface elevations and increasing sediment deposition at Tuttle Creek Lake in the future cause additional water-access and safety issues due to shallower pools and exposed bottom areas. There are two notable drought periods over the 100-period of analysis: 2044 (translates to past year of 1940) 2060 and 2061 (translates to past years of 1956 and 1957). There are three notable high water or flood years over the 100-year period of analysis: 2055 (translates to past year of 1951), 2097 (translates to past year of 1993), 2123 (translates to past year of 2019)

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions (Table 3-88). During drought conditions, on average in 2044, 2060, and 2061, pool levels in 25 years (2049) are approximately half a foot higher, while in 50 and 100 years, pool levels are between 0.8 feet to 1.6 feet higher than under 2024 FWOP conditions.

Table 3-90. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	+0.43	+0.65
2074	+0.81	+0.07
2124	+1.61	+0.52

Note: The top of the multi-purpose pool is 1,075 feet. Lake elevations are in NGVD 1929.

During the 2060-2061 drought period, under the FWOP 2024 scenarios, the pool is between 1,070 and 1,058 feet (from five to 17 feet lower than multi-purpose pool) between July 2060 and until June 2061 when it rises back to multi-purpose pool level. Future sediment deposition in 2049 and 2074 increases pool elevations up to two feet higher compared to FWOP 2024 scenarios during this drought period.

Drought conditions, similar to those experienced in the mid-1950s, result in relatively lower water surface elevations (between five and 17 feet below multi-purpose pool) for almost two years between 2059 and 2061, which could result in severe implications for recreation with current and future sediment conditions. See Appendix F for more detail on drought impacts to recreation.

In 2024, the USACE sediment modeling indicates that boat ramps at Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park would provide boating access to the lake in 2024 under typical precipitation conditions. In 25 years (FWOP 2049 scenario), recreation areas adjacent to the lake that would remain boat-ramp accessible will be Tuttle Creek, Cove Park, Cedar Ridge State Park, and the areas below the dam. Because water surface elevations would be considerably lower during drought periods than the multi-purpose pool elevation, all recreation areas may not be accessible to boats and may increase safety concerns across the lake compared to typical precipitation water surface elevations.

Under three notable high water or flood years over the 100-year period of analysis, as shown in Table 3-88, on average, water surface elevations are less than a foot higher under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between 2123 water surface elevations and FWOP 2024 and FWOP 2049, FWOP 2074 water surface elevations can be up to eight feet higher. However, at peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal.

The worst flood year in terms of visitation was in 2123 (2019) when, during the year, water surface elevations were above elevation 1,105 feet (NVGD 29) (see threshold table in existing conditions section) between 288 and 291 days under all of the FWOP scenarios. In general, Tuttle Creek Lake is closed to visitation when water surface elevations are 1,105 feet.

Changes in Visitation

This section describes how changes and lake elevations and sediment conditions can potentially impact visitation. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 362,100 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The assessment also compares the impacted visitation to 2018 baseline visitation at all locations at Tuttle Creek Reservoir. In 2018, visitation across Tuttle Creek Reservoir was estimated to be 1,016,600.

In most cases across the basin, visitation across the lakes has been fairly stable over the past 20 years. In some cases, such as at Tuttle Creek Reservoir, visitation at the state parks has been decreasing (Appendix F). It is likely that decreasing visitation is tied to previous and ongoing visitation impacts from sediment accumulation, rendering boat ramps inaccessible and turning reservoir conditions into river conditions in the recreation areas in the upper part of the lake. For this reason, we assume that the sediment modeling is capturing these decreasing visitation trends in the future.

Sediment is the main driver of recreation impacts across the lake, although drought and flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the lake. Due to the considerable impacts to water-based visitors from sediment deposition impacting access, a sediment map-based assessment was conducted for typical precipitation conditions.

In 2024, there are four recreation areas adjacent to Tuttle Creek Reservoir with water-based access and accessible boat ramps: Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park (Table 3-89). In 2049, water-based access would be considerably reduced at Stockdale and Carnahan parks due to the accumulation of sediment in these “arms” of the lake (Appendix F); visitors and recreators could shift from these recreational areas to Tuttle Creek Cove Park and Cedar Ridge State Park, although the boat ramps on the lake currently support high numbers of boaters and boating anglers, indicating limited additional capacity to accommodate additional boaters. An estimated 48,700 water-based recreators (Carnahan and Stockdale) would be affected, and if it is assumed that all water- and shore-based visitation at these two recreation areas shift to another lake or opt not to recreate, 95,500 visitors would be impacted (Table 3-89). These visitors represent from five to nine percent of visitors under baseline conditions (2018) at Tuttle Creek Reservoir. If these recreation areas were converted to accommodate only shore-based activities, perhaps with construction of trails or OHV areas, a new mix of visitors would be anticipated, although it is difficult to ascertain how visitation would ultimately be impacted.

Starting in 2074 (50 years) and continuing through 2124 (100 years), an estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors annually could be impacted by reduced lake access (Table 3-89). According to the USACE

sediment modeling, no boat ramps would be accessible on Tuttle Creek Lake. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these four recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts could also occur (e.g., odors). Affected parks and recreation areas on Tuttle Creek Lake are shown in Table 3-89. A reduction in annual visitation of 123,900 and 318,300 represents a reduction of 12 and 31 percent of 2018 baseline visitation, respectively.

During drought conditions, notably the period between August 2059 and June 2061, consistent with the historic drought of the mid-1950s, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from five to 17 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation. In drought conditions, consistent with mid-1950s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. In addition, modeling shows periods of low to no storage at Tuttle Creek Reservoir during extreme drought conditions. This would have multi-year impacts as the fishery would be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be severely impacted, and revenue sources to maintain the lakes would decrease.

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6132 *Table 3-91. Tuttle Creek Reservoir 2018 Visitation Impacted During Typical Precipitation Conditions*

Tuttle Creek Lake	Visits	Affected by Sediment Deposition in the Future	Percent Water Based (percent)	Percent Shore Based (percent)	FWOP Year When Water-Based Access is Severely Impacted
CARNAHAN PARK	14,100	Y	56.9	43.1	2049
CEDAR RIDGE	154,900	Y	28.9	71.1	2074
FANCY CREEK STATE PARK*	74,100	N	6.5	93.5	Prior to 2024
OBSERVATION POINT	21,400	N	17.6	82.4	Below the dam
ORV AREA	12,700	N	2.0	98.0	Located away from the lake
OUTLET	146,700	N	17.6	82.4	Below the dam
RANDOLPH STATE PARK*	18,600	N	7.5	92.5	Prior to 2024
RIVER POND STATE PARK	362,500	N	54.0	46.0	Below the dam
SPILLWAY CYCLE AREA	14,900	N	17.6	82.4	Below the dam
STOCKDALE	81,400	Y	50.0	50.0	2049
TUTTLE CREEK COVE PARK	67,900	Y	44.8	55.2	2074
Dispersed Use (USACE)**	43,800	Y/N	4.3	95.7	N/A
KDWP Wildlife area/dispersed use	3,600	N/A	N/A	N/A	N/A
Total	1,016,600	N/A	N/A	N/A	N/A
Total visitation at recreation areas affected by sediment in the lake (2049)	*95,500*	N/A	*48,700*	*46,800*	N/A
Total visitation at recreation areas affected by sediment in the lake (2074 and 2124) (excludes dispersed recreation)	*318,300*	*N/A*	*123,900*	*194,400*	N/A
Total visitation at recreation areas affected by water surface elevations (includes water and shore-based recreation and dispersed recreation)	*362,100*	*N/A*	*125,800*	*236,300*	*N/A*

6133 * These areas have already converted to mostly land based recreation, not included in totals at bottom of table
6134 **There is some dispersed recreation that involved boating; for the sediment evaluation, it is assumed that dispersed boaters and shore-based visitors could adjust or modify their
6135 behaviors with increasing sediment deposition; the visitors are not included in the second to last row in the table.

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The impacts to visitation during an extreme drought under all FWOP scenarios would be similar to the visitation impacts described under the FWOP 2074 (50 years) and 2124 (100 years) scenarios above under typical precipitation conditions, when boat ramps and the marina would not be accessible. An estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors could be impacted by reduced lake access during these types of conditions; a reduction in visitation of 123,900 and 318,300 represents between 12 and 31 percent of 2018 visitation. Dispersed visitors could also be impacted by considerably reduced lake elevations as they would not be able to access areas adjacent to the lake to visit; these visitors account for 43,800 visits in 2018. Additional visitation could also be affected in areas that are not directly impacted by changes in lake elevations, such as in the recreation areas below the dam, although these impacts are not included in the estimates. For example, if lower releases impact fishing conditions on fishing success below the dam, there could be additional impacts to recreation and reductions in visitation not captured in the abovementioned estimates.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 146,600, a reduction of approximately 215,000 visitors from 2018 baseline conditions at lake-elevation affected recreation areas. The year 2044 (modeled after 1940 conditions) would have similar impacts to visitation.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Appendix F). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Tuttle Creek Lake in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 32 percent compared to baseline conditions at Tuttle Creek Lake (2018). In comparison, state park data indicated that 2019 visits were 26 percent lower than in 2018, due to flooding conditions, mostly driven by decreases in visitation in the summer and fall months. Annual state park fees, highly correlated with visitation, were $617,000 in 2019, down 18 percent compared to state park fees in 2018.

There could also be impacts to visitation at the recreation areas below the dam (e.g., River Pond State Park, Spillway Cycle Area, Outlet, Observation Point) with potentially higher releases from the dam and localized flooding below the dam and safety closures could occur; these impacts are not captured in these figures. Appendix F below shows how flood conditions affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled “flood years” (2055, 2097, and 2123) to baseline conditions (2018).

In FWOP 2074 and 2124 scenarios, as described above, all water-based visitation at recreation areas affected by changes in lake elevations would be inaccessible due to sediment deposition in the lake. With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds with slightly higher reservoir elevations under

future conditions compared to the FWOP 2024 scenarios. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 362,100 visitors would be affected, representing 35 percent of visitation under baseline conditions at Tuttle Creek Lake (2018).

Under the FWOP 2049 scenarios, only two recreation areas adjacent to the lake remain accessible during typical water surface elevations: Cedar Ridge State Park, and Tuttle Creek Cove Park. Comparing water surface elevations impacts on visitation during the three flood events, water surface elevations are up to one foot higher under the FWOP 2049 conditions compared to FWOP 2024. These slightly higher surface elevations under FWOP 2049 scenario leads to more frequent closures of facilities (water surface elevations above 1,105 feet [NVGD 29]) and small decreases in visitation compared to FWOP 2024 visitation during these flood events, as shown in Appendix F. The most pronounced impacts would occur in the 2123 event, leading to an additional reduction in visitation of 6,100 compared to FWOP 2024 visitation.

Changes in Economic Benefits

Consumer surplus values are measured through the USACE UDV approach further described in Section 3.6.2. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated $3.3M in consumer surplus value. The assessment also compares the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Tuttle Creek Reservoir. In 2018, visitation across Tuttle Creek Reservoir supported approximately $9.6M in consumer surplus values.[6]

Consistent with visitation in 2018, 1,016,600 visitors support 278 jobs and $9.1M in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 362,100 visitors support 104 jobs and $3.4M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Reductions in visitation at Tuttle Creek Reservoir due to sediment deposition would result in lower consumer surplus values as described in this section. In 2024, there are four recreation areas adjacent to Tuttle Creek Lake with water-based access and accessible boat ramps at: Cedar Ridge State Park,

[6] Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park (Table 3-89). In 2049, water-based access would be considerably reduced at Stockdale and Carnahan parks due to the accumulation of sediment in these “arms” of the lake (Appendix F). As described above, it is possible that boaters and anglers at these affected areas could shift to Cedar Ridge State Park and Tuttle Creek Cove Park if capacity is available, move to other lakes in the region, or choose not to recreate at all. If all water-based visitors no longer came to Tuttle Creek Reservoir due to these two recreation areas being unavailable, there would be an annual loss of $436,600 in consumer surplus values. Shore-based visitors at Stockdale and Carnahan Parks contribute an estimated $415,900 in consumer surplus value, and it is likely a portion of these visitors would also be impacted by 2049 sediment conditions by the reduced ability to view and recreate near the lake or by decreased aesthetic qualities (Table 3-90).

In 2074 (50 years) and 2124 (100 years), according to the USACE sediment modeling, the marina and all boat ramps will no longer be accessible on Tuttle Creek Reservoir. An estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the four recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these four recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts are occurring (e.g., odors, reduced fishing success). The water-based visitors at these four recreation areas contribute $1.1M in consumer surplus, while all visitors at these four recreation areas contribute $2.9M in consumer surplus (Table 3-90).

A reduction in all water-based visitors ($1.1M) at these four recreation areas represents 12 percent of all visitation and value at Tuttle Creek Reservoir under baseline conditions, while if all visitors at these four recreation areas Were impacted, 30 percent of baseline visitation and value would be impacted. Dispersed visitors engage in sightseeing, boating, wildlife viewing, and other activities, although their use is not tied to one recreation area. These visitors may also be impacted by increasing sediment deposition, decreasing water-based access, declining fishing success, and aesthetic changes at the lake (see last two rows of Table 3-90).

Table 3-92. Tuttle Creek Reservoir Visitation and Consumer Surplus Impacted by Sediment Deposition During Typical Precipitation Conditions Under FWOP Scenarios

Tuttle Creek Lake	Total Visitation and CS Values	Water Based Visitation and CS Values	Shore Based Visitation and CS Values
Baseline Visitation (2018)	1,016,600	283,800	732,800
Baseline Consumer Surplus Values (2018)	$9,600,000	$2,680,000	$6,920,000
Potential Losses in FWOP 2049[1]			
Potential Losses in Visitation in 2049	95,500	48,700	46,800
Potential Losses in Consumer Surplus in 2049	$852,500	$436,600	$415,900
Potential Losses in FWOP 2074 and 2124 (includes 2049)[2]			
Potential Losses in Visitation in 2074, 2124 (includes 2049)	318,300	123,900	194,400
Potential Losses in Consumer Surplus in 2074, 2124 (includes 2049)	$2,851,500	$1,123,100	$1,728,300
Potential Losses in FWOP 2074 and 2124 (includes 2049 and dispersed recreation)			
Potential Losses in Visitation in 2074, 2124 (includes 2049 and dispersed recreation)	362,100	125,800	236,300
Potential Losses in Consumer Surplus in 2074, 2124 (includes 2049 and dispersed recreation)	$3,277,000	$1,130,000	$2,147,000

[1] Recreation areas impacted by sediment deposition in 2049 include Carnahan and Stockdale parks.
Recreation areas impacted by sediment deposition in 2074 and 2124 include Carnahan and Stockdale parks and Cedar Ridge and Tuttle Creek Cove parks.
Consumer Surplus is expressed in FY22$

- Regional Economic Benefits

  Reductions in visitation at Tuttle Creek Reservoir due to sediment deposition would result in lower regional economic benefits to adjacent communities as described in this section. In 2024, there are four recreation areas adjacent to Tuttle Creek Reservoir with water-based access and accessible boat ramps at: Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park (Table 3-90). In 2049, water-based access would be considerably reduced at Stockdale and Carnahan parks due to the accumulation of sediment in these “arms” of the lake (Appendix F). As described above, it is possible that boaters and anglers at these affected areas could shift to Cedar Ridge State Park and Tuttle Creek Cove Park if capacity is available, move to other lakes in the region, or choose not to recreate at all. If all water-based visitors no longer came to Tuttle Creek Reservoir due to these two recreation areas being unavailable, there would

be an annual loss of 15 jobs and $500,000 in labor income. Shore-based visitors at Stockdale and Carnahan Parks contribute an estimated 13 annual jobs and $400,000 in labor income, and it is likely some of these visitors would be impacted by 2049 sediment conditions and no longer come to the reservoir because of the reduced ability to view and recreate near the lake and decreased aesthetic qualities (Table 3-91).

In 2074 (50 years) and 2124 (100 years), according to the USACE sediment modeling, the marina and all boat ramps would no longer be accessible on Tuttle Creek Reservoir. An estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the four recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these four recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts could also occur (e.g., odors, reduced fishing success).

The water-based visitors at these four recreation areas support 38 jobs and $1.4M in labor income, annually, while all visitors at these four recreation areas contribute 93 jobs and $3M in labor income (Table 3-91). A reduction in all water-based visitors at these four recreation areas accounts for 19 percent of all jobs supported by visitation at Tuttle Creek Reservoir annually under baseline conditions, while if all visitors at these four recreation areas were to no longer visit the lake, there would be a reduction of 33 percent of jobs supported by visitation at the lake compared to baseline conditions. Dispersed visitors engage in sightseeing, boating, wildlife viewing, and other activities, although their use is not tied to one recreation area. These visitors may also be impacted by increasing sediment deposition, decreasing water-based access, declining fishing success, and aesthetic changes at the lake (see last two rows of Table 3-91). Due to the long-term sediment deposition in Tuttle Creek Reservoir, annual losses in jobs and income in the local economy would not be temporary and would persist overtime.

Table 3-93. Tuttle Creek Reservoir Visitation and Regional Economic Benefits Impacted During Typical Precipitation Conditions

Impacts	Visits	Jobs	Labor Income	Gross Regional Product	Economic Output
Baseline Conditions (2018) really n	1.1 million	278	$9.1M	$16.3M	$30.8M
2049 Visitor Impacts (Carnahan and Stockdale)					
Water-based Visitors	48,700	15	$0.5M	$1.0M	$1.8M
Shore-based Visitors	46,800	13	$0.4M	$0.7M	$1.4M
Water- and shore-based Visitors	95,500	27	$0.9M	$1.7M	$3.2M
2074 and 2021 Visitor Impacts (Carnahan, Stockdale, Cedar Ridge, and Tuttle Creek Cove Park)					
Water-based Visitors	123,900	38	$1.4M	$2.5M	$4.5M
Shore-based Visitors	194,400	53	$1.6M	$3.0M	$5.8M
Water- and shore-based Visitors	318,300	93	$3.0M	$5.5M	$10.3M
2074 and 2021 Visitor Impacts (Carnahan, Stockdale, Cedar Ridge, and Tuttle Creek Cove Park and dispersed recreation)					
Water-based Visitors	125,800	39	$1.4M	$2.5M	$4.6M
Shore-based Visitors	236,300	65	$2M	$3.7M	$7M
Water- and shore-based Visitors	362,100	104	$3.4M	$6.2M	$11.6M

*Consumer surplus is expressed in FY22 dollars.

- Drought Conditions
  - Consumer Surplus
  - Under the baseline condition the impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios, for a loss of $1.1 million in consumer surplus values (Appendix F). Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). When reservoir elevations fall below 1,070 feet (NGVD 29), an estimated 50 percent of shore-based visitors could be impacted (Appendix F), with an additional potential loss of between $864,000 and $1.1 million in consumer surplus values annually (Appendix F).

    Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately $1.9 million annually (Appendix F). There would be similar impacts under FWOP 2049, 2074, and

2124 conditions. These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 20 percent compared to 2018 baseline conditions.

Regional Economic Benefits

- Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 70 jobs and $2.3 million during drought conditions under 2024 FWOP compared to baseline conditions (Appendix F). There would be similar impacts under FWOP 2049, 2074, and 2124 conditions. These reductions in economic benefits impacted by changes in lake elevations represent a 25 percent decrease in jobs from total jobs supported from all visitors spending at Tuttle Creek Reservoir under baseline conditions (278 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.
- Flood Conditions
  - Consumer Surplus

    Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $2.1 and $2.9M in consumer surplus values, representing a decrease between 22 and 30 percent of total consumer surplus at Tuttle Creek Lake under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., River Pond State Park, Spillway Cycle Area, Outlet, Observation Point) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

    In FWOP 2074 and 2124 scenarios, as described above, all water-based visitation would be inaccessible due to sediment deposition in the lake. With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds. If all water- and shore-based visitors (lake elevations above 1,105 feet [NVGD 29]) in the lake elevation affected recreation areas were to choose another lake or not recreate at all, 362,100 visitors could be affected, with a loss of $3.3M in consumer surplus values (Appendix F). In the modeled years of 2097 and 2123, average elevations were above the 1,105 feet NVGD 29 threshold at Tuttle Creek Lake.
  - Under the FWOP 2049 scenarios, as described above, only two recreation areas remain accessible adjacent to the lake due to sediment deposition: Cedar Ridge State Park, and Tuttle Creek Cove Park. Under FWOP 2049 conditions, water surface elevations are up to two feet higher compared to

FWOP 2024 conditions during modeled years of 2055 and 2097 and up to three feet higher in 2123. These higher water surface elevations under FWOP 2049 scenario leads to more frequent closures and small decreases in consumer surplus values compared to FWOP 2024 consumer surplus during these flood events.

- Regional Economic Benefits

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 95 jobs and $3.1M in labor income, representing a decrease between 27 and 34 percent of total jobs supported by visitor spending at Tuttle Creek Lake under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., River Pond State Park, Spillway Cycle Area, Outlet, Observation Point) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

In FWOP 2074 and 2124 scenarios, which is very similar to the FWOP 2024 scenario, all water-based visitation would be inaccessible due to sediment deposition in the lake. With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds. If all water- and shore-based visitors in the lake-elevation affected recreation areas were to choose another lake to visit or not come to Tuttle Creek Lake, 362,100 visitors could be affected, with a potential loss of 104 jobs and $3.4M in labor income (Appendix F).

Under the FWOP 2049 scenarios, also similar to the FWOP 2024 scenario, only two recreation areas remain accessible adjacent to the lake due to sediment deposition: Cedar Ridge State Park, and Tuttle Creek Cove Park. Under FWOP 2049 conditions, water surface elevations are up to two feet higher compared to FWOP 2024 conditions during modeled years of 2055 and 2097 and up to three feet higher in 2123. These higher water surface elevations under the FWOP 2049 scenario during flood years leads to more frequent closures and small decreases in regional economic benefits compared to FWOP 2024 conditions during these flood events. The most pronounced impacts would occur in the 2123 event.

- Damages, Revenues, and Fees to States

Visitation to Tuttle Creek Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the state park revenues associated with Tuttle Creek Reservoir were $755,958, second in the Kansas River watershed only to Clinton Reservoir.[7] At Tuttle Creek

[7]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

Reservoir in 2019, these revenues were $617,000, a reduction of 18 percent from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that sediment deposition combined with drought conditions could result in an annual decrease of visitation up to 31 percent of baseline conditions (2018), while flooding impacts would have slightly larger impact, impacting up to 32 percent of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Tuttle Creek Reservoir were $1.3M. The impacts at the KDWP state parks at Tuttle Creek Reservoir include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris at $106,000. These damages are likely to continue to occur in the future with extreme events.

Navigation Releases

The H&H modeling suggest that navigation releases during non-flood and non-drought years (all years across the 100-year period of analysis that have not been identified as drought (2044 and 2060) and flood years (2055, 2097, and 2123)) cause annual reservoir elevations to be approximately a half foot lower than FWOP 2024, 2049, and 2074 scenarios without navigation releases on average across the period of analysis. In FWOP 2124, there is no change in the average reservoir elevations between with and without navigation releases across the period of analysis for typical, non-drought and non-flood years.

Due to these lower pool elevations in the FWOP 2024, 2049, and 2074 scenarios with navigation releases, modeled visitation is on average three to 3.5 percent lower than the FWOP scenarios without navigation releases across all these typical precipitation years. These changes also have similar implications for consumer surplus values and regional economic effects. The effects of sediment deposition in the Lake causes severe impacts to recreation under the FWOP 2049, 2084, and 2124 scenarios, even under typical precipitation conditions, and lower reservoir elevations could worsen these impacts. Under the FWOP 2024 scenario with navigation releases, lower pool elevations in these typical precipitation years could result in reduced visitation on average of approximately 10,700 visitors, with an associated reduction in consumer surplus values of $98,000 compared to the FWOP 2024 scenario without navigation releases. There would be small decreases in regional economic benefits as well.

In the two modeled drought years (2044 and 2060), average reservoir elevations under FWOP 2024 with navigation releases in these years are approximately 1.8 feet lower than reservoir elevations under FWOP 2024 without navigation releases. In FWOP 2049 and FWOP 2074, average reservoir elevations with navigation releases in these years are approximately one foot lower than reservoir elevations under FWOP 2024 without navigation releases. In FWOP 2124, there is no change in the average reservoir elevations between with and without navigation releases across the period of analysis for these two drought years.

The effects of combined drought conditions and sediment deposition in the Tuttle Creek Lake causes severe impacts under all FWOP scenarios. Under FWOP 2024 and 2049 navigation release scenarios, visitation is low at the lake due to the lower water levels during drought conditions; modeling indicates that during drought conditions, there could be an additional reduction of 1,800 and 800 visits, respectively, due to relatively lower reservoir elevations with these navigation releases compared to FWOP scenarios without the navigation release, with very small decreases in consumer surplus and regional economic benefits.

In the three modeled flood years (2055, 2097, and 2123), average reservoir elevations under all FWOP scenarios with navigation releases show very little change compared to the scenarios without navigation releases, resulting in less than a half percent change in visitation under FWOP scenarios with navigation releases and FWOP scenarios without navigation releases. The effect of navigation releases on consumer surplus values and regional economic benefits during flood conditions would be negligible.

Water Quality

All reservoirs in the Kansas River Watershed, including Tuttle Creek Reservoir, will likely experience increasing effects of aging. Future water quality within the basin lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40 percent of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The KDA (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at Tuttle Creek Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Tuttle Creek Reservoir. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the basin. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at basin reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal HAB issues as some flourish under conditions with elevated phosphorus availability and water temperature. Based on 30 years of annual testing at Tuttle Creek Lake, total phosphorus at the dam has been increasing and can be anticipated to increase in the future as fertilizer use in agriculture increases. With increased levels of phosphorus in the future, storm events could result in algal blooms in Tuttle Creek Reservoir, although a number of other factors also impact the development of HABs (e.g., the ability to keep water moving through the reservoir).

Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Tuttle Creek Reservoir. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. Although difficult to predict, turbid conditions at Tuttle Creek Reservoir will likely continue to limit primary production, including HABs. Deteriorating water quality could eventually lead to increased prevalence of HABs in Tuttle Creek Reservoir with adverse impacts to visitors in the future.

Water residence times were estimated for Tuttle Creek Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Perry Reservoir has a very high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 67 percent under the FWOP 2124 scenario. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Angling and Sport Fishery

Sediment conditions will continue to have adverse impacts for the fishery at Tuttle Creek Reservoir. The loss of habitat and water volume due to sedimentation impact the lake's capacity to produce fish. Sedimentation will continue to occur and has the potential to dramatically reduce recreational use of the reservoir, especially for anglers, as only 25 percent of the original multipurpose pool is expected to remain in 50 years. Dredging can be used to clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat, although these efforts have been minimally effective due to rapid sediment accumulation. The high cost of dredging will also likely limit these projects to select

locations. The role of turbidity on the fishery will likely only increase as water volume continues to decrease.

An additional stressor was added to this system when the invasive zebra mussels was first documented in the lake in 2017. The potential negative effects of their presence have not yet been realized. As sedimentation deposition occurs in the future, anglers' fishing success will continue to decrease, causing further stress on these uses at the lake. In addition to sedimentation reducing access to boat ramps and marinas, a further deterrence for anglers will be declining fish abundance and associated fishing success.

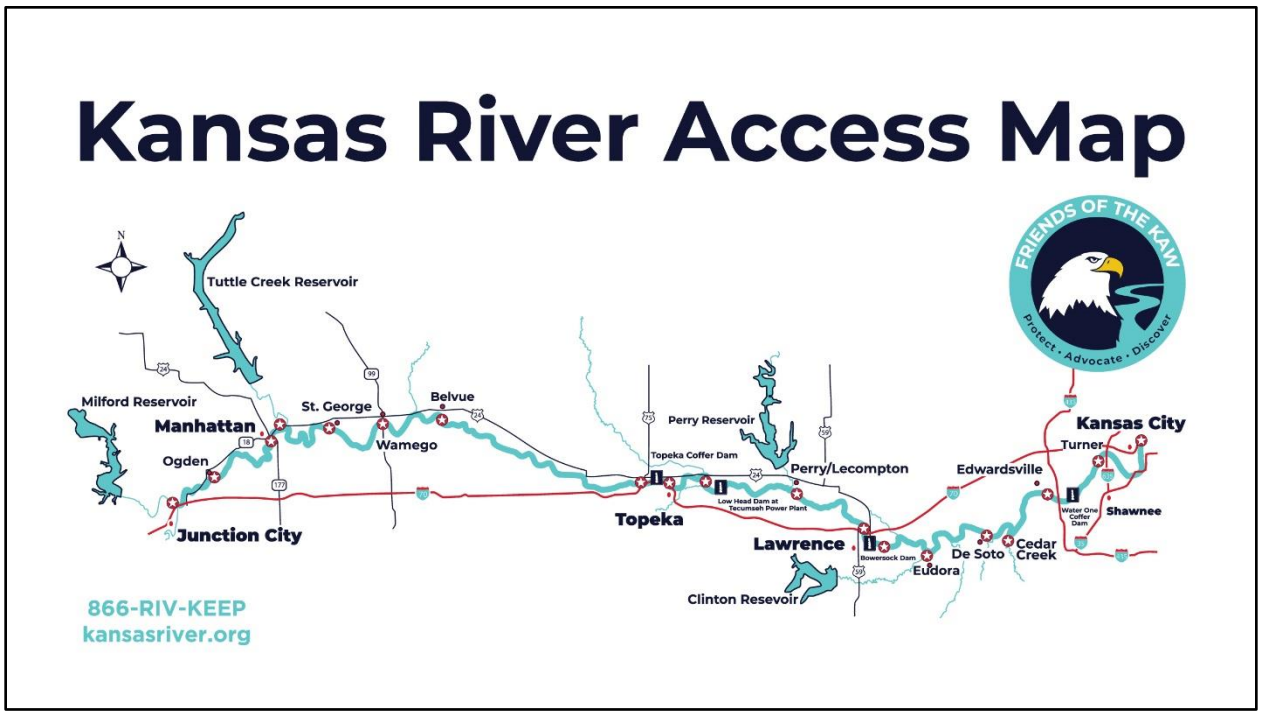
In addition, it is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. Emigration of fish during periods of elevated release rates will likely occur in the future similar to past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Anglers are able to utilize some of the sportfish that regularly emigrate out of the lake. There is well developed angler access immediately below the dam at the outlet structure at the River Pond, which is a lake connected to the river below the dam, and at the low head dam Rocky Ford a mile downstream. There is potential for increasing these angling opportunities as there have been ongoing discussions on how public access can be increased in the undeveloped stretch of the Big Blue River downstream of Tuttle Creek Reservoir. These trends could indicate a shifting of reservoir angling to angling in the river reaches below the dam where future conditions for the fish are not as tenuous. However, as the reservoir fishery considerably declines in the future, angling below the dam may also be adversely impacted.

3.6.4.5 Kansas River Mainstem

The Kansas River mainstem runs for approximately 173 miles from Junction City to Kansas City, Kansas (Figure 3-148). The river spans 10 counties and the major cities of Manhattan, Topeka, Lawrence, and Kansas City. There are 19 access points along the river that allow for many types of recreational opportunities including boating, an increasingly popular activity on the Kansas River. A popular recreation area is the Kaw River State Park, consisting of 76 acres in west Topeka, Kansas.

The Kansas River mainstem was designated as a National Water Trail in 2012 by the National Park Service. It is the world's longest prairie river with outstanding scenic, recreational, historic, and natural characteristics. The Kansas River Water Trail is part of the National Park Service's National Water Trails System, which is a network of water trails open to the public to explore and enjoy. National Water Trails have been established to protect and restore America's rivers, shorelines, waterways, natural areas along waterways, and increase access to outdoor recreation on shorelines and waterways. The National Water Trails are a distinctive national network of exemplary water trails that are cooperatively supported and sustained (National Park Service 2020).

Figure 3-148. Kansas River Recreation Areas



Source: Friends of the KAW 2021

3.6.4.5.1 Existing Conditions

Recreation Activities and Visitation

Just north of Lawrence, Kansas the KAW River Trail is a National Recreation Trail. It consists of a 10-mile walking and biking trail that follows the Kansas River atop the levee on the north side of the Kansas River. Common recreation activities along the Kansas River mainstem include sightseeing, boating, fishing, camping on sandbars, hiking, hunting, biking, and more. In recent years there has been an increase in boating activities such as kayaking, canoeing, and air boating on the river. Fishing is also very common along the Kansas River mainstem, both from the shore and from a boat. Some of the boating access points are also connected to river trails and parks that provide opportunities for sightseeing, hiking, biking, and other recreation activities. When the water is sufficiently low, camping on sandbars within the river channel is also a popular recreation activity.

The Lawrence Levee Trail is a popular river trail for hiking and biking. Located along the north bank of the Kansas River, the Lawrence Levee Trail runs along the top of the flood-control levee on the outskirts of Lawrence, Kansas. The trail offers views of nearby farmland and the river as well as the downtown area of Lawrence on the opposite bank. The trail provides access to Riverfront Park, which features a disc golf course, off-leash dog park, and a wildlife and native grass preserve. At the southeastern end of the trail, various hiking and mountain biking spur trails provide a diverse range of experiences closer to the Kansas River. It also provides the ability to launch kayaks or, if in the middle of a kayaking trip, pull kayaks out of the river to break for lunch or a drink.

Projects to add boating play areas, river drops, and other boating features, are currently underway in several locations along the Kansas River mainstem (Buehler 2020). Boating safety concerns associated with the Topeka Water Plant Weir have prompted the construction of rock structures within the weir to improve water currents and flows. The improvements also include putting in a small whitewater channel for boaters and an environmentally friendly fish channel adjacent to the boating channel for spawning fish.

The City of Lawrence is considering a $1.24M project to repair holes in the weir, stabilize the riverbank south of the dam, and design potential recreational components and access points to the river. The key features of this type of project include drop and play areas for kayaking, fishing, shoreline access, and future opportunities for kayak rental and connections to the Lawrence downtown corridor.

Large, organized events draw many people to the river. There are seven such annual events that, in 2015, were attended by a total of 545 people (Kansas River Commercial Dredging Final Environmental Impact Statement 2017). Annually, there are up to 1,500 people that attend these seven regular events on the Kansas River, including the Manhattan Little Apple Paddle and the Great Kaw Adventure Race, among others. In addition, there are 10 businesses that rent canoes and kayaks along the river, as well as host guided paddle trips and guided fishing trips. These businesses can collectively draw approximately 500 visitors on a summer weekend (USACE and KDWP 2018–2019). One of the organizations, Friends of the Kaw, provides many educational paddle trips for the public. Friends of the Kaw guided 234 participants in 2014 (USACE 2017b) and in 2018 guided close to 1,000 people on the Kansas River (Friends of the Kaw Annual Report 2018).

The Kaw River State Park is a popular recreational area along the Kansas River Mainstem. In 2018, the Kaw River State Park hosted an estimated 42,013 visitors. As described earlier, during spring, summer, and fall months (approximately April through October), an additional estimated 2,000 boaters per month (500 per weekend) are estimated to use the Kansas River mainstem (USACE and KDWP 2018–2019). Although most of the use is by local day visitors, approximately 30 percent of the visitors are estimated to come from regions outside of the Kansas River area (Buehler, 2020). These recreators stay in local accommodations or camp along the river if conditions permit.

Boating use of the Kansas River mainstem has increased over the past decade, with considerable growth in the recent years (Buehler 2020). Subsequently, local emergency services are experiencing an increasing need to help boaters who were not prepared for the river and are acquiring additional equipment to meet these demands. For example, the Johnson County Northwest Consolidated Fire Department and the Leavenworth County Rescue Department have bought new equipment such as airboats and inflatable rafts to assist with rescue operations.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Flooding can result in large adverse effects to river recreation, especially boating and other water-based activities. Hunters, anglers, and campers often utilize the sandbars which are not available in the event of a flood. However, sightseeing along the river can increase as people come to view the flood and experience the power of the river.

Friends of the Kaw has provided some river flow recommendations for paddlers in the Kansas River Mainstem (Buehler 2020). They recommend that novices refrain from paddling in the river if the flow is more than 5,000 cubic feet per second (cfs). Experts are advised against paddling in the river if the flow is more than 8,000 cfs as sandbars begin to disappear. By 11,000 cfs the sandbars are extremely scarce and at 13,000 cfs the sandbars are completely gone. During the 2019 floods, Friends of the Kaw were only able to take two boat trips in April and could not be on the river for the rest of the year due to the high water. These businesses and others that benefit from these trips, such as restaurants and retail establishments, experienced a decrease in revenue. If severe enough, floods can destroy boat ramps, although this did not happen in 2019.

Table 3-94. River Flow Boating Access Thresholds

Flow Ranges (cfs)	<1,000	1,000-1,500	1,500-5,000	5,000-8,000	8,000-11,000	>11,000
Percent of Water-Based Visitors Impacted	100	25	0	50	75	100
Impacts	People find it difficult to paddle the river as the channel is narrow	Water quality can be impacted, causing unpleasant odors	No impacts	Novice paddlers should refrain from boating on the river	Sandbars become scarce; paddling is extremely difficult	Sandbars are mostly gone

Just like with flooding, drought can also have adverse effects on recreation on the Kansas River. When the flow of the river is under 1,500 cfs, water quality can be impacted, causing unpleasant odors. Additionally, when the flow of the river is under 1,000 cfs people find it difficult to paddle the river, as the channel is narrow and people will end up walking most of the prairie-based sand river, with longer boating travel times and considerable effort.

- Sand and gravel dredging along the Kansas River mainstem can be dangerous to boaters, particularly if dredgers are actively mining sand, because the cables that attach the dredge to the bank can be a hazard to boaters. Cables can be just under the surface of the water, above the surface of the water, or moving up and down near the surface of the water. The dredge operators are not always aware when boaters approach, which can be dangerous for boaters, especially when the water is moving fast, and/or is very noisy. Also, some fishermen like to fish at night when visibility is limited, and cables are likely not lowered/lifted for safety. There is concern that members of the public and even many seasoned boaters do not know that these cables exist, so their presence can be even more dangerous to these users of the river. Currently, there are seven dredging locations along the river (https://kansasriver.org/protect/sand-and-gravel-dredging/in-river-dredging-who-and-where/). The dredge site in De Soto, Kansas experiences considerable recreational use, causing the greatest issues with boaters compared to the other six locations.

3.6.4.5.2 Future Without Project Conditions

Changes in Flow

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods,

low flow (drought) periods, and high flow (flooding) periods. To identify the low flow and high flow years, average annual flows were analyzed across the period of record. Four years were chosen to evaluate high flow conditions, with average annual flows on the river above 11,000 cfs, while one year was chosen to evaluate low flow conditions, with average annual flows below 1,000 cfs. See Table 3-92 for a description of impacts to recreation at various flow access thresholds.

Drought years include:

- 2060 (1956).

Flood years include:

- 2055 (1951)
- 2077 (1973)
- 2097 (1993)
- 2123 (2019).

Typical precipitation years include all other years.

Average annual flows on the Kansas River Mainstem are expected to change depending on the amount of precipitation received. Additionally, while not directly influenced by sediment, flows are indirectly influenced by how much sediment accumulates in the nearby reservoirs, because that plays a large role in how much flow is released from the reservoirs into the mainstem. On average, river flows at the Topeka gage are higher in future FWOP scenarios. The impacts to flow under the different FWOP scenarios are shown in Table 3-93.

Table 3-95. Average Annual Flows on Kansas River

FWOP Scenario	Average Annual Flows (cfs)
2024	5,210
2049	5,230
2074	5,250
2124	5,280

Represents average across the period of record at the Topeka gage.

There is one low flow year over the period of analysis: 2060 (translates to past year of 1956). There are four high flow years over the period of analysis: 2055 (translates to past year of 1951), 2077 (1973), 2097 (1993), and 2123 (2019).

Table 3-94 shows the average annual flows for those extreme precipitation years across all FWOP scenarios.

Table 3-96. Average Annual Flows During Extreme Precipitation Years

Extreme Precipitation Year	Average Annual Flow (cfs)
2060	860
2055	22,580
2077	19,020
2097	26,290
2123	17,520

Note: River flows on the Kansas River mainstem with no impacts to boating range from 1,500 cfs to 5,000 cfs (Table 3-92)

During the 2060 low flow period, under the FWOP 2024 scenarios, the riverine flow dips to a record low of 615 cfs, and for the year averages 860 cfs.

The worst modeled future flood year in terms of visitation was in 2097 (modeled after 1993 conditions) when, during the year, flows average 26,290 cfs (see threshold table in existing conditions section) under all of the FWOP scenarios. In July of 2097, the flow of the river rises to a record high of 153,000 cfs. In general, the Kansas River becomes very difficult, if not impossible, to recreate on when flows are above 11,000 cfs.

Changes in Visitation

In 2018, 19,700 people visited the river for (water-based) recreation purposes. This is the baseline visitation for a typical precipitation year.

During drought conditions, such as those experienced in 1956, flows are considerably lower across all FWOP scenarios than the normal flow range, as well as the thresholds important for recreation. During low flow conditions, all water-based access on the river would be impacted and/or limited under all FWOP scenarios.

Modeling of flows in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation could be decreased by 15,900 visitors from 2018 baseline conditions. Under FWOP 2049 and FWOP 2074, there are slight increases in visitation compared to FWOP 2024 conditions because of slightly higher river flows during the modeled year 2060. However, under FWOP 2124 scenario in the modeled year 2060, visitation would be 11 percent lower than FWOP 2024 conditions.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2077 (1973) 2097 (1993), and 2123 (2019). Modeling of flows across all FWOP scenarios shows considerable impacts to visitation during these high flow conditions. Under similar conditions to those experienced in 2019, the model indicates a potential visitation decrease of 84 percent compared to baseline conditions (2018).

Appendix F shows how flood conditions under the 2024 FWOP affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled “flood years” (2055, 2097, and 2123) to baseline conditions (2018). With flows as high as they were in 1993, modeled by the 2097 event, nearly all water-based recreation on the Kansas River would be eliminated. Visitation under all future FWOP scenarios would experience similar visitation impacts as those described under the FWOP 2024 scenario.

Changes in Economic Benefits

This section describes how changes in flows on the Kansas River can potentially impact recreation consumer surplus values. In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical precipitation conditions on the river under the baseline year, 2018. Consistent with visitation in 2018, 19,700 visitors support 12 jobs and $612,700 in labor income in the local economy under baseline conditions.

- Typical Precipitation Conditions

Recreational visitation during baseline conditions at the on the river support an estimated $191,900 annually in consumer surplus value.

- Drought Conditions
  - Consumer Surplus

    The impacts to visitation during low flows (below 1,000 cfs) would impact all water-based visitation under all FWOP scenarios.

    Modeling of river flows under FWOP 2024 conditions show that in the modeled low flow year of 2060 (modeled after 1956 conditions), reduced visitation of 15,900 would translate to a potential loss in consumer surplus values of approximately $154,100 annually (Appendix F). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 81 percent compared to 2018 baseline conditions. In the modeled year 2060, consumer surplus under all future FWOP scenarios would experience similar impacts as those described under the FWOP 2024 scenario.
  - Regional Economic Benefits

    Modeling of flows under FWOP 2024 conditions show that in the modeled drought year of 2060 (translates to past year of 1956), reduced boating visitation would lead to a potential loss of 10 jobs and $494,400 in labor income during low flow conditions under 2024 FWOP compared to baseline conditions (Appendix F). Low flow periods often come with droughts which can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, steps to mitigate losses in visitation, and the demand for recreation on the river. In the modeled 2060, regional economic benefits under all future FWOP scenarios would be similar as those described under the FWOP 2024 scenario.
- Flood Conditions
  - Consumer Surplus

    Within the 100-year period of analysis, considerable high flow events would occur in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of high flow events under FWOP 2024 conditions show that in modeled high flow years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $138,300 and $186,000 in consumer surplus values, representing a decrease between 72 and 97 percent of total consumer surplus under baseline conditions (Appendix F). In the modeled flood years, consumer surplus under all future FWOP scenarios would experience similar impacts as those described under the FWOP 2024 scenario.
  - Regional Economic Benefits

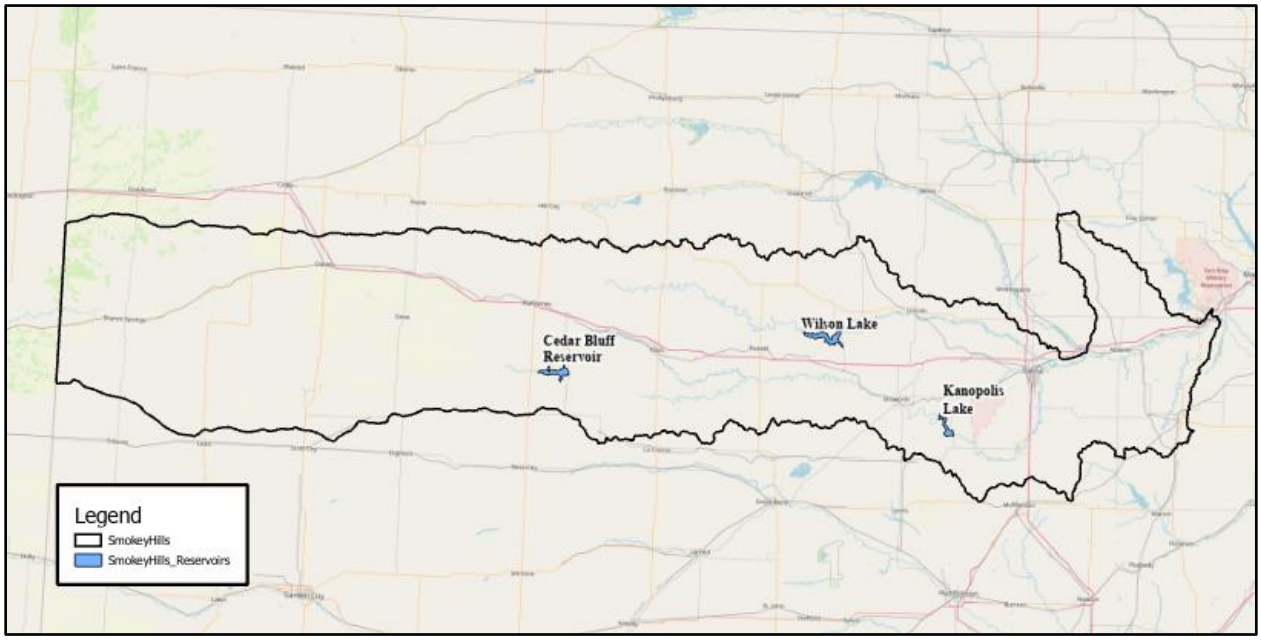
    Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of flows under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 6-12 jobs and $444,000 and $593,300 in labor income supported by boating

visitor spending at and around the Kansas River under baseline conditions (Appendix F). In the modeled flood years, regional economic benefits would be similar under all future FWOP scenarios as those described under the FWOP 2024 scenario.

3.6.5 Smoky Hill-Saline Regional Planning Area

The Smoky Hill-Saline RPA is in the central part of Kansas and includes two USACE reservoirs, Kanopolis and Wilson Lakes, and Cedar Bluff reservoir, operated by USBR. Figure 3-149 outlines the Smoky Hill-Saline Regional Planning Area and shows the location of the three reservoirs.

Figure 3-149. Smoky Hill-Saline Regional Planning Area



3.6.5.1 Kanopolis Reservoir

Kanopolis Lake is a dammed reservoir located on the Smoky Hill River in Ellsworth County, 31 miles southwest of Salina and a few miles southeast of the town of Kanopolis (Figure 3-150) (USACE Kanopolis Lake Map). It is part of the Smoky Hill-Saline Regional Planning Area.

3.6.5.1.1 Existing Conditions

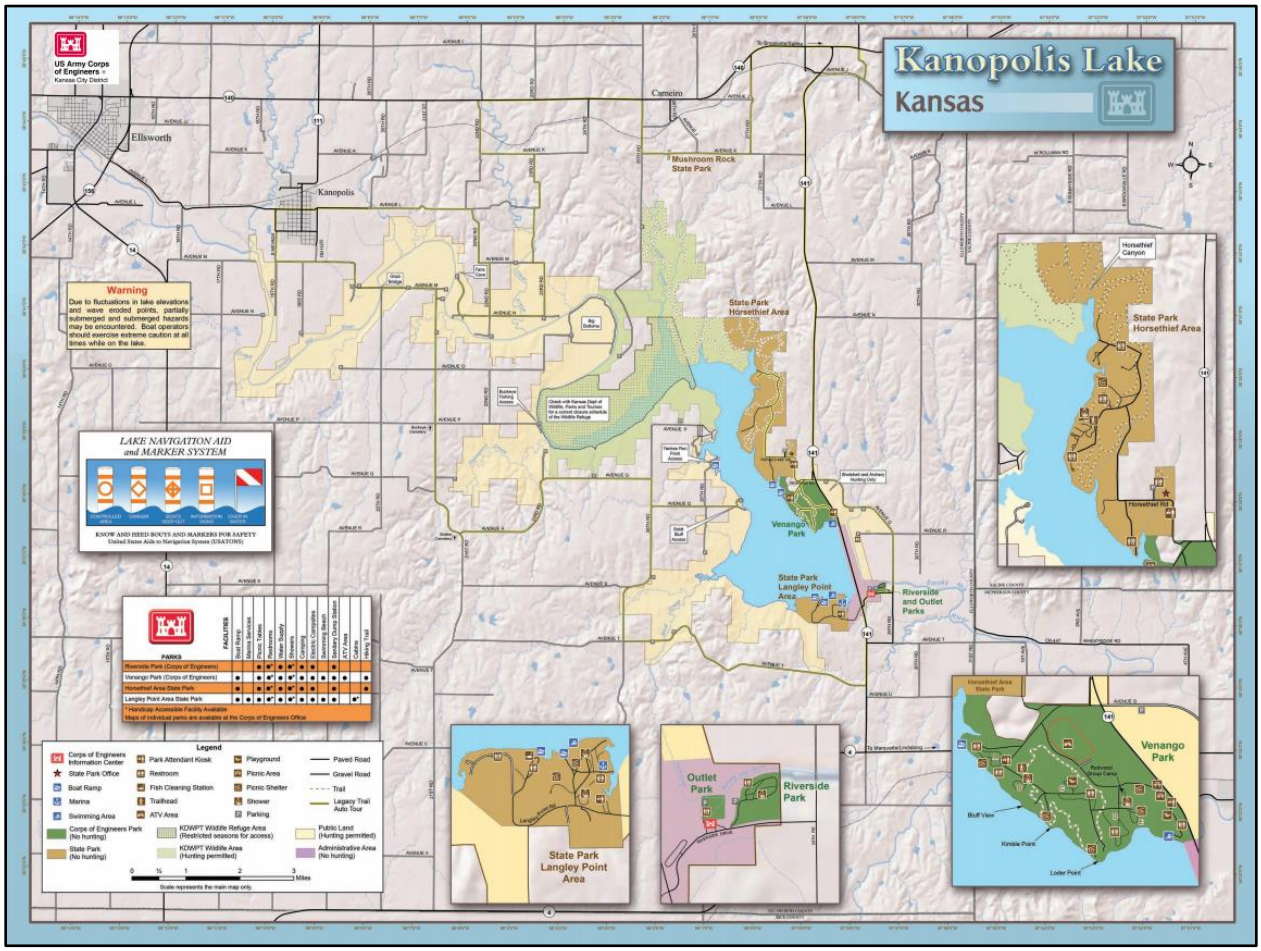
Recreation Facilities and Visitation

KDWP manages the Smoky Hill Wildlife Area, and Kanopolis State Park which is divided into Horsethief Area (eastern shore), and Langley Point Area (southern shore). The USACE manages Venango Park, Outlet Park, Riverside Park, Boldt Bluff, and Yankee Run. Below highlights the recreational infrastructure and opportunities available at Kanopolis Lake:

- Camping Sites
- Swimming Areas

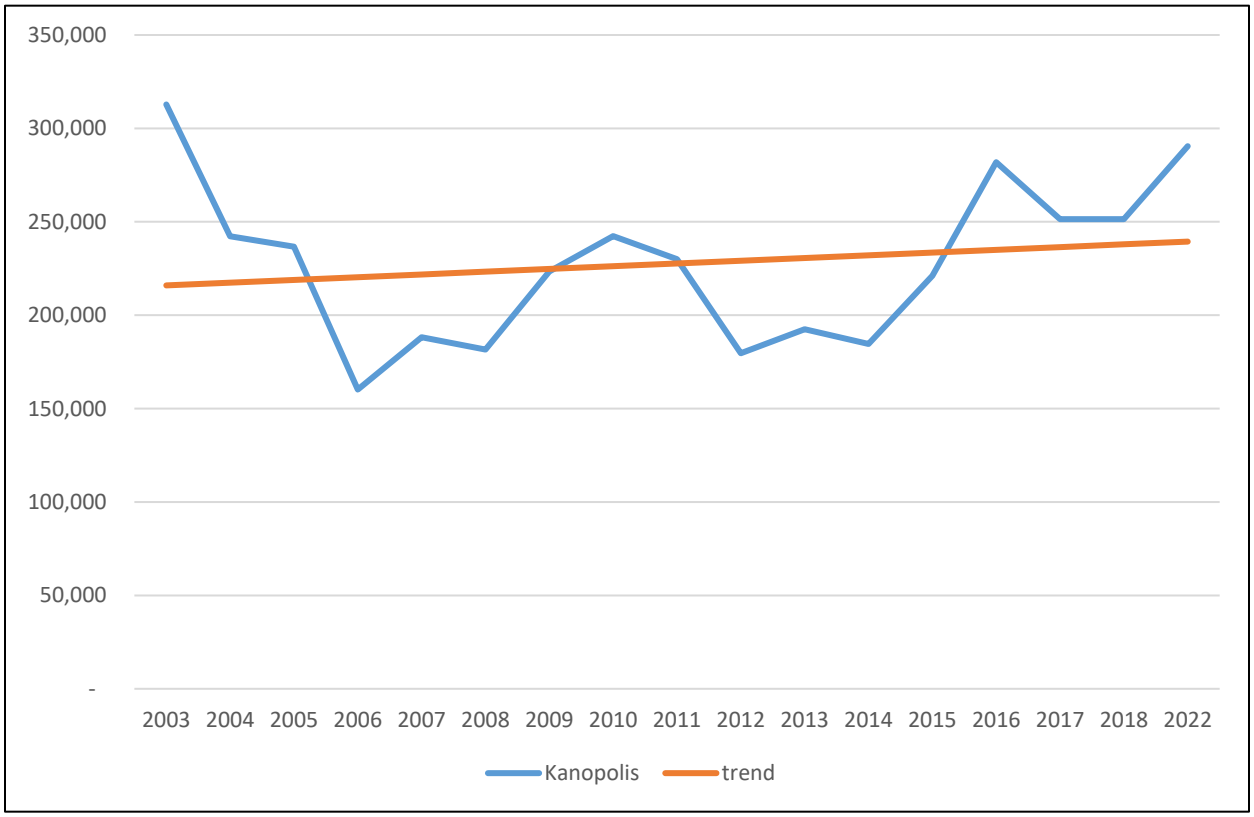
- Trails (hiking, biking, horses, ATV, etc.)
- Baseball Field
- Hunting
- Fishing
- Marina
- Boat Ramps.

Figure 3-150. Kanopolis Reservoir Recreation Areas



According to combined USACE and KDWP data, visitation at the lake in 2018 was approximately 399,300 people. The state parks at Kanopolis Lake accounted for 64 percent of visitation in 2018, with most of the use at South Shore (Langley Point) State Park. KDWP visitation data at the state parks indicate a relatively stable trend of visitation over the last 20 years as shown in Figure 3-151.

Figure 3-151. Kanopolis Reservoir Visitation, 2003-2022



Dispersed recreation, recreation that takes place outside of the established recreation areas, accounted for approximately 3 percent of visitation in 2018 (USACE VERS). In 2018, camping was the most popular recreational activity at Kanopolis Lake, accounting for 36 percent of visitation (USACE VERS 2018). Water-contact activities (swimming, etc.) were the second-most popular form of recreational activity, accounting for 16 percent of visitation. Hunting and wildlife viewing visits was the least popular recreational activity, accounting for an estimated one percent of total visitation.

Sport Fisheries

This section provides a summary of sport fishing at Kanopolis Reservoir. Additional information is provided in the Appendix E. The 2013 Kansas Licensed Angler Survey listed Kanopolis Reservoir as the ninth-most preferred reservoir location to fish in Kansas. It is the 10th-most actually fished reservoir in the state. The proximity to Salina and McPherson makes this a popular destination for anglers inhabiting these urban centers in central Kansas. However, sedimentation has the potential to dramatically reduce use to the reservoir, especially for anglers.

Drought conditions in late 2012 and early 2013 precluded the use of any boat ramps on Kanopolis Reservoir. A temporary, custom ramp made of Marston mats was used to allow boat anglers access to the reservoir. Any decrease of elevation below multipurpose pool limits access to boats, and in many cases to shore anglers throughout much of the reservoir due to exposing mud flats. Projected sedimentation

rates will further reduce access if new boat ramps are not built. Use by anglers will dramatically decline if boats are not able to access the reservoir.

Sport fish populations are likely to shift from pelagic predators (e.g., crappie, saugeye) to generalists (catfish species, common carp) if sedimentation rates continue as projected, due to overall surface acreage decreasing and habitat composition shifting entirely to sand and silt. Water clarity will likely continue to decline as sedimentation worsens and common carp and windy conditions keep benthic silt suspended within the water column. Turbid water conditions can dramatically impact productivity by reducing light penetration and limiting phytoplankton production to the far upper level of the water column. If saugeye and crappie populations decline the angler use is likely to decline as anglers look for alternative locations with a more diverse fish population.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Kanopolis Reservoir is currently experiencing impacts to recreation from sedimentation. Sediment was dredged out of South Shore boat ramp area in 2010 and 2020. Currently, the boat ramp at Yankee Run is only accessible to smaller boats, such as jon boats and kayaks, because of shallow water conditions. At the multipurpose pool elevation of 1,463, access to the Horsethief boat ramp is lost, the Buzzard Bay boat ramp gets restricted, and marina access is limited. All of these restrictions and closures are due to sediment accumulation. Sediment also creates shallower water, creating worse and sometimes even dangerous boating conditions. A lake elevation of 1,467.5 feet is ideal for recreation at current sediment levels, but that will change as more sediment accumulates and decreases depth while elevation remains constant.

In addition to affecting boating and water recreation, sedimentation at Kanopolis Reservoir affects fisheries conditions and angler opportunities. The lake has historically had a considerable crappie population; however, sediment deposition has led to a loss of structure or topographical components in the lake important to fish habitat that has affected this species and likely other fish species.

Kanopolis Reservoir experienced flooding during the spring of 2019, resulting in the closing of many recreation areas. Due to the spring flood event in the Missouri River basin, the lake was above the top of multipurpose pool for over 60 days in 2019, with a max crest of 33 feet above top of multipurpose pool (USACE 2020). Annual visitation was 24 percent lower in 2019 compared to annual visitation in 2018. The Venango recreation area closed in June and was also partially closed in July and August. Venango recreation area almost fully opened in September of 2019, with only severely damaged areas remaining closed.

Drought conditions decrease water surface elevation the longer they persist, and that can have negative effects on recreation at the lake. When water-based access is limited or no longer available due to low water, boaters, campers, and other visitors do not come to the lake. This impact can be especially profound because according to lake staff, boat ramps and electrical campsite availability seem to be the largest drivers for visitation (KDWP 2020b). When the lake is low, all visitation is affected, even from visitors who would not participate in water-based activities. The region surrounding Kanopolis Reservoir suffered a drought during the mid-2000s as well as in 2012 and 2013. In 2006, the lake was so low that no boat ramps were usable.

HABs are algae population explosions (blooms) that can release toxins that are dangerous to animals, including humans. Historically, HABs have not been an issue at Kanopolis Reservoir, however in 2020 there was a HAB watch.

Critical Lake Elevations for Recreation

Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Kanopolis Lake as well as the corresponding impacts to visitation. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. The critical lake elevations for recreation at Kanopolis Lake are in Tables 3-95 and 3-96.

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6938 *Table 3-97. Critical Lake Elevations for Recreation at Kanopolis Reservoir[1]*

Lake Elevations	<1,462 feet	1,462–1,466 feet; multi-purpose pool is 1,463 feet	1,466–1,469 feet	1469–1,483 feet	1,483–1,495 feet	>1,495 feet
Visitation Impacts	Only one boat ramp is operable, and all other water-based access is no longer accessible, including beach.	Affects approximately 25 percent of boat ramps and access points become unusable; only smaller boats can access ramps.	Normal recreation conditions.	Affects a number of boat ramps, beach, some primitive campsites, and secondary access; approximately 25 percent of recreational facilities and areas are closed; Riverside Park remains operational.	Only a few recreation areas would remain open; electrical and primitive campsites mostly closed, and some park roads affected; approximately 75 percent of the recreation facilities and areas are closed. Riverside Park below the dam remains fully operational.	Restrooms and park roads are affected in all parks located on the main lake. Riverside Park below the dam remains fully operational.
Quality of Recreation Effects	Access to the water is one of the main drivers of visiting the lake. If you remove access whether it be a boat ramp, muddy shoreline that you can't access the water safely, or a beach that has a mud flat between the sand and water, it will impact recreation at the lake.	There are safety impacts; lower elevations and shallow water conditions affect the ability for first responders to reach boaters or visitors with response boats.	Normal recreation conditions.	Ramps and docks start to become unusable; Hazards become hidden by flood waters. Beaches start becoming unusable.	Ramps unusable due to hidden lanes, launching normal/deep draft boats becomes more difficult. Many hidden hazards.	Closed

6939 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Kanopolis Reservoir. Lake elevations in NGVD 1929.

6940 *Table 3-98. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations	<1,462 feet	1,462–1,466 feet; multi-purpose pool is 1,463 feet	1,466–1,469 feet	1469–1,483 feet	1,483–1,495 feet	>1,495 feet
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	25%	0%	0%	20%	75%	100%

6941 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Kanopolis Reservoir. Lake elevations in NGVD 1929.

6942

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3.6.5.1.2 Future Without Project Conditions

Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios. These precipitation conditions are typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. four years were chosen to evaluate flood conditions, with average annual elevations at Kanopolis Reservoir above 1,468 feet (NGVD 29), while one year was chosen to evaluate drought conditions, with average annual elevations below 1,457 feet (NGVD 29). See Table 3-95 and Table 3-96 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2028 (1924).

Flood years include:

- 2055 (1951)
- 2077 (2073)
- 2097 (1993)
- 2123 (2019).

Typical years include all other years.

Sedimentation has and will continue to impact recreation at Kanopolis Reservoir, more so than any other lake in the basin except for Tuttle Creek Reservoir. According to the USACE sedimentation analysis, the boat ramps on the eastern side of the reservoir, including those at Venango Park and East Shore State Park (Horsethief), will not be accessible in future years, starting in 2049. By 2049, at South Shore State Park, one boat ramp and the marina will no longer be accessible. By 2074, both boat ramps in the South Shore State Park and the marina will not be accessible. By 2074, the boat ramp at Yankee Run and along with the whole area in general will be fully silted in.

Dredging boat ramps can potentially mitigate/counter the effects of sedimentation and maintain access for boat ramps in the East and South Shore State Parks and in Venango Recreation Area. However, the enactment of this temporary measure is uncertain and dependent on funding availability. Without any management actions (e.g., dredging, reallocation), all boating and marina access to Kanopolis Reservoir would no longer be available in approximately 50 years, beginning in 2074. Lake managers have indicated that these conditions would result in a severe reduction in visitation if sediment on boat ramps and the marina are not mitigated. Not only would water-based visitors be affected, but also those visitors that come to view or be next to the lake. Boaters, anglers, and other water-contact activities at the recreational areas around the lake accounted for 124,000 visits in 2018, 31 percent of total visitation. Other shore-based visitors could also be affected, including special event attendees, campers, picnickers, and sightseers. Shore-based visitors at the recreation areas around the lake accounted for 249,000 or 62 percent of total visitation in 2018. Because the future is uncertain, sediment effects in years 50 to 100 could result in a reduction of visitation at the

recreation areas around the lake between 31 percent (water-based visitors–124,000) to 62 percent (water-based visitors and half of shore-based visitors–248,500) of 2018 visitation unless the adverse effects of sedimentation are mitigated. Maps of sediment accumulation at Kanopolis Reservoir are shown in Appendix F. The impacted visitation and years when access would be lost at the various recreation areas are summarized in Appendix F.

*Table **3-99**. 2018 Visitation Impacted by Sediment During Typical Precipitation Conditions*

Tuttle Creek Lake	Visits	Affected by Sediment Deposition in the Future	Percent Water Based	Percent Shore Based 9%)	FWOP Year When Water-Based Access is Severely Impacted
East Shore State Park	90,000	Y	24.3	75.7	2049
Information Center and Administration Area	3,500	N	22.1	87.9	Below Dam
Riverside Park	16,300	N	41.6	58.4	Below Dam
South Shore State Park	164,900	Y	30.8	69.2	2049
Venango Park	83,600	Y	42.5	67.5	2049
Yankee Run	18,600	Y	75.5	24.5	2049
Outlet Park	4,500	N	36.5	63.5	Below Dam
Dispersed Use (USACE)*	13,200	Y	90.3	9.7	2049
KDWP Wildlife Area	4,700	N	36.5	63.5	N/A
Total	399,300	N/A	206,000	193,300	N/A
Recreation areas affected by sediment in the lake (2049)	370,300	N/A	195,100	175,200	N/A

On average, the lake's average surface elevation is expected to increase very slightly over time. In 2124, Kanopolis Reservoir is expected to be just over one-tenth of a foot higher than the average surface elevation under the FWOP 2024 scenarios Additional information is provided in Appendix B.

Table 3-100. Average Water Surface Elevations at Kanopolis Reservoir Across the Period of Record

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	1,463.36	
2049	1,463.39	0.03
2074	1,463.39	0.03
2124	1,463.49	0.13

Note: The top of the multi-purpose pool is 1,463 feet (NGVD 29).

Table 3-101. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	-0.39	+0.15
2074	-0.68	+0.95
2124	-2.53	+2.63

Note: The top of the multi-purpose pool is 1,463 feet (NGVD 29).

During the 2028-2029 drought period, under the FWOP 2024 scenarios, the pool elevation drops from 1,463 feet (NGVD 29) (multi-purpose pool level) to 1,453 feet (NGVD 29) between May 2028 and October 2028 before gradually returning to multi-purpose pool level in December 2029. This could result in severe implications for recreation with current and future sediment conditions.

In 2024, the USACE sediment modeling indicates that boat ramps at East Shore State Park and South Shore State Park, would provide boating access to the lake in 2024 under typical precipitation conditions. In 25 years (FWOP 2049 scenario), no recreation areas adjacent to the lake will remain boat-ramp accessible. Because water surface elevations would be considerably lower during drought periods than the multi-purpose pool elevation, all recreation areas may not be accessible to boats and may increase safety concerns across the lake compared to typical precipitation water surface elevations.

Under the notable high water or flood years over the 100-year period of analysis on average, water surface elevations are up to 2.6 feet higher under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between FWOP 2124 water surface elevations and FWOP water surface elevations can be up to 21 feet higher.

The worst flood year in terms of surface elevation was 2055, when, out of the whole year, water surface elevations were above elevation 1,495 feet (NGVD 29) (Appendix F) for 42 days for all FWOP scenarios. In general, Kanopolis Reservoir is closed to visitation when water surface elevations are 1,495 feet (NGVD 29).

Changes in Visitation

In 2018, 370,300 people visited recreation areas that are potentially impacted by changing lake elevations in the future; this figure includes dispersed recreators. The study team also compare the impacted visitation to 2018 baseline visitation at all locations at Kanopolis Reservoir. In 2018, visitation across Kanopolis Lake was estimated to be 399,300.

Trends in state park data over the past 16 years (2023–2022, excluding 2019–2021) indicate increasing visitation at approximately 0.7 percent as under baseline conditions. If past trends continue in the future, in approximately 75 years, visitation could be close to 1.5 times greater under baseline conditions. These future increases in visitation will have implications to consumer surplus and regional economic effects if these factors influencing visitation are not being captured in the modeling effort, with the potential for 150 percent of the impacts under FWOP 2124 scenario as estimated under this modeling effort.

Sediment is the main driver of recreation impacts across the lake, although drought and flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the lake. Due to the considerable impacts to water-based visitors from sediment deposition impacting access, a sediment map-based assessment was conducted for typical precipitation conditions.

In 2024, there are four recreation areas adjacent to Kanopolis Reservoir with water-based access and accessible boat ramps: East Shore State Park, South Shore State Park, Venango Park, and Yankee Run (Table 3-97). In 2049, water-based access would be considerably reduced at all five of the recreation areas and no boat ramps would be accessible due to the accumulation of sediment (Appendix F). An estimated 195,100 water-based recreators would be affected, and if it is assumed that all water- and shore-based visitation at these recreation areas shift to another lake or opt not to recreate, 370,300 visitors would be impacted (Table 3-97). These visitors represent 49 percent and 93 percent, respectively, of visitors under baseline conditions (2018) at Kanopolis Reservoir. If these recreation areas were converted to accommodate only shore-based activities, perhaps with construction of trails or OHV areas, a new mix of visitors would be anticipated, although it is difficult to ascertain how visitation would ultimately be impacted.

During drought conditions, notably the year 2028, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from 10 to 21 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation (Tables 3-95 and 3-96). During these conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios.

The impacts to visitation during an extreme drought under all FWOP scenarios would be similar, though not as pronounced, to the visitation impacts due to sediment accumulation as described under the FWOP 2049, 2074, and 2124 scenarios above under typical precipitation conditions. An estimated 195,100 (water-based) and 370,300 (both water- and shore-based) visitors could be impacted by reduced lake access during these types of conditions. Additional visitation could also be affected in areas that are not directly impacted by changes in lake elevations, such as in the recreation areas below the dam, although these impacts are not included in the estimates. For example, if lower releases impact fishing conditions on fishing success below the dam, there could be additional impacts to recreation and reductions in visitation not captured in the abovementioned estimates.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2028 (modeled after 1924 drought conditions), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 247,200, a reduction of approximately 123,100 visitors from 2018 baseline conditions at lake-elevation affected recreation areas.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at the recreation areas

adjacent to the lake in these years (Appendix F). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Kanopolis Reservoir in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 29 percent compared to baseline conditions at Kanopolis Reservoir (2018). In comparison, state park data indicated that 2019 visits were 17 percent lower than in 2018, due to flooding conditions, mostly driven by decreases in visitation in the summer and fall months.

There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam and safety closures could occur; these impacts are not captured in these figures. Appendix F shows how flood conditions affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled “flood years” (2055, 2077, 2097, and 2123) to baseline conditions (2018).

During flooding conditions, up to roughly 50 percent of visitors at lake-elevation-affected areas could be impacted, and potentially even more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenarios.

Changes in Economic Benefits

Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated $4.1M in consumer surplus value. We also compare the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Kanopolis Reservoir. In 2018, visitation across Kanopolis Reservoir supported approximately $5.2M in consumer surplus values.[8] Consistent with visitation in 2018, 399,300 visitors support 104 jobs and $3.9M in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 370,300 visitors support 96 jobs and $3.6M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Reductions in visitation at Kanopolis Lake due to sediment deposition would result in lower consumer surplus values as described in this section. In 2049, water-based access would be considerably reduced at all parks adjacent to Kanopolis Reservoir due to the accumulation of sediment (Appendix F). An estimated 195,100 (water-based) and 370,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer

[8] Consumer surplus values are estimated with recreation visitor day and the Corps’ UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts are occurring (e.g., odors, reduced fishing success). If all water-based visitors no longer came to Kanopolis Reservoir, there would be an annual loss of $2,235,100 in consumer surplus values. Shore-based visitors at Kanopolis Reservoir contribute an estimated $1,902,700 in consumer surplus value, and it is likely a portion of these visitors would also be impacted by 2049 sediment conditions by the reduced ability to view and recreate near the lake or by decreased aesthetic qualities (Appendix F).

- Regional Economic Benefits

  In 2049, according to the USACE sediment modeling, the marina and all boat ramps will no longer be accessible on Kanopolis Reservoir. An estimated 195,100 (water-based) and 370,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts could also occur (e.g., odors, reduced fishing success). FWOP 2074 and 2124 impacts would be similar to those described for FWOP 2049.

- Drought Conditions
  - Consumer Surplus

    The impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under the FWOP 2024 scenario, a loss of $2.2M in consumer surplus values. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.) With elevations below 1,462 feet (NGVD 29), an estimate 25 percent of shore-based visitors could also be impacted (Tables 3-95 and 3-96), leading to a potential loss of $0.5M in addition to the loss of water-based consumer surplus for a total loss of $2.7M.
  - Regional Economic Benefits

    The impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. If these visitors did not come to the reservoir, there would be a loss in annual regional economic benefits of 44 jobs and $1.8M in labor income compared to baseline conditions. Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.
- Flood Conditions

- Consumer Surplus

  Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $0.7 and $1.8M in consumer surplus values (Appendix F). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

- Regional Economic Benefits

- Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2077 (2073), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 59 jobs and $2.2 million in labor income in 2055 (Appendix F). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled. Damages, Revenues, and Fees to States

  Visitation to Kanopolis Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Kanopolis Reservoir were $261,111.[9]

  Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that sediment deposition combined with drought conditions could result in an annual decrease of visitation up to 93 percent of baseline conditions (2018) if all visitation ceases at lake-elevation-affected recreation areas.

  During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

  Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Kanopolis Reservoir were $204,000. The impacts at the KDWP state parks at Kanopolis Reservoir include damages to docks, fish cleaning stations, and campsites, as well as

[9]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

actions to remove debris are estimated at $142,000 for a total recreational repair cost of $346,000. These damages are likely to continue to occur in the future with extreme events.

Water Quality

All reservoirs in the basin, including Kanopolis Reservoir, will likely experience increasing effects of aging as discussed previously. Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at Kanopolis Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Kanopolis Reservoir. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the basin. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at basin reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal HAB issues as some flourish under conditions with elevated phosphorus availability and water temperature. Based on 30 years of annual testing at Kanopolis Reservoir, total phosphorus at the dam has been increasing and can be anticipated to increase in the future as fertilizer use in agriculture increases. With increased levels of phosphorus in the future, storm events could result in algal blooms in Kanopolis Reservoir, although a number of other factors also impact the development of HABs (e.g., the ability to keep water moving through the reservoir).

Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Kanopolis Reservoir. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. While historically not an issue, deteriorating water quality could eventually lead to increased prevalence of HABs in Kanopolis Reservoir with adverse impacts to visitors in the future.

Water residence times were estimated for Kanopolis Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Perry Reservoir has a high

sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 56 percent under the FWOP 2124 scenario. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Angling and Sport Fishery

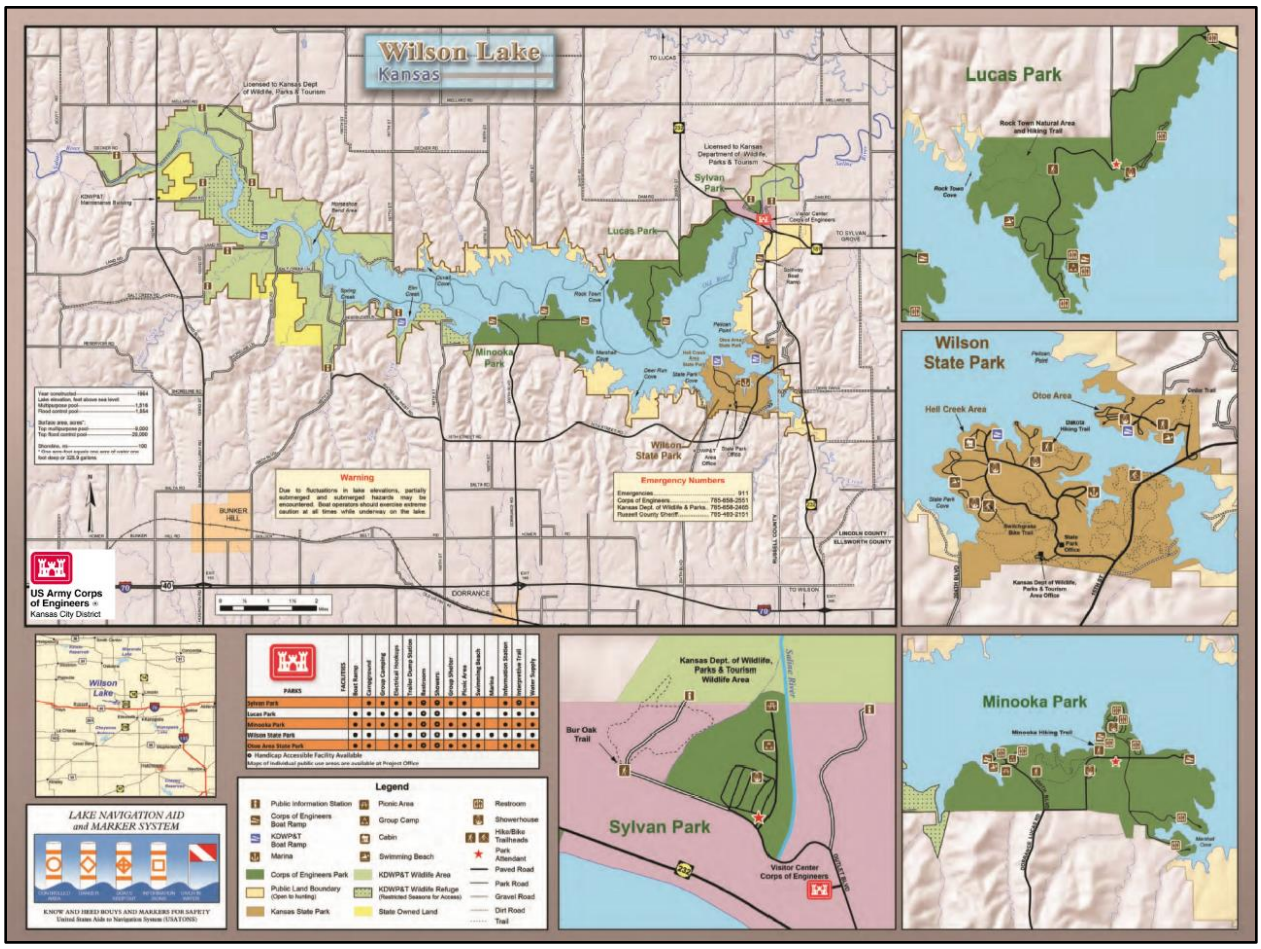
Sediment conditions will continue to have adverse impacts for the fishery at Kanopolis Reservoir. The loss of habitat and water volume due to sedimentation impact the lake's capacity to produce fish. Sedimentation will continue to occur and has the potential to dramatically reduce recreational use of the reservoir, especially for anglers. Dredging can be used to clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat, although these efforts have been minimally effective due to rapid sediment accumulation. The high effort and cost of dredging will also likely limit these projects to select locations. The role of turbidity on the fishery will likely only increase as water volume continues to decrease.

In addition, it is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. Emigration of fish during periods of elevated release rates will likely occur in the future similar to past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Anglers are able to utilize some of the sportfish that regularly emigrate out of the lake. There are several factors that fisheries biologists need to continue to monitor in the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can lead to creating the BMPs to be able to maintain these fish populations in a constantly changing environment.

3.6.5.2 Wilson Reservoir

Wilson Reservoir and dam are operated by the USACE; the lake is in central Kansas, five miles north of Interstate 70 in the Saline River Valley in Russell and Lincoln County (Figure 3-152). The reservoir is located 13.4 miles from the city of Lucas, Kansas, and about 25 miles from the city of Russell, Kansas. The USACE is authorized to operate both Wilson dam and reservoir for the purposes of flood control, recreation, fish and wildlife management and water quality improvement. It was authorized for irrigation storage, but it is not operated for that purpose.

Figure 3-152. Wilson Reservoir Recreation Areas



3.6.5.2.1 Existing Conditions

Recreation Facilities and Visitation

Wilson Reservoir is a 9,000-acre impoundment on the eastern border of Russell County, Kansas on the Saline River. Wilson Reservoir has a variety of different recreation facilities and activities, including four parks managed by KDWP or the USACE. There are numerous recreational opportunities available at Wilson Reservoir:

- Recreation Areas and Parks
- Picnic Sites
- Camping Sites
- Playgrounds
- Swimming Areas
- Trails
- Boat Ramps
- Marina Slips.

According to combined state park and USACE data, total visitation for 2018 was 461,300. The most popular areas are the state parks, including Hell Creek and Wilson State Parks (and Lake Wilson marina), accounting for 30 percent of visitation in 2018. Other popular recreation areas are USACE parks, Minooka Park and Lucas Park, both accounting for about 19 percent of total visitation in 2018.

Overnight camping and lodge stays accounted for 29 percent of activities at the lake, while picnicking and sight-seeing account for 10 percent and 7 percent, respectively. Water-contact activities accounted for 20 percent of activities, while boating and angling accounted for 18 percent and 6 percent, respectively. Special events drew an estimated 4,600 visitors in 2018, 1 percent of all activities. iSportsman hunting data isn't currently available for Wilson Reservoir. The study team assumed that 1 percent of total visitation (4,612 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, the assessment assumed that 21 percent of that figure (969) accounts for wildlife viewing based on a FWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas[3] (USFWS 2017).

There are 26 miles of mountain biking trails in Wilson State Park, noted as an "epic" trail by the International Mountain Biking Association. An estimated 10 percent of the visitation at Wilson State Park is associated with the mountain biking use. The area is also known for its bass fishing. According to lake staff in 2019 and 2020 up to 20-30 percent of anglers preferred to fish for bass.

Sport Fisheries

This section provides a summary of sport fishing at Wilson Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). In terms of angling, the 2013 Kansas Licensed Angler Survey lists Wilson Reservoir as the number one preferred reservoir for fishing in the state, and it's also the number one most actually fished reservoir in the state. Angler preference for a specific species often varies based upon changes in species dominance that results from water fluctuation history and the impact of invasive species in the reservoir. Walleye and striped bass have ranked in the top four species preferred by anglers at Wilson Reservoir in the past four creel surveys. Largemouth bass have been ranked during the last two surveys. Since the last survey the number of anglers targeting bass has increased due to the rise in lake levels creating excellent habitat and an abundant bass population (Appendix E).

Due to its high salinity, Wilson Reservoir isn't used as a public water supply and hasn't experienced the elevation fluctuations of other western Kansas reservoirs. However, starting in 2006 the reservoir elevation began to decline and in April of 2016 hit a record low of 10.5 feet below multipurpose pool. This was remedied by heavy rains in June that added 5 feet of storage. More heavy storms in late August and early September filled the reservoir 2.5 feet beyond the multipurpose pool. This helped contribute to excellent sport fish populations from 2016 to 2019. Flooding in 2019 killed a high amount of grass and other shoreline vegetation. The reservoir doesn't have many issues with HABs, although they have occurred irregularly (Appendix E).

Drought conditions and ANS are the main stressors of sport fish populations within Wilson Reservoir. ANS alter the food webs in the reservoir, and their direct consumption of fish eggs creates recruitment issues for sport fish. Most management efforts have

been directed at mitigating the negative effects of ANS. Dense annual stockings of striped bass was the main management technique for controlling white perch from 2000 to 2015. However, the drought from 2012 to 2016 caused poor health and slow growth of the striped bass population and efforts to improve their condition by lowering stocking rates and relaxing harvest regulations began in 2016. These efforts immediately improved conditions for striped bass but, unfortunately white perch numbers rebounded along with the lake levels in 2016 and their population has since increased dramatically. White perch provide an alternative forage for sport fish at Wilson Reservoir but their extreme abundance, interspecific competition, and appetite for fish eggs creates more negative than positive results. Zebra mussel numbers seem to be positively correlated with inflow and typically remain low in abundance, but periods of high inflow experienced in 2016 and 2019 increased their numbers temporarily (Appendix E).

Drought conditions reduced visitation considerably from 2012-2016. Visitation improved starting in 2017, due in part to competitive bass fishing tournaments. Periods of drought and reduced surface elevation that allow vegetation to grow along exposed shorelines provide optimal habitat for largemouth bass when the reservoir refills. It is possible that high weekend use by bass anglers have precluded other user groups from visiting but that has not been documented. The distance from population centers might impact use in years of high gasoline prices. However, that might impact camping and general day use more than angling use and visitation (Appendix E).

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Sediment accumulation at Wilson Reservoir is low and has not caused any major impacts other than some local impacts to recreation in the past. Some shoreline erosion and deposition of silt has become an increasing concern. At Wilson Reservoir, the upper third of the lake is where the majority of sediment is deposited. The upper end of the lake, known as “Horseshoe Bend,” acts as a natural depository for most sedimentation and debris. Several boat ramps in this region have dealt with local sedimentation and require periodic cleanouts.

The land surrounding the upstream portion of the lake is managed by KDWP. The lands consist of mostly agricultural leases that provide public access and hunting. A wildlife refuge is also located in this area. Lower elevations have been noted to provide better habitat for threatened and endangered species such as the whooping crane. However, high elevations can flood roadways and limit vehicular access.

The area suffered a drought during the mid-2000s as well as in 2012, 2013, 2014, and 2015. In 2006, the pool was very low from lack of streamflow from little to no precipitation. Low lake elevations rendered boat ramps unusable and decreased both water-based and shore-based recreation. The economy in the adjacent communities suffered in 2006. Localized dredging has been undertaken to maintain access to boat ramps during drought conditions.

Drought impacts hunting at Wilson Reservoir. An example of these impacts as cited by the lake’s wildlife manager includes “On opening morning of upland bird season in November 2012, there were approximately 140 upland bird hunters at Wilson Wildlife Area. On opening morning of upland bird season in November 2013, there were 33 upland bird hunters on Wilson Wildlife Area. Likewise, there was a significant decline in

pheasant and quail survey results on the wildlife area between 2012 and 2013. Deer hunter numbers remained stable regardless of drought conditions."

Because of the closures during drought conditions, visitation in 2012 and 2013 mostly occurred at the Spillway Ramp and the Hell Creek ramp. Visitation was reduced by approximately 30 percent during this time due to limited water access as only two out of nine ramps were accessible.

Due to the spring flood event in 2019 in the Missouri River basin, the reservoir was above normal pool for more than 60 days, with a max crest of 11 feet above top of multipurpose pool (USACE 2020). At the end of May in 2019, approximately half of the campsites were closed at Minooka Park and Lucas Park due to campsite flooding. The Minooka Park lift station was flooded, closing the main shower building and dump station. Water receded in late July and parts of the recreation areas and facilities were closed during August for repair construction to flooded sites. Additional flooding occurred during the last 2 weeks of August, damaging the repaired recreation infrastructure and access roads. The recreation areas were not fully repaired until June of 2020. Visitation overall decreased 27 percent in 2019, compared to visitation in 2018. This was driven mostly by a 65 percent visitation decrease during the fall (September–December) (USACE and KDWP 2018–2019).

Flooding in 2019 also had a negative impact on hunting at both Kanopolis and Wilson Reservoirs. The wildlife manager was cited as stating "Receding flood waters resulted in poor habitat conditions on impacted acres and access issues. Some hunters that were planning fall hunting trips during spring/summer of 2019 opted to hunt elsewhere based on flood reports."

Critical Lake Elevations for Recreation

Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Wilson Reservoir as well as the corresponding impacts to visitation. Future reservoir sedimentation for Wilson Reservoir and any impacts to recreation are described in Appendix F.

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7424 *Table 3-102. Critical Lake Elevations for Recreation at Wilson Reservoir[1]*

Lake Elevations	<1,512 feet	1,512–1,515 feet	1,515–1,518 feet; multipurpose pool is 1,516 feet	1,518–1,524 feet	1,524–1,529 feet	>1,529 feet
Visitation Impacts	Boat ramps are difficult to access, and water-based visitation is considerably decreased. No real impacts to campsites or facilities but lack of water access deters visitation.	Approximately 40 percent of ramps become inaccessible in this range.	Normal recreational conditions. 100 percent accessible ramps.	Impacts to water-based access, camping and day use from high water levels. Approximately half of the recreation areas are closed and/or half of the lake visitation is affected.	Impacts to water-based access, camping and day use from high water levels. Approximately 3/4 of the recreation areas are closed and/or half of the lake visitation is affected.	Most of the recreation areas and parks are closed.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Underwater hazards begin to surface; boating safety becomes an elevated concern for all boating visitors.	Normal recreational conditions.	Hazards become hidden by flood waters; boating safety becomes an elevated concern for all boating visitors; roadways become inundated, sewage lift stations have to be closed, limited vehicular access around the park.	Hazards become hidden by flood waters; boating safety becomes an elevated concern for all boating visitors; roadways become inundated, sewage lift stations have to be closed, limited vehicular access around the park.	Closed

7425 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Wilson Reservoir. Lake elevations are in NGVD 1929.

7426 *Table 3-103. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations	<1,512 feet	1,512–1,515 feet	1,515–1,518 feet; multipurpose pool is 1,516 feet	1,518–1,524 feet	1,524–1,529 feet	>1,529 feet
Water-based Visitor Impacts	100%	40%	0%	50%	75%	100%
Shore-based Visitor Impacts	0%	0%	0%	50%	75%	100%

7427 The information in this table was developed with input from USACE and KDWP staff familiar with Wilson Reservoir. Lake elevations are in NGVD 1929.

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3.6.5.2.2 Future Without Project Conditions

Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years or periods, average annual elevations were analyzed across the period of record. Two years were chosen to evaluate flood conditions, with average annual elevations at Wilson Reservoir above 1,518 feet, while 24 years were chosen to evaluate drought conditions, with average annual elevations below 1,512 feet. Where drought years occurred over several years they are assessed as a drought period. Impacts to recreation from flooding start to occur above 1,518 feet elevation with impacts to water based access and camping and day use affected. At 1,529 feet elevation most of the recreation areas and parks are closed. Wilson Reservoir frequently experiences drought conditions and high evaporation with extended periods of drought often occurring. At 1,512 feet elevation the reservoir is four feet below top of multipurpose pool and boat ramps are difficult to access and water-based recreation is considerably decreased with almost no water-based recreation access. Boating safety is a high concern for all visitors from unmarked underwater hazards. See Tables 3-100 andTable 3-103 for a description of impacts to recreation at different lake elevation thresholds.

Drought years/periods include:

- 2025-2031 (1921-1927)
- 2038 (1934)
- 2041 (1937)
- 2058-2060 (1954-1956)
- 2093-2096 (1989-1992)
- 2108-2111 (2004-2017)
- 2117-2120 (2013-2016).

Flood years include:

- 2055 (1951)
- 2097 (1993).

Typical years include all other years.

It is estimated that approximately 459 acre-feet of sediment accumulates on average annually in Wilson Reservoir. Sediment will continue to accumulate in Wilson Reservoir with an expected additional 8.7 percent loss of the multipurpose pool over the next 25 years (2049) and 13.2 percent loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 203,400 acre-feet in 2074. Sedimentation has not generally impacted recreation at Wilson Reservoir, but some shoreline erosion and deposition of silt has become an increasing concern.

While sediment will continue to accumulate (8.7 percent loss of the multipurpose pool over the next 25 years and 13.2 percent loss over the next 50 years) and the delta could

extend, the size of the multipurpose pool and the lake's recreational opportunities are expected to be impacted very minimally. Appendix F shows the depths of Wilson Reservoir at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years). In terms of sediment concerns Wilson Reservoir doesn't have as many issues compared to Kanopolis Reservoir and other lakes. Sediment modeling shows that Cedar Creek boat ramp is currently not accessible. Wilson Reservoir staff indicated that small craft boating is currently accessible at/near multipurpose pool (shallow watercraft ex. Jon boats). Visitation is primarily shallow watercraft for hunting/fishing and dependent on elevations (Kanopolis and Wilson Lake Meeting, 1/15/21). An estimated 3,466 visitors came to this area in 2018. Additionally, Elm Creek boat ramp appears to be inaccessible after 2124. Visitation to this area was 3,466 in 2018. Other areas that are projected to be impacted by sediment (by 2124) include: 2 boat ramps at Minooka Park.

Wilson Reservoir does not loose significant storage over the 100-years of the FWOP. However, the average and median FWOP elevations are all below the top of multipurpose pool which is reflective of the frequent drought conditions observed there. The FWOP 2024 and FWOP 2049 scenarios are very similar as the sediment conditions do not change dramatically in this timeframe for Wilson Reservoir. However, as more sediment accumulates with each additional FWOP scenario the average pool elevation also increases (Appendix B).

Wilson Reservoir modeling shows that the pool elevation does not drop as far into the multipurpose pool in the later FWOP scenarios . This is likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at Wilson Reservoir. Additional information is provided in Appendix B.

Table 3-104. Average Water Surface Elevations at Wilson Reservoir

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	1,513.2	-
2049	1,513.2	+0.08
2074	1,513.4	+0.23
2124	1,513.6	+0.46

Note: The top of the multi-purpose pool is 1,516 feet (NGVD 29).
Represents average across the period of record.

There are seven notable drought periods assessed for Wilson Reservoir over the 100-period of analysis: 2025–2031 (translates to past years of 1921–1927), 2038 (translates to past year of 1934), 2041 (translates to past year of 1937), 2058–2060 (translates to past years of 1954–1956), 2093–2096 (translates to past years of 1989–1992), 2108–2111 (translates to past years of 2004–2017), and 2117–2120 (translates to past years of 2013–2016). There are two notable high water or flood years over the 100-year period of analysis: 2055 (translates to past year of 1951) and 2097 (translates to past year of 1993).

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions (which are approximately nine feet above for flood years and five feet below

for drought years of top of multipurpose pool on average). During drought conditions, on average, pool levels in 25 years (2049) are approximately 0.16 feet higher, while in 50 and 100 years, pool levels are approximately 0.49 to 1.03 feet higher on average under FWOP 2074 and FWOP 2124 FWOP conditions, respectively, compared to FWOP 2024. This is still greater than nine feet below the top of multipurpose pool experience under baseline conditions.

Table 3-105. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years (feet)	Change in Average Water Surface Elevations from 2024 During Flood Years (feet)
2049	0.16	+0.04
2074	0.49	+0.14
2124	1.03	+0.36

Note: The top of the multi-purpose pool is 1,516 feet (NGVD 29).

Drought conditions, similar to those experienced in past drought periods, result in relatively lower water surface elevations (between five and 19 feet below multipurpose pool) for one to six years, which could result in severe implications for recreation at Wilson Reservoir.

Under two notable high water or flood years over the 100-year period of analysis on average, water surface elevations are higher on average under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024 (which are approximately nine feet above top of multipurpose pool on average). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (0.04 to 0.36 feet higher).

The worst modeled future flood year in terms of visitation was in 2055 (compared to 1951) when, during the year, water surface elevations were above elevation 1,525 feet (NGVD 29) (see threshold table in existing conditions section) for an extended period of time under all of the FWOP scenarios. In general, Wilson Reservoir is closed to 75 percent visitation when water surface elevations are 1,524 feet (NGVD 29).

Changes in Visitation

In 2018, 418,200 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Wilson Reservoir. In 2018, visitation across Wilson Reservoir was estimated to be 461,300.

Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

During drought conditions, notably the period between 2025 and 2031, consistent with the historic drought of 1920s, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from five to 19 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation. In drought conditions, consistent with the 1920s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP

scenarios. These drought events would have multi-year impacts as the fishery would be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be severely impacted, and revenue sources to maintain the lakes would decrease.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2025 to 2031 (modeled after 1920s drought conditions, the largest reduction in water surface elevations), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be on average annually 295,500, a reduction of approximately 165,800 visitors from 2018 baseline conditions at lake-elevation affected recreation areas. The other drought years/periods would have similar impacts to visitation as the 2025 to 2031 drought period.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions) and 2097 (1993). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Appendix F). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Wilson Reservoir in 2055, consistent with conditions experienced in 1951, indicates a potential visitation decrease of 62 percent to 73 percent at lake-elevation affected areas compared to baseline conditions at Wilson Reservoir (2018).

With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails, and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenario. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 418,200 visitors would be affected, representing 91 percent of visitation under baseline conditions at Wilson Reservoir (2018). Appendix F shows how flood conditions under the 2049, 2074, and 2124 FWOP scenarios affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled “flood years” (2055 and 2097) to baseline conditions (2018).

Impacts on visitation under the two flood events could be high similar to past flood events. However, comparing water surface elevation impacts on visitation under the 2049, 2074, and 2124 FWOP scenarios during the three flood events, water surface elevations are minimally impacted (2049: 0.1-foot increase; 2074: 0.1-foot increase; and 2124: 0.4-foot increase) compared to FWOP 2024. These minimal changes in water surface elevations under the two FWOP scenarios compared to FWOP 2024 during the two flood events has minimal effect on visitation compared to baseline visitation (2018) and shows some minor increases in impacts as shown in Appendix F.

Changes in Economic Benefits

Consistent with visitation in 2018, 461,300 visitors support 136 jobs and $4.3M in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 418,200 visitors support 125 jobs and $4.0M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated $5.5M in consumer surplus value. The study team also compared the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Wilson Reservoir. In 2018, visitation across Wilson Reservoir supported approximately $6.2M in consumer surplus values.[10]
  - Regional Economic Benefits

    Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.
- Drought Conditions
  - Consumer Surplus

    The impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). With elevations below 1,512 feet (NGVD 29), an estimated 100 percent of water-based visitors could be impacted (see Appendix F).

    Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions are very similar and show that in modeled droughts years reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately $1.4 to $1.7M annually (Appendix F). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 25 percent to 31 percent compared to 2018 baseline conditions.
  - Regional Economic Benefits

    Impacts from sediment are not discussed as Wilson Reservoir does not lose significant storage over the 100 years of the FWOP.

    Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years/periods of 2025-2031 (translates to past years of 1921–1927), 2038 (1934), 2041 (1937), 2058-2060 (1954–1956), 2093–2096 (1989–1992), 2108–2111 (2004–2017), and 2117–2120 (modeled after 2013–2016 conditions), reduced

[10] Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

visitation would lead to a potential loss of 52 to 60 jobs and $1.8 to $2.1M during drought conditions under 2024 FWOP compared to baseline conditions (Appendix F). These reductions in economic benefits impacted by changes in lake elevations represent a 42 percent to 49 percent decrease in jobs from total jobs supported from all visitor spending at Wilson Reservoir under baseline conditions (136 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049, FWOP 2074, and FWOP 2124 conditions show that in modeled drought years of 2025-2031 (translates to past years of 1921–1927), 2038 (1934), 2041 (1937), 2058-2060 (1954–1956), 2093-2096 (1989–1992), 2108–2111 (2004–2017), and 2117–2120 (modeled after 2013–2016 conditions), reduced visitation would lead to a potential loss of 50 to 60 jobs and $1.7 to $2.1M during drought conditions under 2024 FWOP compared to baseline conditions (Appendix F). These reductions in economic benefits impacted by changes in lake elevations represent a 40 percent to 49 percent decrease in jobs from total jobs supported from all visitor spending at Wilson Reservoir under baseline conditions (136 annual jobs).

- Flood Conditions
  - Consumer Surplus

    Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions) and 2097 (1993). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 are very similar and conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $3.4 and $4.1M in consumer surplus values, representing a decrease between 62 percent and 75 percent of total consumer surplus at Wilson Reservoir under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., Sylvan Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.
  - Regional Economic Benefits

    Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions) and 2097 (1993). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 76 to 92 jobs and $2.4 to $2.9M in labor income, representing a decrease between 56 percent to 67 percent of total jobs supported by visitor spending at Wilson Reservoir under baseline conditions (Appendix F). There could also be impacts to visitation at the recreation areas below the dam (e.g., Sylvan Park) with potentially higher

releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Under the FWOP 2049, 2074, and 2123 scenarios, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2055, 2097, and 2123 (Appendix F). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (Appendix F) and the impacts to the regional economic benefits (i.e., jobs and labor income) remain fairly consistent compared FWOP 2024 for the modeled years of 2055, 2097, and 2123.

- Damages, Revenues, and Fees to States

Visitation to Wilson Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting, and fishing license revenues, concessionaire fees. In 2018, the state revenues associated with Wilson Reservoir were $486,000, fifth in revenue in the state of Kansas.[11] At Wilson Reservoir in 2019, these revenues were $527,000, an increase of 8 percent from 2018 revenues due to increased visitation from flooding events in the surrounding region.

Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 42 percent of baseline conditions (2018), while flooding impacts would have larger impact, impacting up to 73 percent of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Wilson Reservoir were $453,000. The impacts at the KDWP state parks at Wilson Reservoir include recreation damages were estimated to be $52,000. These damages are likely to continue to occur in the future with extreme events.

Due to low sedimentation rate, lack of harmful agal blooms, and quality fishing opportunities it is unlikely that use and visitation at Wilson Reservoir will decline significantly in the future (KDWP 2020c).

[11]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

Water Quality

Wilson Reservoir has not experienced recreation impacts from HABs. Deteriorating water quality could eventually lead to new occurrence of HABs in Wilson Reservoir with adverse impacts to visitors in the future. Impacts from HABs has been implicated in local economic impact from decrease in tourism/recreational visitation and are expected to continue in the future (Appendix G).

As described it is estimated that approximately 459 acre-feet of sediment accumulates on average annually at Wilson Reservoir. Sediment will continue to accumulate with an expected additional 8.7 percent loss of the multipurpose pool over the next 25 years and a 13.2 percent loss over the next 50 years (Appendix D). Reduced volume means less dilution and can equate to higher concentration of nutrients stored in the lake system. With the expected low amount of sediment expected to accumulate in Wilson Reservoir issues related to reduced dilution will not likely impact water quality or recreation at Wilson Reservoir.

Excess chloride and sulfate, caused by naturally occurring salt compounds from the Dakota Aquifer entering from the Saline River via groundwater additions to inflow streams, are the main impairments to Wilson Reservoir. Natural background chloride and sulfate levels on Saline River above Wilson Reservoir consistently exceed water quality criteria of 250 mg/L which prevents achievement of KDHE state water quality criteria of 250 mg/L.

Wilson Reservoir watershed has considerably less row crop agriculture, sediment runoff, and fertilizer and pesticide runoff than other lakes in the Kansas River Basin. Water quality can degrade during extended wet periods or flood conditions as observed in 2019. During this time, the degraded conditions are less extreme than those experienced in other watersheds.

All reservoirs in the watershed, including Wilson Reservoir, will likely experience increasing effects of aging. Future water quality within watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Continued and enhanced water quality impairment may be expected at Wilson Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoir. Based on an assessment of runoff/streamflow, sediment yield, and TN and TP yield under climate change runoff to Wilson Reservoir is expected to have a low increase in runoff/streamflow, sediment yield, TN yield, and TP yield as Wilson Reservoir is considered the “clearest lake in Kansas” as a result of considerably less row crop agriculture, sediment runoff, and fertilizer and pesticide runoff than other lakes in the basin.

Water residence times were estimated for Wilson Reservoir (Appendix G). Extended residence time allows for longer dilution and settling time as well as biological attenuation of agricultural runoff which improves water quality downstream of Wilson Reservoir. A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool

have the largest decreases in residence time expected in the future. Wilson Reservoir does not have a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 15 percent under the FWOP 2124. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Impacts are expected to continue and potentially increase (see Appendix G) in the future causing reduced visitation and reduced visitor experience at Wilson Reservoir.

Angling and Sport Fishery

Biennial stockings for striped bass will continue to be requested from the culture system. Walleye and blue catfish will be stocked as needed, generally when natural recruitment fails for one to three years.

Wilson Reservoir was ranked as the most preferred reservoir to fish by anglers during the 2013 Licensed Angler Survey. Due to low sedimentation rate, lack of harmful agal blooms, and quality fishing opportunities it is unlikely that use and visitation at Wilson Reservoir will decline significantly in the next 100 years. Angling will continue at Wilson Reservoir in the future, but targeted species may vary depending on fluctuating factors that affect fish abundance and condition or their habitat. If a fish species highly sought by anglers declines this could affect the angling experience in the future and fisherman may choose to move to another reservoir.

Water levels will continue to fluctuate due to the variable annual precipitation in the region with drought conditions in some years that cause a decline in pool elevations and inundation of specific habitats (e.g., coves, shorelines) leading to a lack of vegetation and structure near the shoreline used for fish spawning and escape habitat. In other years high water elevations that are sustained will provide excellent habitat for young of the year fish allowing some fish species to have good year classes recruited to the fishery (e.g., largemouth bass). However, significant flooding can kill large areas of common reed grass and shoreline vegetation utilized by fish species. Zebra mussels and white perch could continue to increase at Wilson Reservoir altering food webs in the reservoir and consuming fish eggs creating recruitment issues for sport fish.

While sedimentation will continue to occur (3.3 percent loss of the multipurpose pool over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. Shoreline erosion and deposition of silt will continue to cause stressors to fish populations leaving littoral areas unvegetated and silting in important areas fish use for spawning, nursery habitat, and protective cover.

KDWP will continue to monitor and regulate sport fishing populations to provide the best conservation of the resource for anglers. Habitat improvements, most likely in the form of brush piles as fish attractors and shoreline vegetation for improved littoral productivity, will be accomplished intermittently. Boat ramps will continue to be assessed to provide reasonable boat access for anglers. Shoreline access will be maintained for bank anglers.

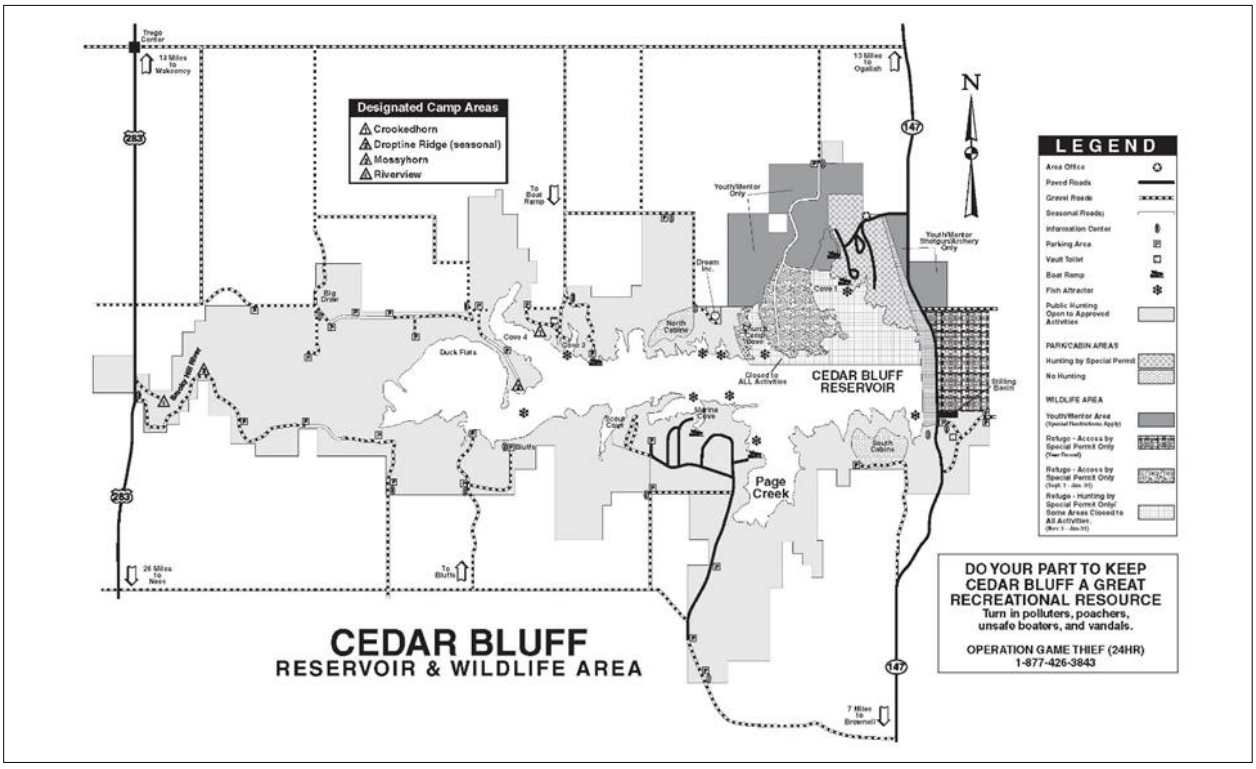
Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations,

habitat work, aquatic vegetation enhancement, fish stocking, and special studies, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Wilson Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Wilson Reservoir (Appendix E).

3.6.5.3 Cedar Bluff Reservoir

Cedar Bluff State Park surrounds Cedar Bluff Reservoir, which is located on the Smoky Hill River in west central Kansas about 15 miles south of WaKeeney (Figure 3-153). Cedar Bluff State Park is divided into two, unique areas along the shorelines of Cedar Bluff Reservoir. The Bluffton Area, on the north shore, provides nearly 350 acres for visitors. The Page Creek Area, on the south shore of the reservoir, is nearly 500 acres in size. It is not quite as developed but provides some of the finest primitive camping in the state with its large shade trees and sandy shorelines.

Figure 3-153. Cedar Bluff Reservoir Recreation Areas



3.6.5.3.1 Existing Conditions

Recreation Facilities and Visitation

The reservoir has 50 miles of shoreline and offers year-round fishing. The Bluffton Area provides a variety of facilities to meet the outdoor enthusiasts needs. The following list highlights the various recreational opportunities at Cedar Bluff (Cedar Bluff 2020 Annual Report):

- Boat Ramps
- Utility Campsites
- Undesignated Primitive Sites
- Designated Primitive Sites
- Group Campground
- Trail Systems
- Rental Cabins.

In 2018, total visitation at Cedar Bluff Reservoir was 182,261. In addition, the KDWP is responsible for administering the contract for 104 private cabins that are located on USBR property. Cedar Bluff Wildlife Area has boat launching facilities, primitive camp sites, and shoreline fishing access. Visitation associated with use of the private cabins and the Cedar Bluff Wildlife Area are not included in the 2018 visitation estimates (USACE 2021d). iSportsman hunting data was not available for Cedar Bluff Reservoir. The assessment assumed that 1 percent of total visitation (1,823 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, 20 percent of that figure (365) accounts for wildlife viewing based on a FWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas[3] (USFWS 2017).

Cedar Bluff State Park is host to numerous special events. The biggest event is the annual OK Kids Day event. Cedar Bluff State Park also hosts campout events for Boy Scouts, Girl Scouts and 4-H clubs, family reunions, weddings, school field trips, and several fishing tournaments. In the past Cedar Bluff State Park has also hosted several concerts and outdoor festivals (USACE 2021d).

Sport Fisheries

This section provides a summary of sport fishing at Cedar Bluff Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (Appendix E). The general objective of fisheries management at Cedar Bluff Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. While Cedar Bluff Reservoir does not have a lake level management plan, the reservoir tends to be managed using a simple approach of obtaining and retaining as much as water as possible for as long as possible.

Cedar Bluff Reservoir anglers tend to be non-specific in terms of the types of species they prefer, fishing for species that can be harvested. Angler preference for a specific species often varies based upon changes in the availability of species that are affected by surface water fluctuation, with anglers fishing for species that dominate the reservoir at the time they are fishing. The top sport fish, in order of harvest, based on the most recent creel surveys, are bass, crappie, and walleye. Other sport fish in the reservoir include bluegill, black bullhead, channel catfish, flathead catfish, green sunfish, smallmouth bass, spotted bass, and wiper (hybrid striped bass). Largemouth bass were highly preferred by anglers in the 2003 creel survey because refilling of the reservoir in

the mid to late-1990's resulted in excellent black bass quality. Conversely, as the reservoir pool elevation declined through the 2000's and early 2010's, increased walleye recruitment promoted development of a population attractive to anglers. Regardless of the reservoir water level and relative sportfish population status, bass, crappie, and walleye are popular fisheries among Cedar Bluff Reservoir anglers in most years. Recent, lower rates of fish harvesting compared to historic levels are generally reflective of an increase in reservoir pool, which spreads out the existing fish population, resulting in reduced catch per unit effort by fishermen.

According to the most recent 2019 creel survey, total angler trips were estimated to be 26,008 (Appendix E). Angler effort (defined as angler-hours per acre) at Cedar Bluff often ranks in the 75 percentile or higher when compared to other Kansas reservoirs. Anglers typically come from western Kansas, with fishers from eastern Kansas and eastern Colorado frequenting the lake to a lesser degree.

Water inflows, drought conditions, sedimentation, and water quality impact angling preferences and fishing success. When past drought conditions have been accompanied by municipal requests to release water, the lake elevation has declined more quickly, which further decreases fish species reproduction when it has occurred in the past during the fish spawning season. Decreased fish reproduction in the past has negatively affected catch rates and total sport fishing catch. Historically, sedimentation caused docks to be silted in overtime at Cedar Bluff Reservoir, affecting angler access to the reservoir. Additionally, during low inflow conditions in the past, sedimentation has blocked inflows into the reservoir which further decreases low pool elevations. When this has occurred during the spawning season it has resulted in reduced recruitment and reproduction, reducing future fish catch rates. However, there have been no major historic issues with sedimentation directly impacting fish habitat and angling at Cedar Bluff Reservoir. As Cedar Bluff Reservoir has a low maximum release rate for water, high inflow events tend to raise the level of the reservoir, flooding terrestrial vegetation and positively impacting fisheries and angling success rates in the following years. Finally, Cedar Bluff Reservoir generally possesses adequate water quality to provide sportfish habitat and survival, with low turbidity, although there are some localized areas of degraded water quality due to vegetation decomposition during warm water periods. In general, water quality conditions and sedimentation have had minimal impacts on sport fishing at Cedar Bluff Reservoir (USACE 2021d).

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

During the drought of 2006, the pool at Cedar Bluff Reservoir was down 15 feet (KDWP 2006). Cedar Bluff State Park staff have adapted to reoccurring drought conditions and have sought out new opportunities during low water conditions. As water levels fall, some boat ramps and beach areas become unusable. However, as the levels fall other boat ramps and beach areas become usable. Typically, the visitation to Cedar Bluff State Park mirrors the rise and fall of the water levels of the reservoir. As the lake rises, visitation is higher and vice versa (USACE 2021d).

Cedar Bluff Reservoir began rising in late May of 2018 and throughout most of 2019. By the end of 2019 the reservoir had risen over 16 feet in elevation. When this rise in elevation began, Cedar Bluff Reservoir was almost 27 feet below top of multipurpose

pool. Even with the rise in water level, the reservoirs elevation never approached flood pool. The visitation was higher over this time period (4 percent higher compared to 2018) because several other reservoirs in the state were flooding and were closed or partially closed to recreation. None of the recreational facilities were damaged in the rise of water levels at Cedar Bluff State Park. However, the shoreline access for fishing was limited due to the rise in elevation (USACE 2021d).

Cedar Bluff State Park has not been impacted beyond minor localized effects by sediment issues (USACE 2021d).

Groundwater mining from the Ogallala Aquifer to supply water for agricultural irrigation, principally occurring from 1960 to 1980 has led to decreased flow in the Smoky Hill River Basin in Western Kansas (Buchanan et al. 1998). The reduced flow has resulted in a widely fluctuating reservoir pool. Reallocation of stored water in Cedar Bluff Reservoir has reduced water withdrawals such that evaporation and seepage are the two primary losses of water from the reservoir pool. These reductions in inflow combined with decreased discharge, results in a slow water level decline punctuated by periods of water level stability during most years. Net water level decline is generally the norm. However, cyclic periods of increased precipitation that occur approximately every 20 to 30 years, result in localized flooding that substantially increases reservoir pool elevation (Appendix E).

Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Cedar Bluff Reservoir. Working with the KDWP fisheries experts, critical lake elevations for recreation were identified at Cedar Bluff Reservoir as well as the corresponding impacts to visitation. These lake elevations are used to qualitatively assess the impacts to visitation and economic benefits under FWOP conditions for Cedar Bluff Reservoir.

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7944 *Table 3-106. Critical Lake Elevations for Recreation at Cedar Bluff Reservoir[1]*

Lake Elevations	<2,095 feet	2,095–2,115 feet	2,115–2,125 feet	2,125-2,144 feet; multi-purpose pool is 2,144 feet	2,144–2,155 feet	>2,155 feet
Visitation Impacts	1 boat ramp usable. Shoreline access dependent on road availability.	3-4 ramps useable. Shoreline access dependent on road availability.	4 boat ramps usable. Shoreline access dependent on road availability.	6-7 boat ramps usable. No shoreline access issues. Permanent infrastructure opportunities are maximized.	2 boat ramps available at the upper end of elevations. Shoreline access dependent on water inundation as levels increase.	No boat ramps available. Much of the permanent infrastructure is under water.
Quality of Recreation Effects	Boating access is very limited. Large expanses of sandy shoreline exposed. Aquatic habitat becomes limited while terrestrial wildlife and habitat acreage increases. Remaining water becomes more turbid.	Boating access decreases as ramps become unusable with decreasing water levels. Aquatic habitat continues to decrease. Terrestrial habitat and wildlife opportunities continue to increase due to falling water levels.	Access to shoreline dictated by availability of roads. Aquatic habitat is decreased. Terrestrial habitat opportunities increase.	Very little access issues. Recreation opportunities maximized between 2135 and 2144. Aquatic and terrestrial habitat ideal.	At lower elevations within this range, park recreation opportunities are maximized. Aquatic wildlife habitat increases. Terrestrial habitat decreases.	Most park facilities closed as infrastructure becomes inundated. Boat access severely limited due to ramps under water. Aquatic wildlife habitat increased. Terrestrial wildlife habitat decreased.

7945 [1] The information in this table was developed with input from KDWP staff familiar with Cedar Bluff Reservoir. Lake elevations are in NVGD 1929.

7946 *Table 3-107. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations	<2,095 feet	2,095–2,115 feet	2,115–2,125 feet	2,125–2,144 feet; multi-purpose pool is 2,144 feet	2,144–2,155 feet	>2,155 feet
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

7947 The information in this table was developed with input from KDWP staff familiar with Cedar Bluff Reservoir. Lake elevations are in NGVD 1929.

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3.6.5.3.2 Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of HABs, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Cedar Bluff Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir. Many of the western reservoirs do not have sufficient inflows for there to be notable sediment impacts.

Recreation Facilities and Visitation

KDWP will continue to operate and maintain the existing recreation facilities at Cedar Bluff Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (182,261 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Cedar Bluff Reservoir is expected to realize continued pool wide elevation fluctuations. Withdrawal of water from the Ogallala aquifer and Smoky Hill River alluvium for agricultural irrigation at current rates, and continued encroachment of phreatophyte species along the riparian corridors of the river and associated tributaries, will likely decrease baseflow and subsequent inflow into the reservoir. This will likely widen the amplitude of reservoir pool elevation fluctuation and promote the probability of extreme pool dewatering.

Sport Fisheries

At reduced pool, decreased water quality and reduced habitat availability and diversity, limit sportfish population abundance and welfare. When Cedar Bluff Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited. During periods where water levels are higher in the multipurpose pool than on average shoreline access for fishing could be limited in the future similar to past example.

The stocking of intermediate-sized channel catfish will be continued in the future, if recent stockings reveal improvement of population abundance. Wiper fry will be stocked at a moderate rate, biannually, for the foreseeable future. Largemouth bass fingerlings will be stocked when trophic and habitat conditions resulting from substantial reservoir pool elevation increases occur.

The direction which angler use and visitation at Cedar Bluff takes is unclear, as changes in socio-economic factors greatly influence public involvement in angling. For example, increased participation of families in youth sporting activities reduces participation in angling. However, the unforeseen emergence and response to COVID-19 in 2020

greatly increased public participation in angling and other outdoor recreation at Cedar Bluff Reservoir during the 2020 visitation season.

Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Cedar Bluff Reservoir will be similar to past conditions with only minor localized effects by sediment issues.

Similar to past droughts staff will adapt where possible and look for new opportunities for visitors to still recreate at the reservoir. In the future during drought conditions some boat ramps and beach areas could become unusable, but others may become usable. Visitation will reflect the rise and fall of the water levels with higher visitation as the reservoir rises and lower when the reservoir falls. With climate change these rise and falls could be more frequent and prolonged leading to longer effects to recreation in the future.

Cedar Bluff Reservoir typically is not at top of multipurpose pool and often not into the flood pool during flooding conditions. Visitors will often come to the reservoir when other reservoirs have limited access. This is expected to continue in the future at Cedar Bluff Reservoir. In 2018, the revenues associated with Cedar Bluff Reservoir were $449,000.[12] At Cedar Bluff Reservoir in 2019, these revenues were $582,00, an increase of 17 percent from 2018 revenues due to increased visitation from higher multipurpose pool elevations and flooding events in the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent rises in the multipurpose pool which could lead to more increases in visitation with the higher multipurpose pool levels.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Tables 3-104 and 3-105 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region.

Water quality at Cedar Bluff Reservoir and expected future conditions related to water quality are included in Appendix E. Impairments associated with high phosphorus load and naturally occurring sulfate in the lake, naturally occurring metals, suspended solids and bacteria in the watershed will continue and potentially will decrease with the established TMDL. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

3.6.6 Solomon-Republican Regional Planning Area

The Solomon-Republican RPA is in the northern-central part of the state. The RPA includes Keith Sebelius Lake (Prairie Dog State Park), Kirwin Reservoir, Lovewell Reservoir, Waconda Lake (Glen Elder Dam), and Webster Reservoir. All of these reservoirs are managed by USBR, and all reservoirs include state parks, managed by KDWP, except for Kirwin Reservoir, which is encompassed by the Kirwin NWR,

[12]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.

managed by the (FWS). Figure 3-154 outlines the Solomon-Republican Regional Planning Area and its reservoirs.

Figure 3-154. Solomon-Republican Regional Planning Area



3.6.6.1 Keith Sebelius Reservoir (Norton Wildlife Area)

Norton Wildlife Area, located 3 miles southwest of Norton, comprises Keith Sebelius Reservoir and adjacent lands except for the Prairie Dog State Park and Federal Operation Areas (Figure 3-155). Generally located from north to south, Prairie Dog State Park (Figure 3-156), the Keith Sebelius Reservoir, and then the Norton Wildlife Area are all part of the features in this area. Technically, Keith Sebelius Reservoir is part of the Norton Wildlife Area.

3.6.6.1.1 Existing Conditions

Recreation Facilities and Visitation

In general, the lake offers water sports, picnicking, wildlife viewing, boating, fishing, camping, hiking, hunting, winter sports and RV access. The following recreational amenities are offered:

- Campsites
- Picnic Areas
- Cabins
- Boat Ramps
- Beach Area.

Total visitation at Prairie Dog State Park in 2018 was 161,734, although this estimate does not include hunting trips visitation to Norton Wildlife Area. Approximately 65 percent of the visitors participate in water-based visitation, including boating, swimming,

and angling, while 35 percent of visitors participate in shore-based activities, including camping, sight-seeing, and picnicking. The public lands manager at Keith Sebelius Reservoir estimates approximately 10,000 hunting and fishing visits to the lake annually. iSportsman hunting data isn't currently available for Keith Sebelius Reservoir. The study team assumed 1 percent of total visitation (1,617visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, it was assumed that 20 percent of that figure (323) accounts for wildlife viewing based on a FWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas[3] (USFWS 2017). Special Events at Prairie Dog State Park include bass fishing tournaments approximately twice a month with about 10 boats, Carp Derby twice a year with around 200 fish harvested, archery shoots once a month all summer, and 5K walk/runs 3 times a year averaging about 50 participants. Weddings and reunions ranging from 50 to 250 guests happen about once a month throughout the summer. OK Kids Day draws 650 adults and kids. Other draws include high school and elementary field trips, kayak races, and Adobe home tours year-round.

Figure 3-155. Keith Sebelius Reservoir Recreation Areas

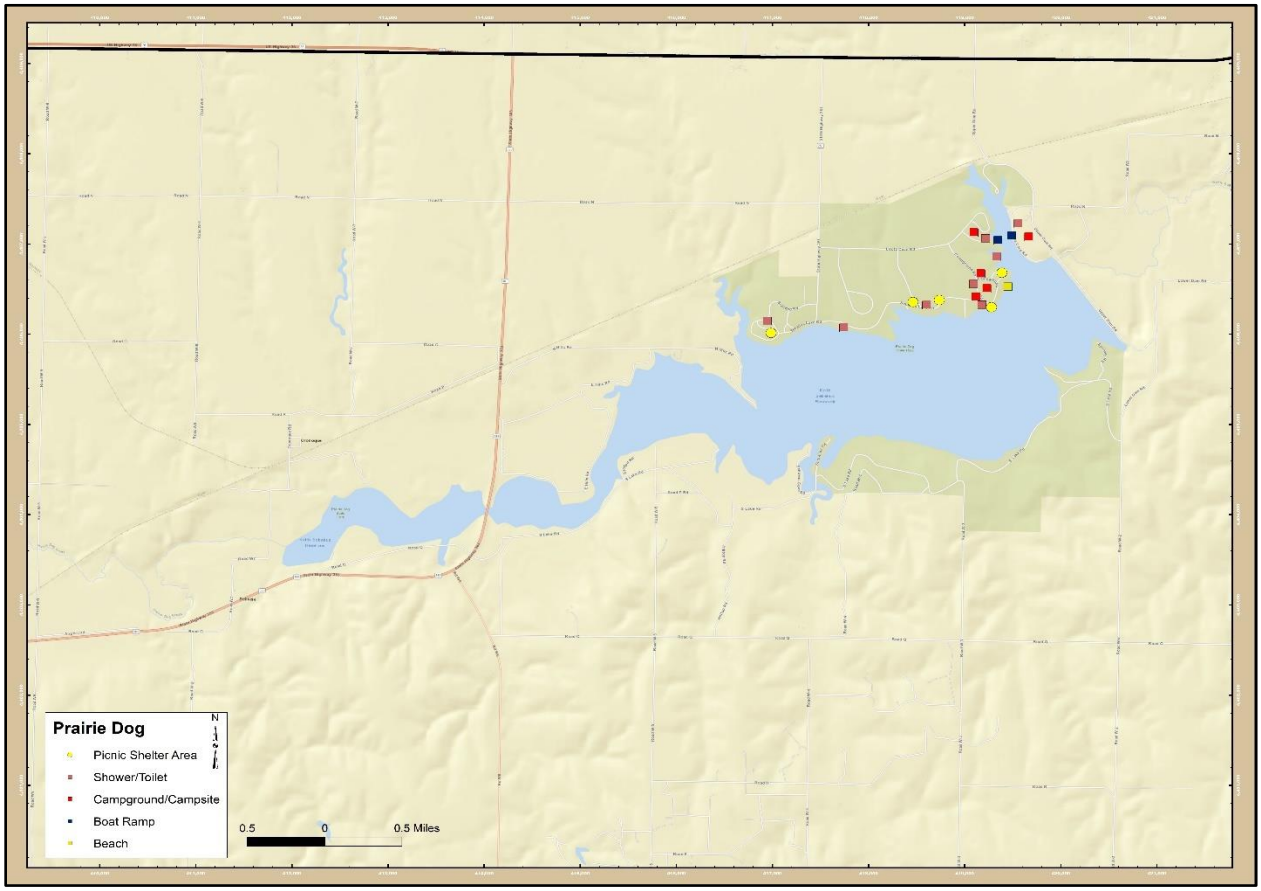

Figure 3-156. Prairie Dog State Park



Sport Fisheries

This section provides a summary of sport fishing at Keith Sebelius Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Fisheries management objectives are conducted to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality (Appendix E).

Keith Sebelius anglers tend to be non-specific in terms of the types of species they prefer, with 48 percent saying they have no fish preference (KDWP 2016). The top sport fish, in order of harvest, based on the most recent creel surveys is saugeye and wiper. Other sportfish at Keith Sebelius Reservoir include crappie, largemouth bass, channel catfish, flathead catfish, bluegill, black bullhead, green sunfish, smallmouth bass, and walleye (Appendix E). According to the last creel survey in 2016, the number of angler trips were estimated to be 15,950 (KDWP 2016). Typically, saugeye is mainly targeted by anglers in the spring and early summer, usually drawing big crowds. However, at Keith Sebelius Reservoir it appears that anglers are targeting them all year long and are the second most sought after species. Spotted bass along with the largemouth bass are a highly sought-after species at Keith Sebelius Reservoir. Thus, drawing a lot of bass club tournaments from all over Kansas and the surrounding states. Spotted bass numbers have steadily declined the last five years due to the water clarity during sampling and their ability to avoid sampling techniques. The third most sought-after

species is the wiper. Wiper numbers are typically relatively stable, and anglers are pretty good at catching them. Channel catfish, flathead catfish, black crappie, and white crappie are usually in the top four species that anglers target at Keith Sebelius Reservoir.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

In 2006, Kansas and other neighboring states experienced a severe drought. Reservoir storage in the multipurpose pool at Keith Sebelius Reservoir was very low. A minimum pool agreement with the local irrigation district kept the pool from going completely dry but the pool elevation was 18 feet below multipurpose pool (KDWP 2006).

Again in 2012, drought conditions caused the water level to decrease due to increased irrigation usage from the reservoir; the reservoir ranged from six to 10 feet below multipurpose pool. Visitation slowly decreased throughout the drought period as fishing and boating also decreased. According to an economic report written in 2018, the reservoir experienced droughts in 2011, 2012 and 2013. In January of 2013 the multipurpose pool was 48.1 percent full (KWO 2018).

While reservoir elevations at Keith Sebelius Reservoir are typically below top of multipurpose pool during years with high water conditions higher reservoir elevations can greatly increase recreational use and visitation. Keith Sebelius Reservoir increased about 8 feet in 2019 when the reservoir was about 12 feet below multipurpose pool at the time. According to USBR data, 2019 revenue was 25 percent higher than 2018, while visitation increased by 1 percent (KDWP 2018–2019).

Sedimentation within the reservoir has not had any noticeable effect on use or operations at the reservoir. There have not been any management actions needed to address issues associated with sediment.

Keith Sebelius Reservoir has had a HAB every year since blooms were first recorded in 2014 at the reservoir. The blooms usually last about three or four weeks and occur during June and July. Recreation and visitation doesn’t decrease much during HAB blooms; however, the beach is often closed to swimming and angling if the blooms become denser. In 2019 there was a watch in July and a warning in June, and there was a corresponding decrease in visitation in June compared to years without a HAB event.

Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Keith Sebelius Reservoir. Working with the KDWP fisheries experts, critical lake elevations for recreation were identified at Keith Sebelius Reservoir as well as the corresponding impacts to visitation. These lake elevations are used to qualitatively assess the impacts to visitation and economic benefits under FWOP conditions for Keith Sebelius Reservoir.

8140 *Table 3-108. Critical Lake Elevations for Recreation at Keith Sebelius Reservoir[1]*

Lake Elevations	<2,775 feet	2,775–2,280 feet	2,280–2,304 feet; multi-purpose pool is 2,304.3 feet	2,304–2,331 feet	2,331–2,341 feet	>2,341 feet
Visitation Impacts	There is no boating or water-based access; other shore visitation is decreased from lack of water access.	25% of boating access is available, all other recreation largely unaffected.	No access issues.	80% of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75% of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	No impacts	Safety becomes an issue for remaining visitors.	Closed

8141 [1] The information in this table was developed with input from KDWP staff familiar with Keith Sebelius Reservoir. Lake elevations are in NVGD 1929.

8142 *Table 3-109. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations	<2,775 feet	2,775–2,280 feet	2,280–2,304 feet; multi-purpose pool is 2,304.3 feet	2,304–2,331 feet	2,331–2,341 feet	>2,341 feet
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

8143 The information in this table was developed with input from KDWP staff familiar with Keith Sebelius Reservoir. Lake elevations are in NVGD 1929.

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3.6.6.1.2 Future Without Project Conditions

Recreation Facilities and Visitation

Keith Sebelius Reservoir has within its pool allocations a component for irrigation. If irrigation withdrawals continue, then the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least three to four feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool and has been down around 30 feet a few different times since construction.

When Keith Sebelius Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two. KDWP will continue to operate and maintain the existing recreation facilities at Keith Sebelius Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (161,734 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Sport Fisheries

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Keith Sebelius Reservoir.

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue into the future to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Keith Sebelius Reservoir (Appendix E). At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare.

While sedimentation will continue to occur (9.2 percent loss of the multipurpose over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Keith Sebelius Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future. Fisheries management objectives will continue to

optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fish species that inhabit Keith Sebelius Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Keith Sebelius Reservoir.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

While sedimentation will continue to occur (9.2 percent loss of the multipurpose [MP] over the next 50 years) the effects of sediment on recreation at Keith Sebelius Reservoir will be similar to past conditions with only minor localized effects by sediment issues.

Similar to past droughts water levels will decrease due to increased irrigation usage causing visitation to slowly decrease during drought periods and fishing and boating will decrease. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Keith Sebelius Reservoir typically is not at top of multipurpose pool and often not into the flood pool during flooding conditions. Visitors will often come to the reservoir when other reservoirs have limited access. This is expected to continue in the future at Keith Sebelius Reservoir. In 2018, the revenues associated with Keith Sebelius Reservoir were $201,124.[13] With expected climate prediction of more frequent extreme flood events this may lead to more frequent rises in the multipurpose pool which could lead to more increases in visitation with the higher multipurpose pool levels.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Tables 3-106 and 3-107 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region.

Water quality at Keith Sebelius Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus load and naturally occurring arsenic in the watershed will continue and potentially will decrease with the established TMDL. HAB will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

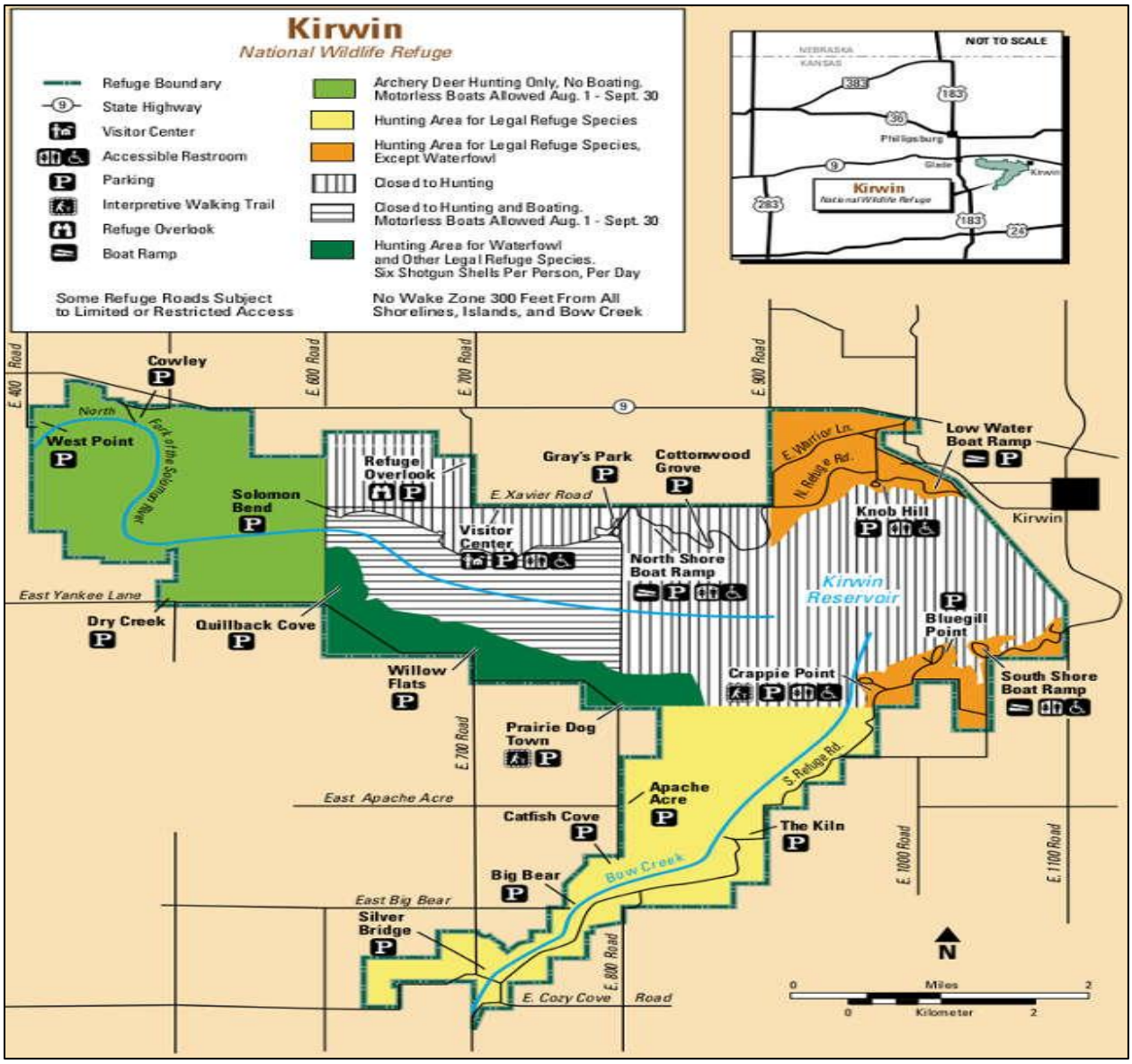
3.6.6.2 Kirwin Reservoir

Kirwin Reservoir is located 4 miles west and one mile south of Kirwin, Kansas, and 11 miles southeast of Phillipsburg, Kansas. Kirwin NWR surrounds Kirwin Reservoir; it was created as the first wildlife refuge in Kansas (established 1954). It offers year-round fishing, in addition to winter sports, boating, hunting and wildlife viewing. Kirwin Reservoir is managed by the USBR. The Kirwin NWR was established as an overlay project on the irrigation and flood control reservoir. U.S. Fish and Wildlife refuge staff

[13]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.

manage all activities on the reservoir and its surrounding lands, except for irrigation and flood control. The primary purpose of the Kirwin NWR is to provide nesting cover, food and shelter for songbirds, waterfowl, upland game birds, and mammals. The Kirwin NWR is displayed in Figure 3-157.

Figure 3-157. Kirwin Reservoir National Wildlife Refuge



3.6.6.2.1 Existing Conditions

Recreation Facilities and Visitation

There are three picnic areas and three boat ramps at Kirwin NWR. In 2017, total visitation was 134,309. Fishing activity alone accounted for 40,000 recreation visits, and boating accounted for 5,500 visits. (USFWS 2017). Hunting is allowed for legal refuge species in locations surrounding the reservoir.

Sport Fisheries

This section provides a summary of sport fishing at Kirwin Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Kirwin Reservoir is to optimize fishing opportunities by maintaining fish populations (Appendix E). Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

Kirwin Reservoir has within its pool allocations a component for irrigation withdrawals that can create wide fluctuations in water levels. Typically, the reservoir elevation drops at least 4 to 5 feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. Recent years have been wetter than normal, however, when it gets dry the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Kirwin Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two (Appendix E).

Kirwin Reservoir anglers tend to be pretty specific in terms of the types of species they prefer. According to 2018 creel results 84 percent of anglers had a preferred species (KDWP 2018). According to the most recent creel survey done in 2018 there were approximately 10,178 anglers at Kirwin Reservoir (KDWP 2018). The top sport fish, in order of harvest is white bass. Other sportfish at Kirwin Reservoir include crappie, largemouth bass, channel catfish, flathead catfish, bluegill, black bullhead, green sunfish, and walleye (Appendix E). White bass numbers are typically relatively stable, and anglers are pretty good at catching them. The second most sought after species are channel and flathead catfish. Their numbers typically stay relatively consistent, however, the population does better when the water elevations remain higher. Black and white crappie are also a popular species at Kirwin Reservoir, but the population is rather cyclical due to the reoccurring lowering of water levels for irrigation needs. Walleye and largemouth bass fishing also draws large numbers of anglers at the reservoir most of the year. Largemouth bass population numbers and angling success can be affected by low water elevations.

If the invasive species Phragmites increases at Kirwin Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Kirwin Reservoir has not been impacted by sediment with only localized sediment occurring causing minor impacts to recreation.

Irrigation releases from Kirwin Reservoir typically start in middle June and are not shut off until late August. Typically, the North Fork Solomon River and Bow Creek do not flow enough water to keep up with irrigation releases. As discussed under sportfish during drought conditions the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool and it has been down around 30 feet a few different times since construction. Once the reservoir gets this low it usually takes a significant rain event or series of events to get it back up to multipurpose pool. During the drought of 2006 Kirwin Reservoir was 23.9 feet below multipurpose pool (KDWP 2006). The area experienced additional droughts in 2012 and 2013. In January of 2013 the multipurpose pool at Kirwin was 68.1 percent full (KWO 2013).

Critical Lake Elevations for Recreation

Critical lake elevations for recreation were not available for Kirwin Reservoir. The impacts to visitation and economic benefits under FWOP conditions for Kirwin Reservoir were assessed qualitatively using information from past years when conditions created impacts to recreation.

3.6.6.2.2 Future Without Project Conditions

Recreation Facilities and Visitation

Kirwin Reservoir is authorized and operated to include irrigation storage. If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least three to five feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. There are typically no issues related to access for water and shore-based recreation from these drops.

When Kirwin Reservoir drops to lower pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two.

KDWP and FWS will continue to operate and maintain the existing recreation facilities at Kirwin Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (134,309 visitors annually).

Sport Fisheries

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Kirwin Reservoir are not expected to change in the

future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Kirwin Reservoir (Appendix E).

While sedimentation will continue to occur (2.4 percent loss of the multipurpose over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Keith Sebelius Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Kirwin Reservoir will be similar to past conditions with only minor localized effects by sediment issues.

In the future during drought conditions boating access could become limited and visitation for shore-based recreation would decrease from the lack of water access. Safety concerns for boaters also become an issue during drought and lower multipurpose pool elevations from unmarked underwater hazards. Extreme drops in water elevation in the multipurpose pool are likely to occur, in the future and may be as low as 15 to 20 feet below top of multipurpose pool or as low as 30 feet below similar to past conditions during drought. When these conditions occur, there is no boating access and shore-based visitation is reduced. Aesthetic values also could decrease dramatically as exposed shorelines grow. Visitation will reflect the rise and fall of the water levels with higher visitation as the reservoir rises and lower when the reservoir falls. With climate change the rise and falls could be more frequent and prolonged leading to longer effects to recreation in the future.

Kirwin Reservoir typically is not at top of multipurpose pool and often not into the flood pool during flooding conditions. With expected climate prediction of more frequent extreme flood events this may lead to more frequent rises in the multipurpose pool which could lead to more increases in visitation with the higher multipurpose pool levels.

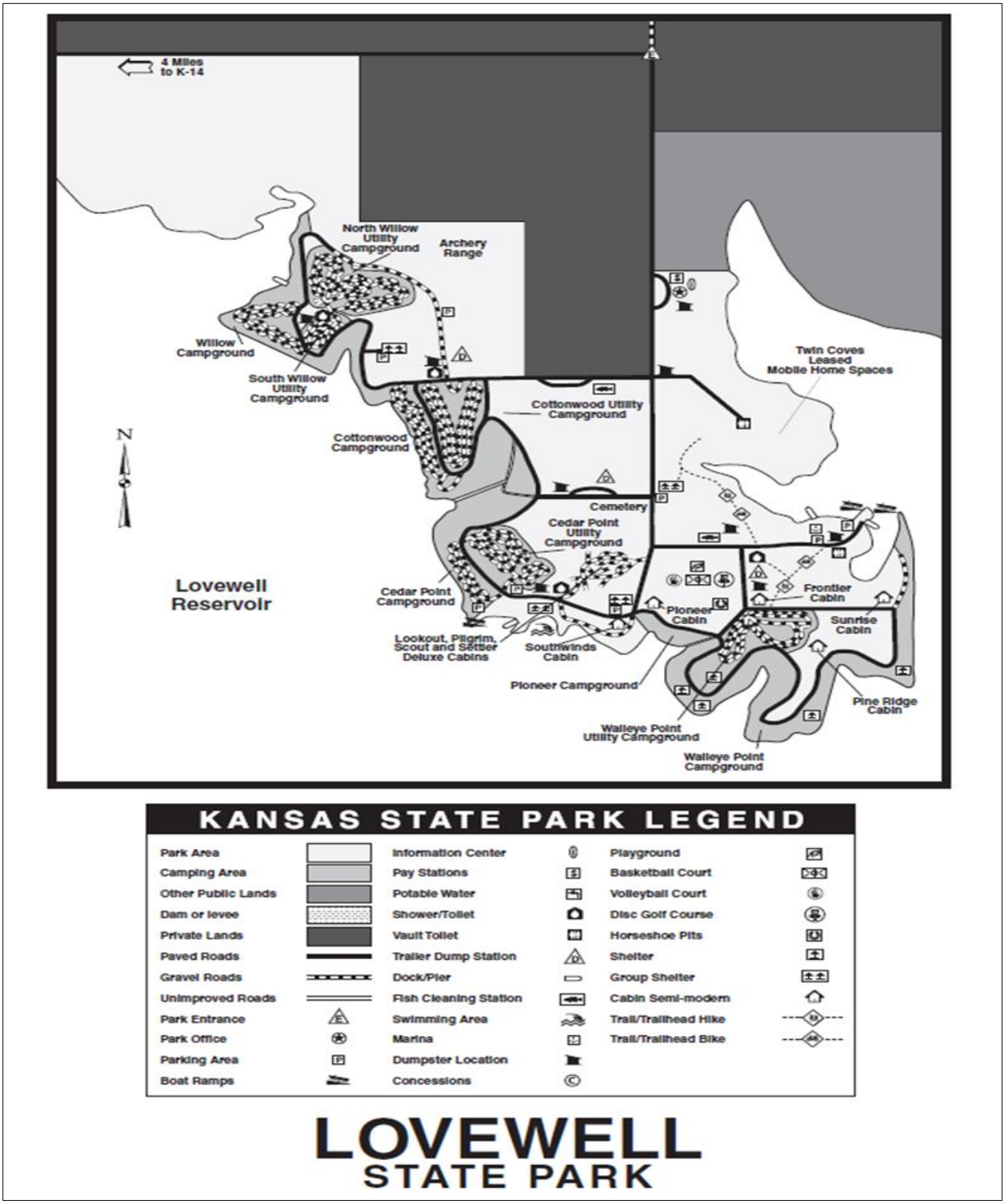
During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region.

Water quality at Kirwin Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments to Kirwin Reservoir and the Upper North Fork Solomon River are associated with nutrients and naturally occurring selenium in the watershed will continue and potentially will decrease with the established TMDL. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

3.6.6.3 Lovewell Reservoir

Lovewell State Park, surrounding Lovewell Reservoir, is in northcentral Kansas. Located 18 miles northeast of Mankato on US Hwy. 14, Lovewell is 6.4 miles south of the Nebraska/Kansas state line (Figure 3-158).

8370 *Figure 3-158. Lovewell Reservoir Recreation Areas*



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3.6.6.3.1 Existing Conditions

Recreation Facilities and Visitation

The reservoir offers boating, fishing (year-round), water sports, wildlife viewing, RV access, picnicking and hunting (recreation.gov). With 44 miles of shoreline, Lovewell State Park hosts the following recreational amenities (2020 Lake Report):

- Archery Range
- Disc Golf Course
- Beach
- Camping Cabins
- Campgrounds
- Campsites
- RV Hookups
- Mobile Home Site
- Picnic Area
- Boat Ramps.

The reservoir does host some annual events like the Lovewell Reservoir fun day in August, a campground Christmas (in August), a lake fireworks display, and a 3D archery shoot both in September.

In 2018, annual visitation to Lovewell Reservoir was 251,975 visitors. Approximately 65 percent of the visitors participated in water-based activities (swimming, angling, and boating) while 35 percent participated in shore-based activities. Approximately 65,000 additional visitors are associated with the Private Cabin Permit area. According to 2018 iSportsman data 0.5 percent of total visitation (1,261 visits with full compliance) is hunting within wildlife areas. Additionally, it is assumed that 20 percent of that number (252) accounts for wildlife viewing based on a FWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas[3] (USFWS 2017).

Sport Fisheries

This section provides a summary of sport fishing at Lovewell Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Lovewell Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities conducted include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construct fish attractors to enhance angler success, and maintain/improve angling access (Appendix E).

Angler effort (angler-hours/acre) at Lovewell Reservoir ranks anywhere from the 25th to the 75th percent when compared to other Kansas reservoirs depending on the year. Anglers hailing from the surrounding communities and Nebraska exert most of the pressure, with fishers from eastern Kansas and south-central Kansas frequenting the lake to a lesser degree (Appendix E). Lovewell Reservoir anglers tend to be opportunistic in terms of species they prefer to fish for. Angler preference for a specific

species often varies based upon changes in species dominance that result from water fluctuation history or recent recruitment. For example, no preference has been the most popular response when anglers are asked what they are fishing for in two of the past four surveys. The strong walleye population had anglers respond with that species most often in 2005 but walleye have declined to second during the past three surveys. Channel catfish are always found in the top four, ranging from first in 2011 to fourth in 2006 and 2015, depending on other opportunities. White bass are also a critical species for anglers and were in the top three during 75 percent of the surveys. Crappie numbers fluctuate more than most species and angler effort toward them is highly variable with this species only showing up in 2005. Many of the no preference anglers are likely “crappie fishing” but are happy to catch anything. The indiscriminate selection of target species has become more prominent as well with many anglers less focused on one species but rather preferring a mixed bag or taking advantage of whatever species is most readily available at the time. Lovewell Reservoir anglers tend to be harvest minded. White bass, channel catfish, and crappie comprise the largest contributions to angler's creel in most years.

The population dynamics of black crappie, bluegill, and white crappie have fluctuated based upon reservoir level history as recruitment is generally stable at a low level or during stable or declining water levels. However, there is a positive correlation between recruitment and reservoir level. Increased reservoir pool elevation will likely improve recruitment conditions that should increase abundance of black crappie, bluegill, and white crappie in the future. Lovewell Reservoir traditionally has a strong channel catfish population due to the high numbers of gizzard shad, abundant spawning and brood rearing areas, and relatively low angling pressure compared to other reservoirs. Channel catfish numbers have steadily increased since a low in 2014. Numerous upstream sources have likely contributed to the largemouth bass population, which is typically a low-density, high-quality population. Due to the annual water level fluctuations, habitat needed for proper largemouth bass recruitment and survival is limited and the population has never reached a desired number. Natural reproduction has not been sufficient to maintain a strong population of walleye, thus supplemental stocking is frequently utilized. Anglers will continue to realize a limited walleye population characterized by poor to fair recruitment but excellent growth rates. The future of walleye in Lovewell Reservoir is precarious and saugeye may be the better option given the habitat conditions and their ability to not flush from reservoirs during high release events. The white bass population has been good to very good over the past 15 to 20 years but the latest sample illustrated their numbers had declined. Lovewell dropped from 8th to 20th among the state’s reservoirs for white bass density and is ranked 19th for preferred fish. Wiper are a hybrid species requiring stocking on a regular basis to maintain population abundance. They have existed at a low-density population and supplement the white bass fishery by providing larger, trophy fish while also helping to control the gizzard shad population. Despite extensive stocking of fry and fingerlings, their numbers have never been extremely high as is the case in other Kansas reservoirs.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

During flood events, water levels have reached over seven feet above the top of the multipurpose pool four times including 1,589.8 feet (NVGD 29) in 1987, 1,590.7 feet (NGVD 29) in 1974, 1,591.6 feet (NGVD 29) in 1993, and the highest recorded level was 1,593.0 (NGVD 29) feet in 2019, 10.4 feet above conservation. Flooding in the summer of 2019 caused impacts for recreation, limiting access to the lake and recreational activities, and causing HABs. Visitation was 11 percent lower in 2019 compared to 2018 (KDWP 2018–2019). Vehicle revenues were down 10 percent overall, however daily vehicle permit sales were down over 20 percent, mostly due to the flooded conditions in 2019 and lack of access to day use areas for the summer season. Camping revenues were also down in 2019. This also has a direct effect on state park visitation and the economy surrounding the reservoir. Special Event permit revenues decreased approximately 30 percent compared to recent years, due to the flooding conditions.

Because water can be diverted from the Republican River, Lovewell Reservoir does not experience long-term drought conditions like other reservoirs in the area. The area suffered a drought in 2012 and 2013; the multipurpose pool was 67.3 percent full in January of 2013 although recreational access was not affected. Lovewell Reservoir has not had sedimentation issues that affect recreation.

HABs are occasionally an issue at Lovewell Reservoir. In 2015 there were three warnings in June and July, and in 2019 there were two in July and August. These warnings seemed to have more of an impact on visitation in 2015, corresponding to a 9 percent and 66 percent decrease in visitation compared to averages during June and July respectively. No monthly decrease in visitation was observed during the HAB warnings in 2019.

Lovewell Reservoir is expected to continue a similar water level fluctuation pattern soon as irrigation to meet farmland requirements both above and below the reservoir remains of upmost importance. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Lovewell Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Lovewell Reservoir. Working with the KDWP fisheries experts, critical lake elevations for recreation were identified at Lovewell Reservoir as well as the corresponding impacts to visitation. These lake elevations are used to qualitatively assess the impacts to visitation and economic benefits under FWOP conditions for Lovewell Reservoir.

Table 3-110. Critical Lake Elevations for Recreation at Lovewell Reservoir[1]

Lake Elevations	<1,571.7 feet	1,571.7–1,582.6 feet	1,582.6–1584.1 feet; multi-purpose pool is 1,582.6 feet	1,584.1–1,589.1 feet	1,589.1–1,595.3 feet	>1,595.3 feet
Visitation Impacts	There is limited to no boating or water-based access; other shore visitation is decreased from lack of water access.	25 percent of boating access is available; all other recreation largely unaffected.	No access issues.	100 percent of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75 percent of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	No impacts	Safety becomes an issue for remaining visitors.	Closed

[1] The information in this table was developed with input from KDWP staff familiar with Lovewell Reservoir. Lake elevations are in NGVD 1929.

Table 3-111. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<1,571.7 feet	1,571.7–1,582.6 feet	1,582.6–1584.1 feet; multi-purpose pool is 1,582.6 feet	1,584.1–1,589.1 feet	1,589.1–1,595.3 feet	>1,595.3 feet
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

[1] The information in this table was developed with input from KDWP staff familiar with Lovewell Reservoir. Lake elevations are in NGVD 1929.

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3.6.6.3.2 Future Without Project Conditions

Recreation Facilities and Visitation

KDWP will continue to operate and maintain the existing recreation facilities at Lovewell Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (251,975 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Lovewell Reservoir is expected to continue a similar water level fluctuation pattern as irrigation to meet farmland requirements both above and below the reservoir will remain of upmost importance. Changes are being made to improve the efficiency of the water delivery system which should take some strain off the water volume requirements. Other discussions have been ongoing regarding future alternatives to water storage including raising the multipurpose pool of Lovewell Reservoir to increase water volume or construction of another reservoir in the area for additional water storage. These options continue to be discussed but no decisions have been finalized. When Lovewell Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

Sport Fisheries

At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. The stocking of fry, fingerling, and intermediate-sized walleye will continue annually to boost recruitment and supplement the limited natural reproduction which occurs. Blue catfish were stocked for five years but are now set to expand with natural reproduction and will not be stocked again. Wiper fry, fingerlings, and intermediates are also stocked annually to maintain this aggressive predator. Saugeye are thought to have the potential to recruit, grow, and survive in Lovewell Reservoir compared with their walleye cousins and may be stocked in the future. With Milford Reservoir downstream containing a viable walleye population, special care must be considered before adding a new species to the watershed. This potential new stocking will continue to be evaluated and ideally a solution that can improve the Lovewell Reservoir fishery while also maintaining the Milford Reservoir fishery can be agreed upon.

The direction which angler use and visitation at Lovewell Reservoir takes is unclear, as changes in socio-economic factors greatly influence public involvement in angling. For example, increased participation of families in youth sporting activities reduces participation in angling. However, the unforeseen emergence and response to COVID-19 greatly increased public participation in angling and other outdoor recreation at Lovewell Reservoir during the 2020 season.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Lovewell Reservoir will be similar to past conditions with only minor localized effects by sediment issues. Sediment will continue to accumulate in Lovewell Reservoir with an expected additional 2.2 percent loss of the multipurpose pool over the next 25 years (2049) and 4.1 percent loss over the next 50 years (2074) (Appendix D).

While Lovewell Reservoir typically does not experience long-term drought conditions similar to past droughts water levels will decrease due to increased irrigation usage causing visitation to slowly decrease during drought periods and fishing and boating could decrease. Impacts to recreation can occur when reservoir elevations are below top of multipurpose pool with reduced boating access and limited water recreation and limited to no boating access when elevations are 17 feet below top of multipurpose pool. Safety also becomes an issue during these conditions from underwater hazards. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Lovewell Reservoir has experienced impacts during past flooding events with higher pool elevations that caused impacts to recreation and damages to recreation infrastructure. These impacts are expected to continue in the future at Lovewell Reservoir during high flood pool conditions. Impacts from reduced access for boating and shore-based recreation start at approximately seven feet above top of multipurpose pool and above 1,595.3 feet (NGVD 29) all recreation is closed at the reservoir. In 2018, the revenues associated with Lovewell Reservoir were $565,400.[14] At Lovewell Reservoir in 2019, these revenues were $567,400, an increase of less than 1 percent from 2018 revenues. During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Tables 3-108 and 3-109 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent impacts to recreation and damages to recreation infrastructure.

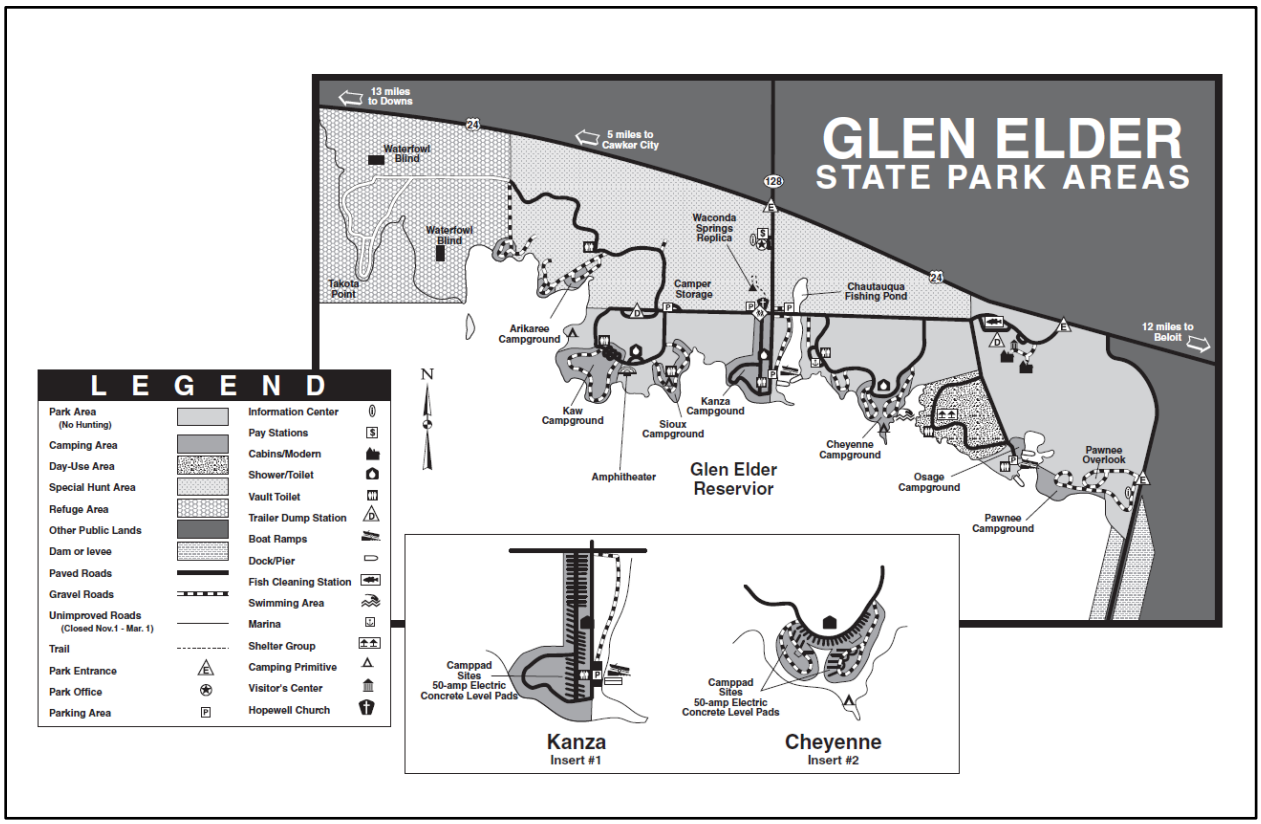
Water quality at Lovewell Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus load and naturally occurring arsenic and selenium in the watershed will continue and potentially will decrease with the established TMDL. HAB will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

3.6.6.4 Waconda Reservoir

Waconda Reservoir and State Park is located one mile west of Glen Elder, Kansas near highway US 24 (Figure 3-159). The lake was built in 1968 for irrigation, flood control, and recreation. Because the irrigation district below the reservoir was never fully established, the demand for water for irrigation is lower than other western Kansas lakes, and the water level has historically remained relatively stable. Waconda Reservoir has 100 miles of shoreline; Glen Elder State Park is located on the northeastern shore of Waconda Reservoir. Glen Elder Wildlife Area encompasses almost 13,200 land acres surrounding the lake. The reservoirs, state park, and wildlife area offer numerous recreational amenities such as boating, camping, fishing, hunting, picnicking, RV access, water sports and wildlife viewing.

[14]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.

Figure 3-159. Waconda Reservoir Recreation Areas



3.6.6.4.1 Existing Conditions

Recreation Facilities and Visitation

Glen Elder State Park/Waconda Reservoir includes the following recreational amenities:

- Utility Campsites
- Primitive Campsites
- Boat Ramps
- Cabins

Annual visitation at the State Park was 201,962 visitors in 2018, while visitation at the wildlife area was estimated to be 5,978 hunting and wildlife viewing visits (iSportsman, 2021; USFWS, 2017). Visitation at Glen Elder State Park has increased over the past two decades. At Glen Elder State Park, trends in state park data over the past 16 years (2023–2022, excluding 2019–2021) indicate increasing visitation at approximately 1.5 percent per year.

According to USBR, approximately 75 percent of the visitors participate in water-based activities (swimming, angling, and boating) while 25 percent participate in shore-based activities. The wildlife area has many different access points around the lake including public hunting fields and a few small campgrounds. Glen Elder State Park hosts many events throughout the year, including the Youth Fishing Tournament, Youth and Women's Pheasant Hunt, Lakefest, many fishing tournaments, weddings, archery

shoots, family reunions, Boy Scout/Girl Scout events, school field trips, and outdoor concerts. This wide range of events is everything from small gatherings to large gatherings. Some of the park hosted events that provide meals, drinks, and prizes to youth (KDWP 2020c).

Sport Fisheries

This section provides a summary of sport fishing at Waconda Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Specific fisheries management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, constructing fish attractors to enhance angler success, and maintaining and improving angling access (Appendix E). The Waconda Reservoir lake level management plan identifies the need to increase the water levels between April and June to support nursey habitat.

Waconda Reservoir anglers tend to be opportunistic and based on fish availability and water level fluctuation. The last two creel surveys conducted in 2014 and 2019 indicated that most anglers take advantage of whatever species is most readily available at the time. White bass, channel catfish, and crappie comprise the largest contributions to angler's creel in most years (Appendix E).

According to the last creel survey conducted in 2019 there were approximately 43,568 anglers at Waconda Reservoir (Appendix E). Waconda Reservoir is expected to realize fairly stable water levels as it lies on the on the western edge of the wetter portion of the state that provides adequate rainfall to maintain water levels at the reservoir. Periods of extended drought force the water level to decline 2 to 5 feet occasionally, but outside of extreme drought situations, water is abundant. River inflow is steady enough to maintain most water levels. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Waconda Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited. (Appendix E).

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Like other reservoirs in the state, Waconda Reservoir saw an increase in water elevation in late May 2019. According to USACE existing conditions modeling, the reservoir rose 8 feet above the top of multipurpose pool between early May to June in 2019. The state park was closed as roads were under water, and campers would not have a safe access route within the campground. Water levels remained high, maintaining closures within the park through Labor Day, causing a decline in visitation and entrance fees and revenues. Approximately 80 percent of the primitive areas were flooded or closed due to no road access. The flood conditions of 2019 had an impact on visitation; visitation was down 14 percent compared to 2018 levels (KDWP 2020c).

In 2006, 2007, 2012 and 2013 the area suffered a drought. In 2012, water levels were low due to drought conditions and boat access became limited with decreases in vitiation during these conditions. The multipurpose pool at Waconda Reservoir was fuller than many of the other reservoirs in the region at 85 percent full in January of

2013. In 2006, Waconda Reservoir was down 7.7 feet, which was extremely low for the lake (KDWP 2006).

Waconda Reservoir and Glen Elder State Park have not experienced many issues with sedimentation, besides impacts to fish habitat and other issues after flooding events when flood waters recede. At Waconda Reservoir and Glen Elder State Park sedimentation impacts sport fisheries habitat by making certain areas shallower resulting in less habitat for fish. The Osage boat ramp is the main boating access area where sediment can build up and remain after flood waters recede.

Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Glen Elder State Park/Waconda Reservoir. KDWP fisheries experts identified critical lake elevations for recreation at Glen Elder State Park/Waconda Reservoir. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. Future reservoir sedimentation for Waconda Reservoir and any impacts to recreation are described in Appendix F.

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Table 3-112. Critical Lake Elevations for Recreation at Glen Elder State Park/Waconda Reservoir[1]

Lake Elevations	<1,445.6 feet	1,445.6–1,453 feet	1,453–1,457 feet; multi-purpose pool is 1,455.6 feet	1,457–1,461.6 feet	1,461.6–1475.6 feet	>1,475.6 feet
Visitation Impacts	There is no boating or water-based access; other shore visitation is decreased from lack of water access.	25 percent of boating access is available, all other recreation largely unaffected.	No access issues.	80 percent of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75 percent of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	No impacts	Safety becomes an issue for remaining visitors.	Closed

[1] The information in this table was developed with input from USACE and KDWP staff familiar with Waconda Lake. Lake elevations are in NGVD 1929.

Table 3-113. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<1,445.6 feet	1,45.6–1,455.6 feet	1,455.6 feet; multi-purpose pool is 1,455.6 feet	1,455.6–1,461.6 feet	1,461.6–1475.6 feet	>1,475.6 feet
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	60%	10%	0%	0%	75%	100%

[1] The information in this table was developed with input from USACE and KDWP staff familiar with Waconda Lake. Lake elevations are in NGVD 1929.

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3.6.6.4.2 Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. The FWOP scenarios that include navigation releases are considered in Appendix F. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Appendix F, respectively.

Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Two years were chosen to evaluate flood conditions (2055, 2097), with average annual elevations above 1,461 feet (NGVD 29), when significant impacts to recreation can occur. The modeled year 2023, corresponding with 2019, was also included; average annual elevations in 2123 were modeled to be 1458 feet (NGVD 29) although the water surface elevations were considerably higher in after May. Three drought periods were chosen to evaluate drought conditions, with average annual elevations below 1,453 feet (NGVD 29). See Tables 3-110 and 3-111 for a description of impacts to recreation at different lake elevation thresholds. Typical years include all other years.

Flood years include:

- 2055 (1951)
- 2097 (1993)
- 2123 (2019).

Drought years include:

- 2029–2030 (1925–1926)
- 2059–2060 (1955–1956)
- 2110–2111 (2006–2007).

Sediment conditions at Waconda Reservoir/Glen Elder State Park have not recently had impacts to recreation at Waconda Reservoirs, although sedimentation can reduce the amount of fish habitat, notably after flood events. The Osage boat ramp is the main boating access area where sediment can build up and remain after flood waters recede.

Appendix F shows the depths of Waconda Reservoir at multi-purpose pool under FWOP conditions in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years). During typical precipitation conditions (at multi-purpose pool), the USACE sediment modeling indicates that the boat ramps at Glen Elder State Park (marina and Osage Campground) would provide boating access in the future and would not be largely impacted by sediment. The sediment modeling indicates that the largest impacts from deposition would occur in the northwestern portion of the reservoir (Glen Elder State Park is located in the northeastern portion of the reservoir).

During drought conditions, the effects of sediment deposition on recreational access could become more severe as decreasing water surface elevations reduce the depths of the lake (see description on water surface elevations). In addition, boating safety concerns and obstacles are more pronounced with a shallower lake. During flooding conditions, sediment deposition affects the operations of the reservoir and in general can increase water surface elevations as sediment fills the pool over time.

Water surface elevations at Glen Elder State Park/Waconda Reservoir are generally higher in the future with increasing sediment deposition in the lake. Table 3-112 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake is slightly less than a foot higher in 2049 and 2074 compared to 2024 conditions. In 2124, Tuttle Creek Lake is just under one foot higher than under the FWOP 2024 scenarios without navigation releases. Additional information is provided in Appendix B.

Table 3-114. Average Water Surface Elevations at Glen Elder State Park/Waconda Reservoir

FWOP Scenario	Average Water Surface Elevations	Change in Average Water Surface Elevations from 2024 (feet)
2024	1455.16	-
2049	1455.24	0.08
2074	1455.31	0.15
2124	1455.46	0.30

Note: The top of the multi-purpose pool is 1,455.6 feet (NGVD 29).
Represents average across the period of record.

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions. During drought conditions, on average in 2029, 2030, 2059, 2060, 2110, and 2111, pool levels in 25 years (2049) are approximately 0.4 feet higher, while in 50 and 100 years, pool levels are between 0.7 feet to 1.3 feet higher than under 2024 FWOP conditions.

Table 3-115. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	+0.36	+0.03
2074	+0.70	+0.16
2124	+1.29	+0.13

Note: The top of the multi-purpose pool is 1,455.6 feet (NGVD 29).

During the 2060-2061 drought period, similar to those experienced in the mid-1950s, under the FWOP 2024 scenarios, the pool is between 1,453 and 1,448 feet (NGVD 29) (from two to six feet lower than the top of multi-purpose pool) between January 2060 and until June 2061 when it rises back to multi-purpose pool level. Future sediment deposition in 2049 and 2074 increases pool elevations up to one foot higher compared to FWOP 2024 scenarios, while sediment conditions in 2124 FWOP scenarios increase pool elevations by up to two feet during this drought period.

During the 2110-2111 drought period, similar to those experienced in the 2006-2007, under the FWOP 2024 scenarios, the pool is between 1,452 and 1,450 feet (NGVD 29) (from four to eight feet lower than the top of multi-purpose pool). Future sediment deposition in 2049 and 2074 increases pool elevations up to two feet higher compared to FWOP 2024 scenarios, while sediment conditions in 2124 FWOP scenarios increase pool elevations by up to four feet during this drought period.

Under three notable high water or flood periods over the 100-year period of analysis, on average, water surface elevations are less than 0.2 feet higher under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between 2123 water surface elevations and FWOP 2024 water surface elevations can be up to two feet higher. At peak water surface elevations in the modeled years of 2055 and 2123, there are higher water surface elevations under future scenarios; the modeled year of 2097 shows minimal differences water surface elevations at peak pool levels.

The worst flood year in terms of visitation was in 2055 (1955) when, during the year, water surface elevations were above elevation 1,475 feet (NGVD 29) (see threshold table in existing conditions section) for 99 days under 2024 and 2049 FWOP scenarios; there is only a few days of difference when compared to 2074 and 2124 scenarios. In general, Glen Elder State Park/Waconda Reservoir is closed to most visitation when water surface elevations are 1,475 feet NGVD 29.

Changes in Visitation

This section describes how changes, lake elevations, and sediment conditions can potentially impact visitation. Relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 209,300 people visited recreation areas that are potentially impacted by lake elevations, including Glen Elder State Park. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Waconda Reservoir, including visitation to the wildlife area. In 2018, visitation across Glen Elder State Park/Waconda Reservoir, including the wildlife area, was estimated to be 215,200.

In most cases across the Kansas River Basin, visitation across the lakes has been fairly stable over the past 20 years. However, Glen Elder State Park is experiencing an increase in visitation, which has implications to future visitation, consumer surplus, and regional economic impacts.

Although sediment affects water surface elevations, the sediment modeling indicates that it is not notably affecting the two boat ramps at Cheyenne and Osage Sediment under the FWOP scenarios (Appendix F). However, increased sediment accumulation along with flood conditions could impact accessibility of these boat ramps more frequently and severely in the future during flooding conditions. With stable lake elevations anticipated in the future, Glen Elder State Park and Waconda Reservoir are

anticipated to continue to draw people to the lake, approximately 215,200 visitors per year (2018 levels).

At Glen Elder State Park, trends in state park data over the past 16 years (2023-2022, excluding 2019-2021) indicate increasing visitation at approximately 1.5 percent per year. If past trends continue in the future, in 75 years, visitation would be close to twice as much as under baseline conditions, although many factors that are difficult to predict can affect future visitation (for example, price of gas, reservoir conditions, economic cycles, availability of alternative recreation areas, etc.). Only reservoir water surface elevations are included in the modeling of visitation.

Slightly higher water surface elevations under the FWOP 2049, 2074, and 2,124 scenarios contribute to slightly higher visitation under these scenarios. Compared to FWOP 2024 modeled visitation during “typical conditions” of 195,500 (excludes the wildlife area), visitation would increase by 1,200, 1,800, and 2,700 visitors per year on average under typical precipitation conditions under FWOP 2049, 2074, and 2,124 scenarios, respectively.

During drought conditions, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (up to eight feet lower than multi-purpose pool during the 2110–2111 drought period) and considerably below thresholds important for recreation (1,453 feet) for part of this period. In drought conditions, consistent with mid-2000s water conditions, most water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. Multiple years with low water levels can impact the fishery, with additional impacts to anglers and fishing success.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2110-2111, modeled after mid-2000s drought conditions, visitation at Glen Elder State Park would be 105,400, a reduction of approximately 103,900 visitors from 2018 baseline conditions at Glen Elder State Park (Appendix F). The drought period 2029 to 2030 (modeled after 1920s conditions) would have similar impacts to visitation, while conditions in 2059 to 2060 (modeled after the mid-1050s conditions) would have fewer impacts to visitation compared to the other two drought periods.

Under the FWOP 2049, 2074, and 2124 scenarios, slightly higher water surface elevations would increase accessibility at Waconda Reservoir, with higher visitation compared to FWOP 2024 visitation, an estimated increase of 2,700, 9,200, and 23,600 visits per year during these drought conditions, respectively.

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at Glen Elder State Park (Appendix F). A reduction in visitation at Waconda Reservoir would be most sever in in 2055, consistent with conditions experienced in 1951, indicates a potential visitation decrease of 57 percent compared to baseline conditions at Waconda Reservoir (2018).

Under the FWOP 2049, 2074, and 2122 scenarios, water surface elevations during the three flood events are up to four feet higher compared to FWOP 2024, leading to more closures and reduced visitation. Compared to FWOP 2024 scenarios, visitation during these flood events would on average be 1, 3, and 5 percent lower under FWOP 2049, 2074, and 2124 scenarios, respectively. The most pronounced impacts would occur in the 2055 event, leading to an additional annual reduction in visitation of 1,000, 1,200, and 1,600 visitors compared to FWOP 2024 visitation under FWOP 2049, 2074, and 2124 scenarios.

Changes in Economic Benefits

As described previously, trends in state park data over the past 16 years (2003–2022, excluding 2019–2021), indicate increasing visitation at approximately 1.5 percent per year. If past trends continue in the future, in 75 years, visitation would be close to twice as much as under 2018 baseline conditions. These future increases in visitation will have implications to consumer surplus and regional economic benefits if these factors influencing visitation are not being captured in the modeling effort, with the potential for more than twice the 2018 consumer surplus value under the FWOP 2124 scenario as estimated. However, many factors that are difficult to predict can affect these values (for example, price of gas, reservoir conditions, economic cycles, availability of alternative recreation areas, etc.). Consistent with visitation in 2018, 215,300 visitors to Glen Elder State Park and the wildlife area support 78 jobs and $2.2M in labor income in the local economy; 209,300 visitors at Glen Elder State Park support 62 jobs and $1.7M in labor income.

- Typical Precipitation Conditions
  - Consumer Surplus

    Under stable reservoir elevations, visitation consistent with 2018 baseline conditions would continue to support consumer surplus values, of approximately $1.7M at Glen Elder State Park and the wildlife area.
  - Regional Economic Benefits

    Under stable reservoir elevations, visitation consistent with 2018 baseline conditions would be expected to continue to support regional economic benefits in the local economy surrounding Glen Elder State Park and the wildlife area, estimated to be 78 jobs and $2.2M in labor income.
- Drought Conditions
  - Consumer Surplus

    The impacts to visitation during an extreme drought would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2110 and 2111 (modeled after mid-2000s conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately $800,000 annually (Appendix F). These

reductions in consumer surplus represent an annual decrease of 50 percent compared to 2018 baseline conditions at Glen Elder State Park.

Under the FWOP 2049, 2074, and 2124 scenarios, slightly higher water surface elevations would increase accessibility at Waconda Reservoir, with higher consumer surplus, an estimated increase of 2 percent, 7 percent, and 21 percent during these drought conditions compared to FWOP 2024 levels, respectively.

- Regional Economic Benefits

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2110 to 2011 (modeled after mid-2000s conditions), reduced visitation would lead to a potential loss of 31 jobs and $865,000 in labor income during drought conditions under 2024 FWOP compared to baseline conditions at Glen Elder State Park (Appendix F). There would be similar impacts under FWOP 2049, 2074, and 2124 conditions. These reductions in economic benefits impacted by changes in lake elevations represent a 39 percent decrease in jobs from total jobs supported from all visitor spending at Waconda Reservoir under baseline conditions (78 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

- Flood Conditions
  - Consumer Surplus

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between $540,000M and $945,000M in consumer surplus values, representing a decrease between 34 and 59 percent of total consumer surplus at Glen Elder State Park under baseline conditions (Appendix F).

Under the FWOP 2049, 2074, and 2122 scenarios, water surface elevations during the three flood events are up to four feet higher compared to FWOP 2024, leading to more closures, reduced visitation and consumer surplus values. Compared to FWOP 2024 scenarios, consumer surplus values during these flood events would on average be 1, 3, and 5 percent lower under FWOP 2049, 2074, and 2124 scenarios, respectively. The most pronounced changes in consumer surplus values compared to FWOP 2024 values would occur in the 2124 event, leading to an additional annual reduction of $26,000, $50,000, and $86,000 in consumer surplus values under FWOP 2049, 2074, and 2124 scenarios, respectively.

  - Regional Economic Benefits

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of up to 40 jobs and $1.1M in labor income, representing a decrease up to 50 percent of total jobs supported by visitor spending at Waconda Reservoir under baseline conditions (Appendix F).

- Damages, Revenues, and Fees to States

Visitation to Glen Elder State Park contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Glen Elder State Park were $317,992.[15] At Glen Elder State Park in 2019, these revenues were $297,964, a reduction of 6 percent from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in $31.2M in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 48 percent of baseline conditions (2018), while flooding impacts would have slightly larger impact, impacting up to 57 percent of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure ($1,500) associated with damage from the 2019 flood at Glen Elder State Park include damages to docks, campsites, and parking lots. These damages are likely to continue to occur in the future with extreme events.

Water Quality

All reservoirs in the basin, including Waconda Reservoir, will likely experience increasing effects of aging. Future water quality within the basin lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40 percent of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The

[15]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

KDA (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued and enhanced water quality impairment may be expected at Waconda Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Waconda Reservoir. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the basin. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at basin reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication.

Waconda Reservoir is associated with high phosphorus from inflows captured by eutrophication sulfates. Waconda Reservoir has relatively high total phosphorus mean, which is the primary cause of eutrophic conditions leading to increased algal production. Similarly, mean chlorophyll concentrations are also considered eutrophic (KDHE 2003a). In addition, total nitrogen mean value at Waconda Reservoir exceeded the EPA Ecoregional Recommended Criteria (EPA 2001). However, HAB warnings have not been issued by KDHE in recent years.

Although HAB warnings have not been issued for Waconda Reservoir in recent years, deteriorating water quality could eventually lead to increased prevalence of HABs in Waconda Reservoir with adverse impacts to visitors in the future. Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Waconda Reservoir. Extreme or persistent HAB conditions can also deter visitors from coming to the lake.

Angling and Sport Fishery

In the future, Waconda Reservoir is expected to have fairly stable water levels as it lies on the western edge of the wetter portion of the state that currently provides adequate rainfall to maintain the water level. Water levels play a crucial role in fish production and angler participation, affecting state park visitation and the local economy surrounding the reservoir. Generally, Waconda Reservoir possesses adequate water quality to promote sportfish survival during typical precipitation conditions, and turbidity at the lake falls within the ideal range for Kansas reservoirs. These conditions are anticipated to continue in the future, supporting fish habitat and angler visitation.

However, periods of extended drought generally force a decrease in the water surface elevations from 2 to 5 feet. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Waconda Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited. Specific conductivity and total dissolved solids are normally high and become extremely concentrated as the reservoir volume decreases. The stress on the fishery is likely to continue in the future with drought conditions, with adverse impacts to fishing success for anglers, decreased angler visitation, and reduced regional economic benefits to adjacent communities; climate change may cause more severe and frequent drought events, increasing the likelihood of these conditions in the future.

In addition, sediment will continue to accumulate in Waconda Reservoir with an expected additional 13 percent loss of the multipurpose pool over the next 25 years (2049), 20 percent loss over the next 50 years (2074), and further sediment deposition expected over 100 years (Appendix D). Many sportfish such as walleye, white bass, black bass and Centrarchid sportfish prefer to deposit eggs on clean, larger-grain substrates to avoid suffocation of eggs by silt. Thus, availability and diversity of rock substrate is important to successful reproduction of these and other fish species. Silt deposited in Waconda Reservoir from sedimentation can reduce the diversity of rock substrate in the reservoir affecting reproduction of fish species that rely on this habitat. Loss of fish habitat is anticipated to continue into the future with increasing sediment deposition, with the potential for reduced fishing success for anglers.

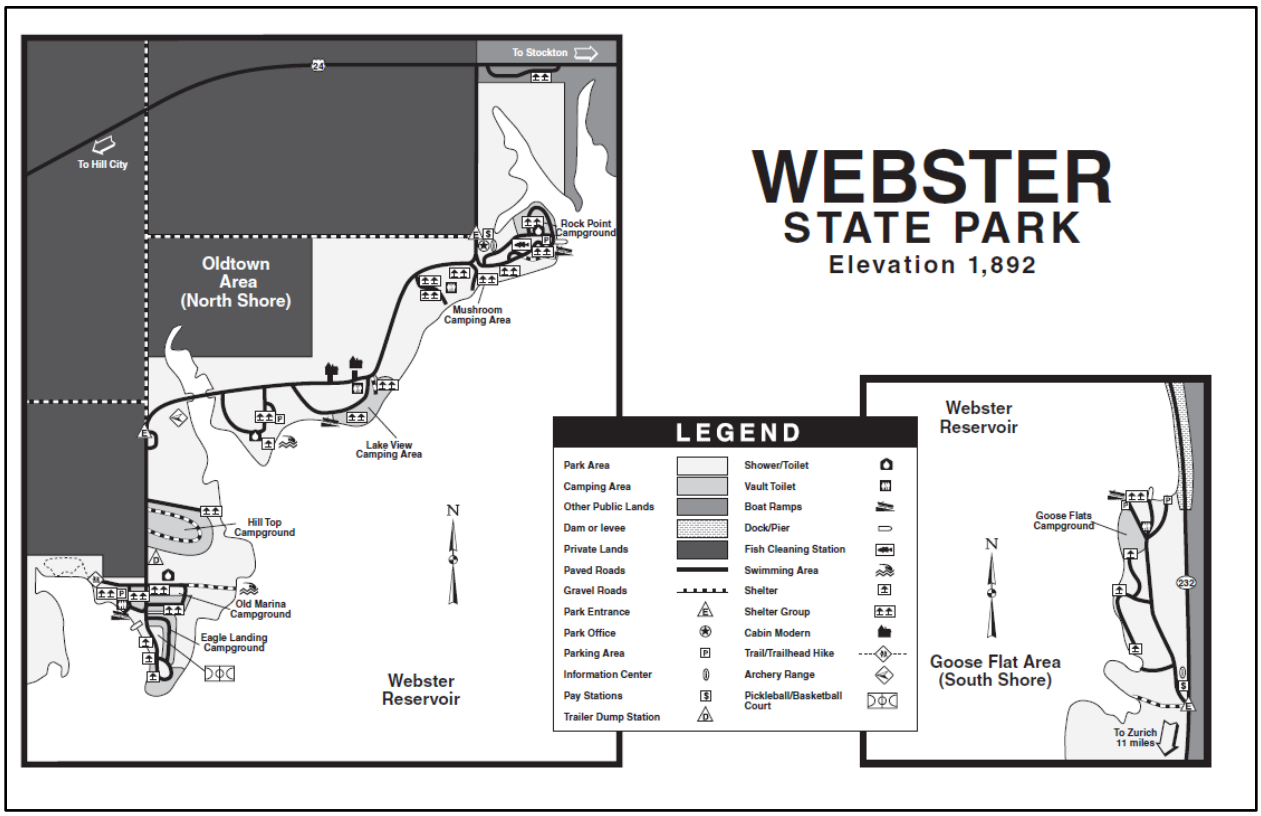
3.6.6.5 Webster Reservoir

Webster Reservoir is located eight miles west of Stockton, Kansas between Woodston and Osborne, Kansas on the South Fork of the Solomon River (

Figure 3-160). Webster State Park is an 880-acre prairie setting of rolling hills, and visitors often see deer, turkeys, quail, pheasants, and many wildflowers. The 3,700 acres of open water offer many fishing opportunities in Webster Reservoir. Located in the central flyway, the lake is a stopping place for many species of waterfowl and shorebirds and offers opportunities for outdoor enthusiasts for hunting, wildlife watching, and photography.

Webster Wildlife Area encompasses 8,018 acres mostly surrounding the Solomon River west of Webster Reservoir. At the Wildlife Area, a variety of wildlife habitats are maintained to enhance wildlife. The lake is known for its walleye, crappie, white bass, and channel catfish.

Figure 3-160. Webster Reservoir Recreation Areas



3.6.6.5.1 Existing Conditions

Recreation Facilities and Visitation

Webster Reservoir offers 50 miles of shoreline and the following recreational amenities: boating, camping, fishing, hunting, water sports and picnicking. Specifically, the area offers:

- Campgrounds
- Campsites
- Picnic Areas
- Beaches
- Boat Ramps
- Private Cabins (administered by KDWP on USBR property).

The KDWP is also responsible for administering the contract for eight private cabins that are located on USBR property. In 2018, visitation to the area was 102,522 visitors. This visitation estimate does not include visits to the private cabin areas and the wildlife area. iSportsman hunting data isn't currently available for Webster Reservoir. It is assumed that 1 percent of total visitation (1,025 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, it is assumed that 20 percent of that number (205) accounts for wildlife viewing based on a FWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas[3](USFWS 2017).

Approximately 65 percent of the visitors to the lake participate in water-based activities (swimming, angling, and boating) while 35 percent participate in shore-based activities. Webster Reservoir hosts numerous events throughout the year. These events include fireworks displays and activities for children. Some smaller events are the Webster Car Show and Stockton Cross Country race. Webster State Park also hosts campout events for Boy Scouts, Girl Scouts and 4-H clubs, and family reunions, weddings, school field trips and several fishing tournaments.

Sport Fisheries

This section provides a summary of sport fishing at Webster Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (Appendix E). The general objective of fisheries management at Webster Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends), stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access (Appendix E).

Reservoir sportfish species accounts and factors affecting their abundance and distribution are included below. It is notable that inherent variability exists in statistics generated from fish population sampling efforts. Changes in reservoir water level, abundance and distribution of flooded terrestrial vegetation, turbidity or lack thereof, etc. can alter fish behavior and feasibility of deploying sampling gear, thus potentially increasing variability of sampling results. As a result, sampling results must be viewed with a degree of skepticism, require interpretation by workers utilizing the data, and often require a series of greater than one year for representative trends to become apparent (Appendix E).

According to the last creel survey, the number of angler trips in 2017 was estimated to be 12,937 (Appendix E). Walleye are the first most sought after species, according to the last creel survey conducted in 2017. The species is highly sought after and grow rather quickly. Black and white crappie are the second most sought after species. The crappie population is rather cyclical, due to the fact that Webster Reservoir is an irrigation reservoir. When the water level is around multipurpose pool (1,892.45 feet [NGVD 29]) they do rather well, however, when the elevation gets below 1,884 feet (NGVD 29) they suffer. Crappie habitat improved considerably over the last four years as the reservoir elevations rose and remained around multipurpose pool or slightly above multipurpose pool during crappie spawns. Channel catfish and flathead catfish both occur in Webster Reservoir and are usually in the top four species that anglers target. Channel catfish numbers typically stay relatively consistent. However, the population typically does better at the higher water elevations than they do at the lower elevations. Flathead catfish are also sampled and usually occur in lower numbers than channel catfish. White bass are the fourth most sought after species. White bass numbers are typically relatively stable, and anglers are pretty good at catching them. There is no creel limit, and they grow rather quickly, thus, enticing anglers of all ages and gender.

If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Webster Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two. While sedimentation will continue to occur (3.3 percent loss of the MP over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Webster Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future. Fish species that inhabit Webster Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Webster Reservoir.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

During the 2018 and 2019, Webster Reservoir recreational facilities were affected by flooding. Both years, the water level reached approximately seven feet above multipurpose pool. Once water levels reach 2.1 feet above multipurpose pool, the Rock Point utility campground and Lakeview primitive campground and road are affected; the main park road must close at 5.5 feet above multipurpose pool. In 2018, Rock Point campground and Lakeview primitive campground/road was closed for 1.5 months, and the main park road was closed for 13 days. In 2019, Rock Point Campground and Lakeview primitive campground/road was closed for 4.5 months total on two different occasions, and the main road was closed for 1.5 months. Four areas required rip rap for shoreline stabilization: Old Marina, the road east of the archery range, Lakeview and Goose Flats (Webster Annual Report 2020). Despite this, visitation increased by 30 percent overall compared to 2018. This was driven by a very large increase in the fall (September–December) of 127 percent (USACE and KDWP 2018–2019).

Webster State Park is not heavily impacted by sediment, as an irrigation lake, it gets drawn down regularly. Occasionally, sediment will accumulate when the water levels are low, but there is little impact to recreation.

It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool and it has been down around 30 feet a couple different times (1972 and 1992) since construction. Once the reservoir gets this low it usually takes a significant rain event or series of events to get it back up to multipurpose pool. The area experienced a drought in 2012 and into 2013. In 2012, even though the reservoir water levels were relatively low, visitation and annual fees and revenues were some of the highest recorded at Webster State Park. Historically, water levels are positively correlated with visitation; water levels increase, and visitation also increases. In 2012, the reservoir during peak season ranged from three feet to 12 feet below multipurpose pool, which is a common level, and all facilities and boat access points were usable. The multipurpose pool was 47.7 percent full in January of 2013.

More recently, HABs have also had a potential impact on visitation. During a “HAB watch,” park users are advised that HABs have been seen and may still be present and to use caution when getting in the water. Typically, after watches have been announced, day use slows although camping reservations are not typically affected. When a HAB “warning” is announced, the swimming beach is closed and contact with water must be avoided. HAB warning levels significantly decrease day use and camping reservations. In 2018, Webster had three closures in June and August, the only lake in the Kansas River Basin to experience closures from HAB hazards in 2018. There were HAB warnings in July, September and October, and visitation fell by 21 percent, 50 percent, and 43 percent respectively compared to monthly averages. There were HAB closures in June and August, and visitation dropped 7 percent and 39 percent respectively compared to monthly averages. Overall visitation dropped by 15 percent compared to 2017. In 2020 a HAB watch was issued in July and remained in effect until early September. The watch was lifted, only to be reinstated in mid-September and lifted in late September (Webster Annual Report 2020).

Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Webster Reservoir. KDWP fisheries experts, critical lake elevations for recreation were identified at Webster Reservoir as well as the corresponding impacts to visitation. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife.

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9176 *Table 3-116. Critical Lake Elevations for Recreation at Webster Reservoir[1]*

Lake Elevations	<1,860 feet	1,860–1,869 feet	1,869–1,879.6 feet; multipurpose pool is 1,892.45 feet	1,879.6–1,894.4 feet	1,894.4–1,896.3 feet	>1,923.7 feet
Visitation Impacts	There is no boating or water-based access; other shore-based visitation is decreased from lack of water access.	25 percent of boating access is available with limited water recreation, all other recreation largely unaffected.	No access issues	Low access issues	Main road is closed below the bait shop, boat ramps access is limited; 75 percent of lake shore access is closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	Boating access becomes affected at the upper end of this elevation range	25 percent of primitive camping affected in the State Park at the bottom end of this elevation. Safety becomes an issue.	Closed

9177 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Webster Lake. Lake elevations are in NGVD 1929.

9178 *Table 3-117. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations	<1,860 feet	1,860–1,869 feet	1,869–1,879.6 feet; multipurpose pool is 1,892.45 feet	1,879.6–1,894.4 feet	1,894.4–1,896.3 feet	>1,923.7 feet
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	50%	0%	0%	0%	75%	100%

9179 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Webster Lake. Lake elevations are in NGVD 1929.

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3.6.6.5.2 Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of HABs, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Webster Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir.

Recreation Facilities and Visitation

KDWP will continue to operate and maintain the existing recreation facilities at Webster Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (102,522 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Webster Reservoir is expected to continue a similar water level fluctuation pattern as irrigation to meet farmland requirements both above and below the reservoir will remain of upmost importance. When Webster Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

Sport Fisheries

At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Webster Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two.

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Webster Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Webster Reservoir.

Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Webster Reservoir will be similar to past conditions with only minor localized effects by sediment issues. Sediment will continue

to accumulate in Webster Reservoir with an expected additional 2.2 percent loss of the multipurpose pool over the next 25 years (2049) and 3.3 percent loss over the next 50 years (2074) (Appendix D).

Similar to past droughts water levels will decrease due to increased irrigation usage causing visitation to slowly decrease during drought periods and fishing and boating could decrease. Impacts to recreation can occur when reservoir elevations are more than 23 feet below top of multipurpose pool with reduced boating access and limited water recreation. Safety also becomes an issue during these conditions from underwater hazards. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Webster Reservoir typically can experience long periods of drought that can occur over multiple years when the water elevations are substantially below the top of multipurpose pool and often when high inflows occur it does not cause water elevations into the flood pool. Similar to other reservoirs in this part of the basin visitors will come to the reservoir when other reservoirs have limited access. However, Webster Reservoir has experienced impacts during past flooding events with higher pool elevations that caused impacts to recreation and damages to recreation infrastructure. These impacts are expected to continue in the future at Webster Reservoir during high flood pool conditions. Impacts from reduced access for boating and shore-based recreation start at approximately two feet above top of multipurpose pool and above 1923.7 feet all recreation is closed at the reservoir. In 2018, the revenues associated with Webster Reservoir were $217,027.[16] At Webster Reservoir in 2019, these revenues were $267,647, an increase of 19 percent from 2018 revenues due to increased visitation from higher multipurpose pool elevations and flooding events in the region.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Tables 3-114 and 3-115 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent impacts to recreation and damages to recreation infrastructure.

Water quality at Webster Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus and sediment load and naturally occurring sulfate and selenium in the watershed will continue and potentially will decrease with the established TMDL. HAB will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

3.6.7 Harlan County

The Harlan County Reservoir includes a dam and a reservoir of 13,250 acres and 75 miles of shoreline located in Harlan County in south-central Nebraska (Figure 3-161). Its

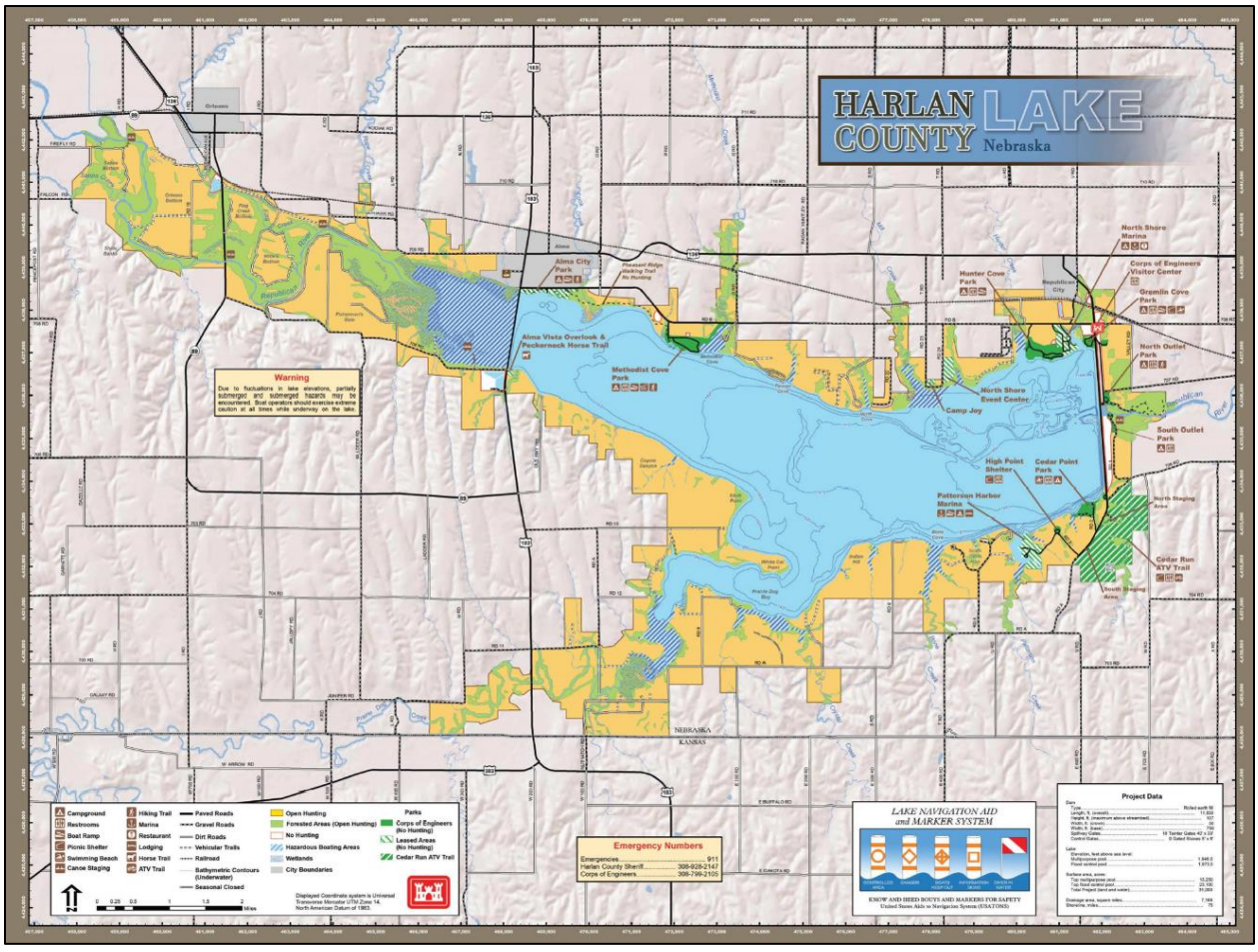
[16]These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.

southernmost part extends into northern Phillips County, Kansas. Harlan County Lake is located seven miles from the Nebraska/Kansas state line and 60 miles south of Kearney, Nebraska, a town of approximately 30,000 residents. Harlan County Reservoir is Nebraska's second largest lake.

Harlan County Reservoir has two marinas that are adjacent to full-time trailer courts. This creates a small-town experience on USACE lands. Both areas have over 100 trailers, over 100 campsites, restaurants, as well as the marina. Patterson Harbor also has cabins that can be leased. USACE manages and maintains all parks/recreation areas except for the marina which is privately run (USACE 2021e).

There are several housing developments that are adjacent to USACE property at Harlan County Reservoir hosting second homes for many in the region. One community, Republican City, Nebraska, has over 50 percent of the residences owned by people from the area (USACE 2021e).

Figure 3-161. Harlan County Reservoir Recreation Areas



3.6.7.1 Existing Conditions

3.6.7.1.1 Recreation Facilities and Visitation

Harlan County Reservoir offers a variety of recreational amenities, including:

- Boat Ramps
- Visitor Center
- Swimming Areas
- Marinas
- Playgrounds
- ATV Trails
- Picnic Areas/Shelters
- Campsites
- Fish Cleaning Stations
- Trails (walking, biking, horseback)
- Alma City Park.

Visitation in 2018 was 921,938 visitors (USACE VERS). The area's most popular recreation areas in 2018 were North Shore Marina and Patterson Marina representing 28 percent and 24 percent of total visitation, respectively (2018 USACE VERS). In terms of activities, camping and water-contact activities were the most popular representing 25 percent and 20 percent of all activities, respectively. Angling and boating accounted for 7 percent and 12 percent of total activities at the reservoir in 2018. Hiking, jogging, sightseeing and picnicking accounted for 28 percent of activities at the reservoir (2018 USACE VERS). Float trips using tubes and canoes is a popular sport below the dam at Harlan County Reservoir, attracting about 1,000 people a day during the summer. The study team has assumed that 1 percent of total visitation (8,181 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, it is assumed that 20 percent of that figure (1,636) accounts for wildlife viewing based on a FWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Nebraska[3] (USFWS 2017).

There are three large fishing tournaments in May and June that draw many visitors on a consistent basis. The City of Alma, Nebraska puts on a 4th of July-road race, parade, and firework show at Harlan County Reservoir. These special events accounted for 2 percent of activities in 2018.

3.6.7.1.2 Sport Fisheries

This section provides a summary of sport fishing at Harlan County Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Current fisheries management activities include fish stocking, fishery surveys, fishing regulations, angler access improvements, aquatic habitat restoration, and outdoor education. Priority management species for the Harlan County Reservoir sport fishery, determined by population histories and angler preferences, are walleye, white bass, and channel catfish. Wipers are managed as a species with trophy potential with a low-density population goal. Crappie, largemouth bass, and northern pike are typically included in sport fishery management details when the reservoir is at higher elevations (1,940 msl and above).

Based on creel surveys at Harlan County Reservoir walleye, white bass, channel catfish make up the majority of fishing trips, comprising 84 percent of the total trips on average. The average annual percentages for angler trips seeking walleye, white bass, and channel catfish were 31 percent, 39 percent, and 14 percent, respectively. Average annual trips for anglers seeking walleye, white bass, and channel catfish were 8,533, 11,768, and 3,556, respectively. For walleye, the long-term averages for annual catch and harvest were 12,748 and 2,834, respectively. Walleye catch and harvest were low from 2008 to 2010, but generally increased since 2010 (Appendix E).

With wide fluctuating water levels associated with drought periods and contrasting high inflows, reservoir waters levels have varied greatly over time. Some fish species temporarily benefit from water level patterns experienced at Harlan County Reservoir. When years of drought and low reservoir water levels are followed by high inflows and high reservoir water levels, shoreline-oriented species such as largemouth bass and crappie benefit from an abundance of flooded shoreline terrestrial vegetation. Many coves at Harlan County Reservoir have experienced major shoreline erosion where they connect to the reservoir and are now separated from the main reservoir during lower water level periods. Coves with major erosion problems include Bone, Indian, Methodist, Prairie Dog, and Tipover Coves. USACE dredging operations are used to maintain connection to the main reservoir at Gremlin and Patterson Coves and provide access for all boating activities. The USACE has placed rock on shorelines at Gremlin, Methodist, and Patterson Coves to protect public access and campground resources.

Large water level fluctuations are likely to continue as this reservoir serves multiple purposes including reducing flood risk and providing irrigation. These circumstances create challenges at low water levels including reduced connectivity with cove habitat, which reduces spawning and rearing habitat for shoreline orientated species such as crappie, largemouth bass, and bluegill. Low water levels can also increase the chances of HABs and fish kills while decreasing user access and recreational opportunities. Extremely high-water levels (above multipurpose pool) can present challenges as well including excessive shoreline erosion and damage to infrastructure such as breakwaters, fishing piers, and boating access developments. Harlan County Reservoir is also used as the storage reservoir for water dedicated to the Republican River compact between Colorado, Nebraska and Kansas, which tends to lead to increased water releases during the time of the year when small fish are vulnerable to entrainment.

Addressing erosion and disconnection of cove habitat has been a priority at Harlan County Reservoir. For example, a large aquatic habitat project was completed in 2012-2013 at Gremlin and Patterson Coves, which included bank stabilization, protection breakwaters, dredging, and angler access improvements. This project was planned and funded by NGPC through the Aquatic Habitat Program. A second aquatic habitat project was initiated in 2022 and is currently in the planning phases with USACE Continuing Authorities Program (CAP) Section 1135 Ecosystem Restoration funding. This goal of this project is to improve habitat and connectivity at Methodist Cove, which is located on the northwest edge of the reservoir.

The introduction of invasive species is also a concern at Harlan County Reservoir. Although zebra and quagga mussels have yet to be detected in Harlan County

Reservoir, these invasives are common in nearby Kansas reservoirs posing a potential future threat to the aquatic resources, infrastructure, and recreational opportunities in this reservoir. Continued monitoring and outreach/education efforts will be important for minimizing the potential for future introductions.

3.6.7.1.3 Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Harlan County Reservoir is a fairly flat-bottomed lake, so even small elevation changes result in large drops in surface areas. On average, the lake drops four to eight feet per year from what is considered normal pool elevation. However, during droughts the pool can decrease from 10 to 12 feet over multiple years. These low elevations can result in visitation to the lake dropping by up to 50 percent. The shorelines surrounding the lake are essentially all composed of loess material, and continued erosion and sedimentation have closed off most of the natural coves.

Drought conditions can impact recreation and irrigation activities at Harlan County Reservoir and downstream, as seen during the drought of 2012. When Harlan County Lake water levels are low, fish species are unable to reach the coves which provide critical spawning and rearing habitat. Low water conditions are typical as the lake is within a region with low average annual rainfall and during periods of use for irrigation water supply. Low water conditions are negatively affecting the abundance of fish species (USACE 2020). Boater access and shifts in usage patterns are a challenge during drought years, like 2012. The boat ramps in Hunter Cove, Methodist Cove and the City of Alma become unusable during these low water conditions. To mitigate the lack of access, low water ramps have been built in both Cedar Point and Hunter Cove. Dredging has allowed for boating access at both Gremlin and Patterson coves down to the minimum pool level. Harlan County Reservoir has a congressionally authorized cutter head dredge that is used to remove sediment in these areas. Dredging can only be completed during very specific lake levels, limiting the ability to mitigate these adverse effects. Harlan County Lake is legally bound to a minimum elevation of 1927 feet.

Due to the spring flood event in 2019, the lake was above multipurpose pool for over 100 days, with a max crest of 10 feet above top of multipurpose pool (USACE 2020). Due to high water and erosion a tremendous amount of silt washed into boat ramp areas and channels. Areas affected include Patterson, Methodist, Hunter, and Gremlin coves. Irrigation releases impact the viability of tubing below the dam, which are controlled by the USBR. Water levels at or above 600-700 cfs can be dangerous, as can levels below 200-250 cfs. The campground at Methodist Cove, was closed from July 6th for the remainder of the season in 2019. Additional closures occurred in Hunter Cove, Gremlin Cove, and Cedar Point. In addition, the North Shore Marina was closed in the beginning of July as well. This marina has a considerable impact on overall visitation as there are 135 full time trailer homes, 150 campsites, a large restaurant and marina store. Overall, the 2019 flood contributed to a 15 percent decline in visitation compared to 2018. This was driven by 25 percent decrease in the winter (January–April) and a 16 percent decrease in the summer (May–August) (USACE and KDWP 2018–2019).

Shortly following dam closure in 1951 wave action in the new lake environment began eroding loess soils along the new shoreline and depositing sediment into the lake. Wind, waves, and water current patterns transport eroded sediments throughout the lake resulting in the sedimentation of several cove entrances, making access to these coves during low water periods difficult to impossible for both fish and boats (USACE 2020). Sedimentation in coves and marinas has also impacted fish habitat and visitation. Drought conditions can shift silt around and fill in coves in the lake. At about six feet below the multipurpose pool most coves lose recreational access. Sediment impacts water-based visitation the most, especially angling opportunities due to loss in spawning habitat. Sediment deposition occurs primarily from shoreline erosion of areas surrounding the reservoir. Congress approved a dredge for Harlan County in the 1970s just to keep marinas, coves, and boat ramps open, and it has been used on average every two to three years. All cove access is now completely blocked in areas that have not been dredged (USACE 2021e).

There are some HAB impacts at Harlan County Reservoir. Health alerts have been issued at the reservoir twice in the past ten years, in 2013 and 2019. The average concentration of microcystin typically peaks in early July before releases from the reservoir increase for downstream irrigation needs (Boyer 2021). HABs are not considered an ongoing issue at Harlan County Reservoir, despite the lake having high nutrient levels compared to lakes in Kansas. Most blooms are short lived and can be shifted quickly by wind gusts or flushed out by irrigation releases. When HAB blooms do occur, appropriate signage is posted in affected areas. Lake managers have indicated that they observe lower visitation during HAB events.

3.6.7.1.4 Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Harlan County Reservoir. Working with the USACE lake staff and NGPC fisheries experts, critical lake elevations for recreation were identified at Harlan County Reservoir as well as the corresponding impacts to visitation. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife.

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9448 *Table 3-118. Critical Lake Elevations for Recreation at Harlan County Reservoir[1]*

Lake Elevations	<1,933 feet	1,933–1,942 feet	1,942–1,948 feet; multi-purpose pool is 1,945.7 feet	1,948–1,952 f–t	1,952–1,955 feet	>1,955 feet
Visitation Impacts	Only boater access available at Cedar and Hunter low water ramps; other shore visitation is decreased from lack of water access. Vegetation on exposed lakebed limits activity.	Primary ramp at Hunter is unavailable at 1,942 feet. Methodist boat ramp is inaccessible at 1,935 feet and no access to the west end of the lake is available.	No access issues – All ramps open.	All boating access is available; shoreline use is limited to a few areas in coves, most beach access is gone.	Boat ramps become inaccessible; 100 percent of lake shore access closed.	Boat access is “Use at Own Risk” or out of marina slips.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface. All coves close off that are not maintained by dredging.	No impacts	Jetties at Methodist begin to go under water. Patterson and Gremlin jetties go underwater.	Safety becomes an issue for visitors, jetties are all under water.	Lake is use at own risk.

9449 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Wilson Reservoir. Lake elevations are in NGVD 1929.

9450 *Table 3-119. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds*

Lake Elevations	<1,933 feet	1,933–1,942 feet	1,942–1,948 feet; multi-purpose pool is 1,945.7 feet	1,948–1,952 feet	1,952–1,955 feet	>1,955 feet
Water-based Visitor Impacts	100%	40%	0%	50%	75%	100%
Shore-based Visitor Impacts	0%	0%	0%	50%	75%	100%

9451 [1] The information in this table was developed with input from USACE and KDWP staff familiar with Wilson Reservoir. Lake elevations are in NGVD 1929.

9452

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3.6.7.2 Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of HABs, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents, information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Harlan County Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir.

3.6.7.2.1 Recreation Facilities and Visitation

USACE will continue to operate and maintain the existing recreation facilities at Harlan County Reservoir with the exception of the marina which is privately operated. Visitation during average water years will be similar to the visitation under baseline conditions (921,938 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Harlan County Reservoir is expected to continue a similar water level fluctuation pattern as irrigation to meet farmland requirements both above and below the reservoir will remain of upmost importance. The impacts associated with conditions when Harlan County Reservoir is at low pool elevations will occur including reduced connectivity with cove habitat and impacts to reservoir fisheries. Issues related to high water levels will also occur during these conditions including excessive shoreline erosion and damage to infrastructure and boating access developments.

3.6.7.2.2 Sport Fisheries

Priority management species could change over time dependent on monitoring and survey results and changes to angler preference. USACE and the NGPC will continue to prioritize aquatic habitat projects similar to those at Gremlin, Patterson, and Methodist Coves which include bank stabilization, protection breakwaters, dredging, and angler access improvements. Invasive species will continue to be an issue posing a potential threat to aquatic resources, infrastructure, and recreational opportunities in the reservoir. Nebraska Game and Parks will continue to monitor and conduct outreach/education efforts to minimize future introductions of invasive species. Management activities will also continue in the future including stocking fish, evaluating fish population surveys, conducting aquatic-based research, improving and maintaining aquatic habitat, and improving and maintaining angler access and providing law enforcement.

Despite the challenges discussed here, Harlan County Reservoir provides valuable benefits to both humans and fish and wildlife. The Nebraska Game and Parks Fisheries Division will remain committed to managing aquatic resources at Harlan County Reservoir including but not limited to stocking fish, evaluating fish population surveys,

conducting aquatic-based research, improving and maintaining aquatic habitat, improving and maintain angler access and providing law enforcement.

3.6.7.2.3 Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Harlan County Reservoir will be similar to past conditions with only minor localized effects by sediment issues. The shorelines surrounding the reservoir will continue to erode and sedimentation will cause further closure of the natural coves making access to these coves during low water periods difficult to impossible for both fish and boats. Sediment will continue to accumulate in Lovewell Reservoir with an expected additional 1.6 percent loss of the multipurpose pool over the next 25 years (2049) and 2.5 percent loss over the next 50 years (2074) (Appendix D).

Conditions similar to past droughts water levels will be similar to past periods of drought resulting in drops in visitation. Boating access and shifts in usage will continue to occur and be a challenge. Impacts to recreation can occur when reservoir elevations are below top of multipurpose pool with reduced boating access and limited water recreation and limited to no boating access when elevations are 12 feet below top of multipurpose pool. Safety also becomes an issue during these conditions from underwater hazards. Aesthetic values decrease dramatically as exposed shorelines grow. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Harlan County Reservoir has experienced impacts during past flooding events with higher pool elevations that caused impacts to recreation and damages to recreation infrastructure. These impacts are expected to continue in the future at Harlan County Reservoir during high flood pool conditions. Impacts from reduced access for boating and shore-based recreation start at approximately three to seven feet above top of multipurpose pool and above 1955 feet boaters can access the reservoir, but it is at their own risk or from the marina as boat ramps are inaccessible. Shore-based access is also closed at approximately seven feet above top of multipurpose pool During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Tables 3-116 and 3-117 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent impacts to recreation and damages to recreation infrastructure.

Water quality at Harlan County Reservoir and expected future conditions related to water quality are included in Appendix E. Impairments associated with excessive total phosphorus and total nitrogen concentrations will continue. HABs will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

3.7 Water Quality

Water quality is a broad topic including physical, chemical, and biological characteristics of surface waters in the Kansas City District with potential impacts to nearly all components of the watershed study.

As outlined in USACE ER 1110-2-8154, Water Quality and Environmental Management for USACE Civil Works Projects (2018), “water quality is an integral component of all USACE civil works missions.” The Kansas City District Water Quality Program works within the guiding principles of ER-8154 to ensure that all applicable state and federal water quality standards are met, water quality degradation of USACE resources is avoided or minimized, and project responsibilities (i.e., project authorizations, authorized project purposes, and applicable regulatory requirements) are attained.

The Kansas City District Water Quality Program has maintained a long-term and robust water quality monitoring and data collection program to meet the needs of all lake Projects as well as collaborative efforts with other USACE Districts, government agencies, watershed conservation groups, universities, and NGO’s regarding water quality issues of USACE projects. Chemical, physical, and biological parameters are measured to evaluate water and lakebed sediment quality. The USACE uses this data to describe conditions and changes from the inflow streams, within the main lake, and outflow focusing on eutrophication, nutrients, sediment, herbicides, metals, and contaminants. This data is critical to investigating problems that may arise, such as HABs, bacteria issues, and fish kills, as well as design and implement modifications to improve water management procedures.

The objective of this section is to provide the baseline water quality information needed to properly evaluate potential management strategies/measures for e sustainment of quality water for human use, ecosystem restoration, and water quality protection and improvement as outlined herein. Additional analyses and discussion can be found in Appendix G.

3.7.1 Study Area

Detailed information regarding USACE and USBR project purposes, history, and physical design features and other project specific pertinent data are referenced in Section 3.2.2 Kansas River Basin Reservoir System of this document. Detailed information regarding historical water quality at the Kansas City District lakes and watersheds is provided in various Project specific water quality reports (USACE 2010–2019). Figure 2-1 shows the locations of federal reservoirs within the basin.

Man-made lakes are usually termed “reservoirs” or “impoundments,” depending on designated use and regional preferences. To provide consistency, this report uses the term “lake” to describe standing water that has not been officially designated by another name.

3.7.2 Water Quality Summary

The availability of high-quality water for commercial, industrial, and residential uses is vitally important for the water users of Kansas. Activities to further protect and improve the water quality of Kansas to avoid degradation of the State’s water resources are

imperative for current and future water users. State natural resource agencies have designated 16 of the 18 lakes in the Basin as “impaired” from nutrient related impacts (e.g., excess nitrogen and/or phosphorus, general eutrophication, excess chlorophyll/algae measures, dissolved oxygen sags resulting from algae blooms) due in part to agricultural runoff. Inflow streams flowing into Basin lakes are frequently impaired from a range of pollutants including, but not limited to, fecal bacteria, herbicides like atrazine, and chemical contamination from naturally occurring compounds found in geological deposits (e.g., chloride and sulfate salts, selenium, and arsenic). Approximately 86 percent of the Kansas assessed stream miles are impaired for one of their uses and less than 5 percent of the state’s assessed wetlands are able to support aquatic life and recreational uses (KWO 2021a). Excess nutrients can promote HABs under ideal growing conditions. HABs have impacted six lakes in the basin since 2011. Milford Lake has been the hardest hit, with HAB warnings impacting recreation 7 of 10 years in our period of analysis.

All reservoirs in the Kansas River Watershed will likely experience increasing effects of aging as sediment loading will diminish storage capacity (KRRFSS Appendix D, Reservoir Sedimentation), deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. As water quality conditions degrade within a water body, use of water from that source, as well as downstream uses, can be negatively impacted. Negative impacts from degrading/poor water quality conditions can include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, decreased recreational opportunities, fish consumption advisories, and diminished biological diversity in streams and lakes.

3.7.3 Methods

3.7.3.1 General

Water quality data used for this document is a compilation of available data from KDHE and the NWK Water Quality Program in accordance with NWK Project Work Plan (PWP) and Quality Assurance Project Plan (QAPP) for the Kansas City District Water Program (USACE 2019). Annual lake reports for water quality monitoring at USBR lakes was provided by the KDHE-Bureau of Water, Watershed Planning, Monitoring and Assessment. (https://www.kdheks.gov/befs/lakes_monitoring.htm). General sampling dates and sample location maps are located within the body of this document. Data quality management issues for the study were likewise addressed in this document.

3.7.3.2 Baseline Water Quality Sampling

Kansas City District Water Quality Program has monitored baseline status and trends of water quality conditions at Kansas City District projects for at least thirty years. Baseline definition is the least rigorous constraint of our data set considering 18 lakes per month are planned with minimal concurrent sampling. Every attempt is made to avoid runoff conditions and sampling is rescheduled if local rainfall exceeds one inch in 24 hours prior to sampling. However, high water and runoff is included in the data set and typically appears as outliers. Monitoring entails the collection of inflow (i.e., major streams flowing to lake), in-lake from each major tributary arm of lake, and outflow (i.e., directly below the dam) data for water quality problem identification and to provide a sufficiently robust water quality database for watershed and reservoir environmental

modeling. Consequently, lakes with more tributary arms will have more in-lake water quality sites and generally more variation in the results. In-lake data collection includes sampling of both lake waters and sediments in accordance with established Kansas City District standard operating procedures (SOPs) (USACE 2003). A summary of available in-lake sediment quality data is provided in the body of this document while a more comprehensive report on sediment characteristics for all Kansas City District Lakes is in the appendix (James 2009).

Water quality sampling is conducted April–September by Kansas City District personnel at standardized inflow, lake, and outflow sites. Inflow sites, pesticide, total metals, and bottom chemistry samples are collected every third year due to funding limitations. Sample sites have been spaced to account for differences in sub watersheds and water quality influence on their respective lake arm as well the horizontal gradients common to large reservoirs. Inflow sites are typically collected from the river thalweg via bridges. In-lake sample sites are located in the river channel of lake arms. Outflow sites are located in the thalweg and typically collected from shore, fishing access points in the USACE outlet parks, or bridges within a mile of the dam.

Field data recorded at each site included Secchi disk transparency and vertical profiles of water temperature, dissolved oxygen, pH, conductivity, and nephelometric turbidity. Vertical profiles of field water quality parameters were recorded at the surface (0.3-meter (m) depth) and at 1-m depth intervals throughout the entire water column. Profile data were electronically logged and downloaded to a personal computer (PC) to minimize data transcription errors.

Surface water samples for physical, chemical, and biological laboratory analyses are collected at an approximate depth of 0.3 m at each site while bottom samples are collected 0.3 m from bottom sediments. Lake-bed sediments samples are collected using a petite ponar dredge from standardized lake sample locations and typically analyzed for nutrient and metal concentrations. Dredging project discussions/proposals necessitate increased bed sediment analysis including pesticide and potential industrial contaminants. Chlorophyll *a* samples to describe productivity are a composite sample of three grab samples taken from top, middle, and bottom of photic zone as measured by Secchi disc.

Analytical parameters initially employed for water samples as well as laboratory methods used for each constituent are included in Table 3-118. The list includes a broad range of common limnological parameters including those important for water supply evaluation, watershed conservation metrics, and those necessary to support water quality modeling efforts. Field sampling effort has periodically increased by up to 100 percent to meet modeling data needs or to evaluate watershed conservation and/or TMDL development. Parameters have been eliminated from routine sampling that were consistently below analytical detection limits, those that exhibited little spatial and temporal variability, and those for which data were being collected using field instruments (e.g., nephelometric turbidity). Parameters listed below will be referred to by common name or commonly used symbology (i.e., total phosphorus, TP) in the body of the text to simplify nomenclature.

Table 3-120. Analytical Parameters and Methods for Water Samples[1]

Category	Parameter	Analytical Method
Nutrients	Total phosphorus–P	EPA 365.2/SM 4500-PE/EPA 6010B
Nutrients	Total ortho-phosphorus-P	EPA 365.2/SM 4500-PE/EPA300.0
Nutrients	Nitrate+Nitrite–N	EPA300.0
Nutrients	Ammonia–N	EPA 350.1
Nutrients	Total Kjeldahl (TKN)–N	EPA 351.2/I-4515-91
Inorganics	Total alkalinity	SM 2320-B
Solids	Total suspended solids	EPA 160.2/SM 2540-D
Total Metals	Arsenic, Copper, Iron, Lead, Manganese, Nickel, Zinc, Mercury, Selenium, Cadmium, Chromium	EPA 200.7/200.9
Total Anions	Bromide, Chloride, Sulfate	EPA 300.0
Other	Chlorophyll *a*	EPA 445.0
Other	Total organic carbon	SM 5310-C
Organics	Chlorinated pesticides	SW-846 8081 A
Organics	Chlorinated herbicides	SW-846 8081 A

Note: [1]Sample analysis completed by USACE contract or federal labs from 2010 to 2019.

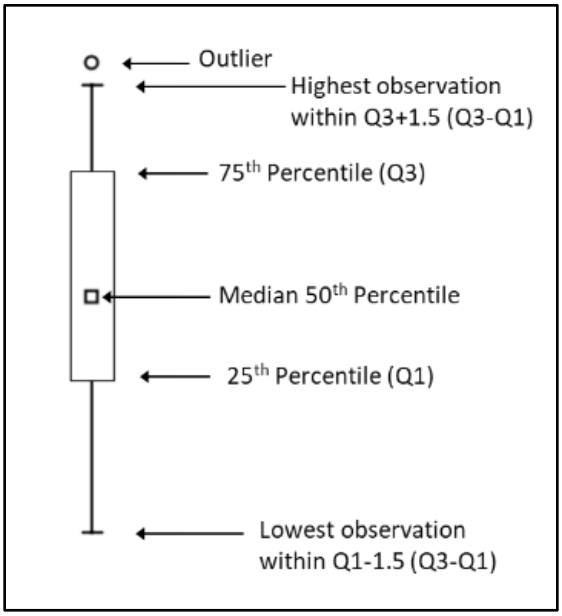
KDHE provided physical and chemical data for use in this report collected and analyzed for USBR lakes and streams from 2010–2019 according to their published Lake and Wetland Chemistry and Monitoring Plan (KDHE 2014).

3.7.3.3 Statistical Analyses

Statistical and graphic analyses were conducted using Statistica V13.5 (TIBCO Software Inc) and Microsoft Excel for 365 V16. For hypothesis testing, differences were considered statistically significant at $\alpha=0.05$ for water quality samples using either parametric or non-parametric analysis dependent upon normal data distribution identified by the Shapiro-Wilk test. Laboratory results reported herein include results which may be estimated as half of the minimum detection limit based on the assumption that a range of all values between the minimum detection limit and zero could be present. This conservative approach is an acceptable way to reduces analysis bias and avoid skewing data (EPA 1991).

Box-and-whisker plots were used for illustration of much of the data throughout this report. These plots are used to compare distributions, quickly and visually, across groups, using quartiles. Figure 3-162 is a generalized presentation of how these plots can be interpreted.

Figure 3-162. Box and Whisker Plot Example



3.7.3.4 Residence Time

Water residence time (RT) is calculated as an estimate of how long a compound will remain in a lake's system. This variable is determined by the flow (inflow or outflow) and storage volume of the lake, as well as the sedimentation (i.e., loss of storage) received by a lake over time.

Residence time was calculated using HEC-ResSim to model two different scenarios; existing conditions (0-year FWOP) and FWOP conditions (100-year FWOP). Each reservoir was modeled with historically observed average daily inflows for both scenarios over a 100-year timeframe with change of storage volume due to sedimentation as the experimental variable. HEC-ResSim generated estimated lake storage, discharges, and evaporation from these simulations. Observed average residence time was also calculated for the 1990-2022 period for comparison to 0-year FWOP simulation.

The general equation to estimate the average residence time of a lake is dependent on the storage of the lake, inflows, and outflow. This equation works with inflow or outflow and is defined as follows:

$$RT = \frac{Avg\ Storage}{Avg\ Flow}$$

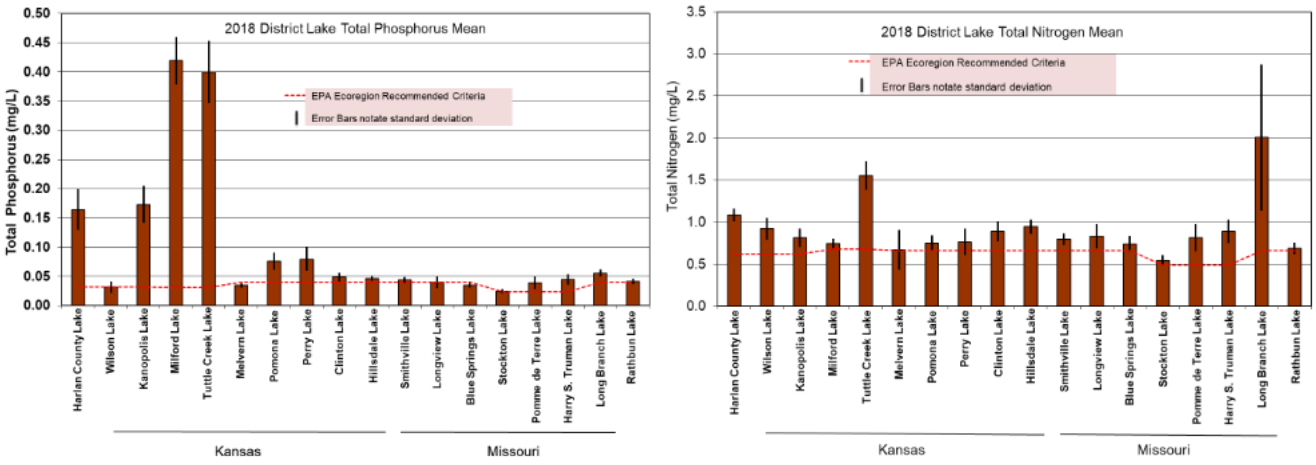
3.7.4 Reservoir Water Quality

Sample results from Kansas City District Water Quality Program and select data from state agencies are described in detail in the following sections. In general, discussion of water quality results in the following sections will primarily focus on general water quality overview of baseline or existing conditions as well as future conditions without project improvements or changes.

3.7.4.1 U.S. Army Corps of Engineers Lakes Water Quality

State natural resource agencies have designated 16 of the 18 lakes in the Basin as "impaired" from nutrient related impacts (e.g., excess nitrogen and/or phosphorus, general eutrophication, excess chlorophyll/algae measures, dissolved oxygen sags resulting from algal blooms) resulting primarily from agricultural runoff. Most lakes in the Kansas City District exceed EPA Ecoregional Nutrient Criteria (EPA 2001) for both total phosphorus and total nitrogen with Basin Lakes ranking at the top (Figure 3-163). Inflow streams flowing into Basin lakes are frequently impaired from a range of pollutants including, but not limited to, fecal bacteria, herbicides like atrazine, and chemical contamination from naturally occurring compounds found in ground water flowing through geological deposits forming chloride and sulfate salts, selenium, and arsenic. Excess nutrients can lead to HABs under ideal growing conditions. HABs have impacted six lakes in the Basin since 2011. Milford Lake has been the hardest hit, with HAB warnings impacting recreation 7 of 10 years in the period of analysis.

Figure 3-163. Kansas City District Lakes Phosphorus and Nitrogen Concentrations for 2018



Representative average annual phosphorus and nitrogen concentration of 18 Kansas City District lakes in 2018.

Nutrient rich runoff and soil loss from fields and stream banks work in tandem to compound water quality problems and are linked to the most frequent Kansas lake impairment summarized as eutrophication. Excess nutrients frequently lead to potentially HABs while accumulation of sediment in lakes reduces storage capacity for water use. Reduced volume means less dilution and equates to higher concentration of all compounds stored in the lake system. This age-related process leads to increasing susceptibility of reservoirs to contamination and internal loading of nutrients, metals and compounds stored in lake-bed sediment.

3.7.4.1.1 Harlan County Lake

Harlan County Lake is a 13,000-acre impoundment on the Republican River in Nebraska. The Republican River flows from Harlan County Lake through fertile agricultural land into Milford Lake and then into the Kansas River. The primary water quality threats to Harlan County Lake are nutrients, sediment, and toxic cyanobacteria blooms (Figure 3-164). Drought conditions have also impacted Harlan County Lake by reducing the surface acreage by nearly 50 percent in 2004, 2005, and 2014. During

normal water level years, the lake experiences a 4–6 foot summer drawdown related to irrigation releases. Dredging has occurred to maintain boat access in coves with two marinas. Blue-green algal blooms have occurred periodically with health alerts for the USACE swim beach, including algae toxin being reported by Nebraska Department of Energy and Environment (Nebraska DEQ Beach Watch).

Figure 3-164. Harlan County Lake Boat Ramp in Shallow Cove During Harmful Algal Bloom



(USACE 2007)

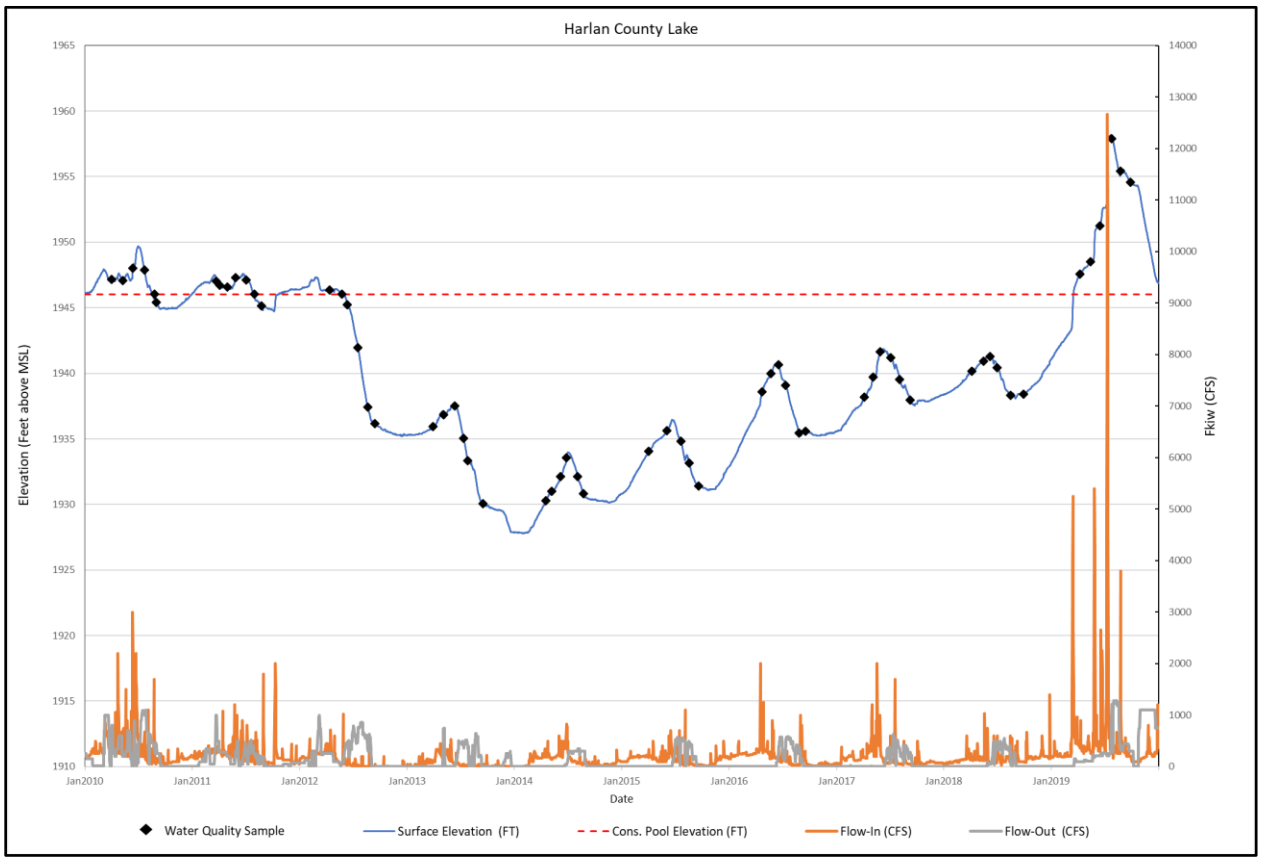
Reservoir Hydrologic Data Summary

Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics like flow, water residence time, and lake mixing/stratification which in turn influence physical and chemical process, frequently resulting in biological response.

Water quality sampling events by Kansas City District staff were conducted monthly at Harlan County from 2010–2019 coinciding with the typical recreational season (April through September) (Figure 3-165). Drought conditions were observed at the end of 2013 with surface elevation falling below 1,930 feet while recovery period is apparent beginning in 2015. Flooding and corresponding high-water period were observed in 2019 as inflows exceeded 12,500 cfs.

Average water residence time for Harlan County Lake of 23.8 months was calculated from historic water management records for the period 1990-2022 using HEC-ResSim software. Harlan County Lake average water residence time was the longest of all Kansas River Watershed lakes in this study. Extended residence time allows for longer dilution and settling time as well as biological attenuation of agricultural runoff which improves water quality downstream of Harlan County. Accumulation of sediments and storage of sediment bound contaminants have negative implications for water quality as extended water residence time is a contributor to eutrophication including negative impacts to temperature and oxygen profiles from algal growth and potential increase in HABs, increase potential of internal nutrient loading and loss of pool volume.

Figure 3-165. Time Series of Daily Water Surface Information 2010–2019

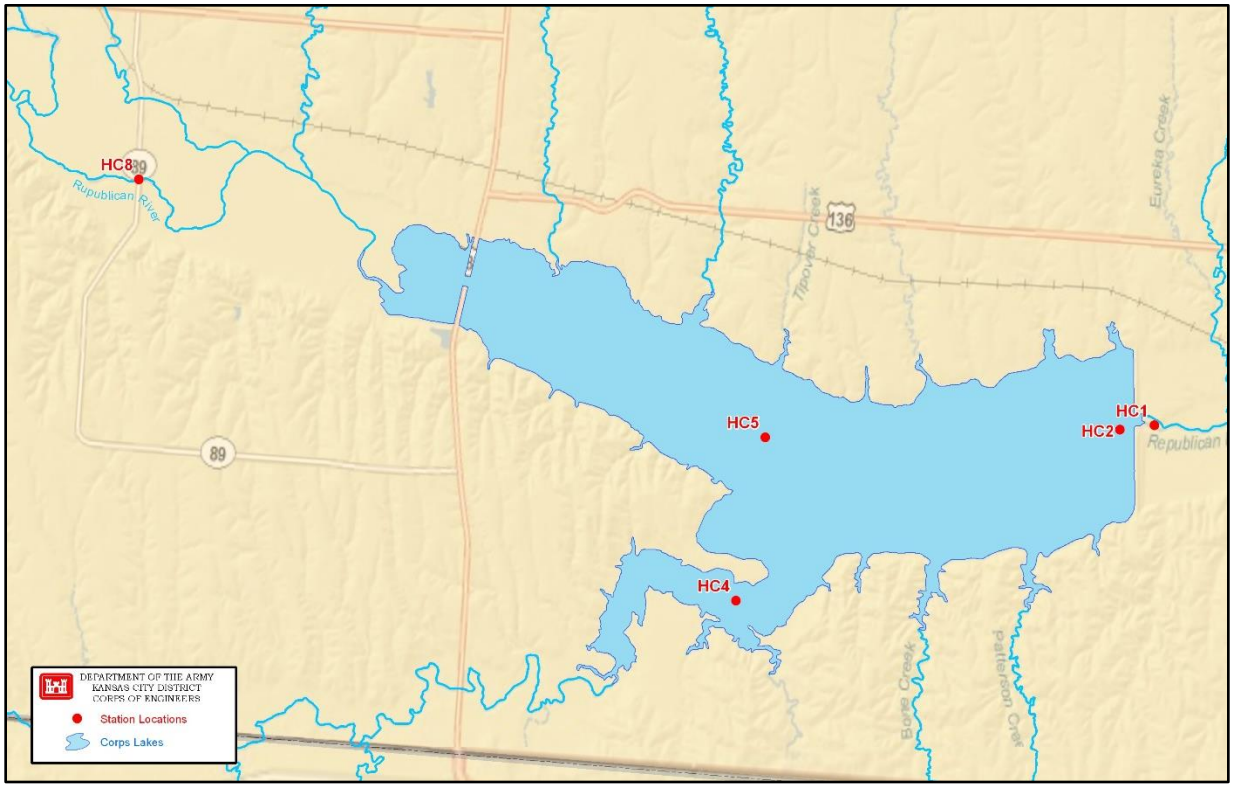


Series includes daily water surface elevation, inflow, out, and multipurpose pool elevation for the period Jan. 2010 through Dec. 2019 from DSS data (Data Storage System Visual Utility Engine [HEC-DSSVue]). Water quality sample dates are plotted corresponding with lake surface elevation for reference.

Water Quality Sample Locations

Historic water quality sample sites at Kansas City District lake projects are generally named in decreasing numeric order from inflow site(s) to the outflow site below the dam (Figure 3-166). To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow.

Figure 3-166. Map of Historic Harlan County Reservoir USACE Water Quality Sample Sites



Map of historic USACE water quality sample sites including inflow stream(s), lake water quality/bed sediment sample sites, and outflow.

Impaired Waters

Harlan County Lake is listed in the most recent (2018) Nebraska 303(d) list of impaired waters (https://www.nebraskamap.gov/datasets/nebraska::streams-303d/about) due to excessive total phosphorus and total nitrogen concentrations. Nebraska Department of Environmental and Energy (NEDEE) and U.S. Environmental Protection Agency (EPA) work with water quality partners to reduce nutrient inflow into Harlan County Lake to improve water quality. Eutrophic conditions, indicative of excessive algae production, is an impairment with wide ranging impacts ranging from taste and odor problems in drinking water to objectionable algal growth interfering with recreational activities with potentially toxic conditions. In 2018, Harlan County Lake ranked above average among District Lakes for both total phosphorus and total nitrogen measured at the site nearest the dam (Figure 3-163). Both total phosphorus and total nitrogen 10-year mean values (Table 3-118) as well as 2018 nutrient measures exceeded recommended nutrient criteria set by NEDEE and EPA Ecoregion (Figure 3-163).

Inflows/Outflows

The water quality at Harlan County Lake may vary greatly between inflow site on the Republican River and outflow site. Inflows from runoff, groundwater, and streams introduce sediment, suspended particles, and soluble chemicals, influencing the lake's physical, chemical, and biological composition. Nutrient imbalances in the inflow water directly impact the lake's trophic state and primary production. Water exiting through the

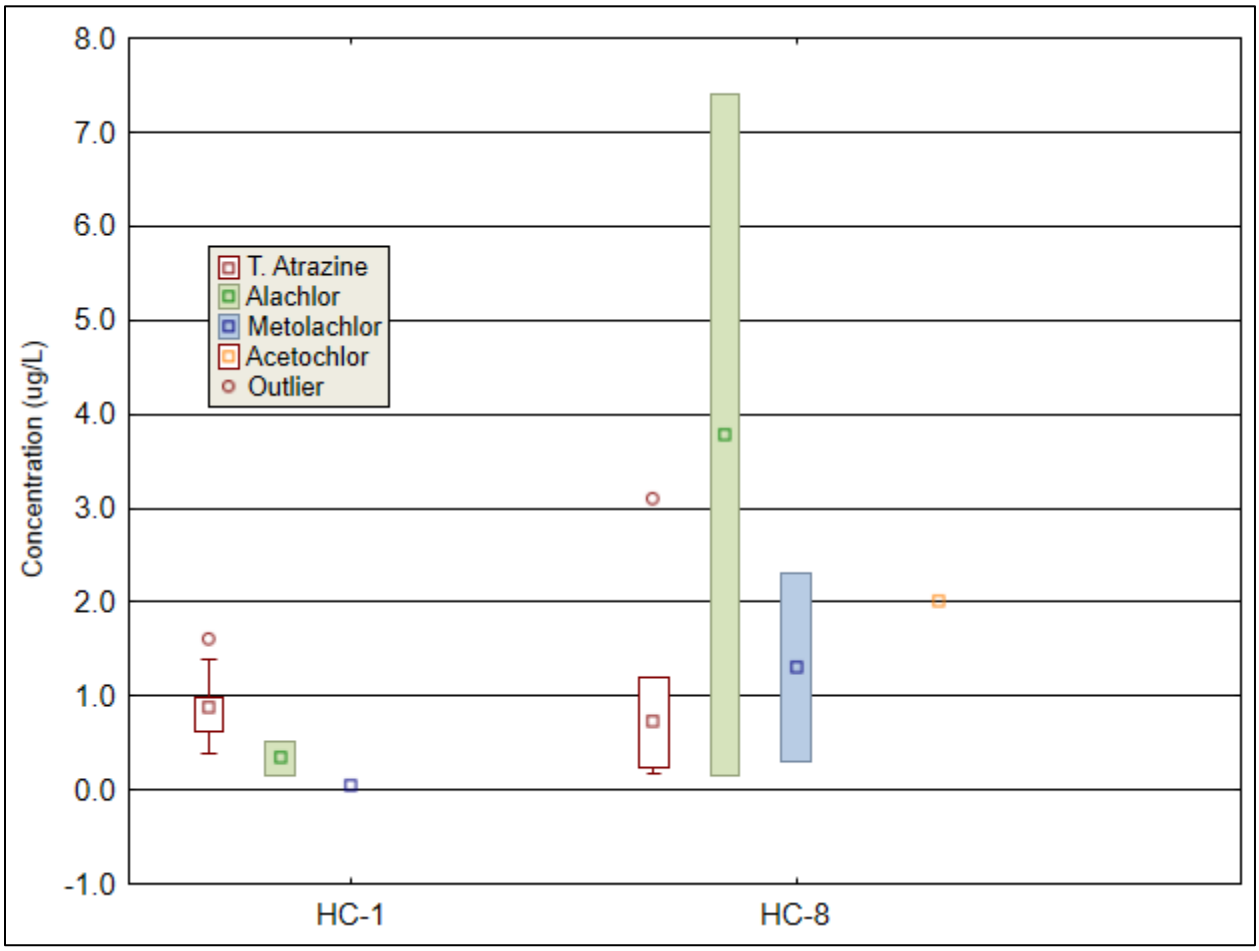
dam can differ markedly from inflows, as the lake often attenuates or stores nutrients, pesticides, and metals, acting as a sink. Anoxic water release during stratified periods, or supersaturation during flood releases, further alters physical water quality.

Herbicides have been monitored at Harlan County Lake by Kansas City District Water Quality Program personnel since 1996. The list of herbicides detected have included mostly chlorinated species and chemical constituents of atrazine, alachlor, metolachlor, cyanazine, metribuzin, simazine, acetochlor, 2, 4-D, and glyphosate. EPA regulation of herbicide licensing to reduce chemical persistence and mobility in the environment and improved farming practices have helped reduce the number and concentration of chemicals detected in Kansas City District Water Quality samples. Herbicides, such as atrazine and alachlor, peak during planting season but are typically higher in inflows compared to outflows, meeting water quality criteria. (Figure 3-167).

Nutrient concentrations in the Harlan County Lake and watershed are considered high as defined by “impaired waters” status as outlined in NEDEE 303(d) list of impaired waters. Fertile agricultural watersheds in Nebraska are likely to provide excess nutrients to inflow streams (Manning et al. 2020) with different delivery rates and fate in Harlan County Lake and downstream. In the rural landscape, nitrogen deposition is more likely associated with agriculture or fertilizer application (Arbuckle and Downing 2001; Boyer et al. 2002) while phosphorus loading is associated with soil erosion and farming practices as well as sewage effluent and runoff from urban watersheds (Downing and McCauley 1992; Withers and Jarvie 2008). Total nitrogen and bioavailable forms of nitrate/nitrites decreased from the inflow site to the outlet from attenuation and denitrification/biological uptake (Figure 3-168). Ammonia nitrogen increases from anoxic conditions found in the bottom strata near the dam leads to seasonal increases in ammonia in releases from Kansas City District lakes. Consequently, ammonia in concentrations at the outlet were significantly higher than those measured at the inflow site (Figure 3-168).

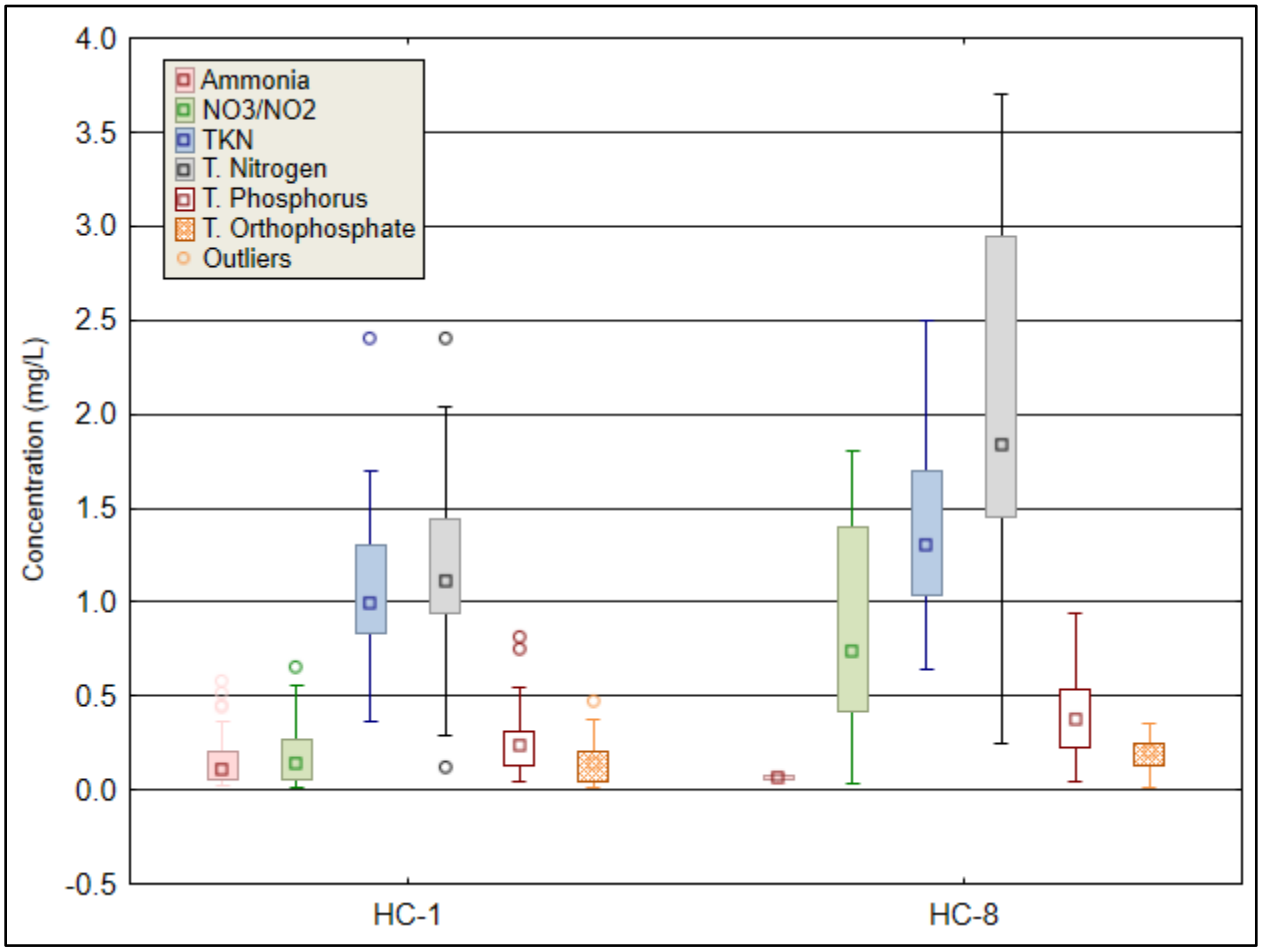
Metal compounds, including iron, manganese, and arsenic, are found in both inflow and outflow samples, with some exceeding EPA drinking water standards. These differences underscore the complex interplay of various factors shaping water quality in Harlan County Lake and its watershed.

Figure 3-167. Herbicide Concentration Upstream and Downstream of Harlan County Lake From 2010–2019



Herbicide concentration measured from surface samples collected at Harlan County Lake inflow (HC-8) and outflow (HC-1) USACE water quality sample sites from 2010–2019.

Figure 3-168. Nutrient Concentration Upstream and Downstream of Harlan County Lake From 2010–2019



Nutrient concentration measured from surface samples collected at Harlan County Lake inflow (HC-8) and outflow (HC-1) USACE water quality sample sites from 2010–2019.

Lake Water Quality

The water quality at Harlan County Lake is influenced by nutrient-rich inflow and frequent wind mixing. Soil erosion from fields and stream banks contribute to water quality issues, primarily eutrophication. Eutrophication results from excess nutrients, leading to algal blooms and sediment accumulation, which reduces water storage capacity and dilution potential, especially in older reservoirs.

Herbicide concentrations in Harlan County Lake were generally low, with the most common herbicide (total atrazine) consistently below EPA drinking water criteria at all sites. Other herbicides were mostly below detection limits, but a few data points indicated the presence of alachlor, metolachlor, and cyanazine at upper lake sites including HC-5 following spring inflows.

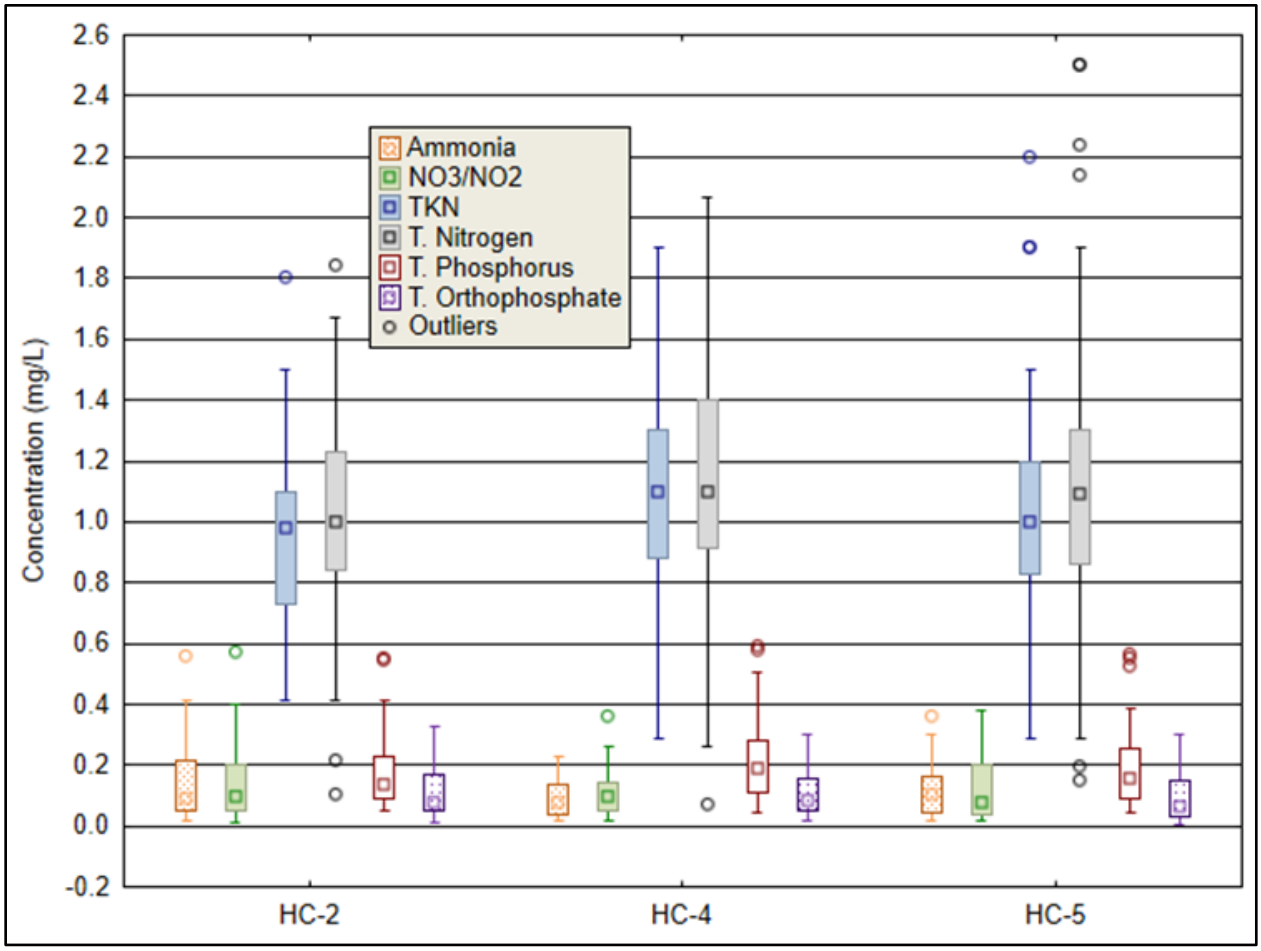
Excess nutrients, particularly phosphorus, have been a long-standing concern at Harlan County Lake, leading to eutrophication concerns for much of its seventy-year history. In a National Eutrophication Survey commencing in 1972, Harlan County Lake was classified as hypereutrophic and was ranked last for trophic quality (i.e., soluble

phosphorus, Secchi depth, chlorophyll a, dissolved oxygen sag) of nine Nebraska impoundments of concern for accelerated eutrophication (EPA Region VII 1976). In the 2019 (most recent) Kansas City District Water Quality report, total phosphorus medians from all lake sites exceeded hypereutrophic thresholds and were at least 6 times higher than NEDEE phosphorus criteria (0.062 mg/L) (USACE 2019). Excessive phosphorus, duration of flood water storage, and increased water clarity during the hottest part of the summer were optimum conditions for blue-green algal blooms which can dominate the phytoplankton community during late summer months. Water level fluctuations and turbid conditions at Harlan County Lake have not prevented emergent macrophytes (e.g., bulrush (*Scirpus* spp.), cattail (*Typha* spp.), sedges (*Carex* spp.)) from thriving in shallow water lake fringe and cove areas at Harlan County Lake. Internal sources of orthophosphate released by bottom sediments are also a frequent occurrence in late summer as soluble phosphorus concentrations increase without inflows from June-September (USACE 2019).

Total phosphorus median and 50 percent of all phosphorus records (interquartile range) collected from 2010–2019 from all lake sites (Figure 3-169) were above the Trophic State Index (TSI) hypereutrophic threshold (0.096 mg/L) (Carlson 1977). Soluble orthophosphate which feeds planktonic algae growth is proportionally high at all lake sites.

Nitrogen found in nitrate/nitrite compounds is the primary form assimilated by aquatic plants and converted to organic forms of nitrogen as part of the TKN measured in water. Conversion of soluble forms of nitrogen to organic forms (i.e., algae cells) is a common form of denitrification observed in eutrophic lakes which can lead to nitrogen limitation of primary production in summer months (Xiaofeng et al. 2012). Ten-year sample results indicate TKN comprises most of the total nitrogen found in Harlan County Lake with forms available to aquatic plants and algae (i.e., nitrate-N and ammonia-N) comprising the smallest amount (Figure 3-169). Kansas City District water quality program's seasonal bias highlights this process as sampling season is scheduled April-September annually. The general nutrient pattern observed in Harlan County and other hypereutrophic Kansas City District lakes is when high phosphorus concentrations are measured in surface waters and algae growth is high (i.e., not light-limited), TKN is also elevated. Conversely, where phosphorus and algae are low, TKN is also low. High algae biomass is not theorized to be caused by the high TKN, but rather the algae comprise much of the organic-N in the TKN measurements as described by Heiskary and Lindon (2010).

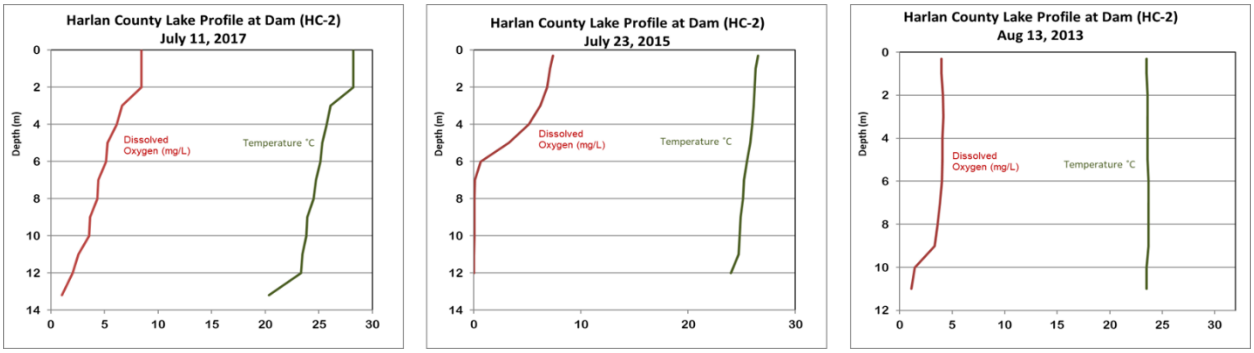
Figure 3-169. Harlan County Lake Nutrient Concentration From 2010–2019



Nutrient concentration from surface samples collected at Harlan County Lake USACE water quality sample sites from 2010–2019.

Harlan County Lake undergoes thermal stratification of varying intensity and duration during the summer, with the lower lake areas near the dam experiencing anaerobic conditions at different depths during summer months depending on weather conditions, available nutrients, biological interactions leading to biochemical oxygen demand, and water management (Figure 3-170). Stratification affects temperature, dissolved oxygen, and nutrient release, impacting aquatic life and chemical processes. The lake's water quality and can also be influenced by weather patterns, wastewater releases, and dam operations.

Figure 3-170. Harlan County Lake Representative Temperature and Dissolved Oxygen Profiles



Representative temperature and dissolved oxygen profiles from Harlan County Lake USACE water quality sample sites from 2017, 2015, and 2013.

A summary of descriptive statistics for chemical analysis results at site nearest the dam is found in Table 3-119. Bottom samples are typically collected from Kansas City District lakes every third year with total metals collected during August, when peak stratified conditions are most likely. When the lake is mixed or not stratified, bottom sample results are nearly identical to surface sample results for most analytes. Anaerobic conditions allow for oxidation/reduction reactions to release chemical compounds, including metals, which we attempt to quantify with bottom samples. Non-detection or results below minimum detection level occur on occasion and have been included in sample results (Table 3-119) as the value of half of the reported minimum detection limit to reduce bias based on the assumption that the analyte is present at a concentration below laboratory quantification (EPA 1991). Sample size, sampling effort, and non-normal distribution constraints are best addressed with the use of descriptive statistics are used to describe and summarize sample results. Nitrogen results were similar at surface and bottom samples, including ammonia. Orthophosphate, metals, and suspended solids are typically concentrated in the bottom during the few months when lakes are stratified. Comparison between surface and bottom samples during stratified months highlight differences which are dampened when all months are combined. No statistical differences between surface and bottom samples were detected.

Table 3-121. Water Quality Summary Statistics for April 2010 Through September 2019[1]

Parameter	Sample Depth	Mean	SE[2]	SD[3]	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.09	0.01	0.12	0.56	0.04	0.01	60
Ammonia (mg/L)	Bottom	0.09	0.04	0.14	0.54	0.02	0.01	13
NO3/NO2 (mg/L)	Surface	0.10	0.01	0.11	0.57	0.05	0.01	60
NO3/NO2 (mg/L)	Bottom	0.12	0.03	0.11	0.41	0.08	0.01	13
TKN (mg/L)	Surface	0.92	0.04	0.30	1.80	0.98	0.15	58
TKN (mg/L)	Bottom	0.95	0.09	0.31	1.80	0.84	0.64	13
Total Nitrogen (mg/L)	Surface	1.00	0.04	0.33	1.84	1.02	0.11	59
Total Nitrogen (mg/L)	Bottom	1.07	0.08	0.29	1.83	0.97	0.68	13
Total Phosphorus (mg/L)	Surface	0.17	0.01	0.11	0.55	0.14	0.05	60
Total Phosphorus (mg/L)	Bottom	0.21	0.05	0.18	0.74	0.17	0.07	13
Total Orthophosphate (mg/L)	Surface	0.10	0.01	0.08	0.33	0.07	0.01	58
Total Orthophosphate (mg/L)	Bottom	0.16	0.05	0.15	0.71	0.12	0.01	13
Chlorophyll a (ug/L)	Photic Zone	16.68	3.46	24.68	160.00	10.00	0.45	51
Total Organic Carbon (mg/L)	Surface	7.30	0.87	4.10	24.00	5.90	4.50	22
Total Organic Carbon (mg/L)	Bottom	8.93	1.64	5.90	27.00	7.30	4.60	13
Total Iron (ug/L)	Surface	134.05	55.95	79.12	190.00	134.05	78.10	2
Total Iron (ug/L)	Bottom	210.00	10.00	14.14	220.00	210.00	200.00	2
Total Manganese (ug/L)	Surface	41.70	6.30	8.90	48.00	41.70	35.40	2
Total Manganese (ug/L)	Bottom	353.00	291.00	411.54	644.00	353.00	62.00	2
Total Suspended Solids (mg/L)	Surface	8.76	0.73	5.67	35.20	8.10	1.40	60
Total Suspended Solids (mg/L)	Bottom	13.95	1.16	4.19	21.00	15.00	8.40	13

Notes: 1/Chemical and chlorophyll-a samples taken from Harlan County Lake near dam site HC-2.
2/Standard Error=SE; 3/Standard Deviation=SD.

Surface and bottom physical water quality results were selected from water quality profiles to compile descriptive statistics summary found in Table 3-120. Differences in sample size can be attributed to different equipment (i.e., the number of probes on a multi-probe data sonde) being used for data collection. Temperature and dissolved oxygen sensors are present on all data sondes used by Kansas City District Water Quality Program while pH, conductivity, and turbidity sensors are only available during intensive surveys which occur every three years. Calibration issues or sensor failure also account for a minor reduction in number of sample results presented in Table 3-120. Turbidity differences between bottom and surface samples is attributed to settling of solids and metals throughout months and influences of seasonal stratification.

Table 3-122. Harlan County Lake Physical Water Quality Summary for 2010–2019[1]

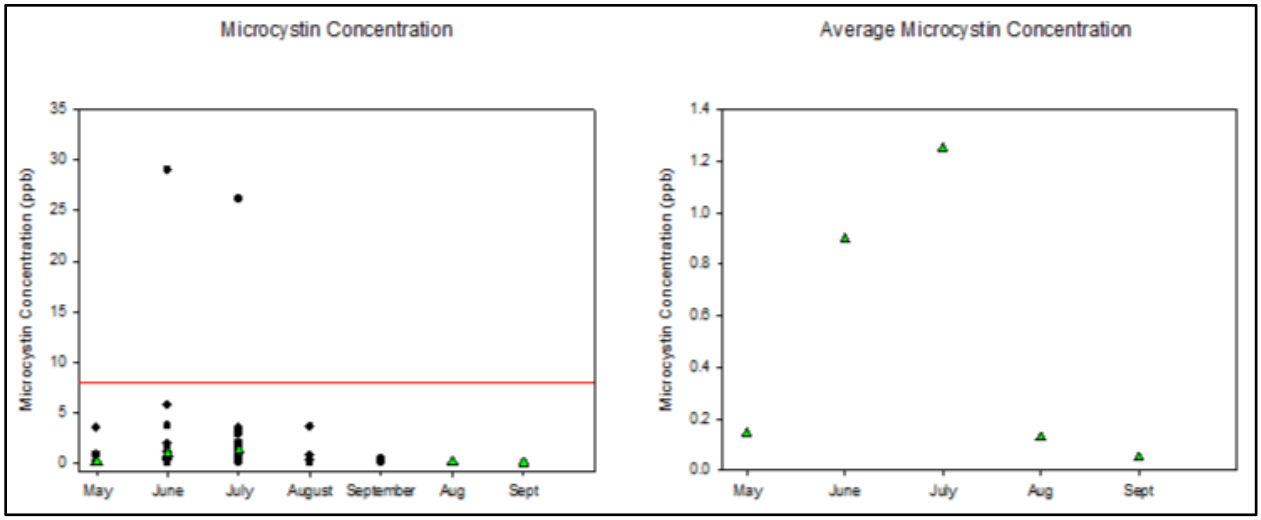
Parameter	Sample Depth	Mean	SE[2]	SD[3]	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	8.5	0.2	1.9	13.9	8.4	4.0	167
Oxygen, Dissolved (mg/l)	Bottom	6.3	0.2	3.0	12.9	6.8	0.1	174
pH (Standard Unites)	Surface	8.5	0.1	0.3	8.9	8.6	7.6	53
pH (Standard Unites)	Bottom	8.3	0.1	0.4	8.9	8.4	7.2	56
Secchi Depth (m)	Surface	0.7	0.1	05	3.3	0.7	0.1	147
Specific Conductance (µS/cm)	Surface	660.4	7.5	54.5	754.4	656.0	477.9	53
Specific Conductance (µS/cm)	Bottom	650.3	13.8	103.7	768.0	659.9	472.1	56
Turbidity, Field (NTU)	Surface	23.1	5.9	42.7	284.9	12.0	1.0	53
Turbidity, Field (NTU)	Bottom	119.8	40.2	287.4	1621.0	26.7	1.0	51
Water Temperature (°C)	Surface	20.5	0.5	6.1	31.3	22.7	6.5	167
Water Temperature (°C)	Bottom	19.5	0.4	5.9	28.9	21.2	6.3	174

Notes: 1. Summary statistics for physical water quality parameters, from all sites and dates, Harlan County Lake, April 2010 through September 2019.
2. Standard Error=SE
3. Standard Deviation=SD.

Harlan County Lake is a hypereutrophic lake with nearly ideal physical and chemical conditions for production of HABs. An abundance of soluble orthophosphate and a low (i.e., less than 12) TN:TP ratio are two frequent water quality conditions associated with proliferation of blue-green algae which could produce toxins in freshwater (Downing, J. A., and E. McCauley 1992; Xiaofeng et al. 2012) and have been present at HAB prone lakes in Kansas City District (USACE 2019). Reduced water clarity from inorganic turbidity in the upper lake is likely the factor limiting cyanobacteria at Harlan County Lake. Zebra mussels have increased Secchi measures at all Kansas City District lakes within 5 years of colonization which has led to an increase in HABs at zebra mussel infested lakes.

The algal toxin microcystin is monitored by the Nebraska Department of Environment and Energy (NEDEE) weekly at swim beaches from May-September. This common toxin, produced by numerous species of cyanobacteria, triggers the issuance of Public Health Alerts for beaches as outlined by NEDEE public web document (http://dee.ne.gov/NDEQProg.nsf/OnWeb/SWMA). Health Alerts have been issued at the reservoir twice in the past ten years, 2013 and 2019. The average concentration of microcystin typically peaks in early July before releases from the reservoir increase for downstream irrigation needs (Figure 3-171). Average monthly toxin concentration from Harlan County beach monitoring is below EPA recommended recreational warning threshold of 8 ppb (EPA 2019).

Figure 3-171. Harlan County Swim Beach Total Mycrocystin and Average Microcystin-2010–2019



Total microcystin and average microcystin concentration measured at Harlan County swim beaches from 2010–2019 (Courtesy of Nebraska Department of Environment and Energy).

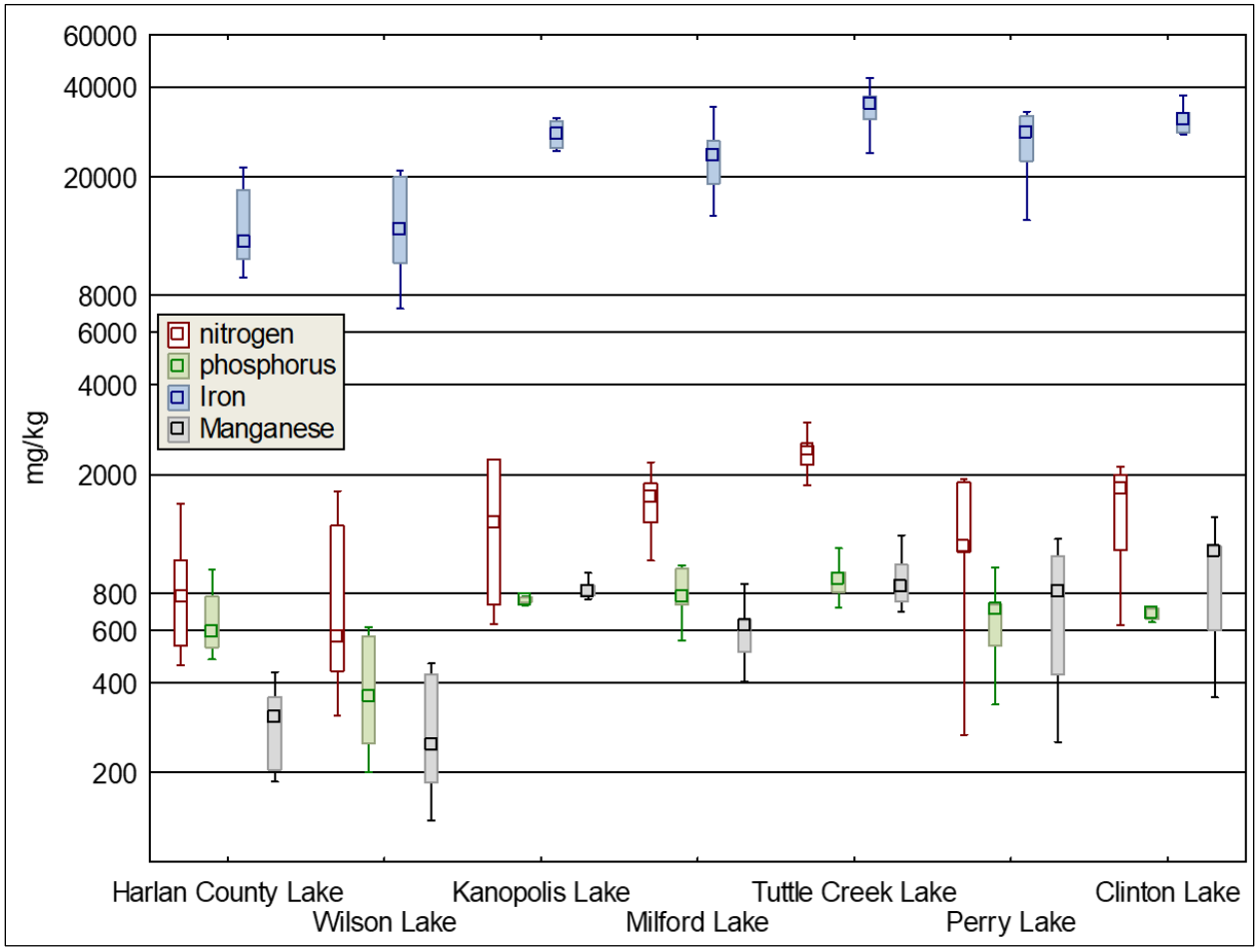
Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discuss until aging lakes begin to release phosphorus back into the water column causing HABs and other water quality issues (Pettersson 1998; Søndergaard et al. 2003) or when sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984). Numerical sediment quality guidelines (SQC) including sediment quality objectives, criteria and standards have been developed and used by government agencies for ecosystem protection. Assessing sediment quality of prospective dredged materials and evaluating ecological risk assessments is a critical step for reservoir sustainability discussions (Long and MacDonald 1998). Several publications have outlined methodologies for assessing sediment quality relative to the potential for adverse effects on sediment-dwelling organisms in freshwater systems (MacDonald et al. 1992; US EPA 1992, 1997; Ingersoll et al. 1996, 1997; Smith et al. 1996). A unified approach for sediment quality assessment based on freshwater ecosystem effects (MacDonald et al. 2000) allows lake owners, management agencies, and regulatory agencies to make informed decisions based on consensus-based concentration thresholds derived from aquatic toxicology data and EPA recommendations for common metals found in USACE Kansas City District lakes. Kansas City District Water Quality Program initiated collection of baseline lake sediment data in 2016 (Figure 3-173) to gather baseline sediment nutrient and trace metal contamination data at standardized lake water quality sites. Based on long-term monitoring water quality sample results, less likely contaminants like polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), and chlorinated pesticides are not frequently included in lake-bed sediment samples.

Median nitrogen, phosphorus, iron, and manganese concentrations reported in lake-bed sediment results from Harlan County Lake ranked near the lowest of Kansas City District Lakes in the Kansas River watershed (Figure 3-172). Nitrogen and phosphorus concentrations from Harlan County Lake were within the reported range, but less than

average when compared to results from lakes from Southeast and Northern United States (Barko, J.W. and R.M Smart 1986). Total metal concentrations from Kansas City District sample results (Figure 3-173) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed (MacDonald et al. 2000).

Figure 3-172. Kansas River Watershed U.S. Army Corps of Engineers’ Lake-bed Sediment Results 2008–2019



Data compiled from all USACE bed sediment samples for select nutrient and metals from all Kansas River Watershed Lake sites collected from 2008–2019

Figure 3-173. Harlan County Lake-bed Sediment Chemical Concentration 2017 and 2020

Station	Date mm/dd/yyyy	Time hhmm	Ammonia Nitrogen mg/kg	Nitrate-Nitrite Nitrogen mg/kg	Total Kjeldahl Nitrogen mg/kg	Phosphorus mg/kg	Arsenic mg/kg	Copper mg/kg	Iron mg/kg	Lead mg/kg	Manganese mg/kg	Nickel mg/kg	Zinc mg/kg	Cadmium mg/kg	Chromium mg/kg	Total Solid %	T. Mercury mg/kg
HC-2	9/13/2017	1000	206	<5.2	2210	770	9.0	19.1	19600	16.8	412	20.0	75.7	0.97	23.1	31.9	
HC-4	9/13/2017	1100	98.1	<4.6	1600	672	9.1	20.4	21500	16.7	407	22.8	86.1	1.0	23.2	35.8	
HC-5	9/13/2017	1030	26.1	<3.1	534	479	5.8	7.8	10600	8.4	186	12.2	40.6	0.46	11.5	58.8	
HC-2	9/24/2020	1000	118	1.11	667	778	14	19.2	20700	13.4	434	18.5	70.5	1.81	28.4		0.0216
HC-4	9/24/2020	1020	15.8	<3.1	574	656	13.2	15	18100	10.3	295	16.2	61.2	ND	23		0.0206
HC-5	9/24/2020	1050	7.27	7.4	458	525	13.6	8.64	10800	6.31	246	12.8	36.6	ND	13.7		0.0144

3.7.4.1.2 Milford Lake

Milford Lake is the largest lake in Kansas (15,709 acres) and is located on the Republican River in Kansas. The Republican River flows from Harlan County Lake through fertile farmland into Milford Lake and then into the Kansas River. The primary water quality threats to Milford Lake, as summarized by the current Total Maximum Daily Load (TMDL) for eutrophication, include nutrients, sediment, toxic cyanobacteria blooms, and dissolved oxygen sags.

In 2011, KDHE collaborated with USACE and stakeholders to develop and implement public policies addressing recreational health risks associated with HABs. Analytical results have been used to provide recommendations to public lake managers, including federal, state, and city authorities. From 2011 to 2015, HABs appeared to be a chronic issue with significant impacts on recreation and the local economy. In 2015, KDHE designated three zones (Zones A, B, and C) to increase management flexibility for HABs, which often cluster on the downwind or leeward side of Zone C. Zone-specific public health advisories have proven effective in Kansas, allowing recreational use of lakes when HABs are confined to relatively small and discrete areas. Perry Lake and Tuttle Creek Lake were also delineated into management zones. Current KDHE HAB policy and resources can be found at: Harmful Algal Bloom | KDHE, KS.

Watershed conservation efforts have gained higher priority in state and local rankings to address Milford Lake's hypereutrophic conditions and chronic HABs. HAB impacts have been linked to local economic effects, such as a decrease in tourism and recreational visitation, changes in property values, and potential threats and increased costs to downstream water supply (Pearce 2020; Graham et al. 2012). Two programs lead the way for watershed improvements at Milford Lake. The Watershed Restoration and Protection Strategy (WRAPS) program is a KDHE planning and management tool used to identify watershed restoration and protection needs, establish management goals, develop plans (e.g., EPA-approved 9-Element Watershed Plans), and implement goals to address water resource concerns (WRAPS Program). Most priority goals/targets of the WRAPS Plans for sub-basins in the Kansas River Watershed align with strategies and measures included in this study. The WRAPS process is in the implementation and monitoring phase of their process to administer programs using BMPs to reduce phosphorus loads originating in Kansas by 617,204 pounds per year, nitrogen loads

originating in Kansas by 2,341,263 pounds per year, and a sediment load reduction goal of 32,999 tons per year.

The Milford Watershed Regional Conservation Partnership Program (RCPP) (https://www.milfordwatershed.org/rcpp) is a collaborative effort between the KWO and regional entities aimed at improving water quality in Milford Lake and its upstream areas. This program is a result of a $2.88M grant awarded through the NRCS.

Reservoir Hydrologic Data Summary

Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics related to flow (i.e., volume, load, and concentration), water residence time, and lake mixing/stratification which in turn influence physical and chemical process, frequently resulting in biological response. Figure 3-174 illustrates reservoir hydrologic data with overlay of water quality sampling events.

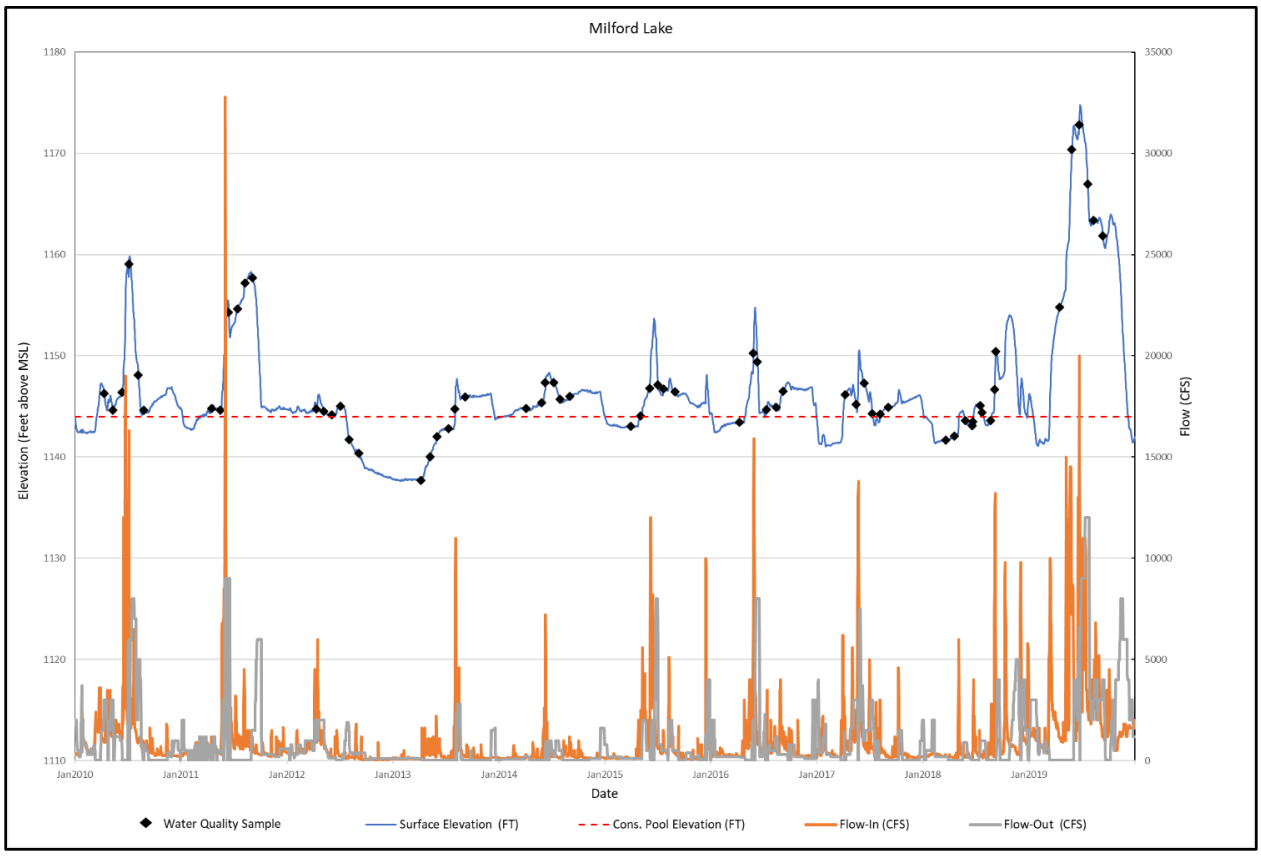
Water quality sampling events by USACE staff were conducted monthly from 2010–2019 coinciding with the typical recreational season (April–September). Low inflow periods were observed at the end of 2012 with surface elevation falling below 1,138 feet while recovery period is apparent beginning late spring of 2013. Significant flooding with a corresponding high-water period was observed in 2019 as inflows peaked at 20,000 cfs with six or more events exceeding 10,000 cfs from March through August. Surface elevation of Milford Lake peaked at 30.8 feet above conservation-pool elevation (CPE) and exceeded CPE for 268 days in 2019. Nutrient budget (i.e., nutrients entering, nutrients loading from internal sources, nutrients leaving) and hydraulic residence time impact water quality and HABs at Milford Lake.

Milford Lake average water residence time of 7.7 months was calculated from historic water management records for the period from 1990 to 2022 using HEC-ResSim software. Milford Lake average water residence time is slightly below the average of 10.8 months for seven USACE Kansas River Watershed lakes in this study. The shorter residence time at Milford Lake allows for less time for dilution, settling, and biological attenuation of agricultural runoff. This has implications for the water quality downstream in the Republican River.

The importance of water residence time at Milford Lake extends to sediment accumulation and the storage of sediment-bound contaminants. Seasonal variations in water quality are noticeable, particularly in late summer. During this period, water residence time rapidly increases due to reduced inflows linked to summer weather patterns, coupled with managed outflow reductions to maintain lake surface elevation targets. Consequently, there is an increase in soluble nutrient concentrations from plant sources, in addition to external nutrient contributions from inflow streams, concurrent with reduced outflows.

These conditions during summer often lead to increased algal growth and the potential for HABs, as discussed in subsequent sections.

Figure 3-174. Milford Lake Time Series of Daily Water Surface Information

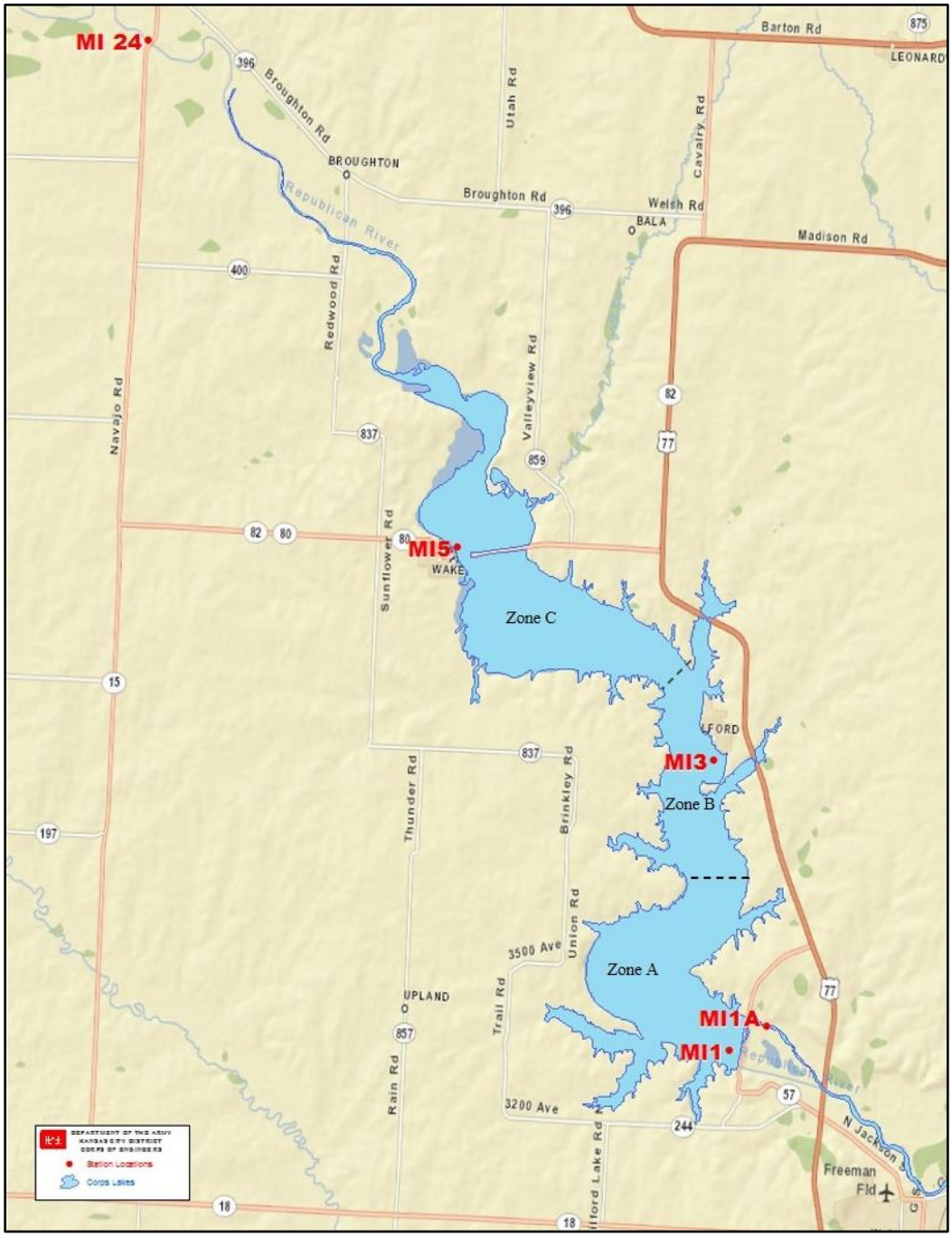


Time series of daily water surface elevation, inflow, outflow, and multipurpose pool elevation for the period Jan. 2010 through Dec. 2019 from DSS data (HEC-DSSVue). Water quality sample dates are plotted corresponding with lake surface elevation for reference.

Water Quality Sample Locations

Historic water quality sample sites at Kansas City District lake projects are generally named in decreasing numeric order from inflow sites to the outflow site below the dam (Figure 3-175). KDHE HAB management zones have been added to map for reference. To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow.

Figure 3-175. Milford Lake Historic USACE Water Quality Sample Sites



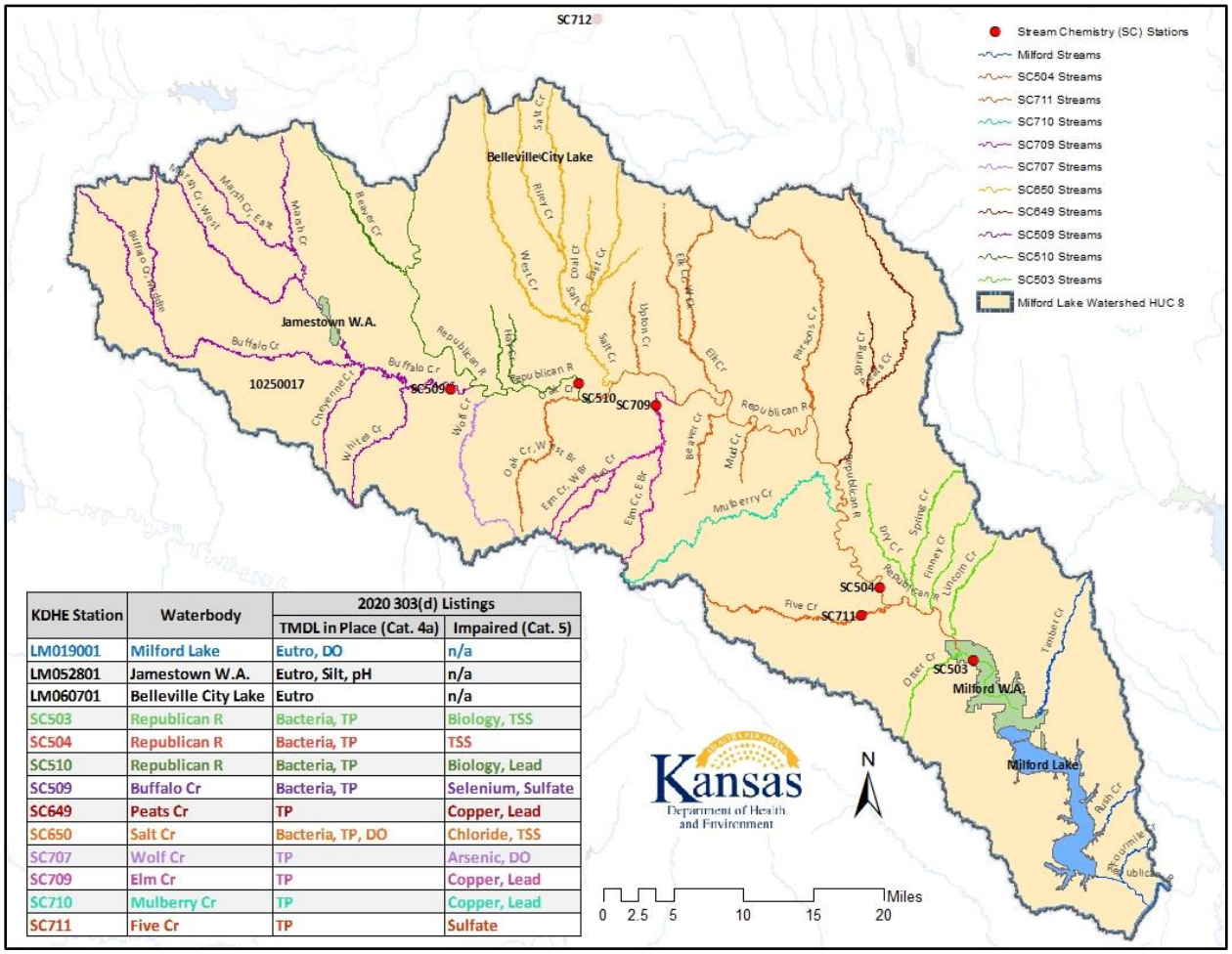
Map of historic USACE water quality sample sites including inflow stream(s), lake water quality/bed sediment sample sites, and outflow sites as well as KDHE HAB management zones.

Impairments

The Milford Lake watershed includes ten impaired stream segments listed on the 2020 303(d) list (Figure 3-176) impacted primarily by metals, salt compounds, and/or sediments. Inflow streams appear to attenuate chemical impairments to levels below state water quality standards before they enter Milford Lake near the town of Wakefield,

Kansas. Nutrient and sediment impacts, directly related to HABs and low dissolved oxygen, persist in Milford Lake as supported by Eutrophication TMDL.

Figure 3-176. Impaired Waters and Total Maximum Daily Loads of Milford Lake and Watershed



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM019001	Milford Lake	Eutro, DO	n/a
LM052801	Jamestown W.A.	Eutro, Silt, pH	n/a
LM060701	Belleville City Lake	Eutro	n/a
SC503	Republican R	Bacteria, TP	Biology, TSS
SC504	Republican R	Bacteria, TP	TSS
SC510	Republican R	Bacteria, TP	Biology, Lead
SC509	Buffalo Cr	Bacteria, TP	Selenium, Sulfate
SC649	Peats Cr	TP	Copper, Lead
SC650	Salt Cr	Bacteria, TP, DO	Chloride, TSS
SC707	Wolf Cr	TP	Arsenic, DO
SC709	Elm Cr	TP	Copper, Lead
SC710	Mulberry Cr	TP	Copper, Lead
SC711	Five Cr	TP	Sulfate

Inflows/Outflow

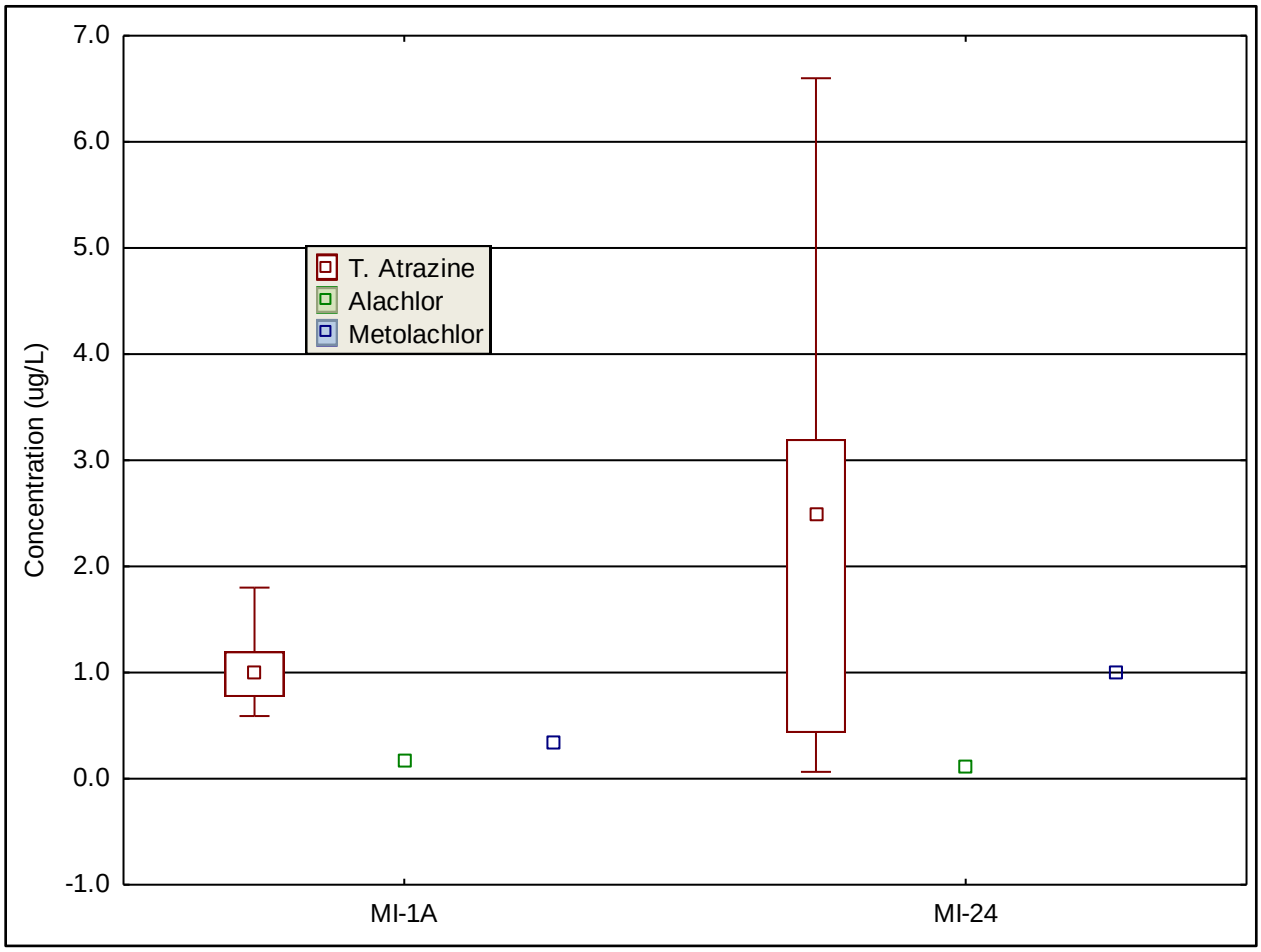
Lakes and reservoirs store sediment and associated chemical compounds carried by inflows and runoff. Sediment, nutrient, contaminant, and geological sources in the watershed and associated inflows influence lake water quality including water clarity, nutrient concentration, chemical contamination, and element ratio and nutrient balance in receiving waters. These factors also have implications for biological response in the streams and receiving waters including trophic state and which type of plants and algae dominate the primary production in the system.

Nutrient sources, geology, and land-use are primary influences on water quality in inflow streams in the watershed which influence Milford Lake. Water exiting through the dam or outlet works of USACE lakes can be quite different than the inflows as large amounts of nutrients, pesticides, and metals are processed and/or stored in the lake causing a sink effect (Satoh et al. 2002). Chemical compounds solubilized under anoxic conditions when lakes are thermally stratified are seasonal exceptions. Dissolved oxygen concentrations below state water quality standards in outflows related to release of

anoxic water rarely occur at Milford lakes due to infrequent thermal stratification. Supersaturation of gasses during flood releases can potentially lead to water quality issues downstream of dams. However, this specific concern is unlikely at Milford Dam due to relatively minor pressure differences as water exits the dam, and the presence of turbulence helps in equalizing gas pressure, mitigating the risk of supersaturation.

Atrazine is the most common herbicide detected in Milford Lake inflows and outflow. Herbicides are not listed as impairments for Milford Lake by KDHE. Slightly less than 50 percent of inflow sample results for total atrazine at the inflow site near Clay Center are below the EPA drinking water criteria of 3 ug/L (EPA 1995) while no samples from the outflow exceeded criteria (Figure 3-177).

Figure 3-177. Herbicide Concentration Upstream and Downstream of Milford Lake 2010–2019



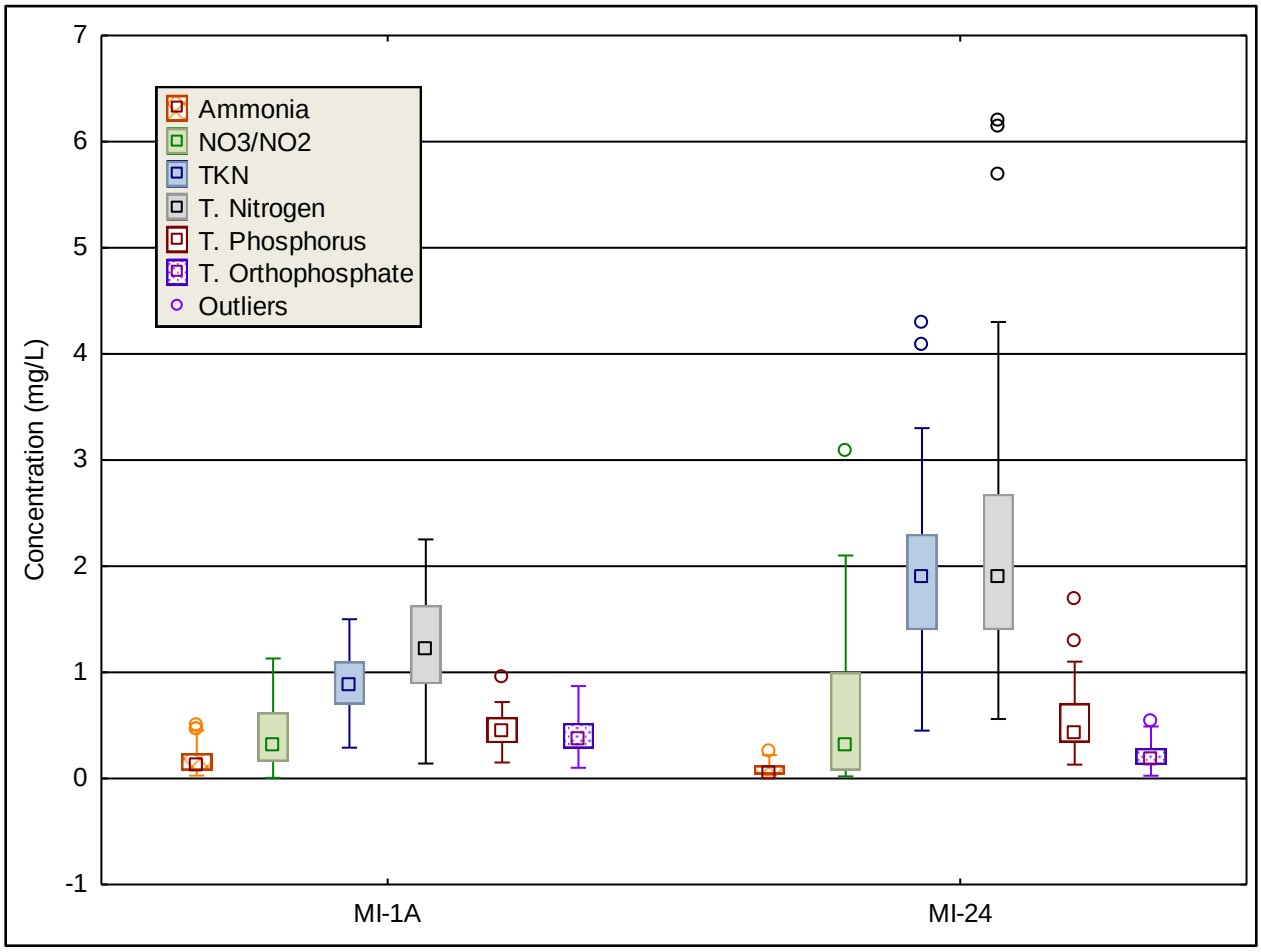
Fertile agricultural watersheds in northern counties of Kansas provide excess nutrients to inflow streams, Milford Lake and downstream. In the rural landscape, nitrogen deposition is more likely associated with agriculture or fertilizer application (Arbuckle and Downing 2001, Boyer et al. 2002) while phosphorus loading is associated with soil erosion and farming practices as well as sewage effluent and runoff from urban watersheds (Downing and McCauley 1992; Withers and Jarvie 2008).

Total nitrogen and organic nitrogen (TKN) concentration decreased significantly from the inflow site to the outlet from attenuation and denitrification/biological uptake (Figure

3-178). Median bioavailable forms of nitrate/nitrites were similar at inflow and outflow sites but more variable in the inflow, likely associated with runoff events. Ammonia nitrogen increases from anoxic conditions found in the bottom strata near the dam leads to seasonal increases in ammonia in releases from Kansas City District lakes. Consequently, ammonia in concentrations at the outlet exceeded those measured at the inflow site (Figure 3-178).

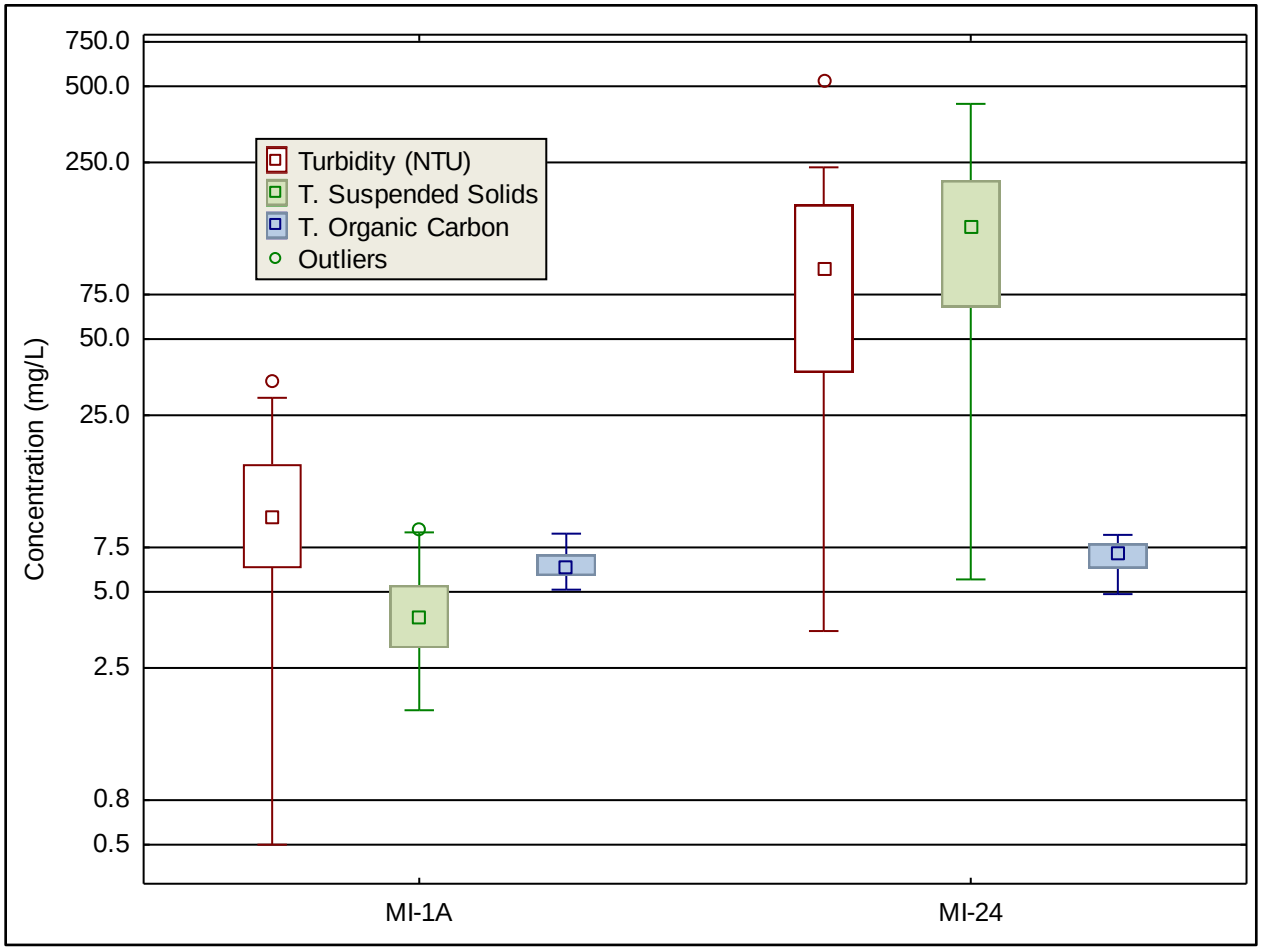
Inflow total phosphorus median concentrations and interquartile range were similar to outflow results with outliers more common in inflow due to rain events with potential runoff. Seasonal increases of soluble orthophosphate related to anoxic conditions at the dam resulted in median and maximum orthophosphate concentrations outflows exceeding those found in the inflow (Figure 3-178).

Figure 3-178. Nutrient Concentration Upstream and Downstream of Milford Lake From 2010–2019



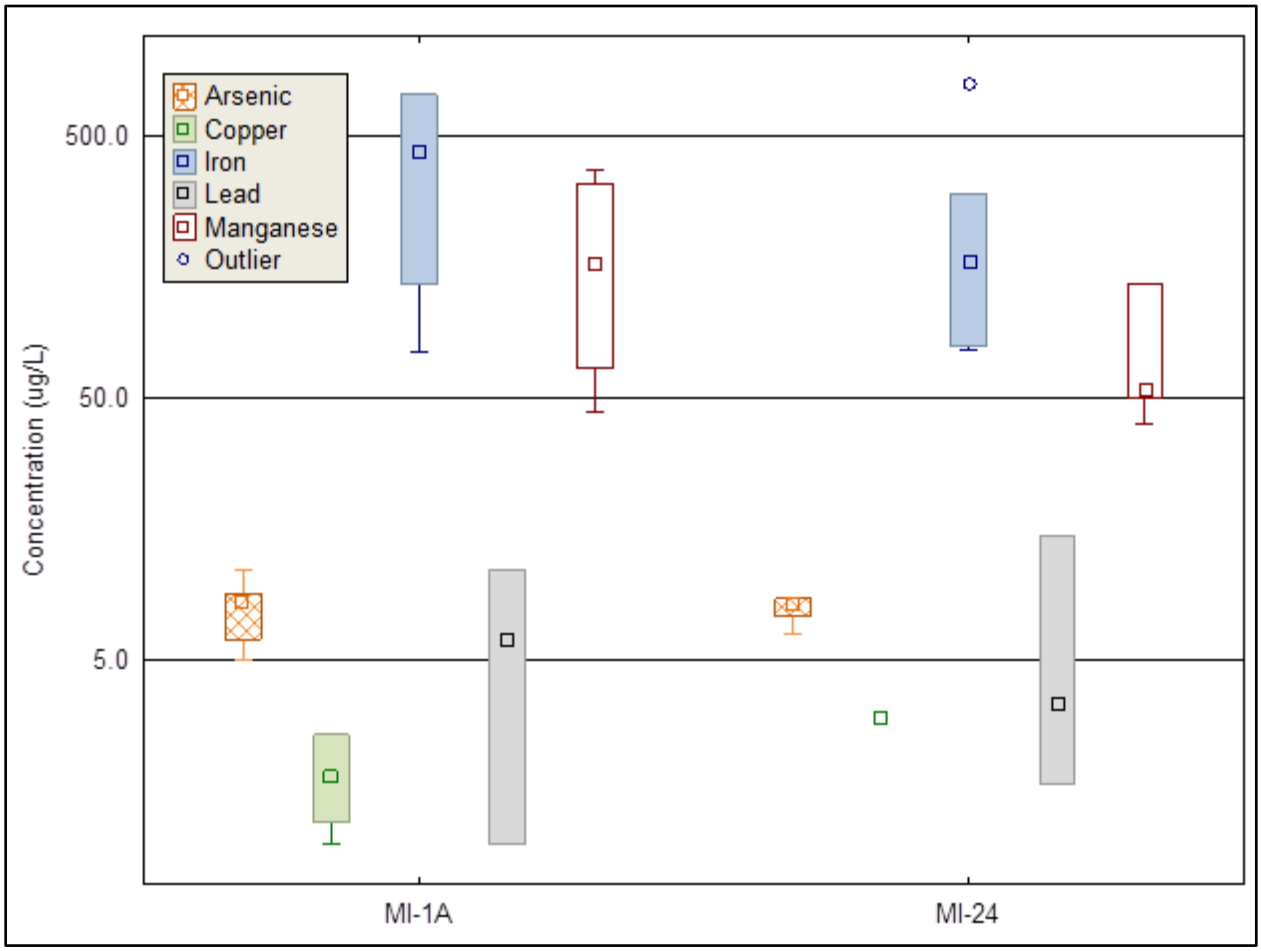
Water clarity improves as water moves from the river through Milford Lake to the outflow. The Republican River inflow site can be described as more turbid with significantly more suspended solids than the outflow (Figure 3-179) as median turbidity and TSS from MI-24 exceed all data records from the outflow site (MI-1A) during the 10-year period. Total organic carbon concentration was similar between the two sites.

Figure 3-179. Water Clarity Metrics Upstream and Downstream of Milford Lake From 2010–2019



Anoxic conditions near the lake bottom in summer months create the most efficient sampling strategy to quantify metal/metalloids solubilized from lake-bed sediment under redox conditions, which can impact water quality of releases from lower strata. Inflow streams give a more direct relationship to metals released in the watershed that will eventually make their way to the lake. Median concentrations of iron and manganese were significantly greater in the outflow samples than those collected from the inflow site (Figure 3-180). Median and interquartile ranges were similar between inflow and outflow sites for lead and arsenic. Milford Lake outlet and inflow samples contained moderate to high concentrations of naturally occurring iron, manganese and arsenic. However, samples did not exceed EPA drinking water standards for arsenic (maximum allowable concentration 10 ug/L or ppb). EPA classifies iron and manganese as secondary contaminants (i.e., altered taste, odor, and color of drinking water). Water suppliers remove metals and contaminants from finished products.

Figure 3-180. Total Metal Concentration Measured Upstream and Downstream of Milford Lake From 2010–2019



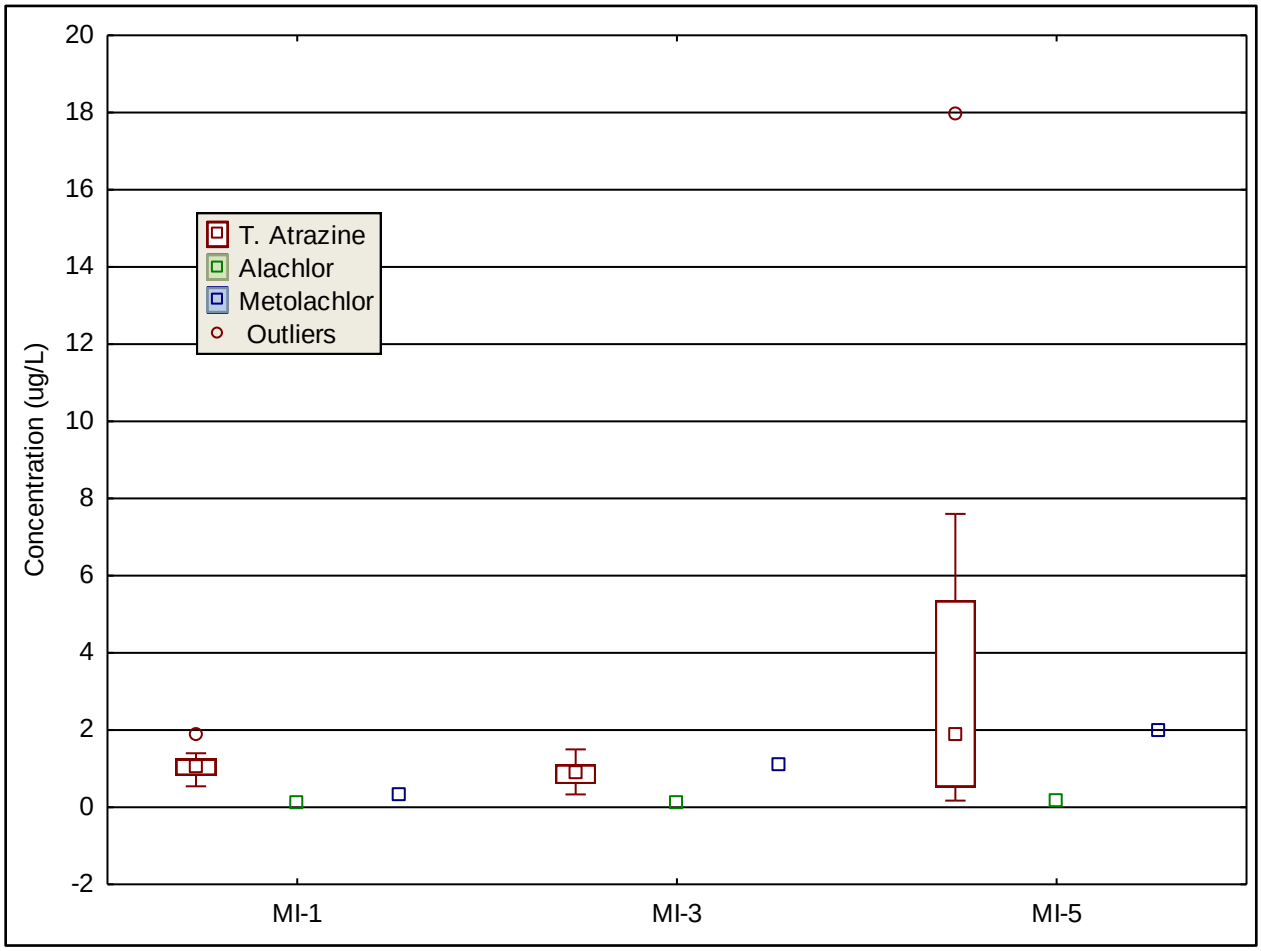
Lake Water Quality

Milford Lake, the largest lake in Kansas, is classified as hypereutrophic due to excessive nutrients, particularly biologically available orthophosphate. This has led to its listing as impaired by KDHE. The hypereutrophic status of the lake primarily impacts authorized purposes of recreation water supply, downstream water quality, and fish/wildlife conservation with minimal affect to flood reduction and navigation support. The excessive nutrients and frequent HABs in the lake pose challenges to maintaining water quality for various uses and can hinder recreational activities, impact fish and wildlife habitats, and potentially affect downstream water quality. Efforts to reduce phosphorus in the watershed are prioritized to address these issues and improve the lake's overall condition.

USACE and KDHE pesticide sample results indicate three common herbicides detected in Milford Lake are found in higher concentrations in the Republican River and diminish as water moves through the lake. Concentrations of atrazine exceeding EPA drinking water criteria of 3 ug/L is apparent in at least 25 percent of samples (Figure 3-181) while concentrations of atrazine were less variable and less concerning at lower lake sites.

KDHE Lake and Wetland Monitoring Program Reports (KDHE 2007; 2010) also discuss detection of pesticides in Milford Lake at levels below state water quality standards.

Figure 3-181. Milford Lake herbicide concentration from 2010–2019

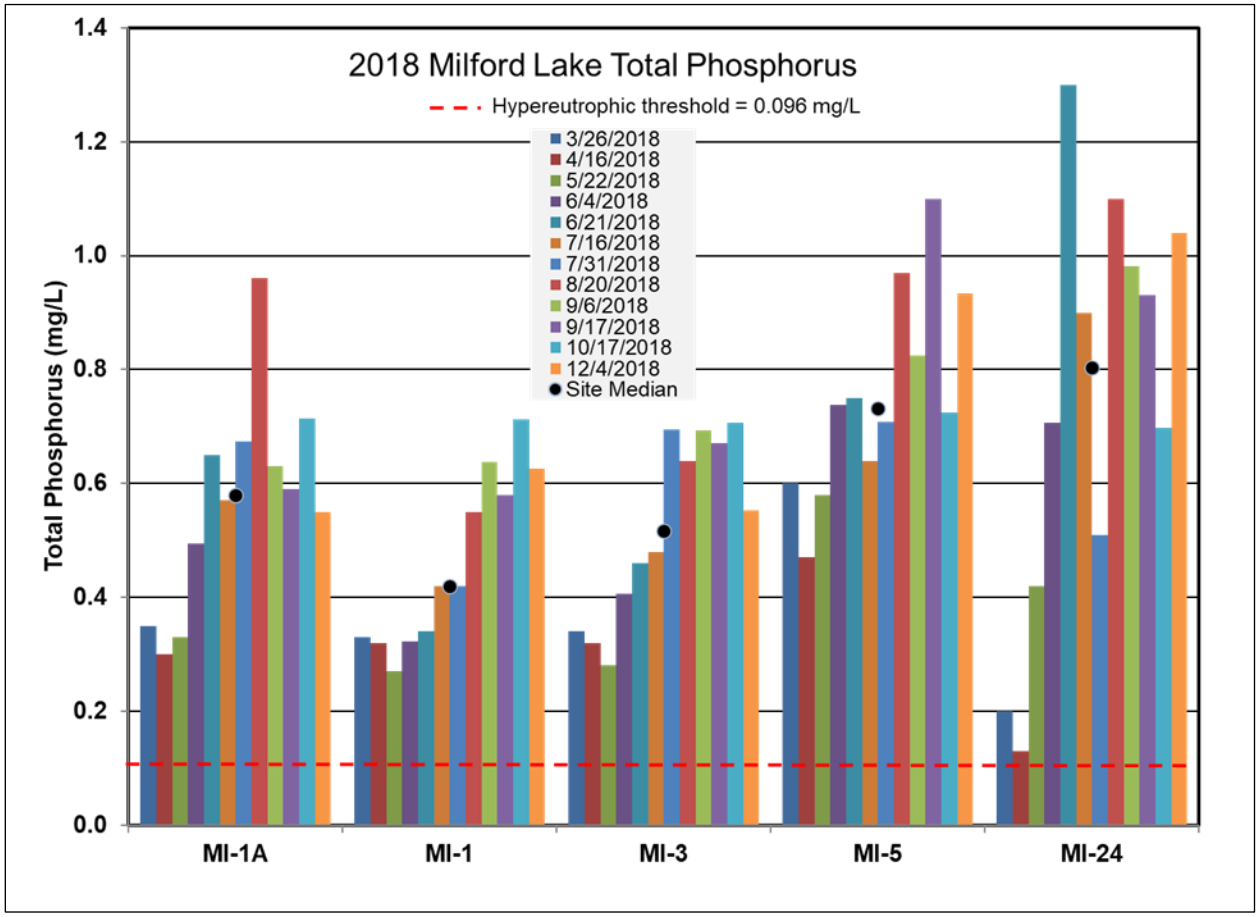


Controlling eutrophication is important to most lake managers, but it is critical to hypereutrophic systems (Jeppesen et al. 2003) as undesirable conditions develop for aquatic life and longevity and utility of the reservoir come into question (Smith et al. 1999). Hypereutrophic conditions are present when chlorophyll a concentration exceeds 30 µg/L (KDHE 2014) or phosphorus concentrations exceed 0.096 mg/L (Carlson, 1977). Mean total phosphorus for Milford Lake near the dam (MI-1) from 2010–2019 was 0.39 mg/L or 4 times greater than the hypereutrophic threshold (Figure 3-182). Plant available orthophosphate typically comprises more than 70 percent of the total phosphorus measured during summer months at all stations (USACE unpublished data 2010–2019) but comprised 87 percent of total phosphorus near the dam (Figure 3-183). An intensive Milford nutrient study conducted by USGS in 2018 reported orthophosphate comprised 77 percent or more of the total phosphorus at 28 of 30 sample sites during July, August, and October. (Leiker et al. 2021). Kansas City District Water Quality Program also increased sampling effort during 2018 to better describe nutrient movement and sources in Milford Watershed. Median total phosphorus concentrations decreased from the Republican River and at each lake site along the gradient from upper to lower lake while lake sites experienced steady increases in total

phosphorus from May through October (Figure 3-182). This pattern of phosphorus attenuation as water moves through the lake and a steady increase in phosphorus measured at lake sites throughout the summer months is frequently observed at Milford Lake except when flood conditions increase and homogenize nutrient concentrations lake-wide (USACE 2010–2019).

Nutrient sample data from 2010–2019 Milford Lake illustrates a positive trend in total phosphorus (Figure 3-183) while no trends were apparent in nitrogen analytes or sediments. A negative trend in total nitrogen to total phosphorus ratio, important to cyanobacteria dominance of phytoplankton community (Elser et al. 2007. Downing and Mckauley 1992) is apparent at Milford Lake (Figure 3-184) and several other district lakes with HABS. A detailed statistical trend analysis including seasonally adjusted comparisons are discussed in FWOP section.

Figure 3-182. Milford Lake total phosphorus concentration from March-December 2018



10254 *Figure 3-183. Milford Lake total phosphorus concentration and linear trend line from 2010–2019*

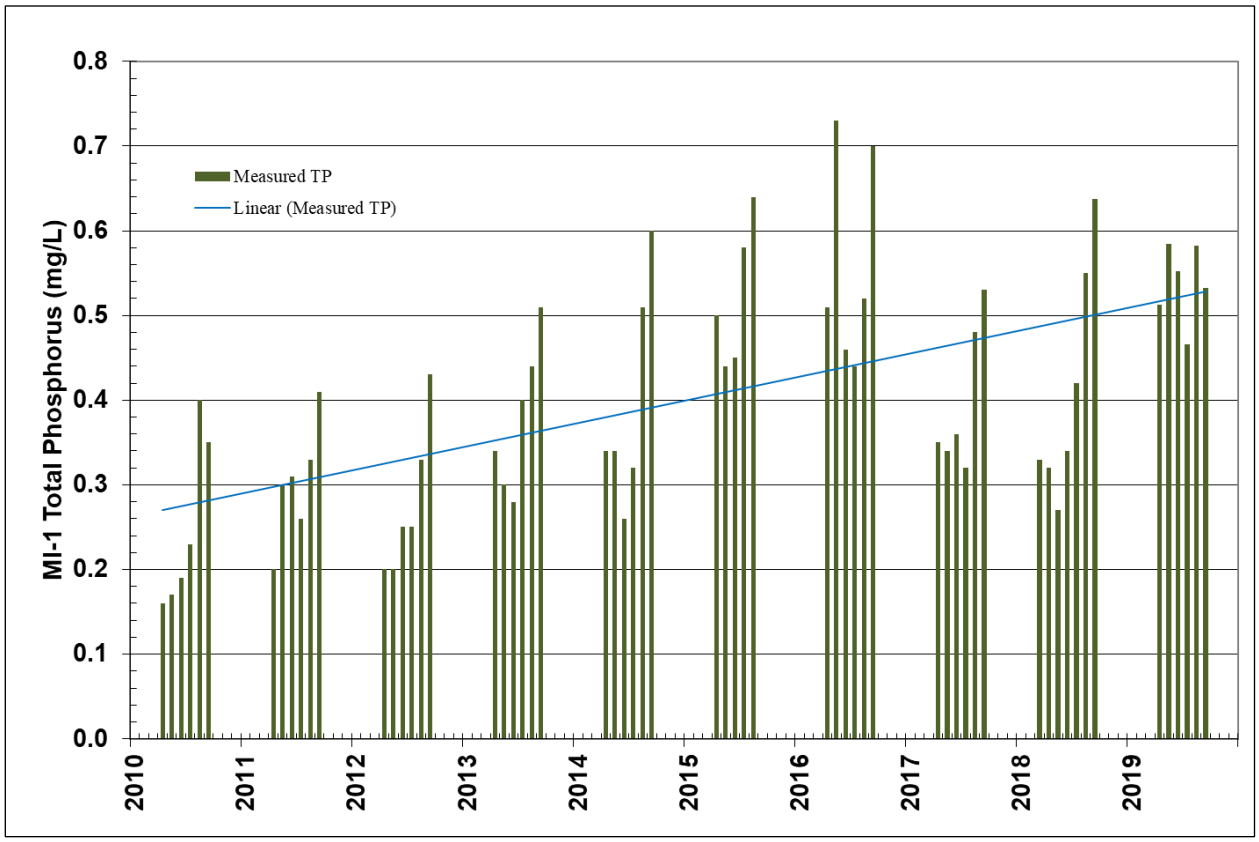


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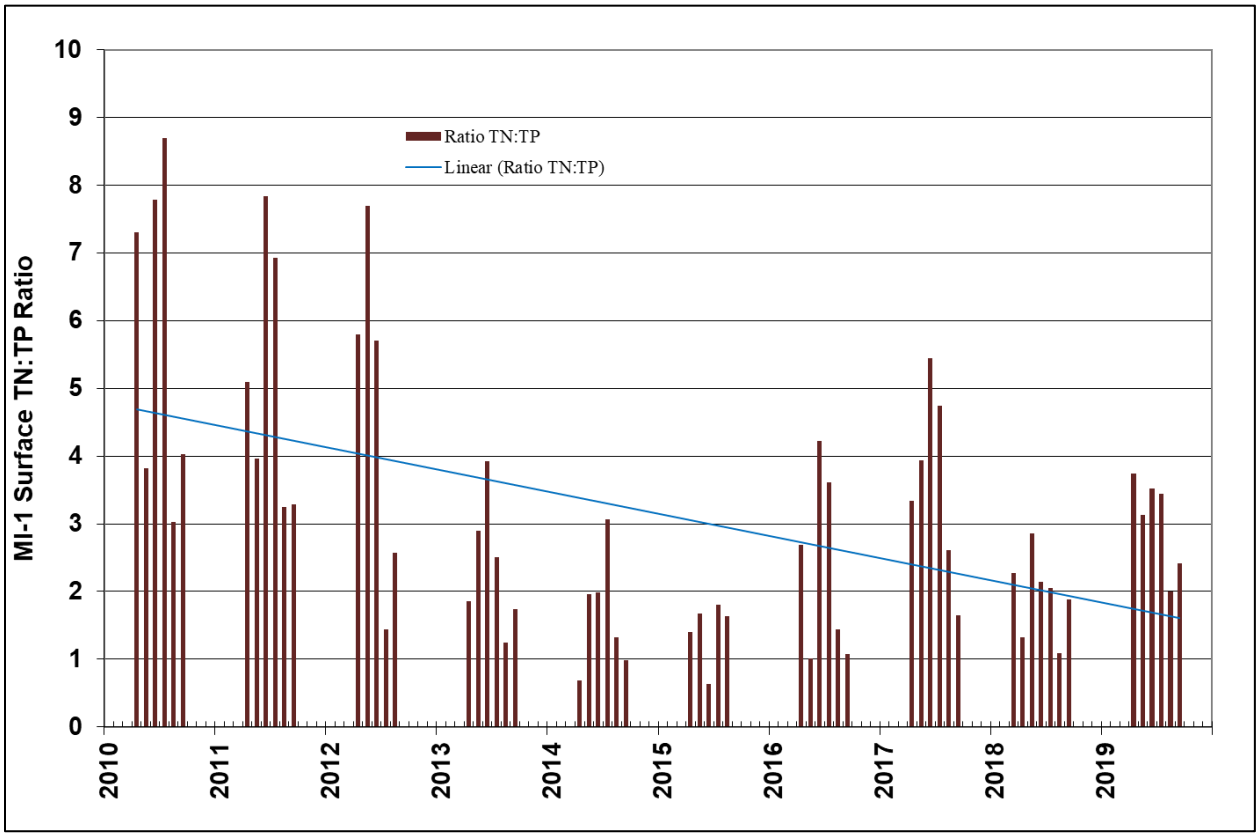
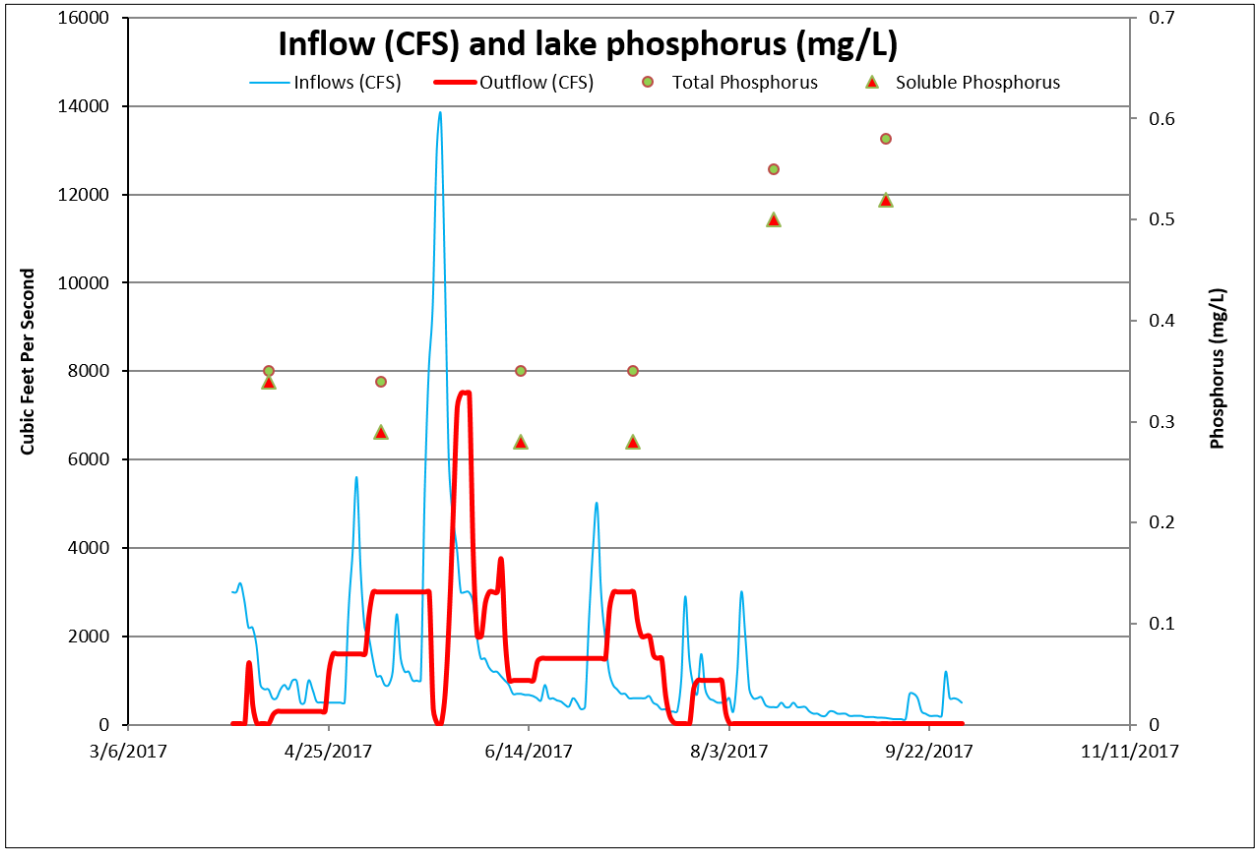
Figure 3-184. Milford Lake ratio of total nitrogen to total phosphorus and linear trend line from 2010–2019



Historic water quality data trends and increasing HABS at Milford Lake were the impetus to plan for adjustments to lake level management allow a draw-down during the spring and summer of 2016. The drawdown was planned to reduce cyanobacteria resting cell availability and limit internal nutrient loading from lake-bed sediment to potentially reduce HABs (KWO 2016). Large inflows prevented the successful drawdown. Lake level management to impact nutrient and HAB dynamics and reduce hydraulic residency time during HAB season continues to be the least cost prohibitive and low risk HAB remediation tool. Research on this topic was proposed in 2019 and supported by 12 Kansas City Districts with similar need (USACE-Environmental Laboratory ERDC 2019). Confounding rain events have influenced water management decisions in 2017 and 2019 while evaluations of lake level management actions on HABs were in progress. Anecdotal evidence of low HAB duration/intensity during low water periods in 2012–2013 and during periods with larger releases during prime HAB seasons as observed June–August of 2017 (Figure 3-185), and the absence of HABs during August flood releases of 2019 support the theory that operational changes to lake level management may be a tool to mitigate HABs.

Figure 3-185. Milford Lake Phosphorus Concentrations and Hydraulic Data April through September 2017



Ten-year nutrient data in Figure 3-186 indicate nitrate/nitrite and ammonia nitrogen were similar between the three lake sites, except outliers at the upper lake site. Median total nitrogen and TKN at the upper Milford Lake site exceeded the interquartile range of the lower lake site at the dam, likely due to presence of organic matter and algae present in higher concentration in upper lake samples. Median and maximum total phosphorus was greatest in the upper lake (MI-5) from 2010 to 2019 while median and minimum orthophosphate was lowest at this sample location (Figure 3-186), indicating biological uptake of orthophosphate by phytoplankton during summer months.

Mass balance estimates using Kansas City District intensive sampling results from 2018 indicate Milford Lake acts as a phosphorus sink, with considerably greater mass of total phosphorus entering the lake from inflows than leaving through the outlet (Figure 3-187). Brief periods of net loss of phosphorus from Milford Lake were evident in June and July 2018. Stored phosphorus in Milford Lake will increase internal loading risk as the lake ages and contributes to degraded water quality and HAB risks despite watershed conservation/nutrient reduction measures directed at runoff and external loading (Juracek 2014; Pettersson 1998; Søndergaard et al. 2003)

Figure 3-186. Milford Lake nutrient concentrations 2010–2019

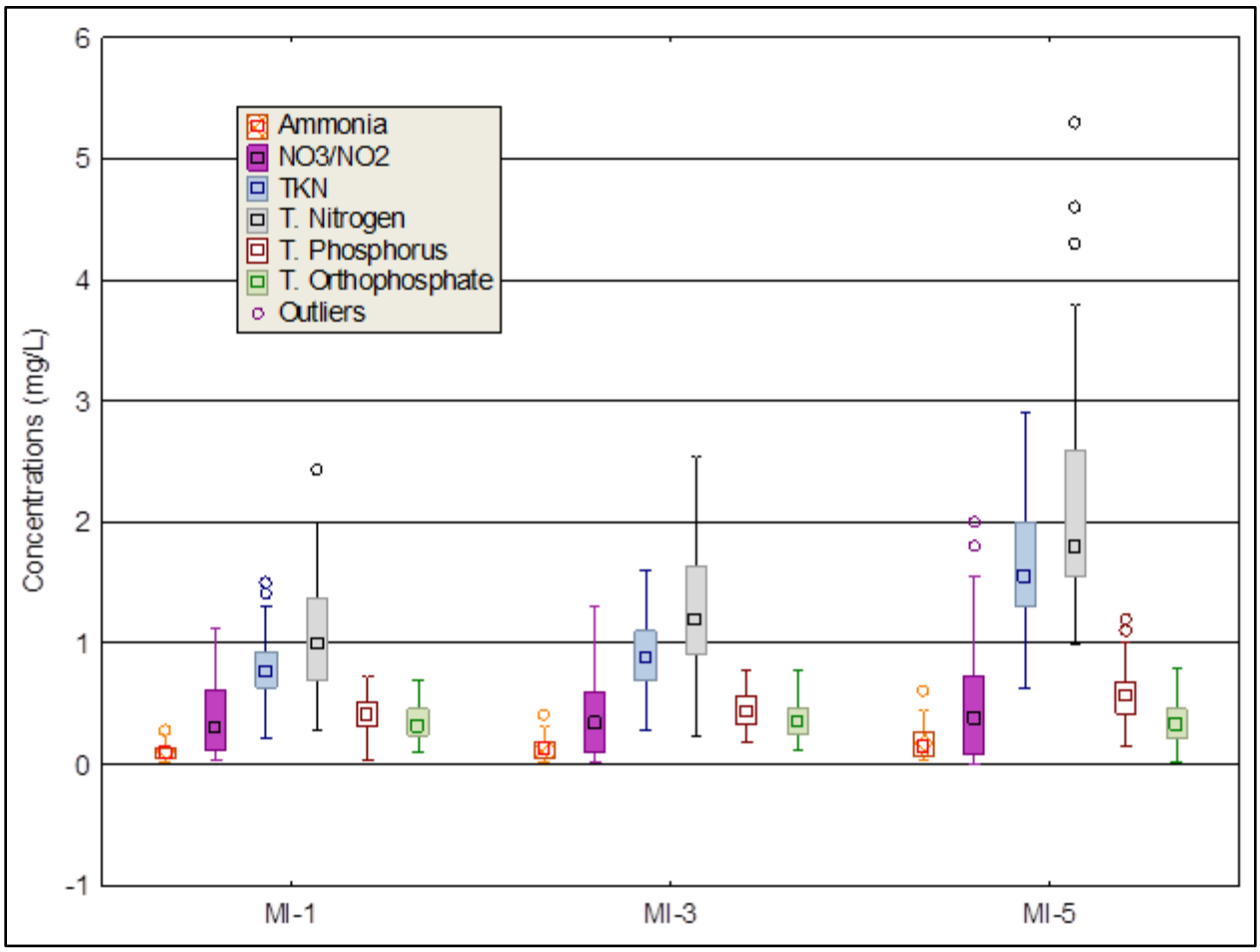
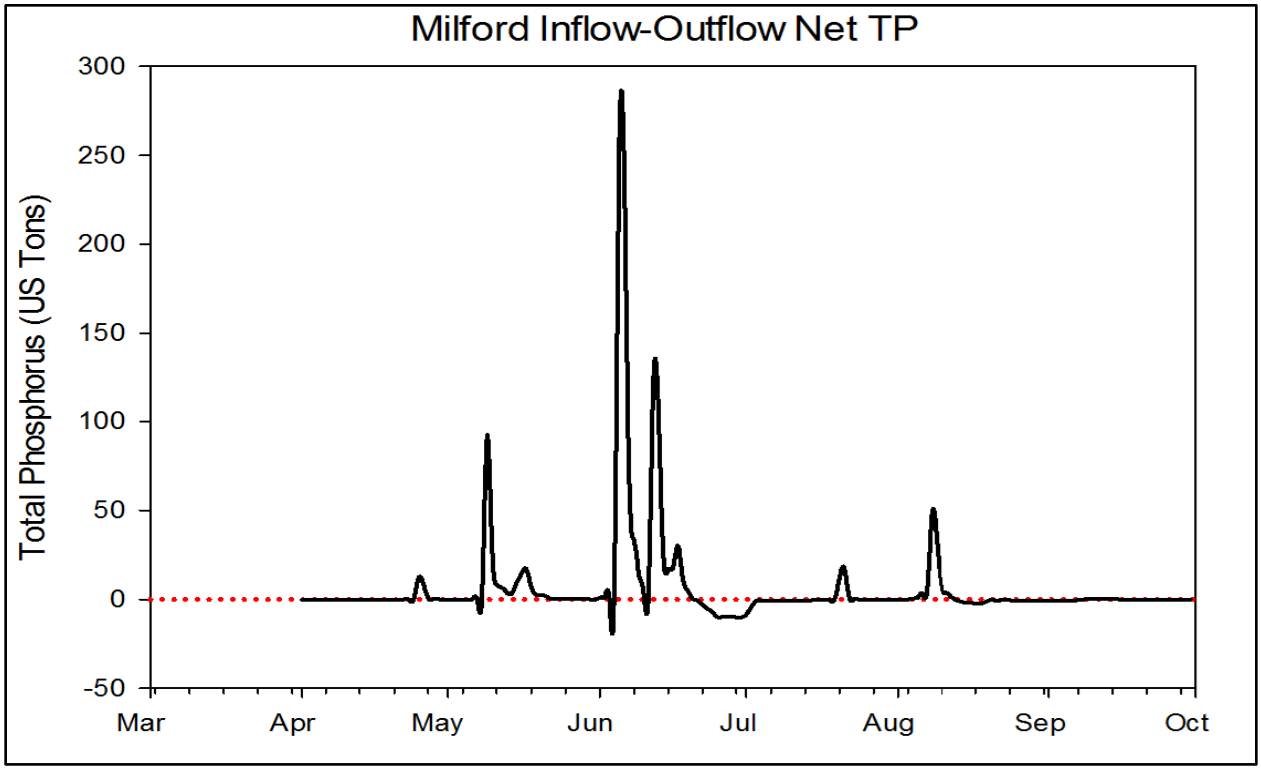
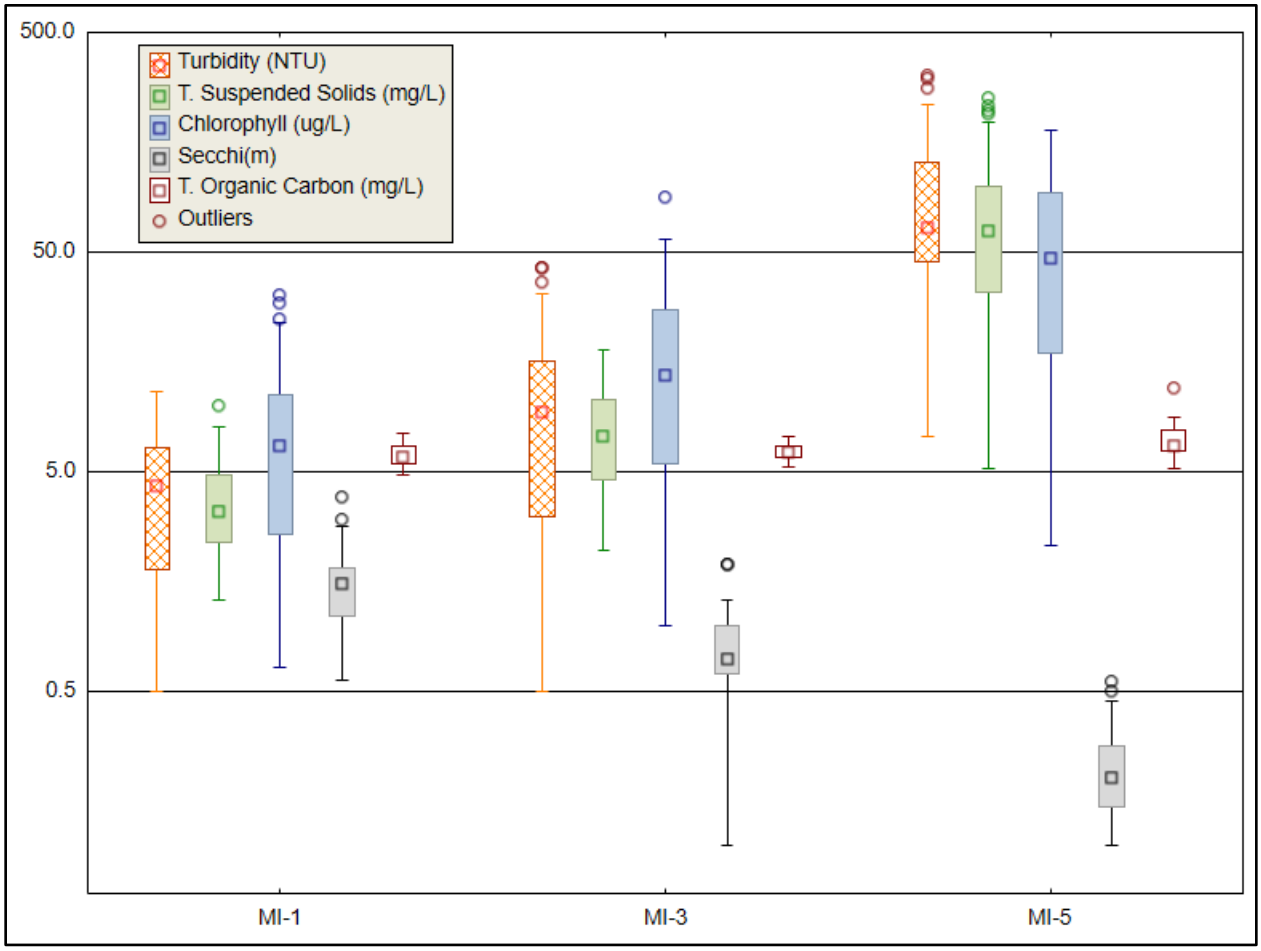


Figure 3-187. Milford Lake Total Phosphorus Budget from March through December 2018



Influences on light availability or water clarity include, but not limited to, inorganic sediment, organic carbon, turbidity, and phytoplankton (i.e., chlorophyll-a) (Testa et al. 2019). Light availability is a critical metric which influences biological productivity through light limitation of photosynthesis. Median total suspended solids, turbidity, and chlorophyll *a* concentrations were significantly higher and more variable at the upper lake site than mid and lower lake sites (Figure 3-188). Turbidity and TSS were an order of magnitude higher at the upper lake site. Consequently, Secchi depth was significantly different between all three sites as interquartile ranges do not overlap at any of the three sample locations with an order of magnitude difference observed between upper and lower lake sites (Figure 3-188). Organic carbon was slightly higher in samples from the upper lake site as expected from larger phytoplankton densities and influence from HABS.

Figure 3-188. Milford Lake Water Clarity Metrics from 2010–2019



A summary of descriptive statistics of chemical analysis results at the site nearest the dam is found in Table 3-121. Bottom samples are typically collected from Kansas City District lakes every third year with total metals collected during the peak stratified month of August when stratified conditions are most likely. Seasonal periods when the lake is mixed (not stratified), bottom sample results are nearly identical to surface sample results for most analytes. Anaerobic conditions allow for oxidation/reduction reactions to release chemical compounds, including metals, which we are trying to quantify with bottom samples. Non-detection or result below minimum detection level occur on occasion and have been included in sample results (Table 3-121) as the value of half of the reported minimum detection limit to reduce bias based on the assumption that the analyte is present at a concentration below laboratory quantification (EPA 1991). Sample size for bottom total metals samples was not sufficient for inclusion in the Table 3-121. All nutrient results, including orthophosphate, do not appear to differ between top and bottom samples in Table 3-121. Metals, orthophosphate, and suspended solids are typically more concentrate in the bottom samples during stratified months. However, total suspended solids was the only laboratory analyte with significant differences (Wilcoxon Signed-Rank Test; p=0.018) detected between surface and bottom samples at Milford Lake from April 2010 through September 2019 (Table 3-121).

Milford Lake nutrient results in Table 3-121 are indicative of impairment at the site near the dam as median total nitrogen (TN; 1.01 mg/L) and total phosphorus (TP; 0.39 mg/L) fall within the hypereutrophic range (Carlson 1977) and exceed Central Great Plains median and statewide benchmark (KDHE 2013). Chlorophyll a values at the dam were not in the eutrophic or impaired range as median chlorophyll a at the lower lake site was 6.6 ug/L while mean was 8.44 ug/L for the period April 2010 through September 2019. The use of summer chlorophyll values are applicable for trophic state index calculations due to increased seasonal variability during the Spring months (Carlson 1977). KDHE reported long-term chlorophyll a average for 1996–2012 as 21.4 ug/L at KDHE sample site near the dam while Kansas City District average for the same period was 16.32 ug/L. KDHE chlorophyll a sample average is much higher than long-term averages from two different periods reported by USACE collections. This can be explained by seasonal variability as KDHE samples are typically collected in summer months while Kansas City District Water Quality Program statistics include 6 samples per year which include the months of April, May, and September when chlorophyll values are lower. Leiker et al. (2021) report chlorophyll a, phycocyanin (i.e., blue-green algal pigment) and algal toxin microcystin concentrations can vary greatly at Milford Lake during the months of July-October as phytoplankton community and relative abundance change.

Table 3-123. Milford Lake Chemical Water Quality Parameters and Chlorophyll a Summary Statistics[1]

Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.09	0.01	0.10	0.68	0.06	0.01	57
Ammonia (mg/L)	Bottom	0.12	0.04	0.14	0.46	0.06	0.01	16
NO_3/NO_2 (mg/L)	Surface	0.33	0.04	0.33	1.13	0.21	0.01	59
NO_3/NO_2 (mg/L)	Bottom	0.25	0.07	0.28	0.79	0.15	0.01	16
TKN (mg/L)	Surface	0.75	0.04	0.28	1.50	0.74	0.15	60
TKN (mg/L)	Bottom	0.71	0.07	0.26	1.40	0.69	0.29	16
Total Nitrogen (mg/L)	Surface	1.09	0.06	0.48	2.43	1.00	0.29	59
Total Nitrogen (mg/L)	Bottom	0.96	0.09	0.36	1.51	0.93	0.32	16
Total Phosphorus (mg/L)	Surface	0.40	0.02	0.14	0.73	0.40	0.04	60
Total Phosphorus (mg/L)	Bottom	0.45	0.04	0.17	0.79	0.41	0.20	16
Total Orthophosphate (mg/L)	Surface	0.33	0.02	0.15	0.70	0.32	0.003	60
Total Orthophosphate (mg/L)	Bottom	0.33	0.05	0.19	0.63	0.29	0.003	16
Total Suspended Solids (mg/L)	Surface	3.34	0.31	2.38	14.00	2.75	1.00	60
Total Suspended Solids (mg/L)	Bottom	12.99	6.94	27.77	116.00	4.90	1.00	16
Total Organic Carbon (mg/L)	Surface	6.90	0.55	2.67	17.00	6.10	4.80	23
Total Organic Carbon (mg/L)	Bottom	5.41	0.45	1.75	10.80	5.20	3.20	16
Chlorophyll *a* (ug/L)	Photic Zone	8.44	1.41	9.76	51.70	4.80	0.50	48

Note: *SE=Standard Error; ** SD=Standard Deviation
[1/]Summary statistics for chemical water quality parameters and chlorophyll *a* from Milford Lake site near the dam (MI-1), April 2010 through September 2019.

Surface and bottom physical water quality results selected from water quality profiles to compile descriptive statistics summary are in Table 3-122. Temperature and dissolved oxygen sensors are present on all data sondes used by Kansas City District Water Quality Program while pH, conductivity, and turbidity sensors may not be available each month. Calibration issues or sensor failure also account for a reduced number of sample results presented in Table 3-122. Turbidity differences between surface and bottom samples is attributed to settling of solids and metals throughout months and at locations with or without stratification. Temperature and dissolved oxygen concentration of are typically ideal for coolwater fish and native aquatic species. Periods of low D.O. below Kansas Water quality standards for dissolved oxygen (5 mg/L) are relative short lived and usually related to turnover events or short period of oxygen sag from periods of cloudy weather or rain increase biochemical oxygen demand.

Table 3-124. Milford Lake Physical Water Quality Parameters for 2010-2019[1]

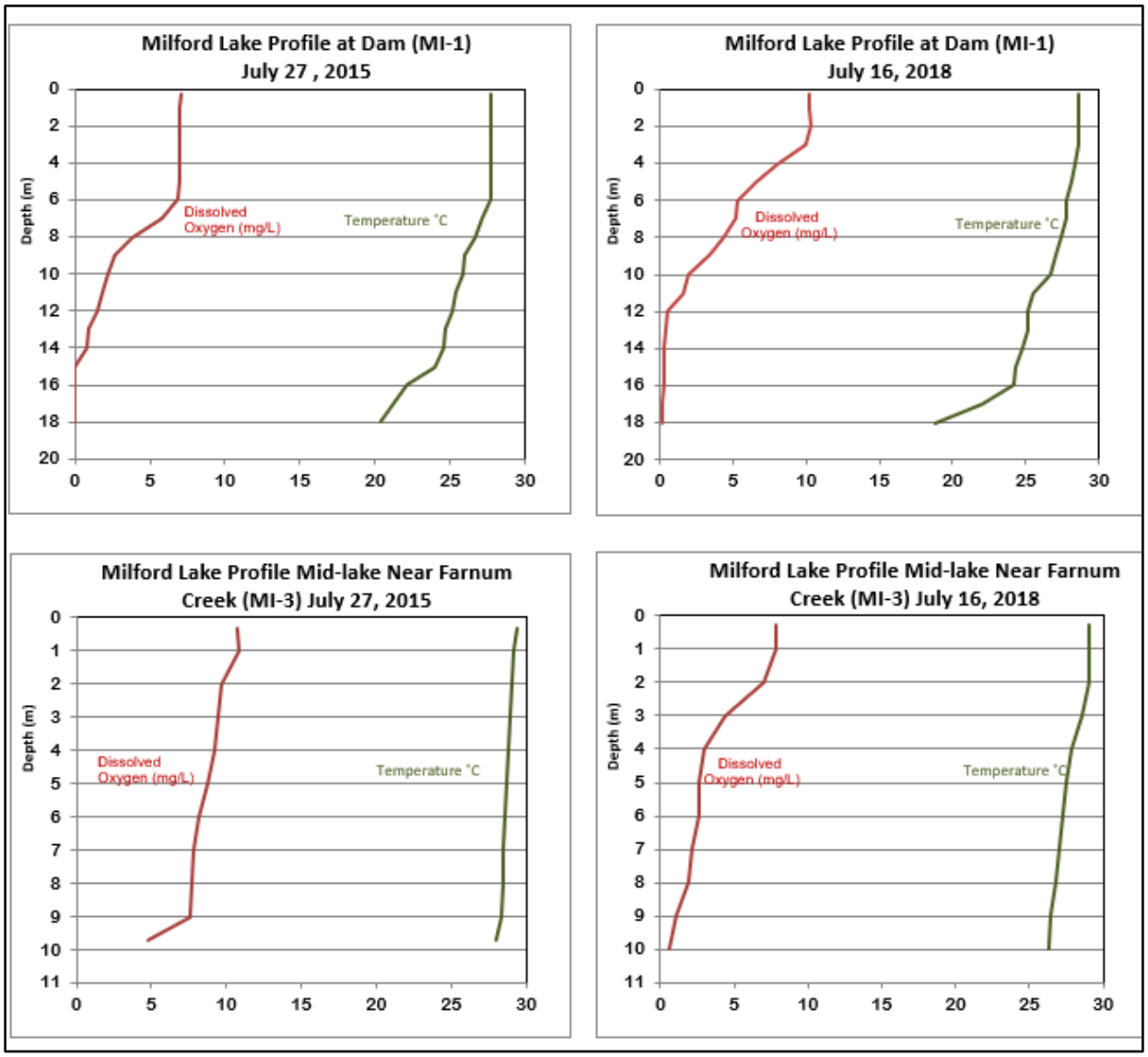
Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	7.9	0.15	1.9	12.23	7.8	3.1	163
Oxygen, Dissolved (mg/l)	Bottom	5.7	5.8	5.9	11.7	5.9	0.12	148
pH (Standard Unites)	Surface	8.3	0.03	0.4	9.1	8.4	7.4	153
pH (Standard Unites)	Bottom	8.3	0.03	0.4	8.8	8.2	7.3	144
Secchi Depth (m)	Surface	0.9	0.06	0.7	3.8	0.8	0.1	130
Specific Conductance (µS/cm)	Surface	670.2	11.1	137.9	1058.0	684.7	164.4	153
Specific Conductance (µS/cm)	Bottom	677.5	11.6	139.5	1060.0	687.3	164.8	144
Turbidity, Field (NTU)	Surface	34.1	4.4	54.6	315.5	9.6	<1	153
Turbidity, Field (NTU)	Bottom	149.9	30.8	360.9	2337.0	23.4	<1	137
Water Temperature (°C)	Surface	21.1	0.5	6.3	30.1	23.5	5.2	163
Water Temperature (°C)	Bottom	19.8	0.5	6.0	29.1	21.5	5.1	153

Notes *SE=Standard Error; ** SD=Standard Deviation
[1]Summary statistics for physical water quality parameters, from all sites and dates, Milford Lake, April 2010 through September 2019.

The lower half of Milford Lake typically undergoes thermal stratification in July and August, while upper lake sites are generally too shallow to stratify or mixed by wind and/or flow throughout the summer (USACE 2019). Water density from differences in temperature and salinity, distribution of heat, in-lake currents, reservoir releases, and wind action play a role in this process (Wetzel 2001). Physical changes in water composition during stratified conditions from water temperature and density differences lead to chemical and biological changes in the absence of oxygen (anaerobic conditions). A representative compilation of stratified conditions at lower (MI-1) and mid-lake (MI-3) Kansas City District Water Quality Sites from ten years of temperature and dissolved oxygen profiles is shown in Figure 3-189. During July 2015 and 2018, weak thermal stratification is evident at lower lake sites MI-1 and MI-3 with gradual decline of dissolved oxygen and temperature occurring over range of depths without a distinct thermocline. Dissolved oxygen declined to near zero in three of four lower lake samples illustrated in Figure 3-189. When weak stratification occurs, fish and aquatic organisms have suitable habitat with adequate temperature and oxygen conditions while chemical composition resembles mixed conditions with a relatively small volume of water under anoxic conditions. Temperature and D.O. profiles in Figure 3-189 illustrate stratified

conditions when fish and aquatic life were forced to adapt and move to shallower water to maintain oxygen preferences and tolerate much warmer water. This temperature/dissolved oxygen “crunch” can stress aquatic life and is part of the basis for the dissolved oxygen TMDL for Milford when KDHE documented dissolved oxygen deficiencies (i.e., concentrations less than 5 mg/L) (KDHE 2014a).

Figure 3-189. Milford Lake temperature and dissolve oxygen profiles



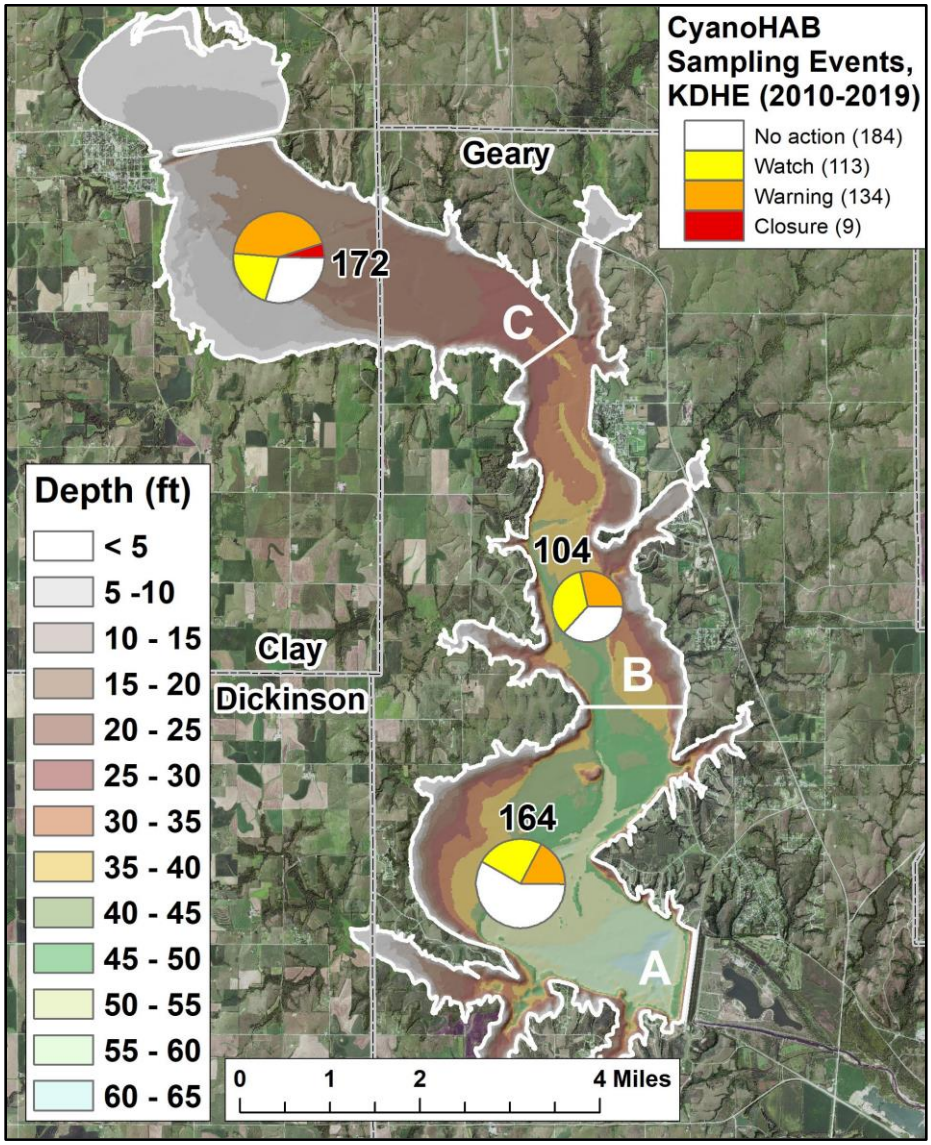
The hypereutrophic conditions at Milford Lake produce ideal physical and chemical conditions for production of HABs. An abundance of plant nutrients like orthophosphate and a low (i.e., <12) TN:TP ratio are two frequent water quality conditions associated with proliferation of blue-green algae which could produce toxins in freshwater (Downing, J. A., and E. McCauley 1992; Xiaofeng et al. 2012). Ideal nutrient conditions combine with exceptional water clarity have led to an increase in HAB frequency, magnitude, and duration since 2010 (USACE 2019; KDHE 2022). A summary of negative impacts include, but not limited to, serious illness to recreational users after

HAB contact and verified dog fatalities from contacting HAB toxins (Trevino-Garrison et al. 2015), economic decline from reduced recreation and tourism (Pearce 2020; Terrill 2015), cyanobacterial toxin and taste-and-odor metabolites presence at drinking water intakes on the Kansas River (Graham et al. 2012) and has been associated with decline in local realty market from bad smell and negative media coverage from HABs (Groves personal communication 2017).

KDHE CyanoHAB monitoring program started in 2010 (KDHE 2022). Infrequent algal blooms without quantified toxins were observed and discussed by Kansas City District and KDHE water quality staff prior to 2010 and included one public complaint leading to a tentative HAB announcement in 2006 (USACE 2012). A marked increase in monitoring effort and increase in public reporting of HABs increases public awareness to the benefit of public safety but increased monitoring efforts has been blamed for inflating HAB reporting associated with media trends. This sudden increase in public monitoring and public awareness from state and federal agencies coincided with, and was directly linked to, a noticeable increase in HAB frequency that cannot be accurately quantified due to lack of monitoring data prior to 2010 when USACE categorized HAB toxins associated with infrequent and unpublicized blooms as “emerging issues” (USACE 2010).

Since 2010, Milford Lake HABs are most frequent and most concentrated in the upper end or Zone C (Figure 3-190) as cyanobacteria and resulting toxin follow a gradient related to orthophosphate from the upper lake to the lower lake. Prevailing winds during prime HAB conditions in the summer months tend to blow from the south/southwest which help concentrate buoyant cyanobacteria cells in the north end of Milford (Zone C) (Figure 3-190), which often creates a situation with dangerous toxin concentrations in the upper lake and while lower lake (Zone A) cell count and toxin concentrations are considered safe (i.e., “no action”). Nine instances (e.g., weeks) of extreme HABS consisting of 2,000 ug/L of microcystin and/or 10 million cells/mL when closure/hazard status was recommended by KDHE occurred in Zone C.

Figure 3-190. Milford Lake CyanoHAB sampling events from 2010–2019



Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discussions until aging lakes begin to release or “recycle” nutrients (e.g., phosphorus) back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) and/or sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984. A unified approach for sediment quality assessment based on freshwater ecosystem effects (MacDonald et al. 2000) allows lake owners, management agencies, and regulatory agencies to make informed decisions based on consensus-based concentration thresholds derived from aquatic toxicology data and EPA recommendations for common metals found in Kansas City District lakes. Kansas City District Water Quality Program initiated collection of baseline lake sediment data in 2016 (Figure 3-191) to gather baseline sediment nutrient and trace metal contamination data at standardized lake water quality sites. Based on long-term monitoring water

quality sample results, less likely contaminants like polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), and chlorinated pesticides have not been included in recent lake-bed sediment samples.

Nitrogen and phosphorus concentrations from Milford Lake sediment samples were moderate when compared to results from a diverse sample of North American Lakes (Barko, J.W. and R.M Smart 1986). Metal concentrations from Milford Lake sample results (Figure 3-191) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed (MacDonald et al. 2000). Similarly, Christensen and Juracek (2000) reported exceedance of “threshold effect level” (TEL) of four metals from lake-bed sediment core samples, but concentrations were less than PEC values.

Figure 3-191. Milford Lake Bed Sediment Chemical Concentration From 2016–2017

Site	Date	Time	Ammonia	TKN	T. Phosphorus	Arsenic	Copper	Iron	Lead	Manganese	Nickel	Zinc	Cadmium	Chromium	Total Solids
Station	mm/dd/yyyy	hhmm	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	%
MI-1	9/6/2016	1130	49.8	1460.0	581.0	5.4	9.1	14800	14.6	531.0	17.7	59.4	0.69	17.5	
MI-3	9/6/2016	1230	57.0	1380.0	554.0	8.1	13.4	19100	16.7	403.0	21.5	74.5	0.64	20.6	
MI-5	9/6/2016	1300	303.0	1820.0	771.0	8.6	14.7	18900	19.4	630.0	19.5	78.2	0.76	20.3	
Site Median			**57.0**	**1460.0**	**581.0**	**8.1**	**13.4**	**18900**	**16.7**	**531.0**	**19.5**	**74.5**	**0.7**	**20.3**	
Mean			**136.6**	**1553.3**	**635.3**	**7.4**	**12.4**	**17600**	**16.9**	**521.3**	**19.6**	**70.7**	**0.7**	**19.5**	
MI-1	9/11/2017	1115	120	2200	955	8.0	17.2	24700	18.7	1100	28.5	81.6	0.60	31.0	26.4
MI-3	9/11/2017	1145	232	2750	780	8.6	22.1	34300	25.4	829	33.2	122	0.77	36.1	21.4
MI-5	9/11/2017	1215	153	2750	983	8.5	23.9	31800	24.1	858	31.7	125	0.89	33.9	30.5
Site Median			**153.0**	**2750.0**	**955.0**	**8.5**	**22.1**	**31800**	**24.1**	**858.0**	**31.7**	**122.0**	**0.8**	**33.9**	**26.4**
Mean			**168.3**	**2566.7**	**906.0**	**8.4**	**21.1**	**30267**	**22.7**	**929.0**	**31.1**	**109.5**	**0.8**	**33.7**	**26.1**

Milford Lake Wetlands Habitat Restoration Project

The Milford Lake Wetlands Restoration Project was a Kansas City District, U.S. Army Corps of Engineers Section 1135, (CAP) project sponsored by the KDWP with additional support and funding from the Kansas Wildscape Foundation (Figure 3-192). The organization raising funds for beneficial projects in Kansas involved construction of ten wetland sites on property located adjacent to the Republican River and Milford Lake near Junction City, Kansas.

The low berm wetland sites range in size from 60 to over 400 acres affecting approximately 2,100 acres of the 23,000 acres of the Milford Lake Project lands licensed to and managed by KDWP. The project was completed in phases, with final completion in 2005. The wetland project was a showcase of local, State and Federal cooperation to provide wetland habitat for fish and wildlife.

Water quality benefits to the Republican River and Milford Lake were anticipated as a secondary benefit of the wetland habitat project. The wetland would provide a limited function as a sediment and nutrient trap for flood waters with some potential to reduce nutrients from inflow water trapping by burial/storage of sediment bound nutrients, vegetation uptake, biogeochemical transformations including denitrification, and microbial degradation (Fisher and Acreman 2004; O’Geen et al. 2010).

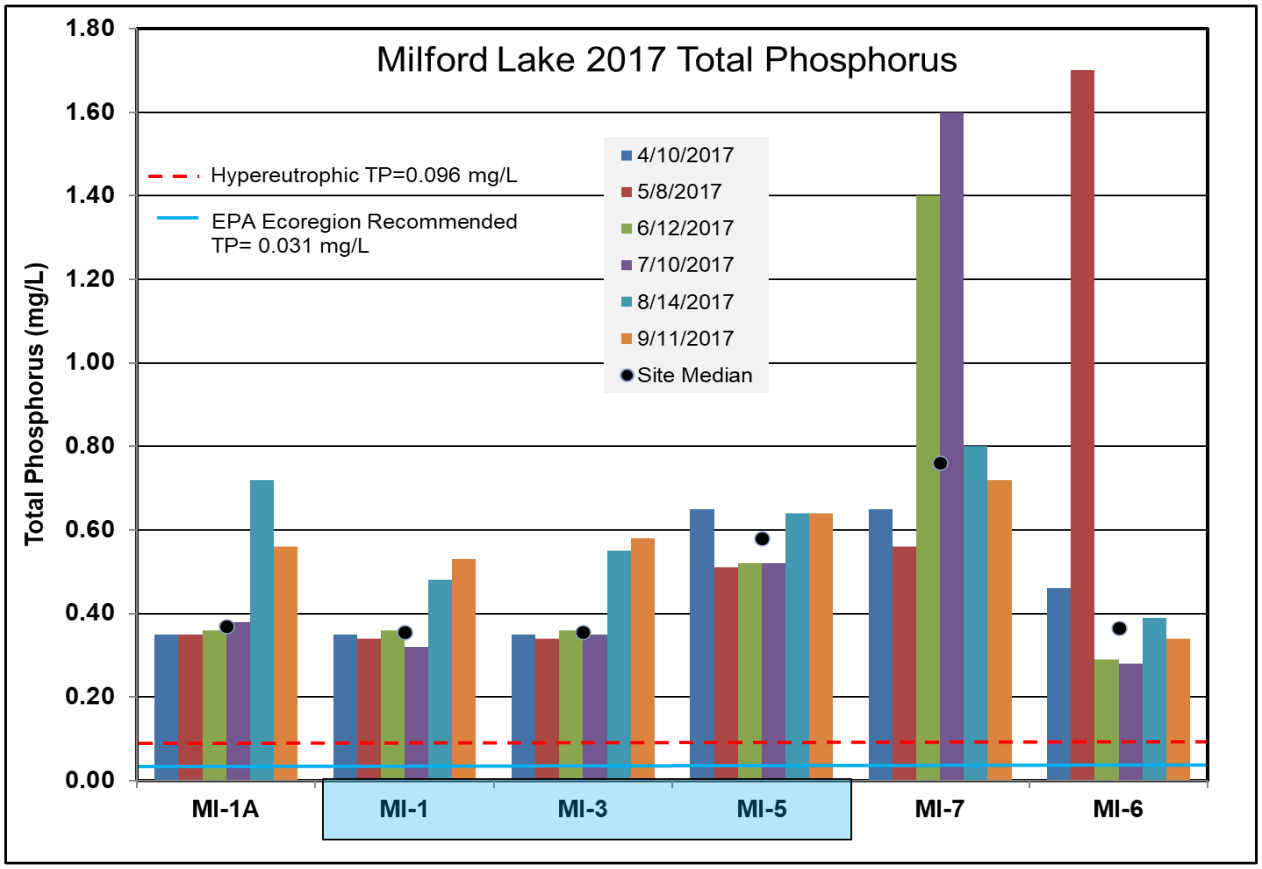
Figure 3-192. Milford Lake Wetlands Restoration Project



In 2017, Milford Lake Wetlands were added as water quality sites to the Kansas City District Water Quality Program to describe nutrient concentrations at the lower terminus of the wetland complex (MI-7) relative to the adjacent Republican River (MI-6), standardized lake sites (MI-1, MI-3, MI-5), and the outflow site (MI-1a).

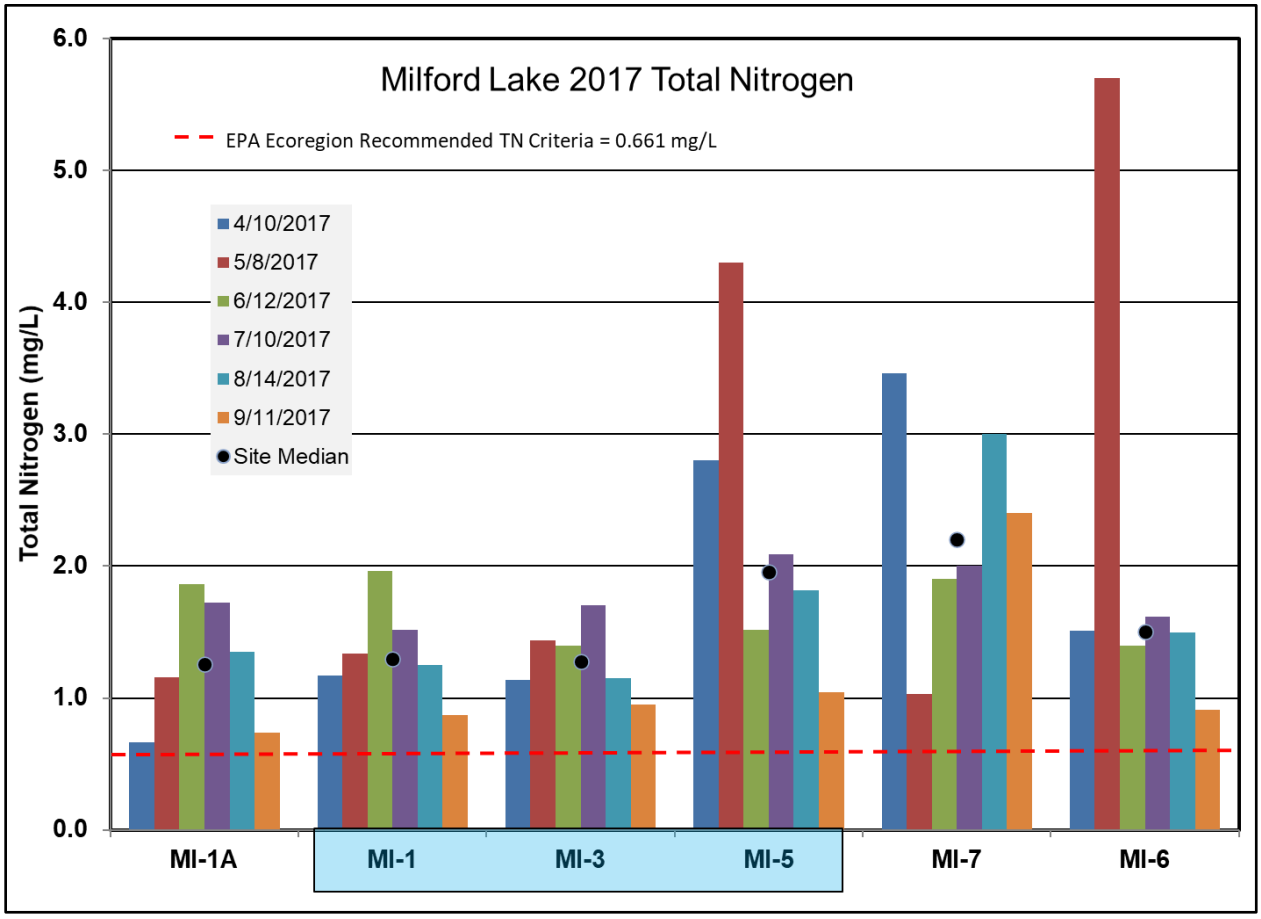
Depending on the form of phosphorus a variety of physical, chemical, and biological processes will occur resulting in a wetland acting as a sink, source, or transformer. Long-term removal or a net reduction of phosphorus from a lake or wetland ecosystem can only occur through active management when vegetation is harvested or when sediment bound phosphorus is removed from the system. Extreme concentrations of total phosphorus were reported in 2017 samples of shallow wetland site MI-7 (Figure 3-193). Median total phosphorus concentrations were eight times higher than the hypereutrophic threshold indicative of waters prone to excessive aquatic plant and algae growth. Peak total phosphorus concentrations occurred in June and July as evapotranspiration reduced water volume while it is assumed that internal loading mechanisms described by Søndergaard et al. (2003) including release from lake-bed sediments via chemical diffusion and bioturbation from fish and invertebrates increased soluble phosphorus present in samples. Phosphorus is apparently stored in the wetland cells when compared to the adjacent Republican River site (MI-6) during most months. High flow periods when significant flows leave the wetland invariably led to phosphorus loads transferred downstream to Milford Lake. USACE water quality sampling protocol limits sampling during high flow periods when possible. Consequently, much of the phosphorus transfer downstream from the wetland was not captured. Peak total phosphorus measured at MI-6 in May 2017 was related to increased flow but may not be directly attributed to loss from wetland.

Figure 3-193. Milford Lake Monthly Total Phosphorus Outflow Concentrations April through September 2017



Nitrogen enters wetlands in organic and inorganic forms. Three main processes responsible for nitrogen retention and removal in a wetland are denitrification, sedimentation, and uptake by vegetation (Mitsch and Gosselink 2000; Reddy and D'Angelo 1994; Saunders and Kalff 2001). The gaseous phase of nitrogen in the wetland nitrogen cycle can be permanently removed from soil and water column through the denitrification process. The pattern of denitrification is apparent at lake sites from July-September, but not evident at the wetland site MI-7 in 2017 (Figure 3-194).

Figure 3-194. Milford Lake Monthly Total Nitrogen Outflow Concentrations 2017



3.7.4.1.3 Wilson Lake

Wilson Lake (9,045 acre) has been named the clearest lake in Kansas, built on the Saline River in 1964. Wilson Lake is operated for flood control, downstream water quality, fish and wildlife, and recreation. The primary threats to water quality, fish and wildlife, and recreation purposes are best described by current KDHE TMDLs for chloride and sulfate originating from natural sources in the Dakota Aquifer and with a relatively small amount of augmentation by oil-field brine (KDHE 2004). Natural background chloride levels in the Saline River above Wilson Lake consistently exceed water quality criteria of 250 mg/L. Wilson Lake is one of the two lakes in the Kansas River Watershed without a TMDL or listed as impaired status directly related to excess nutrients.

Reservoir Hydrologic Data Summary

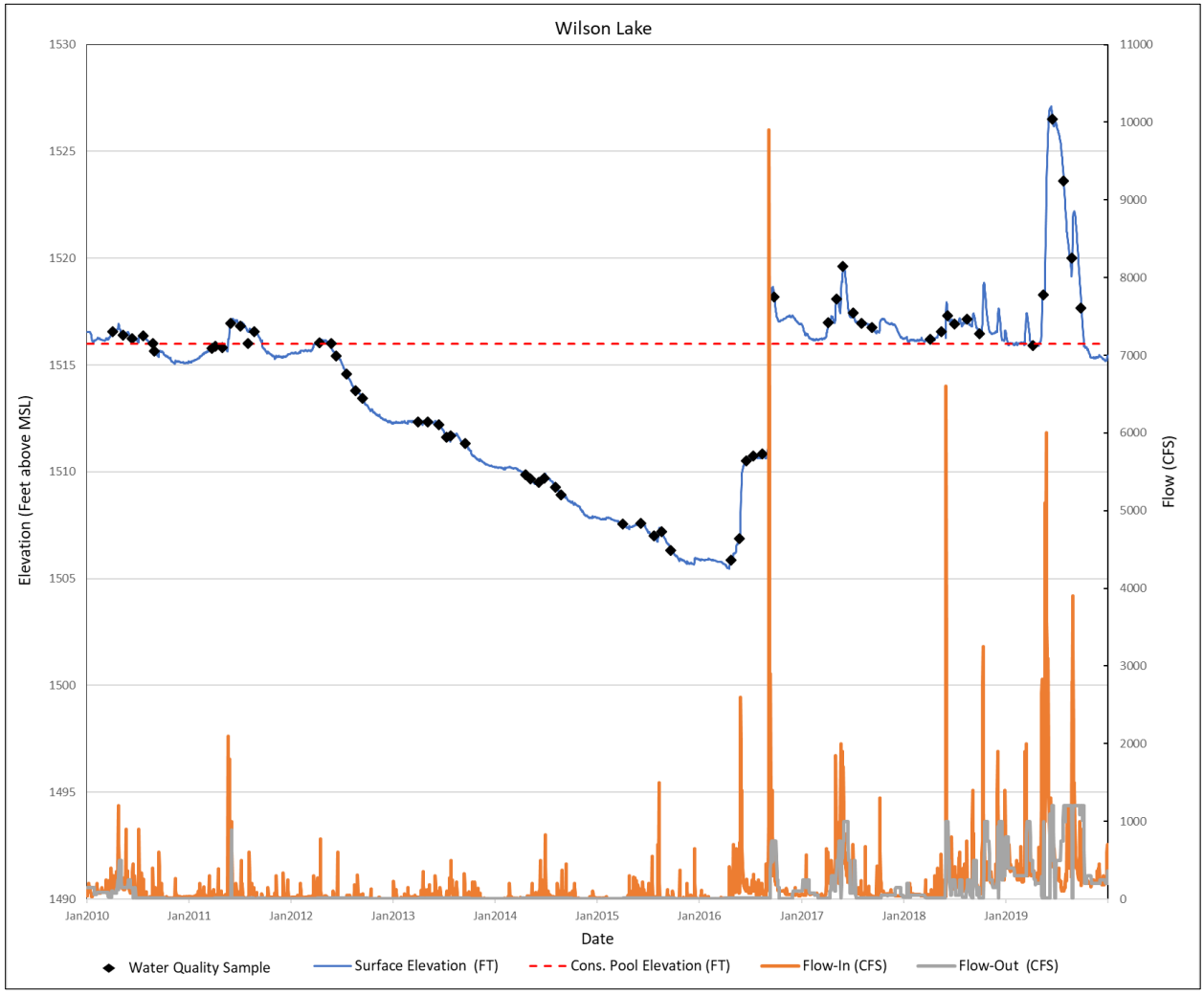
Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics related to flow (i.e., volume, load, and concentration), water residence time, and lake mixing/stratification which in turn influence physical and chemical process, frequently resulting in biological response. Figure 3-195 illustrates Wilson Lake hydrologic data with overlay of water quality samplings events.

Water quality sampling events by Kansas City District Water Quality Program staff were conducted monthly from 2010–2019 coinciding with the typical recreational season (April–September). Low inflow and lake level below multipurpose pool was observed at the end of 2012 with surface elevation falling below 1,506 feet while recovery period is apparent in spring of 2016. Significant flooding and corresponding high-water period was observed in 2019 with inflows exceeding 6,500 cfs. Surface elevation of Wilson Lake peaked at 11 feet above CPE and exceeded CPE for 159 days in 2019.

Average water residence time for Wilson Lake of 23.6 months was calculated from historic water management records for the period 1990-2022 using HEC-ResSim software. Wilson Lake average water residence time was second longest of Kansas River Watershed lakes in this study. Extended residence time allows for longer dilution and settling time as well as biological attenuation of agricultural runoff which improves water quality downstream of Wilson Lake. Wilson Lake frequent mixing and relatively short thermal stratification reduces many of potential negative impacts of longer residence time.

Water management and hydrologic conditions are critical factors for salinity and concentration of ions in Kansas River basin outflow related to quality of downstream water supplies due to naturally occurring salinity in the basin’s geographic formations. Analysis of salinity and dam operations at Wilson Lake is presented in Appendix G of this document. This study provides a basis for evaluating the effectiveness of alternative operational scenarios for salinity management and describes conceptual operation strategies aimed at decreasing the number of releases made in which the outflows chloride concentrations exceed threshold conditions of 325 mg/L at Wilson Lake. This threshold represents the approximate 70th percentile for outflow chloride concentrations in the baseline simulations using 100-years of historical data. Two operational strategies capable of eliminating releases exceeding the chloride concentration thresholds are outlined in this document.

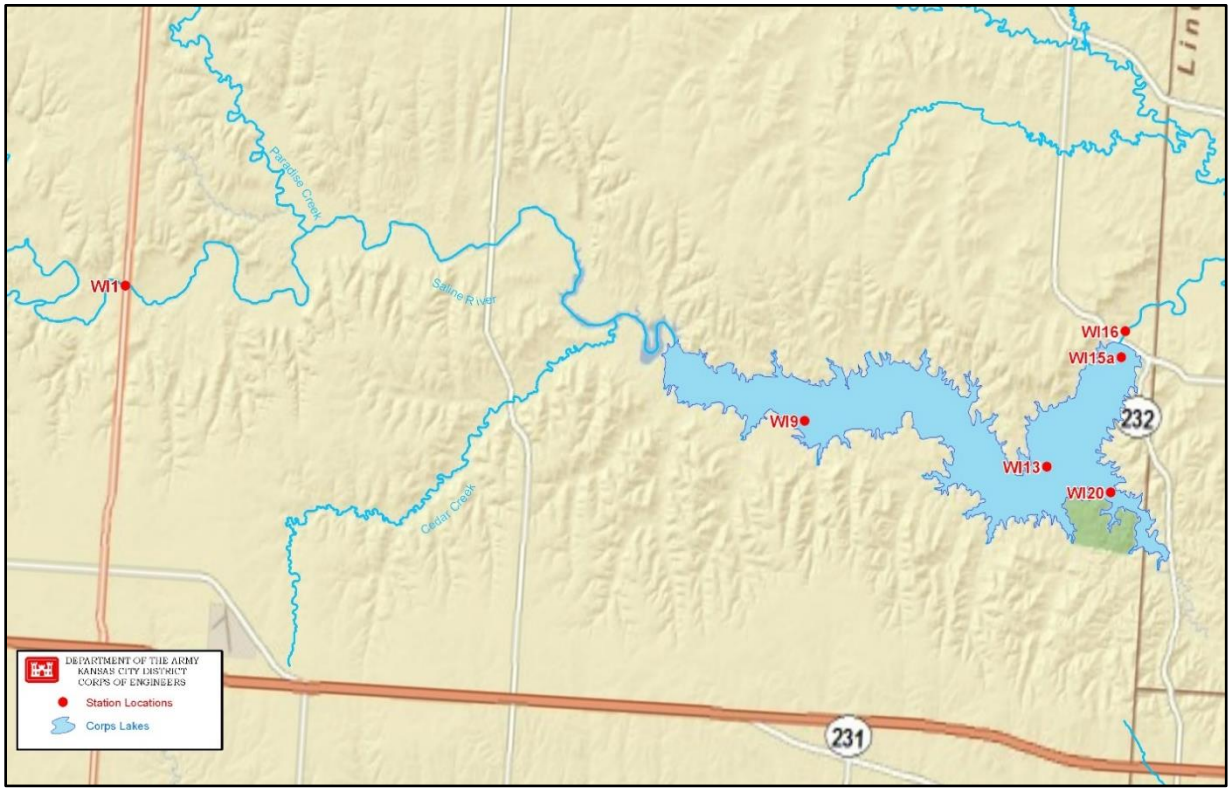
Figure 3-195. Wilson Lake Time Series of Daily Water Surface Elevation and Pool Information



Water Quality Sample Locations

To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow. Saline River sample locations for inflow samples are at site WI-1 while outflow samples are collected below Wilson Lake dam from site WI-16 (Figure 3-196). Lake sample locations on main lake and Hell's Creek tributary arm in river channel at each sample location.

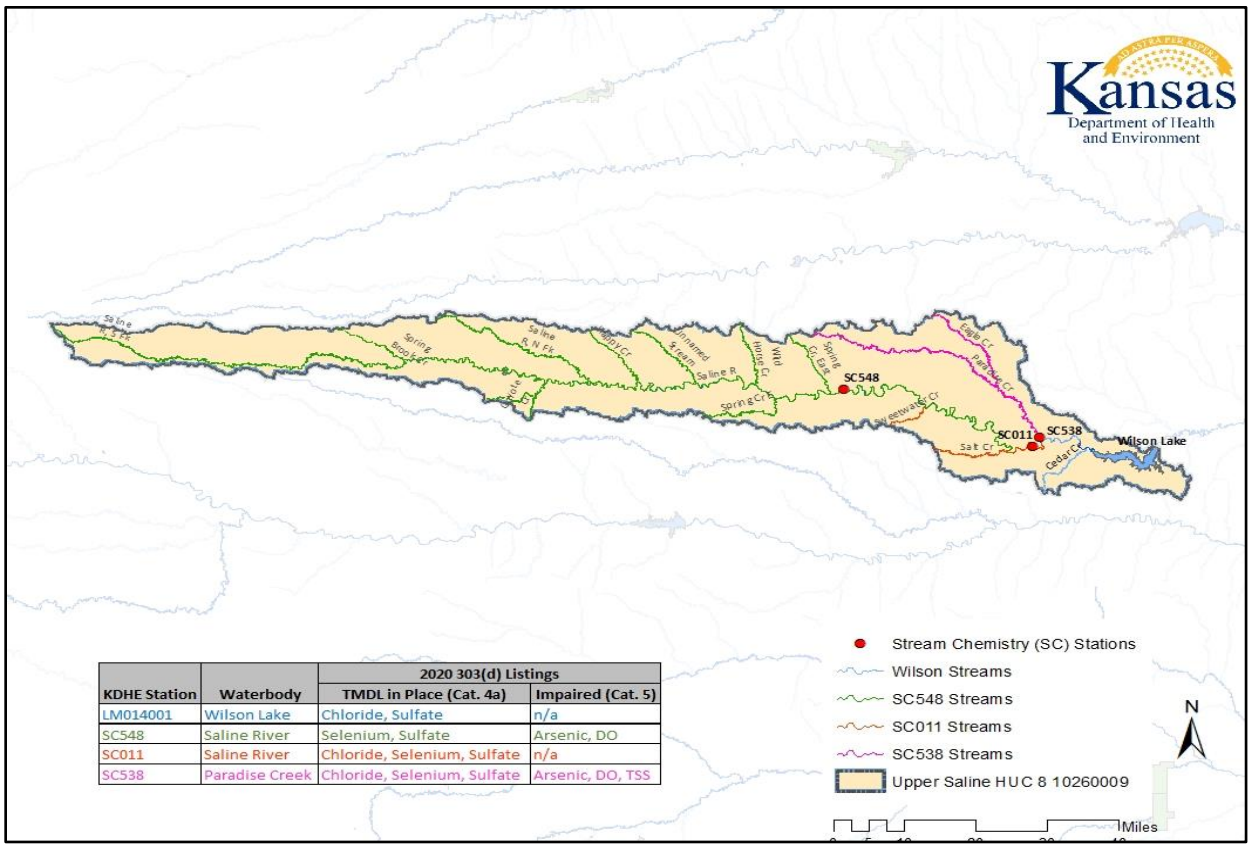
Figure 3-196. Wilson Lake Historic U.S. Army Corps of Engineers' Water Quality Sample Sites



Impairments

Wilson Lake and inflow impairments including TMDLs at Wilson Lake for chloride and sulfate are caused by naturally occurring salt compounds from the Dakota Aquifer entering the Saline River via groundwater additions to inflow streams (Figure 3-197). Natural background chloride and sulfate levels on Saline River above Wilson Lake consistently exceed water quality criteria of 250 mg/L which prevents achievement of KDHE state water quality criteria of 250 mg/L. When the source of naturally occurring substances …"due to intrusion of mineralized groundwater, the existing water quality shall be maintained, and the newly established numeric criteria for domestic water supply shall be the background concentration" (KDHE 2018). Dilution from freshwater from rain events reduces the concentration of compounds while some inflow from springs may have the opposite effect. Water quality related to salt ions and TMDL attainment at Wilson Lake generally degrades with reduced inflow and water levels below multi-purpose pool elevation associated with drier weather periods.

Figure 3-197. Wilson Lake and Watershed Impaired Waters and Total Maximum Daily Loads



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM014001	Wilson Lake	Chloride, Sulfate	n/a
SC548	Saline River	Selenium, Sulfate	Arsenic, DO
SC011	Saline River	Chloride, Selenium, Sulfate	n/a
SC538	Paradise Creek	Chloride, Selenium, Sulfate	Arsenic, DO, TSS

Inflows/Outflow

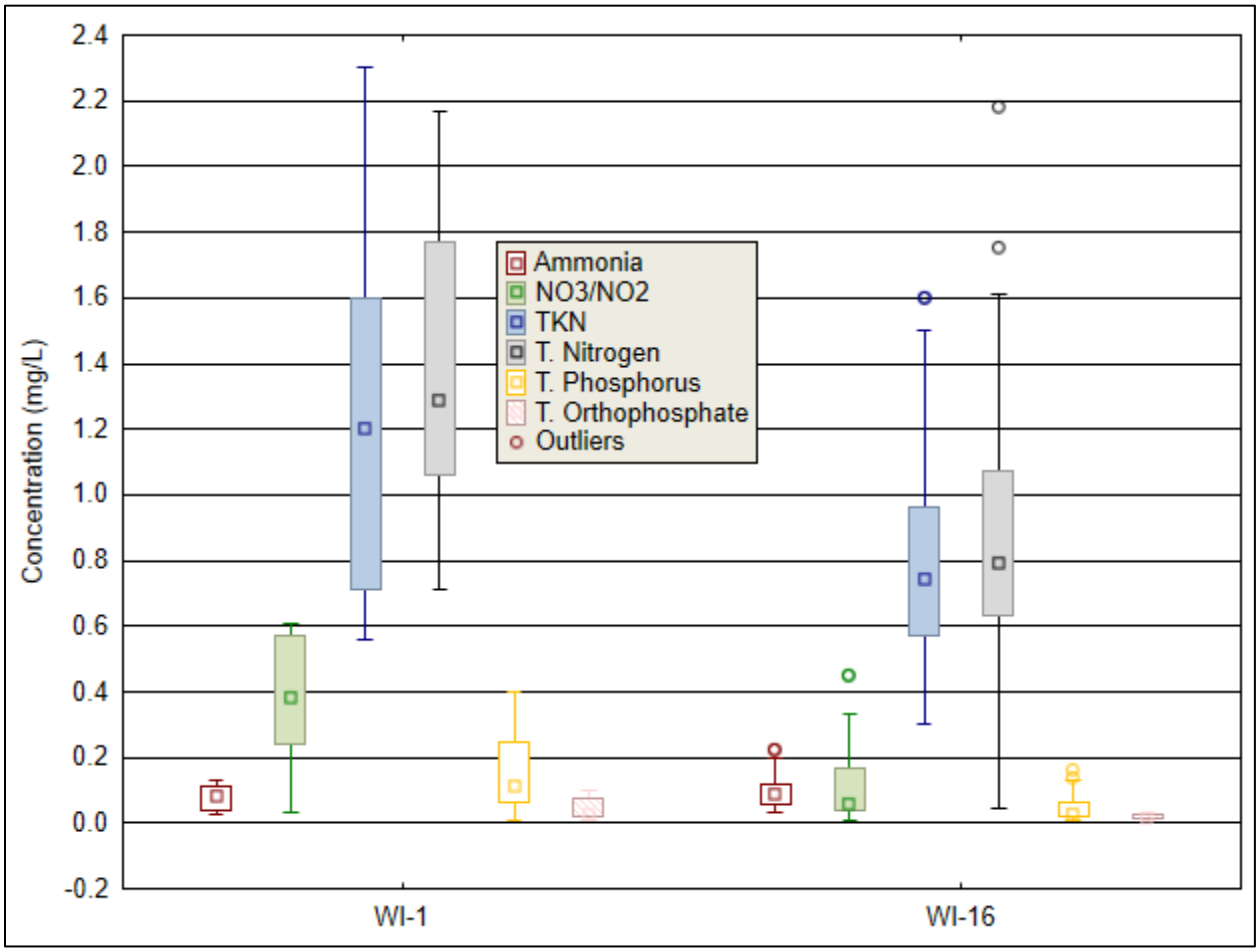
Row crop agriculture is a relatively low percentage of land use in Wilson Lake watershed compared to other Kanas City District Lakes in Kansas. Consequently, herbicide and fertilizer runoff influence water quality less than most Kansas lakes. While most herbicide sample results are below minimum reporting limit, common corn herbicides atrazine and metolachlor were detected in Wilson inflow and outflows in concentrations less than EPA drinking water criteria.

Nutrient concentrations above and below Wilson Lake (Figure 3-198) show a great deal of attenuation resulting from settling and biological process. Sample means of all nutrient analytes in Figure 3-198, except ammonia, are significantly ($P<0.05$) lower at the outflow than in Saline River samples above Wilson Lake. Soluble or plant available nutrients (e.g., orthophosphate and nitrate) results were below minimum detection limit in many outlet samples due in large part to biological conversion in the lake environment.

Water clarity measures of turbidity and total suspended solids demonstrate similar decreases in concentration from settling of sediment and reduced algal cell influence (Figure 3-199). Sample means of turbidity and total suspended solids are significantly less ($P<0.05$) in the outflow compared to Saline River samples. Total organic carbon results in Figure 3-199 are similar above and below Wilson Lake with median and sample mean values separated by less than 10 percent difference or 1 mg/L in concentration.

Chloride and sulfate ion concentration at inflow and outflow sites are illustrated in Figure 3-200. Median values for these salt compounds are similar at inflow and outflow sites. Changes in measured concentration of these ions due to dilution from local rain events as well as proximity to high salinity groundwater during drier periods is the primary cause of increase variability at Saline River site (WI-1).

Figure 3-198. Nutrient Concentrations Upstream and Downstream of Wilson Lake from 2010–2019



10626 *Figure 3-199. Water Clarity Influences Upstream and Downstream of Wilson Lake from 2010–2019*

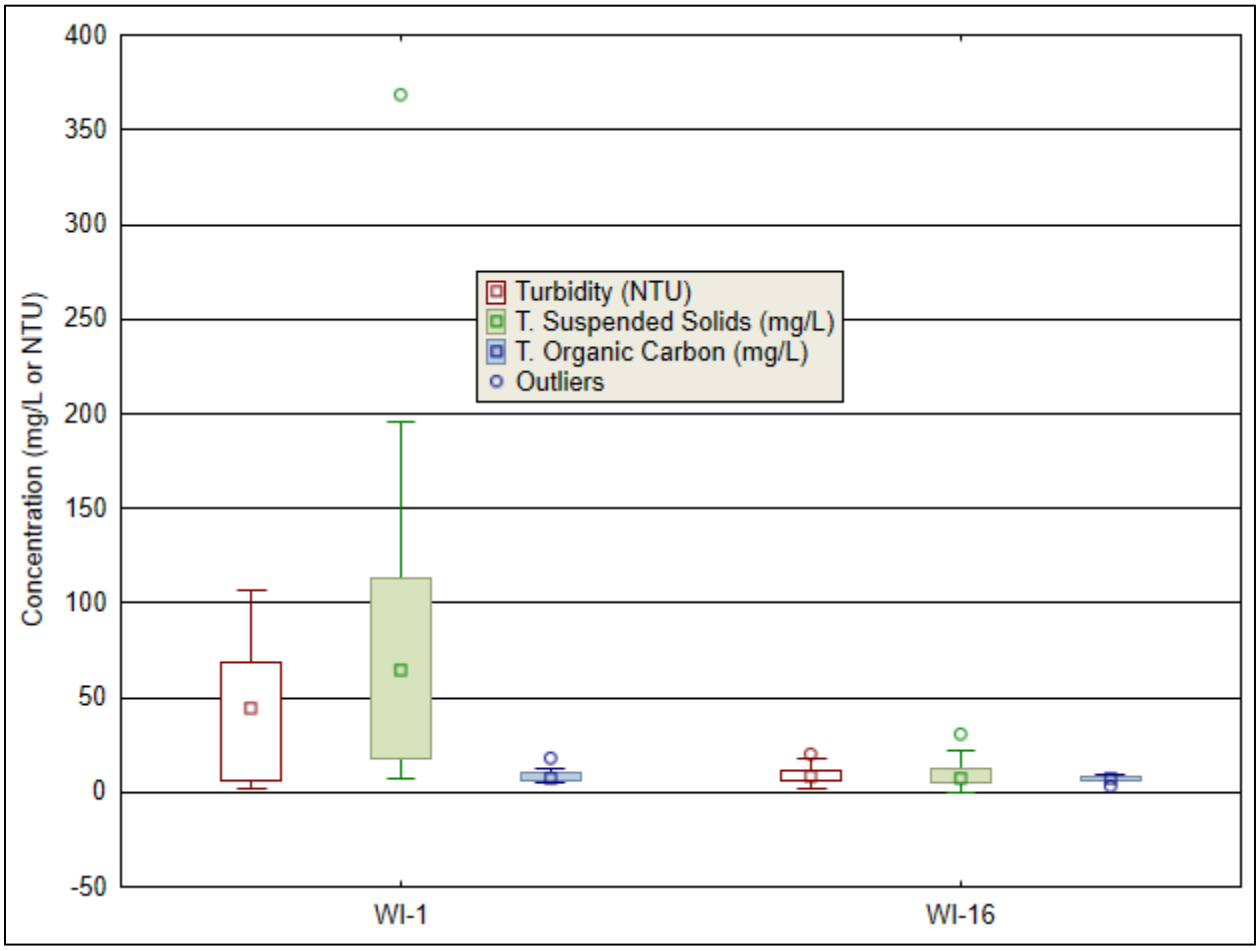


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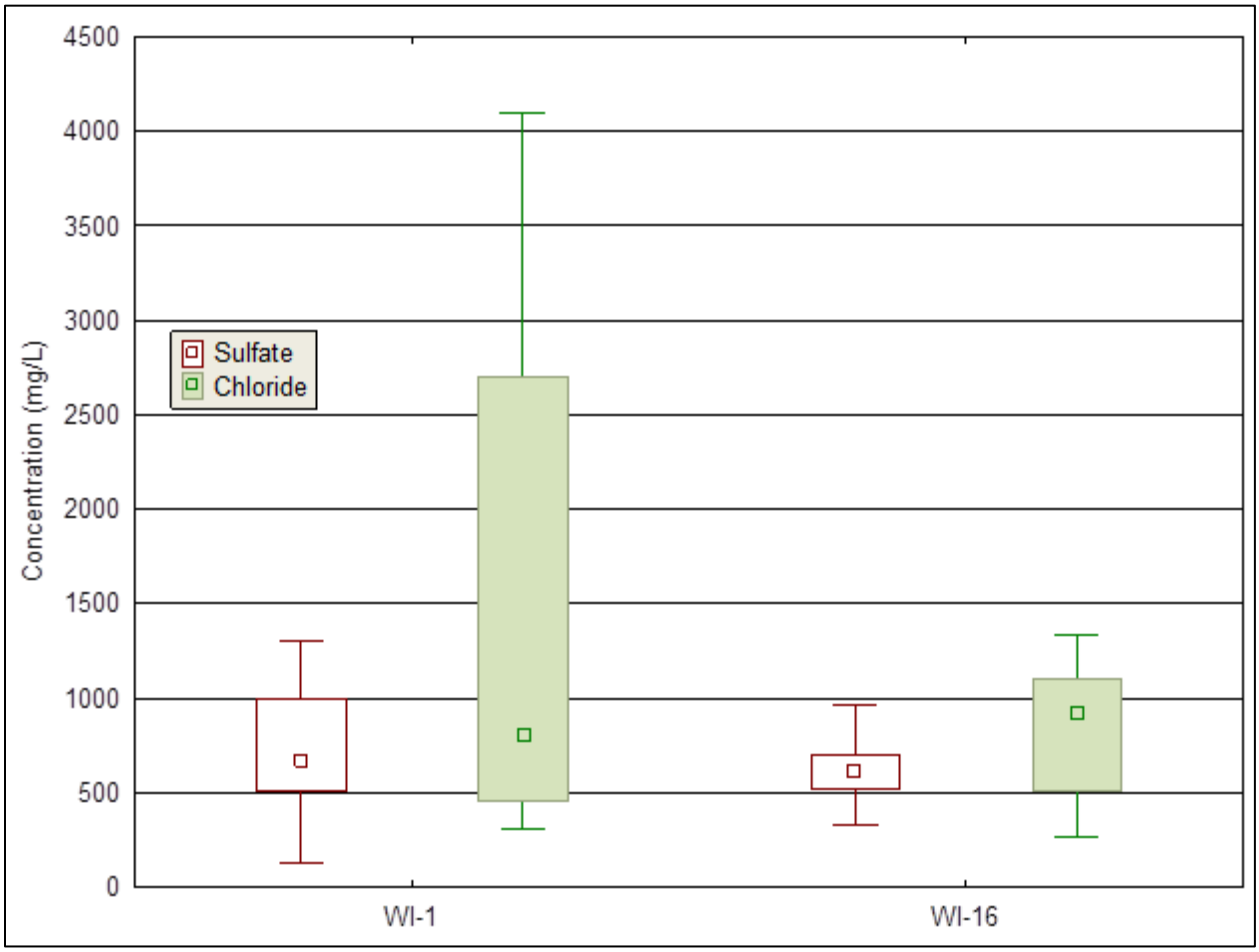
Figure 3-200. Naturally Occurring Salts Upstream and Downstream of Wilson Lake from 2010–2019



Lake Water Quality

Naturally occurring salts in the watershed are the main cause of water quality concerns at Wilson Lake and linked to numerous chloride and sulfate TMDLs for Domestic Water Supply and Acute Aquatic Life Support in Smoky Hill/Saline River Basin streams described by KDHE (2004). Wilson Lake watershed has considerably less row crop agriculture, sediment runoff, and fertilizer and pesticide runoff than other lakes in the Kansas River Basin. Water quality can degrade during extended wet periods or flood conditions as observed in 2019. During this time, the degraded conditions are less extreme than those experienced in other watersheds.

Physical and chemical attenuation (e.g., dilution, dispersion, chemical changes, and uptake by organisms) of compounds and settling of suspended matter leads to a general decrease in concentration of many constituents of water quality, often interpreted as improved water quality, as water moves through a reservoir system (Bosch et al. 2009). This process will be evident with many analytes in graphic representations in lake water quality sections. The following section is an overview of chemical and physical data from surface samples from 4 lake sites, describes chemical and physical differences between surface and bottom strata at the site near the dam

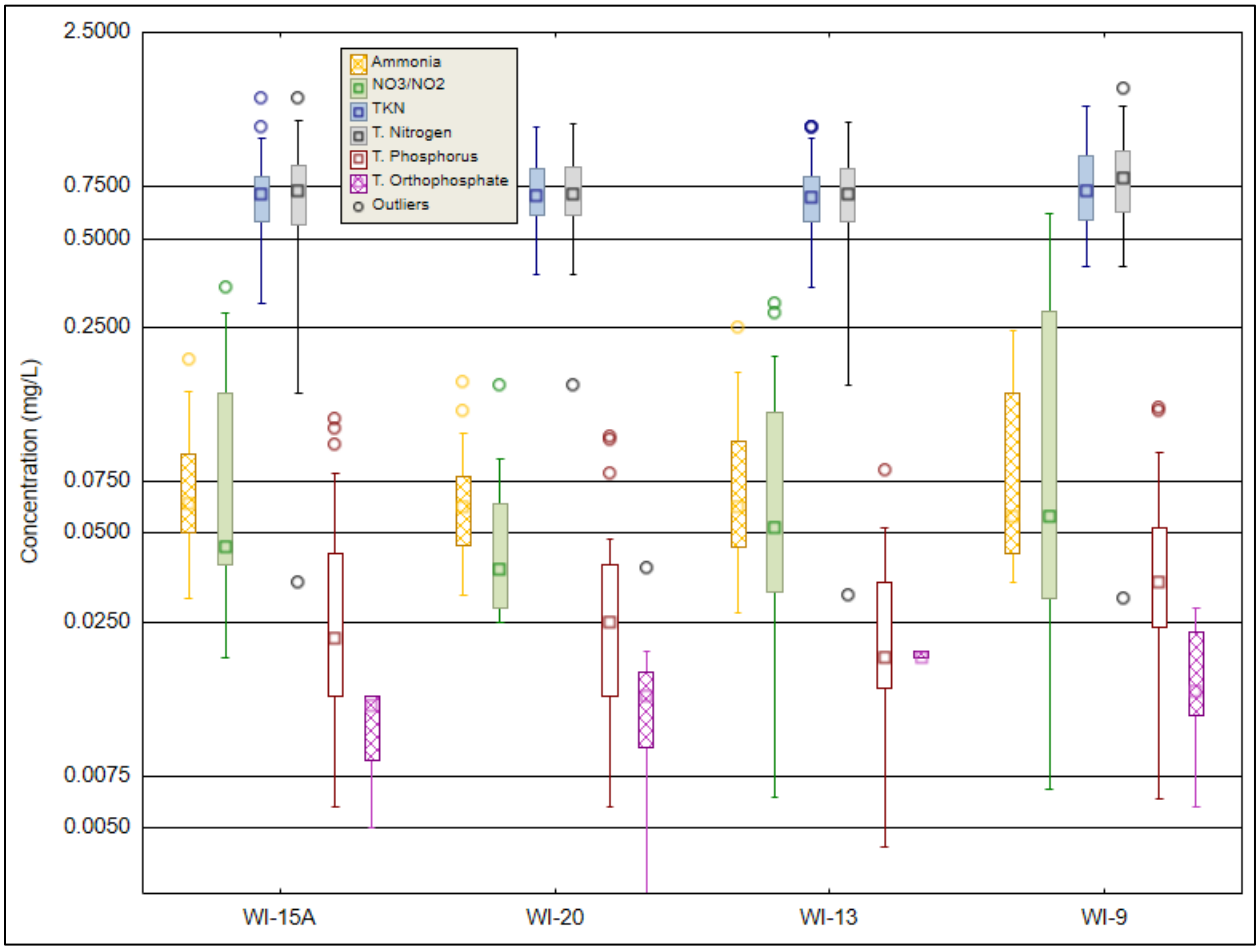
and stratification, and briefly describes available phytoplankton and cyanobacteria data related to public health advisories.

Wilson Lake nutrient data is illustrated in Figure 3-201. Ammonia, nitrate/nitrite, and both phosphorus measures were below minimum reporting limit in many samples which is also apparent in Table 3-123. Total nitrogen concentration decreases slightly from the upper lake site to the lower three sites while median values of other nitrogen analytes measures are similar at upper and lower sites. Attenuation and denitrification occurs on a smaller scale than many of the larger reservoirs in the District. Median bioavailable forms of nitrate/nitrite and ammonia were similar between sample sites but more variable at the upper lake site (WI-9). Median total phosphorus and soluble orthophosphate concentrations were slightly lower at the sample location near the dam (WI-15a). Large inflows and high water above normal high-water line resulted in record high nutrient concentrations in Wilson Lake and are responsible for most of the outliers at the upper end of the distribution. Wilson Lake total phosphorus values meet EPA Ecoregion recommendations (Figure 3-163) while all the other District lakes far exceed Ecoregion recommendations and most watershed conservation milestones.

Water quality measures affecting water clarity in the “clearest lake in Kansas” are presented Figure 3-202. Median Secchi measures indicate water transparency increases from 0.55 meters at the upstream site (WI-9) to 1.75 meters at the dam with maximum Secchi depth of 4 meters. Median turbidity, total suspended solids, and chlorophyll *a* exceed the 75th percentile (Q3) of respective measures at three lower lakes sites and median turbidity at WI-9 exceeds all turbidity records at the dam (WI-15a). Median total organic carbon was similar at all sites but more variable at Hell’s Creek arm site (WI-20).

Sulfate and Chloride concentrations typically exceed EPA drinking water criteria (250 mg/L) at all Wilson Lake sites (Figure 3-203). Proximity to inflows with proportionally more fresh water following rain events increases variability and reduces concentrations during wetter periods. Median and interquartile range of sulfate and chloride were nearly identical between lower lake sites WI-15a, WI-13, and WI-9.

Figure 3-201. Wilson Lake Nutrient Concentrations from 2010–2019



10681 *Figure 3-202. Wilson Lake Water Clarity Influences from 2010–2019*

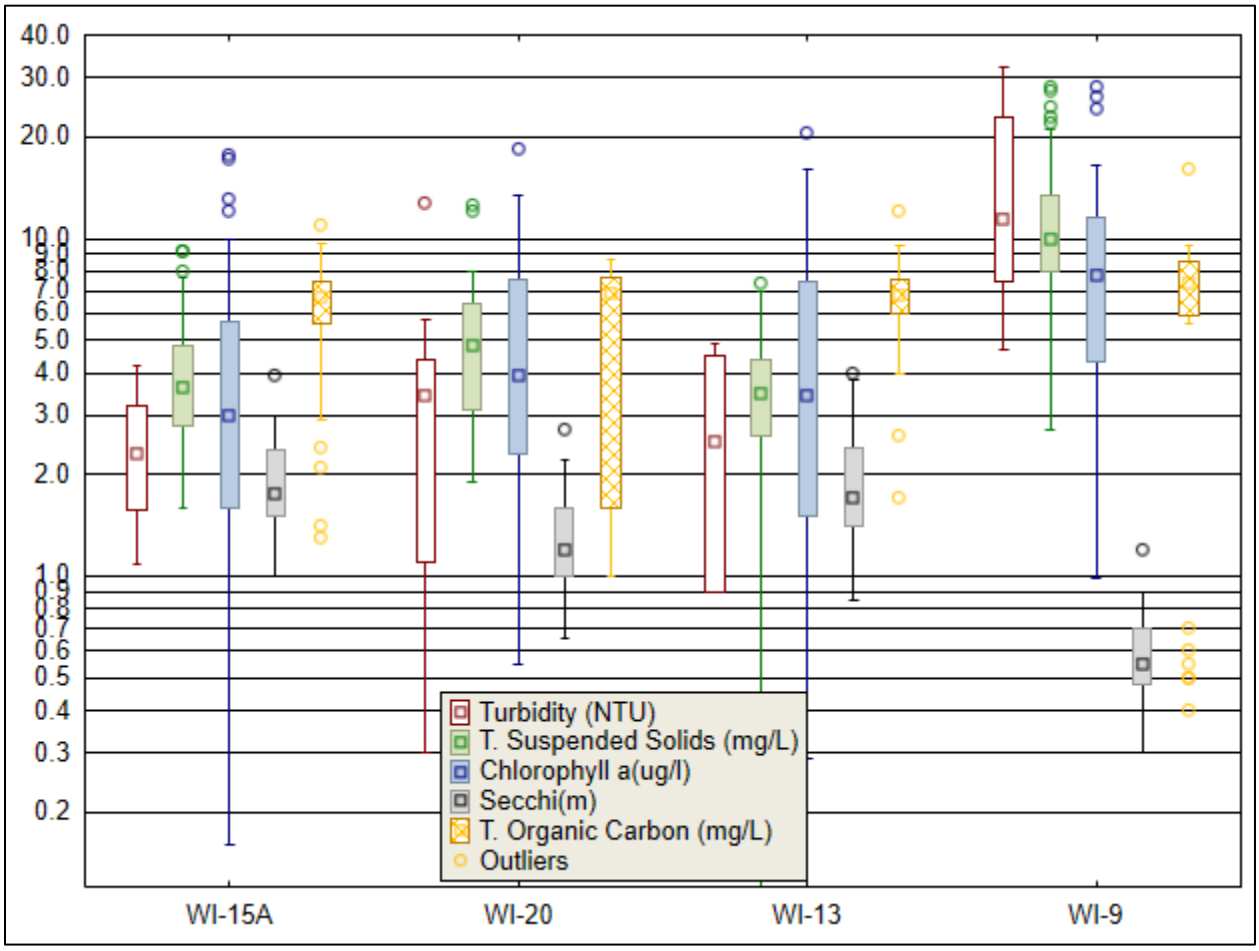


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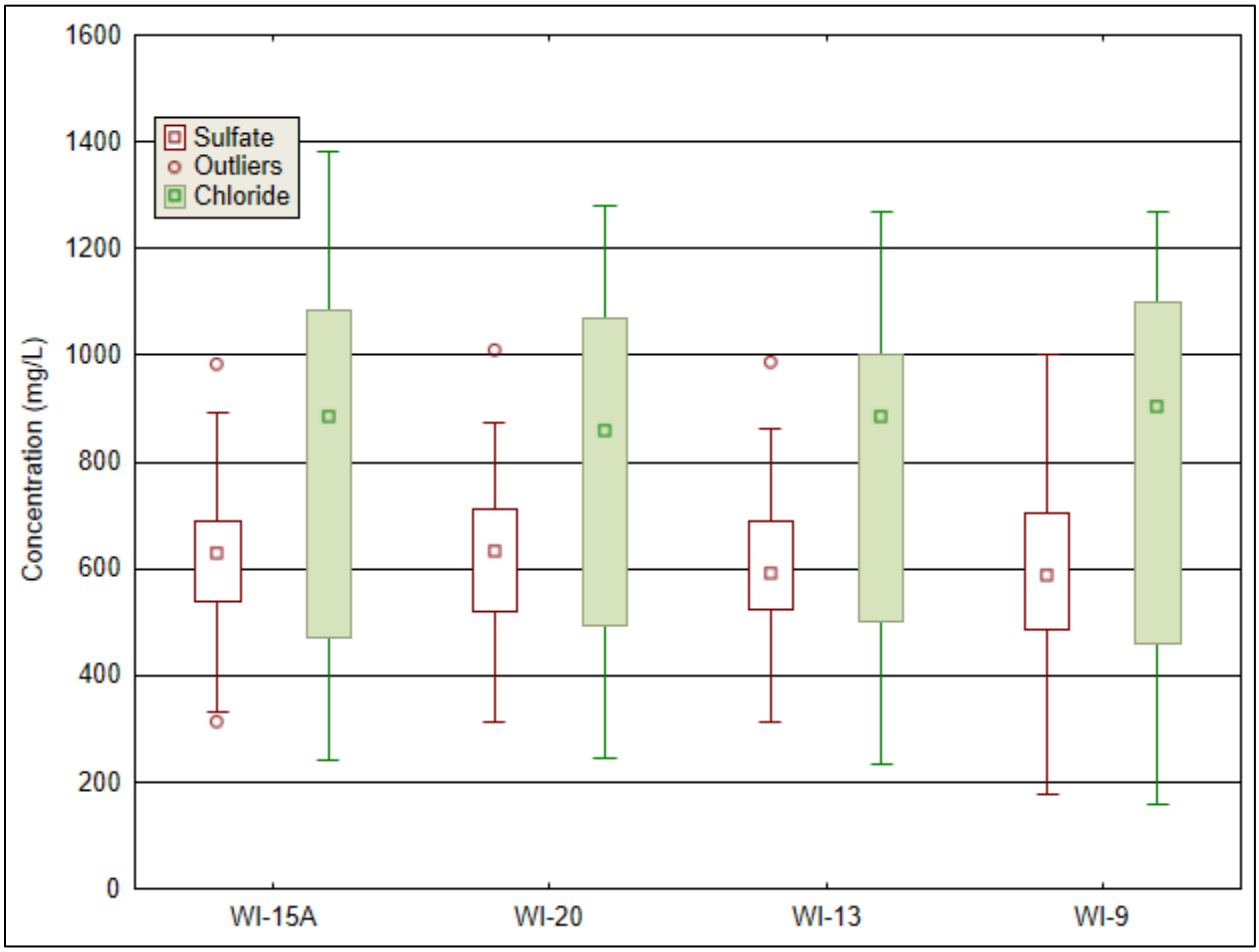
Figure 3-203. Wilson Lake Naturally Occurring Salts from 2010–2019



Water quality chemistry differences between surface and bottom samples at Wilson Lake site nearest the dam (WI-15a) are described in statistical summary Table 3-123. Non-detection or results below minimum detection level are frequent and have been included in sample results as the value of half of the reported minimum detection limit to reduce bias based on the assumption that the analyte is present at a concentration below laboratory quantification (EPA 1991). USACE collects bottom samples routinely from Kansas City Districts lakes every third year with total metals collected during the month of August when stratified conditions are most likely to show increased metal solubility due to anoxic conditions near the bottom. Wilson Lake stratifies for short periods in the summer months. When not stratified, frequent mixing homogenizes chemical and physical conditions and sample results are similar from top to bottom excepting unfiltered analytes sediment or heavier particles involved (e.g., TSS, turbidity). If all sample results were below minimum reporting limit or sample size was less than 3, NA was recorded in Table 3-123.

Physical water quality data from profiles collected at Wilson Lake are presented in Table 3-124. Thermal mixing is apparent as temperature and dissolved oxygen results are similar at surface and bottom sites. Frequent mixing or lack of a thermocline is also apparent in representative summer profiles from Wilson Lake (Figure 3-204). Profiles from upper and lower lake sites in July 2015 are typical with no signs of thermal

stratification. The second set of profiles collected in August 2017 represent the most stratified conditions observed during the 10-year analysis period. The presence of oxygen in bottom layers increases available habitat for aquatic species and decreases the rate of enrichment of hypolimnetic waters with phosphorus and metals released at lower rates from lake sediments in the presence of oxygen (Jensen et al. 1992).

Table 3-125. Wilson Lake Summary statistics for chemical water quality parameters 2010–2019[1] (sheet 1 of 2)

Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.05	0.01	0.05	0.19	0.02	0.01	60
Ammonia (mg/L)	Bottom	0.02	0.01	0.02	0.08	0.02	0.01	13
NO3/NO2 (mg/L)	Surface	0.06	0.02	0.13	0.66	0.01	0.01	60
NO3/NO2 (mg/L)	Bottom	0.23	0.07	0.25	0.60	0.09	0.01	13
TKN (mg/L)	Surface	0.70	0.03	0.22	1.50	0.69	0.30	60
TKN (mg/L)	Bottom	0.70	0.12	0.43	1.40	0.64	0.14	13
Total Nitrogen (mg/L)	Surface	0.72	0.03	0.27	1.51	0.71	0.01	60
Total Nitrogen (mg/L)	Bottom	0.89	0.11	0.41	1.49	1.06	0.15	13
Total Phosphorus (mg/L)	Surface	0.04	0.01	0.05	0.29	0.02	0.01	60
Total Phosphorus (mg/L)	Bottom	0.02	0.01	0.02	0.06	0.02	0.001	13
Total Orthophosphate (mg/L)	Surface	0.01	0.00	0.00	0.01	0.01	0.01	60
Total Orthophosphate (mg/L)	Bottom	0.01	0.001	0.001	0.02	0.001	0.001	13
Total Suspended Solids (mg/L)	Surface	3.94	0.24	1.82	9.20	3.60	1.60	60
Total Suspended Solids (mg/L)	Bottom	14.25	3.59	15.25	68.00	9.50	2.20	13
Total Organic Carbon (mg/L)	Surface	6.18	0.45	2.42	11.00	6.70	1.30	29
Total Organic Carbon (mg/L)	Bottom	7.62	0.35	1.46	11.00	7.20	6.20	17

Table 3-126. Wilson Lake Summary statistics for chemical water quality parameters 2010–2019[1] (sheet 2 of 2)

Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Chlorophyll a (ug/L)	Photic Zone	3.89	0.52	4.16	17.60	2.80	0.16	60
Total Chloride (mg/L)	Surface	734.51	52.25	350.49	1380.00	700.00	243.00	45
Total Chloride (mg/L)	Bottom	962.29	61.86	163.67	1120.00	969.00	627.00	7
Total Sulfate (mg/L)	Surface	605.46	18.93	150.27	983.00	626.00	313.00	60
Total Sulfate (mg/L)	Bottom	634.11	25.59	108.57	822.00	650.00	468.00	18
Total Iron (ug/L)	Surface							NA
Total Iron (ug/L)	Bottom	249.5	27.21	54.41	330.00	229.00	210.00	4
Total Manganese (ug/L)	Surface							NA
Total Manganese (ug/L)	Bottom	146.75	45.45	90.90	263.00	127.00	70.00	4

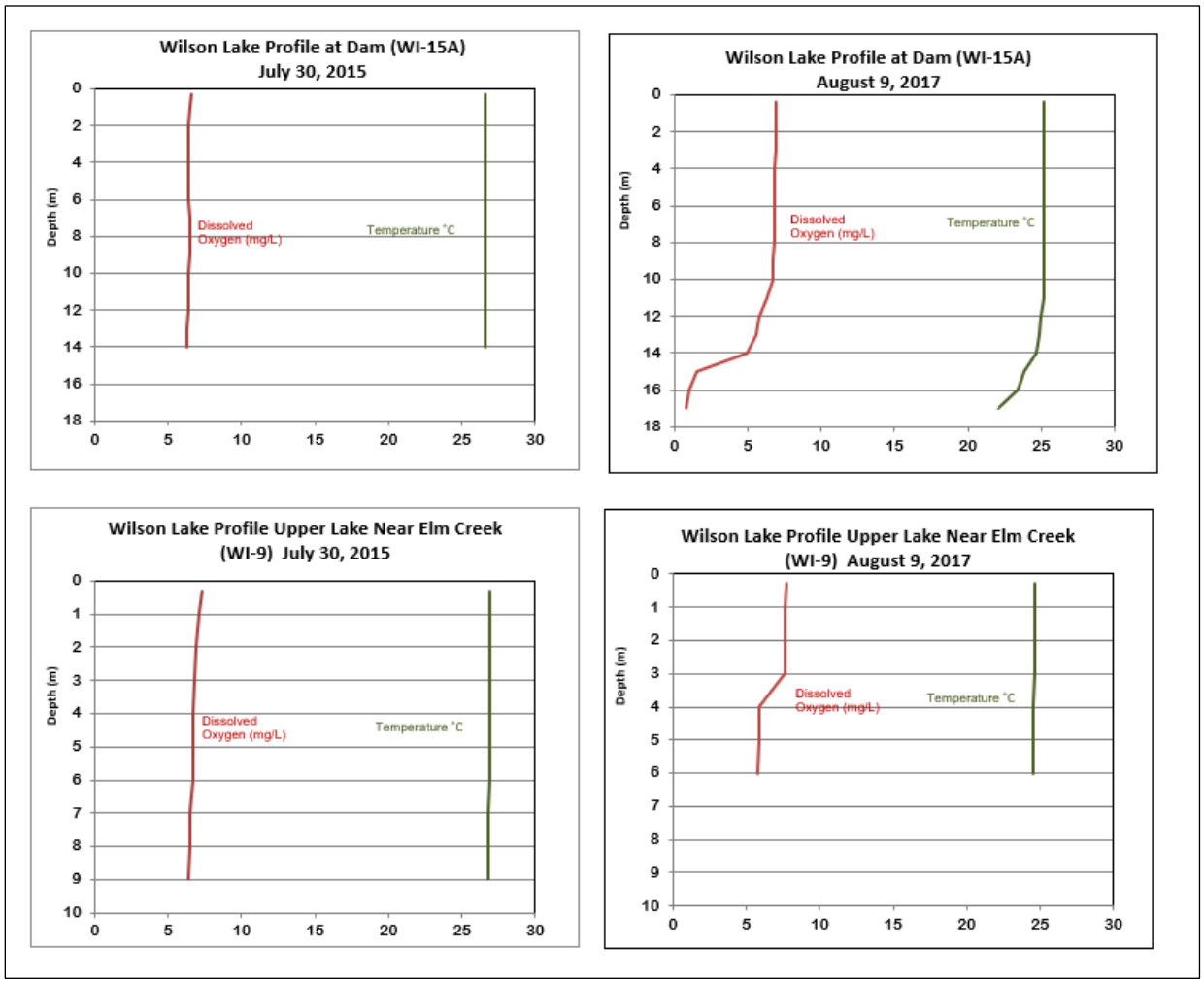
Notes: *SE=Standard Error; ** SD=Standard Deviation
[1]Summary statistics for chemical water quality parameters from Wilson Lake site near the dam (WI-15A), April 2010 through September 2019.

10718 *Table 3-127. Wilson Lake Summary Statistics for Physical Water Quality Parameters 2010–2019*

Parameter	Sample Depth	Mean	SE*	SD*	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	8.4	0.07	1.3	12.3	8.1	5.8	252
Oxygen, Dissolved (mg/l)	Bottom	7.0	0.2	2.4	11.9	7.0	0.1	197
pH (Standard Unites)	Surface	8.2	0.03	0.3	9.0	9.3	6.7	83
pH (Standard Unites)	Bottom	8.1	0.03	0.3	8.8	8.1	7.1	68
Salinity (‰)	Surface	2.4	0.1	0.5	2.9	2.4	1.2	34
Salinity (‰)	Bottom	2.5	0.1	0.4	2.9	2.7	1.6	34
Secchi Depth (m)	Surface	1.5	0.1	0.8	4.0	1.4	0.3	113
Specific Conductance (µS/cm)	Surface	3814.0	85.9	782.5	5058.0	3478.0	1751.0	83
Specific Conductance (µS/cm)	Bottom	3561.0	103.3	851.7	5056	3270.0	1590.0	68
Turbidity, Field (NTU)	Surface	8.2	0.03	0.3	34.9	1.6	0.5	81
Turbidity, Field (NTU)	Bottom	16.9	3.2	26.3	146.3	7.5	0.5	68
Water Temperature (°C)	Surface	21.6	0.4	5.9	29.6	24.0	6.7	252
Water Temperature (°C)	Bottom	20.2	0.4	5.9	28.35	25.5	6.2	197

10719 Notes: *SE=Standard Error; ** SD=Standard Deviation
10720 [1]Summary statistics for physical water quality parameters, from all sites and dates, Wilson Lake, April 2010 through
10721 September 2019.
10722

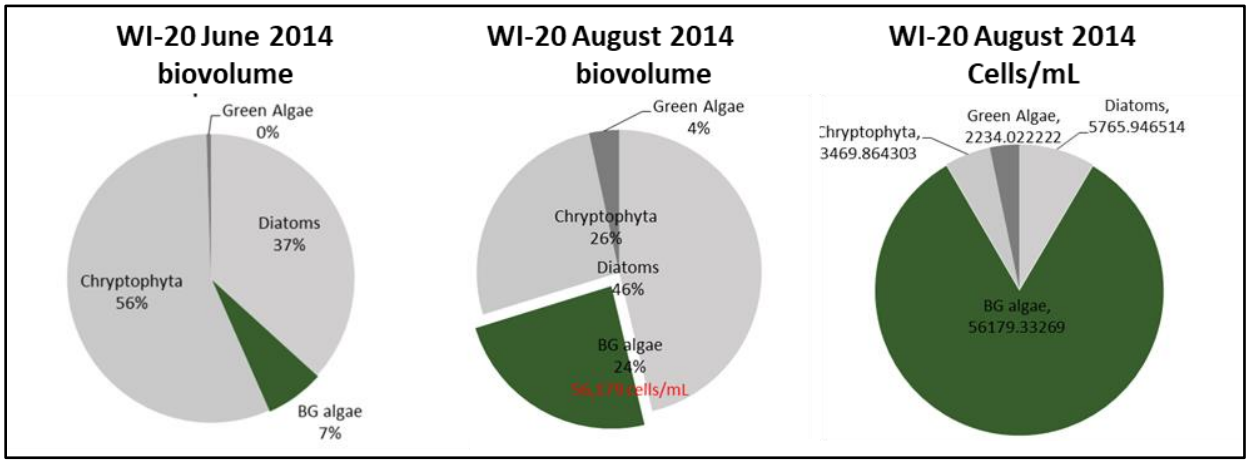
Figure 3-204. Wilson Lake Representative Temperature and Dissolved Oxygen Profiles



The phytoplankton community at Wilson Lake has not been sampled at regular intervals and cyanobacteria have not led to public health advisories as of 2022. KDHE results from 2006 and 2009 show species dominance shift as 77 percent green algae (Chlorophyta) was dominant in a single sample in 2006 (KDHE 2007) while cyanobacteria accounted for 77 percent of phytoplankton in a single sample from 2009 (KDHE 2010). USACE samples show similar results with cyanobacteria and diatoms comprising the highest percent composition from intensive surveys of 2014 and 2017 (Figure 3-205) with low cell densities typically less than 50,000 cells/mL (USACE unpublished data 2014, 2017). Cell count and biovolume units of measure were both reported in 2014 samples highlighting the differences in the percent composition by biovolume (i.e., volume of a sample occupied by cells of one genera) and cell count (number of cells/mL) estimated from counts from subsamples. The August 2014 sample in Figure 3-205 illustrates that higher cell counts of smaller cells (e.g., blue-green algae) may not be what is visually dominant in a sample (i.e., biovolume). While cell count for sum of all cyanobacteria (56,179 cell/mL) in August sample below is nearly ten times diatom cell count (5,765 cell/mL), the larger diatoms in the sample are visually dominant due to biovolume they occupy. Algal toxins microcystin, cylindrospermopsin, and

anatoxin-a were not detected above minimum reporting limit (<0.15 ug/L) in 2014 and 2017 samples.

Figure 3-205. Wilson Lake Select Phytoplankton Composition Graphs



Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discussions until aging lakes begin to release or “recycle” nutrients (e.g., phosphorus) back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) and/or sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984). A unified approach for sediment quality assessment based on freshwater ecosystem effects (MacDonald et al. 2000) allows lake owners, management agencies, and regulatory agencies to make informed decisions based on consensus-based concentration thresholds derived from aquatic toxicology data and EPA recommendations for common metals found in USACE Kansas City District lakes.

Median concentrations of nitrogen, phosphorus, manganese, and iron from Wilson Lake-bed samples ranked lowest of seven Kansas City District Lakes in the Kansas River watershed (Figure 3-172). Wilson Lake sediment concentrations (Figure 3-206) of arsenic, cadmium, and nickel exceeded the respective threshold-effects guidelines (MacDonald et al., 2000) in which toxic biological effects occasionally occur. This is typical for reservoirs in eastern Kansas (Juracek 2003, 2004; Juracek and Mau 2002). Metal and trace element concentrations reported in Kansas City Districts bed sediment results (Figure 3-206) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed (MacDonald et al. 2000).

Figure 3-206. Wilson Lake Bed Sediment Chemical Concentration in Sediment 2010–2019

Station	Date mm/dd/yyyy	Time hhmm	Ammonia MG/KG	Nitrate-Nitrite Nitrogen MG/KG	Total Kjeldahl Nitrogen MG/KG	Phosphorus MG/KG	Arsenic MG/KG	Copper MG/KG	Iron MG/KG	Lead MG/KG	Manganese MG/KG	Nickel MG/KG	Zinc MG/KG	Cadmium MG/KG	Chromium MG/KG	Total Solids %
WI-20	9/14/2017	1300	8.0	<2.5	413	216	4.6	4.8	10500	6.3	194	9.8	24.8	0.22	6.9	67.2
WI-9	9/14/2017	1200	37.0	<2.5	1760	547	9.6	20.3	21000	20.4	410	31.7	99.3	1.2	23.0	36.2
WI-13	9/14/2017	1130	117	<7.2	1970	558	12.3	19.4	23800	20.8	614	31.5	111	0.83	23.7	25.9
WI-15A	9/14/2017	1100	36.4	<2.8	661	314	6.2	11.6	15800	10.6	205	17.5	34.2	0.34	14.6	55.7

3.7.4.1.4 Kanopolis Lake

Kanopolis Lake (3,406 acre) is the oldest USACE lake in Kansas, built on the Smoky Hill River in 1948. Located 141 miles downstream from Cedar Bluff Lake, Kanopolis Lake is operated for flood control, downstream water quality, and public water supply. The primary water quality threats are best described by current KDHE TMDL for eutrophication from non-point nutrient sources, failing onsite waste-water systems (KDHE 2011b), and chloride and sulfate originating from natural sources in the Dakota Aquifer with some augmentation by oil-field brine (KDHE 2004).

Reservoir Hydrologic Data Summary

Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics related to flow (i.e., volume, load, and concentration), water residence time, and lake mixing/stratification which in turn influence physical and chemical processes, frequently resulting in biological responses. Figure 3-207 illustrates Kanopolis Lake hydrologic data with overlay of water quality samplings events.

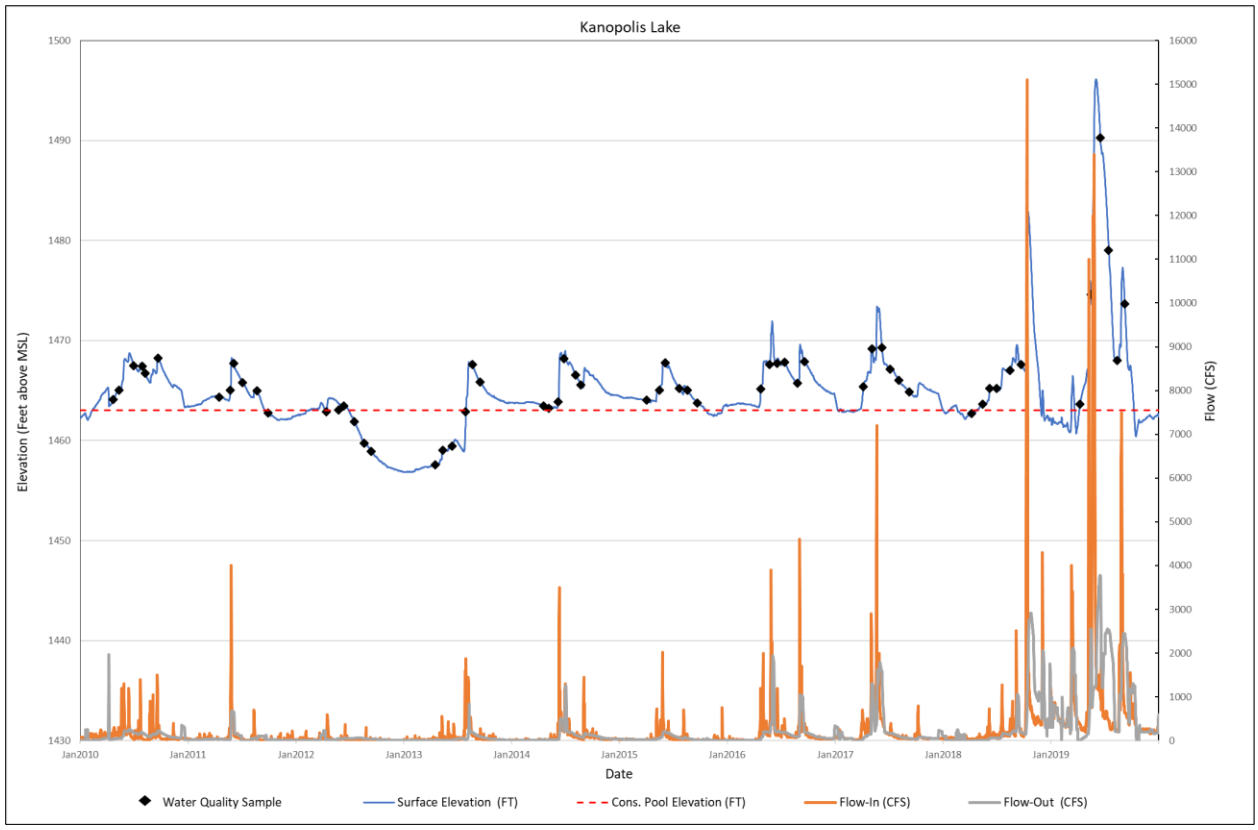
Water quality sampling events by Kansas City District staff were conducted monthly from 2010–2019 coinciding with the typical recreational season (April–September). Low inflow and lake level below multipurpose pool was observed at the end of 2012 with surface elevation falling below 1,456 feet while recovery period is apparent in spring of 2013. Significant flooding and corresponding high-water period in 2019 followed inflows exceeding 13,000 cfs. Surface elevation of Kanopolis Lake peaked at 33 feet above CPE and exceeded CPE for 268 days in 2019.

Kanopolis Lake average water residence time of 4.5 months was calculated from historic water management records for the period 1990–2022 using HEC-ResSim software. Kanopolis Lake average water residence time is below the average of 10.8 months for seven USACE Kansas River Watershed lakes in this study. Short residence times can lead to pronounced seasonal shifts and dynamic water quality at Kanopolis Lake with less time allowed for dilution, settling, and biological attenuation of sediment, nutrients, and other contaminants.

Water management and hydrologic conditions are critical factors for salinity and concentration of ions in Kansas River basin outflow related to quality of downstream water supplies due to naturally occurring salinity in the basin’s geographic formations. Analysis of salinity and dam operations at Wilson and Kanopolis Lakes is presented in Appendix G of this document. This study provides a basis for evaluating the effectiveness of alternative operational scenarios for salinity management and describes conceptual operation strategies aimed at decreasing the number of releases made in which the outflows chloride concentrations exceed threshold conditions of 200 mg/L at Kanopolis Lake. This threshold represents the approximate 70th percentile for

outflow chloride concentrations in the baseline simulations using 100-years of historical data. Two operational strategies capable of eliminating releases exceeding the chloride concentration thresholds are outlined in this document.

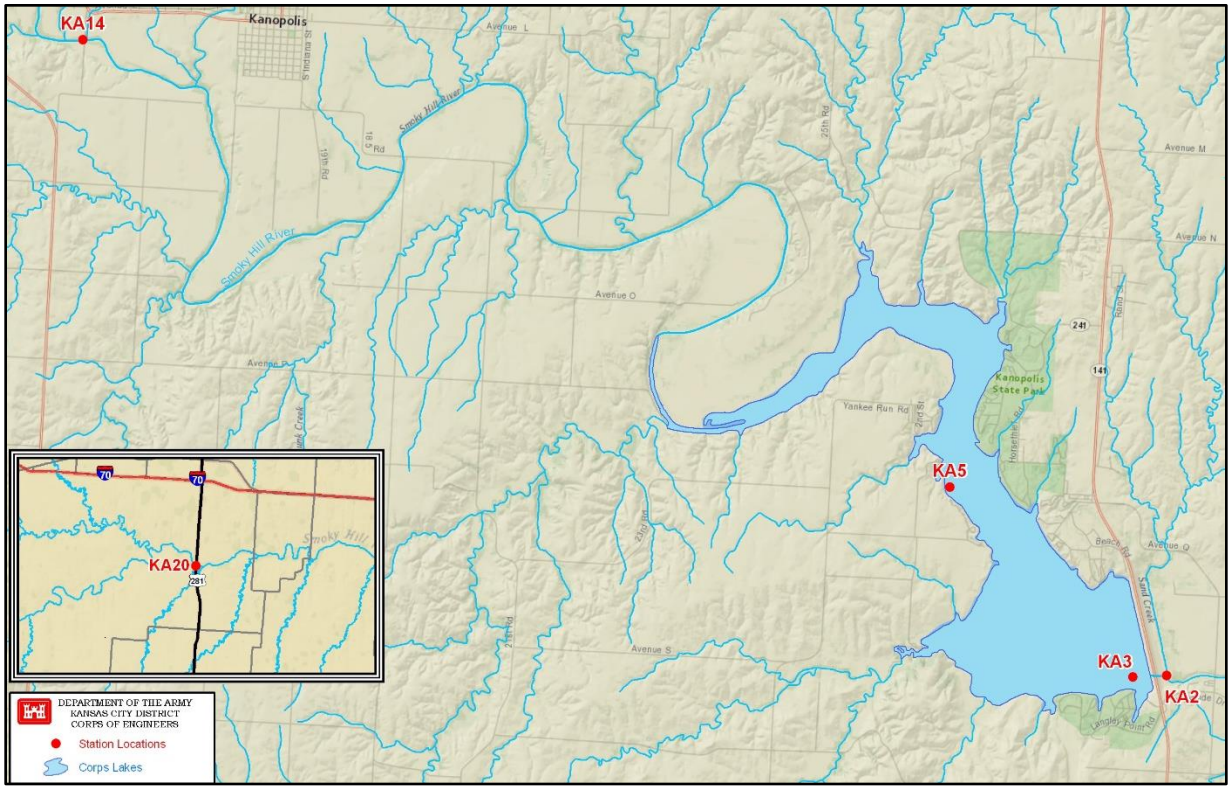
Figure 3-207.Kanopolis Lake Time Series of Daily Water Surface Elevation and Pool Information



Water Quality Sample Locations

Historic water quality sample sites at Kansas City District lake projects are generally named in decreasing numeric order from inflow sites to the outflow site below the dam (Figure 3-208). Inflow sites KA-20 and KA-14 are both on Smoky Hill River. Inflow KA-20 was chosen to document influence from the city of Russel, Kansas on stream water quality and located approximately 64 miles upstream of the lake boundary. To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow.

Figure 3-208. Kanopolis Lake U.S. Army Corps of Engineers' Water Quality Sample Sites

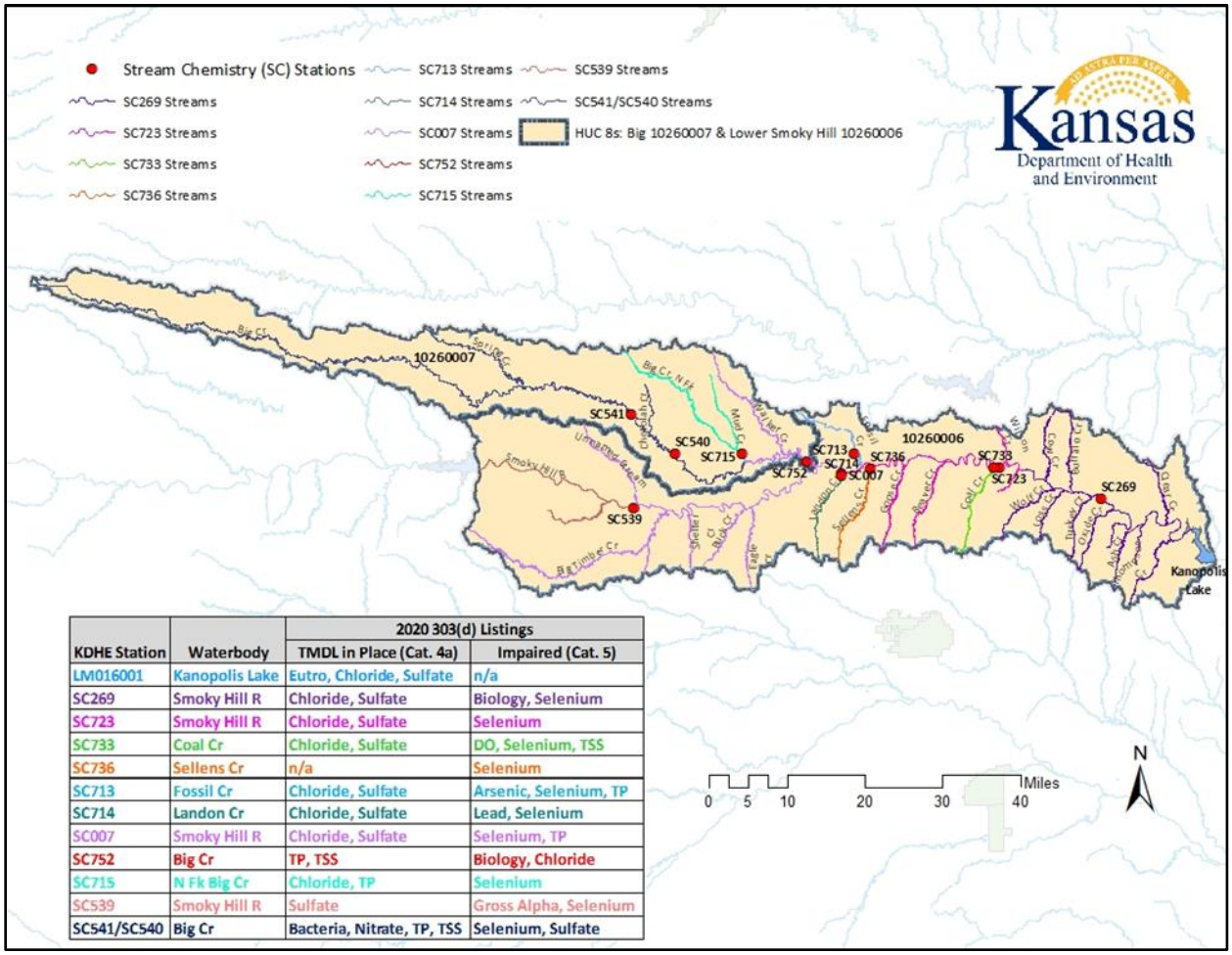


Impairments

The Kanopolis Lake watershed includes eleven impaired stream segments listed on the 2020 303(d) list (Figure 3-209) mostly associated with discharge of saline groundwater from the Dakota aquifer and naturally occurring selenium (KDHE 2004). Elevated salinity and nutrients have led to established TMDLs for most of the Kanopolis Lake watershed (Figure 3-209). The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting Drinking Water Use according to current EPA standard of 250 mg/L of chloride used to establish the TMDL. The elevated background of chloride plus additional inputs from brine discharge in Russell County, consistently above 250 mg/L, makes achievement of the Standard unlikely at lower flow conditions at mainstem Smoky Hill River KDHE sample stations 007, 269, and 723 (Figure 3-209). The specific stream criteria to supplant the general standard low-flow standard is planned to be developed in subsequent phases of 303(d) process (KDHE 2004). Impairments listed above do not extend below Kanopolis Lake.

The approved WRAPS plan for Big Creek and Middle Smoky Hill River Watersheds, which includes Kanopolis Reservoir, outlines a range of prioritized watershed issues providing opportunities and a functional mechanism for regional entities to improve water quality. The Kanopolis Lake eutrophication TMDL is targeted for nutrient and sediment reduction measures by the active WRAPS group.

Figure 3-209. Kanopolis Lake Impaired Waters and Total Maximum Daily Loads



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM016001	Kanopolis Lake	Eutro, Chloride, Sulfate	n/a
SC269	Smoky Hill R	Chloride, Sulfate	Biology, Selenium
SC723	Smoky Hill R	Chloride, Sulfate	Selenium
SC733	Coal Cr	Chloride, Sulfate	DO, Selenium, TSS
SC736	Sellens Cr	n/a	Selenium
SC713	Fossil Cr	Chloride, Sulfate	Arsenic, Selenium, TP
SC714	Landon Cr	Chloride, Sulfate	Lead, Selenium
SC007	Smoky Hill R	Chloride, Sulfate	Selenium, TP
SC752	Big Cr	TP, TSS	Biology, Chloride
SC715	N Fk Big Cr	Chloride, TP	Selenium
SC539	Smoky Hill R	Sulfate	Gross Alpha, Selenium
SC541/SC540	Big Cr	Bacteria, Nitrate, TP, TSS	Selenium, Sulfate

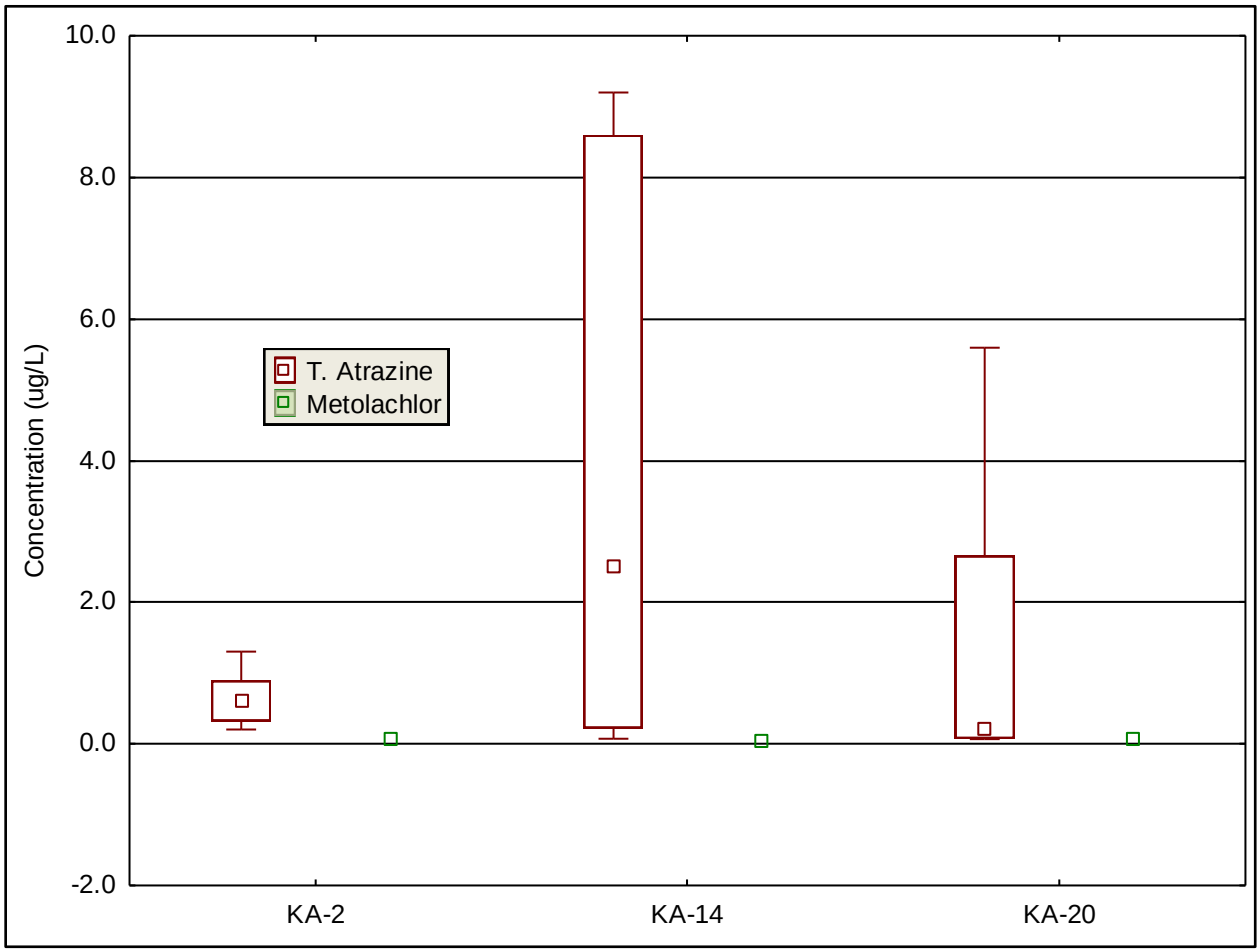
Inflows/Outflow

Lakes and reservoirs store suspended particles and soluble chemicals entering reservoirs from runoff, groundwater, and inflow streams. Different sediment, nutrient, contaminant, and geological sources in the watershed and associated inflows influence lake water quality including water clarity, nutrient concentration, chemical contamination, and element ratio or nutrient balance in receiving waters. These factors also have implications for biological response in the streams and receiving waters including trophic state and which type of algae dominate the primary production in the system.

Water exiting through the dam or outlet works of USACE lakes can be quite different than the inflows as large amounts of nutrients, pesticides, and metals are processed and/or stored in the lake causing a sink effect (Satoh et al. 2002). Chemical compounds solubilized under anoxic conditions when lakes are thermally stratified are seasonal exceptions to this trend. Low dissolved oxygen concentrations in outflows due to release of anoxic water during stratified periods and supersaturation during flood releases degrade water quality and can be stressful or lethal to aquatic life below dams.

Atrazine is the most common herbicide detected in Kanopolis Lake inflows and outflow. Herbicides are not currently listed as impairments for Kanopolis Lake by KDHE. The median of inflow sample results for total atrazine at the inflow sites are below the EPA drinking water criteria of 3 ug/L while no samples from the outflow exceed this criterion (Figure 3-210).

Figure 3-210. Herbicide Concentration Upstream and Downstream of Kanopolis Lake from 2010–2019



Inflows into Kanopolis Lake carry high nutrient loads (Figure 3-211) associated with sediment and non-point source nutrients. Median total nitrogen and organic nitrogen (TKN) measured at inflow sites exceed the 75th percentile (Q3) found in the outflow which is indicative of significant biological attenuation and denitrification occurring in Kanopolis Lake. Ammonia and orthophosphate are two soluble nutrients where export exceeds input or where median values measured in export samples exceed respective median values in inflows. Three outliers observed in inflow nutrients (TP and NO_3) in Figure 3-222 are associated with sampling in proximity of runoff or rain events.

Water clarity is greatly improved from longer residency time in Kanopolis Lake. Median turbidity and total suspended solids are up to three times greater at inflow sites than the outflow (Figure 3-213). Suspended particles and sediment settle and accumulate in Kanopolis Lake improving water clarity metrics at the outflow site.

Ten-year median chloride and sulfate concentrations from USACE samples collected at the outflow site below Kanopolis Lake (Figure 3-215) do not exceed EPA drinking water standards and are diluted by numerous tributaries in the 64 river miles separating upper inflow sites and Kanopolis Lake. Smoky Hill River chloride sample medians are 2–3 times greater than the outflow site.

Figure 3-211. Nutrient Concentrations Upstream and Downstream of Kanopolis Lake from 2010–2019

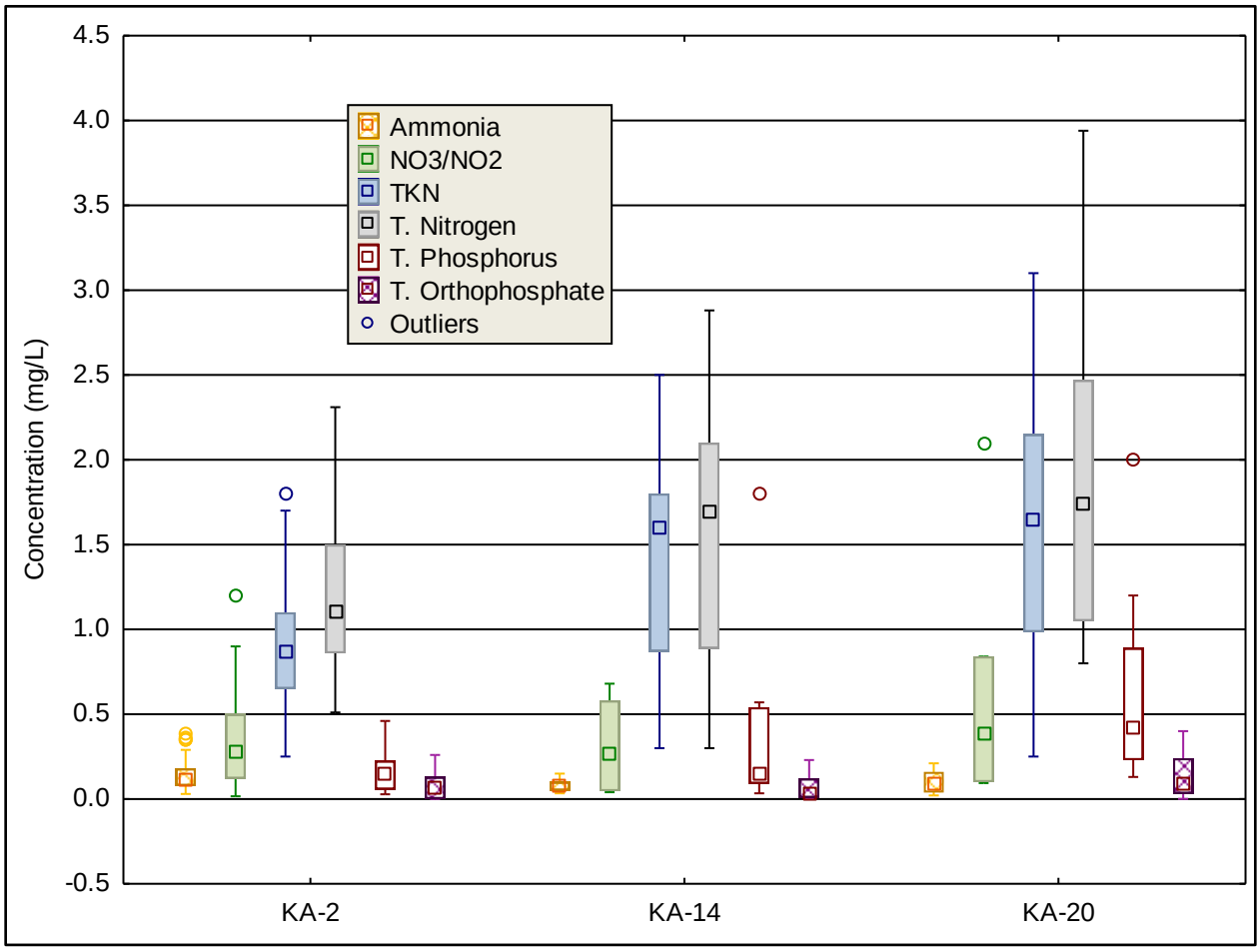


Figure 3-212. Water Clarity Influences Upstream and Downstream of Kanopolis Lake from 2010–2019

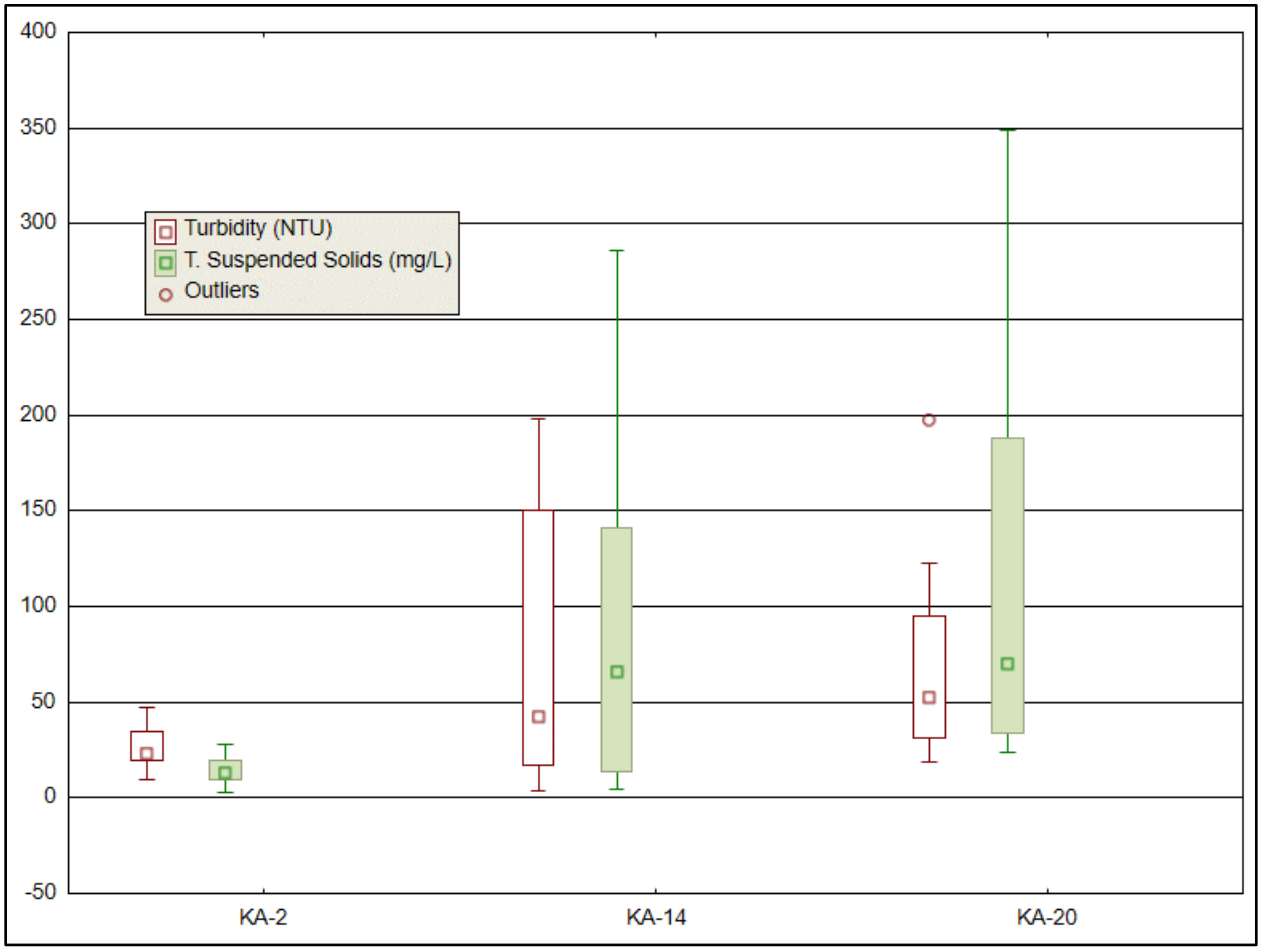
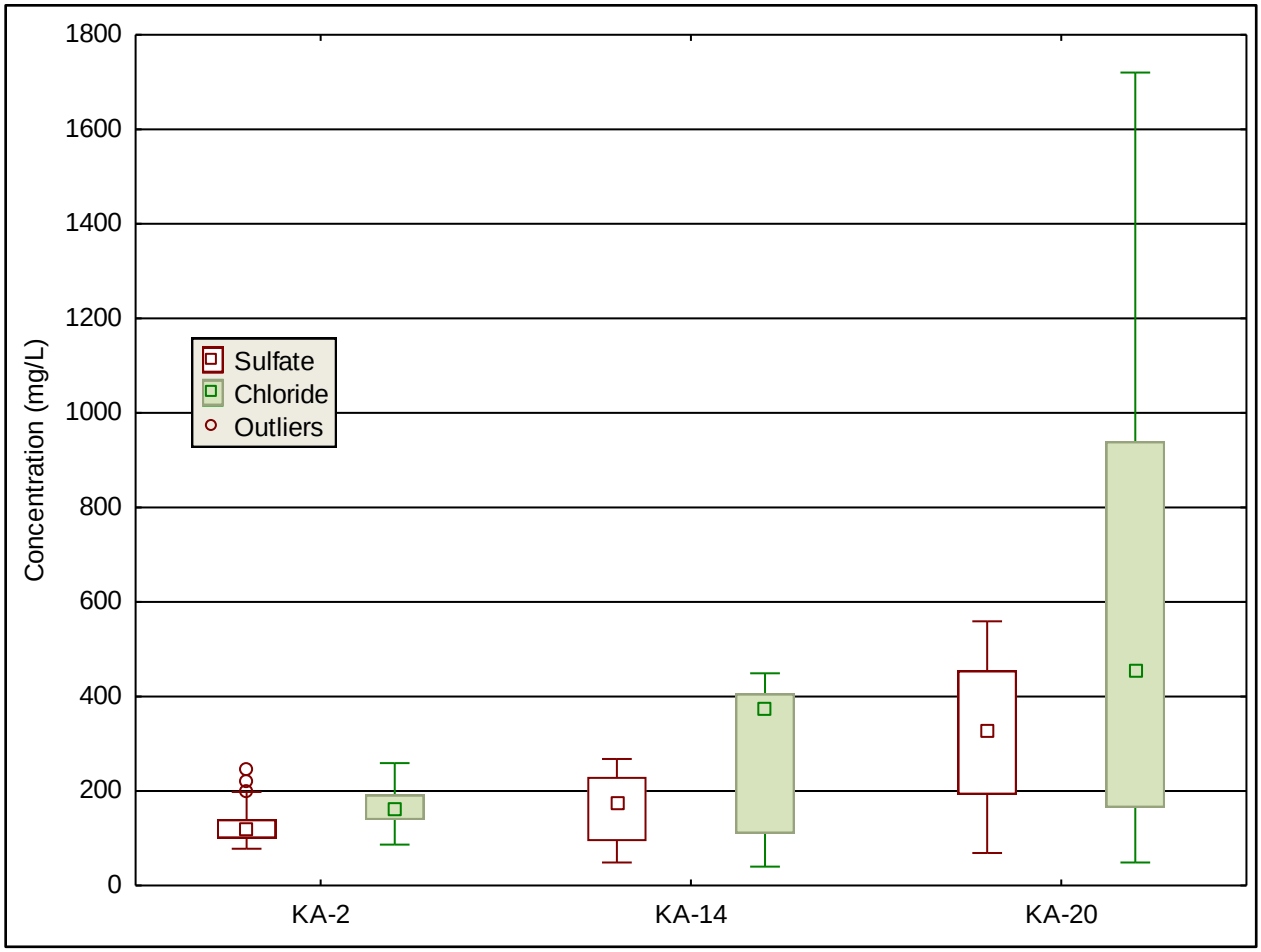


Figure 3-213. Naturally Occurring Salts Upstream and Downstream of Kanopolis Lake from 2010–2019



Lake Water Quality

Nutrient rich runoff and naturally occurring salts in the watershed lead to water quality problems at Kanopolis Lake linked to TMDLs for eutrophication and chloride/sulfate ions as described by 303d listing by KDHE. KDHE WRAPs have modeled phosphorus and nitrogen load reductions of 48 percent to 52 percent respectively, are needed in Big Creek Middle Smoky Hill River Watersheds to meet TMDL goals for Kanopolis Lake (Kanopolis Reservoir- Big Creek Middle Smoky Hill River Watersheds 9 Element Watershed Protection Plan 2011b). Increased nutrients and sediment accumulating in Kanopolis Lake will lead to a decline in water quality and reduced storage capacity for water use. This age-related process makes older reservoirs more susceptible to contamination and internal loading of nutrients, metals and compounds stored in lake-bed sediment (Juracek 2014).

Physical and chemical attenuation (e.g., dilution, dispersion, chemical changes, and uptake by organisms) of compounds and settling of suspended matter leads to a general decrease in concentration of many constituents of water quality, often interpreted as improved water quality, as water moves through a reservoir system (Bosch et al. 2009). This process will be evident with many analytes in graphic representations in lake water quality sections. The following section is an overview of

chemical and physical data from surface samples from two lake sites. Chemical and physical differences between surface and bottom strata at the site near the dam and stratification are described along with a brief description of available phytoplankton and cyanobacteria data related to public health advisories.

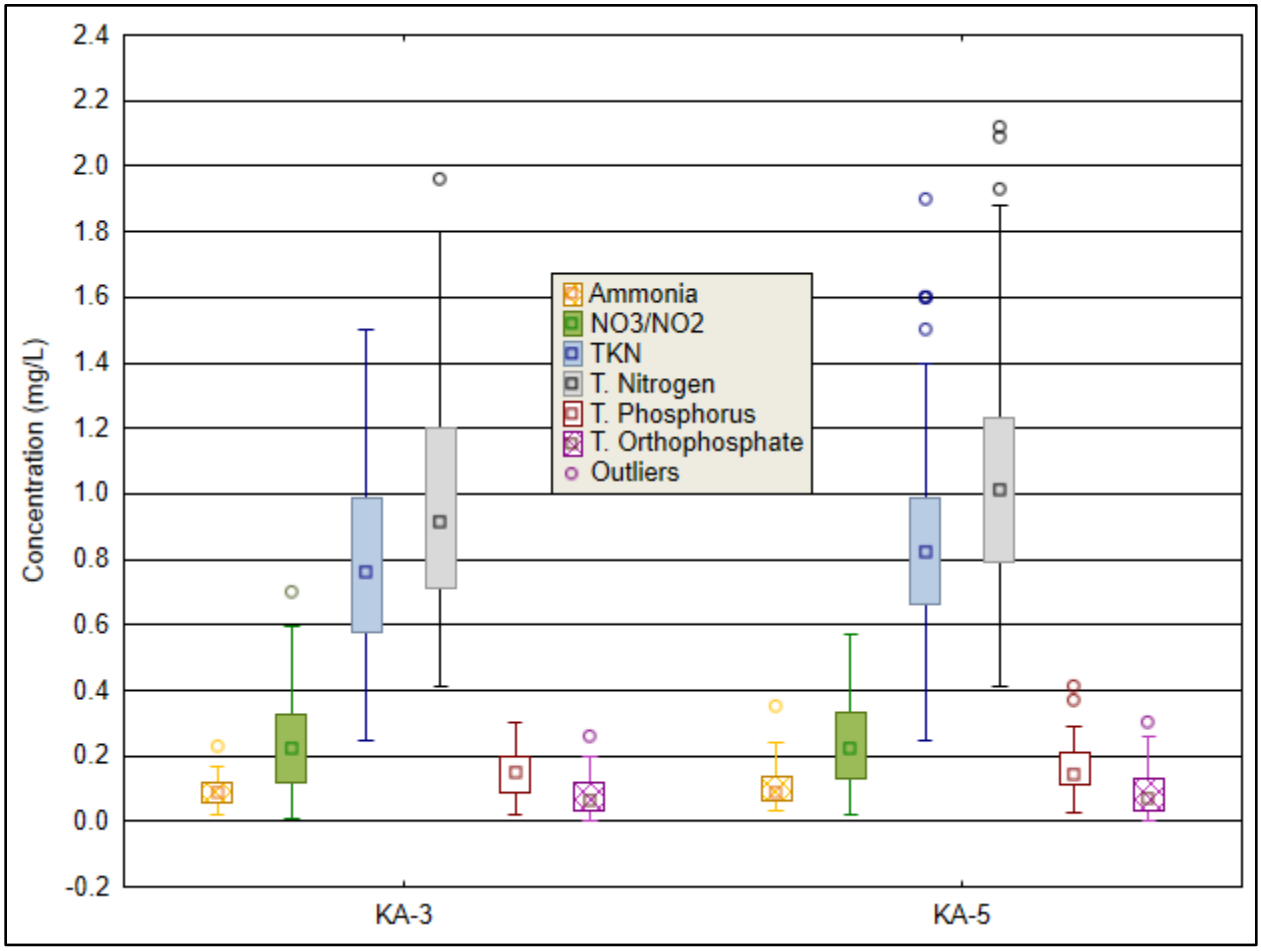
Herbicides are detected in relatively low concentrations in Kanopolis Lake samples. Two common herbicides detected in samples include atrazine which did not exceed EPA recommendations for maximum exposure of 3 ppb in samples collected from 2010–2019.

Excess nutrients are the primary impact to water quality at Kanopolis Lake as indicated by eutrophication TMDL targeted to reduce phosphorus loading associated permitted discharges and farming practices. Phosphorus concentrations are typically in the top 5 of 18 Kansas City District lakes (Figure 3-163).

Total nitrogen and organic nitrogen (TKN) concentrations decreases slightly from the upper lake site to the dam (Figure 3-214). Kanopolis Lake is relatively linear with less than 4 miles between standardized upper and lower lake sites. Attenuation and denitrification/biological uptake occur, but on a smaller scale than many of the larger reservoirs in the district. Median bioavailable forms of nitrate/nitrite and ammonia were similar between sample sites.

Total phosphorus and soluble orthophosphate concentrations (Figure 3-214) were less variable at lower lake site KA-3 near the dam. Mean total phosphorus from 10-year reporting period (Table 3-125) exceeded hypereutrophic threshold of 0.09 mg/L (Carlson 1977) as well as EPA Ecoregion recommendations.

Figure 3-214. Kanopolis Lake Nutrient Concentrations from 2010–2019



A summary of Kanopolis Lake descriptive statistics of chemical analysis results at the site nearest the dam is found in Table 3-125. Bottom samples are typically collected from Kansas City District lakes every third year with total metals collected during peak stratified month of August when stratified conditions are most likely to influence metal solubility. During seasonal periods when the lake is mixed (not stratified), bottom sample results are nearly identical to surface sample results for most analytes. Anaerobic conditions allow for oxidation/reduction reactions to release chemical compounds, including metals, which can be elevated in bottom samples. Small sample size for metals results is related to three-year sample frequency for 10-year analysis period. Results below minimum detection level have been included in sample results as the value of half of the reported minimum detection limit to reduce bias based on the assumption that the analyte is present at a concentration below laboratory quantification (EPA 1991).

Kanopolis water column is rarely stratified with obvious thermal and chemical mixing observed in surface to bottom results (Table 3-125). Significant differences were detected (Wilcoxon Signed-Rank Test; $p<0.05$) between surface and bottom results for NO3/NO2 and TSS.

Table 3-128. Kanopolis Lake Summary Statistics for Chemical Water Quality Parameters 2010–2019[1]

Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.07	0.01	0.06	0.32	0.06	0.01	60
Ammonia (mg/L)	Bottom	0.10	0.02	0.06	0.21	0.08	0.02	12
NO3/NO2 (mg/L)	Surface	0.17	0.02	0.17	0.70	0.12	0.01	60
NO3/NO2 (mg/L)	Bottom	0.05	0.01	0.05	0.17	0.03	0.03	12
TKN (mg/L)	Surface	0.79	0.04	0.31	1.50	0.76	0.20	60
TKN (mg/L)	Bottom	0.75	0.09	0.29	1.10	0.88	0.15	12
Total Nitrogen (mg/L)	Surface	0.96	0.05	0.37	1.96	0.91	0.22	60
Total Nitrogen (mg/L)	Bottom	0.81	0.09	0.29	1.17	.090	0.20	12
Total Phosphorus (mg/L)	Surface	0.14	0.01	0.07	0.30	0.15	0.02	60
Total Phosphorus (mg/L)	Bottom	0.14	0.02	0.06	0.25	0.13	0.08	12
Total Orthophosphate (mg/L)	Surface	0.08	0.01	0.06	0.26	0.06	0.00	60
Total Orthophosphate (mg/L)	Bottom	0.07	0.02	0.07	0.20	0.05	0.003	12
Total Suspended Solids (mg/L)	Surface	11.88	1.29	10.03	76.00	9.40	1.00	60
Total Suspended Solids (mg/L)	Bottom	20.3	15.76	16.2	250.00	17.00	3.60	12
Total Organic Carbon (mg/L)	Surface	6.84	0.61	2.94	15.00	5.80	4.40	23
Total Organic Carbon (mg/L)	Bottom	5.25	0.33	1.06	7.70	5.15	3.70	10
Chlorophyll a (ug/L)	Photic Zone	9.47	1.34	9.60	53.10	6.40	0.83	51
Sulfate (mg/L)	Surface	145.86	5.15	39.25	248.00	133.00	79.41	58
Sulfate (mg/L)	Bottom	171.2	12.95	50.15	250.00	160.00	113.00	12
Chloride (mg/L)	Surface	164.44	10.07	45.02	242.00	156.00	70.90	20
Chloride (mg/L)	Bottom	164.60	7.85	17.56	184.00	173.00	141.00	5
Total Iron (ug/L)	Surface	523.00	93.95	162.72	696.00	500.00	373.00	3
Total Iron (ug/L)	Bottom	604.75	143.25	286.50	992.00	560.50	306.00	3
Total Manganese (ug/L)	Surface	559.20	485.59	841.07	1530.00	97.60	50.00	3
Total Manganese (ug/L)	Bottom							NA

Notes: *SE=Standard Error
**SD=Standard Deviation
[1/]Summary statistics for chemical water quality parameters from Kanopolis Lake site near the dam (KA-3), April 2010 through September 2019.

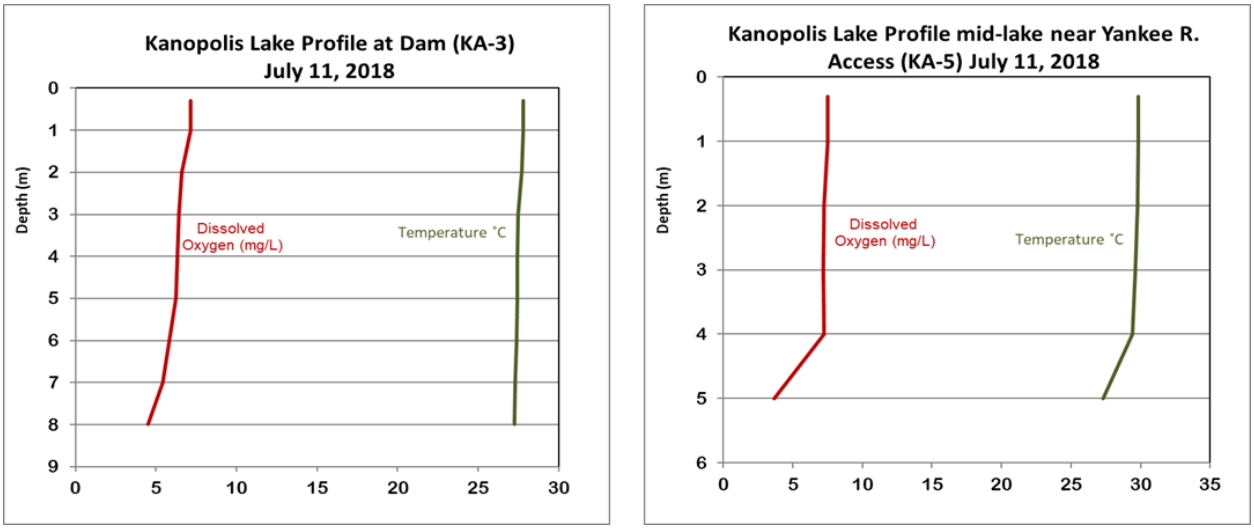
Physical water quality data from profiles collected at Kanopolis Lake are presented in Table 3-126. Thermal mixing is apparent as temperature and dissolved oxygen results are similar at surface and bottom sites. Significant difference ($p<0.05$) between surface and bottom turbidity was detected as water quality profiles frequently found increased turbidity in the bottom meter of depth (Table 3-126) regardless of temperature and oxygen mixing. Frequent mixing or lack of a thermocline is apparent in a representative summer profile from Kanopolis Lake (Figure 3-215). The presence of oxygen in bottom layers increases available habitat for aquatic species and decreases the rate of enrichment of hypolimnetic waters with phosphorus and metals released at lower rates from lake sediments in the presence of oxygen (Jensen et al. 1992).

10973 *Table 3-129. Kanopolis Lake Summary statistics for physical water quality parameters 2010–2019[1]*

Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	8.0	0.1	1.4	11.7	7.8	4.5	115
Oxygen, Dissolved (mg/l)	Bottom	6.5	0.2	2.5	11.5	6.7	0.1	115
pH (Standard Units)	Surface	8.4	0.1	0.5	9.9	8.4	7.2	34
pH (Standard Units)	Bottom	8.4	0.1	0.7	10.0	8.3	7.7	33
Salinity (‰)	Surface	0.7	0.03	0.07	0.8	0.7	0.6	12
Salinity (‰)	Bottom	0.7	0.03	0.07	0.8	0.7	0.6	12
Secchi Depth (m)	Surface	0.5	0.02	0.05	1.3	0.5	0.2	102
Specific Conductance (µS/cm)	Surface	1146.0	46.0	268.3	1156.0	1208.0	709.7	34
Specific Conductance (µS/cm)	Bottom	1160.0	45.2	259.9	1555.0	1225.0	711.2	34
Turbidity, Field (NTU)	Surface	21.6	2.4	0.4	67	22.3	3.4	34
Turbidity, Field (NTU)	Bottom	139.3	58.1	328.6	1712.0	35.6	6.1	32
Water Temperature (°C)	Surface	20.6	0.6	6.9	31.2	22.8	5.8	115
Water Temperature (°C)	Bottom	21.9	0.5	5.4	29.8	23.4	7.5	115

10974 Notes: *SE=Standard Error; **SD=Standard Deviation
10975 [1]Summary statistics for physical water quality parameters, from all sites and dates, Kanopolis Lake, April 2010 through
10976 September 2019.

10977 *Figure 3-215. Kanopolis Lake Representative Temperature and Dissolved Oxygen Profiles*



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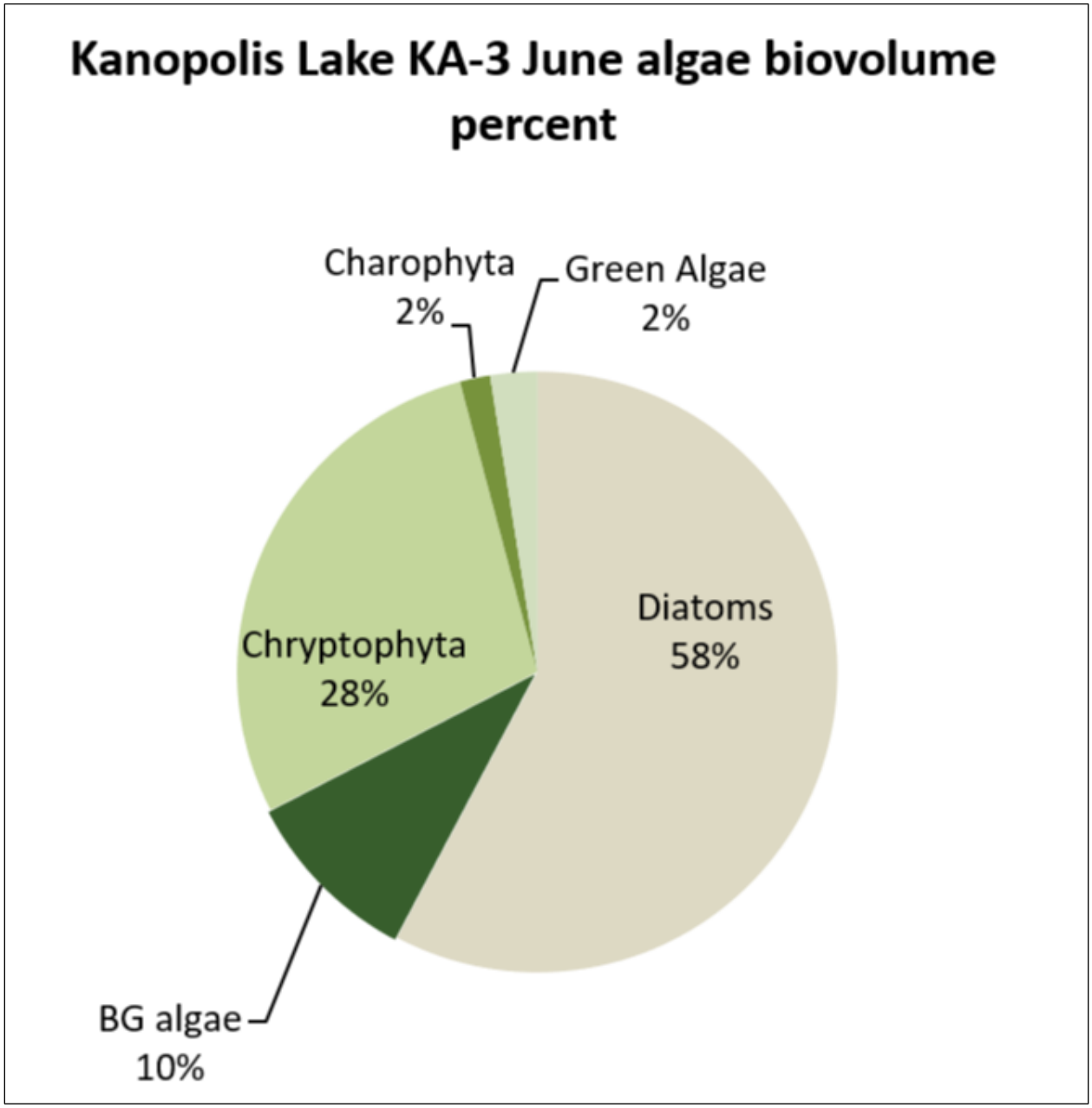
Phytoplankton at Kanopolis Lake can historically be characterized as relatively low-density populations (<50,000 cells/mL) dominated seasonally by green algae (Chlorophyta), diatoms (Bacillariophyta) and infrequently by cyanobacteria from short lived blooms (KDHE 2007; KDHE 2010; USACE unpublished data 2014) (Figure 3-216). Kanopolis lake trophic state typically scores as eutrophic or slightly eutrophic based on algal chlorophyll TSI scores (KDHE 2010) but inorganic turbidity may impede algal growth (USACE unpublished data 2014).

Figure 3-216. Kanopolis Lake KA-3 June 2014 Algae Biovolume Percentages



Large inflows followed by an extended period of elevated lake level in 2019 (Figure 3-217) led to a nutrient pulse including high phosphorus levels up to four times the 10-year median values (USACE 2019). This nutrient pulse led to Kanopolis Lake

experiencing the first HAB warnings since implementation of KDHE HAB Policy in 2011. The 2020 bloom was located near USACE managed public swim beaches and resulted in a 6-week beach closure during peak Covid-19 conditions with very high public use and limited sampling due to Covid policies. Results from USACE beach samples (Figure 3-218) indicate that Veningo Beach (site name KA-V. Beach) exceeded KDHE warning threshold of 250,000 cells/mL.

Figure 3-217. Kanopolis Lake Beach Cyanobacteria Samples Collected During 2020 Harmfal Algaeal Bloom Event

STATION	SAMPLE DATE	GENUS	DIVISION	TALLY	DENSITY cells/L	TOTAL BV um^3/L	NOTES	cell/mL
KA SSSP Beach	6/8/2020	Aphanizomenon cf. flosaquae	Cyanobacteria	102	4.69E+07	2.82E+09		46917
KA SSSP Beach	6/8/2020	Microcystis sp.	Cyanobacteria	20	9.20E+06	4.39E+08		9199
		TOTAL		122	5.61E+07	3.26E+09		56116
KA-V.Beach	6/8/2020	Aphanizomenon sp.	Cyanobacteria	547	2.52E+08	1.42E+10		251603
		TOTAL		547	2.52E+08	1.42E+10		251603

Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discussions until aging lakes begin to release or “recycle” nutrients (e.g., phosphorus) back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) and/or sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984). Kansas City District Water Quality Program initiated collection of baseline lake sediment data at all District lakes in 2016 with 2018 the first opportunity to collect Kanopolis Lake samples (Figure 3-218) in the standard 3-year intensive sampling rotation.

Nitrogen and phosphorus concentrations from Kanopolis Lake sediment samples were low to moderate when compared to results from a group of lakes from Southeast and Northern United States (Barko, J.W. and R.M Smart 1986). Metal concentrations reported in Kansas City District lakebed sediment results (Figure 3-218) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed (MacDonald et al. 2000).

Figure 3-218. Kanopolis Lake Bed Sediment Chmeical Concentrations 2018

				Ammonia MG/KG	Nitrate-Nitrite MG/KG	Total Kjeldahl Nitrogen MG/KG	Phosphorus MG/KG	Arsenic MG/KG	Copper MG/KG	Iron MG/KG	Lead MG/KG	Manganese MG/KG	Nickel MG/KG	Zinc MG/KG	Cadmium MG/KG	Chromium MG/KG
KA-3	0.1	9/13/2018	1115	41.5	<4.1	<49.8	753	12.4	15.1	24300.0	17	935.0	22	74.1	0.3	20.60
KA-5	0.1	9/13/2018	1130	83.6	9.0	1380	920	11.4	24.3	31500	20.5	825	30.9	115	0.91	32.8

3.7.4.1.5 Perry Lake

Perry Lake is an 11,146-acre lake built on the Delaware River in Kansas reaching full pool in 1970. The primary water quality threats to Perry Lake are summarized by current TMDL for eutrophication are nutrients enrichment with occasional dissolved oxygen problems due to infrequent algal blooms.

The Watershed Restoration and Protection Strategy (WRAPS) program is a KDHE planning and management tool used to identify watershed restoration and protection needs, establish management goals, establish plans (e.g., EPA approved 9-Element Watershed Plans) and implement goals to address water resource concerns

(https://www.kdheks.gov/nps/wraps/). Most priority goals/targets of the WRAPS Plans for subbasins in the Kanas River Watershed align with strategies and measures included in this study. The WRAPS process is in the implementation and monitoring phase of their process to administer programs using BMPs to reduce phosphorus loads originating in Kansas by 617,204 pounds per year, nitrogen loads originating in Kansas by 2,341,263 pounds per year and sediment load reduction goal of 32,999 tons per year.

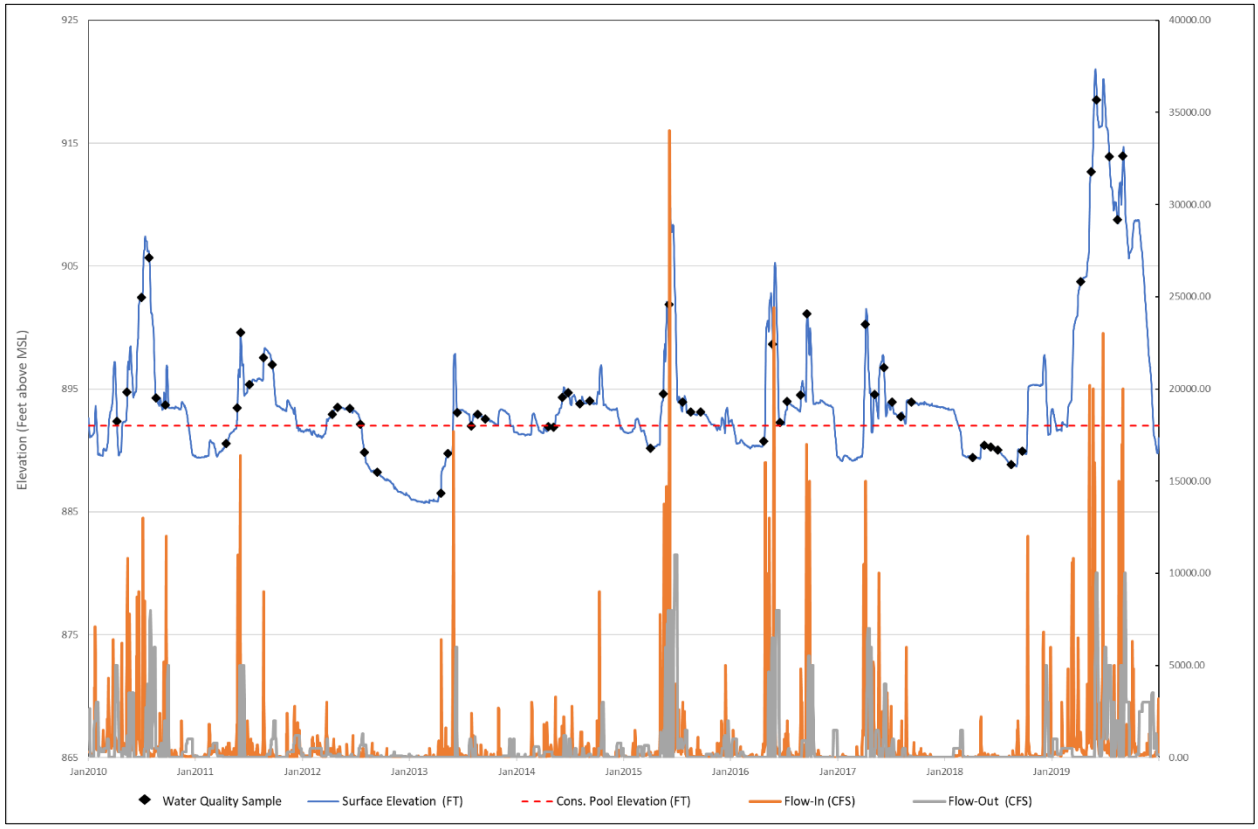
Reservoir Hydrologic Data Summary

Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics like flow, water residence time, and lake mixing/stratification which in turn influence physical and chemical process, frequently resulting in biological response.

Water quality sampling events by Kansas City District staff were conducted monthly from 2010 to 2019 coinciding with the typical recreational season (April through September) (Figure 3-219). Dry/drought periods were observed at the end of 2012 and 2018 with surface elevation falling below 897 feet in spring of 2013. High water conditions when pool elevation exceeds multipurpose pool were evident nearly every summer at Perry Lake as outflows were managed to maintain multipurpose pool elevation. Significant flooding and corresponding high-water period were observed for most of 2019 as several inflow events measured at or above 20,000 cfs contributed to record pool elevations across the Midwest. Perry Lake peaked at 28 feet above multipurpose pool elevation in 2019.

Perry Lake average water residence time of 5.6 months was calculated from historic water management records for the period 1990-2022 using HEC-ResSim software. Perry Lake average water residence time is below the average of 10.8 months for seven USACE Kansas River Watershed lakes in this study. Short residence times can lead to pronounced seasonal shifts and dynamic water quality at Perry Lake with less time allowed for dilution, settling, and biological attenuation of sediment, nutrients, and other contaminants.

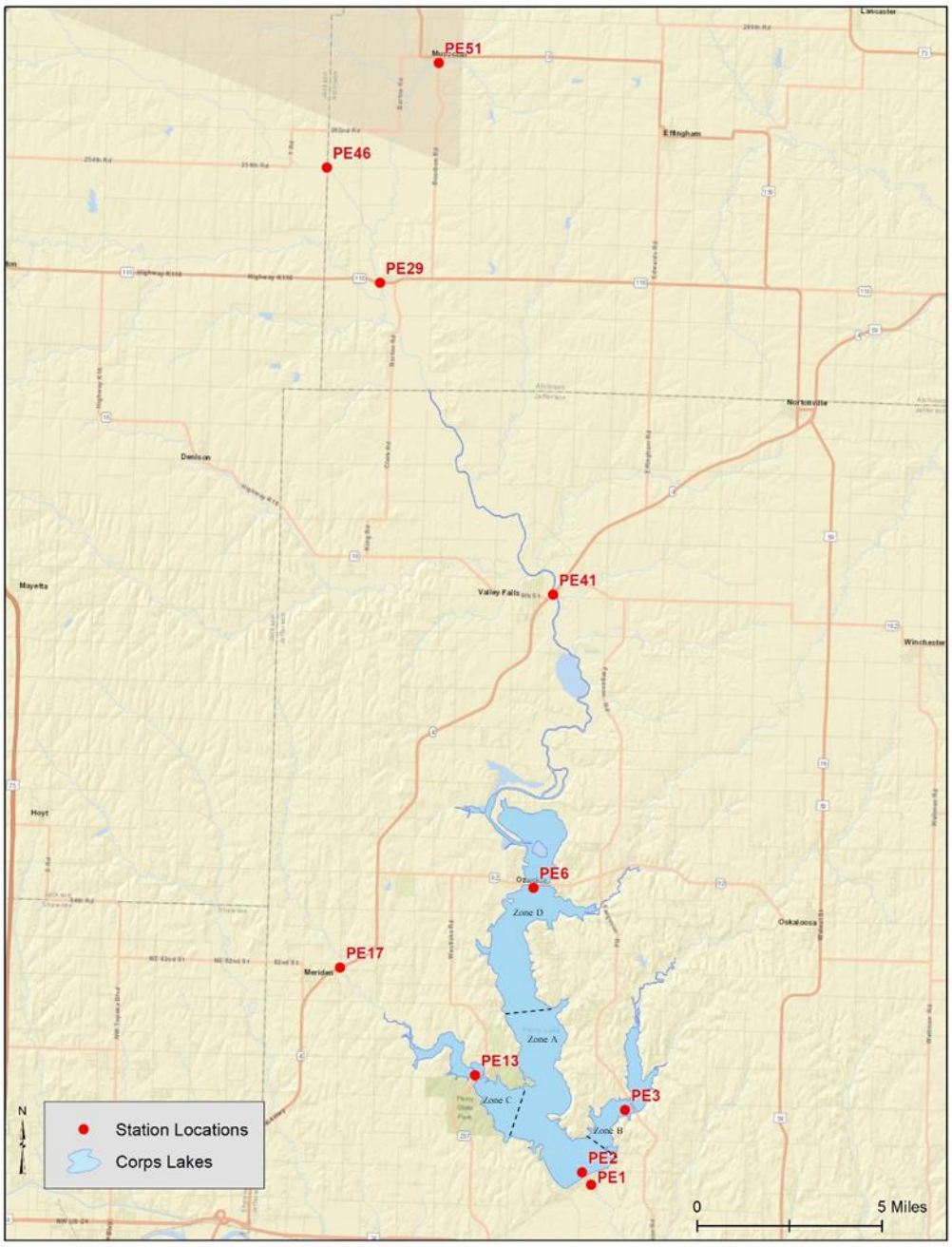
Figure 3-219. Perry Lake Time Series of Daily Water Surface Elevation and Pool Information



Water Quality Sample Locations

Historic water quality sample sites at Kansas City District lake projects are generally named in decreasing numeric order from inflow sites to the outflow site below the dam (Figure 3-220). Perry Lake has 3 extra inflow sites which were monitored to provide additional data for KDHE WRAPS planning efforts during development of EPA 9-Element Watershed Plan and provide additional support of impaired waters monitoring in the upper watershed. KDHE HAB management zones are included in Figure 3-220 for reference. To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow.

11072 *Figure 3-220. Perry Lake Historic USACE Water Quality Sample Sites*



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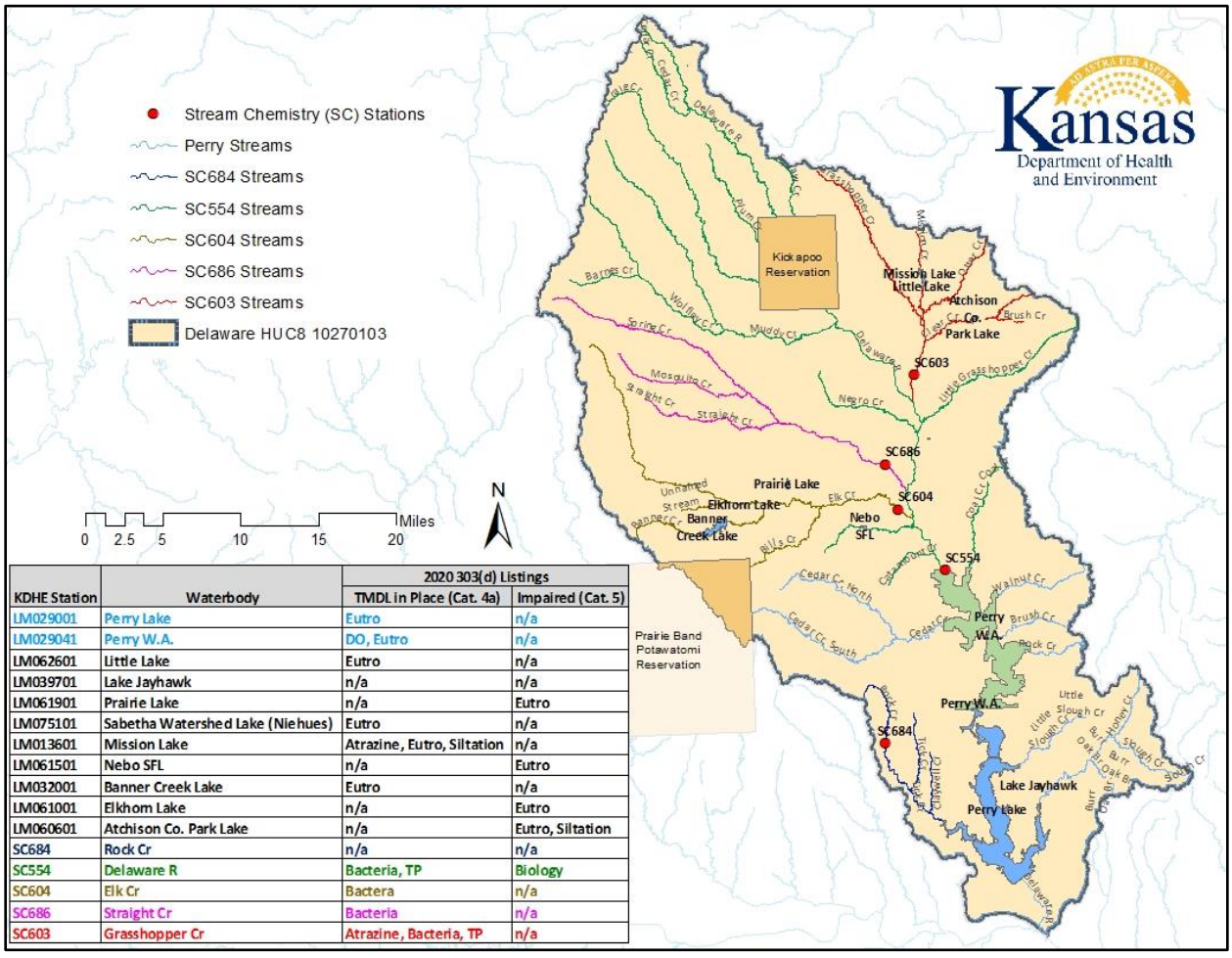
11074 **Impairments**

11075 Section 303(d) of the CWA requires that states develop a list of “impaired” water bodies
11076 that do not sufficiently meet water quality standards to support specific designated
11077 use(s). These impaired streams and lakes require additional protection (e.g., TMDLs)
11078 and restoration work (e.g., conservation planning, BMPs, in-stream and corridor
11079 improvements) in order to achieve water quality standards and restore designated uses
11080 of the waters.

The Perry Lake watershed includes four impaired stream segments listed on the 2020 303(d) list (Figure 3-221) impacted generally by bacteria, nutrients, and herbicide. Inflow streams appear to attenuate much of the bacteria and herbicide to levels below state water quality standards before they enter Perry Lake. Nutrient and sediment impacts, directly related to HABs and low dissolved oxygen, persist in Perry Lake as Eutrophication TMDL supports.

Figure 3-221 Perry Lake and Watershed Impaired Waters and Total Maximum Daily Loads



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM029001	Perry Lake	Eutro	n/a
LM029041	Perry W.A.	DO, Eutro	n/a
LM062601	Little Lake	Eutro	n/a
LM039701	Lake Jayhawk	n/a	n/a
LM061901	Prairie Lake	n/a	Eutro
LM075101	Sabetha Watershed Lake (Niehues)	Eutro	n/a
LM013601	Mission Lake	Atrazine, Eutro, Siltation	n/a
LM061501	Nebo SFL	n/a	Eutro
LM032001	Banner Creek Lake	Eutro	n/a
LM061001	Elkhorn Lake	n/a	Eutro
LM060601	Atchison Co. Park Lake	n/a	Eutro, Siltation
SC684	Rock Cr	n/a	n/a
SC554	Delaware R	Bacteria, TP	Biology
SC604	Elk Cr	Bactera	n/a
SC686	Straight Cr	Bacteria	n/a
SC603	Grasshopper Cr	Atrazine, Bacteria, TP	n/a

Inflows/Outflow

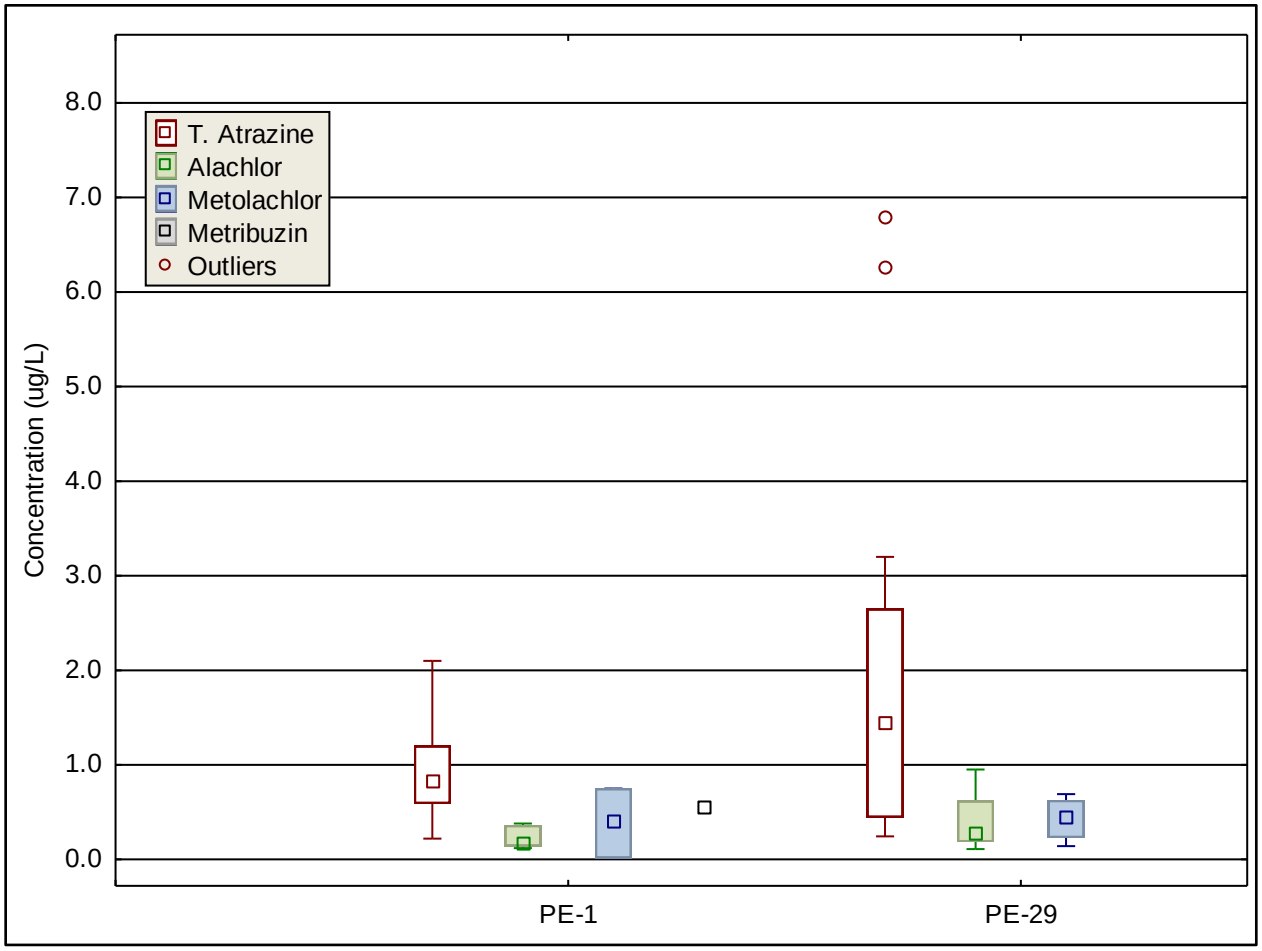
Lakes and reservoirs store sediment and associated chemical compounds carried by inflows and runoff. Sediment, nutrient, contaminant, and geological sources in the watershed and associated inflows influence lake water quality including water clarity, nutrient concentration, chemical contamination, and nutrient balance in receiving waters. These factors also have implications for biological response in the streams and receiving waters including trophic state and which type of plants and algae dominate the primary production in the system.

Nutrients sources, geology, and land-use are primary influences on water quality in inflow streams in the watershed which influence Perry Lake. Water exiting through the dam or outlet works of USACE lakes can be quite different than the inflows as large

amounts of nutrients, pesticides, and metals are processed and/or stored in the lake causing a sink effect (Satoh, Y., Ura, H., Kimura, T. et al. 2002). Chemical and nutrient compounds solubilized under anoxic conditions when lakes are thermally stratified are seasonal exceptions to the sink effect as they are released into lower strata and occasionally to the river below. Similarly, low dissolved oxygen concentration in outflows related to release of anoxic water during stratified periods and supersaturation during flood releases are problematic physical water quality conditions exhibited below dams.

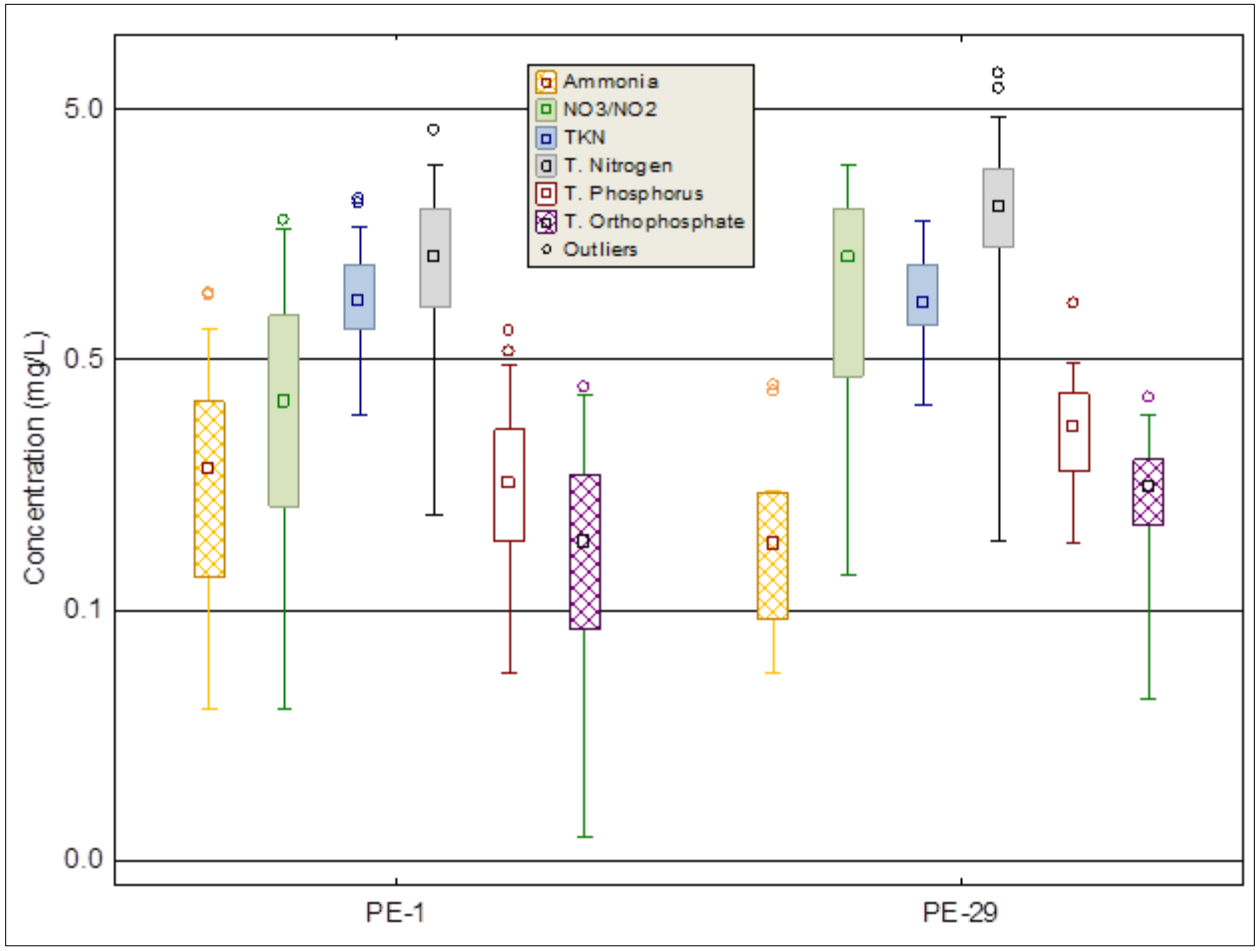
Herbicides have been monitored at Perry Lake by Kansas City District Water Quality personnel since 1996. The list of herbicides detected have included mostly chlorinated species and chemical constituents of atrazine, alachlor, metolachlor, cyanazine, metribuzin, simazine, acetochlor as well as 2, 4-D and glyphosate. EPA regulation of herbicide licensing to reduce chemical persistence and mobility in the environment have reduced the number and concentration of chemicals detected in Kansas City District water quality samples. Total atrazine and alachlor concentrations peak in the spring and are associated with runoff events as herbicides mobilize and enter the Delaware River in concentrations typically much higher than those exiting through the outlet. Median concentrations of monitored herbicides in the outflow are lower than corresponding medians from inflow (Figure 3-222). Concentrations of atrazine and detectable levels of alachlor in the outflow persist at levels below EPA drinking water standards 3 ug/L and 2 ug/L, respectively. Instances of total atrazine exceeding EPA drinking water standards of 3 ug/L were documented on Delaware River above Perry Lake between 2010 and 2019 according to USACE Water Quality Program Data (unpublished data 1996–2019).

Figure 3-222. Herbicide Concentrations Upstream and Downstream of Perry Lake 2010–2019



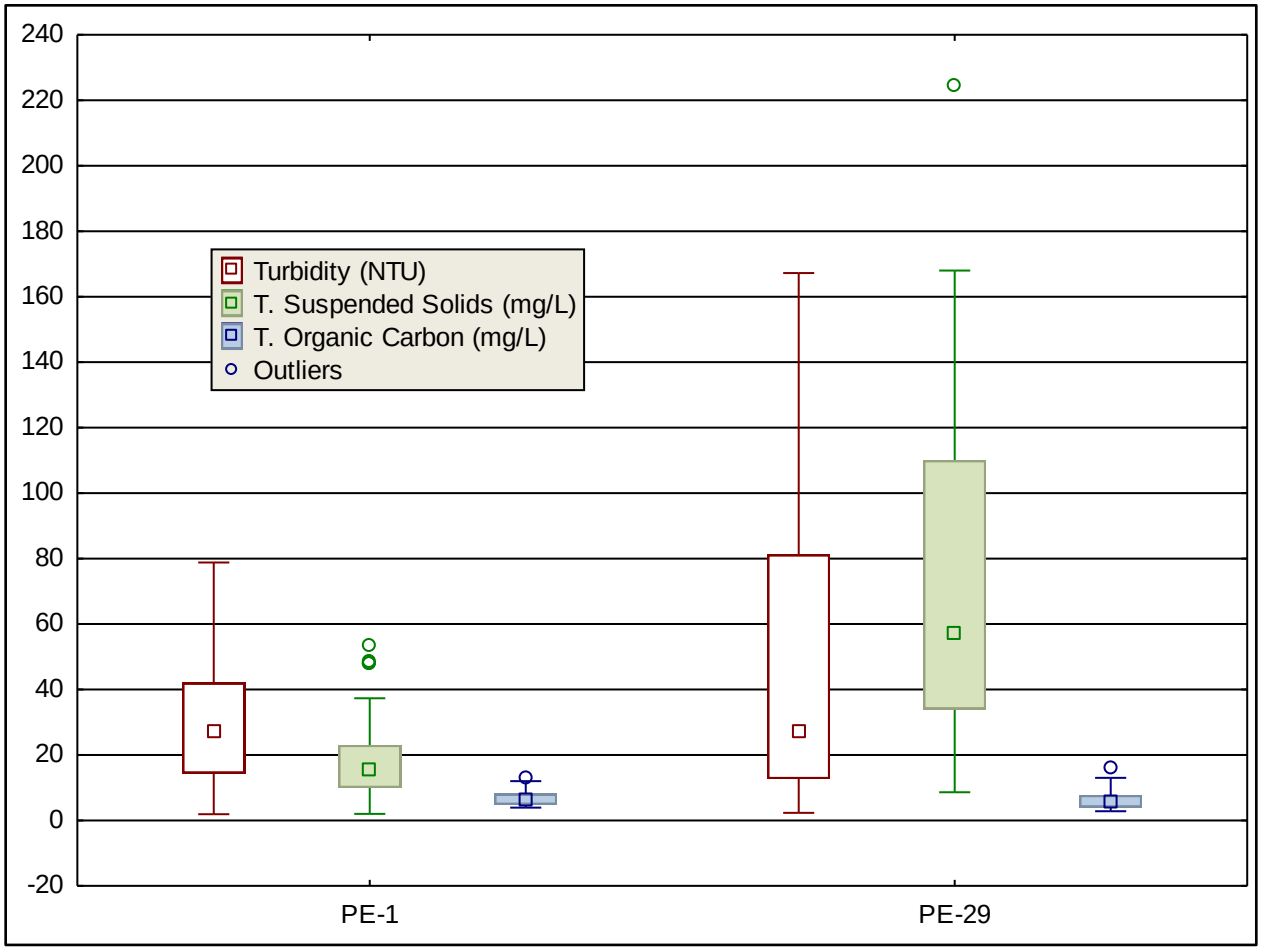
Inflows into Perry Lake carry high nutrient loads (Figure 3-223) associated with sediment and non-point source nutrients. Median total nitrogen and soluble form nitrate (NO3) measured at the Delaware River site both exceed the 75th percentile (Q3) found in the outflow indicative of significant biological attenuation and denitrification in Perry Lake. Ammonia-N concentrations were higher in the outflow as release from deep water near the dam frequently have high ammonia concentration under stratified conditions. TKN median and distribution were similar between inflow and outflow sites during our study period. Both phosphorus and orthophosphate medians were 1.5 times higher at the inflow site than respective median values measured at the outflow.

Figure 3-223. Nutrient Concentrations Upstream and Downstream of Perry Lake from 2010–2019



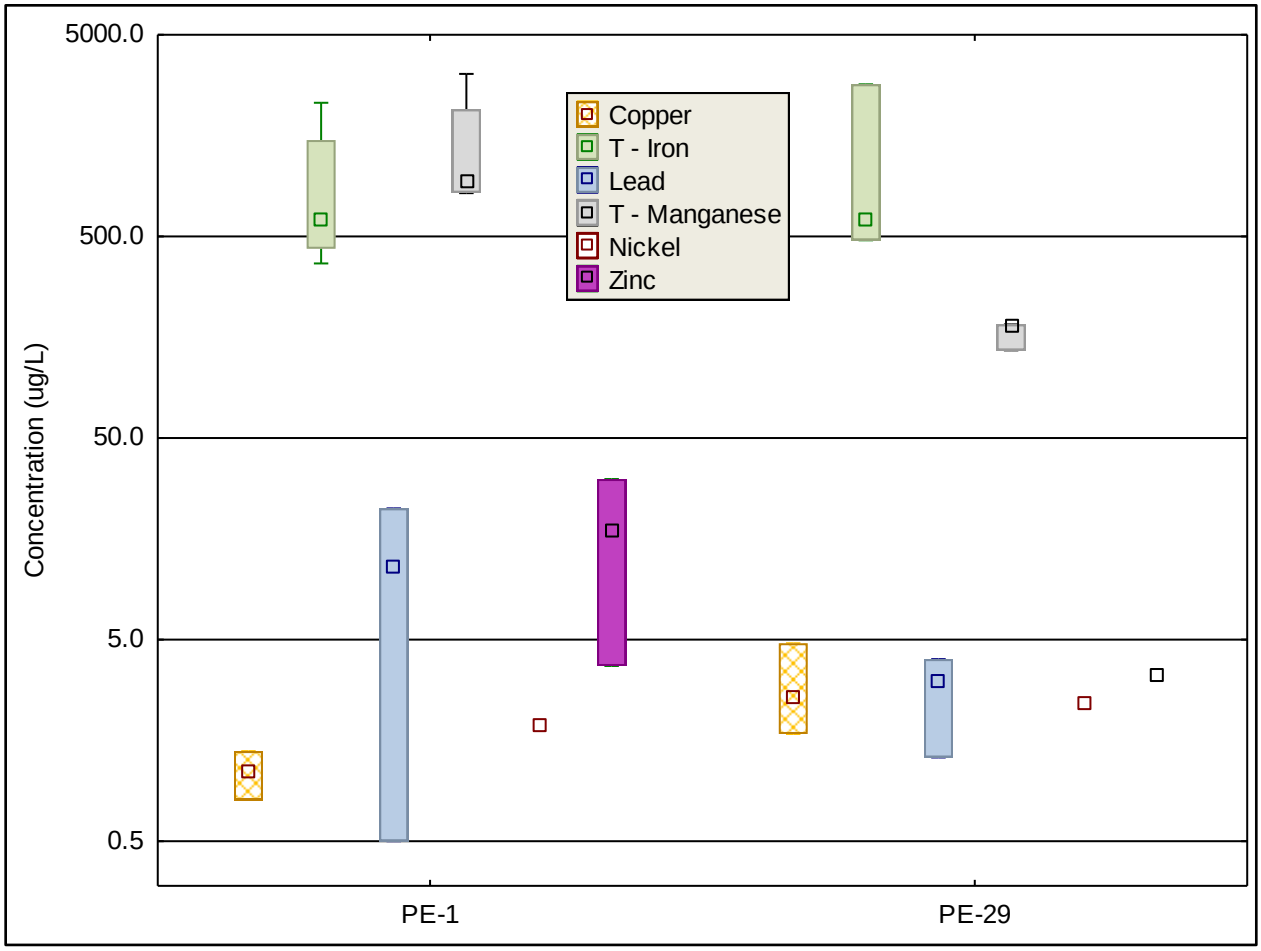
Perry Lake inflows carry inorganic sediment and well as suspended organic matter which influence water clarity. Attenuation of sediment through Perry reservoir is apparent as median TSS at the inflow exceeds over 99 percent of TSS records from the outflow (Figure 3-224). There was not a significant change of total organic carbon detected in Perry Lake inflow and outflow sample data. Median turbidity values were also similar between inflow and outflow data with more than 50 percent increase in variation in the upper quartile as effects from runoff events and mobile sediment load are more likely influence water quality above the reservoir.

Figure 3-224. Water Clarity metrics upstream and downstream of Perry Lake from 2010–2019



Types of trace elements reported as total metals (e.g., dissolved+particulate) in water quality samples were similar in Perry Lake inflow and outflow (Figure 3-225). Summer conditions at the site near the dam of Perry Lake is strongly stratified in summer months (Figure 3-225) creating an anoxic layer in the bottom strata. The lack of oxygen creates conditions allowing for mobilization or “desorbtion” of certain sediment bound elements and nutrients due to chemical reduction or electron exchange in the absence of oxygen which is often assisted by anerobic bacteria (Kimborough 1999). Elevated concentrations of solubilized metals iron, lead, and manganese are common during summer months in the outflow releases of stratified reservoirs including Perry Lake. Kimborough (1999) describes how removal of anoxic hypolimnetic water in reservoir releases could be a tool for managing certain redox sensitive elements where drinking water sources are impacted.

Figure 3-225. Total metal concentration upstream and downstream of Perry Lake from 2010–2019



Lake Water Quality

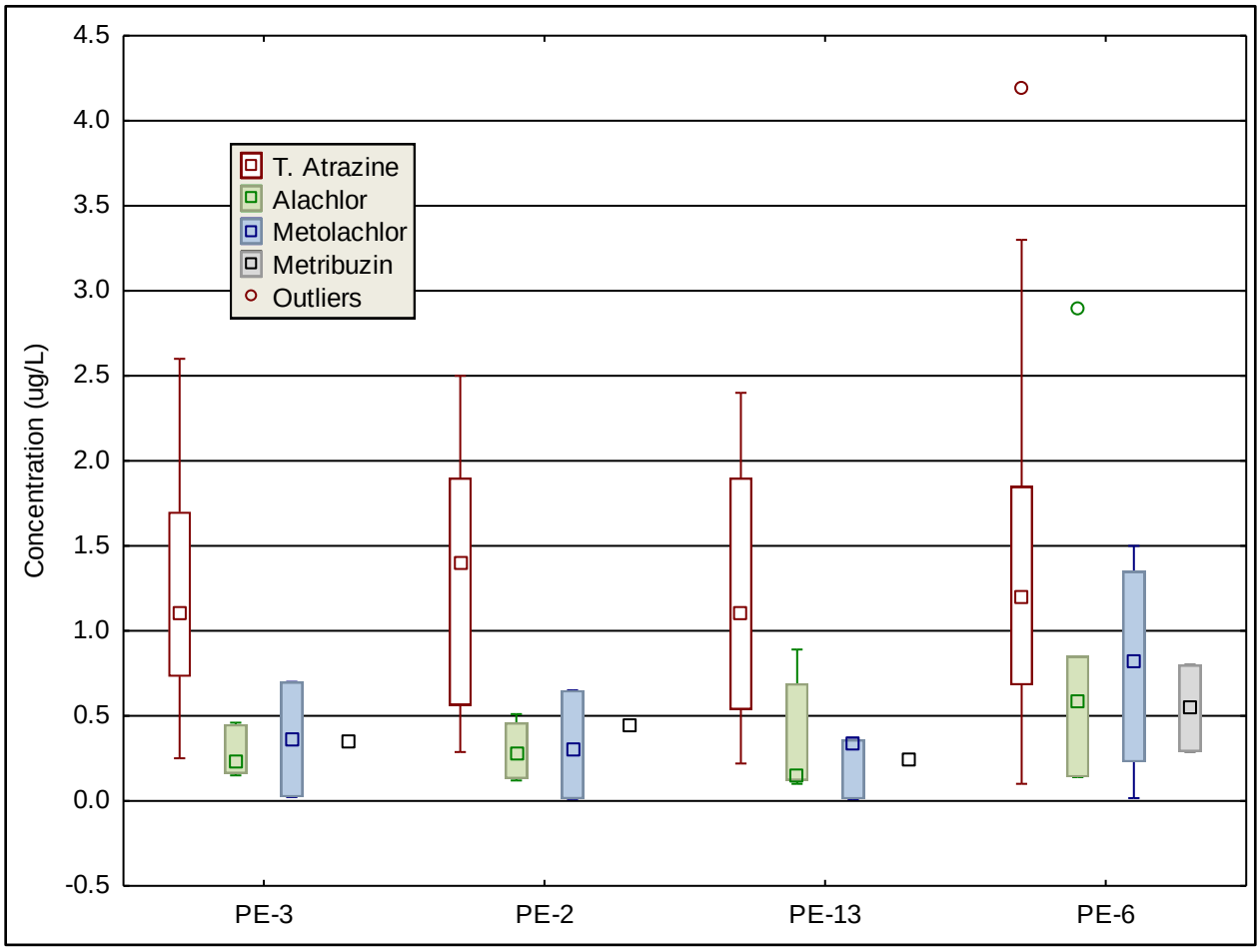
Nutrient rich runoff and soil loss from fields and stream banks work in tandem to compound water quality problems linked to the most frequent Kansas City District lake impairment summarized as eutrophication. Sedimentation and eutrophication problems associated with non-point source pollution are a top priority with watershed conservations efforts. Although the dominate land use in the Perry Lake watershed is hay/pasture with row crop agriculture representing only 27 percent of the watershed, increased row crop production is anticipated due in part to increased demand for biofuels. Yasarer et al. (2016) demonstrate via SWAT modeling of Perry Lake watershed that sediment and nutrient loads show the greatest increase when pasture and CRP acres are converted to row crop agriculture. Increased nutrients and sediment accumulating in Perry Lake will lead to decline in water quality and reduced storage capacity for water use. This age-related process makes older reservoirs more susceptible to contamination and internal loading of nutrients, metals and compounds stored in lake-bed sediment (Juracek 2014).

Physical and chemical attenuation (e.g., dilution, dispersion, chemical changes, and uptake by organisms) of compounds and settling of suspended matter leads to a general decrease in concentration of many constituents of water quality, often

interpreted as improved water quality, as water moves through a reservoir system (Bosch et al. 2009). This process will be evident with many analytes in graphic representations in lake water quality sections. The following section is an overview of chemical and physical data from surface samples at four lake sites, describes chemical and physical differences between surface and bottom strata at the site near the dam and stratification, and briefly describes available phytoplankton and cyanobacteria data related to public health advisories.

USACE and KDHE pesticide sample results indicate that three common herbicides were detected in Perry Lake but are found in higher concentrations in the Delaware River and diminish as water moves through the lake. Concentrations of atrazine exceeding EPA drinking water criteria of 3 ug/L were reported only at the upstream most site near Old Town (PE-6) (Figure 3-226). Concentrations of atrazine and three other herbicides were found at low concentration at lower lake sites (Figure 3-226). KDHE Lake and Wetland Monitoring Program Reports (KDHE 2007, 2010) report detection of pesticides in Perry Lake below state water quality standards.

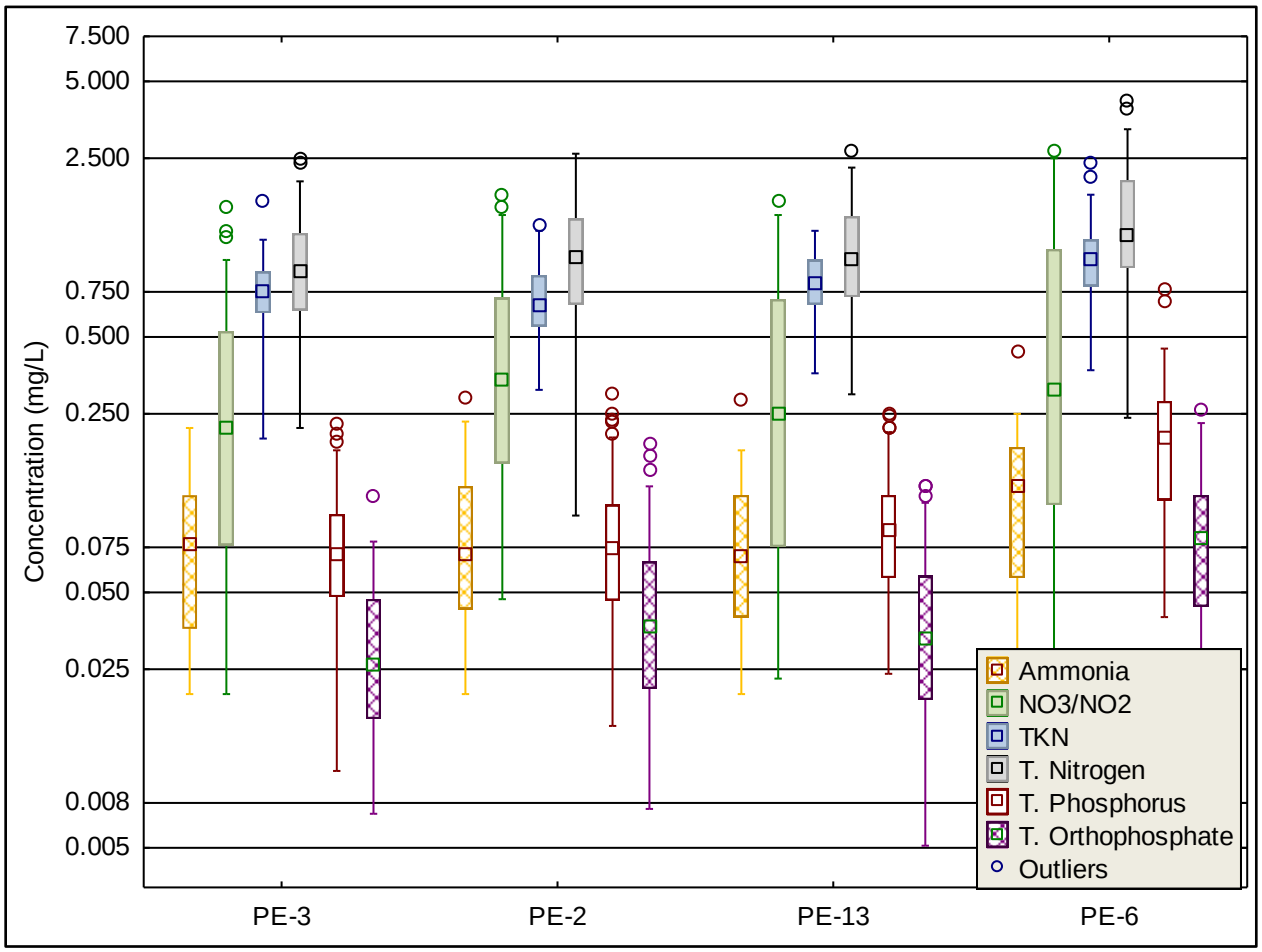
Figure 3-226. Perry Lake herbicide concentrations



Ten-year nutrient data (Figure 3-227) indicate nitrate/nitrite and ammonia nitrogen available for aquatic plant and phytoplankton growth were similar between three lower lake sites but more abundant at upper lake site (PE-6). Both TKN and total nitrogen

showed minor attenuation from upstream sites to lower lake sites. Median TKN at the PE-6 exceeded the interquartile range of the lower lake (PE-2) site at the dam, likely due to presence of organic matter and algae present in higher concentration in upper lake samples. Median and maximum total phosphorus and soluble orthophosphate were greatest at upper site (PE-6) with significant decrease in both measures of phosphorus at lower lake sites indicating biological uptake of orthophosphate by phytoplankton and settling of sediment-bound phosphorus.

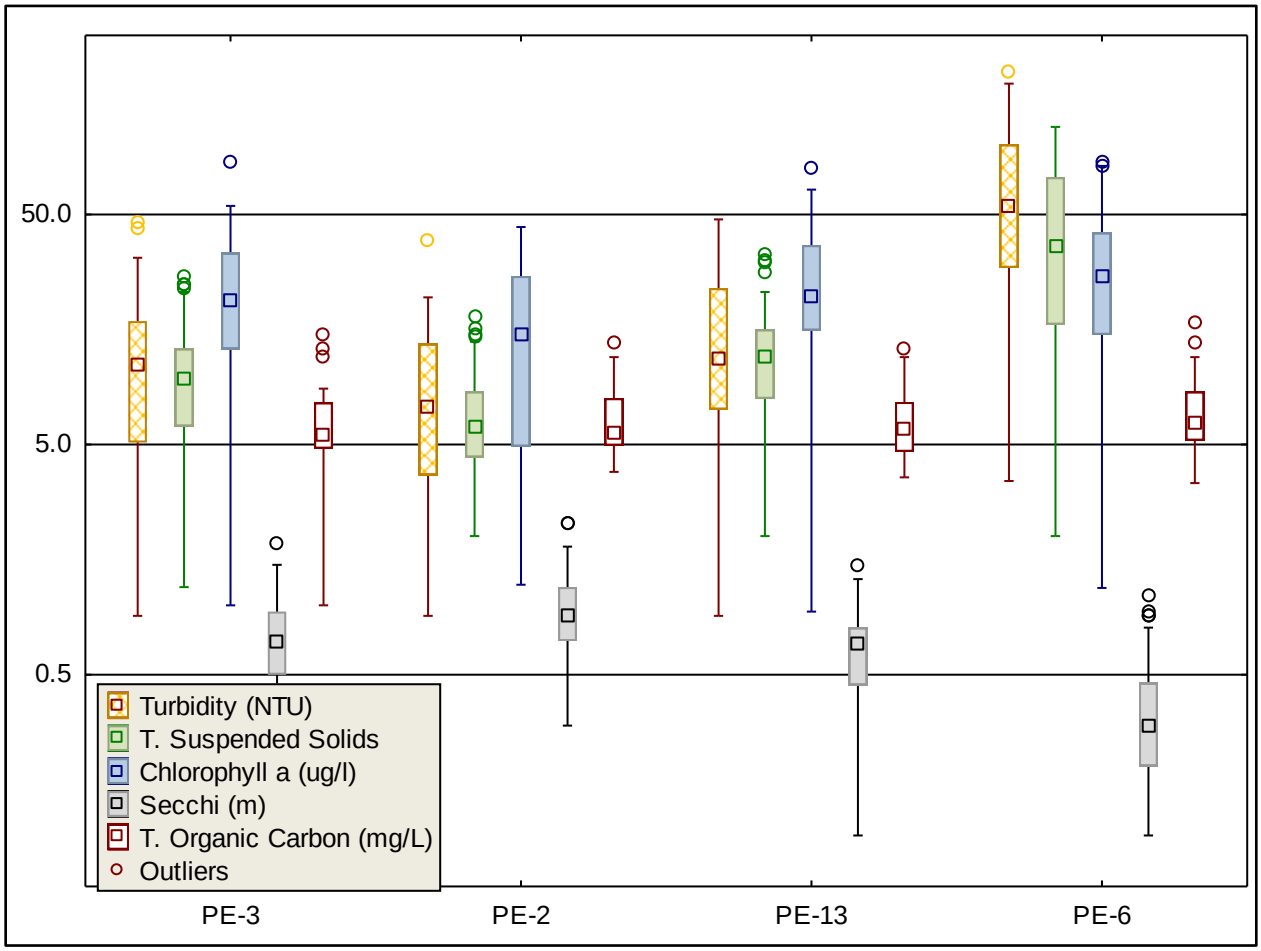
Figure 3-227. Perry Lake nutrient concentrations



Influences on light availability or water clarity including inorganic sediment, organic carbon, turbidity, and phytoplankton (Testa et al. 2019). Light availability is a critical metric which influences biological productivity through light limitation of photosynthesis. Median total suspended solids, turbidity, and chlorophyll *a* concentrations were higher at the upper lake site than mid and lower lake sites (Figure 3-228). Similarly, median turbidity and TSS exceeded all recorded data, including outliers, at lower lake sites PE-2 and PE-3. Consequently, Secchi depth was significantly less at upper lake site than all three lower lakes sites. Median Secchi values from 0.7-0.9 meters at lower Perry Lake sites are less than ideal (1-3 meters) for rooted aquatic plant growth, but emergent aquatic vegetation is present at low density in coves and low energy shoreline areas in the upper reaches of Perry Lake. Chlorophyll *a* values exceeding 12 ug/L indicate that

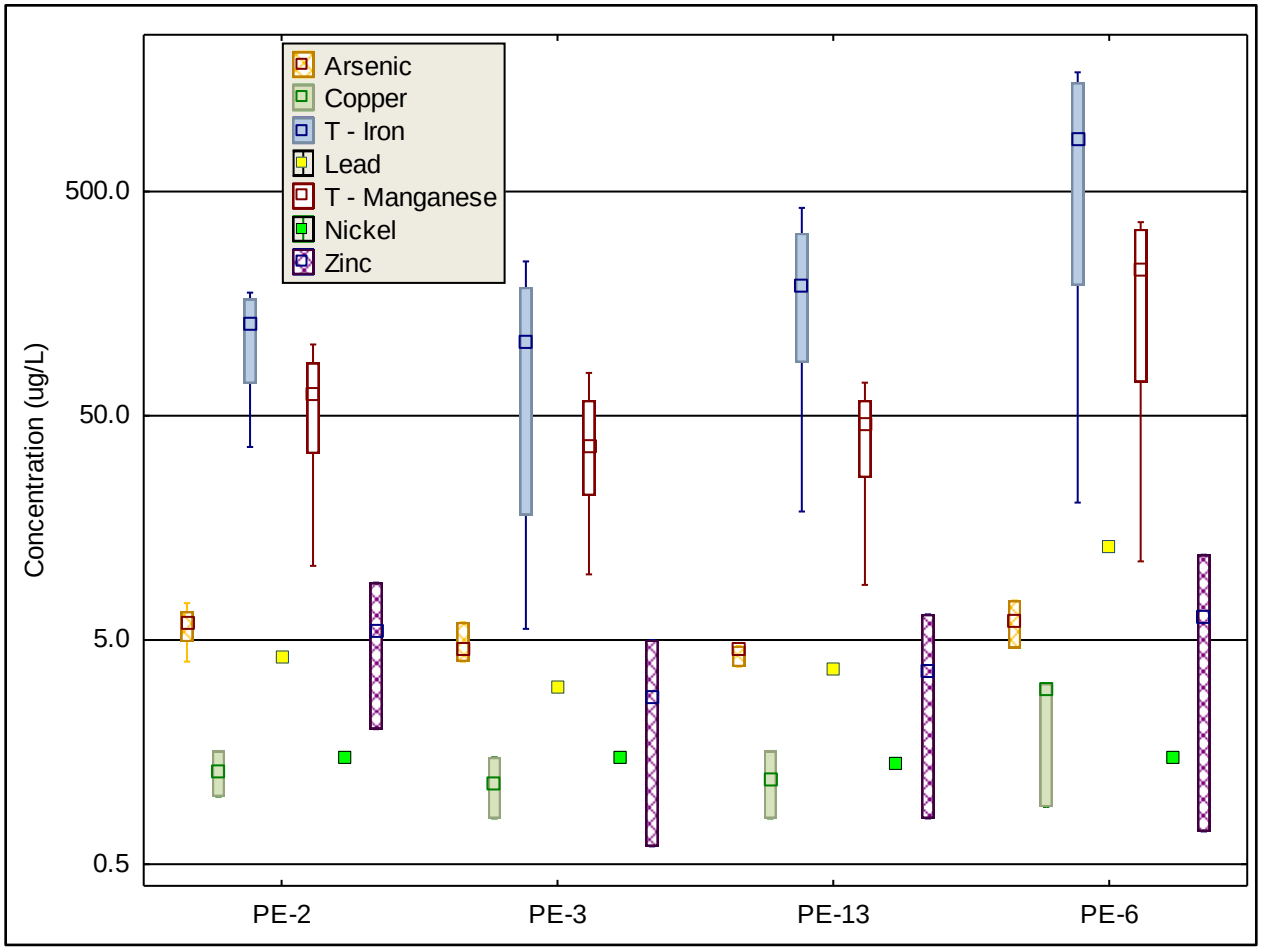
phytoplankton is thriving as the basis of primary productivity to support aquatic life including occasional HABs (Figure 3-228).

Figure 3-228. Perry Lake Water Clarity Metrics



Median total iron, manganese, zinc, and copper were significantly higher at upper lake sites than three lower lake sites (Figure 3-229). Lead and nickel were detected in low concentration in single samples from 2010–2019 as indicated by single data points with limited representation of data distribution and quartile range in box-whisker plot.

Figure 3-229. Perry Lake total metal concentrations



A summary of descriptive statistics for chemical analysis results at the site nearest the dam (PE-2) is found in Table 3-127. Bottom samples are typically collected from Kansas City District lakes every third year with total metals collected during the month of August when stratified conditions are most likely. When the lake is mixed or not stratified, bottom sample results are nearly identical to surface sample results for most analytes. Anaerobic conditions allow for oxidation/reduction reactions to release chemical compounds, including metals, which we are trying to quantify with bottom samples. Results less than minimum detection level are frequent and have been included in sample results as the value of half of the reported minimum detection limit to reduce bias based on the assumption that the analyte is present at a concentration below laboratory quantification (EPA, 1991) (Table 3-127). Sample size, sampling effort, and normality distribution constraints are best addressed with the use of descriptive statistics to describe and summarize sample results. Perry Lake chemical results were significantly different between top and bottom sample groups for TSS (Wilcoxon Signed-Rank Test; p=0.005) and total manganese (P=0.008) had significantly different sample means between surface to bottom samples.

Table 3-130. Perry Lake chemical water quality summary statistics 2010–2019[1]

Parameter	Sample Depth	Mean	SE*	SD**	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.05	0.01	0.06	0.29	0.03	0.01	60
Ammonia (mg/L)	Bottom	0.17	0.04	0.21	0.62	0.07	0.00	22
NO3/NO2 (mg/L)	Surface	0.42	0.06	0.43	1.80	0.27	0.01	60
NO3/NO2 (mg/L)	Bottom	0.43	0.08	0.36	1.30	0.32	0.02	22
TKN (mg/L)	Surface	0.66	0.03	0.27	1.36	0.65	0.15	60
TKN (mg/L)	Bottom	0.75	0.09	0.43	1.70	0.67	0.15	22
Total Nitrogen (mg/L)	Surface	1.08	0.07	0.55	2.61	1.02	0.21	60
Total Nitrogen (mg/L)	Bottom	1.17	0.10	0.46	2.08	1.18	0.22	22
Total Phosphorus (mg/L)	Surface	0.09	0.01	0.06	0.30	0.07	0.02	60
Total Phosphorus (mg/L)	Bottom	0.15	0.02	0.09	0.39	0.12	0.02	22
Total Orthophosphate (mg/L)	Surface	0.04	0.01	0.05	0.24	0.03	0.04	60
Total Orthophosphate (mg/L)	Bottom	0.08	0.01	0.07	0.25	0.06	0.00	22
Total Suspended Solids (mg/L)	Surface	7.36	0.61	4.76	24.40	5.95	2.00	60
Total Suspended Solids (mg/L)	Bottom	21.07	4.31	20.20	98.00	19.47	3.20	22
Total Organic Carbon (mg/L)	Surface	6.69	0.50	2.66	14.00	5.65	3.80	28
Total Organic Carbon (mg/L)	Bottom	5.58	0.42	1.88	11.00	5.00	3.60	20
Total Iron (ug/L)	Surface	117.83	32.29	62.58	177.00	129.00	36.30	4
Total Iron (ug/L)	Bottom	1953.00	1064.17	2128.35	4680.00	1536.00	60.00	4
Total Manganese (ug/L)	Surface	60.03	19.25	38.50	104.00	62.70	10.70	4
Total Manganese (ug/L)	Bottom	2147.50	602.17	1204.33	3550.00	1985.00	1070.00	4

Notes: [1/] Summary statistics for chemical water quality parameters from Perry Lake site near the dam (PE-2), April 2010 through September 2019.
*SE=Standard Error
** SD=Standard Deviation

Physical water quality differences between surface and bottom samples pooled from all Perry Lake water quality sites are described in the statistical summary Table 3-128. The USACE collects physical water quality data profiles monthly at all lake sites during the sampling season. When the lake is not stratified (mixed), bottom sample results are similar to surface sample results for many analytes. Specific conductance was the only physical characteristic that was similar from surface to bottom results, as reported in Table 3-128. Paired T-Tests results indicate that surface and bottom sample means were significantly different ($P<0.05$) for dissolved oxygen and turbidity.

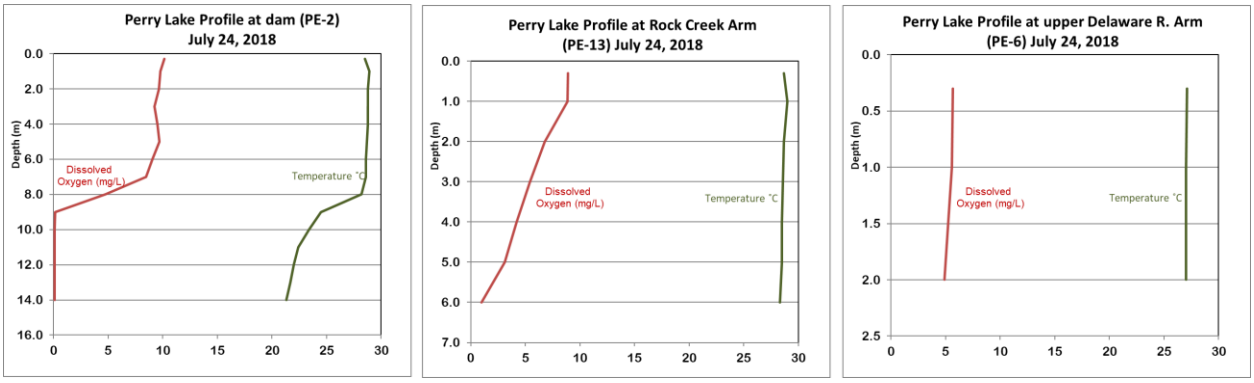
Table 3-131. Perry Lake Physical Water Quality Summary Statistics[1]

Parameter	Sample Depth	Mean	SE	SD	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	8.8	0.1	2.2	16.7	8.5	2.9	223
Oxygen, Dissolved (mg/l)	Bottom	4.6	0.2	3.4	12.9	4.5	0.1	223
pH (Standard Units)	Surface	8.2	0.1	0.4	9.4	8.2	7.0	170
pH (Standard Units)	Bottom	7.8	0.04	0.5	9.7	7.8	6.9	170
Secchi Depth (m)	Surface	0.6	0.02	0.4	2.3	0.9	0.3	47
Chlorophyll a (ug/L)	Photic Zone	16.22	1.78	12.86	44.10	14.00	1.00	52
Specific Conductance (µS/cm)	Surface	329.1	3.6	46.8	537.0	332.0	207.4	173
Specific Conductance (µS/cm)	Bottom	337.6	3.8	51.6	545.5	340.9	196.2	173
Turbidity, Field (NTU)	Surface	27.4	4.0	53.1	451.0	12.2	1	173
Turbidity, Field (NTU)	Bottom	86.7	11.9	159.4	1605.0	54.7	1.5	178
Water Temperature (°C)	Surface	22.9	0.4	5.9	32.0	25.1	6.4	223
Water Temperature (°C)	Bottom	21.2	0.3	5.6	32.0	22.8	6.1	223

Note: [1/] Summary statistics for physical water quality parameters, from all sites and dates, Perry Lake, April 2010 through September 2019.
*SE=Standard Error
** SD=Standard Deviation

The lower lake site PE-2 typically experiences strong thermal stratification in July and August, while upper lake sites may experience weak stratification or are mixed throughout the summer (USACE 2019). Differences in water density from differences in temperature and salinity, distribution of heat, in-lake currents, reservoir releases, and wind action play a role in the stratification process (Wetzel 2001). Physical changes in water composition during stratified conditions from water temperature and density differences lead to chemical and biological changes in the absence of oxygen (anaerobic conditions). A representative compilation of water profiles from Perry Lake sites (Figure 3-227) illustrates the typical summer conditions including strong stratification with apparent thermocline at 8 meters of depth at lower lake (PE-2) and mild stratification with no apparent thermocline at mid-lake at Rock Creek Arm (PE-13), and no stratification nor thermocline at upper lake on Delaware River Arm (PE-6). Temperature and D.O. profiles in 2018 illustrate differences in stratified conditions when fish and aquatic life habitat is partially limited to shallower and much warmer water. This temperature/dissolved oxygen “crunch” can stress aquatic life. Currently the TMDLs in Perry Watershed for dissolved oxygen deficiencies do not include Perry Lake (Figure 3-230) (KDHE 2014a).

Figure 3-230. Perry Lake Temperature and Dissolved Oxygen Profiles



Hypereutrophic conditions at Perry Lake produce ideal chemical conditions for production of HABs. An abundance of plant nutrients nitrate and orthophosphate and a low (i.e., <12) TN:TP ratio are two frequent water quality conditions associated with proliferation of blue-green algae which could produce toxins in freshwater (Downing, J. A., and E. McCauley 1992; Xiaofeng et.al. 2012; Havens et al. 2003). The presence of a healthy zebra mussel population at Perry Lake has also been associated with increased risk of the common HAB producing cyanobacterium Microcystis aeruginosa (Raikow et al., 2004; Knoll et al., 2008; Sarnelle et al., 2005). Less than optimal sunlight penetration in the photic zone due to high turbidity (Havens et al. 2003) is the most likely factor limiting relatively low-density cyanobacteria blooms at Perry Lake.

KDHE CyanoHAB monitoring program started in 2010 (KDHE 2022) and has evolved with scientific knowledge of cyanobacteria and understanding of Kansas HABs. Perry Lake is one of three large lakes in Kansas with “zoned” management allowing for more precise recreational health advisories for four distinct areas (Harmful Algal Bloom | KDHE, KS.)

HAB advisories, based on EPA recommendations, to manage risk to recreational (whole-body contact) lake users currently designates three recommendations for lake managers based on algae cell count density and/or algal toxin concentration thresholds in order of increasing severity from Watch-Warning-Hazard.

HABs have occurred infrequently at Perry Lake and have been based on high cell count exceeding KDHE health public health thresholds (KDHE unpublished weekly HAB reports 2010-2021) with low concentration of algal toxins. Perry Lake experienced the most significant algal bloom conditions in July 2011. This lake-wide bloom was most intense in the Old Town region on the Delaware River and the Rock Creek Arm on the west side of the lake. KDHE issued a Public Health Warning which impacted the entire lake including a two-week closure of swim beaches and reduced recreational traffic at the lake. Cyanobacteria cell counts also exceeded warning status in Perry Lake in all zones for one week in 2017 and two weeks in Zone B during 2018 and (KDHE unpublished weekly HAB reports 2017, 2018). The most recent KDHE health advisory at Perry Lake was an eight week “watch” due to cell count and visual observations by USACE Rangers and USGS scientist(s) in 2020 (Figure 3-231). Swim beaches at Perry Lake have been closed due to flooding, bacteria safety concerns, and up to two weeks due to HAB warning in 2011 and 2017.

Figure 3-231. Perry Lake during 2020 KDHE issued Harmful Algal Bloom Watch



USACE photo.

Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discussions until aging lakes begin to release or “recycle” nutrients (e.g., phosphorus) back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) and/or sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984). Kansas City District Water Quality Program initiated collection of baseline lake sediment data in 2016 (Figure 3-232).

Nitrogen and phosphorus concentrations from Perry Lake sediment samples were low to moderate when compared to results from a group of lakes from Southeast and Northern United States (Barko, J.W. and R.M Smart 1986). Metal concentrations reported in Kansas City District lakebed sediment results (Figure 3-229) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed (MacDonald et al. 2000).

Figure 3-232. Perry Lake Bed Sediment Chemical Concentration From 2016 and 2019

Station	Date	Ammonia Nitrogen	Nitrate-Nitrite Nitrogen	Phosphorus	Total Kjeldahl Nitrogen	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Total Solids	Mercury
	mm/dd/yy	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	MG/KG	%	MG/KG
PE-2	9/7/2016	24.7	<2.6	<296	512.0	5.2	0.3980	9.2	6.4	8740	9.1	511.0	10.2	71.8	
PE-3	9/7/2016	93.7	<5.2	748.0	1650.0	10.8	0.9450	28.4	20.8	27100	21.0	747.0	31.4	36.3	
PE-13	9/7/2016	14.3	4.3	338.0	820.0	8.4	0.2460	15.7	8.7	15000	11.3	407.0	17.3	73.7	
PE-6	9/7/2016	76.6	<2.8	534.0	1140.0	7.8	0.4720	17.8	12.2	16500	14.8	504.0	20.2	58.6	
PE-7	9/7/2016	92.4	<2.9	462.0	1100.0	8.3	0.5210	19.9	13.2	17800	15.6	552.0	21.7	55.5	
ite Median		**76.6**	**4.3**	**498.0**	**1100.0**	**8.3**	**0.4720**	**17.8**	**12.2**	**16500.0**	**14.8**	**511.0**	**20.2**	**58.6**	
Mean		**60.3**	**4.3**	**520.5**	**1044.4**	**8.1**	**0.5164**	**18.2**	**12.3**	**17028.0**	**14.4**	**544.2**	**20.2**	**59.2**	
PE-2	8/6/2019	15.3	3.4	590.0	275.0	5.9	0.3040	10.8	12.1	27300	13.6	483.0	24.9		0.0272
PE-3	8/6/2019	13.2	1.1	1100.0	519.0	11.7	0.5470	11.8	17.3	31700	18.5	427.0	28.9		0.0372
PE-13	8/6/2019	18.3	<2.8	973.0	268.0	9.6	0.3460	11.6	17.2	33000	17.5	355.0	29.3		0.0339
PE-6	8/6/2019	37.3	3.6	508.0	412.0	3.9	0.2130	8.2	8.0	14300	10.8	253.0	15.0		0.0162
ite Median		**16.8**	**3.4**	**781.5**	**343.5**	**7.8**	**0.3**	**11.2**	**14.7**	**29500.0**	**15.6**	**391.0**	**26.9**		**0.0306**
Mean		**21.0**	**2.7**	**792.8**	**368.5**	**7.8**	**0.4**	**10.6**	**13.7**	**26575.0**	**15.1**	**379.5**	**24.5**		**0.0286**

3.7.4.1.6 Tuttle Creek Lake

Tuttle Creek Lake is a 10,900-acre impoundment built on the Big Blue River reaching full pool in 1963. Sedimentation at Tuttle Creek Lake has reduced the surface area by 4900 acres from 1957-2010 according to USACE engineers. Blue River watershed drains roughly equal area of row crop and grassland in Nebraska and Kansas before entering Tuttle Creek Lake and then the Kansas River. Sediment runoff is at the root of primary water quality threats to Tuttle Creek Lake and smaller impoundments in the watershed summarized by current Total Maximum Daily Load (TMDL) for siltation and eutrophication. TMDLs for atrazine, *E. coli* bacteria and excessive phosphorus have been defined for most streams in the watershed above Tuttle Creek Lake.

During Tuttle Creek Lake construction, Kansas and Nebraska entered an interstate compact (https://agriculture.ks.gov/divisions-programs/dwr/interstate-rivers-and-compacts/big-blue-river-compact), finalized in 1971, to promote interstate comity with equitable water apportionment while continuing active pollution abatement programs in each of the two states. The current administration of the Blue River Compact provides stream flow targets for Big Blue and Little Blue Rivers during summer months.

Watershed conservation efforts have increased in priority for state and local rankings to address sedimentation and water quality in Tuttle Creek Lake. The Watershed Restoration and Protection Strategy (WRAPS) program is a KDHE planning and management tool used to identify watershed restoration and protection needs, establish management goals, establish plans (e.g., EPA approved 9-Element Watershed Plans) and implement goals to address water resource concerns (https://www.kdheks.gov/nps/wraps/). Most priority goals/targets of the approved WRAPS Plans for subbasins in the Kanas River Watershed align with strategies and measures included in this study. The WRAPS process is in the implementation and monitoring phase of their process to administer programs using BMPs in Tuttle Creek Lake watershed to meet TMDLs and reduce phosphorus loads originating in Kansas by 3.6 million lbs/yr., sediment load reduction goal of 3 million tons/year, and atrazine reduction of 55.9 thousand lbs/yr (KDHE 2018).

Reservoir Hydrologic Data Summary

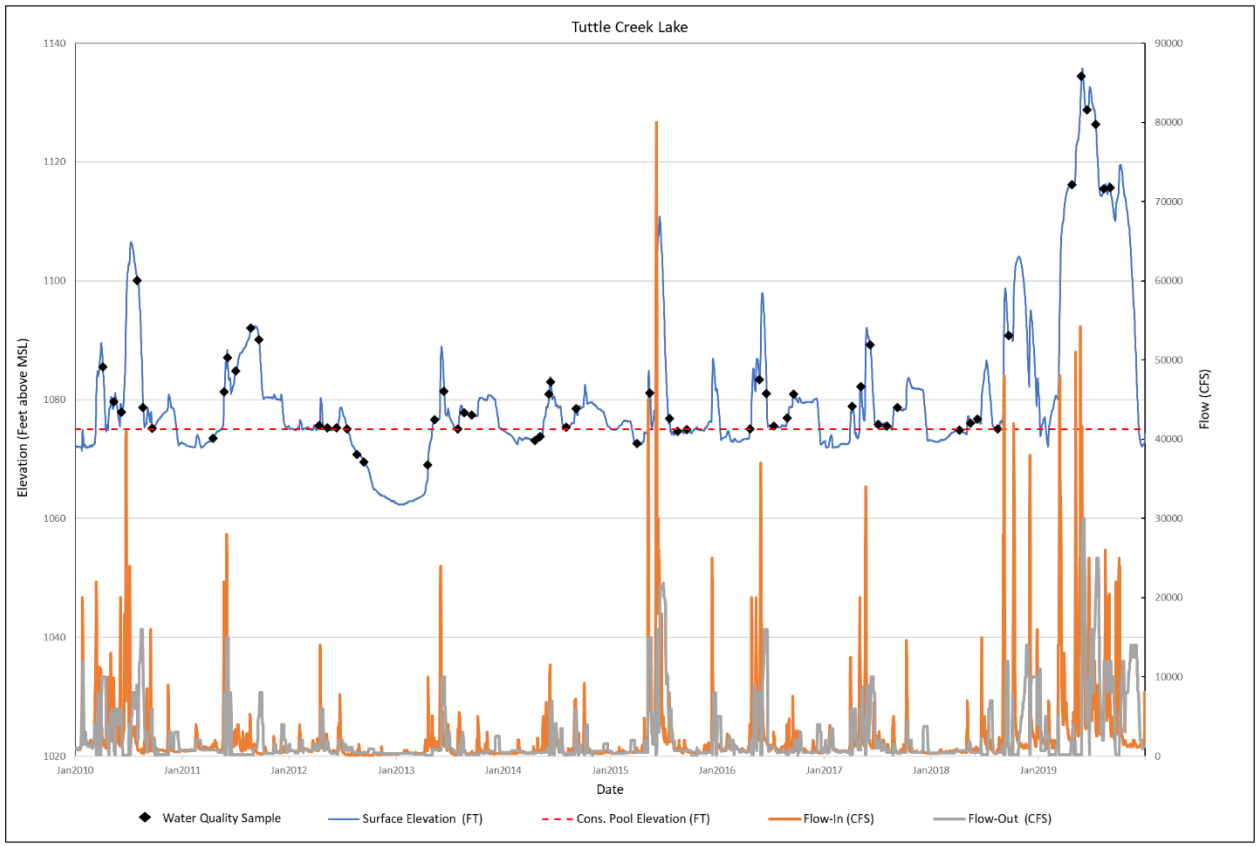
Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics related to flow (i.e., volume, load, and concentration), water residence time, and lake mixing/stratification which in turn influence physical and chemical process, frequently resulting in biological responses.

Figure 3-233 illustrates reservoir hydrologic data with overlay of water quality sampling events.

Water quality sampling events by Kansas City District staff were conducted monthly from 2010–2019 coinciding with the typical recreational season (April–September). Low inflow periods were observed at the end of 2012 with lake surface elevation falling to 1,062 feet while recovery period is apparent beginning late spring of 2013. Significant flooding with a corresponding high-water period was observed in 2019 as inflows peaked at 54,200 cfs with three events exceeding 48,000 cfs from March through August. Surface elevation of Tuttle Creek Lake peaked at 60.7 feet above CPE and exceeded CPE for 306 days in 2019.

Tuttle Creek Lake average water residence time of 2.5 months was calculated from historic water management records for the period 1990-2022 using HEC-ResSim software. Tuttle Creek Lake average water residence time is below the average of 10.8 months for seven USACE Kansas River Watershed lakes in this study. Short residence times can lead to pronounced seasonal shifts and dynamic water quality at Tuttle Creek Lake with less time allowed for dilution, settling, and biological attenuation of sediment, nutrients, and other contaminants.

Figure 3-233. Tuttle Creek Lake Time Series of Daily Water Surface Elevation and Pool Information

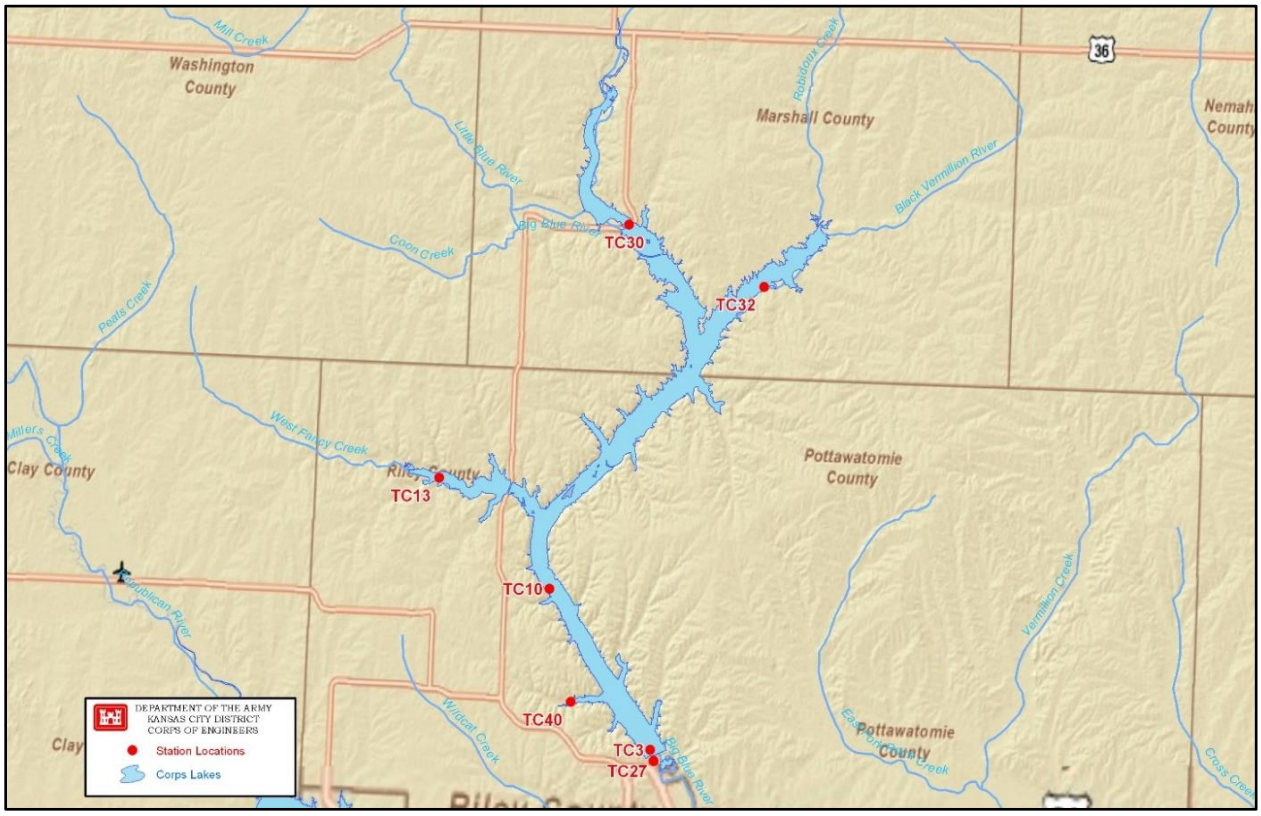


Water Quality Sample Locations

Historic water quality sample sites at Kansas City District lake projects are named in decreasing numeric order from inflow sites to the outflow site below the dam with

exceptions at Tuttle Creek Lake outlet and inflow (Figure 3-234). To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow.

Figure 3-234. Tuttle Creek Lake Historic U.S. Army Corpsof Engineers' Water Quality Sample Site

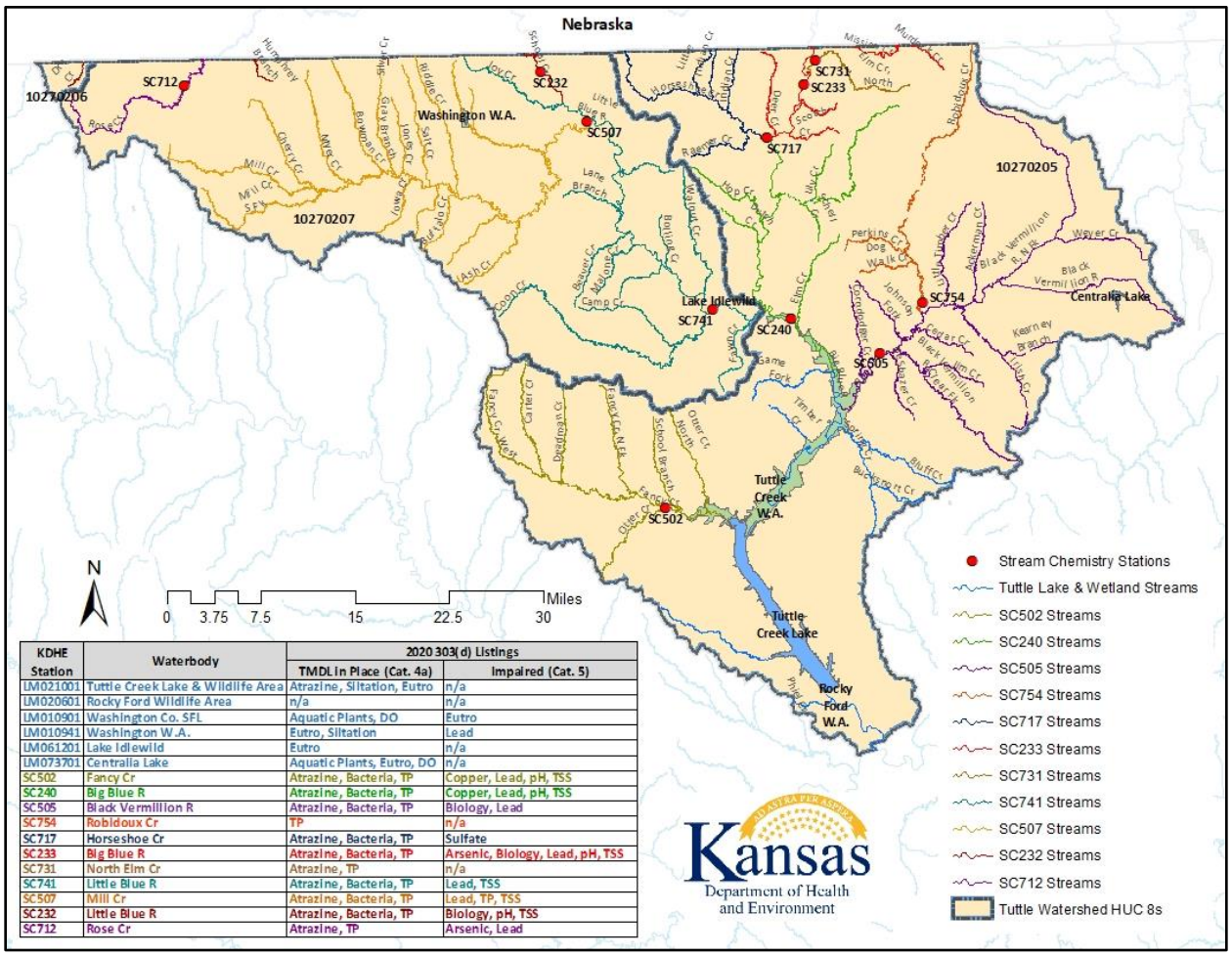


Impairments

Section 303(d) of the CWA requires that states develop a list of "impaired" water bodies that do not sufficiently meet water quality standards to support specific designated use(s). These impaired streams and lakes require additional protection (e.g., TMDLs) and restoration work (e.g., conservation planning, BMPs, in-stream and corridor improvements) in order to achieve water quality standards and restore designated uses of the waters.

The Tuttle Creek Lake and 10 stream segments in the watershed are listed on the 2020 303(d) list (Figure 3-235) most impacted by atrazine, bacteria, and phosphorus in the lake with impairments but no TMDLs listed for metals, pH, total suspended solids, and impaired biological resources in inflow streams. Tuttle Creek Lake "eutrophication" TMDL indicates that silt and nutrients entering the lake accelerate the natural aging process and degrade water quality for aquatic life. Sediment driven turbidity limits sunlight penetration at Tuttle Creek Lake, thereby limiting primary productivity and lowering risk of HABs.

11418 *Figure 3-235. Tuttle Creek Lake Impaired Waters and Total Maximum Daily Loads 2020*



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM021001	Tuttle Creek Lake & Wildlife Area	Atrazine, Siltation, Eutro	n/a
LM020601	Rocky Ford Wildlife Area	n/a	n/a
LM010901	Washington Co. SFL	Aquatic Plants, DO	Eutro
LM010941	Washington W.A.	Eutro, Siltation	Lead
LM061201	Lake Idlewild	Eutro	n/a
LM073701	Centralia Lake	Aquatic Plants, Eutro, DO	n/a
SC502	Fancy Cr	Atrazine, Bacteria, TP	Copper, Lead, pH, TSS
SC240	Big Blue R	Atrazine, Bacteria, TP	Copper, Lead, pH, TSS
SC505	Black Vermillion R	Atrazine, Bacteria, TP	Biology, Lead
SC754	Robidoux Cr	TP	n/a
SC717	Horseshoe Cr	Atrazine, Bacteria, TP	Sulfate
SC233	Big Blue R	Atrazine, Bacteria, TP	Arsenic, Biology, Lead, pH, TSS
SC731	North Elm Cr	Atrazine, TP	n/a
SC741	Little Blue R	Atrazine, Bacteria, TP	Lead, TSS
SC507	Mill Cr	Atrazine, Bacteria, TP	Lead, TP, TSS
SC232	Little Blue R	Atrazine, Bacteria, TP	Biology, pH, TSS
SC712	Rose Cr	Atrazine, TP	Arsenic, Lead

11419

11420 **Inflows/Outflow**

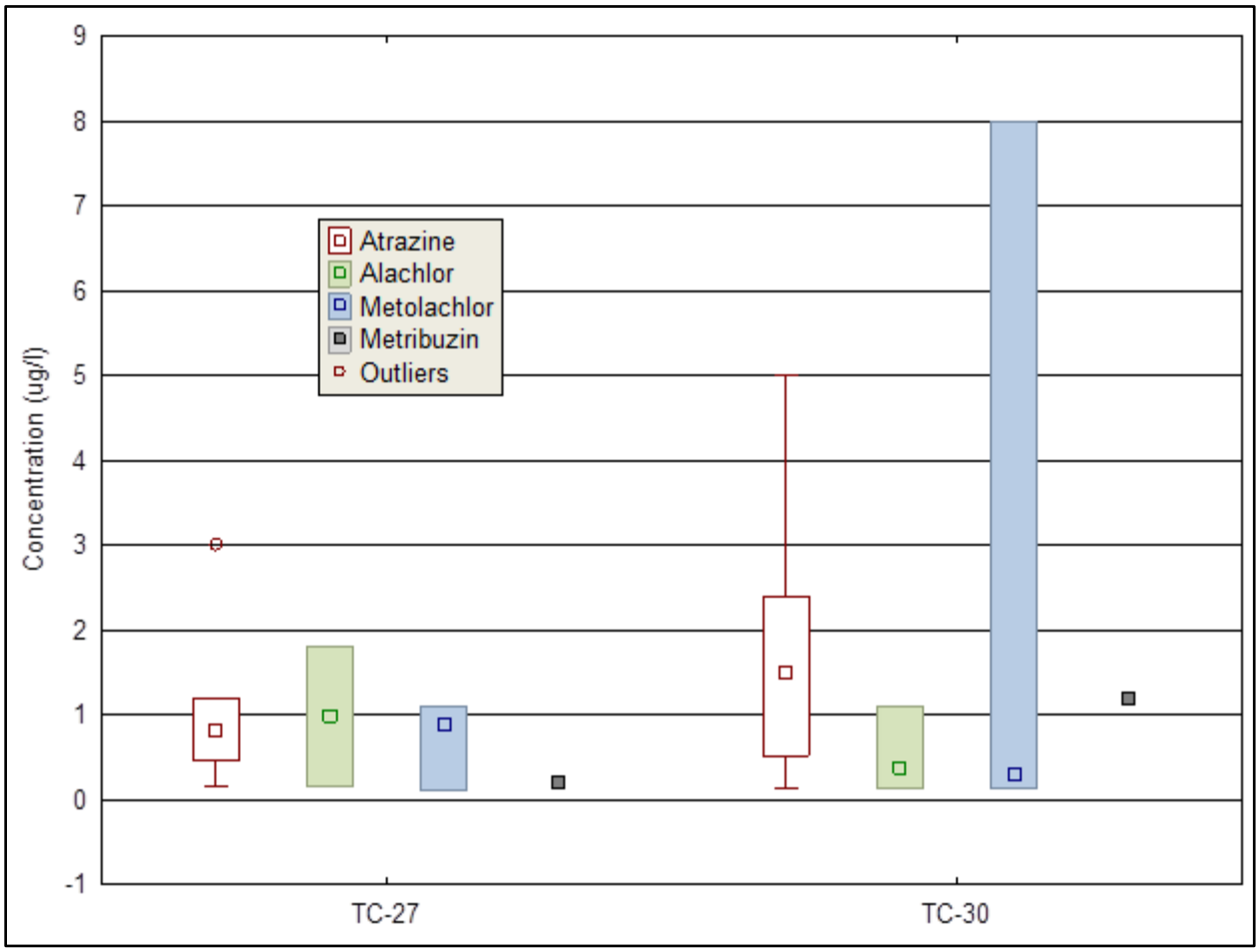
11421 Lakes and reservoirs store sediment and associated chemical compounds carried by
11422 inflows and runoff. Sediment, nutrient, contaminant, and geological sources in the
11423 watershed and associated inflows influence lake water quality including water clarity,
11424 nutrient concentration, chemical contamination, and nutrient balance in receiving
11425 waters. These factors also have implications for biological response in the streams and
11426 receiving waters including trophic state and which type of plants and algae dominate
11427 primary production in the system.

11428 Nutrients sources, geology, and land-use are primary influences on water quality in
11429 inflow streams in the watershed which influence Tuttle Creek Lake. Water exiting
11430 through the dam or outlet works of USACE lakes can be quite different than the inflows
11431 as large amounts of sediment, nutrients, pesticides, and metals are processed and/or
11432 stored in the lake causing a sink effect (Satoh et al. 2002).

11433 Herbicides have been monitored at Tuttle Creek Lake by Kansas City District Water
11434 Quality personnel since 1996. The list of herbicides detected have included chemical
11435 constituents of atrazine, alachlor, metolachlor, cyanazine, metribuzin, simazine,
11436 acetochlor as well as 2, 4-D and glyphosate. EPA regulation of herbicide licensing to

reduce chemical persistence and mobility in the environment has helped reduce the number and concentration of chemicals detected in Kansas City District Water Quality samples in the last decade. Total atrazine and alachlor concentrations peak in the spring and are associated with runoff events as herbicides mobilize and enter the inflows in concentrations typically much higher and more variable than those exiting through the outlet (Figure 3-236). Kansas City District collects herbicides samples only during spring months when application and runoff are more likely. Alachlor, metolachlor and metribuzin are frequently below laboratory detection limits. Concentrations of atrazine and detectable levels of alachlor in the outflow were reported at levels below EPA drinking water standards 3 ug/L and 2 ug/L, respectively. Instances of total atrazine exceeding EPA drinking water standards of 3 ug/L are documented on most inflow streams above Tuttle Creek Lake between 2010–2019 according to USACE Water Quality Program Data (unpublished 1996–2019) and many are on the KDHE Impaired Waters list with TMDLs for atrazine (Figure 3-236).

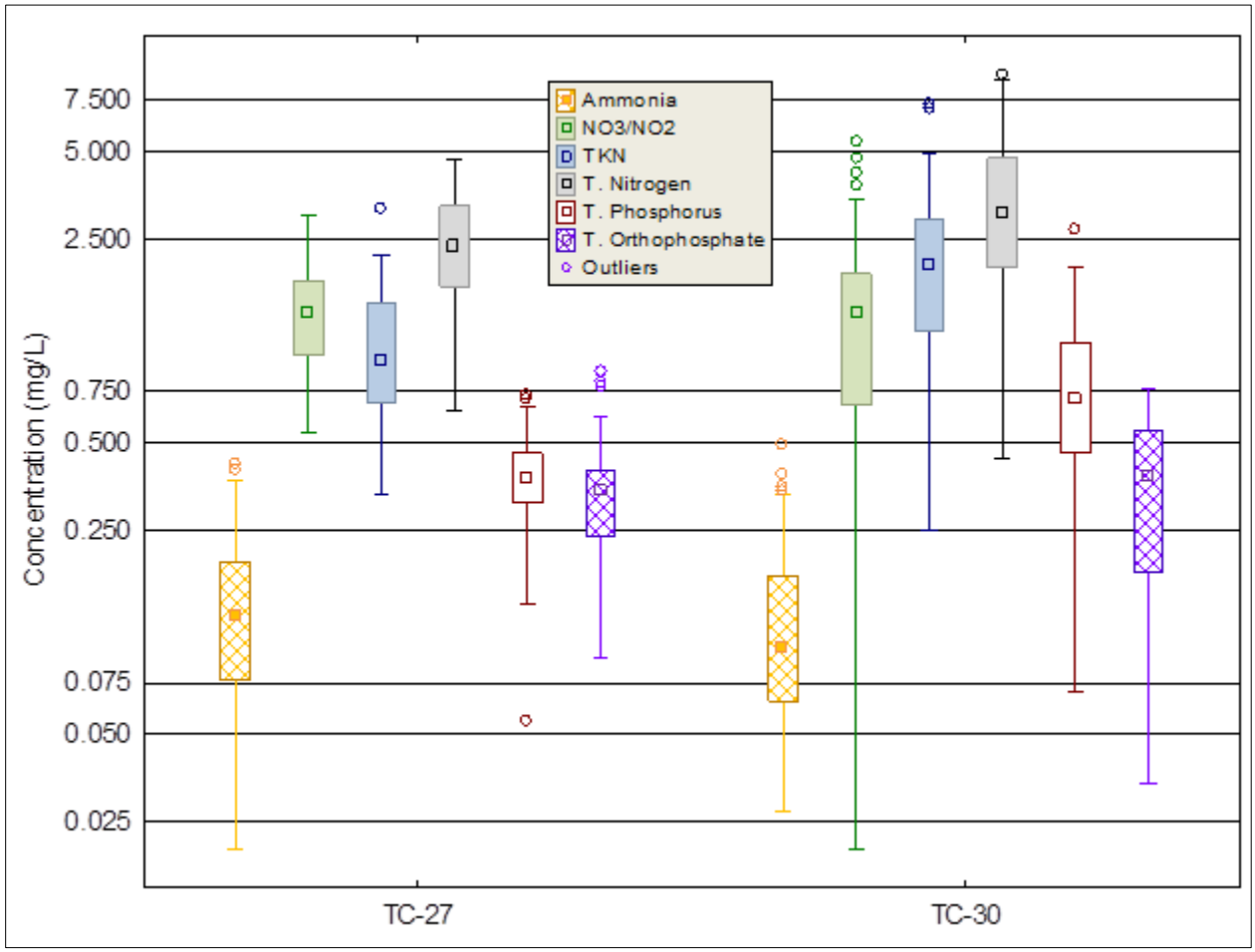
Figure 3-236. Herbicide concentrations upstream and downstream of Tuttle Creek Lake from 2010–2019



Herbicide concentration measured from surface samples collected at Tuttle Creek Lake Outflow (TC-27) and main inflow (TC-30) USACE water quality sample sites from 2010–2019.

Total nitrogen and organic nitrogen (TKN) concentration decreased significantly from the inflow site to the outlet from attenuation and denitrification/biological uptake (Figure 3-237). Median bioavailable forms of nitrate/nitrites were similar at inflow and outflow sites with more variable results and outliers recorded at inflow site. Ammonia nitrogen increases from anoxic conditions found in the bottom strata near the dam leads to seasonal increases in ammonia in releases from many Kansas City District lakes including Tuttle Creek as demonstrated by ammonia sample results in Figure 3-237. Total phosphorus median concentrations in the inflow were significantly higher than median outflow concentrations and more variable as sediment bound phosphorus increases are associated with rain events and runoff. Seasonal increases of soluble orthophosphate resulting from anoxic conditions at the dam led to several outliers at the outflow. Median orthophosphate was slightly higher at inflow site (Figure 3-237).

Figure 3-237. Nutrient concentrations upstream and downstream of Tuttle Creek Lake from 2010–2019



Inflow streams flowing into Tuttle Creek Lake are the primary influence on water quality. The Big Blue River (site TC-30) is historically very turbid with high sediment load leading to sedimentation issues, degraded aquatic habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, water temperature effects, and increased eutrophication. Much of the

water clarity is related to sediment and suspended particles. Sediment trapping efficiency has been estimated up to 98 percent (Juracek 2011a) for Tuttle Creek Lake. Consequently, median TSS and turbidity results from inflow (TC-30) exceed 99 percent of the comparable results from the outlet (Figure 3-103). Fine sediment particles remain in suspension throughout Tuttle Creek Lake including through the outflow as TSS and turbidity results are much higher than adjacent Milford Lake outflow (Figure 3-179). Total organic carbon results are slightly higher and more variable above Tuttle Creek Lake than the outflow (Figure 3-228).

Total metals in the watershed recurring in Kansas City District Water Quality Program sample results are iron, lead, manganese, arsenic, and copper. Copper, lead, and arsenic are listed as impairments by KDHE at seven inflow streams including Big Blue River (Figure 3-235). Iron, lead, and copper are found in significantly greater concentration at the inflow site than the outlet while manganese and arsenic results are similar (Figure 3-239).

Figure 3-238. Water Clarity Metrics Upstream and Downstream of Tuttle Creek Lake from 2010–2019

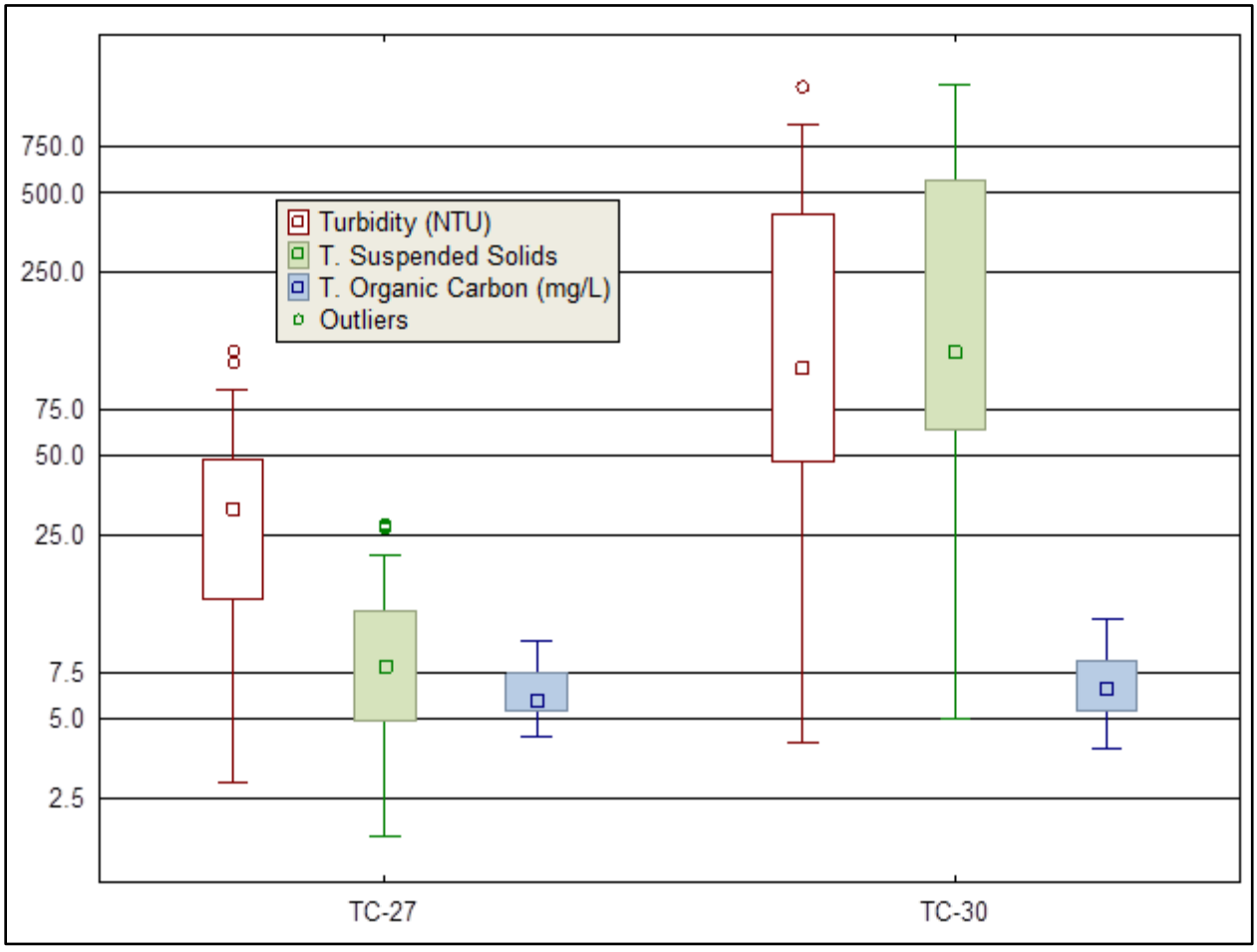
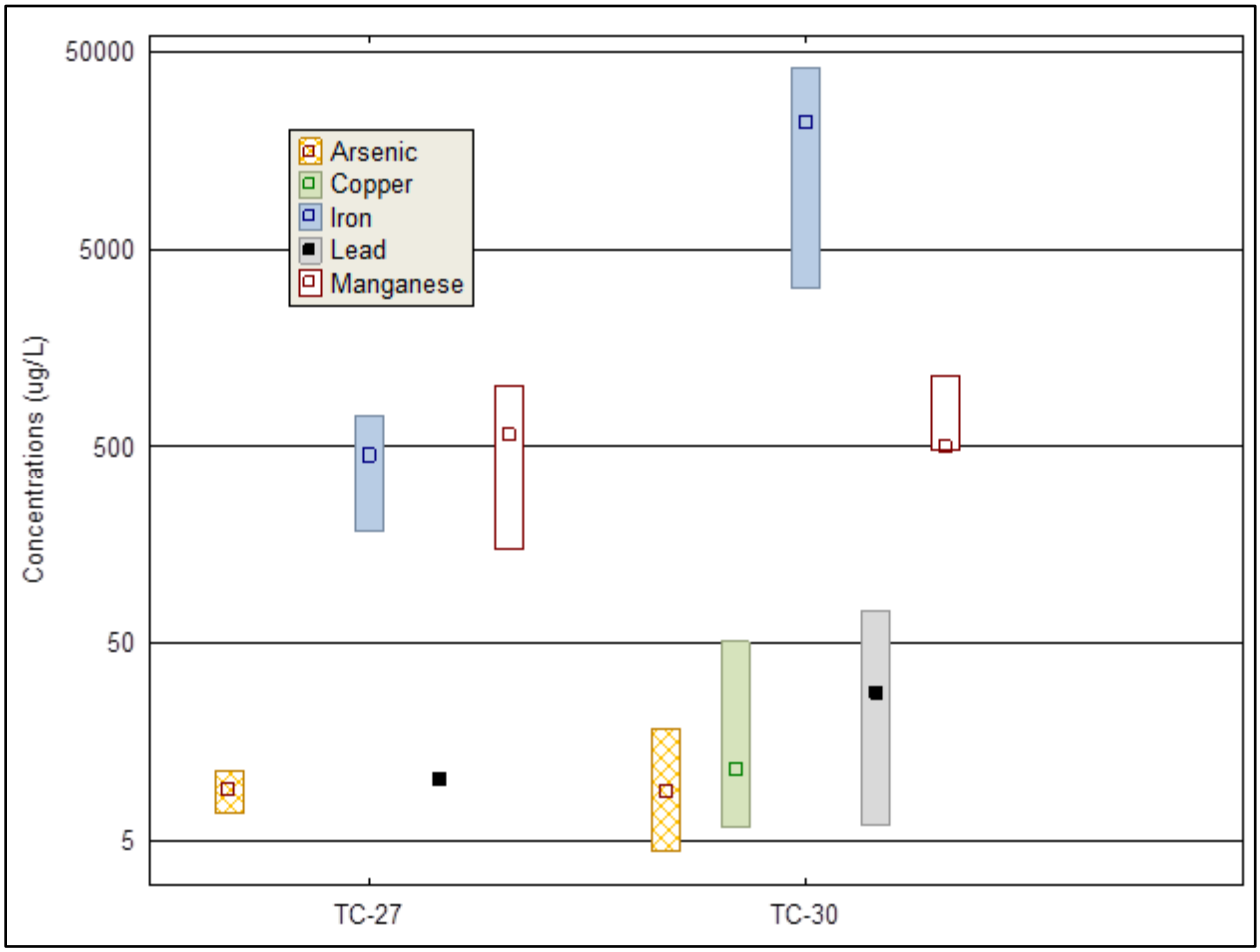


Figure 3-239. Total Metal Concentrations Upstream and Downstream of Tuttle Creek Lake from 2010–2019



Lake Water Quality

Tuttle Creek Lake has been listed as impaired by KDHE and classified as hypereutrophic due to excess phosphorus concentrations. TMDLs for Tuttle Creek Lake were developed to prioritize phosphorus, sediment, and atrazine reduction in the watershed.

Sediment from soil and stream bank erosion in the watershed consist of fine particle sized clay with high phosphorus content resulting in very turbid and nutrient rich water. Tuttle Creek Lake has ranked in the top two for total nitrogen and/or total phosphorus average concentration from 2010–2019 including a low water period due to drought in 2012 and record pool elevation in 2019 as well as a representative year in 2018 (Figure 3-163). High turbidity from suspended clay particles limit sunlight available for algae and cyanobacteria growth in Tuttle Creek Lake. Without light limitation, cyanobacteria would adapt well to the high nutrient environment leading to HABs that would likely exceed Milford Lake in magnitude and duration.

USACE and KDHE pesticide sample results indicate atrazine, alachlor, and metolachlor were occasionally detected in spring samples at Tuttle Creek Lake with higher concentrations at the upper lake site nearer inflow streams. Atrazine concentrations

exceeding EPA drinking water criteria of 3 ug/L (Figure 3-240) were only found in the upper lake site. KDHE water quality monitoring results (KDHE 2007, 2010) from Tuttle Creek Lake documented detectable levels of aforementioned herbicides and atrazine degradation byproducts concentrations below EPA drinking water standards or KDHE numeric criteria for aquatic life (KDHE 2005). Atrazine and metolachlor were reported by KDHE as the most common and most concentrate herbicides, similar to Kansas City District Water Quality Program results.

Nutrient dynamics in Tuttle Creek Lake are less influenced by bio-attenuation due to light limited primary productivity than other district lakes. Total nitrogen, soluble forms of nitrate/nitrite, ammonia nitrogen, and orthophosphate were found at similar concentrations at upper and lower lake sites with slightly more variability due to proximity to inflow documented at upper lake sites (Figure 3-241). TKN and total phosphorus were reported in higher concentration and were more variable at the upper lake site than lower lake site likely due to gravitational settling of sediment bound phosphorus and organic nitrogen related to suspended particle matter and bacterial activity (Tappin et al. 2010).

A positive trend is observed in the measured total phosphorus concentrations from 2010–2019 (Figure 3-244) from samples at the site TC-3 near the dam. This relatively common trend in Kansas City District lakes indicates an increasing concentration of phosphorus in the reservoir water over time.

Concurrently, nitrogen concentrations did not display a significant trend, indicating that nitrogen levels have remained relatively stable during the same sampling period. A negative trend in the Total Nitrogen to Total Phosphorus ratio (TN:TP) as evident in Figure 3-245 can play a crucial role in the dominance of cyanobacteria within the phytoplankton community. Excessive phosphorus levels can potentially favor cyanobacteria over beneficial phytoplankton when the TN:TP ratio is less than 12 (Elser et al. 2007; Xiaofeng et al. 2012; Downing and Mckauley 1992), as illustrated in Figure 3-244 at Tuttle Creek Lake. Detailed statistical trend analysis of a longer period of sample results are discussed in FWOP (Section 3.7.5).

11542 *Figure 3-240. Tuttle Creek Lake Herbicide Concentrations 2010–2019*

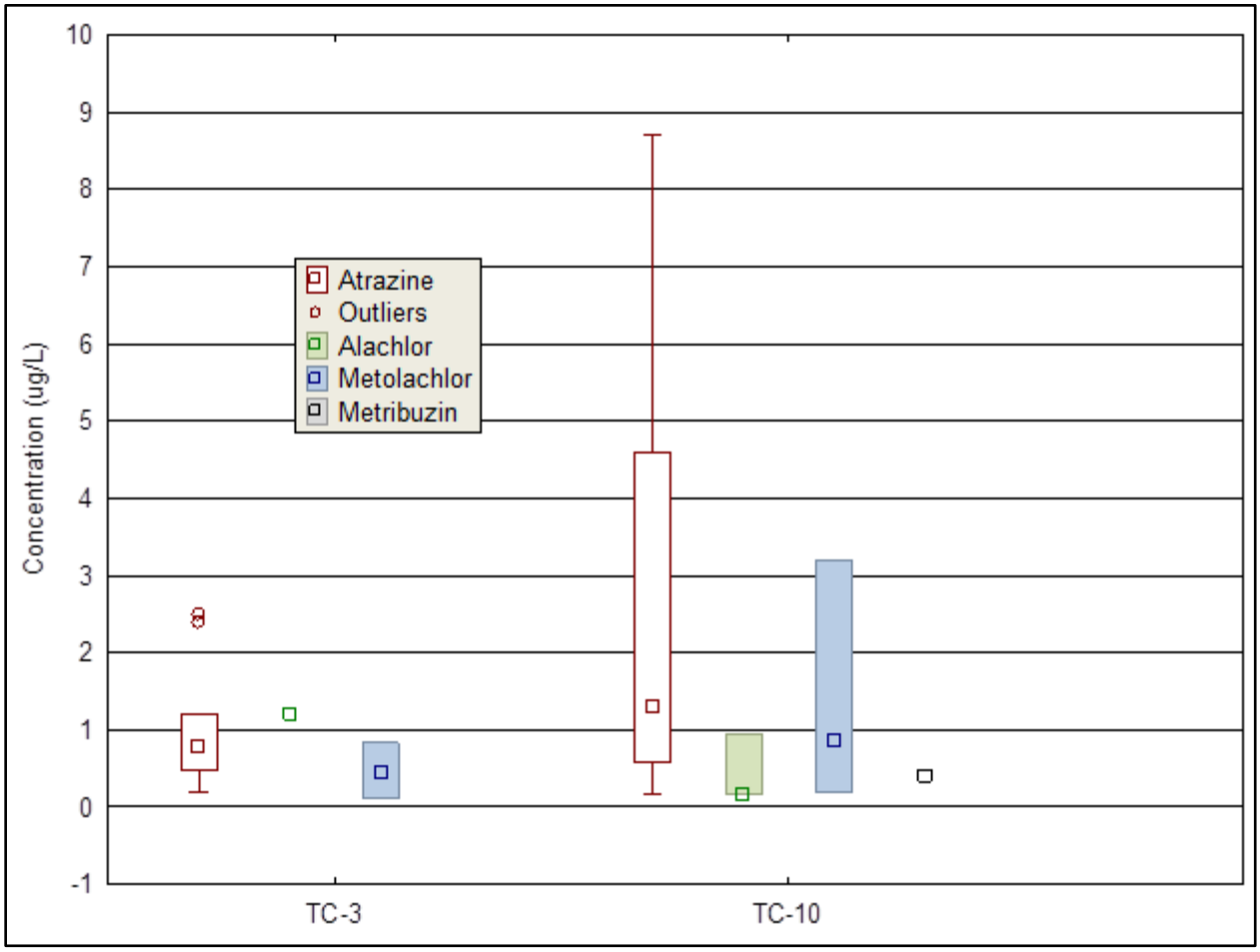


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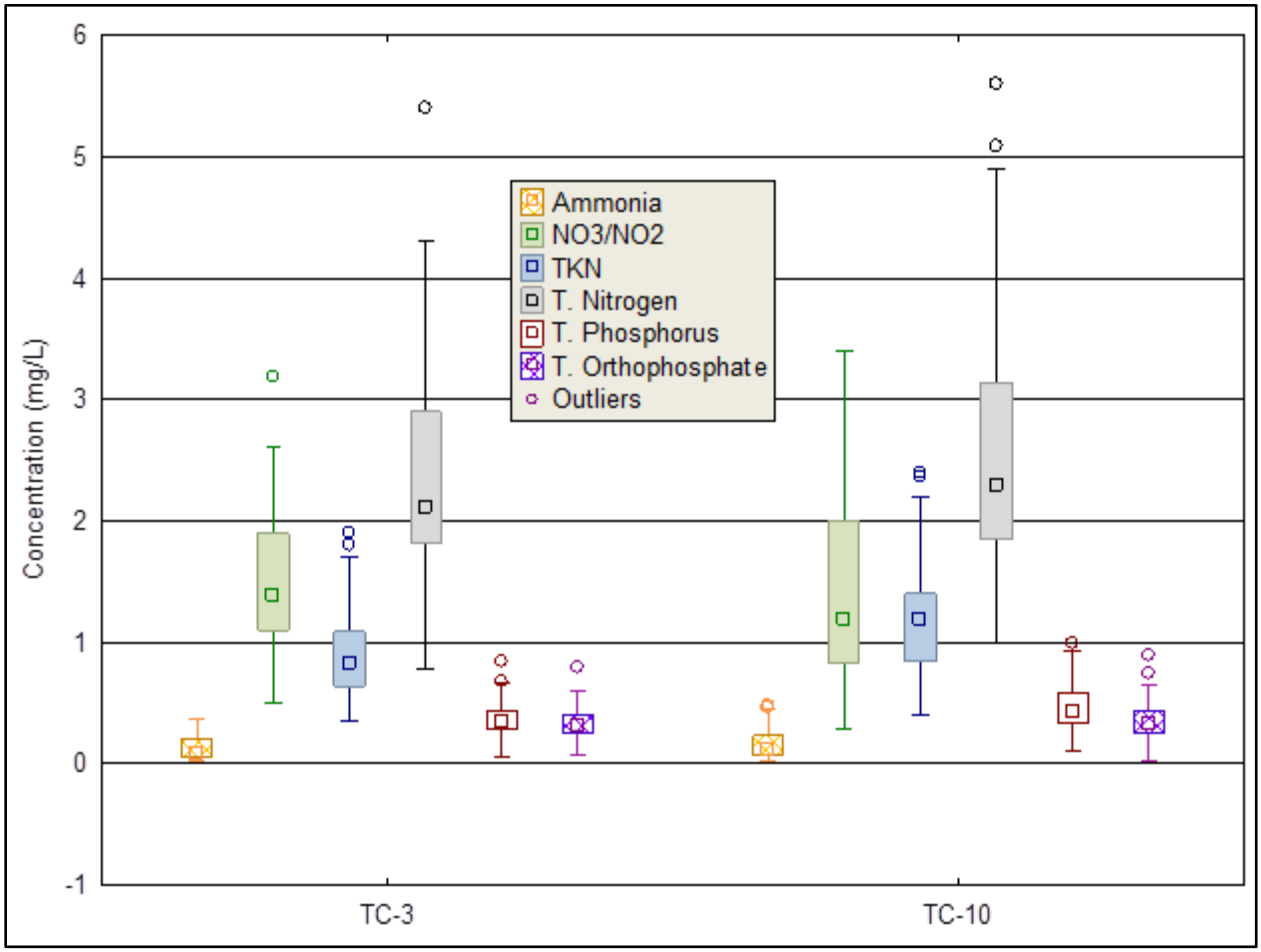
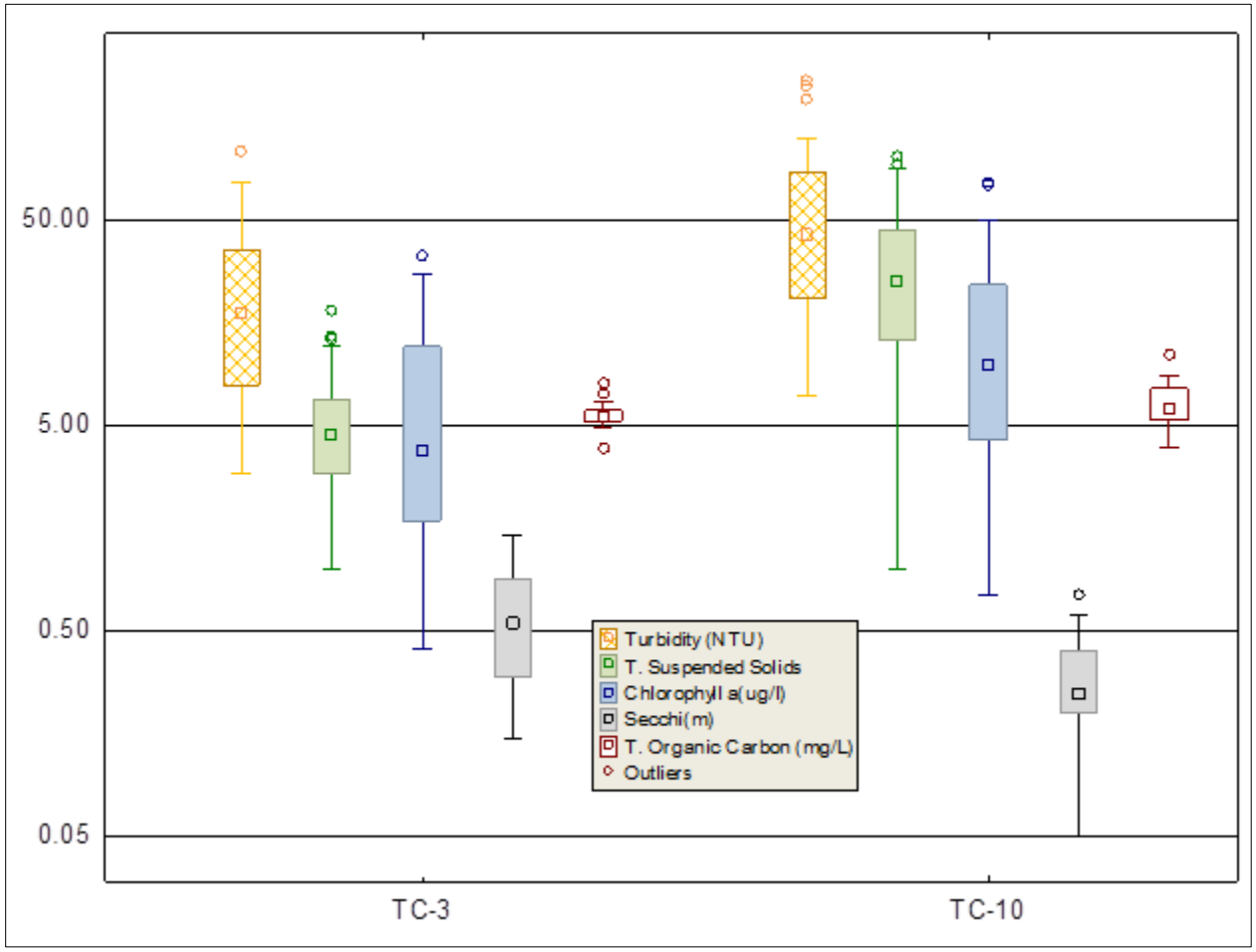
Figure 3-241. Tuttle Creek Lake Nutrient Concentrations 2010–2019



Factors influencing water clarity and light availability encompass inorganic sediment, organic carbon, turbidity, and phytoplankton (quantified through chlorophyll-a concentration) (Testa et al. 2019). The availability of light is critical to biological productivity by imposing limitations on photosynthesis due to light scarcity. Tuttle Creek Lake demonstrates hypereutrophic phosphorus concentrations (>0.096 mg/L), as defined by Carlson (1977), and light limited by inorganic turbidity. Nutrient and sediment influx leads to the classification of trophic states as either hypereutrophic or argillotrophic (KHDE 2007 and 2010), contingent on the year of sampling. In either scenario, the elevated inorganic turbidity can hinder the establishment of a thriving phytoplankton community (Bhutaiani 2009; Huisman 1999).

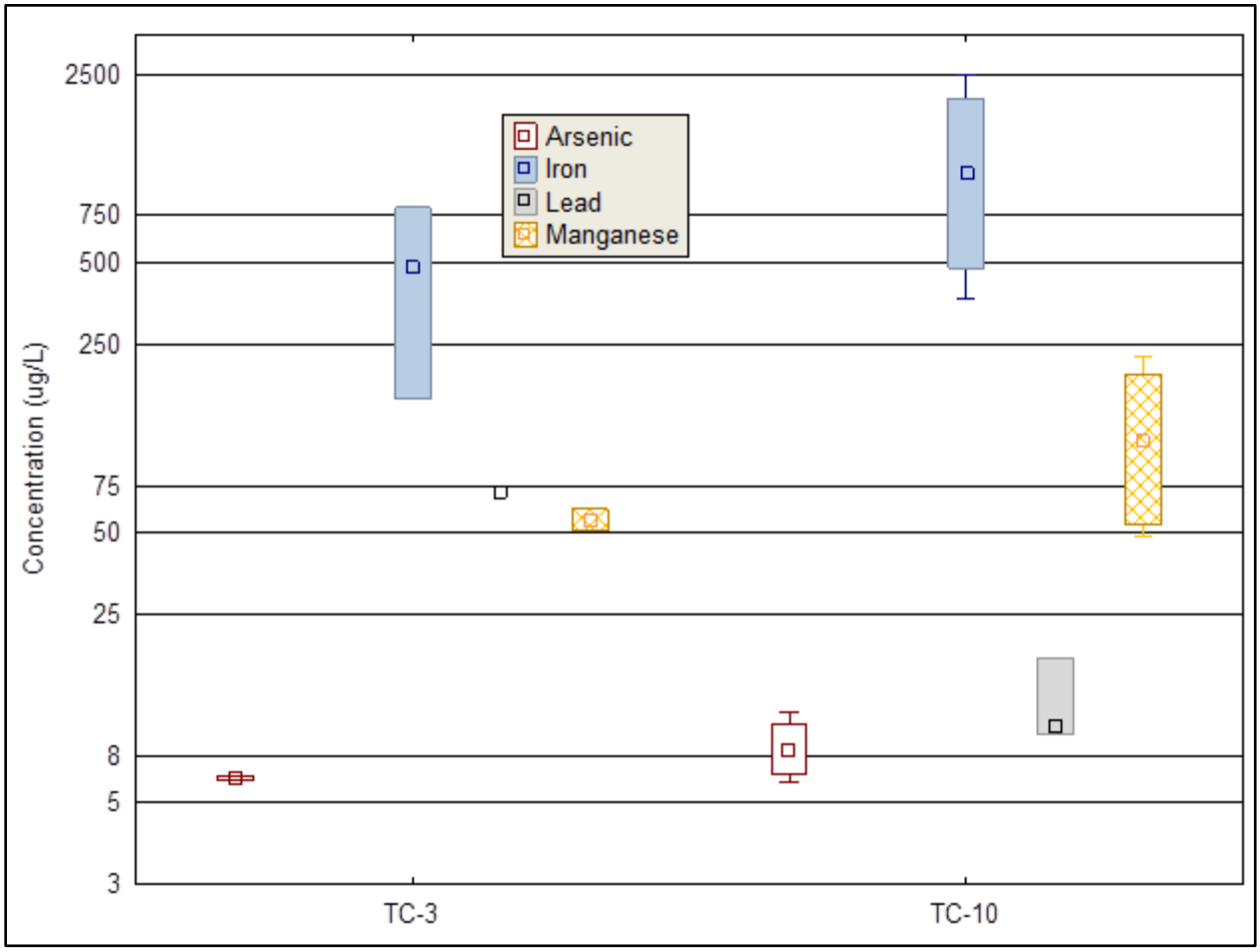
Upper lake sites exhibit reduced water clarity as a result of higher turbidity, suspended solids, and chlorophyll from phytoplankton growth (Figure 3-242). Concentrations of total organic carbon are elevated and exhibit greater variability at the upper lake site. As depicted in Figure 3-242, lower lake site (TC-3) had significantly lower turbidity and suspended solids promoting greater Secchi depth measurements than the upper site when comparing median values of TC-3 to interquartile range of upper lake sites.

Figure 3-242. Tuttle Creek Lake Water Clarity Metrics 2010–2019



Iron, lead, manganese, arsenic, and copper from total metals samples are commonly detected in Kansas City District Water Quality Program samples at Tuttle Creek Lake but have led to impairment designation. Seven inflow streams including Big Blue River are listed as impaired by KDHE (Figure 3-243) due to copper, lead, and arsenic impacts to aquatic life. Total metal concentrations in Tuttle Creek Lake water diminish through gravitational settling with relatively low concentrations found in water quality samples near the dam (TC-3). Iron and manganese are the most common and concentrate metals found in water quality samples from Tuttle Creek Lake.

Figure 3-243. Tuttle Creek Lake Total Metal Concentration 2010–2019



11578 *Figure 3-244. Tuttle Creek Lake Total Phosphorus Concentration And Linear Trend Line from 2010–2019*

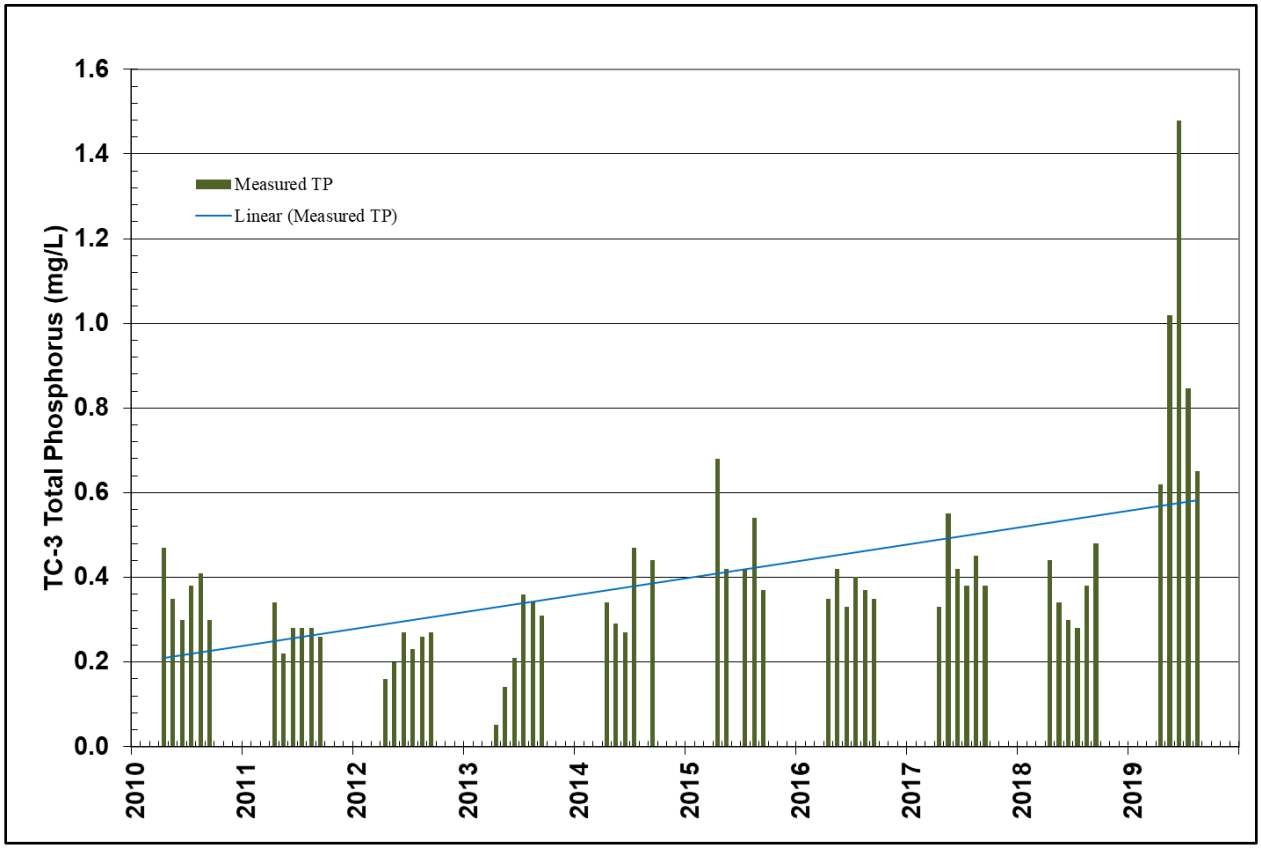


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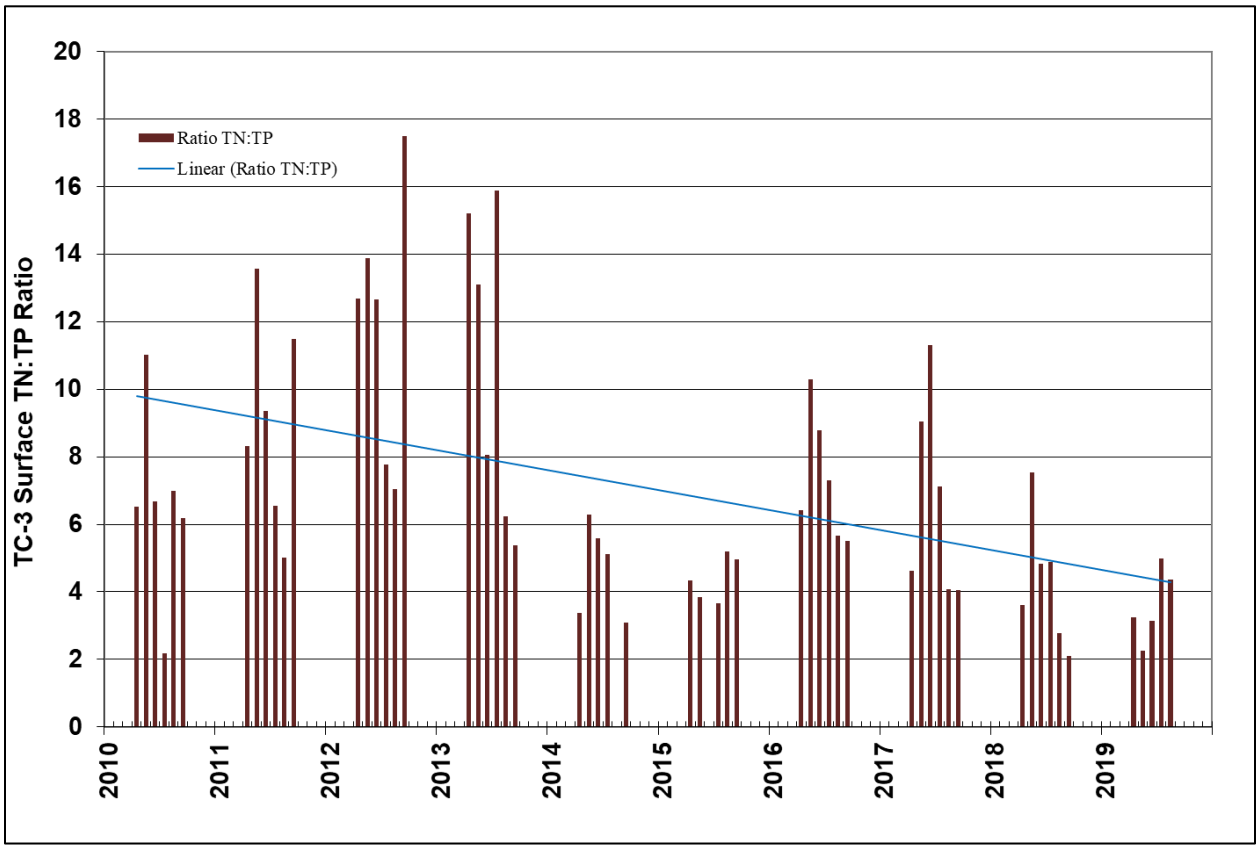
Figure 3-245. Tuttle Creek Lake Ratio of Total Nitrogen to Total Phosphorus and Linear Trend Line from 2010–2019



Annual nutrient measures in Tuttle Creek Lake rank near the top of all Kansas City District lakes (Figure 3-163). Mean and median surface and bottom measures at Tuttle Creek Lake are similar for chemical water quality parameters (Table 3-129) due in part to infrequent thermal stratification. From 2017–2019, bottom samples were only collected during the month of August which imparts a temporal or seasonal bias to bottom chemistry data as well as reduced sample size while demonstrating minor differences between surface and bottom samples when stratification should be most evident. No statistical differences between surface and bottom samples were detected.

11593 *Table 3-132. Tuttle Creek Lake Summary Statistics for Chemical Water Quality Parameters 2010–2019*

b	Sample Depth	Mean	SE	SD	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.11	0.03	0.20	1.30	0.04	0.01	59
Ammonia (mg/L)	Bottom	0.03	0.01	0.03	0.11	0.02	0.01	13
NO3/NO2 (mg/L)	Surface	1.47	0.08	0.61	3.20	1.40	0.02	59
NO3/NO2 (mg/L)	Bottom	1.41	0.09	0.34	2.00	1.40	0.79	13
TKN (mg/L)	Surface	0.90	0.07	0.57	4.10	0.82	0.20	59
TKN (mg/L)	Bottom	0.64	0.11	0.40	1.50	0.72	0.20	13
Total Nitrogen (mg/L)	Surface	2.37	0.12	0.89	5.40	2.13	0.89	59
Total Nitrogen (mg/L)	Bottom	2.05	0.17	0.62	2.91	1.98	0.99	13
Total Phosphorus (mg/L)	Surface	0.40	0.03	0.23	1.48	0.35	0.05	59
Total Phosphorus (mg/L)	Bottom	0.33	0.03	0.12	0.64	0.31	0.21	13
Total Orthophosphate (mg/L)	Surface	0.32	0.02	0.17	0.88	0.32	0.00	59
Total Orthophosphate (mg/L)	Bottom	0.27	0.03	0.12	0.46	0.26	0.09	13
Total Suspended Solids (mg/L)	Surface	5.68	0.64	4.88	27.40	4.50	0.00	59
Total Suspended Solids (mg/L)	Bottom	7.50	1.85	6.67	26.30	4.80	2.00	13
Total Organic Carbon (mg/L)	Surface	6.29	0.50	2.28	15.00	5.50	3.90	21
Total Organic Carbon (mg/L)	Bottom	6.13	0.75	2.71	15.00	5.30	4.80	13
Total Iron (ug/L)	Surface	515.67	189.68	328.53	802.00	588.00	157.00	3
Total Iron (ug/L)	Bottom	643.33	249.03	431.33	936.00	846.00	148.00	3
Total Manganese (ug/L)	Surface	57.33	3.23	5.60	61.60	59.40	51.00	3
Total Manganese (ug/L)	Bottom	195.13	74.67	129.33	326.00	192.00	67.40	3

11594 Note: Summary statistics for chemical water quality parameters from Tuttle Creek Lake site near the dam (TC-3), April 2010
11595 through September 2019.

11596 Physical water quality profiles are collected monthly by the Kansas City District Water
11597 Quality Program to describe physical conditions, aquatic habitat, and define thermal
11598 strata. Descriptive statistics of surface and bottom data selected from profile dataset are
11599 provided in Table 3-130. Dissolved oxygen is critical to aquatic life and can be used to
11600 define available habitat under a variety of seasonal conditions. Tuttle Creek Lake does
11601 not frequently develop a defined thermocline in summer months and is best described
11602 as weakly stratified for less than two months of the summer as depicted in Figure 3-246.
11603 During the short period of stratification, the top 4-6 meters of depth provide well
11604 oxygenated habitat for aquatic life with small variations in temperature from top to
11605 bottom. The most notable physical water quality difference at Tuttle Creek Lake is that
11606 characteristically high turbidity is typically greater and more variable near the bottom
11607 while peak turbidity values are recorded near the surface at upper lake sites related to
11608 high flow periods (Figure 3-246).

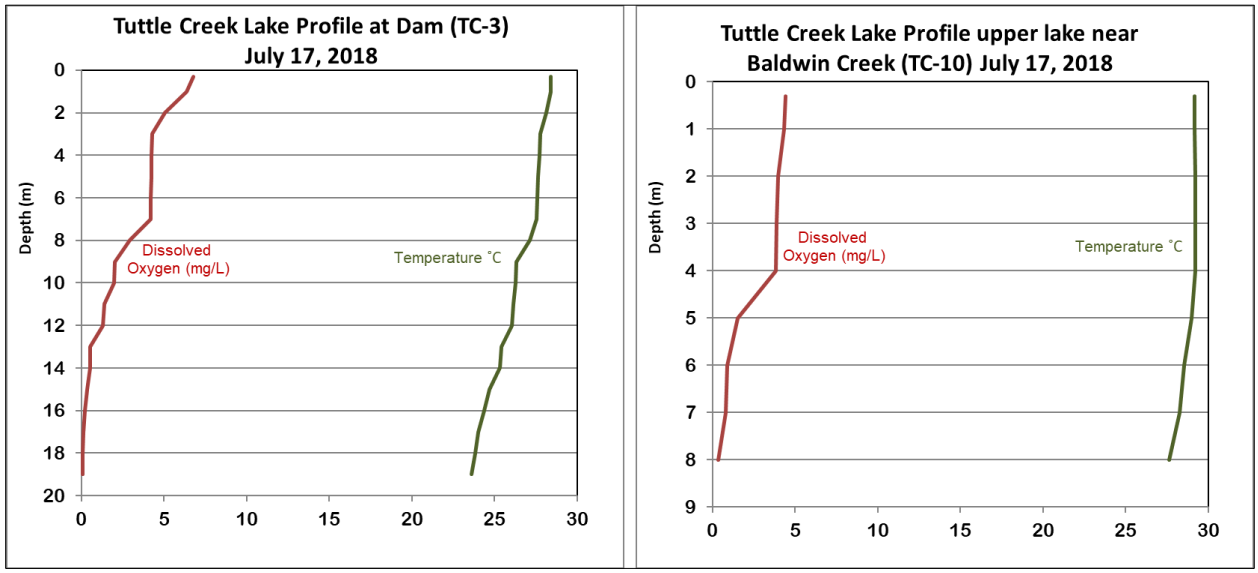
11609

Table 3-133. Tuttle Creek Lake Summary Statistics for Physical Water Quality Parameters 2010–2019

Parameter	Sample Depth	Mean	SE	SD	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	7.6	0.2	1.9	12.8	7.3	3.6	106
Oxygen, Dissolved (mg/l)	Bottom	5.5	0.3	3.0	11.6	5.6	0.1	111
pH (Standard Units)	Surface	8.1	0.04	0.5	10.1	8.1	7.3	106
pH (Standard Units)	Bottom	7.9	0.04	0.5	10.1	7.9	7.0	119
Secchi Depth (m)	Surface	0.5	0.03	0.3	1.5	0.4	0.1	103
Chlorophyll *a*	Photic Zone	6.42	1.01	7.50	33.00	3.10	0.27	55
Specific Conductance (µS/cm)	Surface	462.5	10.8	110.7	760.0	453.3	220.0	106
Specific Conductance (µS/cm)	Bottom	461.9	9.6	104.9	740.0	464.8	230.9	119
Turbidity, Field (NTU)	Surface	60.3	14.0	144.8	1260.0	22.9	1.0	106
Turbidity, Field (NTU)	Bottom	107.5	21.4	232.2	119.0	39.8	1.0	119
Water Temperature (°C)	Surface	21.4	0.6	6.4	29.5	23.1	7.1	106
Water Temperature (°C)	Bottom	20.6	0.6	6.3	29.2	22.9	6.8	118

Note: Summary statistics for physical water quality parameters, from all lake sites and dates, Tuttle Creek Lake, April 2010 through September 2019.

Figure 3-246. Tuttle Creek Lake Representative Temperature and Dissolved Oxygen Profiles 2018



Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discussions until aging lakes begin to release or “recycle” nutrients (e.g., phosphorus) back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) and/or sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984). Kansas City District Water Quality Program initiated collection of baseline lake-bed sediment data focused on nutrients and herbicides at Tuttle Creek Lake in 2017 (Figure 3-251) which have been pooled for this report with more comprehensive lake-bed sediment results collected in 2018 for discussions of potential bed sediment removal project(s) at Tuttle Creek Lake.

Median concentrations of nitrogen, phosphorus, and iron from Tuttle Creek samples exceeded those of Kansas City District Lakes in the Kansas River watershed (Figure 3-172). Comparable results of lake-bed sediments from Midwest reservoirs were not available. Tuttle Creek nitrogen and phosphorus concentrations were low to moderate when results were compared to lakes from southeast and northern United States (Barko, J.W. and R.M Smart 1986). Median values of phosphorus and TKN from Kansas City District bed sediment results (Figure 3-247) both exceeded respective maximum values reported in a similar USGS study of Tuttle Creek bed sediment (Juracek and Mau 2002). Trend analysis of phosphorus concentration in cesium-aged sediment cores by Juracek and Mau (2002) did not reveal significant trends from the 1960s-1999 time-period. Metal concentrations reported in NWK bed sediment results (Figure 3-247) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed (MacDonald et al. 2000). Similarly, Juracek and Mau (2002) reported concentrations of arsenic, chromium, copper, nickel, silver, and zinc in bottom-sediment samples of Tuttle Creek Lake exceeded the threshold-effects level as outlined in EPA sediment quality guidelines (U.S. Environmental Protection Agency 1997) while nickel was the only analyte tested with one sample exceeding the probable-effect level.

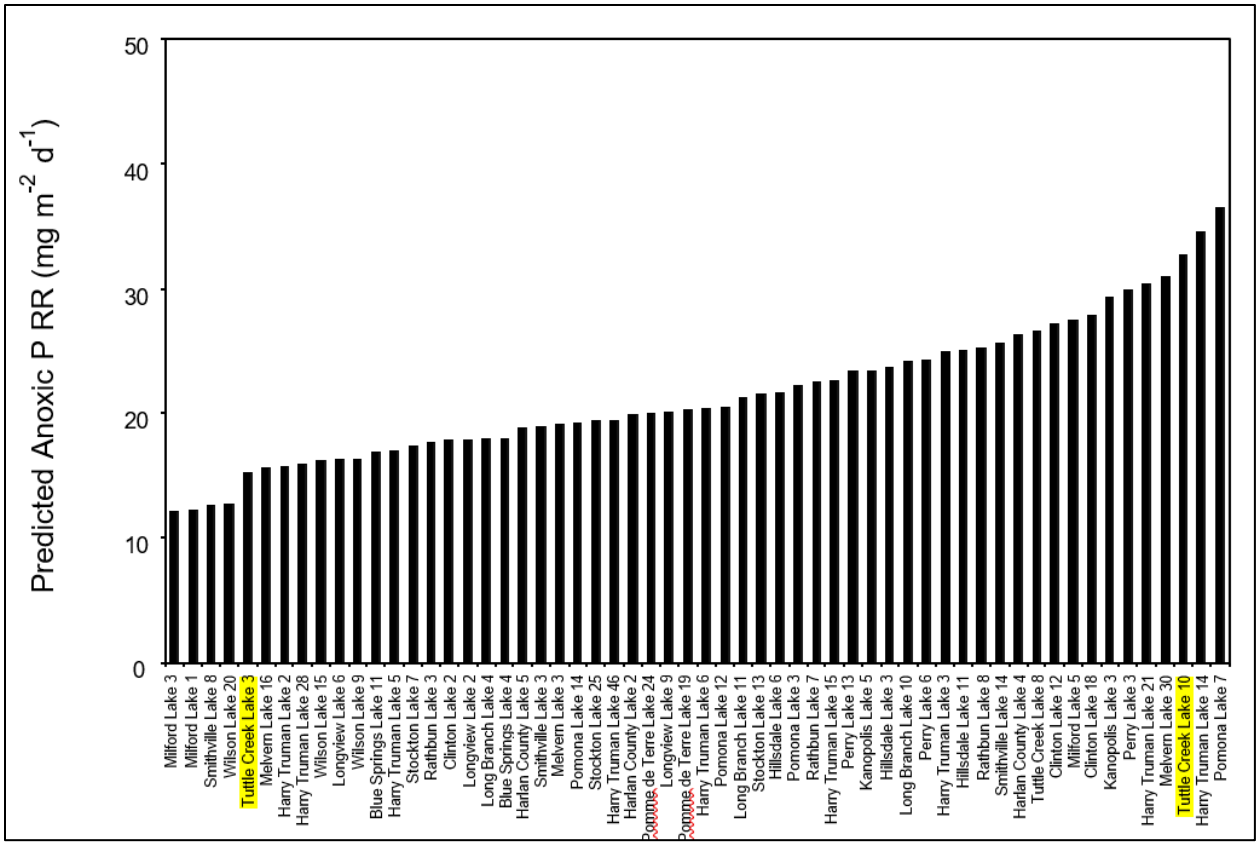
*Figure 3-247. Tuttle Creek Lake Bed Sediment Chemical Concentrations 2017 and 2018**

Station	Date mm/dd/yyyy	Ammonia Nitrogen mg/kg	otal Kjeldahl Nitroge mg/kg	Phosphorus mg/kg	Arsenic mg/kg	Copper mg/kg	Iron mg/kg	Lead mg/kg	Manganese mg/kg	Mercury mg/kg	Nickel mg/kg	Zinc mg/kg	Cadmium mg/kg	Chromium mg/kg	Selenium mg/kg	Aluminum mg/kg	Barium mg/kg	Beryllium mg/kg	Cobalt mg/kg	Vanadium mg/kg	otal Solid %
TC-3	8/23/2017	137	2800	1190	10	33	37900	28	1250	0.50	41	142	0.70	40							23
TC-3.1	8/23/2017	250	2990	1150	12	36	42800	41	1100	<0.3	43	162	0.91	48							22
TC-3.2	8/23/2017	145	2450	926	9	30	36500	31	1060	<0.3	39	138	0.72	40							24
TC-3.3	8/23/2017	151	2750	1130	9	32	39200	32	1200	<0.3	41	145	0.81	43							22
TC-4	8/23/2017	298	2820	1190	12	36	40400	33	1030	<0.3	43	150	0.81	45							23
TC-4.1	8/23/2017	318	2570	1200	11	33	40100	33	1120	0.4	40	142	0.77	44			no data				21
TC-5	8/23/2017	232	2740	1150	11	38	42500	33	1130	0.31	45	163	0.87	46							24
TC-6	8/23/2017	199	2510	1190	12	32	38300	34	878	0.34	40	143	0.87	42							28
TC-7	8/23/2017	263	2210	1110	10	30	36000	30	771	0.32	39	136	0.79	40							30
TC-10	8/23/2017	167	2250	931	10	29	33500	25	765	<0.3	37	126	0.74	37							33
TC-10.5	8/23/2017	253	2200	899	9	27	28100	23	767	0.27	33	108	0.75	31							37
TC-11	8/23/2017	247	1840	819	8	22	24000	21	719	<0.3	28	92	0.67	27							43
TC-S2	8/24/2018	75	3660	1120	12	30	37900	30	1070	<0.3	36	140	0.48	44		49000	386	2.8	15	79	23
TC-S3	8/25/2018	86	2240	991	12	27	34900	27	847	<0.3	34	131	0.48	40		44900	360	2.6	14	73	25
TC-S4	8/26/2018	192	2300	1010	11	27	35100	27	1050	<0.3	33	131	0.48	41	1.32	45900	359	2.6	13	74	22
TC-S5	8/27/2018	307	2470	1150	14	29	38100	30	1120	<0.3	36	142	0.56	44	1.82	49800	382	2.8	15	77	22
TC-S6	8/28/2018	167	2620	1040	14	30	39600	30	1020	<0.3	36	149	0.47	46	2.40	51900	386	2.9	14	83	21
TC-S7	8/29/2018	245	2320	938	12	23	29800	21	1130	<0.3	29	105	0.36	35	2.86	38100	304	2.2	13	62	26
Median		216	2490	1115	11	30	37900	30	1055	0.33	38	141	0.73	41	2.11	47450	371	2.7	14	76	23

Note: *Analytes not detected at quantifiable concentration in USACE samples include 121 herbicides, pesticides, pcb, and metals.

Internal loading of legacy phosphorus back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) increases the potential of HABs in lakes and impact biota in receiving waters during sediment management/removal activities. These concerns have also been expressed by management agencies and stakeholders regarding many aging lakes in the Kansas City District. ERDC Environmental Lab study of sediment characteristics of Kansas City District lakes (James Unpublished Report. 2009) provides useful information related to fate of nutrients in lakes and bed sediment perturbation. James (2009) calculated potential rates of phosphorus release under anoxic conditions using regression relationships between redox-sensitive phosphorus and anoxic phosphorus release rates (anoxic P release=(redox-sensitive P, g·m-2·cm-1 · 15.1)–0.7) developed by Pilgrim et al. (2007) for eutrophic lakes in Minnesota. Potential phosphorus release rates ranged between approximately 12 and 37 mg·m-2·d-1 for Kansas City District Lakes with upper Tuttle Creek Lake ranking third of all lake sites evaluated (Figure 3-248).

Figure 3-248. Ranges in the predicted phosphorus (P) release rate (RR) under anoxic conditions as a function of Kansas City District lake and station



(James. Unpublished report. 2009)

3.7.4.1.7 Clinton Lake

Clinton Lake is a 7,205-acre multi-purpose impoundment built on the Wakarusa River, reaching full pool in 1980. Flood control, water quality, recreations, fish and wildlife, and water supply to most of Douglas County, Kansas are Clinton Lake Project operating purposes.

Watershed conservation efforts have increased in priority for state and local rankings to address sedimentation and water quality issues at Clinton Lake. The Watershed Restoration and Protection Strategy (WRAPS) program is a KDHE planning and management tool used to identify watershed restoration and protection needs, establish management goals, establish plans (e.g., EPA approved 9-Element Watershed Plans) and implement goals to address water resource concerns (https://www.kdheks.gov/nps/wraps/). Most priority goals/targets of the approved WRAPS Plans for subbasins in the Kanas River Watershed align with strategies and measures included in this study. The WRAPS process is in the implementation and monitoring phase of their process to administer programs using BMPs in Clinton Lake watershed to meet TMDLs on inflow streams and reduce nutrient and fecal loads to meet water quality milestones in Clinton Lake (KDHE 2020).

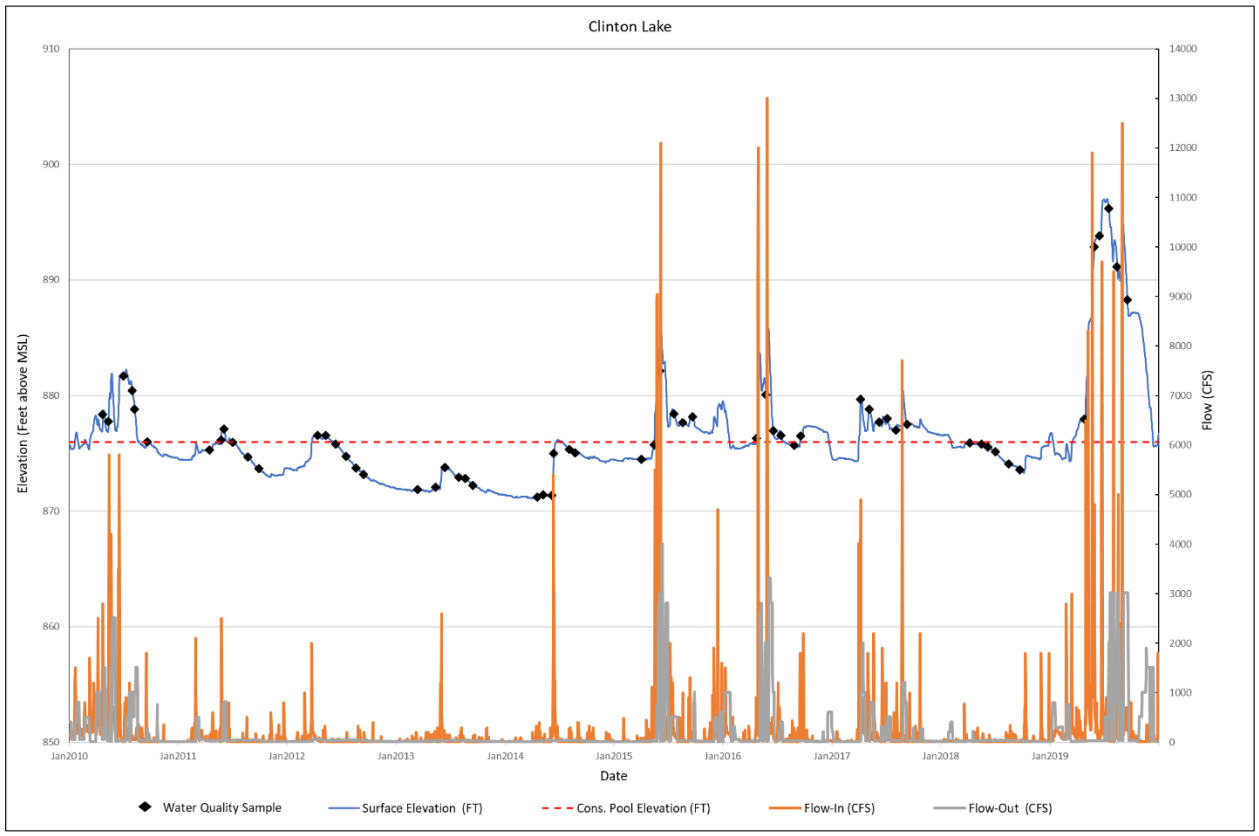
Reservoir Hydrologic Data Summary

Water management data is critical to interpreting water quality results as hydrologic conditions factor into critical metrics related to flow (i.e., volume, load, and

concentration), water residence time, and lake mixing/stratification which in turn influence physical and chemical process, frequently resulting in biological response. Figure 3-249 illustrates reservoir hydrologic data with overlay of water quality sampling events.

Water quality sampling events by Kansas City District staff were conducted monthly from 2010–2019 coinciding with the typical recreational season (April–September). Low inflow periods were observed in 2013–2014 with surface elevation falling below 872 feet while recovery period is apparent beginning late spring of 2015. Significant flooding with a corresponding high-water period was observed in 2019 as inflows peaked at 12,500 cfs with four events exceeding 9,000 cfs from April through August. Surface elevation of Clinton Lake peaked at 21 feet above CPE and exceeded CPE for 271 days in 2019.

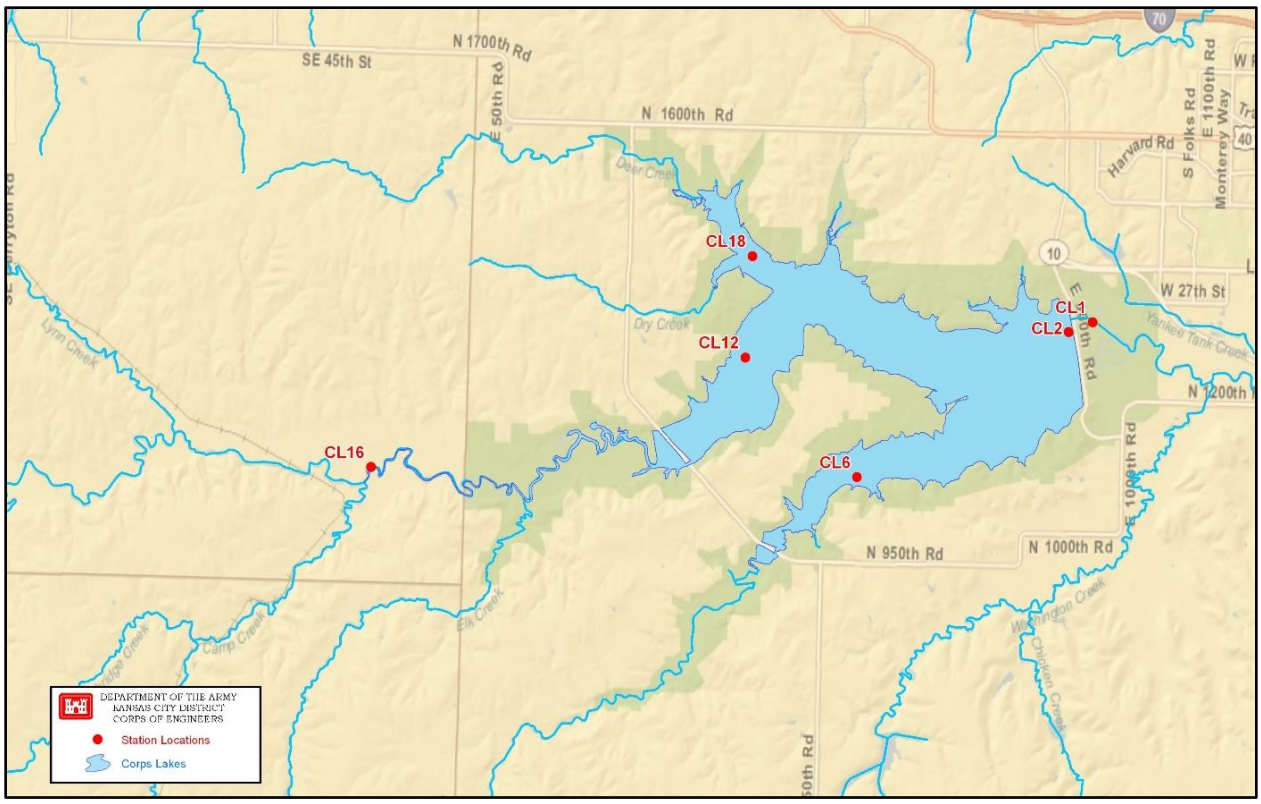
Figure 3-249. Clinton Lake Time Series of Daily Water Surface Elevation and Pool Information



Water Quality Sample Locations

Historic water quality sample sites at Kansas City District lake projects are generally named in decreasing numeric order from inflow sites to the outflow site below the dam (Figure 3-250). To provide a representative collection of chemical and physical water quality conditions as water moves from inflow streams, through the lake and exits through the outflow, sample sites are strategically located at safe bridges at stable inflow locations, in the river channel of each main tributary arm of the lake, in the old river channel near the dam, and in an accessible area in the channel of the outflow.

Figure 3-250. Clinton Lake U.S. Army Corps of Engineers' Water Quality Sample Sites

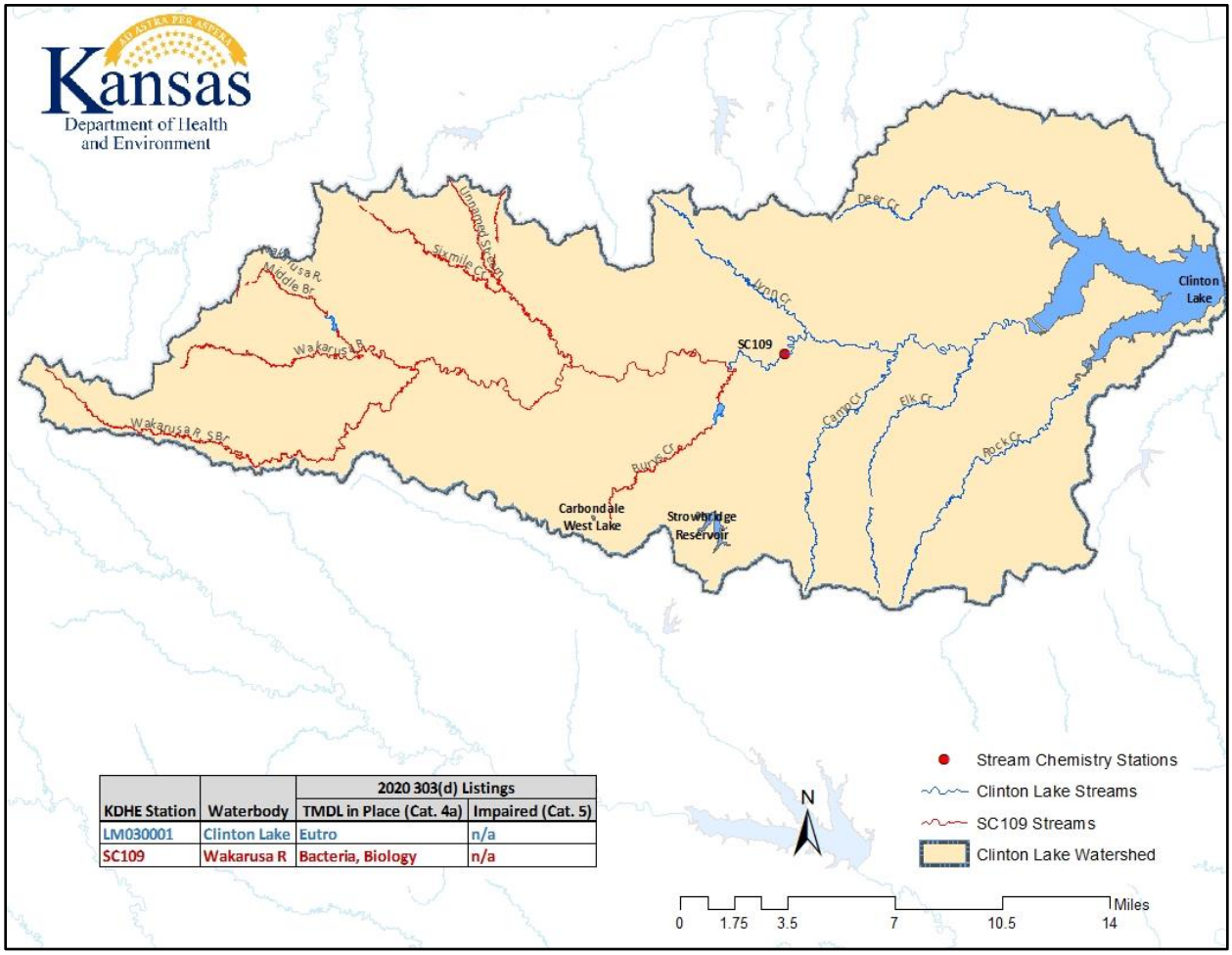


Impairments

Excess nutrients and fecal bacteria comprise Clinton Lake and inflow TMDLs defined in 303(d) list provided by KDHE (Figure 3-251). These impairments can impact authorized purposes of Clinton Lake. Excess nutrients leading to elevated algal density, as defined by chlorophyll *a* concentration, is the basis of KDHE eutrophication TMDL. Cyanobacteria blooms occur at low to moderate cell density at Clinton Lake but frequently result in taste and odor issues for drinking water customers utilizing Clinton Lake. Recreation has been impacted by closed swim beaches due to *E. coli* bacteria, but algal blooms have not reached advisory thresholds at Clinton Lake as of this writing.

Frequent fecal coliform bacteria exceedances at Wakarusa River and other Clinton Lake tributaries continue to support impaired status. Permitted municipal waste-water treatment, livestock waste management systems, inadequate rural on-site septic systems, and wildlife contribute to the fecal load and the TMDL which has remained since 2000 (KDHE 2000). Fecal bacteria TMDL impacts support of aquatic life, primary contact recreation, and all other designated uses of affected areas. USACE managed swim beaches at Clinton Lake are infrequently closed due to E. coli bacteria, but frequent use by Canada geese and local runoff is the most likely source of contamination.

Figure 3-251. Clinton Lake Total Maximum Daily Loads 2020



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM030001	Clinton Lake	Eutro	n/a
SC109	Wakarusa R	Bacteria, Biology	n/a

Inflows/Outflow

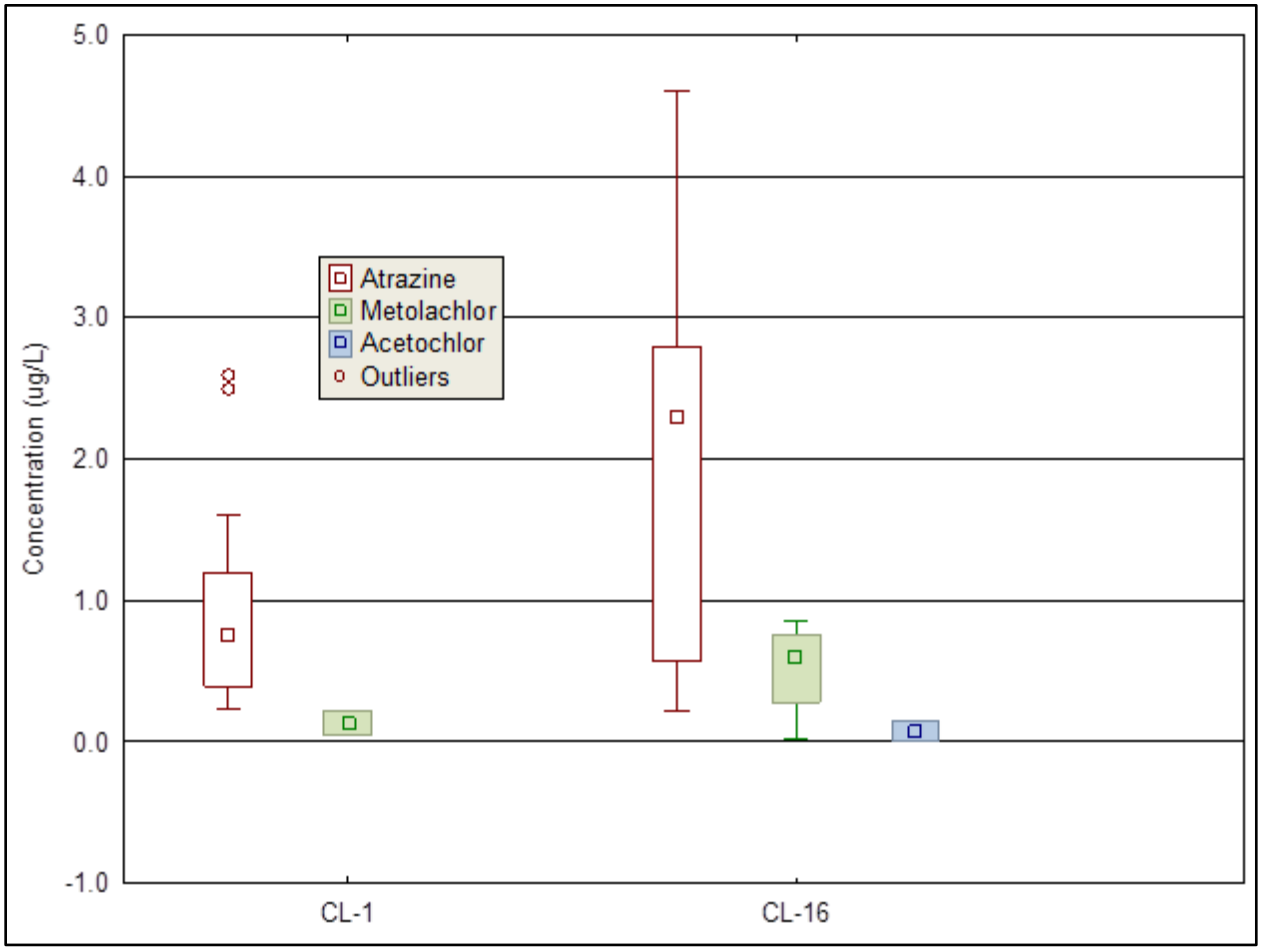
Lakes and reservoirs store sediment and associated chemical compounds carried by inflows and runoff. Sediment, suspended particles, and soluble chemicals enter reservoirs from runoff, groundwater, and inflow streams. Different nutrient and geological sources associated with inflows and source water influence water quality in physical, chemical, and biological composition. Nutrient balance in receiving waters has direct implications on trophic state and is linked to types of plant and algae species or primary production in the lake. Water exiting through the dam or outlet works of USACE lakes can be quite different than the inflows as large amounts of nutrients, pesticides, and metals are attenuated (i.e., processed/converted to other forms, diluted) or stored in the lake causing a sink effect (Satoh et al. 2002). Many physical changes including temperature, turbidity and dissolved oxygen concentration in outflows are related to release of anoxic water from depths during stratified periods or potential for supersaturation during flood releases.

Clinton Lake inflow streams originate at the eastern edge of the Flint Hills in the Upper Wakarusa watershed extending 40 miles west from the largely forested Lawrence-Douglas County area out into the Tallgrass Prairie areas of Shawnee, Osage, and

Wabaunsee counties. Natural Resource Conservation Service (NRCS) data for the BMP applications and surveys of the watershed indicate that approximately 60 percent of the cropland and 40 percent of the grassland in the watershed are still in need of conservation practices to minimize runoff and erosion (KDHE 2011a).

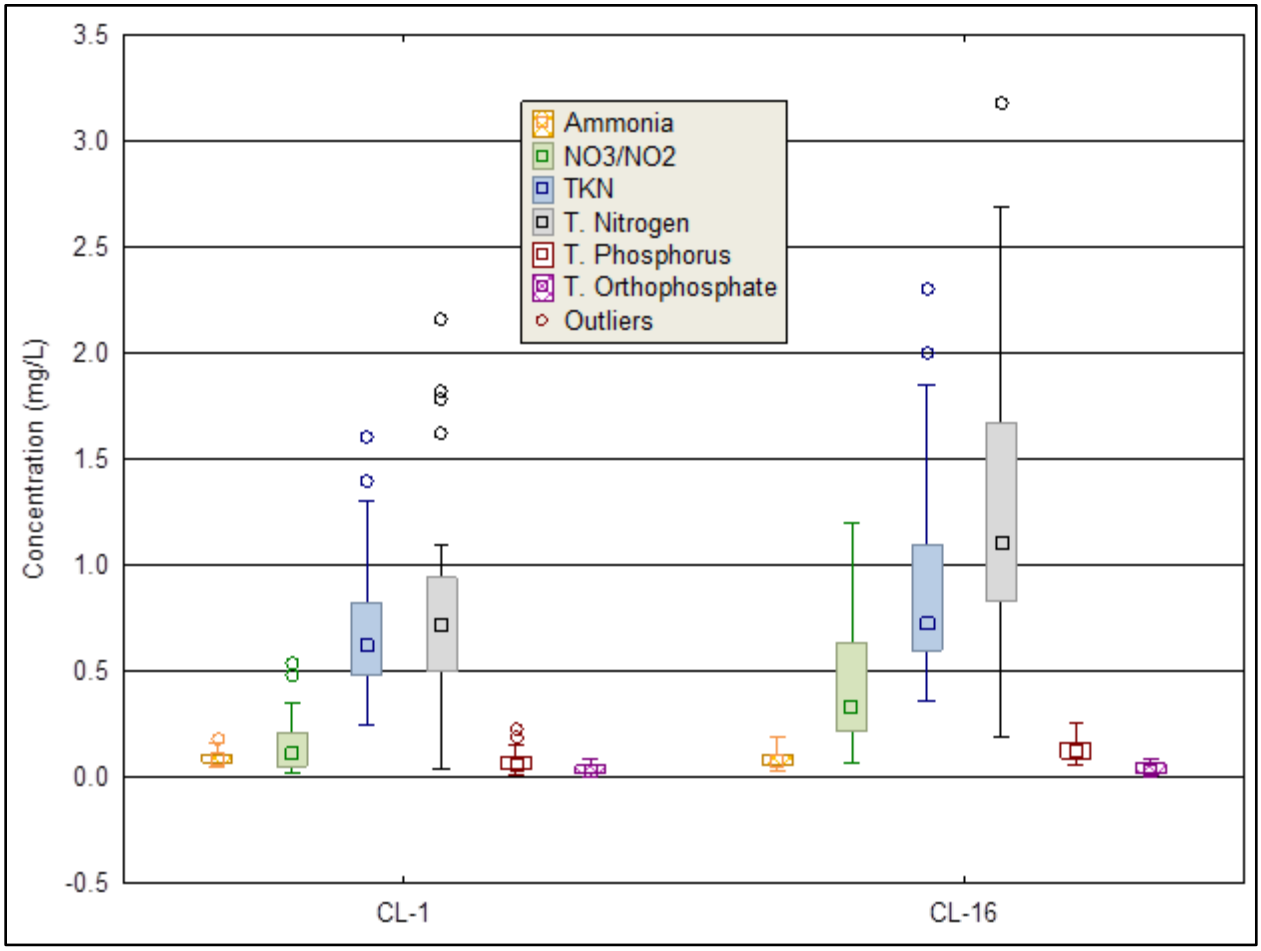
Herbicides have been monitored at Clinton Lake by Kansas City District Water Quality staff since 1996. The list of herbicides detected have included mostly chlorinated species and chemical constituents of atrazine, alachlor, metolachlor, cyanazine, metribuzin, simazine, acetochlor, 2, 4-D, and glyphosate. EPA regulation of herbicide licensing to reduce chemical persistence and mobility in the environment have reduced the number and concentration of chemicals detected in Kansas City District Water Quality samples. Total atrazine and alachlor concentrations peak during planting season in the spring and are associated with runoff events as herbicides mobilize and enter the Republican River in concentrations typically much higher than those exiting through the outlet. Median concentrations of atrazine in Figure 3-252 indicate inflows consistently have higher atrazine than the outflow Clinton Lake–1 (CL-1) while median values and interquartile range of data at both sample sites during the period of analysis fall below the EPA drinking water criteria of 3 ug/L. Similarly, detectable levels of metolachlor and alachlor in the inflow and outflow are less than EPA drinking water standards 3 ug/L and 2 ug/L, respectively (EPA 1995).

Figure 3-252. Herbicide Concentrations Upstream and Downstream of Clinton Lake from 2010–2019



Inflows into Clinton Lake carry nutrient loads (Figure 3-253) associated with sediment as well as point and non-point source nutrients. Median values for total nitrogen, nitrate/nitrite, and total phosphorus measured at inflow site exceeds the 75th percentile (Q3) found in the outflow which is indicative of significant attenuation and denitrification occurring in Clinton Lake. Mann-Whitney U Tests of all nutrient analytes grouped by sample site in Figure 3-253 detect significant differences ($P<0.05$) in sample means between inflow and outflow NO_3/NO_2, TKN, TN, and TP.

Figure 3-253. Nutrient Concentration Upstream and Downstream of Clinton Lake from 2010–2019



Water clarity improves from residency in Clinton Lake as suspended particles and sediment settle out. Median turbidity and total suspended solids are up to three times greater at inflow sites than the outflow (Figure 3-254) while total organic carbon mean values at inflows and outflow were not significantly different (P=0.096).

Total metals discussions for Clinton Lake inflows and outflow (Figure 3-255) are limited for valid comparison due to small sample size related to concentrations below minimum detection limit (e.g., As, Cu, Ni, and Zn) combined with the 3-year sample frequency allowing for maximum of 3 data sets in a 10-year period of analysis. Mean values of total iron (µ=1,441 ug/L), total lead (µ=5.4 ug/L), and total manganese (µ=265 ug/L) calculated for samples at Cl-16 on the Wakarusa River did not exceed acute criteria Kansas water quality standards (KDHE 2018).

11790 *Figure 3-254. Water Clarity Metrics Upstream and Downstream of Clinton Lake from 2010–2019*

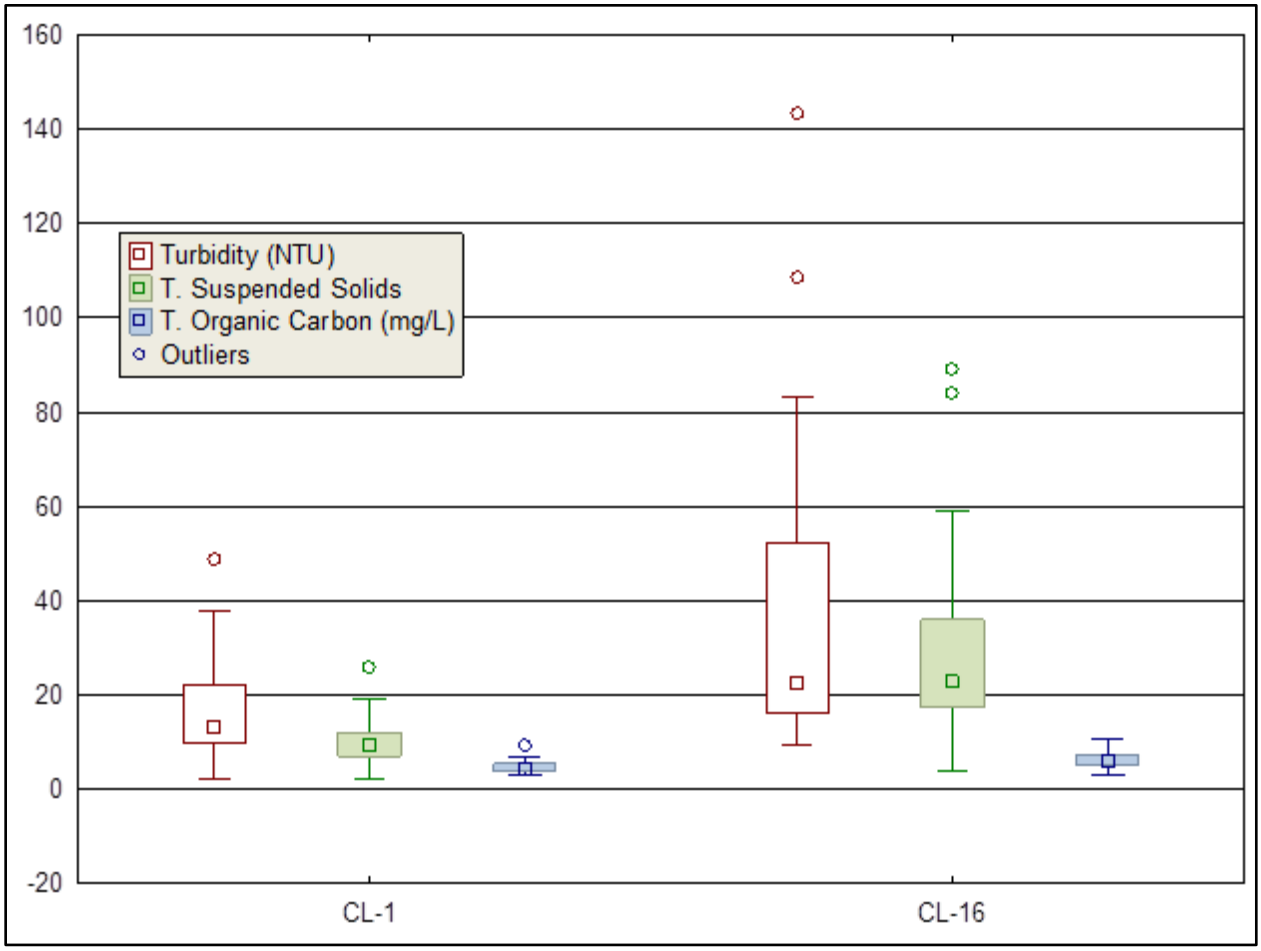


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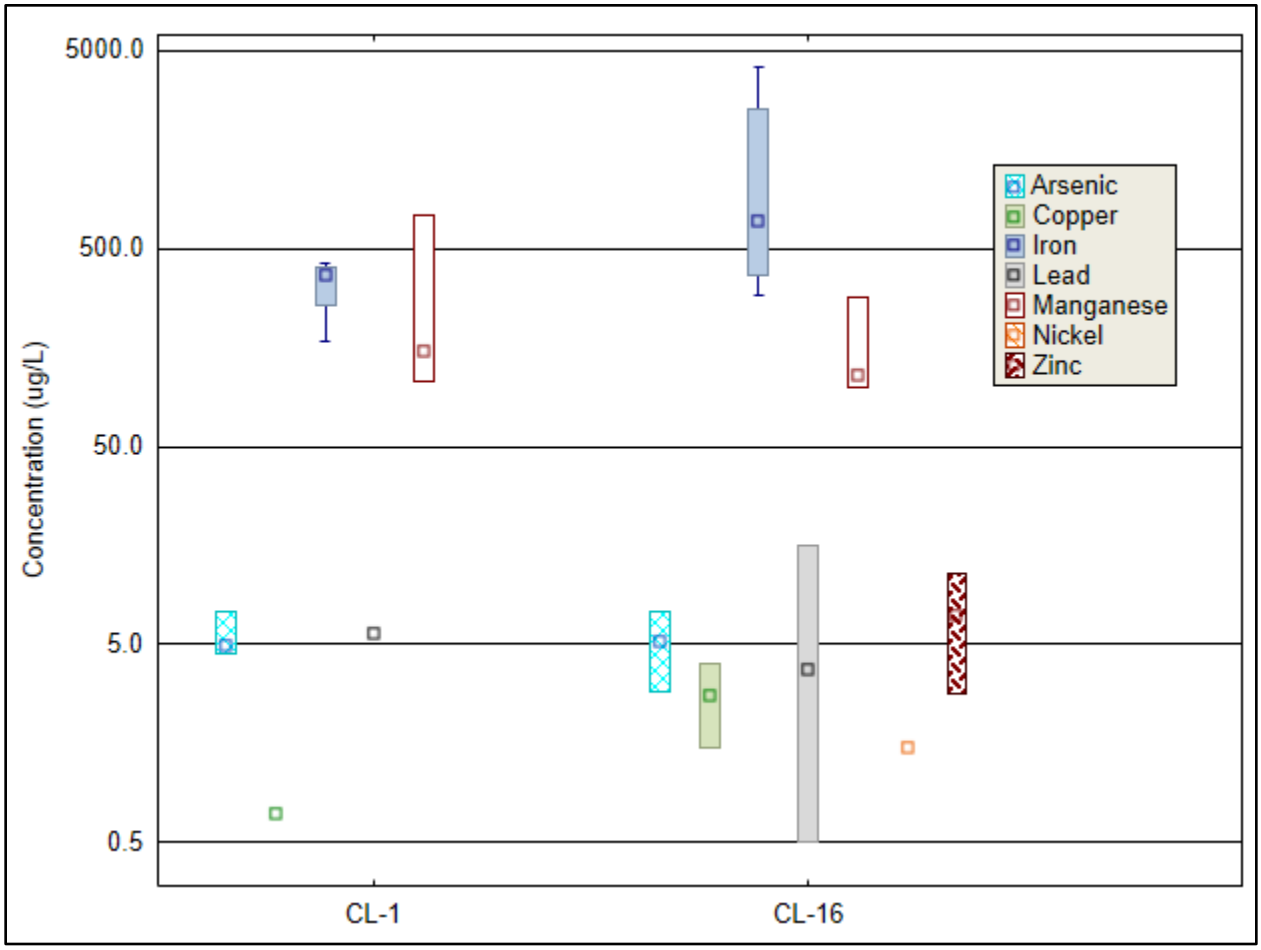
Figure 3-255. Total Metals Upstream and Downstream of Clinton Lake From 2010–2019

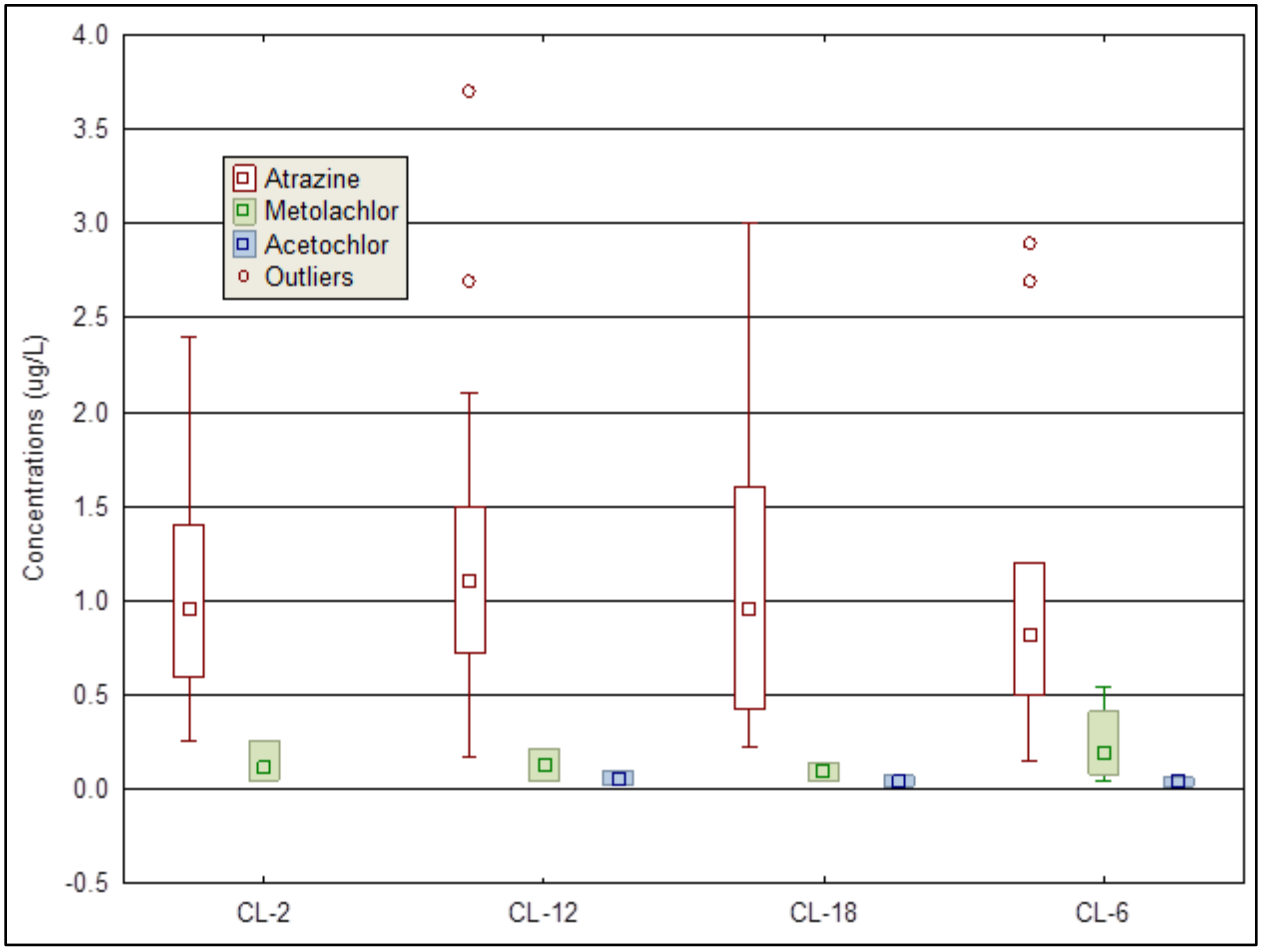


Lake Water Quality

Physical and chemical attenuation (e.g., dilution, dispersion, chemical changes, and uptake by organisms) of compounds and settling of suspended matter leads to a general decrease in concentration of many constituents of water quality, often interpreted as improved water quality, as water moves through a reservoir system (Bosch et al. 2009). This process will be evident with many analytes in graphic representations in lake water quality sections. The following section is an overview of chemical and physical data from surface samples from four lakes sites, describes chemical and physical differences between surface and bottom strata at the site near the dam and stratification, and briefly describes available phytoplankton and cyanobacteria data related to public health advisories.

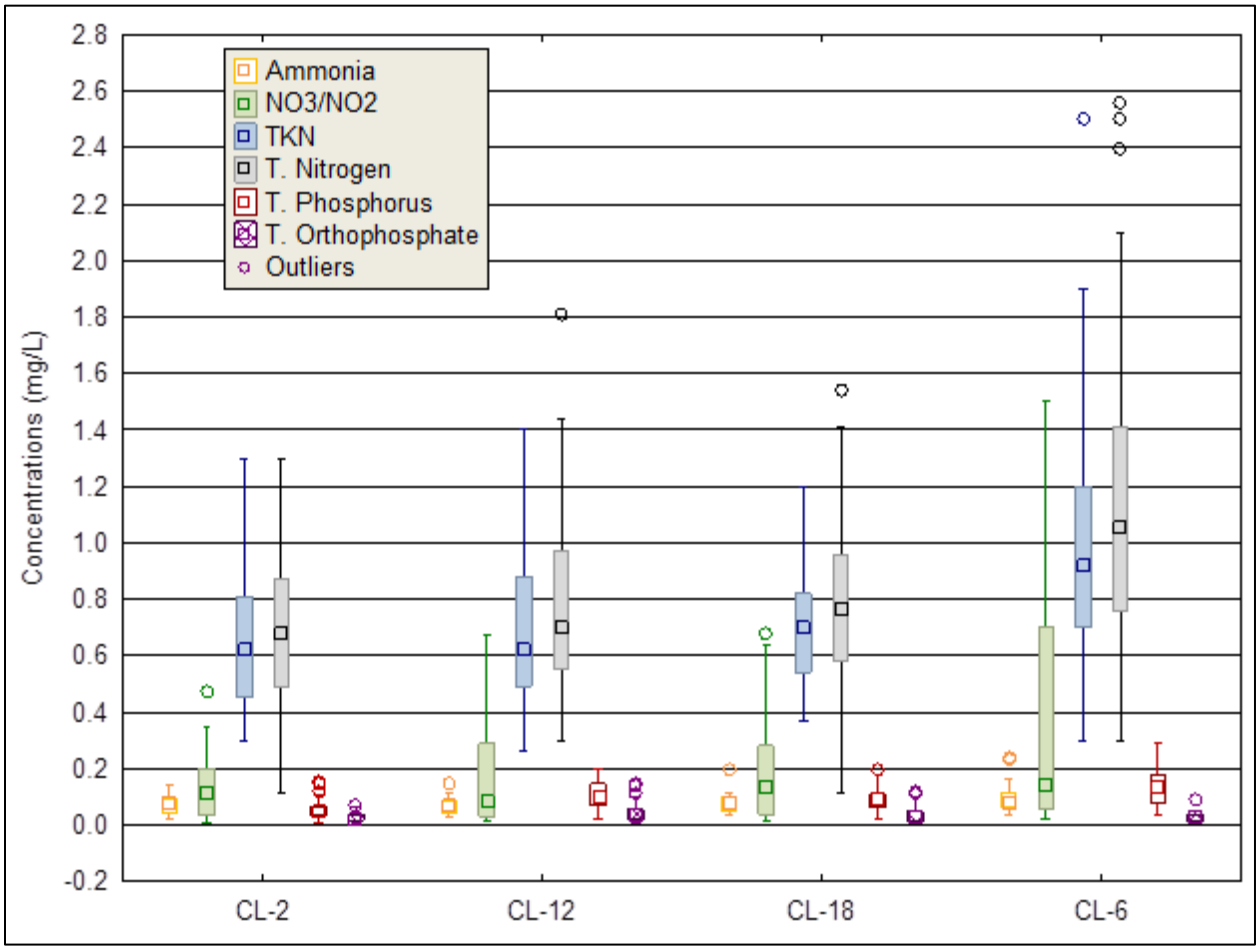
Herbicides are detected in relatively low concentration in Clinton Lake samples. Three common herbicides detected in lake samples include atrazine, metolachlor, and acetochlor (Figure 3-256). EPA recommendations for maximum exposure of 3 ppb of atrazine was exceeded in one of fifty-five samples collected from 2010–2019.

Figure 3-256. Clinton Lake Herbicide Concentrations 2010–2019



Nutrient enrichment and sediment loads degrade water quality and reduce expected lifespan of USACE district lakes including Clinton Lake. Sediment and phosphorus reduction goals for Clinton Lake with a BMP implementation schedule spanning 50 years are outlined in Upper Wakarusa River WRAPS 9 Element Watershed Plan (KDHE 2020). WRAPs 10-year milestones for total phosphorus in Clinton Lake is 0.048 ug/L for the 2011-2021 evaluation period. Mean and median total phosphorus from 2010–2019 at the lower lake site near the tower was 0.06 mg/L and 0.05 mg/L, respectively (Figure 3-257, Table 3-131). Nutrient concentrations are all more variable and frequently measured higher concentrations at the Rock Creek Arm site (CL-6) with median values for TN, TKN, and TP exceeding the interquartile range of the respective medians at CL-2, CL-12, and CL-18.

Figure 3-257. Clinton Lake Nutrient Concentrations 2010–2019



Clinton Lake inflows carry inorganic sediment and well as suspended organic matter impacting water clarity. Attenuation of sediment and other compounds affecting water clarity through Clinton Lake is apparent as median TSS, turbidity, total organic carbon, and chlorophyll a at the three upper lake sites (CL-12, CL-18, CL-6) all exceed 75th percentile (Q3) of the respective data reported from the lower Clinton Lake site (CL-2) (Figure 3-258). Similarly, median Secchi depth measures at the CL-2 exceeded 80–99 percent of Secchi data from upper lake sites as water transparency increased from decreased turbidity and suspended matter.

Total metals concentration from surface samples from Clinton Lake sites are represented in Figure 3-259. Small sample size due to limited sampling effort and several sample results below minimum reporting limit have limited the utility of the data. Ranked in order of relative abundance, iron, manganese, arsenic, copper, and lead were present at all at Clinton Lake USACE water quality sample sites from 2010–2019. Seven additional metals were included in total metals analysis from 2010–2019 with results reported as below the minimum detection level. Median total manganese and total lead values at sample site CL-2 are below the 25th percentile (Q1) of the three upper lakes sites indicating a significant decline from upper to lower lake sites. Several sample results below minimum reporting limit for copper, arsenic and lead at CL-2 indicate a similar decline in metal concentration from upper to lower lake sites.

11846 *Figure 3-258. Clinton Lake Water Clarity Metrics 2010–2019*

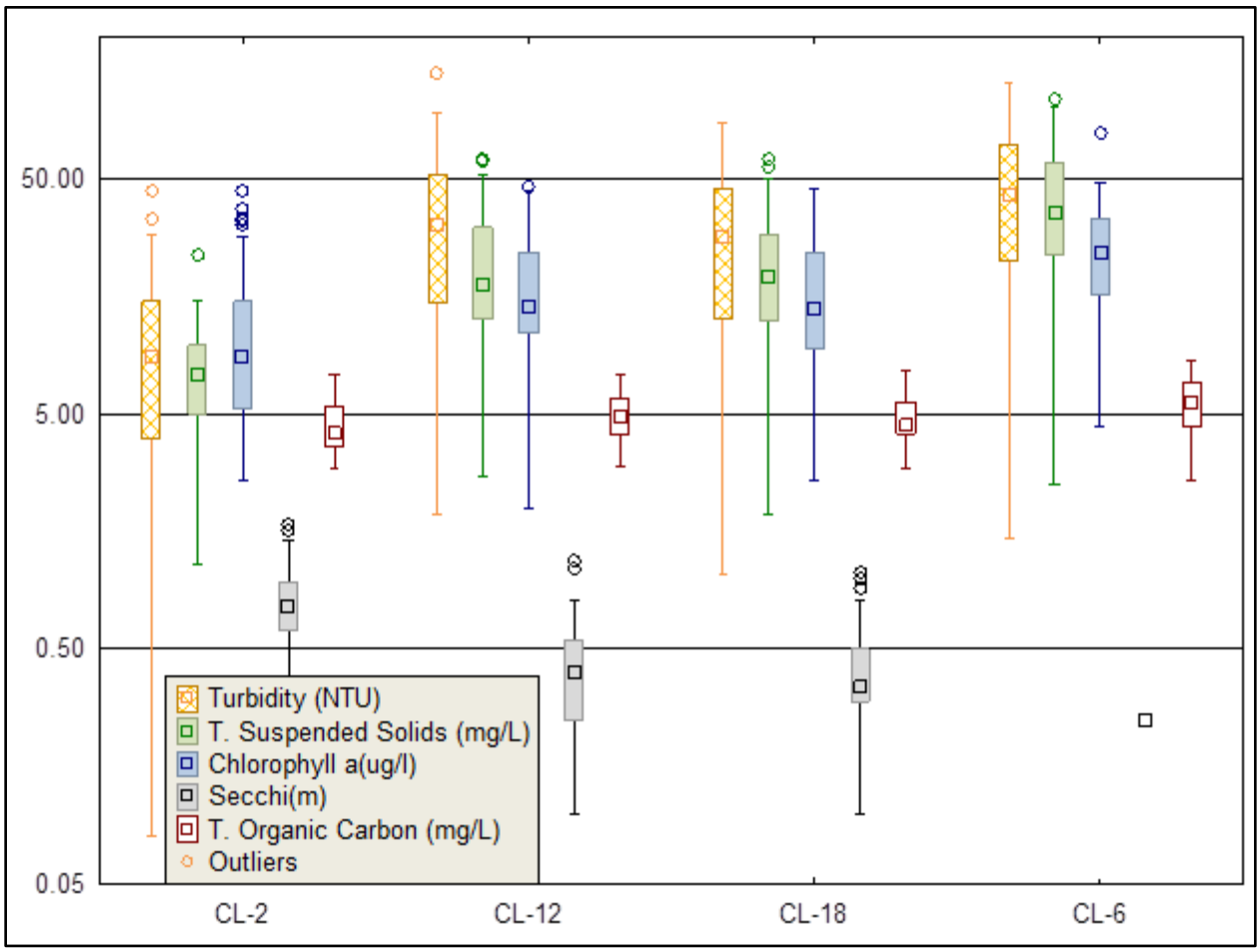


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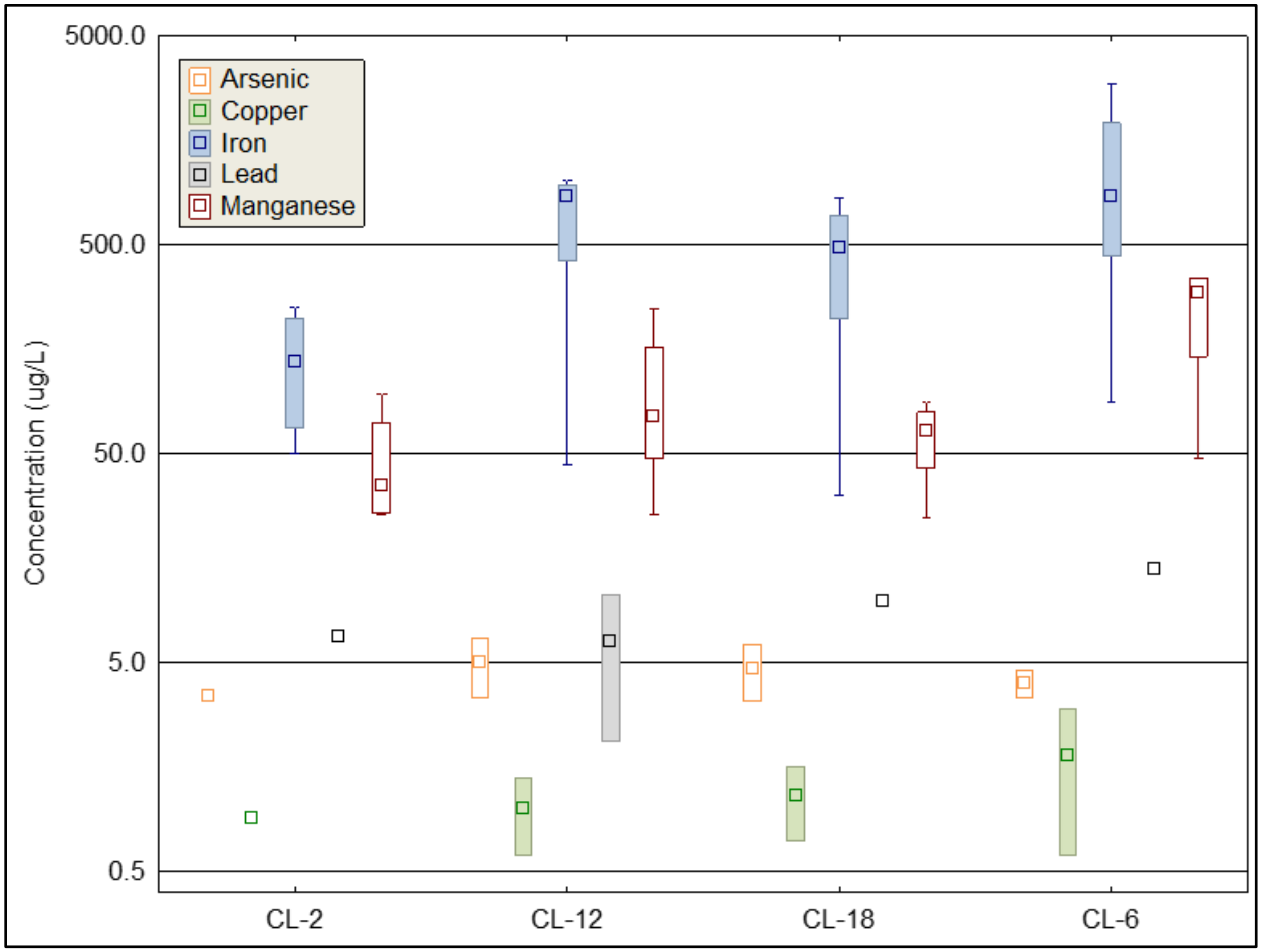
Figure 3-259. Clinton Lake Total Metal Concentration 2010–2019



Water quality chemistry differences between surface and bottom samples at Clinton Lake site nearest the dam (CL-2) are described in statistical summary Table 3-131. USACE collects bottom samples routinely from Kansas City District lakes every third year with total metals collected during the month of August when stratified conditions are most likely to show increased metal solubility due to anoxic conditions near the bottom. When the lake is not stratified (mixed) bottom sample results are similar to surface sample results for most analytes. Clinton Lake chemical results were significantly different (Wilcoxon Signed-Rank Test; $p<0.05$) between top and bottom sample groups for ammonia, total phosphorus, total orthophosphate, total suspended solids, total iron, and total manganese.

11862 *Table 3-134. Clinton Lake Summary Statistics for Chemical Water Quality Parameters 2010–2019[1]*
11863 *(sheet 1 of 2)*

Parameter	Sample Depth	Mean	SE	SD	Maximum	Median	Minimum	N
Ammonia (mg/L)	Surface	0.04	0.01	0.04	0.14	0.04	0.02	60
Ammonia (mg/L)	Bottom	0.14	0.06	0.21	0.74	0.03	0.02	14
NO_3/NO_2 (mg/L)	Surface	0.08	0.01	0.11	0.47	0.02	0.007	60
NO_3/NO_2 (mg/L)	Bottom	0.16	0.05	0.20	0.76	0.11	0.01	14
TKN (mg/L)	Surface	0.58	0.04	0.29	1.30	0.56	0.14	60
TKN (mg/L)	Bottom	0.86	0.19	0.69	2.70	0.59	0.14	14
Total Nitrogen (mg/L)	Surface	0.66	0.04	0.30	1.31	0.66	0.15	60
Total Nitrogen (mg/L)	Bottom	1.02	0.22	0.84	3.46	0.66	0.29	14
Total Phosphorus (mg/L)	Surface	0.06	0.01	0.03	0.16	0.05	0.01	60
Total Phosphorus (mg/L)	Bottom	0.11	0.03	0.12	0.50	0.06	0.01	14
Total Orthophosphate (mg/L)	Surface	0.02	0.01	0.02	0.07	0.01	0.01	60
Total Orthophosphate (mg/L)	Bottom	0.04	0.02	0.06	0.18	0.01	0.01	14
Total Suspended Solids (mg/L)	Surface	8.02	0.70	5.42	37.00	7.20	1.00	60
Total Suspended Solids (mg/L)	Bottom	18.26	3.08	11.53	45.00	14.00	6.60	14
Total Organic Carbon (mg/L)	Surface	4.94	0.45	2.61	16.10	4.20	2.90	33
Total Organic Carbon (mg/L)	Bottom	4.64	0.30	0.91	6.15	4.30	3.70	9
Chlorophyll *a* (ug/L)	Photic Zone	11.9	1.29	9.43	44.0	8.7	2.6	53
Total Iron (ug/L)	Surface	175.43	49.68	86.05	252.00	192.00	82.30	4

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Table 3-135. Clinton Lake Summary Statistics for Chemical Water Quality Parameters 2010–2019[1] (sheet 2 of 2)

Parameter	Sample Depth	Mean	SE	SD	Maximum	Median	Minimum	N
Total Iron (ug/L)	Bottom	1084.7	639.29	1278.59	2930.0	679.50	49.80	4
Total Manganese (ug/L)	Surface	181.58	126.69	253.38	559.00	70.40	26.50	4
Total Manganese (ug/L)	Bottom	661.43	461.06	922.11	2030.00	295.00	25.70	4

Note: [1]Summary statistics for chemical water quality parameters from Clinton Lake site near the dam (CL-2), April 2010 through September 2019.

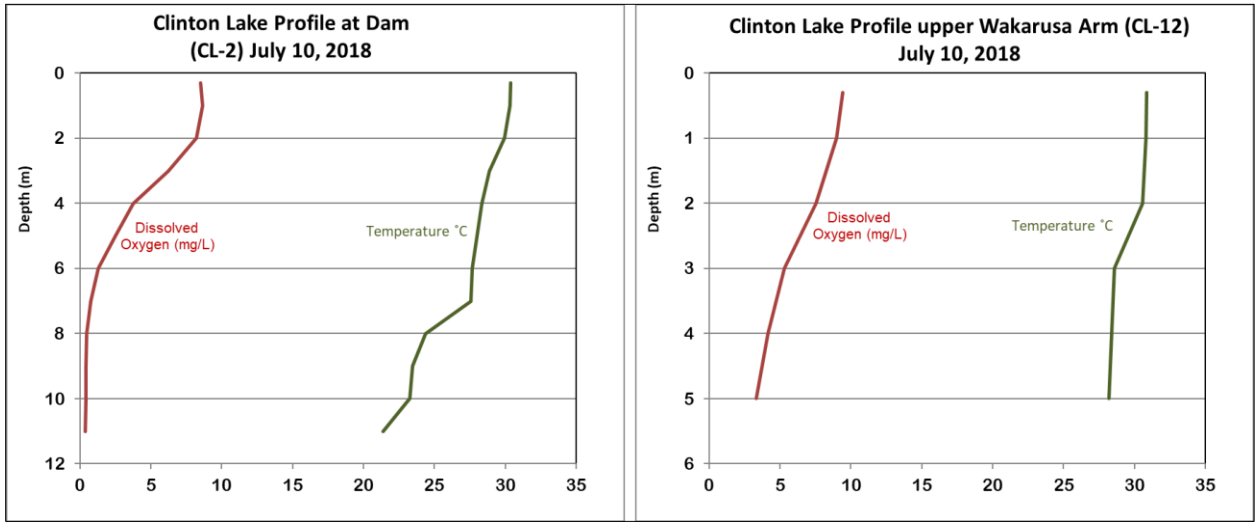
Physical water quality differences between surface and bottom samples pooled from all Clinton Lake water quality sites are described in statistical summary Table 3-132. USACE collects physical water quality data profiles at all lakes sites monthly during sampling season. Reduced habitat availability due to low D.O. and elevated temperature during short periods of thermal stratification is common below the thermocline as noted near the dam (CL-2) in Figure 3-260. Upper lake sites typically mix enough to prevent formation of a thermocline but still experience lower oxygen near the bottom without being anoxic as illustrated at site CL-12 in Figure 3-260. Dissolved oxygen sag may occur during low light conditions and/or large inflows combined with extended periods of cloudy weather. Dissolved oxygen sags from respiration caused by excess algae production, as defined by chlorophyll *a* concentration exceeding 12 ug/L (Figure 3-260, Table 3-132), is the most common short-term impact of eutrophication and is basis for TMDL on Clinton Lake.

Table 3-136. Clinton Lake Summary Statistics for Physical Water Quality Parameters 2010–2019[1]

B	Sample Depth	Mean	SE	SD	Maximum	Median	Minimum	N
Oxygen, Dissolved (mg/l)	Surface	8.3	0.1	1.4	12.0	8.1	4.7	124
Oxygen, Dissolved (mg/l)	Bottom	5.0	0.3	3.0	10.5	6.6	0.1	127
Water Temperature (°C)	Surface	24.2	0.5	5.2	32.9	25.7	9.4	124
Water Temperature (°C)	Bottom	21.3	0.4	4.9	29.5	22.8	8.9	127
pH (Standard Units)	Surface	8.2	0.03	0.3	9.3	8.2	7.6	124
pH (Standard Units)	Bottom	7.9	0.03	0.4	8.6	7.9	7.1	127
Secchi Depth (m)	Surface	0.6	0.03	0.3	1.9	0.5	0.1	108
Secchi Depth (m)	Bottom							NA
Specific Conductance (µS/cm)	Surface	327.9	3.9	43.3	523.0	323.6	223.3	124
Specific Conductance (µS/cm)	Bottom	331.6	3.6	40.6	414.1	327.0	242.9	127
Turbidity, Field (NTU)	Surface	23.9	4.4	48.9	501	13.2	1.0	124
Turbidity, Field (NTU)	Bottom	54.1	6.2	58.6	580.2	30.4	1.0	125

Note: Summary statistics for physical water quality parameters, from all sites and dates, Clinton Lake, April 2010 through September 2019.

Figure 3-260. Clinton Lake Representative Temperature and Dissolved Oxygen Profile 2018



Lake-bed Sediment Quality

Sediment quality (i.e., nutrients and contaminants) is frequently ignored in water quality discussions until aging lakes begin to release or “recycle” nutrients (e.g., phosphorus) back into the water column by various mechanisms (Pettersson 1998; Søndergaard et al. 2003) and/or sediment removal discussions trigger contaminant concerns (Peterson, S.A. 1984). Kansas City District Water Quality Program initiated collection of baseline lake-bed sediment data focused on nutrients and herbicides at Clinton Lake in 2016 (Figure 3-261).

Median concentrations of nitrogen, manganese, and iron from Clinton Lake-bed samples ranked as top two of seven Kansas City District Lakes in the Kansas River watershed (Figure 3-172) while sediment phosphorus ranks near the median for District lakes. Median total nitrogen and total phosphorus bed sediment results from 2016 and 2019 Kansas City District bed sediment results (Figure 3-261) from all Clinton Lake sites were 775 mg/kg and 852 mg/kg, respectively. A study of Clinton Lake-bed sediment by USGS (Juracek 2011b) reported higher median nutrient values of 2,300 mg/kg and 990 mg/kg, respectively with uniform nitrogen distribution between lake sites and in core samples indicating consistent nitrogen inputs over time with inconclusive trend results to clearly define a possible increase in phosphorus inputs over time. Clinton Lake sediment concentrations of arsenic, cadmium, and nickel exceeded the respective threshold-effects guidelines (MacDonald et al. 2000) in which toxic biological effects occasionally occur. This is typical for reservoirs in eastern Kansas (Juracek, 2003, 2004; Juracek and Mau 2002) and comparable TEC exceedances for arsenic, chromium, and nickel reported for Clinton Lake sediment USGS (Juracek 2011b). Metal and trace element concentrations reported by USGS and Kansas City District bed sediment results (Figure 3-261) did not exceed the “probable effect concentration” (PEC) in which harmful effects to sediment dwelling aquatic organisms are likely to be observed.

Figure 3-261. Clinton Lake Chemical Concentration in Lake Bed Sediment Samples 2016 and 2019

Station	Date	Ammonia MG/KG	Total Nitrogen MG/KG	Phosphorus MG/KG	Copper MG/KG	Iron MG/KG	Lead MG/KG	Manganese MG/KG	Nickel MG/KG	Zinc MG/KG	Arsenic MG/KG	Cadmium MG/KG	Chromium MG/KG
CL-12	9/13/2016	212.0	1983.0	1010.0	22.0	36900.0	24.1	1440.0	38.8	120.0	15.3	1.0	37.7
CL-18	9/13/2016	50.4	1123.0	532.0	12.4	18600.0	14.2	599.0	22.2	62.9	9.7	0.7	19.9
CL-6	9/13/2016	66.6	1563.0	90.9	17.8	19700.0	16.2	435.0	28.7	74.8	8.1	1.1	22.6
Site Median		**66.6**	**1563.0**	**532.0**	**17.8**	**19700.0**	**16.2**	**599.0**	**28.7**	**74.8**	**9.7**	**1.0**	**22.6**
Mean		**109.7**	**1556.3**	**544.3**	**17.4**	**25066.7**	**18.2**	**824.7**	**29.9**	**85.9**	**11.0**	**0.9**	**26.7**
CL-12	9/17/2019	99.8	775.0	920.0	15.0	37500.0	21.4	416.0	34.1	68.0	6.8	0.5	12.6
CL-18	9/17/2019	85.4	676.0	874.0	15.0	33300.0	21.0	407.0	32.9	67.6	6.6	0.8	13.1
CL-2	9/17/2019	53.2	628.0	693.0	11.8	28200.0	15.6	358.0	25.0	49.1	6.1	0.3	11.5
CL-6	9/17/2019	99.2	664.0	852.0	15.2	33700.0	20.1	294.0	32.4	66.1	6.2	0.8	13.0
Site Median		**92.3**	**670.0**	**863.0**	**15.0**	**33500.0**	**20.6**	**382.5**	**32.7**	**66.9**	**6.4**	**0.6**	**12.8**
Mean		**84.4**	**685.8**	**834.8**	**14.3**	**33175.0**	**19.5**	**368.8**	**31.1**	**62.7**	**6.4**	**0.6**	**12.6**

3.7.4.2 Upstream U.S. Bureau of Reclamation Reservoirs

Six USBR reservoirs in the Kansas River watershed are described herein using USBR documents and water quality data and TMDL information provided by KDHE. Hydrological and water management data was provided by USACE using HEC-DSSVue.

For detailed information on sample collection methods, see the Lake and Wetland Chemistry Monitoring Program Quality Assurance Management Plan. Website link: http://www.kdheks.gov/environment/qmp/download/Lake_and_Wetland_Part_III.pdf.

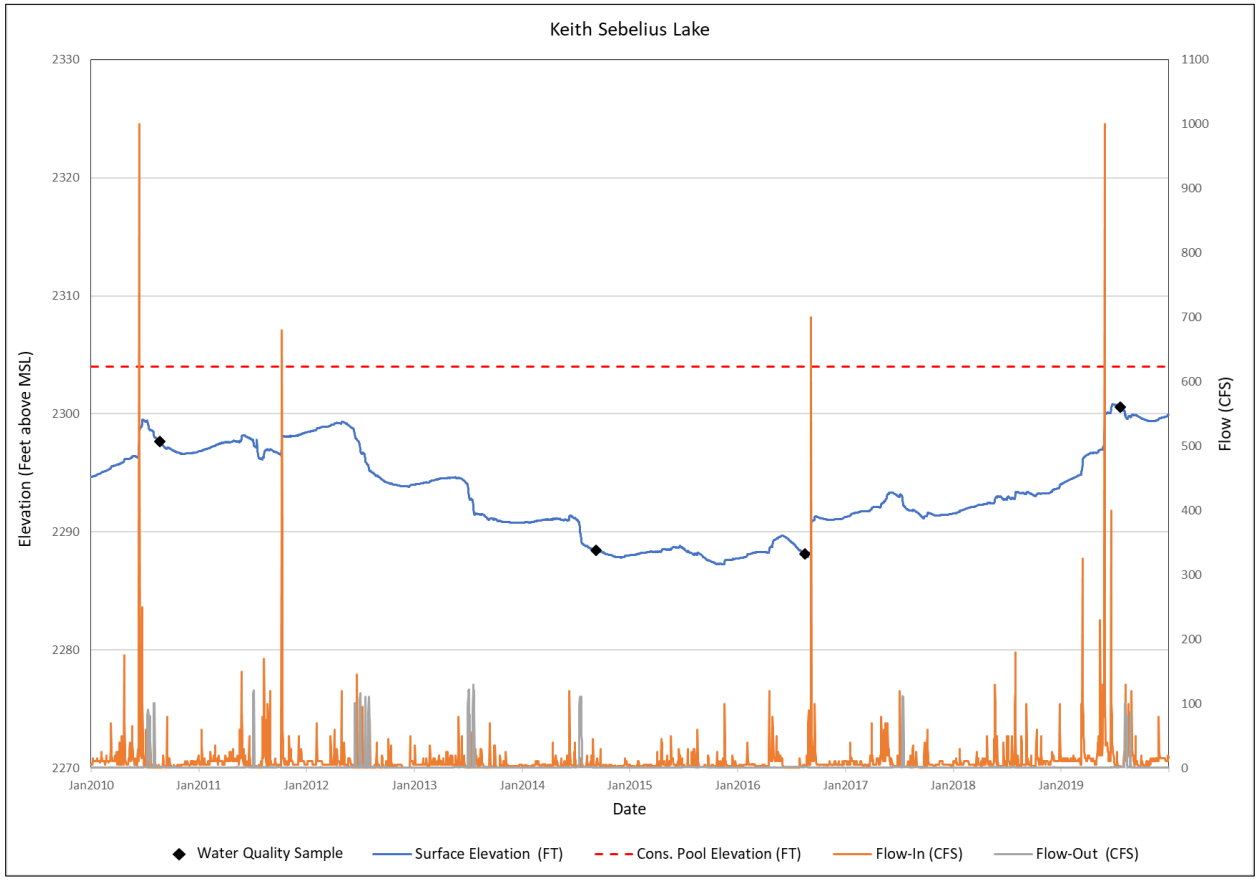
3.7.4.2.1 Keith Sebelius Lake

Keith Sebelius Lake (multipurpose pool area of 2,181 acres, volume of 34,510 acre-feet, and a 715 mi^2 drainage area) was created in 1967 in Norton County, Kansas on the Prairie Dog Creek as part of USBR water supply project called the Almena Unit. The project consists of Norton Dam and Keith Sebelius Reservoir (formerly Norton Reservoir), Almena Diversion Dam, Almena Main and South Canals, and a system of laterals and drains serving 5,763 acres of project lands and the city of Norton, Kansas. Flood protection, recreation, and fish and wildlife benefits are also project purposes as authorized by the Flood Control Act of 1946.

Reservoir Hydrologic Data Summary

Surface elevation of Keith Sebelius Lake did not meet multipurpose pool elevation in 2010–2019 evaluation period (Figure 3-262). Four water quality sampling events are plotted with lake surface elevation for reference. Water quality sampling in 2019 followed the most significant pool raise of the decade. Low inflow periods were observed in 2012–2015 with surface elevation falling 17 feet below multipurpose pool while recovery period is apparent beginning fall of 2017.

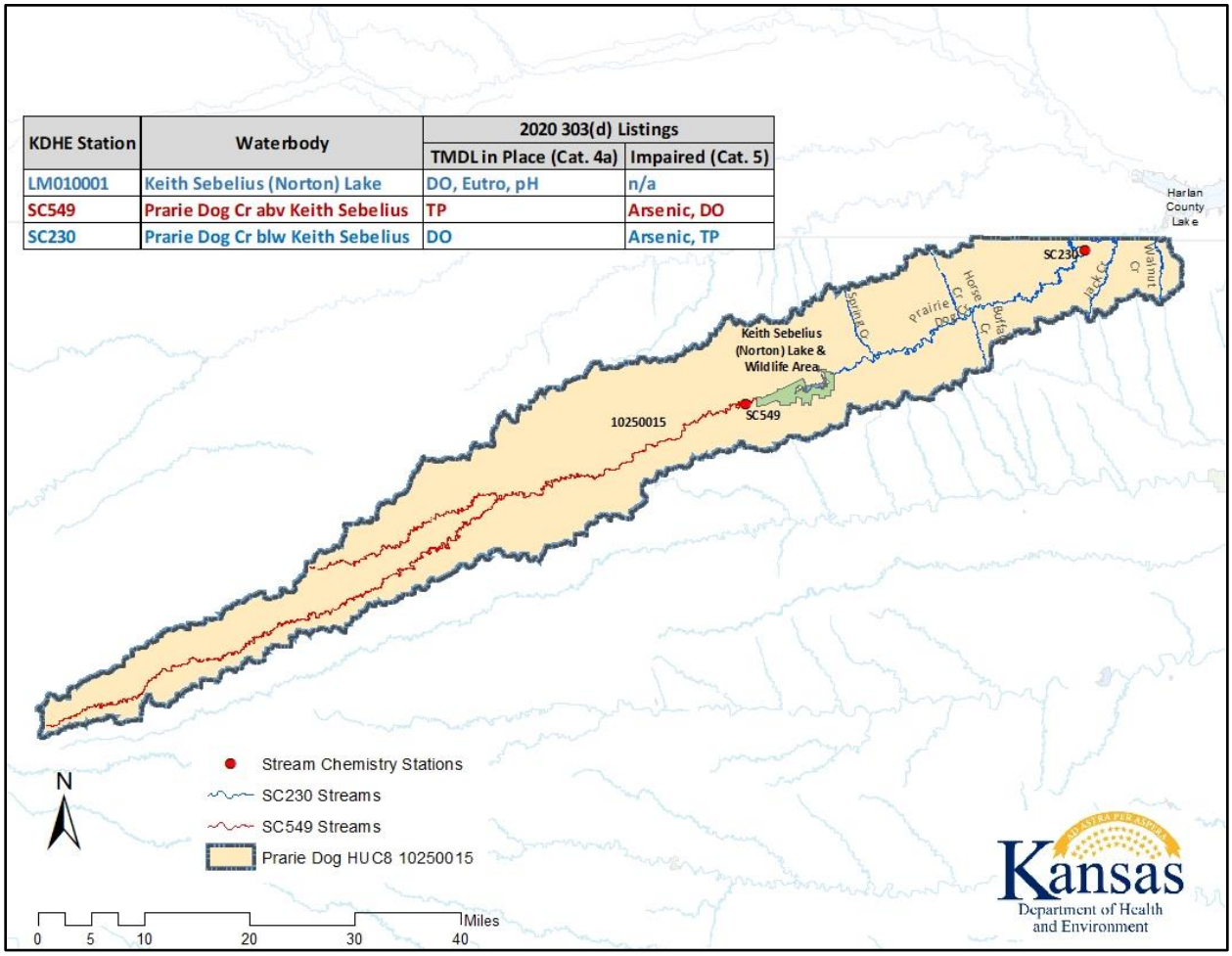
Figure 3-262. Keith Sebelius Lake Time Series of Daily Water Surface Elevation and Pool Information



Impairments

Impairments to Keith Sebelius Lake and Prairie Dog Creek are associated with high phosphorus load and naturally occurring arsenic in the watershed (Figure 3-263). The TMDL designated for accelerated eutrophication or enrichment from phosphorus is linked to increased aquatic plant growth as measured by average chlorophyll *a* concentration exceeding 12 ug/L (KDHE 2003a). Prolific algae growth can be beneficial algae or cyanobacteria but high densities create conditions for secondary water quality problems for aquatic life also listed as TMDLs for dissolved oxygen sags and elevated pH. To determine impairments (TMDLs) for Upper and Lower Prairie Dog Creek, and Keith Sebelius Lake, Prairie Dog Creek WRAPS consulted with KDHE to determine load reductions targets needed for focused BMPs and water quality milestones for Keith Sebelius Lake (Norton Lake in WRAPS Plan) (KDHE 2012a).

Figure 3-263.Keith Sebelius Lake Impaired Waters and Total Maximum Daily Loads



Field Measured Water Quality Data Summary

Physical water quality conditions for Keith Sebelius Lake are provided in Figure 3-264. Minimum dissolved oxygen value of 5 mg/L and maximum pH of 8.3 represent the worst conditions for two variables collected during the sample period for surface samples. These values do not exceed their respective water quality criteria as observed in Prairie Dog Creek data used for TMDL justification (KDHE 2003a). Mean and median Secchi values of approximately one meter and median turbidity of 8.6 NTU provide for a functional photic zone and do not suggest light limitation to productivity, similar to previous water quality report for Keith Sebelius (Norton) Lake (KDHE 2012b).

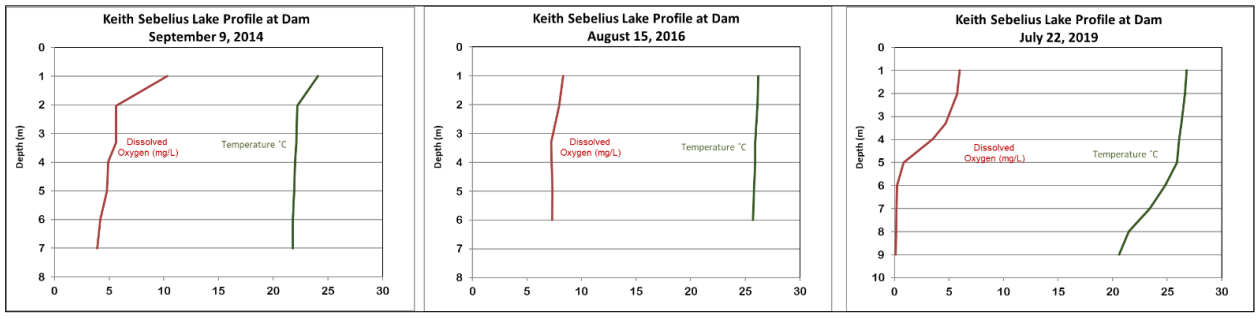
Temperature and dissolved oxygen profiles for field data collected from 2014–2019 are presented in Figure 3-265. Weak thermal stratification occurs for short periods of time on many shallow Kansas lake as frequent wind mixing frequently destabilizes thermocline formations. Increased water depth and a likely increase in biochemical oxygen demand associated with nutrient pulse from large inflow provided better conditions for thermal stratification at Keith Sebelius and other Kansas lakes in 2019 as evidence of a defined thermocline with dissolved oxygen and temperature decline at 5

meters of depth. The profiles for 2014 and 2016 are more common during summer conditions at the USBR Lakes in Kansas.

Figure 3-264. Physical Water Quality Statistics From Kanasas Department of Health and Environment Field Measurements of Keith Sebelius Lake From 2010–2019

Variable	Keith Sebelius Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
D.O. mg/L	8	7.47	7.17	5.00	10.51	5.53	9.44	2.27	0.80
Temp °C	10	26.15	26.60	24.20	27.00	26.00	27.00	1.07	0.34
Secchi (m)	4	0.99	0.97	0.58	1.45	0.61	1.38	0.45	0.22
pH	8	8.17	8.20	7.89	8.30	8.07	8.30	0.16	0.06
Conductivity umho/cm	8	734.56	730.00	632.90	840.00	651.80	820.00	91.38	32.31
Turbidity NTU	8	9.39	8.64	4.30	17.00	4.76	13.50	5.19	1.84

Figure 3-265. Keith Sebelius Lake Representative Temperature and Dissolved Oxygen Profiles 2014–2019



Laboratory Water Quality Analysis Summary

Water quality sample laboratory results from KDHE Monitoring and Analysis Unit are provided for Keith Sebelius Lake in Figure 3-266. Values below minimum reporting limits influence sample size in some analytes (e.g., zinc and total suspended solids) while other analytes (e.g., ammonia, orthophosphate, mercury) measured below reporting limits in all samples and consequently were omitted from results table.

Pesticide detections were infrequent and well below KDHE surface water quality standards numeric criteria (KDHE 2018). Atrazine is the most common pesticide found in Kansas lakes. Maximum concentrations of atrazine did not exceed EPA drinking water criteria of 3 ug/L.

Total nitrogen mean value at Keith Sebelius Lake was 1.16 mg/L which compares to the high nitrogen USACE lakes (e.g., Tuttle Creek, Perry, and Milford lakes) (Figure 3-163) and exceeds EPA Ecoregional Recommended Criteria of 0.62 mg/L (EPA 2001). Total nitrogen mean was less than 10-year lake milestone of 1.17 mg/L defined in WRAPS 9-Element for 2011-2020 (KDHE 2012a).

Keith Sebelius Lake total phosphorus mean of 0.182 mg/L is above the hypereutrophic threshold (Carlson 1977) and more than two times the 10-year lake milestone of 0.078 mg/L defined in WRAPS 9-Element for 2011-2020 (KDHE 2012a). Eutrophic conditions with high phosphorus load have combined with adequate water clarity to increase algal production. Mean chlorophyll a concentration of 31.2 ug/L was more than two times the WRAPS 10-year lake milestone of 12.2 ug/L as well as TMDL goal (KDHE 2003a). Cyanobacteria blooms have led to increased HAB Warnings due to toxic algae including

the most recent public health warning lasting 5 weeks of the recreational season of 2022.

Bromide concentrations are of concern for water treatment operations due to byproducts as bromide is converted to bromate in their treatment process and there are EPA disinfection byproduct limitations on the amounts of bromate (KWO personal communication, 2022). Increasing bromide trends from 1995 to present in Upper Republican watershed, including Prairie Dog Creek subbasin, is of concern for future water supply. Median Keith Sebelius Lake bromide concentration of 0.48 mg/L is nearly twice the median bromide value of 1995-2019 Prairie Dog Creek values (KDHE unpublished report).

Total metals in Keith Sebelius Lake surface samples did not exceed Kansas Surface Water Quality numeric criteria including Domestic Water Supply of 0.010 mg/L of total arsenic (KDHE 2018).

Figure 3-266. Water Quality Chemistry Statistics From Kansas Department of Health and Environment Surface Samples of Keith Sebelius Lake From 2010–2019

Variable	Keith Sebelius Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
Atrazine µg/L	5	1.012	0.710	0.560	1.900	0.590	1.300	0.580	0.259
Metolachlor µg/L	1	0.330	0.330	0.330	0.330	0.330	0.330		
TKN nitrogen mg/L	8	1.168	1.180	0.770	1.600	0.855	1.450	0.340	0.120
T. nitrogen mg/L	8	1.168	1.180	0.770	1.600	0.855	1.450	0.340	0.120
Chlorophyll a µg/L	8	31.2	26.9	17.5	52.5	18.7	44.2	14.9	5.3
Alkalinity mg CaCO3/L	8	205.5	210.0	190.0	212.2	200.0	211.0	9.6	3.4
Bromide mg/L	8	0.537	0.485	0.250	0.930	0.345	0.730	0.265	0.094
Chloride mg/L	8	74.2	75.0	49.5	97.0	55.4	93.0	20.8	7.4
Sulfate mg/L	8	54.3	55.0	40.7	67.0	42.4	66.0	12.6	4.4
Total organic carbon mg/L	8	9.149	9.150	8.141	10.000	8.376	10.000	0.822	0.291
Phosphorus mg/L	8	0.182	0.170	0.110	0.260	0.140	0.232	0.057	0.020
Total suspended solids mg/L	2	21.500	21.500	21.000	22.000	21.000	22.000	0.707	0.500
Arsenic mg/L	8	0.007	0.008	0.006	0.008	0.007	0.008	0.001	0.0002
Boron mg/L	8	0.122	0.123	0.078	0.170	0.086	0.155	0.039	0.014
Copper mg/L	5	0.002	0.001	0.001	0.002	0.001	0.001	0.000	0.0002
Iron mg/L	8	0.208	0.177	0.054	0.420	0.087	0.330	0.146	0.052
Magnesium mg/L	8	29.6	29.0	22.0	38.0	23.0	36.5	7.2	2.6
Manganese mg/L	8	0.120	0.113	0.090	0.159	0.093	0.149	0.030	0.011
Nickel mg/L	8	0.002	0.002	0.001	0.002	0.001	0.002	0.0003	0.0001
Selenium mg/L	6	0.002	0.003	0.002	0.003	0.002	0.003	0.001	0.0002
Zinc mg/L	1	0.007	0.007	0.007	0.007	0.007	0.007		
Strontium mg/L	6	0.546	0.575	0.479	0.590	0.479	0.580	0.053	0.021
Uranium mg/L	5	0.006	0.006	0.003	0.006	0.006	0.006	0.001	0.001

3.7.4.2.2 Lovewell Lake

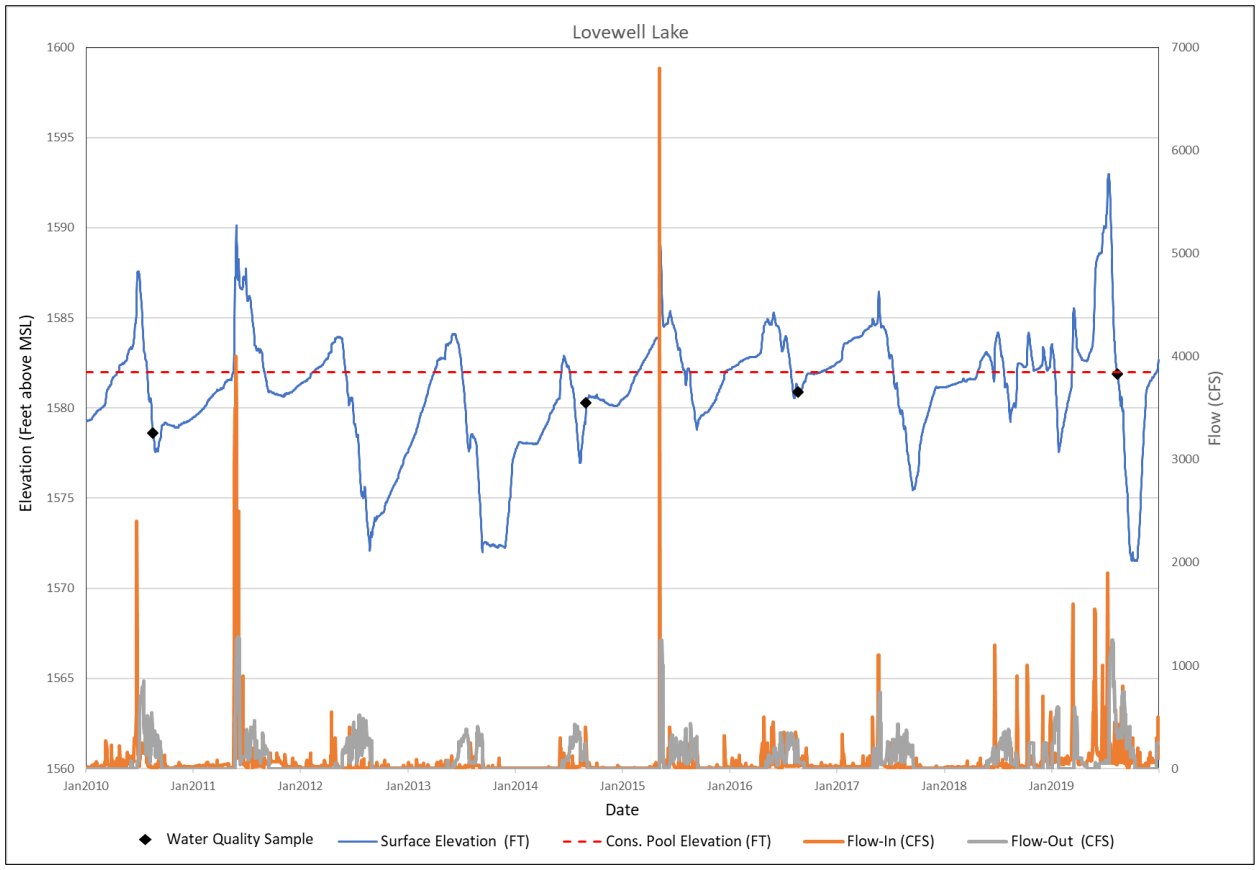
Lovewell Lake in Jewell County, Kansas, was completed on White Rock Creek in the Republican River basin in 1957 for flood control and irrigation. Lovewell Lake is managed by USBR with recreation bolstered by a popular state park managed by KDWP including 2,215 acres of land adjacent to the 2,987-acre lake.

Reservoir Hydrologic Data Summary

Surface elevation of Lovewell Lake moves around multipurpose pool elevation as flood control and irrigation requirements were apparent during 2010–2019 period (Figure 3-267). Four water quality sampling events are plotted with lake surface elevation for reference. Water quality sampling events were near normal pool including 2019 which

followed a significant pool fluctuation but occurred at multipurpose pool elevation. Low periods of inflow were observed in 2012–2015 with multipurpose pool elevation attained annually during the spring rise.

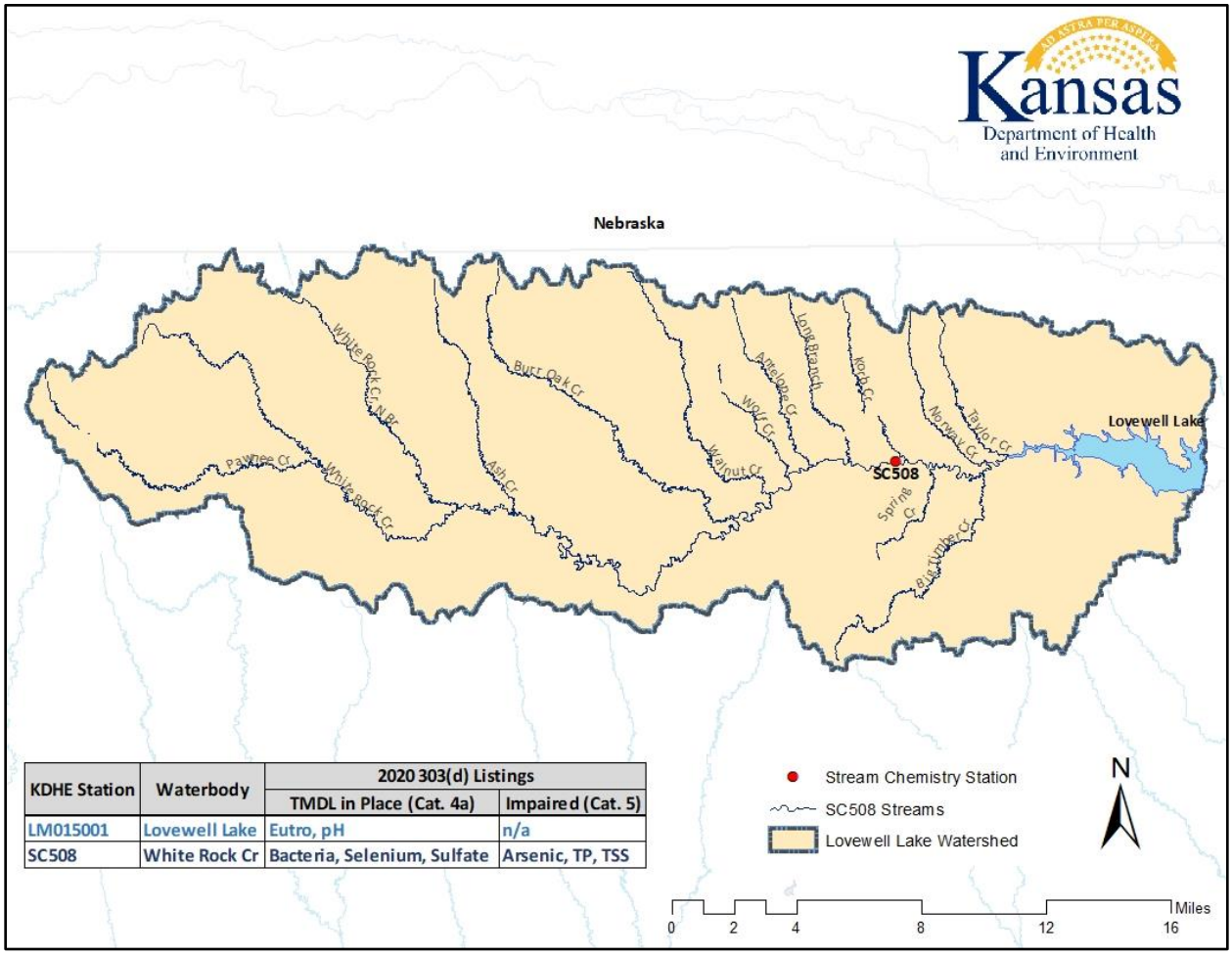
Figure 3-267. Lovewell Lake Time Series of Daily Water Surface Elevation and Pool Information



Impairments

Impairments to Lovewell Lake and White Rock Creek are associated with high phosphorus load and naturally occurring arsenic and selenium in the watershed (Figure 3-268). The TMDL designated for accelerated eutrophication or enrichment from phosphorus is linked to increased aquatic plant growth as measured by average chlorophyll *a* concentration exceeding 12 ug/L and resulting in elevated pH (KDHE 2003a).

12046 *Figure 3-268. Lovewell Lake Impaired Waters and Total Maximum Daily Loads*



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM015001	Lovewell Lake	Eutro, pH	n/a
SC508	White Rock Cr	Bacteria, Selenium, Sulfate	Arsenic, TP, TSS

12047

12048 **Field Measured Water Quality Data Summary**

12049 Physical water quality conditions for Lovewell Lake are provided in Figure 3-269.
12050 Daytime conditions recorded by field staff highlight minimum dissolved oxygen value of
12051 6.4 mg/L and maximum pH of 8.1 as the worst conditions for two variables potentially
12052 impacted from eutrophication. These values do not exceed their respective water quality
12053 criteria. Mean and median Secchi values of less than 0.5 meter and median turbidity of
12054 24 NTU support the assertion that light limitation to primary productivity may occur at
12055 Lovewell Lake with high values for shading coefficient and non-algal turbidity reported
12056 by KDHE (2012).

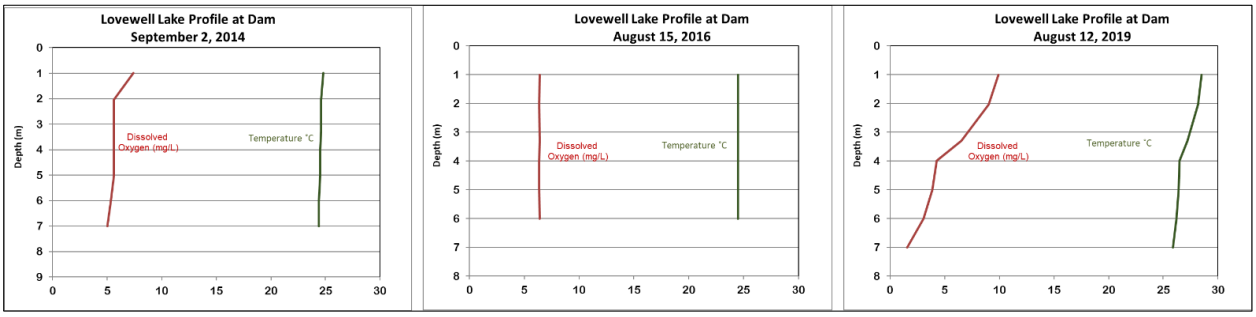
12057 Temperature and dissolved oxygen profiles for field data collected from 2014–2019 are
12058 presented in Figure 3-270. Weak thermal stratification occurs for short periods of time
12059 on many shallow Kansas lakes as frequent wind mixing frequently destabilizes
12060 thermocline formations. Increased water depth and a likely increase in biochemical
12061 oxygen demand associated with nutrient pulse from large inflow provided conditions for
12062 rapid dissolved oxygen decline at depth of 4 meters with minor evidence of thermal
12063 stratification at Lovewell Lake in 2019. The profiles for 2014 and 2016 show full mixing

from top to bottom which are more common during summer conditions at the USBR Lakes in Kansas.

Figure 3-269. Physical Water Quality Statistics from Kansas Department of Health and Environment Field Measurements of Lovewell Lake from 2010–2019

Variable	Lovewell Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
D.O. mg/L	8	8.09	7.82	6.43	9.93	6.85	9.52	1.45	0.51
Temp °C	10	26.75	27.10	24.40	29.00	25.00	28.40	1.79	0.57
Secchi (m)	4	0.41	0.42	0.37	0.45	0.38	0.45	0.04	0.02
pH	8	7.92	8.01	7.50	8.10	7.80	8.07	0.23	0.08
Conductivity umho/cm	8	605.76	600.00	590.00	633.50	590.00	621.30	18.97	6.71
Turbidity NTU	8	22.24	24.00	11.00	32.70	17.60	25.50	7.27	2.57

Figure 3-270. Lovewell Lake Representative Temperature and Dissolved Oxygen Profiles 2014–2019



Laboratory Water Quality Analysis Summary

Water quality sample laboratory results from KDHE Monitoring and Analysis Unit are provided for Lovewell Lake in Figure 3-271. Values below minimum reporting limits influence sample size in some analytes (e.g., nitrate, metolachlor) while other analytes (e.g., zinc, ammonia, orthophosphate, mercury) measured below reporting limits in all samples and consequently were omitted from results table.

Pesticide detections were infrequent and well below KDHE surface water quality standards numeric criteria (KDHE 2018). Atrazine is the most common pesticide found in Kansas lakes. Maximum concentrations of atrazine did not exceed EPA drinking water criteria of 3 ug/L.

Total nitrogen mean value at Lovewell Lake was 1.1 mg/L which compares to the high nitrogen USACE lakes (e.g., Tuttle Creek, Perry, and Milford lakes) (Figure 3-163) and exceeded EPA Ecoregional Recommended Criteria of 0.62 mg/L (EPA 2001). Soluble nutrients like ammonia and nitrate were relatively low concentration.

Lovewell Lake total phosphorus mean of 0.292 mg/L is above the hypereutrophic threshold (Carlson 1977) and is the primary cause of eutrophic conditions leading to biological response of increased algal production. Mean chlorophyll a concentration of 47.3 ug/L far exceeds hypereutrophic threshold of 30 ug/L (KDHE 2003a). Cyanobacteria typically comprises less than 60 percent of the phytoplankton population at Lovewell Lake according to KDHE report (2012). The most recent KDHE issued HAB warning was June 2021 which resulted in state park beach closure.

Total metals in Keith Sebelius Lake surface samples did not exceed Kansas Surface Water Quality numeric criteria with exception of one sample matching the Domestic Water Supply criteria of 0.010 mg/L of total arsenic (KDHE 2018).

Figure 3-271. Water Quality Chemistry Statistics from Kansas Department of Health and Environment Surface Samples of Lovewell Lake from 2010–2019

Variable	Lovewell Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
Atrazine µg/L	4	0.998	1.005	0.780	1.200	0.845	1.150	0.188	0.094
Metolachlor µg/L	1	0.580	0.580	0.580	0.580	0.580	0.580		
Nitrate mg/L	4	0.282	0.282	0.200	0.364	0.200	0.364	0.094	0.047
TKN nitrogen mg/L	8	0.975	1.035	0.490	1.395	0.740	1.184	0.326	0.115
T. nitrogen mg/L	8	1.116	1.135	0.490	1.758	0.805	1.401	0.454	0.161
Chlorophyll a µg/L	8	47.36	47.22	39.97	55.34	42.51	52.05	5.56	1.97
Alkalinity mg CaCO3/L	8	192.81	195.00	180.00	201.42	185.00	200.52	9.17	3.24
Bromide mg/L	6	0.431	0.348	0.290	0.660	0.300	0.640	0.171	0.070
Chloride mg/L	8	26.93	26.83	22.00	32.00	24.50	29.38	3.48	1.23
Sulfate mg/L	8	78.18	74.00	73.00	90.88	74.00	82.80	7.77	2.75
Total organic carbon mg/L	8	7.151	7.273	6.300	7.900	6.432	7.800	0.718	0.254
Phosphorus mg/L	8	0.292	0.282	0.260	0.350	0.265	0.317	0.034	0.012
Total suspended solids mg/L	8	22.88	21.50	11.00	39.00	12.00	33.00	11.57	4.09
Arsenic mg/L	8	0.009	0.009	0.008	0.010	0.008	0.009	0.001	0.000
Boron mg/L	8	0.090	0.089	0.069	0.120	0.076	0.100	0.018	0.006
Copper mg/L	6	0.002	0.002	0.002	0.002	0.002	0.002	0.000	0.000
Iron mg/L	8	0.454	0.430	0.250	0.727	0.265	0.633	0.198	0.070
Magnesium mg/L	8	18.32	18.49	15.00	22.00	16.28	20.00	2.52	0.89
Manganese mg/L	8	0.102	0.104	0.092	0.110	0.094	0.110	0.009	0.003
Nickel mg/L	8	0.002	0.002	0.002	0.003	0.002	0.003	0.000	0.000
Selenium mg/L	8	0.002	0.002	0.002	0.003	0.002	0.003	0.000	0.000
Strontium mg/L	8	0.566	0.565	0.550	0.586	0.555	0.576	0.013	0.005
Uranium mg/L	6	0.007	0.007	0.006	0.008	0.006	0.008	0.001	0.000

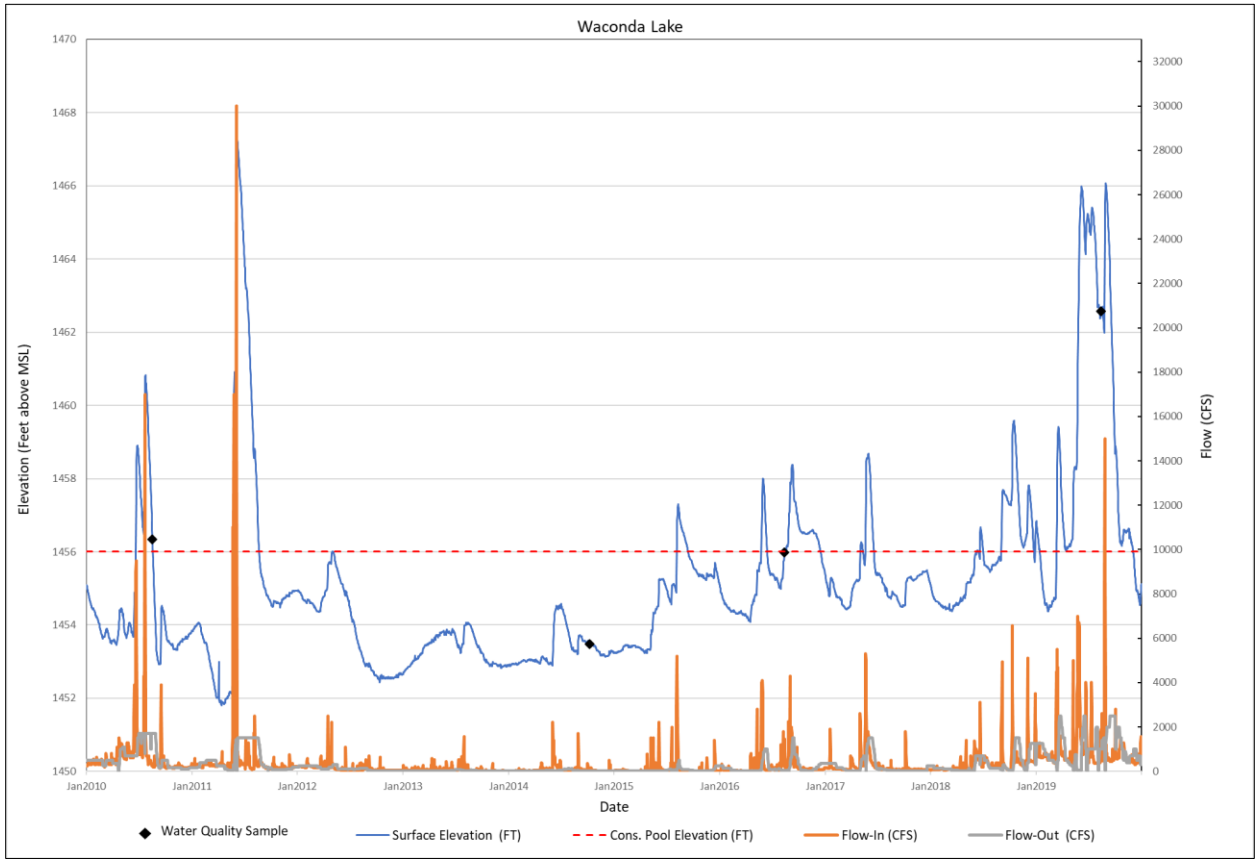
3.7.4.2.3 Waconda Lake

Glen Elder Dam forming Waconda Lake was completed in 1969. USBR describes benefits of flood protection to the lower Solomon River Valley and dependable water supply to Beloit and three rural water districts. Downstream water quality support and irrigation of approximately 30,000 acres are also listed as project purposes as authorized. Waconda Lake is 12,602 surface acres located in Mitchell and Osbourne Counties, Kansas, on the Solomon River flowing into the Smoky Hill River basin. KDWP manages 13,200 acres of wildlife area as well as Glen Elder State Park offering outstanding outdoor recreational opportunities for anglers, camping, swimming, bicycling, horseshoes, volleyball, softball, boating, archery, and water skiing.

Reservoir Hydrologic Data Summary

Surface elevation of Waconda Lake demonstrates a typical wave form of flood control and irrigation peaks associated with a spring rise/flood control while water supply and irrigation lend to the trough (Figure 3-272). Seasonal inflow events and flood control needs are noted in 2011 and 2019. Four water quality sampling events are plotted with lake surface elevation for reference. Water quality sampling events were near normal pool in 2010 and 2016 while 2019 sample event coincided with a significant pool fluctuation. Low inflow period was observed in 2013–2015 with multipurpose pool elevation attained annually during the spring rise after 2016.

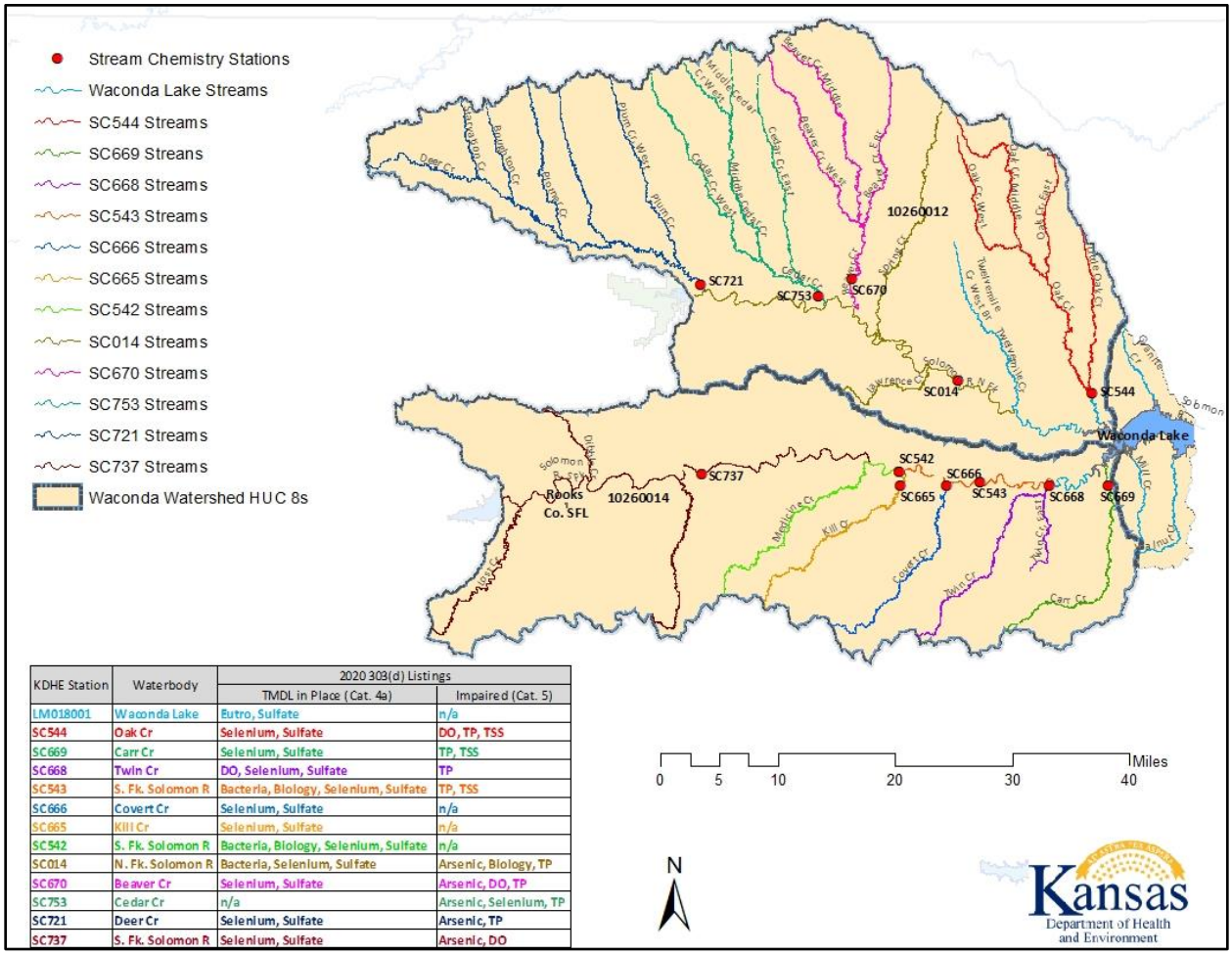
Figure 3-272. Waconda Lake Time Series of Daily Water Surface Elevation and Pool Information



Impairments

Waconda Lake TMDL is associated with high phosphorus from inflows captured by eutrophication TMDL and sulfates (Figure 3-273). The eutrophication TMDL hopes to curb enrichment from phosphorus which manifests in increased aquatic plant growth as measured by average chlorophyll *a* concentration exceeding 12 ug/L (KDHE 2003a). A range of TMDLs and impairments to inflow streams include high priority *E. coli* TMDL on South Fork Solomon River with others of lower priority related to nutrients, metals, and biological impairment (KDHE 2011c).

12129 *Figure 3-273. Waconda Lake Impaired Waters and Total Maximum Daily Loads*



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM018001	Waconda Lake	Eutro, Sulfate	n/a
SC544	Oak Cr	Selenium, Sulfate	DO, TP, TSS
SC669	Carr Cr	Selenium, Sulfate	TP, TSS
SC668	Twin Cr	DO, Selenium, Sulfate	TP
SC543	S. Fk. Solomon R	Bacteria, Biology, Selenium, Sulfate	TP, TSS
SC666	Covert Cr	Selenium, Sulfate	n/a
SC665	Kill Cr	Selenium, Sulfate	n/a
SC542	S. Fk. Solomon R	Bacteria, Biology, Selenium, Sulfate	n/a
SC014	N. Fk. Solomon R	Bacteria, Selenium, Sulfate	Arsenic, Biology, TP
SC670	Beaver Cr	Selenium, Sulfate	Arsenic, DO, TP
SC753	Cedar Cr	n/a	Arsenic, Selenium, TP
SC721	Deer Cr	Selenium, Sulfate	Arsenic, TP
SC737	S. Fk. Solomon R	Selenium, Sulfate	Arsenic, DO

12130

12131 **Field Measured Water Quality Data Summary**

12132 Physical water quality conditions for Waconda Lake are provided in Figure 3-274.
12133 Daytime field measurements of surface water near the dam are likely to provide the best
12134 of water quality results. Attenuation of nutrient and sediment impacts reported in inflow
12135 streams are evident as data presented from KDHE field samples in Figure 3-274
12136 describe optimum physical water quality for support of aquatic life.

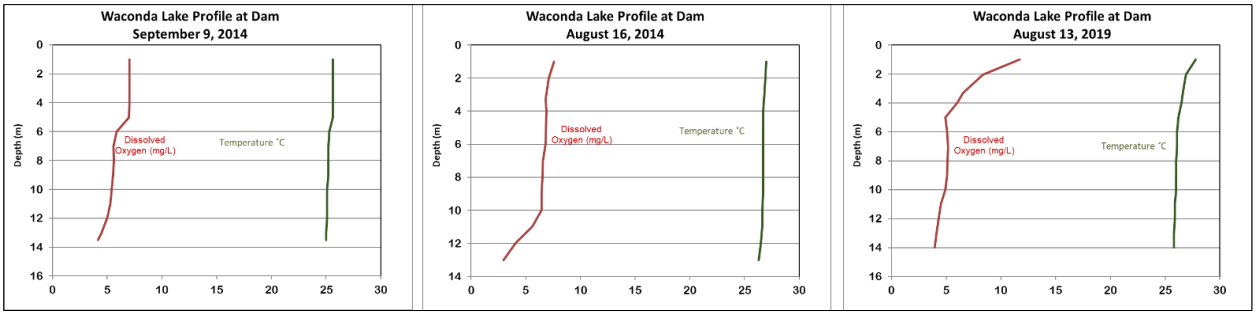
12137 Temperature and dissolved oxygen profiles for field data collected from 2014–2019 are
12138 presented in Figure 3-275. Weak thermal stratification occurs for short periods of time
12139 on many shallow Kansas lake as frequent wind mixing frequently destabilizes
12140 thermocline formations. Increased water depth and a likely increase in biochemical
12141 oxygen demand associated with nutrient pulse from large inflows provided better
12142 conditions for thermal stratification and rapid decline of dissolved oxygen with depth at
12143 Waconda Lake in 2019. Profiles for 2014 and 2016 are more common during summer
12144 conditions at Waconda Lake and other USBR Lakes in Kansas.

12145

Figure 3-274. Physical Water Quality Statistics from Kansas Department of Health and Environment Field Measurements of Waconda Lake From 2010–2019

Variable	Waconda Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
D.O. mg/L	8	8.31	7.35	6.97	11.62	7.09	9.52	2.01	0.71
Temp °C	10	27.31	27.90	25.60	28.10	27.00	28.00	0.99	0.31
Secchi (m)	4	1.13	1.01	0.92	1.60	0.96	1.31	0.31	0.16
pH	8	7.92	7.91	7.60	8.20	7.75	8.12	0.23	0.08
Conductivity umho/cm	8	956.29	937.60	850.00	1100.00	862.55	1050.00	107.50	38.01
Turbidity NTU	8	5.51	4.41	3.80	9.90	4.05	6.73	2.29	0.81

Figure 3-275. Waconda Lake Representative Temperature and Dissolved Oxygen Profiles 2014–2019



Laboratory Water Quality Analysis Summary

Water quality sample laboratory results from KDHE Monitoring and Analysis Unit are provided for Waconda Lake in Figure 3-276. Values below minimum reporting limits influence sample size in some analytes (e.g., nitrate, metolachlor, copper) while other analytes (e.g., ammonia, orthophosphate, mercury) measured below reporting limits in all samples and consequently were omitted from results table.

Pesticide detections were infrequent with atrazine and metolachlor maxima well below KDHE surface water quality standards numeric criteria (KDHE 2018). Atrazine is the most common pesticide found in Kansas lakes. Atrazine did not exceed EPA drinking water criteria of 3 ug/L.

Total nitrogen mean value at Waconda Lake was 0.92 mg/L which compares to the high nitrogen USACE lakes (e.g., Tuttle Creek, Perry, and Milford lakes) (Figure 3-163) and exceeds EPA Ecoregional Recommended Criteria for subecoregion 27 of 0.62 mg/L (EPA 2001). Soluble nutrients like ammonia and nitrate were relatively low in concentration or below reporting limits.

Waconda Lake total phosphorus mean of 0.104 mg/L is above the hypereutrophic threshold (Carlson 1977) and is the primary cause of eutrophic conditions leading to biological response of increased algal production. Similarly, mean chlorophyll concentration of 24.7 ug/L is considered eutrophic (KDHE 2003a). Cyanobacteria can dominate phytoplankton community with 91 percent blue-green cell composition reported in 2010 KDHE (2012). Cyanobacteria have not prompted KDHE HAB warnings in recent years.

Total metals in Waconda Lake surface samples did not exceed Kansas Surface Water Quality numeric criteria (KDHE 2018).

Figure 3-276. Water Quality Chemistry Statistics from Kansas Department of Health and Environment Surface Samples of Waconda Lake from 2010–2019

Variable	Waconda Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
Atrazine µg/L	4	1.275	1.300	1.100	1.400	1.200	1.350	0.126	0.063
Metolachlor µg/L	4	0.428	0.455	0.330	0.470	0.390	0.465	0.066	0.033
Nitrate mg/L	2	0.510	0.510	0.506	0.513	0.506	0.513	0.005	0.004
Nitrite mg/L	2	0.158	0.158	0.158	0.158	0.158	0.158	0.0000	0.0000
TKN nitrogen mg/L	8	0.750	0.755	0.650	0.840	0.685	0.815	0.076	0.027
T. nitrogen mg/L	8	0.917	0.755	0.650	1.503	0.685	1.151	0.355	0.125
Chlorophyll a µg/L	8	24.77	25.51	19.76	29.10	20.91	28.23	3.84	1.36
Alkalinity mg CaCO3/L	8	144.90	139.75	130.00	170.00	130.00	159.85	17.70	6.26
Bromide mg/L	8	0.471	0.407	0.400	0.670	0.401	0.540	0.123	0.044
Chloride mg/L	8	75.57	74.00	63.70	91.00	67.45	83.50	10.48	3.71
Sulfate mg/L	8	224.85	229.83	180.00	260.00	189.55	260.00	38.29	13.54
Total organic carbon mg/L	8	7.840	7.629	6.700	9.500	7.100	8.531	1.061	0.375
Phosphorus mg/L	8	0.104	0.095	0.062	0.160	0.066	0.144	0.043	0.015
Arsenic mg/L	8	0.007	0.007	0.005	0.008	0.005	0.008	0.001	0.0005
Boron mg/L	8	0.113	0.115	0.083	0.140	0.094	0.130	0.022	0.008
Copper mg/L	6	0.002	0.002	0.001	0.002	0.001	0.002	0.000	0.000
Iron mg/L	8	0.108	0.105	0.042	0.160	0.083	0.142	0.040	0.014
Magnesium mg/L	8	20.60	20.50	17.11	24.00	18.34	23.00	2.64	0.93
Manganese mg/L	8	0.038	0.039	0.028	0.044	0.034	0.042	0.006	0.002
Nickel mg/L	8	0.005	0.003	0.002	0.025	0.002	0.003	0.008	0.003
Selenium mg/L	8	0.003	0.003	0.002	0.004	0.003	0.004	0.001	0.0002
Zinc mg/L	1	0.006	0.006	0.006	0.006	0.006	0.006		
Strontium mg/L	8	0.960	0.969	0.800	1.100	0.819	1.100	0.151	0.053
Uranium mg/L	6	0.007	0.007	0.005	0.009	0.005	0.009	0.002	0.001

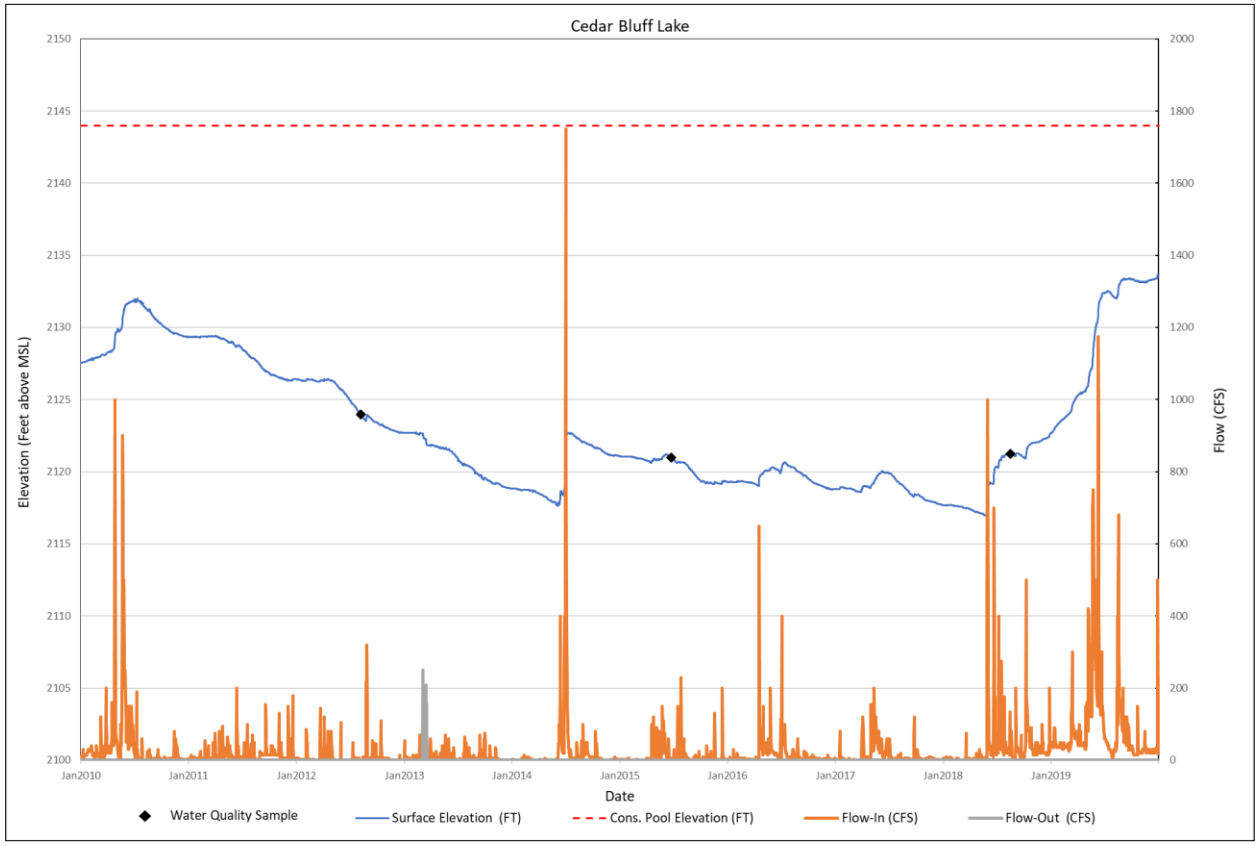
3.7.4.2.4 Cedar Bluff Lake

Cedar Bluff Lake earthen dam and reservoir were completed in 1951. USBR describes benefits of flood protection to Smoky Hill River Basin and water supply to the Cedar Bluff National Fish Hatchery and the city of Russell, Kansas. Irrigation of approximately 6,800 acres and recreation are also listed as project purposes as authorized. Cedar Bluff Lake is 6,869 surface acres located in Trego County, Kansas on the Smoky Hill River. KDWP manages 9,000 acres of wildlife area in addition to Cedar Bluff State Park providing an excellent base camp for hunters, fishermen, and year-round explorers.

Reservoir Hydrologic Data Summary

Surface elevation of Cedar Bluff Lake did not meet multipurpose pool elevation in 2010–2019 evaluation period (Figure 3-277). Three water quality sampling events are plotted with lake surface elevation for reference. Low inflow periods were observed in 2011–2014 with surface elevation falling 28 feet below multipurpose pool while recovery period began in 2019.

12193 *Figure 3-277. Cedar Bluff Lake Time Series of Daily Water Surface Elevation and Pool Information*



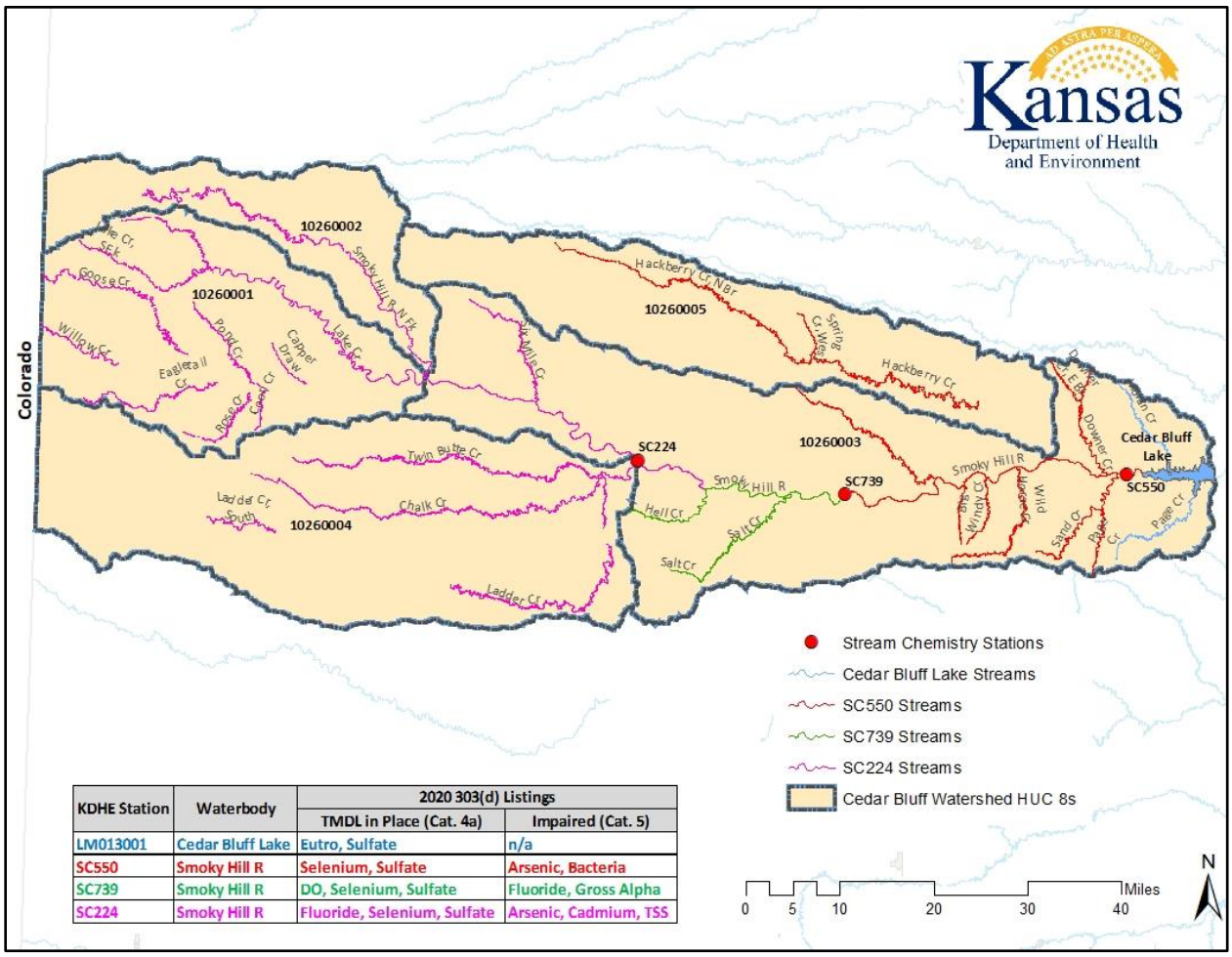
12194

12195 **Impairments**

12196 Impairments to Cedar Bluff Lake and Upper Smoky Hill River are associated with high
12197 phosphorus load and naturally occurring sulfate in the lake, and naturally occurring
12198 metals, suspended solids and bacteria in the watershed (Figure 3-278). The TMDL
12199 designated for accelerated eutrophication or enrichment from phosphorus is linked to
12200 increased aquatic plant growth as measured by average chlorophyll a concentration
12201 exceeding 12 ug/L (KDHE 2003b). Cedar Bluff Lake trophic state and chlorophyll a
12202 concentration are highly variable due to weather and hydrologic conditions. Sampling
12203 events from 2008-2012 had average summer chlorophyll a reported as 7.5 ug/L while a
12204 1991 survey reported chlorophyll *a* values up to 58.9 ug/L with hypereutrophic
12205 conditions.

12206

12207 *Figure 3-278. Cedar Bluff Lake impaired waters and Total Maximum Daily Loads*



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM013001	Cedar Bluff Lake	Eutro, Sulfate	n/a
SC550	Smoky Hill R	Selenium, Sulfate	Arsenic, Bacteria
SC739	Smoky Hill R	DO, Selenium, Sulfate	Fluoride, Gross Alpha
SC224	Smoky Hill R	Fluoride, Selenium, Sulfate	Arsenic, Cadmium, TSS

12208

12209 **Field Measured Water Quality Data Summary**

12210 Physical water quality conditions for Cedar Bluff Lake are provided in Figure 3-279.
12211 Daytime conditions recorded by KDHE field staff highlight minimum dissolved oxygen
12212 value of 4.7 mg/L and maximum conductivity value of 2900 umho/cm due to elevated
12213 ion concentrations. Mean and median Secchi values exceeding 1.5 meters and median
12214 turbidity less than 5 NTU support the assertion light limitation and shading are not
12215 impacting primary productivity (KDHE 2012b).

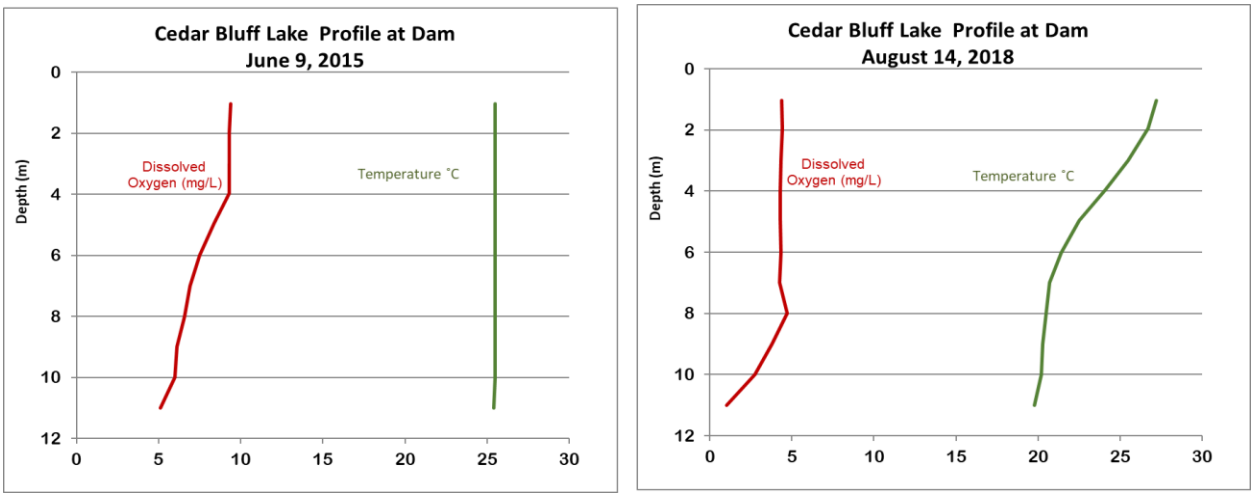
12216 Temperature and dissolved oxygen profiles for field data collected from 2015 and 2018
12217 are presented in Figure 3-280. Weak thermal stratification occurs for short periods of
12218 time on many shallow Kansas lakes as frequent wind mixing frequently destabilizes
12219 thermocline formations. Both profiles at Cedar Bluff Lake during low water years 2015
12220 and 2018 indicate thermal mixing with gradual dissolved oxygen decline at depths of 4
12221 and 8 meters, respectively (Figure 3-280).

12222

Figure 3-279. Physical Water Quality Statistics from Kansas Department of Health and Environment Field Measurements of Cedar Bluff Lake from 2010–2019

Variable	Cedar Bluff Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
D.O. mg/L	6	7.20	7.70	4.47	9.30	4.71	9.30	2.14	0.88
Temp °C	8	26.85	27.05	25.50	28.00	26.00	27.60	0.94	0.33
Secchi (m)	3	1.90	1.83	1.51	2.36	1.51	2.36	0.43	0.25
pH	6	7.81	7.92	7.30	8.20	7.40	8.10	0.37	0.15
Conductivity umho/cm	6	2730.83	2800.00	2479.00	2900.00	2506.00	2900.00	190.14	77.63
Turbidity NTU	6	4.56	4.00	2.50	7.22	2.80	6.81	2.01	0.82

Figure 3-280. Cedar Bluff Lake Representative Temperature and Dissolved Oxygen Profiles 2014–2019



Field data collected 2010–2019 provided courtesy of KDHE.

Laboratory Water Quality Analysis Summary

Water quality sample laboratory results from KDHE Monitoring and Analysis Unit are provided for Cedar Bluff Lake in Figure 3-281. Values below minimum reporting limits influence sample size in some analytes (e.g., nitrate, metolachlor) while other analytes (e.g., ammonia, orthophosphate, mercury) measured below reporting limits in all samples and consequently were omitted from results table.

Pesticide detections were infrequent and well below KDHE surface water quality standards numeric criteria (KDHE 2018). Atrazine is the most common pesticide found in Kansas lakes. Maximum concentrations of atrazine did not exceed EPA drinking water criteria of 3 ug/L.

Total nitrogen mean value at Cedar Bluff Lake of 1.3 mg/L which compares to the high nitrogen USACE lakes (e.g., Tuttle Creek, Perry, and Milford lakes) (Figure 3-163) and exceeded EPA Ecoregional Recommended Criteria of 0.62 mg/L (EPA 2001). Soluble nitrogen forms ammonia and nitrate were below detection limit.

Cedar Bluff Lake total phosphorus mean of 0.047 mg/L was similar to the slightly eutrophic value of 0.044 mg/L reported in interim conditions for 2008-2012 period of analysis for TMDL establishment (KDHE 2003b updated in 2014). Mean chlorophyll concentration of 14.5 ug/L exceeds eutrophic threshold but was lower than 58.9 ug/L under hypereutrophic TSI conditions also reported from in TMDL data discussion from 1991 (KDHE 2003b). Cyanobacteria comprised 79 percent of the phytoplankton

population at Cedar Bluff Lake (KDHE 2010). The most recent KDHE issued HAB warning was June 2012.

Total metals in Cedar Bluff Lake surface samples did not exceed Kansas Surface Water Quality numeric criteria (KDHE 2018).

Maxima value of total selenium from Cedar Bluff Lake samples of 5 ug/L is equal to the chronic concentration numeric criteria for support of aquatic life due to background levels in Smoky Hill River above Cedar Bluff Lake.

Median sulfate concentration of 1,200 mg/L exceeded the 700 mg/L as defined as natural background concentration reported in Kansas Surface Water Standards (KDHE 2018). Samples collected in low water years of 2015 and 2018 are likely to see higher concentration in the absence of dilution from fresh water provided from rainfall events.

Similarly, bromide concentrations in Cedar Bluff Lake during low water years may be concerning to downstream water supply/treatment operations. Median value of 0.822 mg/L and maxima of 1.2 mg/L were the highest respective values in the KDHE data set from USBR lakes in 2010–2019.

Figure 3-281. Water Quality Chemistry Statistics from Kansas Department of Health and Environment Surface Samples of Cedar Bluff Lake from 2010–2019

Variable	Cedar Bluff Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
Atrazine µg/L	3	0.797	0.610	0.3800	1.400	0.3800	1.400	0.5350	0.30889
TKN nitrogen mg/L	6	1.334	1.308	1.2900	1.400	1.3000	1.400	0.0516	0.02107
T. nitrogen mg/L	6	1.334	1.308	1.2900	1.400	1.3000	1.400	0.0516	0.02107
Chlorophyll a µg/L	6	14.55	12.13	6.47	25.42	7.27	23.90	8.22	3.36
Alkalinity n mg CaCO3/L	6	102.71	95.50	92.59	120.00	92.69	120.00	13.45	5.49
Bromide mg/L	6	0.937	0.822	0.7700	1.200	0.8093	1.200	0.2046	0.08354
Chloride mg/L	6	209.62	210.00	198.79	220.00	198.95	220.00	9.46	3.86
Sulfate mg/L	6	1105.00	1200.00	910.00	1200.00	920.00	1200.00	147.21	60.10
Total organic carbon mg/L	6	14.080	14.000	12.9100	15.000	13.5700	15.000	0.8167	0.33340
Phosphorus mg/L	3	0.047	0.054	0.0330	0.055	0.0330	0.055	0.0124	0.00717
Arsenic mg/L	4	0.005	0.005	0.0038	0.005	0.0039	0.005	0.0008	0.00039
Boron mg/L	6	0.322	0.321	0.3100	0.330	0.3183	0.330	0.0076	0.00310
Copper mg/L	6	0.009	0.003	0.0031	0.020	0.0033	0.020	0.0086	0.00352
Iron mg/L	4	0.047	0.047	0.0330	0.061	0.0335	0.061	0.0159	0.00794
Magnesium mg/L	6	102.17	100.00	96.13	110.00	96.87	110.00	6.27	2.56
Manganese mg/L	4	0.103	0.103	0.1000	0.107	0.1000	0.107	0.0039	0.00195
Nickel mg/L	6	0.010	0.005	0.0037	0.020	0.0040	0.020	0.0080	0.00327
Selenium mg/L	4	0.005	0.005	0.0048	0.005	0.0049	0.005	0.0002	0.00009
Zinc mg/L	3	0.006	0.007	0.0051	0.007	0.0051	0.007	0.0011	0.00065
Strontium mg/L	6	4.319	4.400	4.0453	4.500	4.0671	4.500	0.2083	0.08505
Uranium mg/L	6	0.018	0.017	0.0167	0.020	0.0167	0.020	0.0016	0.00067

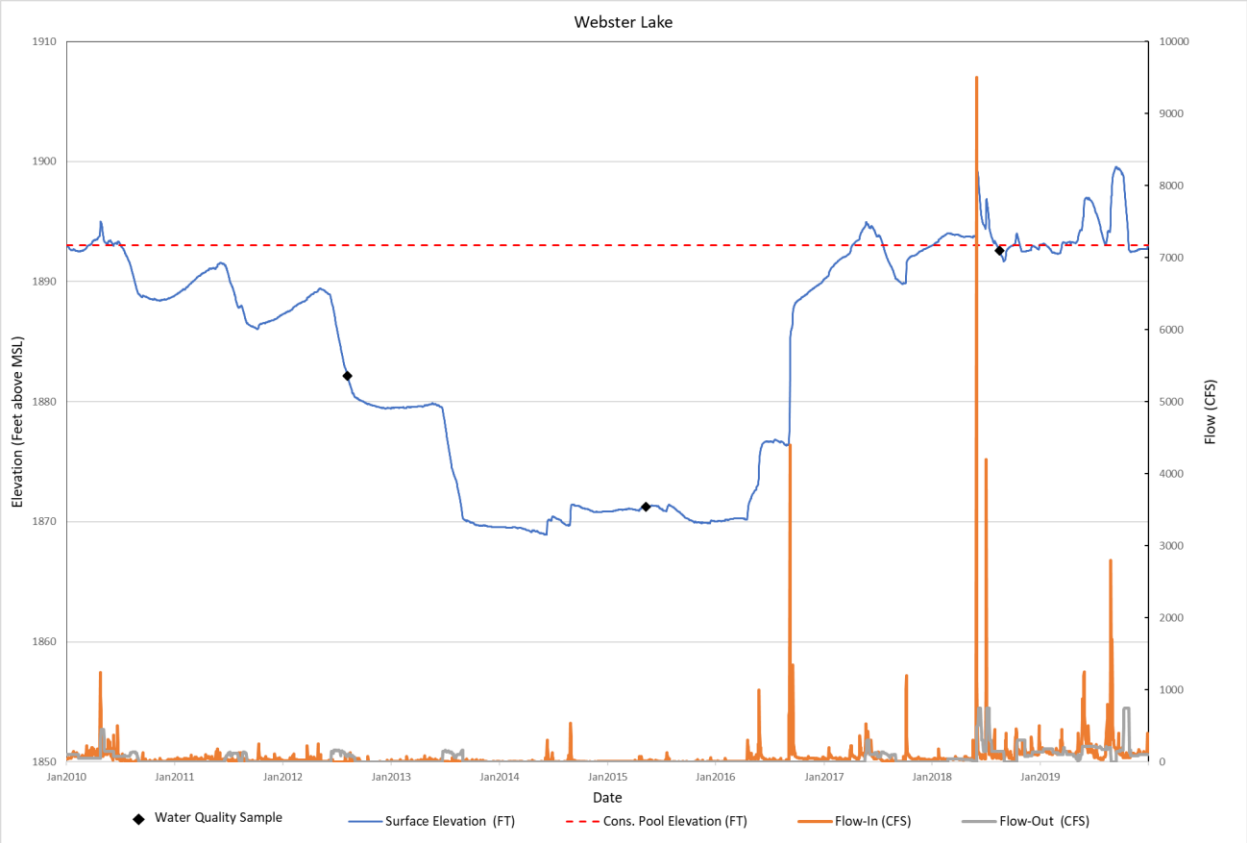
3.7.4.2.5 Webster

Webster Lake is a 3,767-acre impoundment of South Fork Solomon River built in Rooks County, Kansas, in 1953. The USBR Webster Unit provides flood control benefits, irrigation water to 8,500 acres of the Webster Irrigation District No. 4, fish and wildlife conservation, and recreation opportunities. The area around Webster Lake includes an 880-acre state park managed by KDWP within surrounding public land totaling 3,164 land acres with 50 miles of shoreline.

Reservoir Hydrologic Data Summary

Webster Lake multipurpose pool elevation was difficult to maintain during much of the 2010–2019 evaluation period (Figure 3-282) due to low inflows from 2012–2016 as water demand for irrigation outpaced inflows. Multipurpose pool elevation was maintained 2017–2019 as rainfall events allowed for recharge of the pool volume. Three water quality sampling events are plotted with lake surface elevation for reference in Figure 3-282. Water quality sampling events were near multipurpose pool in 2019 while previous samples were at surface elevations 11 and 22 feet below multipurpose pool elevation.

Figure 3-282. Webster Lake Time Series of Daily Water Surface Elevation and Pool Information

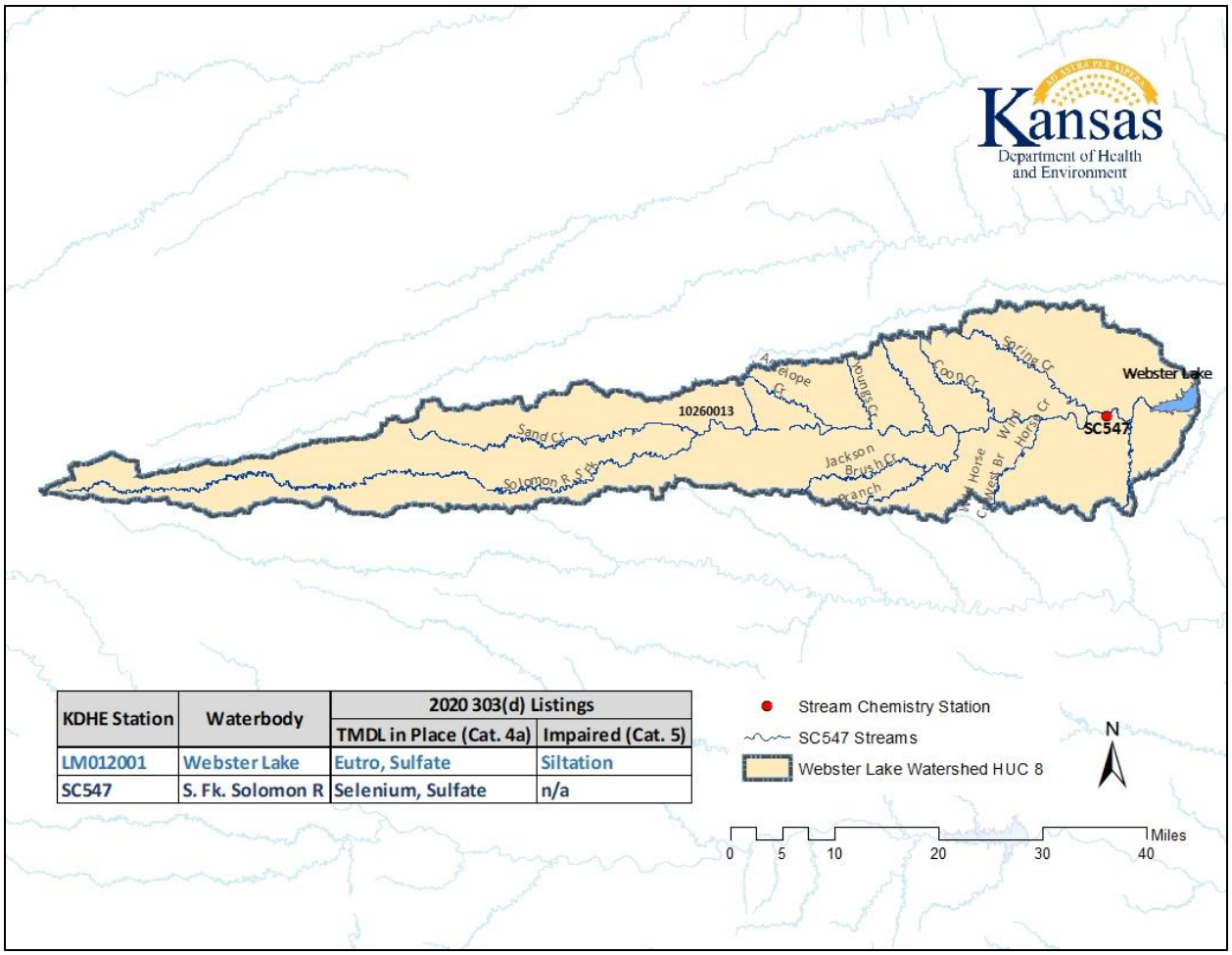


Time series of daily water surface elevation, inflow, outflow, and multipurpose pool elevation for the period Jan. 2010 through Dec. 2019 from DSS data (HEC-DSSVue). Water quality sample dates are plotted corresponding with lake surface elevation for reference.

Impairments

Impairments to Webster Lake and South Fork of Solomon River are associated with high phosphorus and sediment load, naturally occurring sulfate in the lake, and naturally occurring sulfate and selenium in the watershed (Figure 3-283). The TMDL designated for accelerated eutrophication or enrichment from phosphorus is linked to increased aquatic plant growth as measured by average chlorophyll *a* concentration exceeding 12 ug/L (KDHE 2003c). Webster Lake trophic state was classified as eutrophic based on summer chlorophyll a concentration (KDHE 2010). Siltation and selenium impairments affect upper areas and river above Webster Lake with minimal effect on water quality near the dam.

Figure 3-283. Webster Lake Impaired Waters and Total Maximum Daily Loads



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM012001	Webster Lake	Eutro, Sulfate	Siltation
SC547	S. Fk. Solomon R	Selenium, Sulfate	n/a

Impaired waters and TMDLs of Webster Lake and watershed from 2020 303(d) list (Courtesy of KDHE).

Field Measured Water Quality Data Summary

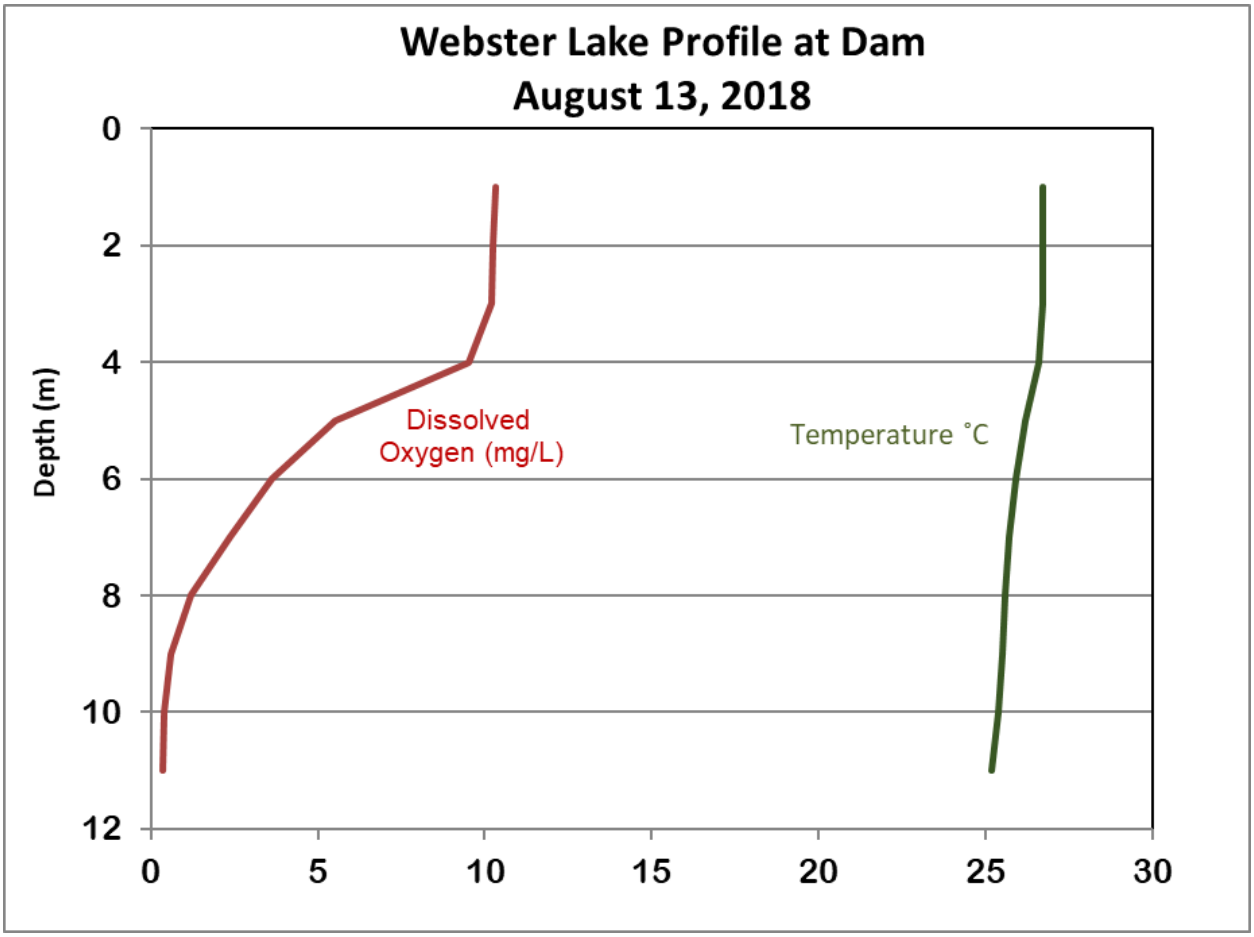
Physical water quality conditions for Webster Lake are provided in Figure 3-284. Minimum dissolved oxygen value of 8 mg/L and maximum pH of 8.2 are acceptable values which represent the worst conditions for two physical analytes from surface samples collected during the sample period which may degrade due to eutrophication. Median Secchi values of approximately one meter and median turbidity of 12.6 NTU provide for a functional photic zone and do not suggest light limitation to productivity similar to previous water quality reports for Webster Lake (KDHE 2007, 2010).

Temperature and dissolved oxygen profile for one field sample collected in August 2018 indicates weak thermal stratification with significant oxygen decline at depth (Figure 3-285). Weak thermal stratification occurs for short periods of time on many shallow Kansas lake as frequent wind mixing frequently destabilizes thermocline formations. Biochemical oxygen demand resulting from high algae density are apparent when thermal stratification occurs and when thermal variation is low and while dissolved oxygen declines rapidly at depth as illustrated in this instance (Figure 3-285).

Figure 3-284. Physical Water Quality Statistics from Kansas Department of Health and Environment Field Measurements of Webster Lake From 2010–2019

Variable	Webster Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
D.O. mg/L	6	9.6	9.9	8.7	10.3	8.7	10.2	0.7	0.3
Temp °C	8	28.2	28.8	26.7	29.0	27.0	29.0	1.1	0.4
Secchi (m)	3	1.1	1.0	0.8	1.4	0.8	1.4	0.3	0.2
pH	6	8.1	8.1	8.1	8.2	8.1	8.2	0.0	0.0
Conductivity umho/cm	6	1485.5	1556.5	1000.0	1900.0	1000.0	1900.0	406.2	165.8
Turbidity NTU	6	13.5	12.7	6.2	22.0	6.2	21.0	6.9	2.8

Figure 3-285. Webster Lake Representative Temperature and Dissolved Oxygen Profile 2018



Field data collected 2018 provided courtesy of KDHE.

Laboratory Water Quality Analysis Summary

Water quality sample laboratory results from KDHE Monitoring and Analysis Unit are provided for Webster Lake in Figure 3-286. Values below minimum reporting limits influence sample size in some analytes (e.g., zinc and nitrate) while other analytes (e.g., ammonia, orthophosphate, mercury) measured below reporting limits in all samples and consequently were omitted from results table.

Pesticide detections were infrequent and well below KDHE surface water quality standards numeric criteria (KDHE 2018). Atrazine is the most common pesticide found

in Kansas lakes. Maximum concentrations of atrazine did not exceed EPA drinking water criteria of 3 ug/L.

Total nitrogen mean value at Webster Lake was 1.36 mg/L which compares to the high nitrogen USACE lakes (e.g., Tuttle Creek, Perry, and Milford lakes) (Figure 3-163) and exceeds EPA Ecoregional Recommended Criteria of 0.62 mg/L (EPA 2001).

Webster Lake total phosphorus mean of 0.08 mg/L is in the eutrophic category (Carlson 1977). Eutrophic conditions with high phosphorus load have combined with adequate water clarity to increase algal production. Mean chlorophyll a concentration of 41.4 ug/L is more than four times the TMDL goal of 8 ug/L (KDHE 2003c). Average chlorophyll *a* concentrations are reportedly elevated during drought conditions when compared to high water periods due to increased “clay turbidity” associated with inflows (KDHE 2003c). Cyanobacteria blooms have led to increased HAB Warnings due to toxic algae including the most recent public health warning lasting 12 weeks of the recreational season of 2021.

Bromide concentrations are of concern for water treatment operations due to byproducts as bromide is converted to bromate in their treatment process and there are EPA disinfection byproduct limitations on the amounts of bromate (KWO personal communication, 2022). Increasing bromide trends from 1995 to present in Solomon River Basin is of concern for future water supply. Webster Lake median bromide concentration of 0.615 mg/L is similar to 2020 values found in Upper South Fork Solomon River (KDHE unpublished report).

Total metals in Webster Lake surface samples did not exceed Kansas Surface Water Quality numeric criteria including Domestic Water Supply of 0.010 mg/L of total arsenic (KDHE 2018).

Figure 3-286. Water Quality Chemistry Statistics from Kansas Department of Health and Environment Surface Samples of Webster Lake From 2010–2019

Variable	Webster Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
Atrazine µg/L	3	0.973	0.770	0.350	1.800	0.350	1.800	0.746	0.431
Metolachlor µg/L	1	0.310	0.310	0.310	0.310	0.310	0.310		
Nitrate mg/L	1	0.194	0.194	0.194	0.194	0.194	0.194		
TKN nitrogen mg/L	6	1.327	1.200	1.080	1.700	1.181	1.600	0.256	0.105
T. nitrogen mg/L	6	1.359	1.288	1.080	1.700	1.200	1.600	0.246	0.101
Chlorophyll a µg/L	6	41.390	33.000	9.900	81.400	10.220	80.820	32.638	13.324
Alkalinity mg CaCO3/L	6	125.735	127.205	120.000	130.000	120.000	130.000	4.616	1.884
Bromide mg/L	6	0.624	0.615	0.545	0.710	0.549	0.710	0.073	0.030
Chloride mg/L	6	146.582	155.747	84.000	200.000	84.000	200.000	52.360	21.376
Sulfate mg/L	6	445.167	495.502	280.000	610.000	280.000	510.000	134.909	55.076
Total organic carbon mg/L	6	12.335	12.000	10.980	14.000	11.030	14.000	1.364	0.557
Phosphorus mg/L	4	0.085	0.087	0.073	0.092	0.080	0.090	0.008	0.004
Total suspended solids mg/L	4	15.500	15.000	12.000	20.000	12.500	18.500	3.697	1.848
Arsenic mg/L	4	0.006	0.006	0.006	0.007	0.006	0.007	0.000	0.000
Boron mg/L	6	0.155	0.166	0.100	0.200	0.100	0.200	0.045	0.019
Copper mg/L	6	0.008	0.002	0.002	0.020	0.002	0.020	0.009	0.004
Iron mg/L	4	0.091	0.090	0.085	0.099	0.087	0.095	0.006	0.003
Magnesium mg/L	6	40.601	42.804	24.000	55.000	25.000	54.000	13.532	5.524
Manganese mg/L	2	0.060	0.060	0.060	0.060	0.060	0.060	0.000	0.000
Nickel mg/L	6	0.010	0.005	0.003	0.020	0.004	0.020	0.008	0.003
Selenium mg/L	4	0.004	0.004	0.004	0.005	0.004	0.005	0.001	0.000
Zinc mg/L	1	0.006	0.006	0.006	0.006	0.006	0.006		
Strontium mg/L	6	1.533	1.645	0.950	2.000	0.960	2.000	0.475	0.194
Uranium mg/L	6	0.018	0.019	0.016	0.020	0.016	0.020	0.002	0.001

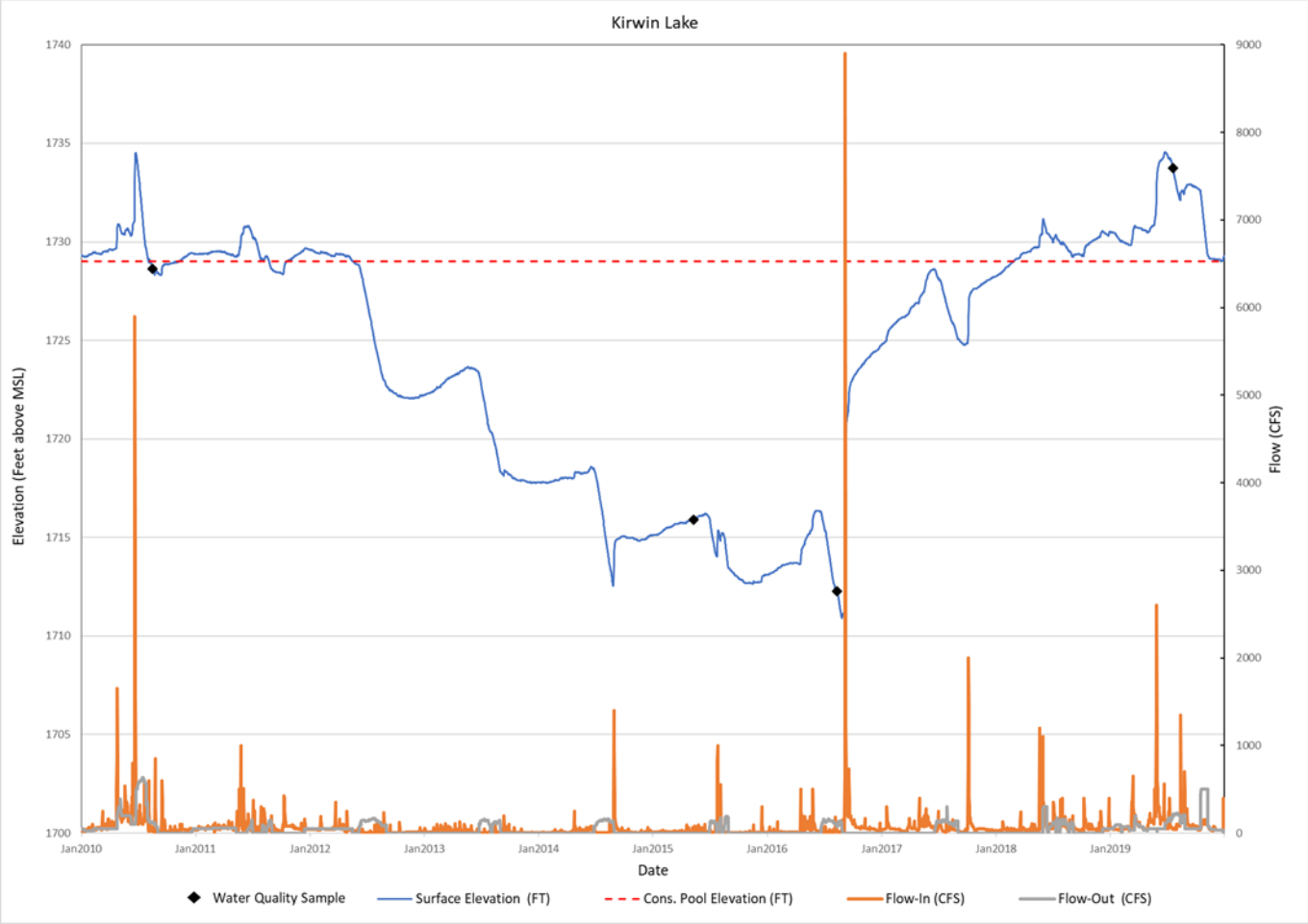
3.7.4.2.6 Kirwin Lake

Kirwin Dam, on the North Fork of the Solomon River near Kirwin, Kansas, was completed in August 1955. Authorized by the Flood Control Act of December 1944, Kirwin Lake provides flood control benefits and irrigation for 11,435 acres. Bureau of Sport Fisheries and Wildlife administers 10,700 acres of Kirwin Reservoir and lands at the Kirwin NWR. Popular recreational activities at Kirwin include fishing, boating, swimming, camping, wildlife viewing, and water skiing.

Reservoir Hydrologic Data Summary

Kirwin Lake multipurpose pool elevation was difficult to maintain during much of the 2010–2019 evaluation period (Figure 3-287) due to low inflows from 2012–2016 as water demand for irrigation outpaced inflows. Multipurpose pool elevation was maintained 2018–2019 as rainfall events allowed for recharge of the pool volume. Four water quality sampling events are plotted with lake surface elevation for reference in Figure 3-287. Water quality sampling events were near multipurpose pool in 2010 while subsequent samples were at surface elevations 15 and 17 feet below multipurpose pool elevation. Following a wetter year, 2019 water quality sample occurred 4 feet above multipurpose pool elevation.

Figure 3-287. Kirwin Lake Time Series of Daily Water Surface Elevation and Pool Information

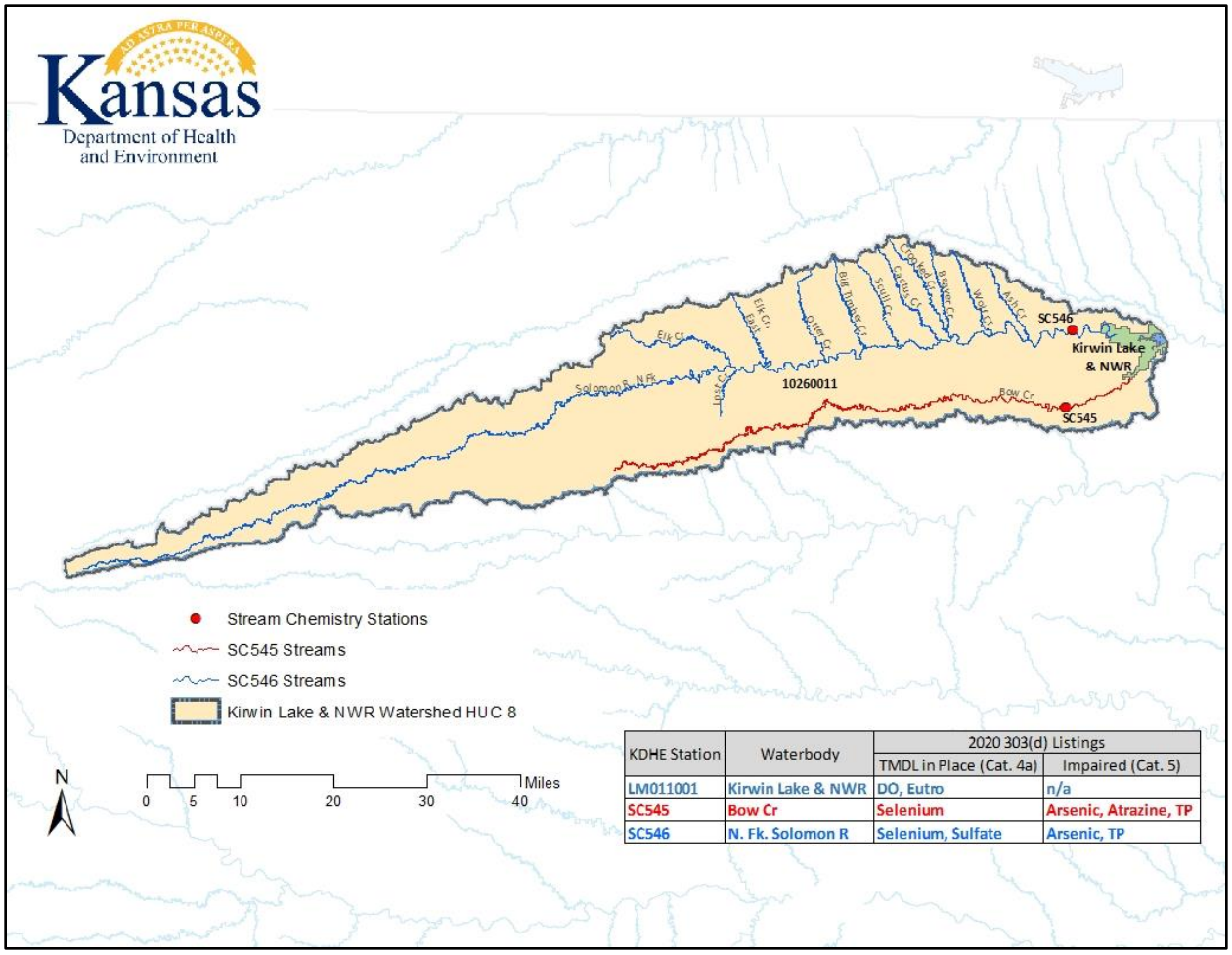


Time series of daily water surface elevation, inflow, outflow, and multipurpose pool elevation for the period Jan. 2010 through Dec. 2019 from DSS data (HEC-DSSVue). Water quality sample dates are plotted corresponding with lake surface elevation for reference.

Impairments

Impairments to Kirwin Lake and Upper North Fork of Solomon River are associated with nutrients and naturally occurring selenium in the watershed (Figure 3-288). The TMDL designated for accelerated eutrophication or enrichment from phosphorus is linked to increased aquatic plant growth as measured by average chlorophyll *a* concentration of 24 ug/L and total phosphorus of 0.132 mg/L (KDHE 2003d). Kirwin Lake trophic state was classified as very eutrophic based on summer chlorophyll a concentration (KDHE 2003d, 2010). Selenium impairment affects upper lake areas and the river above Kirwin Lake with minimal effect on water quality near the dam.

Figure 3-288. Kirwin Lake Impaired Waters and Total Maximum Daily Limits



KDHE Station	Waterbody	2020 303(d) Listings	
		TMDL in Place (Cat. 4a)	Impaired (Cat. 5)
LM011001	Kirwin Lake & NWR	DO, Eutro	n/a
SC545	Bow Cr	Selenium	Arsenic, Atrazine, TP
SC546	N. Fk. Solomon R	Selenium, Sulfate	Arsenic, TP

Impaired waters and TMDLs of Kirwin Lake and watershed from 2020 303(d) list (Courtesy of KDHE).

Field Measured Water Quality Data Summary

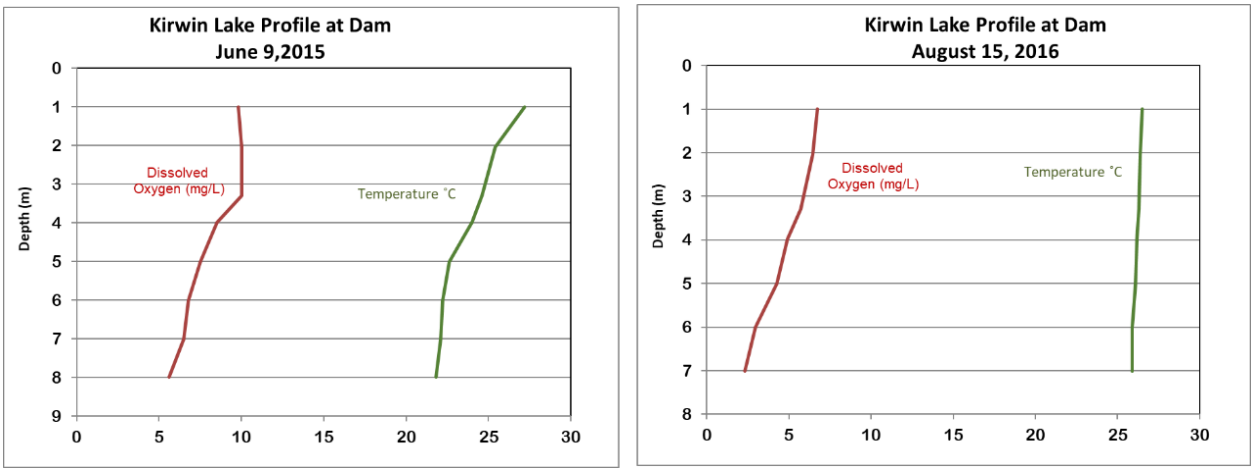
Physical water quality conditions for Kirwin Lake are provided in Figure 3-289. Minimum dissolved oxygen value of 6.8 mg/L and maximum pH of 8.2 are acceptable values which represent the worst conditions for two physical analytes from surface samples which may degrade due to eutrophication. Median Secchi value 1.5 m. and median turbidity of 4.9 NTU provide for a functional photic zone and do not suggest light limitation to productivity similar to previous water quality report for Kirwin Lake (KDHE 2012b).

Temperature and dissolved oxygen profile for 2018 and 2016 indicates very weak stratification with oxygen decline at depth (Figure 3-290). Weak thermal stratification occurs for short periods of time on many shallow Kansas lakes as frequent wind mixing frequently destabilizes thermocline formations. Biochemical oxygen demand resulting from high algae density are apparent as thermal variation is low and while dissolved oxygen declines gradually at depth (Figure 3-290).

12410 *Figure 3-289. Physical Water Quality Statistics from Kansas Departmnet of Health and Environment Field*
12411 *Measurements of Kirwin Lake from 2010–2019*

Variable	Kirwin Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
D.O. mg/L	8	7.81	7.35	6.79	9.80	7.07	8.55	1.22	0.43
Temp °C	11	27.23	27.00	26.70	28.00	27.00	27.40	0.42	0.13
Secchi (m)	4	1.59	1.50	0.83	2.54	1.02	2.17	0.75	0.37
pH	8	7.94	7.95	7.70	8.20	7.75	8.10	0.20	0.07
Conductivity umho/cm	8	942.21	915.00	832.60	1100.00	842.55	1045.00	115.88	40.97
Turbidity NTU	8	5.57	4.98	3.20	9.70	3.45	7.40	2.55	0.90

12412
12413 *Figure 3-290. Kirwin Lake Representative Temperature and Dissolved Oxygen Profiles 2014–2019*



12414
12415 Field data collected 2010–2019 provided courtesy of KDHE.

12416 **Laboratory Water Quality Analysis Summary**

12417 Water quality sample laboratory results from KDHE Monitoring and Analysis Unit are
12418 provided for Kirwin Lake in Figure 3-291. Analytes measured below reporting limits in all
12419 samples (e.g., ammonia, orthophosphate, mercury) were omitted from results table.

12420 Pesticide detections were infrequent and below KDHE surface water quality standards
12421 numeric criteria (KDHE 2018). Atrazine is the most common pesticide found in Kansas
12422 lakes. Maximum concentrations of atrazine did not exceed EPA drinking water criteria of
12423 3 ug/L.

12424 Total nitrogen mean value at Kirwin Lake was 0.8 mg/L is below average total nitrogen
12425 of USACE lakes (e.g., Tuttle Creek, Perry, and Milford lakes) (Figure 3-163) and
12426 exceeds EPA Ecoregional Recommended Criteria of 0.62 mg/L (EPA 2001).

12427 Kirwin Lake total phosphorus mean of 0.06 mg/L is in the mesotrophic category
12428 (Carlson 1977) and less than half of the eutrophic conditions measured during TMDL
12429 period 1986-2001(KDHE 2003d). Mean chlorophyll concentration of 15 ug/L exceeds
12430 eutrophic threshold and TMDL endpoint of 12 ug/L (KDHE 2003d). Cyanobacteria is
12431 accounted for 92 percent of phytoplankton community in 2010 sample (KDHE 2012b).
12432 Cyanobacteria blooms have led to HAB Warnings due to toxic algae including the most
12433 recent public health warning lasting 3 weeks of the recreational season of 2017.

Total metals in Kirwin Lake surface samples did not exceed Kansas Surface Water Quality numeric criteria including Domestic Water Supply of 0.010 mg/L of total arsenic (KDHE 2018).

Figure 3-291. Water Quality Chemistry Statistics from Kansas Department of Health and Environment Surface Samples of Kirwin Lake From 2010–2019

Variable	Kirwin Lake Descriptive Statistics-KDHE 2010-2019 Surface Samples								
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std.Dev.	Standard Error
Atrazine µg/L	4	0.828	0.845	0.420	1.200	0.630	1.025	0.319	0.160
TKN nitrogen mg/L	8	0.805	0.872	0.460	1.000	0.670	0.950	0.203	0.072
T. nitrogen mg/L	8	0.805	0.872	0.460	1.000	0.670	0.950	0.203	0.072
Chlorophyll a µg/L	8	15.021	13.780	4.730	27.480	9.290	20.910	8.557	3.025
Alkalinity mg CaCO3/L	8	155.38	158.70	130.00	170.00	147.84	165.00	13.91	4.92
Bromide mg/L	6	0.495	0.396	0.350	0.720	0.390	0.720	0.175	0.071
Chloride mg/L	8	65.147	63.854	50.000	83.000	50.236	80.000	16.041	5.671
Sulfate mg/L	8	222.98	218.74	180.00	280.00	188.20	255.00	39.81	14.07
Total organic carbon mg/L	8	8.609	8.413	7.500	10.000	7.972	9.300	0.931	0.329
Phosphorus mg/L	8	0.063	0.066	0.034	0.086	0.047	0.078	0.019	0.007
Arsenic mg/L	8	0.007	0.006	0.006	0.008	0.006	0.007	0.001	0.000
Boron mg/L	8	0.094	0.095	0.069	0.120	0.075	0.110	0.021	0.007
Copper mg/L	6	0.002	0.002	0.002	0.002	0.002	0.002	0.000	0.000
Iron mg/L	8	0.076	0.080	0.041	0.100	0.056	0.097	0.024	0.008
Magnesium mg/L	8	25.07	25.50	19.30	30.00	20.63	29.50	4.81	1.70
Manganese mg/L	6	0.045	0.037	0.028	0.069	0.029	0.068	0.019	0.008
Nickel mg/L	8	0.002	0.002	0.002	0.003	0.002	0.003	0.000	0.000
Selenium mg/L	8	0.003	0.003	0.002	0.004	0.003	0.004	0.001	0.000
Zinc mg/L	2	0.007	0.007	0.006	0.009	0.006	0.009	0.002	0.001
Strontium mg/L	8	0.947	0.941	0.810	1.100	0.842	1.050	0.119	0.042
Uranium mg/L	6	0.009	0.009	0.008	0.011	0.008	0.011	0.001	0.001

3.7.5 Future Without Project Conditions

3.7.5.1 Water Quality Summary

The availability of high-quality water for commercial, industrial, and residential uses is vitally important for the water users of Kansas. Activities to further protect and improve the water quality of Kansas to avoid degradation of the State's water resources are imperative for current and future water users. State natural resource agencies have designated 16 of the 18 lakes in the Kansas River Basin as "impaired" from nutrient related impacts (e.g., excess nitrogen and/or phosphorus, general eutrophication, excess chlorophyll/algae measures, dissolved oxygen sags resulting from algae blooms) due in part to agricultural runoff. Inflow streams flowing into Basin lakes are frequently impaired from a range of pollutants including, but not limited to, fecal bacteria, herbicides like atrazine, and chemical contamination from naturally occurring compounds found in geological deposits (e.g., chloride and sulfate salts, selenium, and arsenic). Approximately 86 percent of the state's assessed stream miles are impaired for one of their uses and less than 5 percent of the state's assessed wetlands are able to support aquatic life and recreational uses (KWO 2021a). Excess nutrients can promote HABs under ideal growing conditions. HABs have impacted six lakes in the basin since 2011. Milford Lake has been the hardest hit, with HAB warnings impacting recreation 7 of the last 10 years. As accumulation of sediment reduces storage capacity of reservoirs, and internal nutrient loading increases, water quality problems are expected to intensify.

As water quality conditions degrade within a water body, use of water from that source as well as downstream uses can be negatively impacted. Negative impacts from degrading/poor water quality conditions can include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, decreased recreational opportunities, and fish consumption.

3.7.5.1.1 Reservoir Aging, Sedimentation, and Water Quality

The transport of sediment is a natural function in river ecosystems. Mass quantities and particle sizes transported depend upon watershed geology, topography, climate, land use/cover, and land management. Most natural river reaches are approximately balanced with respect to sediment inflow and outflow (Morris & Fan 1998). Storm events generating high run-off volumes transport the majority of sediment and nutrient loads. Sheet, rill, gully, and ephemeral gully erosion from hillslopes are major sources of most sediment introduced into stream channels. Other sources include landslides, debris flows, streambanks, irrigation, and roadsides (NRCS 2021). Functional riparian and aquatic habitats evolve in association with transported sediment quantity and composition (Hauer et al. 2018).

Dam construction dramatically alters streamflow and sediment transport. Impounded stream and river segments result in lower flow velocities that efficiently trap sediment. Initial sediment trapping efficiency is often greater than 90 percent in large reservoirs (Juracek 2014). As deposition occurs decreases in surface area, storage capacity, depth, and residence time affect physical, chemical, and biological components of reservoir ecosystems (Juracek 2014; Miranda 2017). Dammed reaches may again achieve an approximate sediment transport balance as impoundments fill with sediment and no longer provide water storage and other benefits. Declining storage reduces and eventually compromises the capacity for flow regulation, water supply, flood control benefits, hydropower, navigation, recreation, and environmental benefits that depend on releases from storage (Morris & Fan 1998). Despite increased demand for sustainable water supply, reservoir capacity is consistently diminishing due to sedimentation (Hotchkiss and Huffaker 2017).

Physical, chemical, and biological systems downstream of impoundments are also profoundly affected. Dams alter downstream flow rate, timing, duration, and volume. Water temperature, dissolved oxygen concentrations, transport of sediment, nutrients, and the mobility of resident and migratory species are affected. Seasonal flow patterns are altered, affecting life cycle requirements of native plant and animal species (IWR 2016; Juracek 2014). Altered downstream flow variability can impair or eliminate native fish and macroinvertebrate communities. Downstream of reservoirs, stream substrate changes from a mix of fine and course particles to exclusively course or armored substrate leading to significant ecological habitat effects (Juracek 2014; Miranda 2017; IWR 2016; Shelley, Boyer, Granet, & Williams 2016).

Reservoirs generally receive larger sediment loads than natural lakes because of larger contributing watersheds. The ratio of watershed area to water surface area is usually higher for reservoirs (Miranda & Bettoli 2010). Accumulation of sediment in reservoirs is accelerated by land use practices (tillage, grazing, development) in the watershed exposing vulnerable soils to precipitation runoff and erosion. Delivered sediment loads

carry significant quantities of organic materials, nutrients, and contaminants. Most captured sediments in large reservoirs are fine-grained silts and clays affecting water clarity and capable of transporting nutrients and contaminants.

The progressive storage loss in reservoirs due to sedimentation is a fundamental aspect of reservoir aging, although all reservoirs do not age at the same rate. Climate, watershed geological characteristics, drainage network density, slope, land cover and land use, basin management, unique reservoir characteristics, and reservoir operational management practices play critical roles in the aging process. Within a single watershed, a small fraction of the landscape is usually responsible for a large percentage of the sediment yield and sediment transport may exhibit distinct seasonal variation due to timing of periods of precipitation and protective vegetative cover (Morris & Fan, 1998). Reservoirs with watersheds dominated by cropland and/or urban development may exhibit hypereutrophic (highly productive) conditions, irrespective of chronological age (Carney 2009). Deposited and suspended sediments affect aquatic habitat and life contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects. Elevated turbidity in surface waters impairs physical, chemical, and biological components of aquatic ecosystems, and leads to decreased aesthetic and recreational value. Turbidity can affect water temperature causing temperate reservoirs to warm more slowly in spring/summer, experience higher warm season surface temperatures, and cool more slowly in fall/winter. Alteration of heat budgets affects biotic and abiotic processes influencing growth rates, reaction rates, constituent solubility, and water density. Sediment accumulation enhances eutrophication and impairs water quality. Elevated levels of suspended matter increase the capacity for sorption and transport of nutrients, heavy metals, and organic compounds such as pesticides. High levels of suspended sediments may also result in limiting primary production despite high nutrient availability through diminished light availability. Fine sediment particles may remain in suspension for considerable periods of time affecting water clarity. Wind and wave action can resuspend fine sediments exacerbating water clarity and quality issues.

Dissolved oxygen concentrations affect rates of reduction of inorganic substances and the distribution of aerobic and anaerobic organisms. Higher water column oxygen demand is associated with turbid inflows and accompanying organic materials. Sediment oxygen demand, the rate of oxygen consumption by bacteria and other organisms metabolizing organic matter in the sediment, is often high in reservoir zones where sediment is deposited. Warm season water temperature increases, due to diminished reservoir depth and increased turbidity, results in lower water column dissolved oxygen concentrations. Dissolved oxygen concentration saturation decreases with increasing water temperature.

Sediment is a critical component of reservoir systems serving as habitat for benthic invertebrates, influencing macrophyte distribution, accumulating nutrients and regulating nutrient recycling, controlling concentrations of dissolved oxygen and other dissolved constituents, and accumulating contaminants (Miranda 2017). Interactions between mineral properties of sediment and water chemistry determine whether sediment

becomes a source or a sink of nutrients or other contaminants. Under anoxic hypolimnetic conditions, desorption of nutrients and other contaminants from sediment into the water column can occur. As a reservoir loses storage to sediment accumulation, less ambient lake water is available for diluting incoming sediment, nutrient, and chemical loads, leading to higher turbidity and nutrient concentrations, and decreased chemical constituent buffering (Shelley, Boyer, Granet, & Williams 2016). The potential exists for naturally occurring (selenium, arsenic, sulfate, chloride, …) impairments to intensify and extend beyond lakes with reduced volume, reduced chemical buffering and attenuation.

Water quality discussions assessing future expectations in Kansas River Watershed lakes necessarily focus on the effects of water residence time, and the physical transport of constituents through a reservoir, on eutrophication, thermal stratification, chemical composition, heavy metal/nutrient accumulation, and primary production. Residence time has been described at the most important factor influencing water quality (Jørgensen 2003) with water management inducing measurable effects influencing biogeochemical processes. Managed changes in residence time, and resulting relative strength of thermal stratification, are dynamic factors influencing nutrient and sediment transport that have been used to alter water quality with various levels of success (Olsson, et al. 2022; Jørgensen 2003). Similarly, temporal differences (i.e., annual, seasonal, diurnal...) in residence time influence the fate of constituents and processes affecting water quality (Rueda, Moreno-Ostos, & Armgengol 2006) as well as phytoplankton community (Reynolds, Maberly, Parker, & De ville 2012).

With increases in available nutrients and increased warm-season water temperatures, phytoplankton may periodically proliferate (bloom) under specific environmental conditions. Proliferation and collapse of blooms can promote epilimnetic dissolved oxygen supersaturation and hypolimnetic anoxia. Cyanobacteria exhibit optimal growth rates at temperatures generally higher than eukaryotic primary producers. Many cyanophytes can regulate buoyancy and in stagnant waters rise to the surface and effectively shade out competitors. Some species of common cyanobacterial genera tolerate environmentally stressful conditions outcompeting other freshwater phytoplankton. Under climate change scenarios, the frequency of cyanobacterial HABs is likely to increase, primarily due to water temperature increases tempered by nutrient levels, and climatic impacts on hydrology that drive nutrient transport (Chapra, et al., 2017). Climate change is likely to affect patterns, intensities, and duration of precipitation and droughts and hydrologic changes may further enhance cyanobacterial dominance. Larger and more intense precipitation events can increase nutrient enrichment of water bodies from enhanced surface runoff and groundwater discharge. Accelerating anthropogenic nutrient loading, rising temperatures, enhanced vertical stratification, and increased atmospheric CO2 supplies are likely to favor cyanobacterial dominance in a wide range of aquatic ecosystems (Paerl & Huisman 2009).

All reservoirs in the Kansas River Watershed will likely experience increasing effects of aging. Continued sediment loading will diminish storage capacity (KRRFSS, Appendix D, Reservoir Sedimentation), deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected.

This analysis of potential future water quality conditions in the Kansas River Watershed is based on observed temporal trends of select water quality constituents, and estimation of constituent transport under climate change scenarios. Trend analyses elucidate what may be expected in the future based on what has been observed. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surfaces to streams and reservoirs.

3.7.5.1.2 Trend Analysis: Total Nitrogen, Total Phosphorus, and Total Suspended Solids

Temporal water quality data for seven USACE reservoirs within the Kansas River Watershed was provided by NWK. The maximum period of record included monthly (April through September) observations from 1996 through 2020. Data were available for Clinton Lake (CL), Harlan County Lake (HC), Kanopolis Lake (KA), Milford Lake (MI), Perry Lake (PE), Tuttle Creek Lake (TC), and Wilson Lake (WI). Data analyzed were restricted to in-lake dam site locations (surface (S) and bottom (B)) if available, and upstream in-flow sites if available. Trend analysis focused on total nitrogen (TN) and total phosphorus (TP) concentrations, the TN:TP ratio, and total suspended solids (TSS) concentrations. In-lake water quality data was supplemented with corresponding daily reservoir variables including inflow, outflow, storage, and pool elevation.

The Mann-Kendall (M-K) trend test is a nonparametric test which does not require the underlying data to follow a specific distribution. The M-K test can be used to determine increasing or decreasing trends in measurement values of a response variable observed during a certain time period. If an increasing trend in measurements exists, then the measurement taken first from any randomly selected pair of measurements should, on average, have a lower response (concentration or value) than the measurement collected at a later point (U.S. EPA 2015a).

The Theil-Sen (T-S) Line test represents a nonparametric version of the parametric Ordinary Least Squares (OLS) regression analysis and requires the values of the time variable at which the response measurements were collected. The T-S procedure does not require normally distributed trend residuals and responses as required by the OLS regression. Unlike the M-K test, actual concentration values are used in the computation of the slope estimate associated with the T-S trend test. The test is based upon the calculation of slope estimates for every pair of distinct measurements, and the median slope value is used as an estimate of the unknown population slope (U.S. EPA 2015a). The median slope value mitigates the influence of extreme (outlier) observations.

Water quality constituent concentration data often includes ‘censored’ data, where laboratory analysis results are not quantifiable (below the analysis method detection limit) and are reported as less than the method numeric limit of quantification. U.S. EPA’s ProUCL (U.S. EPA 2015b), and ‘R’ packages Non-detects and Data Analysis (NADA) (Lee 2020) and NADA2 (Julian & Helsel 2021) have been developed to analyze censored data.

Sampling dates were recorded with each water quality constituent concentration/value observation. Because the ProUCL program does not recognize dates, the time variable was derived as number of days since January 1, 1990. M-K trend and T-S line tests

were performed with ProUCL. R packages NADA and NADA2 were used to further examine trends accounting for covariate influence (inflow, outflow, storage, and pool elevation) using the M-K trend test, and for seasonal (monthly) variation using the Seasonal Kendall trend test.

Results of the M-K trend and T-S line tests are presented in Table 3-137. Bold 'Increasing' and 'Decreasing' entries in the table indicate trend test p-value results less than 0.05. 'No Trend' entries indicate resulting p-values greater than 0.05. 'NA' table entries imply trend calculation is not applicable.

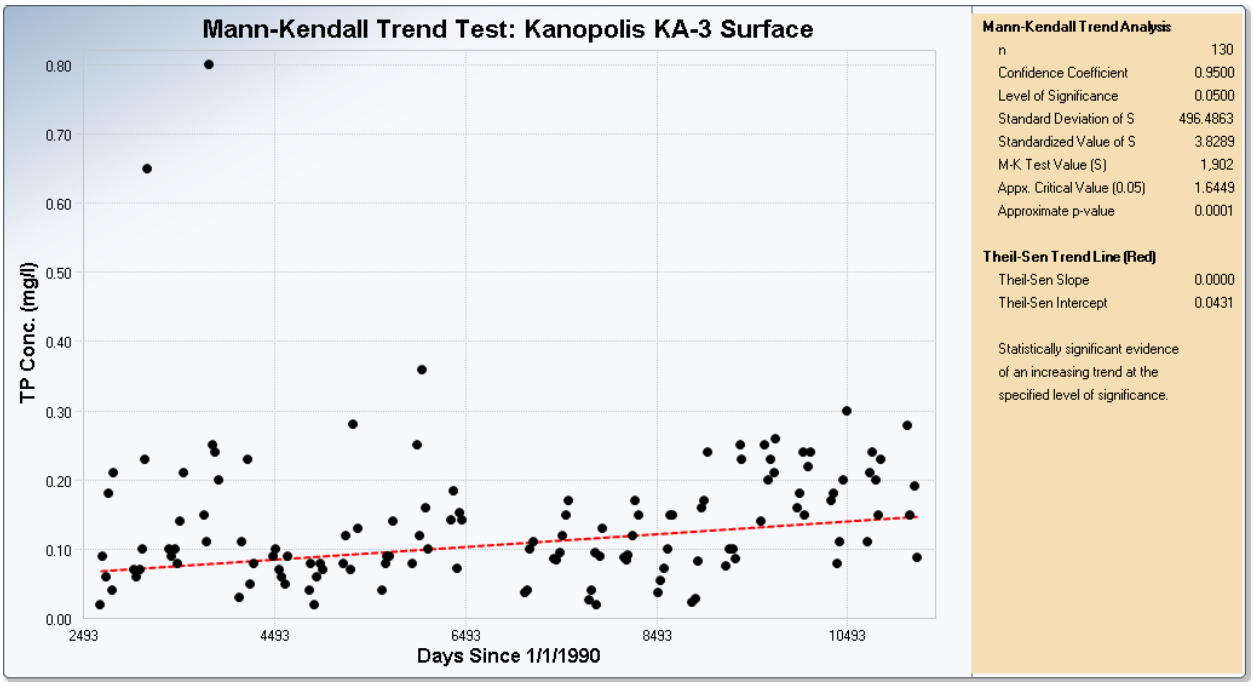
Noteworthy (p-value<0.05) TN trends only occurred at dam site bottom locations at Harlan County Lake (HC-2B), Kanopolis Lake (KA-3B), and Milford Lake (MI-1B), and all were decreasing. TP trend analysis revealed increasing trends at five of the seven lakes at dam site surface locations (e.g., Figure 3-292 and Figure 3-293). Only two dam site bottom locations revealed TP trends, one increasing (MI-1B) and one decreasing (WI-15AB). Increasing inflow site TP concentration trends were reported at Clinton (CL-16), Milford (MI-24), and Perry (PE-41). One decreasing inflow site TP trend was noted at Wilson (WI-1).

All noteworthy TN:TP trends at dam site surface locations (five of the seven lakes) were decreasing. Example graphics are shown in Figure 3-294 and Figure 3-295. Inflow sites showed decreasing TN:TP trends at five of the seven lakes. TSS concentration trends were infrequent, but decreasing trends were noted at CL-16, MI-1S, and WI-15AS and B. The Wilson Lake inflow (WI-1) TSS concentration revealed an increasing trend.

12661 *Table 3-137. Results of M-K trend tests using ProUCL (U.S. EPA, 2015b)*

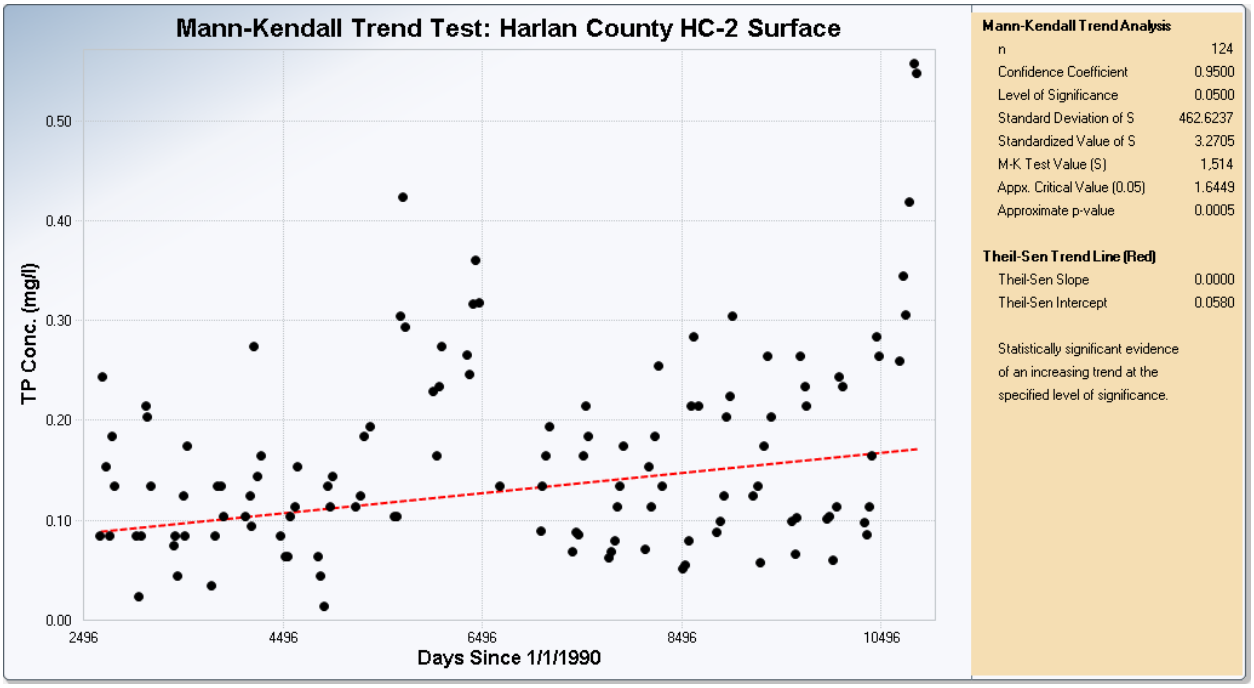
Lake	Site	TN (mg/l)	TP (mg/l)	TN:TP	TSS (mg/l)
Clinton	CL-2S (dam)	No Trend	Increasing	Decreasing	No Trend
	CL-2B (dam)	No Trend	No Trend	NA	No Trend
	CL-16 (inflow)	No Trend	Increasing	Decreasing	Decreasing
Harlan Co.	HC-2S (dam)	No Trend	Increasing	Decreasing	No Trend
	HC-2B (dam)	Decreasing	No Trend	NA	No Trend
	HC-8 (inflow)	No Trend	No Trend	Decreasing	No Trend
Kanopolis	KA-3S (dam)	No Trend	Increasing	Decreasing	No Trend
	KA-3B (dam)	Decreasing	No Trend	NA	No Trend
	KA-14 (inflow)	No Trend	No Trend	Decreasing	No Trend
Milford	MI-1S (dam)	No Trend	Increasing	Decreasing	Decreasing
	MI-1B (dam)	Decreasing	Increasing	NA	No Trend
	MI-24 (inflow)	No Trend	Increasing	Decreasing	No Trend
Perry	PE-2S (dam)	No Trend	No Trend	No Trend	No Trend
	PE-2B (dam)	No Trend	No Trend	NA	No Trend
	PE-17 (inflow)	No Trend	No Trend	No Trend	No Trend
	PE-29 (inflow)	No Trend	No Trend	No Trend	No Trend
	PE-41 (inflow)	No Trend	Increasing	No Trend	No Trend
Tuttle Creek	TC-3S (dam)	No Trend	Increasing	Decreasing	No Trend
	TC-30 (inflow)	No Trend	No Trend	Decreasing	No Trend
Wilson	WI-15AS (dam)	No Trend	No Trend	No Trend	Decreasing
	WI-15AB (dam)	No Trend	Decreasing	NA	Decreasing
	WI-1 (inflow)	No Trend	Decreasing	No Trend	Increasing

12662 Increasing and Decreasing trends indicated by test p-values<0.05; NA=not applicable/not calculated.
12663
12664 *Figure 3-292. M-K Trend Test and T-S Trend Line for TP Concentration at Kanopolis Lake (KA-3)*

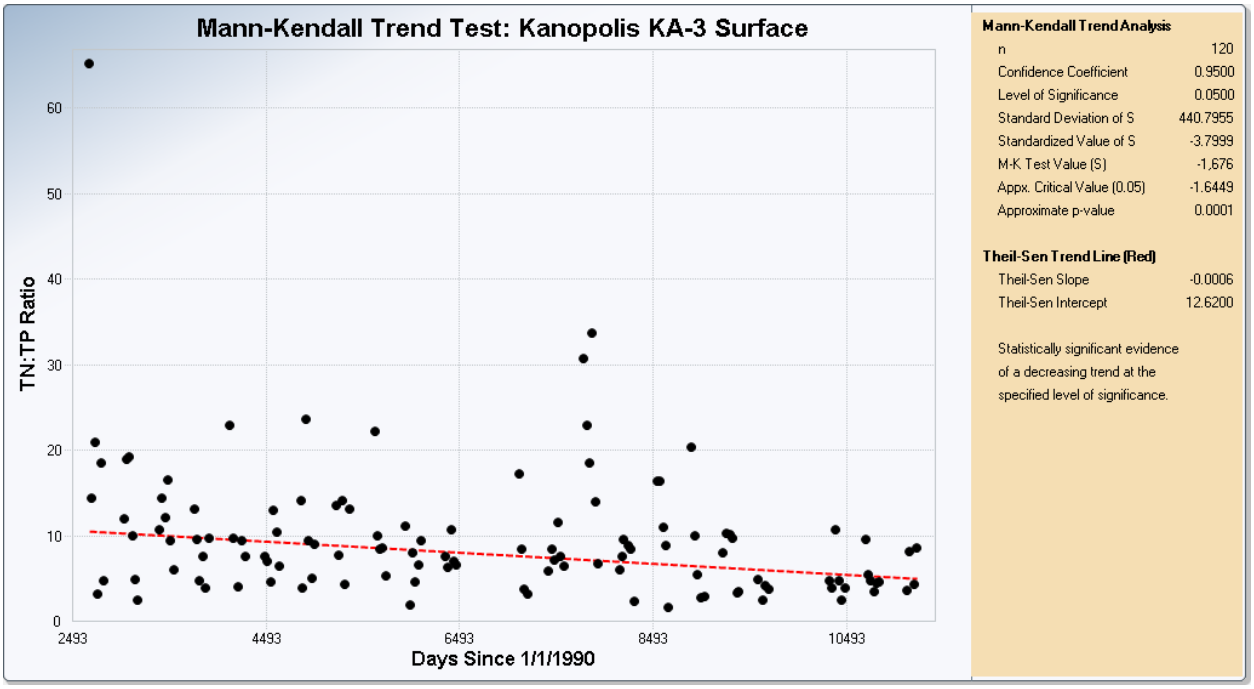


12665
12666 Note: The estimated slope of the Theil-Sen trend line is 9.3067E-6 mg/l/d (or 0.0034 mg/l/yr).

12667 *Figure 3-293. M-K Trend Test and T-S Trend Line for TP Concentration at Harlan County Lake (HC-2)*

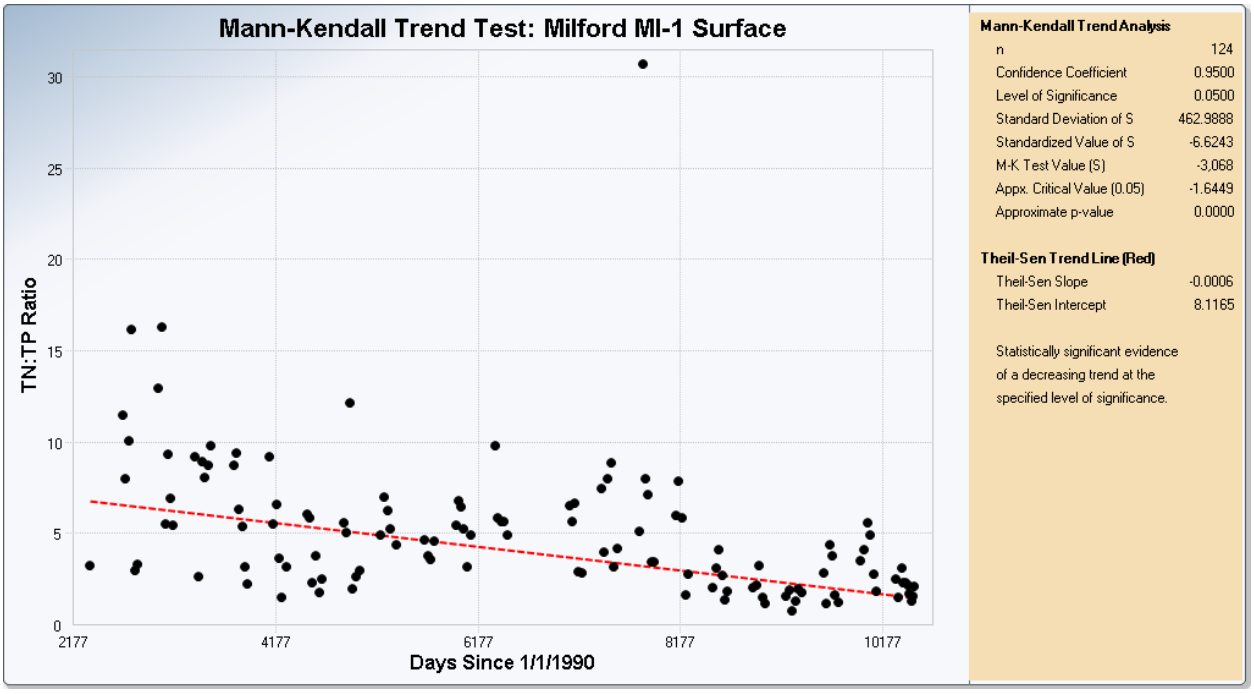


12668
12669 Note: The estimated slope of the Theil-Sen trend line is 1.0103E-5 mg/l/d (or 0.0037 mg/l/yr).
12670
12671 *Figure 3-294. M-K Trend Test and T-S Trend Line for TN:TP Ratio at Kanopolis Lake (KA-3)*



12672
12673

12674 *Figure 3-295. M-K Trend Test and T-S Trend Line for TN:TP Ratio at Milford Lake (MI-1)*



12675

12676 A temporal trend analysis of TN, TP, TN:TP, and TSS observations at dam site surface
12677 sites including daily corresponding reservoir attributes (flow in [cfs], flow out [cfs],
12678 storage [acre-feet], and pool elevation [ft]) as covariates was performed (

12679

Table 3-138). Incorporation of covariates in the trend analysis did not alter TN trend results; no noteworthy TN trends were revealed.

The Clinton Lake dam site surface location showed a significant increasing TP trend with no covariates included in the analysis, but with covariates no TP trend was revealed. Increasing TP trends with covariates included were noted at dam surface sites at Harlan Co., Kanopolis, Milford, and Tuttle Creek. At Harlan Co. Lake, site HC-2 (surface), inclusion of daily lake storage and pool elevation as covariates (separately) resulted in no significant trend. Corresponding to TP trend analysis without covariates, dam site surface locations at Perry (PE-2) and Wilson (WI-15A) revealed no TP trends with covariates.

Addition of covariates in analysis of TN:TP trends at dam surface sites resulted in fewer significant decreasing trends. Data available was insufficient to process information at Clinton, Kanopolis, Perry, and Wilson. Both Milford and Tuttle Creek revealed significant decreasing TN:TP trends with each covariate included.

Covariate inclusion in TSS trend analysis at dam surface sites revealed significant decreasing trends at Milford and Wilson, corresponding to analysis without covariates.

Table 3-138. Results of M-K trend tests with a covariate using NADA2 (Julian & Helsel, 2021) in R (R Core Team, 2020)

Lake	Site	Covariate	TN	TP	TN:TP	TSS
Clinton	CL-2	Flow-In	No Trend	No Trend	NA	No Trend
		Flow-Out	No Trend	No Trend	NA	No Trend
		Storage	No Trend	No Trend	No Trend	No Trend
		Elev.	No Trend	No Trend	No Trend	No Trend
Harlan Co.	HC-2	Flow-In	No Trend	Increasing	No Trend	No Trend
		Flow-Out	No Trend	Increasing	No Trend	No Trend
		Storage	No Trend	No Trend	No Trend	No Trend
		Elev.	No Trend	No Trend	No Trend	No Trend
Kanopolis	KA-3	Flow-In	No Trend	Increasing	NA	NA
		Flow-Out	No Trend	Increasing	NA	NA
		Storage	No Trend	Increasing	NA	NA
		Elev.	No Trend	Increasing	NA	NA
Milford	MI-1	Flow-In	No Trend	Increasing	Decreasing	Decreasing
		Flow-Out	No Trend	Increasing	Decreasing	Decreasing
		Storage	No Trend	Increasing	Decreasing	Decreasing
		Elev.	No Trend	Increasing	Decreasing	Decreasing
Perry	PE-2	Flow-In	No Trend	No Trend	NA	No Trend
		Flow-Out	No Trend	No Trend	NA	No Trend
		Storage	No Trend	No Trend	NA	No Trend
		Elev.	No Trend	No Trend	NA	No Trend
Tuttle Creek	TC-3	Flow-In	No Trend	Increasing	Decreasing	No Trend
		Flow-Out	No Trend	Increasing	Decreasing	No Trend
		Storage	No Trend	Increasing	Decreasing	No Trend
		Elev.	No Trend	Increasing	Decreasing	No Trend
Wilson	WI-15A	Flow-In	No Trend	No Trend	NA	NA
		Flow-Out	No Trend	No Trend	NA	NA
		Storage	No Trend	No Trend	NA	Decreasing
		Elev.	No Trend	No Trend	NA	Decreasing

Increasing and Decreasing trends significant at p<0.05; NA=sufficient data not available/not calculated.

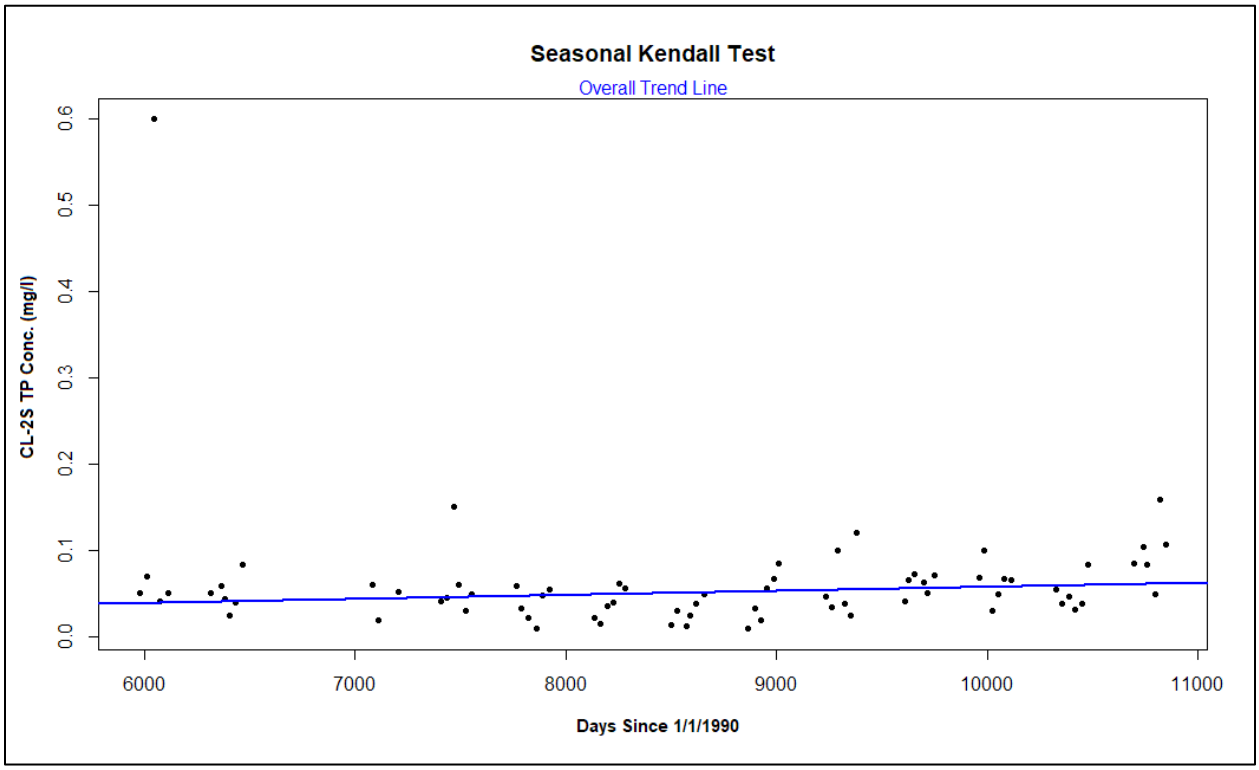
TN, TP, TN:TP, and TSS dam site surface data at the seven lakes were evaluated for trends using the Seasonal Kendall (SK) test which performs the M-K calculations for each season, months in this application, and then combines the results. Constituent data available were from sampling efforts from April through September in most years. For monthly ‘seasons’, April observations are only compared to other April observations, etc. No comparisons are made across seasonal boundaries. The results of the analysis are found in Table 3-139.

No significant TN trends were revealed at any of the lake’s dam site surface locations. Significant increasing TP trends were noted at five of the seven lakes (not Perry and Wilson). Significant decreasing TN:TP trends were found at Clinton, Kanopolis, Milford Lakes, and Tuttle Creek. Two lakes, Milford and Wilson, revealed significant decreasing TSS trends.

12713 *Table 3-139. Results of Seasonal Kendall trend tests using NADA2 (Julian & Helsel, 2021) in R (R Core*
12714 *Team, 2020)*

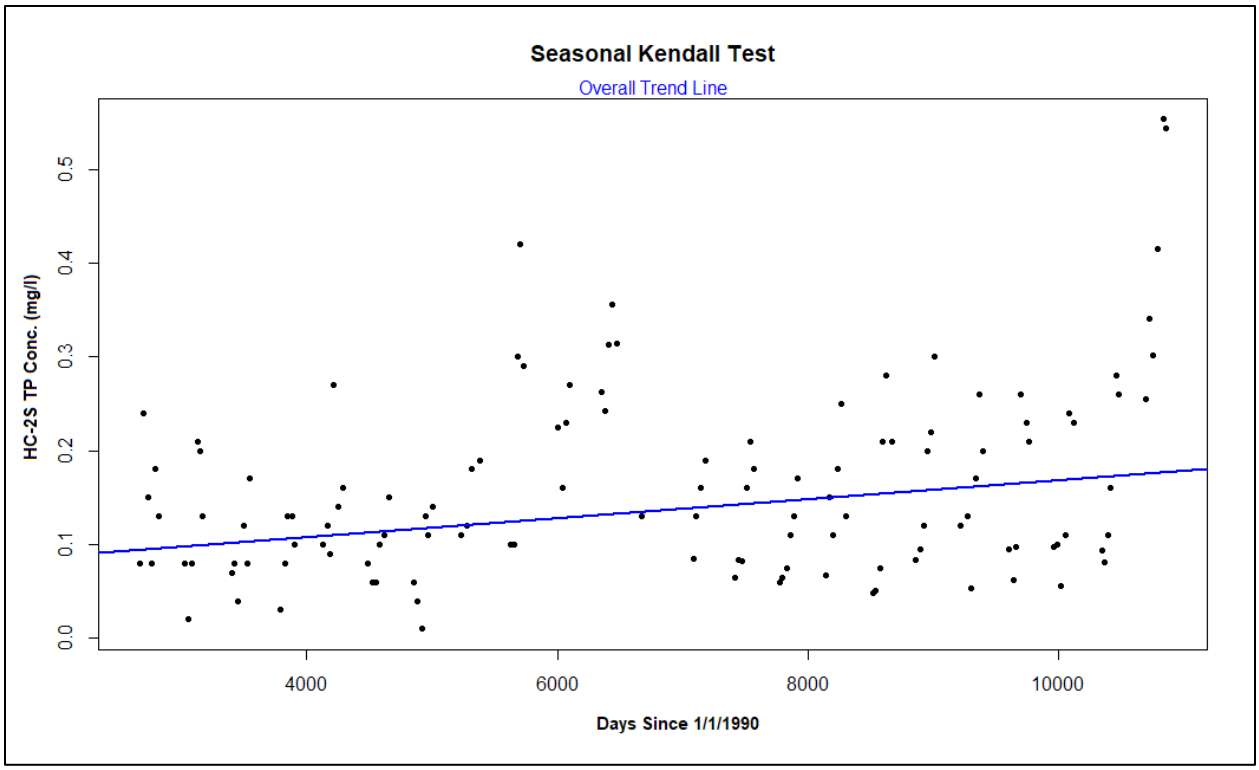
Lake	Site	TN	TP	TN:TP	TSS
Clinton	CL-2	No trend	Increasing	Decreasing	No Trend
Harlan Co.	HC-2	No Trend	Increasing	No Trend	No Trend
Kanopolis	KA-3	No Trend	Increasing	Decreasing	No Trend
Milford	MI-1	No Trend	Increasing	Decreasing	Decreasing
Perry	PE-2	No Trend	No Trend	No Trend	No Trend
Tuttle Creek	TC-3	No Trend	Increasing	Decreasing	No Trend
Wilson	WI-15A	No Trend	No Trend	No Trend	Decreasing

12715 Increasing and Decreasing trends significant at p<0.05; NA=sufficient data not available/not calculated.
12716
12717 *Figure 3-296. SK Trend Test Result (p<0.05) for TP Concentrations at Clinton Lake (CL-2S)*

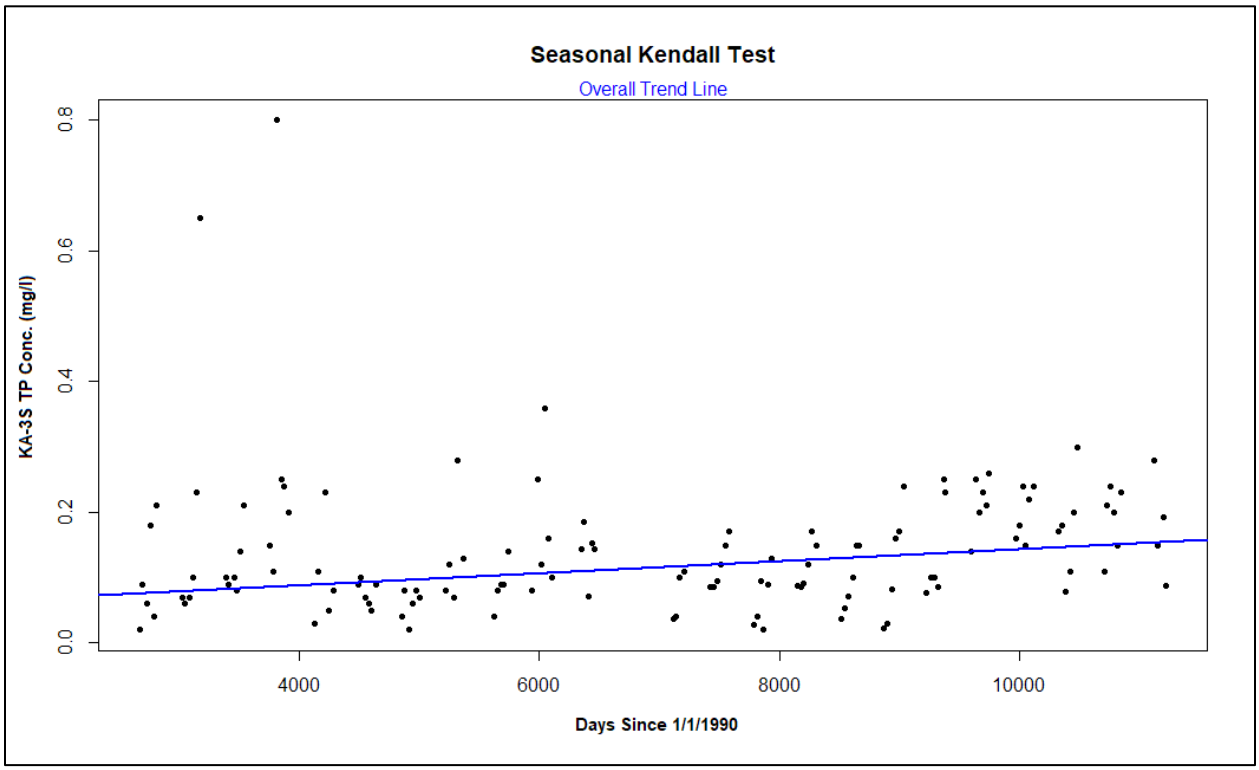


12718
12719

12720 *Figure 3-297. SK Trend Test Result (p<0.05) for TP Concentrations at Harlan County Lake (HC-2S)*

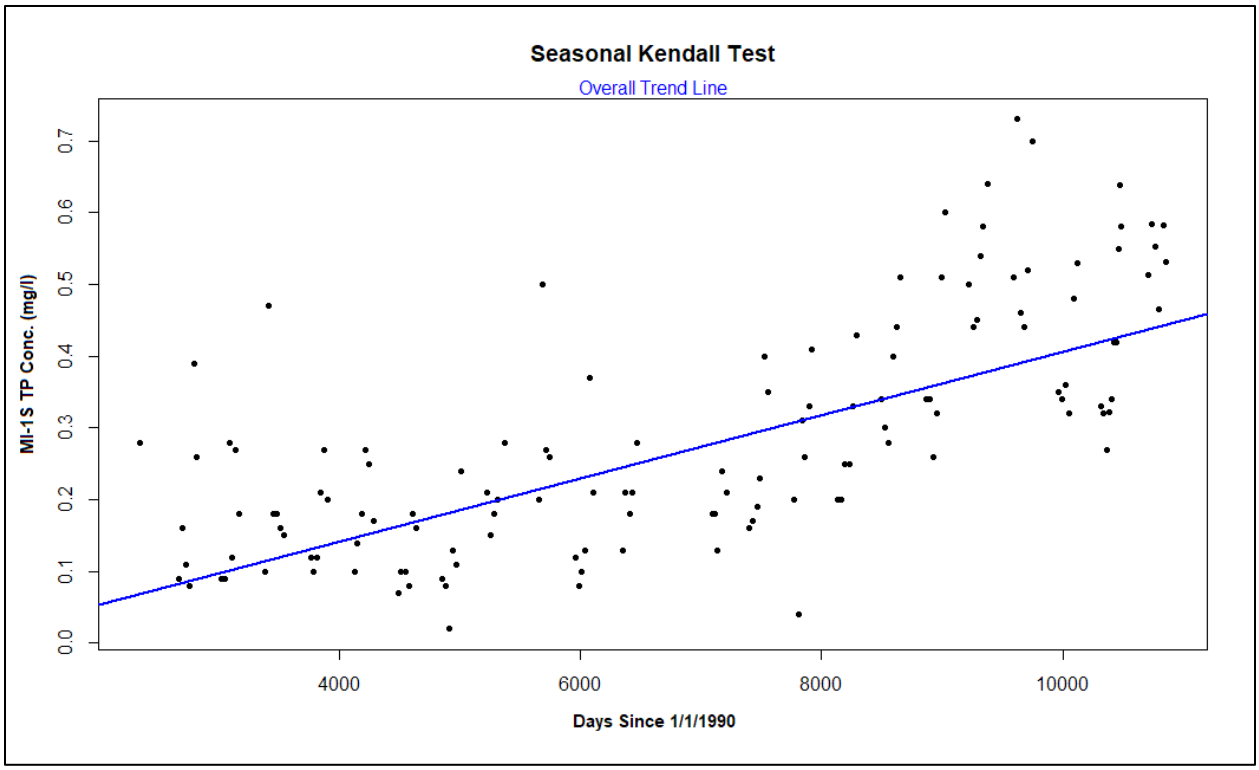


12721
12722
12723 *Figure 3-298. SK Trend Test Result (p<0.05) for TP Concentrations at Kanopolis Lake (KA-3S)*

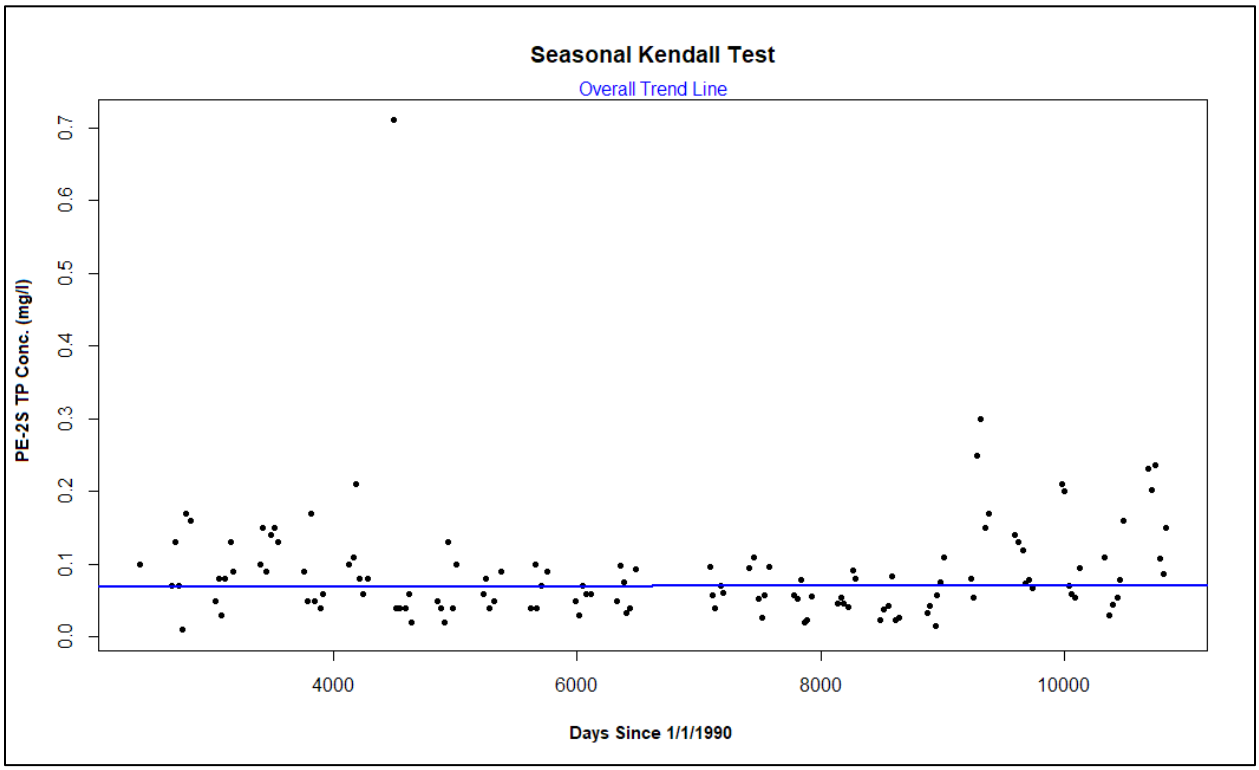


12724
12725

12726 *Figure 3-299. SK Trend Test Result (p<0.05) for TP Concentrations at Milford Lake (MI-1S)*

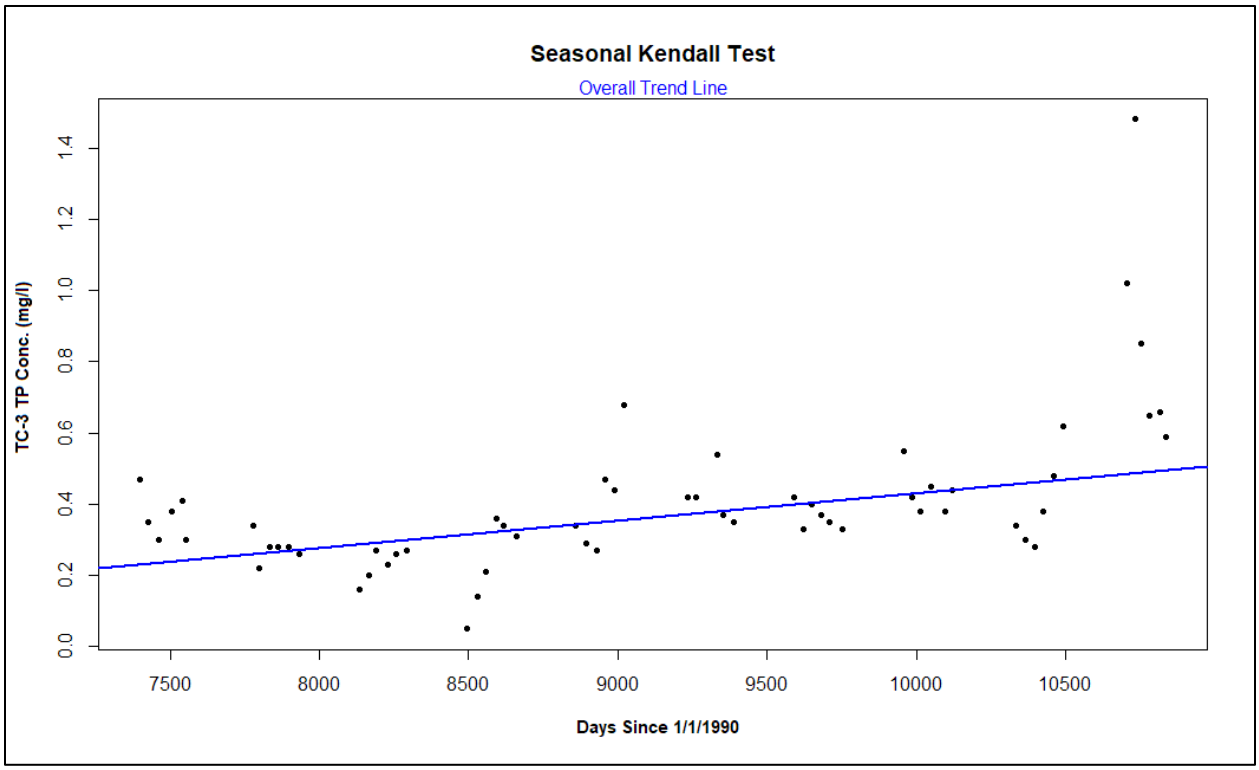


12727
12728
12729 *Figure 3-300. SK Trend Test Result (p>0.05) for TP Concentrations at Perry Lake (PE-2S)*



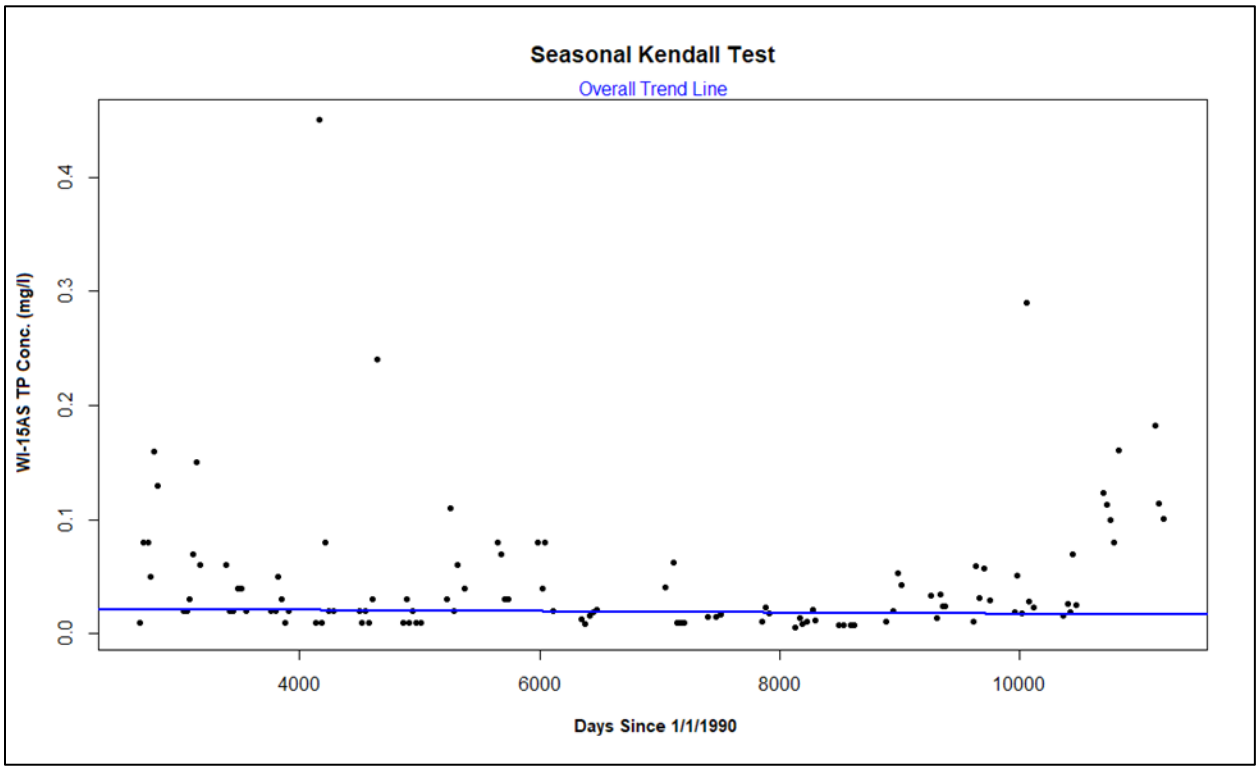
12730
12731

12732 *Figure 3-301. SK Trend Test Result (p<0.05) for TP Concentrations at Tuttle Creek Lake (TC-3)*



12733
12734

12735 *Figure 3-302. SK Trend Test Result (p>0.05) for TP Concentrations at Wilson Lake (WI-15AS)*



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Trend Analysis Conclusions

The nutrients nitrogen and phosphorus are abundantly available throughout the Kansas River Watershed. A watershed-wide pattern of increasing in-lake TP concentrations suggests potential for continued eutrophication (high algal productivity) at Kansas Watershed reservoirs. Phosphorus is often considered a nutrient limiting primary productivity, although nutrient limitation of phytoplankton growth may vary temporally and geographically between phosphorus and nitrogen. Observed decreasing TN:TP ratios observed may indicate an enhanced opportunity for seasonal HAB issues as some flourish under conditions with elevated phosphorus availability and water temperature, with certain genera of cyanophytes capable of nitrogen fixation.

Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. Trends in land use and management can be monitored. As a significant portion of the total area of the watershed is currently classified as ‘Cultivated Crops’ (approximately 51.5 percent), based on the 2016 National Land Cover Database (NLCD) (Yang, et al. 2018), it can be assumed that continued, and increasing (Figure 3-303), fertilizer use will continue to influence the water quality of runoff, groundwater, streams, and lakes. Additionally, the 2016 NLCD indicates approximately 40 percent of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The KDA (2021) publishes total numbers of livestock (cattle, sheep, hogs). Trending increasing numbers of animals require feed and produce increased quantities of manure (Figure 3-304).

Figure 3-303. Total Fertilizer Sold in Kansas by Fiscal Year (Kansas Department of Agriculture, 2021)

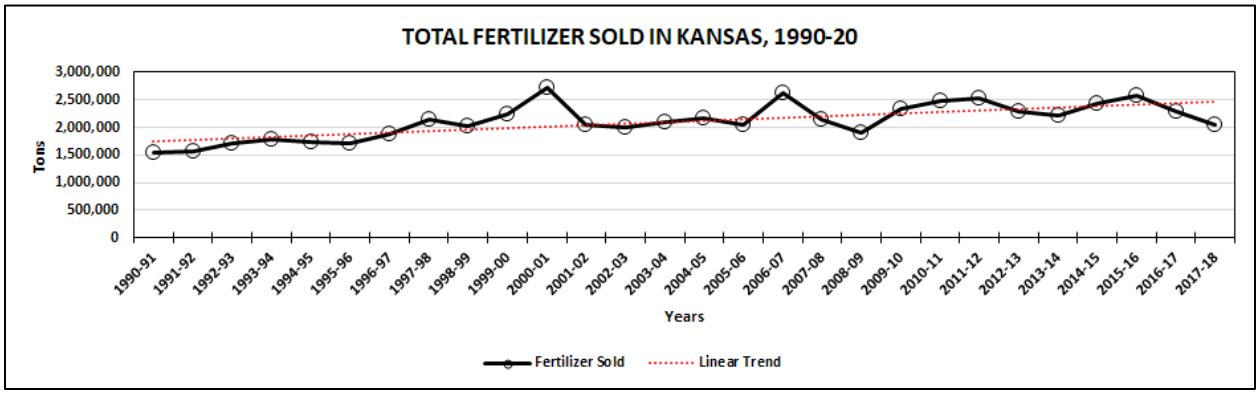
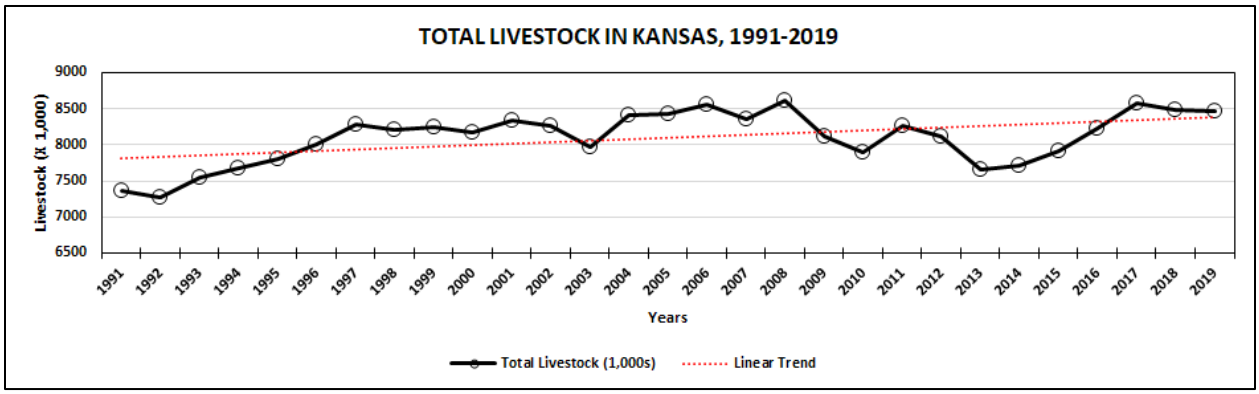


Figure 3-304. Total Livestock in Kansas by Year (Kansas Department of Agriculture, 2021)



3.7.5.1.3 Climate Change and Streamflow Trends

Based on the USACE CHAT (USACE 2021a) providing estimates of potential future hydrology for HUC-8 watersheds using climate models and scenarios from the Coupled Model Intercomparison Project Phase 5 (CMIP-5), future runoff trends can be estimated (Nguyen, et al. 2020). The CHAT utilizes 32 projected future Global Climate Model (GCM) simulations based on accelerated CO_2 levels for representative concentration pathways (RCPs) 4.5 and 8.5. RCP 4.5 represents rising radiative forcing stabilizing at 4.5 W/m^2 before 2100, and RCP 8.5 represents rising radiative forcing pathway leading to 8.5 W/m^2 in 2100, where radiative forcing expresses the change in energy in the atmosphere due to greenhouse gas emissions. CHAT options include evaluation of whether there is evidence of a statistically significant trend (defined as p-value < 0.05) in the mean of the 64 (32 for each RCP) simulated timeseries for both the historic simulation period (water years 1951-2005) and the projected future simulation period (water years 2006-2099). The Mann-Kendall test trend results were captured for this effort in evaluation of future runoff trends by HUC-8 within the three HUC-4 regions spanning the Kansas River Watershed. Results are presented below in Table 3-140. The generally increasing trends in streamflow across the watershed, due to future climate conditions with predicted regional future precipitation increases and the likelihood of increased frequency of extreme precipitation events, can be expected to transport increased quantities of sediment and nutrients.

12786 *Table 3-140. Results of M-K Test for Future Trends in Mean Annual Max of Average Monthly Streamflow*
12787 *at HUC-8 Watersheds in the Kansas River Watershed (U. S. ACE, 2021a)*

HUC-8	Name	States	Future (2006-2099) Streamflow Trend
10250001	Arikaree	CO, KS, NE	No Trend
10250002	North Fork Republican	CO, KS, NE	No Trend
10250003	South Fork Republican	CO, KS, NE	Increasing
10250004	Upper Republican	KS, NE	No Trend
10250005	Frenchman	CO, NE	Increasing
10250006	Stinking Water	CO, NE	NA
10250007	Red Willow	NE	Increasing
10250008	Medicine	NE	NA
10250009	Harlan County Reservoir	KS, NE	Increasing
10250010	Upper Sappa	KS	NA
10250011	Lower Sappa	KS, NE	Increasing
10250012	South Fork Beaver	CO, KS	NA
10250013	Little Beaver	CO, KS	NA
10250014	Beaver	KS, NE	Increasing
10250015	Prairie Dog	KS, NE	Increasing
10250016	Middle Republican	KS, NE	Increasing
10250017	Lower Republican	KS	Increasing
10260001	Smoky Hill Headwaters	CO, KS	NA
10260002	North Fork Smoky Hill	CO, KS	NA
10260003	Upper Smoky Hill	KS	Increasing
10260004	Ladder	CO, KS	NA
10260005	Hackberry	KS	NA
10260006	Middle Smoky Hill	KS	Increasing
10260007	Big	KS	Increasing
10260008	Lower Smoky Hill	KS	Increasing
10260009	Upper Saline	KS	Increasing
10260010	Lower Saline	KS	No Trend
10260011	Upper North Fork Solomon	KS	Increasing
10260012	Lower North Fork Solomon	KS, NE	Increasing
10260013	Upper South Fork Solomon	KS	Increasing
10260014	Lower South Fork Solomon	KS	Increasing
10260015	Solomon	KS	Increasing
10270101	Upper Kansas	KS	Increasing
10270102	Middle Kansas	KS	Increasing
10270103	Delaware	KS	Increasing
10270104	Lower Kansas, Kansas	KS, MO	Increasing
10270201	Upper Big Blue	NE	NA
10270202	Middle Big Blue	NE	Increasing
10270203	West Fork Big Blue	NE	Increasing
10270204	Turkey	NE	Increasing
10270205	Lower Big Blue	KS, NE	Increasing
10270206	Upper Little Blue	KS, NE	Increasing
10270207	Lower Little Blue	KS, NE	Increasing

12788 Increasing trends using M-K test defined as p value < 0.05; NA=not available.
12789

3.7.5.1.4 Hydrologic and Water Quality System Methodology: Projected Future Water Quality

The Hydrologic and Water Quality System (HAWQS) version 1.2 (HAWQS, 2020) is a web-based interactive water quantity and quality modeling system that employs the Soil and Water Assessment Tool (SWAT) (Arnold, et al. 2013). SWAT is a basin-scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large watersheds with varying soils, land uses, and management conditions over time. The model is physically based in that it requires spatially referenced data describing weather, hydrology, soil types and attributes, topography, land use/cover, and land management. HAWQS provides users with interactive web interfaces and maps; pre-loaded input data; a user guide, and online development, execution, and storage of a user's modeling projects. The United States Environmental Protection Agency (EPA) Office of Water (OW) supports and provides project management and funding for HAWQS. The Texas A&M University Spatial Sciences Laboratory and EPA subject matter experts provide ongoing technical support including system design, modeling, and software development.

Historical weather data and future climate scenarios are available within HAWQS. Historical weather data available in HAWQS includes archived National Climate Data Center and NWS precipitation and air temperature data (Menne, Durre, Vose, Gleason, & Houston 2012). Climate change scenarios are based on representative concentration pathways (RCPs) that capture a range of plausible greenhouse gas concentration futures approximating total radiative forcing in the year 2100. RCP4.5 scenarios, an intermediate scenario where greenhouse gas emissions peak approximately mid-century (2050) as a result of less stringent mitigation efforts, were used for modeling climate change effects in the Kansas River Watershed. Twelve Global Climate Models (GCMs) included in HAWQs provide a representative range of plausible projections across all of the U.S. EPA Regions. CMIP-5 (Taylor, Stouffer, & Meehl 2012) GCMs currently in HAWQS include CanESM2, CCSM4, GISS-E2-R, HadGEM2-ES, Model for Interdisciplinary Research on Climate (MIROC) 5, ACCESS1-3, Geophysical Fluid Dynamics Laboratory (GFDL)-CM3, HadGEM2-CC, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM-CHEM, and MRICGCM3. Details with respect to future climate inputs in HAWQS are described in HAWQS (2017).

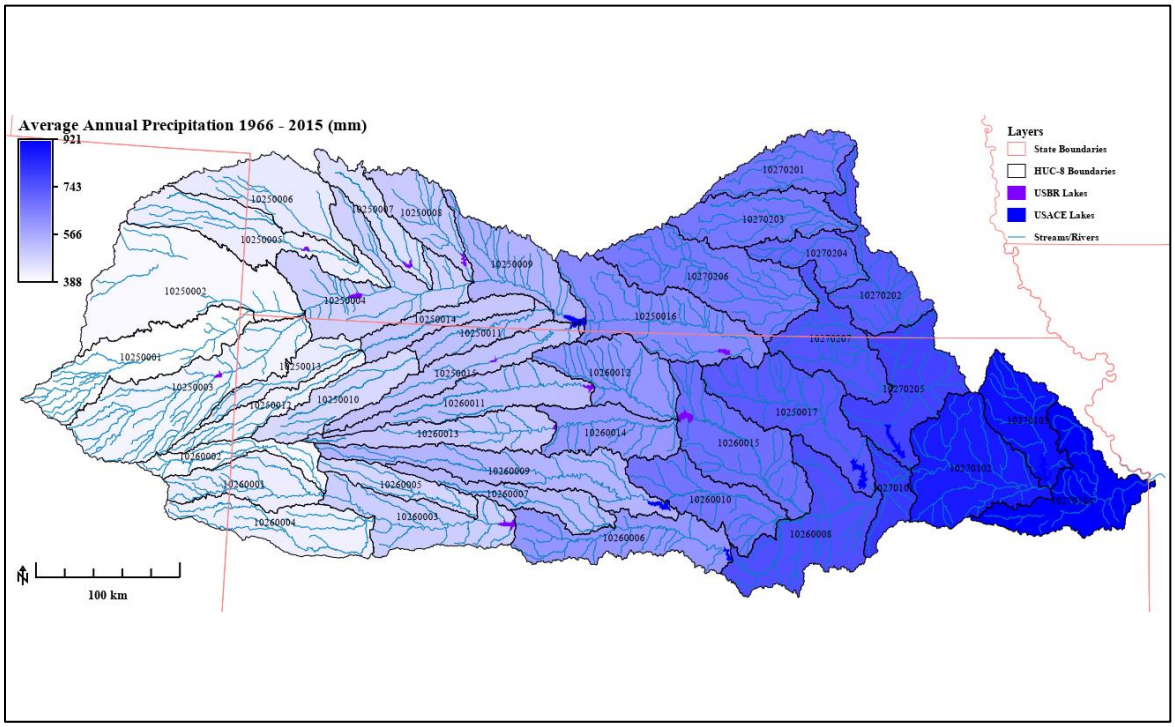
A model of the Kansas River Watershed was generated in HAWQS at the HUC-8 scale with base inputs including elevation (USGS 2010), 2006 land use/cover (Fry, et al. 2011), soil types and attributes (Soil Survey Staff 2010), crop land management (USDA-NASS 2010), and historical weather information (Menne, Durre, Vose, Gleason, & Houston 2012). No modifications were made to adjust hydrologic output. The only alterations made to the default generated watershed model included addition of cropland fertilizer to replace crop nutrient uptake, and adjustments of reservoir size/volume attributes (USACE 2021b). A base scenario was run for a 50-year period (1966 through 2015).

Following the base run, climate change scenarios were run for a 50-year future period (2029 through 2078) under each available GCM. Climate change scenario results were aggregated in Excel (Microsoft Corporation 2020) and compared to the base run using spreadsheet analysis and GRASS GIS software (GRASS Development Team 2020).

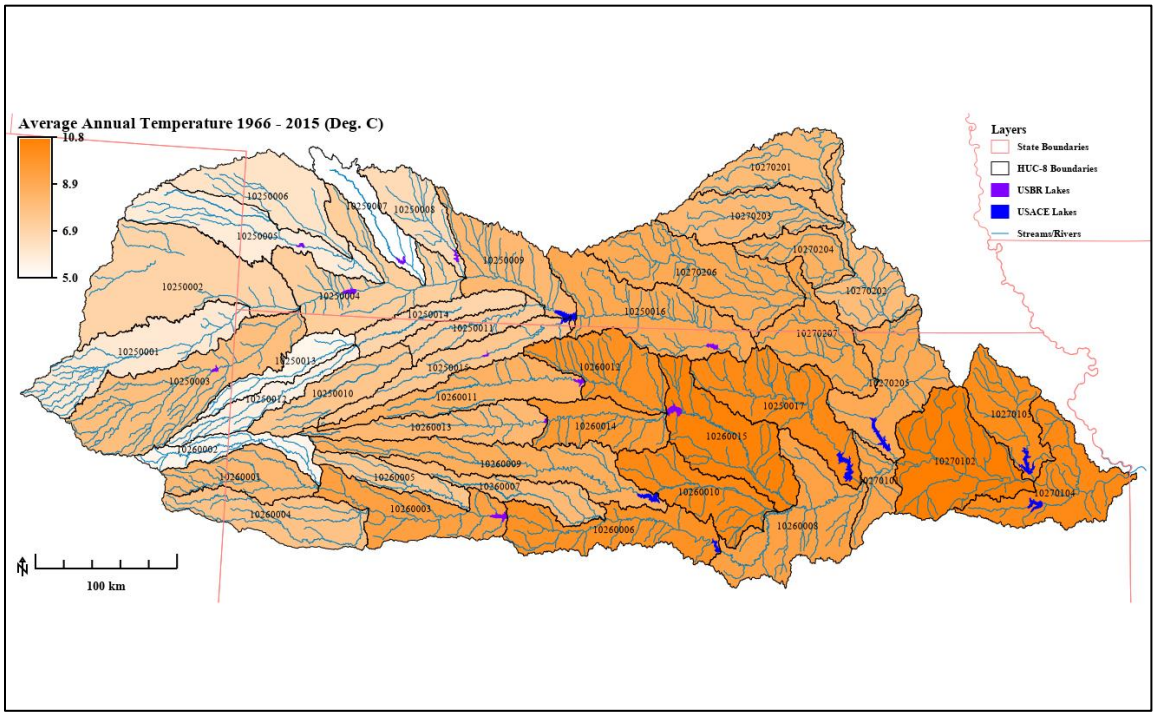
Qualitative graphic summaries of differences in average annual precipitation, air temperature, streamflow, and transport of sediment and nutrients (N and P) from subbasins (HUC 8) within the watershed were generated. These qualitative estimates represent potential hydrologic conditions and pollutant transport under a FWOP activities.

The Kansas River Watershed exhibits a gradient of precipitation as it extends across the state, with average annual precipitation ranging from approximately 388 mm/year in the west (HUC 10250001) to approximately 921 mm/year in the east (HUC 10270104) over the 50-year period from 1966 through 2015 (Figure 3-305). Over the same period, average annual air temperature ranged from 5 to 11 degrees Celsius (Figure 3-306).

Figure 3-305. Modeled Average Annual Precipitation by HUC-8 in the Kansas River Watershed (1966–2015)



12849 *Figure 3-306. Modeled Average Annual Temperature by HUC-8 in the Kansas River Watershed*
12850 *(1966–2015)*

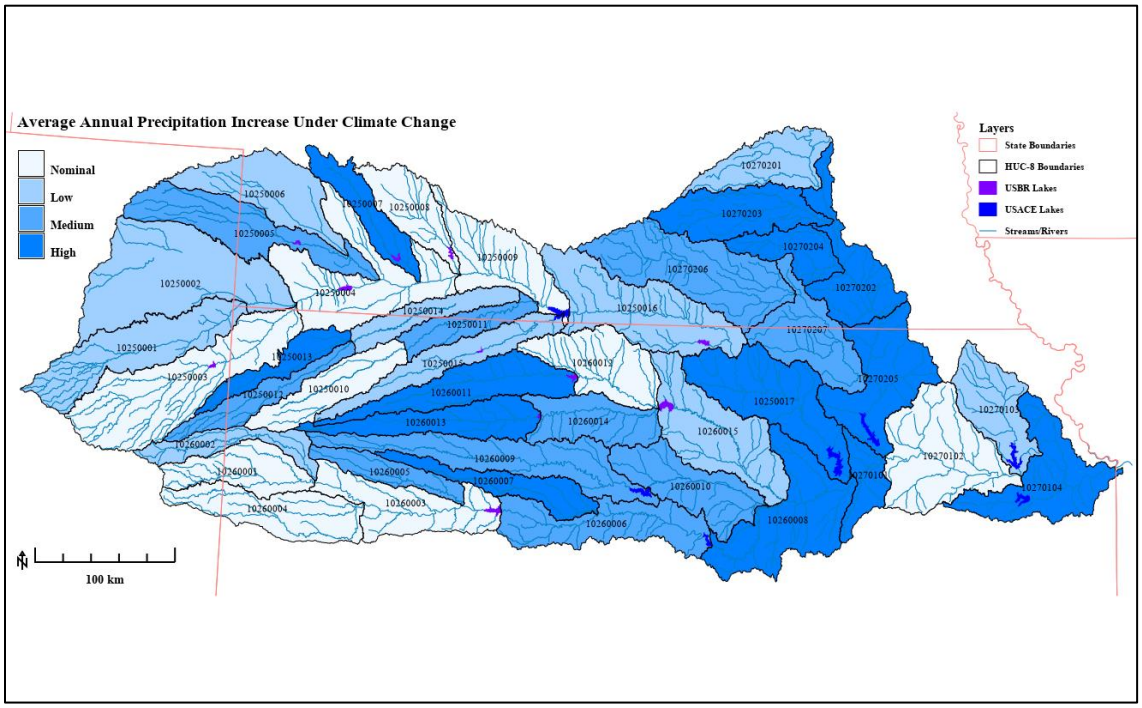


12851

12852 Aggregated output from modeled RCP4.5 GCMs, compared to output from the 1966
12853 through 2015 period, indicate generally increasing precipitation across the watershed
12854 (Figure 3-307), and generally warmer average annual temperatures with greatest
12855 increases in the western half of the Kansas River watershed (Figure 3-308).

12856

12857 *Figure 3-307. Projected Future (2029–2079) Average Annual Precipitation Increases over the Base*
12858 *Period (1966–2015) under Twelve Aggregated RCP4.5 GCMs using HAWQS (SWAT)*



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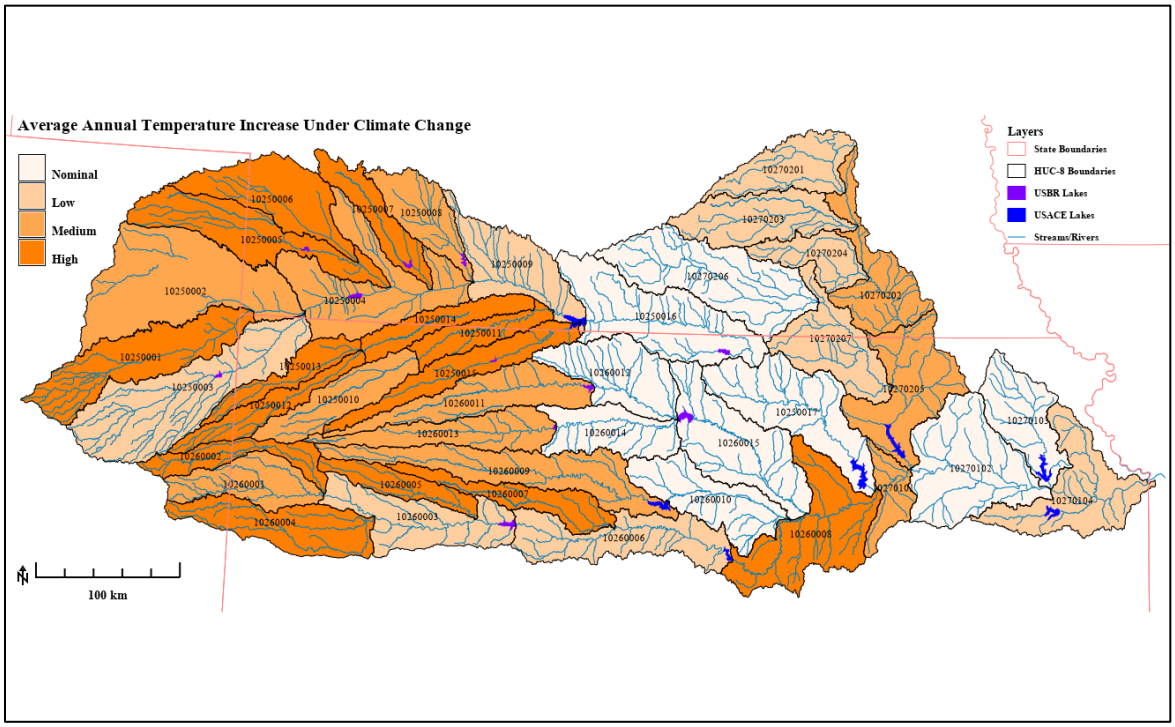
12860
12861 *Figure 3-308. Projected Future (2029–2079) Average Annual Air Temperature Increases over the Base*
12862 *Period (1966–2015) under Twelve Aggregated RCP4.5 GCMs using HAWQS (SWAT)*

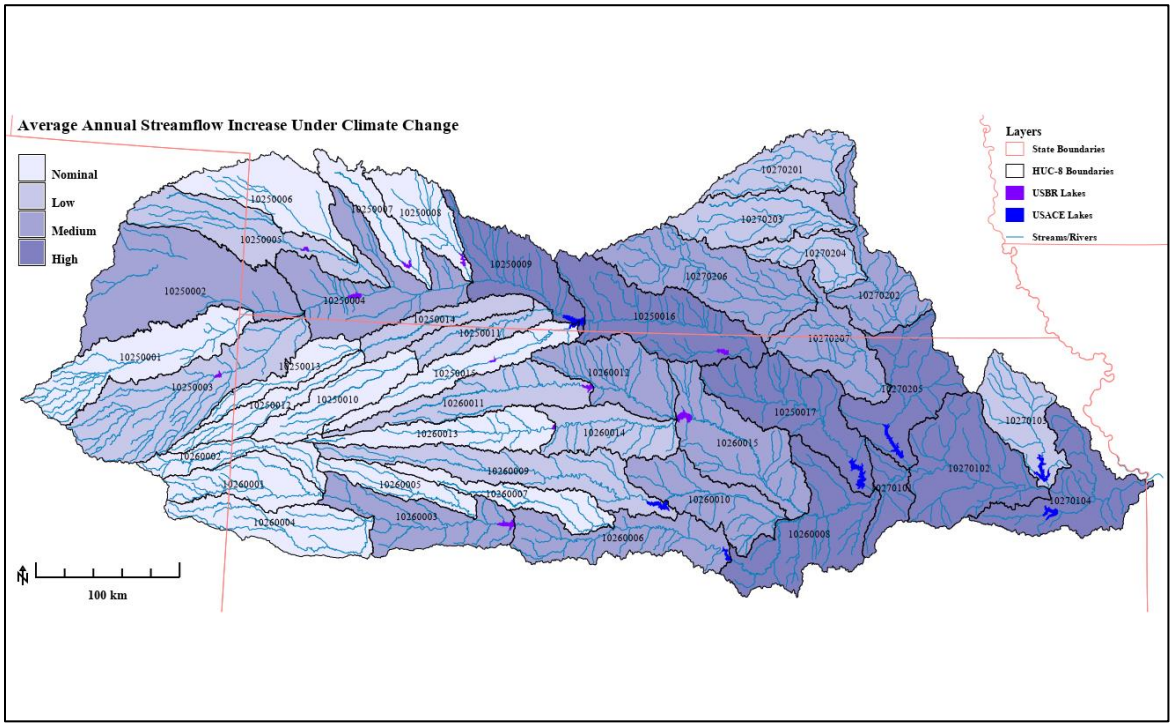


12863

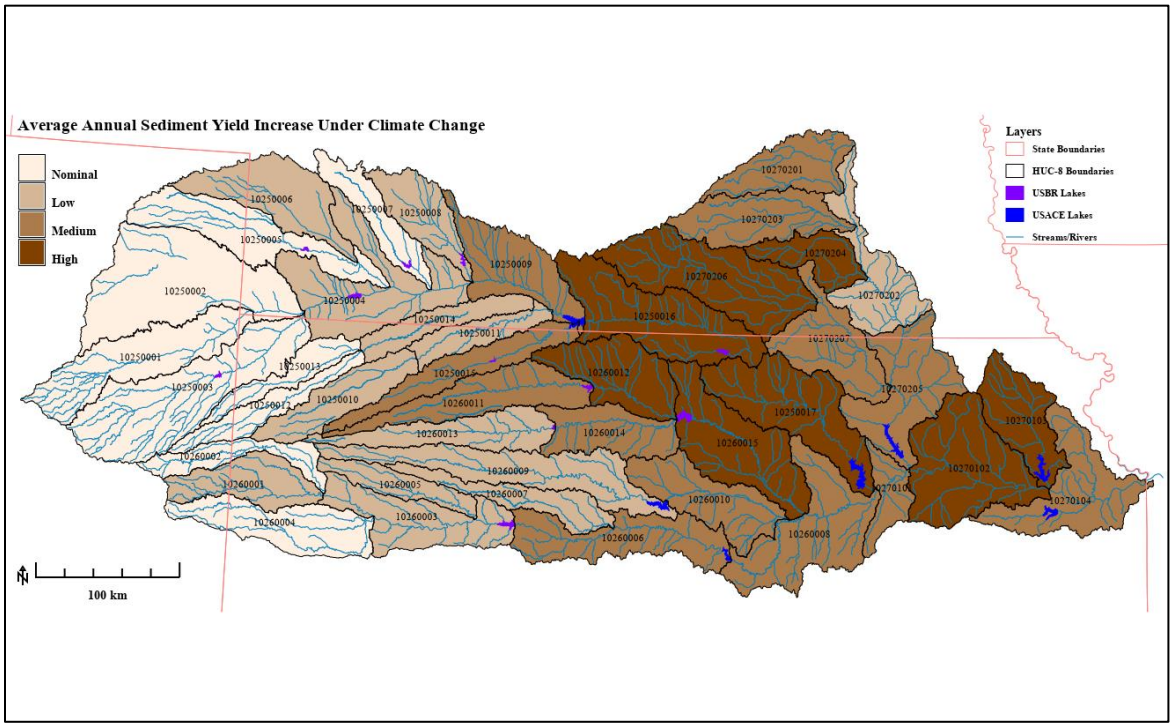
12864 The RCP4.5 GCMs, input into the watershed SWAT models, collectively suggest
12865 generally increased average annual streamflow (Figure 3-309), especially in the eastern

half of the watershed. Average annual streamflow increases under future climate conditions modeled in HAWQS (aggregated RCP4.5 GCMs) over significant portions of the Kansas River Watershed correspond with USACE CHAT (USACE 2021a) future streamflow predictions. The aggregate projected increases in average annual precipitation, air temperature, and streamflow contribute to higher (than 1966–2015) expected average annual sediment yield (Figure 3-310), total nitrogen yield (Figure 3-311), and total phosphorus yield (Figure 3-312).

Figure 3-309. Projected Future (2029–2079) Average Annual Streamflow Increases over the Base Period (1966–2015) under Twelve Aggregated RCP4.5 GCMs using HAWQS (SWAT)



12877 *Figure 3-310. Projected Future (2029–2079) Average Annual Sediment Yield Increases over the Base*
12878 *Period (1966–2015) under Twelve Aggregated RCP4.5 GCMs using HAWQS (SWAT)*



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12880

12881 *Figure 3-311. Projected Future (2029–2079) Average Annual Total Nitrogen Yield Increases over the*
12882 *Base Period (1966–2015) under Twelve Aggregated RCP4.5 GCMs using HAWQS (SWAT)*

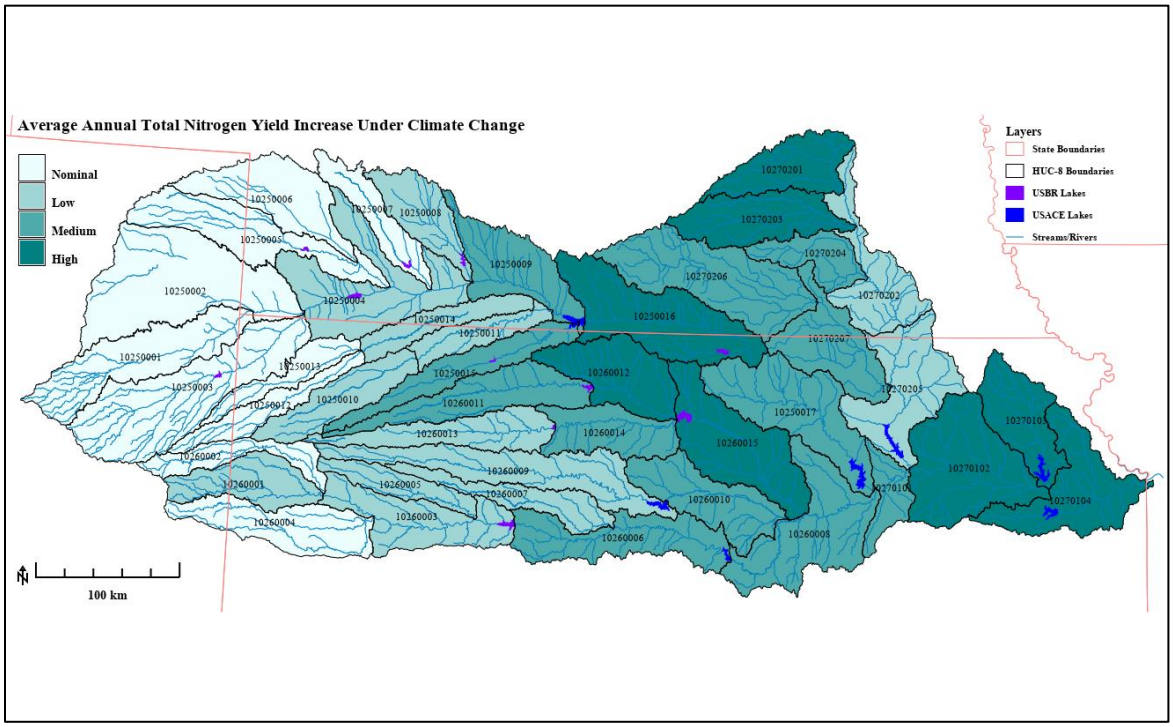

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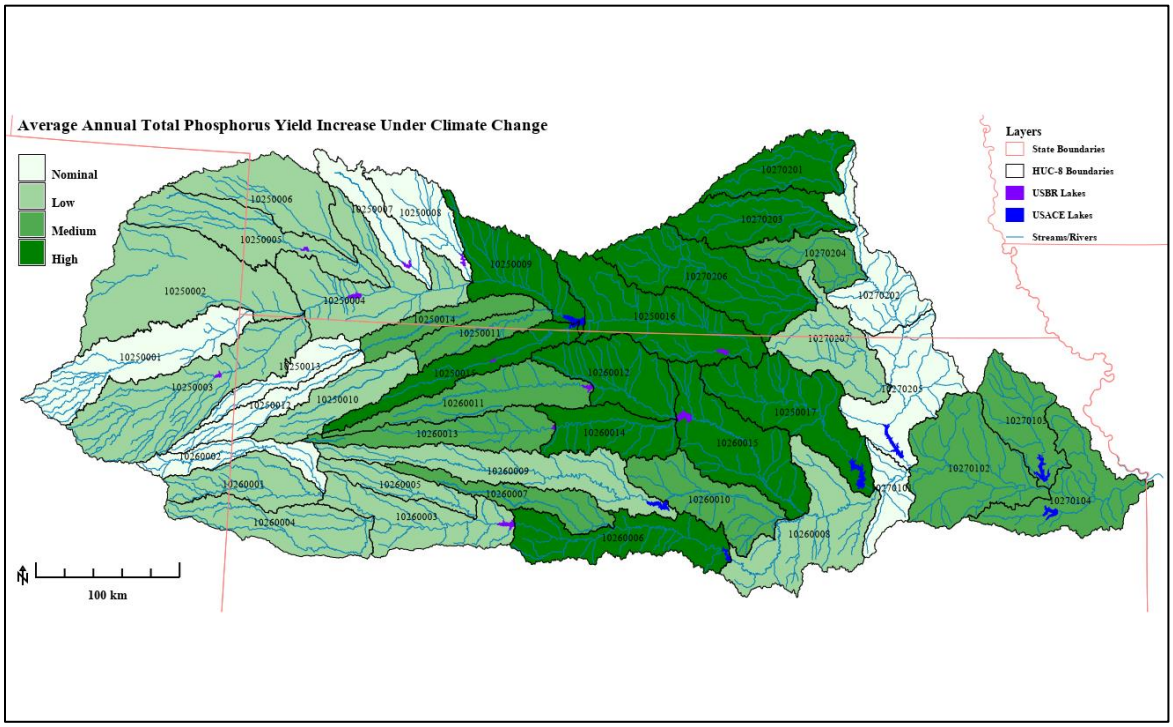
Figure 3-312. Projected Future (2029–2079) Average Annual Total Phosphorus Yield Increases over the Base Period (1966–2015) under Twelve Aggregated RCP4.5 GCMs using HAWQS (SWAT)



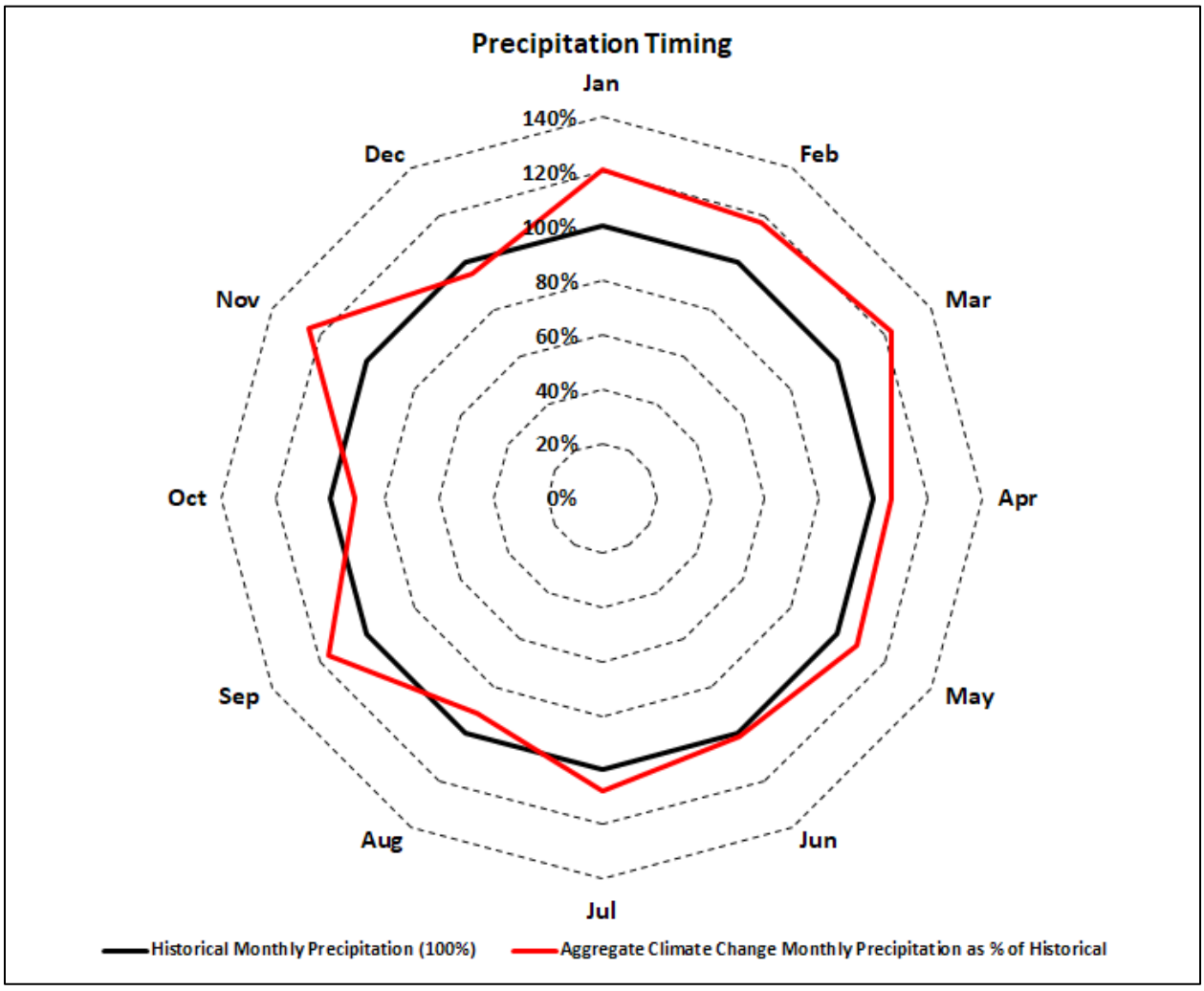
Modeled anticipated average annual changes under aggregate GCMs for HUC8s containing USACE reservoirs are summarized in Table 3-141 below. Increases in future average annual precipitation generate increased average annual runoff carrying larger quantities of sediment and nutrients to reservoirs in the watershed. Higher delivered quantities of sediment and nutrients lead to increased rates of sedimentation, and increased levels of eutrophication.

Table 3-141. Summary of projected future climate (2029–2079) effects relative to base period (1966–2015) for HUC8s containing USACE reservoirs

HUC8	Lake	Runoff/ Streamflow	Sediment Yield	TN Yield	TP Yield
10270104	Clinton	▲	▲	▲	▲
10250009 10250015	Harlan Co.	▲ —	▲ ▲	▲ ▲	▲ ▲
10260006	Kanopolis	▲	▲	▲	▲
10250017	Milford	▲	▲	▲	▲
10270103	Perry	▲	▲	▲	▲
10270205	Tuttle Creek	▲	▲	▲	—
10260009	Wilson	▲	▲	▲	▲
Change Indicators: — = Nominal Change, ▲ = Low increase, ▲ = Medium Increase, ▲ = High Increase					

Suggested increases in transport of sediment and nutrients under aggregated GCMs is due in part to the seasonal timing of precipitation. Modeled aggregate future climate scenarios suggest average annual precipitation increases (over historical quantities) in months of the year when vegetative cover is not present to mitigate surface runoff and sediment transport (Figure 3-313). Detail with respect to frequency, intensity, and duration of future precipitation events is uncertain, but modeled predictive scenarios, in aggregate, suggest increased precipitation quantities January through March, September, and November. Increased precipitation in these months translates to increases in runoff, transporting increased quantities of sediment, carrying increased quantities of soluble and sediment bound nutrients (nitrogen and phosphorus).

Figure 3-313. Modeled Kansas River Watershed Historical (1966–2015) Monthly Average Precipitation (Black Line) Compared to Twelve Aggregated RCP4.5 GCMs Monthly Average Precipitation (Red Line)



The strongest consensus amongst the literature supports a trend of increasing temperatures and precipitation in the region resulting in increased frequency in the occurrence of extreme storm events. Extremes in climate will also magnify periods of wet and dry weather resulting in longer more severe droughts and larger more extensive storms (Appendix A-Climate Change Assessment). Future water quality of USACE reservoirs in the Kansas River Watershed will be impacted by these trends.

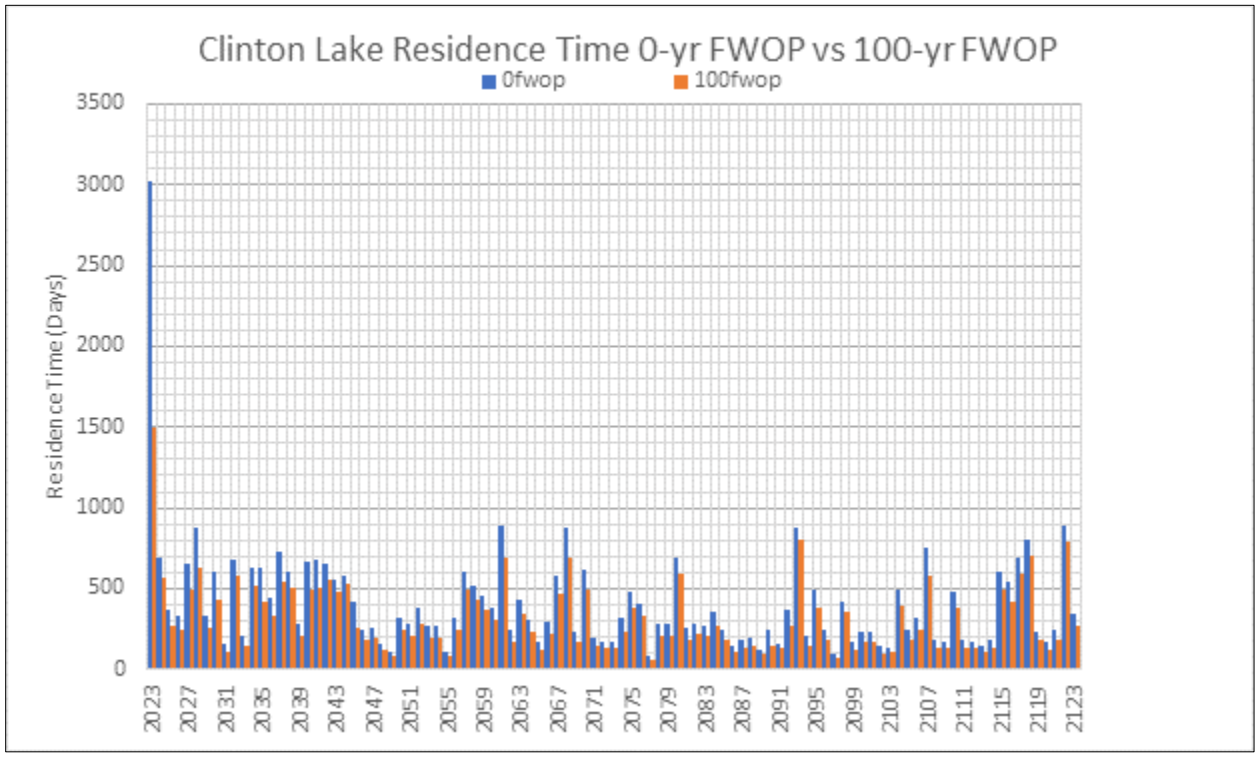
3.7.5.1.5 Kansas River Basin Residence Time

Water residence times at select influential reservoirs in the Kansas River watershed were estimated by U.S. Army Corps of Engineers Kansas City District, Engineering Division Hydrology and Hydraulics, River Engineering and Restoration Section (CENWK-EDH-R) for years 2024 and 2124 with models created using HEC-ResSim (Appendix B) and data set for the lower seven mainstem reservoirs on tributaries of the Kansas River. The 0-year FWOP (2024) scenario represents existing physical conditions. The second scenario, 100-year FWOP (2124), represents change in reservoir storage over 100 years due to sediment deposition. Each scenario was modeled with historically observed average daily inflows over a 100-year timeframe. HEC-ResSim generated estimated lake storage, discharge, and evaporation from these simulations which were used in residence time calculation. The average residence time for lakes in each scenario was calculated and compared based on the residence time difference. Results reveal that the 100-year FWOP (2124) residence time decreases as lake storage diminishes due to sedimentation. Average residence times for select lakes likely to influence Kansas River water quality are presented in Table 3-138. Reduced residence time results in less time for nutrient and sediment constituent settling within reservoirs with decreased MPP volumes. Lakes with higher sedimentation rates (e.g., Tuttle Creek, Kanopolis, and Perry Lakes) are, as expected, those with the largest percent decrease in residence time in the 100-year comparison. A graphic representation of differences between 0-Year (2024) and estimated 100-Year (2124) residence time at Clinton Lake is shown in Figure 3-314. Figure 3-315 (Tuttle Creek Lake) and Figure 3-316 (Milford Lake) reveal the expected inverse relationship between annual average outflow and residence time.

Table 3-142. Average Lake Residence Time for Select Kansas River Watershed Lakes

Lake	Average Residence Time 0-year (2024) Existing Conditions (Months)	Average Residence Time 100-year FWOP (Months)	Average Residence Time Observed: 1990–2022 (Months)	Percent Decrease 0-year to 100-year (percent)
Clinton	9.0	7.0	9.0	22
Kanopolis	2.7	1.2	4.5	56
Milford	7.3	6.4	7.7	12
Perry	5.0	3.0	5.6	40
Tuttle Creek	2.4	0.8	3.0	67
Waconda	11.2	8.5	10.3	24
Wilson	24.7	20.9	N/A	15

12941 *Figure 3-314. Clinton Lake Residence Time Comparing 0-Year (2014, 0fwop) and 100-Year (2124,*
12942 *100fwop) Future without Project*



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12945 *Figure 3-315. Tuttle Creek Lake Annual Average 0-Year Residence Time and Annual Average Outflow*

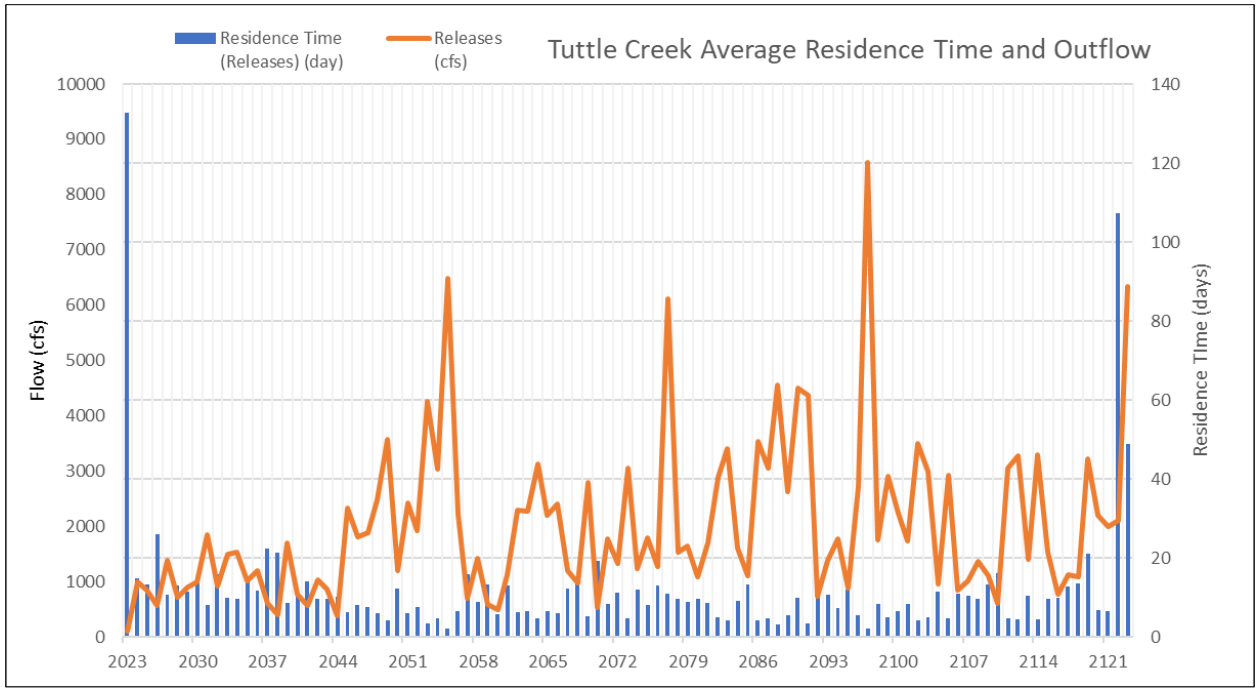

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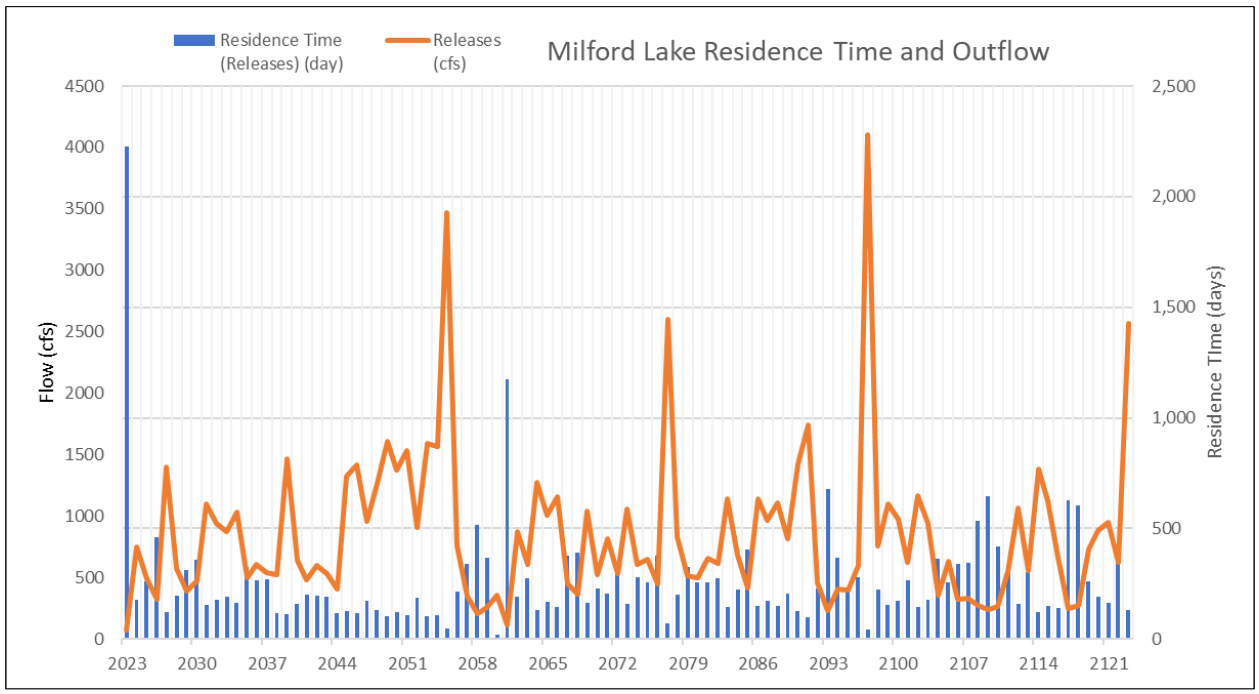
Figure 3-316. Milford Lake Annual Average 0-Year Residence Time and Annual Average Outflow



An additional residence time analysis was done for Clinton Lake and Tuttle Creek Lake using observed historic data from January 1990 to December 2022. The observed data included inflows, lake storage, releases, and evaporation. Cyclic analysis was performed describing the monthly trend of residence time based on percentiles and the average. The data reveals seasonality in residence time which decreases during the wetter periods and increases during the dry periods. Graphic examples are shown in Figure 3-317 for Clinton Lake and Figure 3-318 for Tuttle Creek Lake.

Figure 3-317. Clinton Lake Monthly Residence Time Calculated using Observed (1990–2022) Data

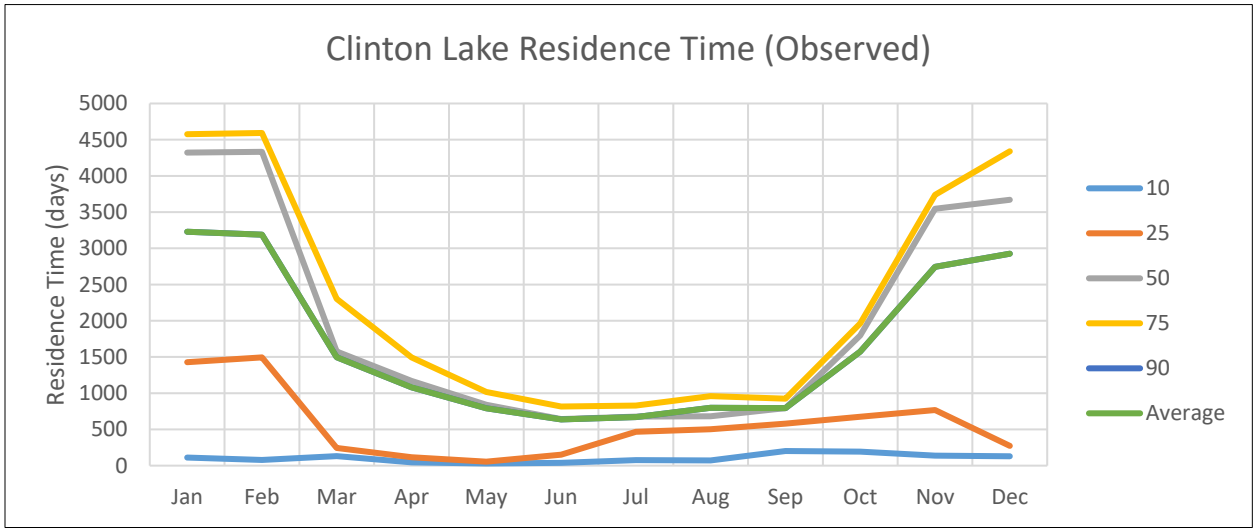
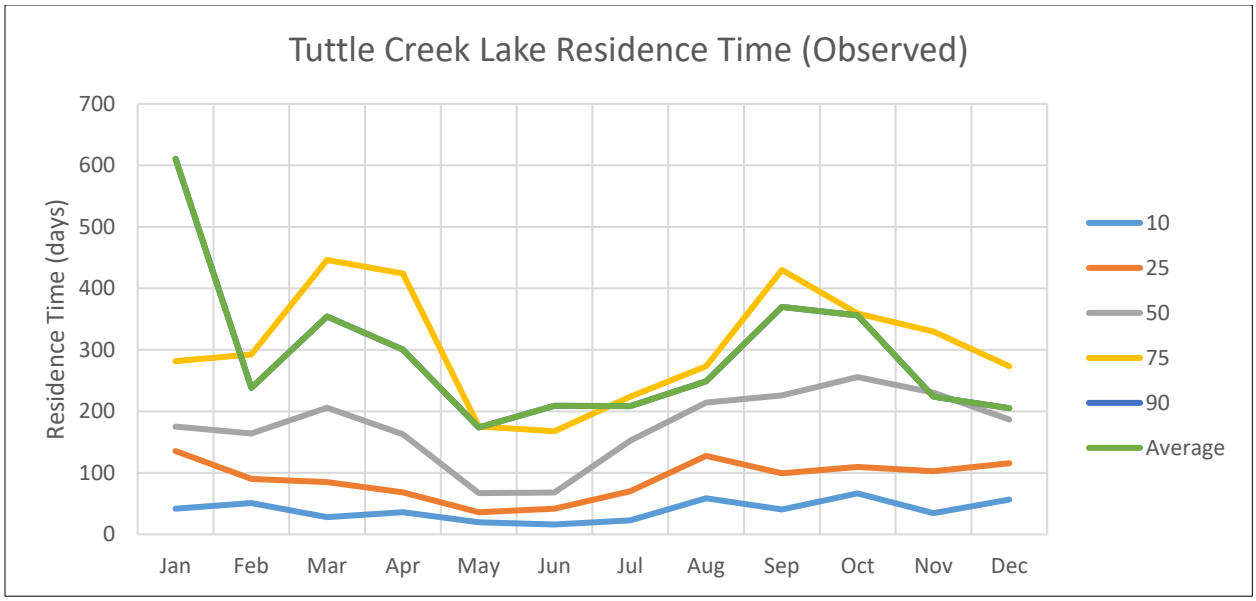


Figure 3-318. Tuttle Creek Lake Monthly Residence Time Calculated using Observed (1990–2022) Data



Additional watershed (SWAT) simulations were run incorporating estimated volume change due to sedimentation at select reservoirs in the watershed estimated by CENWK-EDH-R for years 2024 (Year 0), 2049 (Year 25), 2074 (Year 50), and 2124 (Year 100). Estimated future multipurpose pool (MPP) volumes for USACE reservoirs in the watershed are listed in Table 3-143. Watershed simulations using historic climate inputs (1966–2015) were run with adjusted MPP volumes estimated for years 2024, 2049, 2074, and 2124 to aid quantifying potential sediment and nutrient transport changes due to diminishing pool volumes. The SWAT watershed model simulates lakes/reservoirs simplistically, tracking sediment and nutrients carried by water. Modeled in-reservoir transformation of nutrients is limited to removal by settling.

Table 3-143. Estimated Future Multipurpose Pool Volumes at Kansas River Watershed USACE reservoirs

Lake	Year 0 (2024) Est. MPP Volume (acre-feet)	Year 25 (2049) Est. MPP Volume (acre-feet)	Percent of 2024 Volume (percent)	Year 50 (2074) Est. MPP Volume (acre-feet)	Percent of 2024 Volume (percent)	Year 100 (2124) Est. MPP Volume (acre-feet)	Percent of 2024 Volume (percent)
Clinton	112,200	103,900	93	96,700	86	83,900	75
Harlan Co.	309,400	304,000	98	300,700	97	291,100	94
Kanopolis	43,300	34,800	80	30,200	70	18,300	42
Milford	366,500	355,800	97	349,900	95	333,000	91
Perry	182,900	159,400	87	139,900	76	105,200	58
Tuttle	216,600	153,000	71	106,500	49	29,200	13
Wilson	228,100	218,000	96	209,000	92	190,100	83

For subbasins (HUC8s) containing reservoirs with diminishing MPP volume, simulations predicted nominally decreasing reservoir contributions to ground water due to increasingly smaller MPP volume and area. Predictably, model simulation revealed no

significant changes in pollutant (sediment, TN, and TP) export rates from land surfaces to streams in subbasins with diminishing reservoir MPP volumes.

It is important to emphasize that estimates of transport of sediment and pollutants (TN and TP) for subbasins, reaches, and reservoirs, with future diminished storage volume in select reservoirs are based on annual averages of 50-year simulations driven by historic daily climate inputs (1966–2015). Precipitation and air temperature vary significantly from year to year (and day to day). Consequently, simulated annual average estimates of transport of sediment and pollutants are highly variable. For example, for the simulation with 2024 MPP volume estimates, standard errors of mean TN transported into the select reservoirs ranged from 11 to 24 percent of the mean. Similarly, standard errors of TN transported out of the same select reservoirs ranged from 14 to 28 percent of the mean. Standard errors of mean TP transported into and out of the reservoirs were marginally higher. Relative differences of annual average sediment and pollutant transport included in discussions below should be assessed considering this inherent variability.

For stream reaches in subbasins containing reservoirs with diminishing MPP volumes, simulations predicted nominal changes in sediment transport mass due to volume loss. Bulk quantities of sediment load transported from land surfaces to stream reaches deposits instream and at reservoir locations. Incrementally increasing annual average quantities of TN and TP are transported through reservoir reaches to reaches immediately downstream. This is primarily due to reduced water residence time within reservoirs as a function of reduced MPP volume.

For example, HUC8 10250016 (Middle Republican), the Republican River reach immediately below Harlan County Lake, receives and transports incrementally more TN and TP mass with decreasing Harlan County Lake volume. Simulations showed 2049 reservoir volume resulted in 0.2 percent more TN and TP mass in the reach over 2024 lake volume. 2074 volume resulted in 0.2 and 0.3 percent more TN and TP mass, respectively, over 2024. Estimated 2124 Harlan County Lake volume resulted in 0.4 percent more TN and TP mass in the reach over that transported in 2024.

HUC8 1026008 (Lower Smoky Hill) receiving flows below USACE reservoirs Kanopolis and Wilson shows increased transport of TN and TP mass with 2049 volumes (0.3 and 0.4 percent, respectively), 2074 volumes (0.6 and 0.7 percent, respectively), and 2124 volumes (1.1 and 1.4 percent, respectively) over modeled mass transported in 2024.

HUC8s 10270101 (Upper Kansas) below Milford Lake, and 10270102 (Middle Kansas) below both Milford and Tuttle Creek Reservoir revealed simulated increases in TN and TP mass transport over 2024. 2049 MPP volumes increased downstream TN and TP transport 0.3 and 0.4 percent, respectively, over 2024 for HUC 10270101; and 0.6 and 1.0 percent, respectively, for HUC 10270102. 2074 MPP volumes increased transport over 2024 by 0.5 and 0.7 percent, respectively, for HUC 10270101, and 0.9 and 1.7 percent, respectively, for HUC 10270102. Modeled 2124 MPP volumes increased TN and TP mass transport over 2024 MPP volumes by 1.0 and 1.3 percent in HUC10270101, and 1.4 and 2.7 percent in HUC10270102.

HUC8 10270104 (Lower Kansas) below Perry Lake and containing Clinton Lake showed similar modeled trends with TN and TP transport increases over 2024 MPP

volumes of 0.5 and 0.9 percent, respectively, for 2049 volumes; 0.8 and 1.6 percent for 2074 volumes; and 1.2 and 2.4 percent for 2124 MPP volumes.

For reservoirs with diminishing MPP volume, model simulations related decreased volume (and area) to less annual average direct precipitation on the reservoir surfaces, less annual average evaporation from the reservoirs, and less seepage. Simulations revealed incrementally increasing annual average export of TN and TP from reservoirs with diminishing MPP volumes due to reduced settling time in reservoirs. Table 3-140 below shows comparison of simulated masses of TN and TP into and out of reservoirs with reduced MPP volume due to sedimentation relative to 2024. For each reservoir, simulations predicted incrementally increasing average annual nutrient mass exported, compared to 2024, with diminishing MPP volumes. Milford Lake results indicate a unique trend where nutrient mass entering the reservoir during the years 2049, 2074, and 2124 increases due to higher incremental export from the upstream reservoir, Harlan County Lake. Concurrently, Milford Lake's estimated average residence time for 2124 (as shown in Table 3-138) reflects the smallest percentage decrease from the 2024 estimates, supporting the expectation of relatively minor changes in nutrient export. While the annual average flow into and out of the reservoirs remains relatively consistent across the simulations, the reduction in MPP volumes leads to a decrease in average annual residence time and the time available for nutrient settling.

Table 3-144. Comparison of Simulated TN and TP Mass Into and Out of Kansas River Watershed USACE Reservoirs, Relative to 2024, With Decreasing Future MPP Volume

Lake	Year	TN In Percent Change from 2024 (kg)	TN Out Percent Change from 2024 (kg)	TP In Percent Change from 2024 (kg)	TP Out Percent Change from 2024 (kg)
Clinton	2049	0.0	1.1	0.0	1.4
	2074	0.0	1.9	0.0	2.2
	2124	0.0	3.4	0.0	3.4
Harlan Co.	2049	0.0	0.4	0.0	0.4
	2074	0.0	0.5	0.0	0.7
	2124	0.0	0.8	0.0	1.1
Kanopolis	2049	0.0	1.4	0.0	1.8
	2074	0.0	2.2	0.0	2.9
	2124	0.0	4.4	0.0	5.9
Milford	2049	0.1	0.4	0.1	0.5
	2074	0.1	0.6	0.1	0.8
	2124	0.2	1.1	0.2	1.6
Perry	2049	0.0	3.3	0.0	4.4
	2074	0.0	6.3	0.0	8.3
	2124	0.0	12.0	0.0	16.3
Tuttle Creek	2049	0.0	1.1	0.0	1.7
	2074	0.0	1.8	0.0	3.0
	2124	0.0	3.2	0.0	5.2
Wilson	2049	0.0	0.7	0.0	0.9
	2074	0.0	1.3	0.0	1.7
	2124	0.0	2.5	0.0	3.4

Temporally decreasing MPP volume due to sedimentation in selected reservoirs, in combination with projected increases in runoff/streamflow and transport of sediment and nutrients under aggregate future GCMs suggests future decreases in retention time, and future decreases in trapping efficiency at those reservoirs with substantial volume loss. Lower reservoir retention time leads to higher quantities of sediment and

especially nutrients (TN and TP) passed through reservoirs to downstream segments. Future climate projections suggesting increased runoff from land surfaces carrying increased sediment and nutrient loads may exacerbate sediment accumulation rates (volume loss) and nutrient enrichment.

As stated above, State natural resource agencies have designated 16 of the 18 lakes in the Kansas River Basin as “impaired” from nutrient related impacts (e.g., excess nitrogen and/or phosphorus, general eutrophication, excess chlorophyll/algae measures, dissolved oxygen sags resulting from algae blooms) due in part to agricultural runoff. Excess nutrients can promote HABs under ideal growing conditions. As accumulation of sediment reduces storage capacity of reservoirs, and internal nutrient loading increases, water quality problems are expected to intensify.

Basic causes and drivers of algal blooms include excess nitrogen and phosphorus, warming temperatures, slow moving water, and sunlight. Management of reservoirs during extreme events directly impacts water quality conditions within reservoirs. Runoff from extreme rainfall events withheld in a reservoir to minimize downstream flooding, may lead to periods where the nutrient rich water, with sediment settling and warming conditions, could enhance conditions for epilimnetic algal blooms and hypolimnetic anoxia.

Watershed modeling results could be enhanced with the custom construction of a SWAT model of the Kansas River Watershed. Enhanced resolution and custom selection of subbasin outfall points would allow for more accurate simulation of stream reaches and reservoirs and provide the opportunity for a more robust calibration of overall watershed water, sediment, and nutrient transport and loading estimates.

3.8 Environmental Justice

All federal agencies are required to consider how the impact of their actions may disproportionately increase risk and/or create burdens on communities historically underserved by federal benefits or underrepresented in planning and decision making about those benefits. USACE requirements to conduct an Environmental Justice analysis come from Executive Order (EO) 14008, Tackling the Climate Crisis at Home and Abroad, January 27, 2021, and the subsequent Implementation Guidance, Memorandum for Commanding General, U.S. Army Corps of Engineers: Implementation of Environmental Justice and the Justice40 Initiative. The USACE Implementation Guidance states, “Environmental justice and disproportionate impacts to ‘disadvantaged’ communities shall be considered throughout the Civil Works programs and in all phases of project planning and decision-making, consistent with the goals and objectives of various Administration policies.” The Implementation Guidance directs PDTs to use the Council on Environmental Quality’s Climate and Economic Justice Screening Tool (CEQ-CEJST) to identify disadvantaged communities with environmental justice concerns within the watershed study area. To do that, the CEQ-CEJST data was downloaded and subsequently uploaded into ArcGIS, where it could be adjusted to the project shapefile for the Kansas River basin providing the data for the project area.

The watershed study considered whether an FWOP in the basin could result in disproportionate burdens for census tracts and communities that classify as being disadvantaged economically and/or socially vulnerable.

The study found that the FWOP scenario would likely lead to higher risks of water supply shortages; continued and likely higher risks of flood events; and degradation of water quality, ecosystem services, and recreational facilities associated with public reservoirs and land. All persons, households, and communities in the basin could experience these consequences. But some persons, households, and communities crossing thresholds for disadvantage will be less able to adapt, respond, or recover after these changes. This analysis identifies likely impacts on disadvantaged and socially vulnerable communities if no action is taken to protect the overall health of the basin.

3.8.1 Definition of Environmental Justice

Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, regarding the development, implementation, and enforcement of environmental laws, regulations, and policies, with no group bearing a disproportionate burden of environmental harms and risks.

3.8.2 Disadvantage Defined

3.8.2.1 Headquarters, U.S. Army Corps of Engineers Definitional Guidance

Pursuant to direction from Congress in Section 160, WRDA 2020 to define an "economically disadvantaged community," the Assistant Secretary of the Army for Civil Works (ASA) adopted the following definition in a March 14, 2023, memo:

> *An economically disadvantaged community is defined as meeting one or more of the following:*
>
> *a) Low per capita income—The area has a per capita income of 80 percent or less of the national average;*
>
> *b) Unemployment rate above national average—The area has an unemployment rate that is, for the most recent 24-month period for which data are available, at least 1 percent greater than the national average unemployment rate;*
>
> *c) Indian country as defined in 18 U.S.C. 1151 or in the proximity of an Alaska Native Village;*
>
> *d) U.S. Territories; or*
>
> *e) Communities identified as disadvantaged by the CEQ-CEJST (https://screeningtool.geoplatform.gov).*

The CEQ-CEJST uses census data to identify census tracts that classify as economically disadvantaged and/or have characteristics of social vulnerability. The CEQ-CEJST defines economic disadvantage as census tracts that meet any of the following criteria:

- The census tract is both at or above the threshold of the 65th national percentile for low income, and at or above the threshold of the 90th national percentile for at least one of the eight other burden categories (climate, energy, traffic, housing,

pollution, water, health, and workforce). Low income is defined as at or below 200 percent of the Federal poverty level. 200 percent of the poverty level is defined for a two-person household as an annual income of $39,400. 200 percent of the poverty level for a four-person household is an annual income of $60,000. These thresholds are produced by the U.S. Census Bureau.

- The tract is on land within the boundaries of Federally Recognized Tribes.
- The tract is completely surrounded by disadvantaged communities and is at or above the 50th national percentile for low income.

In practical terms, the CEQ-CEJST threshold for economic disadvantage of 200 percent of federal poverty income is roughly equivalent in dollars and cents to a per capita income of 80 percent or less of the national average.

As defined, communities and households that are disadvantaged have historically been underserved by federal benefits due to methods for calculating economic benefits used to justify federal expenditures. Property values are a significant factor in economic benefits determinations. Low property values are generally associated with low household income. As a result, projects that might have benefitted communities with low incomes and property values have often been rejected because of a low ratio of cost to benefit for the federal investment.

These same communities and households have also been underrepresented in the planning and decision-making processes because of economic and employment factors that may accompany lower incomes. These factors may include non-standard work schedules in service and retail sectors, working more than one job, and meeting designs that are oriented towards majority cultural norms. Typical public meeting practices have created inadvertent barriers to civic participation by choosing meeting times that do not accommodate non-standard work schedules, using communication methods (digital, literacy and language barriers) not accessible to the communities as a whole, and meeting norms that favored the majority culture.

Disadvantaged households and communities generally have a harder time than non-disadvantaged communities in preparing for, responding to, and recovering from water resources problems and challenges. They often bear a disproportionate burden for the risk of environmental and climate related harms because of their limited disposable income and constrained housing choices. These factors also limit the ability to adapt and respond to emergent climate risks.

3.8.2.2 Social Vulnerability

Social vulnerability is considered to include individual characteristics related to health, intellectual and sensory processing capability. Being under the age of five years or over 65 years or disabled, being socially or civically isolated, and having limited English proficiency make a person more vulnerable to the consequence of natural disasters, extreme weather events, or other disruptions in daily services.

While the term is more commonly used in emergency management and public health, such characteristics often intersect with economic disadvantage magnifying the challenges created by economic disadvantage and hindering the ability to adapt or

respond to flood events, extreme drought, and the other disruptions that could flow from the problem areas under investigation in the watershed study.

3.8.2.3 Screening is a First Step

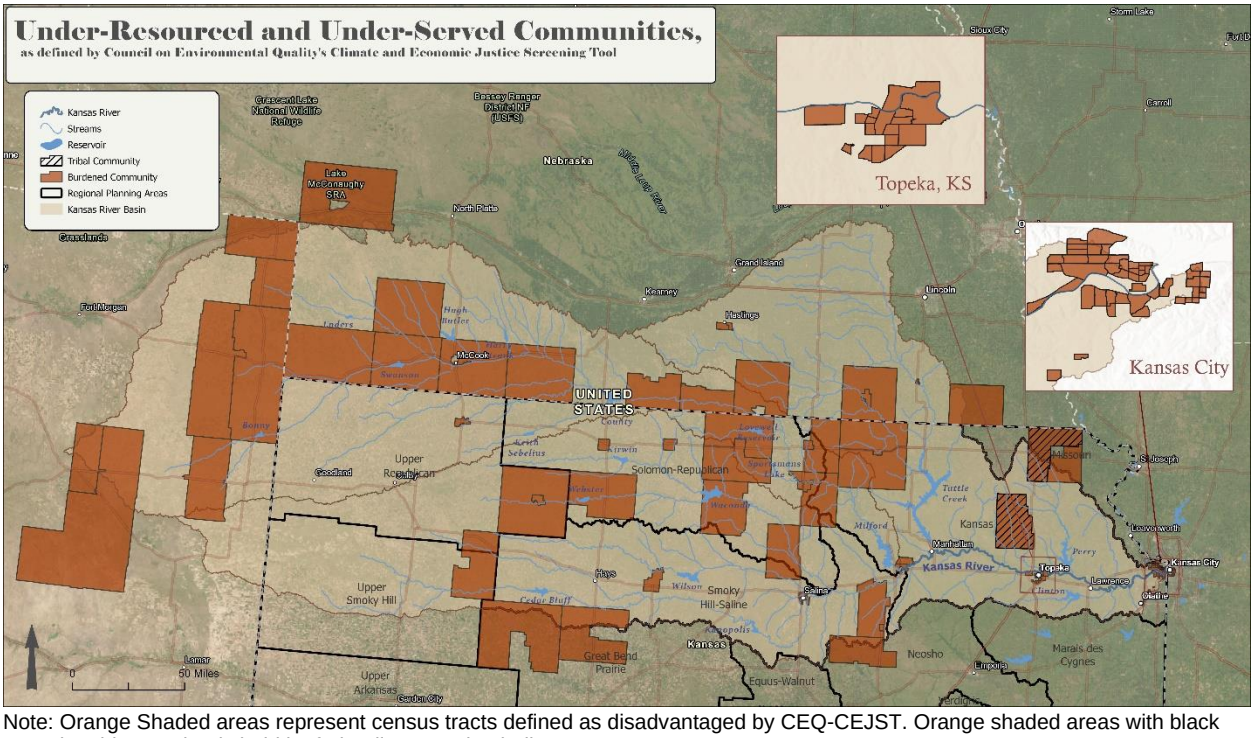
Applying the CEQ-CEJST screening tool is the first step to identify demographic information and trends in a project area. That information supports additional discussion with local partners and community members to further understand what community conditions actually exist on the ground. Likewise, those conversations are the gateway to understand methods for communication and trusted messengers for delivering information..

3.8.2.4 Disadvantage in the Basin Study Area

Historically, there have been many barriers to federal investment in communities having high minority populations, limited English proficiency populations, and populations with little formal education. Communities that do not have these characteristics have had and continue to have an easier time accessing federal investments that can protect those communities from flood damages.

Figure 3-319 is a map overlaying the CEQ-CEJST categories of disadvantage over the study area. Disadvantaged communities exist all across the basin in rural as well as the expected urban areas.

Figure 3-319. Under-Resourced and Underserved Communities in the Kanas River Basin



Note: Orange Shaded areas represent census tracts defined as disadvantaged by CEQ-CEJST. Orange shaded areas with black cross hatching are lands held by federally recognized tribes.

The basin is spread across three states: Colorado, Nebraska, and Kansas. Neither the states of Colorado nor Nebraska were active participants in the study. Upper reaches of the basin in Colorado and Nebraska are predominantly rural areas, as defined by the

U.S. Census. Urban areas, as defined by the U.S. Census, have more than 2,500 but less than 50,000 inhabitants scattered across the area defined.

Because the states of Colorado and Nebraska were not active participants in the study, the EJ analysis focused primarily on areas of the basin in the State of Kansas. Because the study partners, KWO and KDWP, focused most of their energy on the lower basin, that is reflected in the EJ analysis.

Basin wide, 118 out of the 422 census tracts are considered to be low income because those tracts are classified in the 65th national percentile for the percent of their population that is below twice the federal poverty limit. These 118 tracts have a total population of 335,896 people out of the total basin population of 1,500,708 people.

In the basin, roughly 25 percent of the population is non-white. Non-white residents are not automatically defined as economically disadvantaged in either the CEQ-CEJST or in USACE guidance. Regardless of their economic status, non-white individuals may experience amplified burdens due to historical cultural and civic practices that impair civic and economic participation. Examples include barriers to voting and redlining of neighborhoods preventing federal loans for home purchases.

The majority of the non-white population resides in the bigger population centers along the river such as Kansas City and Topeka. Of the 422 tracts, 22 are in the 90th percentile or higher nationally for the percent of their population that is not proficient in English as a second language. These 22 tracts have a total population of 50,749 people. Similar to the minority population, the majority of the limited English proficiency population resides in the bigger population centers along the river such as Kansas City and Topeka.

Little formal education is a prevalent condition throughout the basin with roughly 9 percent of the population over 25 years old having less than a high school diploma. Formal education is a component of workforce burden in the CEQ-CEJST. The triggering threshold is a population with 10 percent of people ages 25 years or older whose high school education is less than a high school diploma.

In the basin, there are five tracts with major transportation barriers (average relative cost and time spent on transportation relative to other tracts). These tracts are in the Kansas counties of Leavenworth and Osage and Gage County, Nebraska. These are tracts that are in the 90th percentile nationally for transportation barriers scores defined by the United States Department of Transportation. These tracts are separate from the low-income tracts in the basin, which would presumably face similar challenges when responding to floods as it relates to transportation costs and time, due to rural locations and limited economic resources.

High traffic proximity and volume are another facet of transportation burdened when paired with the low-income threshold. This would make it harder and slower to evacuate in the event of a flood safety emergency, contributing to life safety endangerment. Within the basin, 16 tracts are in the 90th percentile nationally for traffic proximity and volume, all of them being in the Kansas City metro area.

A large portion of employment in low-income rural communities in the basin is concentrated in agricultural areas. Flooding can severely disrupt this industry, wiping

out crops and cutting income for farmers and supporting businesses for months or even years. Drought can also produce similar consequences. There are 52 tracts in the basin that experience extremely high levels (90th percentile or higher nationally) for expected agricultural loss rate, a factor in the determination of CEQ-CEJST climate change vulnerability. Expected agricultural loss rate is a statistic that comes from the Natural Hazards Risk Index, and it is determined by dividing a region's agriculture value at risk of being loss due to natural hazards by the region's total agriculture value. The 52 tracts experiencing high levels of expected agricultural loss rate have a total population of 152,528 persons.

While not a category of disadvantage in the CEQ-CEJST tool, the PDT determined that age was another factor to be considered when analyzing the disadvantaged status of a community and its vulnerability in terms of flood risk, drought, or the degradation of water supply, water quality, ecosystems services, and recreation. Individuals over the age of 65 years are likely to experience social vulnerability independent of their economic status. Older adults, on average, are more likely to experience lack of mobility, disability, hearing impairment, and visual impairment that can interfere with initiating preparedness activities, receiving and responding to warnings, and recovering from hazardous events or adapting to change. To be considered disadvantaged due to age, the PDT determined a tract must have a population aged 65 and older that is greater than the 85th percentile nationally. The PDT determined that the 85th national percentile was an appropriate threshold based on the CEQ-CEJST tool using the 65th percentile nationally as a threshold for low income, and the 90th percentile nationally as a threshold for all other categories of burden. By adding this EJ category, an additional 11 tracts that would not have otherwise been classified as disadvantaged were added to the list of disadvantaged tracts, bringing the total number of disadvantaged tracts to 124 out of the 422 total tracts in the basin.

Many rural counties throughout the Kansas River Basin are also facing twin demographic trends: population declines and aging populations. Population decline is not a factor in determining whether or not a census tract is disadvantaged; however, this contributes to decreases in tax revenues thus constricting available funds for municipalities and counties to respond to extreme weather events.

3.8.2.5 Tribal Nations in the Kansas River Basin

Lands held by Tribal Nations are automatically considered as economically disadvantaged as defined in the ASA's memo defining economic disadvantage.

There are two federally-recognized Tribes within the study area: the Prairie Band Potawatomi Nation (PBPN) and the Kickapoo Tribe of Kansas. PBPN tribal lands are embedded in a census tract defined as partially disadvantage by the CEQ-CEJST tool. Land surrounding the Tribal land is above the triggering threshold for legacy pollution and expected population loss due to climate change (fatalities and injuries from natural hazards).

CEQ-CEJST classifies the census tract surrounding the Kickapoo Tribal land as disadvantaged both for meeting the socio-economic threshold and for other categories of burden—expected population loss due to climate change (fatalities and injuries from

natural hazards) and the lack of greenspace (definition excludes crop land) adjacent to housing.

Tribal Nations in the watershed study area have used the Tribal Partnership Program (TPP) to address some of water resources challenges in their communities.

In the Solider Creek Watershed study, the PBPN is working with the Kansas City District under a Section 203 Integrated Feasibility and Environmental Assessment study to investigate the restoration of stream, floodplain and riparian habitat functions lost due to changes in land use and increasing stream instability throughout the Soldier Creek watershed. The Tribe has identified water supply, water quality, and ecosystem conditions as issues of concern.

The Kickapoo Tribe worked with the Kansas City District to conduct the Delaware River Watershed Assessment. One concern of the Tribe was the need for a reservoir on Plum Creek to provide a reliable water source, some flood control, and recreational opportunities for Tribal members. Such a project might have been accomplished under federal law PL-556 which allows dams to be built under the authority of state watershed boards. However, the Nemaha-Brown Watershed board declined to use eminent domain, therefore there was no construction. The Watershed Assessment did lead to a Section 14 Streambank stabilization of a bridge on Kansas Highway 20, a road that bisects the reservation. The maintenance of the road is key for access to public schools and emergency services by Tribal members. Another project repaired a low head weir structure on the Delaware River that contributed raw water to the Tribe.

The water resource issues identified in these selected projects are comparable to the issues that are important to other rural communities with census tracts defined as economically disadvantaged. These include water supply, water quality, recreational opportunities, and infrastructure.

3.8.2.6 Assumptions About Disadvantage and How It Affects Households and Communities in a Future Without Project

Economic disadvantage, defined as census tracts in the 65th national percentile for the percent of population with household incomes at 200 percent or less of the federal poverty level, creates a number of conditions that reduce household flexibility to respond to an FWOP likely including rising temperatures, extreme rain events, and extreme drought. For example:

- Housing options are more limited, and households may be housing burdened, that is spending more than 30 percent of gross household income on housing costs. Owned property may not be as valuable, all forms of infrastructure serving less valuable housing may not be maintained, the landlords of rental properties may not be motivated to invest in mitigation or preparedness, limited disposable income will inhibit the purchase of insurance and likely constrain personal or property preparedness or mitigation actions. Finding suitable and affordable housing is a challenge under normal circumstances. If households are displaced by floods, the ability to repair and return is likely limited. Individuals who are both disabled and have low income are unlikely to return home after evacuation, according to an analysis by the Census Bureau.

- Transportation options are more limited. Households that are classified as economically disadvantaged likely have less reliable transportation options due to the costs of maintaining a vehicle and fuel costs. Transportation challenges can be compounded by limited housing options if affordable housing is more distant from work, services, and school. Although there are public transportation options in urban areas, most areas of disadvantage in the watershed study area have no or very limited public transportation. Limited transportation options may affect the ability to evacuate. These limited options will also likely make it more difficult to sustain employment and access other services if flooding causes prolonged detour routes, such as those seen during the prolonged flooding along the Missouri River in 2019.
- Less disposable income for preparation for, response to, or recovery from risks and consequences. Economically disadvantage households have less disposal household income for preparedness for either flood risk or disruptions in water supply and/or quality.
- Household members with incomes of 200 percent or less of the U.S. poverty level are more likely to be working in retail, service, or other industries with non-standard hours. Employment in these sectors may be unstable with unpredictable hours and little tolerance for missed shifts regardless of the reason, including flooded roads or long travel times due to detours during floods. These types of disruptions may also increase transportation costs due to fuel costs for longer drives.
- Household broadband access may be more tenuous in low-income households affecting the ability to receive warnings and other important information. Although the percentage of all adults with smart phones has risen, even among low-income individuals, the ability to access the internet and digital sources of information can be limited due to factors other than income. Many areas within the study area are rural. Rural communities often have less access to high-speed internet connections. According to Broad Band Now, an advocacy group, Kansas ranks 48th for internet coverage, speed, and availability https://broadbandnow.com/Kansas. In addition, Kansans are getting older; and many older adults do not have or are not comfortable with digital tools. According to the U.S. Census Bureau, nearly 25 percent of the Kansas population will be over age 60 by 2030. While the data is statewide, the overall trend is likely applicable within the basin study area.
- Although not an automatic predictor of lower income, households composed of adults over the age of 65 or with disabilities may have additional social and physical vulnerabilities that also affect their ability to respond to or results in disproportionate burdens from FWOP consequences. Vulnerabilities can arise from limited mobility; sensory processing issues (visual, hearing, cognitive); the necessity of assistance for activities of daily living; and the need for specialized transportation services.

3.8.2.7 Assumptions about Impact of Underserved Communities on Local Governments and Quasi-Governmental Service Delivery Units

Jurisdictions with multiple census tracts identified as disadvantaged by the CEQ-CEJST tool will have a more limited tax base to support preparedness, response, recovery, and mitigation for flood risks and disruptions in water supply or quality. The limited tax base affects the ability to deliver services, protect and repair infrastructure, and to sustain conditions conducive to economic activity. It is likely that the jurisdiction is not able to devote many resources to recreation so recreational opportunities provided by USACE facilities may be especially important to providing local quality of life and the known health benefits of green space.

3.8.2.8 Framework for Analyzing Impact of Disadvantage in a Future Without Project Scenario

The following questions guided the analysis of likely effects on disadvantaged populations in the KRRFSS under FWOP:

- What are the findings of the KRRFSS FWOP?
- What is the risk to underserved communities if there are no interventions in the watershed?
- What locations in the basin may be most affected?

3.8.3 Future Without Project Conditions Flood Risk and Impact on Disadvantaged Communities

3.8.3.1 Study Findings

The existing conditions analysis concluded there is a continued flood risk for communities currently at high risk. As depicted in Figures 3-320 to 3-323, risk rises from the 0.1 percent annual exceedance probability (AEP) to the 0.2 percent AEP.

Under a qualitative climate change assessment of future conditions, the literature review found that increases in temperature and precipitation are likely under projected climate change. There is an expectation of increased extreme storm events including extreme droughts.

Combining the flood risk to life with the climate change assessment suggests there will be increased risks of flooding within the basin in areas that already experience flood risk. There is also potential for even broader impacts from flooding as a result of possible extreme rain events.

3.8.3.2 Potential Impacts on Disadvantaged Communities from Likely Increased Flood Risk

The team did not develop a FWOP flood risk scenario. To consider how future flood risk might progress, the team overlaid data from the CEQ-CEJST onto the existing conditions LifeSim heat maps developed for 0.1 and 0.2 percent AEP flood events addressed in Appendix H, Kansas River Economics and LifeSim. For the purpose of considering a FWOP for disadvantaged communities, the team inferred that flood risk conditions would likely increase over time due to the interaction of climate change and

demographic trends. Figures 3-320 through 3-323 identify locations within or adjacent to disadvantaged census tracts with likely higher risk of life loss from specified flood events.

Under the 0.1 percent AEP scenario, census tracts exist in Junction City and Kansas City, Kansas, where residents meet the threshold of disadvantage and also have a higher risk of life loss. If there are more extreme rain events in the future with associated flooding, these census tracts and those adjacent to them will be at a higher risk. These areas will also see flood damage and the prospect of evacuation.

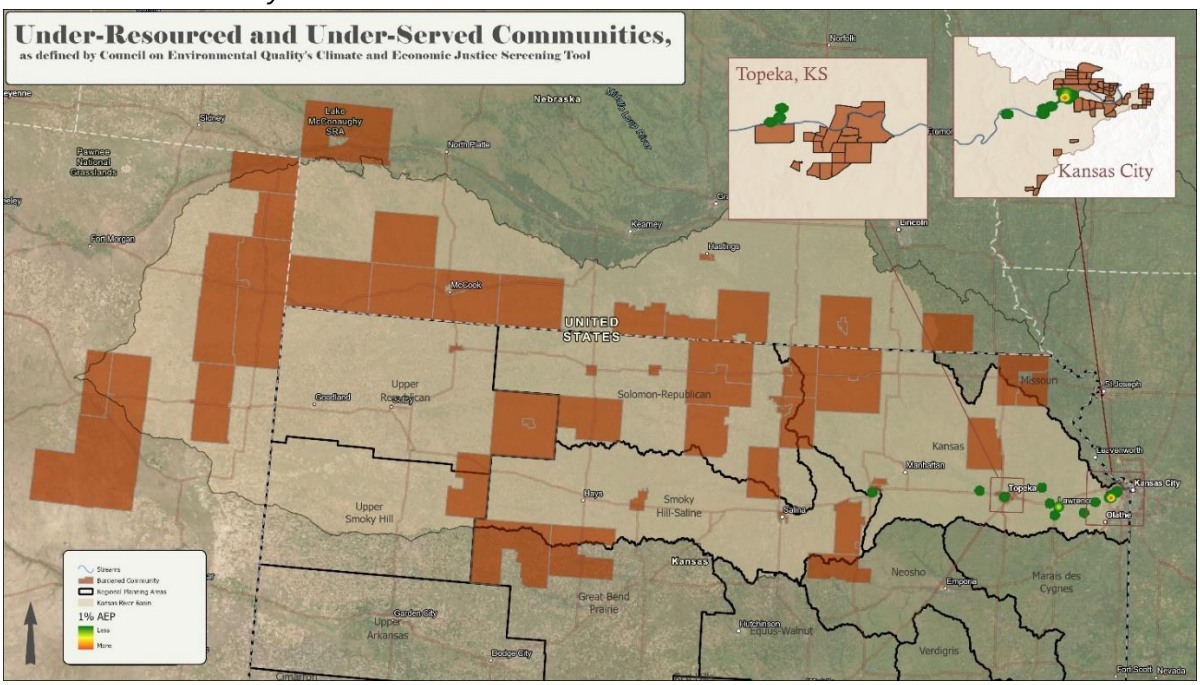
The census tract in Kansas City, Kansas, with higher life loss risk does not reach the 90th-percentile threshold for linguistic isolation (the share of households where no one over the age of 14 speaks English very well) but it does reach the 82nd percentile nationally. This suggests communication at any point in the flood risk management cycle will encounter language and likely cultural barriers.

The 0.2 percent AEP scenario illustrates how the risks expand within census tracts that are vulnerable under the 0.1 percent AEP scenario to include additional census tracts.

Consistent with earlier assumptions, households that meet the threshold of disadvantage may bear disproportionate burdens related to that risk due to communication and transportation barriers. They may also bear disproportionate burdens in recovering from flood damages. Although data from the Census Bureau concludes that low income and disability both increase the likelihood that household members will not return to their dwellings after evacuation.

Although the disadvantaged census tracts in Manhattan, Kansas, do not show up on the heat map, there may be a high number of college-aged, transient renters in the tract. Regardless of the reason for transience, these individuals and households face numerous communication barriers to receiving information and may have landlords that are not attuned to flood risk much less mitigation of risk.

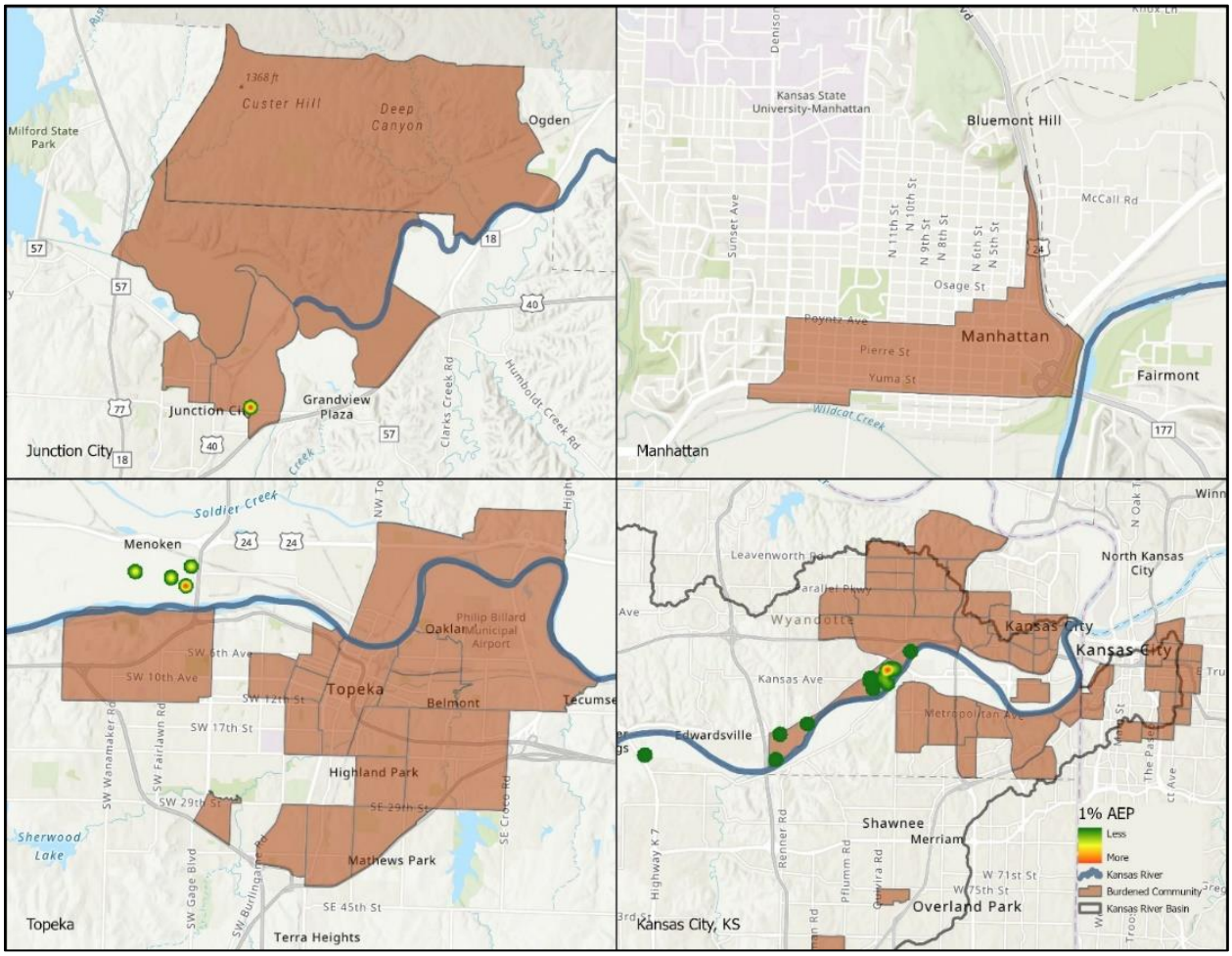
13436 *Figure 3-320. Under-Resourced and Under-Served Communities Overlay with the 0.1 Percent Annual*
13437 *Exceedance Probability Scenario*



13438
13439 Note: Orange shaded areas represent census tracts defined as disadvantaged by CEQ-CEJST. Per the legend, green to red
13440 shaded dots identify locations at highest risk for life loss during a 0.1 percent AEP flood event.

13441

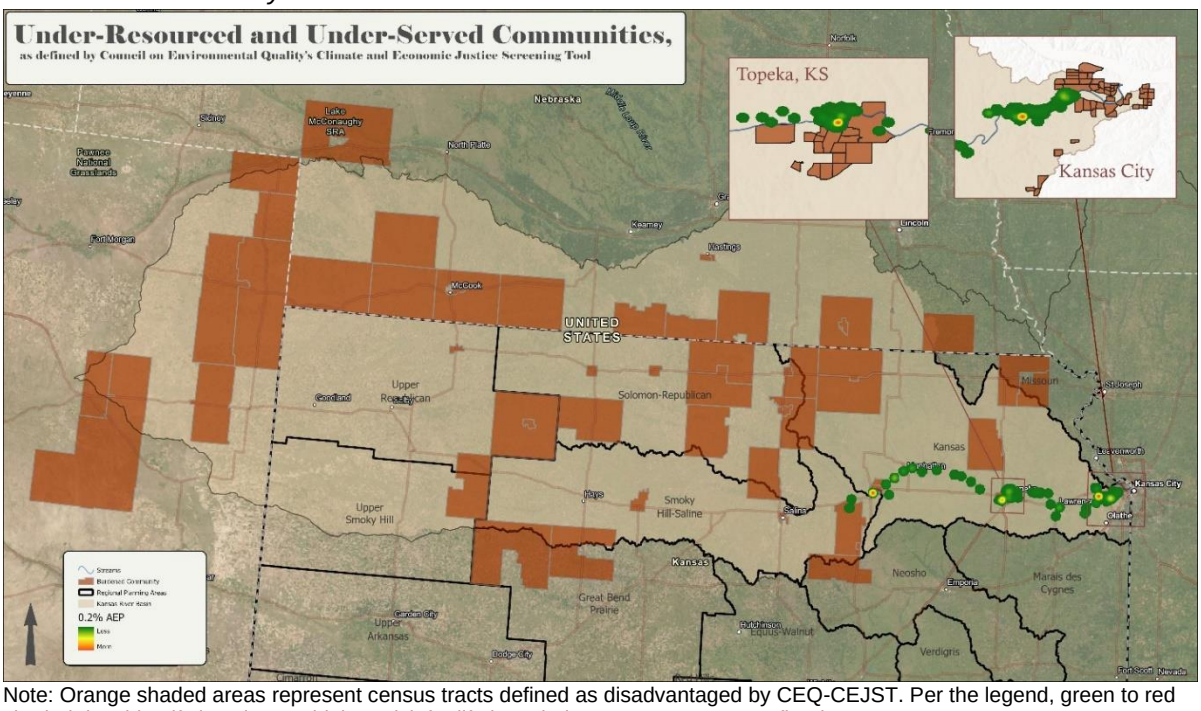
13442 *Figure 3-321. Under-Resourced and Under-Served Communities Overlay with the 0.1 Percent Annual*
13443 *Exceedance Probability Scenario for Four Municipalities Along the Kansas River*



13444
13445 Note: Close up view of Figure 3-320 census tracts that are disadvantaged in four municipalities along the Kansas River. Brown
13446 areas represent census tracts defined as disadvantaged by CEQ-CEJST. Per the legend, green to red shaded dots identify
13447 locations at highest risk for life loss during a 0.1 percent AEP flood event.

13448

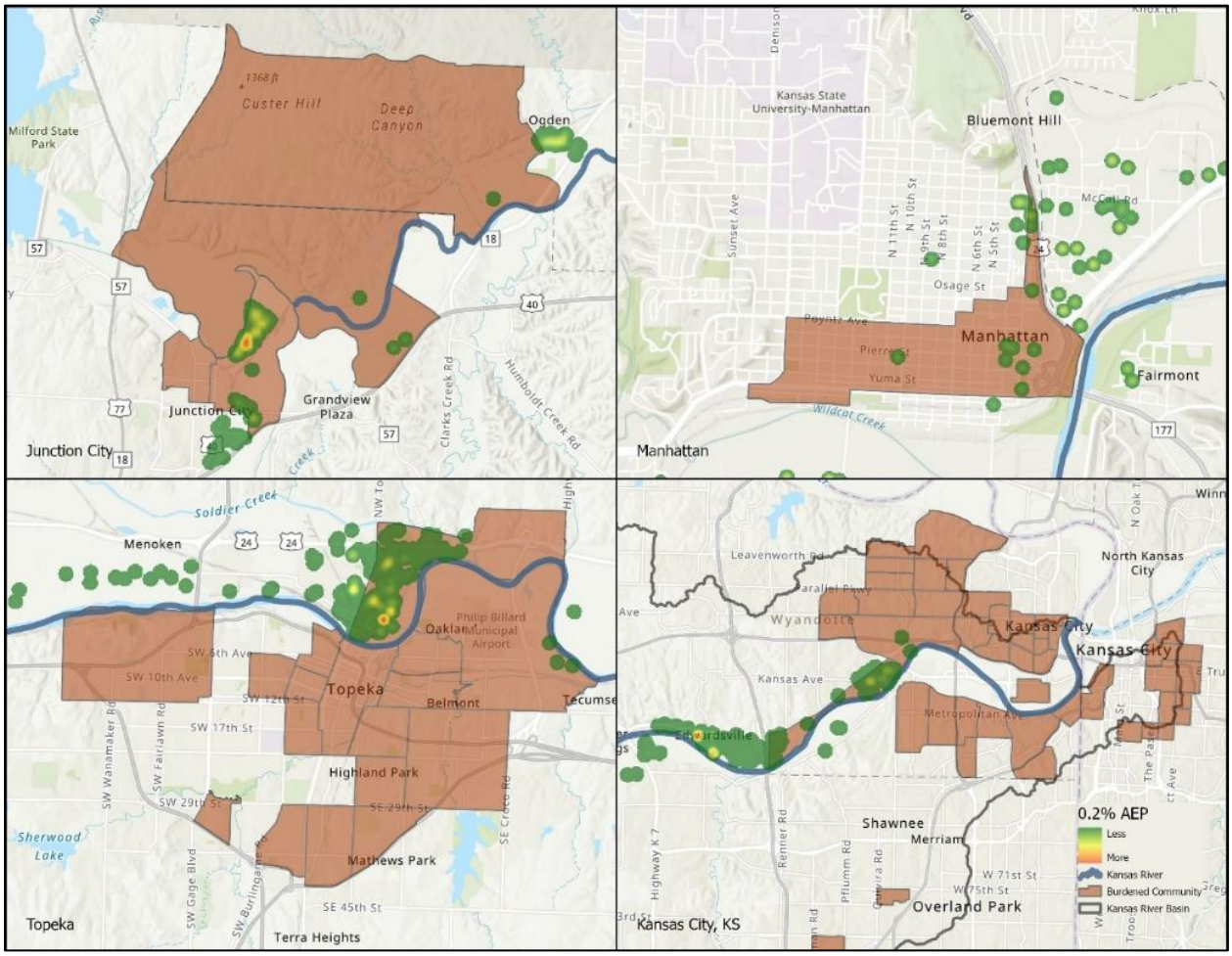
13449 *Figure 3-322. Under-Resourced and Under-Served Communities Overlay with the 0.2 Percent Annual*
13450 *Exceedance Probability Scenario*



13451
13452 Note: Orange shaded areas represent census tracts defined as disadvantaged by CEQ-CEJST. Per the legend, green to red
13453 shaded dots identify locations at highest risk for life loss during a 0.2 percent AEP flood event.

13454

Figure 3-323. Under-Resourced and Under-Served Communities Overlay with the 0.2 Percent Annual Exceedance Probability for Four Municipalities Along the Kansas River



Close up view of Figure 3-322 census tracts that are disadvantaged in four municipalities along the Kansas River. Brown areas represent census tracts defined as disadvantaged by CEQ-CEJST. Per the legend, green to red shaded dots identify locations at highest risk for life loss during a 0.2 percent AEP flood event.

3.8.3.3 Potential Impacts on Disadvantaged Communities from Flood Damage, Evacuation Stress, Employment Disruption

As described earlier, the team used the existing conditions on inundation maps for both the 0.1 percent AEP and 0.2 percent AEP as a baeline to consider how future climate change and demographic changes might affect communities. The same census tracts that screened as disadvantaged and at more risk for potential life loss will also likely have more risk of inundation. As described in the assumptions, households that are categorized as economically disadvantaged will face a disproportionate risk of property loss, restricted ability to repair and return, and be at a higher risk of never returning to their home.

3.8.4 Future Without Project Conditions Water Supply/Water Quality Impact on Disadvantaged Communities Future Conditions

3.8.4.1 Study Findings

The qualitative climate change assessment concluded there is an increased likelihood of extreme droughts. If there are periods of extended drought, there may be future shortages in meeting all water supply and water quality demands in the basin. Shortages may interfere with maintenance of base levels of streamflow on the Kansas River.

The study notes that population growth in some areas of the basin will create an overall increase in demand for water supply. At the same time, sedimentation in reservoirs will reduce the overall water storage available to meet that increased demand.

Water quality impairments may be compounded by agricultural runoffs at the reservoirs as well as in river and stream reaches in the basin. Based on the climate assessments projection of increased temperatures, additional threats to water quality will include warm-season water temperatures and HABs in reservoirs.

Separate from the consequences of increased temperatures, projected rates of continued sedimentation will lead to increased turbidity.

3.8.4.2 Potential Impacts on Disadvantaged Communities from Likely Decreased Water Supply and Degradation of Water Quality

Disadvantaged and underserved households and communities experience disproportionate impacts if there are shortages in water supply. Shortages or disrupted supplies will likely lead to price increases. If there is a need for individual households to haul drinking water, there will be increased transportation costs. Disadvantaged households and communities will have less disposable income to meet price hikes and additional transportation costs and disadvantaged households in rural locations may experience challenges in transporting sufficient water for daily consumption.

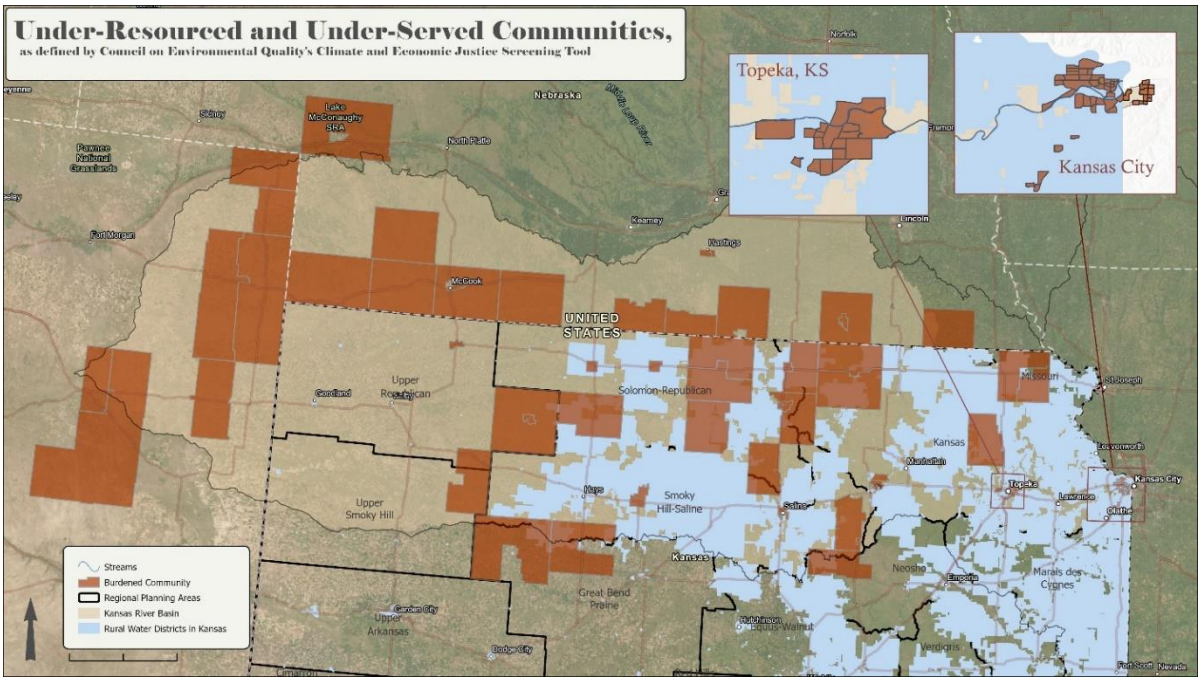
Degradation in water quality could also prompt the need to replace drinking water through additional household purchases and add transportations costs.

Water suppliers will likely be burdened with greater costs for treatment even if supply is sufficient.

3.8.4.3 Potential Impact on Water Suppliers in the Kansas River Basin from Likely Decreased Water Supply and Degradation of Water Quality

Household and commercial water supply in the basin is provided by municipal water systems, private water supply districts, and rural water districts. This analysis does not consider private domestic residential groundwater wells.

Figure 3-324. Under-Resourced and Under-Served Communities Overlay with Rural Water Districts



Note: Orange shaded areas represent census tracts defined as disadvantaged by CEQ-CEJST. Blue shaded areas identify rural water districts in Kansas.

All public water suppliers in Kansas are encouraged to have a drought continency plan as part of a broader water conservation plan to guide actions during prolonged drought. Public water suppliers are defined in Kansas Statutes Annotated 82a as anyone purchasing water from the State of Kansas Water Marketing Program or participating in the Water Assurance District Program sponsoring or purchasing the public water supply or portion of a multipurpose Small Lakes Program project, transferring water under Water Transfers Act, or applying for a loan from the State Revolving Fund). Activation of conservation plans will precede implementation of drought continency plans.

Public water suppliers monitor the trends described herein. If trends continue, suppliers may move proactively to reinforce infrastructure subject to stress or damage during prolonged droughts. Increases in water rates could be spread over time but nonetheless go up for consumers.

While water supply and water quality problems will require different actions, they both entail increased costs and the possibility of restrictions on public use.

Public water suppliers serving census tracts categorized as disadvantaged may also have a reduced tax base or revenue available to make necessary adaptations to meet interrupted water supply or degraded water quality.

3.8.5 Future Without Project Conditions Ecosystems and Recreation and Impact on Disadvantaged Communities Future Conditions

3.8.5.1 Study Findings

Without interventions in the Kansas River basin, ecological resources (habitats and species) and recreational opportunities will degrade. These changes will be amplified by the climate change trends identified in the qualitative climate assessment—increased

temperatures, an overall increase in participation in some parts of the basin, and more extreme rain and drought events.

Lost ecosystem services will amplify the progression of problems considered in this study, e.g., flood risk, sedimentation, water supply and quality, and recreation.

3.8.5.2 Potential Impacts on Disadvantaged Communities from Ecosystem and Recreational Facilities Deterioration

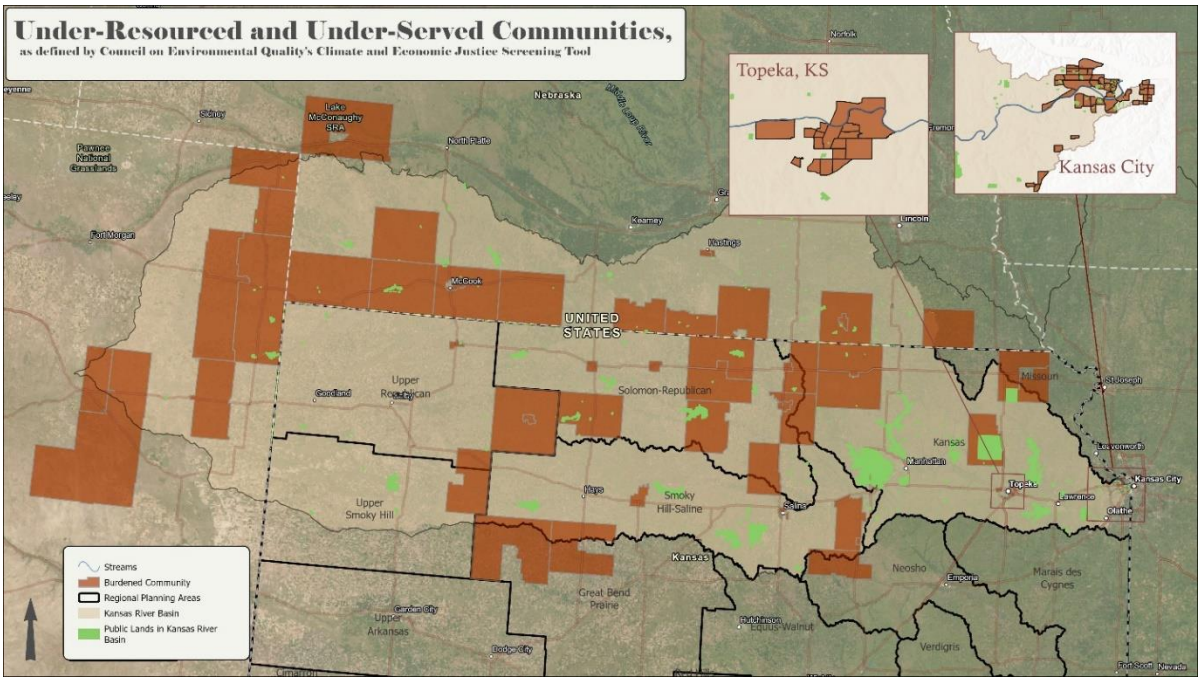
Kansas as a whole, and residents in the Kansas River basin specifically, have limited access to public land. Kansas consistently ranks near the bottom of state rankings based on the availability of public land for recreation.

High quality outdoor recreational opportunities are associated with better physical and mental health outcomes. Households and communities that are defined as economically disadvantaged typically struggle with a range of chronic health issues that can benefit from increased physical activity and engagement with the natural environment, yet these communities typically have less green space and fewer recreational opportunities. While not always a free resource, access to public lands and facilities is generally less expensive than private lands and not dependent on having social connections to landowners. Thus, access to public lands and natural environments are generally less accessible to disadvantaged communities.

If trends identified in the watershed study continue, disadvantaged communities in Kansas will have less access to low-cost natural environments and recreational opportunities.

The loss of ecosystem services will likely amplify negative trends in flood risk and both water supply and quality for which disadvantaged households and communities have less capability to adapt and respond.

Figure 3-325. Under-Resourced and Under-Served Communities Overlay with Rural Water Districts



Note: Orange shaded areas represent census tracts defined as disadvantaged by CEQ-CEJST. Green shaded areas identify public land owned by the federal, state, and county governments across the Kansas River Basin. This provides high level view of how proximate public recreation areas are to communities with disadvantaged census tracts.

3.8.6 Conclusions

The watershed study documents a set of trends in the basin that will likely lead to increased flood risk, degradations in water supply and quality, and deterioration in ecosystems and recreational facilities. A future without interventions to reverse these trends will have consequences for households and communities all across the basin. Households and communities meeting the definition of disadvantaged as defined by HQUSACE will bear disproportionate risks and burdens because of their constrained ability to adapt or recover to negative consequences.

Future efforts by governmental or nongovernmental entities to reverse identified trends and steer towards a healthier watershed require a whole-of-community approach. Whole of community typically describes cross-jurisdictional, neighborhood, and community organization efforts to collectively assess needs then jointly determine the best way to combine their strengths, assets, and capacities to solve problems and capitalize on opportunities.

In particular, future efforts to improve the health of the basin will require seeking out and engaging communities through targeted outreach and by working to involve these communities in planning and decision-making processes.

3.9 Land Use

The basin encompasses more than 60,000 square miles (38,400,000 acres). It is a diverse area accommodating a variety of land cover types and uses, as inhabitants have taken advantage of productive, largely free-draining soils and flat to moderate or gently sloping terrain.

Kansas and the Kansas River are named for the Kansa or Kaw people who lived for generations in the area. The land gradually lowers in elevation from west to east. Elevations in the basin vary from nearly 6,000 feet near Cedar Point, Colorado, to approximately 720 feet at Kansas City, Kansas. Western Kansas is arid and flat while eastern Kansas is relatively wet, with large streams and springs, forests, rolling hills, and tallgrass prairie. In between is central Kansas, with characteristics of both ends of the state. There are 11 distinct geographic regions in the state with four of them in the basin including the Flint Hills, Glaciated Region, High Plains, and the Smoky Hills (Figure 3-326).

The western portions of the basin lie in the High Plains Region where topography is generally flat with minimal hills. The central portion of the Basin is dominated by the Smoky Hills. East of the Smoky Hills, the Kansas River passes through the Flint Hills Region and then follows the southern limits of the Glaciated Region east to the Missouri River at Kansas City, Kansas (Figure 3-326).

Western regions of the basin in the High Plains Region are characterized by soils with high infiltration underlain by the Ogallala Aquifer, which is the main source of groundwater in western Kansas. Groundwater is the source of most (greater than 90 percent) of irrigation water in western Kansas. Irrigation allows high-value crops to be produced in areas of the State where it could be challenging to grow them under natural precipitation levels and allows many agricultural producers to supplement natural precipitation levels insufficient to grow a cultivated crop. The Smoky Hill Region is characterized by hills capped with sandstone or limestone. Rangeland grazing and haying are common practices in this region. The Flint Hills Region has shallow, rocky soils and is mostly used for grazing. Soils in the Glaciated Region in northeast Kansas consist mainly of rich loess soils which are intensively farmed.

Historic and current land use is described in this section, including a GIS evaluation of current land use and ownership characteristics, as provided in the 2016 NLCD (Dewitz 2019) and the USGS Protected Areas Database of the United States (PAD-US) (USGS 2018) maps showing broad categories of land use (e.g., water, urban, forest, grassland, cropland, private lands, state lands).

3.9.1 Historic Land Uses

The Kansas territory opened to settlement in 1854. It was not until after the Civil War, however, that Kansas experienced a significant increase in population. Free and inexpensive land provided by the Homestead Act and the railroads attracted many settlers. In the years following the passage of the Homestead Act in 1862, more than 70 percent of the immigrants arriving in the first two decades were engaged in agricultural pursuits. After the Civil War and before 1890, the population of Kansas increased by the greatest amount in its history. More than one million people streamed into Kansas seeking a new life on the frontier (Kansas Historical Society 2001).

In the 19th century, Kansas was primarily agricultural. Farmers experimented with a variety of crops. They learned farming in the eastern half of the state was different from the western half. Through droughts and floods, they learned how to improve farming techniques. In 1867, a cattle hub, where cattle could be herded and loaded on a train to be shipped to points in the east, was established in Abilene, Kansas. Kansas surpassed

other states in the surrounding region in the production of winter wheat in 1876. Agriculture remained the principal occupation for Kansas until the 1920s (Kansas Historical Society 2001).

Figure 3-326. Physiographic Map of Kansas

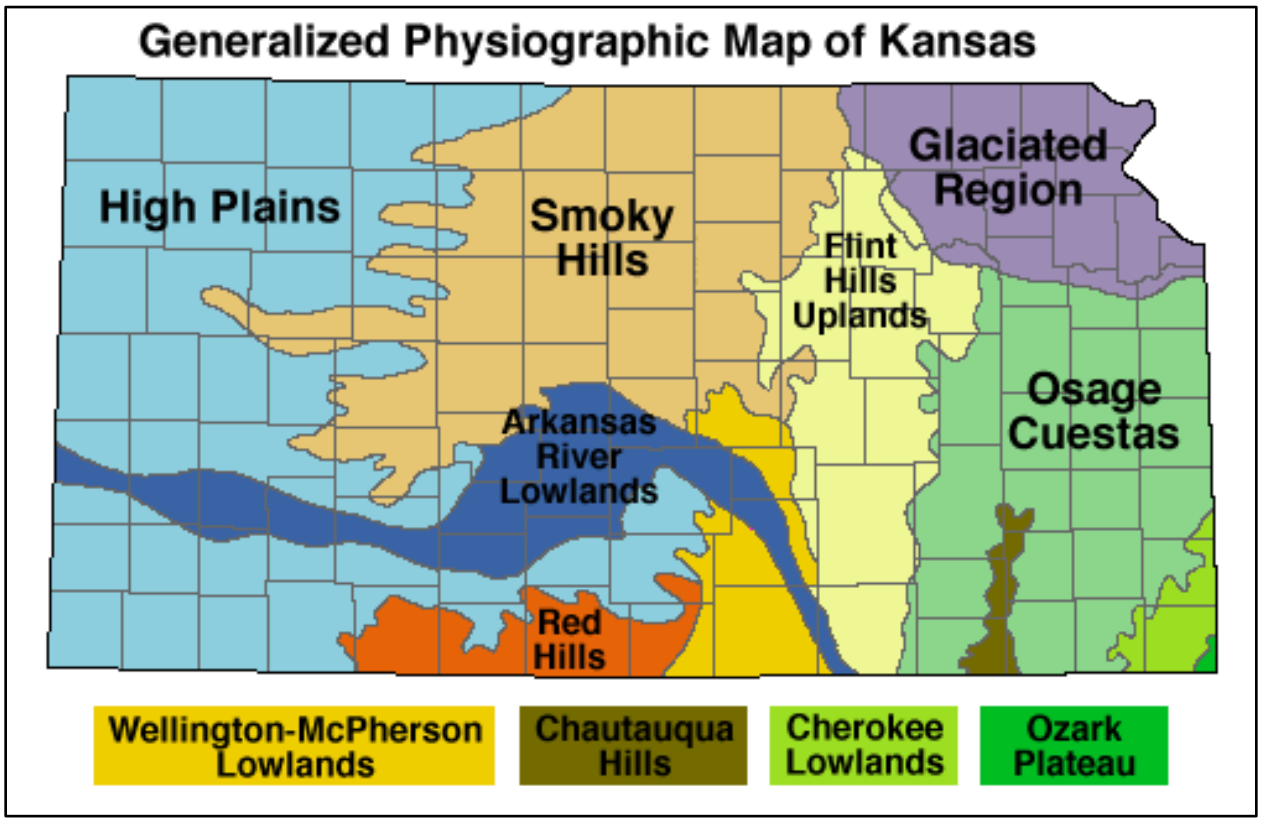


Photo Source: http://www.kgs.ku.edu/Physio/physio.html.

Since the 1950s, more than half of the State's residents live in urban areas. In 2005, a little more than half of all Kansans lived in one of the five most populated counties of the State, and well over two-thirds of state residents lived in an "urban place" (Worley 2006). From 2010 to 2015, estimates show the population of Kansas grew 2.1 percent, but nearly all of that growth can be attributed to just three counties—Johnson, Wyandotte, and Douglas— which grew by a combined 4.9 percent. This accounted for 84 percent of all the new growth in the state over the five-year period (Lawrence Journal–World 2016). Table 3-141 provides current and projected population information.

3.9.2 Current Land Uses

The NLCD was used to analyze the most generalized land cover classifications occurring in the watershed (Dewitz 2016). The NLCD divides land cover across the United States into 16 broad categories, using Landsat imagery and data provided by a consortium of federal agencies. Because NLCD classifications are general and presented at 30-meter resolution, they can mask important distinctions between sites. However, this same broad-brush approach also provides a straightforward, easily interpretable representation of the conditions and overall makeup of the watershed study area.

Today, all suitable land in the Kansas River valley is devoted to agriculture (USACE 1966). The western portion of the basin is primarily in dryland farming with sorghum and wheat the primary crops with areas of irrigated cropland (Rohweder 2015). The eastern two-thirds of the basin are in various agricultural uses with much of the floodplain area and many upland areas in crops such as corn, wheat, soybeans, and milo. Lands with steeper topography are mostly in pasture and hay.

Current land use is a mixture of agricultural (cropland and pasture/hay); urban developed areas (high, medium, and low density) including in Junction City, Manhattan, Topeka, Lawrence, and Kansas City, Kansas; grasslands; forested lands; transportation corridors; and extensive water bodies such as lakes, rivers, ponds, and wetlands. The Kansas River Watershed contains 15 of the 16 NLCD land cover classifications. Table 3-141 and Figure 3-327 provide summarized NLCD land cover information. As the table indicates, the three largest land use categories are cultivated crops (52 percent), herbaceous (37 percent), and hay/pasture (4 percent). Herbaceous grassland areas are typically used for grazing. Together these three types cover 92 percent of the total 38.4 million acres within the basin. Water covers approximately 233,124 acres or 0.6 percent of the study area.

13673 *Table 3-145. Acres of Land Use in the Kansas River Basin*

NLCD Classification	Description	Acres	Percent of Total
Open Water	Open water, usually less than 25 percent cover of vegetation or soil.	233,124	0.6
Developed, Open Space	A mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of cover. These areas commonly include large-lot, single-family housing units, parks, golf courses, and vegetation planted in developments for recreation, erosion control, or aesthetics.	1,125,005	2.9
Developed, Low Intensity	A mixture of constructed materials and vegetation. Impervious surfaces account for 20 to 49 percent of total cover. These areas commonly include single-family housing units.	322,156	0.8
Developed, Medium Intensity	A mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas commonly include single-family housing units.	80,356	0.2
Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 to 100 percent of total cover.	30,468	0.1
Barren Land (Rock/Sand/Clay)	Bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other earthen material. Vegetation accounts for less than 15 percent of total.	26,907	0.1
Deciduous Forest	Forested areas dominated by trees generally greater than 16 feet tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.	966,818	2.5
Evergreen Forest	Forested areas dominated by trees greater than 16 feet tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	8,733	<0.1
Mixed Forest	Forested areas dominated by trees generally greater than 16 feet tall, and greater than 20 percent of total vegetation. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.	56,750	0.2
Shrub/Scrub	Shrubs less than 16 feet tall with canopy typically greater than 20 percent of total vegetation. This class includes shrubs and trees in early successional stages or stunted from environmental conditions.	83,724	0.2
Grasslands/Herbaceous	Graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation cover. These areas are not subject to tilling but are used for grazing.	14,136,535	36.8
Pasture/Hay	Grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	1,353,086	3.5
Cultivated Crops	Production of annual crops and perennial woody crops. Crops account for greater than 20 percent of total vegetation. This class also includes land being tilled.	19,796,358	51.5
Woody Wetlands	Forests or shrublands account for greater than 20 percent and the soil is periodically covered with water.	141,919	0.4
Emergent Herbaceous Wetlands	Perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically covered with water.	93,205	0.2
Totals		38,455,153	100

13674 Source: Dewitz 2019

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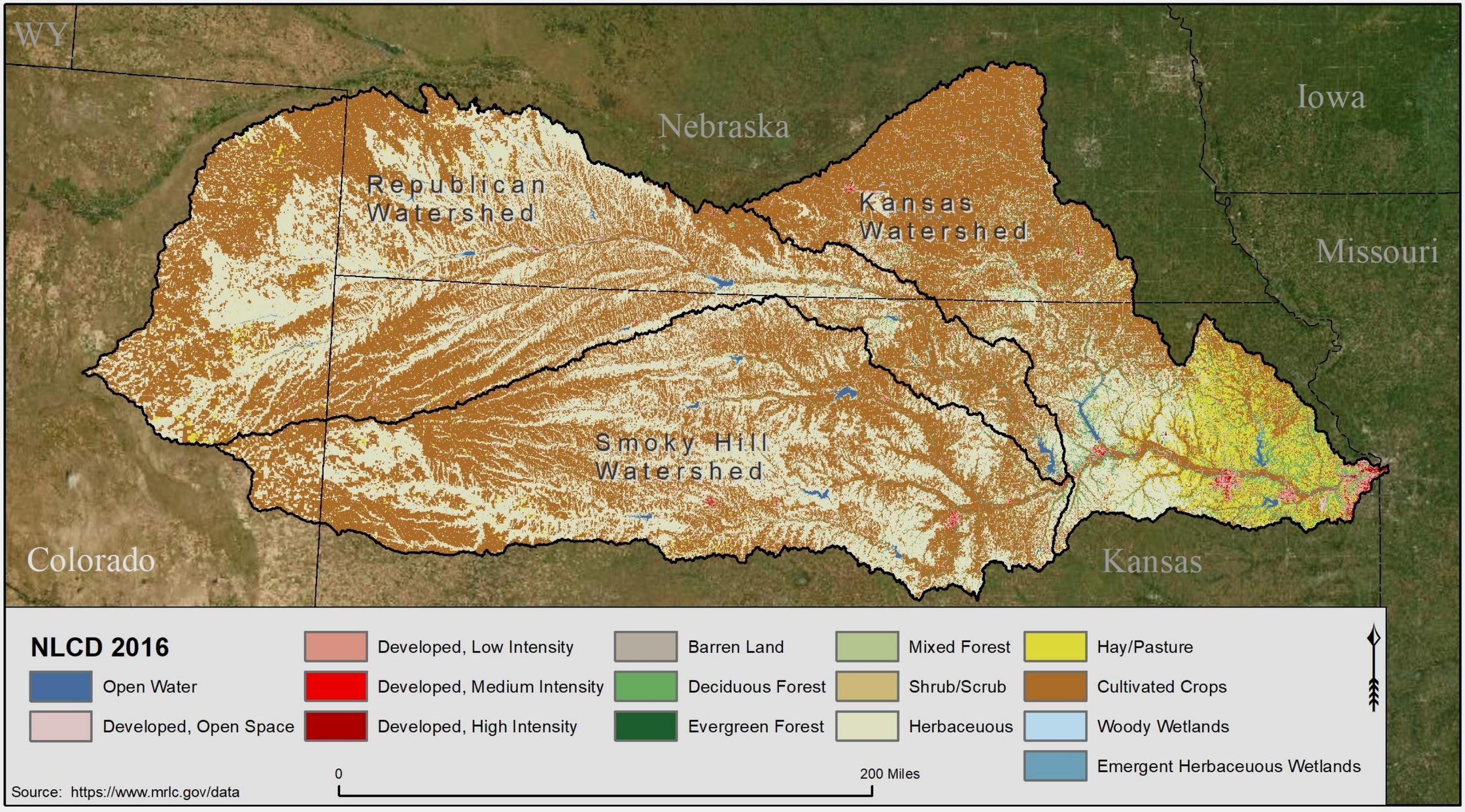
13676 *Figure 3-327. Land Use in the Kansas River Basin*



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3.9.3 Land Ownership

Land ownership refers to the type of agency or entity owning and typically managing land parcels within an area. In the basin, there are lands owned by federal, state, and local governments as well as Tribes and private lands. Data from PAD-US, which is published by the USGS Gap Analysis Program, includes an inventory of federal and non-federal lands. The PAD-US database is administered by the USGS and includes data from counties, cities, federal agencies, states, and national non-profit organizations. The PAD-US data also includes private lands if they have a conservation easement or similar state or federal protection status.

Table 3-142 presents the acreage of these federal, state, and locally owned lands, as well as Tribal and other lands (e.g., private, or NGO owner) in the study area by HUC 4 watershed (see Figure 3-327)—Kansas (HUC 1027), Republican (HUC 1025), and Smoky Hill (HUC 1026)—based on data from the PAD-US. USACE ownership and management of the reservoirs accounts for large amounts of federal land ownership in the basin.

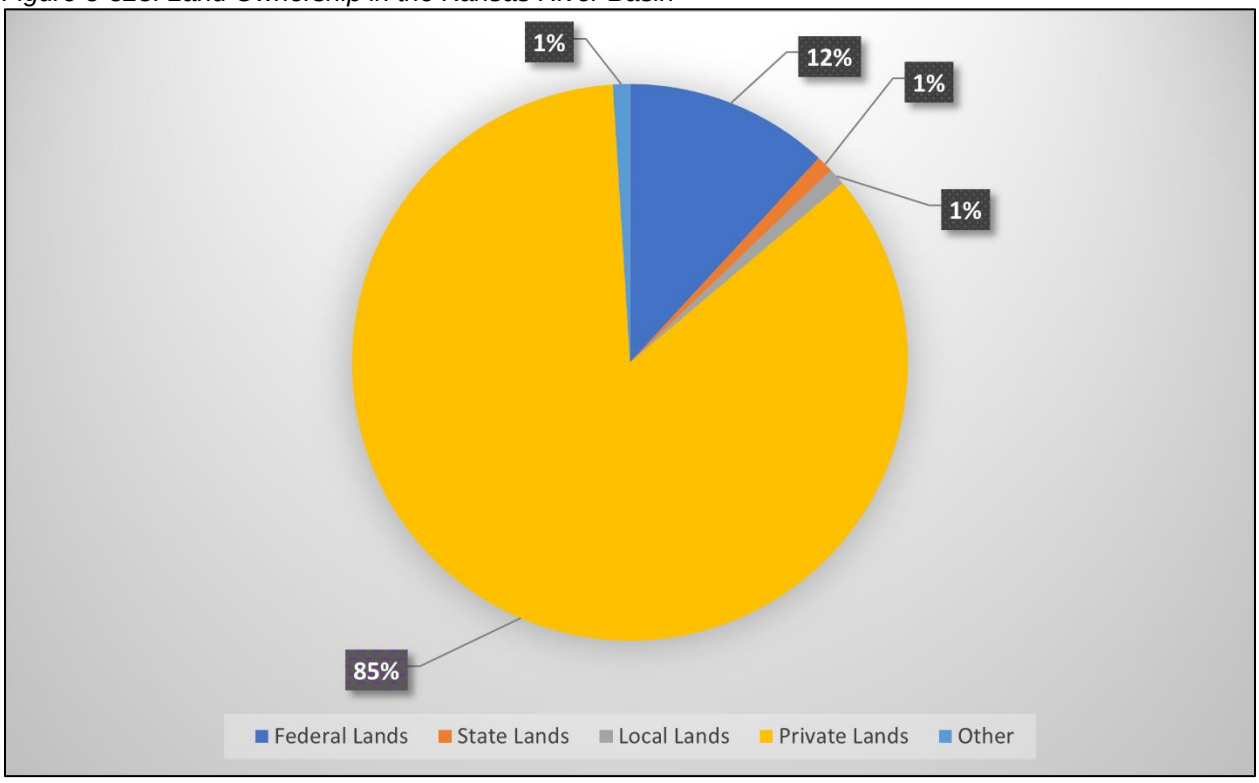
The basin is vastly privately owned (i.e., 85 percent) (USGS 2018). The States of Kansas, Nebraska, and Colorado own 1 percent of the land, the Federal government owns 12 percent of the land, local governments own less than 1 percent of the land, and other entities (e.g., non-governmental agencies, private lands with easements) own less than 1 percent of the land. Table 3-142 and Figure 3-328 summarize this data by watershed (USGS 2018).

13704 *Table 3-146. Land Ownership*

Watershed Percent of Watershed Percent in each State	Private Ownership (acres)[1]	Federal	State	Local Government	Other Entities[2]
Kansas	5,902,136.9	3,799,910.3	40,038.8	1,058.8	44,543.5
Percent of watershed	60	39	<1	<1	<1
Occurs in KS	70%	24%	70%	100%	68%
Occurs in NE	30%	76%	30%	0%	32%
Occurs in MO	<1%	<1%	<1%	0%	0%
Republican	14,893,009.5	924,381.6	243,140.7	695.7	61,767.8
Percent of watershed	92	6	2	<1	<1
Occurs in KS	32%	13%	7%	67%	3%
Occurs in NE	36%	86%	3%	29%	3%
Occurs in CO	32%	1%	90%	4%	94%
Smoky Hill	12,636,681.5	110,574.9	63,703.8	72.1	26,685.0
Percent of watershed	98	1	<1	<1	<1
Occurs in KS	95%	100%	66%	100%	100%
Occurs in NE	<1%	<1%	0%	0%	0%
Occurs in CO	5%	0%	34%	0%	0%

13705 Source: USGS 2018
13706 Notes:
13707 1. The difference in acreage between the total acres in a watershed and that portion of the watershed that is identified as federal,
13708 state, local, tribal, and other lands, which provide an estimate of privately owned lands.
13709 2. Other entities may include NGOs or private landowners with conservation easements or other agreements that provide for
13710 protected land status. The PAD-US definition of a protected area is, “Dedicated to the preservation of biological diversity and to
13711 other natural, recreation and cultural uses, managed for these purposes through legal or other effective means.” (PAD-US 2021)

13712 *Figure 3-328. Land Ownership in the Kansas River Basin*



13713

3.9.3.1 Kansas Watershed (HUC 1027)

Federally owned or managed lands in the Kansas Watershed include the USACE Tuttle Creek, Perry, and Clinton reservoirs and their associated recreation management areas; Homestead National Monument and Brown v. Board of Education National Historic Site; FWS NWR and Resource Management Areas; Flint Hills Legacy Conservation Area; Rainwater Basin Wetland Management District; and Department of Defense (DOD) facilities (Fort Riley, National Guard training sites) (USGS 2018).

State owned or managed lands in the Kansas Watershed include state conservation areas (e.g., Green Wildlife Area, Leavenworth Wildlife Area, Clinton Wildlife Area); state recreation areas (e.g., Douglas State Fishing Lake, Pottawatomie State Fishing Lake); state parks (e.g., Perry State Park, Tuttle Creek State Parks); state historic or cultural areas (e.g., Rock Creek Station State Historical Park); and conservation easements on private lands managed for biodiversity (USGS 2018).

Lands owned by other entities include those owned by NGOs, regional agency special districts (e.g., Lower Big Blue Natural Resources District, Upper Big Blue River Natural Resources District), and private lands managed for conservation, recreation, and watershed protection (e.g., Grassland Reserve Program, Wetlands Reserve Program) (USGS 2018).

3.9.3.2 Republican Watershed (HUC 1025)

Federally owned or managed lands in the Republican Watershed include the USACE Harlan County and Milford reservoirs and their associated recreation management areas; USBR resource management areas associated with reservoirs in Colorado (Bonny Lake), Kansas (Keith Sebelius, Lovewell), and Nebraska (Enders, Harry Strunk, Hugh Butler, Swanson); USBR grazing allotments; Flint Hills Legacy Conservation Areas; and DOD facilities (Fort Riley) (USGS 2018).

State owned and managed lands in the Republican Watershed include state conservation areas (i.e., Norton Wildlife Area, Jamestown Wildlife Area); state recreation areas (e.g., Guide Rock Diversion Dam); state parks (e.g., Lovewell State Park, Prairie Dog State Park); state historic or cultural areas (e.g., Champion Mill State Historic Park); and conservation easements on private lands managed for biodiversity (USGS 2018).

Lands owned by other entities include those owned by NGOs (e.g., Ducks Unlimited); regional agency special districts; and private lands managed for conservation, recreation, and watershed protection (e.g., Grassland Reserve Program, Wetlands Reserve Program) (USGS 2018).

3.9.3.3 Smoky Hill Watershed (HUC 1026)

Federally owned or managed lands in the Smoky Hill Watershed include the USACE Kanopolis and Wilson reservoirs and their associated recreation management areas; USBR resource management areas associated with reservoirs in Kansas (Cedar Bluff, Glen Elder, Kirwin); Nicodemus National Historic Site; Kirwin NWR; Flint Hills Legacy Conservation Area; Rainwater Basin Wetland Management District; and DOD facilities (National Guard Training Center) (USGS 2018).

State owned and managed lands in the Smoky Hill Watershed include state conservation areas (e.g., Cedar Bluff Wildlife Area, Glen Elder Wildlife Area, Maxwell Wildlife Refuge); state recreation areas (e.g., Geary State Fishing Lake and Wildlife Area, Logan State Fishing Lake and Wildlife Area); state parks (e.g., Cedar Bluff State Park, Glen Elder State Park, Wilson State Park, Webster State Park, Kanopolis State Park); and conservation easements on private lands managed for biodiversity (USGS 2018).

Lands owned by other entities include those owned by NGOs (e.g., The Nature Conservancy, Smoky Hill Audubon Wildlife Sanctuary) and private lands managed for conservation, recreation, and watershed protection (e.g., Grassland Reserve Program, Wetlands Reserve Program) (USGS 2018).

3.9.3.4 Flowage Easements

Flowage easement lands are privately owned lands on which the United States government acquired a perpetual right to flood the property in connection with the operation of the reservoir, to prohibit construction or maintenance of any structure for human habitation, and to approve all structures constructed on flowage easement land, except farming fencing. Flowage easements rights were procured for each of the seven USACE reservoirs (i.e., Clinton, Perry, Tuttle Creek, Milford, Harlan, Wilson, Kanopolis) in the basin. These lands were procured in lieu of fee simple title based on a metes and bounds description, on an elevation, or a combination of both. The land acquired in fee are those lands so frequently inundated as to destroy their usefulness or economic value. Table 3-143 provides the total acres acquired for flowage easement and the elevation of the flowage easement line for each of the seven USACE reservoirs in the basin.

Table 3-147. U.S. Army Corps of Engineers Flowage Easements for Kansas River Basin Reservoirs

USACE Reservoir	Flowage Easement (acres)	Flowage Easement Elevations (feet)
Clinton Reservoir	660	908.4
Perry Reservoir	2,761	926.0
Tuttle Creek Reservoir	26,260	1140.0
Milford Reservoir	4,622	1182.0
Wilson Reservoir	12,569	1582.0
Kanopolis Reservoir	892	1507.0
Harlan Reservoir	1,230	1973.5
Total	48,993	

3.9.3.5 Agricultural Leases

USACE leases the lands surrounding reservoirs within the basin. These leases are for agricultural, grazing, or hay harvesting purposes and are a beneficial management tool as a means of wildlife habitat development, prevention of undesirable vegetation, or prevention of wildlife danger. Leases are awarded mostly on a competitive basis typically for terms of 3–5 years with requirements for specific uses (e.g., portion of crops

left for wildlife habitat). The specific purposes for each lease vary depending on the qualities of each land tract and the natural resource management goals.

3.9.3.6 Kansas Department of Wildlife Parks and Tourism Leases

KDWP leases lands associated with reservoirs in the basin. The land is used for wildlife management and public hunting opportunities. These areas provide a variety of habitats for breeding, nesting, rearing, resting, stopover, and cover for numerous wildlife species including game and non-game wildlife such as migratory and native waterfowl, mammals, amphibians, and reptiles.

3.9.4 Land Use Transitions 2001–2016

Since the lands within the basin (i.e., Kansas, Nebraska, and Colorado) were first settled, conversion of the natural landscape to farmland, pasture, and urban area has occurred at varying rates and to varying extents. While several of the urban areas in the basin experienced moderate to significant growth in recent years, vast areas of the basin experienced minor change in land use over relatively long periods of time. Table 3-144 compares recent changes in land type from 2001 to 2016.

Table 3-148. Change by Land Type 2001–2016

Land Type	2001 (acres)	Percent of Total	2016 (acres)	Percent of Total	Percent Increase/ Decrease
Open Water	244,035	0.6	233,124	0.6	-4.5
Developed, Open Space	1,118,174	2.9	1,125,006	2.9	0.6
Developed, Low Intensity	314,543	0.8	322,157	0.8	2.4
Developed, Medium Intensity	67,297	0.2	80,356	0.2	19.4
Developed, High Intensity	24,638	0.1	30,468	0.1	23.7
Barren Land (Rock/Sand/Clay)	23,062	0.1	26,908	0.1	16.7
Deciduous Forest	974,538	2.5	966,819	2.5	-0.8
Evergreen Forest	8,872	<0.1	8,734	<0.1	-1.6
Mixed Forest	54,893	0.1	56,751	0.1	3.4
Shrub/Scrub	89,572	0.2	83,724	0.2	-6.5
Grasslands/Herbaceous	14,697,026	38.2	14,136,536	36.8	-3.8
Pasture/Hay	1,405,340	3.7	1,353,087	3.5	-3.7
Cultivated Crops	19,207,914	49.9	19,796,359	51.5	3.1
Woody Wetlands	142,830	0.4	141,919	0.4	-0.6
Emergent Herbaceous Wetlands	82,421	0.2	93,206	0.2	13.1
Totals	38,455,153	100%	38,455,153	100%	N/A

Source: Dewitz 2019

These changes show a relatively stable land use pattern over a 16-year period. Changes in various land types over the 16-year period include increases in land cover

categorized as developed, medium intensity; developed, high intensity; barren land; and emergent herbaceous wetlands; each showing changes over this period. Land types that decreased include open water, deciduous forest, evergreen forest, shrub/scrub, herbaceous, hay/pasture, and woody wetlands.

Generally speaking, over the period between 2001 and 2016, most land use transitions moved from a more pervious (more absorption of precipitation) use type to a more impervious (less absorption, more runoff during precipitation events) use type. However, the amount of land use transitions to more impervious use type is negligible (approximately 1.6 percent). Development of land, no matter the purpose, has the effect of changing how water interacts with the land. Changes in the amount and type of vegetative cover can impact the amount of water that infiltrates through the ground and the amount of water lost through evapotranspiration (water evaporation in the atmosphere from the soil surface). Additionally, disturbing soils through tillage (preparation of the soil for planting), as often occurs when transitioning from grassland or pasture to cultivated crops, may increase sediment runoff. Transitions from largely vegetated areas (grass/pasture, forests, shrub/scrub) to developed open space or developed low, medium, and high intensity land uses indicates ever-increasing amounts of runoff during precipitation events and decreasing opportunities for groundwater recharge. Without enforcement of stormwater management regulations, greater amounts of runoff indicate increased changes of flooding in smaller urban stream corridors. Increases in the developed areas in the basin will likely increase runoff in the areas of development but are unlikely to substantially increase runoff for the basin as a whole.

Much of the agricultural community and many rural residents in the basin rely on either surface water or groundwater resources for irrigation and drinking water supplies. Quantities of available groundwater are declining in many areas, often due to overdevelopment for irrigation. Groundwater in the alluvial aquifers associated with areas bordering streams and rivers on the eastern portion of the basin experience declines separating the interconnectedness with the stream and groundwater, reducing baseflow into the stream. Further reductions in groundwater recharge due to additional placement of impervious pavements and reliance on efficient stormwater movement systems, threaten these dependent communities. This trend towards more placement of impervious surfaces also indicates the potential for more stormwater runoff and issues from flooding in the future.

3.9.5 Future Without Project Conditions

A method for forecasting future land use within a defined area such as the basin is to use forecasts of future population growth. This growth is tempered and directed by the economic development and land use strategies found in county and municipal jurisdiction comprehensive plans. Population projections for the basin area are based upon U.S. Census and the Center for Economic Development and Business Research at Wichita State University data (CEDBR at Wichita State 2020) for the Kansas counties within the basin. For the purpose of forecasting future population, only those counties having a substantial portion of their land area in Kansas within the basin (43 counties as shown in Table 3-145) were used in the projection. Forecasting of future population is not included for Nebraska or Colorado, however, the Center for Public Affairs Research,

University of Nebraska at Omaha (2015) reported that across all 93 counties in Nebraska the population would increase by 17 percent (327,525 persons) from 2020 to 2050. Most of the counties in Nebraska and Colorado within the basin are rural in nature with relatively small populations and, therefore, were not included in a detailed assessment of the watershed.

CEDBR at Wichita State (2020) data indicates net future population in the basin will rise by approximately 44 percent (or 801,193) persons by the year 2070. Table 3-145 shows anticipated population change per county. The six counties most likely to realize land use/land cover changes due to this additional population growth are Johnson County (77 percent, 533,026 persons); Geary County (189 percent, 86,017 persons); Douglas County (47 percent, 68,124 persons); Riley County (48 percent, 44,451 persons) Pottawatomie County (121 percent, 33,056 persons); and Leavenworth County (34 percent, 32,765 persons) with Johnson County expected to increase the most. All of these counties are located in the eastern portion of the basin. Table 3-145 also notes an additional eight counties projecting a less than 15 percent increase in population and 29 counties projecting a 1–42 percent (405–2,607 persons) decrease in population between 2020 and 2070.

Table 3-149. Population Projection by County (sheet 1 of 2)

County	2020	2070 (Projected)	Delta	Percent Change (Increase/Decrease)
Atchison County	16,522	14,728	-1670	-11
Cheyenne County	2,645	2,014	-665	-24
Clay County	8,419	7,587	-760	-10
Cloud County	9,202	7,330	-1889	-20
Decatur County	2,908	1,991	-941	-32
Dickinson County	19,707	19,459	156	-1
Douglas County	126,661	186,177	68124	47
Ellis County	29,716	33,927	4898	14
Ellsworth County	6,479	5,938	-405	-8
Geary County	42,541	123,047	86017	189
Gove County	2,618	2,028	-612	-23
Graham County	2,546	1,622	-969	-36
Jackson County	13,755	14,447	1109	5
Jefferson County	19,214	16,323	-2607	-15
Jewell County	2,861	1,801	-1169	-37
Johnson County	628,444	1,113,185	533026	77
Leavenworth County	83,755	112,080	32765	34
Lincoln County	3,026	1,900	-1205	-37
Logan County	2,896	2,925	100	1
Marshall County	9,882	7,848	-2088	-21
Mitchell County	6,310	5,377	-905	-15
Nemaha County	10,396	10,897	670	5
Norton County	5,545	4,547	-1003	-18
Osborne County	3,652	2,647	-1036	-28

Table 3-150. Population Projection by County (sheet 2 of 2)

County	2020	2070 (Projected)	Delta	Percent Change (Increase/Decrease)
Ottawa County	5,991	4,299	-1676	-28
Phillips County	5,418	4,301	-1127	-21
Pottawatomie County	25,534	56,354	33056	121
Rawlins County	2,510	2,060	-446	-18
Republic County	4,581	2,637	-2088	-42
Riley County	80,983	119,698	44451	48
Rooks County	5,188	4,171	-1003	-20
Russell County	7,213	7,430	391	3
Saline County	56,897	54,366	-1325	-4
Shawnee County	183,150	187,278	8553	2
Sheridan County	2,478	1,755	-757	-29
Sherman County	5,905	3,991	-1992	-32
Smith County	3,630	2,482	-1222	-32
Thomas County	8,005	8,050	146	1
Trego County	2,966	2,215	-712	-25
Wabaunsee County	7,022	6,154	-797	-12
Wallace County	1,498	1,104	-414	-26
Washington County	5,531	5,334	-264	-4
Wyandotte	167,639	182,847	19,478	9
Totals	1,641,837	2,356,351	801,193	44

Source: CEDBR at Wichita State 2020

Over a 50-year period of analysis (per range of data available from the CEDBR at Wichita State [2020]), population increase should not result in significant changes in land use across the entire basin but will likely result in substantial land use conversions in the six counties referenced above. Based upon past population increases in the basin and the effects on land use types, this relatively small increase in population may result in some expansion of the developed/low density and developed/medium density land use categories to higher levels of residential density assuming that such expansion would be at the edges of existing urban areas where public infrastructure is located or in small, extra-urban subdivisions to which public infrastructure has been extended. In each case, county and municipal requirements for stormwater management (contained in comprehensive plans) would likely address runoff from all but the greatest precipitation events.

Land use within the basin is not expected to change appreciably within the short-term. The far eastern portion of the basin is already urban in large areas. Small areas of forests, scrub-shrub, wetland, herbaceous vegetation, and agricultural lands (hay/pasture) within the basin would be expected to convert to urban land uses in the long-term as this seems to be the trend (Table 3-145).

3.10 Biological Resources

The Kansas River, tributaries to the Kansas River, and their floodplains consist of terrestrial and aquatic habitat types that sustain assemblages of fish and wildlife species. These assemblages include species that live year-round in waters and on the

floodplain and migratory species for which the ecosystem provides vital seasonal habitat like wintering and breeding, movement corridors, and stopover habitats. Kansas has 798 species of vertebrates including 468 bird species, 89 mammals, 144 fish, 53 reptiles, and 30 amphibians (Rohweder 2015) (https://ksoutdoors.com/Services/Kansas-SWAP). Additionally, Kansas has approximately 24,000 species of invertebrates, including mussels, crustaceans, and insects.

Many species in the basin are adapted to the extremes in temperature and precipitation and can live in abundance throughout the basin. A fair number, however, are restricted to eastern forest or arid high plains (Collins 1985, as cited in Rohweder 2015). Most amphibian species are restricted to water sources that occur in eastern Kansas. Reptile species follow a similar pattern. Resident bird species occur across Kansas; however, the greatest number of bird species are found on the eastern side of the state. Eastern Kansas is located in the heart of the Central Flyway, the flight path for many migratory bird species. The area offers shelter, food, and rest. Many mammals also live in the Kanas River Basin. The highest number of mammal species live in the western portion of the state. The wide variety of *Rodentia* in the area demonstrates this pattern.

The Kansas River is relatively wide and shallow with a meandering course and a sandy bed. Channel widths vary from 300 to 1,000 feet from the confluence of the Smoky Hill and Republican Rivers at Junction City, Kansas and the mouth of the Big Blue River at Manhattan, Kansas (Figure 2-1). Below Manhattan, Kansas, the channel alternates between a minimum width of 600 feet at many locations to a maximum width of approximately 1,500 feet. The river is typically braided in the wider sections with considerable willow growth along the banks and on low islands. One impoundment exists on the Kansas River at Lawrence, Kansas, above the Bowersock Dam, a low, hydroelectric dam. There are also several weirs located on the Kansas River (Johnson County Weir, Topeka Weir). These structures affect erosion by preventing any degradation occurring on the downstream side of the structure from proceeding downstream. The slack water areas behind these structures provide localized areas of aggradation.

The Republican River below Milford Lake Dam is a sand bed stream flowing through valley alluvium of sandy silt. The Smoky Hill River below Kanopolis Lake Dam is a meandering channel through a wide valley of moderately deep soils. The river ranges from 120 to 250 feet wide near Salina, Kansas. Old oxbows are in various stages of reclamation, but active bank erosion is evident on nearly every bend of the river. The Big Blue River downstream from Tuttle Creek Dam varies in width from 200 to 300 feet. The channel is generally well armored with sand, gravel, and stones for several miles below the Rocky Ford Dam, an abandoned privately-owned run-of-the-river hydroelectric plant. The channel has a long history of caving banks due to the erosion of sand strata, which are found near the bottom at numerous locations. The Delaware River below Perry Dam ranges from 50 feet and 100 feet in width, except in the Kansas River floodplain where it has widened to approximately 300 feet. Channel depths vary greatly. Channelization of the Delaware River above Highway 24 began in 1960. Seven smaller tributaries with drainage areas enter the Kansas River downstream of Junction City, Kansas. These tributary channels are generally steeper and proportionately smaller, but otherwise have many of the characteristics of the Kansas River channel.

The Kansas River floodplain is generally a flat topographic feature where conditions are favorable for development of woody plants during prolonged drought periods. The reaches of the Republican, Saline, and Big Blue rivers below the reservoirs and the lower Smoky Hill River are much like the Kansas River. The Solomon and Delaware rivers have comparatively narrow, deep, and well-defined channels in the lower reaches where willow growth is less likely to develop but where degradation is likely. The Smoky Hill River just below Kanopolis Reservoir is much like these latter mentioned streams. Here, degradation has amounted to about four feet for about a mile and then progressively less until, at ten miles downstream, no trend is discernable (USACE 1966).

USACE reservoirs in the Kansas River Basin currently provide a variety of terrestrial and aquatic habitats for fish and wildlife resources. This includes resident populations as well as migratory species that use the basin as important stopovers during spring and fall migrations. The reservoirs and surrounding federal lands provide public opportunities for angling, waterfowl hunting, upland bird hunting, and big game hunting. Non-consumptive activities such as wildlife watching, which is growing in popularity, are also supported by these reservoirs. The consumptive and non-consumptive opportunities provided to the public generate millions of dollars of revenues in the local and regional area and are important economic engines for these communities. This revenue is used to enhance management activities on these lands.

Over the past 150 years, humans have altered the Kansas River and its tributaries through channelization, impoundments from dams and levees, bank stabilization, dredging, disconnection of the river and floodplain, and modified geomorphology and hydrology, creating changes to river and floodplain habitats (see Section 3.10.1 Stressors to Biological Resources in the Watershed). During this timeframe, large portions of fish and wildlife habitats have been converted to agriculture lands, urban areas, and open water reservoirs. The native diversity of flora and fauna in Kansas, and the study area, is declining due to a variety of stressors, including habitat loss, habitat degradation, diseases, and competition and predation from invasive species. Past conservation actions have had noteworthy success but have not provided sufficient achievement in addressing the overall current decline in species and the terrestrial and aquatic habitats that they require. There is a need for a comprehensive, systematic, and proactive approach that involves multiple agencies and an interested public to conserve biological resources and diversity.

The biological resources subsections and discussions are broken out by distinct areas like conservation regions based on climate (temperature and precipitation). Maps showing the broad habitat types occurring within the watershed are included to aid the discussion (Figure 3-327). The conservation regions defined by the Kansas State Wildlife Action Plan (SWAP) are shortgrass prairie, central mixed grass prairie, and eastern tallgrass prairie (Rohweder 2015) and were adopted and are described here as the western, central, and eastern regions (Figure 3-327). These designations are used for describing and assessing the biological resources in the watershed study. The SWAP further identifies geographically explicit areas within Conservation Regions called EFA. EFAs represent landscapes where conservation actions can be applied to benefit wildlife. A unique set of conservation actions designed to address specific

biological resource concerns for each EFA, Species of Greatest Conservation Need (SGCN), and priority habitats are included for terrestrial and aquatic species and habitats (see Rohweder 2015). There are also statewide conservation issues affecting biodiversity not specific to certain EFAs including: residential and commercial development, agriculture (farming and ranching), energy production, natural systems modification, pollution, and invasive species. Climate change was also assessed by analyzing the vulnerability of a subset of the state's SGCN to climate change to assist in the development of strategies to address the expected climatic effects (Rohweder 2015). Table 3-146 includes the common species from various wildlife species found in each region and their preferred habitat types.

A qualitative discussion of expected changes, if any, to fish and wildlife and the associated habitats of the Kansas River watershed, federally and state listed special status species, and invasive species are included. The assessment of the FWOP condition considers future planned development or conversion of native vegetation to a use not compatible with existing native fish and wildlife species and their associated habitats, in addition to planned habitat management and restoration efforts.

3.10.1 Stressors to Biological Resources in the Watershed

Issues regarding the conservation of native wildlife in the Kansas River Watershed are closely related and can be complex in the way they interact. Due to a variety of stresses, including habitat loss and degradation, diverse fauna is declining. Stressors from invasive species include fragmentation, disease, predation, and competition. A comprehensive, systematic, and proactive approach that involves multiple agencies and an interested public is needed to conserve Kansas' biological diversity.

The Kansas EFA's each have a list of Species of Greatest Conservation Need (SGCN), their priority habitats, and a set of conservation actions to address the specific resource concerns facing these species and habitats. The Kansas River Basin has seven aquatic EFA's: Upper Republican, Shortgrass Prairie, Central Mixed Grass Prairie, Kansas-Lower Republican, Smoky Hill, Eastern Tallgrass Prairie, and Missouri and eight terrestrial EFA's: Arikaree Breaks, Playa Landscape, Shortgrass Prairie, Smoky Hill River Breaks, Central Mixed Grass Prairie, Smoky Hills, Flint Hills, and Eastern Tallgrass Prairie (Rohweder 2015).

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14019 *Table 3-151. Common Wildlife Species and Habitat Types (sheet 1 of 6)*

Wildlife Assemblage	Common Name	Scientific Name	Common Habitat Type	Western Region	Central Region	Eastern Region
Waterfowl, Wading, and Shorebirds	Great blue heron	*Ardea herodias*	Wetlands	X	X	X
	Green heron	*Butorides virescens*				X
	Black-crowned night-heron	*Nycticorax nycticorax*		X	X	X
	Canada goose	*Branta canadensis*		X	X	X
	Greater white-fronted goose	*Anser albifrons*			X	X
	Mallard	*Anas platyrhynchos*		X	X	X
	Wood duck	*Aix sponsa*				X
	American coot	*Fulica americana*		X	X	X
	Northern pintail	*Anas acuta*		X		
	Northern shoveler	*Spatula clypeata*		X	X	X
	Cinnamon teal	*Spatula cyanoptera*		X		
	Blue-winged teal	*Spatula discors*		X		
	Gadwall	*Mareca strepera*		X		
	Lesser scaup	*Aythya affinis*		X	X	X
	Common merganser	*Mergus merganser*		X	X	X
	Pied-billed grebe	*Podilymbus podiceps*		X	X	X
	Belted kingfisher	*Megaceryle alcyon*		X	X	X
	Upland sandpiper	*Bartramia longicauda*		X	X	X
	Spotted sandpiper	Actitis macularius				X

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14022 *Table 3-152. Common Wildlife Species and Habitat Types (sheet 2 of 6)*

Wildlife Assemblage	Common Name	Scientific Name	Common Habitat Type	Western Region	Central Region	Eastern Region
Songbirds	Northern flicker	*Colaptes auratus*	Forest	X	X	X
	Red-bellied woodpecker	*Melanerpes carolinus*			X	X
	Red-headed woodpecker	*Melanerpes erythrocephalus*			X	X
	Downy woodpecker	*Picoides pubescens*			X	X
	Hairy woodpecker	*Dryobates villosus*			X	X
	American crow	*Corvus brachyrhynchos*		X	X	X
	Black-capped chickadee	*Poecile atricapillus*		X	X	X
	Tufted titmouse	*Baeolophus bicolor*				X
	White-breasted nuthatch	*Sitta carolinensis*				X
	Northern cardinal	*Cardinalis*			X	X
	Warbling vireo	*Vireo gilvus*			X	X
	Bullock's oriole	*Icterus bullockii*		X		
	Orchard oriole	*Icterus spurius*			X	
	Baltimore oriole	*Icterus galbula*				X
	Brown creeper	*Certhia americana*		X	X	X
	Great crested flycatcher	*Myiarchus crinitus*				X
	Purple martin	*Progne subis*			X	X
	Yellow-billed cuckoo	*Coccyzus americanus*			X	X
	Cedar waxwing	*Bombycilla cedorum*			X	X

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14025 *Table 3-153. Common Wildlife Species and Habitat Types (sheet 3 of 6)*

Wildlife Assemblage	Common Name	Scientific Name	Common Habitat Type	Western Region	Central Region	Eastern Region
Songbirds	Red-winged blackbird	*Agelaius phoeniceus*	Wetlands	X	X	X
	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*		X		
	Common yellowthroat	*Geothlypis trichas*			X	X
Raptors	Bald eagle	*Haliaeetus leucocephalus*	Wetlands, shores of reservoirs, streams, rivers	X	X	X
	Northern harrier or marsh hawk	*Circus cyaneus*		X	X	X
	Red-shouldered hawk	*Buteo lineatus*				X
Amphibians	Plains spadefoot	*Spea bombifrons*	Floodplain	X	X	X
	Great Plains toad	*Anaxyrus cognatus*		X	X	X
	Woodhouse's toad	*Anaxyrus woodhousii*		X	X	X
	Blanchard's cricket frog	*Acris blanchardi*		X	X	X
	American toad	*Anaxyrus americanus*				X
	Western narrow-mouthed toad	*Gastrophryne olivacea*			X	X
	Plains leopard frog	*Lithobates blairi*		X	X	X
	Small-mouthed salamander	*Ambystoma texanum*				X
	Boreal chorus frog	*Pseudacris maculata*	Forest, grasslands, wooded hills, marshes	X	X	X
	Spotted chorus frog	*Pseudacris clarkia*			X	
	Strecker's chorus frog	*Pseudacris streckeri*			X	
	Cope's gray treefrog/gray treefrog complex	*Hyla chrysoscelis/versicolor*				X
	Green treefrog	*Hyla cinerea*				X

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14027 *Table 3-154. Common Wildlife Species and Habitat Types (sheet 4 of 6)*

Wildlife Assemblage	Common Name	Scientific Name	Common Habitat Type	Western Region	Central Region	Eastern Region
Amphibians	Crawfish frog	*Lithobates areolatus*	Forest, grasslands, wooded hills, marshes			X
	Northern leopard frog	*Lithobates pipiens*				X
	Spring peeper	*Pseudacris crucifer*				X
	Great Plains narrow-mouthed toad	*Gastrophyryne olivacea*			X	
	Red-spotted toad	*Anaxyrus punctatus*			X	
	Western tiger salamander	*Ambystoma mavortium*	Permanent aquatic habitats	X	X	X
	American bullfrog	*Lithobates catesbeianus*			X	X
Reptiles	Yellow mud turtle	*Kinosternon flavescens*	Rivers, sloughs, oxbow lakes, ponds, drainage ditches (semi-aquatic)	X	X	
	Snapping turtle	*Chelydra serpentina*			X	X
	Painted turtle	*Chrysemys picta*			X	X
	Spiny softshell	*Apalone spinifera*			X	
	Smooth softshell	*Apalone mutica*				X
	Pond slider	*Trachemys scripta*		X	X	
	Ouachita/false map turtle	*Graptemys ouachitensis psuedogeographica*			X	
	Plain-bellied watersnake	*Nerodia erythrogaster*		X		X
	Common gartersnake	*Thamnophis sirtalis*	Edges of streams, marshes, sloughs, ponds, wooded areas near water	X	X	X
	Graham's crayfish snake	*Regina grahamii*			X	X
	Common watersnake	*Regina grahamii*			X	X
	Diamond-backed watersnake	*Nerodia rhombifer*				X
	Western ribbon snake	*Thamnophis proximus*		X	X	X

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14029 *Table 3-155. Common Wildlife Species and Habitat Types (sheet 5 of 6)*

Wildlife Assemblage	Common Name	Scientific Name	Common Habitat Type	Western Region	Central Region	Eastern Region
Reptiles	Rough greensnake	*Opheodrys aestivus*	Edges of streams, marshes, sloughs, ponds, wooded areas near water			X
	Plains gartersnake	*Thamnophis radix*		X	X	X
Mammals	Opossum	*Didelphis virginiana*	Along rivers, streams, lakes, wooded areas along streams	X	X	X
	Bobcat	*Lynx rufus*		X	X	X
	Beaver	*Castor canadensis*		X	X	X
	Porcupine	*Erethizon dorsatum*				X
	Long-tailed weasel	*Mustela frenata*		X	X	X
	Mink	*Mustela vison*			X	X
	Muskrat	*Ondatra zibethicus*		X	X	X
	Fox squirrel	*Sciurus niger*			X	
	Ord's kangaroo rat	*Dipodomys ordii richardsoni*		X		
	Silky pocket mouse	*Perognathus flavus bunkeri*		X		
	Meadow vole	*Microtus pennsylvanicus*			X	
	White-footed mouse	*Peromyscus leucopus*			X	
	Franklin's ground squirrel	*Spermophilus franklinii*				X
	Eastern chipmunk	*Tamias striatus*				X
	Southern bog lemming	*Synaptomys cooperi*				X
	Evening bat	*Nycticeius humeralis*				X
	Striped skunk	*Mephitis*	Forest borders, brushy fields near water	X	X	X
	White-tailed deer	*Odocoileus virginianus*		X	X	X

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14031 *Table 3-156. Common Wildlife Species and Habitat Types (sheet 6 of 6)*

Wildlife Assemblage	Common Name	Scientific Name	Common Habitat Type	Western Region	Central Region	Eastern Region
Mammals	Coyote	*Canis latrans*	Forest borders, brushy fields near water	X	X	X
	Red fox	*Vulped fluva*				X
	Gray fox	*Urucyon cineoatgentus*				X
	Woodchuck	*Marmota monax bunkeri*				X
	Eastern cottontail rabbit	*Sylvilagus aquaticus*				X
	Keen’s myotis	*Myotis keenii septentrionalis*			X	

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3.10.1.1 Dams and Water Management

The impacts of dams, and the use and management of water, on fish, wildlife, and their habitats are complex. Dams replace stream and floodplain habitats, and their operation affects the timing and volume of downstream flows, as well as the timing and volume of water within the reservoir. These changes indirectly affect closely-related habitat characteristics like oxygen levels, sediments, and type of riparian vegetation. Crucial habitat for many wildlife species, such as riparian and wetland plants, require specific conditions for growth and reproduction. The quantity of surface and groundwater directly relates to the survival of these species. Likewise, water quality, temperature, chemical composition, and sedimentation affect survivability of aquatic species. Dams and impoundments fragment stream habitat by preventing or reducing aquatic organism movement. The ways in which water is managed and used can either support or degrade specific habitats of aquatic and riparian species. Long-term, water releases from dams increase the rate of streambank erosion by keeping high flows within the banks of a stream for long periods. Dam operations alter the frequency and extent of out-of-bank flows into the floodplain, which can short-circuit groundwater recharge and change floodplain sediment deposition rates. These changes can reduce the enrichment of floodplain soils, alter the ability of floodplains to reduce peak flow events, and change the capacity of floodplain soils to filter and reduce nutrient loading. The presence of levees prevents elevated flows from spilling across the floodplain and inundating areas that connected to the river. Levees are important in the formation and maintenance of aquatic and floodplain habitats. Inundation of the floodplain is a keystone event for many larger river ecosystems and riverine species, resulting in year class formation of fish, access to food sources and carbon, and access to spawning and rearing habitats.

Dams, and the use and management of water in the Kansas River Basin, replaced stream and floodplain habitats, affecting the timing and volume of downstream flows. The timing and volume of water within the reservoirs has also affected fish, wildlife, and their habitats. River-floodplain connectivity, related flooding, and inundation of fish and wildlife habitats influence the quantity, quality, distribution, and variety of habitats available to animal species. Flows and channel geometry, and other physical components of the river, positively or negatively impact habitat availability. Low flows can increase habitat availability for terrestrial and aquatic species that use either exposed shoreline habitats or the shallows. High flows can create or condition habitats for future use. Diverse river channel morphology and channel dimensions provide a variety of conditions in the basin, such as varying depths and water velocities that support species life processes. Dam operations and the presence of levees prevent flows from inundating many areas of the floodplain within the basin.

3.10.1.2 Stream Channelization

Portions of many streams in the basin are channelized in attempts to rapidly move storm water or increase farmable acreage. Channelization reduces stream length and the amount of stream habitat available for aquatic organisms. The lack of bends in channelized systems reduces a stream’s ability to effectively dissipate energy, resulting in higher velocities and increased erosion. Excessive erosion causes stream incision, reducing floodplain connectivity and the quality and quantity of riparian habitat. Attempts

to stabilize eroding banks with riprap or concrete further exacerbates stream incision and riparian habitat loss. Channelization and resulting high stream velocities, combined with reduced floodplain connectivity, often leads to more destructive flood events when levees are breached or overtopped.

3.10.1.3 Residential and Commercial Development

Impermeable surfaces often affect hydrology. Impermeable surfaces prevent infiltration of storm water, increasing the quantity of surface runoff into creeks and streams. Stream degradation and downstream scour and erosion cause infrastructure, like culverts, to become perched and act like barriers that fragment stream habitat and prevent aquatic organism passage.

3.10.1.4 Agriculture

Farming near stream channels can reduce riparian habitats, resulting in erosion and sedimentation, and increasing total suspended solids in flowing waters. The use of surface water drainage systems to reduce crop inundation accelerates water flow off the floodplain, reducing the natural filtration process that recharges groundwater and increasing peak flood flows. Another agricultural threat, due to groundwater irrigation (to sustain crop agriculture) and land practices (terraces) is groundwater depletion and the loss of base stream flows, particularly in western Kansas. Livestock overgrazing near riparian habitats has direct vegetation impacts and reduces the natural filtration capacity of the soil through compaction, resulting in increased nutrient loads and surface water runoff into streams. Livestock runoff often contains bacteria, nutrients, and other contaminants that produce excessive algae growth, spike unionized ammonia, and lower dissolved oxygen, thereby impairing water uses for aquatic life.

Historically, there is a substantial loss of terrestrial and aquatic habitats in the Kansas River watershed due to conversion to agricultural, urban development, and construction of dams and levee systems. Because of the habitat losses and modifications, native plant and animal populations have been reduced and fragmented. Historic and existing conditions for assemblages of fish and wildlife and associated habitats within the Kansas River watershed were developed with references to some common species found in various habitats. Habitat alterations having occurred are described in this study, along with resultant conditions that influence the amount, quality, distribution, and variety of habitats, both positively and negatively.

3.10.1.5 Energy Production

Infrastructure construction for oil and gas development, and the water used, directly affect aquatic wildlife. Oil and gas drilling use a significant amount of water, reducing the availability of water for wildlife. Water used in drilling contains added chemicals and water from deep-formation wells are highly concentrated with saline and other contaminants. Aquatic and terrestrial species have short- and long-term direct and indirect effects from disposal of contaminated drilling water into surface and groundwater resources.

3.10.1.6 Invasive Species

Invasive and other problematic species negatively affect native aquatic species and habitats. Invasive plants impact riparian areas by reducing streamflow. They out-compete native species, creating monocultural stands with little diversity. Invasive species reduce habitat richness that fish and wildlife species require. Introduced predatory species directly impact populations of native aquatic species through predation.

Invasive species can have devastating impacts on the natural environment, as well as high economic impacts if not controlled. Examples of invasive species based on broad groups (invertebrates, vertebrates, plant species, aquatic species, and terrestrial species) are included in subsection 3.10.5, Invasive Species. Aquatic nuisance and invasive species having severe impacts on existing fisheries resources, including deleterious species introductions and dispersal, are also present in the Kansas River Basin. The impacts of invasive species, including displacement of native species, and how they affect fish and wildlife are discussed in subsection 3.10.5, Invasive Species.

3.10.1.7 Climate Change

Climate strongly influences the distribution and abundance of species. Climate changes influence species and ecosystems by altering fundamental interactions with other species and the physical environment. Climate models predict changes in annual precipitation that vary geographically and temporally. The eastern half of Kansas could see increases in precipitation of up to 11 inches per year in the 2090 to 2099 timeframe. The west will see a drying climate in the short and long term, but there is a high level of disagreement between models. Due to climate change, east and west precipitation predictions could have substantial implications for future water use and allocation patterns in the state of Kansas. Additional information related to climate change in the Kansas River Basin is included in Section 3.1 Climate and Precipitation.

There is much uncertainty on how climate change would impact fish and wildlife species. Documented effects include shifts in species distributions, changes in phenology of species, and de-coupling of co-evolved interactions. While there is uncertainty in the variations of climate change impacts, there are predictable impacts that fish, wildlife, and their habitats will experience. Changes in temperature and precipitation will lead to changes in the water cycle, impacting both aquatic and terrestrial species. There will be an increase in extreme events such as floods, droughts, heat waves, and severe storms, which will alter habitats by increasing wildfires, pests, disease, and invasive species. Increasing temperatures may cause range shifts and expansion or contraction of flora and fauna. Increasing temperatures may also change the seasons and their associated physiological processes, shifting phenology of species. The temporal alignment of food availability and reproduction may shift. Due to reduced precipitation and increased temperatures in streams, rivers, and lakes, many aquatic species will suffer. Altered flooding regimes may also affect the abundance and quality of spawning and rearing habitats.

Many species and habitats will be negatively affected by climate change and may require a special set of actions to ensure their survival. The Kansas SWAP (Rohweder

2015) conducted a climate change vulnerability assessment on several SGCN, which is discussed elsewhere in this section.

3.10.2 Aquatic Habitat and Species

Open water habitats like main channels, secondary channels, open water sloughs, backwaters, oxbows, and pools in riverine systems provide a diverse range of flows and depths, providing habitat for various species including large river fish and macroinvertebrates, spawning and juvenile fish, shorebirds, turtles, migratory birds, and furbearers. Habitat needs in open waters include fish spawning, feeding, and breeding areas for migratory birds and furbearers, breeding, nesting, shorebird foraging land, and habitat for macroinvertebrates that are consumed by aquatic and terrestrial species. A variety of species, including avian species, forage in open water habitats along rivers in the basin.

Wetlands remaining along the Kansas River occur both in the floodplain and the river. Floodplain wetlands include farmed wetlands, scrub-shrub wetlands, palustrine emergent wetlands, and forested wetlands. Floodplain wetlands are supported by overland runoff, overbank flooding and occasionally by high water tables. In-stream wetlands primarily occur on islands within the Kansas River. Emergent wetland habitat provides foraging, breeding, rearing, nesting, and shelter habitat for species, including intermittent, permanent, and ephemeral pool species. Fish and amphibians that require emergent wetlands during spawning, nursery, and breeding periods and waterfowl that forage in emergent wetlands are also dependent on this type of habitat. Fringe wetlands and vegetated mudflats provide a link between the channel and backwaters and a refuge for young of the year (YOY) fish and juvenile turtles, as currents are slow and predators are less abundant.

Herbaceous wetland habitat is declining in quantity. With its level landscape and fertile soils, the western region of the basin is the most extensively farmed region in Kansas. Playas are a natural conduit for groundwater recharge and potential stream flow. Human activity, including plowing, drainage, livestock watering, and irrigation, significantly impacts the condition of playa lakes, thereby either decreasing the amount of water into the system or completely draining the wetland.

Figure 3-329. Wetland Complex Above Milford Lake, Kansas



Much of the flood control flexibility of USACE Kansas City District's (NWK) reservoir project system is derived to regulate each reservoir within broad bands defined by the seasonal phase diagrams (see Section 3.2 Reservoir and River Infrastructure, Reservoir Operations, Hydrology/Hydraulics, and Flood Risk). Flexibility increases when normal basin runoff occurs. Flexibility decreases as the flood control pools fill and the urgency to evacuate accumulated flood control storage arises. The Kansas River Basin is subject to prolonged droughts and the goal is to maintain the reservoirs at multipurpose pool. This draws attention for opportunities to increase environmental flows for fish and wildlife habitats. Table 3-146 includes common wildlife found in each region and their preferred habitat type.

Most reservoirs in the Kansas River Basin have excellent potential and opportunities to manage upper lake areas for waterfowl and shorebirds and to manage lake levels for the benefit of fisheries and aquatic habitat in the reservoir pools. Most USACE reservoirs implement these opportunities, with Milford, Kanopolis, and Clinton Reservoirs as the best examples.

Aquatic habitat types were identified from the document, Fish Ecoregions of Kansas: Stream fish assemblage patterns and associated environmental correlates (Hawks et al. 1986), from the Kansas Gap Land Cover Map (Gergely et al. 2019), and with additional input provided by the staff of KDWP (Table 3-147; Figure 3-330 and Figure 3-337).

14214 *Table 3-157. Acres of Aquatic Habitat in the Kansas River Basin*

Habitat Type	Western Region		Central Region		Eastern Region		Totals	
	Acres	Stream Miles	Acres	Stream Miles	Acres	Stream Miles	Acres	Stream Miles
Lotic (Rivers and Streams)	N/A	544	N/A	713	N/A	3,145	-	4,402
Lentic (Reservoirs)	3,482	N/A	73,873	N/A	88,214	N/A	165,569	-
Wetlands (Floodplain forest, herbaceous wetland, riparian shrubland)	28,490	N/A	404,101	N/A	155,518	N/A	587,749	-
Totals	31,972	544	477,974	713	243,732	3,145	753,318	4,402

14215 ### 3.10.2.1 Western Region

14216 In the western portion of the basin, the South Fork Republican River flows from its origin
14217 in eastern Colorado through the northwest corner of Kansas and into Nebraska, where it
14218 joins with the Republican River. The river is a habitat for state-listed species such as
14219 flathead chub (*Platygobio gracilis*), brassy minnow (*Hybognathus hankinsoni*), and
14220 plains minnow (*Hybognathus placitus*). Use of groundwater and surface water from
14221 rivers and streams for irrigation is lowering the water level and, as a result, many
14222 streams in the western portion of the basin are drying up.

14223 Herbaceous wetland habitat in the western portion of the basin includes grass and forb
14224 playa lakes, low or wet prairie, freshwater marsh, and bulrush marsh. Playa lakes are
14225 the predominant herbaceous wetlands of the area. Playa lakes are small, circular basins
14226 and most are shallow, clay-lined, ephemeral wetlands that hold water during rainy
14227 periods. Because rainfall is the only source of water, playa lakes go through a wet-dry
14228 cycle each year. The condition of the playa lakes has been significantly impacted by
14229 human activity. Plowing, drainage, livestock, watering, and irrigation have severely
14230 altered them by decreasing the amount of water input into the system or eliminating the
14231 wetland altogether. They have also been polluted by sedimentation and runoff of
14232 fertilizers and pesticides. Grasses and forbs include scarlet globemallow (*Sphaerlcea*
14233 *coccinea*), blue mudplantain (*Heteranthera limosa*), prairie zinnia (*Zinnia grandiflora*),
14234 muhly grass (*Muhlenbergia torreyi*), knotweed (*Polygonum* spp.), watergrass
14235 (*Echinochloa* spp.), and western wheatgrass grow in more mesic sites such as the
14236 margins of playas. Prairie cordgrass (*Spartina pectinata*) thrives in the low or wet prairie
14237 habitat. Many bulrush (*Scirpus* spp.) and cattail (*Typha* spp.) species are found in
14238 freshwater and bulrush marshes. Herbaceous wetland habitats are currently declining.

14239 ### 3.10.2.2 Central Region

14240 In the central portion of the Kansas River Basin, aquatic habitat includes rivers, streams
14241 and their tributaries in the Kansas, Smoky Hill, Solomon, and Saline river basins. These
14242 rivers and their flowing tributaries have sandy, shallow beds, with few deep chutes,
14243 sloughs, and oxbows. Many reservoirs are in this region, including Wilson Reservoir,
14244 Kanopolis Reservoir, Cedar Bluff Reservoir, Waconda Reservoir, Lovewell reservoir,
14245 Webster reservoir, Kirwin reservoir, and Keith Sebelius Reservoir. The lower

Republican River flows south from Nebraska until it joins the Smoky Hill River to form the Kansas River. Most of the streams in this system have sand substrates. The eastern large rivers are the portion of the Kansas River that flows through this region. The Kansas River has a sandy bottom with few deep chutes, sloughs, and oxbows. The wide, shallow banks are subject to seasonal flooding.

Herbaceous wetland habitat in the central region of the basin includes salt marsh/prairie, spikerush playa lake, playa lake, low or wet prairie, freshwater marsh, cattail marsh, and weedy marsh. In freshwater marshes, prairie cordgrass, sedges, and cattails dominate, and vegetation may be tall and dense. In salt marshes, inland salt grass (*Distichlis spicata*) and seepweep (*Suaeda depressa*) dominate, but other grasses, sedges, spike-rush (*Eleocharis* spp.) and various forbs may be important. Vegetation is usually of low to medium height. Grasslands and shrublands are the primary habitat found in playa clusters and are an important water source for prairie wildlife and serve as stopover locations for migrating waterfowl and shorebirds.

Both seeps and springs are places where ground water moves naturally to the earth's surface either into a body of water or onto land. Springs differ from seeps in that the ground water flows from the earth at a rate enough to form a current. With seeps, the ground water oozes out of the soil or rock without distinct flow. Beginning as precipitation that falls to the surface, spring water moves down into the subsurface by gravity until it reaches a less permeable layer of rock, such as shale. Many rock layers in Kansas slope subtly to the west. The groundwater moves down the slope through permeable rock until it reaches a location where the rock has been exposed to the atmosphere by erosion. This type of spring is called a contact spring, the most common type of spring in Kansas. There are a few springs in Kansas, known as artesian springs, where water is forced to the surface by pressure rather than by gravity. Artesian springs were more common in the state before heavy pumping lowered the water table and lessened the pressure that might have created artesian conditions.

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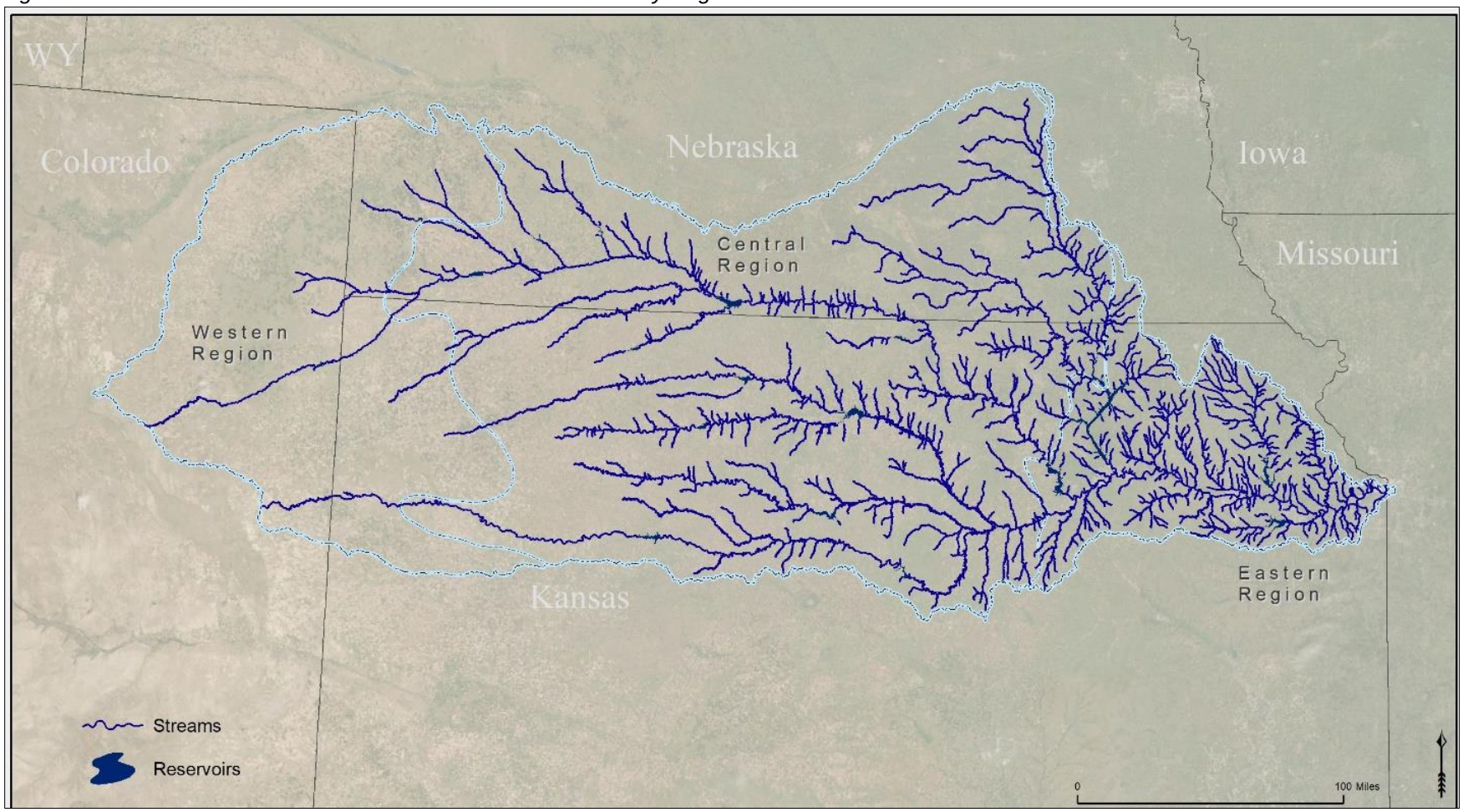
14277 *Figure 3-330. Lentic and Lotic Habitat in the Kansas River Basin by Region*



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3.10.2.3 Eastern Region

Eastern streams/small rivers include the small rivers, streams, and their tributaries in the Kansas River basin in eastern Kansas while eastern large rivers include only the Kansas River. Many of the streams in the Eastern Region are channelized in an attempt to rapidly move storm water or to increase farmable acreage. Channelization reduces stream length and stream habitat available for aquatic organisms. The lack of sinuosity in channelized systems reduces the ability of a stream to effectively dissipate energy, resulting in high velocities and increased erosion. Excessive erosion can cause streams to become incised reducing floodplain connectivity and the quality and quantity of riparian habitat. Subsequent attempts to stabilize eroding banks with riprap or concrete further exacerbate stream incision and riparian habitat loss. Channelization and resulting high stream velocities combined with reduced floodplain connectivity often lead to more dangerous and destructive flood events.

Human activities have had the greatest effect on aquatic habitat in the Eastern Region, with water consumption and agriculture depleting the water levels and polluting the remaining water.

Herbaceous wetlands in this region are comprised of low or wet prairie, freshwater marsh, cattail marsh, and weedy marsh. These habitats are in the floodplains along rivers and streams, in swales associated with rivers, or as margins of lakes and impoundments. These are mostly seasonal and permanent wetlands. The dominant species include softstem bulrush (*Scirpus validus*), spike rush, and sedges (*Carex* spp.). Prairie cordgrass thrives in the low or wet prairies. Many bulrush (*Scirpus* spp.) and cattail species are found in freshwater and cattail marshes. Ragweeds (*Ambrosia* spp.), and sorrel (*Rumex* spp.) dominate weedy marshes.

Reservoirs in this region include Milford Reservoir, Tuttle Creek Reservoir, Perry Reservoir, and Clinton Reservoir.

3.10.2.4 Fisheries

Existing fish populations provide quality, unique, and diverse fishing opportunities throughout the study area. Decades of sportfish management, monitoring, and research has led to fisheries that are highly sought after by anglers, not only locally and statewide, but also regionally and nationally. Kansas reservoir, spillway, and river destinations offer multiple species for recreation, tournaments, harvest for table fare, and once-in-a-lifetime trophy opportunities. Certain species also provide excellent bow fishing, trot lining, set lining, float lining, hand fishing, bait collecting, seining, snagging, and spearfishing opportunities. Current management projects and decisions impact fisheries resources and angler opportunities in a myriad of ways, both beneficial and detrimental.

3.10.2.4.1 Riverine Fisheries

A diverse fish community exists within the Kansas River. Kansas has two distinct fish communities, one that inhabits big, murky rivers and the other that lives in shallow, clear, tree-lined streams. Many of the species found in the Kansas River are typical of those found in large, turbid rivers. They include non-game, game, and forage species like the sunfish, minnow, sucker, catfish, gar, bass, perch, and drum families. The

presence or absence of various fish species is determined by species preference for specific habitat types such as pools, riffles, or tributaries. Table 3-148 includes species that occur in the Kansas River and their habitat requirements.

Many native fish species in Kansas have declined, with fifteen species currently listed on the Kansas State Threatened and Endangered Species list (see Section 3.10.4 Federally and State Listed Special Status Species). Thirty-one are listed as state Species in Need of Conservation (SINC), and four species are extirpated or nearly extirpated including the flathead chub, American eel [*Anguilla rostrata*], chestnut lamprey [*Ichthyomyzon castaneus*], and plains minnow. The primary reason for these declines are the changes made in the stream and river systems. Dams in the Kansas River Basin reduce high-flow signals that some species need to trigger breeding. This reduces the amount of habitat available during peak flows and limits the amount of food that washes in when side channels, ephemeral streams, and high-water channels are suddenly inundated and connected to the mainstem of the river.

14339 *Table 3-158. Riverine Fish Species (sheet 1 of 3)*

Common Name	Scientific Name	Channel	Spawning Habitat	Current/ Depth	Turbidity	Substrate/ Depth
Plains minnow	*Hybognathus placitus*	backwater, sandbar pools	pelagic, shallow backwater	low flow or wide flux, shallow	turbid preferred, clear ok	sand/shifting
Carmine shiner	*Notropis percobromus*		clean gravel, slow velocity	swift pools and riffles	clear	limestone, rocky, gravel
Sand shiner	*Notropis stramineus*	along sandbars	mud, sand, gravel	moderate flow, pool, run	clear to turbid	sand, gravel
Silver chub	*Macrhybopsis storeriana*	backwater, pools	pelagic	shallow, but in summer deep		silty riffles, sand, gravel
Fathead minnow	Pimephales promelas	pools			turbid	mud, firm
Green sunfish	*Lepomis cyanellus*				tolerant	pools near veg.
River carpsucker	*Carpiodes carpio*	secondary, backwater, pools	migrates, margins in vegetation, adhesive	faster		looser material
Red shiner	*Cyprinella lutrensis*	main, backwater and pools	shallow, gravel, vegetation	shallow, slow	tolerate high turbidity and silt	riffles
Black bullhead	*Ameiurus melas*	pools	under log, cover	shallow, little flow	turbid	soft bottom
Common carp	*Cyprinus carpio*	pools, backwater	shallow, eggs adhere to vegetation	not high gradient	tolerate high	all
Orangespotted sunfish	*Lepomis humilis*	pools, backwater	nest sand, fine gravel			sand, gravel, mud
Common shiner	*Luxilus cornutus*		adhesive eggs stick to gravel		tolerate turbidity if flow and no siltation	riffles, pools, coarse, no veg.

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14342 T*able 3-159. Riverine Fish Species (sheet 2 of 3)*

Common Name	Scientific Name	Channel	Spawning Habitat	Current/ Depth	Turbidity	Substrate/ Depth
Sturgeon chub	*Macrhybopsis gelida*	main, edge not thalweg	pelagic	fast/strong, shallow, low discharge	turbid	fine gravel, coarse sand, silt
White crappie	*Pomoxis annularis*	open, deep	nests near deep structure		tolerates	
Largemouth bass	*Micropterus salmoides*	backwater	submerged or overhanging structure		clear	submerged logs, rocks, plants
Suckermouth minnow	*Phenacobius mirabilis*		on gravel riffles	riffles, runs greater than 10 centimeters deep	moderate	gravel, sand
Sicklefin chub	*Macrhybopsis meeki*	main, edge not thalweg	pelagic	strong, deep	turbid	sand, gravel/ smooth, silt
Creek chub	*Semotilus atromaculatus*		spring, gravel nests above riffles	low flow/shallow	clear, turbid ok if clean spawning gravel	gravel
Bluntnose minnow	*Pimephales notatus*	pools, backwater	nest under rock			gravel
Brassy minnow	*Hybognathus hankinsoni*	backwater	shallow backwater, in vegetation, temperature triggered (between 16°C and 27°C)	low velocity	clear	silt, sand
Bigmouth shiner	*Notropis dorsalis*	main		shallow, slow		shifting sand

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14345 Table 3-160. Riverine Fish Species (sheet 3 of 3)

Common Name	Scientific Name	Channel	Spawning Habitat	Current/ Depth	Turbidity	Substrate/ Depth
Central stoneroller	*Campostoma anomalum*		gravel riffle near pools, protracted in variable temperature, condition, turbidity, discharge	tolerate short-term intermittent	semi-tolerant	unsilted gravel riffles
Black buffalo	*Ictiobus niger*		slower flow	deep, fast		riffles
Gizzard shad	*Dorosoma cepedianum*	secondary	surface of shallow, open water		tolerates	
White sucker	*Catostomus commersonii*		swift current, gravel		tolerates, but prefer clear	pools, riffles
Blue sucker	*Cycleptus elongatus*	main	migrate, deep swift riffles	swift, turbulent riffles, deep chutes	intolerant silt	bedrock with gravel, sand, hard clay
Flathead catfish	*Pylodictis olivaris*			high flow recruit		
Freshwater drum	*Aplodinotus grunniens*	secondary, floodplain	deep pools		clear to turbid	clean sand, gravel
Smallmouth buffalo	*Ictiobus bubalus*	main, pool, oxbow, mouth	no current	low current	clear	firm
Blue catfish	*Ictalurus furcatus*	main		swift, deep		sand, coarse
Channel catfish	*Ictalurus punctatus*		migrates		tolerant	woody debris, riffles, some pools, runs
Bullhead minnow	*Pimephales vigilax*	pools, backwater			tolerant	sand, silt
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	main, edge not thalweg		high flow recruit		

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High flows drive channel and off-channel erosion and deposition along rivers, strongly shaping river channel and off-channel habitats and the timing and tempo of natural creation and erosion of these habitats. This affects the overall capacity of the channel, the complexity of the shoreline, and the types of river channel and off-channel habitats available along the river, the amount of each type available, and their relative stability. These factors strongly shape the taxonomic and functional composition of fish species in the Kansas River Basin. Changes in high-flow frequency, magnitude, duration, and timing changes the availability, diversity, and relative stability of channel and off-channel habitats, thereby changing the overall productivity and entire biotic composition of the river, including the types, quantities, and diversity of aquatic species present and their spatial distributions. Other factors affect these relationships as well, such as turbidity and suspended sediment load, connectivity between the river and its natural off-channel habitats, and vegetation on low-lying ground both within and off channel. High flows under natural conditions of flow and channel morphology connect the river with, and give aquatic species access to, off-channel and backwater habitats, where food supplies and refuge are plentiful. These flows make possible the movement of organic matter, dissolved nutrients, smaller aquatic animals, and food between off-channel and main channel habitats. This exchange of living, particulate, and dissolved matter provides significantly crucial inputs that support the entire river food web and stimulates primary productivity in off-channel habitats. Changes in high-flow frequency, magnitude, duration, and timing drastically alter the inputs of living, particulate, and dissolved matter that fuel the river food web; reduce reproduction or access to critical refuge habitat for river fish that depend on the natural flooding of off-channel habitats for their viability and reduce off-channel nutrient uptake and primary productivity.

The Kansas River Sustainable Rivers Project (SRP) (https://www.hec.usace.army.mil/sustainablerivers/) (Baker et. al. 2021) looked at the presence and absence of fish species across different segments of the Kansas River pre-1964 and post-2003. It examined trends that support a decrease or increase in certain fish guilds and habitat needs of each species to determine if any are impacted by changes in flows. The following changes were noted when comparing all fish species:

- 39 fish species were present in both time periods.
- Five fish species were absent from both time periods yet collected at least once in between: southern redbelly dace (*Chrosomus erythrogaster*), chestnut lamprey, shoal chub (*Macrhybopsis hyostomus*), flathead chub, and spotfin shiner (*Cyprinella spiloptera*).
- Three fish species present in the pre-1964 data were absent in the post-2003 data: hornyhead chub (*Nocomis biguttatus*), common shiner, and bigmouth shiner.
- 46 fish species not collected in pre-1964 were collected post-2003. Of these 46 fish species,
    - six were stocked in reservoirs: redear sunfish, goldfish, walleye [*Sander vitreus*], smallmouth bass [*Micropterus dolomieu*], striped bass [*Morone saxatilis*], paddlefish [*Polyodon spathula*]

- four were carp species: bighead [*Hypophthalmichthys nobilis*], black [*Mylopharyngodon piceus*], grass [*Ctenopharynagodon idella*], and silver [*Hypophthalmichthys molitrix*]
- nonnative western mosquitofish (*Gambusia affinis*)
- slenderhead darter (*Percina phoxocephala*)
- pallid-shovelnose hybrid
- lake sturgeon (*Acipenser fulvescens*)
- American eel.

Agricultural practices and urban and suburban construction in the basin have increased the amount of silt in streams, suffocating the eggs of bottom-nesting fish and reducing populations of food organisms, which normally live in between rocks and gravel on the stream bottom. There are barriers to fish movement, which fragment populations, prevent individual fish from moving up and down the river system, cut off movement during droughts, and prevent the repopulation of regions that have experienced declines.

Historically, rivers in the Kansas River Basin were extremely turbid even during low flows and this precluded some aquatic organisms like sight-feeding fish and favored others, like fish that rely on odor, touch, and taste, to feed or avoid being eaten. Changes in the frequency or duration of high versus low turbidity levels cause changes in the diversity, abundance, growth, and productivity of all types of native fish species, including large river, at-risk, and sensitive species. The effects of changes in turbidity influence fish composition in benthic and shallow water habitats, as well as the diversity and productivity of fish that use channel borders or floodplain habitats for parts of their life histories. Increased frequency or duration of low-turbidity levels in the Kansas River Basin result in shifts in the composition and abundance of fish species overall. This involves the expansion of fish that do not tolerate turbidity at the expense of native species that are adapted to highly turbid conditions. Removing the amount of suspended sediment in large rivers will improve the ability of sight-feeding predators like largemouth bass to capture minnows and other small fish. As the water in the Kansas River becomes less murky during low water periods, small fish become more vulnerable to predation.

Most of the species that decreased between the pre-1964 and post-2003 time periods prefer, or can tolerate, turbid conditions like the plains minnow, red shiner, black bullhead, and sturgeon chub prefer pools, backwater, silt, sand, or gravel. Species that decreased are aquatic and spawn in backwaters, sand, or gravel. Species that increased, like the white sucker, blue sucker, and smallmouth buffalo, prefer clear waters, bedrock, or firm substrate. Reviewed literature for the Kansas River SRP (Baker et. al. 2021) details the life histories of fish species and was used to determine ideal flows for successful reproduction. Overlaying the flow needs on historic and current hydrographs helped identify the critical timeline for specific flows. The literature shows that turbid, heterogeneous habitat supports many of the fish species that declined, while clearer, homogeneous habitat supports the fish species that increased.

For the complex topography of the channel, off-channel zones, and for the varied topography of the floodplain habitat, sediment entrained by rivers and streams provide the building material for riverine habitats such as sandbars and islands. Without a supply of sediment in the system, and a balance of sediment inputs and outputs across a broad period, critical habitats in the basin will degrade or wash away and will not regenerate. Channelization and levees in the basin restrict water to a narrow channel. Lack of coarse sediment input degrades the channel, turning a naturally slow moving, wide, shallow, braided river into a deep and swift conduit for reservoir releases. Without an adequate sediment supply, substantial changes to river physical processes and ecological conditions may occur. The potential implications of decreased sediment loads include:

- Severe channel downcutting and degradation. Without a supply and movement of sediment into the system, river flows degrade and flush away sediments and the habitats built from sediment.
- Insufficient sediment supply for sandbar formation and maintenance.
- Reduced sediment replenishment of the floodplain resulting in reduced productivity. After sustained degradation and downcutting, river flows no longer overtop banks during high or flood flows. Without the regular pulse of sediment-delivering flood flows on the floodplain, floodplain habitats and conditions degrade, reducing productivity.
- Decreases in native species dependent on sandbar habitats.
- Decreases in native fish that feed effectively in water with little or no light penetration (catfish, drum, sturgeon, and sucker species), and increases in both native and nonnative fish species that feed more effectively in clear water.

Feeding and hunting are other behaviors affected by physical attributes of the environment. Native fish of Kansas are adapted to turbid conditions; therefore, they are typically at a competitive disadvantage in the clearer waters, post-impoundment. With clearer waters and altered flows downstream of dams, nonnative sight feeders have an advantage and outcompete or eat native species (Baker et. al. 2021). Many dimensions of stream flow affect spawning and larval growth, Not only velocity and discharge, but also duration and timing of flows and how flow shapes the channel and alters substrate. Many studies are devoted to aquatic spawners, which broadcast drifting eggs or have a drifting larval stage. Flow timing and temperature has a great impact on these species, which include the chub species, and have decreased in the Kansas River. Flow is necessary to maintain egg buoyancy of these aquatic spawners, including the plains minnow, which showed the greatest decrease from pre- to post-impoundment (Taylor 2014, as cited in Baker et. al. 2021). Perkin and Gido (2011) note the effects of reservoirs on this guild, including: hypolimnion release of cool water delays egg development several kilometers downstream, sustained high flow homogenizes habitat, and river fragmentation disrupts development. These species need long river reaches, over 100 kilometers, for full development of eggs. Perkin and Gido (2011) cite the greatest challenge associated with conservation of aquatic-spawning carp is the need to allow their eggs and larvae to continue development through reservoirs that fragment rivers.

Spawning substrate is also important and can vary within species depending on other habitat conditions. For example, the creek chub habitat suitability index (HSI 1982) indicated that the species needs clear water but can also tolerate turbidity if clean spawning gravel is present. The interaction of flow and temperature on spawning must also be considered. Brassy minnow spawning is temperature triggered, and will not spawn if the temperature drops (Falke, J.A. in. KS14). This plays into the timing and duration of flows and whether the ideal flow occurs at the ideal water temperature. Many native species of the Kansas River not only tolerate water level fluctuations but are adapted to, and thus need, these fluctuations. For example, the common shiner, which decreased in northwest Kansas due to the loss of water level fluctuations, (Cathcart 2014), also shows a decrease in the Kansas River. The right amount of flow in the right place affects fish success, as shown in plains and brassy minnows, which need backwater habitat.

Gerken (2015) studied fish community response to flow magnitude in the Kansas River and concluded that a natural and variable flow regime may be important for maintaining fish community structure in the Kansas River. Gerken made these observations and points about the overall importance of floodplain inundation on riverine ecosystems:

- Species found in main channel habitats were shovelnose sturgeon, blue sucker, red shiner, shortnose gar (*Lepisosteus platostomus*), goldeye (*Hiodon alosoides*), and smallmouth buffalo.
- Species found in the inundated secondary channel: longnose gar (*Lepisosteus osseus*), river carpsucker, freshwater drum, gizzard shad, white bass (*Morone chrysops*), and sauger (*Sander canadensis*)
- “Floods result in a pulse of higher macroinvertebrate densities that may be used as prey for fishes in secondary channel and main channel habitats.”
- “Increased discharges during flooding can increase shear stress near the benthos and cause “catastrophic drift” where most benthic invertebrates enter the drift thereby lowering the density of benthic invertebrates and subsequently increasing the density of invertebrates in the drift.”
- “Although the energy input provided by one inundated habitat may be negligible, the total influx of energy provided by all inundated terrestrial habitats is likely to provide benefits to the riverine ecosystem. Maintaining lateral connectivity in large rivers may benefit many native fishes found in these systems and management and restoration efforts focused on large river fishes may benefit by increasing or maintaining lateral connectivity between main channel and inundated terrestrial habitats.”

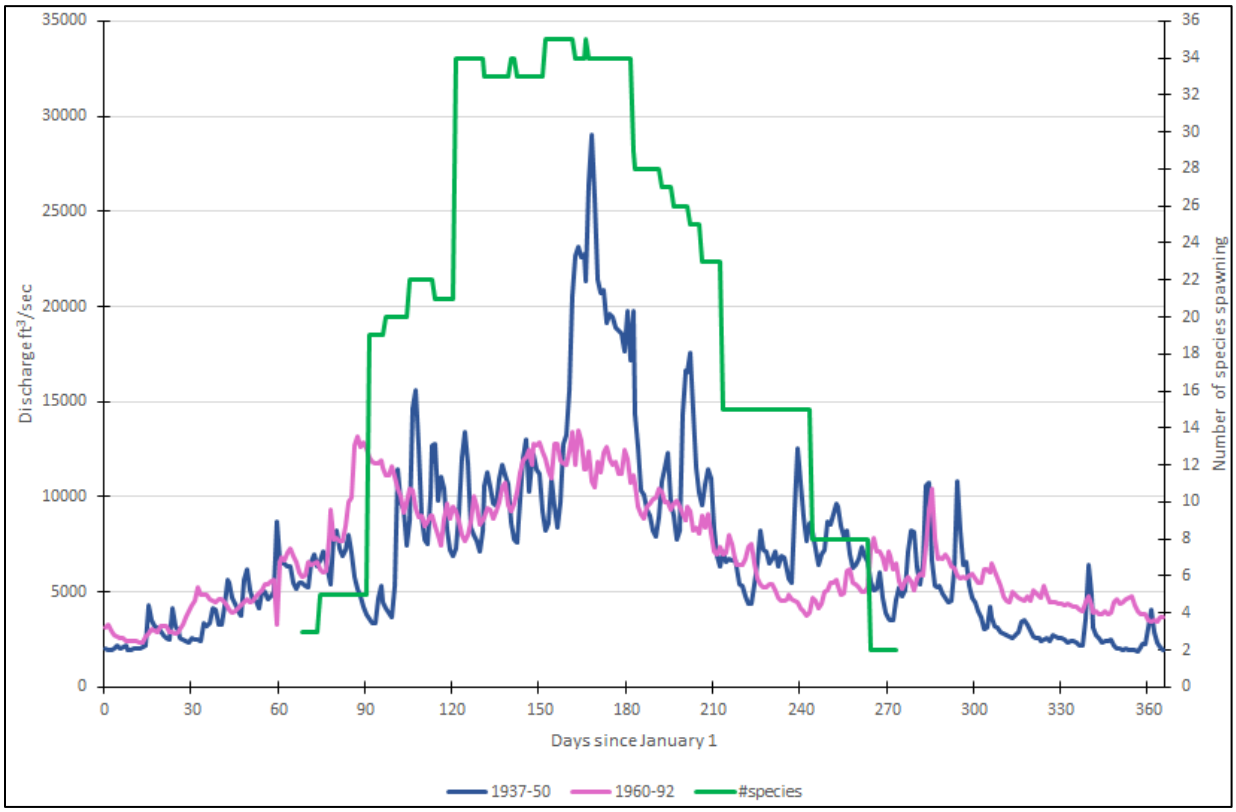
Spawning and Variation in Hydrography

Fish native to the Kansas River are adapted to the interaction and timing of the variable flows typical of prairie rivers. However, reservoirs have disrupted the natural timing and magnitude of flows, moderating and homogenizing conditions, making the river more ideal for nonnative species and less ideal for native species.

Interposing and comparing spawning timing on hydrographs of historic, pre-impoundment, and modern post-impoundment flows shows the trends and changes in natural flow pulses and durations during the spawning season, as well as flow deviations from the natural systems that have occurred over time. The Kansas River SRP (Baker et. al. 2021) obtained spawning periods from the Kansas Fishes Book (KS Fish Commission 2014), compiled in Table 3-149. Additional sources were used for river redhorse species. This table includes all fish that showed change pre- to post-impoundment, plus those that decreased according to Gido et al. 2010, and state-listed species.

Spawning ranges were compiled for 46 species. Critical periods are those that contain the most overlap among species, plus ranges that contain the state-listed species. May 1 through June 30 has the highest overlap of spawning ranges, with 33 to 35 of 46 species spawning during this time. Within that window are three peaks including 34 or more species. Within those three peaks are two peaks (May 20 to 21 and June 15) that capture 7 to 8 of the 11 Threatened and Endangered or SINC species. Chestnut lamprey and shoal chub overlap May 20 to 21. Shoal chub and silvery minnow [*Hybognathus amarus*] overlap on June 15. The hydrograph of pre- and post-impoundment flows plots these peaks. Figure 3-331 highlights the key spawning times of Table 3-149.

Figure 3-331. Number of Fish Species Spawning on the Kansas River



Notes:
1. Lecompton, Kansas
2. Based on discharge data collected before and after construction of the primary federal reservoirs on the main tributaries of the river.
3. The period of record form 1951 through 1959 was excluded because of recorded flooding and construction of the reservoirs occurred during this period.

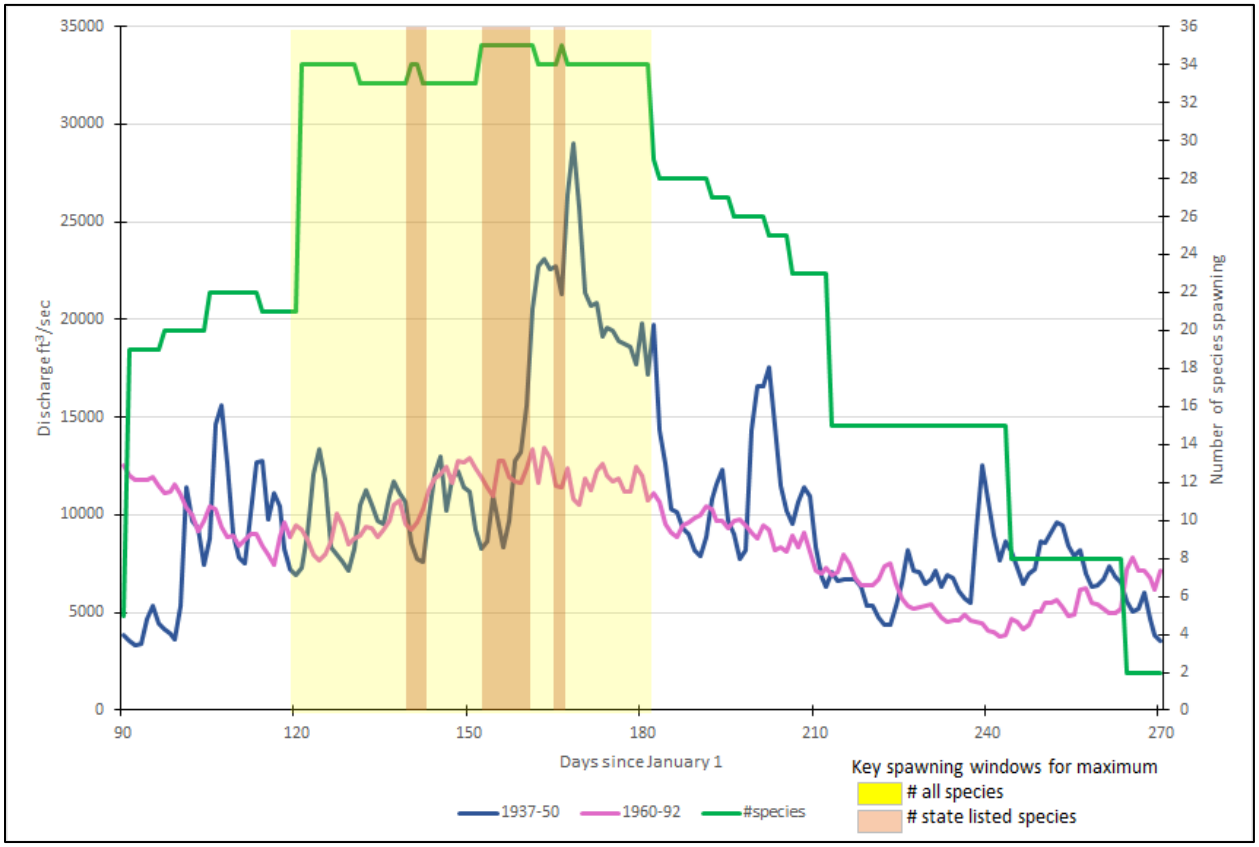
Table 3-161. Critical Spawning Periods May 1 through June 30

Dates	Day of Year	# of Species Spawning	
		All	State-listed
May 1–10	121–130	34	7
May 11–19	131–139	33	7
May 20–21	140–141	34	8
May 22–31	142–151	33	8
June 1–10	152–161	35	8
June 11–14	162–165	34	8
June 15	166	35	9
June 16–30	167–181	34	8

1. May 1 through June 30 is the period with the highest occurrence of fish species spawning (33 to 35 of 46 species)

Most fish species found on the Kansas River spawn between May and June and two critical time periods occur in late May and during June for state-listed species (Figure 3-332).

Figure 3-332. Kansas River Fishes Key Spawning Periods



Notes: Yellow=Maximum number of spawning species; Orange=Maximum number of state-listed species spawning

The minimum, maximum, range, and standard deviation of natural flows were compared to modified flows during each spawning period for state-listed fish species (Table 3-150). The variance between natural compared to modified flows of 4,035 cubic feet per second (cfs) to 4,280 cfs was greatest during the spawning periods of shoal chub, river redhorse, and Johnny darter. The flows from May 1 to June 30, when the majority of fish species spawn, was similar, at 4,228 cfs (Table 3-150). This data shows that variation in flows may enhance spawning success.

Juvenile Development and Hydrography

Newly hatched fish (called fry) require flow rates that influence refuge and food sources. Fry find refuge in debris, under logs and undercuts, in backwater, and in other features that add heterogeneity to a river system. Food sources such as algae and macroinvertebrates also need these features to create a heterogeneous environment. To measure complexity of this system, O'Neill (2010) developed the river complexity ratio (RCR), a metric that measures all types of river structures, and demonstrates that discharge can predict river complexity on the Kansas River (Figure 3-333). The predications determine a time where a river has the most flow refuges created by features within the river, for example, mid-channel sandbars and slackwaters. Low and varied discharge results in higher river complexity. However, Figure 3-333 clearly shows that during fall, when fry need refuge, reservoir discharges maintain flows at a higher level than those which naturally occur, thus river complexity and, therefore, refuge for fry, is reduced. Lower river discharge during the fall season following the critical spawning window would benefit fish species.

14580 *Table 3-162. Discharge During Spawning Periods*

Majority of Species (Days 121–181)				**Plains Minnow (Days 74–263)**		
n=61	natural	modified		n=190	natural	modified
min discharge ft^3/s	7,163	7,680		min discharge ft^3/s	3,356	3,764
max	29,009	13,450		max	29,009	13,450
difference	21,846	5,770		difference	25,653	9,686
std dev	5,756	1,528		std dev	4,926	2,614
std dev difference		4,228		std dev difference		2,311
River Redhorse (Days 91–171)				**River Redhorse (Peak Days 91–120)**		
n=81	natural	modified		n=30	natural	modified
min discharge ft^3/s	3,356	7,416		min discharge ft^3/s	3,356	7,416
max	29,009	13,450		max	15,599	12,055
difference	25,653	6,034		difference	12,243	4,639
std dev	5,594	1,559		std dev	3,527	1,340
std dev difference		4,035		std dev difference		2,186
Johnny Darter (Days 91–181)				**Blue Sucker (Days 91–201)**		
n=91	natural	modified		n=111	natural	modified
min discharge ft^3/s	3,356	7,416		min discharge ft^3/s	3,356	7,416
max	29,009	13,450		max	29,009	13,450
difference	25,653	6,034		difference	25,653	6,034
std dev	5,817	1,537		std dev	5,453	1,458
std dev difference		4,280		std dev difference		3,995
Common Shiner (Days 105–195)				**Common Shiner Peak (Days 131–142)**		
n=91	natural	modified		n=12	natural	modified
min discharge ft^3/s	6,891	7,416		min discharge ft^3/s	7,607	8,863
max	29,009	13,450		max	11,698	10,739
difference	22,118	6,034		difference	4,091	1,876
std dev	5,221	1,528		std dev	1,367	600
std dev difference		3,692		std dev difference		767
Shoal Chub (Days 140–167)				**River Shiner (Days 152–343)**		
n=27	natural	modified		n=92	natural	modified
min discharge ft^3/s	7,607	9,269		min discharge ft^3/s	4,344	3,764
max	23,139	13,450		max	29,009	13,450
difference	15,532	4,181		difference	24,665	9,686
std dev	5,270	1,024		std dev	6,006	2,766
std dev difference		4,246		std dev difference		3,240
W. Silvery Minnow (Days 166–181)				**Sturgeon Chub (Days 172–263)**		
n=16	natural	modified		n=92	natural	modified
min discharge ft^3/s	17,175	10,518		min discharge ft^3/s	4,344	3,764
max	29,009	12,598		max	20,883	12,598
difference	11,834	2,079		difference	16,539	8,833
std dev	3,324	646		std dev	4,321	2,505
std dev difference		2,678		std dev difference		1,816

Notes:
1. Data at Lecompton, KS gage 1937–1950 and 1960–1992
2. Flows in cubic feet per second
3. Natural=Pre-impoundment; Modified=post-impoundment
4. Spawning range=days after January 1
5. n=number of spawning days; min=minimum; max=maximum; difference=difference between min and max; std dev=standard deviation of during spawning periods of the given species; std dev diff=difference between the standard deviation of the natural and modified flows

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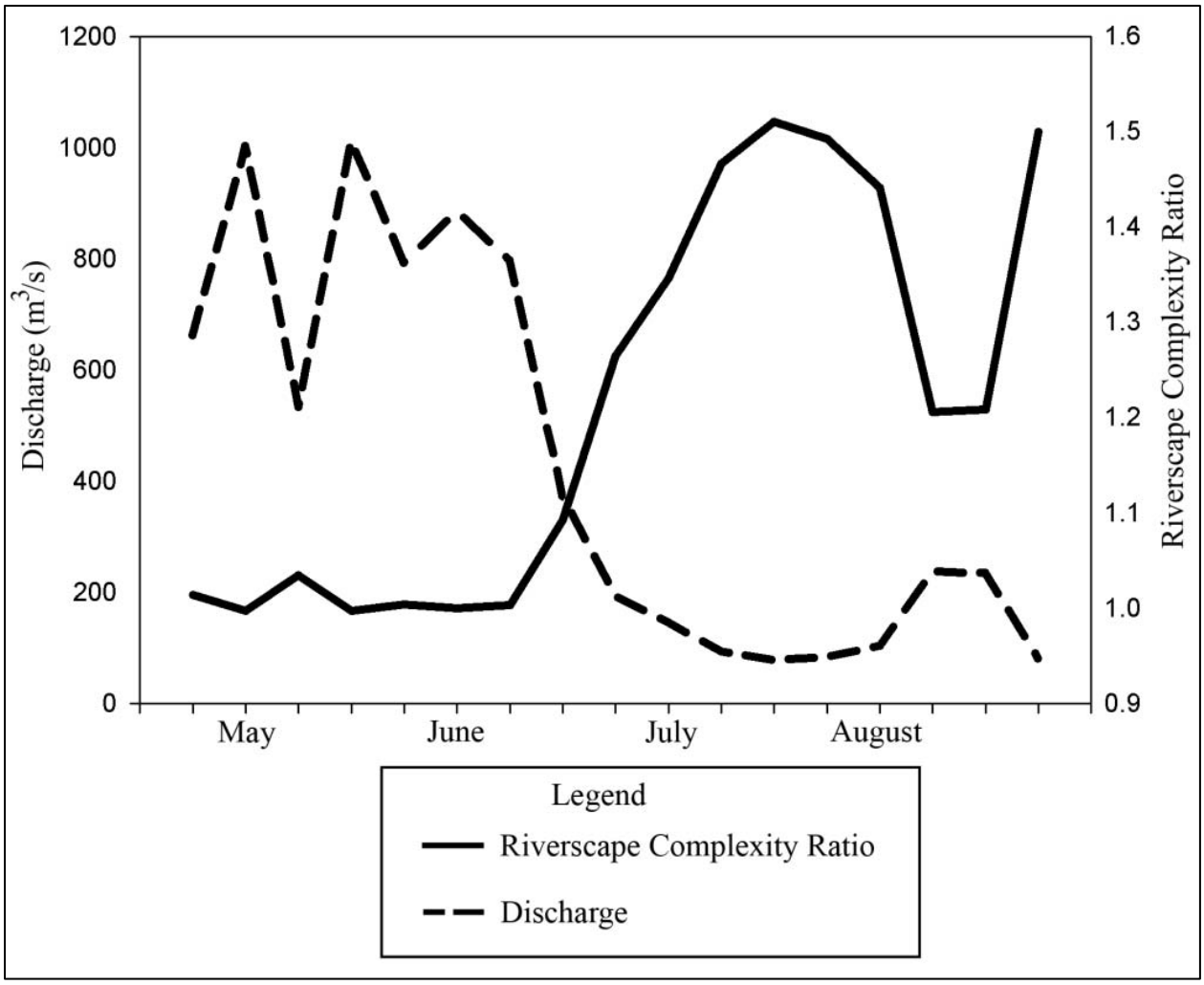
14582 *Figure 3-333. Kansas River—River Complexity Ratio*



14583

14584 According to the RCR, the greatest change on RCR values between the pre- and post-
14585 impoundment flows occurs during the winter months of November through mid-
14586 February. It is during these months that reservoir releases typically elevate flows by as
14587 much as 2,500 cfs above pre-impoundment levels. While winter is a period of limited
14588 fish growth and activity, these months display the largest flow departures from pre-
14589 impoundment flows and represent the highest potential changes in habitat complexity. It
14590 remains unclear if the extent and duration of reduced winter flows are related to fish
14591 community alterations and loss or reductions in individual fish species. The idea that the
14592 maintenance of intermediate flows may be of greater importance is presented below.

14593 In a study of YOY fish in the lower Kansas River, researchers found that intermediate
14594 flow regimes supported high diversity and evenness of YOY fish (Moore and Thorp
14595 2008). Most of these YOY fish were members of the minnow family *Cyprinidae*. Moore
14596 and Thorp hypothesized that higher flows tend to reduce habitat diversity and increase
14597 flow velocities while low flows tend to maximize habitat heterogeneity. But the
14598 diminished flows and harsher water quality of these disconnected habitats reduced
14599 habitat value. They suggested that intermediate flows tend to provide good habitat
14600 diversity and optimum habitat quality for YOY.

King (2004) suggested that low flow periods concentrate prey, resulting in increased foraging success and rapid growth of YOY fish. Moore and Thorp found that the Kansas River exhibits characteristics of the low-flow model.

However, at least in the lower Kansas River, the low-flow recruitment model best explains Moore and Thorp's work. It is the fall and winter flows (aside from flood peak reductions) that show the most departures from pre-impoundment flows. These flow reductions may have moved the system from intermediate to lower, less desirable flow conditions for YOY. One example of the importance of winter flow conditions is the use of 1- to 2-meter-deep habitats with low velocities used by shovelnose sturgeon in the Kansas River. The authors observed that shovelnose sturgeon seem to prefer these moderately deep, slow velocity areas maintained, in part, by discharges ranging from 671 cfs to 1,356 cfs (moderate to low flows).

River Fragmentation Due to Large Dams

Concurrent with the changes in flow regimes associated with all the reservoirs on the major tributaries of the Kansas River is the physical and genetic isolation of fish communities and species inhabiting this large river system. While there are no comprehensive studies of reservoir and impoundment impacts on the immigration, emigration, and life history of fish of the Kansas River Basin, there are many scientific studies of the negative impacts of fragmentation of dendritic ecological networks like streams, caves, and plant architecture. River networks are especially venerable to breaks in network connectivity (see 2017 Freshwater Biology vol. 63). Due to dams, the effects of river discontinuity on fish impacts fish diversity on a global scale (Liermann et al. 2012). Separating the impacts of altered flows from stream fragmentation is difficult where large dams cause both conditions. Research on low-head dams suggest that fragmentation of flow regimes alone impacts fish species richness and functional composition (Tiemann et al. 2004, Santucci et al. 2005, Helms et al. 2011, Perkins et al. 2015).

Because large dams can negatively impact fish species and fish community through flow alterations and fragmentation, it can be assumed that restoring some natural flow regime elements will improve fish community health. Restoring the pre-impoundment flows (or portions of the flow regime) of the Kansas River is an important step in improving the ecological condition of the river and thus its biology. However, fragmentation of this river system by 18 federally operated dams may constrain ecological improvements to improved flows from future reservoir management. This does not lessen the importance of trying to improve flows to the Kansas River but should be considered when measuring future biological responses.

In summary, the variety of spawning and habitat needs of the native fish of the Kansas River and its tributaries point to a need for a heterogeneous flow regime. However, changes in fish species and an increase in non-native species point to a homogenization of habitat and flow corresponding to modification of the river by reservoirs. Hydrographs comparing pre- and post-impoundment flows show this change. Studies on watersheds nested within the entire Kansas River Basin also support this. In the Solomon River Basin, Eberle et al. (2002), found in 1996 and 1997 that 32 percent of native fish species were extirpated, while 51 percent of the fish

composition was nonnative. They attribute this to impoundments and agricultural development, shifting the habitat towards homogenous conditions. Moore and Thorp (2008) suggest that fish have adapted to the dynamic and variable flows in prairie rivers through a more generalist lifestyle and by temporarily using higher flow habitats (except the thalweg) to cope with intermittent loss of prime habitat or extending spawning through favorable and demanding conditions.

The observations by Sanders et al. (1993), in a comprehensive paper about how impoundments have impacted the Kansas River and its biology, state:

- The Kansas River is becoming less turbid.
- Regulated flows have caused spatial and temporal changes in stream flow and the nature of the stream bed.
- Indigenous fish were tolerant of great fluctuations in discharge, shifting sand substrate, high turbidity. Shovelnose sturgeon, chub species (*Platygobio* and *Macrhybopsis*), plains minnow, western silvery minnow, and river carpsucker are especially adapted to these conditions due to their tactile and chemical sensory systems.
- Large, sight-feeding piscivores were rare or absent, and gars and catfish were the main predators.
- Planktivores and visual predators replaced turbid river species after the mid-20th century.
- With reservoirs, the river substrate stabilized and enhanced benthos production, which increased plankton abundance, therefore Centrarchids (except green and orange-spotted sunfish) increased and buffalo, drum, flathead catfish, walleye extended their ranges.

Sanders et al. (1993) also give suggestions for enhancing the Kansas River, including a fish monitoring system, which KDWP implements, altering water rights to allow permanent flows in the western part of the basin, bank stabilization, and control of nonpoint pollution.

Moss and Brunson (1981) prepared the Kansas Stream and River Fishery Resource Evaluation to map relative values of stream fisheries to assist stakeholders and the public in assessing the impact of proposed water development projects on existing fishery resources. Using information on streams or reaches, the authors evaluated nearly all the larger streams in Kansas. To determine stream classifications for selected streams, six criteria were used to create an evaluation matrix to serve as a general guide. The evaluation factors were based on a scale of 1 to 5 with 1 being the best condition. Examples of a rating of 1 are included below. The criteria and overall emphasis were:

- Fishery characteristics—Fish species diversity, quantity, and types of gamefish (Rating 1—Excellent fishery: Sport fish available in sufficient numbers and size to satisfy demand. Good diversity of unique native species present.)
- Angling use—Types and amounts of utilization plus special runs of fish

(Rating 1—Intensive use area: Maintains high use throughout the year and may have regional to statewide importance and some interstate use.)

- Water quality—Concentrations of suspended sediments, pollution, extremes in chemical variables
  (Rating 1—Excellent water quality: Very high-water quality. No visible pollution. Clear, no noticeable silt load.)
- Stream uniqueness—Quality of surrounding setting coupled with amount of disturbance
  (Rating 1—Exceptionally unique area: Very pleasant attractive setting. Stream contains many special features. No disturbances or pollution present).
- Riparian association—Diversity and abundance of vegetation and wildlife
  (Rating 1—Very diverse riparian: At least three growth levels present: overstory, midstory, and understory. Excellent interspersion. Wildlife is diverse and abundant.)
- Habitat restoration, reclamation, or mitigation potential—Sensitivity of the area to disturbance
  (Rating 1—Intolerant area: Uniqueness of fishery is such that no restoration or mitigation is acceptable.)

These evaluations were used to place streams in one of four categories: (1) highest-valued fishery resource; (2) high-priority fishery resource; (3) moderate fishery resource; and (4) limited fishery resource. The range of possible total scores was 60 to 6 (in increments of 3) for the 6 classification criteria. Eight river and stream reaches were placed in the highest-valued fishery resource category with total scores from 60 to 51. Thirteen rivers and 54 stream reaches were placed in the high-priority fishery resource category with total scores from 48 to 33. 10 rivers and 89 stream reaches were placed in the moderate fishery resource category with total scores from 30 to15. One river (South Fork Saline River and four stream reaches (Antelope Creek, Dry Creek, Indian Creek, North Fork Sappa Creek) were placed in the limited fishery resource category with total scores from 12 to 6. The Kansas Stream and River Fishery Resource Evaluation prepared by Moss and Brunson (1981) contains the full list of rivers and streams evaluated and their rankings.

The Kansas SWAP (Rohweder 2015) describes ongoing conservation actions in the basin and includes land and water protection and management measures like encouraging conservation easements on high-quality habitats, promoting improved water quality standards, sound techniques for flood control, erosion control, nonpoint source pollution control, and bank stabilization. Actions include encouraging sand acquisition from off-channel sources, such as the Kansas River valley or reservoirs, to reduce impacts to the river channel, and promoting effective instream flow management through the development and implementation of ecologically appropriate flow regimes.

3.10.2.4.2 Reservoir Fisheries

As discussed previously, KDWP leases lands associated with federal reservoirs in the basin. The land is used for wildlife management and public hunting opportunities. These areas provide a variety of habitats for breeding, nesting, rearing, resting, stopover, and

cover for numerous wildlife species including game and non-game wildlife such as migratory and native waterfowl, mammals, amphibians, and reptiles. A wide variety of resident and migratory bird species utilize these lands and water for at least a portion of the year. A variety of aquatic and terrestrial species inhabit the lake and surrounding project land (Appendix E).

The fisheries division of KDWP manage fisheries in the federal reservoirs. Fisheries management activities include fish sampling, creel surveys, habitat work, aquatic vegetation enhancement, fish stocking, and special studies to monitor fish populations and improve fishing opportunities. A diverse community of fish inhabit the 18 reservoirs in the Kansas River Basin, including sport and non-sport fish species. Tables 3-151 and 3-152 show common sport and non-sport fish species that occur in the reservoirs.

Table 3-163. Common Sport Fish Species

Common Name	Scientific Name
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Black bullhead	*Ameiurus melas*
Blue catfish	*Ictalurus furcatus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Green sunfish	*Lepomis cyanellus*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieu*
Spotted bass	*Micropterus punctulatus*
Striped bass	*Morone saxatilis*
Walleye	*Sander vitreus*
White bass	*Morone chrysops*
White crappie	*Pomoxis annularis*
Wiper	*Morone saxatilis X M. chrysops*

Table 3-164. Common Non-Sport Fish Species

Common Name	Scientific Name
Bigmouth buffalo	*Ictiobus cyprinellus*
Central stoneroller	*Campostoma anomalum*
Common carp	*Cyprinus carpio*
Fathead minnow	*Pimephales promelas*
Gizzard shad	*Dorosoma cepedianum*
Golden shiner	*Notemigonus crysoleucas*
Orangespotted sunfish	*Lepomis humilus*
Log perch	*Percina caprodes*
Longnose gar	*Lepisosteus osseus*
Plains killifish	*Fundulus zebrinus*
Red shiner	*Cyprinella lutrensis*
River carpsucker	*Carpiodes carpio*
Sand shiner	*Notropis stramineus*
Suckermouth minnow	*Phenacobius mirabilis*
Western mosquitofish	*Gambusia affinis*

Seasonal timing of water level fluctuations is key for maintaining healthy fish populations. A spring rise in water levels gives cover for fish like white bass and crappie and assists in spawning. If the spring rise does not occur, fish spawning is hindered and a decrease in fish populations is noticed two to three years later. When water is released from the lake, fish take a couple of days to adjust to the new environment.

Timely water manipulation (water levels, inflow, and outflow) for fisheries management is important for the overall reproduction of fish in the reservoirs. Maintaining an adequate water level and having a rising pool during the spring spawning and egg incubation period are critical for maintaining the fisheries.

USACE NWK water managers and water quality staff have a long history of cooperative management of lake levels using the LLMP (https://www.kwo.ks.gov/docs/default-source/reservoirs/rpt_llmp_wy2023_092822.pdf?sfvrsn=c62c8e14_2) process with stakeholders (state agencies, marina and dock lessees, business owners, and recreational users). This process is the equivalent of agencies and user groups formalizing interest and suggestions for environmental actions that influence water management. Typical suggestions are lake level management for fisheries and waterfowl. Many of the reservoirs in the western region of the basin are utilized heavily for irrigation.

NWK implements a variety of practices through LLMPs that address water management for environmental outcomes:

- Tuttle Creek Reservoir: 1) Prioritize rise and maintenance of lake elevation in late fall through early winter over multipurpose pool to benefit waterfowl and shorebird migration and usage. 2) Initiate slight pool raise in spring to enhance boating access and to create and maintain good nursery and growth conditions

for fisheries, threatened and endangered terns, and plovers nesting downstream. 3) Reduce water level in mid-summer to allow for re-vegetation of areas that benefit waterfowl habitat.

- One of the main objectives of the LLMP at Tuttle Creek Lake is to increase recruitment of crappie in the lake. Coordination between state and federal agencies during moderate flood and drought events can minimize damage to the lake's shoreline habitat that is essential for crappie spawning success from uncontrolled events. Lowering of the lake level in the winter months allows additional storage for frequent spring rises in lake levels, which would require untimely releases, and to lessen the effect of these untimely releases on to allow for crappie spawning success.
- Wilson Reservoir: 1) Prioritize rise and maintenance of pool rise in fall to early winter to flood aquatic vegetation to enhance waterfowl habitat. 2) Initiate slight pool raise in the spring to enhance spawning for fisheries.
- Milford Reservoir: 1) Prioritize rise and maintenance of lake elevation in late fall through early winter to at least one foot over multipurpose pool to benefit wetlands and waterfowl habitat. 2) Maintain drawdown of lake elevation in late winter to control invasive species like zebra mussels and to benefit spawning areas for fisheries. 3) Control maintenance of water levels to create and maintain good spawning, nursery, and growth conditions for fisheries. 4) Manage revegetation and seeding of exposed areas in the summer.
- The Milford Lake LLMP considers the natural inflows of the lake for improvement of fisheries and wildlife habitat. One of the fisheries' functions is to control water releases in the early spring during fish spawning. The winter drawdown helps provide a cushion against having to release high outflows when the walleye are concentrated along the face of the dam and are susceptible to flushing from the lake. For wildlife purposes, maintaining the lake level 1.4 feet below multipurpose pool provides tremendous habitat. With normal fall inflows, the 1-foot rise provides tremendous benefits for wetlands, waterfowl, and hunting access.
- Clinton Reservoir: 1) Alternate yearly water level management plans to enhance conditions for migratory waterfowl and fisheries. 2) Initiate slight pool raise in the spring to benefit fish spawning and provide food and cover for littoral species. 3) Control maintenance of water levels to create and maintain good spawning, nursery, and growth conditions for fisheries. 4) Reduce water level in mid-summer to allow for re-vegetation of areas to benefit migratory waterfowl.
- Perry Reservoir: 1) Prioritize rise and maintenance of lake elevation in late fall through early winter over multipurpose pool to benefit waterfowl habitat. 2) Control maintenance of water levels to create and maintain good spawning, nursery, and growth conditions for fisheries.
- The Perry Lake LLMP considers the natural inflows of the lake to improve both fisheries and wildlife habitat. One of the fisheries' functions is to control water releases in the early spring during fish spawning. For wildlife purposes, the scheduled autumn rise in water level will flood marshy areas, improving waterfowl habitat and hunter access to the upper cove areas of the lake. Although there is enough inflow to achieve the fall rise in only about half the

14813 years, when it occurs, the two-foot rise provides tremendous benefits for
14814 wetlands, waterfowl, and hunting access.

14815 The USBR Nebraska-Kansas Area Office implements a variety of practices through lake
14816 level management plans that address water management for environmental outcomes:

14817 • Keith Sebelius Lake: 1) Store five percent of the flood pool whenever possible.
14818 • Keith Sebelius Lake provides multiple benefits including fish and wildlife benefits
14819 and flood control, irrigation, and recreation. Irrigation drawdowns and evaporative
14820 losses are typically more than inflows. Low-water levels benefit wildlife but have
14821 an adverse impact on the available fish habitats that currently exist in the
14822 reservoir. Holding water levels above conservation levels has reduced the impact
14823 of irrigation losses in the short term and increased productivity of the aquatic
14824 environment, thereby enhancing the fishery resource.
14825 • Lovewell Reservoir: 1) Prioritize rise and maintenance of pool rise in fall through
14826 early winter to flood aquatic vegetation to enhance waterfowl habitat and fish-
14827 rearing areas.
14828 • Spring elevations greater than two feet above the multipurpose pool damage the
14829 reservoir shoreline, park, wildlife area recreation facilities, and flood important
14830 wildlife habitat. When areas in the upper end of the reservoir have water in the
14831 fall, they provide excellent marshy areas, which are conducive to waterfowl
14832 retention and fishery rearing areas. When these areas are too dry or too wet,
14833 fisheries and wildlife resources are reduced.
14834 • Waconda Lake: 1) Maintain lake elevation in late fall through early winter at least
14835 one and a half foot over multipurpose pool to benefit waterfowl habitat; 2) Lower
14836 lake elevation late winter to allow for increasing pool levels in the spring to
14837 contain outflows while improving spawning conditions for fisheries. 3) Control
14838 maintenance of water levels to create and maintain good spawning, nursery, and
14839 growth conditions for fisheries; 4) Initiate slight pool raise in spring to enhance
14840 forage production and maintain nursery habitat; 5) Lower and maintain lake
14841 elevation mid to late-summer to initiate establishment and allow regrowth of
14842 terrestrial vegetation. 6) Initiate slight pool raise in fall to benefit waterfowl
14843 habitat.
14844 • Webster Reservoir: 1) Store five percent of the flood pool whenever possible.
14845 • Webster Reservoir provides multiple benefits including flood control, irrigation,
14846 and recreation. The reservoir has experienced a history of not recharging after
14847 irrigation drawdowns. Low water levels have an adverse impact on the available
14848 fish habitat that currently exists in the reservoir by erratic fluctuations, extreme
14849 drawdowns, and high content withdrawals associated with irrigation. While the
14850 chances of holding water levels above multipurpose pool are remote, it would
14851 reduce the impact of irrigation losses in the short term and increase productivity
14852 of the aquatic environment, thereby enhancing the fishery resource.

14853 Fisheries for reservoirs located in Kansas River Basin were examined in detail.
14854 Technical reports for each reservoir include discussions of fisheries establishment, sport
14855 and non-sport fish species occurrence, factors affecting the fishery, fisheries

management objectives, mitigation actions to minimize factors affecting the fishery, angler use, and sportfish population dynamics and trends. The following sections include summaries for each reservoir in Kansas and Harlan County Dam in Nebraska. Appendix E contains further information included in the technical reports.

Tuttle Creek Reservoir

Sedimentation can affect the natural resources in the lake. Suspended sediments carry nutrients and metals which accelerates eutrophication and limits fishery production for native and game-fish species. High turbidity from suspended sediments has impacts on the ability for sight feeding fish to adequately capture food. During periods of extended high turbidity, the fish sampling data records reduced abundance of forage fish species and lowered body condition of sportfish species.



The Big Blue River is home to a diverse riverine fish community and many of these fish species became permanent residents of Tuttle Creek Reservoir following completion of the dam. The reservoir has been stocked with additional sportfish species, with the intent to improve recreational fishery. The list of stocked fish includes blue catfish, channel catfish, largemouth bass, northern pike (*Esox Lucius*), paddlefish, saugeye (*Sander vitreus* X *S. canadensis*), striped bass, and walleye. The northern pike, striped bass, and walleye stockings occurred in the early years of the new impoundment and these species have been absent from the sampling recorded for over twenty years and are assumed to be extirpated. Fish species that occur at Tuttle Creek Reservoir include 11 sportfish like blue catfish, largemouth bass, and white bass and 14 non-sportfish species like freshwater drum, gizzard shad, and emerald shiner (*Notropos atherinoides*).

Factors that affect the fishery at Tuttle Creek Reservoir include general limnology, water quality like turbidity, water level fluctuations, sedimentation, and invasive or exotic species. Sustained high water events in the multipurpose pool in1973, 1993, and 2019 provided excellent habitat for YOY fish and allowed some species to have good year classes recruited into the fishery. However, release of high waters often leads to rapid

drawdowns in the multipurpose pool, which lead to loss of fish through the outflow of the dam. A common occurrence at Tuttle Creek Reservoir with substantial influence on sportfish abundance is high emigration rates out of the lake during periods of elevated release rates. No other factor reduces sportfish abundance so dramatically or so quickly. One of the best examples of this is the recorded impacts on a robust fishery from a release event in 2007.

Turbidity is a major factor affecting water quality. Sedimentation reduces the lifespan of coves for recreation, creates mudflats (exposed in low water periods), and limits production of desirable benthic organisms. Typically, 60 to 80 percent of suspended matter settles out as water moves from the upper end of the lake towards the dam.

The general objective of fisheries management at Tuttle Creek Dam reservoir is to optimize the quality and diversity of angling opportunities while also sustaining the resource into the future. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends (Appendix E), stocking fish to enhance population abundance as needed, constructing fish attractors to enhance angling opportunities, and other activities for maintaining and improving angling access.

Mitigation for factors affecting sport fishery includes fish sampling for long-term trend monitoring, fish harvest regulations, lake level management plans, and sportfish stockings. Fish harvest regulations require angler harvest to meet management objectives. KDWP makes fishery recommendations to USACE at Tuttle Creek Reservoir for the water level management plan. LLMP for Tuttle Creek Reservoir is described above. Fish stocking at Tuttle Creek Reservoir is either introductory stockings or maintenance stockings. Introductory stockings establish or reestablish a fish species in the reservoir with the belief that the species will sustain itself through natural reproduction. Maintenance stockings increase quantity of fish species for angler usage, particularly for species that have limitations on natural reproduction within the reservoir. Several species have been stocked over time, including blue catfish, channel catfish, paddlefish, wiper, rainbow trout, and saugeye. The plan for future stockings focuses on the perpetuation of saugeye maintenance stockings to sustain sport fishery. In addition, the continuation of paddlefish stockings will occur for evaluation of stocking survival and the potential for the species to produce a self-sustaining population capable of providing a recreational fishery. Channel catfish, rainbow trout, and wiper are stocked in the tailwaters below the dam to provide more diverse local fishing opportunities. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Milford Reservoir

Milford Reservoir is one the most popular fishing destinations in Kansas. Several species are sought after, which draws both in-state and out-of-state anglers. Fish species that occur at Milford Reservoir include 12 sportfish species like blue catfish, largemouth bass, and walleye and 9 non-sport fish species like common carp, goldeye, and shortnose gar.

Factors that affect the fishery at Milford Reservoir include general limnology, water quality (high nutrient loads, dissolved oxygen sags), water level fluctuations, sedimentation, presence and condition of vegetated fisheries habitat, invasive or exotic

species, and algal blooms. Milford Reservoir is listed as impaired by the KDHE and is classified as hypereutrophic due to excessive nutrients, specifically biologically available orthophosphate. Hypereutrophic conditions can lead to undesirable conditions for aquatic organisms and negatively affect the longevity and utility of the reservoir. To gather baseline nutrient and contamination data at standardized lake water quality sites, USACE NWK Water Quality Program began monitoring lake sediments in 2016. Sediment data from 2016 through 2017 yielded moderate to high nitrogen and phosphorus concentrations while total metals concentrations did not exceed the probable effect level established by the EPA. Water quality monitoring will continue as a critical part of a holistic, environmentally sound water quality management strategy so the project to continues to meet applicable federal and state environmental laws, criteria, and standards. Continued monitoring will provide valuable information regarding potential impacts to the Milford Reservoir fish community.

Milford Reservoir is a public water supply and has experienced elevation fluctuations. The reservoir has experienced drought conditions in the past, causing it to drop to elevations below multipurpose pool. Sustained high water events in the multipurpose pool in 1973, 1993, 2019 provide excellent habitat for YOY fish, which can support recruitment of strong year classes for some species. However, high water releases often lead to rapid drawdowns in the multipurpose pool, which can lead to loss of fish through the outflow of the dam.

The multipurpose pool at Milford Reservoir originally included 415,352 acre-feet of capacity. Approximately 11.8 percent of the multipurpose pool has been filled in with sediment, leaving approximately 366,476 acre-feet of capacity (based on 2009 survey results). The estimation is approximately 468 acre-feet of sediment accumulates on average, annually, in Milford Reservoir. Sediment will continue to accumulate in Milford Reservoir with an expected additional 2.5 percent loss of the multipurpose pool over the next 25 years (2049) and 4.0 percent loss over the next 50 years (2074) (Appendix D).

Aquatic vegetation establishment at Milford Reservoir is rare. However, under favorable conditions, water willow (*Justicia americana*) can become established. High water events can flood the water willow and provide refuge to fish and other aquatic organisms.

Within the last two decades, zebra mussels (*Dreissena polymorpha*) have been identified within Kansas waterbodies. They spread by moving off a contaminated boat to an uninfected waterway. They are transported by infected water that may be within bilge, livewells, or motor water intakes. Zebra mussels were first documented in Milford Reservoir on November 16, 2009.

The objective of fisheries management at Milford Reservoir is to create quality fishing opportunities for anglers. Milford Reservoir provides a variety of species for many angler groups. Fish populations are managed through setting length-limit and creel-limit regulations. Fish stockings supplement existing populations, deploy artificial habitat, conduct creel surveys of anglers, and monitor with sampling activities.

Figure 3-334. Artificial Habitat Efforts



Mitigation for factors affecting sport fishery include habitat improvements, fish harvest regulations, lake level management plans, and sportfish stockings. In more recent years, deployment of artificial habitat has occurred to increase fish habitat at various locations at Milford Reservoir. Georgia cubes, Fishiding structures, and cedar trees have been used in various depths to diversify habitat for several fish species. Fish harvest regulations require angler harvest to meet management objectives. KDWP makes fishery recommendations to USACE at Milford Reservoir for the water level management plan. LLMP for Milford Reservoir is described above. Stocking records at Milford Reservoir date back to 1967. Several species have been stocked over time including walleye, wipers, blue catfish, channel catfish, largemouth bass, smallmouth bass, and sauger. Currently, wipers and walleye are stocked on an annual basis. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species accounts and factors affecting their abundance and distribution.

Clinton Reservoir

Fish species that occur at Clinton Reservoir include 14 sportfish species like black crappie, blue catfish, and wiper and 13 non-sport fish species like creek chub, freshwater drum, and sand shiner. Factors that affect the fishery at Clinton Reservoir include general limnology, water quality, water level fluctuations, sedimentation, vegetated fishery habitats, and invasive and exotic species. Many limnological characteristics of Clinton Reservoir are resultant from its large watershed, large surface area (7000 acres), and relatively shallow depths (mean depth=17.0 feet, maximum depth=36.1 feet). The reservoirs large watershed contains a variety of land use practices including grasslands (61.7 percent), forest (14.9 percent), agriculture (12 percent), and urban (6.2 percent). Sedimentation can affect the natural resources in the lake. Suspended sediments carry nutrients and metals which accelerates eutrophication and can limit fishery production for native and game fish species. As the lake fills with sediments from upstream it reduces the water volume available to fish. In addition, the

sediment covers the habitat that many fish species use for foraging or spawning. Furthermore, the large mudflats created in the upper reaches of the lake serves as a disconnect between the lake and the upstream river system that some fish species use for annual migrations or spawning runs. High turbidity from suspended sediments also has impacts on the ability for sight feeders to be able to adequately capture food. During periods of extended high turbidity, the sampling data records lower abundance of forage species and lower body condition of sportfish.

The shrinking reservoir pool often leaves large areas within the basin dewatered for a number of years and allows establishment of terrestrial vegetation. Inundation of vegetation during periods of increased precipitation can increase habitat availability for sportfish. Substantial water level rises promote increased primary productivity resulting from the trophic upsurge associated with flooding of the dewatered reservoir basin. This and change in reservoir trophic status, results in a shift in sportfish species dominance. This translates into increased sportfish body condition and growth. Improved welfare of structure-oriented species occurs until habitat degradation (decomposition) or reduced water availability (receding levels) again limits production and recruitment of this sportfish assemblage. In contrast, primary productivity is reduced during years of declining reservoir levels due to a lack of nutrient input from the watershed above. When suitability or availability of flooded terrestrial vegetation declines, dominance of open-water sportfish increases.

In 2013, zebra mussels were detected in Clinton Reservoir. Zebra mussels are filter-feeders that consume plankton, which are important forage resources for larval fish and native mussels. High competition can result in poor reproductive success of sportfish populations.

The objective of fisheries management at Clinton Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

The sportfish community in Clinton Reservoir is routinely surveyed using a variety of different techniques for targeting specific species. Typically, all sportfish are measured for total length, weight, and total catch. These data are used to calculate relative abundance, size structure, body condition, and year class strength. These data are used to inform species specific management strategies (i.e., harvest regulations, stocking regime). In Kansas, as is the case in many other states, harvest of various sportfish species at waters open to public angling is regulated by length and creel limits. Other specific management activities include stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. Historically, several sportfish species have been stocked in Clinton Reservoir to maintain sportfish populations or create new angling opportunities. Maintenance stockings have occurred for Percids (walleye, sauger, saugeye), largemouth bass, and channel catfish. Introductory stockings have occurred for blue catfish and hybrid striped bass. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Perry Reservoir

There was an existing fishery in the Delaware River, but additional fish were stocked in the reservoir shortly after its completion in 1970. Those fish included bluegill, largemouth bass, and walleye. Over the next decade, additional walleye and largemouth bass were stocked, in addition to white bass, channel catfish, and flathead catfish. In the 1980's, the only fish stocked were largemouth bass and walleye. Walleye stockings on Perry Reservoir ended in 1984 due to high emigration. A decade later, sauger were experimentally stocked to fill the void left by walleye and have been stocked annually ever since. Annual maintenance stockings of largemouth bass began in 1998 and continued until 2007. The following year, smallmouth bass were introduced. Blue catfish were introduced in 2006 and stocked annually until 2012. The latest fish stocked into Perry Reservoir is the American paddlefish. These fish were first stocked into the reservoir in 2019 to re-establish historical populations that migrated up the Delaware River prior to impoundment. Fish species that occur at Perry Reservoir include 11 sportfish species like black crappie, largemouth bass, and sauger and 14 non-sport fish species like common carp, grass carp, and smallmouth buffalo.

Factors that affect the fishery at Perry Reservoir include general limnology, water quality (high nutrient loads, dissolved oxygen sags), water level fluctuations, sedimentation, vegetated fishery habitats, and invasive or exotic species. Stressors on the fishery at Perry reservoir come in many forms. The highest stressor is heavy angling pressure. With Perry reservoir's proximity to major metropolitan areas and the increasing use of social media, it is common to see full parking lots and shorelines when the fishing is at its best. No creel survey was conducted in 2020, but with observations of the amount of people fishing that spring, it is likely that any benefit of the lake being closed during the summer of 2019 was negated by increased harvest in spring of 2020. An additional stressor affecting fish populations is the absence of aquatic vegetation. Water levels that fluctuate with rains and the releases from the reservoir make the establishment and development of aquatic vegetation very difficult. Similarly, the degradation of fish habitat is an issue in Perry reservoir. Any woody habitat inundated when the reservoir was created is nearly gone and bathymetric features, such as channels and ledges, are being covered with sediment that washes in from above.

From 1969 to 2009, the multipurpose pool lost 43,216 acre-feet of storage to sedimentation. This represents 18 percent of the original multipurpose pool volume. Sedimentation causes loss of habitat for reservoir fisheries like coves, shorelines, and flats.

Vegetated fishery habitats in and adjacent to Perry reservoir consist of terrestrial, emergent, and submergent vegetation. After flooding, terrestrial vegetation provides temporary nutrient input, substrate for attachment of periphyton (a complex mixture of algae, cyanobacteria, microbes, and detritus) and other invertebrates, and physical habitat for juvenile and adult fish. Decomposition of flooded terrestrial vegetation degrades water quality in localized areas by decreasing dissolved oxygen causing hypoxia (dissolved oxygen concentrations too low to support fish and other aquatic species). There is almost no emergent or submergent aquatic vegetation in the areas surrounding Perry Reservoir due to the seasonal and yearly water level fluctuations that provide an inconsistent water level for these plants to become established.

Zebra mussels were first documented in Perry Reservoir in October 2007 and are still present. Other potential invasive or exotic species include silver carp, bighead, and black carp, white perch (*Morone americana*), rudd (*Scardinius erythrophthalmus*), and a myriad of crayfish and aquatic vegetation species.

The general objective of fisheries management at Perry Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends (see Appendix E), stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining and improving angling access. In an ideal scenario, water level management would play a more important role in population management. Following snowmelt and spring rains, the reservoir would fill, inundating shoreline terrestrial habitat and adjacent shallow areas. This newly created, flooded habitat would be ideal spawning and nursery habitat for a variety of fish species. The reservoir's water level would then slowly be drawn down over the course of the summer to allow sufficient time for fish to utilize the flooded areas and move off them before being left to dry or in isolated puddles. A slower release throughout the summer could also limit the loss of fish through emigration during releases. More consistent water level management patterns may also allow aquatic vegetation to take hold in the reservoir, further bolstering natural fish habitat. Appendix E contains specific objectives for the reservoir fisheries at Perry Reservoir.

Mitigation factors affecting sport fishery include fish harvest regulations and lake level management plans. Fish harvest regulations regulate angler harvest to meet management objectives. KDWP District Fisheries Biologists can implement special length and creel limits as needed, with proper justification, to regulate angler harvest and meet management objectives. Appendix E includes current special fish harvest regulations in effect at Perry Reservoir. KDWP makes fisheries recommendations to USACE at Perry Reservoir for the water level management plan. LLMP for Perry Reservoir is described above. The Perry Reservoir level management plan considers the natural inflows of the lake to improve both fisheries and wildlife habitat. KDWP periodically conducts creel surveys to quantify angling pressure, harvest patterns, and angler demographics. Due to its proximity to major metropolitan areas, the number of anglers visiting Perry Reservoir is high compared to other Kansas reservoirs. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Wilson Reservoir

Wilson Reservoir has tremendous sportfish populations including, but not limited to, channel catfish, largemouth and smallmouth bass, striped bass, and walleye. Wilson Reservoir is one of the few reservoirs in Kansas with successful introductions of striped bass, currently holding the state record. Striped bass do not reproduce in Kansas and must be continually stocked. Years of high water (2008 through 2012) provided successful recruitment of largemouth bass at the reservoir and has since been a popular destination for bass tournaments. Walleye is one of the most popular species at the reservoir. Although most Kansas reservoirs experience tenuous recruitment of walleye, due to poor spawning habitat, Wilson Reservoir walleye are often successful at reproducing due to the abundant spawning habitat at the reservoir. Blue catfish were

first stocked in Wilson Reservoir in 2006 and the population, although slow growing, appears to be on track to become a reasonable fishery.

Factors that affect the fishery at Wilson Reservoir include general limnology, water quality, water level fluctuations, sedimentation, shoreline erosion, vegetated fishery habitats, and invasive and exotic species. Stressors to the fish populations are a combination of some abiotic and biotic concerns seen in both eastern and western Kansas reservoirs. Wilson Reservoir has clear water and a low nutrient load compared to other reservoirs in the basin. Because of this, the reservoir has not experienced HABs, although colonies of blue-green algae occur occasionally.

Drought conditions have had dramatic impacts on sport fisheries, especially from 2012 to 2016. Since 2012, reservoir elevations have lowered to a record low of nearly 10.5 feet below multipurpose pool in 2016. Common reed grass (*Phragmites australis*) has become ubiquitous along the shorelines and provides reasonable fishery habitats otherwise lacking from this reservoir. However, common reed grass can preclude bank fishing and other recreation in some areas. When lake levels are low there is a lack of aquatic vegetation and structure near the shoreline used for spawning and escape habitat, which results in some species seeing a great reduction in their populations.

Gizzard shad is the primary forage species at Wilson Reservoir but the low productivity in terms of nutrients results in inconsistent recruitment of the species. ANS have altered food webs in the reservoir, but their direct consumption of fish eggs creates recruitment issues for sport fish. White perch have negatively affected walleye and other sport fish, especially inhibiting natural recruitment.

Overall sedimentation is not as concerning here as in other reservoirs due to low inflows and a lower proportion of agricultural land in the watershed. However, shoreline erosion and deposition of silt have become an increasing concern at Wilson Reservoir. This is the most critical stressor to fish populations as shorelines erode and leave littoral areas unvegetated. Shallow, silty littoral habitat fills interstitial spaces in rock and woody cover and leaves most areas unsuitable for fish spawning, nursery habitat, and protective cover. The last shoreline rock armoring on USACE-managed areas was in 1992. Much of the pre-existing armor between elevations 1,516.0 mean sea level (msl) and 1,519.0 msl are broke down and expose vulnerable soils to erosion. The wave and wind erosion from the 2019 flood caused significant loss of soil. Some areas of the KDWP State Park in Hell Creek eroded back into the campsite utilities and exposed water and electric lines.

Fishery management activities include fish sampling, creel surveys, habitat work, aquatic vegetation enhancement, fish stocking, and special studies to monitor fish populations and improve fishing opportunities. A fishery habitat improvement plan has been established and each year fish habitat of natural (trees) and synthetic structures (Georgia Cubes) (Figure 3-334) are placed in a variety of spots around the reservoir to provide cover.

Mitigation factors affecting sport fishery include riprap installation in areas of critical shoreline habitat, standard and supplemental fish sampling to monitor sportfish trends, fish harvest regulations, and sportfish stockings. Riprap was added to shorelines and edges of boat ramp slabs to reduce erosion and undermining by wave action. To

combat this erosion, riprap was installed in the water to reduce wave action on the exposed shoreline, thus providing habitat to the fishery.

Standard fish population sampling is employed on an annual basis and is conducted using standardized methods approved by KDWP Fisheries staff. To develop baseline trend data by which Kansas fisheries are managed, population sampling is applied at Wilson Reservoir and other Kansas waters. Supplemental fish population sampling is conducted at the discretion of the KDWP District Fisheries Biologist to address specific management questions and challenges. Supplemental sampling consists of accepted or experimental methods and often focuses on finer detail resolution fish population parameters. Fish harvest regulations require angler harvests to meet management objectives. KDWP District Fisheries Biologists implement special length and creel limits as needed, with proper justification, to further regulate angler harvest to meet management objectives. Appendix E includes current special fish harvest regulations in effect at Wilson Reservoir.

KDWP makes fishery recommendations to USACE at Wilson Reservoir for the water level management plan. LLMP for Wilson Reservoir is described above. If suitable habitat is present most species are capable of sufficient natural reproduction and recruitment to maintain fishable populations, therefore, stocking is employed on a limited basis at Wilson Reservoir. In the past four creel surveys, walleye and striped bass have ranked in the top four species preferred by anglers at Wilson Reservoir. Largemouth bass ranked high during the last two surveys. Due to the rise in lake levels creating excellent habitat and an abundant bass population, and since the last survey, the number of anglers targeting bass has increased. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Kanopolis Reservoir

Kanopolis Reservoir, a productive system in terms of total phosphorous and associated phytoplankton growth, has abundant sportfish populations including channel catfish, crappie (*Pomoxis annularis*), saugeye, wipers, and white bass. Unfortunately, the reservoir has struggled to provide an adequate largemouth or smallmouth bass fishery. Smallmouth bass have historically been stocked but water quality conditions precluded their establishment. Walleye were stocked commonly over the years and a few still occur but, due to low water retention rates (high flow through), saugeye have been more successful. Fish species that occur at Kanopolis Reservoir include 12 sportfish species and 9 non-sport fish species like central stoneroller, fathead minnow, and plains killifish [*Fundulus zebrinus*]).

Factors affecting the fishery at Kanopolis Reservoir include general limnology, water quality (high nutrient loads, dissolved oxygen sags), water level fluctuations, sedimentation, high flow through, presence and condition of vegetated fisheries habitat, invasive or exotic species, and algal blooms. Water inflows carrying sediments and nutrients have decreased water quality at the reservoir, but it has transitioned into a eutrophic classification as it has aged. Eutrophic lakes are very fertile and have fast fish growth.

Kanopolis Reservoir is a public water supply and has experienced elevation fluctuations, although not to the extent as far western Kansas reservoirs like Cedar Bluff and Webster reservoirs. Normal summer elevation is 1,467.5 feet, four feet above multipurpose pool. After wet years in the mid-1990s, dry years occurred during the mid-2000s. The reservoir experienced drought-like conditions between 2012 and 2013, causing it to drop to an elevation of nearly 1,457.0 feet, 6 feet below multipurpose pool. Boat ramps were unusable for part of 2013. In July 2019 the reservoir rose approximately 33 feet above multipurpose pool, the highest elevation since the 1993 flood and the third highest since the reservoir was impounded. This sustained high-water event provided excellent habitat for YOY fish and several species to had good year classes recruited to the fishery. However, one problem associated with the release of flood waters is the quick nature of the drawdown. These quick drawdowns lead to a decrease in saugeye catch rates in the following years and it is assumed many were lost through the outflow of the dam.

Approximately 36 percent of the multipurpose pool at Kanopolis Reservoir has filled in with sediment leaving approximately 47,170 acre-feet of capacity. It is estimated, on average, that 374 acre-feet of sediment accumulates annually in Kanopolis Reservoir. Sediment will continue to accumulate in Kanopolis Reservoir with an expected additional 18.8 percent loss of the multipurpose pool over the next 25 years (2049) and 29.4 percent loss over the next 50 years (2074) (Appendix D). Sedimentation is the most critical stressor to fish populations as shorelines erode and leave littoral areas unvegetated. Shallow, silty littoral habitat fills in interstitial spaces in rock and woody cover and leaves most areas unsuitable for fish spawning, nursery habitat, and protective cover. Addition of woody habitat has mitigated this loss of habitat but is limited by manpower and budget constraints. The most impactful stressors to the fisheries are high flows through the dam and sedimentation. High flows through the dam cause fish entrainment through the dam that is mostly uncontrollable in years with high inflow. Fish stockings are necessary to resupply the reservoir with sport fish. Walleye typically experience entrainment at high rates, so fisheries staff stock saugeye instead. Saugeye are entrained from the reservoir at lower rates than walleye, but some are still lost during extreme flow through events like the 2019 flood. Due to the age, amount of sediment in the reservoir, and four-foot draw down in the winter, there is limited aquatic vegetation present in Kanopolis Reservoir. This lack of vegetation, along with the lack of structure in the littoral zone, has led to problems establishing some sportfish species in the reservoir, like black bass. Large winter draw down will hamper future vegetation establishment projects, which will lead to most vegetation being exposed and out of the water during winter months.

Zebra mussels, an ANS, were established in Kanopolis Reservoir in 2011 and have since become weakly established throughout the lower portion of the reservoir. There are also Chinese mystery snails (*Bellamya chinensis*) below the reservoir in Sand Creek (referred to as the Kanopolis Seep Stream). No studies have investigated their degree of invasiveness in Kansas. They remain scarce and have had minimal effects.

The objective of fishery management at Kanopolis Reservoir is to create quality fishing opportunities for anglers. Fishery management activities include fish sampling, creel

surveys, habitat work, aquatic vegetation enhancement, fish stocking, and special studies to monitor fish populations and improve fishing opportunities.

Mitigation factors affecting sport fishery include riprap installation in areas of critical shoreline infrastructure, fish sampling to monitor trends, fish harvest regulations, and sportfish stockings. With Kanopolis Reservoir being the oldest reservoir in the state, and with the subsequent sedimentation issues, there is a lack of structure and vegetation. Riprap installed around boat ramps and other erosion areas provide habitat and escape cover to the fishery. These areas also attract anglers. To develop baseline trend data by which Kansas fisheries are managed, standard fish population sampling occurs on an annual basis and is conducted using standardized methods approved by KDWP fishery staff and applied at Kanopolis Reservoir and other Kansas waters. Fish harvest regulations require angler harvest meets management objectives. Saugeye and wiper are stocked biennially at Kanopolis Reservoir to maintain the population. They are stocked more frequently if certain population characteristics are not met. Blue catfish were stocked annually from 2008 to 2015 at a rate of one per acre, and periodically since, at a rate of 10 per acre. Since the change to 10 per acre, blue catfish have established in the reservoir. Largemouth bass were stocked from 2016 to 2020 with some success, but the high water and subsequent releases from the reservoir seem to have depleted those early stockings from the reservoir. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Harlan County Reservoir

Modern fish stocking since the 1980’s has consisted mostly of channel catfish, walleye, and wipers. Crappie, largemouth bass, northern pike, and tiger muskie are occasionally stocked in conjunction with high water elevations. An experimental stocking of rainbow trout in the stilling basin was attempted in the winter months of 2013 and 2014 but was discontinued due to problems with unknown winter release amounts and predation from cormorants.

With the Republican River and other streams as the water source, many fish species have access to Harlan County Reservoir. The current fish population in Harlan County Reservoir consists of a mixture of species stocked by NGPC and species from the watershed. Fish species that occur at Harlan County Reservoir include 12 sportfish species including black crappie, channel catfish, and northern pike and 6 non-sport fish species like common carp, orangespotted sunfish, and river carpsucker.

Factors that affect the fishery at Harlan County Reservoir include general limnology, water quality (high nutrient loads, dissolved oxygen sags), water level fluctuations, sedimentation, vegetated fisheries habitat, and invasive or exotic species. Blue-green algae blooms occur on occasion and the lake has been on the toxic algae advisory list several times in the past 20 years. The NEDEE conduct weekly algae and bacteria samples during the main recreation season and are responsible for public notices and sign postings.

Inflows to Harlan County Reservoir are dependent on the Republican River and several smaller streams. Water levels fluctuate when irrigation releases occur, typically from May to September. The average annual elevation change is about 7.9 feet and has

ranged from 1 foot to 16 feet since 1959. Winter releases are often coordinated with NGPC, selecting gate releases and amounts to minimize fish loss from the reservoir and fish-stranding downstream. With wide fluctuating water levels associated with drought periods and contrasting high inflows, reservoir waters levels have varied over time. Some fish species temporarily benefit from water level patterns experienced at Harlan County Reservoir. When years of drought and low reservoir water levels precipitate high inflows and high reservoir water levels, shoreline-oriented species such as largemouth bass and crappie benefit from an abundance of flooded shoreline terrestrial vegetation. During high-water conditions, emergent and submergent vegetation is abundant in the reservoir. Otherwise, wind and wave conditions keep most shorelines void of aquatic vegetation growth.

Documented aquatic invasive species at Harlan County Reservoir include common reed, salt cedar (*Tamarix spp.*), common carp, and spiny water flea (*Daphnia lumholtzi*). Although zebra mussels are commonly found in nearby Kansas reservoirs, they have not been detected at Harlan County Reservoir despite annual monitoring efforts for zebra and quagga mussels (*Dreissena rostriformis bugensis*) that began in 2010.

Current fishery management activities include fish stocking, fishery surveys, fishing regulations, angler access improvements, aquatic habitat restoration, and outdoor education. Standard fish population surveys, angler surveys, and research projects provide the main source of information to manage the fishery at Harlan County Reservoir. These efforts provide information about the fish populations, angler dynamics, and fishery interactions, which helps formulate fish stocking recommendations, fishing regulations, access developments, and education efforts. Standard fish population surveys have been completed since 1973, and annually since 1989. To facilitate long-term comparisons of fish populations, standard sampling locations have been utilized since the early 1990s. Since 2001, summary reports of fish population survey information occur annually. These reports are provided to the public via the NGPC website. Priority management species for the Harlan County Reservoir sport fishery, determined by population histories and angler preferences, are walleye, white bass, and channel catfish. Wipers are a species with trophy potential and a low-density population goal. When the reservoir is at higher elevations, crappie, largemouth bass, and northern pike are typically included in sport fishery management details. Creel surveys at Harlan County Reservoir started in 1988 and occurred either annually or every other year through 2017.

Figure 3-335. Example of Cove Habitat Showing Sedimentation at Harlan County Reservoir



Keith Sebelius Lake

Northern pike were stocked into Keith Sebelius Reservoir in 1973 and 1976 and are extinct. Fish species that occur at Keith Sebelius Reservoir include 13 sportfish species including black bullhead, largemouth bass, and wiper and 11 non-sport fish species like central stoneroller, fathead minnow, and western mosquitofish.

Factors that affect the fishery at Keith Sebelius Reservoir include general limnology, water quality (high nutrient loads), water level fluctuations, presence and condition of vegetated fishery habitats, and sedimentation. Irrigation is a main part of Keith Sebelius Reservoir. 0Typically, the reservoir is drawn down between three to four feet annually. Once releases cease, the reservoir usually gains one to two feet of water back over the winter, depending on rain events and if Prairie Dog Creek is flowing. It is common for the reservoir to be 15 to 20 feet below multipurpose pool and has been down 30 feet several times since construction. Characteristic of, but not limited to, Keith Sebelius Reservoir, the commonly shrinking reservoir pool often leaves large areas within the basin dewatered for several years, allowing establishment of terrestrial vegetation. When inundation of this vegetation occurs during periods of increased precipitation, habitat availability for sportfish increases. Substantial water level rises promote increased primary productivity resulting from the trophic upsurge associated with flooding of the dewatered reservoir basin. This, and change in reservoir trophic status, result in shifting sportfish species dominance. This translates into increased sportfish body condition and growth. Improved welfare of structure-oriented species occurs until

habitat degradation (decomposition), or reduced water availability (receding levels) again limit production and recruitment of the sportfish assemblage. In contrast, due to a lack of nutrient input from the watershed above, primary productivity reduction occurs during years of declining reservoir levels When suitability or availability of flooded terrestrial vegetation declines, dominance of open-water sportfish increases.

Sedimentation is very minor at Keith Sebelius Reservoir but approximately 45 acre-feet of sediment annually accumulates, on average. Sediment will continue to accumulate in Keith Sebelius Reservoir with an expected additional 6.1 percent loss of the multipurpose pool over the next 25 years (2049) and 9.2 percent loss over the next 50 years (2074) (Appendix D).

Vegetated fisheries habitats occurring in and adjacent to Keith Sebelius Reservoir consist of terrestrial, emergent, and submergent vegetation. After flooding, terrestrial vegetation provides temporary nutrient input, substrate for attachment of periphyton (a complex mixture of algae, cyanobacteria, microbes, and detritus) and other invertebrates, and physical habitat for juvenile and adult fish. Flooded emergent aquatic vegetation provides nutrient input, substrate for periphyton and other invertebrates, and physical habitat for juvenile and adult fish. Presence of all submerged aquatic vegetation species diversify littoral zone habitats within the reservoir and effectively act as escape habitat for young fish and foraging habitat for adult fish. Submerged aquatic beds create shade, thus lowering water temperatures immediately below the bed, providing a thermal refuge during summer. Submerged aquatic macrophyte beds provide fish concealment from avian predators. Currently, there are no invasive species in Keith Sebelius Reservoir. However, limited areas of Phragmites are starting to encroach into the reservoir.

The general objective of fisheries management at Keith Sebelius Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining and improving angling access. Appendix E includes additional information related to the specific objectives for Keith Sebelius Reservoir fishery management.

Mitigation factors affecting sport fishery include fish harvest regulations. Fish harvest regulations require angler harvest to meet management objectives. Currently, walleye and saugeye have special fish harvest regulations of an 18-inch minimum length at Keith Sebelius Reservoir. KDWP District Fisheries Biologists have special length and creel limits to implement as needed, with proper justification, to further regulate angler harvest to meet management objectives. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

Lovewell Reservoir

Most of the extant sportfish species that currently inhabit Lovewell reservoir were stocked within the first few years of post-impoundment. Anglers first captured northern pike in 1974 but the only stocking records are from 1978 and 1979. This species was last sampled in 1985 and is no longer known to occur at Lovewell reservoir. Other

species, including shorthead redhorse and striped bass, have been sampled in the past but are no longer found in the reservoir. An angler captured the state-record shovelnose sturgeon in Lovewell reservoir in 1999 but few are ever sampled. In addition, anglers occasionally catch rainbow trout in the reservoir, as these fish can immigrate from upstream sources in Nebraska. Fish species that occur at Lovewell reservoir include 11 sportfish species including bluegill, largemouth bass, and white crappie and 19 non-sport fish species like emerald shiner, golden shiner, and river carpsucker.

Factors that affect the fishery at Lovewell reservoir include general limnology, water quality (high nutrient loads), water level fluctuations, presence and condition of vegetated fishery habitats, invasive or exotic species, and sedimentation. Lovewell reservoir possesses adequate water quality to promote sportfish survival. Because water can be diverted from the Republican River, Lovewell reservoir does not experience long-term drought conditions like other reservoirs in the area. The annual irrigation protocol allows water level manipulation as needed, with the level slowly allowed to rise from the end of the irrigation season through spring. Occasionally, water levels lower below normal (4 feet to 6 feet below top of multipurpose pool) for maintenance work around the outlet like dredging of accumulated silt material. During flood events, water levels have reached over seven feet above the top of the multipurpose pool four times. Water levels play a crucial role in fish production and angler participation. Vegetated fishery habitats occurring in, and adjacent to, Lovewell reservoir consist of terrestrial, emergent, and submergent vegetation.

Herbaceous to woody terrestrial vegetation common to the area colonizes the reservoir basin during years of low reservoir pool elevation. After flooding, terrestrial vegetation provides temporary nutrient input, substrate for attachment of periphyton (a complex mixture of algae, cyanobacteria, microbes, and detritus) and other invertebrates, and physical habitat for juvenile and adult fish. Flooded emergent aquatic vegetation provides nutrient input, substrate for periphyton and other invertebrates, and physical habitat for juvenile and adult fish. Decomposition of emergent vegetation residual causes hypoxia (dissolved oxygen concentrations too low to support fish and other aquatic species) in areas of dense stands of vegetation during the summer. Submergent aquatic vegetation can establish beds in the littoral zone of the reservoir but like most species in Lovewell reservoir it remains limited due to the annual water level fluctuation cycle. Regardless of native status, presence of all submerged aquatic vegetation species diversify littoral zone habitats within the reservoir and effectively act as escape habitat for young fish and foraging habitat for adult fish. Submerged aquatic vegetation beds create shade, thus lowering water temperatures immediately below the bed providing a thermal refuge to fish during summer. Submerged aquatic macrophyte beds provide fish concealment from avian predators. Several invasive plant species occur at Lovewell reservoir but have not negatively impacted the fisheries due to limited establishment to date.

Sedimentation is very minor at Lovewell reservoir but approximately 31 acre-feet of sediment accumulates on average annually in Lovewell reservoir. Sediment will continue to accumulate in Lovewell reservoir with an expected additional 2.2 percent loss of the multipurpose pool over the next 25 years (2049) and 4.1 percent loss over the next 50 years (2074) (Appendix D).

The general objective of fishery management at Lovewell reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities conducted include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construct fish attractors to enhance angler success, and maintain/improve angling access.

Mitigation for factors affecting the sport fishery include reallocation of pool storage, riprap installation in areas of critical shoreline infrastructure, standard and supplemental fish sampling to monitor sportfish trends, fish harvest regulations, and sportfish stockings. KDWP has requested that the irrigation district and USBR maintain, when possible, a flow of 20 cfs into Lovewell reservoir when the Courtland Canal is in operation and the multipurpose pool is below capacity. This recommended inflow provides excellent fishing around the canal inlet to the reservoir. Riprap has been added to several locations across the reservoir to reduce shoreline erosion which has been a significant problem and accelerated reservoir aging. These riprap areas also provide excellent fishery habitats, especially for largemouth bass, flathead catfish, bluegill, and crappie. Standard fish population sampling is employed on an annual basis and uses standardized methods approved by KDWP fisheries staff and applied at Lovewell reservoir and other Kansas waters to develop baseline trend data by which Kansas fisheries are managed. Fish harvest regulations regulate angler harvest to meet management objectives. KDWP District Fisheries Biologists have special length and creel limits at their disposal to implement, with proper justification, to further regulate angler harvest to meet management objectives. The stocking of fry, fingerling, and intermediate-sized walleye will continue annually to boost recruitment and supplement the limited natural reproduction which occurs. Blue catfish were stocked for five years but are now set to expand with natural reproduction and will not be stocked again. Wiper fry and fingerlings are stocked annually to maintain these low-density populations. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species accounts and factors affecting their abundance and distribution.

Waconda Lake

Fish species that occur at Waconda Lake include 15 sportfish species (e.g., black crappie, white bass, and walleye) and 14 non-sport fish species (e.g., fathead minnow, red shiner [*Cyprinella lutrensis*], and log perch [*Percina caprodes*]).

Factors that affect the fishery at Waconda Lake include general limnology/water quality (e.g., turbidity), water level fluctuations, sedimentation, presence and condition of vegetated fisheries habitat, and invasive/exotic species. Waconda Lake possesses adequate water quality to promote sportfish survival. Specific conductivity and total dissolved solids are normally high and become extremely concentrated as the reservoir volume decreases. Waconda Lake turbidity falls within the ideal range for Kansas reservoirs.

The Waconda Lake watershed is very large and rarely has a shortage of water able to maintain a relatively constant water level. Two reservoirs are located upstream of Waconda Lake, Webster Reservoir on the South Fork Solomon River, and Kirwin Reservoir on the North Fork Solomon River. These also function as water control and

irrigation storage impoundments for the surrounding area. Water levels are normally within 3 feet of the top of the multipurpose pool elevation of 1,455.6 feet, whether high during heavy rainfall events or low during drought conditions. Most droughts cause the reservoir level to decrease to 1,451.0 or to 1,452.0, just 4 feet to 5 feet low, but a significant drought through the 2000s caused the reservoir to reach a record low of 1,446.2 feet on December 19, 2006. Since that drought, water levels remain near top of multipurpose pool with releases most years due to excess amounts of inflow. Water levels play a crucial role in fish production and angler participation. This also has a direct effect on state park visitation and the economy surrounding the reservoir.

Approximately 9.3 percent of the multipurpose pool at Waconda Lake filled in with sediment leaving approximately 219,420 acre-feet of capacity. It is estimated that approximately 670 acre-feet of sediment accumulates on average annually in Waconda Lake. Sediment will continue to accumulate in Waconda Lake with an expected additional 13.4 percent loss of the multipurpose pool over the next 25 years (2049) and 20.4 percent loss over the next 50 years (2074) (Appendix D). Many sportfish such as walleye, white bass, black bass and Centrarchid sportfish prefer to deposit eggs on clean, larger-grain substrates to avoid suffocation of eggs by silt. Thus, availability and diversity of rock substrate is important to successful reproduction of these and other fish species, including those that occur at Waconda Lake. Silt deposited in the reservoir from sedimentation can reduce the diversity of rock substrate in the reservoir affecting reproduction of fish species that rely on this habitat.

Vegetated fishery habitats at Waconda Lake include terrestrial, emergent, and submergent vegetation. Terrestrial vegetation and flooded emergent vegetation provide temporary nutrient input, substrate for attachment of periphyton and other invertebrates, and physical habitat for juvenile and adult fish. Submergent vegetation provides rearing habitat for young fish and foraging areas for adult fish. Submerged aquatic vegetation beds also create shade, thus lowering water temperature immediately below the beds, providing thermal refuge to fish during the summer and provide concealment from avian predators.

Invasive and exotic species such as common reed have only encroached areas of the reservoir in somewhat limited areas due to the water level stability. Common reed is most abundant on the upper end of the reservoir in the river channels and in the back end of some of the major coves. Due to its limited expansion this exotic species has not harmed the reservoir ecosystem of Waconda Lake to the extent observed in other impoundments. Zebra mussels were first discovered in Waconda Lake during August 2013, and it was apparent by that fall the population was well established as adult mussels were encountered during October fish sampling activities throughout the reservoir.

The general objective of fishery management at Waconda Lake is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends (Appendix E), stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

Mitigation for factors affecting the sport fishery include past reallocation of pool storage, riprap installation in areas of critical shoreline infrastructure, fish and biotic/abiotic sampling to monitor trends, fish harvest regulations, and sportfish stockings. Reallocation of pool storage resulted in a more stable reservoir pool elevation and stabilization of habitat availability for fish populations. Riprap has been added to several locations across the reservoir to reduce shoreline erosion which has been a significant problem and accelerated reservoir aging. These riprap areas also provide excellent fishery habitats, especially for smallmouth bass, spotted bass, bluegill, and crappie. Standard fish population sampling is employed on an annual basis and uses standardized methods approved by KDWP fisheries staff and applied at Waconda Lake and other Kansas waters to develop baseline trend data by which Kansas fisheries are managed. Fish harvest regulations regulate anger harvest to meet management objectives. Stocking is an important walleye management activity in many Kansas waters. Considering the difficulty to maintain and spawn captive broodstock, and the propensity of sexually mature walleye to concentrate in discrete spawning areas, gametes are harvested from wild broodstock for culture purposes from several Kansas impoundments each spring. The Waconda Lake walleye population was one of the primary sources to collect and fertilize walleye eggs between 1988 and 2003, often contributing 40 percent or more to the total statewide annual quota. Consequently, optimizing walleye broodfish abundance and welfare has been a management priority at Waconda Lake. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species accounts and factors affecting their abundance and distribution.

Cedar Bluff Reservoir

Fish species that occur at Cedar Bluff reservoir include 13 sportfish species (e.g., black crappie, largemouth bass, and walleye) and 13 non-sport fish species (e.g., fathead minnow, red shiner [*Cyprinella lutrensis*], and orangespotted sunfish).

Factors that affect the fishery at Cedar Bluff Reservoir include general limnology/water quality (e.g., turbidity), water level fluctuations, sedimentation, presence and condition of vegetated fisheries habitat, and invasive/exotic species. Cedar Bluff Reservoir possesses adequate water quality to promote sportfish survival. Degraded water quality occurs in localized areas as residual vegetation decomposes causing hypoxia (dissolved oxygen concentrations too low to support fish and other aquatic species) mostly during warm water periods and during decreases in reservoir lake elevations.

Groundwater mining in the Ogallala Aquifer has led to decreased flow in the Smoky Hill River basin. This reduced flow in the Smoky Hill River has resulted in a widely fluctuating reservoir pool with a net water decline occurring in most years. Timing and duration of water level decline is variable and depends upon precipitation and thus inflow patterns but is most rapid during summer and fall. However, cyclic periods of increased precipitation occur every 20 to 30 years, resulting in localized flooding, increasing reservoir pool elevation. The commonly shrinking reservoir pool often leaves large areas within the reservoir dewatered for several years and allows establishment of terrestrial vegetation. Inundation of vegetation during periods of increased precipitation can increase habitat availability for sportfish. In contrast, sportfish productivity reduces during years of declining reservoirs levels due to a lack of nutrient input from the

watershed above. Poorly timed releases can impact sportfish reproduction and retention of adult sportfish in the reservoir. For example, during 2013 water was released from Cedar Bluff reservoir from March 4 through 18. This timeframe corresponds to the early portion of the walleye spawn. Walleye typically concentrate near the dam to deposit fertilized eggs on riprap on the dam face. Proximity of spawning adults and hatching fry to the dam toe drain entrained individuals of both life stages, flushing them from the reservoir.

Sediment surveys show that sedimentation is occurring at Cedar Bluff reservoir. Many sportfish such as walleye, white bass, black bass and Centrarchid sportfish prefer to deposit eggs on clean, larger-grain substrates to avoid suffocation of eggs by silt. Thus, availability and diversity of rock substrate is important to successful reproduction of these and other fish species, including those that occur at Cedar Bluff reservoir. Silt deposited in the reservoir from sedimentation can reduce the diversity of rock substrate in the reservoir affecting reproduction of fish species that rely on this habitat.

Vegetated fishery habitats at Cedar Bluff reservoir include terrestrial, emergent, and submergent vegetation. Terrestrial vegetation and flooded emergent vegetation provide temporary nutrient input, substrate for attachment of periphyton and other invertebrates, and physical habitat for juvenile and adult fish. Submergent vegetation provides rearing habitat for young fish and foraging areas for adult fish. Submerged aquatic vegetation beds also create shade, thus lowering water temperature immediately below the beds, providing thermal refuge to fish during the summer and provide concealment from avian predators.

Invasive and exotic species such as common reed have encroached areas of the reservoirs forming large, monocultural stands and reduced distribution and abundance of other terrestrial and emergent aquatic vegetation. This shift in vegetation species assemblage has altered the complexity and diversity of fish habitat available upon inundation.

The general objective of fishery management at Cedar Bluff Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends (see Appendix E), stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

Mitigation for factors affecting the sport fishery include past reallocation of pool storage (1995), riprap installation in areas of critical shoreline infrastructure, fish and biotic/abiotic sampling to monitor trends, fish harvest regulations, and sportfish stockings. Reallocation of pool storage in 1995 resulted in a more stable reservoir pool elevation and stabilization of habitat availability for fish populations. Riprap installation added to shoreline edges to reduce erosion also diversified fish habitat. Standard fish population sampling is employed on an annual basis and uses standardized methods approved by KDWP Fisheries staff and applied at Cedar Bluff Reservoir and other Kansas waters to develop baseline trend data by which Kansas fisheries are managed. Fish harvest regulations regulate angler harvest to meet management objectives. Stocking has been employed on a limited basis at Cedar Bluff Reservoir as most

15635 species are capable of sufficient natural reproduction and recruitment to maintain
15636 fishable populations provided suitable habitat is present. However, for some sportfish
15637 species (e.g., walleye) stocking is an important management activity to maintain the
15638 reservoir population. Appendix E contains further details related to these mitigation
15639 actions and information about reservoir sportfish species accounts and factors affecting
15640 their abundance and distribution.

15641 **Webster Lake**

15642 Striped Bass were stocked into Webster reservoir in 1974 and 1976. They were last
15643 sampled in 1990 and a mounted striped bass hangs in the Webster office that was
15644 caught in 1977. No other striped bass have been documented since 1997. Also, anglers
15645 caught the occasional rainbow trout in the reservoir because they were stocked in the
15646 South Fork Solomon River during the winter months in the mid to late 2000s. No
15647 rainbow trout have been stocked in the river since 2010. Fish species that occur at
15648 Webster reservoir include 13 sportfish species (e.g., bluegill, flathead catfish [*Pylodictis*
15649 *olivaris*], and walleye) and 13 non-sport fish species (e.g., central stoneroller, creek
15650 chub [*Semotilus atromaculatus*], and red shiner [*Cyprinella lutrensis*]).

15651 Factors that affect the fishery at Webster reservoir include general limnology/water
15652 quality (e.g., high nutrient loads), water level fluctuations, presence and condition of
15653 vegetated fishery habitats, invasive/exotic species, and sedimentation. Irrigation is a
15654 main part of Webster reservoir with releases typically starting in middle June through
15655 late August. Typically, the South Fork Solomon River does not flow enough water to
15656 keep up with irrigation. The reservoir is usually drawn down between three to five feet
15657 annually. Once releases cease, the reservoir will typically gain one to two feet of water
15658 back over the winter, depending on rain events and if the South Fork Solomon is
15659 flowing. It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool,
15660 and it has reached below 30 feet twice (in 1972 and 1992) since construction. At this
15661 height, achieving multipurpose pool level requires a significant rain event or series of
15662 events. Characteristic of (but not limited to) Webster reservoir, the commonly shrinking
15663 reservoir pool often leaves large areas within the basin dewatered for several years and
15664 allows establishment of terrestrial vegetation. When inundation of this vegetation occurs
15665 during periods of increased precipitation habitat availability for sportfish can increase.
15666 Substantial water level rises promote increased primary productivity resulting from the
15667 trophic upsurge associated with flooding of the dewatered reservoir basin. This and
15668 change in reservoir trophic status, results in a shift in sportfish species dominance. This
15669 translates into increased sportfish body condition and growth. Improved welfare of
15670 structure-oriented species occurs until habitat degradation (decomposition), or reduced
15671 water availability (receding levels) again limits production and recruitment of the
15672 sportfish assemblage. In contrast, primary productivity reduces during years of declining
15673 reservoir levels due to a lack of nutrient input from the watershed above. When
15674 suitability or availability of flooded terrestrial vegetation declines, dominance of open-
15675 water sportfish increases.

15676 Sedimentation is very minor at Webster reservoir but approximately 32 acre-feet of
15677 sediment accumulates on average annually in Webster Reservoir. Sediment will
15678 continue to accumulate in Webster Reservoir with an expected additional 2.2 percent
15679 loss of the multipurpose pool over the next 25 years (2049) and 3.3 percent loss over

the next 50 years (2074) (Appendix D). Vegetated fisheries habitats occurring in and adjacent to Webster reservoir consists of terrestrial and emergent vegetation. These vegetation types and their habitat value for reservoir fisheries are like those mentioned for other reservoirs. One invasive plant species occurs at Webster reservoir (e.g., Phragmites) but has not negatively impacted the fisheries to date.

The general objective of fishery management at Webster reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends (Appendix E), stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

Mitigation for factors affecting the sport fishery include fish harvest regulations. Fish harvest regulations regulate angler harvest to meet management objectives. KDWP District Fisheries Biologists have special length and creel limits at their disposal to implement, with proper justification, to further regulate angler harvest to meet management objectives. Currently, Webster reservoir does not have any special fish harvest regulations in effect and are following all state regulated harvest requirements.

Appendix E includes reservoir sportfish species accounts and factors affecting their abundance and distribution.

Kirwin Lake

The Kirwin NWR was established in 1954 as an overlay project on the irrigation and flood control reservoir. U.S. Fish and Wildlife refuge staff manage all activities on the reservoir and its surrounding lands, apart from irrigation and flood control. The primary purpose of the Kirwin NWR is to provide nesting cover, food and shelter for songbirds, waterfowl, upland game birds, and mammals. Fish species that occur at Kirwin reservoir include 11 sportfish species (e.g., black crappie, largemouth bass, and channel catfish [*Ictalurus punctatus*]) and 13 non-sport fish species (e.g., common carp, creek chub [*Semotilus atromaculatus*], and sand shiner [*Notropis stramineus*]).

Factors that affect the fishery at Kirwin reservoir include general limnology/water quality (e.g., turbidity), water level fluctuations, sedimentation, presence and condition of vegetated fisheries habitat, and invasive/exotic species. Irrigation is a main part of Kirwin reservoir. Irrigation releases from Kirwin reservoir typically start in middle June and do not cease until late August. Typically, the North Fork Solomon River and Bow Creek do not flow enough water to keep up with irrigation releases. The reservoir is usually drawn down between three to five feet annually. Once releases cease the reservoir will typically gain one to two feet of water back over the winter, depending on rain events, and if the North Fork Solomon and Bow Creek are flowing. It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool, and it has been below 30 feet more than once since construction. At that height, achieving the multipurpose pool level requires a significant rain event or series of events.

Characteristic of, but not limited to Kirwin reservoir, the commonly shrinking reservoir pool often leaves large areas within the basin dewatered for several years and allows establishment of terrestrial vegetation. When inundation of this vegetation occurs during

periods of increased precipitation, habitat availability for sportfish can increase. Substantial water level rises promote increased primary productivity resulting from the trophic upsurge associated with flooding of the dewatered reservoir basin. This and change in reservoir trophic status, results in a shift in sportfish species dominance. This translates into increased sportfish body condition and growth. Improved welfare of structure-oriented species occurs until habitat degradation (decomposition), or reduced water availability (receding levels) again limits production and recruitment of this sportfish assemblage. In contrast, primary productivity reduces during years of declining reservoir levels due to a lack of nutrient input from the watershed above. When suitability or availability of flooded terrestrial vegetation declines, dominance of open-water sportfish increases.

Approximately 1.3 percent of the multipurpose pool at Kirwin reservoir filled in with sediment leaving approximately 98,154 acre-feet of capacity. Sediment will continue to accumulate in Kirwin reservoir with an expected additional 1.7 percent loss of the multipurpose pool over the next 25 years (2049) and 2.4 percent loss over the next 50 years (2074) (Appendix D).

Currently there are no invasive species in Kirwin reservoir. However, limited areas of Phragmites are starting to encroach into the reservoir. Quite a few of the draws leading into the reservoir are now being taken over by phragmites and the species will keep working its way into the reservoir.

The general objective of fisheries management at Kirwin reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

Mitigation for factors affecting the sport fishery include fish harvest regulations. Fish harvest regulations regulate anger harvest to meet management objectives. Currently, Kirwin reservoir does not have any special fish harvest regulations in effect and are following all state regulated harvest requirements. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species accounts and factors affecting their abundance and distribution.

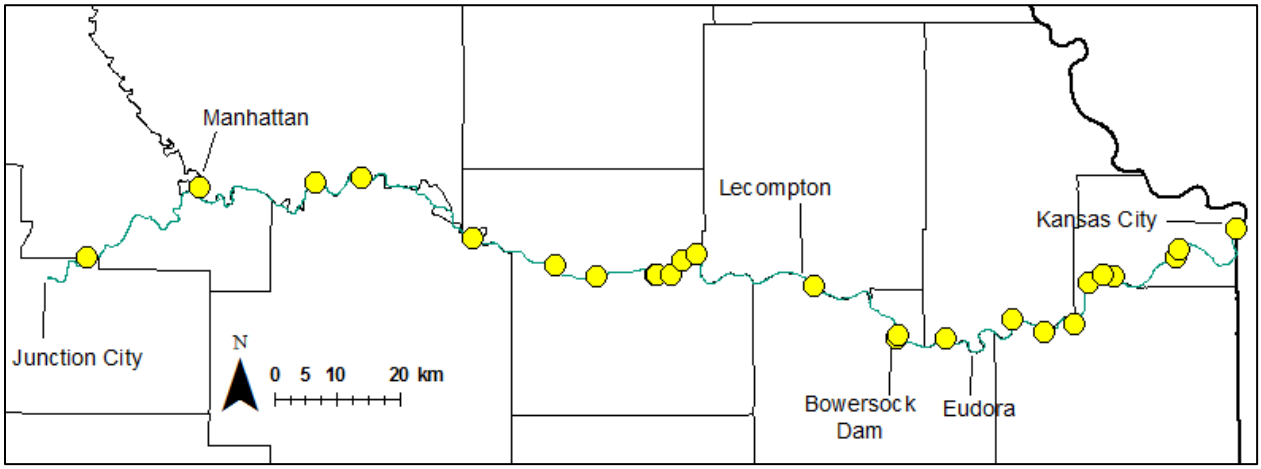
3.10.2.4.3 Mussels

The Kansas River historically supported a diverse assemblage of native freshwater mussels (https://gpnc.org/wp-content/uploads/sites/32/2017/12/KSMussels.pdf). During the urban, industrial, and agricultural development periods, native freshwater mussels experienced a rapid decline in species richness. Today, freshwater mussels are the most threatened fauna on the Kansas River. Of the 48 species historically found in Kansas, 6 are extirpated, 1 lacks reproductively viable populations (i.e., faces imminent extirpation), 38 have suffered evident range reductions or a widespread thinning of former populations), and 23 are designated as threatened, endangered, or SINC (Angelo et al. 2009). Angelo et al. 2009 provides a list of these species along with a thorough literature review and examination of decline in Kansas.

Cringan et al. 2020 provides information on the occurrence and distribution of freshwater mussels in the Kansas River. The study examines major changes occurring in the mussel community over the past 150 years and identifies key natural and anthropogenic factors contributing to these changes. The study also discusses opportunities and challenges relating to the protection and restoration of mussel populations in the Kansas River and its watershed. Cringan et al. 2020 obtained data from available governmental databases, museum shell collections, and published and unpublished studies to determine the occurrences and distributions of individual mussel species in the Kansas River basin. Based on the earliest records (1883 through 1906), the basin once supported at least 32 mussel species with 24 reported historically from the Kansas River.

This report also looked at occurrence of mussel species in the Kansas River by compiling two datasets obtained from KDHE: a dataset of 2009 to 2010 surveys, and a dataset of pre-1990 through 2007 surveys (with collection dates specified as pre- or post-1990). The resulting dataset was reviewed for only Kansas River specimens. The review resulted in 25 Kansas River sites containing 212 records of 25 species found pre-1990 to 2010 (Figure 3-336, Table 3-153).

Figure 3-336. Mussel Data Sites on the Kansas River



Notes: Collected pre1990, 1990-2007, and 2009-2010

15786 *Table 3-165. Presence of Mussels in Kansas River Surveys*

Scientific Name	Common Name	Status[2] (State Listing/ Watershed/ Kansas River)	Pre-1990	1990-2007	2009-2010
Actinonaias ligamentina	mucket	E/x/x	p	-	-
Amblema plicata	threeridge	NA/D/x	p	-	-
Anodontoides ferrusacianus	cylindrical papershell	E/x/x	p	-	-
Corbicula fluminea	Asian clam	I	p	p	p
Cyclonaias pustulosa	pimpleback	NA/D/D	p	p	
Dreissena polymorpha	zebra mussel	I	-	-	p
Fusconaia flava	Wabash pigtoe	NA/D/x	-	p	-
Lampsilis cardium	Plain pocketbook	NA/x/x	p	-	-
Lampsilis siliquoidea	fatmucket	S/D/x	p	p	-
Lampsilis teres	yellow sandshell	S/D/x	p	p	p
Lasmigona complanata	white heelsplitter	NA/D/st?	-	p	-
Leptodea fragilis	fragile papershell	NA/st/st	p	p	p
Ligumia recta	black sandshell	NA/x/x	P	-	-
Ligumia subrostrata	pondmussel	NA/D/x	-	p	p
Megalonaias nervosa	washboard	S/x/x	p	-	-
Obliquaria reflexa	threehorn wartyback	NA/x/x	-	p	-
Obovaria olivaria	hickorynut	NA/X/x/x	p	p	-
Potamilus alatus	pink heelsplitter	NA/D/D	-	p	p
Potamilus ohiensis	pink papershell	NA/st/st	-	p	p
Pyganodon grandis	giant floater	NA/D/st?	-	p	-
Quadrula	Mapleleaf	NA/D/D	-	p	p
Strophitus undulatus	creeper	NA/D/x	p	-	-
Truncilla donaciformis	fawnsfoot	S/D/D	p	p	-
Truncilla truncata	deertoe	S/x/x	p	p	-
Uniomerus tetralasmus	pondhorn	NA/D/D	-	p	-

15787 Notes:
15788 p=presence
15789 Status—D=declining, E=endangered, X=extirpated in Kansas, x=extirpated from watershed or the Kansas River, T=threatened,
15790 S=species in need of conservation concern, st=stable
15791 Angelo et al. 1990; Cringan et al. 2020.

15792 Historical records suggest that 14 freshwater mussel species (Table 3-153) were
15793 extirpated from the Kansas River between 30 to 140 years ago (Cringan et al. 2020).
15794 The hickorynut is now extirpated in Kansas, while in the Kansas/Lower Republican
15795 River basin the plain pocketbook (*Lampsilis cardium*) became eliminated and the

fatmucket became sparsely scattered (Angelo et al. 2009). None were found on the Kansas River in 2009 or 2010. Today, the Kansas River basin supports only 18 mussel species, showing a 44 percent decline in taxa richness. Declines range from 33 to 52 percent in some component watersheds, including the Big Blue, Republican, Smoky Hill, and Wakarusa river basins. Mos-t extant species (pimpleback [*Cyclonaias pustulosa*], creeper [*Strophitus undulatus*], fawnsfoot [*Truncilla donaciformis*], and pondhorn [*Uniomerus tetralasmus*], have seen dramatic reductions in distribution and are now found only in a few isolated, widely scattered habitats. The Kansas River currently supports only nine species, representing a 56 percent decline in taxa richness. Most extant species include a few widely scattered, adult individuals, and populations exhibit little evidence of recent recruitment. Since the turn of the 20th century, dominant mussel species in the Kansas River have changed from three long-lived, slowing maturing species (hickorynut [*Obovaria olivaria*], fatmucket [*Lampsilis siliquodea*], yellow sandshell [*L. teres*]) to two short-lived, rapidly maturing species (fragile papershell [*Leptodea fragilis*], pink papershell [*Potamilus ohiensis*]) (Cringan et al. 2020).

The two introduced species listed in Table 3-153 do not require a host fish for larvae development. The Asian clam (*Corbicula fluminea*) does well in a variety of substrates, flows, and water quality. By 1983 it was well-established in Perry Reservoir and in the Kansas River was found in two locations downstream of Bowersock Dam (Mackie and Huggins 1983). Zebra mussels were found in Perry Lake in 2007 and in the Kansas River by 2009 (KDHE 2010).

Freshwater mussels are sedentary, spending their entire juvenile and adult lives in the same general location, making them unusually sensitive to local changes in water and sediment quality and physical habitat conditions (Cringan et al. 2020). Angelo et al. (1990) cite alterations in stream flows due to impoundments as a contributor to the decline of mussels. Prolonged reservoir discharges into late summer and fall create higher flows than those to which the mussels are adapted and that are important for mussel reproduction. We can see this in the hydrograph at day 270 (October) where post-impoundment flows become and remain higher than pre-impoundment flows. These prolonged discharges often destabilize the downstream benthic substrate, displacing juvenile mussels, hampering interactions between gravid mussels and host fishes, and in some cases eliminating entire mussel assemblages (Cringan et al. 2020 [in draft]). Rapid reductions in reservoir release rates can also strand large numbers of mussels on exposed shorelines and sand and gravel bars (Cringan et al. 2020).

Also, mussels rely on fish as hosts for the glochidia stage of their reproductive cycle (see Cringan et al. 2020 for a list of potential biological hosts for each mussel species), therefore modification of Kansas River flows to improve fish populations and removal of impediments to migration of fish will also benefit mussels. Cringan et al. 2020 cite several interacting factors that have contributed to observed declines in mussel species richness. The major factors are (1) stream siltation and other forms of water and sediment pollution, and (2) changes in physical habitat resulting from the construction of dams, channelization of streams, dredging of sand and gravel, removal of riparian vegetation, and draining of wetlands. Other contributing factors include stream

dewatering, declines in host fish abundance, commercial mussel harvests, and the infiltration of nonindigenous aquatic species.

Some reservoirs in the Kansas River basin (e.g., Tuttle Creek Lake) support mussel communities on at least a transient basis. These species are the most commonly occurring mussel species in the Kansas River and are habitat generalists. Mussel species in reservoirs have become stranded given the often-variable fluctuations in reservoir water levels and reservoirs may also be too unstable to sustain viable mussel populations (as cited in Cringan et al. 2020). The long-term viability of reservoir mussel populations has received limited investigation to date.

Cringan et al. cite the following measures that would benefit mussel recovery efforts in the Kansas River Basin that could be considered by the Kansas River SRP:

- Changes in the seasonal operation of existing flood control dams – Gradual attenuation of high reservoir release rates. Streamflow in the Kansas River is dominated at times by releases from reservoirs, and the rapid attenuation of these releases can strand mussels on exposed sand and gravel bars. Stranding often results in lethal heat stress and heavy predation, and severe or repeated stranding events can jeopardize entire mussel communities (Freske 2001; Obermeyer 2001; Vaughn and Taylor 1999 as cited in Cringan et al. 2020). To minimize stranding-related mortality, reservoir releases should be attenuated over at least a one to two-week period, particularly during the summer and early fall when daytime air temperatures commonly exceed 90 °F (32°C). This precaution is especially important when streamflow falls below the level needed to inundate most sand and gravel bars. In the Kansas River, this level corresponds to about 5,000 cfs (Cringan et al. 2020).

Cringan et al. cite additional measures that are outside of the scope of SRP that would benefit mussel recovery in the basin including:

- Enactment of a moratorium on new dam construction.
- Removal/circumvention of artificial barriers to fish migration.
- Translocation of stranded mussels following reservoir drawdowns.
- Transition to pit mine and quarry-based sources of sand and gravel.
- Moratorium on stream channelization projects.
- Performance of field and laboratory studies.
- Adoption/implementation of protective water quality standards.
- Transition to less polluting farming practices.
- Restoration of riparian areas and riverine wetlands.
- Prohibition on commercial mussel harvests.
- Restrictions on the importation/release of nonindigenous species.
- Development of mussel sanctuaries and mussel restocking programs.
- Transition to dryland crop production.
- Participation in global climate change initiative.

3.10.2.4.4 Other Aquatic Species

Plankton and Benthic Organisms

Phytoplankton is the primary producer in most aquatic ecosystems and represents the first link in the aquatic food chain. Few studies of Kansas River plankton communities have been conducted and much of the available data are old. Powers (1969) listed 225 species of phytoplankton for the Kansas River system, including all its tributaries. In general, the plankton community in the Kansas River is highly variable and is influenced by seasonal climatic changes and discharges from the reservoirs located along tributaries that convey water within the lower Kansas River basin. Large rivers are not suitable to support many zooplankton species or high population densities as they require slow or still water to feed and reproduce and therefore species composition and densities are expected to be low.

Benthic organisms live on or in the bottom of aquatic ecosystems. A major limiting factor for benthic organisms in the Kansas River is the pronounced shifting of the sandy substrate found throughout the river. The continuous shifting of the bed limits the ability of benthic organisms to colonize on or in the substrate.

Species of Greatest Conservation Need

Kansas SGCN must meet at least one or more of the following criteria:

- Native species listed as Candidate under the ESA.
- Native species classified as Kansas threatened, endangered, or SINC.
- Native species assigned a global conservation status rank of G1, G2, or G3 by NatureServe.
- Native species identified as conservation priority through a wide range status assessment, or assessment of large taxonomic divisions; or which has significant conservation implication or has major conservation contribution to the state; or are indicative of a diversity and health of the state's wildlife.
- Native species that are regionally endemic.

The Kansas SWAP (Rohweder 2015) Appendix 2 has a list of SGCN at https://ksoutdoors.com/Services/Kansas-SWAP. KDWP prioritizes SGCN species into two categories. Tier 1 includes species listed as threatened or endangered at the federal or state level, or with global conservation status rank of G1 or G2. All remaining SGCN are assigned to Tier 2 (Rohweder 2015). There are 285 species classified as SGCN, with 63 classified as Tier 1, and 222 classified as Tier 2. Section 3.10.4 Federally and State Listed Special Status Species discusses species that are in Tier 1 listed as threatened or endangered at the federal or state level. Tier 1 species not listed as threatened or endangered at the federal or state level include two amphibians, five insects, three isopods, and one planarian (see Rohweder 2015 Appendix 2). Tier 2 species include 5 amphibians, 82 birds, 11 crustaceans, 53 fish, 1 gastropod, 18 insects, 1 isopod, 16 mammals, 17 mussels, and 18 reptiles (see Rohweder 2015 Appendix 2). Thirteen habitats were identified in the Kansas SWAP (Rohweder 2015) as priority for the survival and health of the SGCN (i.e., shortgrass prairie, mixed prairie,

tallgrass prairie, sand prairie, sandsage shrubland, herbaceous wetlands, playas, seeps and springs, deciduous floodplain, eastern large rivers, eastern streams/small rivers, aquatic areas [lentic and lotic], and riparian shrubland).

3.10.3 Terrestrial Habitat and Wildlife

Historically, vegetation across the Kansas River Basin was mostly comprised of prairie in the west transitioning to a combination of tallgrass prairie and oak hickory woodland in the east. The basin is broadly divided into three groups/regions based on dominant species and height of vegetation: shortgrass prairie (western region), mixed grass prairie (central region), and tallgrass prairie (eastern region). The shortgrass prairie/western region occurs in the western portion of the basin and the tallgrass prairie/eastern region in the eastern third of Kansas. The mixed grass prairie/central region occurs in the central portion of Kansas and is a zone of transition from tallgrass prairie species in the east to shortgrass prairie species in the west.

Terrestrial habitats include wetlands, forests, woodlands, grasslands, and shrublands. Riparian woodland or forested wetland, scrub-shrub wetland, and forests provide habitat for species that require early, successional woody habitat (like the prairie warbler [*Dendroica discolor]*), cavities for nesting (barred owl [*Strix varia*]), standing snags (herons and egrets [*Ardea* and *Egretta* spp.]), and berry, seed, and mast-food sources (bur oak [*Quercus macrocarpa*]). Woody debris is an important habitat that provides cover, nursery, and basking areas for the life of many species. Many species on the floodplain also require woody debris for various life-history stages like shelter and reproduction. The variable canopy structure and understory diversity within these habitats provide a variety of different environmental conditions and food sources specific to individuals and species. These habitats provide nesting, denning, roosting, basking, breeding, shelter, and foraging areas for many wildlife species. Upland grassland habitats provide for the needs of assemblages, including grazing and browsing species. Deer [*Odocoileus* spp.], grassland birds (common yellowthroat [*Geothlypis trichas*]), rodents, snakes, and insects (otoe skipper [*Hesperia ottoe*]) require short, mid, and tall grass prairie vegetation for breeding, nesting, and foraging.

KDWP leases land in the basin associated with reservoirs. The land is used for wildlife management and public hunting opportunities. These lands provide a variety of habitats for breeding, nesting, rearing, resting, stopover, and cover for numerous wildlife species, including game and non-game wildlife such as migratory and native waterfowl, mammals, amphibians, and reptiles. A wide variety of native and migratory bird species utilize these lands and water during the year.

The Kansas River floodplain and the floodplains of its tributaries are important resources that convey large stormwater events and provide high-quality wildlife habitat. The floodplain of the Kansas River is defined as a riverine floodplain, which is comprised of the floodway and the flood fringe. The floodway encompasses the channel and a portion of the adjacent floodplain area necessary to convey floodwaters. The flood fringe is land located outside the floodway that is at or below the base flood elevation and stores but does not effectively convey floodwaters.

Much of the floodplain (74 percent) in the basin is covered by agricultural lands and grasslands, with 6 percent water coverage, and 7 percent woodlands (Table 3-154)

(Gergely et al. 2019). Some of the larger tracts of woodlands are in the eastern half of the floodplain in the bluffs bordering the Kansas River and along some of the river's small tributaries. Woodlands generally have less coverage west of Topeka, Kansas, and are confined to many small drainages and creek valleys branching off the Kansas River and its larger tributaries. In the Fort Riley area northeast of Junction City, Kansas, and north of the Kansas River, the larger tributary valleys are filled with woodlands; however, on privately-owned land south of the river, tributary valleys are mostly cropland. Although few large woodland tracts can be found, a discontinuous riparian forest grows along the entire length of the Kansas River.

Available evidence (https://www.fws.gov/initiative/pollinators/threats) indicates that certain pollinator species have been declining in the United States and can be traced to a multitude of causes, such as intensive agricultural practices, use of certain pesticides, and habitat loss and degradation. Some pollinator species such as bumblebees and honeybees have experienced declines as a result of the spread of pathogens and disease from commercially produced colonies to native populations. Flower-visiting insects account for 50 percent of all known insect extinctions. Reduced pollinator populations can result in decreased pollination of plant species that require pollinators for reproduction. As a result, the plant corresponding to each pollinator could face population declines or even increased threat of extinction. Climate change is also expected to provide additional challenges to pollinator populations, ranging from disruption of migratory paths of pollinators such as hummingbirds and bats, to decoupling of plant-pollinator interactions when plants and pollinators respond differently to climate cues.

Terrestrial habitats were identified from the Kansas Gap Land Cover Map (Gergely et al. 2019), which uses an alliance-level vegetation classification system based on the National Vegetation Classification system. For the purpose of this watershed study, terrestrial habitat types were generalized to reflect the terminology used by conservation practitioners in the state (Table 3-154 and Figure 3-337).

15994 *Table 3-166. Acres of Terrestrial Habitat in the Kansas River Basin by Region*

Habitat Type	Western Region		Central Region		Eastern Region	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
Sand Grassland and Shrubland	1,406,966	14	994,094	5	851	<1
Tallgrass Prairie	2,009	<1	952,448	4	823,661	19
Mixed Prairie	79,655	1	3,832,989	17	40,069	1
Shortgrass Prairie	1,777,058	18	1,787,667	8	<1	<1
Deciduous Forest	17,027	<1	164,884	1	414,395	9
Floodplain Forest	17,427	<1	387,233	2	148,225	3
Evergreen	2,085	<1	17,233	<1	0	0
Herbaceous Wetland/Riparian Shrubland	11,063	<1	16,867	<1	7,293	<1
CRP/Introduced Grass/Weedy Upland	262,713	2	1,502,421	7	1,610,778	36
Cropland	6,545,565	65	12,187,737	56	1,405,564	32
Totals	10,121,568	100	21,843,573	100	4,450,836	100

Source: Gergely et al. 2019

15995 As in Section 3.10.2 Aquatic Habitat and Species, the discussion for terrestrial wildlife
15996 and wildlife habitat is divided into three distinct regions: Western, Central, and Eastern.

15997 ### 3.10.3.1 Western Region

15998 In the western region of the basin (Figure 3-337) dominant grasses are typically of short
15999 stature and have large extensive root systems enabling the plants to better tolerate long
16000 periods of unfavorable conditions. Trees are scarce and desert-type plants, such as
16001 cactus and yucca, are common. The native plants in this area are adapted to stresses
16002 such as drought, grazing, and fire. Cottonwood (*Populus deltoides*) and willow (*Salix*
16003 spp.) are dominant in the west, where they can establish themselves quickly in the river
16004 bottoms and often experience flooding. Moving further westward, the trees begin to hug
16005 waterways, and continuous stands and trees eventually disappear in the western
16006 portion of the basin.

16007 Shortgrass prairie, herbaceous wetlands and playas, and riparian corridor habitats
16008 (deciduous floodplain, aquatic–lotic and lentic, and riparian shrubland), and mixed
16009 prairie occur in the western region. Herbaceous wetlands and playas habitat
16010 descriptions are included in the Aquatic Habitat and Species section.

16011 The Shortgrass Prairie Conservation Region (Rohweder 2015) is in the western region
16012 of Kansas. Habitats associated with water resources in this region, and important for
16013 conservation of biodiversity, include herbaceous wetlands, playas, and riparian corridor
16014 habitats like the deciduous floodplain, lotic and lentic aquatic habitat, and riparian
16015 shrubland. Herbaceous wetland habitats include grass, forb playa lakes, low or wet
16016 prairie, freshwater marsh, and bulrush marsh. Playa lakes are the predominant
16017 herbaceous wetlands of the region and are an important water source for prairie wildlife.
16018 Playa lakes serve as stopover locations for migrating waterfowl and shorebirds.

Riparian corridor habitats are important edge habitats and connect travel corridors between fragmented habitats. The Smoky Hill River floodplain and its surrounding upland habitat provide valuable refuge for wildlife in the region. Shortgrass prairie species include dominant short grass species like buffalo grass (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*). These species are dominant on well-drained soils or rocky slopes and are highly resistant to drought. Associations of blue grama/hairy grama (*Bouteloua hirsuta*) occur on loamy or sandy soils, and blue grama/buffalo grass/western wheatgrass (*Pascopyrom smithii*) on clay soils. While grasses are often dominant in this region, vegetative composition also includes a robust forb component such as heath aster (*Symphyotrichum ericoides*), Engelmann daisy (*Englemannia peristenia*), slimflower scurfpea (*Psoralidium tenuiflorum*), and yarrow (*Achillea millefolium*), along with legumes like milkvetches (*Astragalus* spp.) and locoweeds (*Oxytropis* spp.). Much of the original shortgrass prairie has been converted to crop production.

Rivers are mostly ephemeral in nature and due to the lowering of the water table and surface and ground water withdrawal for irrigation, suffer from decline. Bank destabilization and associated re-stabilization methods negatively affect riparian corridors. Overuse or misapplication of pesticides and fertilizers also contribute to water quality degradation from runoff. Conservation issues identified in the northwestern portion of the basin, the area associated with the South Fork Republican River, includes impacts to riparian habitats due to farming near stream channels and intense livestock grazing, resulting in erosion, sedimentation, and nutrient issues.

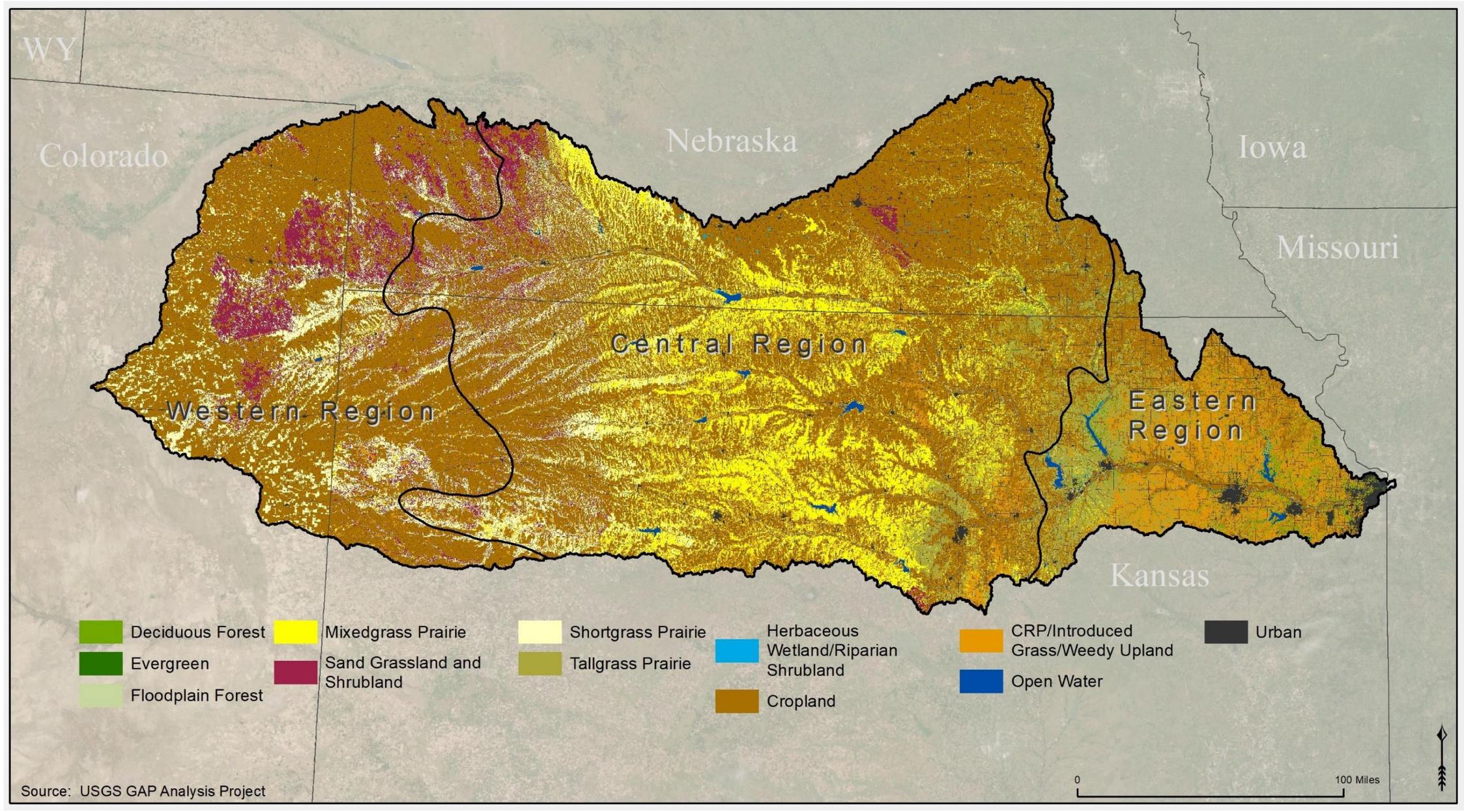
Riparian corridor complex habitats include deciduous floodplain habitats, lotic surface water habitat, lentic surface water habitat, and riparian shrubland. These vegetation communities are important edge habitat and allow for connection of travel corridors between fragmented habitats. The deciduous floodplains are temporarily flooded habitats. Dominant tree species include pecan (*Carya illinoinensis*), bur oak (*Quercus macrocarpa*), green ash, American elm (*Ulmus americana*), eastern cottonwood, sugar maple (*Acer saccharum*), river birch (*Betula nigra*), and hackberry (*Celtis occidentalis*). Aside from the major rivers, surface water (lotic and lentic) in this western portion of the basin is mostly ephemeral in nature due to their dependence on precipitation or snowmelt. Surface water also suffers from decline due to the lowering of the water table and surface and groundwater withdrawal from irrigation. Riparian shrublands occur along rivers, streams, and other surface waters, and are characterized by dominant vegetation types such as willows, indigo bush (*Amorpha* spp.), and the non-native salt cedar (*Tamarix* spp.). Deciduous floodplains and riparian shrublands in the area depend upon flows that are for the most part intermittent.

Approximately 67 percent of the western region is non-native vegetation types (i.e., cropland and CRP/Introduced Grass/Weedy Uplands). CRP are lands that typically were under cultivation and were converted to planting of grasses and forbs suitable to the region that provide cover to control soil erosion, improve water quality and develop wildlife habitat.

Ongoing conservation actions for this region are described in the Kansas SWAP (Rohweder 2015) and include the use of greenways, corridors, buffer strips, drought management plans, playa restoration, and incentive programs for landowners and

managers to promote heterogeneity and diversity of wildlife while maintaining viable farming and ranching operations. Two incentives are to cover crops and defer or limit herbicide applications. Other conservation actions are promotion of sound techniques for flood control, erosion control, non-point source pollution control, and bank stabilization.

16069 *Figure 3-337. Terrestrial Habitat in the Kansas River Basin*
16070 333



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3.10.3.2 Central Region

The central region (Figure 3-337) is a transition area between the western region and the eastern region of the basin. Terrestrial habitats are predominantly mixed grass prairie composed of short-grass, mid-grass, and tall-grass species. Floodplains and rivers and streams fragment prairie habitats in the central region.

Approximately 63 percent of the central region is non-native vegetation types (i.e., cropland and CRP/introduced grass/weedy uplands).

Mixed prairie, sand prairie, herbaceous wetland, aquatic (lotic) areas, seeps and springs, and eastern large river systems occur in the central region of the basin (Figure 3-330). This is a transition area between the western and eastern regions. Herbaceous wetlands, aquatic (lotic) areas, seeps, springs, and eastern large river systems are described in the Aquatic Habitat and Species section.

The Central Mixed Grass Prairie Conservation Region (Rohweder 2015) is in the central region of the Kansas River basin. Associated with water resource habitats in this region, important for conservation of biodiversity, include herbaceous wetland, aquatic areas (lotic), seeps and springs, and large rivers. Herbaceous wetland habitat includes salt marsh and prairie, spike rush playa lake, playa lake, low or wet prairie, freshwater marsh, cattail marsh, and weedy marsh. Playa lakes consist of herbaceous and scrub-shrub vegetation. They are an important water source for prairie wildlife and serve as stopover locations for migrating waterfowl and shorebirds. The Smoky Hill River floodplain and its surrounding upland habitats provide valuable refuge to wildlife in the region. Channelization and urbanization of streams near major cities has led to bank destabilization, stream incision, and loss of riparian habitat. The Blue River, above Tuttle Creek Lake, has undergone substantial channelization, causing extensive habitat loss and leading to increased erosion and sedimentation at Tuttle Creek Lake. Most resident birds occur statewide, with the highest number of species occurring on the eastern side of the state. Kansas is in the heart of the Central Flyway, along the flight path of many migratory bird species. Areas in the basin offer shelter, food, and rest for these migratory birds.

Mixed grass prairie habitat is composed of both short-grass and tall-grass species. Shortgrass species such as buffalo grass and blue grama, are found on the shallow soils of the uplands. Tallgrass species such as big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) are abundant in moist areas. Midsize grasses such as little bluestem (*Schizachyrium scoparium*), tall dropseed (*Sporobolus asper*), and sideoats grama (*Bouteloua curtipendula*), occur elsewhere. Dominant woody species include hackberry, sand plum (*Prunus americana*), and smooth sumac (*Rhus glabra*).

Sand prairie occurs in well-drained soils and is dominated by sand bluestem (*Andropogon hallii*). Other common species are prairie sand reed (*Calamovilfa longifolia*), plains sunflower (*Helianthus petiolaris*), beebalm (*Monarda punctata*), fourpoint evening primrose (*Oenothera rhombipetala),* switchgrass, sand hill plum (*Prunus angustifolia*), and little bluestem. Eastern red cedar (*Juniperus virginiana*) is

scattered over the slopes, and small patches of woody growth including hackberry, elm, and smooth sumac occur in ravine bottoms.

The floodplain and its surrounding upland habitats provide valuable refuge for wildlife in the western portion of the sand prairies. The floodplains, located on the eastern portion of the sand prairies, have mostly been converted to agriculture and large reservoirs fragment the basin including Lovewell, Milford, Tuttle Creek, Perry, and Clinton reservoirs. Additionally, channelization and urbanization of streams near major cities has occurred leading to bank destabilization, stream incision, and loss of riparian habitat.

Agricultural land uses dominate the central region, such as crop cultivation and livestock grazing. Human activity significantly impacts the condition of playa lakes (https://pljv.org/), including agricultural and other land conversion activities resulting in sedimentation and loss of function. Like the western region, playas are a natural conduit for groundwater recharge and potential stream flow. The Smoky Hill River Basin includes actively-grazed rangelands and haying.

Conservation issues include use of surface water for irrigation and terraces built on playas to treat highly erodible land compliance requirements which is lowering groundwater levels and degrading playa hydrology. Conversion of grassland and improper practices result in habitat loss, increased sediment discharge to basins, and increased nutrient runoff, altering surface water hydrology and water quality. The use of surface water from rivers and streams for irrigation, industry, and municipalities lowers the water level. Overuse or misapplication of pesticides and fertilizers also contributes to water quality degradation from runoff while sand dredging in the Kansas River (https://kansasriver.org/protect/sand-and-gravel-dredging/in-river-dredging-who-and-where/) impacts the river channel, riparian area, and tributaries.

Ongoing conservation actions for this region are described in the Kansas SWAP (Rohweder 2015) and include the use of greenways, corridors, buffer strips, drought management plans, playa restoration, and incentive programs for landowners and managers to promote heterogeneity and diversity of wildlife. The conservation actions also include measures to maintain viable farming and ranching operations like cover crops. They have also been polluted by sedimentation and runoff of fertilizers and pesticides. The quality and quantity of riparian corridor habitats are declining as well. Surface waters, other than major defer/limit herbicide applications). Planting of native riparian buffers at least twice the active channel and projects that increase floodplain connectivity would improve riparian and aquatic habitats. Other actions include promotion of sound techniques for flood control, erosion control, non-point source pollution control, and back stabilization.

3.10.3.3 Eastern Region

Forests in the eastern region (Figure 3-337) of the basin occur in river valleys, adjacent drainages, and their associated hillsides. Forests in the east are dominated by cottonwood, green ash (*Fraxinus pennsylvanica*), and elm (*Ulmus* spp.) with occasional shagbark hickory (*Carya ovatus*), bitternut hickory (*Carya cordiformis*), red oak (*Quercus rubra*), white oak (*Quercus alba*), and black oak (*Quercus velutina*) with Ohio

buckeye (*Aesculus glabra*), American bladdernut (*Staphylea trifolia*), and pawpaw (*Asimina triloba*) found as common understory trees.

Approximately 68 percent of the eastern region is non-native vegetation types (i.e., cropland and CRP/introduced grass/weedy uplands).

Tallgrass prairie, herbaceous wetland, eastern streams/small rivers, deciduous forest, eastern large rivers, and deciduous floodplain occur in the eastern region of the basin (Figure 3-330). Herbaceous wetlands, eastern streams/small rivers, and eastern large rivers are further described in the Aquatic Habitat and Species section.

Tallgrass prairies are dominated by warm-season grasses such as big bluestem, switchgrass, little bluestem, and Indian grass. Wildflowers such as violets (*Viola* spp.), coneflowers (*Echinacea* spp.), primroses (*Oenothera* spp.), lobelias (*Lobelia* spp.), beardtongues (*Penstemon* spp.), and sunflowers can be found throughout.

The deciduous forests in this region of the basin are multi-layered forests dominated by oaks and hickory species complemented by an understory of shrubs and herbaceous plants. Oak-hickory forests are composed primarily of black and red oaks and bitternut and shagbark hickories. Other common trees are white oak (*Quercus alba*), chinkapin oak (*Quercus muehlenbergii*), slippery elm (*Ulmus rubra*), osage orange (*Maclura pomifera*), and honeylocust (*Gleditisia triacanthos*). The understory of the forest is composed of several shrubs and forbs. Grasses and grass-like plants are not common in the woodlands and when they occur are confined to scattered clumps. Asian bush honeysuckle (*Lonicera mackii, L. tatarica, L. morrowii)* is an invasive species that is slowly taking over various areas and is often on disturbed sites, forest edges and interiors, floodplains, fields, pastures, and roadsides. The species out-competes native plants for sunlight and resources, which reduces species diversity negatively impacting wildlife habitat and decreasing local ecosystem functionality (KFS 2021).

The Kansas-Lower Republican floodplain, located in the eastern portion of the region, has mostly been converted to agricultural use. Large reservoirs fragment the basin including Milford, Tuttle Creek, Perry, and Clinton reservoirs. The Eastern Tallgrass Prairie Conservation Region (Rohweder 2015) is in the Eastern Region of the Kansas River Basin. Habitats associated with water resources in this region are important for conservation of biodiversity and include herbaceous wetland, streams and small rivers, large rivers, and deciduous floodplain. Herbaceous wetland habitats include low or wet prairie, freshwater marsh, cattail marsh, and weedy marsh. These habitats are in the floodplains along rivers, such as the Kansas, Republican, Blue, Wakarusa, and Delaware rivers, in swales associated with rivers, or as margins of lakes and impoundments, and are mostly seasonal and permanent wetlands. Woody vegetation in this region is scarce, with forests occurring along stream and river bottoms, and areas protected from fire.

Deciduous floodplain vegetation communities are temporarily flooded habitats. In areas that often experience flooding from heavy rains that scour the ground, eastern cottonwood and willows can establish themselves quickly and thrive. Other dominant species are pecan, bur oak, green ash, American elm, sugar maple, river birch (*Betula nigra*), and hackberry. The understory varies depending on how well the woodlands

drain after rainfall. Sedges, scouring rush, and weedy nettles can be found with common shrubs and forbs.

Fertilizer and pesticide pollution runoff from surrounding farm and pasture lands impact herbaceous wetlands in the Eastern Region. Many of the streams in this region are channelized in an attempt to rapidly move storm water or to increase farmable acreage. Channelization reduces stream length and stream habitats for aquatic organisms. The lack of sinuosity in channelized systems reduces the ability of a stream to effectively dissipate energy, resulting in high velocities and increased erosion. Excessive erosion causes streams to become incised, which reduces floodplain connectivity and the quality and quantity of riparian habitat. Subsequent attempts to stabilize eroding banks with riprap or concrete further exacerbate stream incision and riparian habitat loss. Channelization and resulting high stream velocities combined with reduced floodplain connectivity often cause dangerous and destructive flood events.

Conservation issues include an increase in urban, suburban, and exurban rural homes, causing fragmentation of native habitat. Conversion of grassland and improper practices like concrete-lined streams result in habitat loss, increased sediment discharge to basins, and increased nutrient runoff, altering surface water hydrology and water quality. Invasion of woody vegetation and altered fire and grazing regimes reduce species diversity in grasslands. Farming occurs over a large portion of this region but not to the extent as the western and central regions of Kansas. However, because of its fertile soil, the northeastern corner of Kansas is intensively farmed, and the woodlands are confined to major stream courses. Farming near stream channels impacts riparian habitats, resulting in erosion, sedimentation, and nutrient issues. To produce crops, less irrigation is needed in this region. Sand dredging in the Kansas River impacts the river channel, riparian area, and tributaries. There are several large cities close together in this region. Approximately two-thirds of the Kansas population lives in a corridor along the Kansas River between Junction City, Kansas, and Kansas City, Kansas.

Ongoing conservation actions for this region are described in the Kansas SWAP (Rohweder 2015) and include the use of greenways, corridors, buffer strips, drought management plans, playa restoration, and incentive programs for landowners and managers. These conservation actions promote heterogeneity and diversity of wildlife while maintaining viable farming and ranching operations, like cover crops and deferring and limiting herbicide applications. Planting of native riparian buffers at least twice the active channel and projects that increase floodplain connectivity would improve riparian and aquatic habitats. Other actions include promotion of sound techniques for flood control, erosion control, non-point source pollution control, and bank stabilization.

3.10.4 Federally and State Listed Special Status Species

Many federally and state listed threatened and endangered species and species of concern occur in the Kansas River Basin. Many of the listed species rely upon surface waters associated with basin streams and impoundments, adjacent riparian habitats, and/or wetlands for some portion of their life cycles.

Many native fish species in Kansas have declined with 15 species currently listed on the Kansas State Threatened and Endangered Species list, 31 listed as state Species in Need of Conservation (SINC), and 6 species extirpated (i.e., bigeye chub, Iowa darter,

black nose shiner, trout-perch, western sand darter, and pugnose minnow). The primary reasons for these declines are the changes made in the streams and river systems. Dams reduce high flow signals that some species need to trigger breeding, reduce the amount of habitat available during peaks flows, and limit the amount of food that is washed in when side channels, ephemeral streams, and high-water channels are suddenly inundated and connected up to the mainstem of the river. Changes in high-flow frequency, magnitude, duration, and timing, therefore, can drastically alter the inputs of living, particulate, and dissolved matter that fuel the river food web; reduce reproduction or access to critical refuge habitat for river fishes that depend on the natural flooding of off-channel habitats for their viability; and reduce off-channel nutrient uptake and primary productivity. Stream fragmentation and lack of sufficient streamflow to carry eggs (Durham and Wilde 2006) are frequently cited as the most common threats to pelagic spawning minnows (e.g., plains minnow, shoal chub, sturgeon chub, silver chub, flathead chub) in the Great Plains. Decreased turbidity is another commonly cited threat to many fish adapted to turbid water, as competing sight-feeding fish and predators increase with clearer water (Bonner and Wilde 2002). The relationship between stream discharge and specific gravity (related to turbidity) of water compared to that of semi-buoyant eggs (Coleman 2015) may be particularly important for pelagic spawning species.

The Kansas River historically supported a diverse assemblage of native freshwater mussels. During the urban, industrial, and agricultural development of the basin, the native freshwater mussel experienced a rapid decline in species richness. Today, freshwater mussels are perhaps the most threatened fauna on the Kansas River. Of the 48 species historically found in Kansas, 6 are extirpated, 1 lacks reproductively viable populations (i.e., faces imminent extirpation), 38 have suffered evident range reductions or a widespread thinning of former populations), and 23 are designated as threatened, endangered, or SINC (Angelo et al. 2009).

Section 3.10.2 Aquatic Habitat and Species and Section 3.10.3 Terrestrial Habitat and Wildlife includes further information related to changes in the basin and how they influence the status of wildlife and fish species.

3.10.4.1 Critical Habitat

3.10.4.1.1 Federal Special Status Species

Federally-listed species (Table 3-155) are known to occur in the Kansas River Basin but there is no critical habitat found within the Kansas River Basin for these species.

3.10.4.1.2 State Special Status Species

Designated critical habitat for state special status species are found at a variety of locations in the Kansas River Basin.

- The Kansas River contains designated critical habitat for the following state-listed species: plains minnow, flathead chub, shoal chub, silver chub, sturgeon chub, least tern, and piping plover. Many of these species have been documented in the Kansas River within the last 10 years.

16289 • Other streams in the watershed affected by reservoir management that contain
16290 designated critical habitat for state-listed species are White Rock Creek (plains
16291 minnow), the Smoky Hill River (plains minnow), the Republican River (plains
16292 minnow, shoal chub), and the Wakarusa River (mucket mussel).

16293 Counties where designated critical habitat occurs is included by species in Table 3-155.

16294 There are two FWS National Refuge Lands within the Kansas River Basin. The Flint
16295 Hills NWR is located in the Kansas River subbasin, and the Kirwin NWR is located in
16296 the Smoky Hill subbasin. Any activity proposed on lands managed by the NWR system
16297 must undergo a Compatibility Determination conducted by the refuge.

16298 ### 3.10.4.2 Federal Special Status Species

16299 Federally-listed species considered in this watershed study are those designated as
16300 endangered for threatened under the ESA, Migratory Bird Treaty Act of 1918 (MBTA),
16301 Bald and Golden Eagle Protection Act, or the Fish and Wildlife Coordination Act, and
16302 found within the geographic scope of the watershed study.

16303 *ESA Listed*—In accordance with the ESA, the FWS maintains a national list of
16304 endangered and threatened species. Species are added to the list when in danger of
16305 becoming extinct. USACE initiated an informal consultation with the FWS and obtained
16306 a species list from the FWS on October 23, 2020, in order by subbasins (i.e., Kansas,
16307 Republican, and Smoky Hill) within the larger Kansas River Basin. Federally-listed
16308 species in the basin were identified through the FWS Information, Planning, and
16309 Conservation (IPAC) System (Appendix I). There are presently five federally-threatened
16310 and seven federally-endangered species that occur in the Kansas River Basin (see
16311 Table 3-155). Federally-listed threatened and endangered species in the Kansas River
16312 Basin in Kansas are listed in Table 3-155 by watershed. Table 3-155 also includes the
16313 threatened and endangered species in Colorado and Nebraska within the Kansas River
16314 Basin.

16315

16316 *Table 3-167. Federal and State Threatened and Endangered Species (sheet 1 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Kansas Sub Basin							
Myotis septentrionalis	Northern Long-eared Bat	T	—	T	—	N/A	Jewell, Leavenworth, Marshall, Washington
Spilogale putorius	Eastern Spotted Skunk	—	T	—	—	N/A	Jewell, Republic, Washington, Marshall, Nemaha, Brown, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Jackson, Pottawatomie, Riley, Geary, Wabaunsee
Lontra canadensis	Northern River Otter	—	—	T	—	N/A	N/A
Sterna antillarum	Least Tern	E	E	E	—	Wyandotte, Johnson, Pottawatomie, Shawnee, Wabaunsee, Wyandotte	Jewell, Republic, Washington, Marshall, Nemaha, Brown, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Jackson, Pottawatomie, Riley, Geary, Wabaunsee
Charadrius melodus	Piping Plover	T	T	T	—	Douglas, Geary, Jefferson, Johnson, Leavenworth, Pottawatomie, Riley, Shawnee, Wabaunsee, Wyandotte	Jewell, Republic, Washington, Marshall, Nemaha, Brown, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Jackson, Pottawatomie, Riley, Geary, Wabaunsee

16317
16318

16319 *Table 3-168. Federal and State Threatened and Endangered Species (sheet 2 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Kansas Subbasin							
Grus americana	Whooping Crane	E	E	E	—	N/A	Jewell, Republic, Washington, Marshall, Douglas, Jefferson, Shawnee, Riley, Wabaunsee
Charadrius alexandrinus	Snowy Plover	—	T	—	—	N/A	Jewell, Republic, Washington, Marshall, Nemaha, Brown, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Pottawatomie, Riley, Geary, Wabaunsee
Sistrurus tergiminus	Western Massasauga	—		T	—	N/A	
Scaphirhynchus albus	Pallid Sturgeon	E	E	E	—	N/A	Atchison, Wyandotte, Johnson, Douglas
Notropis topeka	Topeka Shiner	E	T	E	—	Geary, Marshall, Pottawatomie, Riley, Shawnee, Wabaunsee	Marshall, Nemaha, Johnson, Douglas, Jefferson, Shawnee, Pottawatomie, Riley, Geary, Wabaunsee
Percina maculata	Blackside Darter	—	T		—	Wabaunsee	Wabaunsee
Platygobio gracilis	Flathead Chub	—	T	T	—	Atchison, Douglas, Nehama, Wyandotte, Johnson, Jefferson	Nemaha, Atchison, Wyandotte, Johnson, Douglas, Jefferson
Nocomis biguttatus	Hornyhead Chub	—	T	—	—	N/A	Douglas, Wabaunsee

16320
16321

16322 *Table 3-169. Federal and State Threatened and Endangered Species (sheet 3 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Kansas Subbasin							
Hybognathus placitus	Plains Minnow	—	T	T	—	Atchison, Douglas, Geary, Jefferson, Jewell, Johnson, Nehama, Pottawatomie, Riley, Shawnee, Waubaunsee, Wyandotte	Jewell, Nemaha, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Pottawatomie, Riley, Geary, Wabaunsee
Macrhybopsis hyostoma	Shoal Chub	—	T	T	—	Atchison, Douglas, Geary, Jefferson, Jewell, Johnson, Pottawatomie, Riley, Shawnee, Wabaunsee, Wyandotte	Jewell, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Pottawatomie, Riley, Geary, Wabaunsee
Macrhybopsis gelida	Sturgeon Chub	—	T	E	—	Atchison, Douglas, Geary, Jefferson, Johnson, Pottawatomie, Riley, Shawnee, Wabaunsee, Wyandotte	Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Pottawatomie, Riley, Geary, Wabaunsee
Macrhybopsis meeki	Sicklefin Chub	—	E	—	—	N/A	Atchison, Wyandotte, Johnson, Douglas
Macrhybopsis storeriana	Silver Chub	—	E	E	—	Atchison, Douglas, Geary, Jefferson, Johnson, Pottawatomie, Riley, Shawnee, Wabaunsee, Wyandotte	Jewell, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Pottawatomie, Riley, Geary, Wabaunsee

16323

16324 *Table 3-170. Federal and State Threatened and Endangered Species (sheet 4 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Kansas Subbasin							
Hybognathus argyritis	Western Silvery Minnow	—	T	T	—	N/A	Nemaha, Brown, Atchison, Wyandotte, Johnson, Douglas, Jefferson
Pomatiopsis lapidaria	Slender Walker Snail	—	E	E	—	Atchison	Atchison
Actinonaias ligamentina	Mucket Mussel	—	E	—	—	Douglas, Wabaunsee	Douglas, Wabaunsee
Cicindela nevadica lincolniana	Salt Creek Tiger Beetle	E	—	E	—	N/A	
Nicrophorus americanus	American Burying Beetle	T	E	E	—	N/A	Marshall, Nemaha, Brown, Atchison, Wyandotte, Johnson, Douglas, Jefferson, Shawnee, Jackson, Pottawatomie, Riley, Geary, Wabaunsee
Asclepias meadii	Mead's Milkweed	T	—	—	—	N/A	Brown, Jefferson, Leavenworth, Douglas
Platanthera praeclara	Western Prairie Fringed Orchid	T	—	T	—	N/A	Riley, Pottawatomie, Jackson, Jefferson, Leavenworth, Shawnee, Douglas, Johnson
Republican Subbasin							
Mustela nigripes	Black-footed Ferret	E	E	—	E	N/A	Rawlins, Thomas, Sherman
Myotis septentrionalis	Northern Long-eared Bat	T	—	T	—	N/A	Jewell

16325
16326

16327 *Table 3-171. Federal and State Threatened and Endangered Species (sheet 5 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Republican Subbasin							
Spilogale putorius	Eastern Spotted Skunk	—	T	—	—	N/A	Rawlins, Decatur, Norton, Thomas, Sherman, Clay
Lontra canadensis	Northern River Otter	—		T	T	N/A	
Vulpes velos	Swift Fox	—	—	E	—	N/A	
Sterna antillarum	Least Tern	E	E	E	E	N/A	Cheyenne, Rawlins, Decatur, Norton, Thomas, Sherman, Clay
Charadrius melodus	Piping Plover	T	T	T	T	N/A	Cheyenne, Rawlins, Decatur, Norton, Thomas, Sherman, Clay
Grus americana	Whooping Crane	E	E	E	E	N/A	Cheyenne, Rawlins, Decatur, Norton; Thomas; Sherman, Clay
Charadrius alexandrinus	Snowy Plover	—	T	—	—	N/A	Cheyenne, Rawlins, Decatur, Norton, Thomas, Sherman, Clay
Notropis topeka	Topeka Shiner	E	T	E	—	N/A	Cheyenne, Decatur
Hybognathus placitus	Plains Minnow	—	T	—	E	Republic, Cloud, Clay	Cheyenne, Decatur, Norton, Republic, Cloud, Clay
Macrhybopsis hyostoma	Shoal Chub	—	T	—	—	Clay, Cloud, Republic	Clay, Cloud, Republic
Platygobio gracilis	Flathead Chub	—	T	—	—	N/A	Cheyenne
Macrhybopsis storeriana	Silver Chub	—	E	—	—	N/A	Clay

16328
16329

16330 *Table 3-172. Federal and State Threatened and Endangered Species (sheet 6 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Republican Subbasin							
Nicrophorus americanus	American Burying Beetle	T	—	E	—	N/A	
Platanthera praeclara	Western Prairie Fringed Orchid	T	—	T	—	N/A	
Penstemon haydenii	Blowout Penstemon	E	—	E	—	N/A	
Smoky Hill Subbasin							
Mustela nigripes	Black-footed Ferret	E	—	—	E	N/A	Graham, Trego, Gove, Sheridan, Thomas, Logan, Wallace, Sherman
Myotis septentrionalis	Northern Long-eared Bat	T	—	—	—	N/A	Ellis, Graham, Osborne, Phillips, Rooks, Russell
Spilogale putorius	Eastern Spotted Skunk	—	T	—	—	Ellis, Trego	Phillips, Smith, Dickinson, Clay, Cloud, Jewell, Ottawa, Saline, Ellsworth, Lincoln, Mitchell, Osborne, Russell, Ellis, Rooks, Graham, Trego, Gove, Sheridan, Decatur, Thomas, Logan, Wallace, Sherman
Sterna antillarum	Least Tern	E	E	—	E	N/A	Phillips, Smith, Dickinson, Clay, Cloud, Ottawa, Saline, Ellsworth, Lincoln, Mitchell, Osborne, Russell, Ellis, Rooks, Norton, Graham, Trego, Gove, Sheridan, Decatur, Thomas, Logan, Wallace, Sherman

16331
16332

16333 *Table 3-173. Federal and State Threatened and Endangered Species (sheet 7 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Smoky Hill Subbasin							
Charadrius melodus	Piping Plover	T	T	—	T	N/A	Phillips, Smith, Dickinson, Clay, Cloud, Jewell, Ottawa, Saline, Ellsworth, Lincoln, Mitchell, Osborne, Russell, Ellis, Rooks, Norton, Graham, Trego, Gove, Sheridan, Decatur, Thomas, Logan, Wallace, Sherman
Grus americana	Whooping Crane	E	E	E	E	N/A	Phillips, Smith, Dickinson, Clay, Cloud, Jewell, Ottawa, Saline, Ellsworth, Lincoln, Mitchell, Osborne, Russell, Ellis, Rooks, Norton, Graham, Trego, Gove, Sheridan, Decatur, Thomas, Logan, Sherman
Charadrius alexandrinus	Snowy Plover	—	T	—	—	N/A	Phillips, Smith, Dickinson, Cloud, Jewell, Ottawa, Saline, Ellsworth, Lincoln, Mitchell, Osborne, Russell, Ellis, Rooks, Norton, Graham, Trego, Gove, Sheridan, Decatur, Thomas, Logan, Wallace, Sherman
Notropis topeka	Topeka Shiner	E	—	—	—	Dickinson, Wallace	Phillips, Dickinson, Saline, Mitchell, Ellis, Trego, Decatur, Wallace
Hybognathus placitus	Plains Minnow	—	T	—	E	Trego, Gove, Logan, Wallace, Clay, Cloud, Jewell	Phillips, Clay, Cloud, Jewell, Osborne, Russell, Ellis, Rooks, Norton, Trego, Gove, Logan, Wallace

16334

16335 *Table 3-174. Federal and State Threatened and Endangered Species (sheet 8 of 8)*

Scientific Name	Common Name	Federal	Kansas	Nebraska	Colorado	Critical Habitat in Basin	Distribution in Kansas
Smoky Hill Subbasin							
Macrhybopsis gelida	Sturgeon Chub	—	T	—	—	N/A	Dickinson
Macrhybopsis hyostoma	Shoal Chub	—	T	—	—	N/A	Cloud, Jewell
Anaxyrus debilis	Green Toad	—	T	—	—	Logan, Wallace	Logan, Wallace
Anadontoides ferussacianus	Cylindrical Papershell Mussel	—	E	—	—	N/A	Russell, Ellis
Nicrophorus americanus	American Burying Beetle	T	E	—	—	N/A	Dickinson, Saline

16336 Notes:
16337 1. No critical habitat found within the Kansas River Basin. Species listed may have state critical habitat in the state but not in the Basin. See Section 3.10.3, Critical Habitat, for more
16338 details.
16339 T=Threatened; E=Endangered

16340 *Migratory Birds*—USACE initiated an informal consultation with the FWS and obtained a
16341 species list from the FWS IPAC System on October 23, 2020, which was listed
16342 subbasins within the larger Kansas River Basin (Appendix I). The migratory birds listed
16343 in these IPAC reports are birds of particular concern either because they occur on the
16344 FWS Birds of Conservation Concern list or warrant special attention in the basin. A list
16345 of migratory birds that could occur in the basin is included in Table 3-156.

16346 *Table 3-175. Migratory Bird Species (sheet 1 of 2)*

Scientific Name	Common Name	Subbasin		
		Kansas	Republican	Smoky Hill
Botaurus lentiginosus	American Bittern	X	X	X
Pluvialis dominica	American Golden-plover	X	X	X
Haliaeetus leucocephalus	Bald Eagle	X	X	X
Coccyzus erythropthalmus	Black-billed Cuckoo	X	X	X
Dolichonyx oryzivorus	Bobolink	X	X	X
Calidris subruficollis	Buff-breasted Sandpiper	X	X	X
Athene cunicularia	Burrowing Owl		X	X
Aimophila cassinii	Cassin's Sparrow		X	X
Dendroica cerulea	Cerulean Warbler	X		
Calcarius ornatus	Chestnut-collared Longspur		X	X
Calidris alpina arcticola	Dunlin	X	X	X
Antrostomus vociferus	Eastern Whip-poor-will	X	X	X
Aquila chrysaetos	Golden Eagle	X	X	X
Zonotrichia querula	Harris's Sparrow	X	X	X
Ammodramus henslowii	Henslow's Sparrow	X	X	X
Limosa haemastica	Hudsonian Godwit	X	X	X
Oporornis formosus	Kentucky Warbler	X	X	X
Rallus elegans	King Rail	X	X	
Calamospiza melanocorys	Lark Bunting	X	X	X
Ixobrychus exilis	Least Bittern	X	X	X
Tringa flavipes	Lesser Yellowlegs	X	X	X
Melanerpes lewis	Lewis's Woodpecker		X	X
Numenius americanus	Long-billed Curlew		X	X
Calcarius mccownii	Mccown's Longspur		X	X
Charadrius montanus	Mountain Plover		X	X
Protonotaria citrea	Prothonotary Warbler	X	X	X
Melanerpes erythrocephalus	Red-headed Woodpecker	X	X	X
Arenaria interpres morinella	Ruddy Turnstone	X	X	X

16347 *Table 3-176. Migratory Bird Species (sheet 2 of 2)*

Scientific Name	Common Name	Subbasin		
		Kansas	Republican	Smoky Hill
Euphagus carolinus	Rusty Blackbird	X	X	X
Calidris pusilla	Semipalmated Sandpiper	X	X	X
Limnodromus griseus	Short-billed Dowitcher	X	X	X
Calcarius pictus	Smith's Longspur	X		
Anthus spragueii	Sprague's Pipit	X	X	X
Numenius phaeopus	Whimbrel	X	X	X
Tringa semipalmata	Willet	X	X	X
Empidonax traillii	Willow Flycatcher		X	X
Hylocichla mustelina	Wood Thrush	X	X	X

16348 *Bald Eagle and Golden Eagle*—The riparian habitat of the Kansas River, its tributaries,
16349 and its associated reservoirs provides ample foraging, loafing, migration, and nesting
16350 habitat for the bald eagle. The bald eagle is a predatory raptor species that feeds on
16351 fish, birds, snakes, and small mammals. Bald eagles are common along the river, its
16352 tributaries, and reservoirs and sightings are reported frequently. In Kansas, nesting
16353 eagles made a return to the state in 1989 at Clinton Dam and have been increasing
16354 ever since. The first successful nest on the Kansas River was seen in 1997. In the years
16355 from 1997 to 2010, there have been 12 nesting territories on the Kansas River
16356 producing a total of 122 fledged eaglets. As of 2010, 173 juvenile bald eagles have
16357 been banded in Kansas.

16358 The golden eagle (*Aquila chrysaetos*) occurs most regularly over open grasslands in
16359 western Kansas, but it winters sporadically eastward. Golden eagles are an uncommon
16360 transient and winter visitor, chiefly in the western portion of the basin. There is one early
16361 report of breeding and recent nesting in four far western counties of Kansas. They are
16362 most common from early October through early April. Midsummer vagrants occur
16363 occasionally in the eastern portion of the basin.

16364 Threats to bald and golden eagles throughout their range include poaching, use of
16365 harmful pesticides, and collisions with vehicles and power lines.

16366 ### 3.10.4.3 State-Listed Species

16367 State-listed threatened and endangered species that could be present within the
16368 Kansas River watershed were identified for Kansas here
16369 (https://ksoutdoors.com/Services/Threatened-and-Endangered-Wildlife); Nebraska
16370 (http://outdoornebraska.gov/wp-content/uploads/formidable/5/Nebraska-State-Species-
16371 List_May2020.pdf); and Colorado (https://cpw.state.co.us/learn/Pages/SOC-
16372 ThreatenedEndangeredList.aspx).

16373 There are 12 threatened, 10 endangered, (Table 3-155) and an additional 44 species on
16374 the SINC List in Kansas that occur within the Kansas River Basin. State-listed
16375 threatened and endangered species in Kansas are listed in Table 3-155 by watershed.

Table 3-155 also includes the threatened and endangered state species in Colorado and Nebraska within the Kansas River Basin. Counties in Kansas that federally- and state-listed threatened and endangered species occurs in is included along with critical habitat that occurs in Kansas within the Kansas River Basin. Details related to distribution of species for Colorado and Nebraska are not included and may be found at http://outdoornebraska.gov/wp-content/uploads/formidable/5/Nebraska-State-Species-List_May2020.pdf and https://cpw.state.co.us/learn/Pages/SOC-ThreatenedEndangeredList.aspx.

The KDWP maintains a list of state-level threatened and endangered species in accordance with the Kansas Nongame and Endangered Species Conservation Act of 1975 (KDWP 2015). State-designated threatened and endangered species statuses are reviewed on five-year intervals and recovery plans are developed to facilitate recovery of listed species. The Kansas SWAP also outlines measures to conserve state-listed species and is used to appropriately allocate conservation funding (Rohweder 2015).

For Kansas state-listed threatened and endangered species, recovery plans are a designated strategy with the objective to guide research and management aimed at enhancing the listed species' population. Ultimately, the goal is to be able to remove the species from threatened and endangered status in the state. Plans are developed based on a species priority list established by the Threatened and Endangered Species Task Force, through public comment, and in accordance with the amount of funds appropriated for this purpose.

Some of the species included here have recovery plans outlining potential threats to the species and their habitats and recovery criteria (https://ksoutdoors.com/Services/Threatened-and-Endangered-Wildlife). For many of the species, additional species information is needed along with management activities for maintaining species populations and information and educational programs for public and private lands. Management activities include working with other state and federal agencies to identify opportunities to recreate habitat conditions needed by the species. One example is activities for the recovery of the western silvery minnow, sicklefin chub, and the sturgeon chub that could include structural modifications to create diversity in flows, depth, and backwaters to provide habitats. Another example is conducting studies on the life history, ecological requirements, population dynamics, and community interactions of the Topeka shiner. Additional management activities related to recovery of state threatened and endangered species can be found here: https://ksoutdoors.com/Services/Threatened-and-Endangered-Wildlife.

Nebraska also has state recovery plans for state endangered and threatened species. Plans are implemented on a priority basis, dealing first with those species in the most immediate danger, those whose life requirements are best known, and those which offer the best opportunity for success.

3.10.5 Invasive Species

Spread of invasive species can overtake and dominate native ecosystems due to a lack of biological or environmental controls. This can change native species distribution and abundance. The use of pesticides to control invasive, non-native species can impact native wildlife. Water resources in the Kansas River Basin have been invaded by ANS

(https://ksoutdoors.com/Fishing/Aquatic-Nuisance-Species) such as zebra mussels (*Dreissena polymorpha*), invasive carp (*Hypophthalmichthys* spp.), and phragmites (*Phragmites australis*). The focus for the watershed study is on ANS.

3.10.5.1 Aquatic Nuisance Species

ANS are nonindigenous species that threaten the diversity or abundance of native species, the ecological stability of infested waters, and any commercial, agricultural, aquacultural, or recreational activities dependent on such waters. In the United States in 1999, non-indigenous species were estimated to cause major environmental damages and losses adding up to more than $138B per year. Approximately 49 percent of the species on the threatened or endangered species lists are primarily at risk because of predation or competition with exotic species (Pimentel et al., 1999). ANS impact the habitats they invade by altering ecosystem processes and reducing the abundance of native species through predation, competition for food and space, hybridization, and the introduction of pathogens and parasites. Additionally, ANS adversely impact society by hindering economic development, preventing recreational activities, decreasing the aesthetic value of nature, and serving as potential vectors of human disease. Management and control of ANS are crucial to ensuring the ecological health of native aquatic ecosystems.

Most introductions of ANS are the result of human activities both intentional and unintentional. Pathways of introduction into water bodies include aquaculture, aquarium trade, commercial navigation, transport via vessel fouling, recreational boating and fishing, sale of bait fish, research activities, and distribution through interconnected waterways. Moving water, mud, animals, or vegetation between waterbodies risks spreading ANS. Examples of this include interbasin water transfers, boats and trailers, bait buckets, fire suppression equipment, construction equipment, irrigation systems, pet releases, and raw water line repair. Several ANS have already been introduced and dispersed in the Kansas River Basin by various pathways. Non-indigenous ANS have few natural controls and spread rapidly, destroying native plant and animal habitat.

ANS not only represent a potential threat to the environment, but they also threaten industry and the economy. These negative impacts include:

- Decreased property values
- Decreased recreational opportunities
- Decreased water quality
- Fouled water intakes
- Frequently burned-out irrigation and water pumps
- Impacts on power generation
- Impeded water flow and decreased efficiency of water delivery systems
- Increased risk of flooding due to increased biomass in water or clogging lake outlets.

The ANS species that are considered of special concern in the Kansas River Basin are included in Table 3-157.

16462 *Table 3-177. Aquatic Nuisance Species of Special Concern*

Common Name	Scientific Name	Distribution and Year of Discovery
Zebra mussel	*Dreissena polymorpha*	Perry Reservoir (2007), Milford Reservoir (2009), Wilson Reservoir (2009), Kanopolis Reservoir (2011), Jeffery Energy Center Lakes (2011), Lake Shawnee (2013), Lake Wabaunsee (2013), Clinton Reservoir (2013), Glen Elder Reservoir (2013), Cedar Bluff Reservoir (2016), Geary State Fishing Lake (2017), Tuttle Creek Reservoir (2017)
Bighead carp	*Hypophthalmichthys nobilis*	Kansas River below Bowersock Dam (1987). Six Bighead Carp have been captured above Bowersock Dam and believed to be fish that migrated over dam during the 1993 flood. No evidence of reproducing population above Bowersock Dam
Silver carp	*Hypophthalmichthys molitrix*	Kansas River below Bowersock Dam (1991)
Common carp	*Cyprinus carpio*	Throughout Kansas River Basin Reservoirs
White perch	*Morone americana*	Wilson Reservoir (1996)
Curly-leaf pondweed	*Potamogeton crispus*	Leavenworth State Fishing Lake (1997), Ottawa State Fishing Lake (1999), Pottawatomie State Fishing Lake #2 (2005), Cedar Bluff Reservoir (2015), Cross Creek Lake (2015), Lake Waubunsee (unknown), Lake Lenexa (unknown)
Eurasian watermilfoil	*Myriophyllum spicatum*	Sheridan State Fishing Lake (1964), Ottawa State Fishing Lake (1974), Scott State Fishing Lake (1995), Cedar Bluff (2006), Lonestar Lake (2011), Washington State Fishing Lake (unknown)
Common reed	*Phragmites australis*	No specific distribution data, but common. Appears to be rapidly expanding within the basin in a generally West to East direction.
Salt cedar	*Tamarix* spp.	No specific distribution data, but common. More prevalent in Western portion of Kansas River basin.
Water hyacinth	*Eichhornia crassipes*	Mary's Lake (1998)
Yellow iris	*Iris pseudacorus*	Pottawatomie State Fishing Lake #1 (1966), Lake Olathe (2019)

16463

3.10.5.1.1 Zebra and Quagga (Dreissenid) Mussels

Figure 3-338. Zebra Mussels on Boat Propeller (photo by KDWP)



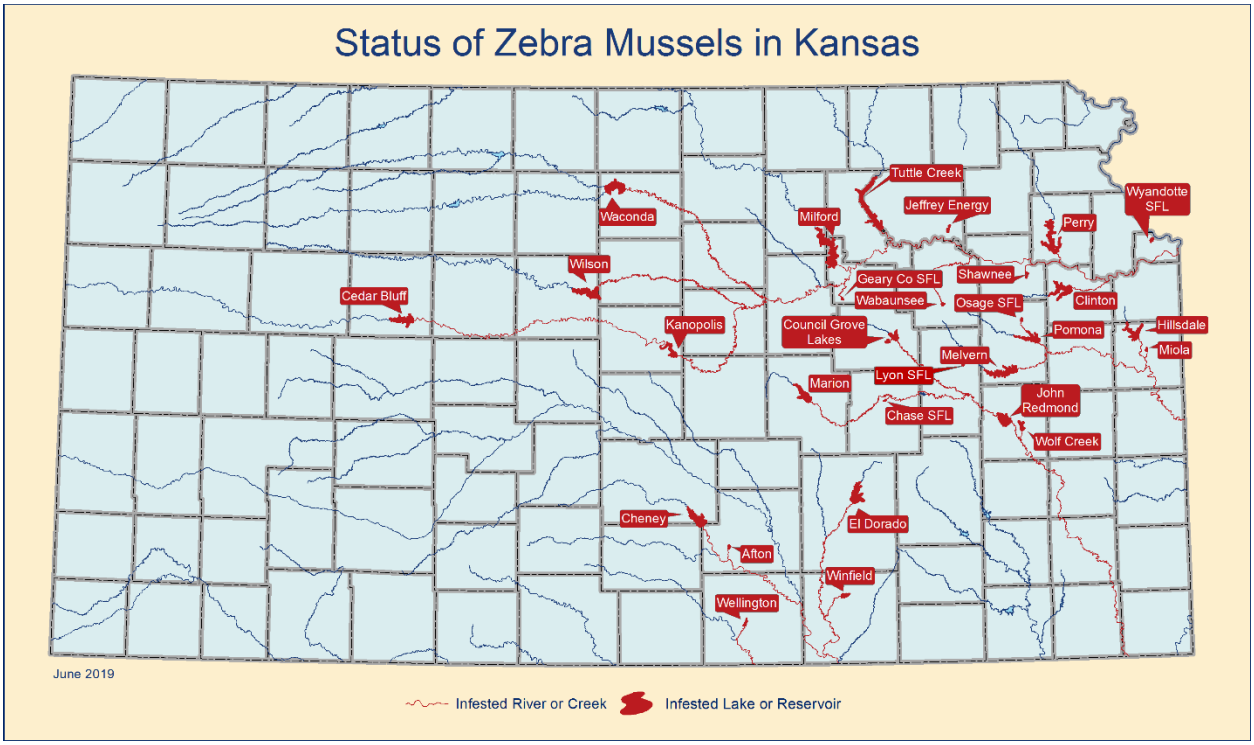
Zebra and quagga mussels (collectively known as Dreissenid mussels) arrived in the North American Great Lakes in the 1980s and rapidly invaded many additional waterways due to their ability to disperse at all life stages. Adults routinely attach to boat hulls and other floating objects and are inadvertently transported by humans to new locations. Juveniles can detach and drift for short distances. Larvae drift downstream in large numbers. Once introduced to a waterbody, the mussels reproduce rapidly, resulting in vast numbers of sharp-shelled adults that coat solid structures and substrates and alter the ecosystem through filter-feeding. Dreissenid mussel invasions cause substantial damage to native wildlife, recreational fishing and boating, drinking-water supply systems, hydroelectric facilities, and agriculture. Established mussel populations are expensive to control and virtually impossible to eradicate. Zebra mussels are present in the Kansas River Basin (Table 3-158, Figure 3-339) while quagga mussels are not. Zebra mussels require a hard substrate (rock, metal, plastic, etc.) for adherence, while quagga mussels can colonize soft sediments (mud, silt, sand, etc.). Because of this ability, establishment of quagga mussels in the Kansas River

Basin would be even more problematic and costly than the current zebra mussel infestations.

Table 3-178. History of Zebra Mussel Infestations

Year First Detected	Waterbody
2007	Perry Reservoir
2009	Milford Reservoir
2009	Wilson Reservoir
2011	Kanopolis Reservoir
2011	Jeffery Energy Center Lakes (2 lakes)
2013	Lake Shawnee
2013	Lake Wabaunsee
2013	Clinton Reservoir
2013	Glen Elder Reservoir
2016	Cedar Bluff Reservoir
2017	Geary SFL
2017	Tuttle Creek Reservoir

Figure 3-339. Status of Zebra Mussels in Kansas

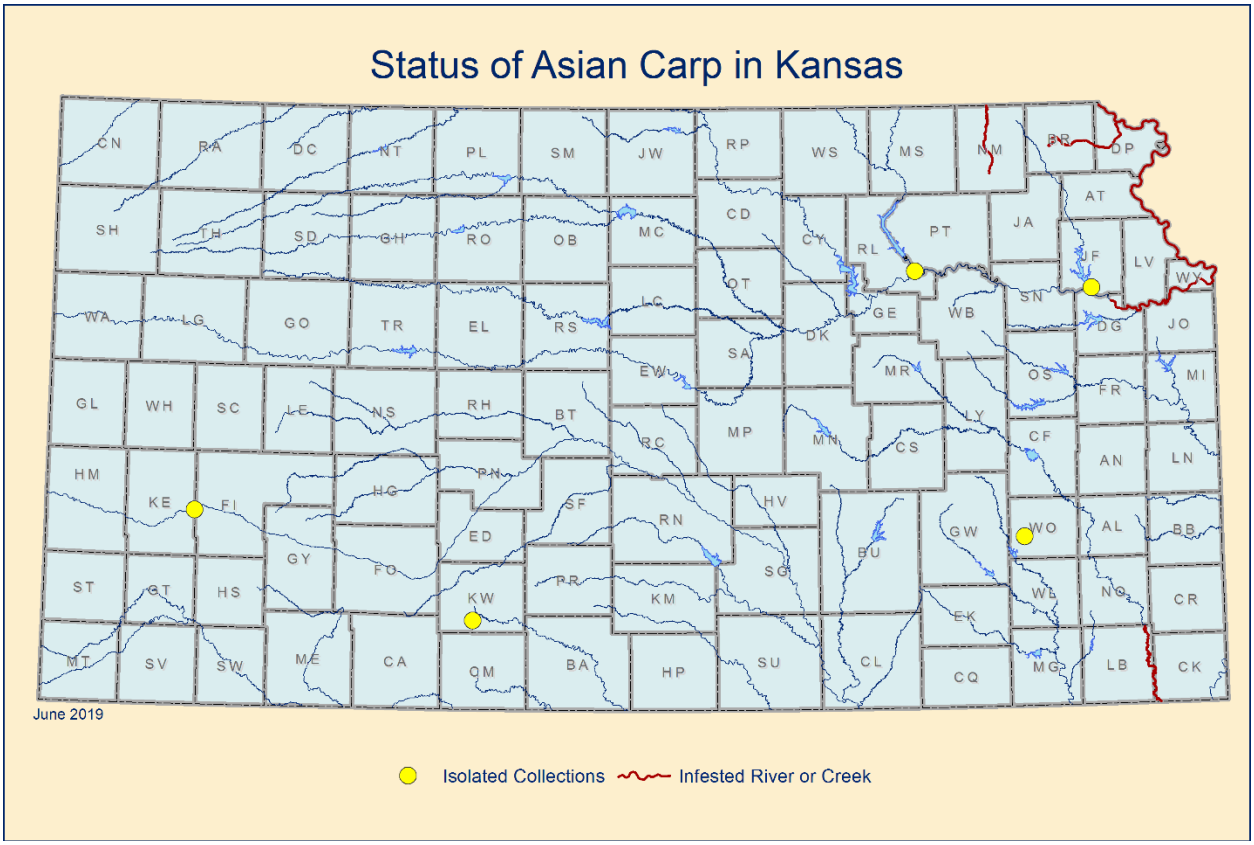


3.10.5.1.2 Invasive Carp

Introduced invasive carps (bighead carp, black carp, grass carp, and silver carp) have become established in many portions of the Mississippi River Basin. These invasive fish were introduced into waters of the United States as the result of combinations of direct stockings by (or authorized by) various agencies, unauthorized stockings by private individuals, and unintentional escapes from university research facilities, federal and state agency facilities, and private aquaculture operations. The feeding habits and population densities of invasive carps cause significant ecological harm where

populations become established. The resulting diminished opportunity for recreational and commercial fishing, boating, and other wildlife-associated recreation causes significant negative economic impact. Bighead carp, grass carp, and silver carp (Figure 3-340) are present and abundant in the lower Kansas River to Bowersock Dam. Only six bighead carp reside upstream of this barrier. These fish likely passed over the Bowersock Dam during extreme flooding in 1993. Invasive carp require about 120,000 cfs flows to pass upstream over the Bowersock Dam. Flows of that magnitude have not occurred since 1993, however, the 2019 floods came close. As of 2020, black carp are not likely to be in the Kansas River but are expanding in population density and range throughout the Mississippi River Basin and are likely to invade the Kansas River in the future.

Figure 3-340. Status of Invasive Carp in Kansas



3.10.5.1.3 White Perch

Figure 3-341. White Perch (photo by KDWP)



White perch were first detected in the Kansas River Basin in Wilson Reservoir in 1996. Although they are known to occasionally travel up or downstream from the reservoir, they have not become common and are likely not reproducing outside of the reservoir. However, they are abundant at problematic levels within Wilson Reservoir and seriously impact the lake's fishery and anglers (Section 4.15.2, Fish and Wildlife, Reservoir Fisheries). White perch feed heavily on baitfish utilized by other species, out-compete native fishes for food and space, and have been associated with declines in walleye and white bass populations.

3.10.5.1.4 Common Carp

Common carp are ubiquitous and are found in most waterbodies in the State of Kansas and throughout the Kansas River Basin. Common carp are regarded as a pest fish because of their widespread abundance and tendency to destroy vegetation and increase water turbidity by dislodging plants and rooting around in the substrate, causing a deterioration of habitat for species requiring vegetation and clean water, and potentially disturbing nesting sites of native fishes. Silt resuspension caused by feeding activities can alter nutrient dynamics in a lake and may be a contributing factor to HABs (Section 3.7, Water Quality).

3.10.5.1.5 Invasive Aquatic Plants

Multiple impoundments within the Kansas River Basin are also infested with invasive, non-indigenous plants such as Eurasian watermilfoil, curly-leaf pondweed, and phragmites. These species are known to reduce or clog water intakes, reduce property values, cause declines in native species, decrease spawning habitat, and reduce useable recreational areas on lakes.

Curlyleaf Pondweed

Curlyleaf pondweed has infested much of the United States and forms dense mats that interfere with recreation and limit the growth of native aquatic plants, posing a significant threat. Curlyleaf pondweed spreads by water movement through a water body and may also be transferred to uninfested waters by humans inadvertently transporting plant fragments, primarily on trailered boats. Curly-leaf pondweed is currently known to occur at Leavenworth State Fishing Lake #2, Cedar Bluff Reservoir, Cross Creek Lake, Lake Waubunsee, and Lake Lenexa.

Eurasian Watermilfoil

Eurasian watermilfoil is spreading rapidly throughout the United States and has been reported in the Kansas River Basin at Sheridan State Fishing Lake, Cedar Bluff Reservoir, Lonestar Lake, and Washington State Fishing Lake. Eurasian watermilfoil can grow under a wide range of environmental conditions and on a variety of bottom substrates. It typically grows in shallow water, but in clear water conditions it can inhabit water up to 30 feet deep. Eurasian watermilfoil's surface canopy can out-compete and eliminate native aquatic vegetation, as well as threaten native fish and wildlife populations. The plant disperses primarily by vegetative propagation through stem fragmentation. Boat propellers and trailers are a major source of long-distance spread of Eurasian watermilfoil.

Common Reed

Figure 3-342. Common Reed (photo by KDWP)



Common reed is common in the Kansas River Basin and is found in many reservoirs and along rivers and streams. Common Reed is a fast-growing plant that forms dense stands that consume available growing space and pushes out native species that are vital to birds, fish, and wildlife. This can lead to a monoculture (displacing all other plant species) stand of vegetation that is difficult to manage. Densely growing Common Reed can grow up to eighteen feet tall. Large populations of common reed alter hydrology, drying up wetlands and impeding water movement. Common reed can spread either through wind-blown or animal deposited seed, however, the most common method of propagation is from thin horizontal structures above or under the ground that sprout new growth at an expansion rate of up to 30 feet per year. The tall stands go dormant each year, creating fire hazards from the thick, dry material. Well established common reed stands are dense and difficult for local wildlife to penetrate and provide little to no food or shelter for wetland dependent wildlife affecting local wildlife populations. Dense stands can impact recreation by reducing areas available for fishing, hunting, and boating, and can impact agriculture by reducing the availability of water for irrigation.

Saltcedar

The Kansas River Basin contains some salt cedar (more prevalent in the western portion of the basin) and is a severe threat to the structure and stability of native plant communities. Salt cedar is a small tree or large shrub that can quickly colonize moist areas due to a constant availability of seeds. The plant's ability to exploit suitable germinating conditions over a long period gives salt cedar a considerable advantage over native riparian species. Mature plants can sprout vegetatively after fire, flood, or treatment with herbicides, and can adapt to wide variations in soils and mineral gradients. Large salt cedar plants can use up to 200 gallons of water a day, reducing, and even eliminating, water flow in streams and rivers. Salt cedar can form dense monocultures and dramatically changing vegetation structure, animal species diversity, soil salinity, and hydrology of sites where it has become dominant. The plants have long and extensive root systems that can tap into deep water tables, allowing them to survive in drought and low water periods. The presence of salt cedar increases salt concentrations in the ground, often preventing the growth and establishment of other plants. Salt cedar does not provide nutrients for local wildlife, including birds.

Water Hyacinth

Water hyacinth, sold as ornamental plants for fishponds, is a fast growing, troublesome aquatic plant with global distributions. Once introduced to a new region, the plant quickly establishes and spreads. Plants grow in ponds, rivers, ditches, and impoundments, and were documented in the Kansas River Basin in Mary's Lake downstream of Clinton Dam. Dense, floating mats of water hyacinth, and the subsequent build-up of organic detritus in the mat, create an environment that supports the growth of emergent aquatic and terrestrial species, including woody species like willows. These floating islands accelerate succession and create concern for navigation and infrastructure and can impede drainage, creating backwater flooding conditions. Recreational use of waters infested with this plant are greatly reduced.

Yellow Iris

Yellow iris is planted as a showy garden or pond plant that has spread from intentional plantings. The species can grow in a range of environmental conditions and can be found in wetlands, shorelines, ditches, streambanks, floodplain forests, and areas of shallow water. Yellow iris has been documented in the Kansas River Basin at Pottawatomie State Fishing Lake #1 and Lake Olathe. Yellow iris forms dense colonies and impenetrable thickets in standing waters, displacing native species and altering habitat for animals. Additionally, all or parts of the plant are poisonous and can cause problems if consumed by livestock. Rhizomes and seeds can be transported downstream further spreading the plant.

Other Invasive Aquatic Plants

The KDWP ANS program does not have the capacity to conduct a formal survey of aquatic plants. The information available is incomplete, and as information on non-indigenous aquatic plants in Kansas is limited; it is likely that additional infestations are present.

Table 3-159 includes other invasive aquatic or semi-aquatic plant species that may occur in the Kansas River Basin for which only non-specific state records exist but were considered in this study.

Table 3-179. Other Invasive Aquatic or Semi-Aquatic Plant Species

Common Name	Scientific Name	Common Name	Scientific Name
Common Barnyard Grass	*Echinochloa crusgalli*	Narrow-leaved Cattail	*Typha angustifolia*
Bitter Dock	*Rumex obtusifolius*	Oak-leaved Goosefoot	*Chenopodium glaucum*
Bittersweet Nightshade	*Solanum dulcamara*	Oriental Lady's Thumb	*Polygonum cespitosum*
Black Alder	*Anus glutinosa*	Parrot Feather	*Myriophyllum aquaticum*
Black-grass Rush	*Juncus gerardii*	Poison Hemlock	*Conium maculatum*
Brazilian Waterweed	*Egeria densa*	Purple Loosestrife	*Lythrum salicaria*
Brittle Waternymph	*Najas minor*	Redtop	*Agrostis gigantea*
Carolina Fanwort	*Cabomba caroliniana*	Rough-stalked Meadow Grass	*Poa trivialis*
Crack Willow	*Salix fragilis*	Spearmint	*Mentha spicata*
Creeping Yellow Cress	*Rorippa sylvestris*	Water Foxtail	*Alopecurus geniculatus var. geniculatus*
European Water Clover	*Marsilea quadrifolia*	Spearmint	*Mentha spicata*
Gingermint	*Mentha × gracilis*	Water-lettuce	*Pistia stratiotes*
Lady's Thumb	*Persicaria maculosa*	Western Water Horehound	*Lycopus asper*
Marsh Fleabane	*Senecio congestus*	White Willow	*Salix alba*
Moneywort	*Lysimachia nummularia*		

3.10.5.1.6 ANS Regulations and Legislation

In accordance with EO 13751, Federal Agencies may not authorize, fund, or carry out actions that are likely to cause or promote the introduction or spread of invasive species. Any future management actions taken due to recommendations of the watershed study would be evaluated on a site-specific level to ensure that compliance with EO 13751 is met.

The KDWP administers policy in Kansas related to ANS, prohibiting the importation, possession, or release of listed ANS (KAR 115-18-10), prohibited release of exotics (KAR 115-20-3), prohibited stocking (KAR 115-8-12), and prohibited transfer of bait fish (KAR 115-8-12). The KDA enacted a quarantine for all federally-listed noxious plants into and within the State of Kansas.

Federal Legislation

In addition to state statutes and regulations, national legislation has also been adopted in response to invasive species issues.

- Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990: Passed to address ANS problems in the United States and established the practice of federal cost-share for implementation of state ANS programs but focused on problems in the Great Lakes region.
- National Invasive Species Act of 1996: Established a national goal of preventing new ANS introductions and limiting the dispersal of existing ANS in all states.
- EO 13112: Established the National Invasive Species Council.
- EO 13751: Set the policy of the United States to prevent the introduction, establishment, and spread of invasive species, as well as to eradicate and control populations of invasive species that are established.
- Lacey Act: Established the federal injurious species list, also includes restrictions and penalties for the interstate movement of injurious invasive aquatic species.

Kansas ANS Regulations

Several laws and regulations are currently in place to help prevent the spread of ANS.

K.A.R. 115-7-3: Use it where you catch it. Wild-caught bait may be used only in the common drainage where taken as long as it is not transported above a dam or natural barrier, except that bluegill and green sunfish collected from non-designated aquatic nuisance waters may be possessed or used as live bait anywhere in the state.

K.A.R. 115-7-10: Take no live fish from waters with an ANS designation. You cannot possess live fish upon departure from a body of water with an ANS designation. If the water contains zebra mussels, invasive carp or white perch, all fish must be dead prior to leaving.

K.A.R. 115-8-6: More use it where you catch it. You can catch minnows, bait fish and other fishing bait for non-commercial purposes on KDWP lands and waters, but it must be used where taken, except that bluegill and green sunfish collected from non-

designated aquatic nuisance waters may be possessed or used as live bait anywhere in the state.

K.A.R. 115-8-12: Don't dump bait. You cannot stock or release wildlife on KDWP lands or waters, navigable publicly-owned waters and federal reservoirs unless authorized. Dispose of unused bait on dry ground or in an approved bait receptacle.

K.A.R. 115-30-13: Drain water. You must drain live wells and bilges and remove drain plugs from all vessels before they are transported on any public highway.

K.A.R. 115-18-10: Protect Kansas from nuisance species. You cannot import, possess, or release the listed live wildlife species without a permit.

K.A.R. 115-20-3(c): Don't release exotic wildlife. You cannot release exotic wildlife onto the lands or into the waters of the state of Kansas.

3.10.5.1.7 National Plans and Frameworks

Through the Federal ANS Task Force, national plans have been developed for select, high-priority, ANS. The goals, objectives, and strategies in these plans provide a path forward for future improved ANS management activities in the Kansas River Basin.

- Quagga-Zebra Mussel Action Plan for Western U.S. Waters (AKA QZAP)
  - https://anstaskforce.gov/QZAP/QZAP_FINAL_Feb2010.pdf
- Management and Control Plan for Bighead, Black, Grass, and Silver Carp in the United States (AKA National Asian Carp Plan)
  - https://www.anstaskforce.gov/Documents/Carps_Management_Plan.pdf
- Missouri River Basin Asian Carp Framework.
  - http://www.micrarivers.org/wp-content/uploads/2018/08/Missouri-River-Basin-Asian-Carp-Framework_180313.pdf

3.10.5.1.8 KDWP ANS Program

In response to ANS threats, in 2005 the Kansas ANS Management Plan was completed and received the Governor's endorsement https://ksoutdoors.com/Fishing/Aquatic-Nuisance-Species/Learn-More-About-Aquatic-Nuisance-Species/Kansas-Aquatic-Nuisance-Species-Management-Plan).

KDWP is charged with leading implementation of the plan to protect Kansas waterbodies for all Kansans with the goals to:

- Prevent new introductions of ANS to Kansas
- Prevent dispersal of established populations of ANS into non-infested waters in Kansas
- Eradicate or control ANS in an environmentally sound manner to minimize the adverse ecological, economic, social, and public health effects
- Educate all aquatic users of ANS risks and how to reduce the harmful impacts of ANS
- Support research on ANS in Kansas and develop systems to disseminate information.

KDWP ANS program staff duties and activities include:

- Promoting development of regulations to combat ANS issues
- Representing the state of Kansas in organizations that coordinate regional and national efforts to manage invasive species
- Conducting research projects pertinent to Kansas ANS priorities
- Permitting and inspecting approximately 200 bait shops statewide
- Sampling 110 lakes across the state to detect new populations of zebra or quagga mussels
- Conducting fish health testing at state and private fish hatcheries, broodfish lakes, and in response to fish kills
- Creating and providing education and outreach materials, including a webpage, signage at waterbodies, radio ads, press releases, Facebook ads, brochures, direct mailings, event displays, presentations, and trainings
- Implementing a watercraft inspection and decontamination program.

As of 2020, the KDWP ANS program maintains active representation and participation in the following invasive species coordinating entities:

- Mississippi River Basin Panel on ANS
  - Website: http://mrbp.org/
- Mississippi Interstate Cooperative Resource Association
  - Website: http://micrarivers.org/
- Missouri River Natural Resources Committee-Asian Carp Technical Committee
- 100th Meridian Missouri River Basin Team
- Western Regional Panel on ANS
  - Website: https://westernregionalpanel.org/
- Western Invasive Species Coordinating Effort
- Western Association of Fish and Wildlife Agencies – Aquatic Invasive Species Working Group
  - Website: https://www.wafwa.org/committees___groups/aquatic_invasive_species_working_group/
- Association of Fish and Wildlife Agencies-Invasive Species Committee
  - Website: https://www.fishwildlife.org/afwa-acts/afwa-committees/invasive-species-committee
- Western Governors Association-Western Invasive Species Council
  - Website: https://westgov.org/
- Lower Mississippi River Conservation Committee-Asian Carp Partnership
  - Website: http://www.lmrcc.org
- KDA Cooperative Agricultural Pest Survey.

- Website: https://agriculture.ks.gov/divisions-programs/plant-protect-weed-control/cooperative-agricultural-pest-survey---caps

3.10.6 Future Without Project

3.10.6.1 Aquatic Habitat and Species and Terrestrial Habitat and Wildlife

Issues in Kansas regarding the conservation of terrestrial and aquatic habitats and their associated species are discussed in the sections above in Sections 3.10.1 Stressors to Biological Resources in the Watershed, Section 3.10.2 Aquatic Habitat and Species, and Section 3.10.3 Terrestrial Habitat and Wildlife. Nebraska and Colorado have also identified statewide issues in their wildlife action plans that are similar to those in Kansas. The diversity of habitats in the basin is declining due to a variety of stresses, including habitat loss (e.g., conversion to other uses; loss of lands enrolled in conservation programs; wetland drainage), habitat degradation (e.g., altered hydrology and channel degradation of rivers and streams; pollution by pesticides and urban and industrial runoff; altered disturbance regime), habitat fragmentation (e.g., transportation and service corridors; energy development), diseases, and competition and predation from invasive species. Past conservation actions have had noteworthy success but have not provided enough achievement in addressing the overall current decline in species and their associated habitats. There is a need for a comprehensive, systematic, and proactive approach that involves multiple agencies and an interested public, for conserving biological diversity in the basin.

Basic physical conditions in the Kansas River watershed are expected to remain relatively unchanged in the future. No major changes to habitat for aquatic species and terrestrial wildlife species are foreseen. There are no comprehensive changes expected to current management policies pertaining to aquatic species and terrestrial wildlife and their habitats in the Kansas River basin. USACE NWK water managers and water quality staff will continue, through cooperative management of lake levels using the LLMP process with stakeholders, to formalize interest and suggestions from environmental actions that can be influenced by water management.

The Kansas SWAP includes conservation measures (listed herin) that would continue to be considered and implemented, if possible, that could prevent or minimize continued declines of fauna and their associated habitats in the Kansas River basin. Measure and strategies developed for the watershed study discussed in Section 5, Recommendations and Implementation Strategy, include more specific information on implementation of some of the Kansas SWAP conservation measures and areas where opportunities exist based on priority of needs.

- Acquire riparian corridor acreages through willing sellers/donors.
- Encourage sand acquisition from the Kansas River valley and/or reservoirs to reduce impacts to the river channel.
- Encourage use of permeable asphalt or pavement and low-impact development practices to improve storm water management by increasing infiltration of water and decreasing/replacing impervious surfaces.
- Identify pollution problem areas and improve conditions detrimental to biodiversity.

- Promote improved water quality standards.
- Promote effective instream flow management through the development and implementation of ecologically appropriate flow regimes.
- Encourage planting of native riparian buffers at least twice the active channel-width to improve aquatic habitats, allowing agroforestry operations in the area farthest from the active channel.
- Promote ecologically sound techniques for flood control, erosion control, nonpoint source pollution control, and bank stabilization.
- Encourage engineering techniques that promote high habitat diversity.
- Encourage the use of fences where necessary to manage riparian corridors, and otherwise conduct proper grazing management.
- Maximize habitat diversity for wildlife species.
- Develop plans to prevent the invasion and spread of ANS.
- Promote restoration of stream channels through natural stream design.
- Promote restoration projects that increase floodplain connectivity in incised streams.
- Promote conservation and restoration of oxbow habitats.
- Promote fish passage designs for new in-stream structures and retro-fit old structures to allow passage.
- Coordinate with the Natural Resource Conservation Service (NRCS) and other partners to develop and implement grazing and land management practices that benefit landowners as well as stream and riparian habitats.

Current climate change predictions indicate a trend of increasing temperatures and precipitation in the region resulting in increased frequency in the occurrence of extremes in climate that will magnify periods of wet and dry weather resulting in longer more severe droughts and larger more extensive storms (Section 3.1, Climate and Precipitation). The potential threat to aquatic ecosystems from sustained drought conditions could be increased for all watersheds in the basin with reduced streamflow and habitat inundation. Lack of water to support reservoir water levels and downstream releases would cause substantial adverse effects to habitats and species. Increased flood flows could cause changes to habitat conditions, increased erosion and sedimentation, damage to habitat improvement projects, and increase the likelihood of invasive species spread. Most vulnerable to climate change are plants and animals living within confined geographic ranges with limited abilities to move rapidly and species migrating to new areas where they meet increased competition for habitat and food. Climate change effects on ecosystem land management include both the geographic loss of habitat and the loss of habitat connectivity. Higher water temperatures resulting from climate change are likely to compromise the health and resilience of existing aquatic and terrestrial species and, thus, make it more challenging for them to compete with nonnative species for survival. The Kansas SWAP includes an assessment of vulnerability to climate change for SGCN. The assessment provides contributions to adaptive management planning by identifying which species or systems are likely to be more strongly affected by project changes; and understanding why these

resources are likely to be vulnerable, including the interaction between climate shift and existing stressors. This assessment supports decision making and provides possible adaptation approaches. Species groups with the highest vulnerability were fish and mussels.

Despite some of these ongoing issues that would occur in the future the state resource agencies would continue climate change adaptation strategies, monitoring, restoration projects, and encourage and promote conservation measures. State resource agencies will continue current efforts to facilitate partnership contacts through ongoing communication and coordination with partners and potential partners. If is expected that through frequent contact with partners and stakeholders, project proposals can be developed to address implementation of actions directed at top ranked species. Monitoring and adaptive management will be facilitated through processes involving state resource agencies and potential partners. Monitoring is crucial to employing adaptive management approaches and ensuring strategies have the desired results. There would also be continued invasive species control as described in Section 3.10.5 Invasive Species.

The sections below discuss expected FWOP conditions for reservoir fisheries within Kansas in the Kansas River basin and Harlan County Reservoir in Nebraska.

3.10.6.1.1 Tuttle Creek Reservoir

The future is not overly bright for the fishery at Tuttle Creek Reservoir. It is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. In addition, the loss of habitat and water volume due to sedimentation will continue to have a compounding effect on the lake's capacity to produce fish. Sedimentation will continue to occur (26 percent loss over the next 50 years) and has the potential to dramatically reduce use to the reservoir, especially for anglers, as only 25 percent of the original multipurpose pool should remain in 50 years. Sedimentation will be a stressor to fish populations in the future as shorelines erode and leave littoral areas unvegetated or littoral habitat silted in, leaving areas unsuitable for fish spawning, nursery habitat, and protective cover. Dredging can clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat. Unfortunately, the high effort and cost of dredging will limit these projects to select locations. Alternatives for removing sediment need research, and a cost analysis should be performed prior to attempts to improve conditions. The role of turbidity on the fishery will only increase as water volume continues to decrease. Like the past, campground water supply intakes will be silted in and will need continual maintenance in the future. An additional stressor has been added to this system as the invasive zebra mussels were first documented in the lake in 2017 and the potential negative aspects have not yet been realized. Other invasive/exotic species at Tuttle Creek Reservoir will continue to be an issue and require measures to control their populations.

However, there are some recent positive changes worth noting. Stocking efforts have created an emerging blue catfish population and early indications are that this species may not be as adversely affected as other sportfish species by the negative characteristics common at Tuttle Creek Reservoir. With this success in mind, a new

paddlefish stocking effort was initiated in 2019 to establish another angling opportunity that can thrive in this lake. It is too early to determine success of paddlefish re-introduction efforts, but these first fish grew well, and many young individuals were seen downstream of the lake in 2020.

Emigration of fish during periods of elevated release rates will occur in the future, like past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Thankfully, anglers can utilize some of the sportfish that regularly emigrate out of the lake. There is well developed angler access immediately below the dam at the outlet structure, at the River Pond, which is a lake connected to the river below the dam, and at the low head dam Rocky Ford a mile downstream. The most recent angler creel survey estimated that over 47,000 anglers visited these tailwater fisheries from March to October in 2013. There is potential for increasing these angling opportunities as there have been ongoing discussions on how public access can increase the undeveloped stretch of the Big Blue River downstream of Tuttle Creek Reservoir.

Fishery management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fishery management measures will continue to include fish harvest regulations, fish stocking, LLMP, and sampling to monitor trends.

Angling will continue at Tuttle Creek Reservoir in the future, but targeted species may vary depending on fluctuating factors (i.e., rapid water level fluctuations and dynamic shifts in water turbidity) that affect fish abundance and condition or their habitat. If a fish species highly sought by anglers declines this could affect the angling experience in the future and fisherman may choose to move to another reservoir. There are opportunities for improving angler access within the lake as well that could help offset some of the historic losses and the ongoing chronic hindrances. Shoreline opportunities could be increased by improving vehicle access via opening closed roads, repairing damaged roads, or exploring new areas to add pathways to the water. It would also be beneficial to define potentially promising bank fishing locations, then develop flood resistant improvements in those areas with the intent of increasing shoreline angler access. As the past, boat ramps will continue to be closed due to insufficient water depths from sedimentation. The addition of new boat ramps is necessary to continue to provide access points to the reservoir for boats. For boating access, it would be beneficial to add new boat ramps, especially ones designed to be usable during high water periods. Additional docks at new or existing ramps would increase usage, especially for boat operators or passengers with movement limitations or disabilities.

3.10.6.1.2 Milford Reservoir

The future of the fishery for Milford Reservoir looks steady for now. However, several factors that fishery biologists need to continue to monitor into the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can assist in creating the BMPs to be able to maintain these fish populations in a constantly changing environment. These fish populations are important to all anglers who utilize Milford Reservoir; therefore, being able to understand how these

populations could be impacted in the future can aid in better management of these fish species.

Water level management will also continue to be crucial to sport fisheries and anglers. Timing of water releases and magnitudes can positively or negatively impact available habitats and types, and successful sportfish reproduction and survival. High releases around spawning could be detrimental both on the local and statewide scale, too, if broodfish species are negatively impacted.

Some mitigation of these issues has begun. The Milford WRAPS and Regional Conservation Partnership Program (RCPP) programs are working with private landowners in the Milford Reservoir watershed to assist in developing, assessing, planning, and implementing BMPs on their land to reduce sedimentation and nutrient loading. KDWP staff along with local volunteers continue to try to deploy fish habitat in crucial areas where habitat is lacking around the reservoir. Educating the public on invasive species identification and prevention aids in the prevention of invasive species spread around the state and the country. Stocking efforts for walleyes and wipers supplement the population to provide quality fishing opportunities for anglers. KDHE staff is crucial in continually monitoring the lake's water quality parameters to try to detect the presence of HABs and ensure safety of the public. Overall, Milford Reservoir is an important resource for many reasons. Therefore, evaluation of lake management at all levels will impact how the reservoir looks in the future. These actions will continue.

3.10.6.1.3 Clinton Reservoir

Clinton Reservoir is filling in with sediment at the detriment of the fish and the anglers who pursue them as well as other interest groups that use the reservoir. Sedimentation of the reservoir reduces the storage capacity and area available to anglers, and fills in any unique, fish attracting bathymetric features (e.g., river channels). Decreased storage capacity will likely result in Clinton Reservoir being more responsive to heavy rains, exhibiting more drastic rises than were experienced when the river was impounded. The more drastic and frequent fluctuations will make the establishment and development of aquatic vegetation even more difficult. Further degradation of existing fish habitat will be countered with the installation of artificial fish habitat, but natural features are likely more appealing to fishes, and it is unknown if the rate of replacement can match the rate of degradation.

There is no reason to believe that use or visitation of Clinton Reservoir will be decreasing in the future. This reservoir is within close proximity to large population centers. The reservoir is already known for its exceptional crappie fishing and receives a good deal of traffic from tournament bass fishing, which is a growing sport. There is also the possibility that in the next ten years, Clinton Reservoir could develop a high-quality blue catfish fishery. If this population takes hold, it is likely to receive increased pressure from metropolitan catfishermen who would like a closer destination than Milford Reservoir.

While angler use may remain constant or increase, access to the reservoir may decrease. Continued siltation at the upper end of the reservoir may hinder angler access to that portion of the reservoir resulting in crowding at lower reservoir boat access areas. Similarly, more frequent, or more drastic water level fluctuations could

result in most, if not all, boat ramps being closed to angler access. Without construction of new, higher elevation boat access points it is possible that anglers may not be able to access the reservoir during times of the year when rains are more frequent.

The loss of bathymetric features and silting in of natural fish attracting features will also negatively affect fish populations. Fish populations may begin to shift toward more riverine population structures which may not align with angler preference. Water level management will also continue to be crucial to sport fisheries and anglers. Available habitats and types, and successful sportfish reproduction and survival, can all be positively or negatively impacted by the timing of water releases and magnitudes thereof. High releases around spawning periods could be detrimental both on the local and statewide scale.

3.10.6.1.4 Perry Reservoir

Perry Reservoir is filling in with sediment at the detriment of the fish and the anglers who pursue them as well as other interest groups that use the reservoir. Sedimentation of the reservoir reduces the storage capacity and the fishable areas, while filling in any unique, fish-attracting bathymetric features (e.g., river channels). Perry Reservoir will be more responsive to heavy rains due to decreased storage capacity, exhibiting more drastic rises than were experienced when the river was impounded 50 years ago. The more drastic and frequent fluctuations will make the establishment and development of aquatic vegetation even more difficult. Further degradation of existing fish habitat will be countered with the installation of artificial fish habitat, but natural features are more appealing to fish, and it is unknown if the rate of replacement can match the rate of degradation.

This reservoir is within close proximity to the majority of the large population centers of Kansas; a one-hour drive from the heart of Kansas City, Kansas. The reservoir is already known for its exceptional crappie fishing and receives a good deal of traffic from tournament bass fishing, which is a growing sport. There is the possibility that in the next ten years, Perry Reservoir could develop a high-quality blue catfish fishery. If this population increases, it is likely to receive increased pressure from metropolitan anglers who would like a closer destination than Milford Reservoir. The reintroduction of paddlefish to Perry Reservoir and the Delaware River could also result in an increase of recreational anglers. If this population increases and some recreational snagging is permissible, many anglers may travel to the reservoir’s upper reaches or spillway in the spring when these fish make their spawning runs.

While angler use may remain constant or increase, access to the reservoir may decrease. Continued siltation at the upper end of the reservoir may hinder angler access to that portion of the reservoir resulting in crowding at more southern boat access areas. Similarly, more frequent, or more drastic water level fluctuations could result in most, if not all, boat ramps closed to angler access. Without construction of new, higher elevation boat access points it is possible that anglers may not be able to access the reservoir during times of the year when rains are more frequent.

The loss of bathymetric features and silting in of natural fish-attracting features will also negatively affect fish populations. Fish populations may begin to shift toward more riverine population structures, which may not align with angler preference. Maintenance

stockings of sauger to supplement the broodstock population and reintroduction stockings of paddlefish will continue. The sauger stockings will continue until broodstock sauger are no longer required. The paddlefish stockings will continue until 2029. At that point, the status of the population will be evaluated.

ANS prevention will continue to be vital to the future of sportfish populations and those that pursue them. Zebra mussels are currently present, but other invasive species to prevent include carp native to Asia, white perch, rudd, and a myriad of crayfish and aquatic vegetation species.

Water level management will also continue to be crucial to sport fisheries and anglers. Available habitats and types, and successful sportfish reproduction and survival, can all be impacted by the timing of water releases and magnitudes thereof. High releases around sauger spawning could be detrimental both on the local and statewide scale, too. KDWP is dependent on adult sauger populations to produce and stock sauger and saugeye across the entire state of Kansas.

3.10.6.1.5 Wilson Reservoir

Biennial stockings for striped bass will continue to be requested from the culture system. They do not reproduce naturally at Wilson Reservoir and must be maintained by stocking. Largemouth bass stockings have had some success, especially as the reservoir is rising after a drought-induced elevation decrease. Stocking largemouth bass during a refilling event allows the population to rebound more rapidly and fill unoccupied niche habitats one or two years quicker than would naturally occur. However, stocking during stable conditions has provided limited success and is not warranted. Walleye and blue catfish will be stocked as needed, generally when natural recruitment fails for one to three years.

Wilson Reservoir ranked as the most preferred reservoir to fish by anglers during the 2013 Licensed Angler Survey. Due to low sedimentation rate, lack of harmful agal blooms, and quality fishing opportunities it is unlikely that use and visitation at Wilson Reservoir will decline significantly in the next 100 years. Angling will continue at Wilson Reservoir in the future, but targeted species may vary depending on fluctuating factors that affect fish abundance and condition or their habitat. If a fish species highly sought by anglers declines this could affect the angling experience in the future and fisherman may choose to move to another reservoir.

Water levels will continue to fluctuate due to the variable annual precipitation in the region with drought conditions in some years that cause a decline in pool elevations and inundation of specific habitats (e.g., coves, shorelines) leading to a lack of vegetation and structure near the shoreline used for fish spawning and escape habitats. In other years, sustained high water elevations provide excellent habitat for YOY fish allowing some fish species to have good year classes recruited to the fishery (e.g., largemouth bass). However, significant flooding can kill large areas of common reed grass and shoreline vegetation utilized by fish species. Zebra mussels and white perch could continue to increase at Wilson Reservoir altering food webs in the reservoir and consuming fish eggs creating recruitment issues for sport fish.

While sedimentation will continue to occur (3.3 percent loss of the multipurpose pool over the next 50 years), it will not create impacts to reservoir fisheries or their habitats in the future. Shoreline erosion and deposition of silt will continue to cause stressors to fish populations leaving littoral areas unvegetated and silting in important areas fish use for spawning, nursery habitat, and protective cover.

KDWP will continue to monitor and regulate sport fishing populations to provide the best conservation of the resource for anglers. Habitat improvements, in the form of brush piles as fish attractors and shoreline vegetation for improved littoral productivity, will be accomplished intermittently. Boat ramps will continue to be assessed to provide reasonable boat access for anglers. Shoreline access will be maintained for bank anglers. A new fish cleaning station was purchased in 2021 to allow ease for anglers to process fish onsite.

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations, habitat work, aquatic vegetation enhancement, fish stocking, and special studies, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Wilson Reservoir will not change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, like what Wilson Reservoir experiences now.

3.10.6.1.6 Kanopolis Reservoir

Biennial stockings for saugeye will continue to be requested from the culture system. They have limited natural recruitment at Kanopolis Reservoir and must be maintained by stocking. KDWP District fisheries staff have stocked largemouth bass fingerlings for five years with limited success. This population is unlikely to improve without dramatic improvements to habitat conditions. Other species will be stocked as necessary but most others (e.g., channel catfish, white bass, crappie) do well without stockings. However, if habitat conditions preclude recruitment of these species, stockings might be attempted and assessed.

Kanopolis Reservoir ranked as the ninth most preferred reservoir to fish by anglers during the 2013 Licensed Angler Survey. The proximity to Salina, Kansas, and McPherson, Kansas, makes this a popular destination for anglers inhabiting these urban centers in central Kansas. Angling will continue at Kanopolis Reservoir in the future, but targeted species may vary depending on fluctuating factors that affect fish abundance and condition or their habitat. If a fish species highly sought by anglers declines this could affect the angling experience in the future and fisherman may choose to move to another reservoir.

Water quality concerns will continue in the future with water inflows continuing to carry sediments and nutrients that decrease water quality and further aging of the reservoir causing eutrophic conditions at the reservoir. As the water quality degrades further this will only exacerbate the problem of establishing aquatic vegetation leading to a further loss of escape, nursery, and spawning habitat. Water levels will continue to fluctuate due to the variable annual precipitation in the region with drought conditions in some

years that cause a decline in pool elevations and inundation of specific habitats (e.g., coves, shorelines). In other years, sustained high water elevations provide excellent habitat for YOY fish allowing some fish species to have good year classes recruited to the fishery (e.g., crappie). However, rapid drawdowns during future high-water events could lead to decreases in fish species abundance (e.g., saugeye) and catch rates if fish are lost through the outflow of the dam. Future entrainment of fish through the dam may require fish stockings to resupply the reservoir with sport fish (e.g., saugeye).

Sedimentation will continue to occur (29.4 percent loss over the next 50 years) and has the potential to dramatically reduce use to the reservoir, especially for anglers. Sedimentation will be a stressor to fish populations in the future as shorelines erode and leave littoral areas unvegetated or littoral habitat silted in, leaving areas unsuitable for fish spawning, nursery habitat, and protective cover. Addition of woody habitat would mitigate some of these impacts to the fishery. Future enhancement projects should incorporate dredging. Dredging can clear sediment from boat ramps to improve access but can also improve shoreline depth for bank anglers and to improve fish habitat. Unfortunately, the high effort and cost of dredging will limit these projects to select locations. Alternatives for removing sediment must be researched, and a cost analysis should be performed prior to attempts to improve conditions.

Installation of riprap in areas of critical shoreline infrastructure will continue in the future as needed and would provide habitat and escape cover for the fishery. Boat ramps will need construction in the future as most boat ramps at Kanopolis Reservoir are inaccessible and only one ramp is usable during current top of multipurpose pool.

Fishery management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fishery management measures will include fish harvest regulations, habitat work, aquatic vegetation enhancement, fish stocking, and special studies, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Kanopolis Reservoir are not expected to change but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, like what is now experienced at Kanopolis Reservoir.

3.10.6.1.7 Harlan County Reservoir

Large water level fluctuations are likely to continue as this reservoir serves multiple purposes including reducing flood risk and providing irrigation. These circumstances create challenges at low water levels including reduced connectivity with cove habitat, which reduces spawning and rearing habitat for shoreline orientated species such as crappie, largemouth bass, and bluegill. Low water levels can also increase the chances of HABs and fish kills while decreasing user access and recreational opportunities. Extremely high-water levels (above multipurpose pool) can present challenges as well including excessive shoreline erosion and damage to infrastructure such as breakwaters, fishing piers, and boating access developments. Harlan County Reservoir is the storage reservoir for water dedicated to the Republican River compact between Colorado, Nebraska, and Kansas, which tends to lead to increased water releases during the time of the year when small fish are vulnerable to entrainment.

Addressing erosion and disconnection of cove habitat is a priority at Harlan County Reservoir. For example, a large aquatic habitat project was completed in 2012 to 2013 at Gremlin and Patterson coves, which included bank stabilization, protection breakwaters, dredging, and angler access improvements. This project was planned and funded by NGPC through the Aquatic Habitat Program. A second aquatic habitat project was initiated in 2022 and is in the planning phases with USACE CAP Section 1135 Ecosystem Restoration funding. This goal of this project is to improve habitat and connectivity at Methodist Cove, which is located on the northwest edge of the reservoir.

The introduction of invasive species is also a concern at Harlan County Reservoir. Although zebra and quagga mussels have yet to be detected in Harlan County Reservoir, these invasives are common in nearby Kansas reservoirs posing a potential future threat to the aquatic resources, infrastructure, and recreational opportunities in this reservoir. Continued monitoring and outreach/education efforts will be important for minimizing the potential for future introductions.

Despite the challenges discussed here, Harlan County Reservoir provides valuable benefits to both humans and fish and wildlife. The Nebraska Game and Parks Fisheries Division will remain committed to managing aquatic resources at Harlan County reservoir including but not limited to stocking fish, evaluating fish population surveys, conducting aquatic-based research, improving and maintaining aquatic habitat, improving and maintain angler access and providing law enforcement.

3.10.6.1.8 Keith Sebelius Lake

Keith Sebelius Reservoir has within its pool allocations a component for irrigation. If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least 2 feet to 4 feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. Recent years have been wetter than normal, however when it gets dry the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Keith Sebelius Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited. This trend should continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, or a combination of the two.

While sedimentation will continue to occur (9.2 percent loss of the MP over the next 50 years), it will not create impacts to reservoir fisheries or their habitats in the future. If the invasive species, Phragmites, increases at Keith Sebelius Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

Fishery management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fishery management measures will continue to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler

use and preferences will also continue to support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir will not change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, like Keith Sebelius Reservoir experiences now.

3.10.6.1.9 Lovewell Reservoir

Lovewell reservoir should experience a similar water level fluctuation pattern soon as irrigation to meet farmland requirements both above and below the reservoir remains of upmost importance. Improvements continue toward the efficiency of the water delivery system which should take some strain off the water volume requirements. Other discussions have been ongoing regarding future alternatives to water storage including raising the multipurpose pool of Lovewell reservoir to increase water volume or construction of another reservoir in the area for additional water storage. These options continue to be discussed but no decisions have been finalized. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Lovewell reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

The stocking of fry, fingerling, and intermediate-sized walleye will continue annually to boost recruitment and supplement the limited natural reproduction which occurs. Blue catfish were stocked for five years but are now set to expand with natural reproduction and will not be stocked again. Wiper fry, fingerlings, and intermediates are also stocked annually to maintain this aggressive predator. Saugeye should have the potential to recruit, grow, and survive in Lovewell reservoir compared with their walleye cousins and may be stocked in the future. With Milford reservoir downstream containing a viable walleye population, special care must be considered before adding a new species to the watershed. This potential new stocking will continue to be evaluated and ideally a solution will be met that improves the Lovewell reservoir fishery while also maintaining the Milford reservoir fishery.

The primary recreation activities at Lovewell reservoir vary and are dependent on angler use and visitation and changes in socio-economic factors influence public involvement in angling. For example, increased participation of families in youth sporting activities reduces angler participation. However, the unforeseen emergence and response to COVID-19 increased public participation in angling and other outdoor recreation at Lovewell reservoir during the 2020 season.

3.10.6.1.10 Waconda Lake

Waconda Lake should experience stable water levels as it lies on the western edge of the wetter portion of the state that provides adequate rainfall to maintain the water level. Periods of extended drought force the water level to decline two feet to five feet occasionally, but outside of extreme drought situations water is abundant. The watershed size is simply too large to avoid significant rainfall over long periods of time and river inflow is steady enough to maintain most water levels. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Waconda Lake is at low pool elevations,

aquatic resource-based recreational opportunities available to the public, become more limited.

3.10.6.1.11 Cedar Bluff Reservoir

Cedar Bluff reservoir should experience continued pool wide elevation fluctuations. Withdrawal of water from the Ogallala Aquifer and Smoky Hill River alluvium for agricultural irrigation at current rates, and continued encroachment of phreatophyte species along the riparian corridors of the river and associated tributaries, will decrease baseflow and subsequent inflow into the reservoir. This will widen the amplitude of reservoir pool elevation fluctuation and promote the probability of extreme pool dewatering. At reduced pool, decreased water quality and reduced habitat availability and diversity, limit sportfish population abundance and welfare. When Cedar Bluff reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited.

The stocking of intermediate-sized channel catfish will continue if stockings reveal improvement of population abundance. Wiper fry will be stocked at a moderate rate, biannually, for the foreseeable future. Largemouth bass fingerlings will be stocked when trophic and habitat conditions resulting from substantial reservoir pool elevation increases occur.

Sedimentation in the reservoir will continue in Cedar Bluff reservoir reducing the diversity of rock substrate continuing to affect reproduction of fish species and reducing the overall volume of water in the reservoir. Invasive and exotic species will continue to be a concern, encroaching areas of the reservoir, and reducing the distribution and abundance of important terrestrial and emergent aquatic vegetation altering the complexity and diversity of fish habitat.

Monitoring and stocking efforts will continue as needed at the reservoir to support ongoing management of sportfish populations along with fish harvest regulations.

3.10.6.1.12 Webster Lake

Webster reservoir has within its pool allocations a component for irrigation. If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least 4 feet to 5 feet each year for irrigation if enough water is available for the irrigation district to use. Recent years have been wetter than normal, however, when it gets dry the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Webster reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited. This trend should continue with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two.

While sedimentation will continue to occur (3.3 percent loss of the MP over the next 50 years) it will not create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Webster reservoir there could be issues

related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

Fishery management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fishery management measures will continue to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Webster reservoir will not change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, like Webster reservoir experiences now.

3.10.6.1.13 Kirwin Lake

Kirwin reservoir has within its pool allocations a component for irrigation. If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least 4 feet to 5 feet each year for irrigation if enough water is available for the irrigation district to use. Recent years have been wetter than normal, however, when it gets dry the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Kirwin reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited. This trend should continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two.

While sedimentation will continue to occur (2.4 percent loss of the MP over the next 50 years) it will not create impacts to reservoir fisheries or their habitat in the future. If the invasive species, Phragmites, increases at Kirwin reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

Fishery management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fishery management measures will include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will continue to support management of the fisheries. Fish species that inhabit Kirwin reservoir will not change in the future but will have periods where changes in abundance and shift in sportfish species dominance occur due to conditions that affect habitat quantity and quality, like Kirwin reservoir experiences now.

The FWS will continue to manage all activities on the reservoir and its surrounding lands, apart from irrigation and flood control. These activities will continue to benefit fish and wildlife species at Kirwin reservoir.

3.10.6.2 Federally and State Listed Special Status Species

Statewide issues in Kansas regarding the conservation of native wildlife are discussed in Section 3.10.2 Aquatic Habitat and Species and Section 3.10.3 Terrestrial Habitat and Wildlife. Continued declines on state-listed special status species is expected with potential for federal listing. Many of the state-listed fish species have relatively short lifespans (3 years or less), so consecutive failed year classes could result in considerable population declines, particularly in fragmented reaches of rivers and streams that cannot easily be recolonized (Perkin et al. 2014).

Basic physical conditions in the Kansas River Watershed are expected to remain relatively unchanged in the future. No major changes to habitat for threatened and endangered species are foreseen. There are no comprehensive changes expected to current management policies pertaining to special status species in the Kansas River Basin. The Kansas SWAP includes conservation measures (included below) that would continue to be considered and implemented, if possible, that could prevent or minimize continued declines of special status species in the Kansas River Basin (see FWOP for Aquatic Habitat and Species and Terrestrial Habitat and Wildlife Section 3.10.6.1.

Current climate change predictions indicate that several species will be impacted, some severely, by climate change in the future (e.g., cylindrical papershell). The potential threat to aquatic ecosystems from sustained drought conditions would be increased for all watersheds in the basin. Most vulnerable to climate change are endangered and threatened species, plants and animals living within confined geographic ranges with limited abilities to move rapidly, and species migrating to new areas where they meet increased competition for habitat and food. Climate change effects on ecosystem land management include both the geographic loss of habitat and the loss of habitat connectivity. Higher water temperatures resulting from climate change are likely to compromise the health and resilience of existing aquatic and terrestrial species and, thus, make it more challenging for them to compete with nonnative species for survival. As previously discussed, the Kansas SWAP includes an assessment of vulnerability to climate change for Species of Greatest Conservation Need (SGCN) of which many special status species in Kansas are included on this list. The assessment provides contributions to adaptive management planning by identifying which species or systems are likely to be more affected by project changes; and understanding why these resources are likely to be vulnerable, including the interaction between climate shift and existing stressors. This assessment supports decision making and provides possible adaptation approaches. Species groups with the highest vulnerability were fish and mussels.

Despite some of these ongoing issues that could occur in the future, the state resource agencies will continue recovery actions, climate change adaptation strategies, and restoration projects and encourage and promote conservation measures. State resource agencies will continue current efforts to facilitate partnership contacts through ongoing communication and coordination with partners and potential partners. It is expected that, through frequent contact with partners and stakeholders, project proposals can be developed to address implementation of actions directed at top-ranked species. Monitoring and adaptive management will be facilitated through processes involving state resource agencies and potential partners. Monitoring is crucial

to employing adaptive management approaches and ensuring strategies have the desired results.

3.10.6.3 Invasive Species

The number of new ANS introductions in the Kansas River Basin will continue to grow as new and existing ANS become established in midwestern watersheds, especially those that border the Kansas River Basin.

The environmental and socio-economic costs resulting from ANS infestations will continue to rise with further introductions. Although an awareness of the problems caused by ANS is emerging, the solutions are often not readily available. A newly introduced species can disrupt the natural ecosystems by altering the composition, density, and interactions of native species. A lack of natural controls may allow a new population to increase at an exponential rate and disrupt native species. The introduced species may prey upon, out compete, or transmit disease to the native species. This disruption can cause significant alterations to food webs, nutrient dynamics, and biodiversity. Changes in the ecology of lakes and rivers, degraded habitat value in infested waters, and stunted fish populations may also result from the disruption caused by a newly introduced species.

Many challenges remain for ANS in the Kansas River Basin. Funding and capacity of the KDWP ANS program is severely limited in comparison to the threats that ANS pose. Several ANS currently not found in Kansas are poised to present additional threats to the Kansas River Basin in the future:

- Quagga mussel
- Black carp
- Northern snakehead
- Rusty crayfish
- Red Swamp crayfish
- Golden algae
- Additional plant species: hydrilla, brittle naiad
- Invasive plankton species: spiny waterflea.

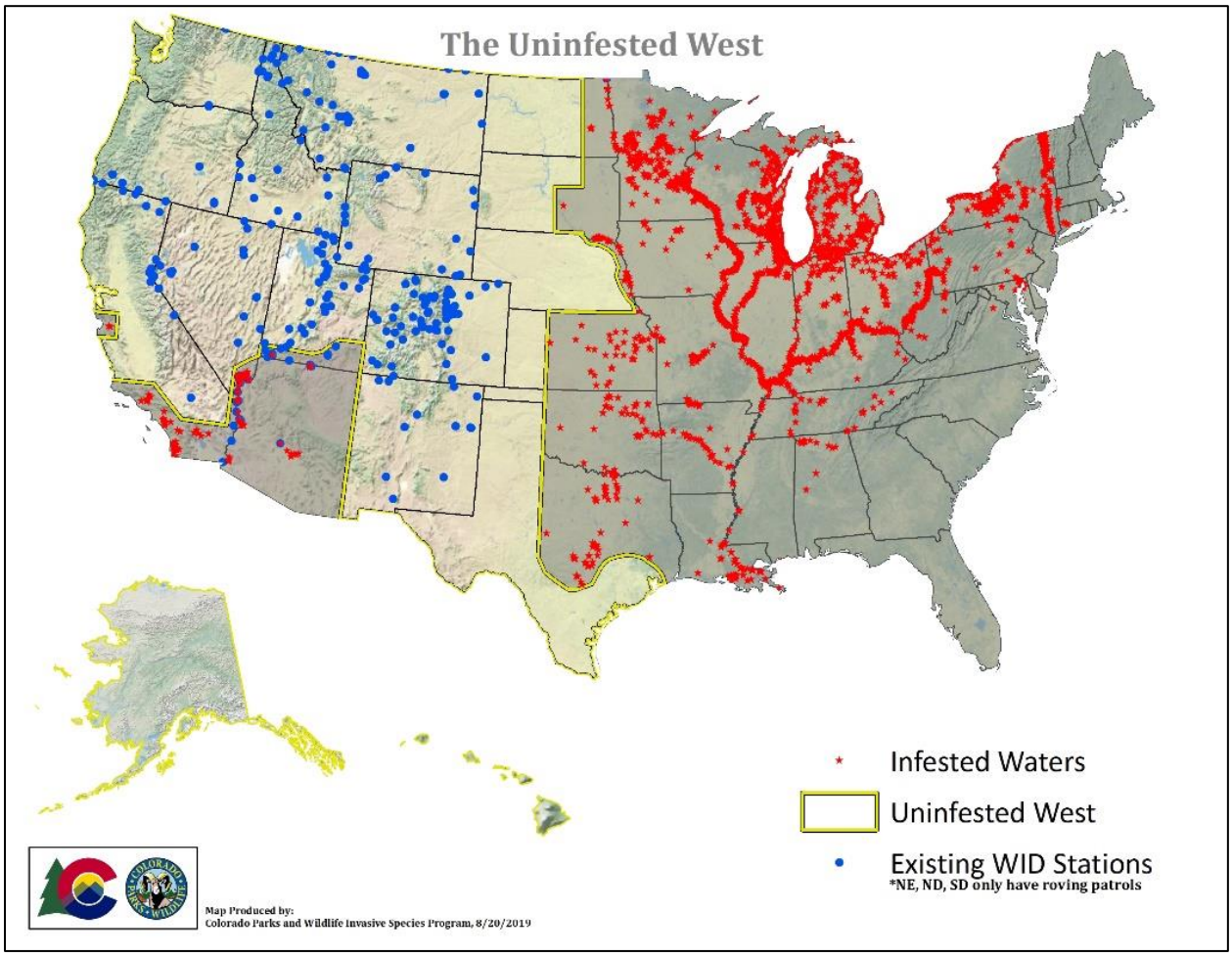
In addition, ANS already found in the Kansas River basin may spread and further impact aquatic resources within the basin. Climate change is likely to further exacerbate ANS issues in the Kansas River Basin in the future. Climate change facilitates the spread and establishment of ANS and creates new opportunities for species to become invasive.

Federal funding opportunities for state-lead ANS management have recently become available with other opportunities anticipated in the future. Among these are FWS grants, USBR grants, and USACE WRDA funds. However, utilizing these funds generally requires matching state dollars. Reduction or removal of these match-requirement hurdles would improve ANS management within the Kansas River Basin.

A robust, adequately funded ANS program that meets the goals of the Kansas ANS Management Plan would minimize ANS impacts to the Kansas River Basin. Other

western states that have invested heavily in building ANS programs have realized many benefits. Development of statewide watercraft inspection and decontamination programs, particularly in the western United States, has proven very successful in preventing the introduction and spread of ANS (as evidenced by Figure 3-343).

Figure 3-343. Water Inspection and Decontamination Stations and Infested Waters in the United States



3.11 Cultural Resources

3.11.1 Existing Conditions

The National Historic Preservation Act (NHPA) of 1966 (P.L. 89-665), as amended, directs federal agencies to assume responsibility for all cultural resources under their jurisdiction. Section 106 of NHPA, along with its implementing regulations, requires agencies to consider potential effects of their actions on historic properties, that is, those properties that are listed, or are eligible for listing, on the National Register of Historic Places (NRHP). Section 110 of NHPA requires federal agencies to develop a plan to inventory all federal land under their management to meet federally-mandated stewardship requirements.

The NHPA implementing regulations, 36 Code of Federal Regulations (CFR) Part 800, requires that federal agencies consult with the State Historic Preservation Officers (SHPO), appropriate Tribal Historic Preservation Officers (THPO), federally-recognized

Native American Tribes, and interested parties to ensure all historic properties, including historic properties of religious or cultural significance to Tribes, are adequately identified, evaluated, and considered in planning for proposed undertakings.

Cultural resources include both tangible and intangible cultural materials, including artifacts, archeological sites, buildings, ships, cemeteries, bridges and dams, works of art, and traditional cultural properties. The study evaluates cultural resources using NRHP eligibility criteria and NRHP makes a determination by assessing whether the effects of the undertaking on historic properties will be adverse. NRHP consults with the SHPO regarding these effects and any actions that might treat or mitigate them.

The NRHP eligibility criteria (36 CFR 60.4) examines a cultural resource's significance in American history, its architecture, and archaeology. NRHP ensures cultural significance is present in districts, sites, buildings, and objects of state and local importance and that they possess aspects of integrity of location, design, setting, materials, workmanship, feeling, and association. Cultural resources must:

- Be associated with events that have made a significant contribution to the broad patterns of a culture's history.
- Be associated with the lives of persons significant to a culture's past.
- Embody the distinctive characteristics of a type, period, region, or method of construction.
- Represent the work of a master or possess high artistic value.
- Represent a significant and distinguishable entity whose components may lack individual distinction.
- Have yielded, or may be likely to yield, information important in prehistory or history.
- Be at least 50 years old, unless exceptional circumstances are present (Criteria Consideration G).

Section 101(d)(6)(A) of NHPA, as amended, provides that properties of traditional religious and cultural importance to Native Americans be evaluated for potential inclusion on the NRHP.

3.11.1.1 Prehistory Background

The Kansas River Basin is located within the Central Great Plains, also known as the Central Plains. The prehistory of the Central Plains is divided into several periods, the names and dates of which vary from state to state, but this study defines as the Paleoindian, Archaic, Plains Woodland, Central Plains Tradition, and Late Prehistoric. The following discussion is based on chapters in *Archeology of the Great Plains* (Wood 1998). The earliest unequivocal evidence of habitation in the Central Plains region is during the Paleoindian period, 11,500 to 8,500 years before present (B.P.), which began as the last ice age was ending. People of this period are characterized as hunter-gatherers of now-extinct megafauna, such as mammoths and giant sloths, who used distinctive, lanceolate-shaped spear points. The Archaic period, 8,500 to 2,500 years B.P., is characterized by an increase in population, larger seasonal encampments, as well as a broader food economy entailing a shift toward foraging and cultivation of

native plants. The Plains Woodland period, 2,500 to 1,000 years B.P., is characterized by the widespread use of pottery, mound construction, permanent village settlements, beginnings of maize cultivation, introduction of the bow and arrow, and trade of exotic items from distant places. During the Central Plains Tradition period, 1,000 to 500 years B.P., some people lived in villages of earth lodges while maize agriculture intensified and was supplemented by new kinds of beans and squash. During Late Prehistoric times 500 to 300 B.P., most groups on the Central Plains intensified bison hunting. Some hunted seasonally from permanent villages and some were highly nomadic. These groups developed into the Plains Tribes who used horses and guns to hunt bison after contact with European explorers and traders. Prehistoric archeological site types range from small artifact scatters to seasonal camps with hearths and storage pits and villages with evidence of houses and trash middens, burial grounds, trails, and landscapes.

3.11.1.2 History Background

The earliest recorded European explorers on the Central Plains were of French and Spanish origin. The Louisiana Purchase of 1803 led to a cascade of changes for the Native American Tribes living east and west of the Mississippi River. A series of treaties shifted Tribes to the west and south to Indian Territory in Kansas and Oklahoma. Explorers, traders, miners, and farmers immigrated to the Central Plains. After the American Civil War, rail connections increased economic activities until major droughts and the Great Depression made farming unprofitable.

Some potential historic sites and district types in the Central Plains are houses, buildings, bridges, roads, trails, neighborhoods, mines, and canals. Additionally, the below-ground remnants of these sites may be potential historic archeological sites.

Today, there is low population density in the Kansas River Basin but there are hundreds of historic and prehistoric sites and cultural resource locations. These cultural resources may be eligible for inclusion on the NRHP.

3.11.1.3 Previous Investigations

A summary of sites, (excluding archeological sites) structures, buildings, objects, and districts in the Kansas River Basin listed on the NRHP (taken from the National Park Service website) is presented in Table 3-160. Archeological sites are included in Table 3-161.

National Historic Landmarks (NHLs) have national significance greater than those listed on the NRHP and are subject to slightly different cultural resource laws. As of October 2019, the NHLs in the Kansas River Basin include one in Colorado, eleven in Kansas, and three in Nebraska.

Archeology site and survey data from the three states within the Kansas River Basin were obtained from different sources. The Office of Archaeology and Historic Preservation provided the Colorado data. The Kansas data is from the Kansas Historical Society. History Nebraska provided source data for the State of Nebraska. The offices in Nebraska and Colorado provided the numbers of archeological surveys and archeological sites and indicated how many of those sites are listed on or are eligible for the NRHP. The Kansas data is on-hand in USACE records, so the site and

survey numbers were derived from USACE (Table 3-161). The number of NRHP-eligible archeological sites is not available for Kansas.

Table 3-180. Summary of NRHP-Listed Properties in the Kansas River Basin (current as of October 2019)

State	Buildings	Structures	Sites*	Objects	Districts*	Landmarks
Colorado	18	1	0	1	4	1
Kansas	491	58	21	1	31	11
Nebraska	158	22	5	0	14	3

*Does not include archeological sites or districts listed on the NRHP

Table 3-181. Summary of Archeological Surveys and Sites within the Kansas River Basin (current as of October 2019)

State	Square Miles	Archeological Surveys	Archeological Sites	NRHP-Listed[1]	NRHP-Eligible
Colorado	8,798	585	1,322	26	45
Kansas	35,017	1,839	7,307	23	not available
Nebraska	15,264	1,569[2]	2,478	9	193

[1]Archeology sites and districts
[2]Since 1988

3.11.2 Future Without Project Conditions

Under FWOP, erosion and sedimentation would continue at current rates and continue to impact cultural resource sites. Prehistoric habitation sites are often located close to sources of permanent water, putting them at high risk of water-related impacts. Individual historic habitation sites may be located away from streams and rivers, but villages and towns developed prior to railroad development were often located along rivers for trade and transportation needs, therefore they are also susceptible to impacts.

At reservoirs and rivers, erosion and wave action can impact shoreline sites adversely. Wave action can undercut vertical banks causing sediment slumps that might include cultural resources. Erosion at sites on level grades is less dramatic but can adversely affect sites over time. Reservoir operations, such as maintaining pool levels, can influence the elevation of the wave action. Similar erosion and wave action can occur along rivers and streams, which exacerbates deeply incised streams. Streambank erosion can also be caused by stream channels migrating into outside bends, revealing previously undisturbed deposits. Low water levels can cause erosion at sites covered by water or alluvium and can expose sites to looting. Burial by sedimentations protects shipwrecks and very old prehistoric sites; however, deep burial can also make sites harder to detect and evaluate prior to beginning federal projects that require deep excavation. Floods and droughts can exacerbate the effects of erosion and looting.

During recent work at Harlan County Lake, Nebraska, (Historic Properties Management Plan [HPMP]; Lopinot et al. 2019), the rates of erosion were measured using historical aerial photographs georeferenced into ArcGIS. Between 1993 and 2016, an average of 0.5 feet to 0.6 feet per year of shoreline was lost from 145 inspected areas around the lake. Erosion this severe is detrimental to the integrity of cultural resource sites and can also expose the sites to looting.

The Coffey site (14PO1), located on the Big Blue River at Tuttle Creek Lake in Kansas, was discovered due to lateral migration of the river into cultural deposits. Excavation at the site revealed thousands of years of human occupation representing an important environmental transition in the mid-continent. Approximately 150 feet of the bank has eroded since 1950 (Mandel 2010).

Cultural resources would benefit from a watershed study because effects from a broader, integrated, system-wide point of view will be considered instead of the typical project-by-project approach. The individual projects anticipated for production through a watershed study, such as infrastructure for water supply or flood risk management, are frequently under the purview of NHPA Section 106, as they often occur on federally-owned land or require federal permits. Consultation with the relevant federally-recognized Indian Tribes, THPOs, and SHPOs should occur during the planning process.

4.0 RISK ASSESSMENT AND UNCERTAINTY EVALUATION

Identification of the highest risks with focus on near-term, corrective efforts ensures prioritization of water resource problems and determines subsequent actions. Near-term efforts are those arising in the next one to ten years. Risk conditions currently exist within the study area, with the potential for increased probability of risk event occurrence and associated consequences under future conditions. These risks, identified and evaluated through review of existing documentation, new assessments, and a series of partner and stakeholder engagement meetings, largely fall within three categories: economic, social, and environmental. This aligns with benefit categories defined in the USACE Policy Memorandum “Policy Directive–Comprehensive Documentation of Benefits in Decision Documents”, dated January 5, 2021, which calls for, “equal consideration of economic, environmental, and social categories.” The principles of this policy directive were applied to inform the risk-based prioritization of identified problems.

A series of six interdisciplinary workshops, called charettes, were held with study partners and external stakeholder and agency subject matter experts to gain input on the problem categories, prioritize areas of risk, and develop an initial array of recommendations. Partner and subject matter experts at these meetings identified stressors and later validated the risk assessment.

4.1 Stressors

The study team, in conjunction with input from partners and stakeholders in the charettes, identified a set of stressors for each problem category. For the purposes of this watershed study, stressors are conditions or events that occur because of the driving problem category. Tables 4-1 through 4-5 outline identified problem statements and associated stressors.

Table 4-1. Flood Risk Problem Statement and Stressors

Flood Risk: Flooding is a reoccurring challenge in the Kansas River Basin that can be costly, both in property loss, and more significantly, in life loss. Flooding events in the Kansas River Basin cause riverine and overland flooding and high reservoir water levels that threaten life safety, and damages homes, businesses, public facilities, agricultural lands, and critical infrastructure (roads, railroads, utilities). Flooding displaces individuals and businesses, damages cultural resources, increases environmental degradation, and causes public health issues.
Stressors
Riverine Flooding: The entire Kansas River Basin is subject to severe riverine flooding at infrequent intervals erratically interspersed by less severe floods of varying magnitudes. Flooding is a reoccurring challenge in the basin that can be costly, both in property loss and, more significantly, in loss of lives. Floods in the basin damaged millions of dollars of private property and crop land as well as critical infrastructure, such as interstate highways, railroads, and state highways. Flooding displaced individuals, impacted delivery of services, and caused repetitive losses in many areas in the basin. Additionally, floods caused damages and lost revenue at recreational facilities managed by federal and state agencies, private entities, and non-profit organizations. The most obvious threat to health and safety is the danger of drowning in flood waters. Swiftly flowing flood waters can easily overcome even good swimmers. If flooding occurs suddenly, people may become trapped in their homes and drown. Additionally, when people attempt to drive through flood waters, their vehicles can be swept away in as little as two feet of water.

High Reservoir Water Levels: The lower Kansas River reservoir system (Milford, Tuttle Creek, Perry, and Clinton) operates to provide flood protection for the Kansas and Missouri rivers. High rainfall events leading to extended periods of storing inflows in the reservoirs causes extended periods of elevated pool elevations and adds to the risk of large surcharge releases from these projects. Extensive impacts can occur when high reservoir water levels happen, causing damages and lost revenue at facilities managed by federal and state agencies, private entities, and non-profit organizations. High water levels damage roadways and utility services surrounding the reservoirs. Additionally, agricultural lands in the upper regions of the reservoirs flood during high reservoir water levels, causing damages and loss of revenue to producers on these lands.

Missouri River flood criteria exists for the Kansas City and Waverly gages. Sometimes, elevated Missouri River flows keep the lower Kansas tributary project releases at low-flow levels for weeks or months on end. That extended period of storing inflows causes extended periods of higher pool elevations and adds to the risk of large surcharge releases from these projects.

Climate Change Implications—Increasing Risk to Urban Areas and Agricultural Lands: Climate change in the basin will show increasing temperatures and precipitation, resulting in increased frequency of extreme storm events. These extremes in climate will result in larger, more extensive storms and increases in streamflow in the basin, particularly for the Republican River and the lower Kansas River. Larger flood volumes in the future could cause higher pool elevations at reservoirs and an inability to contain flood events, with more frequent occurrence of surcharge releases and uncontrolled flows.

Hundreds of levees exist within the basin ranging in size from small agricultural levees to protect farmland to large urban levees constructed to protect people and property. Damages to levees have occurred during past flood events, causing life safety risks and property damages in the areas where water flowed behind leveed areas. With larger flood events caused by climate change, higher water surface elevations have a greater probability of overtopping and will cause longer loading durations on existing levee systems, increasing the likelihood of levee breach. Due to climate change, experts expect greater flood extents will occur in non-leveed areas, causing more damages to unprotected areas.

Flood Response Communications Issues: To better communicate risks to the public, improved communication, coordination, and planning between flood risk management entities and the public in the basin is needed. This includes improved flood forecasting, flood warning systems, and emergency action plans. Many communities do not have adequate warning and response tools.

Due to climate change, the need for improved communications will increase. The likelihood of more frequent activation of flood forecasting and warning systems and more frequent updates to emergency operations plans will also increase.

Sedimentation in Reservoirs and Downstream Erosion: To realize benefits provided by the reservoirs for flood risk management, in-basin reservoir sedimentation needs addressed. Sedimentation in the reservoirs threatens crucial flood risk management infrastructure. Sediment accumulation impedes maintenance of flood control gates and other appurtenances seriously impacting the flood risk mission of USACE. Without deliberate restorative action, sedimentation issues will increase operation and maintenance costs at reservoirs and in downstream river channels. Historical data and projected estimates indicate that the flood control pools in reservoirs will experience sedimentation, with some filling by as much as 17 percent over the next 100 years and experiencing greater frequency of higher water levels compared to existing conditions.

Channels downstream of most federal reservoirs in the basin experience bed degradation and bank erosion because of the sediment trapping in the reservoirs, with varying degrees of downstream bed and bank loss in different reaches. Degradation will continue, increasing risk to downstream infrastructure and uses. Downstream riverbed degradation can impact the long-term sustainability of flood risk reduction levees.

Table 4-1. Reduction in Ability to Meet Water Supply Demands Problem Statement and Stressors

Reduction in Ability to Meet Water Supply Demands: The water supply system throughout the Kansas River Basin is vulnerable to naturally occurring and anthropogenic stressors including reservoir sedimentation, drought, groundwater depletions, the risk of reduced water supply from navigation releases, and climate change implications. Lack of reliable water supply and shortages of water could have a devastating effect on the economy in the basin and the health and welfare of its citizens.
Stressors
Sedimentation: *Loss of Water-Supply Storage in Federal Reservoirs.* Every year, federal reservoirs lose thousands of acre-feet of water storage, as millions of cubic yards of sediment accumulate. All federal reservoirs in the basin have experienced loss of water supply storage and will continue to lose water supply storage in the future. The most extreme case being Tuttle Creek Reservoir, a vital source of water supply, will have only 25 percent of the multipurpose pool remaining in 50 years. In the future, increased sedimentation in reservoirs may not be able to meet water supply targets downstream for intake or reservoir levels in the multipurpose pools. Water storage may be depleted, causing impacts within the reservoirs to water quality, fisheries, and recreation. Lack of reliable water supply and shortages of water could have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Sediment management on the mainstem of the Kansas River is important to maintain infrastructure, including water supply intakes, irrigation diversion structures, and other uses such as recreation and ecological resources. An increase in more extreme flood events due to climate change would lead to an increase in sediment loading in reservoirs already impacted by current inflows of sediment. This will cause loss of additional storage.
Drought: *Societal Consequences and Economic Impacts Associated with Drought Risk*. Periods of drought are normal occurrences in all parts of the basin. Drought can adversely affect surface and groundwater supplies, farming and ranching, and uses of surface water for other purposes, like recreation. Many economic impacts have already occurred in agriculture and related sectors including losses in yields of crop and livestock production, leading to loss of income and increased food costs. Drought can severely impact public water supply through depletion of the raw water availability and increased customer water demand. Other associated problems that may increase water supply costs include limited treatment capacity or limited distribution system capacity. Planning for extreme events, like water conservation management planning that can secure and improve the reliability of water supply, is essential for the future prosperity of Kansas communities and the health of citizens.
Reduced Water Supply from Navigation Releases: Releases for navigation on the Missouri River can be made from Milford, Tuttle Creek, and Perry reservoirs. Currently, approximately 230,000 acre-feet is subject to these releases. If releases are made, the potential reduction in storage at the three reservoirs could lead to inadequate water supply for in-reservoir purposes like recreation and fisheries, and the ability of downstream releases to support water supply, water quality, fish and wildlife, and recreation. These effects are especially significant during drought periods when excessive drawdowns would decrease capability of meeting flow targets and reduce water supply resiliency for multiple communities.
Groundwater Depletion: Groundwater is the predominant public water supply source in many areas within the basin. Groundwater depletions in the basin have led to reductions in available water supply. Groundwater in the basin, primarily from the High Plains Aquifer, provides domestic, municipal, industrial, and agricultural purposes. In western Kansas, the primary source of water is groundwater drawn from wells that reach into the water-bearing aquifers, such as the Ogallala portion. Alluvial aquifers also supply water to many citizens in the basin where, in many parts, it is the only source of drinkable water for public water suppliers and individual domestic wells. Alluvial aquifers are recharged by flow in associated rivers and streams. Groundwater depletion led to loss of base stream flows, particularly in western Kansas, caused by groundwater irrigation for crop production and land practices. In recent years, drought has affected certain communities and regions of the basin on a recurring basis. With a recent drought event (2012-2013), there was a significant reduction in baseflow gain as irrigation demands increased, requiring significant sustained releases from federal reservoirs to maintain low-flow targets and ensure adequate supply to downstream municipal and industrial diversion points. With climate change, this may affect more regions of the state more often.
Climate Change Implications: Lack of reliable water supply and shortages of water could have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Every industry from agriculture, electric power generation, manufacturing, and tourism relies on water to grow and sustain business. Under climate change there would be an increase in the occurrence of drought periods with longer more severe droughts expected. This will cause lower inflows in reservoirs and potentially a lack of water available to support reservoir releases and withdrawals, causing inadequate water supply for users in the basin.

Table 4-2. Degraded and Poor Water Quality Problem Statement and Stressors

Degraded and Poor Water Quality: Water quality throughout the Kansas River Basin is vulnerable to naturally occurring and anthropogenic stressors including HABs, impaired waters, risk to high quality water, stormwater management, and sedimentation. There is a risk, with loss of reservoir storage and future water shortages, of a reduced ability to meet water quality needs within the basin during times of extended drought and to maintain a base level of streamflow. Currently 17 of the 18 federal reservoirs in the basin are considered as impaired and, with expected sedimentation in reservoirs, there could be a reduction in their ability to provide current benefits of chemical buffering
Stressors
Harmful Algal Blooms: HABs continue to plague the region, with many reservoirs experiencing blooms. If conditions lead to a decrease in reservoir volumes and streamflow during drought or low inflow periods, this could lead to an increase in nutrient concentrations and an increased frequency and intensity of HABs.
Impaired Waters: Negative impacts from degrading and poor water quality conditions can increase costs to treat water for public water supply needs, decrease yields for agricultural producers, decrease recreational opportunities, increase fish consumption advisories, and diminish biological diversity in streams and reservoirs.
Water Shortages (Causing Reduced Availability of High-Water Quality for Residential, Commercial, Industrial, and Recreation Uses): Water quality storage maintains minimum flow targets on the Kansas River downstream of the reservoirs. As water quality conditions degrade in reservoirs, use of water from that source, as well as uses downstream, negatively impacts water quality conditions. A decrease in water volumes in reservoirs and streams could lead to increased nutrient concentrations with an increase in water quality degradation. Lower reservoir storage volumes would decrease the ability to maintain water quality reservoir releases.
Inadequate Stormwater Management: Absence of appropriate stormwater management in some areas contributes to degradation in water quality and supply. Pollutants from housing and urban areas, industrial sources, and agricultural activities can end up in water sources, changing water chemistry and thereby impacting aquatic vegetation, invertebrate communities, amphibians, and fish. Pollution can be from direct and indirect sources, which can make it difficult to identify, quantify, and remediate.
Sedimentation: Water quality storage maintains minimum flow targets on the Kansas River downstream of the reservoirs. As accumulation of sediment reduces storage capacity of reservoirs, water quality problems will intensify as reservoir temperature increases. Currently, only Tuttle Creek Reservoir has a portion of the multipurpose pool allocated for water quality. This water quality allocation is too small to support low-flow targets on the lower Kansas River through a drought. Milford and Perry reservoirs' water supply storage volumes provide water quality releases to support minimum flow criteria on the Kansas River. With current sedimentation at Tuttle Creek Reservoir, the water quality allocation will be further reduced, and less water will be available to support downstream uses. Additionally, in the future, the remaining water supply storage may be used for water supply further reducing the availability of water for water quality purposes.

Table 4-3. Ecosystem Degradation and Species Impact Problem Statement and Stressors

Ecosystem Degradation and Species Impact: Changes, loss, and fragmentation of terrestrial and aquatic habitats in the basin led to habitat degradation, loss of heterogeneity, and loss of connectivity of these habitats, leading to declines in species populations in the Kansas River Basin. Invasive and non-native species caused declines in native species and degradation of terrestrial and aquatic habitat.
Stressors
Loss of Riverine and Floodplain Habitat Leading to Species Declines: Historically, there has been a substantial loss and fragmentation of terrestrial and aquatic habitats in the basin from agricultural conversion, urban development, and construction of dams and levees. This led to a reduction in native plant and animal populations. Dams and the use and management of water in the basin has replaced stream and floodplain habitats which affects the timing and volume of downstream flows, as well as timing the volume of water within the reservoirs, affecting fish and wildlife and their habitats. Many streams in the basin experience areas of streambank erosion and head-cuts. Excessive erosion caused stream reaches to become incised, reducing floodplain connectivity and the quality and quantity of riparian habitat. Currently five federally-threatened and seven federally-endangered species inhabit the basin. Designated critical habitats are in a variety of locations in the basin, including the Kansas River and other streams in the watershed affected by reservoir management. Numerous state-listed species also live in the basin. Many of the listed species rely upon surface waters associated with basin streams and impoundments, adjacent riparian habitats, or wetlands for some portion of their life cycles. Sediment trapping behind reservoirs reduced the turbidity in downstream reaches, causing a reduction in species that were present in more turbid environments pre-impoundment. Lack of floodplain connectivity in river reaches below reservoirs led to loss of habitat and species that once thrived in these areas. Streambank erosion is a significant cause of reservoir sedimentation in the basin. Agricultural development and activity and urban

development in the watersheds above the reservoirs led to streambank erosion that contributes to sedimentation. Numerous head-cuts also occurred within in the basin on various streams above and below reservoirs, leading to loss of habitat. Sedimentation in reservoirs led to loss or changes of habitat for species and reductions in species requiring certain habitats for their life history needs, like cove habitats. As sedimentation continues under extreme conditions, as in Tuttle Creek Reservoir, the majority of the reservoir fisheries would disappear due to the highly reduced lake volumes and only areas of shallow water remaining. There are also barriers to aquatic species movement in rivers and streams in the basin, which fragment populations, prevent individuals from moving up and down river systems, and cutting off movement during droughts. Under climate change and during times of increased drought frequency, streamflow and reservoir levels are expected to decrease. This will lead to a decrease in suitable habitat for aquatic species and a decline of species. Drought conditions caused damages to plant and animal species, wildlife habitat, degradation of landscape quality, loss of biodiversity, and soil erosion. A drought period can last for months, years, or decades. The cost of drought locally and nationally is high, and, with climate change, the economic impacts could dramatically increase in the future.
Invasive and Non-native Species: Invasive and non-native species can degrade and impact natural ecosystem functions. Invasive species impact riparian areas by reducing streamflow, outcompeting native species, creating monocultural stands with little diversity, and reducing habitat richness that fish and wildlife species require. Aquatic nuisance species (ANS) in the basin threaten the diversity and abundance of native species, the ecological stability of infested waters, and recreational activities dependent on such waters. Several ANS have been introduced and dispersed in the basin. These species have few natural controls and spread rapidly, causing alterations to food webs, nutrient dynamics, and biodiversity. Invasive, non-indigenous plant species infest multiple impoundments within the basin. These species are known to reduce or clog water intakes, reduce property values, cause declines in native species, decrease spawning habitat, and reduce useable recreational areas on reservoirs. Currently, there is not enough funding or capacity of resources to manage, monitor, and enforce best management practices, like watercraft decontamination and inspection stations, to prevent the spread of invasive species such as zebra mussels. Under climate change, conditions could lead to changes in habitat and a potential for the increased spread of invasive species.
Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains: Seasonal patterns of high and low river flows support animal and plant lifecycles, preserve water quality, and maintain diverse habitats. Dams and the use and management of water in the basin replaced stream and floodplain habitats and affect the timing and volume of downstream flows, as well as timing the volume of water within the reservoirs, which affects fish and wildlife and their habitats.
Loss of Reservoir Fisheries Habitat Leading to Declines: Maintaining habitat for fish is important for reservoir sport fishery. Sedimentation in reservoirs has to impacts to fish populations. As shorelines erode, habitats such as coves, spawning habitats, and nursery habitats become inaccessible and cause the loss of fish habitat structure and vegetation. High-water events also impacted the fisheries, with flooding of habitat leading to reduced aquatic vegetation and entrainment of fish through the dam during high water releases. Low water conditions in reservoirs often leave areas dewatered for long periods of time and reduce primary productivity needed by the fisheries, thereby reducing habitat quality and diversity, which limits fish species abundance and welfare.
Groundwater Depletion: In western Kansas, the primary source of water is groundwater drawn from wells that reach into the water bearing aquifers. Many domestic, municipal, industrial, and agricultural purposes use groundwater. Groundwater depletion led to loss of base stream flows, particularly in western Kansas, from groundwater irrigation for crop production and land practices.

Table 4-4. Loss of Recreation Opportunities Problem Statement and Stressors

Loss of Recreation Opportunities: Flooding, low water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species threaten water-based recreational opportunities. These impacts cause a loss of visitation leading to lost revenue and high costs to repair damages to recreation facilities. Public lands providing recreation opportunities are rare in Kansas, with privately-owned lands accounting for most of the recreational opportunities. State-owned-and-controlled lands for recreation account for only 0.7 percent of the lands in the State of Kansas. Protection of federal and state public lands for recreation is imperative due to their scarcity. These lands must be managed in a way that promotes sufficient recreational opportunities to meet the needs of residents and visitors.
Stressors
Limited Public Lands: Currently, only a small amount of land is publicly owned and used for recreation (0.7 percent), limiting the opportunities to expand or replace any lost facilities when they are damaged from sedimentation or flood waters. Protection of federal and state public lands for recreation is imperative due to their

scarcity. These lands must be managed in a way that promotes sufficient recreational opportunities to meet the needs of residents and visitors.
Reservoir Sedimentation: To realize benefits provided by the reservoirs for recreation and fish and wildlife, sedimentation in reservoirs within the basin needs to be addressed. Sedimentation in reservoirs causes parks and private recreation facilities to close. Boating safety is also a concern with sedimentation. As sedimentation continues, these impacts will increase, and recreational opportunities will decrease in the basin.
Water Quality HABs: HABs can impact use of recreation areas in reservoirs, closing swim beaches, reducing boating activities, decreasing visitation, and causing lost revenue. HABs also cause health and safety concerns for those exposed causing illness and even death. The causes and treatment of HABs need further study and research.
Increased Operational Costs and Lost Revenues from Flooding and Drought: Floods caused damages to recreational infrastructure and facilities, increased operating costs, required closures, and lost revenue at recreational facilities managed by federal and state agencies, private entities, and non-profit organizations. There are limited opportunities to expand or replace lost facilities due to the very small portion of publicly-owned land in the basin. Droughts also caused impacts to recreation by reducing access to areas like coves and reducing the use of infrastructure like boat ramps. Droughts reduced fishing opportunities, caused hazards for boaters, impacted beaches, exposed shorelines, increased erosion potential, and reduced the aesthetic value of the reservoirs. During drought conditions, lakes with substantial sediment depositions—Tuttle Creek, Perry, and Kanopolis—are shallower, exacerbating adverse effects to lake access, boater safety, fish habitat, and recreation. Both drought and flooding adversely affect riverine recreational opportunities on the lower Kansas River, from either decreased streamflow or water levels that are too high to allow safe recreational activities. During drought conditions, when flows are low, water quality impacts cause unpleasant odors, impacting the recreation experience for boaters and paddlers. Flooding and high river flows cause unsafe conditions for people on the Kansas River and limit access for various activities including riverine access points, angling, hunting, and camping.

4.2 Risk Assessment Process and Evaluation

In collaboration with partners and stakeholders, this study qualitatively assessed stressors on risks relating to economic damage, social vulnerability, and environmental degradation. The risk assessment accounted for both probability or likelihood and consequence of the stressor's contributions to risk indices. Risk ratings were evaluated based on current circumstances and included flexibility for risks that are expected to worsen with exacerbated environmental stressors like climate change, population growth, and reservoir sedimentation. The three risk metrics of economic, social, and environmental were evaluated based on the criteria in sections 4.2.1 through 4.2.3.

4.2.1 Economic Risk

Economic risk estimates are the combination of probability and consequences of harm to property, infrastructure, and other assets, as well as to economic systems (measured in monetary terms) and are assured over a 50-year forecasting period of analysis, which spans from 2024 to 2074. Tables 4-6 and 4-7 show the ratings applied to each of the stressors for economic risk:

Table 4-5. Qualitative Probability Metrics for Economic Risk

Probability	Definition
Not Likely to Occur	A stressor would not occur or would happen infrequently and is not expected to increase in the future.
Moderate Chance of Occurring	A stressor has a moderate chance of occurring and contributing to the risk, with a slight increase in the future.
Likely to Occur	A stressor is likely to occur, will contribute frequently to the risk, and will increase in the future.

Table 4-6. Qualitative Consequence Metrics for Economic Risk

Magnitude of Consequence	Definition
No to Low Impact	No impacts are anticipated, or impacts are anticipated to affect a single, individual household or business.
Moderate Impact	Impacts are anticipated to affect a community or town.
High Impact	Impacts are anticipated to affect multiple areas within a watershed and are widespread.

4.2.2 Social Risk

Social risk includes social connectedness, health and safety, and subsistence. Social connectedness refers to a sense of connection to the community and neighborliness. This includes the displacement of people, businesses, and farms, and refers to loss of intangible cultural resources such as folklore, traditions, language, and cultural knowledge. Health and safety accounts for risks to human health and safety including effects on security, life, health, safety, and emergency preparedness. Subsistence includes the ability of individuals and communities to be self-sustaining, such as reliance on natural resources to support a community and livelihoods. Tables 4-8 and 4-9 display evaluation metrics used for social risk.

Table 4-7. Qualitative Probability Metrics for Social Risk

Probability	Definition
Not Likely to Occur	A stressor would not occur or would happen infrequently and is not expected to increase in the future.
Moderate Chance of Occurring	A stressor has a moderate chance of occurring and contributing to the risk, with a slight increase in the future.
Likely to Occur	A stressor is likely to occur or contribute frequently to the risk and will increase in the future.

Table 4-8. Qualitative Consequence Metrics for Social Risk

Magnitude of Consequence	Definition
No to Low Impact	No stressors are anticipated or, if they do occur, would cause temporary or short-term impacts to resources like utilities, roads, services, and agriculture and would not become more severe. Low probability that a stressor will result in any life loss.
Moderate Impact	A stressor that causes moderate and short-to-long-term impacts to resources like utilities, roads, services, or agriculture and may become more severe. There is a moderate risk to life safety from stressors.
High Impact	A stressor causes severe, long-term impacts to resources like utilities, roads, services, and agriculture and will become more severe. There is a substantial risk to life safety from stressors.

4.2.3 Environmental Risk

Environmental risk includes risk for ecosystem service impacts, habitat loss, species loss, and cultural resources loss. Ecosystem services refers to the various benefits provided by certain environmental and natural resources to communities. Cultural

resource loss encompasses the damage or loss of tangible cultural resources. Tables 4-10 and 4-11 show evaluation metrics used for environmental risk:

Table 4-9. Qualitative Probability Metrics for Environmental Risk

Probability	Definition
Not Likely to Occur	A stressor would not occur or would happen infrequently and is not expected to increase in the future.
Moderate Chance of Occurring	A stressor has a moderate chance of occurring or will happen more frequently and may increase slightly in the future.
Likely to Occur	A stressor is likely to occur and will contribute frequently to the risk. It will increase in the future.

Table 4-10. Qualitative Consequence Metrics for Environmental Risk

Magnitude of Consequence	Definition
No to Low Impact	No impacts are anticipated or, if they do occur, would cause temporary or short-term impacts to resources like habitats, species, ecological processes, and cultural) and would not become more severe.
Moderate Impact	A stressor that causes moderate, short to long-term impacts to resources like habitats, species, ecological processes, and cultural) and may become more severe.
High Impact	A stressor that causes severe, long-term impacts to resources like habitats, species, ecological processes, and cultural) and will become more severe.

4.2.4 Risk Assessment Results

Economic, social, and environmental risks received equal consideration; therefore, the problems and stressors ranked as the highest relative risk from any metric were categorized as high. Moderate or low problems and stressors are those for which no relative risk ranking fell among the highest risks. The categories help prioritize strategy implementation that USACE and partners agree are imminent.

The risk assessment used smaller geographic areas in the study area. The geographic areas used include the regional planning areas (RPAs) in the state of Kansas (Figure 4-1). Five RPAs occur within the Kansas River Basin. East to west and north to south, these include the Kansas RPA, Solomon-Republican RPA, Smoky Hill-Saline RPA, Upper Republican RPA, and the Upper Smoky Hill RPA. A Regional Advisory Committee represents each RPA and is made up of groups of local stakeholders representing the varied local water-related issues. The RACs identify and prioritize goals to address water needs in their respective areas and develop regional action plans to meet those goals. One geographic area represented the Upper Republican and the Upper Smoky Hill RPAs for the risk assessment, as they are highly similar in the risks identified.

This study qualitatively considered stressors with risks assessed as likely to occur and with a consequence of high impact important to address and prioritize. For economic metrics, the risks were stressors that are likely to occur and increase in the future and will contribute frequent harm or damage to property, infrastructure, and other assets, as

well as economic systems (measured in monetary terms). These stressors will affect multiple areas within a watershed and become widespread. For social risks, the stressors are likely to occur and increase in the future, will contribute frequently to loss of social connectedness, potential life safety or life loss, have adverse effects to disadvantaged communities, will displace individuals, lessen the ability for subsistence. The ability for subsistence comprises the ability of individuals and communities to be self-sustaining. It is their reliance on natural resources to support community and livelihood. These stressors will cause severe, long-term impacts to resources like utilities, roads, services, and agriculture and will become more severe. Environmental risks include stressors that are likely to occur and increase in the future, contributing frequently to ecosystem service impacts (the various benefits provided by certain environmental and natural resources to communities), habitat loss, and species loss, and would cause severe, long-term impacts to resources like habitats, species, ecological processes, and cultural). They will become more severe.

While still important to address, any risk considered lower risk and not a near-term priority (one to ten years), fell below the thresholds of likely to occur and high impact. The next section includes the risk assessments for each RPA.

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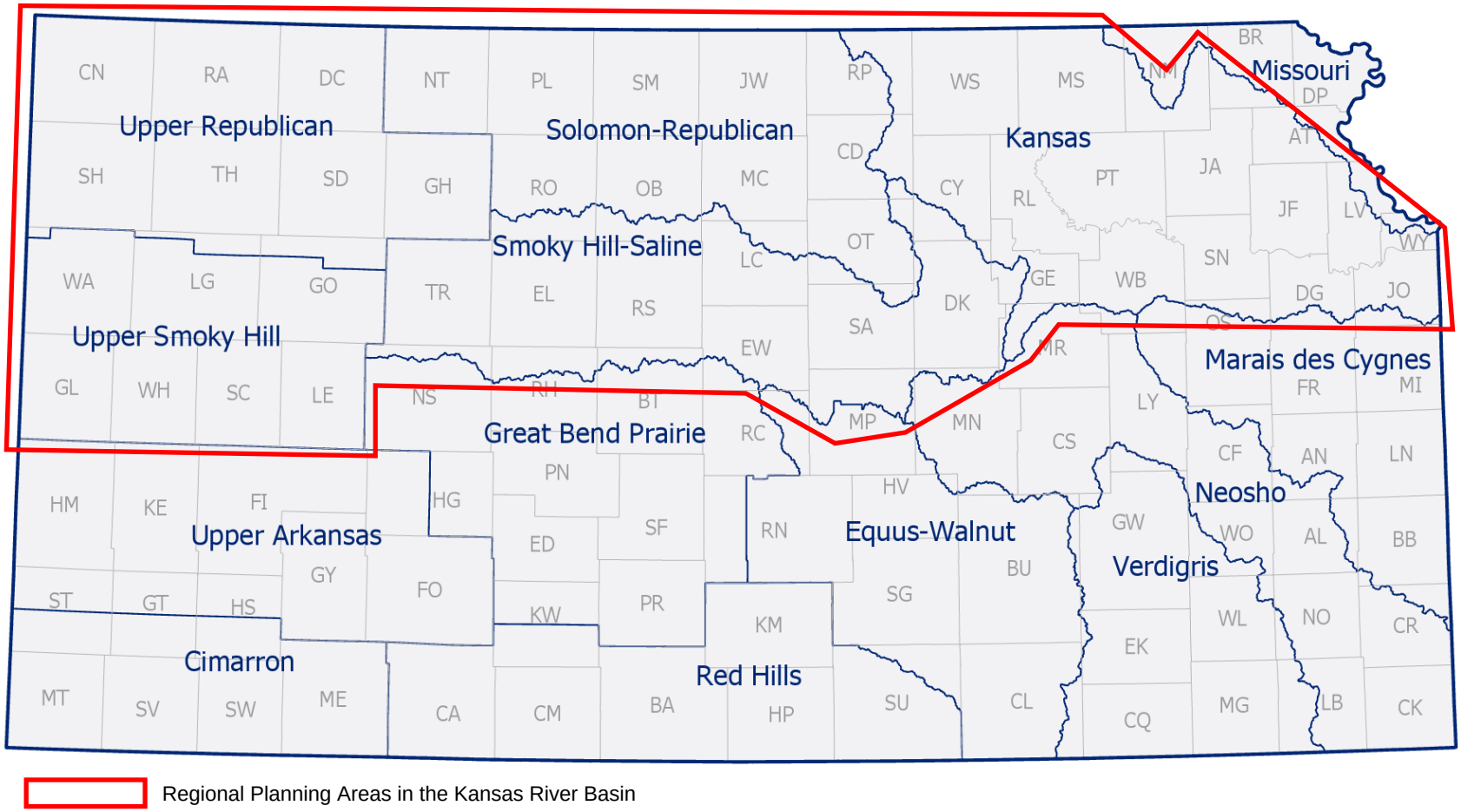
Figure 4-1. Kansas Regional Planning Areas



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4.2.4.1 Kansas Regional Planning Area

The Kansas RPA covers approximately 9,114 square miles of northeast Kansas. There are four major federal reservoirs in the region—the Milford, Tuttle Creek, Perry, and Clinton Reservoirs—and the Kansas River mainstem. These reservoirs provide and serve multiple purposes including flood control, water supply, irrigation, recreation, and fish and wildlife conservation. The Kansas RPA contains the major Kansas cities of Junction City, Manhattan, Topeka, Lawrence, and Kansas City, as well as Johnson County suburbs and many other smaller cities and towns. Tribal lands of Prairie Band Potawatomi and Kickapoo nations are also located in the Kansas RPA.

The Kansas RPA has the largest population of the 12 RPAs in the state of Kansas, with an estimated population of over one million residents. Trends in the Kansas RPA show population growth of greater than 30 percent over the next 30 years. A number of counties in the RPA—Pottawatomie, Geary, Douglas, and Leavenworth—are projected to experience this growth. Most other counties in the Kansas RPA should remain relatively stable with population changes of less than 15 percent. The RPA uses surface and groundwater equally. Municipalities have the largest water usage in the RPA, at 57 percent, followed by irrigation, 23 percent), and industrial, 16 percent). Increasing population and development in portions of the Kansas River corridor, along with aging reservoirs and public water supply infrastructure, indicate a need to evaluate the system capacity to meet future water supply needs in this RPA.

Economic drivers in the Kansas RPA range from agriculture in the upper and western portion to more commercial and industrial in the lower, eastern portion of the RPA. The Kansas River mainstem is in the Kansas RPA and serves as a critical drinking water supply for more than 800,000 people. The Kansas River is also used for irrigation, municipal wastewater, industrial discharges, cooling water for three coal-fired power plants, recreation, and as a source of commercial sand and gravel. Water-based recreation is important to the economy of the Kansas RPA, including at federal reservoirs, state fishing lakes, community lakes, and the Kansas River mainstem, which is designated as a National Water Trail.

Streambank erosion upstream of the reservoirs significantly contributes to the sedimentation in the Kansas RPA and is likely to occur with high impacts. Reservoir sedimentation in this RPA is a major concern, with loss of reservoir capacity occurring at a rate that will, in time, cause a shortage of reservoir storage to meet future projected demands. Sedimentation and erosion that causes streambank erosion, reduced flood and water supply storage in reservoirs, bed degradation downstream of reservoirs, degraded environmental resources, and loss of recreation is likely to occur with a high impact in the Kansas RPA. Sedimentation in the reservoirs threatens crucial flood risk management infrastructure, critical drinking water supply, irrigation, recreation, environmental resources, water quality, and power generation. Lack of reliable water supply and shortages of water could have a devasting effect on the economy in the Kansas RPA. Reservoirs with substantial sedimentation, like Tuttle Creek, will have shallower water in the future, exacerbating adverse effects to environmental resources and recreation. Expected future sedimentation at Tuttle Creek Reservoir would substantially reduce habitat for reservoir fisheries, with an almost complete loss of the fisheries in the future. Water quality will continue to degrade in reservoirs, rivers, and

streams due to reduced water supply in reservoirs and the ability to maintain minimum flow targets on the Kansas River downstream of the reservoirs, causing substantial economic impacts. Alternative water sources (water reuse systems, expanded transmission lines) needed in the future will be expensive to build. Due to a lack of sediment, river channels downstream of the reservoirs are suffering bed degradation and habitat impairment. Riverbed degradation has impacted the Kansas River mainstem and the tributary riverbanks, public infrastructure, and the long-term sustainability of flood risk reduction levees. Sedimentation has increased areas of shallow zones in reservoirs that reduce water quality. Without intentional restorative action to manage reservoir sedimentation, reduction of project benefits will occur and operations and maintenance costs will increase.

Flood risk related to public life safety and economic damages will occur, leading to economic impacts that are widespread with high consequences. From 1980 to 2021, six $1B flooding disaster events occurred in Kansas (KWO 2022). Flooding events in the Kansas RPA caused riverine and overland flooding and high reservoir water levels that damaged homes, businesses, public facilities, agricultural lands, and critical infrastructure like roads, railroads, utilities. Floods also caused damages to recreational infrastructure and facilities, increased operating costs, required closures, and lost revenue at recreation facilities managed by federal and state agencies, private entities, and non-profit organizations. The social risks in the basin are just as important as economic and environmental risks. Flooding in the basin poses a social risk from loss of social connectedness by isolating or displacing individuals due to damage to homes, businesses, infrastructure, property, power outages, and other utility impacts. Loss of a sense of connection to the community from these impacts is likely to occur in the RPA from stressors related to flood risk, sedimentation and erosion, reduced water supply, degraded water quality, and degraded ecosystems. Reduced recreational opportunities will continue in the future. Health and safety risks occurred in the basin and will likely continue in the future during flood events due to blocked roads to homes, hospitals, and other critical areas, power outages that prevent critical care services, including hospital functions and household medical equipment, damaged fire protection systems, structural instability, contamination of drinking water supplies, and injury to individuals (like hypothermia). Flooding can result in high impacts to river recreation, especially boating and other water-based activities. Hunters, anglers, and campers often utilize the sandbars, which are not available during high water events. Excessive flows prohibit people from accessing the river. Businesses and others benefiting from river trips, such as restaurants and retail establishments, experience a decrease in revenue during flooding. High reservoir water levels significantly impact reservoir recreation. These damages and lost revenues can last for long periods. The stressors related to riverine flooding and high reservoir water levels are likely to occur and have a high social impact in the Kansas RPA.

In addition to sedimentation, drought and climate change implications are likely to occur, causing high impacts in the Kansas RPA due to reduced ability to meet water supply demands and loss of recreational opportunities from these stressors. From 1980 to 2021, 17 $1B drought disaster events occurred in Kansas (KWO 2022). Lack of reliable water supply and shortages of water would have a devastating effect on the economy of the Kansas RPA. Every industry, including agriculture, electric power generation,

manufacturing, and tourism relies on water to grow and sustain business. A severe drought could limit water availability and would have more serious consequences for farmers. Significant critical infrastructure is located downstream of the federal reservoirs, including water and wastewater treatment plants, power plants, fire stations, schools, and military installation facilities. Surface water resources in Kansas serve as the source of municipal and industrial water supply for more than two-thirds of the state's population. The basin has repeatedly experienced droughts causing severe economic impacts. In recent years, drought-related agricultural losses in the basin have been significant, with billions of dollars in crop losses and livestock impacts. With approximately two-thirds of the Kansas population relying on surface water for municipal and industrial needs, depletion of these resources creates a significant strain on communities and businesses (KWO 2022). Droughts caused impacts to recreation by reducing access to areas and use of infrastructure at the federal reservoirs and on the Kansas River mainstem and reduced fishing opportunities.

Many of the rivers and streams and the four federal reservoirs in the Kansas RPA are listed as impaired waters. HABs also occur at various locations, with Milford Reservoir experiencing the highest number of HAB events in the state of Kansas. These stressors are likely to occur and have high impacts. Water quality and HABs are also a major contribution to loss of recreational opportunities. The federal reservoirs in this RPA are all designated as impaired from nutrient related impacts (excessive nitrogen or phosphorous, general eutrophication, excess chlorophyll or algae measures, and dissolved oxygen sags resulting from algae blooms. Inflowing streams are often impaired from a range of pollutants. HABs will continue to have economic impacts due to lost use of recreation areas in reservoirs (closing swim beaches, reducing boating activities), decreased visitation, and lost revenue. Negative impacts from the degrading and poor water quality conditions include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, and decreased recreational opportunities.

With a reduction in water availability from sedimentation and drought in the future, water quality impacts would lead to economic impacts from required closures, increased operating costs, lost revenue, and lost use of recreational facilities. Ecosystem degradation and species impacts would result in economic impacts. The loss of habitat and species from sedimentation, drought, climate change, reduced availability of water, and invasive species will require funding. The funding is needed for monitoring, habitat restoration, and to replace lost revenue related to loss of recreation (hunting, fishing, wildlife viewing). Figures 4-2 through 4-4 show the risk assessment results for the Kansas RPA. Because of the small amount of public land used for recreation in Kansas (0.7 percent) there are limited opportunities to expand or replace recreation opportunities in the basin, making it essential to protect these opportunities.

This RPA study assessed all stressors related to ecosystem degradation and species impacts as likely to occur and high impact with the exception of the stressor related to groundwater depletion, which has a moderate chance of occurring. Riparian and freshwater aquatic ecosystems are critical for maintaining health and sustainable habitat within the Kansas RPA. The loss of riverine and floodplain habitat, and of heterogeneity in hydrologic and geomorphic processes, led to declines or loss of native species, with

some becoming threatened or endangered (Pallid Sturgeon, Plains Minnow). It shifted the types of species that are more abundant (increases in species with less-specialized habitat needs). While survey efforts in the region are improving, there are still declines of species occurring and they will continue.

Many of the impacts and risks related to flood risk, the ability to meet water supply demands, degraded or poor water quality, ecosystem degradation, species impacts, and loss of recreational opportunities discussed for the Kansas RPA occur in the remaining three RPAs assessed for risk. The following sections highlight where these risks are the same and where they differ.

Figure 4-2. Kansas Regional Planning Area Economic Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

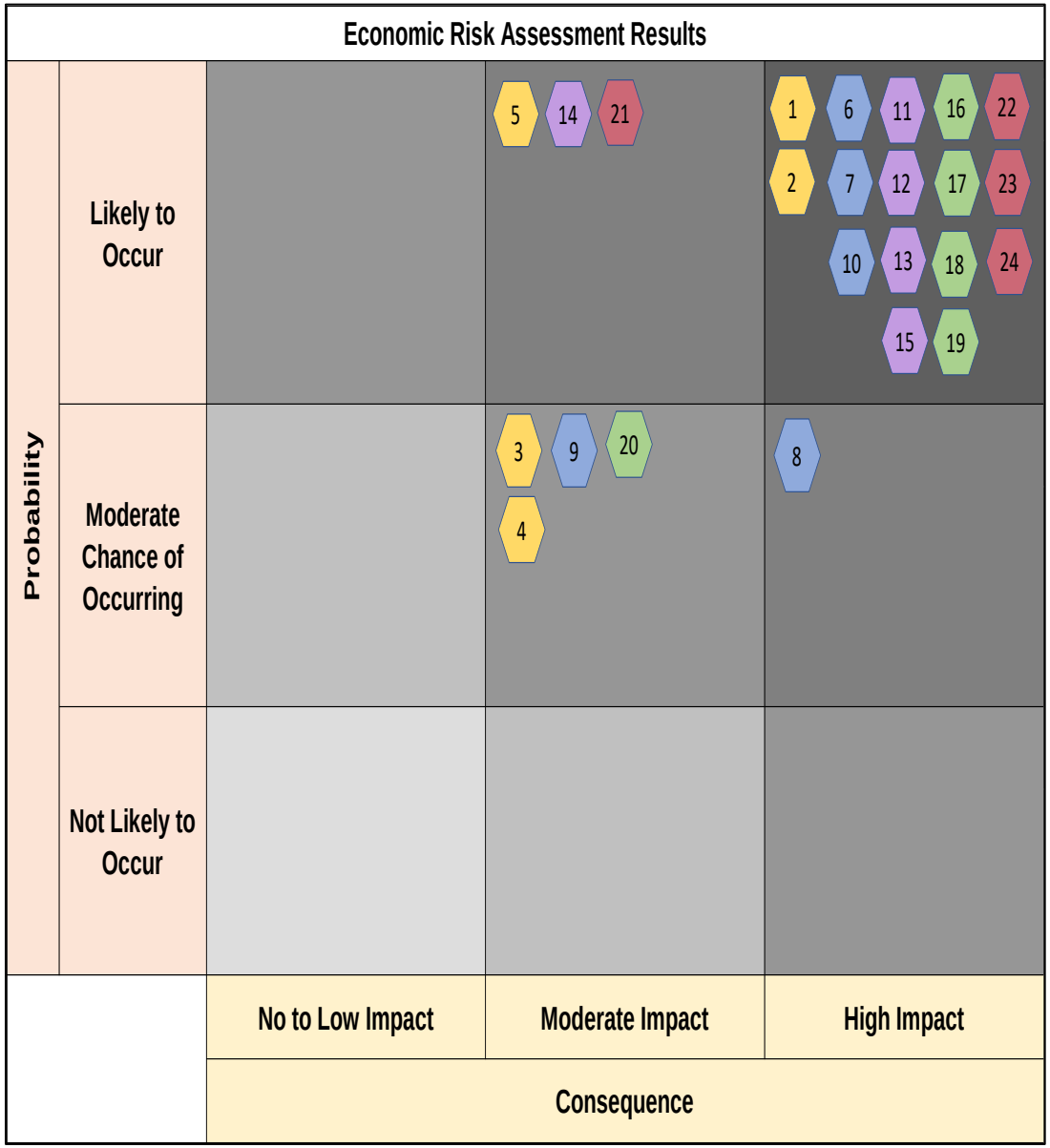


Figure 4-3. Kansas Regional Planning Area Social Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

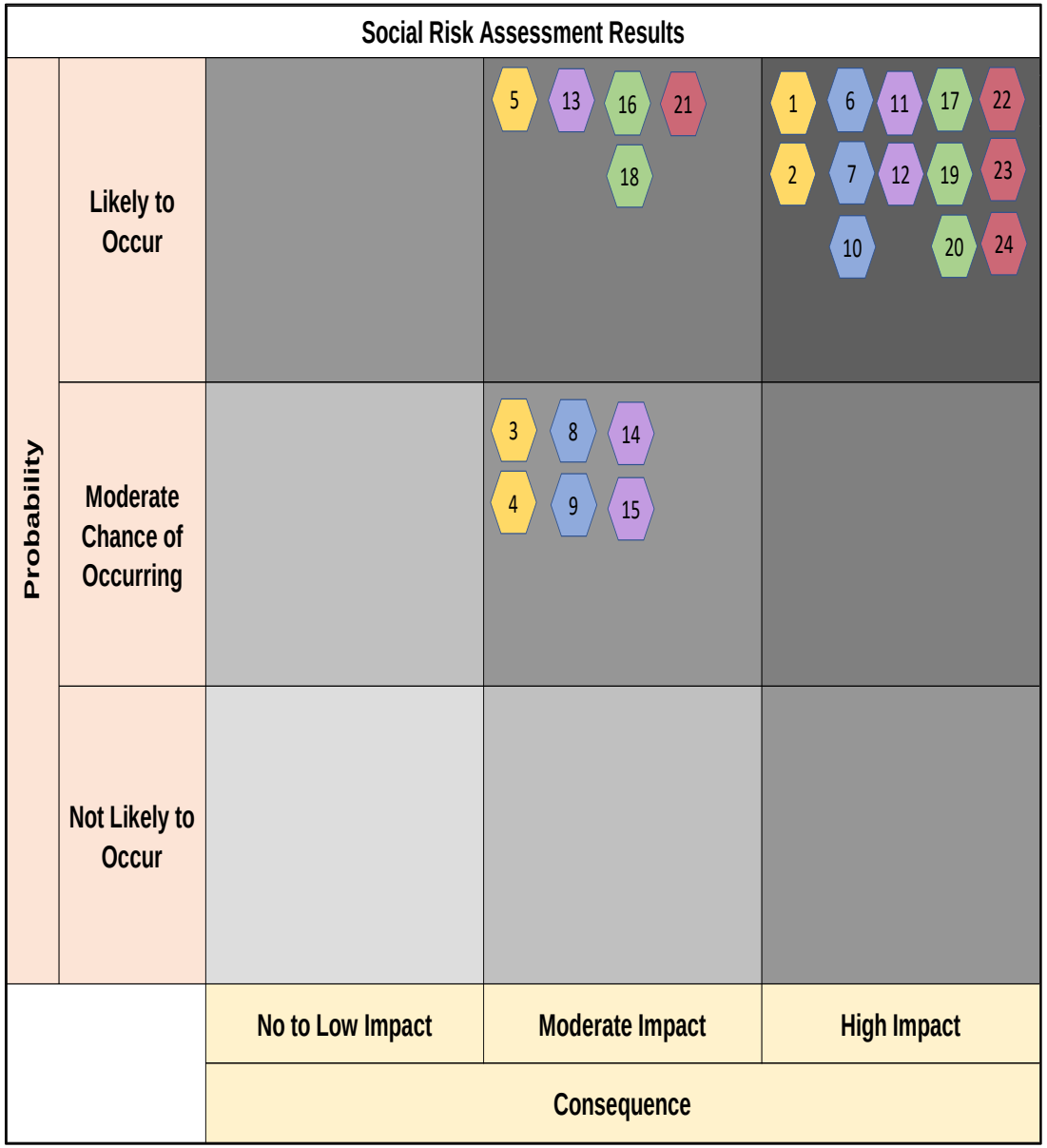
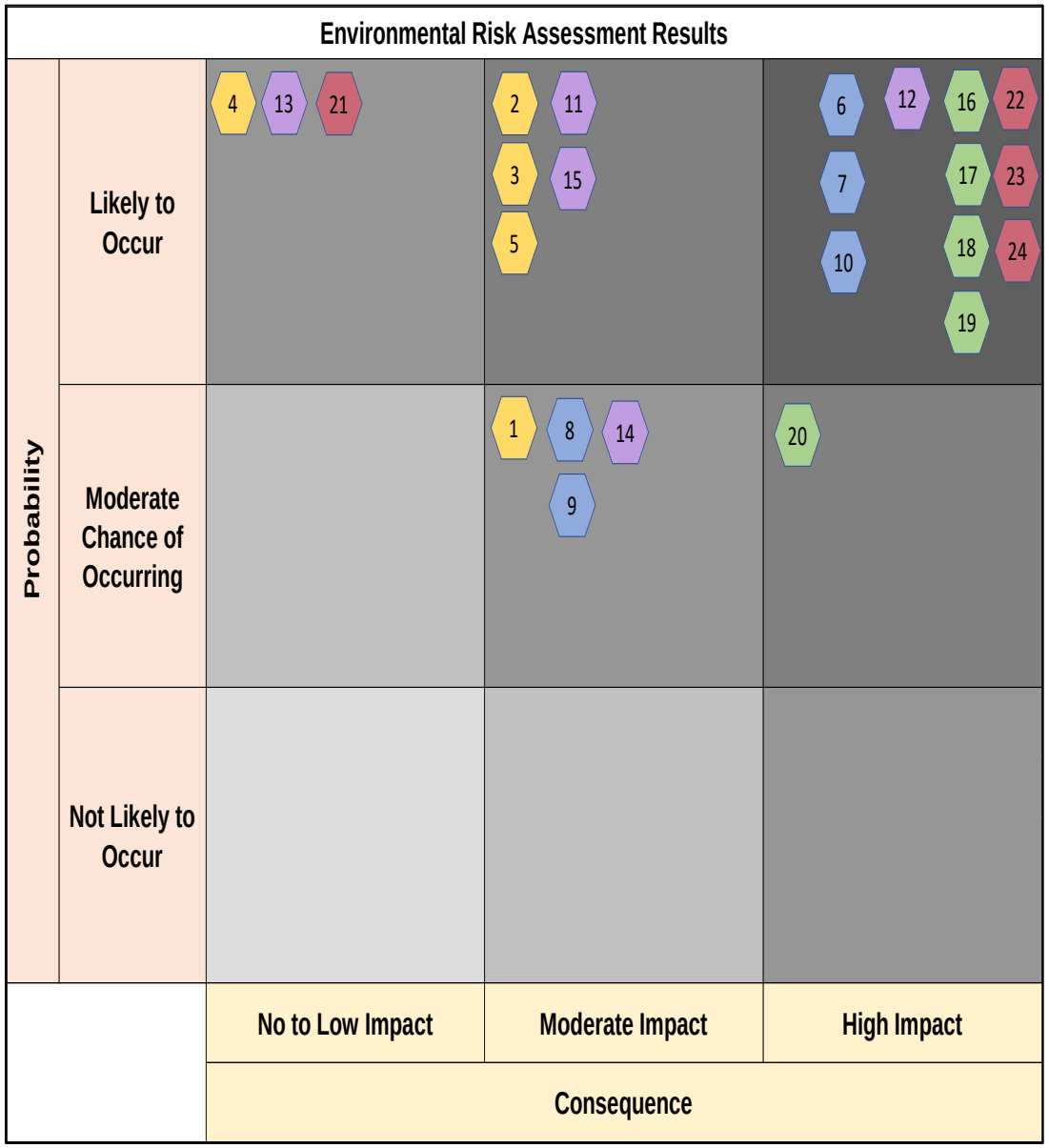


Figure 4-4. Kansas Regional Planning Area Environmental Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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4.2.4.2 Solomon-Republican Regional Planning Area

The Solomon-Republican RPA covers approximately 7,298 square miles of north-central Kansas. There are five major federal reservoirs in the region operated by the USBR—Lovewell, Waconda, Kirwin, Webster, and Keith Sebelius reservoirs. These reservoirs provide and serve multiple purposes, such as flood control, irrigation, recreation, and fish and wildlife conservation. The RPA contains numerous smaller cities and towns in Jewell, Norton, Phillips, and Smith counties, and portions of Cloud, Dickinson, Lincoln, Mitchell, Osborne, Ottawa, Rooks, Republic, and Saline counties.

The major land use activities in the Solomon-Republican RPA include cultivated crops at 51 percent, herbaceous vegetation, 41 percent) with the remaining 8 percent in forest, water, or developed, urban open space (KWO 2022). Population numbers in many of the central and western regions of the RPA peaked in the early 1900s and has been in decline since. Trends in the RPA show population growth will decline for nearly all counties in the Solomon-Republican RPA, with the most substantial decreases in Republic, Jewell, and Smith counties in the northern portion of the RPA. Dickinson County and Saline County populations will remain stable.

Agriculture is the predominant economic activity in the Solomon-Republican RPA with livestock production an important part of the agriculture. Water-based recreation is important to the economy of the Solomon-Republican RPA, including at federal reservoirs and state fishing lakes. The federal reservoirs and their associated wildlife areas attract hunters, fisherman, and boaters. Droughts causing declines in reservoir storage can limit recreation activity, causing high impacts economically, socially, and environmentally.

Streamflow in the Solomon-Republican RPA is dependent on runoff and climatic factors which vary widely year to year. Below average periods of precipitation need reservoir releases. While surface water is the primary source of water in the Solomon-Republican RPA, at 58 percent), groundwater is the primary source for most public water suppliers in the RPA, primarily coming from alluvial deposits along major streams and tributaries. The Dakota Aquifer that underlays the RPA has highly saline water, limiting use of this source (KWO 2022). Irrigation is the largest use in the RPA at 91 percent, followed by municipal use, and a minimal amount used for recreation, industrial, and domestic uses (less than one percent).

Runoff upstream of the reservoirs is the main contributor to the sedimentation in reservoirs in the Solomon-Republican RPA and is likely to occur more often in the future. However, most of the USBR reservoirs have relatively minor amounts of sediment projected to accumulate over the next 50 to 100 years, except for Waconda Reservoir, which could lose approximately 30 percent of the multipurpose pool storage in 50 years. Streambank erosion hotspots occur in the Solomon-Republican RPA and contribute to sedimentation downstream with most located on the Lower Republican River, which flows to Milford Reservoir in the Kansas RPA. Sedimentation and erosion cause streambank erosion, reduced flood and water supply storage in reservoirs, bed degradation downstream of reservoirs, degraded environmental resources, and loss of recreation and is likely to occur and have a high impact in this RPA. Sedimentation in the reservoirs threatens crucial flood risk management infrastructure, irrigation,

recreation, environmental resources, and water quality. Lack of reliable water supply and shortages of water could have a devasting effect on the economy in the Solomon-Republican RPA. Reservoirs with substantial sedimentation, like Waconda Reservoir, will have shallower water in the future, exacerbating adverse effects to environmental resources and recreation. Expected future sedimentation at federal reservoirs could reduce habitat for reservoir fisheries in the future.

Many of the rivers and streams, and the five federal reservoirs in the Solomon-Republican RPA, are on the impaired waters list, and HABs occur at various locations, including four of the five federal reservoirs in the RPA (Keith Sebelius, Kirwin, Webster, and Lovewell reservoirs). These stressors are likely to occur and have high impacts. The Conservation District and Watershed Restoration and Protection Strategy (WRAPS) have three partnership grant programs in the RPA that implement BMPs with an emphasis on nutrient and sediment load reductions (KWO 2022). Water quality and HABs also have a major contribution to loss of recreational opportunities. HABs will continue to have economic impacts from lost use of recreation areas in reservoirs (closing swim beaches, reducing boating activities), decreased visitation, and lost revenue. Negative impacts from the degrading and poor water quality conditions include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, and decreased recreational opportunities.

The flood risk in the Solomon-Republican RPA is similar to the Kansas RPA. Flood risk related to public life-safety and economic damages could occur, leading to economic impacts that are widespread with a high consequence. Flooding events in this RPA have caused riverine and overland flooding and high reservoir water levels that damaged homes, businesses, public facilities, agricultural lands, and critical infrastructure like roads, railroads, and utilities. Floods have also caused damages to recreational infrastructure and facilities, increased operating costs, required closures, and lost revenue at recreation facilities managed by federal and state agencies, private entities, and non-profit organizations. The social risks in the basin are just as important as economic and environmental risks. Flooding in the basin poses a social risk from loss of social connectedness by isolating or displacing individuals due to damaged homes, businesses, infrastructure, property, power outages, and other utility impacts. Loss of a sense of connection to the community from these impacts is likely to occur in the RPA from stressors related to flood risk, sedimentation and erosion, reduced water supply, degraded water quality, degraded ecosystems, and reduced recreational opportunities. Health and safety risks occurred in the basin and will continue during future flood events due to blocked roads to homes, hospitals, and other critical areas; power outages that prevent critical care services (hospital functions, household medical equipment such as oxygen supply); damaged fire protection systems; structural instability; contamination of drinking water supplies, and injury to individuals (hypothermia). The stressors related to riverine flooding and high reservoir water levels are likely to occur and have a high impact socially in the Solomon-Republican RPA.

In addition to sedimentation, drought and climate change are likely to occur, causing high impacts in the Solomon-Republican RPA because of reduced ability to meet irrigation and water supply demands and loss of recreational opportunities. Lack of reliable irrigation, water supply, and shortages of water could have a devastating effect

on the economy of the Solomon-Republican RPA. A severe drought could limit water availability, causing more serious consequences for farmers. The basin has repeatedly experienced droughts that cause severe economic impacts. In recent years, drought-related agricultural losses in the basin have been significant, with billions of dollars in crop losses and livestock impacts. Water quality will degrade in reservoirs, rivers, and streams because of reduced water supply in reservoirs from sedimentation and drought. The inability to maintain minimum flow targets downstream of the reservoir will have substantial economic impacts. Alternative water sources, like water reuse systems and expanded transmission lines, needed in the future are likely to be expensive to build.

With a reduction in water availability from sedimentation and drought, water quality impacts would lead to economic impacts from required closures, increased operating costs, and lost revenue at recreational facilities. Ecosystem degradation and species impacts would result in economic impacts. The loss of habitat and species from sedimentation, drought, climate change, reduced availability of water, and invasive species will require funding. The funding will be needed for monitoring, habitat restoration, and to replace lost revenue related to loss of recreation (hunting, fishing, wildlife viewing). Figures 4-5 through 4-7 show the risk assessment results for the Solomon-Republican RPA.

The risks related to environmental impacts might be as likely to occur with a high impact for stressors related to loss of heterogeneity in hydrologic and geomorphic process in rivers, streams, and floodplains. A moderate risk for stressors is expected, related to loss of riverine and floodplain habitat, which leads to species declines, invasive and non-native species issues, and loss of reservoir fisheries habitat. The loss of native prairies and playa wetlands in the region, including this RPA, led to declines and losses of native species, with some becoming threatened or endangered, like the northern long-eared bat, whooping crane, piping and snowy plover, Topeka shiner, least tern, eastern spotted skunk, plains minnow, shoal and silver chub, and western prairie fringed orchid. While survey efforts in the region have improved, there are still declines of species occurring, which will continue. These declines were assessed as a moderate chance of occurring but if it did occur, it would constitute a high impact. Most of the reservoirs in the Solomon-Republican RPA have low rates of sedimentation, which has less impact to reservoir fisheries. The main invasive species issues in the Solomon-Republican RPA are upland vegetation species.

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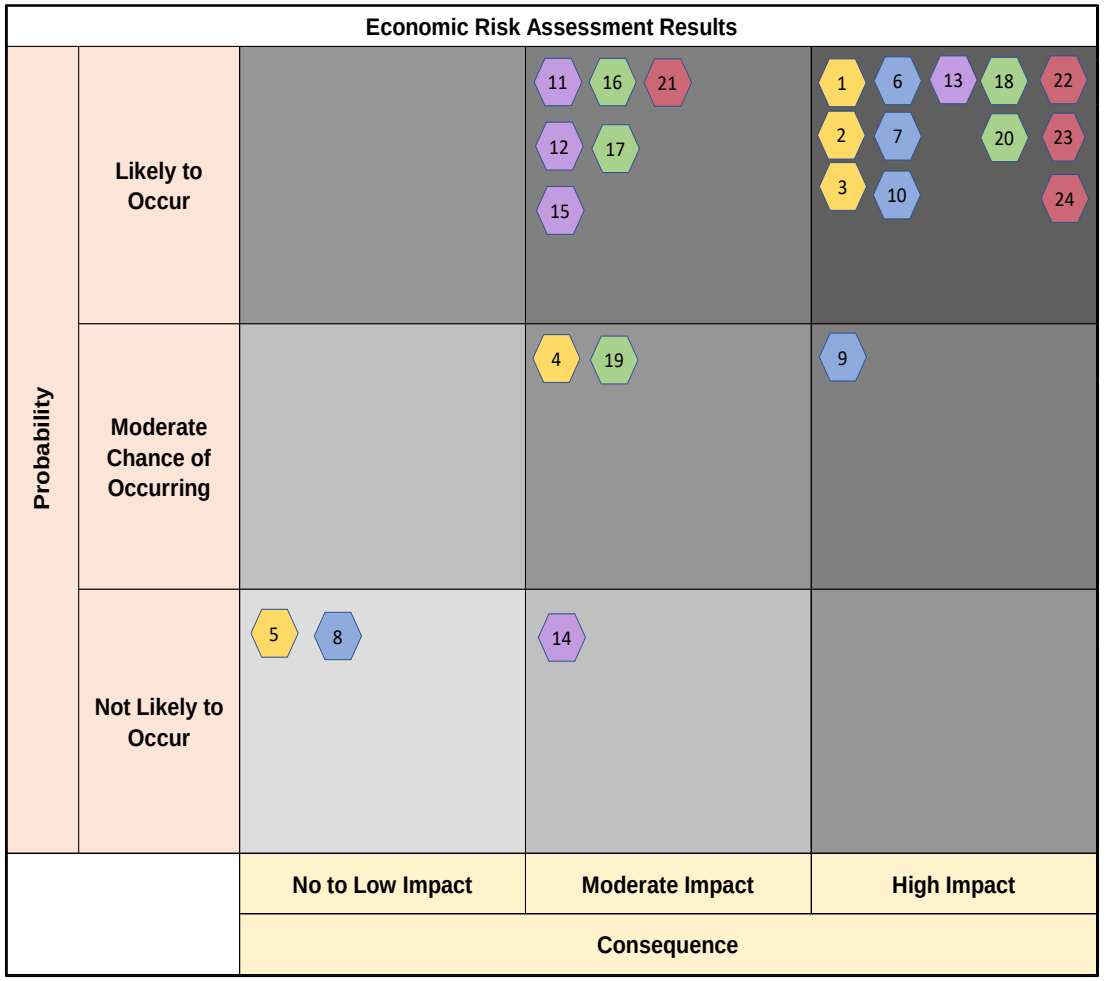
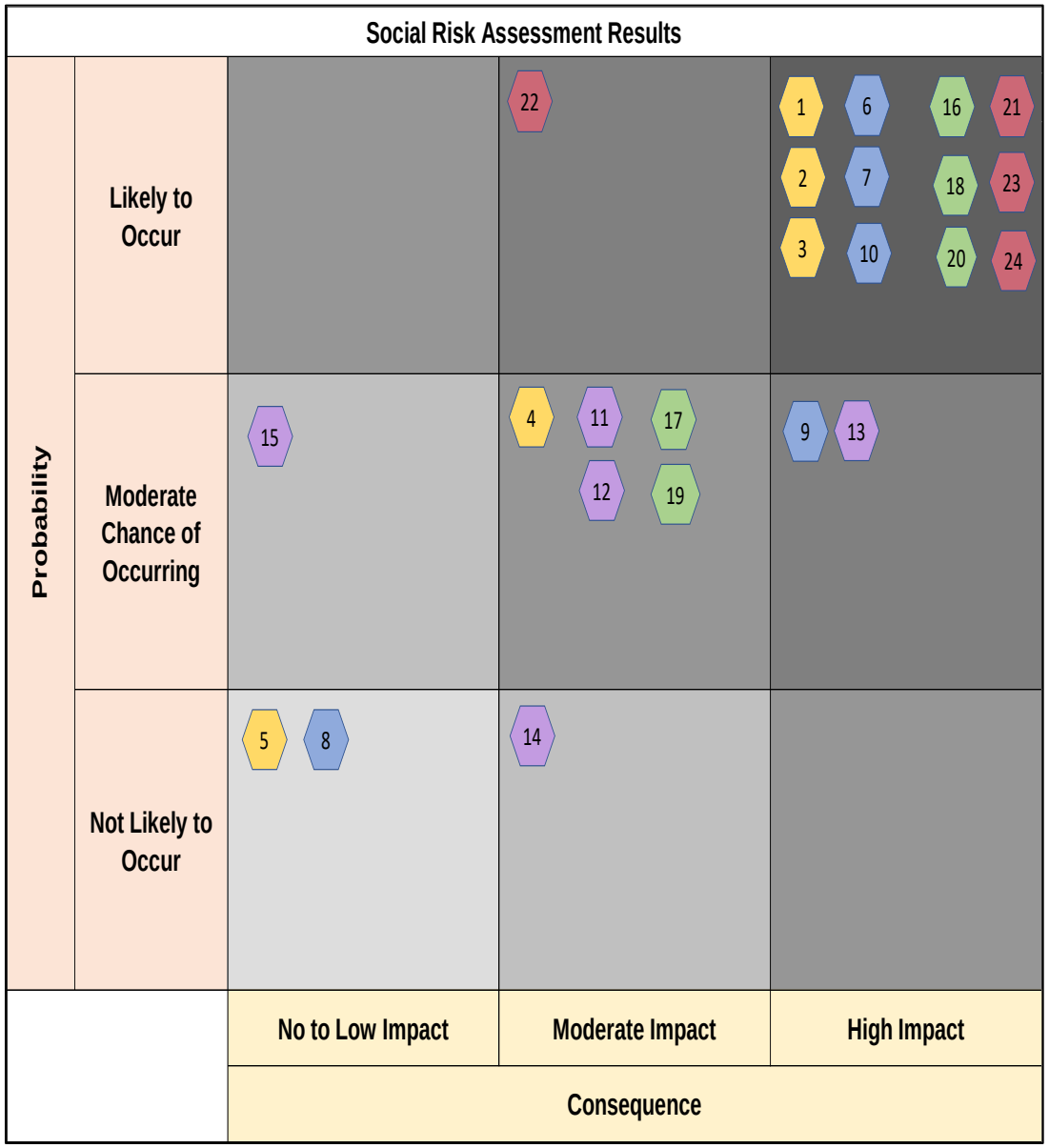
Figure 4-5. Solomon-Republican Regional Planning Area Economic Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



401 *Figure 4-6. Solomon-Republican Regional Planning Area Social Risk Assessment Results*

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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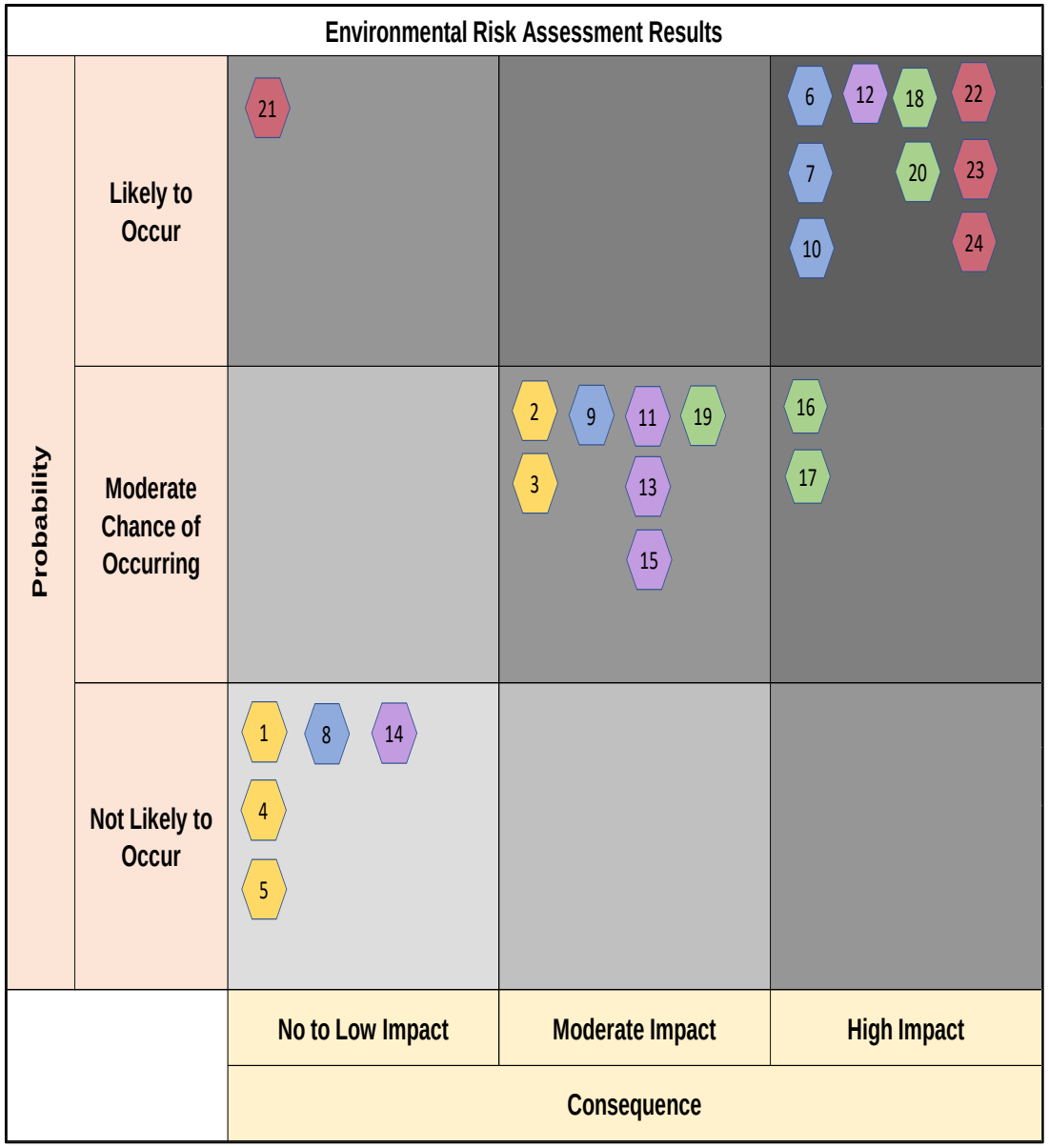
403 *Figure 4-7. Solomon-Republican Regional Planning Area Environmental Risk Assessment Results*

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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4.2.4.3 Smoky Hill-Saline Regional Planning Area

The Smoky Hill-Saline RPA covers approximately 7,240 square miles of central Kansas. There are two major federal reservoirs in the region operated by USACE—the Wilson and Kanopolis reservoirs one USBR reservoir—Cedar Bluff reservoir. These reservoirs provide and serve multiple purposes, such as flood control, water supply, irrigation, water quality, recreation, and fish and wildlife. The Smoky Hill-Saline RPA contains numerous smaller cities and towns in Trego, Ellis, and Russell counties, and portions of Barton, Clay, Cloud, Dickinson, Ellsworth, Geary, Lincoln, Marion, McPherson, Mitchell, Morris, Ness, Osborne, Ottawa, Rice, Rooks, Rush, and Saline counties.

The major land use activities in the Smoky Hill-Saline RPA include herbaceous vegetation (50 percent), cultivated crops, 41 percent), and developed and urban open space at 4 percent). The remaining 5 percent in forest, water, or pasture and hay (KWO 2022). Agriculture is the predominant economic activity in the Smoky Hill-Saline RPA, with livestock production an important part of the agriculture. Oil production is also an important part of the regional economy. The cities of Hays and Salina are the main industrial hubs in the RPA with a variety of industry and manufacturing, along with health care and education. Water-based recreation is important to the economy of the Smoky Hill-Saline RPA, including at federal reservoirs and state fishing lakes. The federal reservoirs and their associated wildlife areas attract hunters, fisherman, and boaters. Droughts that cause declines in reservoir storage can limit recreation activity, causing high impacts economically, socially, and environmentally.

Groundwater is the primary source of water in the RPA at 80 percent), which includes aquifers and alluvial deposits along the Smoky Hill River and the Saline River. Irrigation is the main use for groundwater sources. Surface water in the RPA is primarily used for municipal water, with the Smoky Hill River, Saline River, and federal reservoirs as the main source of water supply. Kanopolis Reservoir is an important principal water source for many users in the Smoky Hill-Saline RPA and most of the population is dependent on the Kanopolis Reservoir and the Smoky Hill River for water.

Runoff upstream of the reservoirs is the main contributor to the sedimentation in reservoirs in the Smoky Hill-Saline RPA and is likely to occur more often in the future. Reservoir sedimentation in this RPA is a major concern, with loss of reservoir capacity at Kanopolis Reservoir occurring at a rate that will, in time, and cause a shortage of reservoir storage that meets future projected demands. There will be only 41 percent of the multipurpose pool remaining in the next 50 years. Sedimentation and erosion are likely to occur and will cause streambank erosion, reduced flood and water supply storage in reservoirs, bed degradation downstream of reservoirs, degraded environmental resources, and loss of recreation. This will be a high impact stressor in the Smoky Hill-Saline RPA. Sedimentation in Kanopolis Reservoir threatens crucial flood risk management infrastructure, critical drinking water supply, irrigation, recreation, environmental resources, and water quality. Lack of reliable water supply and shortages of water could have a devasting effect on the economy in the Smoky Hill-Saline RPA. Sedimentation at Kanopolis Reservoir will lead to shallower water in the future, exacerbating adverse effects to environmental resources and recreation. Expected future sedimentation at Kanopolis Reservoir would substantially reduce habitat for

reservoir fisheries, with an almost complete loss of the fisheries in the future. Water quality will continue to degrade in reservoirs, rivers, and streams due to reduced water supply in reservoirs. The inability to maintain minimum flow targets downstream of the reservoirs will cause substantial economic impacts. Alternative water sources needed in the future, like water reuse systems and expanded transmission lines, are likely to be expensive to build.

Many of the rivers and streams and the three federal reservoirs in the RPA are on the impaired waters list and HABs occur at various locations, including four of the five federal reservoirs in the Smoky Hill-Saline RPA (Keith Sebelius, Kirwin, Webster, and Lovewell reservoirs). Water quality and HABs also contribute to major loss of recreational opportunities. HABs continue to have economic impacts due to lost use of recreation areas in reservoirs (closing swim beaches, reducing boating activities) and decreased visitation causing lost revenue. Negative impacts from the degrading or poor water quality conditions include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, and decreased recreational opportunities. During certain conditions like drought or flooding, high chloride has discharged downstream of Wilson Reservoir, leading to water quality concerns that required releases from Tuttle Creek and Milford Reservoirs to dilute high chlorides on the Kansas River mainstem.

The flood risk in the Smoky Hill-Saline RPA due to the stressors of riverine flooding, high reservoir water levels, and flood risk climate change implications were assessed as likely to occur and, if they occur, would be high impact. Flood risk related to public life-safety and economic damages could occur, leading to economic impacts that are widespread to localized, with a high consequence. Flooding events in the Smoky Hill-Saline RPA caused riverine and overland flooding and high reservoir water levels that damaged homes, businesses, public facilities, agricultural lands, and critical infrastructure like roads, railroads, utilities. Floods have damaged recreational infrastructure and facilities, increased operating costs, required closures, and lost revenue at recreation facilities managed by federal and state agencies, private entities, and non-profit organizations. Like other RPAs in the basin, social risks are just as important as economic and environmental risks. Flooding in the Smoky Hill-Saline RPA poses a social risk from loss of social connectedness by isolating or displacing individuals because of damage to homes, businesses, infrastructure, property, power outages, and other utility impacts. Loss of a sense of connection to the community from these impacts is likely to occur in the Smoky Hill-Saline RPA from stressors related to flood risk, sedimentation and erosion, reduced water supply, degraded water quality, degraded ecosystems, and reduced recreational opportunities. Health and safety risks occurred in the Smoky Hill-Saline RPA and will likely continue in the future during flood events due to blocked roads to homes, hospitals, and other critical areas. Power outages would inhibit critical care services (hospital functions, household medical equipment such as oxygen supply), damage fire protection systems, cause structural instability, cause contamination of drinking water supplies, and increase injury to individuals (hypothermia).

In addition to sedimentation, drought and climate change implications are likely to occur, causing high impacts in the Smoky Hill-Saline RPA because of reduced ability to meet

irrigation and water supply demands and loss of recreational opportunities. Lack of reliable irrigation and water supply, and shortages of water, could have a devastating effect on the economy of the RPA. A severe drought could limit water availability, causing more serious consequences for farmers. The basin repeatedly experienced droughts causing severe economic impacts. In recent years, drought-related agricultural losses in the basin have been significant, with billions of dollars in crop losses and livestock impacts. Water quality will continue to degrade in reservoirs, rivers, and streams due to reduced water supply in reservoirs from sedimentation and drought. The inability to maintain minimum flow targets downstream of the reservoir will cause substantial economic impacts. Alternative water sources needed in the future, like water reuse systems and expanded transmission lines, are likely to be expensive to build.

With a reduction in water availability from sedimentation and drought, water quality impacts would lead to economic impacts from required closures, increased operating costs, lost revenue, and lost use of recreational facilities. Ecosystem degradation and species impacts could result in economic impacts from loss of habitat and species. The loss of habitat and species from sedimentation, drought, climate change, reduced availability of water, and invasive species will require funding. The funding is necessary for monitoring, habitat restoration, and to replace lost revenue related to loss of recreation (hunting, fishing, wildlife viewing). Figures 4-8 through 4-10 show the risk assessment results for the Smoky Hill-Saline RPA.

The risks related to environmental impacts were assessed as likely to occur with a high impact related to loss of riverine and floodplain habitat, leading to species declines; loss of heterogeneity in hydrologic and geomorphic process in rivers, streams, and floodplains; and groundwater depletion. A moderate risk is assessed for stressors related to invasive and non-native species and loss of reservoir fisheries habitat.

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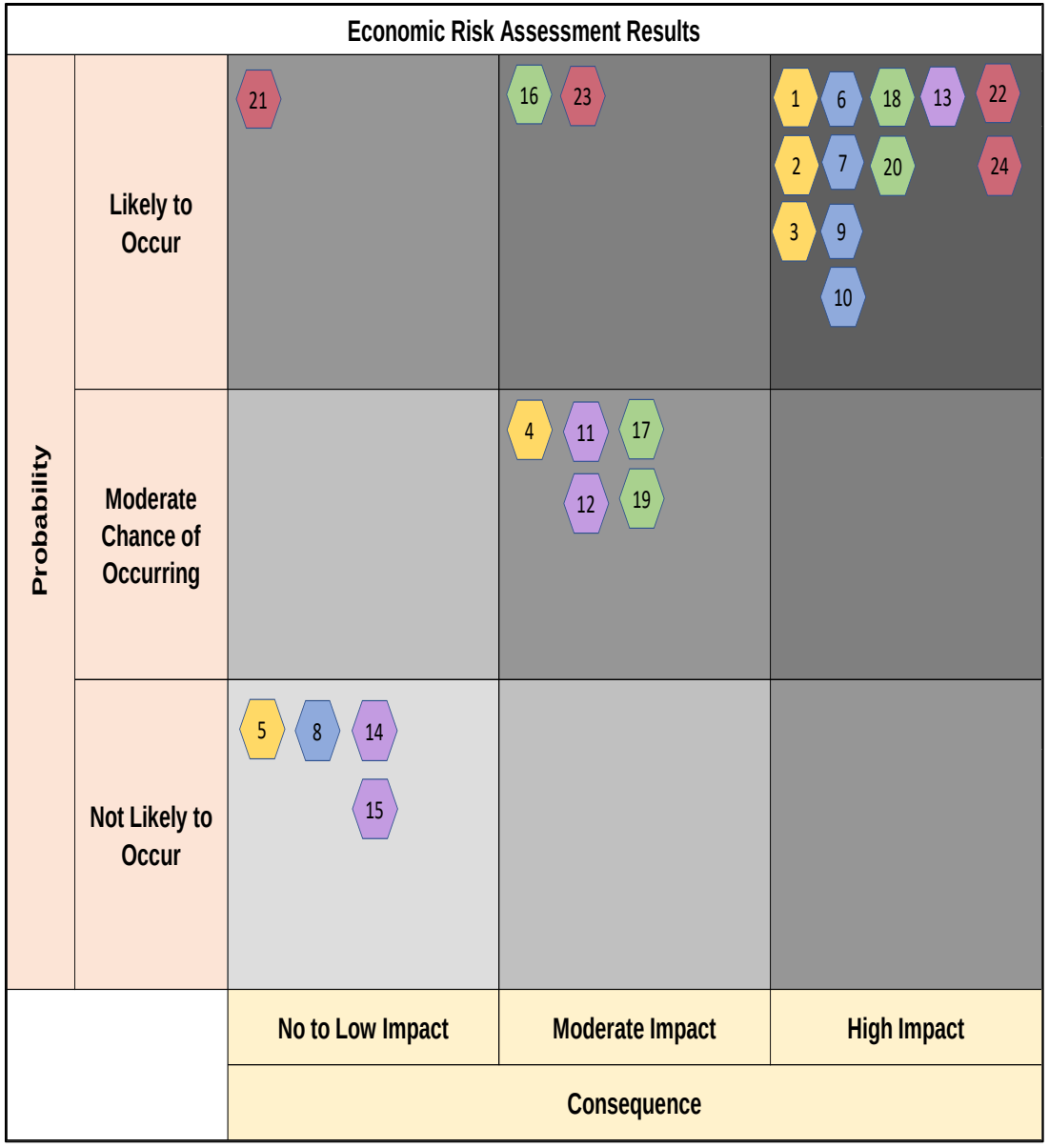
526 *Figure 4-8. Smoky Hill-Saline Regional Planning Area Economic Risk Assessment Results*

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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528 *Figure 4-9. Smoky Hill-Saline Regional Planning Area Social Risk Assessment Results*

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

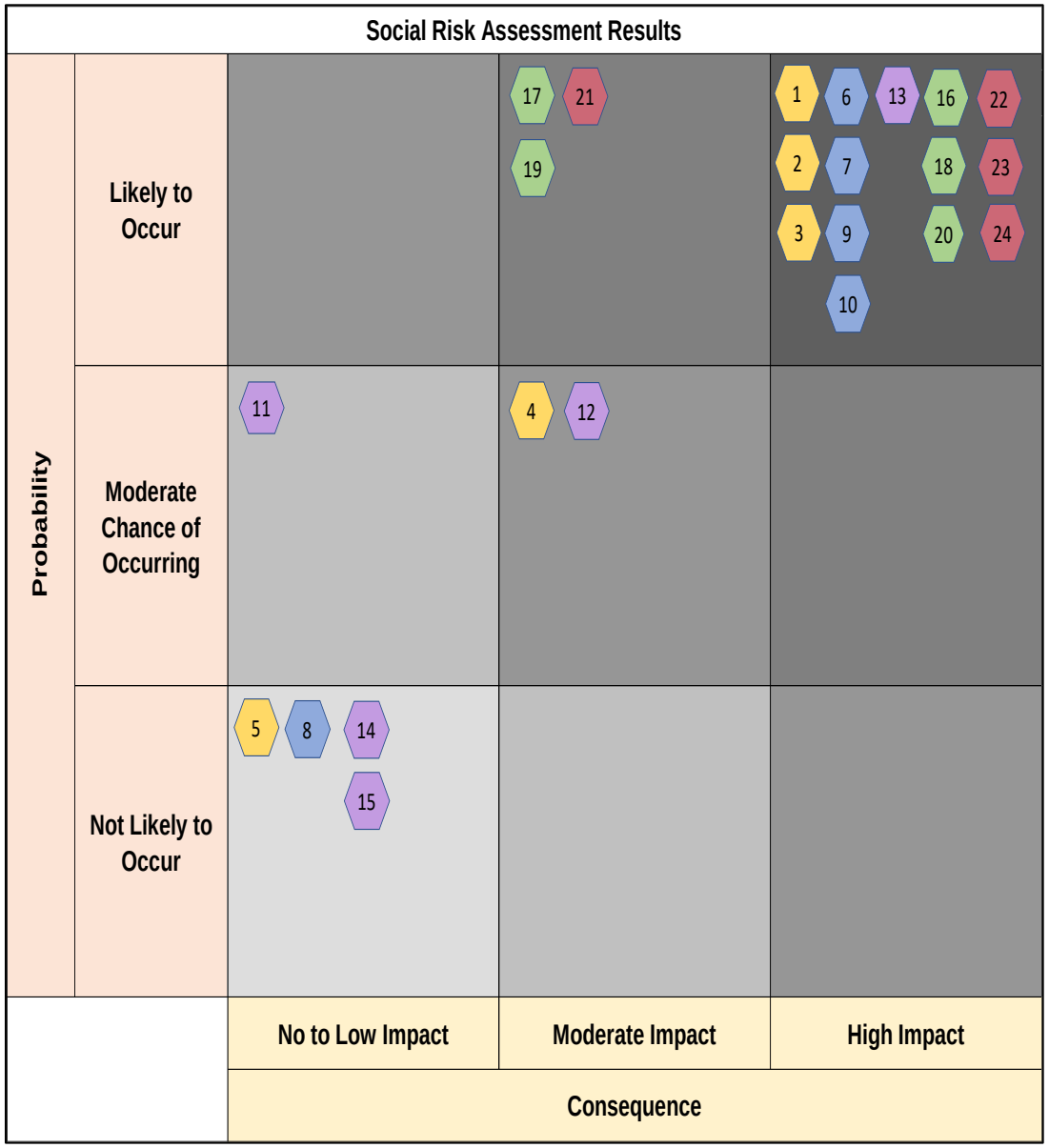

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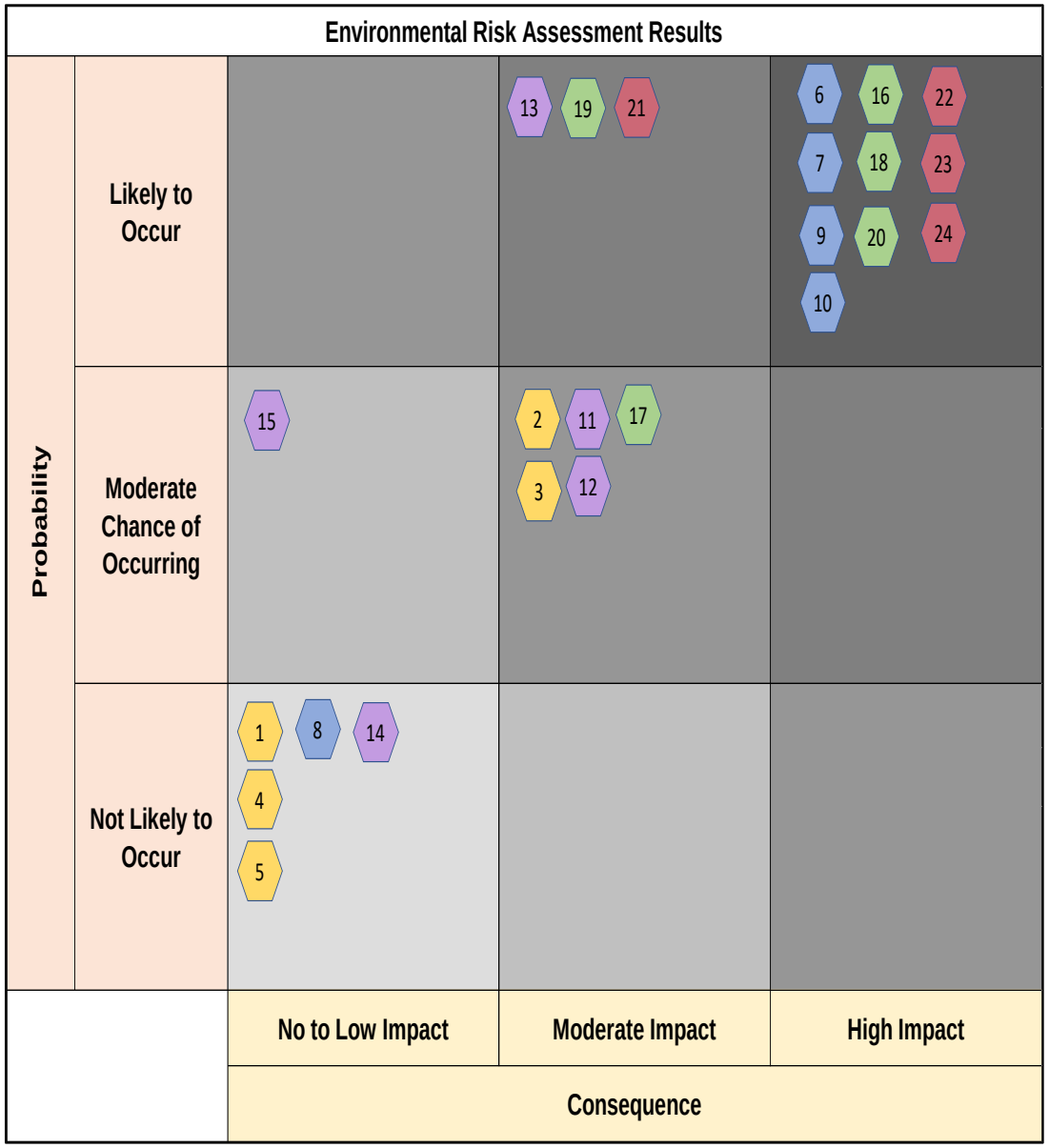
Figure 4-10. Smoky Hill-Saline Regional Planning Area Environmental Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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4.2.4.4 Upper Republican/Upper Smoky Hill Regional Planning Areas

The Smoky Hill-Saline RPA covers approximately 7,240 square miles of central Kansas. There are two major federal reservoirs in the region operated by USACE, Wilson and Kanopolis reservoirs, and one by the USBR, Cedar Bluff Reservoir. These reservoirs provide and serve multiple purposes, such as flood control, water supply, irrigation, water quality, recreation, and fish and wildlife. The RPA contains numerous smaller cities and towns in Trego, Ellis, and Russell counties, and portions of Barton, Clay, Cloud, Dickinson, Ellsworth, Geary, Lincoln, Marion, McPherson, Mitchell, Morris, Ness, Osborne, Ottawa, Rice, Rooks, Rush, and Saline counties.

The major land use activities in the RPA include herbaceous vegetation (50 percent), cultivated crops (41 percent), and developed/urban open space (4 percent), with the remainder (5 percent) in forest, water, or pasture/hay (KWO 2022). Agriculture is the predominant economic activity in the RPA with livestock production an important part of agricultural production. Oil production is also an important part of the regional economy. The cities of Hays and Salina are the main industrial hubs in the RPA with a variety of industry and manufacturing, along with health care and education. Water-based recreation is important to the economy of the RPA, including at federal reservoirs and state fishing lakes. The federal reservoirs and their associated wildlife areas attract hunters, fisherman, and boaters. Drought that causes declines in reservoir storage can limit recreation activity causing a high impact economically, socially, and environmentally from this stressor.

Groundwater is the primary source of water in the RPA (80 percent), which includes aquifers and alluvial deposits along major streams (Smoky Hill River and Saline River). Irrigation is the main use for groundwater sources. Surface water in the RPA is primarily used for municipal water use with the Smoky Hill River, Saline River, and federal reservoirs as the main source of water supply in the RPA. Kanopolis Reservoir is an important principal water source for many users in the RPA and the majority of the population in the RPA are dependent on this source and the Smoky Hill River.

Runoff upstream of the reservoirs is the main contributor to the sedimentation in reservoirs the RPA and is likely to occur more in the future. Reservoir sedimentation in this RPA is a major concern with loss of reservoir capacity at Kanopolis Reservoir occurring at a rate that will in time cause a shortage of reservoir storage to meet future projected demands (i.e., 41 percent of multipurpose pool remaining in the next 50 years). Sedimentation and erosion that causes streambank erosion, reduced flood and water supply storage in reservoirs, bed degradation downstream of reservoirs, and degraded environmental resources and loss of recreation is likely to occur and have a high impact in this RPA. Sedimentation in Kanopolis Reservoir threatens crucial flood risk management infrastructure, critical drinking water supply, irrigation, recreation, environmental resources, and water quality. Lack of reliable water supply and shortages of water could have a devasting effect on the economy in the RPA. Sedimentation at Kanopolis Reservoir will lead to shallower water in the future exacerbating adverse effects to environmental resources and recreation. Expected future sedimentation at Kanopolis Reservoir would reduce habitat for reservoir fisheries substantially with an almost complete loss of this fishery in the future. Water quality will continue to degrade in reservoirs and rivers/streams from reduced water supply in reservoirs and the ability

to maintain minimum flow targets downstream of the reservoirs causing substantial economic impacts. Alternative water sources needed in the future are likely to be expensive (e.g., water reuse systems, expanded transmission lines).

Many of the rivers and streams and the three federal reservoirs in the RPA are on the impaired waters list and HABs occur at various locations, including four of the five federal reservoirs in the RPA (Keith Sebelius, Kirwin, Webster, and Lovewell reservoirs). Water quality and HABs also have a major contribution to loss of recreational opportunities. HABs will continue to have economic impacts from lost use of recreation areas in reservoirs (e.g., closing swim beaches, reducing boating activities) and decreased visitation and lost revenue. Negative impacts from degrading/poor water quality conditions can include increased costs to treat water for public water supply needs, decreased yields for agricultural producers, and decreased recreational opportunities. During certain conditions (drought or flooding) high chloride has discharged downstream of Wilson Reservoir leading to water quality concerns which required releases from Tuttle Creek and Milford Reservoirs to dilute high chlorides on the Kansas River mainstem.

The flood risk in this RPA related to stressors for riverine flooding, high reservoir water levels, and flood risk climate change implications were assessed as likely to occur and if they occur there would be a high impact. Flood risk related to public life safety and economic damages could occur leading to economic impacts that are widespread to localized with a high consequence. Flooding events in this RPA has caused riverine and overland flooding and high reservoir water levels that damaged homes, businesses, public facilities, agricultural lands, and critical infrastructure (e.g., roads, railroads, utilities). Floods have also caused damages to recreational infrastructure and facilities, increased operating costs, required closures, and lost revenue at recreation facilities managed by federal and state agencies, private entities, and non-profit organizations. Similar to other RPAs in the basin social risks are just as important as economic and environmental risks. Flooding in the RPA poses a social risk from loss of social connectedness by isolating or displacing individuals from damage to homes, businesses, infrastructure, and property, power outages, and other utility impacts. Loss of a sense of connection to the community from these impacts is likely to occur in the RPA from stressors related to flood risk, sedimentation/erosion, reduced water supply, degraded water quality and ecosystems, and reduced recreation opportunities in the future. Health and safety risks have occurred in the RPA and will likely continue in the future during flood events through blocked roads to homes, hospitals, and other critical areas; power outages that prevent critical care services (e.g., hospital functions, household medical equipment such as oxygen supply); damaged fire protection systems; structural instability; contamination of drinking water supplies, and injury to individuals (e.g., hypothermia).

In addition to sedimentation, drought and climate change implications are likely to occur causing high impacts in this RPA from reduced ability to meet irrigation and water supply demands and loss of recreational opportunities from these stressors. Lack of reliable irrigation and water supply and shortages of water could have a devastating effect on the economy of the RPA. A severe drought could limit water availability, having more serious consequences for farmers. The basin has repeatedly experienced

droughts causing severe economic impacts. In recent years, drought-related losses in the basin have been significant in agriculture with billions of dollars in crop losses and livestock impacts. Water quality will continue to degrade in reservoirs and rivers/streams from reduced water supply in reservoirs from sedimentation and drought and the ability to maintain minimum flow targets downstream of the reservoir causing substantial economic impacts. Alternative water sources needed in the future are likely to be expensive (e.g., water reuse systems, expanded transmission lines).

With a reduction in water availability from sedimentation and drought in the future water quality impacts that could occur would lead to economic impacts from required closures, increased operating costs, and lost revenue and recreational facilities. Ecosystem degradation and species impacts would result in economic impacts from loss of habitat and species from sedimentation, drought, climate change implications, reduced availability of water, invasive species, etc. that leads to funding needs for monitoring, habitat restoration, and lost revenue from reduced opportunities related to recreation tied to enjoyment of environmental resources (e.g., hunting, fishing, wildlife viewing). Figures 4-11 through Figure 4-13 show the risk assessment results for the Smoky Hill-Saline RPA.

The risks related to environmental impacts were assessed as likely to occur and a high impact for stressors related to loss of riverine/floodplain habitat leading to species declines; loss of heterogeneity in hydrologic and geomorphic process in rivers, streams, and floodplains; and groundwater depletion; and a moderate risk for stressors related to, invasive/non-native species, and loss of reservoir fisheries habitat.

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Figure 4-11. Upper Republican/Upper Smoky Hill Regional Planning Area Economic Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

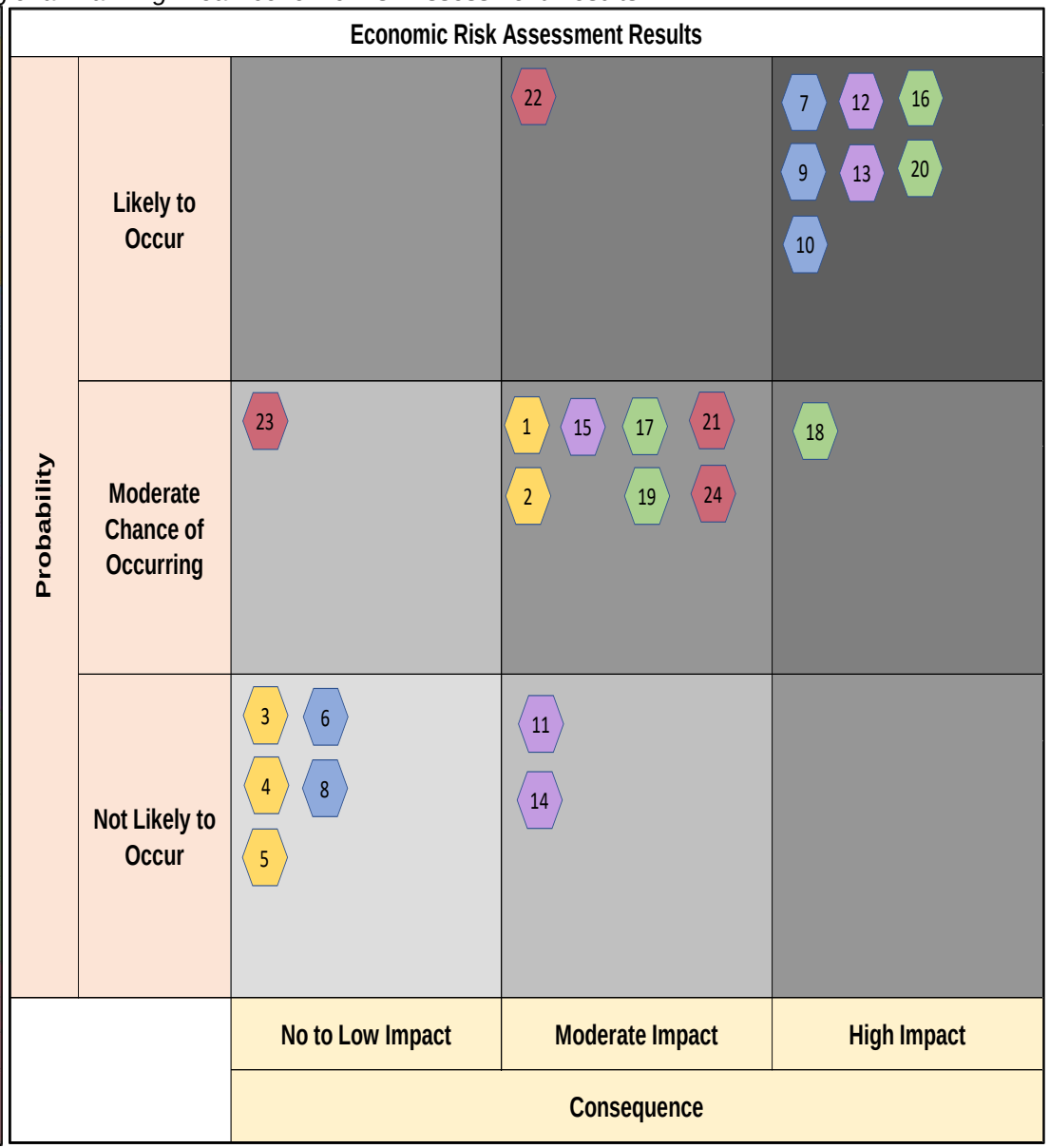


Figure 4-12. Upper Republican/Upper Smoky Hill Regional Planning Area Social Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

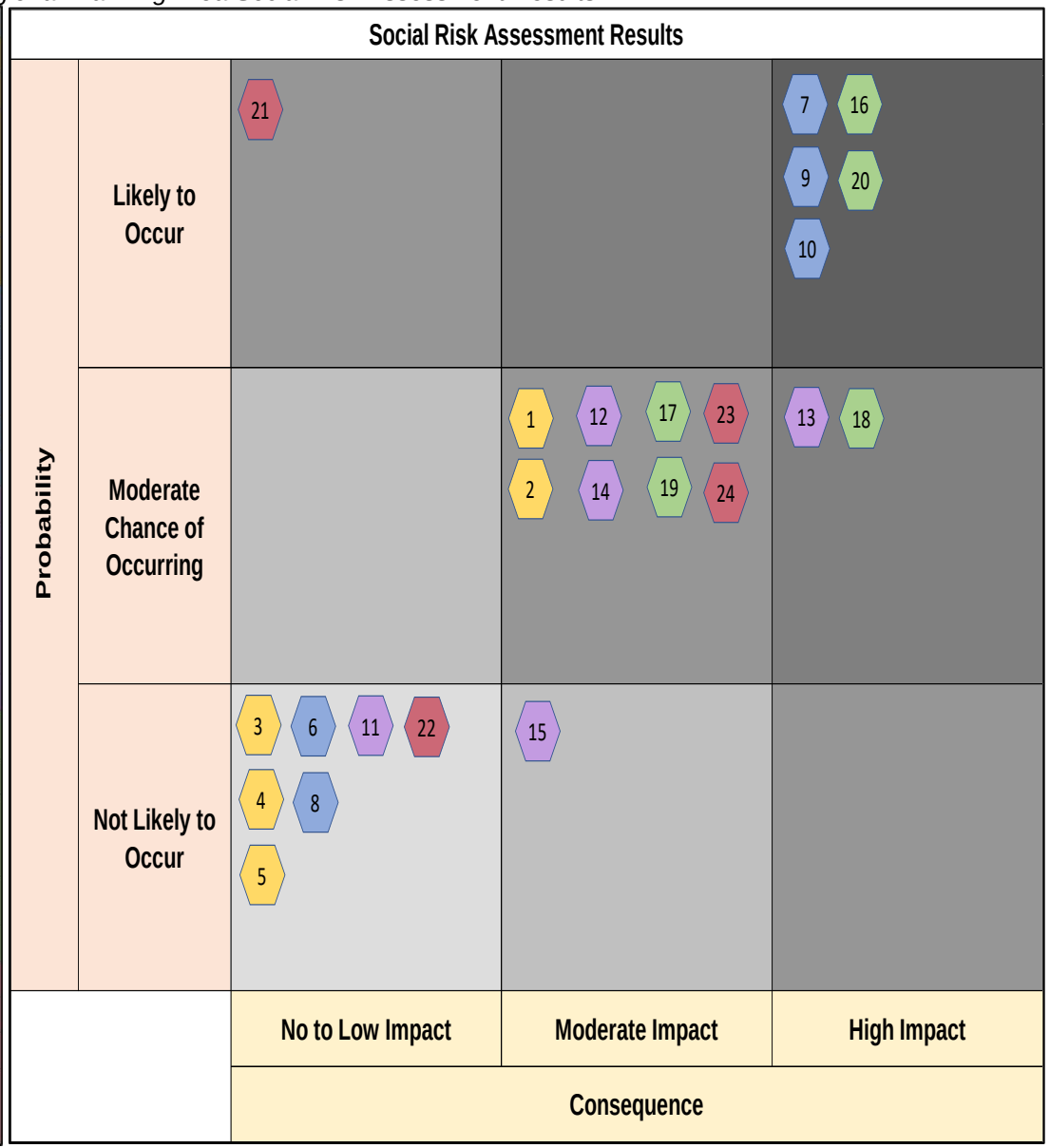
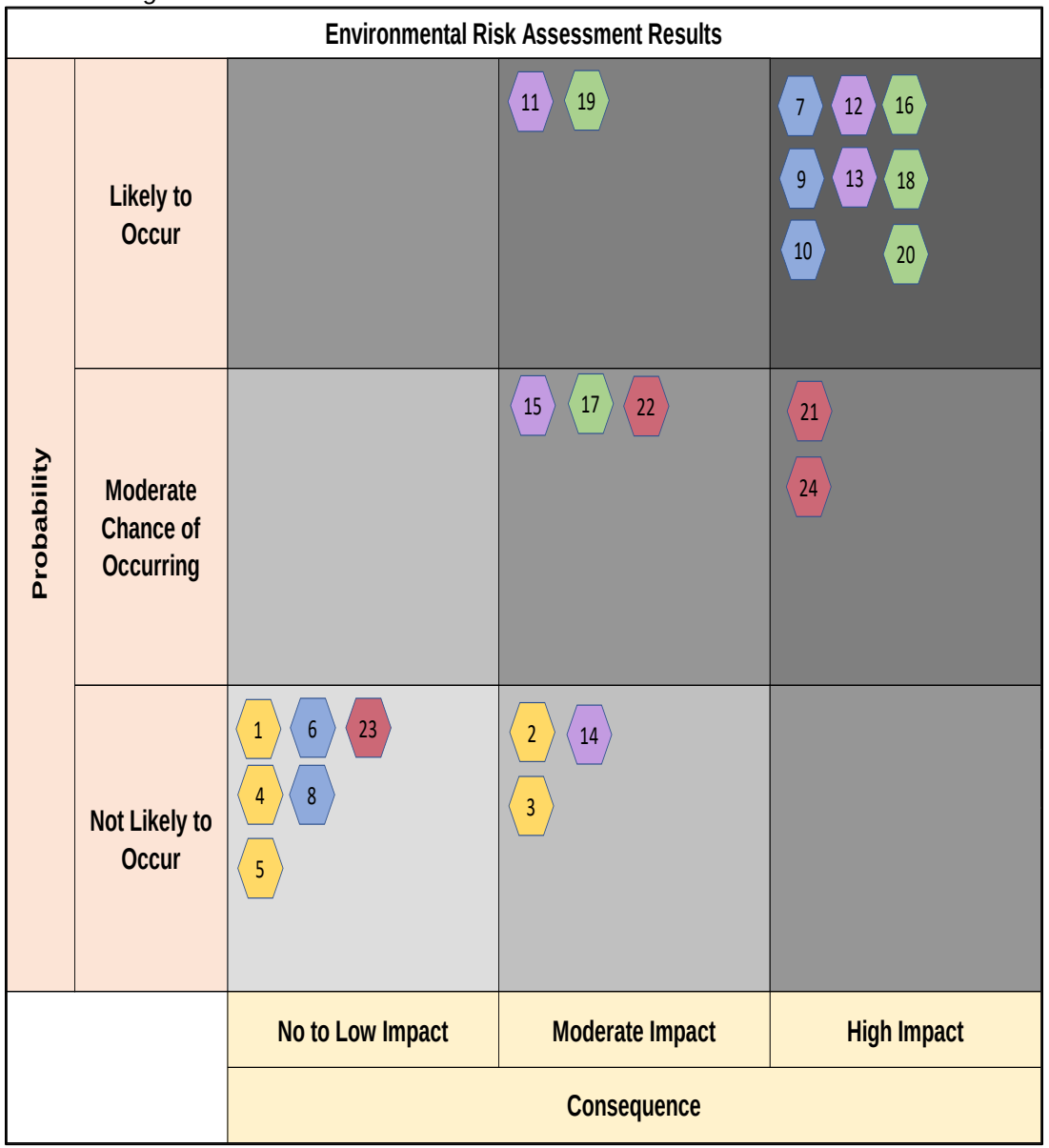


Figure 4-13. Upper Republican/Upper Smoky Hill Regional Planning Area Environmental Risk Assessment Results

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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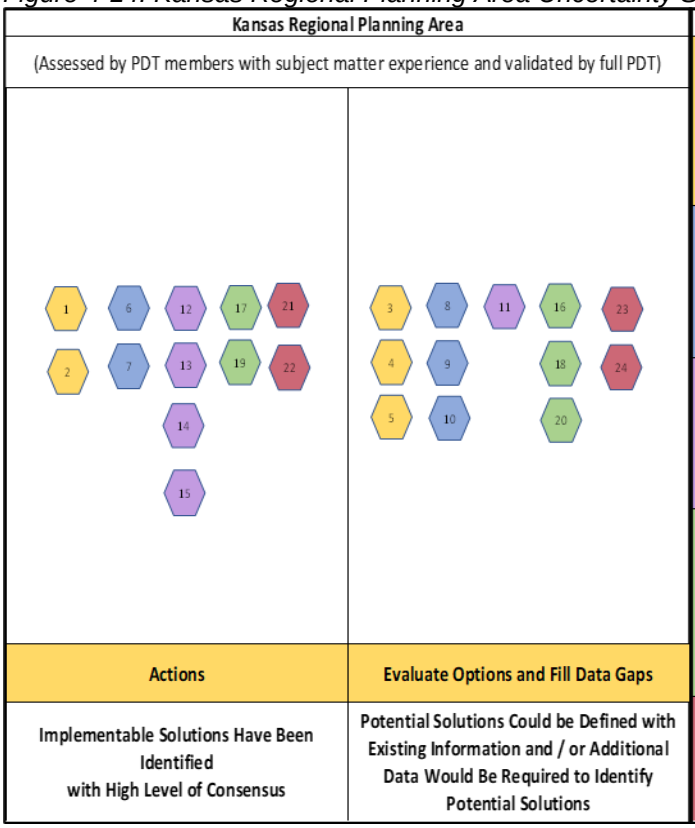
4.3 Uncertainty Analysis

In addition to risk, a qualitative assessment of uncertainty was performed to identify the level of consensus among stakeholders to implement potential risk reduction measures for each problem or stressor. The uncertainty assessment evaluated how much is known about the problem, stressors, and potential solutions. The results of the uncertainty assessment were used to determine the most suitable types of recommendations. If a solution existed and was supported by stakeholders with a strong consensus, the recommendations were classified as actions. If potential solutions were identified but did not have a strong consensus or more data was needed to create potential solutions, the recommendations were classified as evaluate options or fill data gaps. The following categories of consensus were developed to frame risk reduction recommendations and actions and to evaluate and fill data gaps.

- Action—Implementable solutions with a high level of consensus to address the risks resulting from a given stressor.
- Evaluate Options/Fill Data Gaps—Potential solutions are defined with existing information (evaluate options) or additional data would be required to better define the extent and consequence of the problem and or identify potential solutions (fill data gaps)

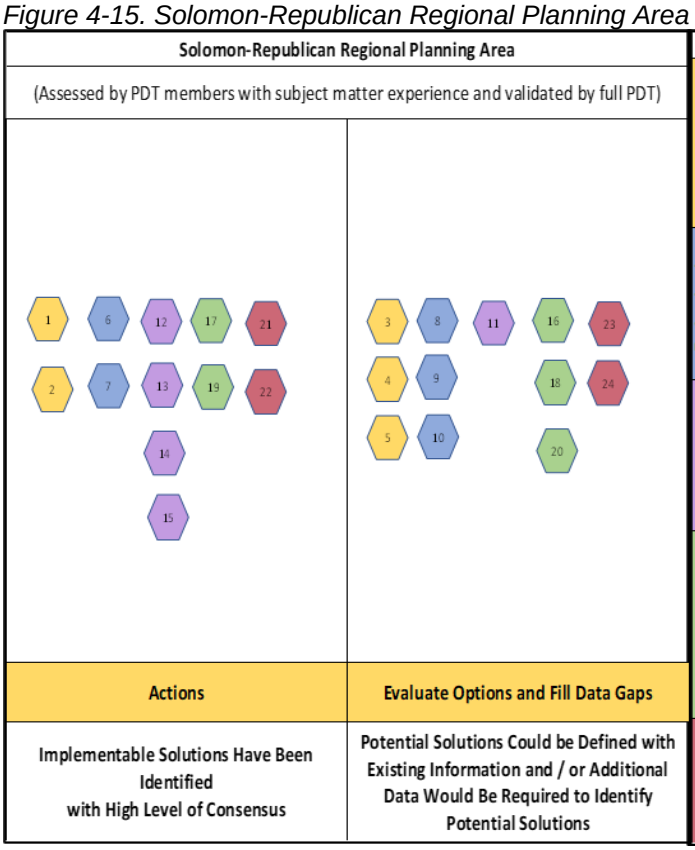
This qualitative uncertainty assessment was conducted through a review of existing information and with input from partners and stakeholders through a series of collaborative workshops and was based on research and knowledge of possible solutions. Similar to the risk assessment the uncertainty evaluation was conducted for each RPA. Figure 4-14 through Figure 4-17 show the results of the collaborative uncertainty analysis.

Figure 4-14. Kansas Regional Planning Area Uncertainty Summary



Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction In Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Impacts to Reservoir Fisheries	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

Figure 4-15. Solomon-Republican Regional Planning Area Uncertainty Summary



Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction In Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Impacts to Reservoir Fisheries	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

690 *Figure 4-16. Smoky Hill-Saline Regional Planning Area Uncertainty Summary*



Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction In Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Impacts to Reservoir Fisheries	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

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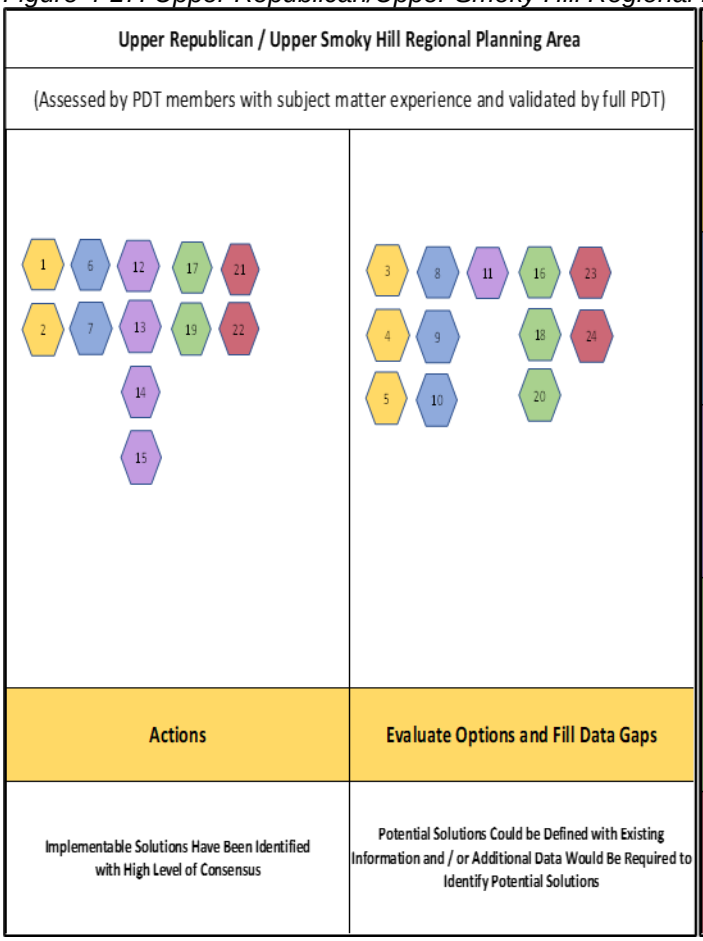
Figure 4-17. Upper Republican/Upper Smoky Hill Regional Planning Area Uncertainty Summary



Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Impacts to Reservoir Fisheries	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24

4.4 Framework for Recommendations

Risk and uncertainty results were used to develop a framework for the appropriate types (uncertainty based) and timing for (risk based) recommendations. For problems or stressors categorized with a high level of risk (high probability and high consequence), immediate or near-term steps should be taken to reduce risks through direct actions or evaluation of potential options for reducing risks, or filling data gaps. Immediate or near-term was defined as the next one to ten years. Immediate actions were identified to reduce high risks for which implementable solutions were identified with a high level of consensus among agencies and stakeholders. Immediate evaluations or fill data gaps were identified to reduce high risks where a strong consensus did not occur or more data was needed. For problems or stressors categorized as moderate or low, incremental, or long-term steps should be taken (or continue) to reduce these risks or may be considered lower priorities that do not require immediate steps. Incremental or long-term was defined as ten years or longer. Incremental actions were identified to reduce major risks with similar uncertainty. Incremental evaluations or fill data gaps were identified to reduce moderate to low risks where a strong consensus did not occur or more data was needed. The risk and uncertainty analyses framed recommendations and helped prioritize actions for near-term verses long-term. The results from the risk and uncertainty analyses placed the stressors into these broad recommendation

categories. The results of the risk and uncertainty analyses were used to develop summaries for each assessed RPA (Figures 4-18 through 4-21).

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721 *Figure 4-18. Kansas Regional Planning Area Risk and Uncertainty Summary*

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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723 *Figure 4-19. Solomon-Republican Regional Planning Area Risk and Uncertainty Summary*

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



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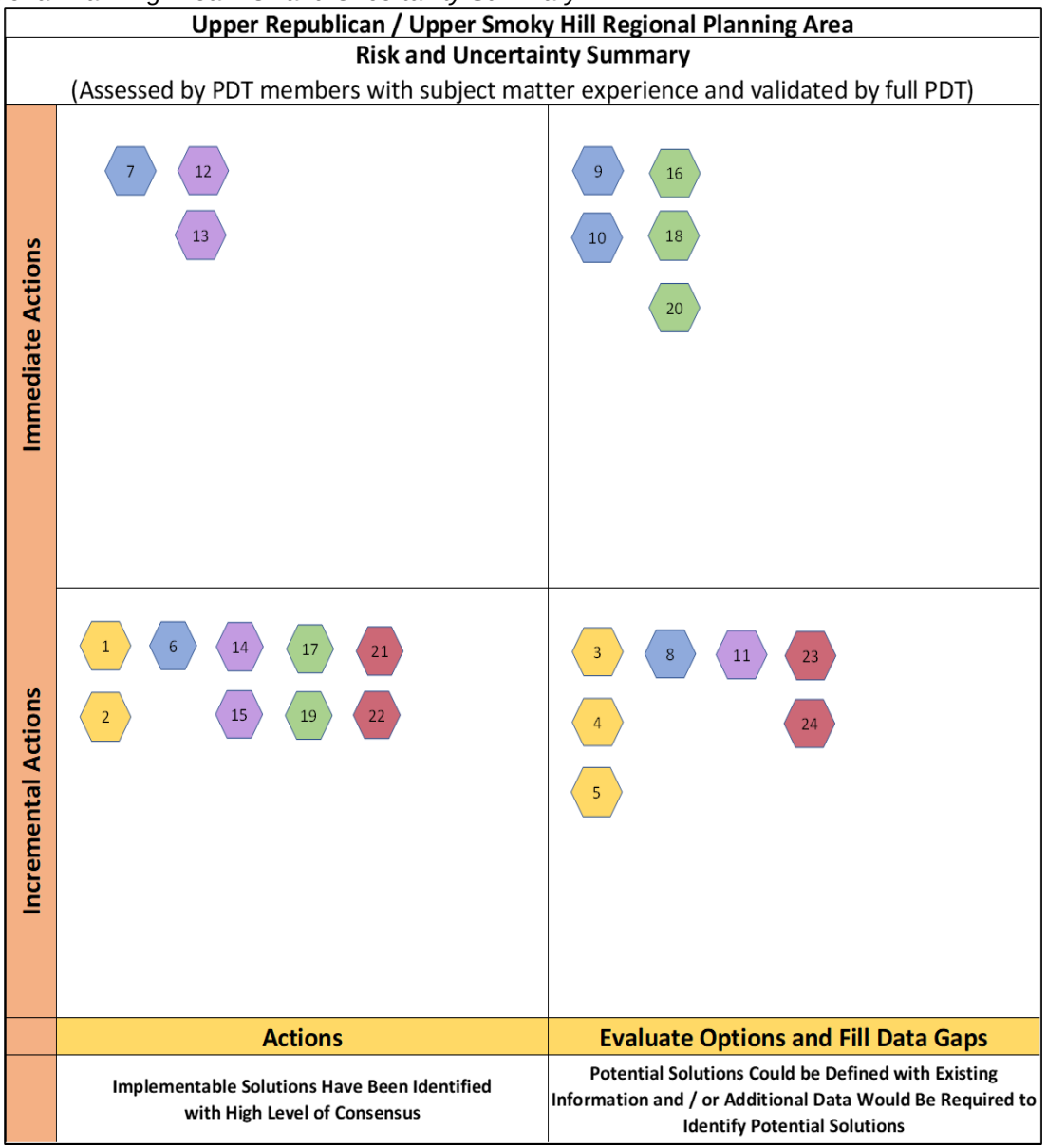
Figure 4-20. Smoky Hill-Saline Regional Planning Area Risk and Uncertainty Summary

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



Figure 4-21. Upper Republican/Upper Smoky Hill Regional Planning Area Risk and Uncertainty Summary

Problem	Stressor	Number
Flood Risk	Riverine Flooding	1
	High Reservoir Water Levels	2
	Climate Change Implications - Increasing Risk to Urban Areas and Agricultural Lands	3
	Flood Response Communications Issues	4
	Sedimentation in Reservoirs and Downstream Erosion	5
Reduction in Ability to Meet Water Supply Demands	Sedimentation	6
	Drought	7
	Reduced Water Supply From Navigation Releases	8
	Groundwater Depletion	9
	Climate Change Implications	10
Degraded / Poor Water Quality	Harmful Algal Blooms	11
	Impaired Waters	12
	Water Shortages (Causing Reduced Availability of High Water Quality)	13
	Inadequate Stormwater Management	14
	Sedimentation	15
Ecosystem Degradation and Species Impacts	Loss of Riverine / Floodplain Habitat Leading to Species Declines	16
	Invasive / Non-native Species	17
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	18
	Loss of Reservoir Fisheries Habitat Leading to Declines	19
	Groundwater Depletion	20
Loss of Recreational Opportunities	Limited Public Lands	21
	Reservoir Sedimentation	22
	Water Quality / Harmful Algal Blooms	23
	Increased Operational Costs and Lost Revenues From Flooding and Drought	24



5.0 RECOMMENDATIONS AND IMPLEMENTATION STRATEGY

Recommendations were developed based on risk and uncertainty prioritization frameworks to help achieve a Shared Vision:

> Within the Kansas River Watershed there are significant water resource challenges including increased flood risk, reduced water availability, reservoir sedimentation, water quality concerns, streambank erosion, increased demand for recreational opportunities, and loss of wetlands and riparian habitats. Sustainable measures must be identified and developed to reduce flood risk, improve sediment management, and mitigate drought, and to address additional existing water resource problems within the watershed. Measures include those necessary to increase the resiliency and sustainability of the system, and identification of viable opportunities for investment in critical infrastructure throughout the basin, including existing reservoirs, to increase their resiliency and maintain capacity for water availability and sustainment, ecosystem restoration, water quality, and recreational amenities.

The risk and uncertainty analyses framed the recommendations and helped prioritize actions for the near- verses long-term. The results from the risk and uncertainty analyses placed the stressors into these broad recommendation categories. The results of the risk and uncertainty analyses informed the development of summaries for each RPA assessed (Figures 4-18 through 4-21).

To reduce potential high risks for which implementable solutions were identified, immediate (near-term) actions were identified and consensus among agencies and stakeholders was achieved. To reduce moderate to low risks with temporary impacts or consequence. incremental (long-term) actions were identified. For problems or stressors categorized as moderate or low, incremental, or long-term steps should be taken to reduce the risks. Risks that do not require immediate steps are considered a lower priority. Immediate or near-term is defined as needing attention within the next one to ten years while incremental or long-term is defined as ten years or longer. Options for immediate evaluations were identified for high risks where sufficient data and information exists to define potential solutions. Options for incremental steps toward evaluation were identified to reduce the moderate to low risks. Data gaps that should be addressed in the near-term were identified for potentially high risks, where warranted; incremental steps to fill data gaps were identified for moderate to low risks.

5.1 Framing Recommendations

The risk and uncertainty assessment recommendations are appropriate for the known level of risk, existing knowledge, and resources. Recommendations follow the broad outline set forth from the risk and uncertainty results (Figures 4-18 through 4-21).

The recommendations were developed by combining management measures through partner input, USACE expertise, and recommendations from existing reports and project requests. The following sections document the management measures considered, proposed recommendations, and possible implementation strategies including potential funding sources and partners.

5.2 Management Measures

Management measures are the building blocks for recommendations. There are many ongoing efforts undertaken by partners, stakeholders, and USACE to address problems across the Kansas River Basin. An array of planning measures to address problems and achieve planning objectives, described in Section 2.5.1, were developed using on-going and forecasted efforts (found in reports or identified during study workshops) and by gathering additional input from stakeholders and subject matter experts (SMEs) on the team.

Measures that contributed to identified planning objectives were retained and compiled into recommendations. ***No measures were screened from further consideration, as all identified measures contributed to the identified planning objectives.*** Recommendations were developed through risk assessment, uncertainty of problem categories, and addressing the most critical needs. Although not all measures are used in recommendations, the comprehensive list of measures is retained for future consideration by interested agencies. Section 4, Risk Assessment and Evaluation, provides details on the described risk assessment process. Table 5-1 contains a list of measures. A checkmark is placed under the problem areas addressed.

5.2.1 .Screening and Evaluation

To refine the list for further evaluation, the management measures and strategies underwent screening. Screening criteria was developed to determine if management measures and actions meet the shared vision statement and objectives of the study.

Each potential measure was assessed for effectiveness regarding the stressors under each problem area. The measures were based on expert knowledge and judgement. The effectiveness screening included:

5.2.1.1 Flood Risk

- Does the measure reduce risks to life safety from riverine flooding and high reservoir water levels?
- Does the measure reduce the societal, environmental, and economic damage consequences associated with flood risk and emphasize improving system resiliency and increasing integrity of the flood system?
- Does the measure reduce the risks to critical infrastructure from flooding at reservoir infrastructures and levees?
- Does the measure reduce the loss of reservoir storage volume and sustain the authorized purpose and benefits for flood control?
- Does the measure reduce bed degradation in channels downstream of reservoirs?
- Does the measure improve communication, coordination, and planning between flood risk management entities and the public during flood events?
- Does the measure increase the adaptability and resiliency of flood risk management in relation to climate change, including extreme events like flooding and drought?

The screening and evaluations conducted for flood risk are in Figures 5-1 and 5-2.

5.2.1.2 Reduction in Ability to Meet Water Supply Demands

- Does the measure increase the reliability and availability, and sustain the authorized purposes and benefits, of water supply?
- Does the measure reduce the economic, social, and environmental impact consequences associated with drought risk and emphasize improving system resiliency and increasing the integrity of the water supply system?
- Does the measure reduce the accumulation of sediment in reservoirs?
- Does the measure increase adoption of watershed practices to reduce future loss of reservoir storage?
- Does the measure increase the adaptability and resiliency of water supply in relation to climate changes, including extreme events like flooding and drought?

The screening and evaluations conducted for water supply are in Figures 5-3 and 5-4.

5.2.1.3 Degraded/Poor Water Quality

- Does the measure protect and improve the availability of high-quality water for residential, commercial, industrial, recreation, and biological resources?
- Does the measure reduce the negative impacts from HABs and impaired waters?
- Does the measure reduce degradation in water quality due to inadequate stormwater management?
- Does the measure increase the reliability and availability of water for downstream uses and water quality flows?

Figure 5-5 shows the screening and evaluations conducted for water quality.

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112 *Table 5-1. Kansas River Basin Management Measures*

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
Operational Measures/ Dams and Reservoir Upgrades	Lower Kansas River Basin Master Manual and Individual Reservoir Water Control Manual (WCM) Updates—Initiate spin-off studies to update the Lower Kansas River Basin Master Manual or individual reservoir project WCMs within the Kansas River Basin (Tuttle Creek Dam, Perry Dam, Clinton Dam, Milford Dam WCMs).	✓	✓	✓	✓	✓
	Missouri River Control Point Modification—Initiate a spin-off study to evaluate modification to control point (Waverly gage) operations for the Kansas River Basin. The WCM update could include this, it is a recommended spin-off USACE project. This could allow for greater flexibility during extreme or high events and quicker evacuation of flood storage at the reservoirs, thereby decreasing risk of surcharge releases and possible downstream flooding along the Kansas River and tributaries. During the study period, USACE Kansas City (NWK) received funding to update the seven USACE WCMs (Milford, Tuttle Creek, Perry, Clinton, Harlan County, Wilson, and Kanopolis) in the Kansas River Basin. The updates for Milford, Tuttle Creek, Perry, and Clinton WCMs are currently underway. WCM updates include coordination with stakeholders during development of alternatives and may, if appropriate, consider changes to control point operations.	✓	✓	✓	✓	✓
	New Reservoir and Dam Construction or Detention Basins—Investigate the feasibility of construction of new reservoirs and dams or detention basins and identify specific sites that can provide additional temporary storage of runoff waters, extending the period of runoff to reduce flood peaks. This could include smaller reservoirs constructed by state agencies and county or local governments. The sites would be prioritized based on problem and flood risk and where the highest benefits would be realized. The Watershed Study Flood Risk Assessment identified areas with potential high life-safety risk or economic damages and the Regional Hazard Mitigation Plans identified areas with potential need.	✓				✓
Levee Upgrades	New or Modified Levees/Dikes/Floodwalls—Coordinate with communities identified as high-risk (potential life loss or damages) that would benefit from new or modified levees, dikes, and floodwalls to determine support needed from federal or state government agencies (USACE, FEMA), KDEM. The Watershed Study Flood Risk Assessment and the Regional Hazard Mitigation Plans identify high-risk communities and further investigation is needed to determine the costs and benefits of building additional infrastructures.	✓				✓
Flow Improvements	Channel Modifications—Identify specific sites wherein widening or deepening the channel would increase flood conveyance. Prioritize the site list based on problem areas and flood risk where the highest benefits could be realized. The Watershed Study Flood Risk Assessment identified areas	✓				✓

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
	with high life-safety risk or economic damages and the Regional Hazard Mitigation Plans identified areas with potential need.					
	High Flow Diversions—Identify specific sites for diversions using naturally or artificially constructed bypass channels or conduits to redirect excess flows away from developed areas. Prioritize the site list based on problem areas and flood risk where benefits could be realized. The Watershed Study Flood Risk Assessment and the Regional Hazard Mitigation Plans identified areas with potential need and the watershed study identified areas with potential high life-safety risk or economic damages.	✓		✓	✓	✓
Floodplain Improvements Non-Structural Flood Risk Measures	Authority for Land Acquisition or Easement Purchase for Flood Control—USACE currently does not have authority to acquire lands or easements for flood control. This would require a new authority and would consist of USACE acquisition of lands and reconnection of old oxbows or easements along the Kansas River mainstem and major tributaries for flood control measures (levee setbacks, floodplain expansion, restoration of oxbows). The State of Kansas may have some instruments for this.	✓				✓
	Floodplain Management Plans—Identify regional and local areas needing floodplain management plans (FMPs). Incorporate evaluation of risk and recommend concrete steps to address the risk with structural and non-structural solutions. Development of an FMP will also increase public awareness of flood risk. The Regional Hazard Mitigation Plans identified areas with potential need. Work with Silver Jackets Program to develop proposals for plans in high-risk communities.	✓	✓	✓	✓	✓
	Kansas Flood Center/Flood Information System—Establish a flood center and a flood information system. The flood center would give Kansans access to the latest technology and resources to help prepare for floods and become more resilient in their effects. The flood center would provide direct services and engage in flood-related projects that help Kansans understand flood risks and make better flood-related decisions.	✓				✓
	Floodplain Regulations—Work with local communities, counties, and regional floodplain managers to establish ordinances, zoning, subdivision regulations, building and housing codes, and sanitary codes with specific flood hazard provisions.	✓		✓	✓	✓
	Flood Risk Studies—Support existing proposals and requests for flood risk management projects. A GI project lists the conversion of the Shunganunga Creek Continuing Authorities Program (CAP) Section 205 Study to a GI Study for flood risk management. The study is needed by the city of Topeka, Kansas, to reduce recurring impacts related to potential life safety risks and significant and dynamic flooding in urban residential and commercial areas.	✓		✓	✓	✓
	Flood Warning/Emergency Plans—Develop flood warning or emergency plans for high-risk communities. Plans should include flood emergency measures like flood-fighting plans, contingency and emergency floodproofing, and emergency evacuation plans.	✓				✓

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
	Floodplain Mapping—Assess flood prone areas to implement future flood reduction measures in the Kansas communities of Belvue, Havensville, Louisville, Onaga, St. George, St. Mary's, Wamego, Alma, McFarland, and Paxico. Increase availability of floodplain maps beyond standard FEMA products to increase understanding of flood risk.	✓				✓
	Silver Jackets Projects Related to Healthy Watersheds—Initiate additional work related to the ongoing Silver Jacket Healthy Watershed work.					
Operational Measures	Modification of Low Flow Target Values to Extend Period of Low Flow Support—Initiate spin-off studies to update the Lower Kansas River Basin Master Manual or individual reservoir project WCMs within the Kansas River Basin (Tuttle Creek, Perry, Clinton, and Milford WCMs) Include modification of low flow target values to extend the period of low-flow support during extended drought periods. During the study period, USACE NWK received funding to update seven USACE WCMs for Milford, Tuttle Creek, Perry, Clinton, Harlan County, Wilson, and Kanopolis) in the Kansas River Basin. The updates for the Milford, Tuttle Creek, Perry, and Clinton WCMs are currently underway. WCM updates will include drought contingency plans and coordination with stakeholders during development of alternatives.		✓	✓		
Resiliency Planning	Water Supply Demand Study—Determine future water supply demands in the Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.		✓	✓	✓	✓
	Kansas Research Priorities Support—Support reservoir research priorities as developed by the Kansas Water Research Coordination Group. USACE NWK and KWO entered a Planning Assistance to States Study (PAS), providing an opportunity to work together on Kansas reservoir research priorities utilizing expertise from state agencies, universities, and USACE. This provides greater benefit by pooling funding to support these efforts. Kansas will continue to look for opportunities to work with USACE on similar efforts.		✓	✓		
	Small Watershed Dam Assessment—Identify existing watershed structures needing restoration or expansion to provide supplemental water supply in the Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.	✓		✓		
	Promote Water Conservation Measures—The State of Kansas currently has Water Conservation Plans for each rural water district (RWD). Updates to water conservation plan guidelines are needed to ensure all communities and RWDs have current water conservation and drought management plans.		✓	✓		
	Drought Communication and Outreach—Conduct drought simulation exercises to educate the public and identify gaps in conservation efforts. Incorporate drought simulation efforts into state hazard planning. Seek		✓	✓		

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
	funding and support for these efforts from federal partners. Develop informational resources for eastern Kansas, similar to Estimated Usable Lifetime of the Ogallala Aquifer, that show municipalities and other public water suppliers at greatest risk of insufficient water supplies to serve area's needs through a drought.					
	Kansas River Alluvial Model—Develop a stream aquifer model of the Kansas River Alluvial Aquifer for Junction City, Kansas, to the junction with the Missouri River that examines the effect of future development scenarios and management of groundwater and river water levels.		✓	✓		
Sediment Reduction	Regional Sediment Management Plans—Conduct a USACE PAS Study to prepare sediment management plans for multiple watersheds in the basin.		✓	✓	✓	✓
	Bank Stabilization/Stabilize Head-cuts—Identify bank stabilization sites and expansion of head-cut assessments to identify potential project sites. Include hydraulic modeling to determine appropriate design features for maximum performance and cost effectiveness.		✓	✓	✓	✓
	Reservoir Bathymetry—Increase the frequency of reservoir bathymetry to monitor progress on sedimentation trends, reservoir storage loss, and future water supply planning projections	✓	✓	✓	✓	✓
Sediment Removal	Tuttle Creek Dam Reservoir Long-Term Sediment Management Plan—Initiate spin-off study to investigate sediment management alternatives for the perpetual sustainment of Tuttle Creek Reservoir's authorized purposes and benefits to lessen negative impacts on the upstream and downstream reaches. Include analysis of technologies to create a long-term recommended plan that supports sustainability of reservoir storage.	✓	✓	✓	✓	✓
	Tuttle Creek Reservoir Water Injection Dredging Demonstration—Initiate a spin-off study to perform a Water Injection Dredging Demonstration at Tuttle Creek Reservoir that assesses the effectiveness of Water Injection Dredging (WID) technology at a range of downstream discharges, pool elevations, and in-reservoir locations for potential long-term implementation. The study will monitor and evaluate both the operational effectiveness and environmental results. USACE NWK received funding to conduct a WID Demonstration at Tuttle Creek Reservoir.	✓	✓	✓	✓	✓
	Kanopolis Reservoir Long-Term Sediment Management Plan—Initiate a spin-off study to investigate sediment management alternatives for the perpetual sustainment of the Kanopolis Reservoir's authorized purposes and benefits to lessen the negative impacts on upstream and downstream reaches. Include analysis of technologies to create a long-term plan that supports sustainability of reservoir storage.	✓	✓	✓	✓	✓
New Water Storage	Kansas River Alluvial System Utilized as a Filtration and Storage System—Study to determine areas of potential artificial recharge in the Kansas River Alluvial Aquifer utilizing the Kansas River Alluvial Model currently in development by the Kansas Geologic Survey.		✓	✓		

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
	Develop a Plan for Multipurpose Small Lakes—Develop a plan for multipurpose small lakes to alleviate regional water supply issues. This would be done in regions where it is not feasible to restore water supply storage in reservoirs.		✓	✓		
	Kanopolis Reservoir Multipurpose Pool Raise Study—Initiate a spin-off study to evaluate a permanent multipurpose pool raise at Kanopolis Reservoir.		✓	✓		
Nutrient and Sediment Reduction	Promote and Incentivize the Adoption of Practices in the Watershed—Continue to promote and support adoption of watershed practices to support water quantity and quality (streambank stabilization, improved soil health, increased riparian vegetation and forest wetlands, cover crops, and decreased till-farming practices). Develop success measures for practices to determine effectiveness. Many good examples of programs in the watershed already exist (Watershed Restoration and Protection Strategy [WRAPS], RCPP).	✓	✓	✓	✓	✓
	Water Quality Flood Monitoring—Support monitoring to evaluate the impact of flood conditions on water quality, such as debris, nutrient runoff, and sedimentation, and incorporate concerns into flood management strategies.	✓	✓	✓		✓
Water Management	Water Quality Communication and Outreach—Continue to support and provide educational outreach encouraging the implementation of watershed conservation practices, in particular soil health initiatives, streambank stabilization, and riparian corridor restoration.			✓		✓
Harmful Algal Blooms	Operational Strategies for HAB Management in Inland Reservoirs—Conduct systematic study on the influence of USACE reservoir control options on HABs. The study would investigate the effectiveness of water-level management and releases to address HABs in reservoirs.			✓		✓
	Harmful Algal Bloom Research—Identification and remediation of causes, prevention, and treatment of HABs, including potential in-lake technologies.			✓		✓
	Harmful Algal Bloom Mitigation and Remediation—A variety of HAB control treatments have been tested in Kansas, including hydrogen peroxide treatment, ultrasonic cavitation, and barley straw additions. There are other treatment options that are cost prohibitive for the current situation but can provide short-term benefits. Mitigation actions should include warnings, closures, data collection, and outreach. These actions should continue and improve as information becomes available.			✓		✓
Reservoir Habitat Improvements	Lake Level Management Plans (LLMP)—Conduct a comprehensive review of LLMPs and their review and implementation process. Greater flexibility and local control is desired to utilize LLMPs more effectively.			✓	✓	✓
Riverine/ Off-Channel/ Watershed Improvements	Support of the Kansas Sustainable Rivers Project (SRP)—Implement ecological flow proposals to mimic natural hydrologic regimes and habitat formation developed from the Kansas River Sustainable Rivers Project.				✓	✓

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
	Continue to refine and adjust these releases as appropriate, like adjustments for wet and dry cycles. Monitor the effectiveness of SRP implementation on riverine species reproduction. Recruitment is needed to determine success or to develop adaptive management measures for further implementation.					
	Upstream Floodplain Ecosystem Restoration—Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects that induce deposition on upstream floodplain in composition with grade control (stage zero projects). These multipurpose projects will provide ecological habitat benefits, reduce sediment flow to downstream waters and reservoirs, reduce water quantity and water quality concerns, and reduce ongoing streambank erosion and head-cuts.	✓	✓	✓	✓	✓
	Removal of Stream Impediments/Fish Barriers—Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects that remove existing stream impediments and fish barriers.				✓	✓
	Support Existing Plans to construct and Maintain Wetlands and Rehabilitate Old Oxbows—Support existing proposals and requests for ecosystem restoration projects. Current projects listed for GI, CAP, or conversion include Smoky Hill River GI, Jersey Creek GI, Rocky Ford GI, and Harlan County Reservoir CAP Section 1135.	✓	✓	✓	✓	✓
	Riparian Corridor Restoration—Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects focused on riparian habitat restoration. These multipurpose projects would provide ecological habitat benefits, reduce sediment to downstream waters and reservoirs, reduce water quantity and water quality concerns, and reduce ongoing streambank erosion and head-cuts.		✓	✓	✓	
Invasive Species Management	Watercraft Decontamination and Inspection—Install watercraft inspection and decontamination stations near federal reservoirs. This could be supported by continued funding through the Kansas State Water Plan Fund for the KDWP Aquatic Nuisance Species (ANS) management and control.		✓	✓	✓	✓
	Invasive/Non-native Species Management—Install watercraft inspection and decontamination stations near federal reservoirs. This could be supported by continued funding through the Kansas State Water Plan Fund for the KDWP ANS management and control.	✓	✓	✓	✓	✓
Research/ Monitoring/ Surveys/ Stocking	Riverine Fisheries Monitoring (species management, recruitment, habitat variables)—Monitor reintroduced populations to determine success and to inform adaptive management for future efforts.				✓	✓

Type of Measure	Measure	Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded/ Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
	Reintroduction of Imperiled Species—Develop habitat suitability requirements and site evaluation methods to identify sites and segments for potential reintroduction of imperiled species. Include establishment of safe harbor agreements and candidate conservation agreements with willing landowners to reintroduce imperiled species on their property.				✓	✓
	Western Streams Base Flow Monitoring—Initiate a spin-off study to monitor baseflow in streams in western Kansas. This would provide a baseline to monitor future reductions in stream baseflow in the future.		✓	✓	✓	
Reservoir Recreation	Develop a Plan for New Low Water Boat Ramps or Extending Existing Boat Ramps—Develop a plan for new lower-water boat ramps or extending boat ramps to mitigate boating access restrictions during low water conditions at USACE reservoirs in the basin and on the Kansas River mainstem.					✓
Riverine Recreation	Public River Access Points Along the Kansas River Mainstem—Develop Kansas River mainstem public access points to meet increasing use of the river for canoeing, kayaking, camping, fishing, hunting, and wildlife viewing. Provide access points for search and rescue efforts. Add amenities like parking, lighting, boat ramps, lifejacket stations, nearby camping areas, potable water, and safety signage to existing access points.					✓
Other Recreation Needs	Expansion/Improvement of Visitation Data—USACE and KDWP collaboration to develop a central storage location for visitor and visitation data, allowing better sharing between state and federal agencies.					✓
	Dashboard to Serve Water Quality and Recreation—Develop an online dashboard or application containing information on river flows, safety hazards, forecast river, and reservoir conditions.			✓		✓

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115 *Figure 5-1. Flood Risk Measures Screening and Evaluation-Objectives*

Problem: Flood Risk											
Type of Measure	**Measure**	**Objective**									
		Objective 1	**Objective 2**	**Objective 3**	**Objective 4**	**Objective 5**	**Objective 6**	**Objective 7**	**Objective 8**	**Objective 9**	**Objective 10**
Levee Upgrades	**New or Modified Levees / Dikes / Floodwalls**	✓	✓					✓		✓	✓
Operational Measures / Dams and Reservoirs Upgrades	**Lower Kansas River Basin Master Manual and/or Individual Reservoir Project Water Control Manuals Update**	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Missouri River Control Point Modification	✓	✓	✓	✓	✓		✓	✓	✓	✓
	New Reservoir / Dam Construction or Detention Basins	✓	✓			✓		✓	✓	✓	✓
Flow Improvements	**Channel Modifications**	✓	✓			✓		✓	✓	✓	✓
	High Flow Diversions	✓	✓			✓		✓	✓	✓	✓
Floodplain Improvements	**Authority for Land Acquisition or Easement Purchase for Flood Control**	✓	✓			✓		✓	✓	✓	✓
	Flood Management Plans	✓	✓	✓		✓	✓	✓	✓	✓	✓
Non-Structural Measures	**Kansas Flood Center/Flood Information System**	✓	✓							✓	✓
	Floodplain Regulations	✓	✓	✓		✓	✓	✓	✓	✓	✓
	Flood and Drought Forecasting	✓	✓	✓	✓					✓	✓
	Flood Risk Feasibility Studies					✓		✓	✓		✓
	Flood Warning/Emergency Plans	✓	✓							✓	✓
	Floodplain Mapping	✓	✓			✓	✓	✓	✓	✓	✓
	Silver Jackets Projects Related to Healthy Watersheds	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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117 *Figure 5-2. Flood Risk Measures Screening and Evaluation-Stressors*

Problem: Flood Risk						
Type of Measure	**Measure**	**Stressor**				
		Riverine Flooding	**High Reservoir Water Levels**	**Climate Change Implications**	**Flood Response Communications Issues**	**Sedimentation in Reservoirs and Downstream Erosion**
Levee Upgrades	**New or Modified Levees / Dikes / Floodwalls**	✓	✓	✓	✓	✓
Operational Measures / Dams and Reservoirs Upgrades	**Lower Kansas River Basin Master Manual and/or Individual Reservoir Project Water Control Manuals Update**	✓	✓	✓	✓	✓
	Missouri River Control Point Modification	✓	✓	✓	✓	✓
	New Reservoir / Dam Construction or Detention Basins	✓	✓	✓	✓	✓
Flow Improvements	**Channel Modifications**	✓	✓	✓	✓	
	High Flow Diversions	✓	✓	✓	✓	
Floodplain Improvements	**Authority for Land Acquisition or Easement Purchase for Flood Control**	✓	✓	✓	✓	
	Flood Management Plans	✓	✓	✓	✓	
Non-Structural Measures	**Kansas Flood Center / Flood Information System**	✓	✓	✓	✓	
	Floodplain Regulations	✓	✓	✓	✓	
	Flood and Drought Forecasting	✓	✓	✓	✓	
	Flood Risk Feasibility Studies	✓	✓	✓	✓	
	Flood Warning/Emergency Plans	✓	✓	✓	✓	
	Floodplain Mapping	✓	✓	✓	✓	
	Silver Jackets Projects Related to Healthy Watersheds	✓	✓	✓	✓	✓

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Figure 5-3. Water Supply Measures Screening and Evaluation-Objectives

Problem: Reduction in Ability to Meet Water Supply Demands											
Type of Measure	**Measure**	**Objective**									
		Objective 1	**Objective 2**	**Objective 3**	**Objective 4**	**Objective 5**	**Objective 6**	**Objective 7**	**Objective 8**	**Objective 9**	**Objective 10**
Operational Measures	**Modification of Low Flow Target Values to Extend Period of Low Flow Support**			✓	✓		✓	✓	✓	✓	✓
Resiliency Planning	**Water Supply Demand Study**			✓	✓					✓	✓
	Kansas Research Priorities Support			✓	✓	✓	✓	✓	✓	✓	✓
	Small Watershed Dam Assessment			✓	✓			✓			✓
	Promote and Incentivize the Adoption of Watershed Practices			✓	✓	✓	✓	✓	✓	✓	✓
	Drought Communication and Outreach			✓	✓	✓	✓			✓	✓
	Kansas River Alluvial Model			✓	✓	✓	✓	✓	✓	✓	✓
Sediment Reduction	**Regional Sediment Management Plans**			✓	✓	✓	✓	✓	✓	✓	✓
	Bank Stabilization / Stabilize Headcuts			✓	✓	✓	✓	✓	✓	✓	✓
	Reservoir Bathymetry			✓	✓	✓	✓	✓	✓	✓	✓
Sediment Removal	**Tuttle Creek Reservoir Long-Term Sediment Management Plan**			✓	✓	✓	✓	✓	✓	✓	✓
	Tuttle Creek Reservoir Water Injection Dredging Demonstration			✓	✓	✓		✓	✓	✓	✓
	Kanopolis Reservoir Long-Term Sediment Management Plan			✓	✓	✓	✓	✓	✓	✓	✓
New Water Storage	**Kansas River Alluvial System as a Filtration and Storage System**			✓	✓	✓	✓	✓	✓	✓	✓
	Construction of Multipurpose Small Lakes			✓	✓				✓		✓
	Harlan County Reservoir Reallocation Study			✓	✓						✓
	Kanopolis Reservoir Conservation Pool Raise Study			✓	✓						✓

Figure 5-4. Water Supply Measures Screening and Evaluation-Stressors

Problem: Reduction in Ability to Meet Water Supply Demands						
Type of Measure	**Measure**	**Stressor**				
		Sedimentation	**Drought**	**Reduced Water Supply From Navigation Releases**	**Groundwater Depletion**	**Climate Change Implications**
Operational Measures	**Modification of Low Flow Target Values to Extend Period of Low Flow Support**	✓	✓	✓	✓	✓
Resiliency Planning	**Water Supply Demand Study**	✓	✓	✓	✓	✓
	Kansas Research Priorities Support	✓	✓	✓	✓	✓
	Small Watershed Dam Assessment	✓	✓			
	Promote and Incentivize the Adoption of Watershed Practices	✓	✓	✓	✓	✓
	Drought Communication and Outreach		✓		✓	✓
	Kansas River Alluvial Model		✓		✓	✓
Sediment Reduction	**Regional Sediment Management Plans**	✓	✓			✓
	Bank Stabilization / Stabilize Headcuts	✓				
	Reservoir Bathymetry	✓				
Sediment Removal	**Tuttle Creek Reservoir Long-Term Sediment Management Plan**	✓	✓			
	Tuttle Creek Reservoir Water Injection Dredging Demonstration	✓	✓			
	Kanopolis Reservoir Long-Term Sediment Management Plan	✓	✓			
New Water Storage	**Kansas River Alluvial System as a Filtration and Storage System**	✓	✓	✓	✓	✓
	Construction of Multipurpose Small Lakes	✓	✓		✓	✓
	Harlan County Reservoir Reallocation Study		✓		✓	✓
	Kanopolis Reservoir Conservation Pool Raise Study	✓	✓		✓	✓

Figure 5-5. Water Quality Measures Screening and Evaluation-Stressors

Problem: Degraded / Poor Water Quality						
Type of Measure	**Measure**	**Stressor**				
		Harmful Algal Blooms	**Impaired Waters**	**Water Shortages (Causing Reduced High Quality Water)**	**Inadequate Stormwater Management**	**Sedimentation**
Nutrient and Sediment Reduction	**Promote and Incentivize the Adoption of Watershed Practices**	✓	✓	✓	✓	✓
	Water Quality Flood Monitoring		✓		✓	✓
Water Management	**Water Quality Communication and Outreach**	✓	✓	✓	✓	✓
	Water Quality Monitoring of the Ogallala Aquifer		✓	✓		
Harmful Algal Blooms	**Operational Strategies for HAB Management in Inland Reservoirs**	✓				
	HAB Research	✓				
	HAB Mitigation and Remediation	✓				

5.2.1.4 Ecosystem Restoration and Management

- Does the measure protect and improve the benefits to fish and wildlife by increasing habitat and improving heterogeneity?
- Does the measure reduce the loss of storage volume of the reservoirs and sustain the benefits to fish and wildlife?
- Does the measure reduce damages to ecosystems and species from drought risk?
- Does the measure increase adoption of watershed practices to protect and improve biological resources, including vegetation and wetlands, wildlife and wildlife habitats, and fisheries and aquatic species?
- Does the measure reduce the negative impacts from invasive and non-native species for native species?
- Does the measure increase the adaptability and resiliency of the system in relation to climate change, including extreme events like flooding and drought?

Figures 5-6 and 5-7 display the screening and evaluations conducted for water quality.

5.2.1.5 Recreation

- Does the measure reduce damages or loss of revenue from flood risk and sustain the benefits of recreation opportunities?
- Does the measure reduce the loss of storage volume of the reservoirs and sustain the benefits of recreation opportunities?
- Does the measure reduce damages or loss of revenue from drought risk and sustain the benefits of recreation opportunities?
- Does the measure protect and improve the availability of high-quality water for recreation uses?
- Does the measure maintain or improve sportfish populations, habitats, and angler access?
- Does the measure protect, promote, and expand recreational opportunities, including boating, fishing, hunting, camping, wildlife viewing, swimming, and picnicking?
- Does the measure increase the adaptability and resiliency of the system in relation to climate change including extreme events like flooding and drought?

Figures 5-8 and 5-9 display the screening and evaluations conducted for water quality.

The four P&G evaluation criteria provide a broad framework for comparing measures and strategies from a variety of perspectives.

- Completeness—the extent to which a given strategy or alternative provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.
- Effectiveness—the extent to which a strategy or alternative alleviates the specified problem and achieves the specified opportunities.

- Efficiency—the extent to which a strategy or alternative is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with the national environment.
- Acceptability—the workability and viability of a strategy or alternative with respect to acceptance by federal and non-federal entities and the public, and compatibility with existing laws, regulations, and public policies.

173 *Figure 5-6. Ecosystems and Species Measures Screening and Evaluation-Objectives*

Problem: Ecosystem Degradation and Species Impacts											
Type of Measure	Measure	Objective									
		Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6	Objective 7	Objective 8	Objective 9	Objective 10
Reservoir Habitat Improvements	Lake Level Management Plans			✓	✓				✓	✓	✓
Riverine / Off-Channel / Watershed Improvements	Support of Sustainable Rivers Project Environmental Flow Proposals			✓	✓				✓	✓	✓
	Upstream Floodplain Ecosystem Restoration			✓	✓	✓	✓	✓	✓	✓	✓
	Removal of Stream Impediments / Fish Barriers			✓		✓	✓	✓	✓	✓	✓
	Construct and Maintain Wetlands and Rehabilitate Old Oxbows			✓	✓	✓	✓		✓	✓	✓
	Riparian Corridor Restoration			✓	✓	✓	✓	✓	✓	✓	✓
Invasive Species Management	Watercraft Decontamination and Inspection						✓	✓	✓	✓	✓
	Invasive / Non-native Species Control						✓	✓	✓	✓	✓
Research / Monitoring / Surveys / Stocking	Riverine Fisheries Monitoring (species management, recruitment, habitat variables)								✓	✓	✓
	Reintroduction of Imperiled Species								✓	✓	
	Western Streams Baseline Flow Monitoring			✓	✓		✓		✓	✓	✓

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Figure 5-7. Ecosystems and Species Measures Screening and Evaluation-Stressors

Problem: Ecosystem Degradation and Species Impacts						
Type of Measure	Measure	Stressor				
		Loss of Riverine / Floodplain Habitat Leading to Species Declines	Invasive / Non-native Species	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	Loss of Reservoir Fisheries Habitat Leading to Declines	Groundwater Depletion
Reservoir Habitat Improvements	Lake Level Management Plans	✓		✓	✓	
Riverine / Off-Channel / Watershed Improvements	Support of Sustainable Rivers Project Environmental Flow Proposals	✓		✓		✓
	Upstream Floodplain Ecosystem Restoration	✓		✓	✓	✓
	Removal of Stream Impediments / Fish Barriers	✓		✓		✓
	Construct and Maintain Wetlands and Rehabilitate Old Oxbows	✓		✓	✓	✓
	Riparian Corridor Restoration	✓	✓	✓		✓
Invasive Species Management	Watercraft Decontamination and Inspection	✓	✓		✓	
	Invasive / Non-native Species Control	✓	✓		✓	
Research / Monitoring / Surveys / Stocking	Riverine Fisheries Monitoring (species management, recruitment, habitat variables)	✓	✓			
	Reintrodution of Imperiled Species	✓				
	Western Streams Baseline Flow Monitoring	✓		✓	✓	✓

Figure 5-1. Recreation Measures Screening and Evaluation-Objectives

Problem: Loss of Recreation Opportunities											
Type of Measure	Measure	Objective									
		Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6	Objective 7	Objective 8	Objective 9	Objective 10
Reservoir Recreation	Construct New Boat Ramps or Extend Existing Boat Ramps				✓			✓		✓	✓
Riverine Recreation	Public Access Points Along the Kansas River Mainstem				✓			✓		✓	
Other Recreation Needs	Expansion / Improvement of Visitation Data				✓					✓	✓
	Dashboard to Serve Recreation and Water Quality			✓	✓	✓				✓	✓

Figure 5-2. Recreation Measures Screening and Evaluation-Stressors

Problem: Loss of Recreation Opportunities					
Type of Measure	**Measure**	**Stressor**			
		Limited Public Lands	**Reservoir Sedimentation**	**Water Quality / Harmful Algal Blooms**	**Increased Operational Costs and Lost Revenues from Flooding and Drought**
Reservoir Recreation	**Construct New Boat Ramps or Extend Existing Boat Ramps**	✓	✓		✓
Riverine Recreation	**Public Access Points Along the Kansas River Mainstem**	✓			✓
Other Recreation Needs	**Expansion / Improvement of Visitation Data**	✓	✓	✓	✓
	Dashboard to Serve Recreation and Water Quality	✓	✓	✓	✓

5.3 Strategies and Recommendations Comparison and Selection

After the measures were screened, they were grouped into strategy types and recommendations. Using the list of measures, the study partners (USACE, KWO, and KDWP) formulated strategies to address identified issues and opportunities, emphasizing the alignment of actions of federal, state, interstate, and local government entities, and expected outcomes resulting from the combination of measures. Strategies and recommendations were developed in the context of options or choices and their projected outcomes and were developed based upon reputable and readily available science and technical analyses. A range of strategies and recommendations were formulated for each focus area (flood risk management, ecosystem restoration and management, water availability and sustainment, water quality, and recreation). Figure 5-10 shows the broad types of strategies and recommendations the team and partners evaluated as part of this watershed study.

Figure 5-3. Types of Recommendations

Flood Risk	Reduction in Ability to Meet Water Supply Demands	Degraded / Poor Water Quality	Ecosystem Degradation and Species Impacts	Loss of Recreational Opportunities
Operational Measures / Dams and Reservoir Upgrades	Operational Measures	Nutrient and Sediment Reduction	Reservoir Habitat Improvements	Reservoir Recreation
Levee Upgrades	Resiliency Planning	Water Management	Off Channel / Watershed Improvements	Riverine Recreation
Flow Improvements	Sediment Reduction	Harmful Algal Blooms	Invasive Species Management	Other Recreation Needs
Floodplain Improvements	Sediment Removal		Research / Monitoring / Surveys / Stocking	
Non-Structural Measures	New Water Storage			

In the recommendations milestone phase of the study, and in consultation with the watershed study partners and experts, the strategies and recommendations were evaluated and further refined in terms of meeting the identified problems, while focusing on the collective values, missions, and Shared Vision. There may be several ways to address the needs within a watershed, so a structured assessment of the pros and cons of each strategy or alternative were used to inform a trade-off analysis.

The strategies and recommendations must clearly describe the overall benefits toward advancing the Shared Vision. It must provide a general assessment of cost effectiveness, sequencing, priority of actionable items, and associated needs. The primary responsible federal and non-federal partners and their associated missions, authorities, programs, and sources for potential future appropriations should also be identified to inform a strategic roadmap that guides implementation and provides measurable value to the nation. The four P&G evaluation criteria were used to evaluate strategies or recommendations.

5.4 Potential Funding and Implementation Resources

Existing authorities and programs will be utilized, when possible, to implement recommendations. Below are explanations of identified funding opportunities from USACE and other agencies. Additional information may be found online through coordination with agency representatives.

5.4.1 USACE Authorities

Below is a summary of all USACE authorities that are available for planning, feasibility studies, technical assistance, or construction efforts. Most authorities require a non-federal cost share; however, cost share waivers may be available, per Section 1156 of WRDA 1986, as amended (33 U.S.C. 2310), for the categories of PAS, GI Studies, and the CAP described below.

- FPMS—Authorized under Section 206 of the Flood Control Act of 1960, as amended, FPMS provides communities with technical and planning services to support effective floodplain management. FPMS efforts are often completed by Silver Jackets teams. Under FPMS, USACE supports both riverine and coastal flood challenges and empowers communities to better understand the risks of flooding and develop plans to communicate and manage that risk. Activities provided under this authority include H&H technical services, general planning guidance, education and outreach material, and NFIP support. Funding is typically 100 percent federally provided, within limits of the authority. Requests for assistance should be in the form of a letter that includes the location and nature of the problem to be investigated.
- Silver Jackets—Silver Jackets teams in states and territories across the United States bring together a partnership of multiple state, federal, tribal, territorial, and local agencies to collaborate on reducing flood risk and other natural disasters. By applying their shared knowledge, the teams enhance response and recovery efforts when events occur. The partnership provides an opportunity for mentoring and networking, enables agencies to better respond and prepare for disasters as a team, and helps achieve communities that are sustainable and resilient to natural disasters, especially flooding. The interagency nature of Silver Jackets teams allows for leveraging of all available resources and authorities, including those from within USACE such as FPMS, to support local flood risk management needs.
- Planning Assistance to States (PAS)—Two types of planning assistance, including preparation of Comprehensive Plans and Technical Assistance, are offered through the PAS program (authorized by Section 22 of WRDA 1974, as amended). Requests for assistance should be in the form of a letter that includes the location and nature of the problem to be investigated.
    - Comprehensive Plans include planning for the development, utilization, and conservation of the water and related resources of drainage basins, watersheds, or ecosystems located within the boundaries of that state or territory (or group of states and territories) to comprehensively address water resource challenges.

- Technical Assistance provided through the PAS program includes support of planning efforts related to the management of water resources, including the provision and integration of hydrologic, economic, or environmental data and analysis in support of water resources management and related land resource development plans. This technical assistance does not include the preparation of site-specific designs or construction. Section 22 technical assistance is only available upon request of a government agency or non-federal interest. Technical assistance activities through the PAS program are cost shared 50 percent) with the non-federal sponsor, and voluntarily-contributed funds in excess of cost share may be provided by the non-federal sponsor. The cost share for technical assistance must be provided by funds (not in-kind).

- General Investigation—USACE is authorized to conduct investigations related to its core mission areas of navigation, flood risk management, and ecosystem restoration, to determine if congressional authorization and implementation of specific civil works projects are warranted. GIs involve a jointly conducted study with a sponsor and, if shown by the study to be feasible, the construction and implementation of the project. This approach requires Congress to provide an authorization to construct and implement the project. There are several types of planning studies and decision documents, but for the GI process, the most common studies are Feasibility Studies, which include optimizing the plans to be built. They are equally cost-shared and are usually completed in 24 to 36 months. The first $100,000 is federally funded. If the study cost exceeds $100,000, the cost share is 50 percent federal and 50 percent non-federal. Project implementation requires both authorization and appropriation from Congress, and the cost share is typically 65 percent federal and 35 percent non-federal. Requests for assistance should be submitted in the form of a letter of intent from a state or local government agency to USACE.
- USACE Engineering with Nature (EWN) Initiative—EWN is the USACE initiative that enables more sustainable delivery of economic, social, and environmental benefits associated with infrastructure. Sustainable water resource infrastructure is achieved through the beneficial integration of engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management. Positive outcomes are achieved through EWN by systematically integrating social, environmental, and economic considerations at every phase of a project. The results are innovative and resilient solutions that are more socially acceptable, viable, equitable, and, ultimately, more sustainable.
- Regional Sediment Management (RSM) Program—RSM is a research program which implements innovative management strategies to optimize the use of sediment and improve the management of projects. The program supports initiatives that develop and demonstrate sustainable practices that systematically increase benefits and reduce lifecycle costs for USACE's navigation, flood risk management, and environmental missions. RSM provides opportunities to collaborate with stakeholders and other agencies to leverage resources, share

technology and data, and develop and implement innovative solutions to improve regional utilization and management of sediments. Proposals are typically solicited once per year in June and are submitted by USACE. Projects do not require a non-federal cost share, however, stakeholder and partner engagement and information sharing is strongly encouraged and considered in the proposal selection process.

- Section 7001 Annual Report—The Section 7001 Annual Report to Congress Process may be used when study authority does not already exist for an area of interest. In Section 7001 of the Water Resources Reform and Development Act of 2014 (P.L. 113-121; 33 U.S.C. §2282d), Congress established an annual process for identifying proposals for site-specific studies and projects within USACE's water resource mission and authorities. The process includes a call for non-federal proposals, which should be submitted to the Planning Division at the regional USACE district and include the area of interest (for Kansas River Basin this is NWK). Inclusion of a proposal in a Section 7001 annual report does not provide congressional authorization or appropriation. Rather, inclusion of a proposal in a report facilitates congressional consideration to authorize the proposal.
- CAP—The CAP is a group of nine legislative authorities under which USACE can plan, design, and implement certain types of water resource projects without additional project specific Congressional authorization. The purpose of the CAP is to plan and implement projects of limited size, cost, scope, and complexity. For all sections, except Sections 204 and 111, the feasibility phase may be initially federally funded up to $100,000. Any remaining feasibility phase costs will be shared fifty-fifty with the non-federal sponsor after executing a feasibility cost sharing agreement. For Section 204 projects, the feasibility phase is performed at 100 percent of federal cost. For Section 111 projects, the feasibility phase costs above the initial $100,000 are cost-shared in the same proportion as the cost-sharing provisions applicable to the construction of the federal navigation project causing the shore damages. Construction is either cost shared at 65 percent federal and 35 percent non-federal, or 75 percent federal and 25 percent non-federal, depending on the authority. Requests for assistance should be in the form of a letter describing the location and nature of the problem and requesting assistance under the program. Table 5-2 shows five of the authorities included in the program for use in the Kansas River Basin.

Table 5-2. CAP Authorities

Authority	Types of Projects	Feasibility Cost Share (Federal—Non-Federal)	Implementation Phase Cost Share (Federal—Non-Federal)	Federal Project Limit
Section 14, Flood Control Act of 1946, as amended. Emergency Streambank and Shoreline Protection.	Construction of bank protection for highways, bridge approaches, municipal water supply systems, sewage disposal plants, churches, hospitals, schools, non-profit public services and known cultural sites endangered by flood-caused bank and shoreline erosion.	100% federal for first $100,000 50%-50% remaining cost	65%—35%	$10M
Section 205, Flood Control Act of 1946, as amended. Small Flood Control Projects.	Projects include levees, floodwalls, impoundments, pumping stations, and channel modifications, as well as non-structural measures, such as flood-proofing, relocation, and flood warning systems.	100% federal for first $100,000 50%—50% remaining cost	65%—35%	$10M
Section 206, Water Resources Development Act of 1996, as amended. Aquatic Ecosystem Restoration	Projects include restoring floodplains, channel modifications, or modification of structures to restore conditions conducive to native aquatic species.	100% federal for first $100,000 50%—50% remaining cost	65%—35%	$10M
Section 1135, Water Resources Development Act of 1986, as amended. Project Modifications for Improvement of Environment.	Modifications to existing USACE structures and operations, or implementation of restoration measures in affected areas.	100% federal for first $100,000 50%—50% remaining cost	75%—25%	$10M

- USACE NWK Water Quality Program—The NWK Water Quality Program has maintained a long-term and robust water-quality monitoring and data collection program to meet the needs of all lake projects. Chemical, physical, and biological parameters are measured to evaluate water and lake-bed sediment quality. USACE uses this data to describe conditions and changes from the inflow and outflow streams within the main lake, focusing on eutrophication, nutrients, sediment, herbicides, metals, and contaminants. This data is critical to investigating problems that may arise, such as HABs, bacteria issues, and fish kills, as well as designing and implementing modifications to improve water management procedures.

5.4.2 Funding Opportunities Available from Other Agencies and Organizations

- FEMA Hazard Mitigation Assistance Grant Programs
  - The HMGP provides funding to rebuild in a way that reduces, or mitigates, future natural hazard losses in communities. HMGP funding is authorized with a presidential major disaster declaration. The amount of funding made available to the applicant is generally 15 percent of the total federal assistance amount provided for recovery from the presidentially declared disaster and is determined by the FEMA-approved Hazard Mitigation Plan.
  - The Building Resilient Infrastructure and Communities (BRIC) is a competitive grant program that supports hazard mitigation projects to reduce the risks from disasters and natural hazards. The BRIC program aims to categorically shift federal focus away from reactive disaster spending and towards proactive investment in community resilience. As a competitive grant program, applicants must apply on a yearly basis and the proposed project must have positive net benefits. BRIC encourages public infrastructure projects, nature-based solutions, and the adoption and enforcement of modern building codes.
  - Emergency Management Performance Grant Program provides funding for emergency management agencies that are implementing National Preparedness Systems and Goals. The goals of preparedness are prevention, protection, mitigation, response, and recovery from the threat of natural hazards.
- Housing and Urban Development (HUD) Disaster Resilience Grants
  - The Office of Community Planning and Development provides billions of dollars in flexible funding to help communities recover from, and build resilience to, climate hazards and natural disasters, particularly low-and-moderate-income communities that are especially vulnerable to current and historic discrimination and disinvestment. The Community Development Block Grant (CDBG) program is both a flexible and widespread program reaching over 1,200 local governments in all states and territories. The program's scope and promotion of community-specific solutions make CDBG a powerful tool for climate resilience. It requires jurisdictions to incorporate resilience to natural hazard risks into their consolidated plan and to discuss how climate change will increase those risks. It also requires verbiage on how jurisdictions will address the impacts of climate change for low-and-moderate-income residents.
  - The Section 108 Loan Guarantee Program (Section 108) provides communities with a source of low-cost, long-term financing for economic and community development projects. Section 108 financing provides an avenue for communities to undertake larger, more costly projects when there are limited resources for upfront investment. Section 108 funds economic development, housing, public facilities, infrastructure, and other physical development projects, including improvements to resilience against natural

disasters. The flexibility of uses makes it one of the most potent and important public investment tools the HUD offers to states and local governments.

- U.S. Department of Agriculture Natural Resources Conservation Service:
  - Agricultural Conservation Easement Program, Agricultural Land Easements (ALE), and Wetland Restoration Easements help restore, protect, and enhance wetlands on eligible lands. ALE protects farmlands and grasslands by limiting non-agricultural uses of the land.
  - Environmental Quality Incentive Program Conservation Incentive combines the best of the Conservation Stewardship Program and the Environmental Quality Incentive Program, providing annual payments for the operation's existing level of conservation and providing financial assistance for the installation of conservation practices or enhancements. Unlike the Conservation Stewardship Program, not all acres under the applicants control need to be enrolled or assessed for eligibility for the Environmental Quality Incentive Program Conservation Incentive.
  - Conservation Stewardship Program is the nation's largest conservation program in terms of participating land. It is designed to help farmers have more robust conservation activities. Agricultural producers and forest landowners looking to increase conservation efforts receive annual payments and financial assistance for an operation's existing level of conservation and for a wide variety of conservation activities.
  - Farm Bill 2014 Regional Conservation Partnership Program (RCPP) funds solutions to natural resource challenges. By leveraging collective resources and collaborating on common goals, RCPP demonstrates the power of public-private partnerships in delivering results for agriculture and conservation. There is a current RCPP for Milford Lake that implements BMPs within the Milford Lake watershed to decrease nutrient runoff.
  - Emergency Watershed Protection Program is a program that relieves imminent hazards to life and property caused by floods, fires, windstorms, and other natural hazards. Financial and technical assistance is provided to remove debris from streams, protect destabilized streambanks, establish cover on critically eroded lands, repair conservation practices, and purchase floodplain easements.
- U.S. Environmental Protection Agency (EPA):
  - Agency Clean Water State Revolving Funds—The Clean Water State Revolving Fund program is a federal and state partnership that provides communities with low-cost financing for a wide range of water quality infrastructure projects. Projects eligible to receive assistance are construction of publicly owned treatment works, nonpoint source pollution programs, national estuary programs, decentralized wastewater treatment systems, stormwater systems, water conservation plans, watershed pilots, energy efficiency plans, water reuse plans, security measures at publicly owned treatment works, and technical assistance.

- Nonpoint Source and the Section 319 Grant Program—Under Section 319 of the CWA, the EPA provides annual grants to states to control nonpoint sources of pollution, such as agricultural runoff, mining activities, and malfunctioning onsite septic systems. In states where onsite systems are identified as a significant source of such pollution, these funds may be used to construct, upgrade, or repair onsite systems.
- Water Quality Monitoring Grant Program—Also known as the Section 106 Grant Program funds projects that enhance existing monitoring efforts to help achieve long-term monitoring program goals.

- The following programs and organizations are described in Section 1 and could provide funding opportunities to support study recommendations:
  - Kansas WRAPS Groups
  - KRPI
  - The KAWS
  - LEMAs
  - Kansas Wetland Program
  - KDWP Stream Survey and Monitoring Program
  - The Playa Lakes Joint Venture (PLJV)
  - KDHE:
    - Stream Chemistry Monitoring Program
    - Stream Biological Monitoring Program
    - Harmful Algal Bloom Response Program
  - KDWP ANS Program
  - KDA DOC:
    - Water Transition Assistance Program
    - Riparian Quality Enhancement Initiative
    - Sediment and Nutrient Reduction Initiative
    - Streambank Protection Program
    - Riparian and Wetland Program
    - Water Quality Buffer Initiative
    - Water Resources Cost Share Program
    - Watershed Planning Assistance Program
    - Flood Control and Lakes Programs
      - Multipurpose Small Lakes Program
      - Water Supply Restoration Program
      - Watershed Dam Construction Assistance
    - KFS Programs
      - Riparian Restoration Initiative
      - Assessment of Riparian Forests to Reduce Sedimentation of Federal Reservoirs.

5.5 Recommendations

Recommendations follow the broad outline set forth from the risk and uncertainty results (Figures 5-11 through 5-14). The following sections document the proposed recommendations and possible implementation strategies, including potential funding sources and partners. Recommendations were formulated by carrying forward management measures that addressed a specific problem area or stressor while adhering to the risk and uncertainty framework. Recommendations include either stand-alone measures (if the measure is distinctly unique) or are combined with similar measures for a comprehensive recommendation. The recommendations provided in the section below address issues related to risks with a nexus to water resources.

The team held coordination meetings with partners to gain input and concurrence on the recommendations. Partners provided valuable insights on recommendations and on-going efforts. Potential agencies that could champion the implementation of recommendations are noted in the following recommendation tables. Letters of support from these key agencies are included in Appendix L.

Any solutions recommended must comply with all federal or state regulations. Examples include federal environmental laws (Code of Regulations (eCFR.gov)), USACE Regulations–Navigation and NEPA (33 CFR Part 200 et seq.), NEPA (40 CFR Part 1500-1508), ESA (50 CFR Part 402), CWA (40 CFR Parts 121 and 230), Fish and Wildlife Coordination Act (16 USC 661), Migratory Bird Treaty Act (50 CFR Part 21), NHPA (36 CFR Part 800), Clean Air Act (40 CFR Part 93, Subpart B), Wild and Scenic Rivers (36 CFR Part 297), and applicable Eos, such as:

- EO 11988—Floodplain Management
- EO 11990—Protection of Wetlands
- EO 12322—Water Resources Projects
- EO 12898—Environmental Justice
- EO 13112—Invasive Species
- EO 13690—Federal Flood Risk Management Standards
- EO 13751—Invasive Species Safeguarding the Nation
- EO 13990—Climate Crisis
- EO 14008—Tackling the Climate Crisis

Cost included for recommendations are rough estimates and includes professional labor only. Costs are denoted by the following scale:

- $ $0–$1M
- $$ $1M–$5M
- $$$ $5M+

There is no obligation from the USACE, other federal agencies, or the study partners to implement any of the proposed recommendations.

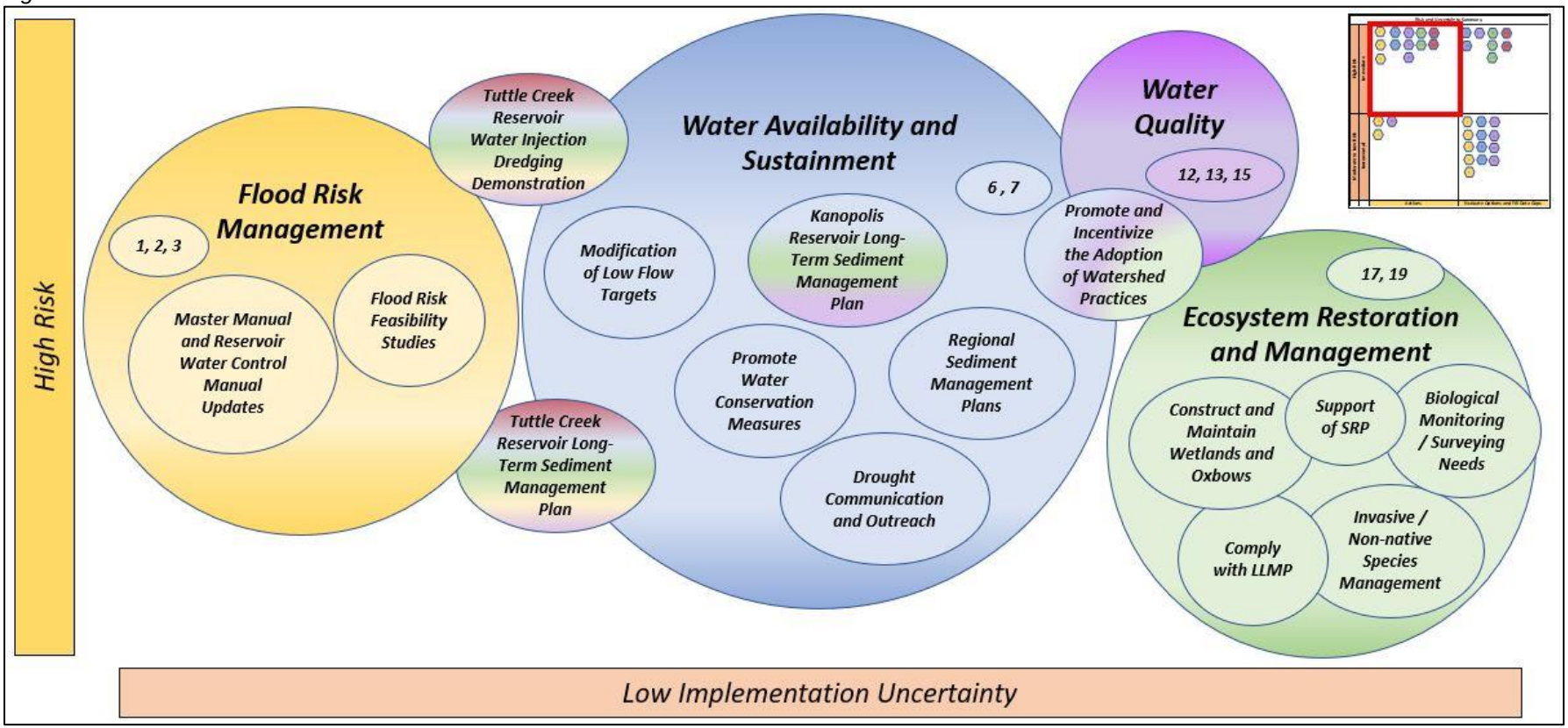
5.5.1 Immediate Actions

Immediate and near-term actions address stressors with high risk and low implementation uncertainty. These should be pursued as soon as possible (ASAP) and within ten years. Immediate actions may require some level of analysis to appropriately implement the measure in the basin. Figure 5-11 shows immediate actions to reduce risks related to floods, reduction in the ability to meet water supply demands, degraded and poor water quality, degraded ecosystems, and species declines.

5.5.1.1 Flood Risk

Flood risk stressors with solutions categorized as immediate, near-term actions include riverine flooding and high-water reservoir levels. Flooding is a costly, reoccurring challenge in the Kansas River Basin, both in property loss and, more significantly, in loss of lives. Flooding events in the Kansas River Basin has caused riverine and overland flooding and high reservoir water levels that threaten life safety and damage homes, businesses, public facilities, agricultural lands, and critical infrastructure like roads, railroads, and utilities. Flooding events displace individuals and businesses, damage cultural resources, increase environmental degradation, and cause public health issues. The entire Kansas River Basin is subject to severe riverine flooding at infrequent intervals, erratically interspersed by less severe floods of varying magnitudes. Floods in the basin have damaged millions of dollars of private property and crop land, as well as critical infrastructure such as interstate highways, railroads, and state highways. Kansas River Basin flooding has displaced individuals, impacted delivery of services, and caused repetitive losses in many areas. Additionally, floods have caused damages and lost revenue at recreational facilities managed by federal and state agencies, private entities, and non-profit organizations. The most obvious threat to health and safety is the danger of drowning in flood waters. Swiftly flowing flood waters can easily overcome even good swimmers. If flooding occurs suddenly, people may become trapped in their homes and drown. Additionally, as little as two feet of water can sweep away vehicles when people attempt to drive through flooding.

Figure 5-4. Basin-wide Immediate Actions



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Immediate actions should be taken to reduce economic, social, and environmental risks associated with these stressors. USACE is currently undertaking updates to individual reservoir WCMs in the Kansas River Basin, which will include alternatives and changes to operations that will provide greater flexibility and further reduce the impacts of riverine flooding and high reservoir water levels. USACE is conducting a flood risk management study for areas near Topeka, Kansas, along Shungununga Creek, that are impacted by riverine flooding. The proposed measures to reduce the effects of flooding on life safety and economic damages are higher than the costs allowed under the current USACE study being conducted under the CAP Section 205. Therefore, USACE and the City of Topeka, Kansas, submitted a request for the new start feasibility study under the USACE GI Program. The watershed study generated information relative to potential flood risk at more specific locations (Appendix H). This information will be used to work with federal and state agencies and regional and local communities to reduce this risk. Actions could include partnerships between non-federal sponsors and USACE under USACE programs and authorities (e.g., GI, CAP, PAS, FPMS, Silver Jackets). This will require additional collaboration beyond the watershed study and investment in other opportunities with partners. Some of the areas with potential flood risk could rise to the level of immediate actions. Table 5-3 shows near-term actions shown as flood risk recommendations.

Table 5-3. Flood Risk Recommendations-Immediate Actions

Focus	Recommendation	Potential Partners and Funding
Lower Kansas River Basin Master Manual and/or Individual Reservoir Project WCM Update	Initiate spin-off studies to update the Lower Kansas River Basin Master Manual or individual reservoir project WCMs within the Kansas River Basin for Tuttle Creek, Perry, Clinton, and Milford.	Estimated Cost: $-$$ Potential Funding: USACE WCM Updates Other Potential Partners/Stakeholders: USACE, KWO, KDWP, KDA, KDHE NDNR, NGPC, USBR Priority Area(s): USACE Reservoirs
Flood Risk Feasibility Studies	Support existing proposals and new requests for flood risk management projects.	Estimated Cost: $$ Potential Funding: USACE, City of Topeka, Kansas Other Potential Partners/Stakeholders: USACE, City of Topeka, Kansas Priority Area(s): Shungununga Creek, Topeka, Lawrence, Junction City, Manhattan, Shawnee, Edwardsville, Muncie

5.5.1.2 Reduction in Ability to Meet Water Supply Demands

Water supply stressors with solutions categorized as immediate, near-term actions include sedimentation and drought. Immediate actions should be taken to reduce economic, social, and environmental risks associated with these stressors. Current low-flow targets were set to maintain sufficient flows past surface water intakes, support instream uses, and maintain the ecosystem. As municipal and industrial diverters have modified intake structures or moved to alluvial collector well use, current flow targets

have been reduced. During periods of drought, reservoir storage will lower, leading to reduced ability to meet flow targets in the downstream reaches at Topeka and De Soto, Kansas. The loss of water supply storage in reservoirs from sedimentation will further exacerbate these risks and will further increase the risk of not meeting downstream water supply targets. Lack of reliable water supply and shortages of water could have a devasting effect on the economy of Kansas and the health and welfare of its citizens. Drought can severely impact a public water supply through depletion of raw water and increased demand for customer water. Every industry from agriculture, electric power generation. manufacturing, and tourism relies on water to grow and ultimately sustain its business. Many economic impacts have occurred in agriculture and related sectors leading to loss of income and increasing food costs.

USACE is currently undertaking updates to individual reservoir WCMs in the Kansas River Basin, which include alternatives for development and preparation of drought contingency plans. Included are any potential changes to operations that provide greater flexibility and reduce the impacts of drought. Use of adaptive lake-level management plans to determine when reservoir drawdowns should not happen would better manage water availability during periods of low inflow, reduced precipitation, or the onset of drought. Modification of low-flow target values, extending the period of low-flow support from the reservoirs will be considered for part of these updates. The State of Kansas has expressed an interest and will participate in USACE discussions to determine the parameters for this recommendation.

Two USACE reservoirs in the basin with the highest expected future sedimentation rates are Tuttle Creek and Kanopolis. Loss of multipurpose pool storage at these two reservoirs would substantially impact the ability to provide downstream flows for water supply uses. USACE and KWO have submitted a request for the new start feasibility study under the USACE GI Program for a Tuttle Creek Reservoir Long-term Sediment Management Plan. The Plan will investigate sediment management alternatives for the perpetual sustainment of Tuttle Creek Reservoir’s authorized purposes and benefits. Assessments were conducted for the watershed study on potential measures that could be considered in the GI study, like drawdown flush, water injection dredging, and in-lake hydraulic dredging with downstream discharge. Additional information related to this plan is included in Appendix D. USACE, in partnership with KWO, is conducting the Tuttle Creek Reservoir WID Demonstration to assess the effectiveness of WID technology for potential long-term implementation. Once authorized, this could be one of the measures considered for the GI Study. USACE also recommends initiation of a spin-off study to investigate long-term sediment management alternatives at Kanopolis Reservoir. KWO proposes to conduct Regional Sediment Management Plans for multiple smaller watersheds within the basin and anticipates a partnership with USACE under the PAS program. Other recommendations to reduce the inability to meet water supply demands include promotion of water conservation measures, promotion and incentivization for adoption of watershed practices, and drought communication and outreach (Table 5-4). Table 5-4 includes near-term actions for reduced ability to meet water supply demands.

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Focus	Recommendation	Potential Partners and Funding
Modification of Low Flow Target Values to Extend Periods of Low Flow Support	Initiate spin-off studies to update the Lower Kansas River Basin Master Manual or individual reservoir project WCMs within the Kansas River Basin (Tuttle Creek, Perry, Clinton, and Milford) Include modification of the low flow target values to extend the period of low flow support during extended drought periods.	Estimated Cost: $-$$ Potential Funding: USACE WCM Updates Other Potential Partners/Stakeholders: USACE, KWO, KDWP, KDA, KDHE NDNR, NGPC, USBR Priority Area(s): USACE Reservoirs
Tuttle Creek Water Injection Dredging Demonstration	Initiate a spin-off study to perform a WID Demonstration at Tuttle Creek Reservoir to assess the effectiveness of WID technology at a range of downstream discharges, pool elevations, and in-reservoir locations for potential long-term implementation. Monitor and evaluate both operational effectiveness and environmental results.	Estimated Cost: $$ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: USACE. KWO Priority Area(s): Tuttle Creek Reservoir
Tuttle Creek Reservoir Long-Term Sediment Management Plan	Initiate a spin-off study to investigate sediment management alternatives for the perpetual sustainment of Tuttle Creek Reservoir's authorized purposes and benefits. Lessen negative impacts on the upstream and downstream reaches. Include analysis of technologies to create a long-term recommended plan that supports sustainability of reservoir storage.	Estimated Cost: $$ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: KDWP, KDHE Priority Area(s): Tuttle Creek Reservoir, Lower Big Blue HUC 8 watershed
Kanopolis Dam Reservoir Long-Term Sediment Management Plan	Initiate a spin-off study to investigate sediment management alternatives for the perpetual sustainment of Kanopolis Dam reservoir's authorized purposes and benefits. Lessen negative impacts on the upstream and downstream reaches. Include analysis of technologies to create a long-term recommended plan that supports sustainability of reservoir storage.	Estimated Cost: $$ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: KDWP, KDHE Priority Area(s): Kanopolis Dam reservoir, Middle Smoky Hill HUC 8 watershed
Regional Sediment Management Plans	Conduct a USACE PAS Study to prepare sediment management plans for multiple watersheds in the basin.	Estimated Cost: $ Potential Funding: USACE PAS, USACE Research and Development (R&D), USACE RSM, KWO Other Potential Partners/Stakeholders: WRAPS, Watershed Districts, CD Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds

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Table 5-4. Reduction in Ability to Meet Water Supply Demands Recommendations-Immediate Actions (sheet 2 of 2)

Focus	Recommendation	Potential Partners and Funding
Promote Water Conservation Measures	The State of Kansas currently has Water Conservation Plans for each RWD. Updates to water conservation plan guidelines are necessary to ensure all communities and rural water districts have current water conservation and drought management plans.	Estimated Cost: $ Potential Funding: KWO, KDA Other Potential Partners/Stakeholders: RWDs Priority Area(s): Basin-wide
Promote and Incentivize the Adoption of Watershed Practices	Continue to promote and support adoption of watershed practices to support water quantity and quality (streambank stabilization, improved soil health, increased riparian vegetation and forest wetlands, cover crops, not till farming practices). Success measures should be developed for practices to determine effectiveness. Many good examples of programs in the watershed already exist (WRAPS, RCPP).	Estimated Cost: $-$$ Potential Funding: Other Potential Partners/Stakeholders: WRAPS, KDHE, NRCS, KWO, KDWP, KDA, Tribes, private companies Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds
Drought Communication and Outreach	Conduct drought simulation exercises to educate the public and identify gaps in conservation efforts. Incorporate drought simulation efforts into state hazard planning. Seek funding and support for efforts from federal partners.	Estimated Cost: $ Potential Funding: KWO Other Potential Partners/Stakeholders: KDEM Priority Area(s): Basin-wide

5.5.1.3 Degraded/Poor Water Quality

Water quality stressors with solutions categorized as immediate, near-term actions include impaired water, water shortages, and sedimentation. Immediate actions should be taken to reduce economic, social, and environmental risks associated with these stressors. Water quality throughout the basin is vulnerable to naturally occurring and anthropogenic stressors, including impaired water, risks to high quality water, and sedimentation. Currently 16 of the 18 federal reservoirs in the basin are listed as impaired. Impaired waters increase costs to treat water supply needs, decrease yields for agricultural producers, decrease recreational opportunities, increase fish consumption advisories, and diminish biological diversity in streams and reservoirs. During periods of drought, reservoir storage lowers, leading to reduced ability to meet flow targets for water quality in the downstream reaches at Topeka and De Soto, Kansas. A loss of reservoir storage from sedimentation, and future water shortages, increase the inability to meet water quality demands and maintain a base level of streamflow in the Kansas River Basin. The loss of multipurpose pool storage in reservoirs from sedimentation would further exacerbate these future risks and increase the inability to meet downstream water quality targets. A decrease in water volumes in reservoirs and streams could lead to increased nutrient concentrations with an increase in water quality degradation. Immediate actions to reduce the risk of these stressors are promote and incentivize the adoption of watershed practices such as streambank stabilization, improve soil health, increase riparian vegetation and forested wetlands, cover crops, and decrease till-farming practices. There are many good examples of

these practices in the basin, including WRAPS and RCPP, which continue to expand with additional coordination and funding. Table 5-5 shows immediate actions and recommendations for degraded and poor water quality.

Table 5-5. Degraded and Poor Water Quality Recommendations-Immediate Actions

Focus	Recommendation	Potential Partners and Funding
Promote and Incentivize the Adoption of Watershed Practices	Continue to promote and support adoption of watershed practices to support water quantity and quality (streambank stabilization, improved soil health, increased riparian vegetation and forest wetlands, cover crops, no till farming practices). Develop success measures for practices to determine effectiveness. Many good examples of programs in the watershed already exist (WRAPS, RCPP).	Estimated Cost: $-$$ Potential Funding: Other Potential Partners/Stakeholders: WRAPS, KDHE, NRCS, KWO, KDWP, KDA, Tribes, private companies Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds

5.5.1.4 Ecosystem Degradation and Species Impacts

Ecosystem and species stressors with solutions categorized as immediate, near-term actions include invasive and non-native species in the Kansas RPA and loss of reservoir fisheries habitat, leading to declines. Changes, loss, and fragmentation of terrestrial and aquatic habitats in the basin have led to habitat degradation, loss of heterogeneity, and loss of connectivity of these habitats, leading to declines in species populations in the basin. Invasive and non-native species have caused declines in native species and degradation of terrestrial and aquatic habitat. ANS in the basin threaten the diversity and abundance of native species, the ecological stability of infested waters, and recreation activities dependent on such waters. Multiple impoundments within the basin are infested with invasive, non-indigenous plant species. These species reduce or clog water intakes, reduce property values, cause declines in native species, decrease spawning habitat, and reduce useable recreational areas on reservoirs. Currently, there are not enough funding and capacity resources to manage, monitor, and enforce BMPs to prevent spread. Loss of reservoir fisheries habitat leads to declines from reduced water storage due to drought conditions. Sedimentation impacts fish populations from shoreline erosion, inaccessible habitats, loss of fish habitat structures, and loss of vegetation. Low water conditions often leave areas dewatered for long periods of time and can reduce primary productivity needed by fisheries, depending on re-inundation timing of these areas. A number of the reservoirs in the basin are greater than 50 years old and the originally established fish structure (trees) are now decadent, causing fisheries habitat in many cases to become degraded and decayed. A plan to construct and maintain wetlands within reservoirs would reduce the risks of impacts to reservoir fisheries, providing essential habitat to fish populations for various life stages. The Kansas River Sustainable Rivers project developed environmental flow proposals to better mimic natural hydrologic regimes and provide processes for habitat formation in reaches of the Kansas River downstream of USACE reservoirs. Support of these flow proposals is important to improve conditions downstream of the reservoirs. KDWP, along with support from other entities, such as universities, is responsible for monitoring aquatic species. Monitoring of the

reintroduced populations, to determine success and inform adaptive management for future efforts, would reduce the impacts to fisheries. Development of statewide watercraft inspection and decontamination programs and installation of watercraft inspection and decontamination stations near federal reservoirs could be funded by requests through the Kansas State Water Plan Fund for the KDWP ANS management and control program. These stations have proven very successful in preventing the introduction and spread of ANS. Typically, lake-level management planning occurs between USACE and state agencies on an annual basis in Kansas. A comprehensive review of LLMPs, and the process for review and implementation, would improve reservoir fisheries and provide greater flexibility and local control to utilize LLMPs more effectively. Table 5-6 includes immediate actions included as recommendations for ecosystem degradation and species impacts.

Table 5-6. Ecosystem Degradation and Species Impacts-Immediate Actions

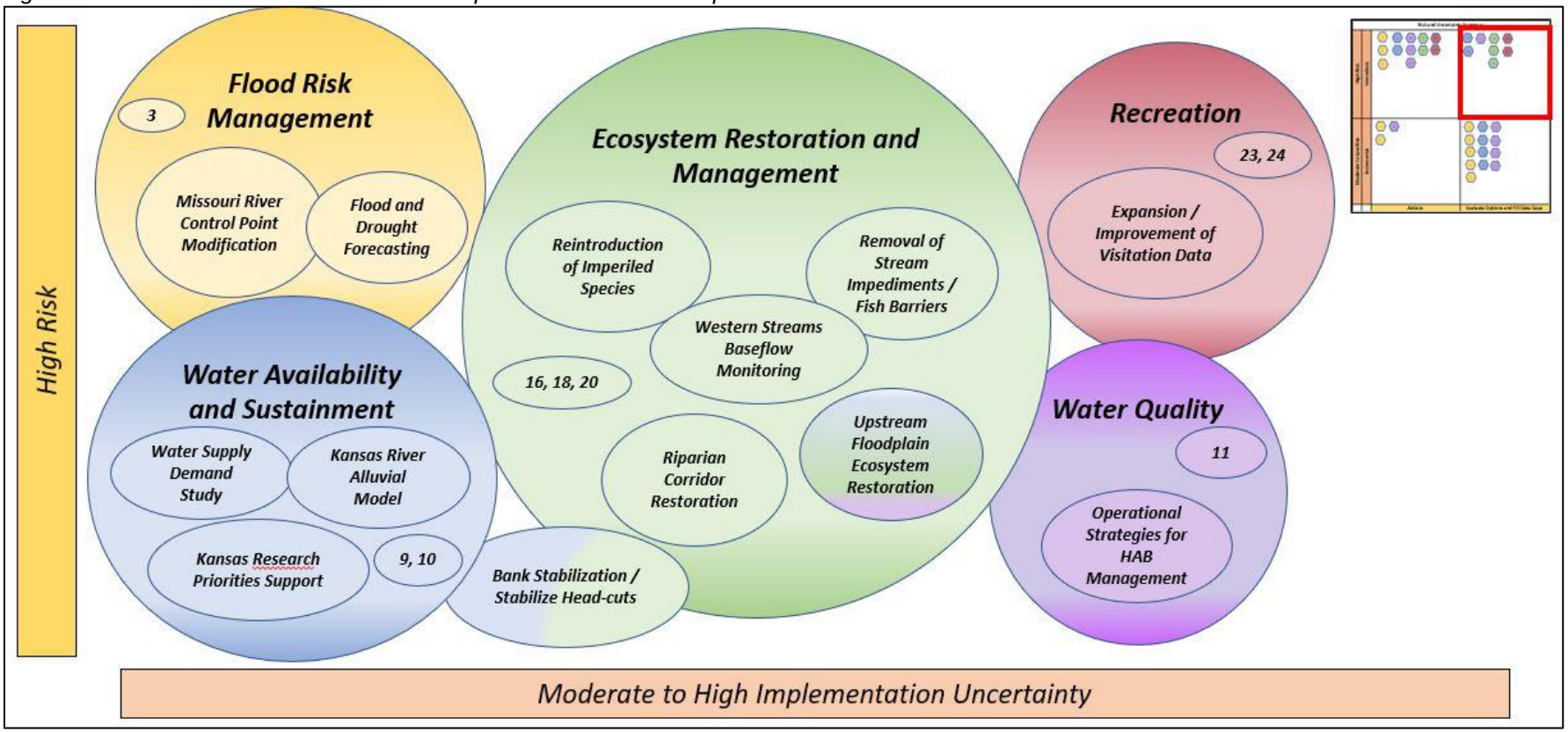
Focus	Recommendation	Potential Partners and Funding
Support Existing Plans to Construct and Maintain Wetlands and Rehabilitate Old Oxbows	Support existing proposals and requests for ecosystem restoration projects. Current projects listed on USACE's new start list for GI, CAP, or conversion include Smoky Hill River GI, Jersey Creek GI, Rocky Ford GI, and Harlan County CAP Section 1135.	Estimated Cost: $-$$ Potential Funding: USACE, City of Salina, Kansas, KDWP, Unified Government of Wyandotte County, Kansas, NGPC Other Potential Partners/Stakeholders: Priority Area(s): Smoky Hill River, Salina, Kansas; Jersey Creek, Wyandotte County, Kansas; Rock Ford; Harlan County Reservoir
Consideration and Evaluation of the Kansas River Sustainable Rivers Project	Implement ecological flow proposals to better mimic natural hydrologic regimes and habitat formation developed from the Kansas River Sustainable Rivers Project and continue to refine and adjust these releases as appropriate (adjustments for wet and dry cycles). Monitor the effectiveness of SRP implementation on riverine species reproduction. Recruitment is needed to determine success. Develop adaptive management measures for further implementation.	Estimated Cost: $ Potential Funding: USACE Other Potential Partners/Stakeholders: USACE, KDWP, KWO, Kansas River Sustainable Rivers Team Priority Area(s): Kansas River mainstem
Biological Monitoring/ Surveying Needs	Monitor reintroduced populations to determine success and inform adaptive management for future efforts.	Estimated Cost: $$ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: NGPC Priority Area(s): Basin-wide
Invasive/Non-native Species Management (Kansas RPA)	Install watercraft inspection and decontamination stations near federal reservoirs. Continue to request funding through the Kansas State Water Plan Fund for the KDWP ANS management and control.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USBR Priority Area(s): Federal Reservoirs
Lake Level Management Plans	Conduct a comprehensive review of LLMPs and the review process and implementation. Greater flexibility and local control are desired to utilize LLMPs more effectively. The SRP E-pools work is currently supporting these efforts.	Estimated Cost: $ Potential Funding: USACE, KWO, KDWP Other Potential Partners/Stakeholders: USACE, KWO, KDWP Priority Area(s): USACE Reservoirs in the Kansas River Basin

5.5.2 Immediate Evaluation Options/Fill Data Gaps

Problems and stressors deemed appropriate for evaluating options in the near-term are those with high risk and moderate levels of implementation uncertainty. Additional

studies are needed to better understand the problem and identify recommended plans. Studies should be initiated in the near-term, ideally within five years, and target implementation should happen between five to ten years. To address problems and stressors that require a more detailed understanding of the problem, recommendations should be categorized as filling data gaps before initiating a study or project. These data gaps should be resolved in the near-term (0 to 5 years) with initiation of a study or implementation of a program taken in incremental steps (five to ten years or sooner, if possible). Figure 5-12 shows near-term evaluations and fill data gaps to reduce risks related to floods, reduction in the ability to meet water supply demands, degraded and poor water quality, degraded ecosystems and species declines, and recreation.

711 *Figure 5-5. Basin-wide Immediate Evaluate Options and Fill Data Gaps*



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5.5.2.1 Flood Risk

Flood risk stressors with solutions categorized as immediate, near-term evaluation options and fill data gaps include climate change implications. The lower Kansas River reservoir system (Milford, Tuttle Creek, Perry, and Clinton) is operated to provide flood protection for the Kansas River and the Missouri River. High rainfall events lead to extended periods of storing inflows in the reservoirs and cause extended periods of elevated pool elevations, which adds to the risk of large surcharge releases from these projects. Extensive impacts happen when high-reservoir water levels occur, causing damages and lost revenue at facilities managed by federal and state agencies, private entities, and non-profit organizations. These impacts damage roadways and utility services surrounding the reservoirs. Additionally, agricultural lands in the upper regions of the reservoirs flood during high reservoir water levels, causing damage and loss of revenue to producers on these lands.

Missouri River flood criteria exists for the Kansas City and Waverly gages. Sometimes, elevated Missouri River flows have the effect of keeping the lower Kansas River tributary project releases at low-flow levels for weeks or months on end. Extensive periods of inflow storage causes extended periods of elevated pool elevations and adds to the risk of large surcharge releases from these projects.

Climate change in the basin is expected to increase temperatures and precipitation, resulting in increased frequency of extreme storm events. These extremes in climate will result in larger, more extensive storms and increased streamflow in the basin, particularly for the Republican River and the lower Kansas River. Larger flood volumes could cause higher pool elevations at reservoirs and an inability to contain flood events, leading to more frequent surcharge releases and uncontrolled flows.

Hundreds of levees exist within the basin ranging in size from small agricultural levees that protect farmland to large urban levees constructed to protect people and property. Damages to levees have occurred during past flood events, causing life safety risks and property damages. Larger flood events due to climate change will cause higher water surface elevations, causing a higher probability of overtopping. The longer loading durations on existing levee systems will increase the likelihood of levee breaches. Climate change will also cause flood extents to occur in non-leveed areas, causing higher damages to unprotected areas.

USACE is updating individual reservoir WCMs in the Kansas River Basin. To provide greater flexibility and further reduce the impacts of riverine flooding and high-reservoir water levels, alternatives development is being included in the WCMs to outline potential changes to operations. Evaluation and modification of control point operations, like the Waverly gage, could be done as part of the WCM updates. This would allow for greater flexibility during extreme or high events and quicker evacuation of flood storage at the reservoirs. It will decrease the risk of surcharge releases and possible downstream flooding along the Kansas River and its tributaries. The State of Kansas and USACE are consistently working on measures and tools to improve flood and drought forecasting. To improve flood response in the future and reduce risks to life safety and economic damages, continuation of these evaluations are a priority. Table 5-7 displays immediate evaluation options and fill data gaps actions.

Table 5-7. Flood Risk Recommendations-Immediate Evaluation Options and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Missouri River Control Point Modification	Initiate a spin-off study to evaluate modification to control point (Waverly gage) operations for the Kansas River Basin. Recommend a spin-off USACE project to update the WCMs. It would allow for greater flexibility during extreme and high events and quicker evacuation of flood storage at the reservoirs. It would decrease the risk of surcharge releases, and possible downstream flooding along the Kansas River and tributaries caused by surcharge releases.	Estimated Cost: $ Potential Funding: USACE WCM Updates Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE Priority Area(s): Milford, Tuttle Creek, Perry, and Clinton Reservoirs

5.5.2.2 Reduction in Ability to Meet Water Supply Demands

The water supply stressors with near-term evaluation options and fill data gaps include groundwater depletion and climate change implications. Groundwater is the predominant public water supply source in many areas within the basin. Groundwater depletions in the basin have led to reductions in available water supply. Groundwater in the basin, primarily from the High Plains Aquifer, is used for domestic, municipal, industrial, and agricultural purposes. In western Kansas, the primary source of water is groundwater drawn from wells that reach into the water bearing aquifers, such as Ogallala. Alluvial aquifers also supply water to many citizens in the basin. Alluvial aquifers are the only source of drinkable water for public water suppliers and individual domestic wells in some parts of Kansas. Alluvial aquifers are generally recharged by flow from associated rivers and streams. In western Kansas, groundwater depletion, due to irrigation, crop production, and land practices has led to both loss of base flows and loss of stream flows. In recent years drought has affected certain communities and regions of the basin on a more frequent basis. During a recent drought event from 2012 to 2013 a significant reduction in baseflow gain was observed as irrigation demands increased. This required significant sustained releases from federal reservoirs to maintain low-flow targets and adequate supply to downstream municipal and industrial diversion points. More areas of Kansas will be affected in this manner due to climate change.

The lack of reliable water supply and shortages of water will have a devastating effect on the economy of Kansas and the health and welfare of its citizens. Every industry from agriculture, electric power generation, manufacturing, and tourism relies on water to grow and ultimately sustain business. Climate change will increase the occurrence of drought periods, with longer more severe droughts expected. Longer droughts will cause lower inflows to reservoirs and a lack of available water to support reservoir releases and withdrawals, causing inadequate water supply for users in the basin.

The State of Kansas has identified the need of a study to determine future water supply demands in basin watersheds, particularly in regions with higher population growth in the future. Numerous reaches upstream of reservoirs have unstable banks and head-cuts that exist and worsen over time. These issues are the main contributors of

sedimentation into downstream reaches and reservoirs. Further assessment is needed to identify bank stabilization sites. To identify potential head-cut sites, an expansion of the head-cut assessment for the watershed study is needed. These projects could be supported through state and local efforts and programs, or through a partnership between USACE and a program like PAS. The State of Kansas is developing a stream aquifer model of the Kansas River Alluvial Aquifer to examine future development and management of groundwater and river water levels. Support of this development model should continue and should be used to identify the best locations for potential groundwater recharge sites. To support reservoir research priorities developed by the Kansas Water Research Coordination Group, USACE and Kansas agencies are creating studies through the PAS program. USACE NWK and KWO have entered into a PAS Study, providing an opportunity to work together on Kansas reservoir research priorities by utilizing expertise from state agencies, universities, and USACE. The state wishes to work with USACE on similar efforts in the future. Table 5-8 shows immediate evaluation options and fill data gaps recommendations.

Table 5-8. Reduction in Ability to Meet Water Supply Demands Recommendations-Immediate Evaluation Options and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Water Supply Demand Study	Determine future water supply demands in the Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.	Estimated Cost: $ Potential Funding: USACE PAS, KWO Other Potential Partners/Stakeholders: Priority Area(s): Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.
Bank Stabilization/ Stabilize Head-cuts	Identify bank stabilization sites, expansion of head-cut assessments, and potential project sites Include hydraulic modeling to determine appropriate design features for maximum performance and cost effectiveness.	Estimated Cost: $ Potential Funding: USACE, KDWP, KWO, WRAPS SLT Other Potential Partners/Stakeholders: Priority Area(s): WRAPS Priority Areas, Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds
Kansas River Alluvial Model	Develop a stream aquifer model of the Kansas River Alluvial Aquifer for Junction City, Kansas, to the junction with the Missouri River to examine the effect of scenarios of future development and management of groundwater and river water levels.	Estimated Cost: $ Potential Funding: KWO, KGS Other Potential Partners/Stakeholders: USGS Priority Area(s): Kansas River mainstem
Kansas Research Priorities Support	Support reservoir research priorities developed by the Kansas Water Research Coordination Group. USACE NWK and KWO recently entered into a PAS Study that provides an opportunity to work together on Kansas reservoir research priorities, utilizing expertise from state agencies, universities, and USACE. Pooled funding is used to support these efforts. Kansas will continue to look for opportunities to work with USACE on similar efforts.	Estimated Cost: $ Potential Funding: USACE PAS, USACE R&D, USACE RSM, KWO Other Potential Partners/Stakeholders: KDHE, KGS, KBS Priority Area(s): Basin-wide

5.5.2.3 Degraded and Poor Water Quality

Water quality stressors with solutions categorized as immediate, near-term evaluation options and fill data gaps include HABs. HABs continue to plague the region, with many reservoirs experiencing blooms. If conditions lead to a decrease in reservoir volumes and streamflow during drought or low inflow periods, an increase in nutrient concentrations and increased frequency and intensity of HABs will be seen. A systematic study of the influence of USACE reservoir control options on HABs should be conducted. The study should investigate the effectiveness of water level management and releases to address HABs in reservoirs. Table 5-9 contains

820 immediate evaluation options and fill data gap actions recommended for degraded and
821 poor water quality.

822 *Table 5-9. Degraded and Poor Water Quality Recommendations-Immediate Evaluations/Fill Data Gaps*

Focus	Recommendation	Potential Partners and Funding
Operational Strategies for HAB Management in Inland Reservoirs	Conduct systematic study of the influence of USACE reservoir control options on HABs. Investigate the effectiveness of water level management and releases to address HABs in reservoirs.	Estimated Cost: $ Potential Funding: USACE PAS, USACE R&D, State of Kansas Programs Other Potential Partners/Stakeholders: USACE, KDHE, KWO Priority Area(s): Milford Reservoir

823 ### 5.5.2.4 Ecosystem Degradation and Species Impacts

824 Ecosystem and species stressors with solutions categorized as immediate evaluation
825 options and fill-data gaps include loss of riverine and floodplain habitats leading to
826 species declines, loss of heterogeneity in hydrologic and geomorphic processes in
827 rivers, streams, and floodplains, and groundwater depletion. Historically, there has been
828 a substantial loss and fragmentation of terrestrial and aquatic habitats in the Kansas
829 River Basin due to agricultural conversion, urban development, and construction of
830 dams and levees. This has reduced native plant and animal populations. Dams, and the
831 use and management of water in the basin, has replaced stream and floodplain habitats
832 and has affected the timing and volume of downstream flows and the timing of volumes
833 of water within the reservoirs, which affects fish and wildlife and their habitats. Many
834 streams in the basin are experiencing areas of streambank erosion and head-cuts.
835 Excessive erosion has caused stream reaches to become incised, reducing floodplain
836 connectivity and the quality and quantity of riparian habitats. There are currently five
837 federally-threatened and seven federally-endangered species listed in the basin.
838 Designated critical habitat is found at a variety of locations in the basin, including the
839 Kansas River and other streams in watershed affected by reservoir management. There
840 are also numerous state-listed species that live in the basin. Many of the listed species
841 rely on surface waters associated with basin streams and impoundments, adjacent
842 riparian habitats, or wetlands for some portion of their life cycles.

843 Sediment trapping behind reservoirs has reduced the turbidity in downstream reaches,
844 causing a reduction in species that occurred in more turbid environments pre-
845 impoundment. Lack of floodplain connectivity in river reaches below reservoirs has led
846 to loss of habitat and species that once thrived in these areas. Streambank erosion is a
847 significant cause of reservoir sedimentation in the basin. Agricultural development and
848 activity and urban development in the watersheds above the reservoirs have led to
849 streambank erosion that contributes to sedimentation. Numerous head-cuts occur within
850 in the basin on various streams above and below reservoirs, leading to loss of habitat.

851 Sedimentation in reservoirs has led to loss or changes of habitat for species and
852 reductions in species that require certain habitats, like coves, for their life history needs.
853 As sedimentation continues under extreme conditions like at Tuttle Creek Reservoir, the
854 majority of the reservoir fisheries will not remain. Sedimentation causes highly-reduced
855 lake volumes and leaves only areas of shallow water.

There are also barriers to aquatic species movement in rivers and streams in the basin, which fragment populations, prevent individuals from moving up and down river systems, and cut off movement during droughts.

Climate change is expected to decrease streamflow and reservoir levels are expected to be lower during times of increased drought frequency. This could lead to a decrease during these conditions in suitable habitat for aquatic species and a decline of species. Drought conditions have caused damages to plant and animal species, wildlife habitats, degradation of landscape quality, loss of biodiversity, and promoted soil erosion through exposure of banks and shorelines. A drought period can last for months, years, and even decades. The cost of drought is high and, with climate change, the economic impacts could dramatically increase in the future.

Seasonal patterns of high and low river flows support animal and plant lifecycles, preserve water quality, and maintain diverse habitats. Dams, and the use and management of water in the basin, have replaced stream and floodplain habitats and affect the timing and volume of downstream flows. The timing of volumes of water within the reservoirs affect fish, wildlife, and their habitats.

In western Kansas and Nebraska, the primary source of water is groundwater drawn from wells that reach into the water bearing aquifers. Groundwater is used for domestic, municipal, industrial, and agricultural purposes. In western Kansas, groundwater depletion, due to irrigation, crop production, and land practices has led to both loss of base flows and loss of stream flows. In recent years, drought has affected certain communities and regions of the basin. Table 5-10 displays several recommendations to reduce risks that cause degraded ecosystems and species impacts. Table 5-10 describes addressing the loss of riverine and floodplain habitats that lead to species declines, loss of heterogeneity in hydrologic and geomorphic processes in rivers, streams, and floodplains, and groundwater depletion. The recommendations include removal of stream impediments and fish barriers, upstream floodplain ecosystem restoration, reintroduction of imperiled species, riparian corridor restoration, and western stream baseflow monitoring.

886 *Table 5-10. Ecosystem Degradation and Species Impacts Recommendations-Immediate Evaluation and*
887 *Fill Data Gaps*

Focus	Recommendation	Potential Partners and Funding
Removal of Stream Impediments and Fish Barriers	Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects. Remove existing man-made or natural stream impediments and fish barriers.	Estimated Cost: $$ Potential Funding: USACE CAP Section 206 Other Potential Partners/Stakeholders: KDWP, Ducks Unlimited, TNC Priority Area(s): Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 Watersheds
Upstream Floodplain Ecosystem Restoration	Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects that induce deposition on upstream floodplains in composition with grade control (stage zero projects). These would be multipurpose projects providing ecological habitat benefits, sediment reduction to downstream waters, reduction of water quantity and water quality concerns, and reduction of ongoing streambank erosion and head-cuts.	Estimated Cost: $$ Potential Funding: USACE, KWO, KDWP, Ducks Unlimited, TNC, WRAPS Other Potential Partners/Stakeholders: CD Priority Area(s): Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds
Reintroduction of Imperiled Species	Develop habitat suitability requirements and site evaluation methods to identify sites and segments for potential reintroduction of imperiled species. Include establishment of safe harbor agreements and candidate conservation agreements with willing landowners to reintroduce imperiled species on their property.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: FWS Priority Area(s):
Riparian Corridor Restoration	Identify sites in the Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds for potential ecosystem restoration projects that focus on riparian habitat restoration. These would be multipurpose projects that provide ecological habitat benefits, sediment reduction to downstream waters (reservoirs), reduction of water quantity and water quality concerns, and reduction of ongoing streambank erosion and head-cuts.	Estimated Cost: $$ Potential Funding: USACE, KDWP, Ducks Unlimited Other Potential Partners/Stakeholders: KWO, TNC, WRAPS, CD Priority Area(s): Lower Big Blue, Lower Republican, Delaware, and Lower Kansas HUC 8 watersheds
Western Streams Baseflow Monitoring	Initiate a spin-off study to monitor baseflow in streams in western Kansas. This would provide a baseline to monitor future reductions in stream baseflow in the future.	Estimated Cost: $ Potential Funding: KWO, KDWP, KDHE Other Potential Partners/Stakeholders: USACE, USGS Priority Area(s): western Kansas streams

5.5.2.5 Loss of Recreational Opportunities

Recreation stressors with solutions categorized as immediate, near-term evaluation options and fill data gaps include water quality, HABs, and increased operational costs and lost revenue from flooding and drought. Water-based recreational opportunities are threatened by flooding, low water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species. These impacts cause a loss of visitation, leading to lost revenue and high costs to repair damage to facilities. HABs impact the use of recreation areas in reservoirs, closing swim beaches, reducing boating activities, decreasing visitation, and causing lost revenue. HABs also cause illness and death for humans exposed during recreational activities. The causes and treatments for HABs needs further study and research.

Floods cause damages to recreational infrastructures and facilities, increase operating costs, require closures, and cause lost revenue at recreational facilities managed by federal and state agencies, private entities, and non-profit organizations. Due to a very small portion of publicly owned land in the Kansas River Basin, there are limited opportunities to expand or replace lost facilities. Droughts have also impacted recreation by causing reduced access to areas like coves, reduced use of structures like boat ramps, reduced fishing opportunities, introduced hazards for boaters, impacted beaches, exposed shorelines, increased erosion potential from exposure of soils, and reduced the aesthetic values of the reservoirs. During drought conditions, lakes with substantial sediment depositions, like Tuttle Creek, Perry, and Kanopolis are shallower, exacerbating adverse effects to access, boater safety, fish habitats, and recreation.

Both drought and flooding have adverse impacts on riverine recreational opportunities on the lower Kansas River due to either decreased streamflow or water levels that are too high to allow safe recreational activities. During drought conditions, when flows are low, water quality impacts cause unpleasant odors which impact the recreational experience and make recreation by boaters and paddlers difficult. Flooding and high river flows in the Kansas River Basin cause unsafe conditions for people and limit access to various activities like riverine access points, and reduce angling, hunting, and camping opportunities.

During the course of the watershed study, a need was identified for development of a central storage location for visitor and visitation data. This would allow for better collaboration and sharing between state and federal agencies throughout the basin. Table 5-11 includes immediate evaluation options and fill data gaps recommendations.

Table 5-11. Loss of Recreational Opportunities Recommendations-Immediate Evaluations and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Expansion and Improvement of Visitation Data	Collaboration between USACE and KDWP to develop a central storage location for visitor and visitation data, allowing for better sharing between state and federal agencies.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USBR Priority Area(s): Basin-wide

5.5.3 Incremental Actions

Recommendations categorized as incremental actions have a low level of implementation uncertainty and pose a moderate risk to life and property loss. The watershed study focused on gaining partner insight and collaboration for high-risk recommendations. As such, recommendations for incremental actions and studies and filling data gaps do not have potential partners listed.

These recommendations should initiate implementation ASAP but could be done long-term, within the next 10 to 25 years. These problems are important to address and pose risks, however, with limited resources, these recommendations may require incremental steps to make continuous progress toward enhancing resiliency. Figure 5-13 shows incremental actions to reduce risks related to flood risk, degraded/poor water quality, degraded ecosystems and species declines, and recreation.

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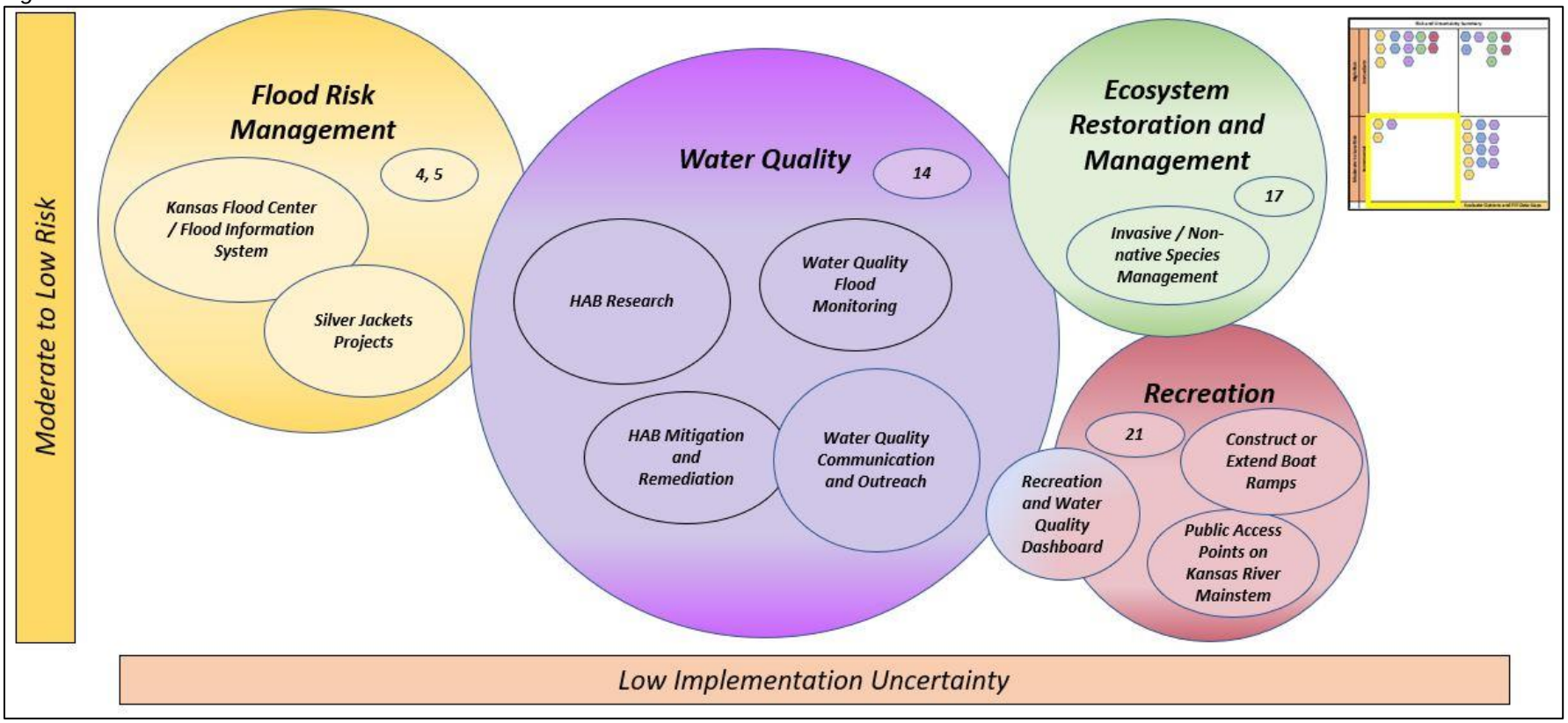
Figure 5-6. Basin-wide Incremental Actions



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5.5.3.1 Flood Risk

Flood risk stressors with solutions categorized as incremental, long-term actions include riverine flooding, high reservoir water levels, climate change implications, flood response communications issues, and sedimentation in reservoirs and downstream erosion. As described previously, riverine flooding and high reservoir water levels are a reoccurring challenge in the basin that can be costly and can have life safety risks. Climate change in the basin is expected to increase temperatures and precipitation, resulting in increased frequency in of extreme storm events. The extremes in climate will result in larger, more extensive storms and increased in streamflow in the basin, particularly for the Republican River and the lower Kansas River. Larger flood volumes in could cause higher pool elevations at reservoirs and an inability to contain flood events, with more frequent occurrence of surcharge releases and uncontrolled flows.

Communications, coordination, and planning between flood risk management entities and the public need improvement to better communicate risks to the public. This includes improved flood forecasting, flood warning systems, and EAPs. Many communities do not currently have adequate warning tools. The need for improved communications will increase with climate change. The likelihood of more frequent activation of flood forecasting and warning systems and more frequent updates to emergency operations plans will be needed.

Sedimentation in reservoirs within the basin is a looming problem in the basin. Sedimentation in the reservoirs threatens flood-risk management infrastructure. Sediment accumulation impedes the function of flood control gates and other appurtenances, which could seriously impact the flood risk mission of USACE. Without deliberate restorative action, sedimentation issues will increase operations and maintenance costs at reservoirs and in downstream river channels. Historical data and projected estimates indicate that the flood control pools at the reservoirs will experience sedimentation, with some filling by as much as 17 percent over the next 100 years. The reservoirs will experience greater frequency of highwater levels compared to existing conditions.

Channels downstream of most federal reservoirs in the basin are experiencing bed degradation and bank erosion as a consequence of the sediment trapping in the reservoirs. This cause varying degrees of downstream bed and bank loss in different reaches. Continued degradation is expected in the future, which risks damage to downstream infrastructure. Downstream riverbed degradation could impact the long-term sustainability of flood risk reduction levees.

During the 2019 flood event in the basin, the State of Kansas identified a desire to establish a flood center and flood information system. The system would give Kansas access to the latest technology and resources to prepare for floods and improve resiliency. These systems could reduce flood response communications issues that occurred during past flood events. The USACE Silver Jackets Program is currently working with the State of Kansas on a healthy watershed project to support implementation BMPs. This will promote soil health and improve infiltration of rainfall at the source, reducing flood flows downstream and the occurrence of sedimentation and erosion.

The watershed study generated information relative to potential flood risk at more specific locations (Appendix H). This information will be used moving forward to continue working with federal and state agencies and regional and local communities to reduce this risk. Actions could include partnerships between non-federal sponsors and USACE under USACE programs and authorities (e.g., GI, CAP, PAS, FPMS, Silver Jackets). This will require additional collaboration beyond the watershed study and investment in other opportunities with partners. Some of the areas with potential flood risk that don't rise to the level of immediate actions could be evaluated in the long-term. Table 5-12 shows incremental actions included as recommendations for flood risk.

Table 5-12. Flood Risk Recommendations-Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Kansas Flood Center/Flood Information System	Establish a flood center and flood information system. The flood center would give Kansans access to the latest technology and resources to help prepare for floods and become more resilient. Providing direct services and engagement in flood-related projects that help Kansans understand their flood risks and make better flood-related decisions.	Estimated Cost: $-$$ Potential Funding: USACE FPMS/PAS, State of Kansas Programs Potential Partners: USACE, NOAA, NWS, KDEM, KWO, KDWP, KDA, KGS, KDHE, KHMT, Kansas Regional HMTs, Tribes Priority Areas: Basin-wide
Silver Jackets Projects Related to Healthy Watersheds	Initiate additional work related to the ongoing Silver Jacket Healthy Watershed projects.	Estimated Cost: $ Potential Funding: USACE Silver Jackets, KDEM, KDHE, KWO Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Basin-wide

5.5.3.2 Degraded/Poor Water Quality

Water quality stressors with solutions categorized as incremental, long-term actions include inadequate stormwater management and HABs in the Kansas RPA. Absence of appropriate stormwater management in some areas contributes to degradation in water quality and supply. Pollutants from housing and urban areas, industrial sources, and agricultural activities end up in water sources where they change water chemistry and impact aquatic vegetation, invertebrate communities, amphibians, and fish. Pollution can be from direct and indirect sources, which makes it difficult to identify, quantify, and remediate. Monitoring of flood waters to evaluate the impacts on water quality, such as debris, nutrient runoff, and sedimentation could reduce these risks. Additionally, coordination and outreach would further reduce the risks and identify areas where work should be performed.

As previously described, HABs plague the region, with Milford Reservoir in the Kansas RPA experiencing some of the highest annual occurrences of HABs. Ongoing research efforts continue to identify and remediate causes of HABS and prevent risks to humans. Mitigation and remediation efforts, such as warnings, closures, data collection, and outreach need to be funded and improved as information becomes available. Table 5-

13 includes incremental actions as recommendations for degraded and poor water quality.

Table 5-13. Degraded and Poor Water Quality Recommendations—Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Water Quality Flooding Monitoring	Monitor the impact of flood conditions, such as debris, nutrient runoff, and sedimentation on water quality. Incorporate concerns into flood management strategies.	Estimated Cost: $ Potential Funding: Other Potential Partners/Stakeholders: USACE, KWO, KDHE Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds
Water Quality Communication and Outreach	Continue to support and provide educational outreach, encouraging the implementation of watershed conservation practices, in particular soil health initiatives, streambank stabilization, and riparian corridor restoration.	Estimated Cost: $-$$ Potential Funding: KWO Other Potential Partners/Stakeholders: WRAPS, KDHE, NRCS, KWO, KDWP, KDA, Tribes Priority Area(s): Lower Republican, Big Blue, Delaware, Lower Kansas HUC 8 watersheds
HAB Research (Kansas RPA)	Identify and remediate causes, prevention, and treatment of HABs, including potential in-lake technologies.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin
HAB Mitigation and Remediation (Kansas RPA)	A variety of HAB control treatments have been proposed and some have been tested in Kansas, including hydrogen peroxide treatment, ultrasonic cavitation, and barley straw additions. There are other treatment options that are cost prohibitive for our current situation but can provide short-term benefits. Other mitigation actions also include warnings and closures and data collection and outreach. These actions should continue and improve as information becomes available.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin

5.5.3.3 Ecosystem Degradation and Species Impacts

Ecosystem and species stressors with solutions categorized as incremental, long-term include invasive and non-native species in the Solomon-Republican, Smoky Hill-Saline, and Upper Republican/Upper Smoky Hill RPAs. As described previously, invasive and non-native species have caused declines in native species and degradation of terrestrial and aquatic habitats. ANS in the basin threaten the diversity and abundance of native species, the ecological stability of infested waters, and recreational activities dependent on such waters. Multiple impoundments within the basin are infested with invasive, non-

indigenous plant species. Generally, the risks from invasive and non-native species are lower in the Solomon-Republican, Smoky Hill-Saline, and Upper Republican/Upper Smoky Hill RPAs so are included under incremental actions. The recommendations for these are the same as those for the Kansas RPA but can done in the long-term. Table 5-14 includes incremental actions included as recommendations for ecosystem degradation and species impacts.

Table 5-14. Ecosystem Degradation and Species Impacts-Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Invasive/Non-native Species Management (Solomon-Republican, Smoky Hill-Saline, and Upper Republican/Upper Smoky Hill RPA)	Install watercraft inspection and decontamination stations near federal reservoirs. Continue to request funding through the Kansas State Water Plan Fund for the KDWP ANS management and control.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: USBR Priority Area(s): Federal Reservoirs

5.5.3.4 Loss of Recreational Opportunities

Recreation stressors with solutions categorized as incremental, long-term actions include limited public lands. State and Federal lands account for approximately 1.3 percent of total lands in Kansas. In Kansas, only a small amount of state-owned and controlled land is publicly owned and used for recreation (0.7 percent), limiting opportunities to expand or replace facilities (recreation facilities lost from sedimentation, facilities damaged from flood waters). Because of the scarcity of federal and state public lands for recreation in Kansas, it is imperative these lands are protected and managed to promote sufficient recreational opportunities to meet the needs of residents and visitors. Recommendations to improve and expand recreational opportunities can reduce the lost opportunities from stressors that impact recreation like flooding, drought, and sedimentation. A substantial amount of river recreation occurs on the Kansas River mainstem. Development of a plan for new boat ramps and public-access points to meet the increasing use of the river for canoeing, kayaking, camping, fishing, hunting, wildlife viewing is needed. Access points are also needed for search and rescue efforts. Additional amenities, like parking, lighting, boat ramps, lifejacket stations, camping areas, potable water, and safety signage are also needed. A public dashboard is needed for users of the Kansas River mainstem to access information on river flows, safety hazards, forecast river or reservoir conditions. A public dashboard would also need to be multi-lingual. Table 5-15 includes incremental actions included as recommendations for loss of recreational opportunities.

Table 5-15. Loss of Recreational Opportunities Recommendations—Incremental Actions

Focus	Recommendation	Potential Partners and Funding
Develop a Plan for New Low-Water Boat Ramps or Extend Existing Boat Ramps	Develop a plan for new lower-water boat ramps or extending boat ramps to mitigate boating access restrictions during low water conditions at USACE reservoirs in the basin and on the Kansas River mainstem.	Estimated Cost: $ Potential Funding: USACE, KDWP Other Potential Partners/Stakeholders: Friends of the Kaw Priority Area(s): USACE reservoirs in the Kansas River Basin and Kansas River mainstem
Public Access Point Along the Kansas River Mainstem	Develop Kansas River mainstem public access points to meet increasing use of the river for canoeing, kayaking, camping, fishing, hunting, and wildlife viewing. Provide access points for search and rescue efforts. Develop a plan for parking lots, lighting, boat ramps, lifejacket stations, camping areas, potable water, and safety signage.	Estimated Cost: $ Potential Funding: KDWP, Friends of the KAW Other Potential Partners/Stakeholders: Priority Area(s): Kansas River mainstem
Dashboard to Serve Recreation and Water Quality	Develop an online dashboard or application for users to access information on river flows, safety hazards, forecast river or reservoir conditions with multi-lingual access.	Estimated Cost: $ Potential Funding: USACE, USGS, KDWP, KWO Other Potential Partners/Stakeholders: Priority Area(s): Basin-wide

5.5.4 Incremental Evaluate Options/Fill Data Gaps

Incremental studies and evaluation options should be initiated ASAP but could be done long-term, such as within the next 10 to 25 years. Studies should further investigate the stressor, determine the most effective solution, and implement strategy to achieve resiliency. Incremental recommendations for filling data gaps and stressors that require more detailed understanding of the problems should be addressed in the next ten years. Figure 5-14 shows incremental evaluations and fill data gaps.

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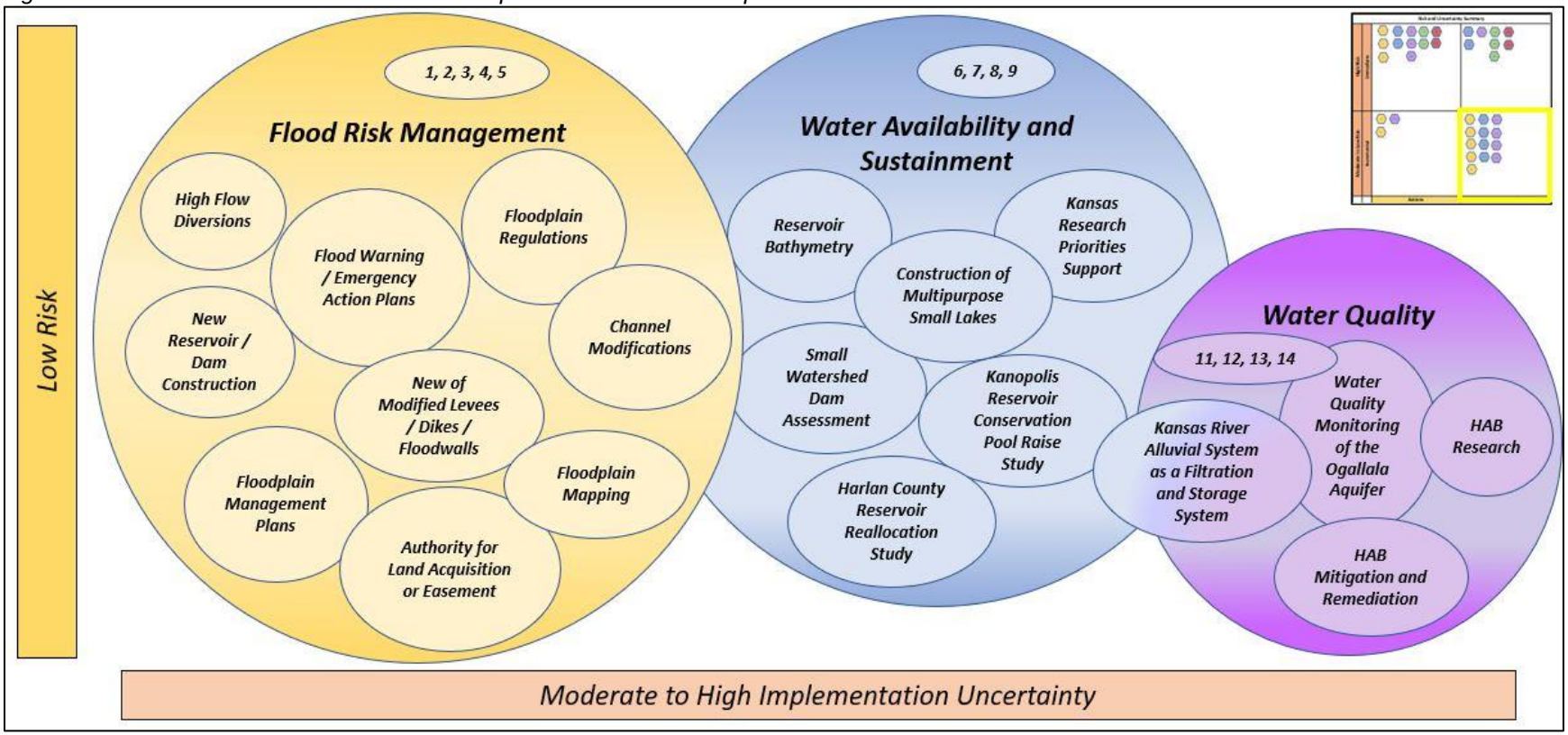
Figure 5-7. Basin-wide Incremental Evaluate Options and Fill Data Gaps



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5.5.4.1 Flood Risk

Flood risk stressors with solutions categorized as incremental and long-term evaluation options and fill data gaps include riverine flooding, high reservoir water levels, climate change, flood response communication issues, sedimentation in reservoirs, and downstream erosion. While the risks associated with these stressors were identified as high, it was decided these should also be addressed in the long-term, therefore, a set of long-term recommendations were identified. These recommendations include a mix of structural, operational, and non-structural flood risk measures described in Table 5-16. Specific regions and locations were identified for some recommendations but evaluations are needed to identify need and interest of local stakeholders.

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1089 *Table 5-16. Flood Risk Recommendations—Incremental Evaluation Options and Fill Data Gaps (sheet 1 of 3)*

Focus	Recommendation	Potential Partners and Funding
New or Modified Levees/Dikes/ Floodwalls	Coordination with communities identified as high-risk for potential life loss or damages that would benefit from new or modified levees/dikes/floodwalls. Determine the need for support from the federal or state government agencies (USACE, FEMA, KDEM). The Watershed Study Flood Risk Assessment and the Regional Hazard Mitigation Plans identify potential communities to determine needs and cost benefits of levee, dike, and floodwall construction.	Estimated Cost: $$-$$$ Potential Funding: USACE FPMS/PAS, USACE GI, NRCS, State of Kansas Programs Other Potential Partners/Stakeholders: City Governments, County Governments Priority Area(s): Cities of: Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, Muncie
High Flow Diversions	Identify specific sites for diversion and redirection of excess flows away from developed areas using naturally or artificially constructed bypass channels or conduits. Prioritize site list based on problem areas, flood risk, and where benefits could be realized. The Watershed Study Flood Risk Assessment and the Regional Hazard Mitigation Plans identified areas with potential need and high life safety risk or economic damages.	Estimated Cost: $$ Potential Funding: USACE FPMS/PAS, USACE GI, NRCS, State of Kansas Programs Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, Tribes, WRAPS, CD, Watershed Districts Priority Area(s): Upper Kansas HUC 8 watershed, Middle Kansas HUC 8 watershed, Lower Kansas HUC 8 watershed; cities of Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, Muncie
Channel Modifications	Identify specific sites to widen or deepen the channel to increase flood conveyance. Prioritize site list based on problem areas, flood risk, and where highest benefits could be realized. The Watershed Study Flood Risk Assessment identified areas with potential high life safety risk or economic damages. The Regional Hazard Mitigation Plans identified areas with potential need.	Estimated Cost: $$ Potential Funding: USACE PAS, USACE GI, NRCS, State of Kansas Programs Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, Tribes Priority Area(s): Upper Kansas HUC 8 watershed, Middle Kansas HUC 8 watershed, Lower Kansas HUC 8 watershed (Wyandotte County); cities of: Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, Muncie

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Table 5-16. Flood Risk Recommendations—Incremental Evaluation Options and Fill Data Gaps (sheet 2 of 3)

Focus	*Recommendation*	*Potential Partners and Funding*
Identification of New Reservoir/Dam or Detention Basins	Identify specific sites to construct new reservoirs and dams or detention basins to provide additional temporary storage of runoff waters, extending the period of runoff with the intent of reducing flood peaks. Include smaller reservoirs constructed by state agencies and county or local government. Prioritize sites based on problems, flood risk, and where the highest benefits could be realized. The Watershed Study Flood Risk Assessment identified areas with potential high life safety risk or economic damages. The Regional Hazard Mitigation Plans identified areas with potential need.	Estimated Cost: $$-$$$ Potential Funding: USACE PAS, USACE GI, NRCS, State of Kansas Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, Tribes Priority Area(s): Upper Kansas HUC 8, Middle Kansas HUC 8, Lower Kansas HUC 8 watersheds; cities of: Junction City, Topeka, Lecompton, Lawrence, Shawnee, Rossville, Edwardsville, Muncie
Authority for Land Acquisition or Easement Purchase for Flood Control	USACE currently does not have authority to acquire lands or easements for flood control. This would require a new authority and would consist of USACE acquisitioning lands and reconnecting old oxbows or easements along the Kansas River mainstem and major tributaries for flood control measures (including levee setbacks, floodplain expansion, restoration of oxbows). The state may have some instruments for this.	Estimated Cost: $-$$$ Potential Funding: USACE Other Potential Partners/Stakeholders: Priority Area(s): Upper Kansas HUC 8, Middle Kansas HUC 8, and Lower Kansas HUC 8 watersheds
Floodplain Management Plans	Identify regional and local areas with a need for FMPs. Incorporate risk evaluation. Recommend concrete steps to address risks using a variety of structural and non-structural solutions. Develop an FMP to increase public awareness of flood risk. The Regional Hazard Mitigation Plans identified areas with potential need. Collaborate with Silver Jackets Program to develop proposals and plans in high-risk communities.	Estimated Cost: $ Potential Funding: USACE FPMS/PAS, NOAA, FEMA, USGS, KDEM, State of Kansas Programs, State of Nebraska programs Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Middle Kansas HUC 8 (Willard County); Upper Kansas HUC 8 (Riley County); Lower Big Blue HUC 8 (Riley County) watersheds

Table 5-16. Flood Risk Recommendations—Incremental Evaluation Options and Fill Data Gaps (sheet 3 of 3)

Focus	Recommendation	Potential Partners and Funding
Floodplain Mapping	Assess flood-prone areas to implement future flood reduction measures in Belvue, Havensville, Louisville, Onaga, St. George, St. Mary's, Wamego, Alma, McFarland, and Paxico, Kansas. Increase availability of floodplain maps beyond standard FEMA products to increase understanding of flood risk.	Estimated Cost: $ Potential Funding: USACE FPMS/PAS, NOAA, FEMA, USGS, KDEM, State of Kansas Programs, State of Nebraska Programs Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Lower Kansas HUC 8 watershed (Shawnee, Johnson, Leavenworth, Wyandotte, Jefferson, Atchison, Jackson, Douglas Counties; cities of Lawrence and Bonner Springs); Delaware HUC 8 watershed (Atchison, Brown, Jackson, Jefferson, Jefferson Counties; city of Horton); Middle Kansas HUC 8 watershed (Shawnee and Jackson Counties; cities of: Rossville, Silver Lake, Topeka, Willard, Belvue, Havensville, Louisville, Onaga, St. George, St. Mary's, Wamego, Alma, McFarland, Paxico); Fillmore County Nebraska; Marshall and Geary Counties in Kansas; city of Manhattan; Lower Big Blue HUC 8 watershed (Riley, Pottawatomie, Marshall Counties; cities of Frankfort, Marysville); Lower Little Blue HUC 8 watershed (Washington and Marshall Counties)
Flood Warning/Emergency Plans	Develop flood warning and emergency plans for high-risk communities. Include flood emergency measures (flood-fighting plans, contingency and emergency floodproofing, emergency evacuation plans).	Estimated Cost: $-$$ Potential Funding: USACE FPMS/PAS, NOAA, FEMA, KDEM, State of Kansas Programs, State of Nebraska Programs Other Potential Partners/Stakeholders: KWO, KDA, KGS, KHMT, Kansas Regional HMTs Priority Area(s): Lower Kansas HUC 8 watershed (Johnson, Wyandotte Counties)
Floodplain Regulations	Establish ordinances, zoning, subdivision regulations, building and housing codes, and sanitary codes with specific flood hazard provisions by working with local communities, counties, and regional floodplain managers.	Estimated Cost: $ Potential Funding: USACE FPMS/PAS, NRCS, State of Kansas Programs, State of Nebraska Programs Other Potential Partners/Stakeholders: KWO, KDWP, KDA, KDHE, KHMT, Kansas Regional HMTs, Tribes Priority Area(s): Lower Kansas HUC 8 watershed (Shawnee, Leavenworth, Jackson, Atchison, Jefferson Counties); cities of Rossville, Bonner Springs, Eudora); Delaware HUC 8 watershed (Atchison, Brown Jackson, Jefferson, Nehama Counties); Middle Kansas HUC 8 watershed(Pottawatomie, Nemaha, Shawnee, Jackson Counties; cities of Rossville; Upper Kansas HUC 8 watershed (Thayer County Nebraska, Marshall, Geary Counties, Kansas); Lower Big Blue HUC 8 watershed (Riley, Pottawatomie, Washington, Marshall Counties); Lower Little Blue HUC 8 watershed (Marshall, Washington Counties)

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5.5.4.2 Reduction in Ability to Meet Water Supply Demands

Water supply stressors with solutions categorized as incremental and long-term evaluation options and fill data gaps include sedimentation, drought, reduced water supply from navigation releases, and groundwater depletion. The majority of these stressors were described previously under immediate actions and are similar for the incremental evaluation options and fill data gaps but, while most of them are high risk in at least one RPA, these stressors should also be addressed long-term and, therefore, Table 5-20 identifies a set of recommendations for later implementation.

A study to determine areas of potential artificial recharge in the Kansas River Alluvial Aquifer is recommended. The study should utilize the Kansas River Alluvial Model currently in development by the Kansas Geologic Survey. Recharge consists of diversion of water during high flow events or when reservoir multipurpose pool allocations are full (above multipurpose pool) and empty into recharge basins. This lessens the impact of reduced reservoir storage capacity by diverting some releases into groundwater recharge projects, supporting baseflow through drought.

Releases for navigation on the Missouri River can be made from Milford, Tuttle Creek, and Perry reservoirs. Currently, approximately 230,000 acre-feet is subject to these releases. If these releases are made, it will lead to inadequate water supply for in-reservoir purposes like recreation and fisheries. It will impact downstream releases that support water supply, water quality, fish, and wildlife, and recreation. The effects are especially significant during drought periods when excessive drawdowns would decrease capabilities to meet flow targets and reduce water supply resiliency for multiple communities. Table 5-17 shows the recommendations.

Table 5-17. Reduction in Ability to Meet Water Supply Demands Recommendations-Incremental Evaluate Options/Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
Develop a Plan for Multipurpose Small Lakes	Develop a plan for multipurpose, small lakes to alleviate regional water supply issues. This would be done in regions where it is not feasible to restore water supply storage in reservoirs.	Estimated Cost: $-$$ Potential Funding: Other Potential Partners/Stakeholders: Priority Area(s):
Kansas River Alluvial System Utilized as a Filtration and Storage System	Determine areas of potential artificial recharge in the Kansas River Alluvial Aquifer. Utilize the Kansas River Alluvial Model currently in development by the Kansas Geologic Survey.	Estimated Cost: $ Potential Funding: KWO Other Potential Partners/Stakeholders: Priority Area(s): Kansas River mainstem
Kanopolis Reservoir Multipurpose pool Raise Study	Initiate a spin-off study to evaluate the possibility of a permanent multipurpose pool raise at Kanopolis Reservoir.	Estimated Cost: $ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: RWD Priority Area(s): Kanopolis Reservoir
Small Watershed Dam Assessment	Identify existing watershed structures that need restoration and have the potential to be made larger. Provide supplemental water supply in the Lower Big Blue, Lower Republican, Delaware, Upper Kanas, Middle Kansas, and Lower Kansas HUC 8 watersheds.	Estimated Cost: $ Potential Funding: KDA, KWO Other Potential Partners/Stakeholders: NRCS Priority Area(s):
Kansas Research Priorities Support	Support reservoir research priorities developed by the Kansas Water Research Coordination Group. USACE NWK and KWO recently entered into a PAS Study that provides an opportunity to work together on Kansas reservoir research priorities, utilizing expertise from state agencies, universities, and USACE. Pooled funding is used to support these efforts. Kansas will continue to look for opportunities to work with USACE on similar efforts.	Estimated Cost: $ Potential Funding: USACE PAS, USACE R&D, USACE RSM, KWO Other Potential Partners/Stakeholders: KDHE, KGS, KBS Priority Area(s): Basin-wide
Reservoir Bathymetry	Increase the frequency of reservoir bathymetry to monitor progress on sedimentation trends, reservoir storage loss, and future water supply planning projections	Estimated Cost: $ Potential Funding: USACE, KWO Other Potential Partners/Stakeholders: USBR Priority Area(s): USACE reservoirs

5.5.4.3 Degraded Poor Water Quality

Water quality stressors with solutions categorized as incremental and long-term evaluation options and fill data gaps include HABs and water shortages in the Solomon-Republican, Smoky Hill-Saline, Upper Republican, and Upper Smoky Hill RPAs. As previously described, HABs plague the region, with reservoirs in the Solomon-

Republican, Smoky Hill-Saline, Upper Republican, and Upper Smoky Hill RPAs experiencing HAB occurrences. Current research efforts continue to identify and remediate causes of HABs in these RPAs and prevent risks to humans. Mitigation and remediation efforts, such as warnings and closures, data collection, and outreach need continued funding and improvement. Table 5-18 includes recommendations for degraded and poor water quality.

Table 5-18. Degraded and Poor Water Quality Recommendations—Incremental Evaluation Options and Fill Data Gaps

Focus	Recommendation	Potential Partners and Funding
HAB Research (Solomon-Republican, Smoky Hill-Saline, Upper Republican, Upper Smoky Hill RPAs)	Identify and remediate causes, prevention, and treatment of HABs, including potential in-lake technologies.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin
HAB Mitigation and Remediation (Solomon-Republican, Smoky Hill-Saline, Upper Republican, Upper Smoky Hill RPAs)	A variety of HAB control treatments have been proposed and some have been tested in Kansas, including hydrogen peroxide treatment, ultrasonic cavitation, and barley straw additions. Other treatment options that are cost prohibitive for our current situation but can provide short-term benefits. Other mitigation actions also include warnings, closures, data collection, and outreach. These actions should continue and improve as information becomes available.	Estimated Cost: $ Potential Funding: USACE, KWO, KDHW Other Potential Partners/Stakeholders: Kansas Biological Survey, Universities Priority Area(s): Federal Reservoirs in the Kansas River Basin

5.6 Implementation Strategy

To help prioritize time and resources, Table 5-19 provides a general timeline for recommendation implementation. Recommendations reflect the level of readiness to implement, with a greater emphasis on accelerating implementation for high risks. The timeline is an estimate based on the urgency of the stressor and possible implementation roadblocks, such as knowledge gaps, local approval, and funding (determined through the uncertainty analysis). Generally, near-term actions should be implemented within ten years. Near-term options should be evaluated within one to ten years and implemented ASAP. Incremental options should be implemented ASAP but may have additional time available for implementation, as the stressor assessed at a moderate to low risk. Evaluation of options to address major stressors should occur within one to ten years, with implementation occurring soon thereafter. Some recommendations have less implementation uncertainty and, therefore, may stray from the timeline explained above.

The implementation strategy will phase implementation, evaluation, and fill data gap recommendations in shorter timeframes than 10 years (0 to 5 years). Immediate recommendations (actions/projects) that are high risk with solutions supported by stakeholders with a strong consensus are proposed for implementation within the next 5

years. Immediate recommendations (evaluations/fill data gaps) that address high risk but did not have potential solutions with a strong consensus are proposed for either evaluation or additional data gathering in the next 5 to 10 years with implementation to occur later (10 or more years). Incremental recommendations (actions/projects and evaluations/fill data gaps) that address moderate to low risk are proposed for evaluation or additional data gathering in 5 to 10 years and either implementation or evaluation to occur later (10 or more years). This phasing approach is included in the Table 5-19.

Recommendation implementation in the future will require alignment of actions of federal, state, interstate, and local government entities identifying and using authorities, programs, and sources for potential future appropriations. Potential agencies that could champion the implementation of recommendations are noted in recommendation tables in Section 5. While the priorities in the basin may shift in the future as new circumstances occur, or new information is developed, this watershed study provides a benchmark for the future.

Table 5-19. Recommendations Implementation Strategy (sheet 1 of 3)

Priority	Stressor	Recommendation	0–5 years	5–10 years	10+ years
Immediate (1–10 years) (Actions/Projects)	Riverine Flooding/High Reservoir Water Levels	Lower Kansas River Basin Master Manual and/or Individual Reservoir Project Water Control Manual Updates	Implement	—	—
		Flood Risk Feasibility Studies-Shungununga Creek	Implement	—	—
	Sedimentation/Drought/Water Shortages/Loss of Recreational Opportunities	Tuttle Creek Reservoir Long-term Sediment Management Plan	Implement	—	—
		Promote and Incentivize the Adoption of Watershed Practices	Implement	—	—
		Tuttle Creek Water Injection Dredging Demonstration	Implement	—	—
		Kanopolis Reservoir Long-Term Sediment Management Plan	Implement	—	—
		Regional Sediment Management Plans	Implement	—	—
		Modification of Low Flow Target Values to Extend Period of Low Flow Support	Implement	—	—
		Promote Water Conservation Measures	Implement	—	—
		Drought Communication and Outreach	Implement	—	—
	Loss of Reservoir Fisheries Habitat Leading to Declines	Biological Monitoring/Surveying Needs	Implement	—	—
		Lake Level Management Plans	Implement	—	—
	Invasive/Non-native Species	Invasive/Non-native Species Management (Kansas RPA)	Implement	—	—
	Loss of Heterogeneity in Hydrologic and Geomorphic Process in Rivers, Streams, and Floodplains	Support Existing Plans to Construct and Maintain Wetlands and Rehabilitate Old Oxbows-Rocky Ford, Smoky Hill River, etc.	Implement	—	—
		Consideration and Evaluation of Sustainable Rivers Project Environmental Flow Proposals	Implement	—	—
	Impaired Waters	Promote and Incentivize the Adoption of Watershed Practices	Implement	—	—

Table 5-19. Recommendations Implementation Strategy (sheet 2 of 3)

Priority	Stressor	Recommendation	0–5 years	5–10 years	10+ years
Immediate (1–10 years) (Evaluations, Fill Data gaps)	Climate Change Implications	Missouri River Control Point Modification	Evaluate	Implement	—
	Sedimentation/Drought/Groundwater Depletion/Water Shortages/Loss of Recreational Opportunities	Water Supply Demand Study	Fill data gaps	Evaluate	Implement
		Bank Stabilization/Stabilize Head-cuts	Fill data gaps	Evaluate	Implement
		Kansas River Alluvial Model	Fill data gaps	Evaluate	Implement
		Kansas Research Priorities Support	Fill data gaps	Evaluate	Implement
	Loss of Riverine/Floodplain Habitat Leading to Species Declines/Loss of Reservoir Fisheries Habitat Leading to Declines	Reintroduction of Imperiled Species	Evaluate	Implement	—
		Western Streams Baseflow Monitoring	Fill data gaps	Evaluate	Implement
		Removal of Stream Impediments/Fish Barriers	Evaluate	Implement	—
		Upstream Floodplain Ecosystem Restoration	Evaluate	Implement	—
		Riparian Corridor Restoration	Evaluate	Implement	—
	Loss of Recreational Opportunities	Expansion/Improvement of Visitation Data	Fill data gaps	Evaluate	Implement
	HABss	Operational Strategies for HAB Management in Inland Reservoirs	Fill data gaps	Evaluate	Implement
Incremental (10+ years) (Actions/Projects)	Flooding-Public Life Safety-Economic Impact/Damages	Kansas Flood Center/Flood Information System	—	Evaluate	Implement
		Silver Jackets Projects Related to Healthy Watersheds	—	Fill data gaps	Evaluate
	Inadequate Stormwater Management/HABs	Water Quality Flood Monitoring	—	Fill data gaps	Evaluate
		HAB Research (Kansas RPA)	—	Fill data gaps	Evaluate
		HAB Mitigation and Remediation (Kansas RPA)	—	Fill data gaps	Evaluate
		Water Quality Communication and Outreach	—	Fill data gaps	Evaluate
	Invasive/Non-native Species	Invasive/Non-native Species Management (Solomon-Republican, Smoky Hill-Saline, Upper Republican/Upper Smoky Hill RPAs)	—	Fill data gaps	Evaluate
	Limited Public Lands	Develop a Plan for New Low Water Boat Ramps or Extending Existing Boat Ramps	—	Evaluate	Implement
		Public Access Points Along the Kansas River Mainstem	—	Evaluate	Implement
		Dashboard to Serve Recreation and Water Quality	—	Fill data gaps	Evaluate

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Priority	Stressor	Recommendation	0–5 years	5–10 years	10+ years
Incremental (10+ years) (Evaluations/Fill data gaps)	Riverine Flooding/High Reservoir Water Levels/Climate Change Implications/Flood Response Communication Issues, Sedimentation in Reservoirs and Downstream Erosion	New or Modified Levees/Dikes/Floodwalls	—	Evaluate	Implement
		High Flow Diversions	—	Evaluate	Implement
		Develop a Plan for New Reservoir/Dam or Detention Basins	—	Evaluate	Implement
		Channel Modifications	—	Evaluate	Implement
		Authority for Land Acquisition or Easement Purchase for Flood Control	—	Fill data gaps	Evaluate
		Floodplain Mapping	—	Fill data gaps	Evaluate
		Flood Warning/Emergency Action Plans	—	Fill data gaps	Evaluate
		Floodplain Regulations	—	Fill data gaps	Evaluate
		Floodplain Management Plans	—	Fill data gaps	Evaluate
	Sedimentation/Drought/Water Shortages/Reduced Water Supply from Navigation Releases/Groundwater Depletion/Loss of Recreational Opportunities	Kansas River Alluvial System as a Filtration and Storage System	—	Fill data gaps	Evaluate
		Small Watershed Dam Assessment	—	Fill data gaps	Evaluate
		Kansas Research Priorities Support	—	Fill data gaps	Evaluate
		Reservoir Bathymetry	—	Fill data gaps	Evaluate
		Kanopolis Reservoir Multipurpose pool Raise Study	—	Evaluate	Implement
		Develop a Plan for Multipurpose Small Lakes	—	Evaluate	Implement
		Harlan County Reservoir Reallocation Study	—	Evaluate	Implement
	HABs	HAB Research (Solomon-Republican, Smoky-Hill Saline, Upper Republican, Upper Smoky Hill RPAs)	—	Fill data gaps	Evaluate
		HAB Treatment (Solomon-Republican, Smoky-Hill Saline, Upper Republican, Upper Smoky Hill RPAs)	—	Fill data gaps	Evaluate

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6.0 CONCLUSIONS

The watershed study team investigated water resource issues and opportunities in the Kansas River Basin and are recommending comprehensive, long-term solutions based on a shared vision for the basin. The study presents current findings and recommendations for future efforts, including potential future projects and studies in which USACE could partner with the State of Kansas, sister Federal agencies, and non-Federal entities. The study makes near-term and long-term recommendations. The watershed study integrated water and related land resource management considerations, seeking sustainable water resource management, and making additional considerations. Ultimately, the watershed study informs multiple stakeholders and decision makers at all levels of government and provides a strategic roadmap toward future investment decisions by multiple agencies. Significant need and opportunities exist in the areas of flood risk management, water supply availability and sustainment, and related purposes, such as ecosystem restoration, water quality, sediment management, and recreation. This integrated watershed study focuses attention on significant objectives and tradeoffs, accounts for uncertainty, and promotes adaptive management, stakeholder collaboration, and systems analysis for watershed-scale planning and evaluation.

Developed in collaboration with federal and state agencies, community/local governments and groups, and stakeholders, the watershed study incorporates the best available scientific literature and robust stakeholder engagement across local and federal partners. This collaboration between partners and stakeholders was a critical aspect of the study and played a crucial role in shaping the outcomes.

This Watershed Study Report is not a project implementation document. The level of detail is at a scale adequate to make watershed-level resource assessments and recommendations. Specific projects identified for potential implementation under existing authorities of USACE (for example, review of existing projects for sediment management), will require separate interim reports to specify project features, include detailed engineering information, and appropriate NEPA documentation.

The prioritized list of recommendations addresses the problems, explores the opportunities, and meets the study objectives. Section 5 explains how proposed recommendations address the problem areas and the risks while fulfilling study objectives and contributing the study goals.

This watershed study can be used with other relevant studies and efforts to initiate further studies or projects that meet the priorities and greatest needs in the basin.

6.1 Potential for Federal Interest

The potential for federal interest in risk reduction measures and strategies benefiting multiple areas in the basin is promising with many that are multi-purpose. The problems and issues addressed exist throughout the basin. Recommendations solving the problems and issues related to the reduction in ability to meet water supply demands, degraded or poor water quality, and loss of recreation opportunities also provide benefits for flood risk and ecosystem restoration and support solutions that have comprehensive benefits.

Recommendations not only include efforts accomplished from partnering with state and local partners on civil works studies, but also USACE can also provide inter-agency support to sister Federal agencies, like the USBR, Environmental Protection Agency (EPA), FEMA, or United States Department of Agriculture (USDA) to assist with water resource projects for which USACE has expertise, but is not the appropriate lead agency, as needed and requested.

Recommendations to address water resource problems and opportunities require intentional action and a substantial investment of time and funding by Federal, State, and local entities. The challenges of studying, planning, and implementing a suite of projects of the magnitude for the basin requires that projects are implemented in phases, based on where the needs are most urgent and where there is consensus and support for implementation among State, regional, and local groups; Tribes; and the Federal government.

The State of Kansas is committed, in partnership with stakeholders, local and regional groups, Tribes, and the Federal government to continue to make investments in water resources infrastructure, innovation, and research. The most recent state legislative bill passed fully funds the Kansas State Water Plan and represents a significant increase in funding to protect essential water resources. The bill funds technical assistance supporting municipalities and other units (i.e., watershed districts), provides water project grant funds for construction and upgrades to water infrastructure projects, and funding for high priority water projects in the state.

Several of the recommendations for this watershed study that include collaboration between the State of Kansas and USACE Kansas City District (NWK) were initiated during the development of recommendations. These projects are considered a high priority and include:

Tuttle Creek Reservoir Water Injection Dredging Demonstration—NWK and the KWO received funding to conduct the Tuttle Creek Reservoir Water Injection Demonstration to assess the effectiveness of the technology for potential long-term sediment management at the reservoir. The study is ongoing and is in the initial planning phase with an expected timeframe of 2025 for conducting the demonstration at Tuttle Creek Reservoir. Following the demonstration, an assessment will be conducted to determine the effectiveness of the technology and the parameters for operations that would optimize long-term use of water injection dredging.

USACE Water Control Manual Updates—NWK was appropriated funding to update water control manuals (WCMs) for the seven USACE reservoirs in the basin (Milford, Tuttle Creek, Perry, Clinton, Wilson, Kanopolis, and Harlan County reservoirs). These updates are being conducted in phases starting with updates to the WCMs for reservoirs on the lower Kansas River (i.e., Milford, Tuttle Creek, Perry, and Clinton reservoirs). Updates for the remaining three reservoirs are expected to begin within the next year. The updates will include an evaluation of the water control rules for reservoir storage or release of water and potential measures for improvement. The updates will bring drought contingency plans up to date and update content and historic data. The manual update process includes exploring more efficient methods of managing water

storage and releases where possible through analysis of the existing controlling criteria and developing and analyzing alternatives to the existing plan.

Smoky Hill River Ecosystem Restoration Feasibility Study—USACE and the City of Salina, Kansas, are working together on a feasibility study to develop a plan for ecosystem restoration on the Smoky Hill River. The study, initiated under the USACE CAP 1135 Program, was recommended for conversion to a USACE GI FS because of the higher level of funding needed to support the preferred plan for ecosystem restoration. The project is ecosystem focused and includes restoration of aquatic habitat functions and features within and near the old Smoky Hill River channel that were lost due to the flood risk management project. Restoration measures include reconnection of the old channel, improvements to base flow, aquatic connectivity and habitat functions, wetland and riparian habitats, and whole system functions. The Smoky Hill River Ecosystem Restoration FS was selected under the GI Program as a new start study. The study is expected to start in 2024.

Harlan County Reservoir Ecosystem Restoration CAP 1135—A FS conducted by NWK in partnership with the NGPC was approved in 2020. Funding was received in 2023 to begin design and implementation for the project to restore habitat at the reservoir in Methodist Cove. The design phase is close to completion with construction of the project expected in fall/winter 2023.

Silver Jackets Project Related to Healthy Watersheds—Silver Jackets coordinated with the KDHE on the Kansas Healthy Watershed Study. The project evaluated the benefit of watershed-wide land use incentives supporting the USDA NRCS soil health management systems. The study evaluates the benefits of regenerative agricultural practice for reducing flood risk by looking at soil related infiltration rates to better represent long-term soil practices in hydrologic analysis. Soldier Creek watershed was selected for the first study. The findings of this effort were integrated into the state hazard mitigation plan. An ongoing spin-off to this effort is an analysis to compare improved soil health versus a structures approach.

Kansas Research Priorities Support—In February 2023, the KWO and NWK entered into a Planning Assistance to States (PAS) Agreement providing the agencies the opportunity to work together on Kansas reservoir research priorities utilizing expertise from state agencies, universities, and USACE. The current study supports current and future water availability and sustainment and water quality through researching and monitoring water sustainability, watershed erosion prevention, HABs, and flood and geomorphic hazard mapping. The State is conducting monitoring and modeling of the Kansas River Alluvial Aquifer that supports recommendations to examine the effects of scenarios of future development and management of groundwater and river water levels. Additional bathymetry studies are being conducted to provide the most recent forecasting of reservoir conditions and the team is looking at other potential techniques for sediment management in reservoirs. Streambank stabilization effectiveness is being evaluated and headcut identification in the basin will be conducted. Research related to HABs will be done and identification of potential areas where riparian wetland complexes could be proposed. Some of the work is being conducted under a Cooperative Ecosystems Unit agreement that assesses the economics of reservoir sedimentation and sustainability at three of the reservoirs in the basin that are projected

to have the high sedimentation in the future (Tuttle Creek, Kanopolis, and Perry reservoirs). The work also includes locating low-head dams and estimating the sediment contribution that a breach would have on downstream reservoirs. Additionally, the agreement allows for creation of an automated method and tool for locating headcuts and application of this method in the basin. These studies pool resources to support these efforts and support numerous recommendations for the watershed study.

Muncie Bluff–Armourdale Watershed Assessment—The Unified Government of Wyandotte County and Kansas City, Kansas, and NWK entered into a PAS Agreement that investigates the Muncie Bluff and Armourdale watersheds to compile data for the enclosed system to cover existing data gaps to gain a better understanding of flooding behind USACE levees and to identify solutions and capital investment needs. The study area includes large tracts with disadvantaged communities. The study area is one of those identified by the flood risk assessment (Appendix H) as having a high risk for life safety and property damages if flood events of a certain magnitude occur (0.1 percent AEP, 0.02 percent AEP). There has been substantial riverine flooding within these watersheds with frequent flooding in many historic areas.

Support of the Kansas River Sustainable Rivers Project—NWK and The Nature Conservancy are working with Kansas state agencies and stakeholders to continue ongoing work on the Kansas River Sustainable Rivers Project to develop an implementation and monitoring plan for proposed environmental flows from USACE reservoirs that would benefit downstream ecology on the Kansas River mainstem. Other ongoing efforts include looking at pool level management measures supporting existing or new plans to promote and improve in-reservoir habitat for fish, waterfowl, migratory birds, and other wildlife that utilize reservoir habitat.

These new initiatives are in addition to the many ongoing efforts by State, regional, local, Tribal, and Federal entities discussed in Section 1.7, Plans, Programs, Studies, and Reports. Existing authorities and programs described in Section 5 will be utilized, when possible, to implement recommendations.

It is critical that State, regional, local, Tribal, and Federal entities work together to strategically plan and implement the needed projects in order to promote efficiency and effectiveness, and to take advantage of synergies, where possible.

6.2 Additional Considerations

The Federal reservoirs and their associated multipurpose storage, owned and operated by USACE in the Kansas River Basin provide substantial economic benefits to the local, regional, and national economy from water supply, recreation, fish and wildlife, and water quality. The Kansas River Basin USACE reservoirs serve as a critical drinking water supply for more than 600,000 people in addition to being used for irrigation, municipal wastewater, industrial discharges, and power generation. There are significant water resource challenges that must be met over the short- and long-term in the Kansas River Basin. The Federal reservoirs operated by USACE have been asked to meet the multi-purpose needs and values of today’s modern society, including an increased demand for flood risk management benefits to large and small communities, recreation facilities, agricultural areas, an increased demand on water supply, a

changing climate, and an increased societal value on protecting and restoring the ecosystem.

Recommendations of this watershed study include those necessary to increase the resiliency and sustainability of the system. The study has identified viable opportunities for investment in critical infrastructure throughout the basin, including the existing reservoirs, to increase their resiliency to provide for water availability and sustainment, ecosystem restoration, water quality, and recreational amenities. With the projected increased demands for the Kansas River Basin, potential for more variable future conditions, potential for higher temperatures, winds, higher reservoir evaporation rates, and uncertainty in future drought frequencies, there is a critical need to implement actions to maintain reservoir storage capacities and increase future water supply security.

The sponsors believe there is shared local and Federal interest in improving long-term management of the reservoirs to better sustain the valuable multipurpose storage created with federal authority and funding. Currently water supply use in USACE reservoirs and sustainment of that storage is a 100 percent local, non-federal partner responsibility. The sustainment of water supply investment that USACE has made available is a matter of Federal interest and could be raised to a level similar to flood risk and navigation. Water supply sources are critical to supporting life and economic activity in the region and the nation, and when considering growing future water supply needs and increasing acute challenges, the sustainment of resources developed under federal authority are strongly in the Federal interest. Future water supply in the Kansas River Basin is threatened by loss of multipurpose pool storage in USACE reservoirs and will have high economic, social, and environmental risks. Elevating water supply to a threat level comparable to flood risk is warranted to meet the multipurpose needs and values of today’s society.

The State of Kansas has established a funding stream and is dedicated to the development of additional funding to support future reservoir sustainability strategies and USACE has an opportunity to partner with the state in evaluating methods to extend the useable lifetimes of USACE projects. The Kansas Legislature invested a substantial amount of state general funds to shore up public water supply programs and the State Water Plan Fund, for investment in water studies and projects. The KWO advises that they are ready, willing, and able to pursue cost-shared efforts toward in-lake reservoir sediment management, both for research and development and/or project implementation.

This consideration could also support creation of a new authority that would allow dredging or other measures applied to federal reservoirs through routine operations and maintenance for the purpose of long-term sustainment of the multipurpose pool and its use for water supply and other purposes that are about sustainment of life and economic development that affect the economy regionally and nationally. USACE should take a broader Federal interest in reservoir sediment management similar to sediment management currently ongoing to coastal ports and harbors.

6.2.1 Research and Development

The State of Kansas also requests consideration of new GIs or a CAP that, through the newly established Research and Development account, provides a mechanism for cost sharing with the Federal Government and non-federal sponsors on research and development (R&D) projects including R&D related to reservoir sustainability and reservoir sediment management. Also, provisions should be made to allow for research and development projects to be components of feasibility studies where that would be useful and viable.

6.2.2 Infrastructure Operations and Maintenance

Water infrastructure in Kansas including dams, levees, reservoirs, treatment plants, distribution lines, etc., were mostly developed 50 to 60 years ago and a large percentage of the facilities need upgrade, repair, or replacement. Reservoirs are filling with sediment, reducing the ability to store multipurpose pool storage and capture flood waters, and many levees and dams may already be unable to provide the desired or needed level of public safety protection. Significant critical infrastructure including water and wastewater treatment plants, power plants, fire stations, schools, and military installation facilities are located downstream of the reservoirs. Sustaining the ability of federal and state infrastructure projects (or operations) to provide these risk reduction benefits for this infrastructure into the future is crucial as replacement of these facilities with the benefits they provide is, for the most part, cost prohibitive.

Underfunding of routine operations and maintenance budgets at USACE reservoirs presents significant economic, flood, and environmental risks to areas in the Kansas River Basin. It is anticipated that for flood risk management, future funding of routine operations and maintenance activities at some Kansas River Basin reservoirs will be less than the amount requested to maintain the current level of service which could lead to a reduction in operational capability and performance. The same issue applies to other purposes and sustainment of reservoir multipurpose benefits as a whole.

6.3 Additional Recommendations

Based on the additional considerations the following recommendations are included for consideration in the future.

- Elevate water supply to a priority equivalent to flood risk management and navigation because future water supply needs are growing and challenges in meeting those needs, and the criticality of water supply in supporting and sustaining life and economic development, continue to mount.
- Establish more flexible and efficient collaboration mechanisms and authorities for USACE to partner with state and other agencies to leverage resources to sustain the water resource benefits provided by USACE reservoirs and other projects where applicable.
- Establish or expand authority or policy to allow for projects at USACE lakes to reduce sediment accumulation for multiple beneficial purposes.

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