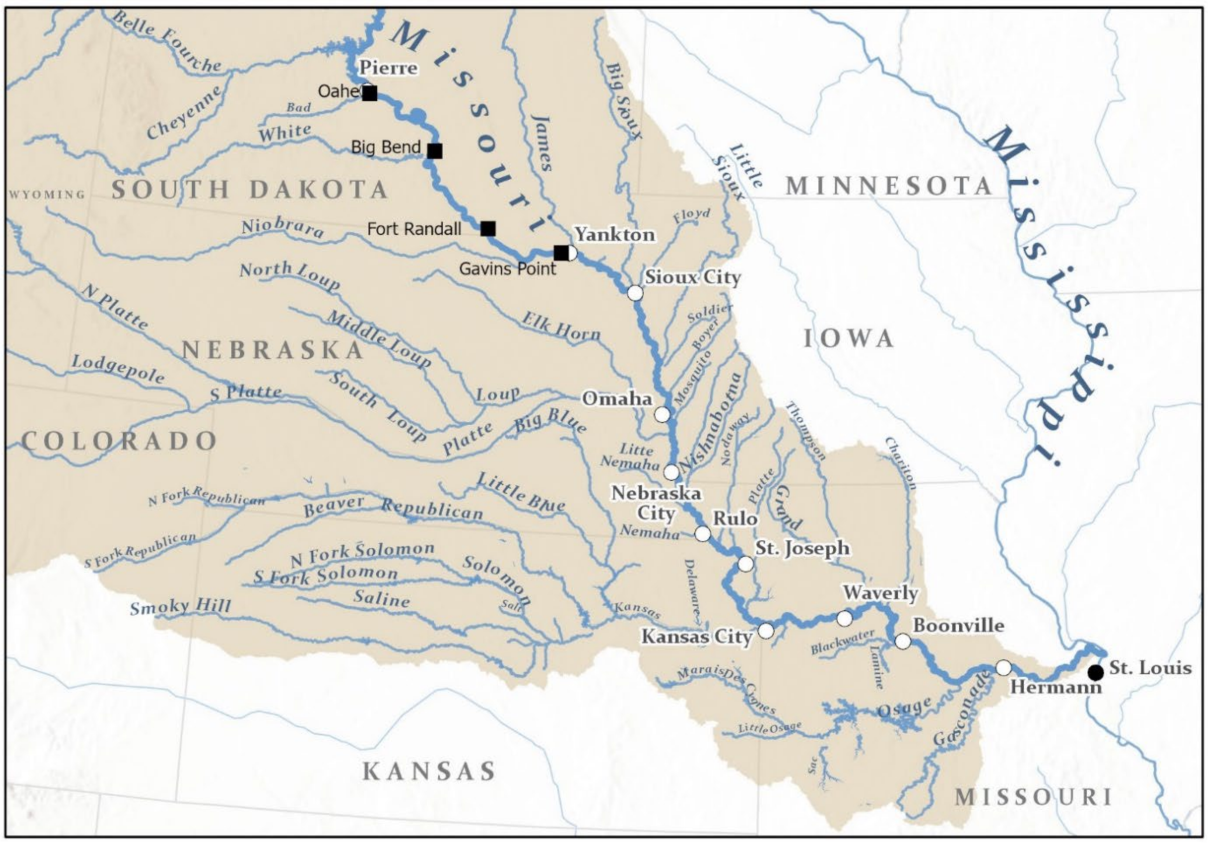
Missouri River
Flow Frequency Study

Yankton, South Dakota to Hermann, Missouri

Appendix C:
Missouri River Basin Depletions Database Report



U.S. Army Corps of Engineers
Northwestern Division
Omaha District, Kansas City District, and
Missouri River Basin Water Management

June 2023

Introduction

The Bureau of Reclamation, Great Plains Regional Office, updated the process used to calculate surface water depletion estimates within the Missouri River Basin. Reclamation created a Microsoft Access database, called the Depletions Database in this report, to automatically compute depletions within the Missouri River Basin. This report documents the data and methods used in the Depletions Database.

> ***Missouri River Basin States Association*** – An organization formed in 1981 as a nonprofit corporation by the Missouri River Basin governors as a successor organization to the Missouri River Basin Commission. This group was to "conduct, encourage, and participate in activities which promote interstate coordination of water resources management in the Missouri River Basin."[1]

In 1977, Reclamation, along with state and other federal agencies within the Missouri River Basin, formed work teams to evaluate the effects of depletions on streamflows in the Missouri River Basin. This study, completed in 1982, was initiated by the Missouri River Basin Commission, later to be known as the Missouri Basin States Association (MBSA).[1] The MBSA study identified the following categories to be evaluated in estimating total depletions within the Missouri River Basin:

irrigation, municipal, industrial, rural domestic, livestock, forest accretions, stock ponds, large and small reservoir evaporation, and conservation land practices (contour farming, tillage, and border grading).

In the MBSA study, 93 node basins were established for calculating depletions. The MBSA covered a period of record of 1944 to 1978. After the MBSA study was completed, Reclamation assumed responsibility for maintaining the data and methods used for estimating Missouri River Basin depletions.

In 2005, Reclamation completed a report titled A *Study to Determine the Historic and Present Level Depletions in the Missouri River Basin* which built upon the work done in the MBSA study by extending the period of record from1929 to 2002 and increasing the number of nodes from 93 to 118. In the 2005 study, Reclamation concentrated on the irrigated agriculture depletions since a large majority of the depletions can be attributed to this use. All other depletion categories were accounted for by using the data developed during the MBSA study by adding an appropriate adjustment to the irrigated agriculture depletions. Figure 1 shows a breakdown of water diversions in the Missouri River Basin by category. Thermoelectric power generation diversions were not included in Figure 1 because thermoelectric power generation depletes a small percentage of water even though thermoelectric power generation diverts a large quantity of water as determined by the USGS water use reports.

[1] U.S. Army Corps of Engineers. *Big Dam Era*. 1993. Page 186.

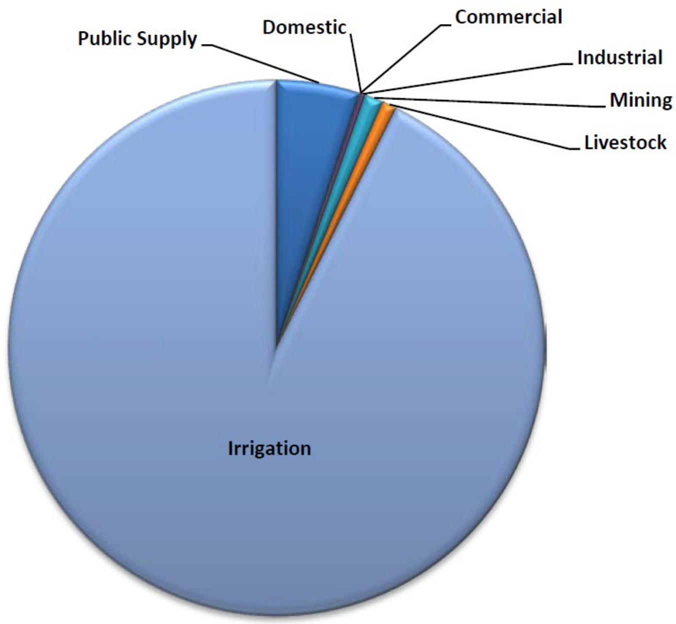


Figure C-1. 1995 water diversions in the Missouri River Basin. Source: USGS Water Use Reports.

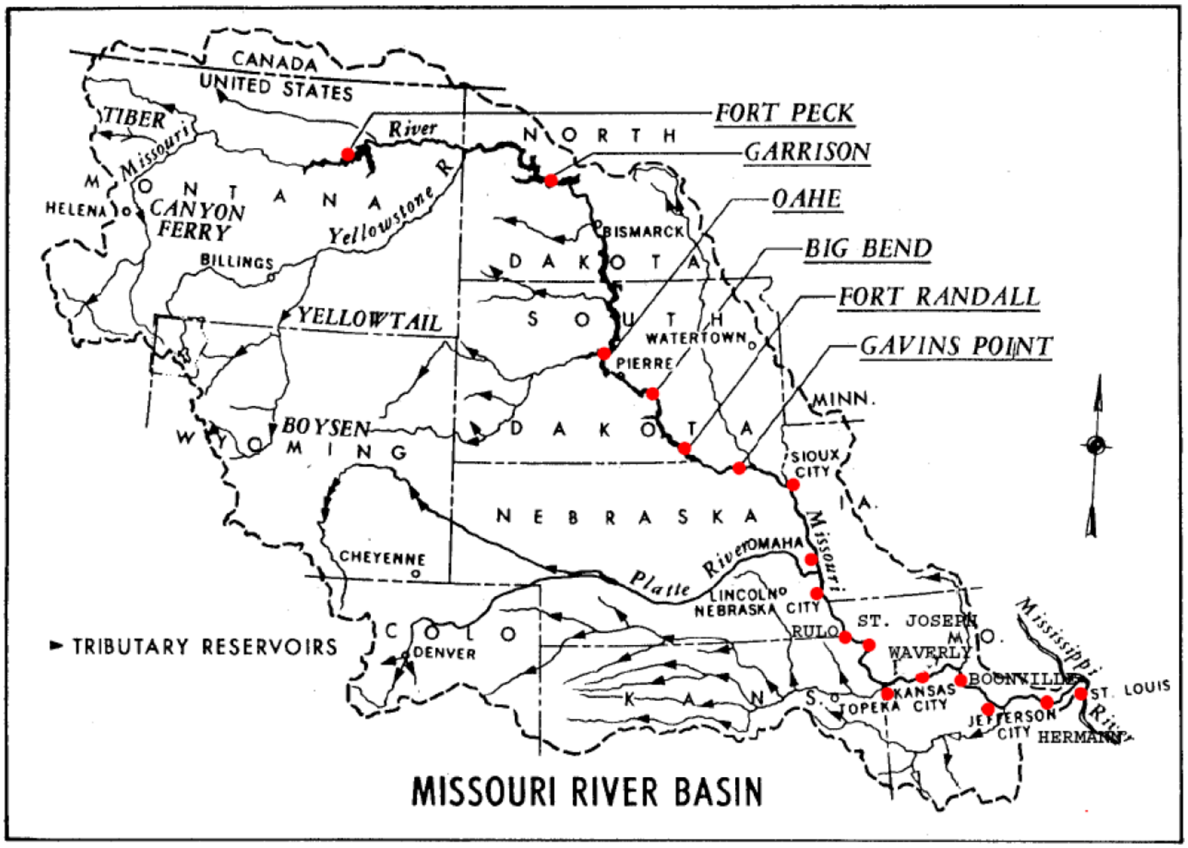
The Depletions Database builds upon both the MBSA study and Reclamation's 2005 study. For the Depletions Database, the MBSA nodes have been replaced with United States Geological Survey (USGS) standard hydrologic units. Each hydrologic unit is assigned a Hydrologic Unit Code (HUC). The USGS publishes water use inventory every five years. The USGS was compiling water use data by HUC when the decision was made to organize the Depletions Database by HUC making it easy to use the USGS water use data. However, since 2000, the USGS has compiled water use data by county instead of HUC. The Depletions Database currently covers the period 1929 to 2007.

Historic Level Depletions – Estimated amount of water depleted from the system from 1929 to 2007, given in acre- feet by month.

Present Level Depletions – Estimated amount of water that would be depleted since 1929 based on the current level of development, given in acre-feet by month.

The same data and methods used in the MBSA study and the 2005 study were used when developing the Depletions Database. The Depletions Database covers the top two depletions categories for water diversions, irrigated agriculture, and public surface water supply systems, which together account for approximately 94 percent of the total estimated depletions in the basin.

In the Depletions Database, both historic and present-level depletions for the Missouri River Basin above Hermann, Missouri are estimated by HUC. The data can also easily be compiled by the following Missouri River reaches for use by the United States Army Corps of Engineers (Corps) in their river operation models.



Missouri River Basin Reaches:

Missouri River - Above Fort Peck Dam, Montana

Missouri River - Fort Peck Dam to Garrison Dam, North Dakota

Missouri River - Garrison Dam to Oahe Dam, South Dakota

Missouri River - Oahe Dam to Big Bend Dam, South Dakota

Missouri River - Big Bend Dam to Fort Randall Dam, South Dakota

Missouri River - Fort Randall Dam to Gavins Point Dam, South Dakota

Missouri River - Gavins Point Dam to Sioux City, Iowa

Missouri River - Sioux City to Omaha, Nebraska

Missouri River - Omaha to Nebraska City, Nebraska

Missouri River - Nebraska City to St. Joseph, Missouri

Missouri River – St. Joseph to Kansas City, Missouri

Missouri River - Kansas City to Boonville, Missouri

Missouri River - Boonville to Hermann, Missouri

Irrigated Agriculture Depletions

This section describes the data requirements, data sources, methods, and assumptions used to estimate irrigated agriculture depletions. The crop irrigation requirement, diversion requirement, and a return flow component are all calculated on a monthly time step to determine the irrigation depletions in each HUC. The difference between the diversion requirement and the return flow is the water loss, or depletion. This value is the sum of the crop use, transmission losses, non-beneficial consumptive uses, and return flow losses.

Depletions – A loss of water from a surface water system resulting from a man induced activity.

Crop Irrigation Requirement – The additional water, supplied by irrigation, needed to supplement the effective precipitation to adequately grow a given crop to maturity.

Diversion Requirement - The amount of water diverted from a surface water source (stream) to satisfy the crop irrigation requirement, and on-farm and conveyance losses.

Return Flow – The portion of the water diverted for a beneficial use that returns to the stream for potential future diversion or in-stream uses.

Irrigated Acreage

The main piece of information required to calculate agriculture depletions is the number of irrigated acres in each HUC. Procedures for collecting irrigated agricultural acres and definitions of the data requested have varied over the years. The U.S. Department of Agriculture (USDA) Census of Agriculture (Ag Census) is the largest and most complete data source available for irrigated acres. Therefore, Reclamation decided to use this data source for the number of irrigated acres. The 2007 Ag Census[2] data is the latest available irrigated acreage data. The Ag Census data are compiled by county. Also used by Reclamation to supplement the Ag Census data are irrigated acreage data collected by several states.

From 1929 to 1940, the Ag Census was conducted every 10 years in coordination with the population census. Since 1944, the Ag Census has been conducted every 5 years. Irrigated acres in each county for the study period are entered into the Depletions Database. Annual values are determined by straight line interpolation between Ag Census values.

Both the MBSA study and Reclamation's 2005 study used Ag Census data. Since the 2005 study was completed, the 2007 Ag Census data became available, and these data are also used in the Depletions Database. Reclamation plans to update the Depletions Database each time new Ag Census data becomes available. The 2012 Ag Census data are expected in either 2013 or 2014.

Some state collected irrigated acreage data are also used in the Depletions Database. The state of Montana performed field verification of irrigated acres in 1975 and 1987. Ag Census data for the counties in Montana are adjusted for the period 1929 through 1975 using the ratio of the State's data to the 1975 Ag Census data, and again for the period 1976 through 2007 using the ratio of the state of Montana's 1987 data to the 1987 Ag Census data.

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[2] U.S. Department of Agriculture reports are available on the internet at http://www.agcensus.usda.gov/Publications/2007/index.asp

During the MBSA study, North Dakota, South Dakota, Colorado, Missouri, and Nebraska, elected to use Ag Census data for the years 1944 through 1973 while providing their own county figures for the ensuing years. The following data provided by the states are used in Depletions Database. For all other years, Ag Census data are used.

- North Dakota: 1974 through 2002
- South Dakota: 1970 through 1977
- Colorado: 1974 through 1978
- Missouri: 1974 through 1978
- Nebraska: 1974 through 1978

Distribution of Irrigated Acres to HUCs

Ag Census data are reported by county, while the Depletions Database calculates depletion estimates by HUC. Therefore, county irrigation data had to be distributed to the appropriate HUCs. Reclamation explored several methods for distributing the county data. The Natural Resources Conservation Service (NRCS) used to release Irrigation Systems Inventory Reports that listed county irrigated data by irrigation type and divided county data into HUCs. However, several Missouri River Basin states, primarily in the lower portion of the basin and with limited irrigation data, did not complete these reports. Therefore, other sources of information were needed.

At one time, the NRCS had an irrigation database for Kansas. The database identified how many irrigated acres by county were located in each HUC. In addition, the Environmental Protection Agency (EPA) maintains a software package called BASINS, which displays total land area under production by county within each HUC. The following data sources are used as follows to distribute each county's irrigated or production acres to the appropriate associated HUC.

- NRCS 1996 Irrigation Systems Inventory Report: Montana, North Dakota, South Dakota, Wyoming, and Colorado
- 2005 NRCS Irrigation Database: Kansas
- EPA's software called BASINS, Version 3.0, June 2001: Minnesota, Missouri, Iowa, and Nebraska

These data are used to estimate what percentage of the irrigated lands (or production land) within each county lies within each HUC. The irrigated acres for each HUC are determined by multiplying the irrigated acreage for each county by the percent of each county's irrigated acres located in each HUC.

Irrigation Data

One of the MBSA study groups requested each Soil Conservation Service, now the NRCS, District Conservationist provide their best estimate of irrigation use within their county. The information requested included the following.

- Verify the 1978 irrigated acre value for their county
- Acreage for each node basin in 1978
- Crop distribution for the acres within each node basin

- Estimate the split between groundwater and surface water use for the years 1944, 1964, and 1978
- Irrigation types and estimates of associated efficiencies

This same information is used in the Depletions Database for the breakdown of irrigated acres into the various irrigation types, crop distribution, groundwater, and surface water split.

Irrigation Categories

The MBSA study divided irrigated acres into eight categories for both surface water and ground water irrigation. The Depletions Database uses these same categories, which include the following:

- Furrow – Full Service Irrigation
- Furrow – Partial Service Irrigation
- Waterspreaders – Full Service Irrigation
- Waterspreaders – Partial Service Irrigation
- Center Pivot Sprinklers – Full Service Irrigation
- Center Pivot Sprinklers – Partial Service Irrigation
- Other Sprinklers – Full Service Irrigation
- Other Sprinklers – Partial Service Irrigation

These categories are used to assign different conveyance system and on-farm efficiencies. Reclamation initially assumed that each type of irrigation system had a unique efficiency associated with it. However, NRCS data indicated there was not a significant difference in some of the irrigation systems. Therefore, irrigated acres within each HUC having the same or similar efficiencies were added together resulting in up to four efficiency groups for each HUC.

Data from the MBSA study were used to estimate the percentage of the irrigated acres in each irrigation category for each HUC. Beginning with the first HUC and using the drainage basin map from the MBSA study, each county was identified, its node basin was determined, and by looking at the input file for that particular node basin, the percentages for the irrigation categories were located and used as input to the Depletions Database.

> ***Conveyance System*** –Portion of the delivery system that provides water from the source of water supply to the farm lateral.
>
> ***On-Farm System*** – Portion of the delivery system that provides water from the field headgate to the crops.

Conveyance system and on-farm efficiencies are needed to calculate diversion requirements. These efficiencies differ among the irrigation categories.

As water moves through the conveyance system, losses from canal seepage, deep percolation, and evaporation are realized. Data for each HUC was taken from estimates provided by the NRCS during the MBSA study. Conveyance system losses were estimated for a variety of systems including open channel, pipe, or a combination of both. In addition, estimated efficiencies vary to account for early season buildup of seepage in the canal prism, peak season irrigation, end-of-season canal draw down, and late season irrigation.

On-farm system losses include deep percolation, operational waste, and in the case of sprinklers, wind drift and spray losses. Data for each HUC are the data provided by the NRCS during the MBSA study. On-farm losses are estimates for a variety of irrigation systems including flood and sprinkler. Monthly losses are estimated to account for more efficient operation during the irrigation season.

Sprinkler Systems

Sprinkler systems were not used in the Missouri River Basin prior to the mid-1940s. Therefore, it was necessary to make adjustments to the subcategories involving sprinkler systems. Originally, the irrigated acreage was computed for each category using the percentages of each county within the HUC. For each irrigation category, one value was used for the entire period of record for each county. An adjustment was used to handle the distribution of acres that assigned to sprinkler systems for the years 1929 through 1953.

All sprinkler acres for the years 1929 through 1943 were added to the furrow, full-service surface water irrigation category. For 1944 through 1953, a ramping process of 10 percent per year was applied to the acres in the sprinkler categories, allowing for gradual development of sprinkler system irrigation over time.

Length of Irrigation Season

During the MBSA study, parameters were established that define the length of time irrigation water is supplied depending irrigation type. These same parameters are used in the Depletions Database.

In the upper portion of the basin, full-service irrigation means that a full-service water supply is provided for each crop for the entire growing season from plant date to harvest date. Partial service provides each crop with a full-service supply until July 1, a 50 percent supply for the month of July, and no additional irrigation water after July 31. Waterspreaders receive a full water supply until June 1, after which no irrigation water is made available to the crops.

In the lower portion of the basin, full-service irrigation means a full-service supply is provided for the entire growing season from plant date to harvest date for each crop. Partial service indicates that each crop receives 50 percent of a full-service supply for each month during the irrigation season. Waterspreader acres receive a double water supply allotment through June 1, after which no irrigation water is made available to the crops.

Crop Data

During the MBSA study, average crop distribution percentages were estimated for each node basin based upon information provided by the NRCS. For the Depletions Database, HUC and node basins maps were used to select the appropriate node basin crop distribution percentages for each HUC. The cropping pattern does not vary over the period of record. It is recognized that this could affect the accuracy of crop irrigation requirement estimates. However, major changes in cropping patterns would be necessary to significantly alter the monthly crop irrigation requirements.

Planting dates and harvest dates were obtained from NRCS Crop Irrigation Guides and information accumulated in the MBSA study. Cover dates were determined based upon the planting date and information from the NRCS.

Climate Data

Monthly mean temperature and total monthly precipitation are also required to calculate the crop irrigation requirement. Climate data were obtained from EarthInfo, Inc., and from the

National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center. Using these two data sources, it was possible to establish long term temperature and precipitation records for representative climate stations in each HUC.

Primary stations were selected based on period of record and location. For each HUC, an attempt was made to identify a centrally located station with a long period of record. If a station did not meet both criteria, the station in the HUC with the longest period of record was selected as the primary climate station. Other nearby stations were selected as secondary stations which were used to fill in data gaps in the record of the primary station.

Two methods are used to calculate crop irrigation requirement: Jensen-Haise and Blaney-Criddle.[3] For the MBSA study and the Depletions Database, the method used varied by state based on each state's preference. For the Jensen-Haise method, solar radiation data are also required to calculate evapotranspiration. Solar radiation is estimated from percent of possible sunshine which comes from published climate stations summaries. Where these data were not available, historical monthly averages are used. There is a computer routine in the Depletions Database that converts percent of possible sunshine data into solar radiation data.

Crop Irrigation and Diversion Requirements

Using the temperature, precipitation, and cropping data described above, the Depletions Database calculates the crop irrigation requirement. For any given year, if the crop irrigation requirement is 115 percent of average or more, a second set of conveyance system and on-farm efficiencies are used because it is assumed to be a drought year. The drought year efficiencies effectively decrease the diversion requirement to account for the potential lack of water in the system. Diversion requirement is calculated using the crop irrigation requirement and conveyance loss efficiencies.

Return Flow Distribution Patterns

Irrigation water that is not consumptively used or lost in other ways is available to be returned to the river system and is available for use again downstream. The return of this water is not instantaneous in many cases, and may require several months to return to the river. In the Depletions Database, all return flows occur within the same HUC in which the water is diverted. The Montana Department of Natural Resources and Conservation provided estimates of return flow patterns for the reach above Fort Peck Reservoir based on upon a Missouri River Basin modeling work performed in the 1980's and 1990's. Data from the MBSA study was used for the remaining HUCs.

Based upon these typical return flow patterns, a portion of the diversion is returned to the river in the same month that the diversion occurs, and the remaining portion is lagged over the following 12 months. The following example illustrates the return flow pattern, assuming that 1.0 AF of the diverted water eventually returns to the river.

[3] Missouri Basin States Association. Technical Paper Agriculture Water Use Including Identification of Irrigated Lands. September 1982. Page 16

Table C-1. Return Flow Pattern Example

	%	Month	Return Flow (in AF)
Return flow during month of diversion	60	July	0.60
Month one following diversion	50	August	0.20 (50% of the remaining 40%)
Month two following diversion	15	September	0.06 (15% of the remaining 40%)
Month three following diversion	13	October	0.05 (13% of the remaining 40%)
Month four following diversion	8	November	0.03 (8% of the remaining 40%)
Month five following diversion	4	December	0.02 (4% of the remaining 40%)
Month six following diversion	3	January	0.01 (3% of the remaining 40%)
Month seven following diversion	2	February	0.01 (2% of the remaining 40%)
Month eight following diversion	1	March	0.01 (1% of the remaining 40%)
Month nine following diversion	1	April	0.01 (1% of the remaining 40%)
Month ten following diversion	1	May	0.00 (1% of the remaining 40%)
Month eleven following diversion	1	June	0.00 (1% of the remaining 40%)
Month twelve following diversion	1	July	0.00 (1% of the remaining 40%)

Non-beneficial consumptive use is a loss that occurs within the irrigation system. It is primarily weeds, trees, and other vegetation growing along canals and ditches that use water that would normally be returned to the stream. The available return flow is adjusted to account for these losses. Accurate figures are very difficult to measure, but a common value used is 15 to 20 percent. In the Depletions Database, a non-beneficial consumptive use value of 20 percent is used for both conveyance system and on-farm losses for all HUCs.

Depletions Due to Groundwater Irrigation

Large capacity wells located near streams can reduce streamflows significantly by reducing aquifer discharge to streams or by inducing flow out of the stream. Factors controlling the degree of depletions include, but are not limited to, the hydraulic connection between the aquifer and stream, distance of well from stream, and quantity and duration of water pumped.

The Kansas River and Platte River sub-basins have a large amount of irrigation supplied by aquifers that have minimal hydraulic connections to streams. Generally, the further a well is from a stream, the less impact it has on stream flow. In the Depletions Database, net groundwater use is approximated using groundwater irrigated acres based on Ag Census data and MBSA groundwater and surface water percentages. The Depletions Database does not include information on the location of groundwater wells in relation to nearby streams. The surface- water depletions already include ground water depletions for all basins except the Kansas River and Platte River. However, a procedure was needed to adjust the groundwater depletion for the Kansas and Platte River Basins.

The MBSA study addressed this issue by utilizing analytical groundwater models and well locations to delineate the reduced effects of irrigation wells on streamflows as the distance from well to stream increases. In the MBSA report, *Technical Paper, Ground Water Depletion*, there is a listing of annual streamflows depletions and groundwater pumpage for the sub-basins in the Kansas and Platte River Basins. A ratio of depletions to irrigation water pumped was developed for each year from 1944 to 1978 (the period of record for the MBSA study).

The procedure used in the Depletions Database for the Kansas and Platter River Basins to approximate the percent of groundwater use that depletes nearby streams is as follows. Groundwater acres are multiplied by the ratios developed in the MBSA study to compute the depletions. For the years not covered by the MBSA study, average ratios are used. The mean ratio from 1944 - 1953 (0.33) was used for years 1929 -1943, and the mean ratio from 1969 - 1978 (0.12) was used for the years 1979 - 2007. The ratios calculated in the MBSA study indicate that the depletions as a percentage of groundwater pumpage decreased over time. The likely explanation is that most wells were initially drilled near streams. As time passed, wells were developed further from streams where there is less hydraulic connection and hence less effect on streamflows.

For the North Fork Republican, Arikaree, and South Fork Republican sub-basins, the MBSA study did not use any analytic groundwater models to determine streamflow depletions via groundwater pumpage. For the Depletions Database, the groundwater usage in these three HUCs is adjusted using the same depletion to pumpage ratios described above.

Using the above steps, the monthly depletions due to net groundwater withdrawals were estimated for 1929-2007. The monthly groundwater depletions were then summed with surface water depletions to arrive at total irrigation depletions by HUC.

For these two river basins, the present-level ground water depletions are calculated the same way as historic, except that the annual average depletion-to-pumpage ratio for 1969-78 (0.12) was applied to every month for 1929 thru 2002, and the present-level net withdrawals were used.

Historic and Present-Level Agriculture Depletions

Historic and present-level depletions are the output of the Depletions Database. As an intermediate step in the computing process, a depletions rate is calculated as acre-feet (AF) depleted per acre irrigated. This depletions rate takes into account the multiple crop types located in the HUC, the climate data, and also takes into account on-farm efficiencies, conveyance system efficiencies, and return flow distribution patterns.

Historic depletions are calculated by multiplying the number of acres historically irrigated by the monthly depletion rate. The resultant is the number of acre-feet historically depleted in each month for each HUC over the period of record.

The present-level depletion is defined as the depletion that would have occurred in a past year given the present level of development. For example, how would the irrigation development of today affect the depletion in 1935 assuming 1935 climate conditions? Present-level irrigation depletions are calculated the same way as historical depletions, except that the 2007 irrigated acreage is used for all years in the period of record (1929 - 2007). The following example illustrates calculation of present-level depletions:

- 1929 irrigated acreage for HUC X is 10,000 acres
- 2007 irrigated acreage for HUC X is 25,000 acres
- July 1929 irrigation depletion rate was .87 AF/acre (depletion is the diversion requirement minus return flow)
- July 1929 historic depletion was 8,700 AF (10,000 acres times X 0.87 AF/acre)
- Present-level depletion for July 1929 would be 21,750 AF (25,000 acres X 0.87 AF/acre) 21,750 AF

Thus, had 25,000 acres of irrigation been in place in July of 1929, the depletion for that month would have been 21,750 AF. Historically, only 8,700 AF of depletion occurred.

Surface Water Public Supply Depletions

During development of the Depletions Database, a need to quantify depletions to streams in the Missouri River Basin by diversions for public water supplies was identified. However, there were minimal sources of data to quantify those depletions, so several assumptions were needed to define a systematic process for quantifying those depletions in the Missouri River Basin.

Public Supply Diversions

USGS water use reports provide data on public water supplies in the Missouri River Basin. These reports are published every 5 years, with more comprehensive reports starting in 1985. Historically, the water use data were aggregated by both counties and HUCs. However, the 2000 and 2005 reports did not aggregate water use by HUC, and it is anticipated that future reports will only include state and county-level data.

Reclamation used the 1985, 1990, and 1995 published USGS water use reports as the basis for calculating public supply consumption information by HUC. The per capita consumption was multiplied by the estimated number of people served by a public water supply in each HUC to calculate total public supply diversion. The process is based on the primary assumption that public supply water usage parallels population growth in a HUC.

Ratios of population served by public supply surface water system to total HUC population were developed from the 1985, 1990, and 1995 USGS water use data. The three ratios were averaged for each HUC, and that average was multiplied by the historic HUC population to estimate population served by public supply surface water systems over the period of record.

The average per capita water use for each HUC was calculated from the 1985, 1990, and 1995 USGS water use data. For each HUC, the per capita use was multiplied by the population served by surface water public systems to estimate the annual surface water public supply diversions.

Public Supply Depletions

USGS[4] estimated that 37 percent of the water diverted for public supplies in Montana is consumed, with the remaining 63 percent returned to surface waters. Reclamation uses this

[4] United State Geological Survey. *Estimated Water Use in Montana in 2000, Scientific Investigations Report*. 2004. Page 39

value for the Depletions Database for all Missouri River Basin states. Public supply water diversions are multiplied by 0.37 to estimate actual consumptive use, or depletions. The monthly distribution of municipal water use developed for the MBSA study was used to distribute the depletions as follows:

Table C-2. Monthly Distribution of Public Water Supply Depletions (in percent)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
3	3	6	7	10	13	18	15	11	8	3	3	100

Population Data

U.S. Census Bureau population data are used in the Depletions Database. Because the Census Bureau data are reported by county, Reclamation developed a GIS application to distribute population data into the respective HUCs that overly the counties. The GIS application calculated the area of each census block group that lies within a particular HUC. The ratio of a block group's area within a HUC to the total block-group area was used to distribute the Census 2000 block group's population into the respective HUCs.

The Census 2000 block-group population has been distributed into respective HUCs. Census data for prior census years are not readily available in GIS format. Therefore, Reclamation used the distribution of the Census 2000 population by HUC for all prior census years and again for 2010. The ratios of county aggregated population by HUC to total county population were calculated and the county ratios were then multiplied by historic county census data to estimate the population by HUC. Population for years between census years was estimated by linear interpolation.

Broomfield County, Colorado, (located in Denver metropolitan area) was established in November 2001. This presented a problem in that the methods used to disaggregate census blocks and counties into respective HUCs in Colorado would have to be redone to accommodate the new county. As a simplifying procedure to incorporate census data for Broomfield into the Depletions Database, 100 percent of Broomfield's population and public supply consumption is in HUC 10190003.

Historic and Present Level Public Supply Depletions

The difference between historic and present level depletions for public supply is straight forward. Historic depletions are the calculated surface water public supply depletions using historic Census Bureau population data. Present level depletions are calculated using the most recent year of Census Bureau population data for every year in the Depletions Database.

Data Summary

The following tables and graphs summarize the depletions data calculated in the Depletion Database. The data are summarized by the Missouri River Basin reaches described in the introduction. The graphs summarize the data annually and the tables summarize the data monthly and annually.