US Army Corps of Engineers
Kansas City District

Draft Integrated Definite Project Report and Draft Environmental Assessment

Blacksnake Creek Section 205

Flood Risk Management

St. Joseph, Missouri

PN # 105940

June 24, 2015

APPENDICES

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APPENDIX A

HTRW PHASE I SITE ASSESSMENT

Phase I Environmental Site Assessment
Blacksnake Creek
Proposed Flood Control Project
St. Joseph, MO

Prepared by
U.S. Army Corps of Engineers
3 March, 2004

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1.0 Summary

A Site Assessment was performed to identify potential environmental impacts on the proposed flood control project on Blacksnake Creek in St. Joseph, Missouri. A database search of appropriate Federal and State records was performed as well as a site reconnaissance. Available Sanborn Maps were obtained in an attempt to identify historical land use. No serious potential impacts to the project were identified. This report discusses methodology used, limitations of the search, and summarizes the findings. Recommendations for addressing findings are provided to minimize adverse environmental impacts.

2.0 Introduction

2.1 Purpose

The Purpose of the Phase I Environmental Site Assessment was to identify hazardous, toxic, and radioactive waste (HTRW) environmental concerns that would negatively impact the proposed flood control project located in St. Joseph, Missouri. The proposed project consists of the raise of the road embankment at Karnes Road. The road raise will act as a retention pond dam during periods of heavy rainfall. A system of levees or flood walls will be required to protect a number of residences adjacent to the ponded area. Issues identified during the preliminary planning phase of a project can significantly reduce adverse impacts during future phases.

2.2 Limiting Conditions and Methodology Used

The methodology used for this assessment generally follows the guidelines of the ASTM Standards on Environmental Site Assessments for Commercial Real Estate, Phase I Environmental Site Assessment Process, E 1527-00. The size of the project, however, required a search over a much larger area than is normally required by the standard. As a result, the database search identified active or open sites in the search area that were not in the immediate vicinity of the project. This assessment narrowed the focus to sites that would directly impact construction of the proposed project. The site investigation focused on the area of the Karnes Road raise, potential borrow areas, and to a lesser extent the temporary ponding area. No individual interviews were conducted.

3.0 Site Description

3.1 Location and Site Characteristics

The proposed flood control project is located on Blacksnake Creek in the city of St. Joseph, Missouri. The project is located at the intersection of Karnes Road and Saint Joseph Avenue. Currently, Blacksnake Creek is a relatively small but deep open channel upstream of Karnes Road. The creek extends to the north outside the limits of the City of St. Joseph. At Karnes Road the channel ties into a concrete double box culvert, and the channel continues underground

in the downstream direction to the confluence with the Missouri River. The land use downstream of Karnes Road is heavily populated mainly with single family residential housing, however, immediately downstream is a recreational park. During periods of heavy rainfall Karnes Road is overtopped which causes flooding in the downstream areas. The area upstream of the proposed project consists mainly of residential, agricultural and light industrial development.

The proposed flood control project consists of the Karnes Road embankment raise, which will act as a temporary retention pond embankment during periods of heavy rainfall. The flood plain upstream of Karnes Road is mainly cropland, pasture and established riparian areas in the proposed ponding area. A levee system or floodwall will also be required to protect adjacent residences along St. Joseph Avenue in the ponding area.

3.2 Past Uses of the Property

To determine historical use of the property the Sanborn Library, LLC, was searched for existing maps of the area. A series of maps were found from the time period between 1911 and 1966, and they are provided in Appendix B. The maps mainly cover the geographic area downstream of the proposed project, but the intersection of Karnes Road and St. Joseph Avenue is included in the coverage. The series of maps show slow residential development of the area. Blacksnake Creek was routed underground South of Karnes Road between 1949 and 1955. From the limited information available, the proposed retention pond area appears to have never been developed.

3.3 Site Plan

A Geographical Information System (GIS) has been developed for this project. An aerial photograph showing all the major features of the proposed project and adjacent areas are provided in Appendix A. Areas noted in the database search as having active issues, as well as other potential environmental concerns noted during the site inspection are identified.

4.0 Records Review

4.1 Standard Environmental Record Sources, Federal and State

Environmental Data Resources, Inc (EDR) was contracted to conduct a search of reasonably available environmental records for sites within an area surrounding the proposed flood control project for Blacksnake Creek as defined by ASTM E 1527-00. The search revealed the findings listed below. A few properties were flagged as having active status with various regulatory agencies, but none of the properties were found to have an immediate impact on the proposed project. Information for all databases searched and additional information for each finding can be found in the EDR report provided in Appendix C.

Federal ASTM Standards

1 RCRIS (Resource Conservation and Recovery Information System) Small Quantity Generators

1 ERNS (Emergency Response Notification System) Records

Federal ASTM Supplemental

1 FINDS (Facility Index System) Records

4.2 Sites of Concern

Of the sites identified in EDR's database search, no sites were found to have an immediate impact on the proposed project.

5.0 Information from Site Reconnaissance

5.1 Records Search

The sites identified in the database search as having an active status with a regulatory agency were located during the site investigation. All three of the sites are upstream of the proposed work area, and only one of the sites is in the general vicinity of the proposed ponded area. None of the sites will have any direct impact on the proposed project. A summary of findings for each of the sites is provided below.

Laidlaw Transit. This property is located at 4713 Saint Joseph Avenue. The property is used as a storage and refueling facility for school buses, and is located directly adjacent to Blacksnake Creek. The exact nature for the database listing is unknown. The proposed retention ponding limits would extend just past this property within the limits of the creek banks, but in no way will this affect construction of the project.

2002 Blackwell. This property is located at 2002 Blackwell Road, directly adjacent to Blacksnake Creek. It appears to be a small automobile salvage yard. It is about 1000 feet upstream of the proposed retention pond limits. The exact nature for the database listing is unknown. This property would have no impact on the proposed construction.

Swift Transportation. This property is located at 5310 Saint Joseph Avenue. The property appears to be a storage and refueling facility for Deffenbaugh Industries vehicles among other things. It is located on a tributary to Blacksnake Creek about 2500 feet upstream of the proposed retention pond limits. The database listing is due to a number of RCRA violations in 1989 that are not yet closed out. This property is outside all limits of the project so will have no impact.

5.2 Visual Inspection

A site visit was made to the proposed project site to perform a visual inspection of the project area. The weather was about 40 degrees, windy, and with a light rain. The following are observations from the inspection that should be considered during planning and design.

Borrow Area
The proposed borrow area is located immediately adjacent to the location for the pond retention structure, just to the north of Karnes Road. Current use of the land is agricultural, and no signs of potential contamination were identified. An empty 55-gallon drum and a couple of small appliances were found in a small drainage ditch adjacent to the borrow area. They will be in the proposed retention pond area and should be removed during construction.

Private Disposal Site
A disposal site was identified on adjacent private property in the proposed ponding area immediately east of the abandoned railroad embankment. The site is wooded and approximately 100 feet square. Contents of the site include a couple of kitchen appliances, debris and two upright 55 gallon drums with unknown (if any) contents. The potential for soil contamination is a possibility at this site, but would be very limited in extent. The nature of any contamination would be unknown. Potential groundwater contamination is not likely. This area is within the limits of the proposed retention pond area, so the contents of the dump should be removed during construction.

Abandoned Railroad Track Embankment
An abandoned railroad track embankment exists along the eastern edge of the proposed retention pond. The tracks, ties and ballast have all been removed, so all that exists is the remnant of a soil embankment from 2 to 4 feet high. The potential for significant contamination in the immediate vicinity of the embankment from historical use is unlikely, however remnants of contaminants are possible. Potential contaminants include creosote from the railroad ties and petroleum products leaking from cars, including greases, hydraulic fluids, brake fluids, and fuel. This material should not be used as borrow.

6.0 Recommendations

6.1 General

A Phase I Environmental Site Assessment was performed in conformance with the scope and limitation of ASTM Standard E 1527-00 for the proposed Blacksnake Creek flood control project. This assessment has revealed little evidence of recognized environmental conditions in connection with the land within or adjacent to the project, other than an abandoned railroad embankment. The following recommendation is provided to prevent adverse impacts of this feature on the proposed project.

6.2 Recommendations

A) It is recommended that the abandoned railroad embankment not be used for borrow to construct any features of the proposed project, although the risk of significant contamination is small. If it is required that this material be used, soil testing should be performed to verify the presence or lack of contamination.

B) There are two upright 55 gallon drums located on adjacent private property within the limits of the proposed retention pond. Prior to removal, the contents of the drums (if any) should be identified so proper disposal measures can be taken.

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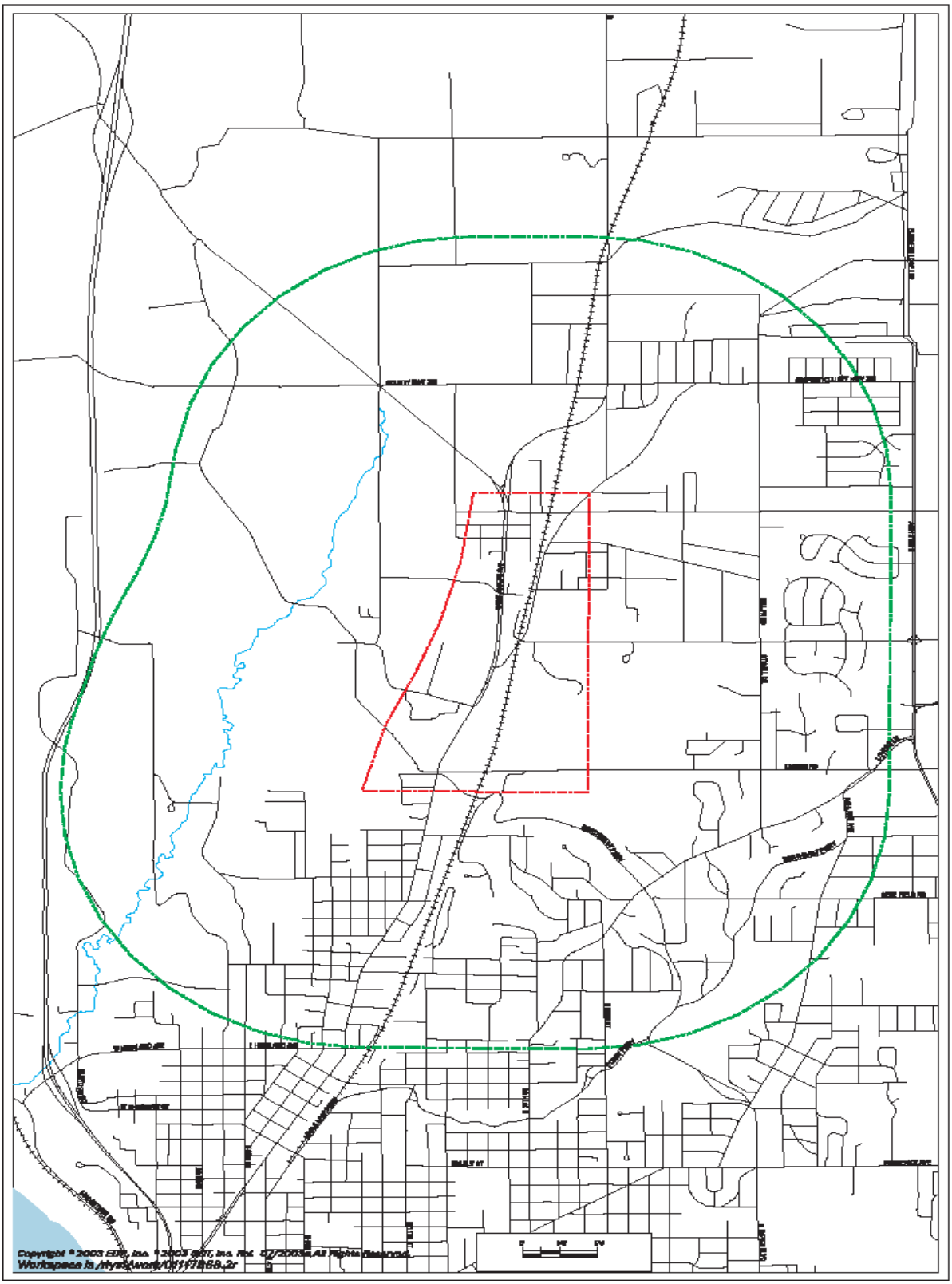
Appendix A

Site Map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Workspace is /hyd/work/0317265.2r

Appendix B

Sanborn Maps

Environmental Data Resources, Inc.

"Linking Technology with Tradition"

Sanborn® Map Transmittal

Ship To: Randy Kuzniakowski
US Army Corps of
601 East 12th Street
Kansas City, MO 64106

Customer Project: na
1101724TWC 816-983-3844

Order Date: 1/27/2004 **Completion Date:** 1/27/2004
Inquiry #: 1119328.1s
P.O. #: na
Site Name: Blackstone Creek SCT 205 Feasibility
Address: Blackstone Creek SCT 205 Feas
City/State: St. Joseph, MO 64505
Cross Streets:

Based on client-supplied information, fire insurance maps for the following years were identified

1911 - 1 Map
1949 - 1 Map
1955 - 1 Map
1963 - 1 Map
1966 - 1 Map

Limited Permission to Photocopy Total Maps: 5

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Electronic Sanborn Map Images
USER'S GUIDE

Thank you for your interest in electronic Sanborn Map images. The following are guidelines for accessing the images and for transferring them to your system. If you have any questions about the use of electronic Sanborn Map images, contact your EDR Account Executive at 1-800-352-0050.

Organization of Electronic Sanborn Image File

- First Page — Sanborn Map Report, listing years of coverage
- Second Page — Electronic Sanborn Map Images USER'S GUIDE
- Third Page — Oldest Sanborn Map Image
- Last Page — Most recent Sanborn Map Image

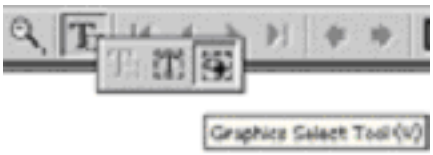
Navigating the Electronic Sanborn Image File

- Open file on screen.
- Identify TP (Target Property) on the most recent map.
- Find TP on older printed images.
- Using Acrobat, zoom to 250% in order to view more clearly.
  - 200-250% is the approximate equivalent scale of hardcopy Sanborn Maps.
- Zooming in on an image:
  - On the menu bar, click "View" and then zoom.
  - Use the magnifying tool and drag a box around the TP area.

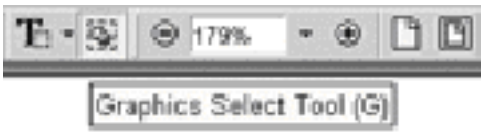
Printing a Sanborn Map from the Electronic File

- EDR recommends printing all images at 300 dpi (300 dpi prints faster than 600 dpi).
- To print only the TP area, cut and paste the area from Adobe Acrobat to your word processor.

  Acrobat Version 4
  - Go to the Menu bar
  - Press and hold the "T" button
  - Choose the Graphics Select Tool
  - Draw a box around the area selected
  - Go to "Menu"
  - Hightlight "Edit"
  - Hightlight "Copy"
  - Go to a word processor such as Microsoft Word, paste and print.



  Acrobat Version 5
  - Go to the Menu bar
  - Click the "Graphics Select Tool"
  - Draw a box around the area selected
  - Go to "Menu"
  - Highlight "Edit"
  - Highlight "Copy"
  - Go to a word processor such as Microsoft Word, paste and print.



Important Information about Email Delivery of Electronic

- Images are grouped intro one file, up to 2MB.
- In cases where in excess of 6-7 map years are available, the file size typically exceeds 2MB. In these cases, you will receive multiple files, labeled as 1 of 3, 2 of 3, etc. including all available map years.
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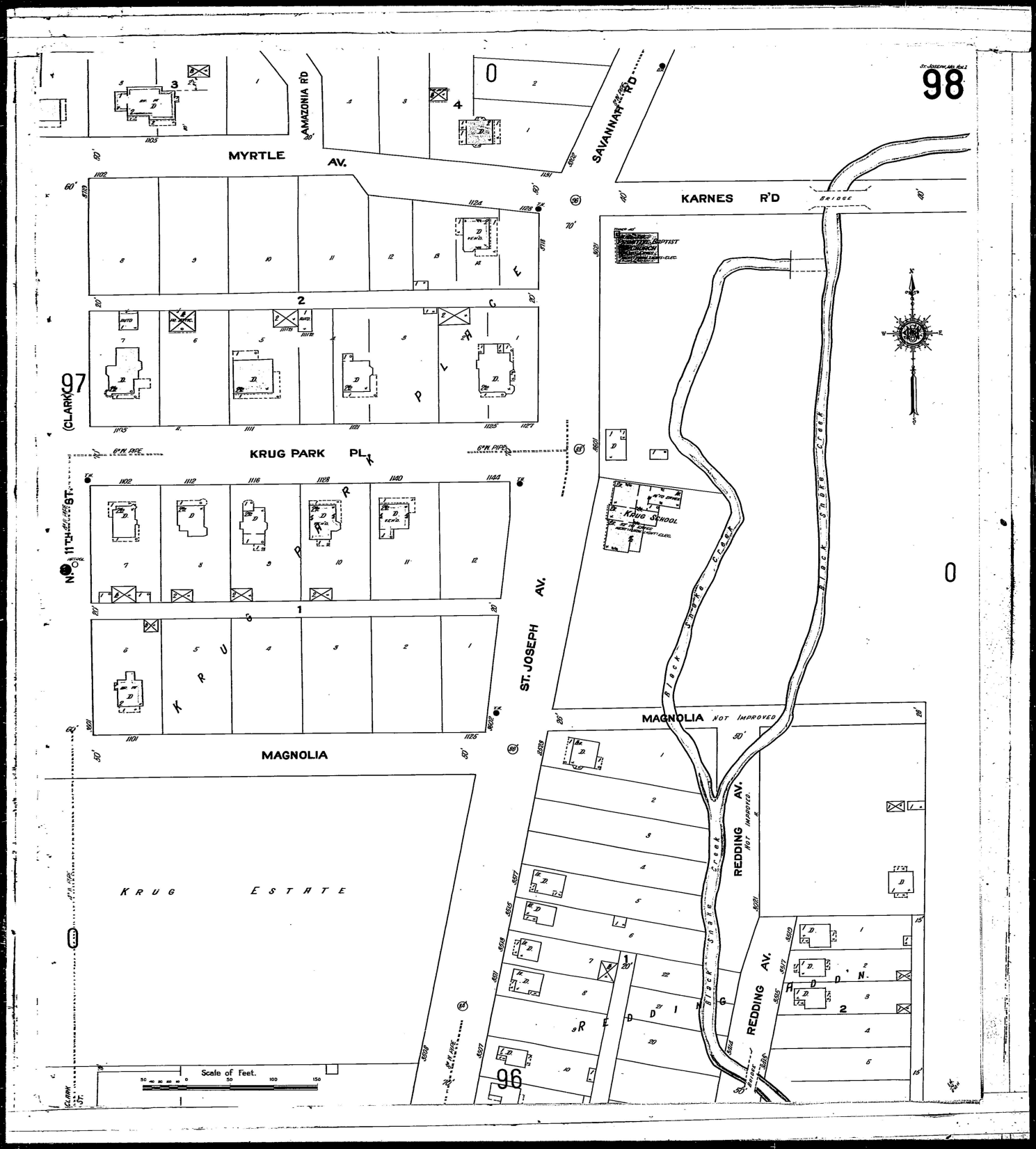

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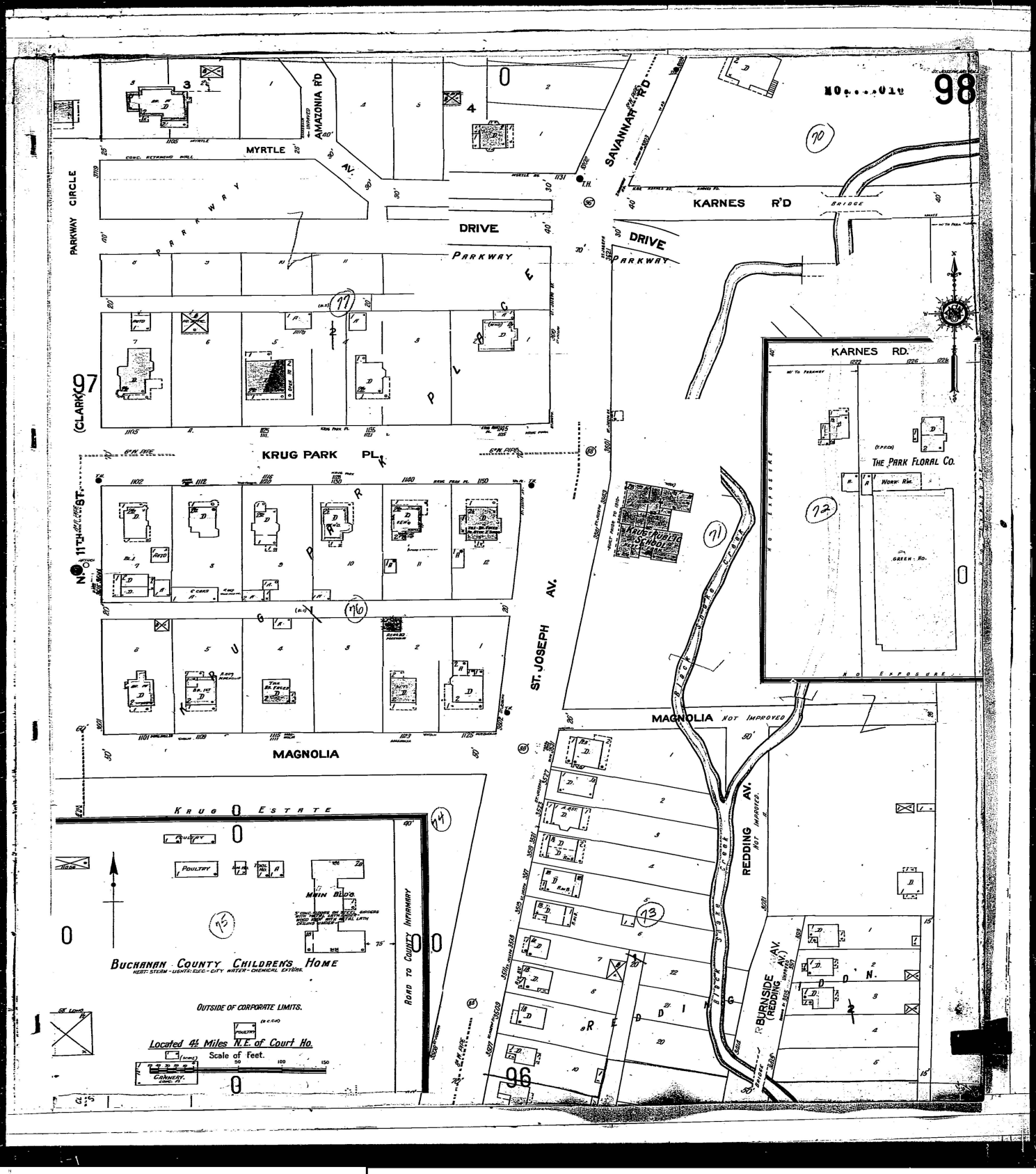

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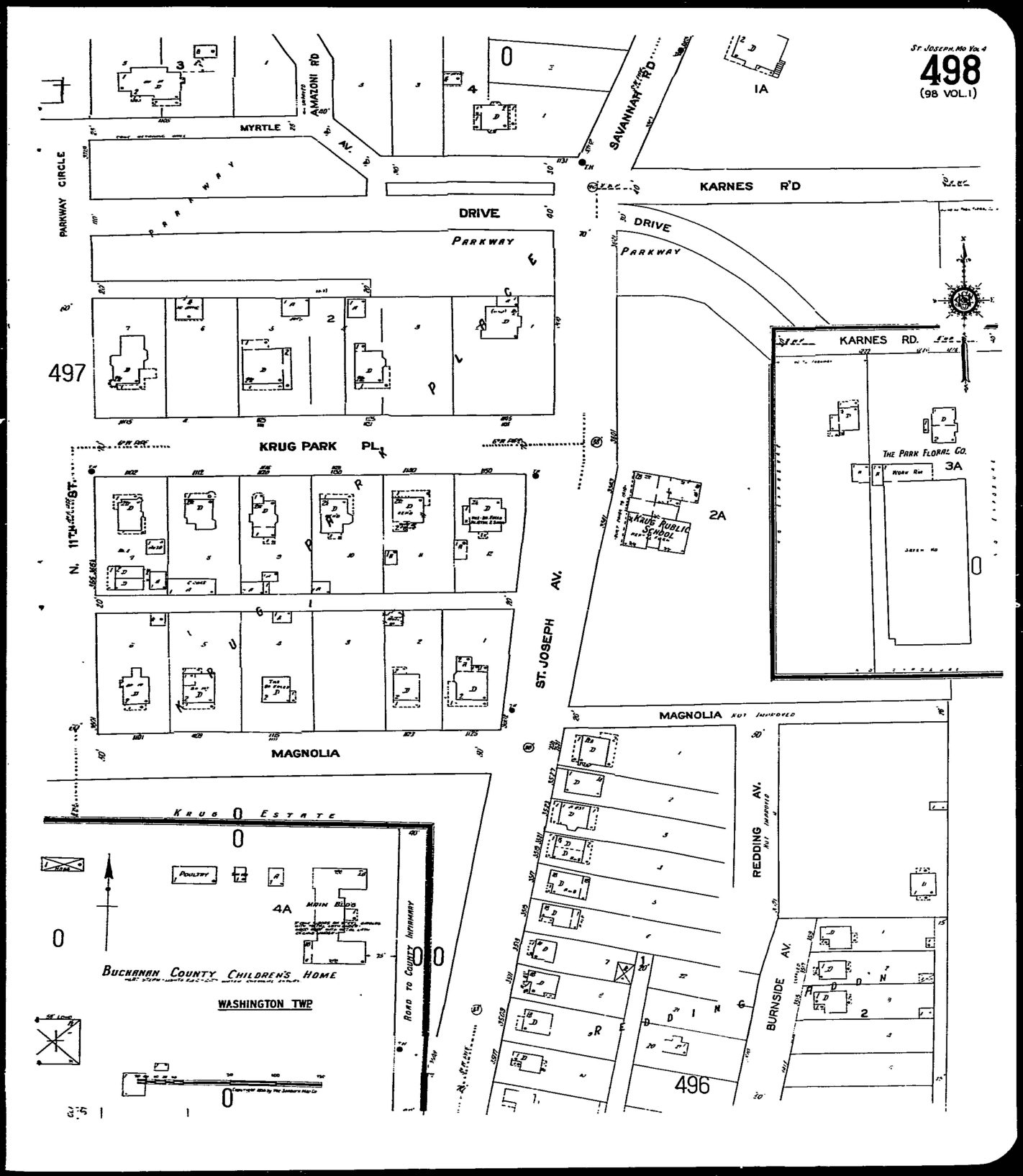

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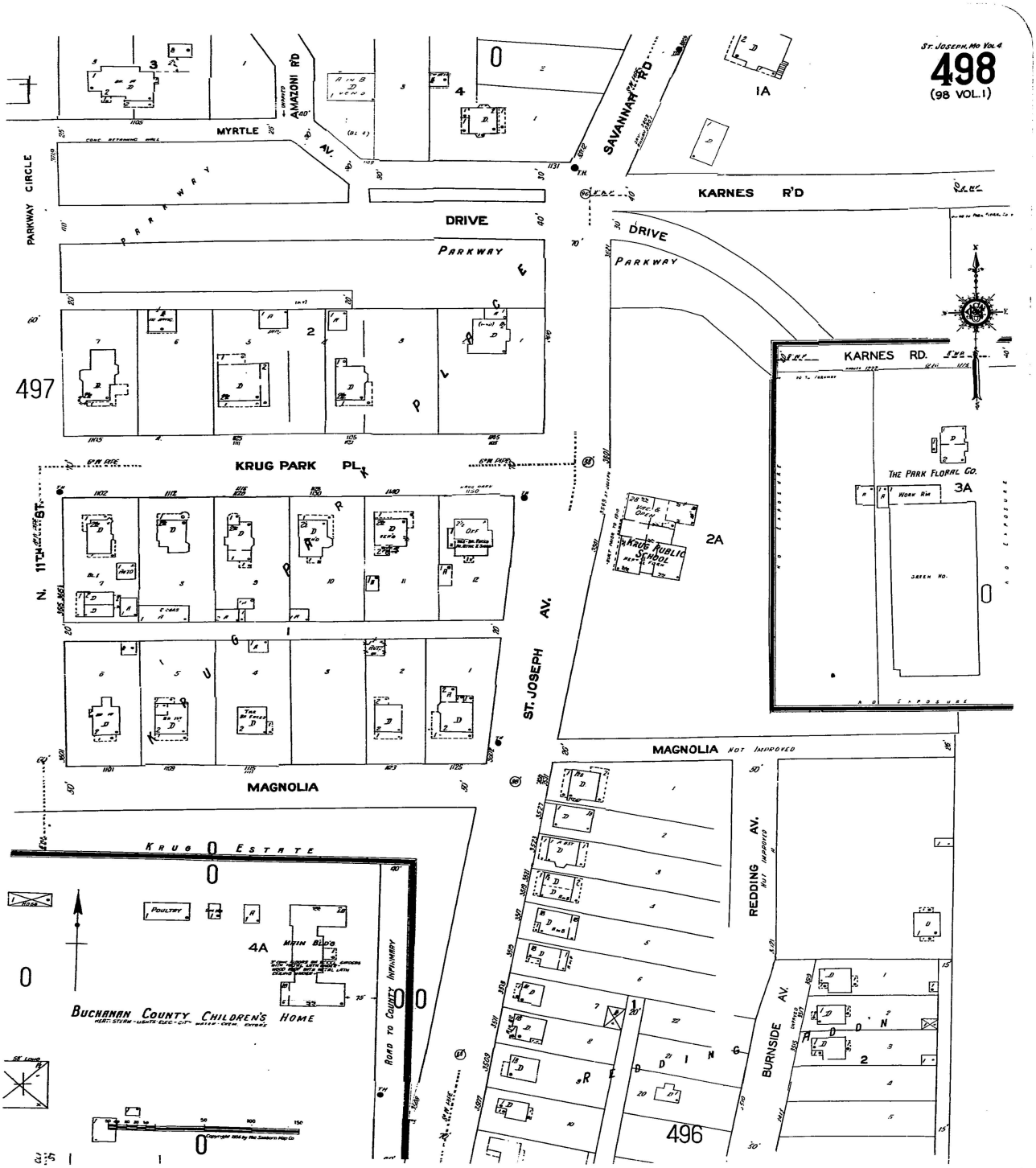

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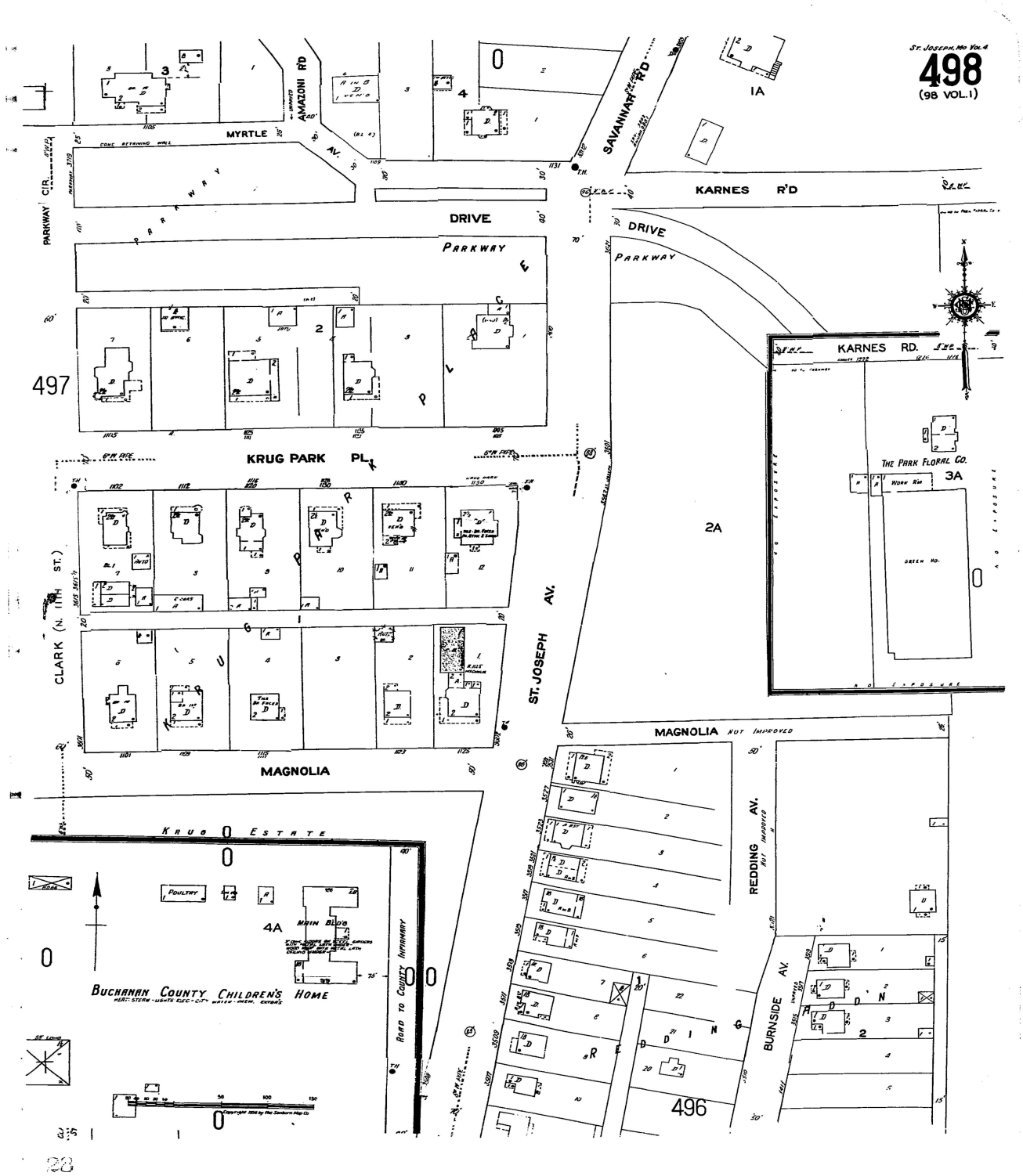

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Appendix C

Environmental Data Resources Database Search Report

The EDR Area Study Report

Study Area
Blackstone Creek, SCT205 Feasibility Study
St. Joseph, MO 64505

February 04, 2004

Inquiry number 01117868.2r

Environmental Data Resources, Inc.

***The* Source For Environmental Risk Management Data**

3530 Post Road
Southport, Connecticut 06890

Nationwide Customer Service

Telephone: 1-800-352-0050
Fax: 1-800-231-6802
Internet: www.edrnet.com

EXECUTIVE SUMMARY

A search of available environmental records was conducted by Environmental Data Resources, Inc. (EDR).

TARGET PROPERTY INFORMATION

ADDRESS

BLACKSTONE CREEK, SCT205 FEASIBILITY STUDY
ST. JOSEPH, MO 64505

DATABASES WITH NO MAPPED SITES

No mapped sites were found in EDR's search of available ("reasonably ascertainable ") government records within the requested search area for the following databases:

FEDERAL ASTM STANDARD

NPL	National Priority List
Proposed NPL	Proposed National Priority List Sites
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERC-NFRAP	CERCLIS No Further Remedial Action Planned
CORRACTS	Corrective Action Report
RCRIS-TSD	Resource Conservation and Recovery Information System
RCRIS-LQG	Resource Conservation and Recovery Information System

STATE ASTM STANDARD

SHWS	Registry of Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites
SWF/LF	Solid Waste Facility List
LUST	Leaking Underground Storage Tanks
UST	Petroleum Storage Tanks
VCP	Sites Participating in the Voluntary Cleanup Program

FEDERAL ASTM SUPPLEMENTAL

CONSENT	Superfund (CERCLA) Consent Decrees
ROD	Records Of Decision
Delisted NPL	National Priority List Deletions
HMIRS	Hazardous Materials Information Reporting System
MLTS	Material Licensing Tracking System
MINES	Mines Master Index File
NPL Liens	Federal Superfund Liens
PADS	PCB Activity Database System
US BROWNFIELDS	A Listing of Brownfields Sites
DOD	Department of Defense Sites
RAATS	RCRA Administrative Action Tracking System

EXECUTIVE SUMMARY

TRIS ..... Toxic Chemical Release Inventory System
TSCA ..... Toxic Substances Control Act
SSTS ..... Section 7 Tracking Systems
FTTS INSP ..... FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)

STATE OR LOCAL ASTM SUPPLEMENTAL

AST ..... Aboveground Petroleum Storage Tanks
MO RRC ..... Certified Hazardous Waste Resource Recovery Facilities
INST CONTROL ..... Sites with Institutional Controls
DEL SHWS ..... Registry Sites Withdrawn or Deleted
SPILLS ..... Environmental Response Tracking Database

BROWNFIELDS DATABASES

US BROWNFIELDS ..... A Listing of Brownfields Sites
Brownfields ..... Brownfields Site List
VCP ..... Sites Participating in the Voluntary Cleanup Program

SURROUNDING SITES: SEARCH RESULTS

Surrounding sites were identified.

Page numbers and map identification numbers refer to the EDR Radius Map report where detailed data on individual sites can be reviewed.

Sites listed in ***bold italics*** are in multiple databases.

Unmappable (orphan) sites are not considered in the foregoing analysis.

FEDERAL ASTM STANDARD

RCRIS: Resource Conservation and Recovery Information System. RCRIS includes selective information on sites which generate, transport, store, treat and/or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). Conditionally exempt small quantity generators (CESQGs): generate less than 100 kg of hazardous waste, or less than 1 kg of acutely hazardous waste per month. Small quantity generators (SQGs): generate between 100 kg and 1,000 kg of hazardous waste per month. Large quantity generators (LQGs): generate over 1,000 kilograms (kg) of hazardous waste, or over 1 kg of acutely hazardous waste from the generator off-site to a facility that can recycle, treat, store, or dispose of the waste. TSDFs treat, store, or dispose of the waste.

A review of the RCRIS-SQG list, as provided by EDR, and dated 12/10/2003 has revealed that there is 1 RCRIS-SQG site within the searched area.

Site	Address	Map ID	Page
SWIFT TRANSPORTATION	***5310 ST JOSEPH AVE***	***1***	***3***

EXECUTIVE SUMMARY

ERNS: The Emergency Response Notification System records and stores information on reported releases of oil and hazardous substances. The source of this database is the U.S. EPA.

A review of the ERNS list, as provided by EDR, and dated 12/31/2002 has revealed that there is 1 ERNS site within the searched area.

Site	Address	Map ID	Page
2002 BLACKWELL	2002 BLACKWELL	2	4

FEDERAL ASTM SUPPLEMENTAL

FINDS: The Facility Index System contains both facility information and "pointers" to other sources of information that contain more detail. These include: RCRIS; Permit Compliance System (PCS); Aerometric Information Retrieval System (AIRS); FATES (FIFRA [Federal Insecticide Fungicide Rodenticide Act] and TSCA Enforcement System, FTTS [FIFRA/TSCA Tracking System]; CERCLIS; DOCKET (Enforcement Docket used to manage and track information on civil judicial enforcement cases for all environmental statutes); Federal Underground Injection Control (FURS); Federal Reporting Data System (FRDS); Surface Impoundments (SIA); TSCA Chemicals in Commerce Information System (CICS); PADS; RCRA-J (medical waste transporters/disposers); TRIS; and TSCA. The source of this database is the U.S. EPA/NTIS.

A review of the FINDS list, as provided by EDR, and dated 10/23/2003 has revealed that there are 2 FINDS sites within the searched area.

Site	Address	Map ID	Page
SWIFT TRANSPORTATION	***5310 ST JOSEPH AVE***	***1***	***3***
LAIDLAW TRANSIT	4713 SAINT JOSEPH AVENU	3	4

EXECUTIVE SUMMARY

Please refer to the end of the findings report for unmapped orphan sites due to poor or inadequate address information.

MAP FINDINGS SUMMARY

Database	Total Plotted
FEDERAL ASTM STANDARD	
NPL	0
Proposed NPL	0
CERCLIS	0
CERC-NFRAP	0
CORRACTS	0
RCRIS-TSD	0
RCRIS Lg. Quan. Gen.	0
RCRIS Sm. Quan. Gen.	1
ERNS	1
STATE ASTM STANDARD	
State Haz. Waste	0
State Landfill	0
LUST	0
UST	0
VCP	0
FEDERAL ASTM SUPPLEMENTAL	
CONSENT	0
ROD	0
Delisted NPL	0
FINDS	2
HMIRS	0
MLTS	0
MINES	0
NPL Liens	0
PADS	0
US BROWNFIELDS	0
DOD	0
RAATS	0
TRIS	0
TSCA	0
SSTS	0
FTTS	0
STATE OR LOCAL ASTM SUPPLEMENTAL	
AST	0
MO RRC	0
INST CONTROL	0
DEL SHWS	0
SPILLS	0
BROWNFIELDS DATABASES	
US BROWNFIELDS	0

MAP FINDINGS SUMMARY

Database	Total Plotted
Brownfields	0
VCP	0

NOTES:

Sites may be listed in more than one database

Coal Gas Site Search: EDR does not presently have coal gas site information available in this state.

---

1 SWIFT TRANSPORTATION — **RCRIS-SQG 1000983543**
5310 ST JOSEPH AVE — **FINDS MOT300010824**
ST JOSEPH, MO 64502

RCRIS:

Owner: SWIFT TRANSPORTATION
EPA ID: MOT300010824

Contact: LARRY DAVIS
(816) 233-3158

Classification: Small Quantity Generator
TSDF Activities: Not reported

Violation Status: Violations exist

Regulation Violated: Not reported
Area of Violation: GENERATOR-ALL REQUIREMENTS (OVERSIGHT)
Date Violation Determined: 10/18/1989
Actual Date Achieved Compliance: Not reported

Enforcement Action: WRITTEN INFORMAL
Enforcement Action Date: 10/18/1989
Penalty Type: Not reported

Regulation Violated: Not reported
Area of Violation: GENERATOR-ALL REQUIREMENTS (OVERSIGHT)
Date Violation Determined: 10/18/1989
Actual Date Achieved Compliance: Not reported

Enforcement Action: WRITTEN INFORMAL
Enforcement Action Date: 10/18/1989
Penalty Type: Not reported

Regulation Violated: Not reported
Area of Violation: GENERATOR-LAND BAN REQUIREMENTS
Date Violation Determined: 10/18/1989
Actual Date Achieved Compliance: Not reported

Enforcement Action: WRITTEN INFORMAL
Enforcement Action Date: 10/18/1989
Penalty Type: Not reported

There are 3 violation record(s) reported at this site:

Evaluation	Area of Violation	Date of Compliance
Compliance Evaluation Inspection	GENERATOR-ALL REQUIREMENTS (OVERSIGHT)	
	GENERATOR-ALL REQUIREMENTS (OVERSIGHT)	
	GENERATOR-LAND BAN REQUIREMENTS	

FINDS:

Other Pertinent Environmental Activity Identified at Site:
Resource Conservation and Recovery Act Information system (RCRAINFO)

Map ID Direction Distance Distance (ft.)	Site	Database(s)	EDR ID Number EPA ID Number
2	**2002 BLACKWELL** **2002 BLACKWELL** **ST. JOSEPH, MO 64505**	**ERNS**	**93322071** **N/A**

The ERNS database may contain additional details for this site.
Please click here or contact your EDR Account Executive for more information.

3	**LAIDLAW TRANSIT** **4713 SAINT JOSEPH AVENUE** **SAINT JOSEPH, MO 64505**	**FINDS**	**1005612065** **110011077084**

FINDS:
Other Pertinent Environmental Activity Identified at Site:
Permit Compliance System (PCS)

ORPHAN SUMMARY

City	EDR ID	Site Name	Site Address	Zip	Database(s)
BUCHANAN COUNTY	S105375141	ST. JOSEPH CITY SANITARY LANDFILL	1/2 MILE E. OF I-29 AND 1/2 MILE S. OF HWY O, SE O		SWF/LF
ST JOSEPH	U003849717	TRIPLE F FEEDLOT	6521 S 59 HWY	64505	UST
ST JOSEPH	1007110052	PAYLESS CASHWAYS INC	4204 N 71 HWY	64506	RCRIS-SQG
ST JOSEPH	1007110053	PAYLESS CASHWAYS INC	4204 N 71 HWY	64506	RCRIS-SQG
ST JOSEPH	U003762754	MURPHY USA #6654	3018 S BELT HWY	64506	UST
ST JOSEPH	U003877215	JESSE'S LAST STOP	12751 COUNTRY PLACE DR.	64505	UST
ST JOSEPH	1006930947	71 KWIK STOP	6113 N HWY 71	64506	RCRIS-SQG
ST JOSEPH	1007105713	SAINT JOSEPH DIESEL INC	JCT I-29 & HWY 71 N	64505	RCRIS-SQG
ST JOSEPH	1007105714	SAINT JOSEPH DIESEL INC	JCT I-29 & HWY 71 N	64505	RCRIS-SQG
ST JOSEPH	1007104935	K HIGHWAY AUTO SALVAGE	.75 MI N ON K HWY	64505	RCRIS-SQG
ST JOSEPH	1007110093	PENSKE AUTO CENTER	2901B S N BELT HWY	64506	RCRIS-SQG
ST JOSEPH	1007110094	PENSKE AUTO CENTER	2901B S N BELT HWY	64506	RCRIS-SQG

Site	Database(s)	EDR ID Number EPA ID Number

ST. JOSEPH CITY SANITARY LANDFILL — **SWF/LF** — **S105375141**
1/2 MILE E. OF I-29 AND 1/2 MILE S. OF HWY O, SE O — **N/A**
BUCHANAN COUNTY, MO

LF:

Facility ID:	0102102	Site Code:	1000103
Permit Number:	122	Permit Status:	Active
Permit Issued:	12/20/77	Permit Expires:	Not reported
Permit Type:	Sanitary Landfill	Close Date:	Not reported
Sub Titled:	Not reported	Regional Office:	KCRO
Operator Title :	Operator		
Operator Company:	City of St. Joseph		
Operator Contact:	William E. Blacketer		
Operator Address:	9431 50th Road SE St. Joseph 64507		
Operator Phone:	(816) 253-9025		
Owner Name:	MUN		
Owner Company:	City of St. Joseph		
Owner Contact:	Bruce Woody		
Owner Address:	9431 50th Road SE St. Joseph, MO 64507		
Owner Phone:	(816) 271-4730		
Mailing Company:	St Joseph Sanitary Landfill		
Mailing Contact:	Mr. William Blacketer		
Mailing Title:	Mr.		
Mailing Address:	9431 50th Road SE St. Joseph, MO 64507		
Mailing Phone:	(816) 271-4730		
Days Open:	0		
Project Grant:	4750042		
Type User:	Not reported		
Current Address:	Yes		
Billing:	True		
GW Monitoring:	Not reported		

TRIPLE F FEEDLOT — **UST** — **U003849717**
6521 S 59 HWY — **N/A**
ST JOSEPH, MO 64505

PAYLESS CASHWAYS INC — **RCRIS-SQG** — **1007110052**
4204 N 71 HWY — **MOR000000117**
ST JOSEPH, MO 64506

RCRIS:

Owner:	PAYLESS CASHWAYS INC (816) 234-6326
EPA ID:	MOR000000117
Contact:	Not reported
Classification:	Small Quantity Generator
TSDF Activities:	Not reported

Site	Database(s)	EDR ID Number EPA ID Number
PAYLESS CASHWAYS INC (Continued)		1007110052

Violation Status: No violations found

PAYLESS CASHWAYS INC **RCRIS-SQG** **1007110053**
4204 N 71 HWY **MOR000000117**
ST JOSEPH, MO 64506

RCRIS:

Owner: PAYLESS CASHWAYS INC
(816) 234-6326
EPA ID: MOR000000117

Contact: Not reported

Classification: Small Quantity Generator
TSDF Activities: Not reported

Violation Status: No violations found

MURPHY USA #6654 **UST** **U003762754**
3018 S BELT HWY **N/A**
ST JOSEPH, MO 64506

UST:

Facility ID:	ST0020820		
Owner:	MURPHY OIL USA INC 200 PEACH ST EL DORADO, AR 71730		
Tank ID:	Not reported	Owner ID:	OW10777
Tank Type:	Below Ground	Tank Status:	Curently in use
Capacity:	12	Substance:	F
Meet 98:	True	Region :	KC
Owner Telephone :	870-862-6411	Date Tank Installed :	12/08/00

Date Piping Installed :	12/29/00
Other Type Of Tank Material :	Not reported
Tank Internal Protection :	Not reported
Other Tank Internal Protection :	Not reported
Tank Internal Protection Date :	/ /
Tank External Protection :	Not reported
Other Type Tank Extrn Protec :	Not reported
Tank External Protec Date :	/ /
Tank Rel Detectn Methods :	AN
Other Tank Rel Detection Methods :	Not reported
Dt Tank Realease Detection Installed :	12/29/00
Types Of Overfill :	123
Piping System :	Pressurized
Pipe Material :	P
Other Type Of Pipe Mat :	Not reported
Pipe Protection :	Not reported
Pipe Protection Date :	/ /
Pipe Release Detection :	LNT
Other Type Of Pipe Rel Detctn :	Not reported
Type Of Subst Tank Holds :	Gasoline, including blends
Other Type Of Tank Subst :	Not reported
Name Of Haz. Substance :	Not reported
Case # Of The Primary Haz Sub :	Not reported
Haz Substance A Mixture :	False
Tank Last Used :	/ /

Site	Database(s)	EDR ID Number EPA ID Number
MURPHY USA #6654 (Continued)		U003762754

Tnk Permanently Closed/ Removed : / /
Tank Fees Waived : False
Admin Fee 585 : 0
Registration Fee 585 : 75.00000
Date Record Added : 01/19/01
Date Record Edited : 01/19/01
Person Adding / Editing Record : GIRARD, L
Amt Assessed By The Current Cycle : 75.00000
Amount Curently Due : 0.00000
Tank Equiped With Spill Protection : True
Date Closed Null : False
Date Of NFA Letter : / /
Tank Used For Emergency Genrtr : False

Facility ID: ST0020820
Owner: MURPHY OIL USA INC
200 PEACH ST
EL DORADO, AR 71730
Tank ID: Not reported
Owner ID: OW10777
Tank Type: Below Ground
Tank Status: Curently in use
Capacity: 12
Substance: F
Meet 98: True
Region : KC
Owner Telephone : 870-862-6411
Date Tank Installed : 12/08/00
Date Piping Installed : 12/29/00
Other Type Of Tank Material : Not reported
Tank Internal Protection : Not reported
Other Tank Internal Protection : Not reported
Tank Internal Protection Date : / /
Tank External Protection : Not reported
Other Type Tank Extrn Protec : Not reported
Tank External Protec Date : / /
Tank Rel Detectn Methods : AN
Other Tank Rel Detection Methods : Not reported
Dt Tank Realease Detection Installed : 12/29/00
Types Of Overfill : 123
Piping System : Pressurized
Pipe Material : P
Other Type Of Pipe Mat : Not reported
Pipe Protection : Not reported
Pipe Protection Date : / /
Pipe Release Detection : LNT
Other Type Of Pipe Rel Detctn : Not reported
Type Of Subst Tank Holds : Gasoline, including blends
Other Type Of Tank Subst : Not reported
Name Of Haz. Substance : Not reported
Case # Of The Primary Haz Sub : Not reported
Haz Substance A Mixture : False
Tank Last Used : / /
Tnk Permanently Closed/ Removed : / /
Tank Fees Waived : False
Admin Fee 585 : 0
Registration Fee 585 : 75.00000
Date Record Added : 01/19/01
Date Record Edited : 01/19/01
Person Adding / Editing Record : GIRARD, L
Amt Assessed By The Current Cycle : 75.00000
Amount Curently Due : 0.00000
Tank Equiped With Spill Protection : True
Date Closed Null : False
Date Of NFA Letter : / /
Tank Used For Emergency Genrtr : False

Facility ID: ST0020820

Site	Database(s)	EDR ID Number EPA ID Number

MURPHY USA #6654 (Continued) U003762754

Owner: MURPHY OIL USA INC
200 PEACH ST
EL DORADO, AR 71730

Tank ID:	Not reported	Owner ID:	OW10777
Tank Type:	Below Ground	Tank Status:	Curently in use
Capacity:	12	Substance:	F
Meet 98:	True	Region :	KC
Owner Telephone :	870-862-6411	Date Tank Installed :	12/08/00

Date Piping Installed :	12/29/00
Other Type Of Tank Material :	Not reported
Tank Internal Protection :	Not reported
Other Tank Internal Protection :	Not reported
Tank Internal Protection Date :	/ /
Tank External Protection :	Not reported
Other Type Tank Extrn Protec :	Not reported
Tank External Protec Date :	/ /
Tank Rel Detectn Methods :	AN
Other Tank Rel Detection Methods :	Not reported
Dt Tank Realease Detection Installed :	12/29/00
Types Of Overfill :	123
Piping System :	Pressurized
Pipe Material :	P
Other Type Of Pipe Mat :	Not reported
Pipe Protection :	Not reported
Pipe Protection Date :	/ /
Pipe Release Detection :	LNT
Other Type Of Pipe Rel Detctn :	Not reported
Type Of Subst Tank Holds :	Other
Other Type Of Tank Subst :	GAS/DIESEL-COMPARTMENTALIZED
Name Of Haz. Substance :	Not reported
Case # Of The Primary Haz Sub :	Not reported
Haz Substance A Mixture :	False
Tank Last Used :	/ /
Tnk Permanently Closed/ Removed :	/ /

Tank Fees Waived :	False	Admin Fee 585 :	0
Registration Fee 585 :	75.00000	Date Record Added :	01/19/01

Date Record Edited :	01/19/01
Person Adding / Editing Record :	GIRARD, L
Amt Assessed By The Current Cycle :	75.00000
Amount Curently Due :	0.00000
Tank Equiped With Spill Protection :	True

Date Closed Null :	False	Date Of NFA Letter :	/ /

Tank Used For Emergency Genrtr : False

JESSE'S LAST STOP **UST** **U003877215**
12751 COUNTRY PLACE DR. **N/A**
ST JOSEPH, MO 64505

UST:

Facility ID: ST0020969
Owner: HOLIDAY, INC.
P.O. BOX 37
AMAZONIA, MO 64421

Tank ID:	Not reported	Owner ID:	OW20299
Tank Type:	Below Ground	Tank Status:	Curently in use
Capacity:	15	Substance:	C
Meet 98:	True	Region :	KC
Owner Telephone :	816-676-1200	Date Tank Installed :	11/07/01

Site	Database(s)	EDR ID Number EPA ID Number
JESSE'S LAST STOP (Continued)		U003877215

Date Piping Installed : 11/15/01
Other Type Of Tank Material : Not reported
Tank Internal Protection : Not reported
Other Tank Internal Protection : Not reported
Tank Internal Protection Date : / /
Tank External Protection : Not reported
Other Type Tank Extrn Protec : Not reported
Tank External Protec Date : / /
Tank Rel Detectn Methods : AI
Other Tank Rel Detection Methods : Not reported
Dt Tank Realease Detection Installed : / /
Types Of Overfill : Plow restrictor @ 90%
Piping System : Pressurized
Pipe Material : Fiberglass reinforced plastic
Other Type Of Pipe Mat : Not reported
Pipe Protection : Not reported
Pipe Protection Date : / /
Pipe Release Detection : LT
Other Type Of Pipe Rel Detctn : Not reported
Type Of Subst Tank Holds : Gasoline, including blends
Other Type Of Tank Subst : Not reported
Name Of Haz. Substance : Not reported
Case # Of The Primary Haz Sub : Not reported
Haz Substance A Mixture : False
Tank Last Used : / /
Tnk Permanently Closed/ Removed : / /
Tank Fees Waived : False Admin Fee 585 : 0
Registration Fee 585 : 75.00000 Date Record Added : 02/27/02
Date Record Edited : 02/27/02
Person Adding / Editing Record : NEVINS, H.
Amt Assessed By The Current Cycle : 75.00000
Amount Curently Due : 0.00000
Tank Equiped With Spill Protection : True
Date Closed Null : False Date Of NFA Letter : / /
Tank Used For Emergency Genrtr : False

Facility ID: ST0020969
Owner: HOLIDAY, INC.
P.O. BOX 37
AMAZONIA, MO 64421
Tank ID: Not reported Owner ID: OW20299
Tank Type: Below Ground Tank Status: Curently in use
Capacity: 15 Substance: C
Meet 98: True Region : KC
Owner Telephone : 816-676-1200 Date Tank Installed : 11/07/01
Date Piping Installed : 11/15/01
Other Type Of Tank Material : Not reported
Tank Internal Protection : Not reported
Other Tank Internal Protection : Not reported
Tank Internal Protection Date : / /
Tank External Protection : Not reported
Other Type Tank Extrn Protec : Not reported
Tank External Protec Date : / /
Tank Rel Detectn Methods : AI
Other Tank Rel Detection Methods : Not reported
Dt Tank Realease Detection Installed : / /
Types Of Overfill : Plow restrictor @ 90%

Site	Database(s)	EDR ID Number EPA ID Number

JESSE'S LAST STOP (Continued) U003877215

Piping System :	Pressurized
Pipe Material :	Fiberglass reinforced plastic
Other Type Of Pipe Mat :	Not reported
Pipe Protection :	Not reported
Pipe Protection Date :	/ /
Pipe Release Detection :	LT
Other Type Of Pipe Rel Detctn :	Not reported
Type Of Subst Tank Holds :	Gasoline, including blends
Other Type Of Tank Subst :	Not reported
Name Of Haz. Substance :	Not reported
Case # Of The Primary Haz Sub :	Not reported
Haz Substance A Mixture :	False
Tank Last Used :	/ /
Tnk Permanently Closed/ Removed :	/ /
Tank Fees Waived : False	Admin Fee 585 : 0
Registration Fee 585 : 75.00000	Date Record Added : 02/27/02
Date Record Edited :	02/27/02
Person Adding / Editing Record :	NEVINS, H.
Amt Assessed By The Current Cycle :	75.00000
Amount Curently Due :	0.00000
Tank Equiped With Spill Protection :	True
Date Closed Null : False	Date Of NFA Letter : / /
Tank Used For Emergency Genrtr :	False

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71 KWIK STOP **RCRIS-SQG** **1006930947**
6113 N HWY 71 **MOP000509463**
ST JOSEPH, MO 64506

RCRIS:

Owner:	RONALD STAGNER (816) 324-3986
EPA ID:	MOP000509463
Contact:	SHERRY DORZWEILER (816) 324-3986
Classification:	Small Quantity Generator
TSDF Activities:	Not reported
Violation Status:	No violations found

SAINT JOSEPH DIESEL INC **RCRIS-SQG** **1007105713**
JCT I-29 & HWY 71 N **MOD083118778**
ST JOSEPH, MO 64505

RCRIS:

Owner:	STEVE WEBSTER NA
EPA ID:	MOD083118778
Contact:	Not reported
Classification:	Small Quantity Generator
TSDF Activities:	Not reported

Site	Database(s)	EDR ID Number EPA ID Number
SAINT JOSEPH DIESEL INC (Continued)		1007105713

Violation Status: No violations found

SAINT JOSEPH DIESEL INC **JCT I-29 & HWY 71 N** **ST JOSEPH, MO 64505**	**RCRIS-SQG**	**1007105714** **MOD083118778**

RCRIS:
Owner: STEVE WEBSTER
NA
EPA ID: MOD083118778

Contact: Not reported

Classification: Small Quantity Generator
TSDF Activities: Not reported

Violation Status: No violations found

K HIGHWAY AUTO SALVAGE **.75 MI N ON K HWY** **ST JOSEPH, MO 64505**	**RCRIS-SQG**	**1007104935** **MOD029980489**

RCRIS:
Contact: Not reported

Classification: Small Quantity Generator
TSDF Activities: Not reported

Violation Status: No violations found

PENSKE AUTO CENTER **2901B S N BELT HWY** **ST JOSEPH, MO 64506**	**RCRIS-SQG**	**1007110093** **MOR000001412**

RCRIS:
Owner: PENSKE AUTO CENTER INC
(810) 614-1116
EPA ID: MOR000001412

Contact: Not reported

Classification: Small Quantity Generator
TSDF Activities: Not reported

Violation Status: No violations found

PENSKE AUTO CENTER **2901B S N BELT HWY** **ST JOSEPH, MO 64506**	**RCRIS-SQG**	**1007110094** **MOR000001412**

Site	Database(s)	EDR ID Number EPA ID Number
PENSKE AUTO CENTER (Continued)		1007110094

RCRIS:

Owner: PENSKE AUTO CENTER INC
(810) 614-1116

EPA ID: MOR000001412

Contact: Not reported

Classification: Small Quantity Generator

TSDF Activities: Not reported

Violation Status: No violations found

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

To maintain currency of the following federal and state databases, EDR contacts the appropriate governmental agency on a monthly or quarterly basis, as required.

Elapsed ASTM days: Provides confirmation that this EDR report meets or exceeds the 90-day updating requirement of the ASTM standard.

FEDERAL ASTM STANDARD RECORDS

NPL: National Priority List
Source: EPA
Telephone: N/A
National Priorities List (Superfund). The NPL is a subset of CERCLIS and identifies over 1,200 sites for priority cleanup under the Superfund Program. NPL sites may encompass relatively large areas. As such, EDR provides polygon coverage for over 1,000 NPL site boundaries produced by EPA's Environmental Photographic Interpretation Center (EPIC) and regional EPA offices.

Date of Government Version: 10/21/03
Date Made Active at EDR: 12/08/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 11/03/03
Elapsed ASTM days: 35
Date of Last EDR Contact: 11/03/03

NPL Site Boundaries

Sources:

EPA's Environmental Photographic Interpretation Center (EPIC)
Telephone: 202-564-7333

EPA Region 1
Telephone 617-918-1143

EPA Region 6
Telephone: 214-655-6659

EPA Region 3
Telephone 215-814-5418

EPA Region 8
Telephone: 303-312-6774

EPA Region 4
Telephone 404-562-8033

Proposed NPL: Proposed National Priority List Sites
Source: EPA
Telephone: N/A

Date of Government Version: 10/14/03
Date Made Active at EDR: 12/08/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 12/01/03
Elapsed ASTM days: 7
Date of Last EDR Contact: 11/03/03

CERCLIS: Comprehensive Environmental Response, Compensation, and Liability Information System
Source: EPA
Telephone: 703-413-0223
CERCLIS contains data on potentially hazardous waste sites that have been reported to the USEPA by states, municipalities, private companies and private persons, pursuant to Section 103 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLIS contains sites which are either proposed to or on the National Priorities List (NPL) and sites which are in the screening and assessment phase for possible inclusion on the NPL.

Date of Government Version: 11/17/03
Date Made Active at EDR: 02/02/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 12/22/03
Elapsed ASTM days: 42
Date of Last EDR Contact: 12/22/03

CERCLIS-NFRAP: CERCLIS No Further Remedial Action Planned
Source: EPA
Telephone: 703-413-0223
As of February 1995, CERCLIS sites designated "No Further Remedial Action Planned" (NFRAP) have been removed from CERCLIS. NFRAP sites may be sites where, following an initial investigation, no contamination was found, contamination was removed quickly without the need for the site to be placed on the NPL, or the contamination was not serious enough to require Federal Superfund action or NPL consideration. EPA has removed approximately 25,000 NFRAP sites to lift the unintended barriers to the redevelopment of these properties and has archived them as historical records so EPA does not needlessly repeat the investigations in the future. This policy change is part of the EPA's Brownfields Redevelopment Program to help cities, states, private investors and affected citizens to promote economic redevelopment of unproductive urban sites.

Date of Government Version: 11/17/03
Date Made Active at EDR: 02/02/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 12/22/03
Elapsed ASTM days: 42
Date of Last EDR Contact: 12/22/03

CORRACTS: Corrective Action Report
Source: EPA
Telephone: 800-424-9346
CORRACTS identifies hazardous waste handlers with RCRA corrective action activity.

Date of Government Version: 12/18/03
Date Made Active at EDR: 02/02/04
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 12/26/03
Elapsed ASTM days: 38
Date of Last EDR Contact: 12/08/03

RCRIS: Resource Conservation and Recovery Information System
Source: EPA
Telephone: 800-424-9346
Resource Conservation and Recovery Information System. RCRIS includes selective information on sites which generate, transport, store, treat and/or dispose of hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA). Conditionally exempt small quantity generators (CESQGs): generate less than 100 kg of hazardous waste, or less than 1 kg of acutely hazardous waste per month. Small quantity generators (SQGs): generate between 100 kg and 1,000 kg of hazardous waste per month. Large quantity generators (LQGs): generate over 1,000 kilograms (kg) of hazardous waste, or over 1 kg of acutely hazardous waste per month. Transporters are individuals or entities that move hazardous waste from the generator off-site to a facility that can recycle, treat, store, or dispose of the waste. TSDFs treat, store, or dispose of the waste.

Date of Government Version: 12/10/03
Date Made Active at EDR: 01/16/04
Database Release Frequency: Varies
Date of Data Arrival at EDR: 12/12/03
Elapsed ASTM days: 35
Date of Last EDR Contact: 01/19/04

ERNS: Emergency Response Notification System
Source: National Response Center, United States Coast Guard
Telephone: 202-260-2342
Emergency Response Notification System. ERNS records and stores information on reported releases of oil and hazardous substances.

Date of Government Version: 12/31/02
Date Made Active at EDR: 02/03/03
Database Release Frequency: Annually
Date of Data Arrival at EDR: 01/27/03
Elapsed ASTM days: 7
Date of Last EDR Contact: 10/27/03

FEDERAL ASTM SUPPLEMENTAL RECORDS

BRS: Biennial Reporting System
Source: EPA/NTIS
Telephone: 800-424-9346
The Biennial Reporting System is a national system administered by the EPA that collects data on the generation and management of hazardous waste. BRS captures detailed data from two groups: Large Quantity Generators (LQG) and Treatment, Storage, and Disposal Facilities.

Date of Government Version: 12/01/01
Database Release Frequency: Biennially
Date of Last EDR Contact: 12/16/03
Date of Next Scheduled EDR Contact: 03/15/04

CONSENT: Superfund (CERCLA) Consent Decrees
Source: EPA Regional Offices
Telephone: Varies
Major legal settlements that establish responsibility and standards for cleanup at NPL (Superfund) sites. Released periodically by United States District Courts after settlement by parties to litigation matters.

Date of Government Version: N/A
Database Release Frequency: Varies
Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

ROD: Records Of Decision
Source: EPA
Telephone: 703-416-0223
Record of Decision. ROD documents mandate a permanent remedy at an NPL (Superfund) site containing technical and health information to aid in the cleanup.

Date of Government Version: 07/09/03
Database Release Frequency: Annually
Date of Last EDR Contact: 01/06/04
Date of Next Scheduled EDR Contact: 04/05/04

DELISTED NPL: National Priority List Deletions
Source: EPA
Telephone: N/A
The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) establishes the criteria that the EPA uses to delete sites from the NPL. In accordance with 40 CFR 300.425.(e), sites may be deleted from the NPL where no further response is appropriate.

Date of Government Version: 10/21/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 11/03/03
Date of Next Scheduled EDR Contact: 02/02/04

FINDS: Facility Index System/Facility Identification Initiative Program Summary Report
Source: EPA
Telephone: N/A
Facility Index System. FINDS contains both facility information and 'pointers' to other sources that contain more detail. EDR includes the following FINDS databases in this report: PCS (Permit Compliance System), AIRS (Aerometric Information Retrieval System), DOCKET (Enforcement Docket used to manage and track information on civil judicial enforcement cases for all environmental statutes), FURS (Federal Underground Injection Control), C-DOCKET (Criminal Docket System used to track criminal enforcement actions for all environmental statutes), FFIS (Federal Facilities Information System), STATE (State Environmental Laws and Statutes), and PADS (PCB Activity Data System).

Date of Government Version: 10/23/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 01/06/04
Date of Next Scheduled EDR Contact: 04/05/04

HMIRS: Hazardous Materials Information Reporting System
Source: U.S. Department of Transportation
Telephone: 202-366-4555
Hazardous Materials Incident Report System. HMIRS contains hazardous material spill incidents reported to DOT.

Date of Government Version: 08/11/03
Database Release Frequency: Annually
Date of Last EDR Contact: 01/19/04
Date of Next Scheduled EDR Contact: 04/19/04

MLTS: Material Licensing Tracking System
Source: Nuclear Regulatory Commission
Telephone: 301-415-7169
MLTS is maintained by the Nuclear Regulatory Commission and contains a list of approximately 8,100 sites which possess or use radioactive materials and which are subject to NRC licensing requirements. To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 10/16/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 01/06/04
Date of Next Scheduled EDR Contact: 04/05/04

MINES: Mines Master Index File
Source: Department of Labor, Mine Safety and Health Administration
Telephone: 303-231-5959

Date of Government Version: 11/25/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 12/29/03
Date of Next Scheduled EDR Contact: 03/29/04

NPL LIENS: Federal Superfund Liens
Source: EPA
Telephone: 202-564-4267
Federal Superfund Liens. Under the authority granted the USEPA by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, the USEPA has the authority to file liens against real property in order to recover remedial action expenditures or when the property owner receives notification of potential liability. USEPA compiles a listing of filed notices of Superfund Liens.

Date of Government Version: 10/15/91
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 11/21/03
Date of Next Scheduled EDR Contact: 02/23/04

PADS: PCB Activity Database System
Source: EPA
Telephone: 202-564-3887
PCB Activity Database. PADS Identifies generators, transporters, commercial storers and/or brokers and disposers of PCB's who are required to notify the EPA of such activities.

Date of Government Version: 09/30/03
Database Release Frequency: Annually
Date of Last EDR Contact: 11/12/03
Date of Next Scheduled EDR Contact: 02/09/04

DOD: Department of Defense Sites
Source: USGS
Telephone: 703-648-5920
This data set consists of federally owned or administered lands, administered by the Department of Defense, that have any area equal to or greater than 640 acres of the United States, Puerto Rico, and the U.S. Virgin Islands.

Date of Government Version: 10/01/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 11/12/03
Date of Next Scheduled EDR Contact: 02/09/04

STORMWATER: Storm Water General Permits
Source: Environmental Protection Agency
Telephone: 202 564-0746
A listing of all facilities with Storm Water General Permits.

Date of Government Version: N/A
Database Release Frequency: Quarterly
Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

US BROWNFIELDS: A Listing of Brownfields Sites
Source: Environmental Protection Agency
Telephone: 202-566-2777
Included in the listing are brownfields properties addresses by Cooperative Agreement Recipients and brownfields properties addressed by Targeted Brownfields Assessments. Targeted Brownfields Assessments-EPA's Targeted Brownfields Assessments (TBA) program is designed to help states, tribes, and municipalities--especially those without EPA Brownfields Assessment Demonstration Pilots--minimize the uncertainties of contamination often associated with brownfields. Under the TBA program, EPA provides funding and/or technical assistance for environmental assessments at brownfields sites throughout the country. Targeted Brownfields Assessments supplement and work with other efforts under EPA's Brownfields Initiative to promote cleanup and redevelopment of brownfields. Cooperative Agreement Recipients-States, political subdivisions, territories, and Indian tribes become BCRLF cooperative agreement recipients when they enter into BCRLF cooperative agreements with the U.S. EPA. EPA selects BCRLF cooperative agreement recipients based on a proposal and application process. BCRLF cooperative agreement recipients must use EPA funds provided through BCRLF cooperative agreement for specified brownfields-related cleanup activities.

Date of Government Version: 07/15/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 12/17/03
Date of Next Scheduled EDR Contact: 03/15/04

RMP: Risk Management Plans
Source: Environmental Protection Agency
Telephone: 202-564-8600
When Congress passed the Clean Air Act Amendments of 1990, it required EPA to publish regulations and guidance for chemical accident prevention at facilities using extremely hazardous substances. The Risk Management Program Rule (RMP Rule) was written to implement Section 112(r) of these amendments. The rule, which built upon existing industry codes and standards, requires companies of all sizes that use certain flammable and toxic substances to develop a Risk Management Program, which includes a(n): Hazard assessment that details the potential effects of an accidental release, an accident history of the last five years, and an evaluation of worst-case and alternative accidental releases; Prevention program that includes safety precautions and maintenance, monitoring, and employee training measures; and Emergency response program that spells out emergency health care, employee training measures and procedures for informing the public and response agencies (e.g the fire department) should an accident occur.

Date of Government Version: N/A
Database Release Frequency: N/A
Date of Last EDR Contact: N/A
Date of Next Scheduled EDR Contact: N/A

RAATS: RCRA Administrative Action Tracking System
Source: EPA
Telephone: 202-564-4104
RCRA Administration Action Tracking System. RAATS contains records based on enforcement actions issued under RCRA pertaining to major violators and includes administrative and civil actions brought by the EPA. For administration actions after September 30, 1995, data entry in the RAATS database was discontinued. EPA will retain a copy of the database for historical records. It was necessary to terminate RAATS because a decrease in agency resources made it impossible to continue to update the information contained in the database.

Date of Government Version: 04/17/95
Database Release Frequency: No Update Planned
Date of Last EDR Contact: 12/08/03
Date of Next Scheduled EDR Contact: 03/08/04

TRIS: Toxic Chemical Release Inventory System
Source: EPA
Telephone: 202-566-0250
Toxic Release Inventory System. TRIS identifies facilities which release toxic chemicals to the air, water and land in reportable quantities under SARA Title III Section 313.

Date of Government Version: 12/31/01
Database Release Frequency: Annually
Date of Last EDR Contact: 12/22/03
Date of Next Scheduled EDR Contact: 03/22/04

TSCA: Toxic Substances Control Act
Source: EPA
Telephone: 202-260-5521
Toxic Substances Control Act. TSCA identifies manufacturers and importers of chemical substances included on the TSCA Chemical Substance Inventory list. It includes data on the production volume of these substances by plant site.

Date of Government Version: 12/31/02
Database Release Frequency: Every 4 Years
Date of Last EDR Contact: 12/08/03
Date of Next Scheduled EDR Contact: 03/08/04

FTTS INSP: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA
Telephone: 202-564-2501

Date of Government Version: 10/16/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 12/22/03
Date of Next Scheduled EDR Contact: 03/22/04

SSTS: Section 7 Tracking Systems
Source: EPA
Telephone: 202-564-5008
Section 7 of the Federal Insecticide, Fungicide and Rodenticide Act, as amended (92 Stat. 829) requires all registered pesticide-producing establishments to submit a report to the Environmental Protection Agency by March 1st each year. Each establishment must report the types and amounts of pesticides, active ingredients and devices being produced, and those having been produced and sold or distributed in the past year.

Date of Government Version: 12/31/01
Database Release Frequency: Annually
Date of Last EDR Contact: 01/19/04
Date of Next Scheduled EDR Contact: 04/19/04

FTTS: FIFRA/ TSCA Tracking System - FIFRA (Federal Insecticide, Fungicide, & Rodenticide Act)/TSCA (Toxic Substances Control Act)
Source: EPA/Office of Prevention, Pesticides and Toxic Substances
Telephone: 202-564-2501
FTTS tracks administrative cases and pesticide enforcement actions and compliance activities related to FIFRA, TSCA and EPCRA (Emergency Planning and Community Right-to-Know Act). To maintain currency, EDR contacts the Agency on a quarterly basis.

Date of Government Version: 10/16/03
Database Release Frequency: Quarterly
Date of Last EDR Contact: 12/22/03
Date of Next Scheduled EDR Contact: 03/22/04

STATE OF MISSOURI ASTM STANDARD RECORDS

SHWS: Registry of Confirmed Abandoned or Uncontrolled Hazardous Waste Disposal Sites
Source: Department of Natural Resources
Telephone: 573-751-1990
State Hazardous Waste Sites. State hazardous waste site records are the states' equivalent to CERCLIS. These sites may or may not already be listed on the federal CERCLIS list. Priority sites planned for cleanup using state funds (state equivalent of Superfund) are identified along with sites where cleanup will be paid for by potentially responsible parties. Available information varies by state.

Date of Government Version: 01/08/04
Date Made Active at EDR: 01/23/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 01/08/04
Elapsed ASTM days: 15
Date of Last EDR Contact: 01/06/04

SWF/LF: Solid Waste Facility List
Source: Department of Natural Resources
Telephone: 573-751-5401
Solid Waste Facilities/Landfill Sites. SWF/LF type records typically contain an inventory of solid waste disposal facilities or landfills in a particular state. Depending on the state, these may be active or inactive facilities or open dumps that failed to meet RCRA Subtitle D Section 4004 criteria for solid waste landfills or disposal sites.

Date of Government Version: 01/12/04
Date Made Active at EDR: 02/02/04
Database Release Frequency: Quarterly
Date of Data Arrival at EDR: 01/20/04
Elapsed ASTM days: 13
Date of Last EDR Contact: 01/19/04

LUST: Leaking Underground Storage Tanks
Source: Department of Natural Resources
Telephone: 573-751-0135
Leaking Underground Storage Tank Incident Reports. LUST records contain an inventory of reported leaking underground storage tank incidents. Not all states maintain these records, and the information stored varies by state.

Date of Government Version: 12/03/03
Date Made Active at EDR: 01/23/04
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 12/29/03
Elapsed ASTM days: 25
Date of Last EDR Contact: 11/17/03

UST: Petroleum Storage Tanks
Source: Department of Natural Resources
Telephone: 573-751-0135
Registered Underground Storage Tanks. UST's are regulated under Subtitle I of the Resource Conservation and Recovery Act (RCRA) and must be registered with the state department responsible for administering the UST program. Available information varies by state program.

Date of Government Version: 12/03/03
Date Made Active at EDR: 01/22/04
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 12/29/03
Elapsed ASTM days: 24
Date of Last EDR Contact: 11/17/03

VCP: Sites Participating in the Voluntary Cleanup Program
Source: Department of Natural Resources
Telephone: 573-526-8913

Date of Government Version: 10/14/03
Date Made Active at EDR: 10/21/03
Database Release Frequency: Semi-Annually
Date of Data Arrival at EDR: 10/15/03
Elapsed ASTM days: 6
Date of Last EDR Contact: 01/12/04

GOVERNMENT RECORDS SEARCHED / DATA CURRENCY TRACKING

STATE OF MISSOURI ASTM SUPPLEMENTAL RECORDS

AST: Aboveground Petroleum Storage Tanks
Source: Department of Agriculture
Telephone: 573-751-7062
Registered Aboveground Storage Tanks.

Date of Government Version: 07/29/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 01/12/04
Date of Next Scheduled EDR Contact: 04/12/04

RRC: Certified Hazardous Waste Resource Recovery Facilities
Source: Department of Natural Resources
Telephone: 573-751-3176

Date of Government Version: 12/16/03
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 12/16/03
Date of Next Scheduled EDR Contact: 03/15/04

SPILLS: Environmental Response Tracking Database
Source: Department of Natural Resources
Telephone: 573-526-3349

Date of Government Version: 04/16/02
Database Release Frequency: Semi-Annually
Date of Last EDR Contact: 04/10/02
Date of Next Scheduled EDR Contact: N/A

DEL SHWS: Registry Sites Withdrawn or Deleted
Source: Department of Natural Resources
Telephone: 573-522-3710
A list of sites that were removed from the Registry or for which Registry action was suspended due to cleanup.

Date of Government Version: 06/30/02
Database Release Frequency: Annually
Date of Last EDR Contact: 01/24/04
Date of Next Scheduled EDR Contact: 04/05/04

INST CONTROL: Sites with Institutional Controls
Source: Department of Natural Resources
Telephone: 573-751-3176

Date of Government Version: 10/24/03
Database Release Frequency: Varies
Date of Last EDR Contact: 01/20/04
Date of Next Scheduled EDR Contact: 04/05/04

EDR PROPRIETARY HISTORICAL DATABASES

Former Manufactured Gas (Coal Gas) Sites: The existence and location of Coal Gas sites is provided exclusively to EDR by Real Property Scan, Inc. ©Copyright 1993 Real Property Scan, Inc. For a technical description of the types of hazards which may be found at such sites, contact your EDR customer service representative.

Disclaimer Provided by Real Property Scan, Inc.

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BROWNFIELDS DATABASES

Brownfields: Brownfields Site List
Source: Department of Natural Resources
Telephone: 573-526-8913

Date of Government Version: 01/16/04 | Date of Last EDR Contact: 01/12/04
Database Release Frequency: Semi-Annually | Date of Next Scheduled EDR Contact: 04/12/04

VCP: Sites Participating in the Voluntary Cleanup Program
Source: Department of Natural Resources
Telephone: 573-526-8913

Date of Government Version: 10/14/03 | Date of Last EDR Contact: 01/12/04
Database Release Frequency: Semi-Annually | Date of Next Scheduled EDR Contact: 04/12/04

US BROWNFIELDS: A Listing of Brownfields Sites
Source: Environmental Protection Agency
Telephone: 202-566-2777
Included in the listing are brownfields properties addresses by Cooperative Agreement Recipients and brownfields properties addressed by Targeted Brownfields Assessments. Targeted Brownfields Assessments-EPA's Targeted Brownfields Assessments (TBA) program is designed to help states, tribes, and municipalities--especially those without EPA Brownfields Assessment Demonstration Pilots--minimize the uncertainties of contamination often associated with brownfields. Under the TBA program, EPA provides funding and/or technical assistance for environmental assessments at brownfields sites throughout the country. Targeted Brownfields Assessments supplement and work with other efforts under EPA's Brownfields Initiative to promote cleanup and redevelopment of brownfields. Cooperative Agreement Recipients-States, political subdivisions, territories, and Indian tribes become BCRLF cooperative agreement recipients when they enter into BCRLF cooperative agreements with the U.S. EPA. EPA selects BCRLF cooperative agreement recipients based on a proposal and application process. BCRLF cooperative agreement recipients must use EPA funds provided through BCRLF cooperative agreement for specified brownfields-related cleanup activities.

Date of Government Version: N/A | Date of Last EDR Contact: N/A
Database Release Frequency: Semi-Annually | Date of Next Scheduled EDR Contact: N/A

OTHER DATABASE(S)

Depending on the geographic area covered by this report, the data provided in these specialty databases may or may not be complete. For example, the existence of wetlands information data in a specific report does not mean that all wetlands in the area covered by the report are included. Moreover, the absence of any reported wetlands information does not necessarily mean that wetlands do not exist in the area covered by the report.

Oil/Gas Pipelines: This data was obtained by EDR from the USGS in 1994. It is referred to by USGS as GeoData Digital Line Graphs from 1:100,000-Scale Maps. It was extracted from the transportation category including some oil, but primarily gas pipelines.

Electric Power Transmission Line Data
Source: PennWell Corporation
Telephone: (800) 823-6277
This map includes information copyrighted by PennWell Corporation. This information is provided on a best effort basis and PennWell Corporation does not guarantee its accuracy nor warrant its fitness for any particular purpose. Such information has been reprinted with the permission of PennWell.

Sensitive Receptors: There are individuals deemed sensitive receptors due to their fragile immune systems and special sensitivity to environmental discharges. These sensitive receptors typically include the elderly, the sick, and children. While the location of all sensitive receptors cannot be determined, EDR indicates those buildings and facilities - schools, daycares, hospitals, medical centers, and nursing homes - where individuals who are sensitive receptors are likely to be located.

AHA Hospitals:
Source: American Hospital Association, Inc.
Telephone: 312-280-5991
The database includes a listing of hospitals based on the American Hospital Association's annual survey of hospitals.

Medical Centers: Provider of Services Listing
Source: Centers for Medicare & Medicaid Services
Telephone: 410-786-3000
A listing of hospitals with Medicare provider number, produced by Centers of Medicare & Medicaid Services, a federal agency within the U.S. Department of Health and Human Services.

Nursing Homes
Source: National Institutes of Health
Telephone: 301-594-6248
Information on Medicare and Medicaid certified nursing homes in the United States.

Public Schools
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on elementary and secondary public education in the United States. It is a comprehensive, annual, national statistical database of all public elementary and secondary schools and school districts, which contains data that are comparable across all states.

Private Schools
Source: National Center for Education Statistics
Telephone: 202-502-7300
The National Center for Education Statistics' primary database on private school locations in the United States.

Daycare Centers: Licensed Child Care Facilities
Source: Department of Health & Senior Services
Telephone: 573-751-2450

Flood Zone Data: This data, available in select counties across the country, was obtained by EDR in 1999 from the Federal Emergency Management Agency (FEMA). Data depicts 100-year and 500-year flood zones as defined by FEMA.

NWI: National Wetlands Inventory. This data, available in select counties across the country, was obtained by EDR in 2002 from the U.S. Fish and Wildlife Service.

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with any questions or comments.

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Appendix B

Public Involvement and Agency Coordination

Blacksnake Creek Public Meeting October 9, 2014
Responses to Public Comments

Detention Basin

• Proponent of 100-year solution (Burnside resident experiences flooding). **The proposed detention basin will retain up to the 25-year return storm at the site. However, the project provides significant flood risk reduction benefits in that many structures will be removed from the 100-yr flood plain, and many others will have flood depths and risk significantly lowered. The project cannot provide 100-yr protection for all structures in the floodplain, this would not be economically feasible. Detention alternatives providing greater protection levels were evaluated, but the resulting project design elements and costs did not fit within the scope of the United States Army Corps of Engineers' (USACE) Section 205 Program. The current solution proposed offers the maximum level of flood protection possible within USACE's Section 205 Program.**

• Bug control and open water? **Design and construction for positive drainage and minimizing the potential for standing water will be important in helping to manage this concern. These are key considerations which will be addressed in the design phase.**

• Basin will result in loss of portion of property. **Some properties will be affected. The impacts to each property will be evaluated during the design phase. The City will be responsible for coordinating directly with property owner's related to the acquisition of property or easements.**

• Pay $170.00 a month to FEMA - ridiculous! Can't sell my house because of it! **The USACE and City recognize the need for additional flood control in the Blacksnake basin. That is one of the main reasons for implementing the Blacksnake Detention Basin project. That said, the Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program not the USACE. To obtain a reduction in flood insurance premiums, a letter of map revision would need to be paid for and completed by the City after completion of the USACE Blacksnake 205 Project. The USACE project is focused on reducing ongoing flood damage and losses in the Blacksnake basin but FEMA will need to be involved at a later date to obtain credit for this effort to reduce the Flood Insurance Premiums.**

• Impact on existing recreational amenities. **The existing ball field located south of Karnes Road will be removed as a result of the project. The proposed USACE Section 205 project does not contain any new recreational features. That said, the City is planning to either relocate recreational features and/or install new recreational features impacted by the USACE Section 205 project. The USACE Section 205 project is strictly focused on the installation of a flood control detention basin while the City, outside of the USACE Section 205 project, is planning to offset the impacts to the recreational features.**

• Request for link regarding federal requirements for combined sewer overflow control. **This information was previously provided directly to the individual who made the request, but is available at: http://www.stjoemo.info/index.aspx?nid=316 .**

• Push west to keep his trees, etc. (lives on the east side of cul-de-sac on Cook Road.) **The detention project will minimize impacts to existing trees at the periphery of the basin footprint where possible. Loss of trees has been identified as a project impact and mitigation is planned. The final footprint of the detention basin will be determined during the design phase.**

• Drainage concerns. **Construction of the project for appropriate drainage is a key design consideration. Drainage issues were mentioned as a concern by some property owners along St. Joseph Avenue due to the potential of levees or floodwalls. The proposed USACE Section 205 project plan does not have built-up features such as levees and floodwalls that would contribute to these concerns along St. Joseph Avenue.**

• Appearance of basin. **Appearance will be a consideration during the design phase of the project. Some meander features and small planting areas may be built where the base flow moves through the basin. Maintenance will also be considered when designing these features.**

• Will you use aggregate surface? If it is clay material it will be swamp-like and could be attractive for Mosquitoes. **Surfacing and drainage issues will be addressed during the design phase. Drainage will be a consideration in the selection of surfacing and designing the grading plan.**

• Access concerns: public access to my backyard. **Public access will not be provided to private properties. Any areas required for public access will be acquired by the City as part of its CSO project. Sensitivity to that subject will be considered and design elements included to minimize visual concerns. Any access requirements for the detention basin will be taken into consideration during the design phase..**

• Aesthetics of losing the trees. **The loss of trees within the basin foot print is unavoidable. The detention project will minimize impacts to existing trees at the periphery of the basin footprint where possible. Mitigation plans have been developed to identify potential locations for replanting. Plantings on the periphery of the basin foot print may also be considered.**

• Easements versus property acquisition. **Acquisition of properties within the detention basin footprint will be required. Maintenance or access easements may also be required. The City is responsible for land acquisition required for the project and will coordinate directly with individual property owners . Final land acquisition requirements will be determined during the design phase.**

• Do not want a levee in my backyard. **Alternatives with built-up structures such as levees and floodwalls are not part of USACE's proposed Section 205 Program project.**

• Question on timing of release of the USACE report. **At the time of the public meeting it was anticipated that a December or January release could be made. Due to the timing of final reviews, the release was delayed. Currently, the report is scheduled for release in 2015.**

• What type of soil was considered in the feasibility study/conceptual design and budget of the basin? **Conceptual design is that the basin topsoil as currently exists would be removed and then**

backfilled for planting back to grass. Some riprap/rocked features to promote proper drainage back into the re-aligned creek and to maintain bank stability in some locations would be required. This issue will receive further consideration during the design phase.

• Rip Rap class aggregate recommended in the main creek channel with a mix Rip Rap to smaller aggregate in the dry bank area to help with soil drying and mosquitoes. **It is anticipated some riprap/rocked features will be required to promote proper drainage back into the re-aligned creek (as well as tieback features to hold the new creek bed alignment in place) and to maintain bank stability in some locations. This will receive further consideration during the design phase.**

• Where will the current sewer main and underground phone cabling be located? Please provide a conceptual plan for relocating these two utilities. **Existing utilities within the design footprint of the detention basin will require relocation. A preliminary realignment for the sewer relocation is shown the USACE report. The City will implement the required relocation of utilities within the detention basin footprint outside of the USACE's Section 205 Program Project. Additional alignment details for relocated utilities will be available during the design phase of the project. Design details along these lines are confidential with the utilities because of safety and security concerns. No comments will be made concerning this information. .**

• Would the service and access road gravel surfaces be upgraded to an asphalt/concrete material? Building codes don't allow addition of gravel driveways. **The road will meet code requirements. This will be addressed during the design phase.**

• What is preventing the two surfaces from being combined into one road, with a gate located at the entrance off of Cook Road? Reduce the cost by having one 12' wide surface vs. 2–12' wide surfaces and a fence. **The roads will meet code as well as utility access requirements. At this time it was assumed that separate roads will be needed for utility access and residential access. This will be reviewed during the design phase.**

• Are there future plans for upgrading the dry basin to a wet basin? What is that expected timeframe? **The current design plan for the USACE's Section 205 Program basin does not include a wet basin.**

• What additional amenities are planned and what is the public access plan? **There is no plan to provide public access or new amenities via USACE's Section 205 detention project. If the City implements any recreational plans for the area, public access issues will be addressed through the City's planning and implementation process. Public access will not be provided to private properties. Any areas required for public access will be acquired by the City.**

• What is the conceptual plan for the buffer between public and private land? **This will be further addressed during the design phase as the final detention basin footprint is established and easements and maintenance accesses are considered. If the City implements any recreational or access plans for the area, public access issues will be addressed through the City's planning and**

implementation process. Public access will not be provided to private properties. Any areas required for public access will be acquired by the City.

• Construction timing. **It is anticipated that the design effort will take approximately two years, after which time construction activities may begin depending on availability of USACE Section 205 Program funding as well as City matching funds.**

• Individual property impact concerns. **There will be impacts to properties located in proximity to the detention basin. The City is responsible for negotiating easements and access needs with property owners on an individual basis.**

Comments related to the basin's technical design referred to the U.S. Army Corps of Engineers.

Blacksnake Creek Stormwater Separation Improvements
Public Meeting Summary

Oct. 9, 2014

Lindbergh Elementary School gymnasium

2812 St. Joseph Ave.

City of St. Joseph, Missouri

5:30 p.m. – 7:00 p.m.

City of St. Joseph Public Works and Transportation Director, Jody Carlson, introduced himself to the audience and said he appreciated everyone's attendance.

Sheila Shockey, Shockey Consulting Services, announced the meeting format for the evening. She said the City of St. Joseph wants to hear from residents in the preliminary stages of the Blacksnake project and as the project progresses. Ms. Shockey identified the speakers who would be presenting, and said that there will be opportunities to talk with them and others following the presentation. Those presenting included Page Burks, Black & Veatch Engineering Manager; Christina Ostrander, U.S. Army Corps of Engineers Project Manager; and Matt Schultze, Black & Veatch Project Manager. Ms. Shockey pointed out the locations of stations to obtain more detailed information and ask questions following the meeting. She introduced Ms. Burks.

Project Goals and Background

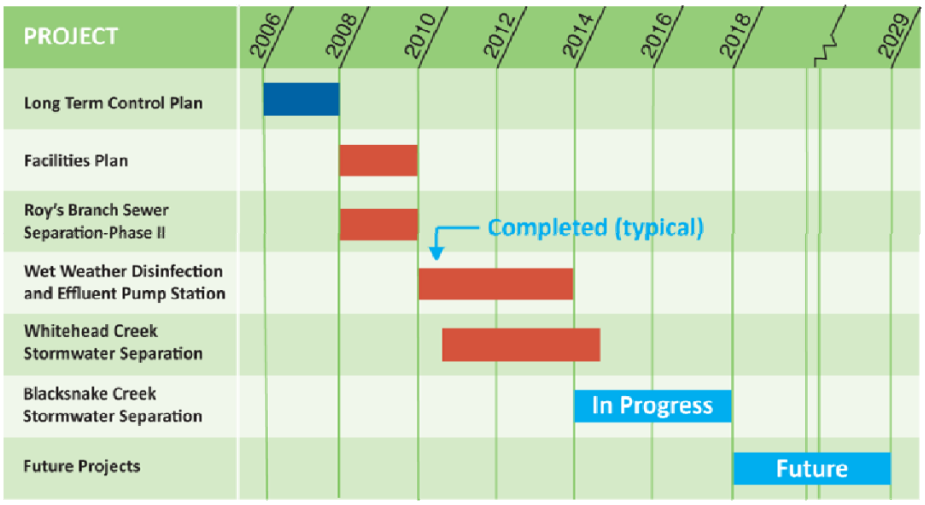
Ms. Burks, Engineering Manager, Black & Veatch, identified the overall goals of the Blacksnake Creek improvements:

- complying with regulatory mandates
- offering improvements with the best value, cost effectiveness to the city
- restoring the corridor; putting things back better than we found them
- integrating project elements to save money
- getting public input on the project.

Ms. Burks talked about the City of St. Joseph's Combined Sewer Overflow (CSO) Control Program, and explained combined sewers' function, and combined sewer overflows, which occur when it rains. The sewage and stormwater flows enter the same combined sewer pipe in St. Joseph, and these mingled flows are considered combined sewage. During dry weather, all of the combined sewer flow goes to the treatment plant where it is treated prior to being sent to the Missouri River. During storm events, the high volume of stormwater overwhelms the combined sewer as well as the treatment plant and the combined sewage overflows directly to the river, resulting in a combined sewer overflow (CSO).

The goal is to reduce the combined sewer overflows to the Missouri River. The City of St. Joseph has agreed to a compliance plan and a schedule, including nine different projects over 20 years.

Initial Phase of the Combined Sewer Overflow Program
Consists of Several Projects



The Blacksnake Creek Stormwater Separation project is required by the Combined Sewer Overflow (CSO) Control Program. By separating the stormwater from the combined sewer, approximately 2 million gallons a day of flow from Blacksnake Creek will be directed to the Missouri River and will not be treated at the plant. In addition to CSO compliance, this will reduce operations and maintenance costs.

The Blacksnake Creek Stormwater Separation Improvements will be integrated with other needed projects in the vicinity – a flood control detention basin at Karnes Road as well as roadway improvements at Karnes Road/Northwest Parkway and Cook Road. Ms. Burks pointed out benefits of integrating different elements in the project area:

- provides the best value and saves money
- provides opportunities for community benefits
- reduces future CSO program costs
  (by addressing other easy-to-separate CSO flows, such as from the Corby Pond area).

Ms. Burks shared the design schedule for the stormwater and roadway improvements:

Design Activity/Stormwater & Roadway	Completion Date
Draft Conceptual Basis of Design Report	September 2014
Final Conceptual Basis of Design Report	December 2014
Surveying & Geotechnical Investigations	Spring 2015
Preliminary Design	Summer 2015
Final Design	Summer 2016

Ms. Burks said the project is in the early phases of the design process and all plans are still concepts at this point. The survey work is scheduled for November 2014 and geotechnical investigations would likely occur in the spring of 2015. The field investigations are required to develop more defined preliminary and final design drawings.

Transporting Stormwater

The methods to transport stormwater have been evaluated at different ranges of flows, such as those during combined sewer overflows or during a 100-year rainfall event. Stormwater can be moved near the surface with a buried pipe, buried box culvert or an open stream channel. It can also be transported with a tunnel, up to 175 feet deep.

Moving the stormwater near the surface would begin at Karnes Road and flow south in the area of the abandoned railway corridor east of St. Joseph Avenue. Ms. Burks showed a topographical illustration with a tunnel, which would likely be used to convey stormwater west to the Missouri River. Tunneling is an effective way to move the stormwater beneath existing infrastructure and challenging topography, such as the river bluffs in this area. Impact to the community would be minimal, occurring only at the entrance and exit of the tunnel. She also showed photos of a working shaft, such as what will be located near the Missouri River, and a tunnel boring machine used to mine the tunnel. The selection of the stormwater conveyance technology will be determined in the preliminary design.

The project team evaluated five different alignment corridors within the Blacksnake Watershed, from Cook Road in the north to Francis Street in the south in an effort to achieve these goals:

- minimize the project cost and the maintenance cost
- minimize private property acquisition
- maximize opportunities for cost-effective community enhancements
- provide the ability to incorporate Corby CSO flows.

An alternative analysis looked at economic and criteria-weighted non-economic factors to determine the “best value” alignment for the City. The non-economic criteria were weighted as follows: functionality, 35 percent; community, 30 percent; sustainability, 20 percent; and constructability, 15 percent.

The City of St. Joseph hosted several events asking the community for their input about community enhancement opportunities and goals for the Blacksnake Creek project. The top four project goals indicated by public input were: growth and development, flood control, ground water and surface water, and safety.

Ms. Burks said the Highland Avenue alignment provides the greatest value to St. Joseph based on an analysis considering economic and non-economic factors.

Detention Basin

Christina Ostrander, Project Manager, U.S. Army Corps of Engineers (USACE), said USACE has worked a number of years on a flood control feasibility study for the project area. She showed the potential location for the detention basin at Karnes Road. She said approximately 140 structures are affected when there is water overtopping at Karnes Road.

Ms. Ostrander presented a recommended plan for the detention basin which includes:

- constructing a dry detention basin with approximately 440 acre-feet of storage
- significantly reducing the flood risk for the St. Joseph Avenue corridor
- preventing an estimated $3 million in annualized economic flood damages
- minimizing risk for approximately 100 structures from a 100-year flood
- working efficiently in coordination with other City plans to maximize benefits to the area.

This would provide detention for up to a 25-year storm event, saving up to $3 million in annualized assessed damages and minimizing flooding for 100 structures.

Ms. Ostrander said the next steps for the detention basin include:

- completing the technical review of the draft feasibility report
- publishing the report for public review and incorporate comments as appropriate
- completing the project design in approximately 2015-2016
- constructing the basin in 2017-2019.

Following determination of final details, the USACE will sign a project partnership agreement (PPA) with the City of St. Joseph.

Ms. Ostrander said recreational features can be included with the basin, but they wouldn't be part of the USACE cost share.

Roadways

Matt Schultze, Project Manager, Black & Veatch

Mr. Schultze said the Metropolitan Planning Organization (MPO) has developed a long-range transportation master plan, including roadways and trails. The City of St. Joseph is integrating roadway

improvements in this project through the 2013 Capital Improvements Sales Tax funds. The goal is to enhance public safety and traffic flows. There are also stormwater hydraulic issues associated with the roadways and including them with the stormwater separation project provides additional efficiencies.

Mr. Schultze showed an aerial photograph of the six-way intersection that will be improved to a four-way intersection in the project area near Northwest Parkway and Karnes Road. Road improvements will also eliminate the nearby aging Northwest Parkway bridge in order to resolve bridge maintenance issues. Enhancing the connectivity to Krug Park and the urban trail system is another benefit to including this work in the project, supporting the MPO transportation master plan.

Cook Road is another street improvement that is integrated with the Blacksnake Creek project. The MPO transportation plan identifies rebuilding Cook Road as a future east-west minor arterial roadway in the northern portion of the City and this project is an initial step toward this goal. In addition, the creek is currently funneled into an undersized culvert in this area; the creek will be opened up to improve flow through that area supporting the stormwater separation project.

Opportunities

Mr. Schultze said that the project is addressing these issues:

- putting things back in a better way
- potentially using green solutions to provide function and be an amenity for the community
- integrating project elements to provide efficiencies, such enhancing cost-effectiveness and minimizing community disruptions
- investing in the Northside community
- improving water quality by reducing CSOs and the associated bacteria
- providing improved roadways is important to the community
- working to provide flood control and reduce flood insurance premiums
- exploring opportunities for nature trails, park improvements, coordination with the Remington Nature Center and future possibilities to add detention basin amenities.

Ms. Shockey talked about additional public involvement opportunities in both the spring and summer of 2015. She invited meeting attendees to interact with people at four different stations, including stormwater conveyance alignment selection, detention, potential easements, and green solutions. Project team members were available at each station to write down comments and respond to questions.

Blacksnake Creek Stormwater Separation Improvements Conceptual Design Public Comments

Public Meeting Oct. 9, 2014
Lindbergh Elementary School gymnasium
2812 St. Joseph Ave.
City of St. Joseph, Missouri
5:30 p.m. – 7:00 p.m.

Meeting Comments (written and verbal)

Public comments received will be considered during preliminary and detailed design.

Detention Basin

- Proponent of 100-year solution (Burnside resident experiences flooding)
- Bug control and open water?
- Basin will result in loss of portion of property
- Pay $170.00 a month to FEMA - ridiculous! Can't sell my house because of it!
- Impact on existing recreational amenities
- Request for link regarding federal requirements for combined sewer overflow control
- Push west to keep his trees, etc. (lives on the east side of cul-de-sac on Cook Road.)
- Drainage concerns
- Appearance of basin
- Will you use aggregate surface? If it is clay material it will be swamp-like and could be attractive for mosquitoes
- Access concerns: public access to my backyard
- Aesthetics of losing the trees
- Easements versus property acquisition
- Do not want a levee in my backyard
- Question on timing of release of the USACE report
- What type of soil was considered in the feasibility study/conceptual design and budget of the basin?
- Rip Rap class aggregate recommended in the main creek channel with a mix Rip Rap to smaller aggregate in the dry bank area to help with soil drying and mosquitoes
- Where will the current sewer main and underground phone cabling be located? Please provide a conceptual plan for relocating these two utilities.
- Would the service and access road gravel surfaces be upgraded to an asphalt/concrete material? Building codes don't allow addition of gravel driveways.
- What is preventing the two surfaces from being combined into one road, with a gate located at the entrance off of Cook Road? Reduce the cost by having one 12' wide surface vs. 2–12' wide surfaces and a fence.
- Are there future plans for upgrading the dry basin to a wet basin? What is that expected timeframe?
- What additional amenities are planned and what is the public access plan?
- What is the conceptual plan for the buffer between public and private land?
- Construction timing
- Individual property impact concerns

Comments related to the basin's technical design referred to the U.S. Army Corps of Engineers.

Roadways

- Consider a roundabout at Karnes Road and St. Joseph Avenue (some discussion for and some against)
- What is the traffic count at Karnes Road and St. Joseph Avenue during the Holiday Park season?
- Extend Northwest Parkway at Karnes Road and St. Joseph Avenue to I-229, rather than Cook Road improvements, creating a gateway to St. Joseph

Conveyance Alignment

- General agreement with selected alignment
- Uncertain on stream channel conveyance method – provide more information

General/Miscellaneous

- Keep the basketball courts in the vicinity of Northside
- Would like to accomplish Krug Park restoration project
- Concerns over easements/acquisition

Blacksnake Creek Stormwater Separation Improvements
Oct. 9, 2014 Public Meeting Comments

Feedback on Top Public Goals for the Project

Top Three

- Safety - improve public safety
- Flood control
- Reduce congestion

Tell Us What You Think About Green Solutions

What do you think of the following green solutions strategies?

Top Four (in order mentioned)

- Transform vacant lots into community gardens
- Restore streams & natural wet places
- Create water features along parkways & parks
- Soak through pavement

What would you like to see in your community?

Top Three

- Restore streams & natural wet places
- Create water features along parkways & parks
- Provide habitat for birds & butterflies

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896

Jane Ledwin
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
608 East Cherry Street, Room 200
Columbia, Missouri 65201

Subject: Blacksnake Creek Proposed Detention Pond Project

Per your request, enclosed is a map of the proposed Blacksnake Creek detention pond project. The area marked "Conservation Pond Site" is a corn field and was the project proponent's original design for the project. However, in a recent meeting with the sponsor, the sponsor proposed the creation of a much larger detention pond and removal of a substantial number of older trees. The proposed site is shown on the map as the light blue shaded area. Please note that this project proposal is preliminary at this point and discussions are still on-going. I am merely requesting input from the Fish and Wildlife Service as to the presence of endangered or threatened species, critical habitat, or species of special concern that may be found in the area. Any information you could provide will be helpful and brought to the attention of the sponsor at any future meeting.

Thanks for your assistance,

Matthew D. Vandenberg
Environmental Resources Specialist
Planning Branch, CENWK, PM-PR
Kansas City District
U.S. Army Corps of Engineers
601 E. 12th Street
Kansas City, Missouri 64106-2896

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Columbia Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0007

Phone: (573) 234-2132 Fax: (573) 234-2181

December 10, 2003

Mr. Matthew Vandenberg
Environmental Resources Specialist
Kansas City District
U.S. Army Corps of Engineers
601 E. 12th Street
Kansas City, Missouri 64103-2896

Dear. Mr. Vandenberg:

Please refer to your recent letter, and November 11, 2003, facsimile, regarding the Section 205 Blacksnake Creek Proposed Detention Pond Project in St. Joseph, Missouri. Our office just moved to a new location so I apologize for the delay. Your letter requested information on federally listed species that may occur in the proposed project area. The U.S. Fish and Wildlife Service (Service) has reviewed that information and submits the following comments pursuant to the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) and the Endangered Species Act of 1973, as amended (16 U.S.C. 1541 et seq.).

The only federally listed species likely to occur in the project area is the Indiana bat.

Indiana bat *(Myotis sodalis)*, Endangered – From late fall through winter Indiana bats in Missouri hibernate in caves in the Ozarks and Ozark Border Natural Divisions. During the spring and summer, Indiana bats use living, injured (e.g., split trunks and broken limbs from lightening strikes or wind), dead or dying trees for roosting throughout the state. Indiana bat roost trees tend to be greater than 9 inches diameter at breast height (dbh) (optimally greater than 20 inches dbh) with loose or exfoliating bark. Most important are structural characteristics that provide adequate space for bats to roost.

Preferred roost sites are located in forest openings, at the forest edge, or where the overstory canopy allows some sunlight exposure to the roost tree, which is usually within 0.6 miles of water. Indiana bats forage for flying insects (particularly moths) in and around the tree canopy of floodplain, riparian, and upland forests.

If trees suitable for use by Indiana bats are to be removed for the proposed project, they must be removed between October 1st and March 30th to avoid the potential injury or death to roosting individuals and maternity colonies. If it is not feasible to schedule tree removal during this

period, the Service requires a survey, to determine the presence or absence of Indiana bats, be conducted by a qualified biologist. Survey efforts should include using a combination of mist nets and bat detection devices [e.g., "Anabat" (© Titley Electronics, Ballina, New South Wales, Australia)]. If it is determined that a survey for Indiana bats is needed, please contact the Missouri Ecological Services Field Office to obtain specific information regarding survey protocol. If surveys indicate that Indiana bats are using trees proposed to be removed during their breeding season (April 1 to September 30) further consultation with the Service under section 7 of the Act will be required.

Although not requested, the Service has continuing concerns regarding alteration/degradation of urban stream corridors. Numerous fish and wildlife species benefit from intact riparian corridors in urban and rural settings. Such corridors also help maintain, and in some cases, improve water quality. It seems the St. Joseph vicinity is experiencing some residential expansion as are many areas north of Kansas City. In considering various project alternatives, we recommend the Corps and local sponsor plan for reasonably foreseeable long-term development of the watershed. In fact, it some areas, several smaller detention basins throughout the watershed may be a more efficient approach to a large basin at the bottom of the watershed. In addition, it may also be more cost-effective to designate greenspace/floodway areas prior to development of the surrounding lands. Lastly, we request a schedule (if possible) for project planning and identification of any Fish and Wildlife Coordination Act input the Corps will need from the Service.

Finally, I suggest you check with the local office of the Missouri Department of Conservation (816/227-3100) regarding specific fish and wildlife resource concerns in the project area.

Thank you for the opportunity to comment on the proposed project. If you have any questions regarding our comments, please call Ms. Jane Ledwin at 573/234-2132, extension 109.

Sincerely,

Rick L Hansen

for Charles M. Scott
Field Supervisor

cc: MDC, Jefferson City, MO (Canaday)

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, KANSAS CITY DISTRICT
635 FEDERAL BUILDING
601 E 12TH STREET
KANSAS CITY MO 64106-2824

Planning, Programs and
Project Management Division

April 5, 2013

Mr. Rick Hansen
U.S. Fish and Wildlife Service
Columbia Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0007

Dear Mr. Hansen:

RE: City of St. Joseph, Missouri Blacksnake Creek Proposed Detention Pond Project for Flood Risk Management

Thank you for your December 10, 2003 response in regards to federally listed species that may occur in the proposed project area. After receiving project input from the public and the City of St. Joseph following the April 7, 2005 public meeting, reformulation has resulted in the exclusion of levees and floodwalls from this project.

All current, proposed alternatives consist of a dry, excavated detention basin of varying capacities located east of St. Joseph Avenue and bounded north and south by Savannah Road and Northwest Parkway, respectively. As a result of feasibility analysis, the current preferred alternative provides approximately 25-year detention capacity and the highest net economic benefits of alternatives considered. The construction footprint is shown in the enclosed figure.

A draft feasibility level document is in progress with an estimated completion date of June, 2013. The current schedule estimates a minimum of 480 additional days for 100% project design completion.

If you have any questions or comments regarding the proposed project, please do not hesitate to contact me at richard.a.skinker@usace.army.mil; 816-389-3134.

Sincerely,

Richard A. Skinker

Richard A. Skinker
Environmental Resources Specialist

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Missouri Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0057
Phone: (573) 234-2132 Fax: (573) 234-2181

May 2, 2013

Mr. Richard A. Skinker
Environmental Resources Specialist
U.S. Army Corps of Engineers
Kansas City District
601 East 12th Street
Kansas City, Missouri 64106-2824

Dear Mr. Skinker:

The U.S. Fish and Wildlife Service (Service) has reviewed the information provided in your April 5, 2013, letter addressing the reformulation of the Blacksnake Creek Proposed Detention Pond Project in Buchanan County, Missouri. The following comments are provided under the authority of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.), National Environmental Policy Act of 1969 (42 U.S.C. 4321-4347), and the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1544).

Thank you for informing us of the reformulation of the project. We do not have any additional comments, but we still recommend tree removal to occur between November 1 and March 31 to minimize impacts to the Indiana bat (*Myotis sodalis).*

Thank you for your interest in the conservation of threatened and endangered species. Should you have questions concerning this response, please contact Josh Hundley at (573) 234-2132, extension 176.

Sincerely,

Amy Salveter
Field Supervisor

Skinker, Richard A NWK

From: Skinker, Richard A NWK
Sent: Wednesday, June 10, 2015 2:53 PM
To: Skinker, Richard A NWK
Subject: FW: Blacksnake Creek Project (UNCLASSIFIED)
Attachments: Recommended Detention Basin Footprint.jpg

Classification: UNCLASSIFIED
Caveats: NONE

-----Original Message-----
From: Skinker, Richard A NWK
Sent: Thursday, June 04, 2015 3:09 PM
To: 'Amy_Salveter@fws.gov'
Subject: Blacksnake Creek Project (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Dear Ms. Salveter,

Thank you for the May 2, 2013 follow-up letter regarding the Blacksnake Creek Project. Following a project public meeting conducted on October 9, 2014, the Recommended Plan consists of excavated, dry detention with an approximate 25-year detention capacity as mentioned in previous correspondence. The construction footprint is shown in the attached figure. The Recommended Plan has the highest net economic benefits of the alternatives considered and feasibility is nearing completion. Please let me know if there are any updates regarding threatened and endangered species and their associated habitats within or adjacent to the construction footprint.

Sincerely,

Richard A. Skinker
Project Manager, PM-PF
Kansas City District
U.S. Army Corps of Engineers
816-389-3134

Classification: UNCLASSIFIED
Caveats: NONE

Classification: UNCLASSIFIED
Caveats: NONE

Skinker, Richard A NWK

From: Salveter, Amy [amy_salveter@fws.gov]
Sent: Thursday, June 04, 2015 5:18 PM
To: Skinker, Richard A NWK
Subject: [EXTERNAL] Re: Blacksnake Creek Project (UNCLASSIFIED)
Attachments: IPaC Instructions.pdf

Mr. Skinker,

We now have a project review tool that will allow project proponents to find information about any threatened or endangered species that could occur in a project area. This online tool serves as the first level of review. You can visit the Information for Planning and Conservation (IPaC) website (http://ecos.fws.gov/ipac) to determine if any proposed, threatened, or endangered species could occur in your project area. IPaC will generate an Official Species List for your project. If activities involved with development of your project will not impact any of the species listed, or if no species potentially occur in your project area, document that decision for you records and no further consultation with the USFWS is necessary. If you think your project may affect any listed species, send a copy of the official species list along with a project description to me. I will assign the project to a biologist for review as appropriate. For your convenience, I have attached a "How To" guide so you can utilize the Service's IPaC website for future projects.

Amy Salveter, Field Supervisor
U.S. Fish and Wildlife Service

Missouri Ecological Services Field Office
101 Park DeVille Dr., Ste. A
Columbia, MO 65203
573-234-2132, ext. 166

On Thu, Jun 4, 2015 at 3:09 PM, Skinker, Richard A NWK <Richard.A.Skinker@usace.army.mil> wrote:

Classification: UNCLASSIFIED
Caveats: NONE

Dear Ms. Salveter,

Thank you for the May 2, 2013 follow-up letter regarding the Blacksnake Creek Project. Following a project public meeting conducted on October 9, 2014, the Recommended Plan consists of excavated, dry detention with an approximate 25-year detention capacity as mentioned in previous correspondence. The construction footprint is shown in the attached figure. The Recommended Plan has the highest net economic benefits of the alternatives considered and feasibility is nearing completion. Please let me know if there are any updates regarding threatened and endangered species and their associated habitats within or adjacent to the construction footprint.

Sincerely,

Richard A. Skinker
Project Manager, PM-PF
Kansas City District
U.S. Army Corps of Engineers

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Columbia Ecological Services Field Office
101 PARK DEVILLE DRIVE, SUITE A
COLUMBIA, MO 65203
PHONE: (573)234-2132 FAX: (573)234-2181

Consultation Code: 03E14000-2015-SLI-0644 June 10, 2015
Event Code: 03E14000-2015-E-00361
Project Name: Blacksnake Creek Section 205 Flood Risk Management Project

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

This response has been generated by the Information, Planning, and Conservation (IPaC) system in order to provide information on natural resources that could be affected by your project. The response is provided by the U.S. Fish and Wildlife Service (Service) under the authority of the Endangered Species Act of 1973 (16 U.S.C. 1531-1543), the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d), the Migratory Bird Treaty Act (16 U.S.C. 703-712), and the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.).

Threatened and Endangered Species

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact our office if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. **Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days.** This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

For assistance in determining if suitable habitat for listed, candidate, or proposed species occurs within your project area or if species may be affected by project activities, please visit species profiles at http://www.fws.gov/midwest/endangered/section7/s7process/lifehistory.html. Indiana bats, gray bats, and northern long-eared bats occur throughout Missouri and the information below may help in determining if your project may affect these species.

Gray bats - Gray bats roost in caves or mines year-round and use forest riparian areas for foraging. If your project will impact caves or mines or will involve tree removal around these areas (particularly within stream corridors, riparian areas, or associated upland woodlots), gray bats could be affected.

Indiana and northern long-eared bats - These species hibernate in caves or mines only during the winter. The rest of the year they roost under loose tree bark in tree crevices or cavities during the day and forage around tree canopies of floodplain, riparian, and upland forests at night. Trees which should be considered potential roosting habitat include those exhibiting loose or shaggy bark, crevices, or hollows. Tree species often include, but are not limited to: shellbark or shagbark hickory, white oak, cottonwood, and maple. If your project will impact caves or mines or will involve clearing forested habitat containing suitable roosting habitat, Indiana bats or northern long-eared bats could be affected. If your project will involve removal of over 5 acres of forested habitat, you may wish to complete a Summer Habitat Assessment prior to contacting our office in order to expedite the consultation process. The Summer Habitat Assessment Form is available in Appendix A of the most recent version of the Range-wide Indiana Bat Summer Survey Guidelines, located at www.fws.gov/midwest/Endangered/mammals/inba/ under the heading Summer Survey Guidance.

If no suitable habitat for any federally-listed, candidate, or proposed species is present, and no species or their critical habitat will be affected, then no further consultation or coordination is required. However, if any of the following apply, please contact our office for further consultation:

1. Designated critical habitat is present within the project area,
2. Suitable habitat for listed, candidate, or proposed species is present within the project area (see above for habitat descriptions for bat species), or
3. You determine that project activities may affect these species or their critical habitat (e.g., project occurs upstream or within a distance such that the species or habitat could be affected).

The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. For additional conservation measures that may benefit species identified in the enclosed list, please contact our office.

Other Considerations

Bald and Golden Eagles - Although the bald eagle has recently been removed from the endangered species list, this species and the golden eagle are protected by the Bald and Golden

Eagle Act and the Migratory Bird Treaty Act. Should bald or golden eagles occur within or near the project area please contact our office for further coordination. For communication and wind energy projects, please refer to additional guidelines below.

Migratory Birds - The Migratory Bird Treaty Act (MBTA) prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Service. The Service has the responsibility under the MBTA to proactively prevent the mortality of migratory birds whenever possible and we encourage implementation of recommendations that minimize potential impacts to migratory birds. Such measures include clearing forested habitat outside of the nesting season (generally March 1 to August 31) or conducting nest surveys prior to clearing to avoid injury to eggs or nestlings.

Communication Towers - Construction of new communications towers (including radio, television, cellular, and microwave) creates a potentially significant impact on migratory birds, especially some 350 species of night-migrating birds. However, the Service has developed voluntary guidelines for minimizing impacts and these can be found at http://www.fws.gov/habitatconservation/communicationtowers.html.

Transmission Lines - Migratory birds, especially large species with long wingspans, heavy bodies, and poor maneuverability can also collide with power lines, In addition, mortality can occur when birds, particularly hawks, eagles, kites, falcons, and owls, attempt to perch on uninsulated or unguarded power poles. In order to minimize these risks, please refer to guidelines developed by the Avian Power Line Interaction Committee's and the Service at http://www.aplic.org/uploads/files/2634/APPguidelines_final-draft_Aprl2005.pdf. Implementation of these measures is especially important along sections of lines adjacent to wetlands or other areas known to support large numbers of raptors and migratory birds.

Wind Energy - To minimize impacts to migratory birds and bats, wind energy projects should follow guidelines located at http://www.fws.gov/windenergy. In addition, please refer to the Service's Eagle Conservation Plan Guidance, located at http://www.fws.gov/windenergy/eagle_guidance.html, which provides guidance for conserving bald and golden eagles in the course of siting, constructing, and operating wind energy facilities.

Next Steps

Should you determine that project activities may impact any of the natural resources described herein, please contact our office for further coordination. Letters with requests for consultation or correspondence about your project should include the Consultation Tracking Number in the header.

If you have not already done so, please contact the Missouri Department of Conservation (Policy Coordination, P. O. Box 180, Jefferson City, MO 65102) for information concerning Missouri Natural Communities and Species of Conservation Concern.

We appreciate your concern for threatened and endangered species and please feel free to contact our office with questions or for additional information.

Amy Salveter

Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Blacksnake Creek Section 205 Flood Risk Management Project

Official Species List

Provided by:

Columbia Ecological Services Field Office
101 PARK DEVILLE DRIVE
SUITE A
COLUMBIA, MO 65203
(573) 234-2132

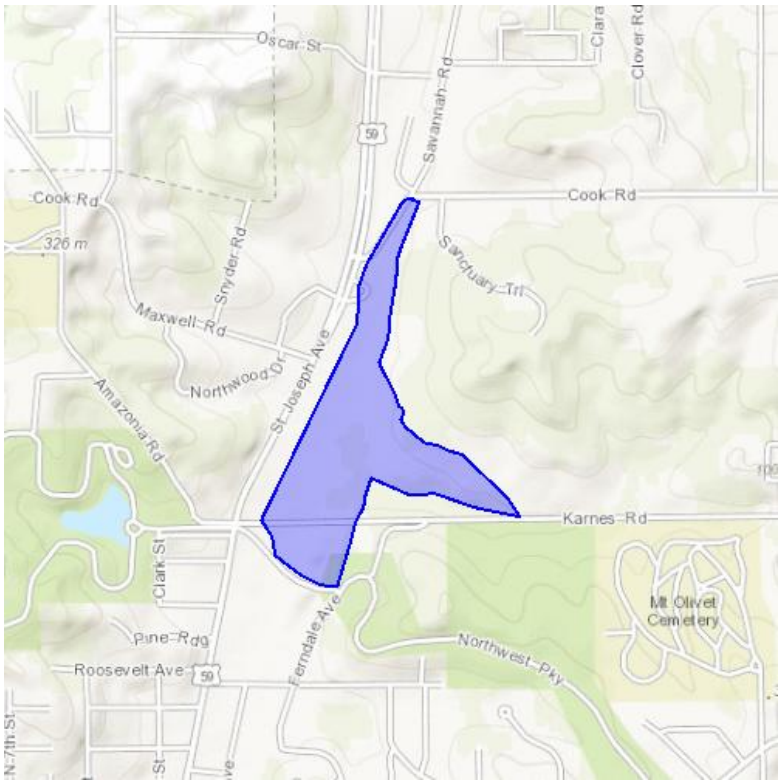
Consultation Code: 03E14000-2015-SLI-0644
Event Code: 03E14000-2015-E-00361

Project Type: LAND - FLOODING

Project Name: Blacksnake Creek Section 205 Flood Risk Management Project
Project Description: The project area center is located at approximately Latitude: 39Â°48'7.08"N, Longitude: 94Â°50'30.48"W. The City of St. Joseph, MO (City) is subject to overland flooding due to combined sewer overflows (CSOs) and the City is required to reduce CSOs to comply with the Clean Water Act. The excavation of 35.6 acres for dry detention is the Recommended Plan to reduce CSOs and associated flooding. Excavation is anticipated to occur within the 2016-2017 fiscal year timeframe.

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

Project Location Map:



Project Coordinates: The coordinates are too numerous to display here.

Project Counties: Buchanan, MO

Endangered Species Act Species List

There are a total of 6 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

Birds	**Status**	**Has Critical Habitat**	**Condition(s)**
Least tern *(Sterna antillarum)* Population: interior pop.	Endangered		
Piping Plover *(Charadrius melodus)* Population: except Great Lakes watershed	Threatened	Final designated	
Red Knot *(Calidris canutus rufa)*	Threatened		
Fishes			
Pallid sturgeon *(Scaphirhynchus albus)* Population: Entire	Endangered		
Mammals			
Indiana bat *(Myotis sodalis)* Population: Entire	Endangered		
Northern long-eared Bat *(Myotis septentrionalis)*	Threatened		

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Appendix A: FWS Migratory Birds

The protection of birds is regulated by the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (BGEPA). Any activity, intentional or unintentional, resulting in take of migratory birds, including eagles, is prohibited unless otherwise permitted by the U.S. Fish and Wildlife Service (50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)). The MBTA has no otherwise lawful activities. For more information regarding these Acts see: http://www.fws.gov/migratorybirds/RegulationsandPolicies.html.

All project proponents are responsible for complying with the appropriate regulations protecting birds when planning and developing a project. To meet these conservation obligations, proponents should identify potential or existing project-related impacts to migratory birds and their habitat and develop and implement conservation measures that avoid, minimize, or compensate for these impacts. The Service's Birds of Conservation Concern (2008) report identifies species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become listed under the Endangered Species Act as amended (16 U.S.C 1531 et seq.).

For information about Birds of Conservation Concern, go to:
http://www.fws.gov/migratorybirds/CurrentBirdIssues/Management/BCC.html.

To search and view summaries of year-round bird occurrence data within your project area, go to the Avian Knowledge Network Histogram Tool links in the Bird Conservation Tools section at:
http://www.fws.gov/migratorybirds/CCMB2.htm.

For information about conservation measures that help avoid or minimize impacts to birds, please visit:
http://www.fws.gov/migratorybirds/CCMB2.htm.

Migratory birds of concern that may be affected by your project:
There are 22 birds on your Migratory birds of concern list.

Species Name	Bird of Conservation Concern (BCC)	Seasonal Occurrence in Project Area
Acadian Flycatcher *(Empidonax virescens)*	Yes	Breeding
Bell's Vireo *(Vireo bellii)*	Yes	Breeding

Least Bittern *(Ixobrychus exilis)*	Yes	Breeding
Rusty Blackbird *(Euphagus carolinus)*	Yes	Wintering
Wood Thrush *(Hylocichla mustelina)*	Yes	Breeding
Worm eating Warbler *(Helmitheros vermivorum)*	Yes	Breeding
Harris's Sparrow *(Zonotrichia querula)*	Yes	Wintering
Black-billed Cuckoo *(Coccyzus erythropthalmus)*	Yes	Breeding
Northern Flicker *(Colaptes auratus)*	Yes	Year-round
Bald eagle *(Haliaeetus leucocephalus)*	Yes	Year-round
Black-crowned Night-Heron *(Nycticorax nycticorax)*	Yes	Breeding
Field Sparrow *(Spizella pusilla)*	Yes	Breeding
Pied-billed Grebe *(Podilymbus podiceps)*	Yes	Breeding
Dickcissel *(Spiza americana)*	Yes	Breeding
Henslow's sparrow *(Ammodramus henslowii)*	Yes	Breeding
Hudsonian Godwit *(Limosa haemastica)*	Yes	Migrating

Kentucky Warbler *(Oporornis formosus)*	Yes	Breeding
Loggerhead Shrike *(Lanius ludovicianus)*	Yes	Year-round
Upland Sandpiper *(Bartramia longicauda)*	Yes	Breeding
Red-headed Woodpecker *(Melanerpes erythrocephalus)*	Yes	Year-round
Short-eared Owl *(Asio flammeus)*	Yes	Wintering
Swainson's hawk *(Buteo swainsoni)*	Yes	Breeding

2015

Missouri Natural Heritage Program Results for Buchanan

Name	State Rank	Global Rank	State Status	Federal Status
Central Plains - Warmwater - Large river	Unranked Code: S?	Not ranked Code: GNR		
Dry loess/glacial till prairie	Imperiled Code: S2	Not ranked Code: GNR		
Dry-mesic loess/glacial till forest	Vulnerable Code: S3	Not ranked Code: GNR		
Dry-mesic loess/glacial till woodland	Vulnerable Code: S3	Not ranked Code: GNR		
Marsh	Imperiled Code: S2	Not ranked Code: GNR		
American Badger *Taxidea taxus*	Vulnerable Code: S3	Secure Code: G5		
Brassy Minnow *Hybognathus hankinsoni*	Vulnerable Code: S3	Secure Code: G5		
Common Gallinule *Gallinula galeata*	Imperiled Code: S2	Secure Code: G5		
Eastern Tiger Salamander *Ambystoma tigrinum*	Vulnerable Code: S3	Secure Code: G5		
Flathead Chub *Platygobio gracilis*	Critically imperiled Code: S1	Secure Code: G5	Endangered Code: E	
Great Plains Skink *Plestiodon obsoletus*	Imperiled Code: S2	Secure Code: G5		
Great Plains Toad *Anaxyrus cognatus*	Vulnerable Code: S3	Secure Code: G5		
Highfin Carpsucker *Carpiodes velifer*	Imperiled Code: S2	Apparently secure Secure Code: G4G5		
Lake Sturgeon *Acipenser fulvescens*	Critically imperiled Code: S1	Vulnerable Apparently secure Code: G3G4	Endangered Code: E	
Least Bittern	Vulnerable	Secure		

Name	State Rank	Global Rank	State Status	Federal Status
Ixobrychus exilis	Code: S3	Code: G5		
Loggerhead Shrike *Lanius ludovicianus*	Imperiled Code: S2	Apparently secure Code: G4		
Long-tailed Weasel *Mustela frenata*	Vulnerable Code: S3	Secure Code: G5		
Marsh Wren *Cistothorus palustris*	Vulnerable Code: S3	Secure Code: G5		
Pale Bulrush *Scirpus pallidus*	Imperiled Code: S2	Secure Code: G5		
Pallid Sturgeon *Scaphirhynchus albus*	Critically imperiled Code: S1	Imperiled Code: G2	Endangered Code: E	Endangered Code: E
Plains Minnow *Hybognathus placitus*	Imperiled Code: S2	Apparently secure Code: G4		
Schweinitz's Flatsedge *Cyperus schweinitzii*	Vulnerable Code: S3	Secure Code: G5		
Skeleton Plant *Lygodesmia juncea*	Vulnerable Code: S3	Secure Code: G5		
Sora *Porzana carolina*	Imperiled Code: S2	Secure Code: G5		
Sturgeon Chub *Macrhybopsis gelida* More information	Vulnerable Code: S3	Vulnerable Code: G3		
Tall Agrimony *Agrimonia gryposepala*	Unrankable Code: SU	Secure Code: G5		
Thirteen-lined Ground Squirrel *Ictidomys tridecemlineatus*	Imperiled Code: S2	Secure Code: G5		
Yellow-headed Blackbird *Xanthocephalus xanthocephalus*	Vulnerable Code: S3	Secure Code: G5		

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
600 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896

January 3, 2013

REPLY TO
ATTENTION OF

Environmental Resources Section
Planning Branch

Mr. Mark Miles
Director and Deputy State Historic Preservation Officer
State Historic Preservation Office
Department of Natural Resources
P. O. Box 176
Jefferson City, Missouri 65102-0176

Dear Mr. Miles:

The U.S. Army Corps of Engineers, Kansas City District (Corps) and the City of Saint Joseph are proposing a Section 205 flood control project along the Blacksnake Creek Basin in Buchanan County. The project would be constructed using federal funding. This letter initiates coordination of the project under Section 106 of the National Historic Preservation Act.

The project area is situated in northern Saint Joseph along Blacksnake Creek, a small tributary on the left bank of the Missouri River (Figure 1). Land use in the immediate vicinity consists of a mix of residential and commercial development. Blacksnake Creek enters the city about 4.3 miles above its mouth and flows south-southwest to its confluence with the river. The channel in the lower 3.2 square miles of the basin is enclosed in a combined sewer of varying size up to 17 feet in diameter. The upper 5 square miles of the basin above the combined sewer inlet at Karnes Road is drained by an open channel. During storm events the flows from the Karnes Road sewer overtop the road and flood residential, commercial, and industrial properties within the city.

The proposed project would excavate a detention basin between St. Joseph Avenue and an abandoned railroad right-of-way; remove the existing Karnes Road within the project area; construct an overflow spillway at the south end of the project; armor Northwest Parkway with riprap so the road will act as spillway for large flooding events; and relocate or modify utilities including sanitary lines, storm sewer, gas, water, electric, and communication lines. The detention excavation would extend from between 5 to 15 feet below the present ground surface. The excavation would also remove a portion of the abandoned railway grade (Figures 2, 3, and 4). Spoil from the excavation will be placed at two locations, one at Elwood Bottoms in Kansas and the other at a softball complex in northwest Saint Joseph. The project area encompasses approximately 26 acres along Blacksnake Creek extending from Savannah Road in the north to Karnes Road in the south.

An archeological background review of the project area was conducted that included an examination of the National Register of Historic Places on-line (NRHP); NRHP documents provided by the Missouri State Historic Preservation Officer (SHPO); the Missouri Department of Natural Resources Archeological Viewer; as well as pertinent Corps records. Geological maps and the Buchanan County Missouri Soil Survey were reviewed to determine the potential for unrecorded archeological sites in the area.

The background review found that one NRHP-listed district, the St. Joseph Park and Parkway System, crosses the southern portion of the proposed project area along Northwest Parkway (Figure 5). The NRHP district consists of 983 acres of park land and includes 11.5 miles of parkways and boulevards. Northwest Boulevard is included in the District, but Karnes road is not listed as a contributing element of the District. Park elements located within the project area including a ball park, tennis court, and swimming pool are not considered contributing elements to the historic district. No archeological or other cultural resources are recorded within or near the proposed project area; however, the area has not been professional surveyed for sites. As the area had not been previously surveyed and was thought to have a moderate potential for unrecorded archeological sites, an archeological survey was conducted for the project area.

I conducted the archeological survey of the project area on 7 June 2013 with the assistance of biologist Richard Skinker. The survey consisted of a pedestrian survey of the entire project area and selective shovel testing. The pedestrian survey focused on areas with adequate ground surface visibility and cut bank exposures. Shovel tests were placed in areas of poor surface visibility that appeared to be relatively undisturbed. Areas of profound ground disturbance such as the former railway line that bisects the project area east of the creek and utility lines were noted, but not surveyed.

The field survey identified no archeological sites in the project area. The proposed project location was found to have been largely disturbed by passed urban development primarily from construction of the now abandoned railroad track and large associated berm and adjacent borrow areas; the Karnes and Northwest Parkway roadways; park development in the southern project area; housing and commercial along the eastern and western project boundaries, and park development.

The armoring of Northwest Parkway would not have an adverse effect on the St. Joseph Park and Parkway System NRHP District as the road would remain in place and there should be little visual impact from the finished project. In addition, the other project impacts would not impact contributing elements of the District as Karnes Road and adjacent field and park are not part of the NRHP District. The project is also unlikely to impact any unrecorded archeological sites within the area of potential effect as past disturbances throughout area make it unlikely that the area contains any unrecorded archeological sites that would be eligible for the NRHP. Because of the above conditions, the Corps has determined that the proposed project would have no adverse effect on the St. Joseph Park and Parkway System NRHP District and would not impact

any other sites eligible for the NRHP outside of the District. At this time, we are requesting your concurrence with this recommendation.

Thank you for your consideration in this matter. If you have any questions or have need of further information please contact me at timothy.m.meade@usace.army.mil or at (816) 389-3138.

Sincerely,

Timothy Meade
District Archeologist

Enclosure

STATE OF MISSOURI
Jeremiah W. (Jay) Nixon, Governor • Sara Parker Pauley, Director
DEPARTMENT OF NATURAL RESOURCES
www.dnr.mo.gov

January 13, 2014

Timothy Meade
District Archaeologist
Corps of Engineers, Kansas City District
600 Federal Building
Kansas City, Missouri 64106-2896

Re: Blacksnake Creek Flood Control Project, St. Joseph (COE) Buchanan County, Missouri

Dear Mr. Meade:

Thank you for submitting information about the above referenced project for our review pursuant to Section 106 of the National Historic Preservation Act (P.L. 89-665) and the Advisory Council on Historic Preservation's regulation 36 CFR Part 800, which require identification and evaluation of cultural resources.

We have reviewed the information provided concerning the above referenced project. We concur with your determination that the proposed flood control project will have **no adverse effect** on the Northwest Parkway, a contributing property to the St. Joseph Park and Parkway System Historic District, a property listed in the National Register of Historic Places.

Please be advised that, should project plans change, information documenting the revisions should be submitted to this office for further review and comment on possible effects to historic properties. In the event that cultural materials are encountered during project activities, all construction should be halted, and this office notified as soon as possible in order to determine the appropriate course of action.

If you have any questions, please write Judith Deel at State Historic Preservation Office, P.O. Box 176, Jefferson City, Missouri 65102 or call 573/751-7862. Please be sure to include the SHPO Log Number (**018-BN-14**) on all future correspondence or inquiries relating to this project.

Sincerely,

STATE HISTORIC PRESERVATION OFFICE

Mark A. Miles
Director and Deputy State
Historic Preservation Officer

MAM:jd

c Scott Des Planques, St. Joseph

Recycled Paper

Skinker, Richard A NWK

Subject: FW: [EXTERNAL] Re: Blacksnake Creek proposed spoil deposit near Elwood, Kansas (UNCLASSIFIED)
Attachments: Blacksnake Creek Spoil Deposit.pdf

-----Original Message-----
From: Meade, Timothy M NWK
Sent: Thursday, April 23, 2015 12:16 PM
To: Skinker, Richard A NWK
Subject: FW: [EXTERNAL] Re: Blacksnake Creek proposed spoil deposit near Elwood, Kansas (UNCLASSIFIED)

-----Original Message-----
From: Tim Weston [mailto:tweston@kshs.org]
Sent: Wednesday, March 26, 2014 11:19 AM
To: Meade, Timothy M NWK
Subject: [EXTERNAL] Re: Blacksnake Creek proposed spoil deposit near Elwood, Kansas (UNCLASSIFIED)

Tim,

Our response letter for this project is attached. Please let me know if you have any questions.

Tim Weston
SHPO Archeologist
Kansas Historical Society
6425 SW 6th Avenue
Topeka, Kansas 66615
(785) 272-8681 ext. 214
tweston@kshs.org

On 3/20/2014 10:46 AM, Meade, Timothy M NWK wrote:
> Classification: UNCLASSIFIED
> Caveats: NONE
>
> Hi Tim,
>
This e-mail is in reference to the proposed spoil deposit location for material excavated for the Blacksnake Creek flood control project we discussed yesterday. The proposed spoil area is located near Elwood, Kansas in the Missouri River flood plain as depicted in the attached aerial map. No ground disturbance is planned for the project. No sites are mapped within or near the proposed spoil are. Please review and provide any comments you may have.
>
> Thanks for your consideration,
>
> Timothy Meade
> District Archeologist/Tribal Liaison
> U.S. Army Corps of Engineers
> Kansas City District
> 600 Federal Building
> 601 E. 12th Street
> Kansas City, MO 64106-2896
> P: (816) 389-3138

6425 SW 6th Avenue
Topeka, KS 66615

Kansas

phone: 785-272-8681
fax: 785-272-8682
cultural_resources@kshs.org

Kansas Historical Society

Sam Brownback, Governor
Jennie Chinn, Executive Director

KSR&C No. 14-03-147

March 26, 2014

Timothy Meade
District Archeologist/Tribal Liason
U.S. Army Corps of Engineers
Kansas City District
600 Federal Building
601 E. 12th Street
Kansas City, Missouri 64106-2896

RE: Blacksnake Creek Spoil Deposit Location
City of Elwood
Doniphan County

Dear Mr. Meade:

In accordance with 36 CFR 800, the Kansas State Historic Preservation Office has reviewed your e-mail message and attached documentation (dated March 20, 2014) describing plans to deposit spoil excavated from the Blacksnake Creek flood control project. Given the factors outlined in your documentation, we concur with the conclusion that the proposed project will have no effect on historic properties as defined in 36 CFR 800. This office has no objection to implementation of the project.

Any changes to the project, which include additional ground disturbing activities, will need to be reviewed by this office prior to beginning construction. If construction work uncovers buried archeological materials, work should cease in the area of the discovery and this office should be notified immediately.

This information is provided at your request to assist you in identifying historic properties, as specified in 36 CFR 800 for Section 106 consultation procedures. If you have questions or need additional information regarding these comments, please contact Tim Weston at 785-272-8681 (ext. 214).

Sincerely,

Jennie Chinn, Executive Director and
State Historic Preservation Officer

Timothy Weston
for

Patrick Zollner
Deputy SHPO

BLACKSNAKE CREEK FLOOD CONTROL PR0JECT
INFORMATIONAL HANDOUT

The Blacksnake Creek area in North St. Joseph has a long history of flooding. There have been damaging floods reported in 1849, 1943, 1959, 1962 and 1984. There have also been many other times where the stream flow overtopped Karnes Road, but not in a great enough amount to cause significant property damage.

The City is currently working with the United States Army Corps of Engineers-Kansas City Division (USACE-KCD) in order to help provide flood relief for this area, which is south of Karnes Road and east of St. Joseph Ave. The USACE has a 205 Program that will provide up to 65% of the cost of the construction.

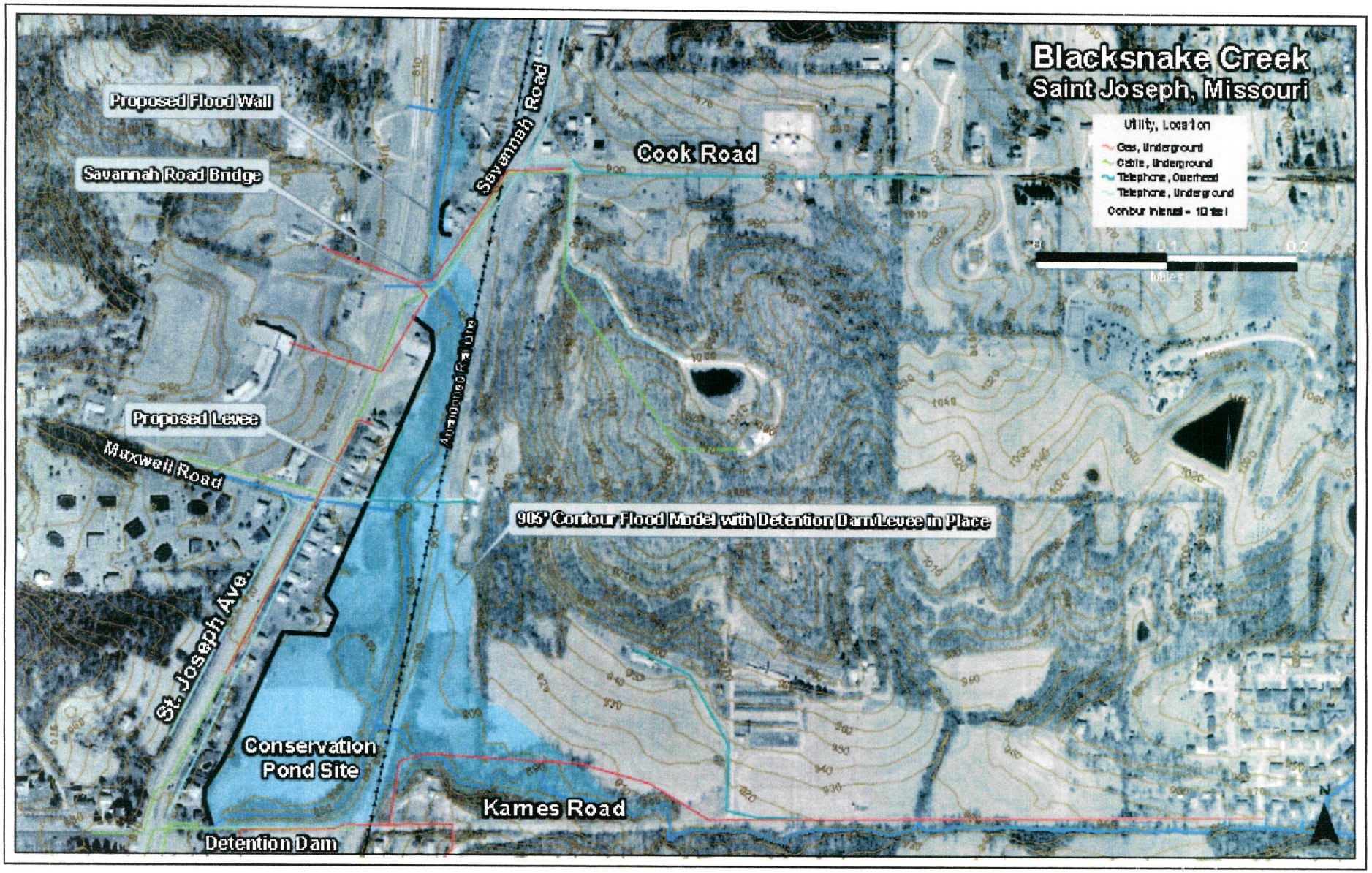
At least two other flood control studies have been completed in the past, with both recommending a similar solution to the one being currently proposed by the USACE-KCD. This current proposal is for a stormwater detention basin to be constructed north of Karnes Road and east of St. Joseph Ave. This proposal is shown in the drawing labeled Attachment 1. During large rain events water that would have normally overtopped Karnes Road would be detained North of Karnes Road. The water would be captured by a new earth dam with Karnes Road being reconstructed on top of the new dam. Karnes Road would be raised in elevation up to 12 feet so that it would be almost a level roadway from St. Joseph Ave. east to past the old railroad right-of-way.

The blue shaded area in attachment 1 is the proposed detention area. During the very large rain events which happen very infrequently, the entire blue shaded area would be utilized to hold back the storm water. The 1984 rainstorm for instance would have filled a significant portion of the blue shaded area but would not likely have filled the entire area.

The enhancements being considered by the City (shown in attachment 2) could include a lake of up to 16 acres, hike and bike trails, water quality improvements and roadway reconstruciton. The project is still in the early stages and the final plan has not yet been identified. It is expected that construction will begin in 2008 or 2009 for which ever flood protection method is ultimately selected.

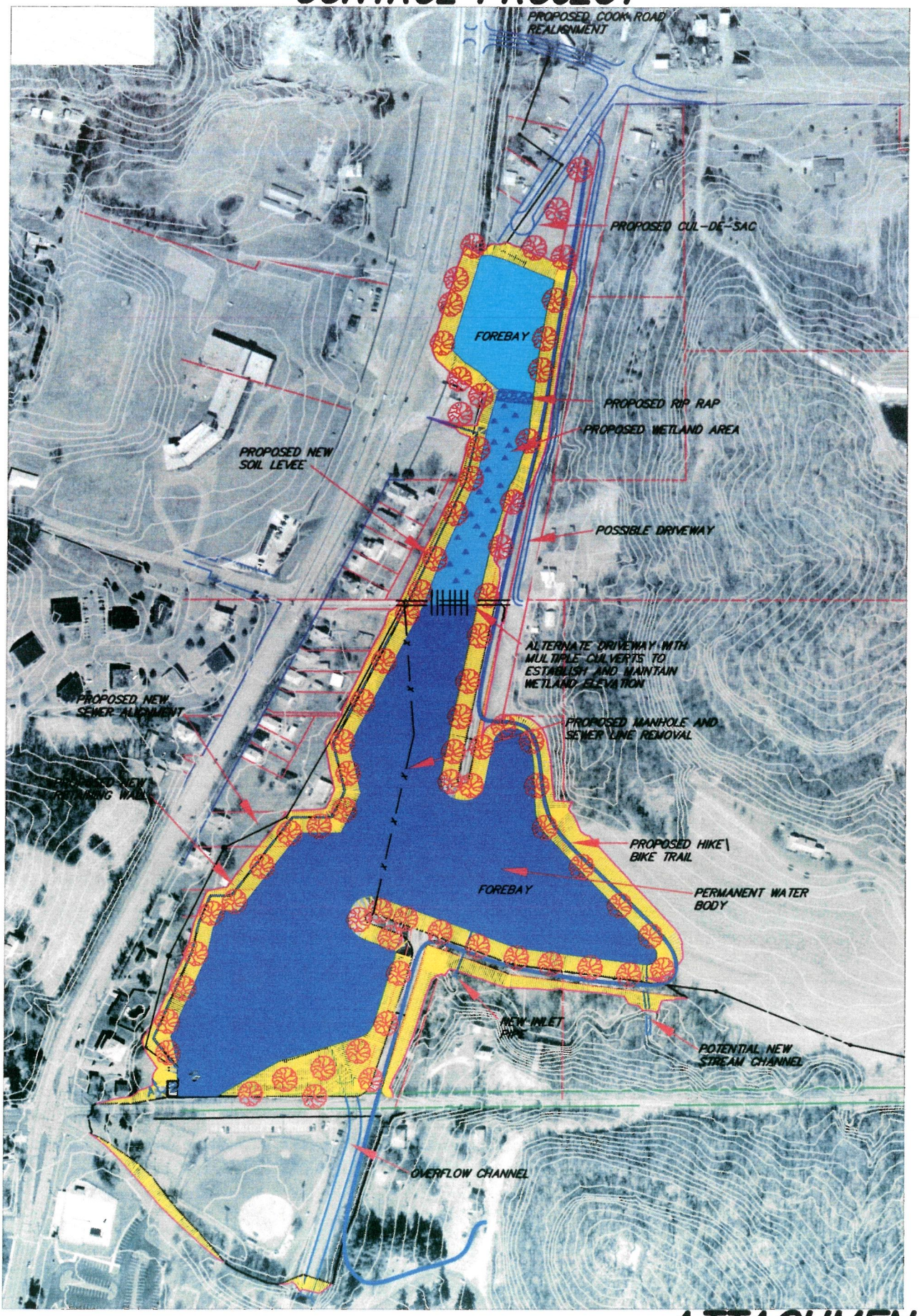
The purpose of tonight's meeting is to present the project to the Council Committees and affected public at this conceptual stage so that input can be provided regarding the project. Additionally city staff is seeking direction from the Council Committees this evening with regard to continued pursuit of the enhancements/alternatives currently proposed by staff. Pursuit of the enhancements and alternatives with the USACE-KCD will likely increase the cost of the feasibility study but will allow for opportunities to review and approve a more detailed design proposal and construction cost estimate.

USACE-KCD BLACKSNAKE 205 FLOOD CONTROL PROJECT



ATTACHMENT 1

POTENTIAL CITY ENHANCEMENTS TO USACE– RCD FLOOD CONTROL PROJECT



ATTACHMENT 2

Comment Form

Blacksnake Creek
Section 205 Feasibility Study
April 7, 2005

Name: _____

Address: _____

Tel. No._____

Tract No._____

What specific concerns do you have regarding your property as it relates to this project?

_____

_____

_____

Is there any additional information you would like to share regarding this project and/or its impact to you property?

_____

_____

_____

Do you believe that relieving the flooding that occurs on the Blacksnake watershed should be a priority project for the City of St. Joseph?

_____

_____

_____

Additional Comments:

_____

_____

_____

Please use back if necessary.

APPENDIX C

HYDROLOGY AND HYDRAULICS

Blacksnake Creek Section 205 Feasibility Study
St. Joseph, Missouri

Appendix C
Report of Hydrologic and Hydraulic Conditions

US Army Corps of Engineers
Kansas City District

February 2015

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Attachment 2 HEC-RAS Model Output
Attachment 3 Alternatives HEC-RAS Flow Load Points
Attachment 4 HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives
Attachment 5 Alternatives HEC-RAS Flow Load Points Including Outlet B

1 INTRODUCTION

The Blacksnake Creek watershed located in the City of St. Joseph, Missouri, is a source of flooding in the developed downstream reach of the creek. Consequently, the city is investigating flood damage reduction measures for the Blacksnake Creek watershed, which includes a proposed detention basin at Karnes Road.

The objective of this study is to develop information and data that the City of St. Joseph can use to make decisions regarding a potential Blacksnake Creek detention basin design project. The scope of this study includes hydrologic modeling with HEC-HMS (Version 3.5) and hydraulic modeling with HEC-RAS (Version 4.1.0) to develop water surface profiles for the 1, 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 Annual Chance Exceedance (ACE) storm events.

1.1 STUDY AREA

Information on the study area was gathered from previous reports completed by Black & Veatch (1998) and URS (2001), which were provided to Kansas City District, US Army Corps of Engineers (CENWK). The following sections describe the extent of the drainage area, land use, flood concerns, and other basin characteristics.

The City of St. Joseph, Missouri, is located in Buchanan County in northwestern Missouri. Blacksnake Creek watershed is part of the St. Joseph storm water drainage area, and covers 8.2 square miles of the approximate 50.4 square miles in the entire St. Joseph drainage area. Blacksnake Creek watershed drains generally from north to the southwest. The creek ultimately empties into the Missouri River. Only the extreme downstream portion of the watershed is within the current Missouri River floodplain. Figures 1 and 2 illustrate the relation of Blacksnake Creek to the entire drainage basin and provide a detailed overview of the study area.

1.2 DRAINAGE AREA DESCRIPTION

Blacksnake Creek watershed is an ungaged basin that includes both closed and open drainage systems. The open systems are predominately located in the upper half of the watershed. Blacksnake Creek is an open channel from its headwaters downstream to Karnes Road. At Karnes Road the creek enters the combined sewer system (CSS), which consists of approximately 20 miles of combined sewers with an average pipe size of 48 inches. During times of low flow, the CSS conveys all flows to a 48-inch reinforced concrete pipe (RCP) through which the flow enters a wastewater treatment plant located at the Missouri River. However, during heavy rains the CSS is overwhelmed and stormwater drain by overland flow through developed areas of the City.

1.2.1 LAND USE AND SOILS

The land use of the watershed is divided between predominately urban land use in the lower basin, which encompasses approximately the southern half of the watershed, and a mix of suburban residential and rural land use in the upper, northern half of the basin. Blacksnake Creek watershed is 57% residential, 6% commercial/industrial, 12% parks, 20% agriculture, and 5% other. The composite impervious percent for the watershed is 29%. Future plans for the upper half of

Blacksnake Creek watershed entail conversion of the existing agricultural lands to more urban/residential development.

Soils in the watershed are primarily Marshall-Contrary soils characterized by well drained soils, with slopes from 2% to 20%. These are predominately silt-loam soils. Near the confluence with the Missouri River, the soils are floodplain soils that are poorly drained and predominately clay.

FIGURE 1 ST JOSEPH MISSOURI WATERSHEDS

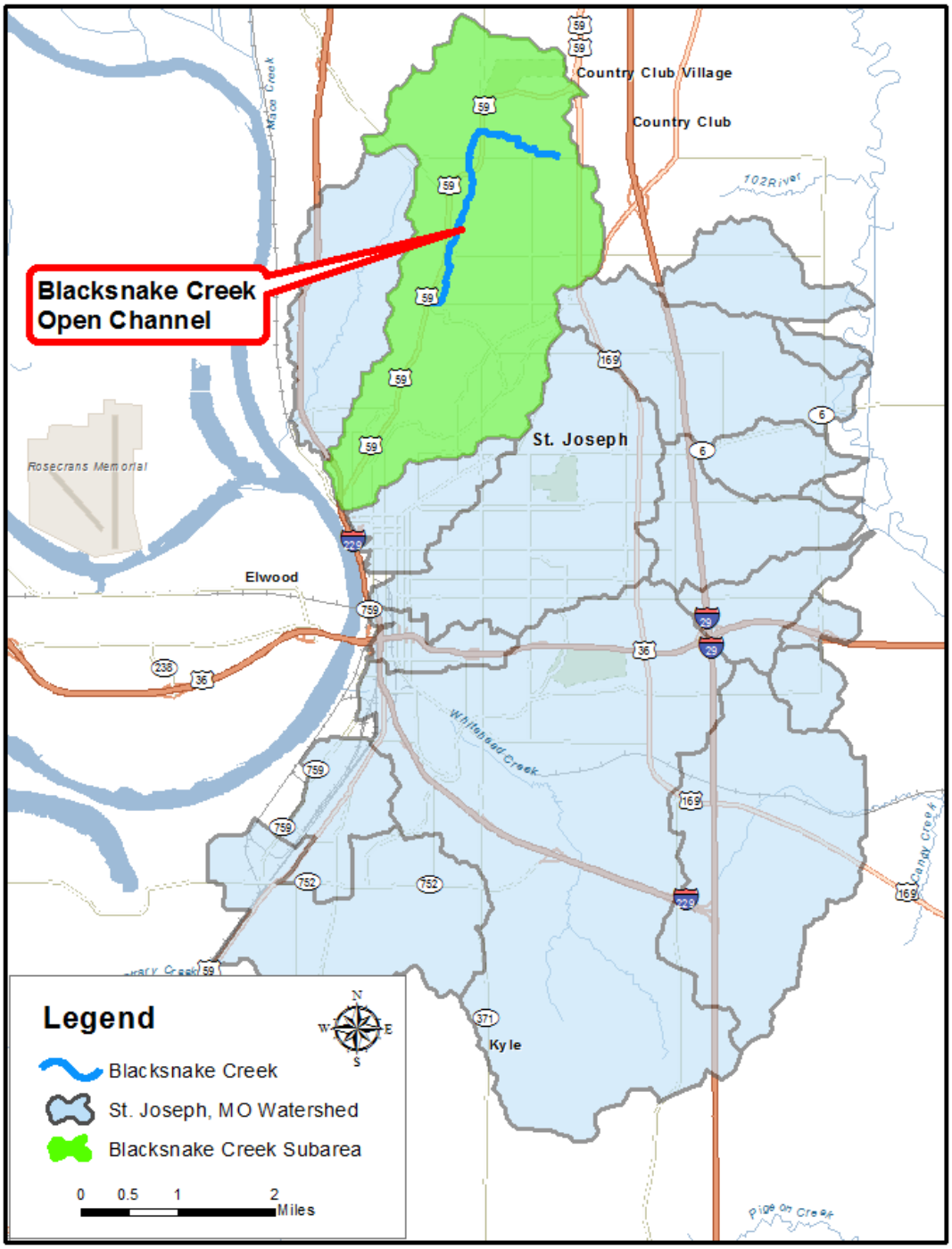
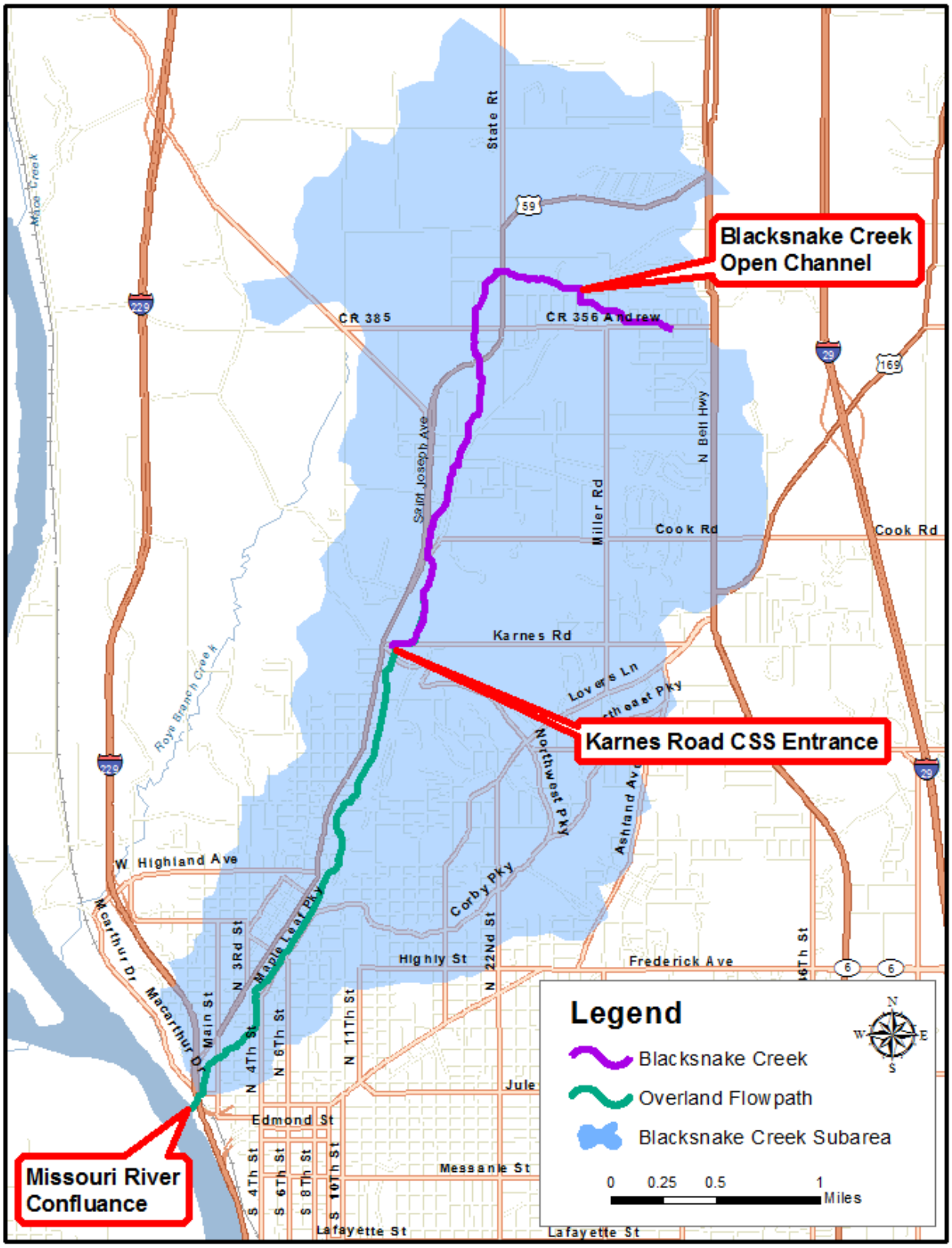


FIGURE 2 BLACKSNAKE CREEK WATERSHED



1.2.2 Flood Concerns

Flooding is a significant issue in the Blacksnake Creek watershed. The main cause of flooding in the basin is flash flooding, which occurs during local storm events over the basin. The inlet capacity at the junction of the creek and the CSS at Karnes Road is exceeded by runoff from the upper watershed during intense storm events. When the CSS inlet is at capacity, water overtops Karnes Road and floods overland into downstream neighborhoods and streets, ultimately flowing into the Missouri River.

The area of most concern is the lower, urbanized portion of the basin, southwest of Karnes Road. This section experiences the most flooding and is served by the CSS. The URS report states, "Approximately 200 homes and businesses are located within the 0.01-ACE floodplain for the Blacksnake Creek below Karnes Road (based on preliminary delineation of the Blacksnake Creek Q3 flood evaluations)." (URS, 2001).

2 Hydrology

2.1 Hydrologic Model Development

A hydrologic evaluation of the Blacksnake Creek watershed in St. Joseph, Missouri, was conducted using the US Army Corps of Engineers, Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HMS), Version 3.5, computer model. The HEC-HMS model was used to simulate the existing conditions runoff hydrographs resulting from rainfalls corresponding to the 1, 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 ACE storm events. The hydrology model development methodology contains six primary components: subarea delineation, rainfall, surface runoff volume, runoff distribution, channel routing, and watershed storage.

2.2 Subarea Delineation

The formation of drainage areas is the first component needed for the hydrologic analysis and sets up the framework for the HMS model. The Blacksnake Creek watershed had been previously studied using the XP-SWMM model. The XP-SWMM model was initially created in 1998 as part of a program to evaluate flooding problems and flood mitigation options in the Blacksnake Creek watershed. For the previous study, the watershed was delineated into 120 subareas, with an average area of 45 acres each. The SWMM subarea delineation was reviewed and verified, using GIS software and two-foot contour data provided by the City of St. Joseph. The SWMM subareas were aggregated to form larger subareas (approximately 160 acres each) for use in the HMS model for this study. Figure 3 shows the Blacksnake Creek watershed and the delineated HMS subareas. Table 1 shows the correlation between the HMS subareas and the SWMM subareas.

2.2.2 Blacksnake Creek Naming Convention:

Subareas draining to Blacksnake Creek were each given a unique alphanumeric name with the format BS-##. "BS" is the two-letter code for the Blacksnake Creek Watershed. "##" is a two-digit subarea identification number. The naming convention was similar for the routing reaches, junctions, and other component elements. Prefix codes "R" and "J" were used to designate

routing reach and junction elements, respectively. The assigned identification number corresponds with the basin number. These alphanumeric names were used in the HMS model, as well as in the GIS shapefiles, and in the results tables.

FIGURE 3 BLACKSNAKE CREEK WATERSHED AND SUBAREAS

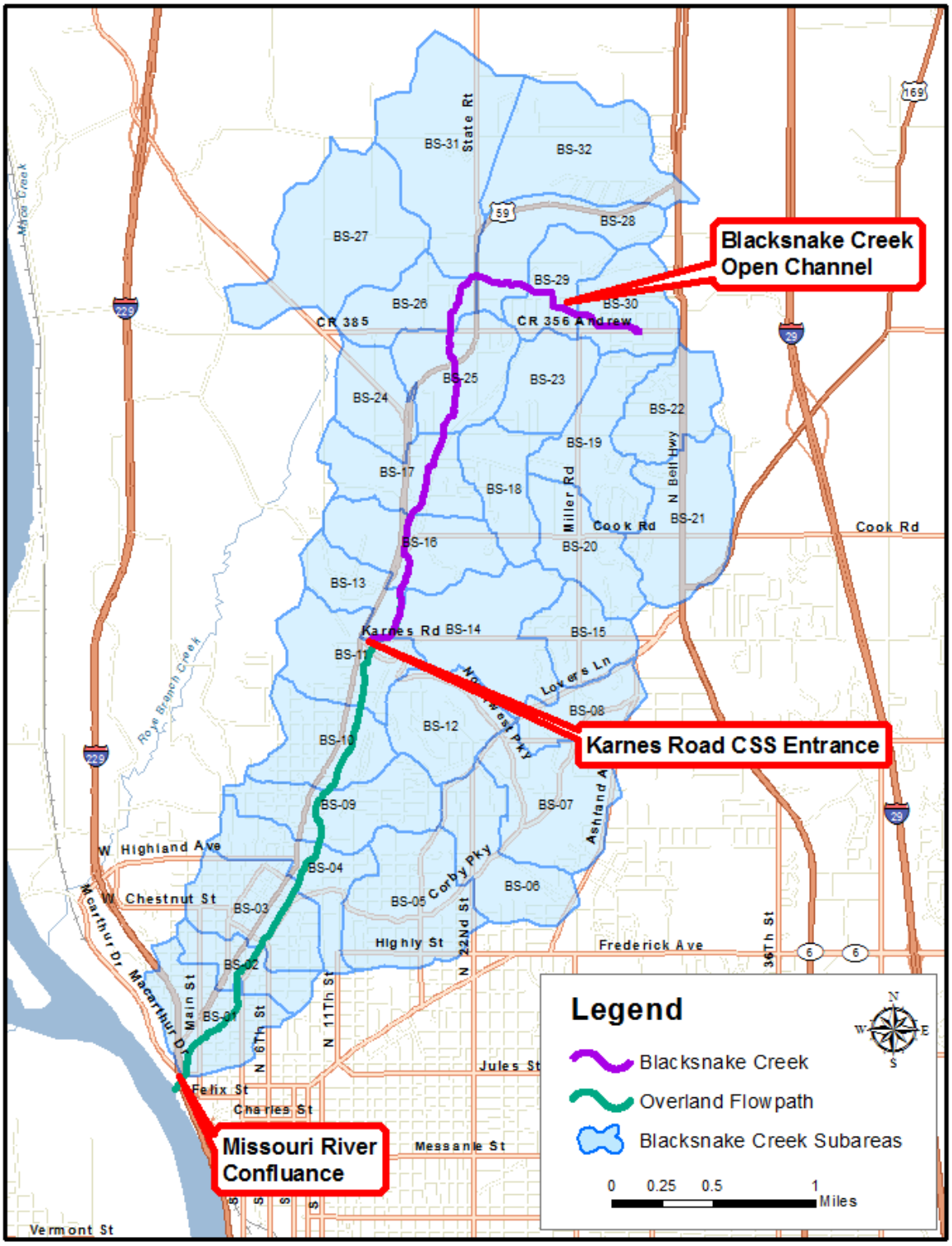


TABLE 1 SUBAREA AGGREGATION

HEC-HMS Subarea ID	Area (Acres)	XP-SWMM Subarea ID	Area (Acres)
BS-01	161	73-5	24.11
		57-6	31.12
		BSS-26	38.54
		BSS-30	67.67
BS-02	84	40-3	22.00
		BSS-21	39.83
		25-6	22.40
BS-03	169	45-9	31.79
		51-8	39.72
		50-3	15.83
		51-3	4.82
		BSS-19B	43.97
		115-1	9.48
		48-28	19.32
		48-23	3.64
BS-04	137	123-22	19.61
		BSS-18	83.61
		67-10	13.18
		52-11	20.48
BS-05	231	GAS-9	112.70
		97-2	42.00
		GAS-17	75.91
BS-06	169	121-1	38.87
		GAS-4	59.28
		166-22	37.69
		166-19A	9.76
		138-21	23.03
BS-07	217	BS-1030	29.86
		BS-1050	26.16
		GAS-1	161.10
BS-08	102	BS-1000	77.48
		BS-1008	24.23
BS-09	176	139-1	66.12
		BSS-13	35.82
		BSS-16	46.35
		139-49	22.07
		127-11	6.08

HEC-HMS Subarea ID	Area, (Acres)	XP-SWMM Subarea ID	Area (Acres)
BS-10	152	127-70	38.49
		BSS-11	85.80
		127-43	27.91
BS-11	164	BSS-2	95.94
		76-12	9.17
		BSS-5	59.14
BS-12	154	225-1	35.56
		BS-1160	60.88
		BS-1120	19.44
		BS-1100	21.38
		BS-1180	16.27
BS-13	89	BS-815	42.02
		BS-835	24.31
		BSS-0	22.68
BS-14	238	BS-985	85.46
		BS-996	50.06
		BS-992	102.30
BS-15	109	BS-940	16.69
		BS-900	6.16
		BS-940A	3.26
		BS-940B	3.11
		BS-975	3.26
		BS-945	38.19
		BS-955	27.99
BS-16	172	BS-795	21.92
		BS-805	46.47
		BS-192	103.80
BS-17	154	BS-775	64.16
		BS-179	79.25
		BS-785	10.88
BS-18	119	BS-675	119.20
BS-19	177	BS-400	13.20
		BS-420	38.28
		BS-660	55.85
		BS-380	8.93
		BS-640	32.22
		BS-630	28.74

TABLE 1 SUBAREA AGGREGATION (CONTINUED)

HEC-HMS Subarea ID	Area (Acres)	XP-SWMM Subarea ID	Area (Acres)
BS-20	137	BS-540	55.98
		BS-503	4.25
		BS-502	9.78
		BS-510	9.29
		BS-500	57.79
BS-21	208	BS-240	26.93
		BS-250	7.09
		BS-620	43.01
		BS-275	15.67
		BS-228	34.44
		BS-230	2.05
		BS-202	22.94
		BS-220	5.97
		BS-200	11.78
		BS-217	38.02
BS-22	128	BS-345	54.08
		BS-300	26.86
		BS-335	16.81
		BS-355	23.63
		BS-360	7.07
BS-23	118	BS-550	111.90
		BS-547	6.40
BS-24	107	BS-700	9.24
		BS-710	14.16
		BS-709	19.56
		BS-720	5.84
		BS-732	32.36
		BS-726	1.63
		BS-740	16.81
		BS-750	7.34
BS-25	169	BS-160	99.72
		BS-150	69.39
BS-26/ BS-27	431	BS-140	431.00
BS-28	157	BS-120	157.00
BS-29	110	BS-109	65.97
		BS-90	14.72
		BS-100	8.98
		BS-106	20.62
BS-30	131	BS-80	47.38
		BS-32	25.40
		BS-50	19.37
		BS-60	9.06
		BS-30	16.50
		BS-10	13.18
BS-31/ BS-32	583	BS-130	583.20

2.3 RAINFALL

The Soil Conservation Service (SCS) design storm with a Type II distribution was used to simulate rainfall events for each return interval. (Note that the Soil Conservation Service (SCS) is now called the Natural Resources Conservation Service or NRCS). This method requires the rainfall depth for a storm duration of 24 hours. The 24-hour rainfall amounts were obtained from the Rainfall Frequency Atlas of the Midwest (Bulletin 71, dated 1992) and are summarized in Table 2. Rainfall amounts representing the nine different return intervals were input into the HMS model.

TABLE 2 RAINFALL DEPTH

Return Period (ACE)	Rainfall Depth for 24-Hour Storm (Inches)
1	2.53
0.5	3.27
0.2	4.25
0.1	4.98
0.04	5.89
0.02	6.58
0.01	7.30
0.004	8.26*
0.002	8.98*

* Values calculated from liner extrapolation

2.3.1 RAINFALL UPDATE

As noted in Section 2.3 the rainfall depths used in the Blacksnake Creek HEC-HMS model were obtained from Bulletin 71, dated 1992. However, since the initial development of the Blacksnake Creek HEC-HMS model, updated rainfall estimates for the Midwestern States were published by the National Oceanic and Atmospheric Administration (NOAA) in 2013. The report is titled "NOAA Atlas 14 – Precipitation Frequency Atlas of the United States – Volume 8 – Version 2.0: Midwestern States". Because this update was released prior to finalizing the feasibility study report the rainfall depths have been modified to reflect the most current data. The new rainfall amounts are summarized in Table 3.

TABLE 3 UPDATED RAINFALL DEPTH COMPARISON (24-HOUR DURATION)

Return Period (ACE)	Bulletin 71 (inches)	NOAA Atlas 14 (inches)	Change in Depth
1	2.53	2.93	0.40
0.5	3.27	3.41	0.14
0.2	4.25	4.24	-0.01
0.1	4.98	4.99	0.01
0.04	5.89	6.10	0.21
0.02	6.58	7.03	0.45
0.01	7.30	8.02	0.72
0.004	8.26*	9.34	1.08
0.002	8.98*	10.6	1.62

* Values calculated from liner extrapolation
** Values calculated from liner interpolation

The updated NOAA Atlas 14 rainfall depths were used in the HEC-HMS model to calculate peak stormwater flow rates.

2.4 RUNOFF VOLUME

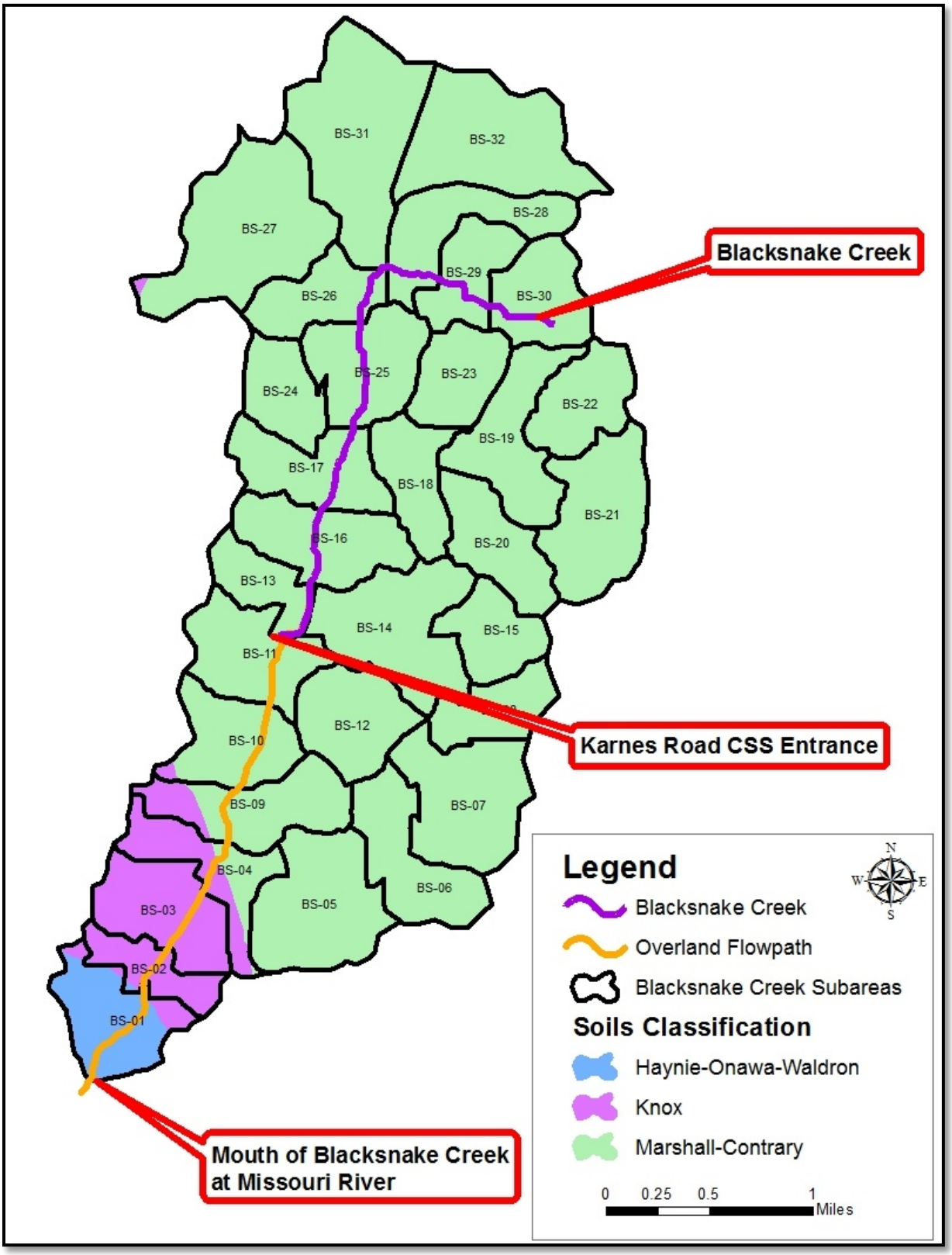
The SCS Curve Number Loss Rate option in the HMS model was used to generate runoff volumes for each subarea. The SCS option uses an initial abstraction value, percent impervious, and a pervious curve number (CN) to estimate runoff volumes from each subarea for a particular design rainfall event.

Initial abstraction is defined as losses from rainfall before runoff begins. Initial abstraction is a function of the CN and was calculated in HMS using the following equation:

$$Ia = 0.2(1000/CN - 10)$$

For the runoff calculation, a CN for pervious area was determined. The CN is a function of the land use condition and hydrologic soil group (HSG). The land use characteristics of the pervious area in the Blacksnake Creek watershed were assumed to be open space and fair condition. Blacksnake Creek watershed is comprised of soils in three different soil type classifications: Haynie-Onawa-Waldron, Marshall-Contrary, and Knox. This information was provided by the City of St. Joseph in a GIS layer electronic file, and was verified using the NRCS Soil Survey of Buchanan County, Missouri. These soils are classified as silty-loam soils and have a HSG "B" classification. Figure 4 shows the soil types and their locations in the Blacksnake Creek watershed. The pervious CN used for all Blacksnake Creek subarea basins was a composite value of 69. This CN value is for HSG "B" classification assuming open area and fair soil condition characteristics, and was obtained using "*Table 2-2a: Runoff Curve Numbers for Urban Areas*" from SCS Technical Release No. 55.

FIGURE 4 BLACKSNAKE CREEK WATERSHED SOIL CLASSIFICATIONS



Percent impervious data for each subarea was extracted from the SWMM model subarea electronic shapefile. These data were used to calculate a composite percent impervious for each HMS subarea. The composite percent impervious values were then verified using aerial photos, site visit pictures and notes, and land use information. The percent impervious values for HMS subareas are provided in Table 4.

TABLE 4 COMPOSITE PERCENT IMPERVIOUS VALUES FOR HMS SUBAREAS

Subarea ID	Percent Impervious	Subarea ID	Percent Impervious	Subarea ID	Percent Impervious
BS-01	53	BS-12	28	BS-23	35
BS-02	55	BS-13	44	BS-24	27
BS-03	48	BS-14	27	BS-25	35
BS-04	49	BS-15	35	BS-26	4
BS-05	30	BS-16	30	BS-27	4
BS-06	26	BS-17	22	BS-28	3
BS-07	20	BS-18	36	BS-29	15
BS-08	29	BS-19	38	BS-30	32
BS-09	45	BS-20	35	BS-31	12
BS-10	39	BS-21	61	BS-32	12
BS-11	18	BS-22	49		

2.5 RUNOFF HYDROGRAPHS

The Clark Unit Hydrograph option in HEC-HMS was used to distribute the runoff volume. This method requires a time of concentration value (Tc) and a basin storage coefficient (R) for each subarea.

The time of concentration is generally defined as the time required for a drop of water to travel from the most hydrologically remote point in the subcatchment (or subarea) to the point of collection, which in the Blacksnake Creek HMS model is the subarea outlet. The time of concentration for each subarea was calculated using a combination of the Kirpich formula for overland flow paths and the Manning's formula for open channels and closed conduits.

Overland flow paths were developed in GIS for each subarea. For each subarea, a runoff flow path length (L) and an average watershed slope (S) were calculated in GIS. Using these values, the Kirpich formula was used to calculate time of concentration in minutes for each subarea.

Kirpich formula: $t_c = 0.0078 L^{0.77} S^{-0.385}$, min

L = length of open channel, ft.
S = average watershed slope, ft/ft.

For subareas with closed conduits, and open channels with defined cross-sections, travel times were calculated based on flow path length and flow velocity. Manning's equation was used to

estimate average flow velocities for both open channels and pipe flow. Average flow velocity in open channels was determined for bank-full flow conditions, using channel slope and the cross-sectional geometry. Average flow velocity in pipes was determined assuming pipes at full capacity. The pipe data was extracted from the SWMM model.

The basin storage coefficient, R, for each subarea was calculated using the following equations:

$R = 1.0 * T_c$ for fan-shaped subarea
$R = 1.67 * T_c$ for average-shaped subarea
$R = 2.33 * T_c$ for linear-shaped subarea

The subarea shape was determined using engineering judgment and available mapping. The values for time of concentration (Tc) and basin storage coefficient (R) for HMS subareas are listed in Table 5.

TABLE 5 TIME OF CONCENTRATION (T_C) AND BASIN STORAGE COEFFICIENT ®

Subarea ID	T_c (hr)	R (hr)	Subarea ID	T_c (hr)	R (hr)	Subarea ID	T_c (hr)	R (hr)
BS-01	0.18	0.30	BS-12	0.22	0.52	BS-23	0.26	0.43
BS-02	0.16	0.26	BS-13	0.36	0.60	BS-24	0.19	0.45
BS-03	0.16	0.27	BS-14	0.32	0.74	BS-25	0.23	0.54
BS-04	0.19	0.31	BS-15	0.24	0.40	BS-26	0.30	0.49
BS-05	0.22	0.51	BS-16	0.24	0.41	BS-27	0.39	0.65
BS-06	0.21	0.35	BS-17	0.25	0.42	BS-28	0.57	1.33
BS-07	0.23	0.39	BS-18	0.32	0.54	BS-29	0.19	0.31
BS-08	0.23	0.54	BS-19	0.36	0.84	BS-30	0.26	0.43
BS-09	0.17	0.28	BS-20	0.22	0.52	BS-31	0.61	1.42
BS-10	0.20	0.47	BS-21	0.16	0.26	BS-32	0.42	0.98
BS-11	0.18	0.29	BS-22	0.24	0.55			

2.6 CHANNEL ROUTING (MUSKINGUM-CUNGE)

The Muskingum-Cunge Routing method was used in the HMS model to route runoff through the watershed. An eight-point channel cross section was developed for each routing reach using the ArcView profiler tool and the Digital Elevation Model (DEM) created from two-foot contour data. Channel length and slope were also determined using this tool. The channel lengths and slopes for the subarea routing reaches are listed in Table 6.

TABLE 6 CHANNEL LENGTH AND SLOPE FOR HMS ROUTING REACHES

Reach ID	Length (Feet)	Slope (ft/ft)
R-01	3,078	0.007
R-02	901	0.002
R-03	1,728	0.004
R-04A	1,341	0.011
R-04B	1,288	0.003
R-05	2,918	0.009
R-06	1,344	0.011
R-07	3,612	0.020
R-09	1,129	0.011
R-10	2,640	0.002
R-11A	706	0.015
R-11B	1,644	0.009
R-13	918	0.005
R-14A	3,234	0.016
R-14B	906	0.002
R-16	2,018	0.002

Reach ID	Length (Feet)	Slope (ft/ft)
R-17	1,081	0.010
R-17A	1,141	0.012
R-18	1,197	0.005
R-18A	613	0.006
R-18B	757	0.017
R-19	984	0.001
R-19A	1,466	0.014
R-20	1,033	0.002
R-21	684	0.018
R-24	736	0.031
R-25	1,247	0.011
R-25A	2,753	0.006
R-26	1,740	0.009
R-27	2,017	0.008
R-28	1,457	0.004
R-29	1,707	0.014

2.7 WATERSHED STORAGE

Existing conditions in the Blacksnake Creek watershed do not include any storage areas designated for flood risk management. Modeling and evaluation of detention storage for flood risk management purposes would be appropriately addressed in a future conditions analysis.

Currently, there are no defined storage areas for Blacksnake Creek watershed existing conditions. Analysis of future conditions would evaluate and model the impact of a detention storage located directly upstream of Karnes Road and the CSS inlet, and the effect this detention would have on flood risk management in the lower portion of the Blacksnake Creek watershed. However, it should be noted that future conditions modeling is not part of the Blacksnake Creek study covered by this report.

2.8 MODEL VERIFICATION

The HEC-HMS model results were compared to the Missouri Urban Regression Curve shown in Figure 5 (Figure 5602-2, Section 5600, *Storm Drainage Systems and Facilities*, Kansas City Metropolitan Chapter, APWA, November 2005). A basin development factor (BDF) of 9 was chosen because it best reflects the development in the Blacksnake Creek study area. Based on this curve, the 0.01-ACE discharge was estimated and compared for two locations within the watershed: at the basin outlet to the Missouri River (Junction J-01 in the HMS model) and at Karnes Road (Junction J-13 in the HMS model). The hydrologic model results were within +/- 10% of the regression equation values. These results are shown in Table 7. Because the Blacksnake Creek watershed is an ungaged system there are no records of measured stream flows to compare to computed discharges.

FIGURE 5 MISSOURI REGRESSION CURVES – RURAL AND URBAN

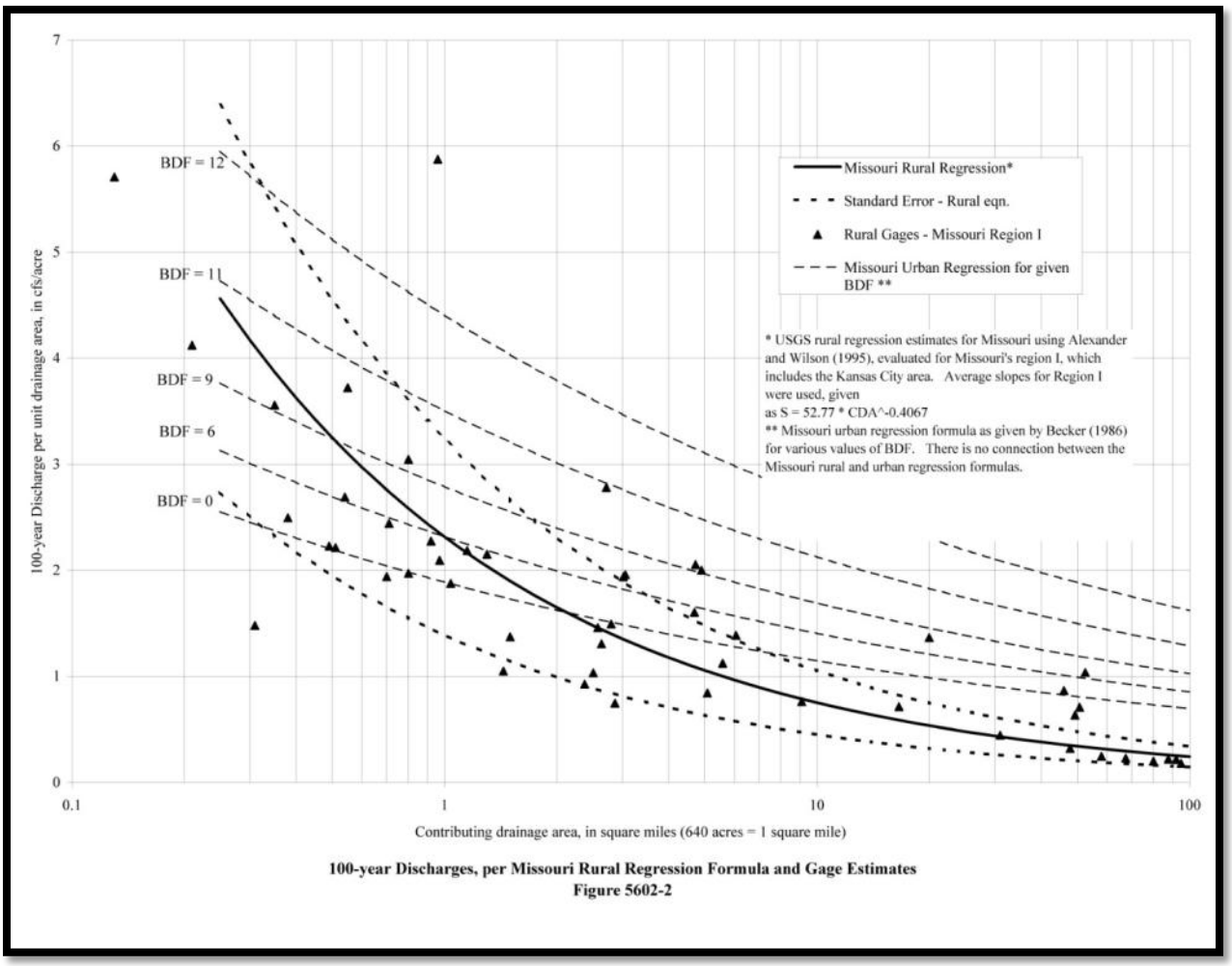


TABLE 7 HEC-HMS MODELING RESULTS COMPARISON

Hydrologic Location ID	Description	0.01 ACE (cfs)	Area (sq. mi.)	Area (acre)	(cfs/ac)	Missouri Urban Regression, 0.01 ACE (cfs/acre)
Junction 01	Basin Outlet at Missouri River	10325	8.21	5,254	1.96	1.72
Junction 13	Karnes Road-End of Open Channel	7296	5.22	3,338	2.18	1.92

2.9 MODEL RESULTS

Table 8 presents the HEC-HMS modeling results for existing conditions at the junctions located at Karnes Road and at the confluence with the Missouri River. Frequency flow rates from HMS were

used to develop the hydraulic model input. The hydraulic model is described in Section 3, which follows.

TABLE 8 HEC-HMS MODELING RESULTS

Hydrologic Location ID	Description	Existing Conditions Peak Flow Rates (cfs)								
		1 ACE	0.5 ACE	0.2 ACE	0.1 ACE	0.04 ACE	0.02 ACE	0.01 ACE	0.004 ACE	0.002 ACE
Junction 13	Karnes Road	1533	1996	2856	3705	4978	6069	7296	8988	10715
Junction 01	Confluence with Missouri River	2069	2725	3943	5135	6994	8578	10325	12717	15099

3 HYDRAULICS

3.1 HYDRAULIC MODEL DEVELOPMENT

Hydraulic modeling was performed using HEC-RAS Version 4.1.0 steady state option. This section provides a description of the methodology used to develop the RAS hydraulic model for the Blacksnake Creek Feasibility Study. The objective was to produce a detailed hydraulic model that reflects the complexities in local topography, provides an effective tool for assessing flood risk, and can be used to evaluate options for reducing flood risk. Based on existing topography and land use conditions, the RAS model simulates the watershed's primary stormwater flow path in the lower portion of the basin. The model extends from just upstream of Karnes Road to the confluence with the Missouri River. The RAS model calculates water surface elevations (WSE) for the design storms described previously in this report.

The paragraphs of this section present descriptions of the development process for the Blacksnake Creek RAS model. Topics include the procedures for developing RAS model parameters and creating the Blacksnake Creek RAS model. Use of the RAS steady state flow option is discussed. RAS results are tabulated and evaluated.

3.2 HEC-RAS MODEL

HEC-RAS model data requirements can be summarized into ten model parameters. Table 9 lists the ten parameters and the methods used to develop the data requirements. These model parameters were developed using a combination of manual procedures, and the automation tools ArcGIS and HEC-GeoRAS in conjunction with GIS data. The following paragraphs describe the HEC-RAS model development procedures.

TABLE 9 HEC-RAS PARAMETER DEVELOPMENT

HEC-RAS Model Parameter	Development Method	Data Requirements
Stream network	ArcGIS	Stream centerline coverage with unique stream reach names
Cross sections (river station and geometry data)	ArcGIS and HEC-GeoRAS	Triangular irregular network (TIN), cross section cut line coverage
Downstream reach lengths (channel and overbanks)	ArcGIS and HEC-GeoRAS	Stream centerline and overbank (left and right) flow path coverage
Manning's n-values	ArcGIS	Manning's n-value assigned based on orthophotos and field observations
Crossings	Manual input using field survey data where available	Roadway profile and bridge opening
Expansion and contraction coefficients	Manual input using standard values and engineering judgment	Contours and cross section cut line coverage
Boundary conditions	Manual input	Known WSE boundary condition
Ineffective flow areas	Manual input using RAS standard procedures and engineering judgment	Contours and cross section cut line coverage
Blocked obstructions	Manual input using RAS standard procedures and engineering judgment	Aerial photography and site visit photos
Channel bank stations	Manual input using RAS standard procedures and engineering judgment	Cross section geometry (station and elevation data)

3.2.1 STREAM NETWORK, CROSS SECTIONS, AND REACH LENGTHS

The first step in developing the RAS model was creation of a RAS geometry file containing the stream centerline, cross section river stations and geometry, and downstream reach lengths for the channel and overbanks. The stream centerline defines the main channel. The model extends from 1,500 feet upstream of Karnes Road to the mouth of Blacksnake Creek at the Missouri River.

Primary drainage for low flow in this reach is currently provided by a closed conduit combined sewer system (CSS). The entrance to the CSS is located at Karnes Road. The Blacksnake Creek watershed upstream of Karnes Road drains into the CSS at this location. There is no defined channel that conveys flows downstream of Karnes Road. Flows in the RAS model below Karnes Road, which exceed the capacity of the CSS, are routed via overland flow.

The Blacksnake Creek RAS model does not include the CSS. The CSS below Karnes Road is a network of closed conduits of various shapes and sizes. These flow conditions cannot be modeled using RAS steady flow. In order to simulate the overland flow in the Blacksnake Creek watershed

below Karnes road, flows into the RAS model are reduced by the inflow into the CSS at Karnes Road. HMS flows into the RAS model below Karnes Road are reduced by the capacity of the CSS. The capacity of the CSS was calculated from the results of the SWMM model, which modeled flows in the network of conduits of the CSS. An average capacity of the CSS below Karnes Road was calculated from the SWMM results and used to develop the flows into the RAS model below Karnes Road.

To represent the geometry of the Blacksnake Creek basin downstream of Karnes Road in HEC-RAS, channel cross-sections were developed using the available two-foot contour information. Cross section river stations mark the location of the cross section along the overland flow path in feet measured upstream from the Blacksnake Creek confluence. Cross section geometry includes station and elevation data. Downstream reach lengths define the distance to the next downstream cross section along the assumed stream channel location, and along the left and right overbanks.

This study used HEC-GeoRAS in conjunction with ArcGIS to prepare an export file of the stream and cross section geometry data values, which were directly imported by RAS. This was used to create a geospatially referenced RAS geometry file.

HEC-GeoRAS is a public domain software program developed by USACE HEC. HEC-GeoRAS uses the following data to create the export file:

3.2.1.1 Triangular Irregular Network (TIN)

The TIN was created from the St. Joseph two-foot contour data using ArcGIS. The TIN is a surface representing the ground topography and is used in conjunction with the cross section cut line coverage to develop station and elevation information for cross section geometry data. A ground surface elevation was recorded at each station along the cross section cut line that crosses a TIN edge.

3.2.1.2 Stream Centerline Coverage

The stream centerline coverage was manually digitized in ArcGIS at the thalweg of the main overland flow path. Available aerial photographs, contour data, and the XPSWMM hydraulic network developed in a previous study were used as guidelines in the development process. HEC-GeoRAS requires a river name and reach name be assigned to each line segment. For the purpose of this study, the river name was assigned “Blacksnake Creek” and the reach name was assigned “Surface.”

3.2.1.3 Cross Section Cut Line Coverage

The cross section cut line coverage is a GIS line coverage that identifies the location and extent of each cross section. The cross section cut line coverage was generated in ArcGIS. Available aerial photographs and contour information were used to lay out the cross section cut lines. Also, the St. Joseph, Missouri, Buchanan County FEMA FIS study (September 1984) was used as a guide in determining the extent of the cross sections.

Cross section cut lines were located in order to represent the average geometry of the stream reach. Cut lines were placed along the stream centerline at changes in geometry, slope, channel width, overbank roughness, and discharge.

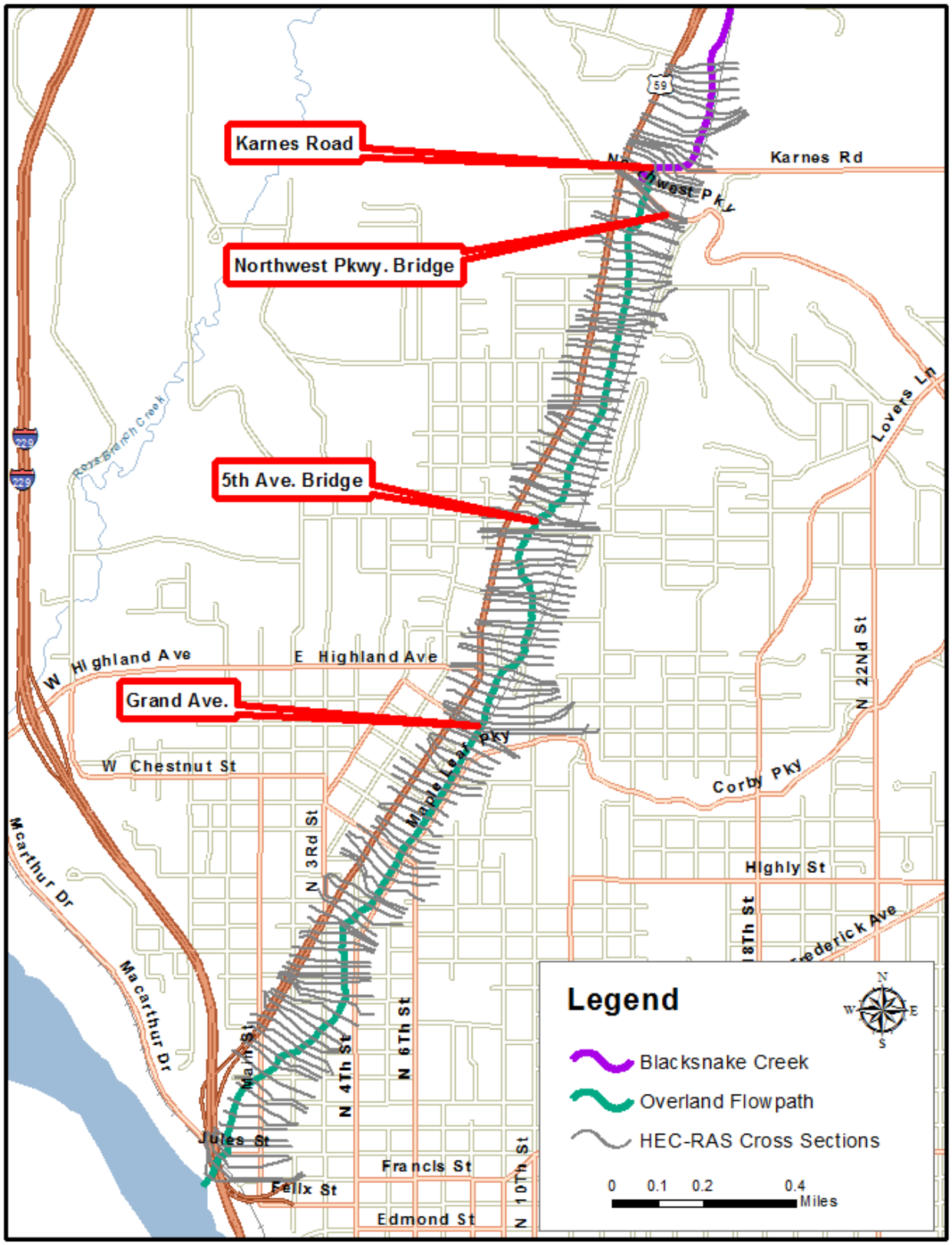
Aerial photographs and field reconnaissance confirm that many obstructions in the form of houses and buildings from residential, commercial, and industrial development exist along the primary overland flow path for Blacksnake Creek. To capture accurately the location and geometry of these obstructions in the HEC-RAS model, cut lines to define cross-sections were placed approximately every 100 feet or less.

Figure 6 shows the layout of the cross section cut lines. The cross section cut lines are oriented from left to right looking downstream. Each cross section is defined by the station-elevation data and the Manning's n-values. The river station for each cross section is the cumulative distance in feet measured from the designated point of confluence of Blacksnake Creek and the Missouri River, upstream to the cross section's location.

3.2.1.4 Overbank Flow Path Coverage

The overbank flow path coverage is a GIS line coverage that represents the average left and right overbank flow paths between each cross section. The overbank flow path coverage is used to determine the downstream reach lengths for the left and right overbanks. Available aerial photographs and the contour information were used as a guide to locate manually the overbank flow paths. In general, the overbank flow path was located on the top of the channel bank at each side of the designated stream centerline.

FIGURE 6 BLACKSNAKE CREEK HYDRAULIC LAYOUT



3.2.2 Manning's n-Values

The Manning's n-values at each cross section were estimated using digital aerial and field photographs. Manning's n-values were selected to represent land surface characteristics as listed in Table 10. The initial n-values were used as a model starting point and were adjusted within the range, if needed, to simulate site specific characteristics. Horizontally-varied Manning's n-values may be input in the HEC-RAS model to capture changes in land use spanning the cross section.

Table 10 Land Surface Characteristics and Associated Manning's n-Values[1]

Land Surface Type	Initial n Value	Range of n-Value
Grass, urban and maintained	0.030	0.025 to 0.035
Trees and brush	0.090	0.035 to 0.160
Brush	0.060	0.035 to 0.160
Residential/Commercial areas2	0.120	0.045 to 0.120
Open field, medium to tall grass	0.035	0.025 to 0.060
Pavement	0.020	0.013 to 0.025
Open Water	0.025	0.016 to 0.033

[1] Source: Open Channel Hydraulics, Chow 1959.
[2] These n-values will be used in developed areas to account for the loss of conveyance caused by buildings.

In order to account for conveyance loss in developed urban areas, the overbank n-values were increased outside of the normal range where there is obstruction from buildings located within the floodplain. The n-values in these areas range from 0.050 to 0.12. A value of 0.050 was used for areas with open space and manicured turf grass. A value of 0.12 was used for fully developed areas with obstructions from homes and buildings. If significant blockage is caused by buildings in the flood fringe, the developed areas were also modeled utilizing blocked obstructions.

3.2.3 Bridge/Roadway Crossings

There are three main bridge/roadway structures that cross the main Blacksnake Creek overland flowpath. These structures are shown on Figure 6; Fifth Avenue Bridge, Northwest Parkway Bridge, and Grand Avenue. During the initial site visit, it was confirmed that the bridge structures do not cross directly over the main overland flow path. They are located on the far left overbank with an average linear distance of over 500 feet from the channel centerline. Based on field observations and model results, the parallel flow path does not effectively convey flow. The site visit report and photos can be found in Appendix B.

For modeling of future conditions, Northwest Parkway Bridge and Fifth Avenue Bridge were added to the model. The eight-foot CMP pedestrian tunnel adjacent to the Northwest Parkway Bridge was also added to the model at cross-section 13384. The multiple opening analysis function in HEC-RAS was used. The computed WSEs were not found to be sensitive to the inclusion or exclusion of the pedestrian tunnel and the two bridges. Possible explanations for this include the structures' elevations, geometry, and distances from the channel centerline.

3.2.4 EXPANSION AND CONTRACTION COEFFICIENTS

The expansion and contraction coefficients were estimated based on the ratio of expansion and contraction of the effective flow area in the floodplain occurring at cross sections and at roadway crossings. Typical coefficients used in the model are listed in Table 11. The expansion and contraction coefficients were input manually using the HEC-RAS cross section editor.

TABLE 11 EXPANSION AND CONTRACTION COEFFICIENTS[1]

Transition Type	Expansion Coefficient	Contraction Coefficient
Gradual	0.3	0.1
Bridge/Roadway Crossing/Obstruction	0.5	0.3
Abrupt	0.8	0.6

[1] Data from HEC-RAS Hydraulic Reference Manual, Page 3-21

In the Blacksnake Creek model, expansion and contraction coefficients were increased at cross-sections that had multiple blocked obstructions or blocked obstructions causing narrowed flow area. The expansion and contraction coefficients of cross-sections directly upstream and downstream of obstructions were also altered to account for the decreased flow area.

3.2.5 BOUNDARY CONDITIONS

A required input for the hydraulic model was specification of a downstream boundary condition. The Blacksnake Creek watershed is much smaller than the watershed of the main stem Missouri River. Peak flow conditions for these two streams result from different hydrologic conditions. Flood conditions on the Missouri River are the result of large regional weather patterns that produce extended, successive precipitation events.

Peak flood conditions in the considerably smaller Blacksnake Creek watershed are produced by intense, localized precipitation events. The coincident occurrence of both conditions is unlikely and statistically independent.

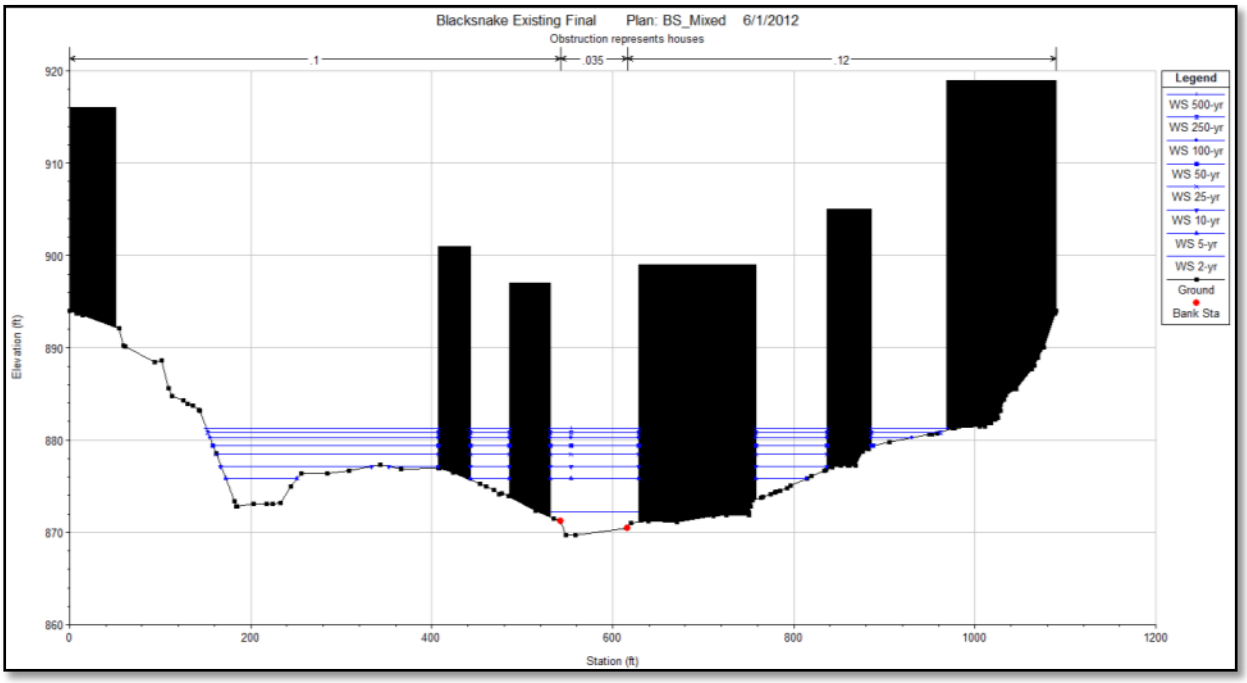
Anecdotal information available from previous reports, and information available to USACE Kansas City District, indicates that on multiple occasions intense, local precipitation in the Blacksnake Creek watershed has occurred while stages in the Missouri River remained below the elevation estimated to have a 0.5 ACE recurrence interval. In addition, due to the steep natural topography near the mouth of Blacksnake Creek, which drops approximately 30 feet over the last 400 feet of the overland flow path, WSEs for Blacksnake Creek are not sensitive to WSEs on the Missouri River for more frequent floods.

For the purpose of this analysis, it was assumed that the Missouri River stage would be no greater than what would be seen for a 0.5 ACE recurrence interval. The 0.5 ACE WSE of 808 feet was determined from the effective FEMA Flood Insurance Study applicable to the Missouri River at the mouth of Blacksnake Creek. This elevation was specified as the downstream boundary condition in the Blacksnake Creek HEC-RAS model.

3.2.6 Blocked Obstructions and Ineffective Flow Areas

Blocked obstructions and ineffective flow areas were determined using the cross section plots, aerial photos, and information collected during field visits. These RAS options were used to simulate buildings, houses, and other large obstructions in the Blacksnake Creek overland flow path. They were input manually using the HEC-RAS cross section editor. Figure 7 shows a typical cross section with multiple blocked obstructions.

Figure 7 Typical Cross Section with Multiple Blocked Obstructions



3.2.7 Channel Bank Stations

The bank stations were located and entered manually by graphically editing the cross sections within HEC-RAS. The bank stations were placed based on review of the GIS generated cross section geometries, the site visit photos and report, and the typical open channel section for developed areas.

3.3 Steady Flow Water Surface Profiles

Stream profiles were developed depicting the 1, 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 ACE WSEs. Frequency flows used were based on output from the HEC-HMS model, which was discussed in Section 2 of this report. Flow change locations were developed with consideration of HEC-HMS junctions, and input into HEC-RAS at geographically correct load points.

Flow change locations downstream of Karnes Road (Junction J-13) include only overland flow. The HEC-RAS model does not include a simulation of the CSS. All flows modeled below Karnes Road are routed via the overland flow path. Flows in the RAS model below Karnes Road are the HMS flows reduced by the average full flow capacity of the CSS, which was calculated to be 1803 cfs. A base flow of 5 cfs is used where this subtraction of flow would result in a negative flow condition. The

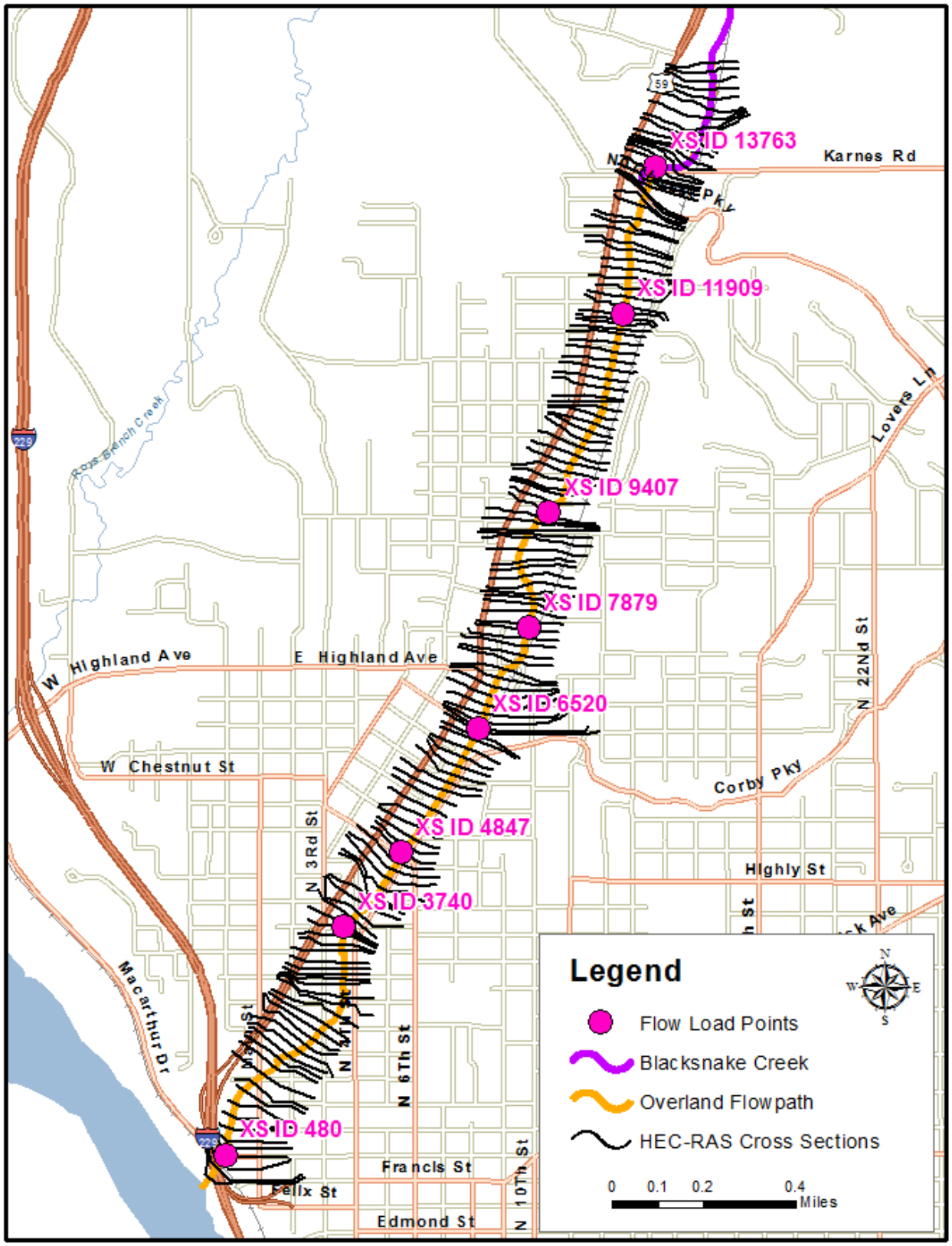
amount of flow at each load point is listed in Table 12. The cross section location of the flow load points in HEC-RAS are shown in Figure 8.

TABLE 12 FLOWS USED IN EXISTING CONDITIONS HEC-RAS MODEL

		Event (ACE)/Peak Flow (cfs)								
HEC-HMS Junction ID	**XS* Station ID**	**1**	**0.5**	**0.2**	**0.1**	**0.04**	**0.02**	**0.01**	**0.004**	**0.002**
J-16	15365	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527	1485	1933	2770	3595	4835	5899	7100	8754	10447
J-13	13763	5	192	1053	1901	3175	4265	5493	7185	8911
J-11	11909	5	343	1272	2191	3577	4756	6082	7912	9774
J-10	9407	5	366	1312	2242	3662	4867	6214	8065	9937
J-09	7879	5	427	1401	2359	3824	5067	6452	8360	10285
J-04	6520	198	829	1995	3139	4914	6421	8082	10365	12650
J-03	4847	230	872	2061	3227	5040	6580	8279	10611	12939
J-02	3740	236	881	2077	3250	5073	6626	8340	10687	13026
J-01	480	266	922	2139	3332	5190	6774	8522	10914	13295

*XS = cross section

FIGURE 8 BLACKSNAKE CREEK FLOW LOADING POINTS



3.4 MODEL RESULTS

Figure 9 illustrates the generated WSE profiles for selected design events from the HEC-RAS model. These are also given in Table 13 for five selected cross-sections. Table 13 also lists the peak flow in cfs, and the average velocity in ft/s, for the selected cross-sections.

TABLE 13 EXISTING CONDITIONS HEC-RAS MODEL RESULTS AT SELECTED CROSS-SECTIONS

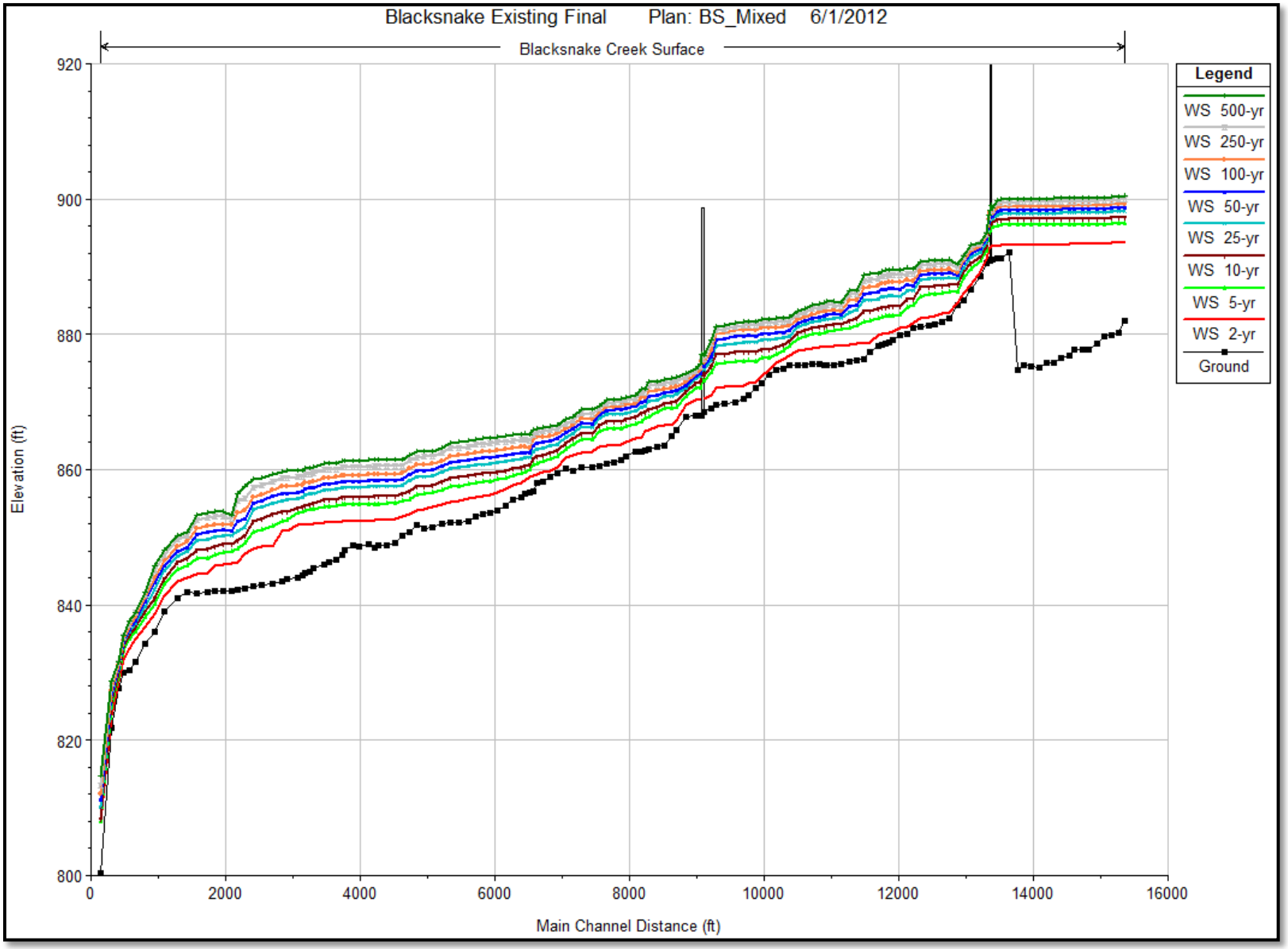
Cross Section	Description	Return Period (ACE)	Q Total* (cfs)	W.S. Elev* (ft)	Vel Chnl* (ft/s)
15365	Upstream of Karnes Road	1	1331	893.44	2.2
		0.5	1732	894.84	3.0
		0.2	2489	896.57	3.1
		0.1	3234	897.44	3.5
		0.04	4369	898.43	3.8
		0.02	5350	899.13	4.0
		0.01	6458	899.83	4.2
		0.004	7983	900.68	4.5
		0.002	9559	901.45	4.6
13763	Karnes Road	1	5	893.01	0.0
		0.5	192	894.47	0.1
		0.2	1053	896.3	0.6
		0.1	1901	897.16	0.9
		0.04	3175	898.11	1.2
		0.02	4265	898.79	1.4
		0.01	5493	899.46	1.5
		0.004	7185	900.27	1.7
		0.002	8911	901.03	1.9
8987	5th Street	1	5	868.36	0.3
		0.5	366	870.62	1.6
		0.2	1312	872.03	3.9
		0.1	2242	872.78	4.8
		0.04	3662	873.62	5.8
		0.02	4867	874.09	6.5
		0.01	6214	874.47	7.4
		0.004	8065	875.19	8.4
		0.002	9937	875.9	8.9

TABLE 13 EXISTING CONDITIONS HEC-RAS MODEL RESULTS AT SELECTED CROSS-SECTIONS (CONTINUED)

Cross Section	Description	Return Period (ACE)	Q Total* (cfs)	W.S. Elev* (ft)	Vel Chnl* (ft/s)
6520	Grand Avenue	1	198	858.07	0.6
		0.5	829	859.11	4.0
		0.2	1995	860.01	7.3
		0.1	3139	860.72	8.8
		0.04	4914	861.95	9.6
		0.02	6421	862.91	10.5
		0.01	8082	864.05	10.7
		0.004	10365	865.52	10.1
		0.002	12650	866.96	9.5
1284	Robidoux Street (US of Missouri River)	1	236	842.25	0.0
		0.5	881	843.77	3.9
		0.2	2077	845.24	6.8
		0.1	3250	846.31	8.4
		0.04	5073	847.44	10.4
		0.02	6626	848.31	11.6
		0.01	8340	849.5	12.4
		0.004	10687	850.42	13.3
		0.002	13026	851.32	14.3

* Q Total = total flow, cfs
W.S. Elev = water surface elevation , feet
Vel Chnl = velocity in the channel, fps

FIGURE 9 EXISTING CONDITIONS WSE PROFILES



3.5 COMPARISON OF RAS AND FEMA FIS WSE

After the HEC-RAS model was developed, the WSEs calculated in HEC-RAS were compared to the WSEs in the St. Joseph, Missouri, Buchanan County FEMA FIS study (September 1984). Table 14 provides a comparison of the resulting RAS model WSEs to those from the FIS study at two locations along Blacksnake Creek – Karnes Road and Grand Avenue.

TABLE 14 WSE COMPARISONS OF BLACKSNAKE CREEK

Location	Design Event (ACE)	HEC-RAS WSE (ft)	FEMA FIS WSE (ft)	Difference (ft)
Karnes Road (13763)	0.1	897.16	N/A[1]	N/A[1]
	0.04	898.79	894.8	4.0
	0.01	899.46	895.5	4.0
	0.002	901.03	896.9	4.1
Grand Avenue (6520)	0.1	860.72	N/A[1]	N/A[1]
	0.04	862.91	860.0	2.9
	0.01	864.05	860.5	3.5
	0.002	866.96	861.4	5.6

Note 1: The FIS assumed that the 0.1 ACE storm flow did not exceed the capacity of the CSS, as such no FIS WSE was created for this storm event by FEMA.

The increases in WSE at hydraulic locations in Table 3-6 were likely due to the additional detail, available information, and assumptions used for this study compared to FEMA FIS. For example:

- Updated topography was used to define cross-sections for the overland flow path
- Urban development has occurred since the FEMA FIS study
- Updated hydrology was developed to define the flood flows used in the hydraulic model.
- The FEMA FIS study assumed the 0.1 ACE discharge to flow underground into the CSS.

4 H&H EVALUATION OF ALTERNATIVES

Eight structural flood mitigation alternatives were considered for Blacksnake Creek. The structural measures considered included the excavation of a detention basin and construction of a detention dam, levee, and floodwall. Initial plan formulation included the development and engineering review of four dry detention plans for the area north of Karnes Road and east of St. Joseph Avenue. Each proposed alternative are briefly outlined below.

Alternative 1 - Alternative 1 raises Karnes Road to elevation 905 NGVD to act as a detention dam but includes no excavation of the existing basin to increase storage. This alternative also includes construction of a levee and a floodwall upstream of Karnes Road to provide protection to existing residences and structures. The levee would be located to the east of and parallel to St. Joseph

Avenue. The floodwall would be located farther upstream, just to the north of Savannah Road. In this alternative, an overflow spillway at Karnes Road would be the point of overtopping.

Alternative 2 - Alternative 2, in addition to the features of Alternative 1, would excavate the detention basin within the Blacksnake Creek floodplain north of Karnes Road between St. Joseph Avenue and an abandoned railroad right-of-way to increase the detention capacity.

Alternative 3 - Alternative 3 would increase the detention capacity of Alternative 2 by extending the detention area to the east of the abandoned railroad right-of-way. The abandoned railroad right-of-way would be removed to access the additional detention volume to the east.

Alternative 4 - Alternative 4 would increase the detention capacity of Alternative 3 by removing a portion of Karnes Road, extending the levee downstream of Karnes Road to Northwest Parkway, and additional excavation within the basin area. This alternative does not include the replacement of Karnes Road. In this alternative, an overflow spillway at Northwest Parkway would be the point of overtopping.

Alternative 5 - The Blacksnake Creek floodplain north of Karnes Road between St. Joseph Avenue and an abandoned railroad right-of-way would be excavated to increase the detention capacity. The abandoned railroad right-of-way along the east side of the basin would be removed to access additional detention volume to the east. An overflow spillway would be constructed at an elevation of 895 NGVD on Karnes Road. In this alternative, an overflow spillway at Karnes Road would be the point of overtopping.

Alternative 6 - Alternative 6 would increase the detention capacity of Alternative 5 by excavating the area between Karnes Road and Northwest Parkway. Culverts would be constructed to provide a connection between the areas north and south of the Karnes Road. In this alternative, an overflow spillway constructed at an elevation of 895 NGVD at Northwest Parkway would be the point of overtopping.

Alternative 7 - Alternative 7 would increase the detention capacity of Alternative 6 by expanding the basin north of Karnes Road to the west. This alternative would require the purchase and demolition of the residences on the west side of the basin along St. Joseph Avenue. In this alternative, an overflow spillway constructed at an elevation of 895 NGVD at Northwest Parkway would be the point of overtopping.

Alternative 8 - Alternative 8 modifies Alternative 6 by removing Karnes Road. The removal of Karnes Road reduces the construction cost by eliminating the need to raise, reconstruct, and armor the road, and for the installation of culverts to provide a hydraulic connection between the basin areas north and south of the road. This alternative was not included in the H&H modeling tables and figures because the results are identical to Alternative 6.

4.1 ALTERNATIVES HYDROLOGY

The HEC-HMS model developed for the existing conditions evaluation noted in Section 2 was used to evaluate each of the proposed alternatives noted above. The primary modification made to the HEC-RAS model included adding a storage node (DP-1) at Karnes Road to model the effects of the proposed detention basins. For each alternative elevation-storage curves were developed based on the proposed excavation extents and were used to define the storage node in each model (Table 15 and Table 16).

TABLE 15 ELEVATION-STORAGE CURVES FOR ALTERNATIVES 1-4

Elevation (feet)	Storage (Acre-feet)			
	Alternative 1	Alternative 2	Alternative 3	Alternative 4
873.50	0.00	0.00	0.00	0.00
874.75	0.03	1.81	3.19	4.04
876.00	0.12	7.23	12.75	16.14
878.00	0.32	14.47	25.49	32.28
880.00	1.34	29.95	52.37	66.25
882.00	2.96	46.41	80.77	102.05
884.00	5.32	63.86	110.79	139.75
886.00	8.56	83.23	143.27	180.21
888.00	13.18	103.57	177.10	222.30
890.00	19.65	124.91	212.30	266.08
892.00	29.62	149.53	250.09	312.75
894.00	45.64	176.23	289.66	361.56
896.00	69.32	208.09	330.93	412.32
898.00	101.23	243.41	373.63	464.75
900.00	138.60	282.08	417.77	518.85
902.00	180.94	325.12	464.04	575.45
904.00	227.63	372.43	519.55	635.06
905.00	252.62	397.66	538.35	664.86
906.00	277.61	422.89	557.15	694.66
907.00	302.61	448.12	575.94	724.47
908.00	327.60	473.35	594.74	754.27

TABLE 16 ELEVATION-STORAGE CURVES FOR ALTERNATIVES 5-7

Elevation (feet)	Storage (Acre-feet)			
	Alternative 5	Alternative 6[1]	Alternative 7	Alternative 8[1]
873.50	0.00	0.00	0.00	0.00
875.00	3.74	4.61	7.07	4.61
876.50	14.98	18.42	28.27	18.42
878.00	29.95	36.85	56.54	36.85
880.00	61.69	75.78	115.28	75.78
882.00	95.34	116.92	176.39	116.92
884.00	131.01	160.42	239.91	160.42
886.00	168.97	206.55	305.62	206.55
888.00	208.53	254.55	373.16	254.55
890.00	249.64	304.38	442.52	304.38
892.00	292.42	356.18	513.91	356.18
894.00	336.90	410.03	587.46	410.03
895.00	359.14	436.95	624.24	436.95
896.00	381.37	463.87	661.01	463.87
897.00	403.61	490.80	697.79	490.80
898.00	425.85	517.72	734.56	517.72
899.00	448.09	544.64	771.34	544.64
900.00	470.32	571.57	808.11	571.57

1 Hydrology and Hydraulic results of Alternative 8 are identical to Alternative 6

Table 17 presents the HEC-HMS modeling results for existing conditions at the junctions located at Karnes Road and at the confluence with the Missouri River. The flow rates noted in the table are the HMS flows reduced by the average full flow capacity of the CSS, which was calculated to be 1803 cfs.

TABLE 17 HEC-HMS 0.01 ACE MODELING RESULTS FOR ALTERNATIVES

Hydrologic Model ID	Location	0.01 ACE Peak Overland Flow Rates (cfs)[1]								
		Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6[2]	Alt-7	Alt-8[2]
Junction DP-1	Karnes Road	5493	4328	3174	1881	202	3127	2220	295	2220
Junction 01	Missouri River Confluance	8522	5461	4514	4489	4463	4356	4347	4300	4347

1 Flows reduced by CSS capacity of 1803 cfs
2 Hydrology and Hydraulic results of Alternative 8 are identical to Alternative 6

4.2 ALTERNATIVES HYDRAULICS

The HEC-RAS model developed for the existing conditions evaluation noted in Section 3 was used to evaluate each of the proposed alternatives. As noted the HEC-RAS model only models the reach down stream of Karnes Road, which is all overland flow that exceeds the capacity of the CSS system. As such, the only modifications made to the HEC-RAS model included modifying the flow files for each alternative. Flows in the RAS model below Karnes Road are the HMS flows reduced by the average full flow capacity of the CSS, which was calculated to be 1803 cfs. A base flow of 5 cfs is used where this subtraction of flow would result in a negative flow condition. The amount of flow and the cross section location of the flow load points in HEC-RAS are provided in Attachment 3. Water Surface Profiles and velocity results from the HEC-RAS model are listed in Tables 18 & 19 respectively.

TABLE 18 HEC-RAS 0.01 ACE WSES AT SELECTED CROSS SECTIONS

Cross Section	Location	Water Surface Elevation (feet)								
		Existing	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8
15365	Upstream of Karnes Road	899.8	899.3	899.3	898.1	897.3	898.7	898.3	897.4	898.3
13763	Karnes Road	899.4	898.8	898.8	897.0	894.2	898.0	897.3	894.5	897.3
8987	5th Street	874.5	874.0	874.0	872.5	871.1	873.5	872.9	870.8	872.9
6520	Grand Avenue	864.1	862.2	862.2	861.0	861.0	861.4	860.9	860.9	860.9
1284	Rubidoux Street	849.5	847.6	847.6	847.0	847.0	847.0	846.9	846.9	846.9

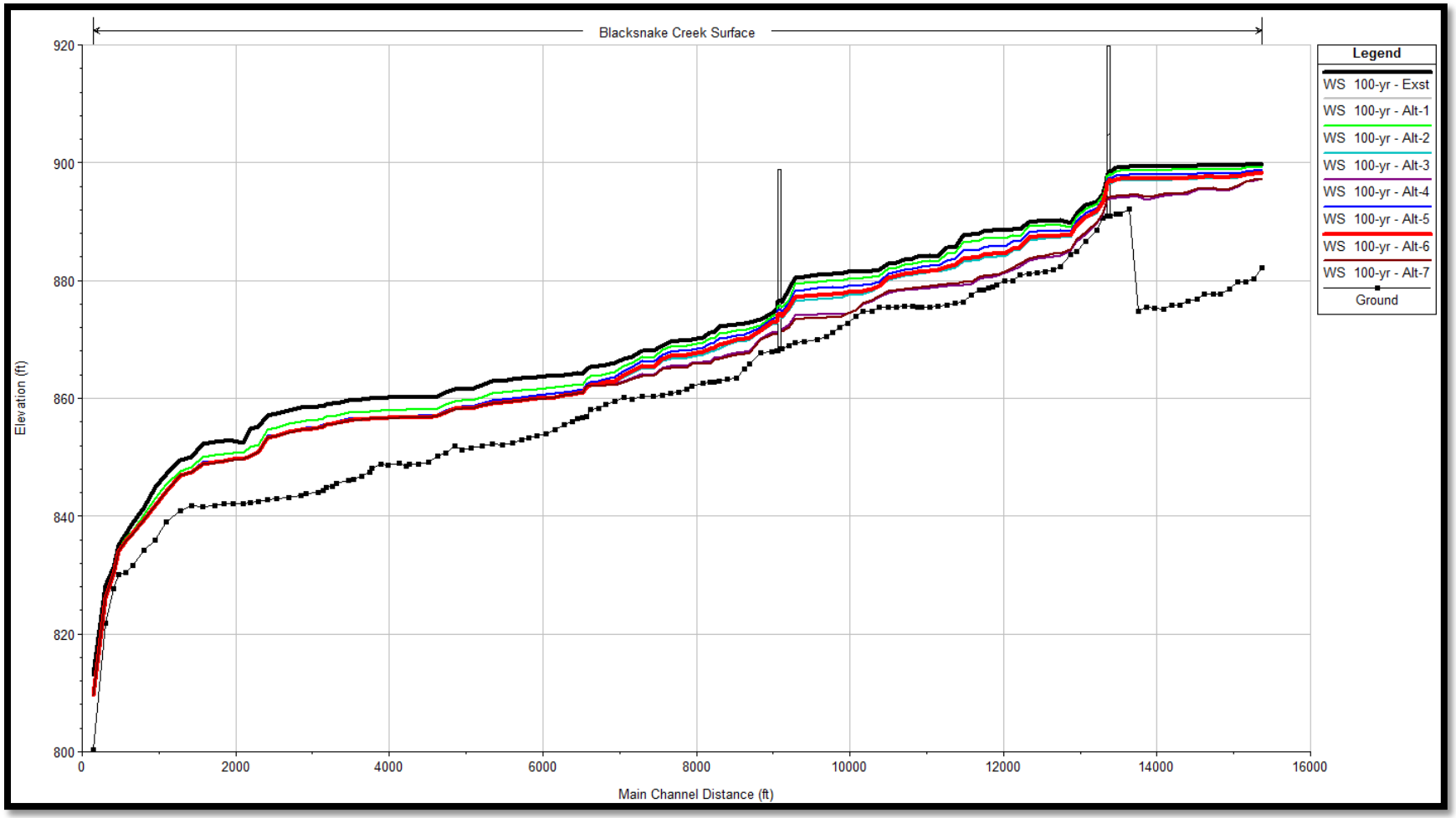
TABLE 19 HEC-RAS 0.01 ACE VELOCITIES AT SELECTED CROSS SECTIONS

Cross Section	Location	Velocities (ft/s)								
		Existing	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7	Alt-8
15365	Upstream of Karnes Road	4.4	4.8	4.8	6.0	7.0	5.3	5.8	6.9	5.8
13763	Karnes Road	1.7	1.5	1.5	0.9	0.2	1.2	1.0	0.2	1.0
8987	5th Street	8.2	6.7	6.7	4.5	2.7	5.8	5.0	2.5	5.0
6520	Grand Avenue	10.4	10.1	10.1	9.1	9.1	9.5	9.0	8.9	9.0
1284	Rubidoux Street	12.9	11.1	11.1	9.5	9.4	9.5	9.3	9.2	9.3

+

The generated WSE profiles for the 0.01 ACE design event from the HEC-RAS models are depicted in Figure 10 for each alternative.

FIGURE 10 0.01 ACE WSE PROFILES FOR EXISTING CONDITIONS AND ALTERNATIVES



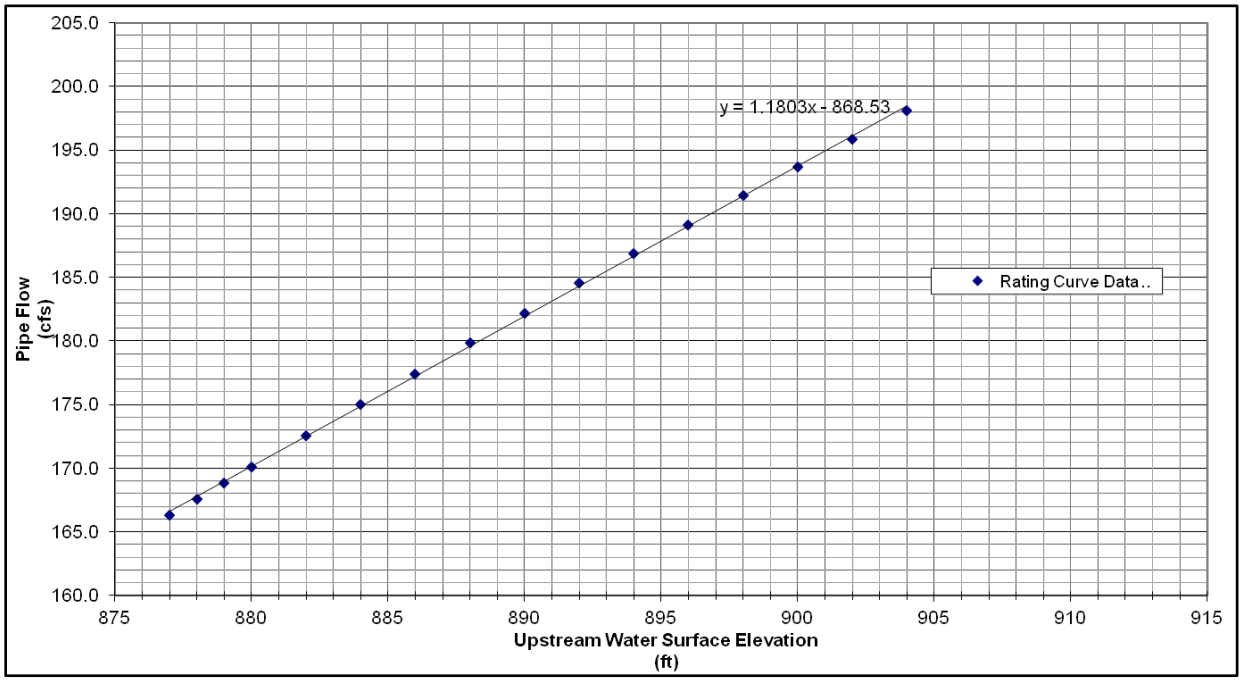
Hydrology and Hydraulic results of Alternative 8 are identical to Alternative 6

4.3 CONSIDERATION OF PROPOSED CSS IMPROVEMENTS

The City of St. Joseph, Missouri, contracted with Black & Veatch engineering firm to develop potential alternatives to remove a portion of the Blacksnake Creek flows from the city's combined sewer system (CSS). For documentation, see the report by Black & Veatch entitled, City of St. Joseph, Missouri, Facilities Plan: Technical Memorandum No. TM-CSO-5, Stormwater Separation Conduits, dated January 15, 2010. The recommended alternative from that report was titled Alternative B, which would divert some Blacksnake Creek flows through a stormwater separation conduit. The proposed inlet of this conduit is located at Karnes Road, just upstream of where Blacksnake Creek flows into the existing Karnes Road CSS entrance.

The City requested that the Kansas City District evaluate flood control Alternatives 1 through 8 with the addition of the proposed stormwater conduit Alternative B. For the purposes of this evaluation, the proposed stormwater separation conduit Alternative B will be called "Outlet B". To assist with evaluating the impacts of Outlet B, Black & Veatch prepared a rating curve for the stormwater separation conduit (Figure 11). The rating curve was used to estimate the peak flow that would be carried by the proposed stormwater conduit.

FIGURE 11 OUTLET B RATING CURVE



The addition of Outlet B was found to either have no effect or provides a slightly lower water surface profile of overland flows downstream of Karnes Road. The amount of flow and the cross section location of the flow load points including the effects of Outlet Bin are provided in Attachment 5. This was the only CSS alternative that was provided for evaluation.

Attachment 1 - Existing Conditions HEC-HMS Model Results

Hydologic Element	Drainage Area (sqmi)	Peak Discharge (cfs)								
		1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
BS-01	0.2522	216.0	264.0	351.6	434.1	560.2	668.3	785.1	942.7	1094.3
BS-03	0.2634	223.6	276.0	372.0	462.9	602.4	722.3	852.1	1027.4	1196.2
BS-04	0.2139	169.4	208.5	280.3	348.2	452.1	541.5	638.1	768.6	894.2
BS-05	0.3603	156.3	201.1	286.0	368.3	496.4	608.1	729.8	895.2	1055.2
BS-06	0.2635	133.2	173.8	250.9	325.6	442.1	543.6	654.1	804.3	949.5
BS-07	0.3392	142.3	189.8	280.7	369.4	509.0	630.8	764.0	945.1	1120.5
BS-08	0.1589	65.2	84.2	120.2	155.2	209.8	257.3	309.1	379.5	447.6
BS-09	0.2757	220.4	273.6	371.4	464.2	606.8	729.6	862.5	1042.1	1215.1
BS-10	0.2378	128.9	161.8	223.2	282.0	373.0	451.7	537.3	653.2	765.1
BS-11	0.2567	123.8	166.7	248.6	328.5	453.7	563.5	683.3	846.3	1004.1
BS-12	0.2399	100.6	130.1	186.1	240.5	325.4	399.2	479.9	589.6	695.8
BS-13	0.1391	66.5	82.5	112.2	140.6	184.3	222.0	262.9	318.3	371.8
BS-14	0.3716	118.1	152.9	219.6	284.6	386.5	475.3	572.4	704.4	832.3
BS-15	0.1701	93.2	118.2	165.1	210.1	279.9	340.5	406.4	495.6	581.9
BS-16	0.2691	134.7	173.2	245.7	315.8	424.8	519.4	622.6	762.8	898.4
BS-17	0.2411	101.3	133.9	196.4	257.4	352.8	436.0	526.9	650.6	770.3
BS-18	0.1863	84.2	106.5	148.3	188.7	251.2	305.4	364.4	444.4	521.7
BS-19	0.2769	97.5	122.3	169.1	214.3	284.4	345.2	411.4	501.3	588.2
BS-20	0.2142	101.1	128.1	178.9	227.8	303.6	369.4	440.9	538.1	632.1
BS-21	0.3249	332.2	401.2	525.6	641.8	818.2	968.9	1131.1	1349.5	1559.4
BS-22	0.2007	113.7	139.8	187.8	233.3	303.3	363.5	428.6	516.7	601.7
BS-23	0.1849	97.0	123.0	171.8	218.7	291.5	354.6	423.2	516.3	606.2
BS-24	0.1671	75.0	97.6	140.4	182.1	247.0	303.6	365.2	449.0	530.1
BS-25	0.2642	121.2	153.7	214.7	273.5	364.7	443.9	530.1	647.0	760.0
BS-26	0.1858	41.3	61.5	101.5	141.7	205.6	262.0	324.0	408.7	491.4
BS-27	0.4869	88.0	130.7	216.2	302.1	439.1	560.6	694.2	877.2	1055.1
BS-28	0.2453	25.3	37.8	63.2	89.1	130.7	167.9	208.9	265.2	320.3
BS-29	0.1723	74.3	101.5	153.9	205.3	286.2	356.9	434.2	539.4	641.3
BS-30	0.2045	101.5	129.8	183.1	234.7	314.8	384.4	460.2	563.0	662.3
BS-31	0.4897	66.0	91.4	141.6	192.1	272.7	344.0	422.5	530.2	635.2
BS-32	0.4216	74.8	104.1	161.9	219.6	311.6	392.8	482.1	604.3	723.2
J-01	8.2094	2069.4	2725.2	3942.5	5135.1	6993.7	8577.8	10325.4	12717.0	15098.6
BS-02	0.1316	125.1	152.5	202.3	249.1	320.4	381.5	447.4	536.3	621.8
J-02	7.9572	2039.4	2684.9	3880.9	5053.6	6876.5	8429.8	10143.0	12490.1	14829.6
J-03	7.8256	2033.3	2675.5	3864.7	5030.4	6843.4	8383.2	10082.9	12414.7	14742.4
J-04	7.5622	2001.3	2632.5	3798.7	4942.7	6717.1	8224.1	9885.6	12168.4	14453.2
J-05	1.1219	410.4	549.4	819.3	1084.3	1502.4	1869.3	2270.6	2816.8	3350.2
J-06	0.7616	290.6	391.1	585.1	775.9	1075.9	1337.6	1625.2	2015.6	2394.3
J-07	0.4981	187.8	251.3	374.1	494.6	684.1	849.8	1030.7	1278.0	1517.9
J-08	0.1589	65.2	84.2	120.2	155.2	209.8	257.3	309.1	379.5	447.6
J-09	6.2264	1702.0	2230.4	3204.8	4162.1	5627.4	6870.1	8255.4	10163.3	12088.4
J-10	5.9507	1656.1	2169.0	3115.1	4045.0	5465.1	6670.7	8017.4	9868.9	11740.6
J-11	5.7129	1643.9	2146.3	3075.6	3994.1	5380.3	6559.7	7885.9	9715.4	11577.8
J-12	0.2399	100.6	130.1	186.1	240.5	325.4	399.2	479.9	589.6	695.8
J-13	5.2163	1533.4	1995.5	2856.2	3704.5	4978.2	6068.6	7296.3	8988.2	10714.6

Attachment 1 - Existing Conditions HEC-HMS Model Results

Hydologic Element	Drainage Area (sqmi)	Peak Discharge (cfs)								
		1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-14	5.0772	1484.6	1932.5	2770.1	3595.4	4835.3	5899.2	7100.2	8754.1	10447.3
J-15	0.1701	93.2	118.2	165.1	210.1	279.9	340.5	406.4	495.6	581.9
J-16	4.5355	1330.9	1732.4	2489.1	3233.5	4369.1	5350.0	6457.8	7982.8	9558.5
J-17	4.2664	1268.8	1669.9	2439.6	3194.4	4365.4	5357.9	6441.2	7921.0	9347.7
J-18	1.3879	723.9	899.3	1224.6	1537.9	2042.5	2442.8	2875.9	3458.4	4024.7
J-19	1.0167	551.5	680.3	917.6	1144.1	1517.7	1801.8	2110.8	2525.9	2928.8
J-19A	0.7398	518.4	634.8	849.0	1051.9	1362.6	1630.1	1914.1	2295.5	2661.0
J-20	0.5256	418.3	508.5	672.2	826.4	1061.4	1265.2	1478.1	1763.2	2035.4
J-22	0.2007	113.7	139.8	187.8	233.3	303.3	363.5	428.6	516.7	601.7
J-23	0.1849	97.0	123.0	171.8	218.7	291.5	354.6	423.2	516.3	606.2
J-24	0.1671	75.0	97.6	140.4	182.1	247.0	303.6	365.2	449.0	530.1
J-25	2.4703	519.9	716.5	1101.8	1485.6	2081.3	2606.8	3187.2	3981.8	4754.1
J-26	2.2061	437.7	609.4	947.8	1285.1	1814.3	2282.0	2796.3	3502.5	4190.1
J-27	0.4869	88.0	130.7	216.2	302.1	439.1	560.6	694.2	877.2	1055.1
J-28	1.5334	315.6	428.1	647.4	865.5	1210.7	1514.2	1846.7	2300.1	2740.9
J-29	0.3768	163.0	215.0	314.5	412.1	564.8	699.0	845.4	1044.4	1238.0
J-30	0.2045	101.5	129.8	183.1	234.7	314.8	384.4	460.2	563.0	662.3
R-01	7.9572	2036.3	2680.4	3875.8	5047.0	6868.2	8420.4	10131.5	12476.2	14812.7
R-02	7.8256	2021.4	2660.7	3845.8	5006.9	6810.8	8348.0	10041.7	12364.5	14680.7
R-03	7.5622	1996.2	2625.1	3790.0	4932.5	6704.0	8208.4	9869.7	12149.2	14428.0
R-04A	1.1219	410.1	548.9	818.0	1082.9	1499.7	1865.3	2265.9	2811.6	3342.6
R-05	0.7616	289.8	390.0	583.2	773.1	1071.6	1332.5	1617.1	2007.1	2384.8
R-06	0.4981	187.4	251.0	373.5	493.7	682.7	848.2	1029.0	1275.8	1514.2
R-07	0.1589	65.1	84.0	120.0	154.9	209.4	256.7	308.4	378.8	446.5
R-04B	6.2264	1691.6	2216.7	3187.2	4138.8	5599.9	6840.6	8220.3	10116.1	12030.0
R-09	5.9507	1655.6	2168.1	3113.9	4043.3	5463.2	6669.0	8013.3	9864.9	11737.2
R-10	5.7129	1601.9	2096.7	3011.6	3909.1	5279.4	6445.0	7745.4	9535.2	11346.6
R-11A	0.2399	100.5	129.8	185.9	240.2	325.1	399.0	479.7	588.8	694.9
R-11B	5.2163	1531.6	1993.7	2853.4	3700.9	4975.3	6065.6	7291.8	8982.0	10708.9
R-14A	0.1701	92.9	117.8	164.5	209.5	279.0	339.3	405.2	494.0	579.8
R-13	5.0772	1482.2	1930.7	2767.4	3591.7	4830.8	5892.1	7087.0	8735.1	10419.5
R-14B	4.5355	1322.1	1722.2	2472.1	3210.2	4319.4	5274.2	6349.2	7832.5	9354.4
R-16	4.2664	1249.7	1627.1	2339.4	3039.1	4107.2	5029.9	6071.1	7505.1	8988.9
R-17	4.0253	1199.3	1575.2	2296.3	3002.7	4095.9	5026.3	6040.5	7429.9	8768.0
R-24	0.1671	75.0	97.5	140.2	181.8	246.8	303.3	364.8	448.7	529.3
R-25	2.4703	519.6	716.0	1101.0	1484.0	2079.8	2605.5	3184.8	3979.3	4750.4
R-17A	1.3879	723.1	898.1	1223.6	1535.3	2040.5	2438.8	2872.7	3454.7	4019.8
R-18A	1.0167	550.6	678.8	915.8	1142.1	1515.1	1799.5	2107.2	2519.5	2921.8
R-18B	0.1849	96.9	122.8	171.6	218.5	291.3	354.1	422.5	515.3	605.1
R-18	1.2016	642.1	794.7	1078.7	1351.0	1793.8	2138.4	2512.8	3015.8	3504.4
R-20	0.2007	108.5	133.5	179.5	223.3	294.0	349.3	408.3	488.1	565.0
R-19A	0.5256	417.2	507.0	670.5	824.5	1059.2	1260.9	1473.2	1757.3	2028.9
R-19	0.7398	457.8	562.9	756.9	941.5	1249.0	1479.0	1726.5	2058.0	2379.2
R-25A	2.2061	435.3	606.1	942.7	1279.2	1806.6	2271.1	2783.7	3486.3	4170.7
J-17A	4.0253	1200.1	1576.4	2297.8	3004.8	4098.6	5029.1	6043.9	7438.9	8783.9

Attachment 1 - Existing Conditions HEC-HMS Model Results

Hydologic Element	Drainage Area (sqmi)	Peak Discharge (cfs)								
		1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-18A	1.2016	646.2	800.9	1085.9	1360.0	1805.2	2152.0	2529.4	3034.7	3526.5
R-27	0.4869	87.7	130.3	215.4	301.0	437.8	558.6	691.9	874.2	1050.1
R-26	1.5334	315.1	427.4	646.4	864.1	1207.8	1509.4	1840.5	2292.2	2731.4
R-29	0.2045	101.1	129.5	182.6	234.1	314.0	383.2	458.9	561.6	660.5
R-28	0.3768	160.1	211.2	308.6	404.1	553.3	683.7	826.8	1022.5	1211.6
J-21	0.3249	332.2	401.2	525.6	641.8	818.2	968.9	1131.1	1349.5	1559.4
R-21	0.3249	331.5	400.7	524.6	640.8	816.7	967.5	1129.1	1345.7	1554.7

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	15365	1-yr	1331	893.00	2.74	485.11	67.14
Surface	15365	2-yr	1732	894.55	2.87	610.05	108.58
Surface	15365	5-yr	2489	896.46	3.11	907.33	209.96
Surface	15365	10-yr	3234	897.35	3.47	1156.16	316.98
Surface	15365	25-yr	4369	898.36	3.85	1495.03	350.83
Surface	15365	50-yr	5350	899.07	4.13	1751.56	370.10
Surface	15365	100-yr	6458	899.76	4.39	2011.61	380.98
Surface	15365	250-yr	7983	900.63	4.69	2346.75	394.56
Surface	15365	500-yr	9559	901.39	4.98	2653.34	407.94
Surface	15261	1-yr	1331	892.80	3.88	352.94	64.92
Surface	15261	2-yr	1732	894.36	3.99	497.74	136.12
Surface	15261	5-yr	2489	896.39	3.65	1023.20	315.43
Surface	15261	10-yr	3234	897.30	3.76	1319.59	330.51
Surface	15261	25-yr	4369	898.32	4.01	1664.07	342.85
Surface	15261	50-yr	5350	899.03	4.23	1909.85	349.10
Surface	15261	100-yr	6458	899.72	4.49	2153.10	358.34
Surface	15261	250-yr	7983	900.58	4.85	2471.44	383.50
Surface	15261	500-yr	9559	901.34	5.09	2765.34	385.83
Surface	15159	1-yr	1331	892.73	3.43	407.67	81.09
Surface	15159	2-yr	1732	894.32	3.43	570.33	127.05
Surface	15159	5-yr	2489	896.36	3.19	1093.92	295.89
Surface	15159	10-yr	3234	897.26	3.38	1365.23	302.91
Surface	15159	25-yr	4369	898.28	3.71	1676.01	310.74
Surface	15159	50-yr	5350	898.98	4.00	1896.16	317.31
Surface	15159	100-yr	6458	899.66	4.31	2116.02	325.92
Surface	15159	250-yr	7983	900.49	4.85	2402.54	381.77
Surface	15159	500-yr	9559	901.24	5.25	2706.19	430.88
Surface	15054	1-yr	1331	892.67	3.22	455.71	81.01
Surface	15054	2-yr	1732	894.27	3.28	606.16	110.42
Surface	15054	5-yr	2489	896.28	3.44	945.75	217.22
Surface	15054	10-yr	3234	897.15	3.87	1170.64	289.76
Surface	15054	25-yr	4369	898.14	4.37	1489.63	351.75
Surface	15054	50-yr	5350	898.84	4.69	1751.72	398.69
Surface	15054	100-yr	6458	899.53	4.98	2039.85	438.10
Surface	15054	250-yr	7983	900.38	5.30	2441.41	503.47
Surface	15054	500-yr	9559	901.16	5.47	2844.37	536.82
Surface	14939	1-yr	1331	892.59	3.19	439.99	76.73
Surface	14939	2-yr	1732	894.19	3.30	614.78	195.46
Surface	14939	5-yr	2489	896.25	3.16	1121.54	290.42
Surface	14939	10-yr	3234	897.13	3.45	1404.06	352.32
Surface	14939	25-yr	4369	898.13	3.81	1792.67	422.42
Surface	14939	50-yr	5350	898.83	4.05	2103.27	463.57
Surface	14939	100-yr	6458	899.52	4.26	2434.30	498.95
Surface	14939	250-yr	7983	900.37	4.48	2878.71	541.08
Surface	14939	500-yr	9559	901.14	4.70	3315.04	593.56

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	14829	1-yr	1331	892.56	2.63	517.27	96.73
Surface	14829	2-yr	1732	894.18	2.66	823.79	240.14
Surface	14829	5-yr	2489	896.23	2.68	1376.17	320.74
Surface	14829	10-yr	3234	897.11	3.00	1678.47	364.85
Surface	14829	25-yr	4369	898.09	3.45	2070.98	425.47
Surface	14829	50-yr	5350	898.78	3.76	2373.75	450.46
Surface	14829	100-yr	6458	899.46	4.07	2687.72	479.47
Surface	14829	250-yr	7983	900.29	4.50	3109.45	545.36
Surface	14829	500-yr	9559	901.05	4.82	3544.42	597.89
Surface	14729	1-yr	1331	892.60	1.39	1347.00	239.19
Surface	14729	2-yr	1732	894.22	1.38	1749.41	260.86
Surface	14729	5-yr	2489	896.26	1.65	2405.48	405.43
Surface	14729	10-yr	3234	897.14	1.92	2784.82	460.11
Surface	14729	25-yr	4369	898.13	2.29	3276.18	529.38
Surface	14729	50-yr	5350	898.82	2.54	3658.37	569.09
Surface	14729	100-yr	6458	899.50	2.80	4059.42	612.95
Surface	14729	250-yr	7983	900.34	3.09	4596.64	688.03
Surface	14729	500-yr	9559	901.10	3.33	5137.19	734.38
Surface	14610	1-yr	1331	892.57	1.52	972.07	234.88
Surface	14610	2-yr	1732	894.20	1.50	1431.81	331.69
Surface	14610	5-yr	2489	896.25	1.55	2338.08	589.94
Surface	14610	10-yr	3234	897.13	1.68	2883.04	642.23
Surface	14610	25-yr	4369	898.12	1.89	3541.65	692.69
Surface	14610	50-yr	5350	898.81	2.05	4040.82	740.16
Surface	14610	100-yr	6458	899.49	2.19	4555.72	771.75
Surface	14610	250-yr	7983	900.33	2.36	5219.08	805.02
Surface	14610	500-yr	9559	901.09	2.51	5840.38	828.82
Surface	14527	1-yr	1485	892.56	1.39	1155.81	248.46
Surface	14527	2-yr	1933	894.19	1.43	1668.73	374.98
Surface	14527	5-yr	2770	896.24	1.47	2727.63	631.37
Surface	14527	10-yr	3595	897.12	1.62	3303.40	678.31
Surface	14527	25-yr	4835	898.11	1.84	4006.30	746.62
Surface	14527	50-yr	5899	898.80	1.99	4539.63	790.97
Surface	14527	100-yr	7100	899.48	2.14	5091.70	824.81
Surface	14527	250-yr	8754	900.32	2.30	5791.75	843.74
Surface	14527	500-yr	10447	901.08	2.45	6438.81	857.34
Surface	14408	1-yr	1485	892.51	1.94	788.78	134.16
Surface	14408	2-yr	1933	894.15	2.02	1140.37	307.29
Surface	14408	5-yr	2770	896.21	1.99	2014.54	531.75
Surface	14408	10-yr	3595	897.08	2.15	2513.02	609.41
Surface	14408	25-yr	4835	898.07	2.36	3144.07	662.46
Surface	14408	50-yr	5899	898.76	2.51	3608.73	680.50
Surface	14408	100-yr	7100	899.44	2.67	4073.92	692.65
Surface	14408	250-yr	8754	900.27	2.86	4658.74	707.91
Surface	14408	500-yr	10447	901.03	3.03	5199.43	722.00

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	14304	1-yr	1485	892.49	2.01	819.83	161.10
Surface	14304	2-yr	1933	894.12	2.10	1161.53	318.81
Surface	14304	5-yr	2770	896.19	2.02	2080.15	533.29
Surface	14304	10-yr	3595	897.07	2.18	2581.22	604.70
Surface	14304	25-yr	4835	898.05	2.40	3197.22	639.30
Surface	14304	50-yr	5899	898.74	2.56	3643.48	654.01
Surface	14304	100-yr	7100	899.42	2.74	4097.00	680.85
Surface	14304	250-yr	8754	900.25	2.93	4670.54	696.07
Surface	14304	500-yr	10447	901.01	3.11	5201.42	710.44
Surface	14199	1-yr	1485	892.49	1.65	989.17	233.62
Surface	14199	2-yr	1933	894.12	1.70	1428.34	354.29
Surface	14199	5-yr	2770	896.19	1.70	2369.32	515.51
Surface	14199	10-yr	3595	897.06	1.90	2838.91	570.48
Surface	14199	25-yr	4835	898.04	2.16	3439.46	627.40
Surface	14199	50-yr	5899	898.73	2.33	3873.50	634.10
Surface	14199	100-yr	7100	899.41	2.51	4303.96	643.21
Surface	14199	250-yr	8754	900.24	2.74	4846.41	663.94
Surface	14199	500-yr	10447	900.99	2.94	5350.16	673.16
Surface	14089	1-yr	1485	892.48	1.64	1106.65	307.39
Surface	14089	2-yr	1933	894.12	1.59	1659.57	363.51
Surface	14089	5-yr	2770	896.19	1.62	2498.68	456.66
Surface	14089	10-yr	3595	897.06	1.83	2916.74	534.69
Surface	14089	25-yr	4835	898.03	2.16	3467.88	583.94
Surface	14089	50-yr	5899	898.72	2.36	3878.39	609.66
Surface	14089	100-yr	7100	899.39	2.56	4294.38	628.84
Surface	14089	250-yr	8754	900.22	2.79	4823.55	646.56
Surface	14089	500-yr	10447	900.97	3.00	5314.05	661.69
Surface	13970	1-yr	1485	892.43	2.11	902.87	257.99
Surface	13970	2-yr	1933	894.09	1.93	1450.54	422.28
Surface	13970	5-yr	2770	896.17	1.77	2494.82	577.15
Surface	13970	10-yr	3595	897.05	1.92	3042.32	653.56
Surface	13970	25-yr	4835	898.03	2.14	3696.70	683.42
Surface	13970	50-yr	5899	898.71	2.30	4172.55	705.27
Surface	13970	100-yr	7100	899.38	2.44	4648.68	710.78
Surface	13970	250-yr	8754	900.21	2.64	5249.09	733.34
Surface	13970	500-yr	10447	900.97	2.80	5804.37	744.84
Surface	13866	1-yr	1485	892.41	2.06	948.91	334.00
Surface	13866	2-yr	1933	894.08	1.89	1596.16	497.29
Surface	13866	5-yr	2770	896.17	1.60	2886.57	676.57
Surface	13866	10-yr	3595	897.04	1.70	3492.77	706.98
Surface	13866	25-yr	4835	898.02	1.87	4193.35	725.47
Surface	13866	50-yr	5899	898.71	2.02	4695.16	737.81
Surface	13866	100-yr	7100	899.38	2.16	5192.64	742.79
Surface	13866	250-yr	8754	900.21	2.32	5810.90	748.93
Surface	13866	500-yr	10447	900.96	2.48	6375.00	754.49

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	13763	1-yr	5	892.45	0.01	1082.86	303.85
Surface	13763	2-yr	192	894.11	0.17	1642.79	385.15
Surface	13763	5-yr	1053	896.18	0.60	2943.89	706.94
Surface	13763	10-yr	1901	897.05	0.90	3573.70	737.16
Surface	13763	25-yr	3175	898.03	1.23	4302.00	754.71
Surface	13763	50-yr	4265	898.71	1.46	4821.38	761.96
Surface	13763	100-yr	5493	899.38	1.67	5333.20	764.91
Surface	13763	250-yr	7185	900.21	1.91	5967.34	768.64
Surface	13763	500-yr	8911	900.96	2.12	6544.28	772.01
Surface	13642	1-yr	5	892.40	2.00	3.19	26.42
Surface	13642	2-yr	192	894.09	0.93	248.17	238.45
Surface	13642	5-yr	1053	896.16	1.31	1351.05	674.81
Surface	13642	10-yr	1901	897.03	1.64	1945.52	696.51
Surface	13642	25-yr	3175	898.00	2.01	2624.90	708.15
Surface	13642	50-yr	4265	898.67	2.28	3107.04	712.59
Surface	13642	100-yr	5493	899.34	2.52	3580.55	713.53
Surface	13642	250-yr	7185	900.16	2.82	4165.47	714.68
Surface	13642	500-yr	8911	900.90	3.08	4695.63	715.73
Surface	13526	1-yr	5	891.93	0.35	14.45	37.70
Surface	13526	2-yr	192	894.04	1.16	230.03	230.36
Surface	13526	5-yr	1053	896.12	1.94	1109.20	588.72
Surface	13526	10-yr	1901	896.97	2.37	1632.04	627.87
Surface	13526	25-yr	3175	897.93	2.82	2245.95	648.81
Surface	13526	50-yr	4265	898.61	3.13	2688.86	668.56
Surface	13526	100-yr	5493	899.27	3.43	3134.89	683.17
Surface	13526	250-yr	7185	900.08	3.76	3698.85	700.06
Surface	13526	500-yr	8911	900.82	4.05	4220.79	712.08
Surface	13467	1-yr	5	891.91	0.46	10.83	27.36
Surface	13467	2-yr	192	893.99	1.76	152.48	147.77
Surface	13467	5-yr	1053	896.06	2.81	882.05	565.13
Surface	13467	10-yr	1901	896.92	3.17	1378.48	585.50
Surface	13467	25-yr	3175	897.88	3.61	1954.24	611.29
Surface	13467	50-yr	4265	898.55	3.92	2369.97	624.64
Surface	13467	100-yr	5493	899.21	4.22	2785.64	637.73
Surface	13467	250-yr	7185	900.03	4.56	3310.99	651.68
Surface	13467	500-yr	8911	900.76	4.86	3795.18	663.22
Surface	13384	1-yr	5	891.84	0.93	5.39	12.79
Surface	13384	2-yr	192	893.86	2.57	104.17	93.91
Surface	13384	5-yr	1053	895.83	3.67	356.52	183.08
Surface	13384	10-yr	1901	896.54	4.95	498.70	217.42
Surface	13384	25-yr	3175	897.28	6.45	674.12	260.51
Surface	13384	50-yr	4265	897.77	7.50	807.49	284.91
Surface	13384	100-yr	5493	898.22	8.54	941.54	309.18
Surface	13384	250-yr	7185	898.79	9.71	1123.99	334.95
Surface	13384	500-yr	8911	899.29	10.73	1296.91	357.14

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	13358	1-yr	5	891.67	2.07	2.41	6.26
Surface	13358	2-yr	192	893.34	5.46	53.49	67.25
Surface	13358	5-yr	1053	894.93	7.38	188.36	154.13
Surface	13358	10-yr	1901	895.53	8.23	296.08	200.44
Surface	13358	25-yr	3175	896.25	9.81	455.39	245.42
Surface	13358	50-yr	4265	896.72	10.87	572.24	278.50
Surface	13358	100-yr	5493	897.17	11.89	690.65	303.12
Surface	13358	250-yr	7185	897.72	13.03	844.35	324.52
Surface	13358	500-yr	8911	898.22	14.03	988.67	338.26
Surface	13295	1-yr	5	890.77	1.65	3.04	40.02
Surface	13295	2-yr	192	891.34	4.02	48.58	102.08
Surface	13295	5-yr	1053	892.37	6.63	189.53	177.82
Surface	13295	10-yr	1901	893.07	7.57	356.35	295.94
Surface	13295	25-yr	3175	893.84	8.43	628.32	427.64
Surface	13295	50-yr	4265	894.28	9.23	818.60	446.71
Surface	13295	100-yr	5493	894.68	10.06	1001.70	464.32
Surface	13295	250-yr	7185	895.06	11.44	1182.04	483.66
Surface	13295	500-yr	8911	895.62	11.93	1467.88	539.42
Surface	13217	1-yr	5	888.94	1.20	4.16	22.14
Surface	13217	2-yr	192	889.71	4.55	54.41	108.36
Surface	13217	5-yr	1053	890.85	7.54	222.72	182.39
Surface	13217	10-yr	1901	891.48	9.21	354.20	230.30
Surface	13217	25-yr	3175	892.31	10.26	583.54	323.58
Surface	13217	50-yr	4265	892.93	10.54	809.89	426.41
Surface	13217	100-yr	5493	893.32	11.42	973.25	517.46
Surface	13217	250-yr	7185	893.75	12.54	1163.91	533.27
Surface	13217	500-yr	8911	894.28	12.92	1406.27	554.29
Surface	13069	1-yr	5	886.85	1.82	2.85	31.08
Surface	13069	2-yr	192	887.89	2.66	112.84	146.90
Surface	13069	5-yr	1053	889.61	4.25	435.90	230.57
Surface	13069	10-yr	1901	890.53	5.49	686.53	330.07
Surface	13069	25-yr	3175	891.55	6.09	1034.30	359.67
Surface	13069	50-yr	4265	892.17	6.66	1263.54	383.04
Surface	13069	100-yr	5493	892.76	7.24	1498.40	409.04
Surface	13069	250-yr	7185	893.45	7.95	1789.37	427.68
Surface	13069	500-yr	8911	894.01	8.68	2032.12	435.16
Surface	12955	1-yr	5	885.36	1.18	4.23	14.49
Surface	12955	2-yr	192	886.59	5.75	33.39	33.06
Surface	12955	5-yr	1053	888.38	7.74	199.41	150.70
Surface	12955	10-yr	1901	889.22	8.97	351.85	207.75
Surface	12955	25-yr	3175	890.12	10.34	564.80	281.22
Surface	12955	50-yr	4265	890.73	11.02	751.05	326.43
Surface	12955	100-yr	5493	891.23	11.90	924.83	361.11
Surface	12955	250-yr	7185	891.83	12.94	1152.98	413.63
Surface	12955	500-yr	8911	892.37	13.64	1391.84	458.42

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	12873	1-yr	5	884.51	1.66	3.01	42.99
Surface	12873	2-yr	192	885.06	4.14	46.84	90.19
Surface	12873	5-yr	1053	886.28	6.72	174.19	119.84
Surface	12873	10-yr	1901	887.29	7.40	308.14	144.61
Surface	12873	25-yr	3175	888.37	8.51	494.71	192.75
Surface	12873	50-yr	4265	889.02	9.46	627.64	215.42
Surface	12873	100-yr	5493	889.70	10.28	787.16	251.17
Surface	12873	250-yr	7185	890.73	10.61	1070.88	299.84
Surface	12873	500-yr	8911	891.85	10.53	1455.89	394.40
Surface	12745	1-yr	5	882.69	0.74	6.79	35.43
Surface	12745	2-yr	192	884.22	1.83	118.27	96.15
Surface	12745	5-yr	1053	886.20	3.82	414.55	243.37
Surface	12745	10-yr	1901	887.33	4.49	755.28	350.87
Surface	12745	25-yr	3175	888.60	4.96	1288.99	480.10
Surface	12745	50-yr	4265	889.42	5.12	1693.55	500.21
Surface	12745	100-yr	5493	890.25	5.27	2116.24	529.43
Surface	12745	250-yr	7185	891.34	5.36	2734.88	587.23
Surface	12745	500-yr	8911	892.43	5.38	3381.82	601.40
Surface	12649	1-yr	5	882.29	1.23	4.07	17.95
Surface	12649	2-yr	192	884.08	2.01	97.44	85.82
Surface	12649	5-yr	1053	886.02	3.90	356.70	220.96
Surface	12649	10-yr	1901	887.16	4.51	684.60	342.79
Surface	12649	25-yr	3175	888.48	4.74	1229.02	451.46
Surface	12649	50-yr	4265	889.31	4.95	1614.67	477.66
Surface	12649	100-yr	5493	890.14	5.15	2021.87	513.69
Surface	12649	250-yr	7185	891.24	5.27	2640.17	579.43
Surface	12649	500-yr	8911	892.34	5.29	3285.22	592.58
Surface	12539	1-yr	5	881.77	1.03	4.87	19.93
Surface	12539	2-yr	192	883.80	2.53	75.94	65.35
Surface	12539	5-yr	1053	885.89	3.34	501.81	377.38
Surface	12539	10-yr	1901	887.12	3.30	984.08	402.59
Surface	12539	25-yr	3175	888.46	3.58	1548.36	456.97
Surface	12539	50-yr	4265	889.28	3.90	1940.15	498.37
Surface	12539	100-yr	5493	890.11	4.17	2376.10	557.37
Surface	12539	250-yr	7185	891.20	4.40	2994.91	570.65
Surface	12539	500-yr	8911	892.30	4.54	3630.19	584.01
Surface	12440	1-yr	5	881.63	0.57	8.82	27.67
Surface	12440	2-yr	192	883.65	2.29	119.65	120.92
Surface	12440	5-yr	1053	885.83	2.97	688.45	365.93
Surface	12440	10-yr	1901	887.07	3.24	1180.89	426.37
Surface	12440	25-yr	3175	888.41	3.65	1787.40	482.82
Surface	12440	50-yr	4265	889.23	4.03	2205.26	539.93
Surface	12440	100-yr	5493	890.06	4.36	2671.23	575.45
Surface	12440	250-yr	7185	891.16	4.80	3318.10	598.87
Surface	12440	500-yr	8911	892.27	4.86	3984.83	601.88

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	12329	1-yr	5	881.53	0.63	7.99	24.89
Surface	12329	2-yr	192	883.35	3.32	64.53	87.96
Surface	12329	5-yr	1053	885.60	4.22	494.46	331.72
Surface	12329	10-yr	1901	886.93	4.03	1067.53	470.29
Surface	12329	25-yr	3175	888.31	4.10	1731.44	495.12
Surface	12329	50-yr	4265	889.13	4.40	2151.04	519.74
Surface	12329	100-yr	5493	889.95	4.86	2592.21	556.59
Surface	12329	250-yr	7185	891.06	5.03	3217.77	571.07
Surface	12329	500-yr	8911	892.18	5.12	3864.74	586.39
Surface	12219	1-yr	5	881.13	2.02	2.47	19.37
Surface	12219	2-yr	192	882.33	5.87	32.71	30.92
Surface	12219	5-yr	1053	884.25	8.52	159.66	87.65
Surface	12219	10-yr	1901	885.25	10.32	255.09	114.68
Surface	12219	25-yr	3175	886.64	11.08	471.85	213.48
Surface	12219	50-yr	4265	887.60	11.23	706.47	260.86
Surface	12219	100-yr	5493	888.68	10.86	1033.64	341.50
Surface	12219	250-yr	7185	890.09	10.24	1553.67	392.76
Surface	12219	500-yr	8911	891.37	9.90	2117.99	486.39
Surface	12124	1-yr	5	880.55	0.66	8.77	44.09
Surface	12124	2-yr	192	881.81	3.14	89.84	76.68
Surface	12124	5-yr	1053	883.89	5.45	436.37	286.64
Surface	12124	10-yr	1901	885.14	5.75	800.26	299.66
Surface	12124	25-yr	3175	886.71	6.07	1293.08	328.17
Surface	12124	50-yr	4265	887.72	6.74	1640.44	368.96
Surface	12124	100-yr	5493	888.75	7.03	2026.04	377.20
Surface	12124	250-yr	7185	890.11	7.33	2545.71	388.92
Surface	12124	500-yr	8911	891.35	7.79	3046.13	421.90
Surface	12010	1-yr	5	880.14	1.08	4.63	28.19
Surface	12010	2-yr	192	881.34	3.12	63.77	63.54
Surface	12010	5-yr	1053	882.94	6.64	203.98	122.86
Surface	12010	10-yr	1901	884.18	7.42	424.77	208.23
Surface	12010	25-yr	3175	885.99	7.36	957.39	381.51
Surface	12010	50-yr	4265	887.28	6.96	1496.18	451.07
Surface	12010	100-yr	5493	888.47	6.70	2038.52	458.04
Surface	12010	250-yr	7185	889.93	6.60	2713.73	466.59
Surface	12010	500-yr	8911	891.22	6.71	3347.90	497.82
Surface	11909	1-yr	5	879.42	0.92	5.44	42.03
Surface	11909	2-yr	343	880.83	3.49	107.99	97.60
Surface	11909	5-yr	1272	882.71	4.70	396.68	283.85
Surface	11909	10-yr	2191	884.17	4.30	872.75	355.95
Surface	11909	25-yr	3577	886.05	4.00	1581.02	393.57
Surface	11909	50-yr	4756	887.31	4.08	2128.15	454.88
Surface	11909	100-yr	6082	888.49	4.15	2668.73	462.88
Surface	11909	250-yr	7912	889.93	4.52	3367.95	534.51
Surface	11909	500-yr	9774	891.22	4.79	4163.13	655.73

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	11853	1-yr	5	879.09	0.77	6.51	50.01
Surface	11853	2-yr	343	880.68	2.72	162.32	167.21
Surface	11853	5-yr	1272	882.68	3.36	661.37	312.59
Surface	11853	10-yr	2191	884.14	3.49	1158.78	356.55
Surface	11853	25-yr	3577	886.02	3.80	1859.50	428.60
Surface	11853	50-yr	4756	887.29	3.92	2412.70	440.35
Surface	11853	100-yr	6082	888.46	4.13	2935.02	446.86
Surface	11853	250-yr	7912	889.91	4.39	3610.56	532.22
Surface	11853	500-yr	9774	891.20	4.76	4408.69	643.56
Surface	11799	1-yr	5	878.85	0.67	8.03	67.14
Surface	11799	2-yr	343	880.59	2.50	191.41	160.49
Surface	11799	5-yr	1272	882.62	3.34	669.08	252.41
Surface	11799	10-yr	2191	884.07	3.77	1052.39	279.11
Surface	11799	25-yr	3577	885.93	4.32	1602.31	331.40
Surface	11799	50-yr	4756	887.17	4.65	2039.30	359.27
Surface	11799	100-yr	6082	888.34	4.97	2462.10	366.48
Surface	11799	250-yr	7912	889.77	5.35	3028.37	458.80
Surface	11799	500-yr	9774	891.06	5.65	3664.92	523.26
Surface	11744	1-yr	5	878.71	0.59	10.53	65.09
Surface	11744	2-yr	343	880.54	2.06	322.14	226.69
Surface	11744	5-yr	1272	882.59	3.11	817.14	250.49
Surface	11744	10-yr	2191	884.04	3.72	1201.78	290.56
Surface	11744	25-yr	3577	885.90	4.43	1818.47	372.56
Surface	11744	50-yr	4756	887.15	4.78	2297.82	388.04
Surface	11744	100-yr	6082	888.31	5.13	2753.23	392.56
Surface	11744	250-yr	7912	889.75	5.54	3408.97	507.92
Surface	11744	500-yr	9774	891.04	5.89	4071.34	516.44
Surface	11693	1-yr	5	878.56	1.04	4.81	26.93
Surface	11693	2-yr	343	880.33	3.38	169.75	155.71
Surface	11693	5-yr	1272	882.34	4.68	519.16	189.07
Surface	11693	10-yr	2191	883.76	5.45	814.97	221.07
Surface	11693	25-yr	3577	885.56	6.36	1261.02	298.85
Surface	11693	50-yr	4756	886.80	6.76	1659.64	327.92
Surface	11693	100-yr	6082	887.96	7.14	2041.72	330.36
Surface	11693	250-yr	7912	889.39	7.61	2593.97	431.59
Surface	11693	500-yr	9774	890.67	8.00	3167.64	450.65
Surface	11577	1-yr	5	877.67	1.34	3.74	20.56
Surface	11577	2-yr	343	879.52	5.16	85.13	74.02
Surface	11577	5-yr	1272	881.97	5.49	533.42	235.60
Surface	11577	10-yr	2191	883.51	5.87	902.81	244.29
Surface	11577	25-yr	3577	885.38	6.54	1405.64	299.35
Surface	11577	50-yr	4756	886.64	6.95	1786.56	305.34
Surface	11577	100-yr	6082	887.80	7.47	2180.75	386.48
Surface	11577	250-yr	7912	889.23	8.04	2744.04	403.30
Surface	11577	500-yr	9774	890.50	8.56	3269.58	420.66

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	11473	1-yr	5	876.70	1.68	2.98	10.90
Surface	11473	2-yr	343	879.43	2.43	219.30	140.09
Surface	11473	5-yr	1272	881.90	3.64	669.57	194.43
Surface	11473	10-yr	2191	883.42	4.51	973.15	208.03
Surface	11473	25-yr	3577	885.28	5.43	1409.35	253.42
Surface	11473	50-yr	4756	886.53	6.00	1732.63	267.36
Surface	11473	100-yr	6082	887.68	6.61	2086.53	335.45
Surface	11473	250-yr	7912	889.08	7.30	2560.40	340.28
Surface	11473	500-yr	9774	890.32	7.93	2982.53	342.84
Surface	11370	1-yr	5	876.34	0.72	6.91	29.03
Surface	11370	2-yr	343	879.24	2.98	119.27	50.56
Surface	11370	5-yr	1272	881.26	5.97	276.05	100.12
Surface	11370	10-yr	2191	882.36	7.96	400.67	132.67
Surface	11370	25-yr	3577	883.80	9.81	611.54	161.62
Surface	11370	50-yr	4756	884.78	10.99	784.25	181.42
Surface	11370	100-yr	6082	885.66	12.13	944.91	182.85
Surface	11370	250-yr	7912	886.72	13.48	1176.08	248.41
Surface	11370	500-yr	9774	887.70	14.55	1431.38	284.47
Surface	11260	1-yr	5	876.22	0.50	9.93	31.55
Surface	11260	2-yr	343	879.11	2.73	127.06	51.84
Surface	11260	5-yr	1272	880.98	5.82	263.20	114.03
Surface	11260	10-yr	2191	881.99	7.80	449.18	255.42
Surface	11260	25-yr	3577	883.60	8.42	887.76	284.43
Surface	11260	50-yr	4756	884.68	8.87	1203.74	300.05
Surface	11260	100-yr	6082	885.63	9.51	1495.34	315.04
Surface	11260	250-yr	7912	886.79	10.11	1936.77	409.05
Surface	11260	500-yr	9774	887.87	10.59	2394.37	442.09
Surface	11148	1-yr	5	876.19	0.33	15.33	31.96
Surface	11148	2-yr	343	878.98	2.76	132.09	67.00
Surface	11148	5-yr	1272	880.68	5.86	290.33	135.55
Surface	11148	10-yr	2191	881.57	7.89	420.12	164.80
Surface	11148	25-yr	3577	882.56	10.16	612.65	207.86
Surface	11148	50-yr	4756	883.29	11.46	770.51	223.26
Surface	11148	100-yr	6082	884.03	12.53	941.27	231.32
Surface	11148	250-yr	7912	884.99	13.60	1163.45	233.39
Surface	11148	500-yr	9774	885.89	14.49	1390.40	299.22
Surface	11039	1-yr	5	876.18	0.25	19.71	31.25
Surface	11039	2-yr	343	878.88	2.42	190.26	149.80
Surface	11039	5-yr	1272	880.59	4.32	518.71	255.64
Surface	11039	10-yr	2191	881.52	5.46	767.99	283.09
Surface	11039	25-yr	3577	882.60	6.59	1091.89	312.33
Surface	11039	50-yr	4756	883.40	7.20	1345.07	314.28
Surface	11039	100-yr	6082	884.21	7.78	1598.15	316.21
Surface	11039	250-yr	7912	885.22	8.44	1918.69	321.38
Surface	11039	500-yr	9774	886.16	8.98	2270.48	392.55

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	10934	1-yr	5	876.18	0.27	18.45	28.41
Surface	10934	2-yr	343	878.67	3.31	135.51	151.20
Surface	10934	5-yr	1272	880.33	5.21	560.97	304.35
Surface	10934	10-yr	2191	881.30	6.07	874.32	345.71
Surface	10934	25-yr	3577	882.42	6.65	1260.43	347.74
Surface	10934	50-yr	4756	883.24	7.03	1547.41	349.25
Surface	10934	100-yr	6082	884.05	7.44	1832.54	350.76
Surface	10934	250-yr	7912	885.08	7.90	2227.48	426.54
Surface	10934	500-yr	9774	886.04	8.27	2640.43	430.43
Surface	10888	1-yr	5	876.17	0.50	9.99	24.28
Surface	10888	2-yr	343	878.61	3.07	162.21	130.82
Surface	10888	5-yr	1272	880.25	4.99	567.40	320.62
Surface	10888	10-yr	2191	881.21	5.86	903.61	381.28
Surface	10888	25-yr	3577	882.34	6.40	1346.81	406.28
Surface	10888	50-yr	4756	883.17	6.73	1691.12	422.39
Surface	10888	100-yr	6082	883.99	7.08	2044.25	438.58
Surface	10888	250-yr	7912	885.01	7.68	2554.32	536.61
Surface	10888	500-yr	9774	885.97	8.01	3096.79	595.71
Surface	10815	1-yr	5	876.13	0.50	9.98	30.66
Surface	10815	2-yr	343	878.52	2.70	149.07	119.55
Surface	10815	5-yr	1272	880.12	4.44	501.50	272.58
Surface	10815	10-yr	2191	881.05	5.45	777.59	322.80
Surface	10815	25-yr	3577	882.14	6.16	1132.65	334.13
Surface	10815	50-yr	4756	882.94	6.65	1409.89	360.38
Surface	10815	100-yr	6082	883.75	7.02	1704.98	361.88
Surface	10815	250-yr	7912	884.81	7.42	2126.43	457.31
Surface	10815	500-yr	9774	885.78	7.76	2570.08	459.08
Surface	10707	1-yr	5	876.09	0.35	14.17	30.53
Surface	10707	2-yr	343	878.43	2.22	228.16	165.84
Surface	10707	5-yr	1272	879.97	4.02	522.67	249.01
Surface	10707	10-yr	2191	880.89	4.84	753.98	254.88
Surface	10707	25-yr	3577	881.96	5.78	1032.41	270.90
Surface	10707	50-yr	4756	882.75	6.37	1253.15	286.45
Surface	10707	100-yr	6082	883.56	6.91	1493.29	302.29
Surface	10707	250-yr	7912	884.59	7.48	1836.54	378.05
Surface	10707	500-yr	9774	885.53	7.97	2193.50	380.86
Surface	10603	1-yr	5	876.07	0.44	11.38	21.18
Surface	10603	2-yr	343	878.23	3.12	164.21	122.00
Surface	10603	5-yr	1272	879.70	4.84	423.65	209.53
Surface	10603	10-yr	2191	880.57	5.77	610.78	233.78
Surface	10603	25-yr	3577	881.57	6.89	849.24	238.88
Surface	10603	50-yr	4756	882.33	7.60	1030.65	240.23
Surface	10603	100-yr	6082	883.10	8.27	1216.76	241.61
Surface	10603	250-yr	7912	884.08	9.02	1490.67	322.30
Surface	10603	500-yr	9774	884.99	9.64	1784.98	328.40

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	10499	1-yr	5	876.03	0.63	7.89	15.79
Surface	10499	2-yr	343	878.01	3.08	168.40	138.28
Surface	10499	5-yr	1272	879.41	4.87	418.16	195.48
Surface	10499	10-yr	2191	880.27	5.82	593.70	211.97
Surface	10499	25-yr	3577	881.25	6.97	820.60	243.71
Surface	10499	50-yr	4756	882.01	7.65	1005.72	245.07
Surface	10499	100-yr	6082	882.78	8.28	1196.44	246.45
Surface	10499	250-yr	7912	883.78	9.00	1473.75	325.59
Surface	10499	500-yr	9774	884.69	9.59	1774.62	333.27
Surface	10376	1-yr	5	875.72	2.14	2.33	16.19
Surface	10376	2-yr	343	877.17	5.44	126.60	164.92
Surface	10376	5-yr	1272	878.33	8.18	346.43	211.44
Surface	10376	10-yr	2191	878.98	10.03	486.31	225.66
Surface	10376	25-yr	3577	880.00	11.03	740.44	263.84
Surface	10376	50-yr	4756	880.99	11.00	1000.95	265.84
Surface	10376	100-yr	6082	881.78	11.68	1212.07	267.45
Surface	10376	250-yr	7912	882.77	12.53	1479.32	269.48
Surface	10376	500-yr	9774	883.65	13.36	1757.15	352.23
Surface	10290	1-yr	5	875.23	0.68	7.82	42.45
Surface	10290	2-yr	343	876.57	4.45	139.31	151.46
Surface	10290	5-yr	1272	877.60	7.26	343.78	253.14
Surface	10290	10-yr	2191	878.41	7.52	574.57	291.80
Surface	10290	25-yr	3577	879.74	7.00	984.88	322.68
Surface	10290	50-yr	4756	880.85	6.75	1344.94	328.16
Surface	10290	100-yr	6082	881.68	7.14	1618.82	331.19
Surface	10290	250-yr	7912	882.72	7.62	1964.54	334.57
Surface	10290	500-yr	9774	883.63	8.11	2335.11	428.68
Surface	10175	1-yr	5	874.96	0.57	10.61	88.40
Surface	10175	2-yr	343	876.05	2.73	180.38	224.45
Surface	10175	5-yr	1272	876.96	4.62	400.39	265.00
Surface	10175	10-yr	2191	878.04	4.70	723.97	309.71
Surface	10175	25-yr	3577	879.55	4.57	1235.37	375.81
Surface	10175	50-yr	4756	880.72	4.58	1689.15	394.12
Surface	10175	100-yr	6082	881.56	4.96	2023.42	400.22
Surface	10175	250-yr	7912	882.61	5.40	2462.39	467.61
Surface	10175	500-yr	9774	883.53	5.81	2922.58	514.74
Surface	10072	1-yr	5	874.08	1.81	2.86	32.16
Surface	10072	2-yr	343	874.95	5.23	89.12	141.46
Surface	10072	5-yr	1272	876.56	4.35	472.85	297.40
Surface	10072	10-yr	2191	877.84	3.98	888.88	341.75
Surface	10072	25-yr	3577	879.45	3.84	1505.07	412.46
Surface	10072	50-yr	4756	880.64	3.83	2003.98	423.06
Surface	10072	100-yr	6082	881.49	4.14	2364.07	429.50
Surface	10072	250-yr	7912	882.54	4.49	2828.48	461.13
Surface	10072	500-yr	9774	883.47	4.81	3282.72	525.12

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	9967	1-yr	5	872.75	0.11	9.66	101.89
Surface	9967	2-yr	343	874.27	1.58	300.34	236.02
Surface	9967	5-yr	1272	876.52	2.02	1105.87	477.96
Surface	9967	10-yr	2191	877.82	2.20	1751.48	520.45
Surface	9967	25-yr	3577	879.43	2.41	2594.25	524.72
Surface	9967	50-yr	4756	880.63	2.56	3224.78	527.80
Surface	9967	100-yr	6082	881.48	2.87	3671.86	529.98
Surface	9967	250-yr	7912	882.53	3.23	4240.04	555.68
Surface	9967	500-yr	9774	883.46	3.56	4807.45	650.24
Surface	9868	1-yr	5	872.16	0.91	5.49	35.90
Surface	9868	2-yr	343	873.48	5.50	62.51	50.40
Surface	9868	5-yr	1272	875.99	5.48	442.03	306.22
Surface	9868	10-yr	2191	877.46	5.18	936.08	356.98
Surface	9868	25-yr	3577	879.13	5.29	1565.85	385.05
Surface	9868	50-yr	4756	880.34	5.46	2034.92	389.21
Surface	9868	100-yr	6082	881.14	6.08	2345.86	391.95
Surface	9868	250-yr	7912	882.14	6.80	2757.34	440.00
Surface	9868	500-yr	9774	883.01	7.46	3159.85	474.16
Surface	9769	1-yr	5	871.35	1.25	4.01	30.21
Surface	9769	2-yr	343	873.45	1.75	240.48	189.30
Surface	9769	5-yr	1272	876.04	2.12	1113.30	495.14
Surface	9769	10-yr	2191	877.49	2.37	1849.42	520.12
Surface	9769	25-yr	3577	879.15	2.68	2722.59	527.62
Surface	9769	50-yr	4756	880.36	2.90	3364.37	531.77
Surface	9769	100-yr	6082	881.16	3.30	3792.49	546.65
Surface	9769	250-yr	7912	882.17	3.76	4379.11	610.46
Surface	9769	500-yr	9774	883.04	4.19	4916.01	616.49
Surface	9696	1-yr	5	870.69	1.10	4.55	24.77
Surface	9696	2-yr	343	873.30	2.74	199.07	147.54
Surface	9696	5-yr	1272	875.93	3.30	873.55	397.00
Surface	9696	10-yr	2191	877.38	3.65	1471.43	425.97
Surface	9696	25-yr	3577	879.04	4.08	2202.55	452.21
Surface	9696	50-yr	4756	880.26	4.32	2754.04	456.34
Surface	9696	100-yr	6082	881.04	4.88	3114.09	476.77
Surface	9696	250-yr	7912	882.02	5.50	3617.85	533.92
Surface	9696	500-yr	9774	882.88	6.05	4078.26	539.49
Surface	9580	1-yr	5	870.34	0.67	7.43	32.06
Surface	9580	2-yr	343	873.18	2.35	249.97	225.94
Surface	9580	5-yr	1272	875.89	2.56	1328.43	448.53
Surface	9580	10-yr	2191	877.34	2.91	1986.10	458.70
Surface	9580	25-yr	3577	879.00	3.34	2782.23	497.06
Surface	9580	50-yr	4756	880.22	3.60	3403.06	519.65
Surface	9580	100-yr	6082	880.99	4.08	3816.35	555.24
Surface	9580	250-yr	7912	881.97	4.63	4377.67	579.98
Surface	9580	500-yr	9774	882.82	5.12	4873.39	583.86

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	9407	1-yr	5	870.02	0.67	7.48	35.27
Surface	9407	2-yr	366	873.12	1.56	276.52	143.84
Surface	9407	5-yr	1312	875.76	2.69	810.15	274.98
Surface	9407	10-yr	2242	877.13	3.51	1269.76	442.45
Surface	9407	25-yr	3662	878.75	4.15	2020.62	466.73
Surface	9407	50-yr	4867	879.95	4.50	2591.30	498.65
Surface	9407	100-yr	6214	880.66	5.16	2959.97	540.50
Surface	9407	250-yr	8065	881.56	5.90	3460.18	560.55
Surface	9407	500-yr	9937	882.34	6.58	3895.50	563.53
Surface	9288	1-yr	5	869.75	0.81	6.15	26.62
Surface	9288	2-yr	366	873.05	1.92	226.31	145.47
Surface	9288	5-yr	1312	875.66	3.10	713.84	207.44
Surface	9288	10-yr	2242	876.98	4.11	1011.58	274.30
Surface	9288	25-yr	3662	878.54	5.06	1597.29	435.13
Surface	9288	50-yr	4867	879.76	5.30	2151.96	483.34
Surface	9288	100-yr	6214	880.44	6.01	2492.89	518.81
Surface	9288	250-yr	8065	881.32	6.75	2961.24	536.07
Surface	9288	500-yr	9937	882.08	7.43	3369.50	539.43
Surface	9210	1-yr	5	869.25	2.12	2.36	10.19
Surface	9210	2-yr	366	871.77	7.80	46.92	25.17
Surface	9210	5-yr	1312	874.41	8.53	219.77	108.67
Surface	9210	10-yr	2242	875.29	10.31	332.83	149.93
Surface	9210	25-yr	3662	876.36	12.18	515.57	203.56
Surface	9210	50-yr	4867	877.33	13.04	739.55	265.14
Surface	9210	100-yr	6214	878.64	12.18	1173.78	357.19
Surface	9210	250-yr	8065	879.33	13.35	1428.52	404.64
Surface	9210	500-yr	9937	879.97	14.26	1698.96	439.15
Surface	9116	1-yr	5	868.77	0.87	5.74	21.90
Surface	9116	2-yr	366	871.01	5.06	72.37	37.59
Surface	9116	5-yr	1312	873.14	5.58	298.91	235.38
Surface	9116	10-yr	2242	873.83	6.70	475.06	274.91
Surface	9116	25-yr	3662	874.93	7.04	815.44	339.68
Surface	9116	50-yr	4867	875.64	7.43	1066.67	374.41
Surface	9116	100-yr	6214	876.26	7.94	1310.73	406.65
Surface	9116	250-yr	8065	876.96	8.60	1607.82	437.75
Surface	9116	500-yr	9937	877.59	9.18	1889.04	462.92
Surface	9052	1-yr	5	868.37	0.44	11.45	32.07
Surface	9052	2-yr	366	870.67	3.56	102.92	47.67
Surface	9052	5-yr	1312	872.02	7.36	181.86	114.68
Surface	9052	10-yr	2242	872.91	8.78	330.35	222.18
Surface	9052	25-yr	3662	873.96	9.63	618.19	314.40
Surface	9052	50-yr	4867	874.57	10.45	821.04	356.00
Surface	9052	100-yr	6214	875.10	11.31	1019.24	390.42
Surface	9052	250-yr	8065	875.79	12.05	1301.66	424.35
Surface	9052	500-yr	9937	876.32	12.90	1531.53	442.50

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	8987	1-yr	5	868.36	0.26	19.10	45.92
Surface	8987	2-yr	366	870.62	2.18	170.96	89.14
Surface	8987	5-yr	1312	872.03	3.84	470.54	296.20
Surface	8987	10-yr	2242	872.78	4.84	699.80	318.16
Surface	8987	25-yr	3662	873.62	6.04	976.18	346.83
Surface	8987	50-yr	4867	874.10	7.04	1148.54	371.13
Surface	8987	100-yr	6214	874.47	8.18	1292.97	390.33
Surface	8987	250-yr	8065	875.17	9.01	1573.38	406.23
Surface	8987	500-yr	9937	875.88	9.53	1886.00	508.57
Surface	8835	1-yr	5	868.18	2.41	2.07	10.66
Surface	8835	2-yr	366	869.93	5.85	129.05	168.14
Surface	8835	5-yr	1312	870.88	9.06	317.66	238.55
Surface	8835	10-yr	2242	871.47	10.74	470.23	278.95
Surface	8835	25-yr	3662	872.11	12.68	660.96	312.78
Surface	8835	50-yr	4867	872.68	13.24	846.83	341.36
Surface	8835	100-yr	6214	873.43	12.88	1119.16	379.68
Surface	8835	250-yr	8065	874.36	12.90	1502.25	459.85
Surface	8835	500-yr	9937	875.20	12.83	1937.02	551.06
Surface	8697	1-yr	5	866.23	1.10	4.54	30.30
Surface	8697	2-yr	366	867.58	4.10	121.49	137.51
Surface	8697	5-yr	1312	869.26	5.33	449.05	244.10
Surface	8697	10-yr	2242	870.21	6.23	698.52	275.57
Surface	8697	25-yr	3662	871.33	7.19	1051.19	348.56
Surface	8697	50-yr	4867	872.10	7.78	1329.60	372.03
Surface	8697	100-yr	6214	872.90	8.17	1628.91	376.93
Surface	8697	250-yr	8065	873.85	8.72	1989.88	382.76
Surface	8697	500-yr	9937	874.69	9.26	2315.44	387.94
Surface	8629	1-yr	5	865.12	1.98	2.53	21.22
Surface	8629	2-yr	366	867.27	3.86	162.65	170.92
Surface	8629	5-yr	1312	869.04	5.45	532.02	263.34
Surface	8629	10-yr	2242	869.95	6.69	793.63	309.53
Surface	8629	25-yr	3662	871.07	7.78	1199.60	409.38
Surface	8629	50-yr	4867	871.85	8.39	1536.80	446.11
Surface	8629	100-yr	6214	872.70	8.63	1925.29	463.77
Surface	8629	250-yr	8065	873.68	9.03	2384.08	472.75
Surface	8629	500-yr	9937	874.54	9.45	2800.06	496.24
Surface	8525	1-yr	5	864.10	0.47	11.39	42.72
Surface	8525	2-yr	366	867.24	1.93	472.18	237.22
Surface	8525	5-yr	1312	868.98	3.67	960.51	308.39
Surface	8525	10-yr	2242	869.86	4.91	1255.25	371.18
Surface	8525	25-yr	3662	870.94	6.32	1693.26	430.95
Surface	8525	50-yr	4867	871.70	7.24	2038.97	480.00
Surface	8525	100-yr	6214	872.53	7.92	2462.55	535.62
Surface	8525	250-yr	8065	873.49	8.85	3009.53	619.78
Surface	8525	500-yr	9937	874.36	9.29	3578.75	665.87

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	8407	1-yr	5	863.97	1.22	4.10	8.94
Surface	8407	2-yr	366	866.91	3.98	134.16	130.80
Surface	8407	5-yr	1312	868.48	5.95	401.58	230.85
Surface	8407	10-yr	2242	869.33	6.85	634.58	315.82
Surface	8407	25-yr	3662	870.58	6.88	1060.00	360.98
Surface	8407	50-yr	4867	871.43	7.01	1379.16	390.36
Surface	8407	100-yr	6214	872.31	7.08	1738.41	421.48
Surface	8407	250-yr	8065	873.29	7.26	2166.52	448.75
Surface	8407	500-yr	9937	874.18	7.38	2573.41	465.22
Surface	8291	1-yr	5	863.40	2.00	2.50	8.41
Surface	8291	2-yr	366	866.51	3.94	118.15	118.90
Surface	8291	5-yr	1312	867.80	6.66	359.58	260.66
Surface	8291	10-yr	2242	868.95	6.56	757.09	428.11
Surface	8291	25-yr	3662	870.37	5.96	1409.27	484.39
Surface	8291	50-yr	4867	871.25	6.01	1846.77	504.74
Surface	8291	100-yr	6214	872.15	6.15	2314.60	530.74
Surface	8291	250-yr	8065	873.14	6.51	2849.82	559.16
Surface	8291	500-yr	9937	874.03	6.91	3381.34	622.73
Surface	8232	1-yr	5	863.27	0.74	6.76	17.43
Surface	8232	2-yr	366	866.43	2.77	157.15	138.20
Surface	8232	5-yr	1312	867.54	5.78	336.44	178.74
Surface	8232	10-yr	2242	868.48	6.88	539.42	241.48
Surface	8232	25-yr	3662	869.70	7.70	861.69	289.43
Surface	8232	50-yr	4867	870.49	8.36	1094.23	302.51
Surface	8232	100-yr	6214	871.25	9.19	1344.95	352.04
Surface	8232	250-yr	8065	872.23	9.63	1701.61	367.00
Surface	8232	500-yr	9937	873.13	10.00	2031.84	369.18
Surface	8173	1-yr	5	863.12	1.43	3.51	10.31
Surface	8173	2-yr	366	865.47	6.82	66.82	97.69
Surface	8173	5-yr	1312	867.10	7.76	460.51	280.67
Surface	8173	10-yr	2242	868.30	7.64	832.95	345.27
Surface	8173	25-yr	3662	869.55	8.53	1297.25	412.54
Surface	8173	50-yr	4867	870.38	8.84	1653.62	433.40
Surface	8173	100-yr	6214	871.18	9.23	2005.50	442.36
Surface	8173	250-yr	8065	872.18	9.70	2453.96	454.68
Surface	8173	500-yr	9937	873.09	10.16	2867.26	458.45
Surface	8085	1-yr	5	862.89	0.71	10.09	47.21
Surface	8085	2-yr	366	865.10	3.83	193.27	119.94
Surface	8085	5-yr	1312	866.77	6.59	465.28	196.38
Surface	8085	10-yr	2242	867.74	8.66	680.70	254.47
Surface	8085	25-yr	3662	868.94	9.96	1010.93	283.77
Surface	8085	50-yr	4867	869.64	10.95	1213.19	286.90
Surface	8085	100-yr	6214	870.32	11.96	1409.41	289.90
Surface	8085	250-yr	8065	871.19	13.07	1665.54	305.35
Surface	8085	500-yr	9937	871.98	14.04	1914.82	325.99

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	7939	1-yr	5	862.21	1.91	2.62	13.98
Surface	7939	2-yr	366	864.66	3.72	210.65	236.88
Surface	7939	5-yr	1312	866.41	4.90	732.99	364.69
Surface	7939	10-yr	2242	867.40	5.75	1122.59	426.46
Surface	7939	25-yr	3662	868.65	6.40	1716.90	505.55
Surface	7939	50-yr	4867	869.36	7.04	2086.85	539.51
Surface	7939	100-yr	6214	870.06	7.60	2467.61	553.65
Surface	7939	250-yr	8065	870.96	8.15	2976.54	571.47
Surface	7939	500-yr	9937	871.79	8.58	3453.71	578.38
Surface	7879	1-yr	5	861.81	1.09	4.59	16.20
Surface	7879	2-yr	427	864.19	5.16	153.06	159.45
Surface	7879	5-yr	1401	866.10	6.05	714.35	403.60
Surface	7879	10-yr	2359	867.20	6.36	1174.19	434.55
Surface	7879	25-yr	3824	868.49	6.96	1749.24	462.65
Surface	7879	50-yr	5067	869.16	7.81	2068.21	476.05
Surface	7879	100-yr	6452	869.83	8.56	2384.78	477.92
Surface	7879	250-yr	8360	870.70	9.35	2800.67	480.37
Surface	7879	500-yr	10285	871.48	10.06	3180.51	482.60
Surface	7767	1-yr	5	861.45	1.11	4.52	13.95
Surface	7767	2-yr	427	864.14	2.28	588.48	360.56
Surface	7767	5-yr	1401	866.05	3.33	1364.10	467.77
Surface	7767	10-yr	2359	867.14	3.95	1892.65	502.35
Surface	7767	25-yr	3824	868.41	4.65	2557.84	538.72
Surface	7767	50-yr	5067	869.08	5.37	2924.71	560.12
Surface	7767	100-yr	6452	869.73	6.09	3297.81	590.56
Surface	7767	250-yr	8360	870.60	6.85	3829.12	633.88
Surface	7767	500-yr	10285	871.39	7.42	4340.22	662.89
Surface	7669	1-yr	5	861.08	0.72	6.95	54.69
Surface	7669	2-yr	427	864.12	0.98	693.76	297.70
Surface	7669	5-yr	1401	866.02	1.85	1381.78	438.00
Surface	7669	10-yr	2359	867.09	2.39	1884.30	494.94
Surface	7669	25-yr	3824	868.36	2.97	2555.03	560.17
Surface	7669	50-yr	5067	869.02	3.48	2932.51	593.04
Surface	7669	100-yr	6452	869.66	3.97	3321.71	627.47
Surface	7669	250-yr	8360	870.51	4.47	3872.25	663.47
Surface	7669	500-yr	10285	871.29	4.89	4403.66	698.77
Surface	7551	1-yr	5	860.98	0.48	10.51	23.12
Surface	7551	2-yr	427	863.95	2.91	227.89	154.27
Surface	7551	5-yr	1401	865.70	4.59	611.46	253.89
Surface	7551	10-yr	2359	866.66	5.73	888.13	323.96
Surface	7551	25-yr	3824	867.89	6.48	1323.78	371.57
Surface	7551	50-yr	5067	868.43	7.49	1526.51	387.04
Surface	7551	100-yr	6452	868.94	8.47	1729.26	401.93
Surface	7551	250-yr	8360	869.70	9.34	2043.75	433.07
Surface	7551	500-yr	10285	870.44	9.92	2374.05	460.87

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	7443	1-yr	5	860.89	1.03	4.84	10.96
Surface	7443	2-yr	427	862.97	6.87	113.39	108.58
Surface	7443	5-yr	1401	864.42	9.48	323.28	186.26
Surface	7443	10-yr	2359	865.26	10.86	498.76	222.57
Surface	7443	25-yr	3824	866.34	12.33	762.45	299.52
Surface	7443	50-yr	5067	867.23	12.09	1065.66	361.23
Surface	7443	100-yr	6452	868.07	11.80	1378.82	383.39
Surface	7443	250-yr	8360	869.06	11.78	1772.12	409.53
Surface	7443	500-yr	10285	869.91	11.99	2134.51	450.22
Surface	7293	1-yr	5	860.65	0.50	12.46	80.94
Surface	7293	2-yr	427	862.95	1.46	499.97	310.76
Surface	7293	5-yr	1401	864.50	2.33	1158.40	452.06
Surface	7293	10-yr	2359	865.43	2.93	1605.59	511.51
Surface	7293	25-yr	3824	866.56	3.57	2206.23	554.50
Surface	7293	50-yr	5067	867.38	3.99	2671.90	601.49
Surface	7293	100-yr	6452	868.16	4.41	3171.56	675.01
Surface	7293	250-yr	8360	869.12	4.87	3848.61	738.17
Surface	7293	500-yr	10285	869.96	5.23	4490.21	785.36
Surface	7167	1-yr	5	860.62	0.30	19.85	43.57
Surface	7167	2-yr	427	862.54	4.67	235.94	238.97
Surface	7167	5-yr	1401	863.76	7.64	593.78	319.00
Surface	7167	10-yr	2359	864.54	9.07	849.79	340.98
Surface	7167	25-yr	3824	865.57	10.40	1217.57	391.43
Surface	7167	50-yr	5067	866.32	11.19	1531.95	440.01
Surface	7167	100-yr	6452	867.05	11.93	1883.42	515.28
Surface	7167	250-yr	8360	868.02	12.50	2411.08	574.63
Surface	7167	500-yr	10285	868.86	13.01	2909.92	612.29
Surface	7051	1-yr	5	860.57	0.74	6.72	36.47
Surface	7051	2-yr	427	862.07	4.25	237.37	279.83
Surface	7051	5-yr	1401	863.08	6.75	576.23	361.85
Surface	7051	10-yr	2359	863.85	7.89	870.07	404.61
Surface	7051	25-yr	3824	864.99	8.47	1381.75	494.86
Surface	7051	50-yr	5067	865.81	8.87	1834.77	588.80
Surface	7051	100-yr	6452	866.62	9.07	2341.56	690.69
Surface	7051	250-yr	8360	867.68	9.13	3113.75	754.86
Surface	7051	500-yr	10285	868.58	9.29	3802.46	787.15
Surface	6934	1-yr	5	859.31		2.26	14.65
Surface	6934	2-yr	427	860.64	6.92	164.16	221.54
Surface	6934	5-yr	1401	861.88	8.37	477.79	276.44
Surface	6934	10-yr	2359	862.83	9.26	758.10	320.85
Surface	6934	25-yr	3824	864.04	10.44	1189.53	409.19
Surface	6934	50-yr	5067	865.03	10.61	1655.53	501.33
Surface	6934	100-yr	6452	865.93	10.81	2131.85	570.20
Surface	6934	250-yr	8360	867.01	11.28	2827.57	717.09
Surface	6934	500-yr	10285	868.04	11.14	3601.11	779.82

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	6822	1-yr	5	858.51		66.18	80.50
Surface	6822	2-yr	427	860.20	1.92	341.91	201.66
Surface	6822	5-yr	1401	861.52	3.64	616.34	228.53
Surface	6822	10-yr	2359	862.49	4.58	873.60	284.15
Surface	6822	25-yr	3824	863.75	5.49	1237.50	290.00
Surface	6822	50-yr	5067	864.76	5.98	1532.95	290.00
Surface	6822	100-yr	6452	865.65	6.58	1830.64	404.60
Surface	6822	250-yr	8360	866.71	7.24	2307.80	469.19
Surface	6822	500-yr	10285	867.64	7.81	2758.09	508.44
Surface	6720	1-yr	5	858.50	0.61	16.98	97.83
Surface	6720	2-yr	427	859.93	3.44	364.14	285.10
Surface	6720	5-yr	1401	861.22	5.57	742.34	301.80
Surface	6720	10-yr	2359	862.19	6.79	1053.13	365.45
Surface	6720	25-yr	3824	863.49	7.75	1563.96	410.85
Surface	6720	50-yr	5067	864.57	8.06	2009.95	419.03
Surface	6720	100-yr	6452	865.48	8.59	2470.16	575.81
Surface	6720	250-yr	8360	866.58	9.13	3113.21	584.00
Surface	6720	500-yr	10285	867.53	9.65	3674.15	608.07
Surface	6620	1-yr	5	858.21	0.29	11.21	52.73
Surface	6620	2-yr	427	859.56	2.82	274.07	279.98
Surface	6620	5-yr	1401	860.95	3.67	710.78	344.86
Surface	6620	10-yr	2359	861.98	4.11	1081.37	379.72
Surface	6620	25-yr	3824	863.35	4.48	1639.02	423.02
Surface	6620	50-yr	5067	864.44	4.98	2126.83	538.49
Surface	6620	100-yr	6452	865.33	6.01	2717.33	794.89
Surface	6620	250-yr	8360	866.50	5.59	3687.26	863.00
Surface	6620	500-yr	10285	867.49	5.32	4541.68	863.00
Surface	6564	1-yr	5	858.21	0.07	77.52	111.17
Surface	6564	2-yr	427	859.46	2.20	264.24	185.78
Surface	6564	5-yr	1401	860.70	3.97	520.86	227.92
Surface	6564	10-yr	2359	861.66	4.87	761.36	276.10
Surface	6564	25-yr	3824	862.97	5.69	1177.13	389.02
Surface	6564	50-yr	5067	864.11	5.77	1725.74	561.76
Surface	6564	100-yr	6452	865.04	5.98	2400.05	847.23
Surface	6564	250-yr	8360	866.30	5.50	3592.17	1034.83
Surface	6564	500-yr	10285	867.35	5.25	4742.60	1165.42
Surface	6520	1-yr	198	858.07	2.34	107.98	130.70
Surface	6520	2-yr	829	859.11	4.58	268.70	175.98
Surface	6520	5-yr	1995	860.01	7.23	440.32	205.54
Surface	6520	10-yr	3139	860.72	8.82	595.95	231.25
Surface	6520	25-yr	4914	861.95	9.82	909.96	286.52
Surface	6520	50-yr	6421	862.91	10.66	1236.56	396.99
Surface	6520	100-yr	8082	864.05	10.36	1786.98	593.51
Surface	6520	250-yr	10365	865.52	9.75	2842.16	920.54
Surface	6520	500-yr	12650	866.97	8.08	4369.27	1141.58

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	6450	1-yr	198	857.66	3.95	80.35	143.08
Surface	6450	2-yr	829	858.63	6.12	257.26	238.91
Surface	6450	5-yr	1995	859.64	7.25	590.47	375.11
Surface	6450	10-yr	3139	860.54	7.13	953.80	435.27
Surface	6450	25-yr	4914	861.99	6.56	1660.01	531.69
Surface	6450	50-yr	6421	863.09	6.09	2255.22	559.76
Surface	6450	100-yr	8082	864.23	5.84	2921.94	595.92
Surface	6450	250-yr	10365	865.65	5.70	3787.84	618.97
Surface	6450	500-yr	12650	867.00	5.65	4635.60	642.67
Surface	6390	1-yr	198	857.27	2.95	92.71	140.45
Surface	6390	2-yr	829	858.35	4.22	371.13	340.76
Surface	6390	5-yr	1995	859.45	4.86	825.51	464.22
Surface	6390	10-yr	3139	860.42	4.83	1291.80	499.67
Surface	6390	25-yr	4914	861.92	4.62	2069.94	538.67
Surface	6390	50-yr	6421	863.03	4.63	2678.94	554.72
Surface	6390	100-yr	8082	864.18	4.67	3324.24	567.34
Surface	6390	250-yr	10365	865.61	4.77	4142.53	573.51
Surface	6390	500-yr	12650	866.96	4.88	4918.71	576.82
Surface	6275	1-yr	198	856.69	3.12	137.96	202.71
Surface	6275	2-yr	829	857.93	4.55	448.92	334.04
Surface	6275	5-yr	1995	859.13	5.35	875.44	378.00
Surface	6275	10-yr	3139	860.18	5.56	1285.90	403.39
Surface	6275	25-yr	4914	861.72	5.73	1960.16	466.63
Surface	6275	50-yr	6421	862.85	5.87	2500.40	491.10
Surface	6275	100-yr	8082	864.02	6.02	3089.12	521.28
Surface	6275	250-yr	10365	865.46	6.18	3856.04	534.73
Surface	6275	500-yr	12650	866.83	6.31	4588.69	542.03
Surface	6158	1-yr	198	856.15	3.21	139.96	157.03
Surface	6158	2-yr	829	857.40	5.05	423.59	307.28
Surface	6158	5-yr	1995	858.76	5.55	890.51	353.65
Surface	6158	10-yr	3139	859.91	5.70	1301.97	365.51
Surface	6158	25-yr	4914	861.50	6.12	1932.35	441.02
Surface	6158	50-yr	6421	862.66	6.21	2454.24	451.38
Surface	6158	100-yr	8082	863.85	6.34	2996.35	461.75
Surface	6158	250-yr	10365	865.31	6.59	3678.59	477.01
Surface	6158	500-yr	12650	866.67	6.84	4343.82	501.23
Surface	6039	1-yr	198	855.71	3.17	149.56	190.01
Surface	6039	2-yr	829	856.97	4.81	484.64	350.62
Surface	6039	5-yr	1995	858.51	4.94	1040.73	374.76
Surface	6039	10-yr	3139	859.71	5.26	1504.37	405.77
Surface	6039	25-yr	4914	861.34	5.55	2198.64	437.78
Surface	6039	50-yr	6421	862.53	5.83	2731.70	464.37
Surface	6039	100-yr	8082	863.73	6.06	3303.83	482.65
Surface	6039	250-yr	10365	865.20	6.36	4028.73	516.05
Surface	6039	500-yr	12650	866.58	6.62	4803.97	600.32

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	5925	1-yr	198	855.26	3.47	130.05	193.47
Surface	5925	2-yr	829	856.63	4.52	472.50	296.78
Surface	5925	5-yr	1995	858.28	4.96	1075.33	400.09
Surface	5925	10-yr	3139	859.53	5.15	1596.56	431.49
Surface	5925	25-yr	4914	861.21	5.42	2351.04	467.28
Surface	5925	50-yr	6421	862.41	5.66	2923.48	483.53
Surface	5925	100-yr	8082	863.60	6.23	3537.52	595.08
Surface	5925	250-yr	10365	865.10	6.39	4452.99	630.53
Surface	5925	500-yr	12650	866.48	6.69	5372.62	696.45
Surface	5821	1-yr	198	854.93	2.70	158.05	226.69
Surface	5821	2-yr	829	856.41	3.61	545.19	279.49
Surface	5821	5-yr	1995	858.12	4.43	1107.01	369.42
Surface	5821	10-yr	3139	859.40	4.86	1596.96	389.00
Surface	5821	25-yr	4914	861.10	5.32	2264.08	411.17
Surface	5821	50-yr	6421	862.30	5.70	2766.64	429.87
Surface	5821	100-yr	8082	863.50	6.06	3299.02	464.38
Surface	5821	250-yr	10365	864.99	6.48	4035.79	502.81
Surface	5821	500-yr	12650	866.37	6.83	4733.20	512.11
Surface	5718	1-yr	198	854.65	2.72	179.02	224.93
Surface	5718	2-yr	829	856.21	3.81	566.25	265.53
Surface	5718	5-yr	1995	857.95	4.80	1182.38	412.29
Surface	5718	10-yr	3139	859.26	5.19	1729.79	424.31
Surface	5718	25-yr	4914	860.98	5.66	2471.67	436.98
Surface	5718	50-yr	6421	862.19	6.08	3008.18	468.26
Surface	5718	100-yr	8082	863.40	6.48	3590.19	496.67
Surface	5718	250-yr	10365	864.90	6.91	4393.95	566.42
Surface	5718	500-yr	12650	866.28	7.26	5238.93	641.80
Surface	5605	1-yr	198	854.47	2.19	239.65	235.93
Surface	5605	2-yr	829	856.04	3.57	663.70	321.95
Surface	5605	5-yr	1995	857.79	4.57	1240.06	335.35
Surface	5605	10-yr	3139	859.10	5.28	1684.55	346.13
Surface	5605	25-yr	4914	860.80	6.10	2290.63	363.15
Surface	5605	50-yr	6421	862.00	6.66	2729.08	375.94
Surface	5605	100-yr	8082	863.19	7.18	3206.93	410.21
Surface	5605	250-yr	10365	864.67	7.79	3842.75	461.13
Surface	5605	500-yr	12650	866.04	8.24	4486.34	472.80
Surface	5469	1-yr	198	854.28	2.45	214.75	222.38
Surface	5469	2-yr	829	855.80	3.93	615.32	309.54
Surface	5469	5-yr	1995	857.58	4.88	1191.60	332.41
Surface	5469	10-yr	3139	858.89	5.56	1633.75	341.57
Surface	5469	25-yr	4914	860.60	6.36	2239.11	366.32
Surface	5469	50-yr	6421	861.79	6.97	2685.49	385.24
Surface	5469	100-yr	8082	862.99	7.50	3176.69	440.70
Surface	5469	250-yr	10365	864.49	8.01	3891.50	496.14
Surface	5469	500-yr	12650	865.87	8.40	4604.44	546.73

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	5343	1-yr	198	854.06	2.64	207.45	266.71
Surface	5343	2-yr	829	855.61	3.56	683.02	334.16
Surface	5343	5-yr	1995	857.42	4.34	1303.25	348.70
Surface	5343	10-yr	3139	858.75	4.97	1769.40	357.25
Surface	5343	25-yr	4914	860.46	5.71	2392.89	368.36
Surface	5343	50-yr	6421	861.66	6.30	2838.34	388.60
Surface	5343	100-yr	8082	862.84	7.09	3341.88	434.80
Surface	5343	250-yr	10365	864.35	7.57	4001.12	442.78
Surface	5343	500-yr	12650	865.74	7.99	4637.94	473.97
Surface	5215	1-yr	198	853.76	2.85	197.02	201.19
Surface	5215	2-yr	829	855.29	4.48	555.44	249.67
Surface	5215	5-yr	1995	857.05	6.04	1006.94	265.09
Surface	5215	10-yr	3139	858.30	7.19	1345.33	275.99
Surface	5215	25-yr	4914	859.89	8.71	1806.16	305.94
Surface	5215	50-yr	6421	861.00	9.69	2151.69	327.86
Surface	5215	100-yr	8082	862.15	10.45	2541.00	349.15
Surface	5215	250-yr	10365	863.61	11.25	3069.70	370.00
Surface	5215	500-yr	12650	864.97	11.84	3574.21	370.00
Surface	5066	1-yr	198	853.31	3.18	160.57	179.57
Surface	5066	2-yr	829	854.78	5.14	462.16	237.27
Surface	5066	5-yr	1995	856.53	6.74	903.18	268.84
Surface	5066	10-yr	3139	857.76	7.88	1246.14	289.18
Surface	5066	25-yr	4914	859.37	9.11	1734.17	314.78
Surface	5066	50-yr	6421	860.49	9.95	2094.89	327.11
Surface	5066	100-yr	8082	861.63	10.77	2482.07	350.74
Surface	5066	250-yr	10365	863.09	11.62	3016.72	391.01
Surface	5066	500-yr	12650	864.52	12.01	3583.45	396.00
Surface	4951	1-yr	198	853.10	2.27	141.15	151.73
Surface	4951	2-yr	829	854.55	3.75	401.43	219.74
Surface	4951	5-yr	1995	856.37	4.49	856.26	277.47
Surface	4951	10-yr	3139	857.62	5.18	1230.92	327.72
Surface	4951	25-yr	4914	859.30	5.53	1811.71	359.30
Surface	4951	50-yr	6421	860.46	5.82	2235.56	371.00
Surface	4951	100-yr	8082	861.63	6.05	2673.87	375.08
Surface	4951	250-yr	10365	863.12	6.35	3237.39	390.57
Surface	4951	500-yr	12650	864.57	6.55	3854.95	448.86
Surface	4847	1-yr	230	852.89	2.61	157.28	203.45
Surface	4847	2-yr	872	854.41	3.13	547.77	312.08
Surface	4847	5-yr	2061	856.30	3.37	1235.19	403.84
Surface	4847	10-yr	3227	857.57	3.61	1764.85	426.61
Surface	4847	25-yr	5040	859.27	3.91	2511.62	452.85
Surface	4847	50-yr	6580	860.43	4.26	3048.21	480.87
Surface	4847	100-yr	8279	861.61	4.58	3637.55	520.06
Surface	4847	250-yr	10611	863.10	5.13	4492.78	648.30
Surface	4847	500-yr	12939	864.56	5.19	5479.98	708.22

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	4737	1-yr	230	852.23	3.56	83.01	107.20
Surface	4737	2-yr	872	853.80	5.17	314.01	178.85
Surface	4737	5-yr	2061	855.57	6.69	711.35	285.15
Surface	4737	10-yr	3227	856.82	7.39	1105.80	370.34
Surface	4737	25-yr	5040	858.69	7.28	1857.26	436.13
Surface	4737	50-yr	6580	859.88	7.50	2401.98	475.21
Surface	4737	100-yr	8279	861.09	7.68	3003.19	521.29
Surface	4737	250-yr	10611	862.62	7.88	3851.80	581.20
Surface	4737	500-yr	12939	864.12	7.94	4781.66	661.55
Surface	4633	1-yr	230	851.79	3.30	88.22	116.11
Surface	4633	2-yr	872	853.52	4.55	353.74	173.49
Surface	4633	5-yr	2061	855.31	6.11	679.21	190.43
Surface	4633	10-yr	3227	856.44	7.42	900.37	220.88
Surface	4633	25-yr	5040	858.04	8.57	1399.51	364.72
Surface	4633	50-yr	6580	859.15	9.23	1834.82	425.95
Surface	4633	100-yr	8279	860.34	9.61	2385.32	486.71
Surface	4633	250-yr	10611	861.92	9.82	3182.01	523.55
Surface	4633	500-yr	12939	863.46	9.92	4062.33	595.83
Surface	4516	1-yr	230	851.30	3.70	92.26	84.95
Surface	4516	2-yr	872	853.20	5.07	414.73	197.67
Surface	4516	5-yr	2061	855.01	6.75	784.58	221.73
Surface	4516	10-yr	3227	856.11	8.18	1113.22	383.39
Surface	4516	25-yr	5040	857.79	8.90	1909.17	523.35
Surface	4516	50-yr	6580	858.96	9.10	2550.55	566.30
Surface	4516	100-yr	8279	860.21	9.20	3324.11	646.41
Surface	4516	250-yr	10611	861.85	9.11	4470.69	726.80
Surface	4516	500-yr	12939	863.43	8.84	5640.05	746.94
Surface	4384	1-yr	230	850.82	3.38	102.95	153.34
Surface	4384	2-yr	872	853.03	3.55	558.64	303.38
Surface	4384	5-yr	2061	854.94	4.03	1258.37	399.00
Surface	4384	10-yr	3227	856.09	4.47	1767.63	461.00
Surface	4384	25-yr	5040	857.81	4.71	2594.44	510.91
Surface	4384	50-yr	6580	858.98	4.96	3229.59	568.15
Surface	4384	100-yr	8279	860.23	5.10	3978.65	622.01
Surface	4384	250-yr	10611	861.87	5.20	5027.62	667.05
Surface	4384	500-yr	12939	863.45	5.22	6119.99	711.06
Surface	4264	1-yr	230	850.58	2.27	260.55	261.51
Surface	4264	2-yr	872	852.99	2.23	1058.61	395.85
Surface	4264	5-yr	2061	854.90	2.88	1974.17	523.65
Surface	4264	10-yr	3227	856.04	3.40	2585.79	540.44
Surface	4264	25-yr	5040	857.77	3.89	3543.97	625.88
Surface	4264	50-yr	6580	858.94	4.24	4318.19	689.69
Surface	4264	100-yr	8279	860.20	4.39	5209.39	715.13
Surface	4264	250-yr	10611	861.84	4.53	6404.04	747.90
Surface	4264	500-yr	12939	863.42	4.64	7630.91	794.41

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	4221	1-yr	230	850.54	1.69	270.46	269.36
Surface	4221	2-yr	872	852.98	1.48	1399.85	530.71
Surface	4221	5-yr	2061	854.89	1.91	2447.01	563.84
Surface	4221	10-yr	3227	856.04	2.31	3157.12	661.70
Surface	4221	25-yr	5040	857.77	2.63	4312.11	676.53
Surface	4221	50-yr	6580	858.94	2.88	5112.11	686.85
Surface	4221	100-yr	8279	860.20	3.08	5983.79	699.37
Surface	4221	250-yr	10611	861.83	3.31	7156.91	737.10
Surface	4221	500-yr	12939	863.42	3.46	8333.19	745.09
Surface	4127	1-yr	230	850.49	1.09	350.76	321.00
Surface	4127	2-yr	872	852.97	1.21	1195.07	382.68
Surface	4127	5-yr	2061	854.88	1.79	1969.03	429.51
Surface	4127	10-yr	3227	856.02	2.26	2538.76	543.94
Surface	4127	25-yr	5040	857.75	2.65	3501.03	567.80
Surface	4127	50-yr	6580	858.92	2.93	4174.52	580.13
Surface	4127	100-yr	8279	860.18	3.15	4910.67	587.83
Surface	4127	250-yr	10611	861.81	3.39	5875.07	590.89
Surface	4127	500-yr	12939	863.40	3.57	6812.95	594.25
Surface	3984	1-yr	230	850.41	1.30	257.30	272.71
Surface	3984	2-yr	872	852.94	1.35	1190.31	428.16
Surface	3984	5-yr	2061	854.84	1.91	2042.15	467.86
Surface	3984	10-yr	3227	855.97	2.41	2624.58	571.28
Surface	3984	25-yr	5040	857.68	2.82	3685.63	651.34
Surface	3984	50-yr	6580	858.85	3.11	4484.91	709.13
Surface	3984	100-yr	8279	860.11	3.34	5405.59	756.22
Surface	3984	250-yr	10611	861.74	3.59	6694.63	823.01
Surface	3984	500-yr	12939	863.33	3.79	8054.26	890.92
Surface	3885	1-yr	230	850.23	3.36	177.30	181.97
Surface	3885	2-yr	872	852.90	2.31	975.66	338.27
Surface	3885	5-yr	2061	854.79	3.12	1640.95	370.36
Surface	3885	10-yr	3227	855.90	4.04	2113.40	485.60
Surface	3885	25-yr	5040	857.61	4.60	3055.76	582.80
Surface	3885	50-yr	6580	858.78	4.88	3745.10	593.82
Surface	3885	100-yr	8279	860.04	5.09	4503.10	606.61
Surface	3885	250-yr	10611	861.69	5.28	5508.79	617.64
Surface	3885	500-yr	12939	863.28	5.42	6501.07	628.95
Surface	3775	1-yr	230	850.11	1.65	298.79	171.71
Surface	3775	2-yr	872	852.87	1.89	1087.13	333.19
Surface	3775	5-yr	2061	854.75	2.68	1930.04	509.37
Surface	3775	10-yr	3227	855.86	3.22	2501.92	528.73
Surface	3775	25-yr	5040	857.58	3.63	3438.42	561.60
Surface	3775	50-yr	6580	858.75	3.96	4109.44	583.97
Surface	3775	100-yr	8279	860.01	4.22	4862.43	607.96
Surface	3775	250-yr	10611	861.66	4.46	5878.24	625.40
Surface	3775	500-yr	12939	863.25	4.63	6883.47	637.29

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	3740	1-yr	236	850.10	1.44	457.73	263.23
Surface	3740	2-yr	881	852.87	1.73	1653.21	611.35
Surface	3740	5-yr	2077	854.75	2.20	2882.56	670.10
Surface	3740	10-yr	3250	855.85	2.65	3636.47	698.13
Surface	3740	25-yr	5073	857.57	2.99	4861.99	724.24
Surface	3740	50-yr	6626	858.75	3.27	5720.68	739.29
Surface	3740	100-yr	8340	860.01	3.50	6679.99	771.36
Surface	3740	250-yr	10687	861.66	3.70	7959.25	780.66
Surface	3740	500-yr	13026	863.25	3.84	9209.90	788.70
Surface	3646	1-yr	236	849.91	3.00	125.17	69.31
Surface	3646	2-yr	881	852.76	3.09	665.00	274.65
Surface	3646	5-yr	2077	854.60	4.11	1348.97	418.60
Surface	3646	10-yr	3250	855.66	4.96	1797.86	429.88
Surface	3646	25-yr	5073	857.36	5.57	2543.44	446.30
Surface	3646	50-yr	6626	858.51	6.08	3063.56	459.45
Surface	3646	100-yr	8340	859.76	6.48	3646.31	473.77
Surface	3646	250-yr	10687	861.39	6.89	4435.63	492.41
Surface	3646	500-yr	13026	862.98	7.18	5228.21	507.18
Surface	3540	1-yr	236	849.79	2.78	186.73	147.41
Surface	3540	2-yr	881	852.71	2.93	794.15	315.86
Surface	3540	5-yr	2077	854.54	3.93	1447.36	395.58
Surface	3540	10-yr	3250	855.59	4.71	1886.82	459.02
Surface	3540	25-yr	5073	857.30	5.14	2746.15	515.97
Surface	3540	50-yr	6626	858.45	5.52	3345.65	525.64
Surface	3540	100-yr	8340	859.70	5.79	4011.59	536.18
Surface	3540	250-yr	10687	861.34	6.06	4901.59	549.19
Surface	3540	500-yr	13026	862.94	6.26	5786.08	561.52
Surface	3466	1-yr	236	849.73	2.30	254.75	198.74
Surface	3466	2-yr	881	852.68	2.62	1045.15	413.00
Surface	3466	5-yr	2077	854.52	3.35	1886.93	487.66
Surface	3466	10-yr	3250	855.56	4.01	2408.07	511.45
Surface	3466	25-yr	5073	857.27	4.42	3311.74	544.73
Surface	3466	50-yr	6626	858.42	4.78	3951.68	567.24
Surface	3466	100-yr	8340	859.68	5.07	4685.63	613.53
Surface	3466	250-yr	10687	861.32	5.48	5772.23	722.53
Surface	3466	500-yr	13026	862.92	5.51	6933.12	727.99
Surface	3309	1-yr	236	849.25	4.23	66.77	76.44
Surface	3309	2-yr	881	852.47	3.92	495.33	189.66
Surface	3309	5-yr	2077	854.17	5.63	924.89	323.49
Surface	3309	10-yr	3250	855.09	6.92	1226.31	327.64
Surface	3309	25-yr	5073	856.81	7.50	1815.55	373.49
Surface	3309	50-yr	6626	857.94	8.05	2249.76	397.86
Surface	3309	100-yr	8340	859.19	8.39	2778.04	437.79
Surface	3309	250-yr	10687	860.86	8.65	3530.47	462.29
Surface	3309	500-yr	13026	862.47	8.83	4293.07	487.85

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	3252	1-yr	236	848.82	5.15	45.95	25.68
Surface	3252	2-yr	881	852.43	3.81	538.39	178.04
Surface	3252	5-yr	2077	854.09	5.71	900.86	291.60
Surface	3252	10-yr	3250	854.95	7.22	1159.70	305.65
Surface	3252	25-yr	5073	856.67	7.86	1715.23	358.60
Surface	3252	50-yr	6626	857.80	8.41	2164.16	418.14
Surface	3252	100-yr	8340	859.08	8.66	2706.21	425.21
Surface	3252	250-yr	10687	860.76	8.88	3424.75	430.03
Surface	3252	500-yr	13026	862.38	9.04	4125.70	434.89
Surface	3184	1-yr	236	848.71	3.42	68.94	21.68
Surface	3184	2-yr	881	852.32	3.96	531.58	233.95
Surface	3184	5-yr	2077	853.87	6.20	975.38	373.97
Surface	3184	10-yr	3250	854.72	7.52	1309.65	419.35
Surface	3184	25-yr	5073	856.57	7.38	2190.69	531.24
Surface	3184	50-yr	6626	857.73	7.44	2850.46	585.40
Surface	3184	100-yr	8340	859.04	7.27	3640.43	623.52
Surface	3184	250-yr	10687	860.75	7.08	4746.13	672.01
Surface	3184	500-yr	13026	862.39	6.94	5878.52	720.99
Surface	3134	1-yr	236	848.69	2.29	103.27	36.80
Surface	3134	2-yr	881	852.31	2.74	428.54	132.37
Surface	3134	5-yr	2077	853.83	4.65	680.84	251.09
Surface	3134	10-yr	3250	854.56	6.32	889.18	307.87
Surface	3134	25-yr	5073	856.26	6.96	1489.57	396.29
Surface	3134	50-yr	6626	857.34	7.44	1964.21	463.84
Surface	3134	100-yr	8340	858.66	7.49	2606.49	511.05
Surface	3134	250-yr	10687	860.40	7.45	3539.20	558.05
Surface	3134	500-yr	13026	862.06	7.44	4509.75	613.47
Surface	3078	1-yr	236	848.60	2.64	89.37	35.03
Surface	3078	2-yr	881	852.23	3.26	407.31	126.32
Surface	3078	5-yr	2077	853.64	5.55	712.29	376.26
Surface	3078	10-yr	3250	854.28	7.43	964.19	401.66
Surface	3078	25-yr	5073	856.03	8.03	1754.74	496.49
Surface	3078	50-yr	6626	857.26	8.04	2381.39	521.38
Surface	3078	100-yr	8340	858.61	7.87	3095.36	539.56
Surface	3078	250-yr	10687	860.37	7.71	4067.31	565.57
Surface	3078	500-yr	13026	862.04	7.65	5046.25	603.51
Surface	2919	1-yr	236	847.43	6.73	35.09	11.88
Surface	2919	2-yr	881	850.98	7.83	154.98	143.88
Surface	2919	5-yr	2077	852.60	8.56	592.91	429.40
Surface	2919	10-yr	3250	853.86	7.66	1185.26	499.85
Surface	2919	25-yr	5073	855.86	6.51	2225.24	540.23
Surface	2919	50-yr	6626	857.12	6.50	2930.97	589.82
Surface	2919	100-yr	8340	858.49	6.53	3779.37	653.37
Surface	2919	250-yr	10687	860.28	6.29	4996.48	699.01
Surface	2919	500-yr	13026	861.98	6.10	6206.46	721.33

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	2843	1-yr	236	847.59	2.02	117.07	31.67
Surface	2843	2-yr	881	851.13	3.35	491.64	310.25
Surface	2843	5-yr	2077	852.44	5.57	1023.29	505.29
Surface	2843	10-yr	3250	853.77	5.97	1834.50	660.46
Surface	2843	25-yr	5073	855.80	5.48	3219.94	704.84
Surface	2843	50-yr	6626	857.07	5.53	4133.34	728.68
Surface	2843	100-yr	8340	858.46	5.52	5159.42	759.82
Surface	2843	250-yr	10687	860.26	5.57	6596.91	830.74
Surface	2843	500-yr	13026	861.96	5.49	8048.86	870.11
Surface	2696	1-yr	236	846.76	6.06	38.94	12.41
Surface	2696	2-yr	881	850.27	6.82	214.50	215.56
Surface	2696	5-yr	2077	851.62	7.77	540.62	277.40
Surface	2696	10-yr	3250	853.37	6.60	1054.37	303.03
Surface	2696	25-yr	5073	855.37	6.63	1684.38	343.64
Surface	2696	50-yr	6626	856.62	6.91	2121.12	356.21
Surface	2696	100-yr	8340	858.00	7.07	2621.76	371.37
Surface	2696	250-yr	10687	859.80	7.20	3312.93	397.60
Surface	2696	500-yr	13026	861.51	7.27	4012.72	421.10
Surface	2531	1-yr	236	846.35	3.10	76.04	36.03
Surface	2531	2-yr	881	849.02	4.40	214.85	88.08
Surface	2531	5-yr	2077	851.11	6.01	468.73	135.48
Surface	2531	10-yr	3250	852.72	6.90	725.85	191.43
Surface	2531	25-yr	5073	854.77	7.40	1165.58	252.90
Surface	2531	50-yr	6626	855.97	7.99	1499.27	300.63
Surface	2531	100-yr	8340	857.42	8.11	1952.49	320.79
Surface	2531	250-yr	10687	859.29	8.25	2576.73	348.31
Surface	2531	500-yr	13026	861.05	8.33	3212.07	374.34
Surface	2409	1-yr	236	846.19	2.68	88.17	31.02
Surface	2409	2-yr	881	848.77	4.50	220.10	87.25
Surface	2409	5-yr	2077	850.79	6.28	451.27	132.81
Surface	2409	10-yr	3250	852.48	6.97	689.71	176.39
Surface	2409	25-yr	5073	854.43	7.88	1141.23	275.53
Surface	2409	50-yr	6626	855.60	8.57	1494.18	322.71
Surface	2409	100-yr	8340	857.15	8.52	2018.53	351.53
Surface	2409	250-yr	10687	859.13	8.40	2743.28	380.78
Surface	2409	500-yr	13026	860.92	8.43	3450.42	415.09
Surface	2293	1-yr	236	845.74	4.36	54.09	23.44
Surface	2293	2-yr	881	847.95	6.43	153.28	81.86
Surface	2293	5-yr	2077	849.14	9.96	253.24	86.38
Surface	2293	10-yr	3250	850.19	11.96	346.65	97.30
Surface	2293	25-yr	5073	851.82	13.33	531.07	128.49
Surface	2293	50-yr	6626	853.47	12.99	770.30	157.34
Surface	2293	100-yr	8340	855.22	12.79	1091.89	223.09
Surface	2293	250-yr	10687	858.22	10.65	1803.19	255.22
Surface	2293	500-yr	13026	860.22	10.24	2419.66	383.21

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	2186	1-yr	236	844.99	5.31	44.47	25.82
Surface	2186	2-yr	881	846.59	7.79	126.47	95.63
Surface	2186	5-yr	2077	848.20	9.57	320.62	129.00
Surface	2186	10-yr	3250	849.49	10.53	487.75	129.00
Surface	2186	25-yr	5073	851.39	11.40	732.42	129.00
Surface	2186	50-yr	6626	853.12	11.63	961.59	137.16
Surface	2186	100-yr	8340	854.89	11.94	1211.88	145.93
Surface	2186	250-yr	10687	857.08	12.43	1569.74	251.76
Surface	2186	500-yr	13026	858.79	12.93	2108.41	349.05
Surface	2091	1-yr	236	844.95	2.13	116.69	84.20
Surface	2091	2-yr	881	846.45	4.54	247.73	88.00
Surface	2091	5-yr	2077	847.87	7.53	372.88	88.00
Surface	2091	10-yr	3250	849.06	9.44	477.10	88.00
Surface	2091	25-yr	5073	850.51	11.86	604.60	88.00
Surface	2091	50-yr	6626	851.50	13.66	692.36	88.00
Surface	2091	100-yr	8340	852.49	15.41	781.63	98.65
Surface	2091	250-yr	10687	853.58	17.65	931.93	191.41
Surface	2091	500-yr	13026	855.01	18.54	1210.70	196.96
Surface	1959	1-yr	236	844.89	1.69	281.99	170.50
Surface	1959	2-yr	881	846.33	3.58	527.11	170.50
Surface	1959	5-yr	2077	847.70	5.94	761.39	170.50
Surface	1959	10-yr	3250	848.93	7.36	970.55	170.50
Surface	1959	25-yr	5073	850.47	9.11	1234.45	172.38
Surface	1959	50-yr	6626	851.58	10.33	1486.27	295.63
Surface	1959	100-yr	8340	852.75	11.22	1846.92	311.18
Surface	1959	250-yr	10687	854.13	12.24	2280.18	316.14
Surface	1959	500-yr	13026	855.36	13.12	2669.66	319.51
Surface	1845	1-yr	236	844.66	3.05	141.33	186.17
Surface	1845	2-yr	881	846.02	4.60	456.03	237.50
Surface	1845	5-yr	2077	847.37	6.43	776.47	240.09
Surface	1845	10-yr	3250	848.64	7.17	1096.41	276.58
Surface	1845	25-yr	5073	850.27	7.82	1733.78	468.02
Surface	1845	50-yr	6626	851.48	7.98	2302.95	471.35
Surface	1845	100-yr	8340	852.74	8.04	2899.90	474.67
Surface	1845	250-yr	10687	854.21	8.28	3598.07	478.53
Surface	1845	500-yr	13026	855.50	8.54	4218.82	481.93
Surface	1729	1-yr	236	843.58	5.67	54.53	76.32
Surface	1729	2-yr	881	845.05	7.08	314.83	302.68
Surface	1729	5-yr	2077	846.93	6.90	930.88	371.90
Surface	1729	10-yr	3250	848.32	7.12	1499.35	436.46
Surface	1729	25-yr	5073	850.04	7.41	2372.87	547.79
Surface	1729	50-yr	6626	851.27	7.75	3062.25	588.15
Surface	1729	100-yr	8340	852.56	7.96	3844.39	616.75
Surface	1729	250-yr	10687	854.05	8.14	4793.79	652.70
Surface	1729	500-yr	13026	855.36	8.40	5653.39	661.91

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	1573	1-yr	236	843.25	1.65	220.23	186.47
Surface	1573	2-yr	881	844.91	2.63	567.98	230.51
Surface	1573	5-yr	2077	846.76	3.68	1027.69	265.31
Surface	1573	10-yr	3250	848.14	4.35	1409.77	282.50
Surface	1573	25-yr	5073	849.84	5.13	1944.58	327.50
Surface	1573	50-yr	6626	851.05	5.70	2340.65	331.73
Surface	1573	100-yr	8340	852.25	6.23	2746.46	345.50
Surface	1573	250-yr	10687	853.62	6.95	3265.70	423.09
Surface	1573	500-yr	13026	854.81	7.57	3804.53	497.08
Surface	1419	1-yr	236	842.84	2.77	132.88	91.86
Surface	1419	2-yr	881	844.31	5.92	287.62	147.10
Surface	1419	5-yr	2077	845.82	8.57	548.83	179.51
Surface	1419	10-yr	3250	846.89	10.38	754.21	211.68
Surface	1419	25-yr	5073	848.08	12.78	1032.90	255.68
Surface	1419	50-yr	6626	848.95	14.27	1266.43	280.89
Surface	1419	100-yr	8340	850.03	15.13	1585.76	315.92
Surface	1419	250-yr	10687	850.98	16.85	1900.85	346.64
Surface	1419	500-yr	13026	851.88	18.17	2226.23	378.20
Surface	1284	1-yr	236	842.25	2.35	229.75	168.49
Surface	1284	2-yr	881	843.77	4.35	501.89	182.52
Surface	1284	5-yr	2077	845.24	6.75	775.82	196.98
Surface	1284	10-yr	3250	846.31	8.41	1003.15	226.83
Surface	1284	25-yr	5073	847.44	10.70	1275.34	253.86
Surface	1284	50-yr	6626	848.31	12.19	1503.35	274.46
Surface	1284	100-yr	8340	849.50	12.94	1845.19	298.30
Surface	1284	250-yr	10687	850.42	14.72	2127.10	313.07
Surface	1284	500-yr	13026	851.32	16.13	2414.58	327.73
Surface	1095	1-yr	236	840.46	5.99	53.56	69.39
Surface	1095	2-yr	881	841.78	8.29	215.20	187.30
Surface	1095	5-yr	2077	843.09	10.10	519.30	252.56
Surface	1095	10-yr	3250	843.84	11.91	710.58	257.15
Surface	1095	25-yr	5073	845.20	12.68	1066.43	264.92
Surface	1095	50-yr	6626	846.33	13.06	1368.90	273.23
Surface	1095	100-yr	8340	847.19	14.65	1634.21	325.19
Surface	1095	250-yr	10687	848.49	14.97	2063.44	331.61
Surface	1095	500-yr	13026	849.64	15.45	2447.51	337.25
Surface	947	1-yr	236	837.81	3.77	67.39	68.09
Surface	947	2-yr	881	838.94	6.46	148.31	74.46
Surface	947	5-yr	2077	840.13	9.59	240.00	80.79
Surface	947	10-yr	3250	841.05	11.57	316.82	88.25
Surface	947	25-yr	5073	842.70	12.57	535.22	182.52
Surface	947	50-yr	6626	843.80	13.28	756.52	215.87
Surface	947	100-yr	8340	844.90	13.99	1020.32	268.55
Surface	947	250-yr	10687	846.07	14.80	1356.60	300.88
Surface	947	500-yr	13026	846.96	15.79	1633.47	319.81

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	807	1-yr	236	836.20	5.33	97.55	122.23
Surface	807	2-yr	881	837.15	8.99	227.88	148.82
Surface	807	5-yr	2077	838.19	12.41	397.97	174.79
Surface	807	10-yr	3250	838.98	14.33	541.61	188.66
Surface	807	25-yr	5073	840.02	16.25	746.56	204.35
Surface	807	50-yr	6626	840.75	17.43	897.29	207.43
Surface	807	100-yr	8340	841.36	19.02	1023.48	208.69
Surface	807	250-yr	10687	842.22	20.47	1210.81	231.24
Surface	807	500-yr	13026	843.02	21.64	1402.50	251.82
Surface	654	1-yr	236	833.84	5.35	67.58	101.63
Surface	654	2-yr	881	834.98	7.81	258.71	220.77
Surface	654	5-yr	2077	835.96	9.70	490.97	253.77
Surface	654	10-yr	3250	836.71	10.81	686.14	266.78
Surface	654	25-yr	5073	837.44	12.94	884.10	269.18
Surface	654	50-yr	6626	837.96	14.49	1024.10	270.86
Surface	654	100-yr	8340	838.80	14.79	1253.00	273.59
Surface	654	250-yr	10687	839.07	17.87	1325.63	274.45
Surface	654	500-yr	13026	839.58	19.62	1466.79	276.12
Surface	571	1-yr	236	832.67	5.34	60.13	83.49
Surface	571	2-yr	881	834.08	6.97	279.11	260.48
Surface	571	5-yr	2077	834.89	9.49	505.16	297.59
Surface	571	10-yr	3250	835.48	11.13	690.36	345.75
Surface	571	25-yr	5073	836.18	12.90	942.88	371.12
Surface	571	50-yr	6626	836.66	14.26	1123.60	389.89
Surface	571	100-yr	8340	836.93	16.48	1232.81	405.54
Surface	571	250-yr	10687	837.86	16.33	1642.12	459.90
Surface	571	500-yr	13026	838.36	17.51	1876.03	468.81
Surface	480	1-yr	266	831.30	5.66	95.34	142.87
Surface	480	2-yr	922	832.19	8.44	248.95	227.07
Surface	480	5-yr	2139	833.27	9.34	590.78	371.20
Surface	480	10-yr	3332	833.73	11.00	761.32	373.30
Surface	480	25-yr	5190	834.31	12.92	978.52	375.96
Surface	480	50-yr	6774	834.71	14.34	1130.18	377.80
Surface	480	100-yr	8522	835.15	15.47	1295.95	379.81
Surface	480	250-yr	10914	835.67	16.86	1496.94	382.22
Surface	480	500-yr	13295	836.15	18.08	1679.76	384.41
Surface	405	1-yr	266	828.04	5.50	79.28	172.31
Surface	405	2-yr	922	828.71	8.59	209.06	217.95
Surface	405	5-yr	2139	829.50	9.61	464.59	396.05
Surface	405	10-yr	3332	830.00	10.50	678.03	440.28
Surface	405	25-yr	5190	830.55	12.02	926.44	469.61
Surface	405	50-yr	6774	830.96	12.78	1122.96	473.29
Surface	405	100-yr	8522	831.33	13.77	1296.18	475.54
Surface	405	250-yr	10914	831.76	15.05	1502.10	478.20
Surface	405	500-yr	13295	832.20	15.93	1713.16	480.91

Attachment 2 - Existing Conditions HEC-RAS Model Results

Reach	Cross Section	Design storm	Peak Flow (cfs)	Water Surface Elevation (ft)	Channel Velocity (ft/s)	Flow Area (sqft)	Top Width (ft)
Surface	298	1-yr	266	823.02	4.67	57.00	86.26
Surface	298	2-yr	922	823.87	6.41	155.75	150.28
Surface	298	5-yr	2139	824.82	8.31	321.87	198.58
Surface	298	10-yr	3332	825.56	9.46	483.88	241.16
Surface	298	25-yr	5190	826.53	10.63	744.98	294.93
Surface	298	50-yr	6774	827.15	11.69	957.12	390.71
Surface	298	100-yr	8522	828.27	11.30	1492.96	538.77
Surface	298	250-yr	10914	828.64	13.13	1694.33	550.16
Surface	298	500-yr	13295	829.90	12.03	2592.30	814.66
Surface	146	1-yr	266	808.00	1.12	237.62	49.49
Surface	146	2-yr	922	808.00	3.88	237.62	49.49
Surface	146	5-yr	2139	808.00	9.00	237.62	49.49
Surface	146	10-yr	3332	808.43	12.85	259.21	51.25
Surface	146	25-yr	5190	810.39	14.04	369.73	61.28
Surface	146	50-yr	6774	811.78	14.75	459.25	68.37
Surface	146	100-yr	8522	813.09	15.40	555.75	86.71
Surface	146	250-yr	10914	815.05	15.10	797.05	150.18
Surface	146	500-yr	13295	816.41	15.36	1068.16	224.47

Attachment 3 - Alternatives HEC-RAS Flow Load Points

Alternative 1		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	1031	2659	4328	6435	8421
J-11	11909.4	5	5	5	5	1186	2906	4689	6951	9098
J-10	9407.3	5	5	5	5	1120	2746	4452	6683	8848
J-09	7879.3	5	5	5	12	1172	2828	4570	6854	9074
J-04	6519.9	5	14	627	1194	2026	3397	5381	8041	10649
J-03	4847.2	5	127	792	1407	2314	3438	5440	8132	10784
J-02	3739.6	5	171	858	1492	2429	3406	5391	8068	10712
J-01	480.2	5	259	988	1663	2664	3550	5461	8169	10854

Alternative 2		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	1297	3174	5572	7819
J-11	11909.4	5	5	5	5	5	1464	3443	6000	8410
J-10	9407.3	5	5	5	5	78	1394	3252	5677	8023
J-09	7879.3	5	5	5	5	351	1452	3341	5812	8214
J-04	6519.9	5	5	511	1107	2006	2744	3959	6783	9562
J-03	4847.2	5	5	676	1320	2294	3095	4003	6851	9666
J-02	3739.6	5	5	742	1405	2409	3235	4164	6784	9581
J-01	480.2	5	61	872	1576	2644	3526	4514	6866	9695

Alternative 3		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	1881	4586	7111
J-11	11909.4	5	5	5	5	5	91	2075	4937	7621
J-10	9407.3	5	5	5	5	5	320	1906	4495	6984
J-09	7879.3	5	5	5	5	266	677	1972	4608	7143
J-04	6519.9	5	5	400	1004	1922	2711	3560	5370	8272
J-03	4847.2	5	5	565	1217	2210	3064	3975	5416	8344
J-02	3739.6	5	5	631	1302	2325	3203	4140	5438	8245
J-01	480.2	5	5	761	1472	2560	3493	4489	5870	8336

Attachment 3 - Alternatives HEC-RAS Flow Load Points

Alternative 4		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	202	2572	4957
J-11	11909.4	5	5	5	5	5	31	314	2804	5326
J-10	9407.3	5	5	5	5	5	260	584	2742	5159
J-09	7879.3	5	5	5	5	204	617	1046	2822	5280
J-04	6519.9	5	5	349	948	1860	2651	3533	4725	6149
J-03	4847.2	5	5	514	1161	2147	3003	3949	5236	6469
J-02	3739.6	5	5	580	1246	2262	3143	4114	5430	6686
J-01	480.2	5	5	710	1417	2497	3433	4463	5860	7203

Alternative 5		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	76	1491	3127	5317	9001
J-11	11909.4	5	5	5	5	180	1673	3403	5730	9017
J-10	9407.3	5	5	5	5	207	1684	3368	5661	8065
J-09	7879.3	5	5	5	5	248	1748	3463	5799	8270
J-04	6519.9	5	5	361	963	1827	2575	4142	6818	9691
J-03	4847.2	5	5	527	1177	2115	2926	4202	6905	9799
J-02	3739.6	5	5	592	1262	2230	3067	4192	6882	9706
J-01	480.2	5	5	722	1432	2465	3357	4356	6973	9828

Alternative 6		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	593	2220	4531	7782
J-11	11909.4	5	5	5	5	5	724	2439	4884	7684
J-10	9407.3	5	5	5	5	5	747	2422	4800	7112
J-09	7879.3	5	5	5	5	162	798	2498	4918	7284
J-04	6519.9	5	5	318	914	1817	2571	3412	5780	8511
J-03	4847.2	5	5	483	1127	2105	2922	3830	5854	8612
J-02	3739.6	5	5	549	1212	2220	3062	3997	5826	8562
J-01	480.2	5	5	679	1383	2455	3352	4347	5904	8670

Attachment 3 - Alternatives HEC-RAS Flow Load Points

Alternative 7		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	295	2302	4459
J-11	11909.4	5	5	5	5	5	5	412	2522	4801
J-10	9407.3	5	5	5	5	5	121	448	2545	4790
J-09	7879.3	5	5	5	5	70	477	881	2625	4906
J-04	6519.9	5	5	236	824	1726	2512	3369	4557	5764
J-03	4847.2	5	5	402	1037	2014	2864	3786	5068	6305
J-02	3739.6	5	5	467	1122	2129	3004	3951	5261	6522
J-01	480.2	5	5	597	1293	2364	3294	4300	5692	7039

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
146	813.1	810.6	810.6	809.7	809.7	809.6	809.6	809.6
298	828.3	826.7	826.7	826.2	826.2	826.1	826.1	826.1
405	831.3	830.7	830.7	830.4	830.4	830.3	830.3	830.3
480	835.2	834.4	834.4	834.1	834.1	834.1	834.1	834.0
571	836.9	836.3	836.3	835.8	835.8	835.8	835.8	835.8
654	838.8	837.6	837.6	837.1	837.1	837.2	837.1	837.0
807	841.4	840.2	840.2	839.5	839.5	839.5	839.4	839.4
947	844.9	842.9	842.9	841.9	841.9	841.9	841.8	841.7
1095	847.2	845.5	845.5	844.4	844.3	844.4	844.2	844.2
1284	849.5	847.6	847.6	847.0	847.0	847.0	846.9	846.9
1419	850.0	848.3	848.3	847.6	847.5	847.6	847.5	847.4
1573	852.3	850.1	850.1	849.0	849.0	849.1	848.9	848.9
1729	852.6	850.3	850.3	849.2	849.2	849.3	849.1	849.0
1845	852.7	850.5	850.5	849.5	849.5	849.5	849.4	849.3
1959	852.8	850.7	850.7	849.7	849.7	849.8	849.6	849.6
2091	852.5	850.7	850.7	849.8	849.8	849.9	849.7	849.7
2186	854.9	851.8	851.8	850.3	850.3	850.4	850.2	850.2
2293	855.2	852.2	852.2	851.0	851.0	851.1	850.9	850.8
2409	857.2	854.7	854.7	853.5	853.5	853.6	853.4	853.3
2531	857.4	855.1	855.1	853.8	853.8	853.9	853.7	853.6
2696	858.0	855.7	855.7	854.4	854.4	854.5	854.3	854.2
2843	858.5	856.1	856.1	854.8	854.8	854.9	854.7	854.6
2919	858.5	856.2	856.2	854.9	854.9	855.0	854.8	854.7
3078	858.6	856.3	856.3	855.2	855.1	855.2	855.0	855.0
3134	858.7	856.5	856.5	855.4	855.4	855.5	855.3	855.2
3184	859.0	856.8	856.8	855.7	855.7	855.8	855.5	855.5
3252	859.1	856.9	856.9	855.8	855.8	855.9	855.7	855.6
3309	859.2	857.1	857.1	856.0	855.9	856.0	855.8	855.8
3466	859.7	857.5	857.5	856.4	856.4	856.5	856.3	856.2
3540	859.7	857.6	857.6	856.5	856.4	856.5	856.3	856.3
3646	859.8	857.6	857.6	856.5	856.5	856.6	856.4	856.3
3740	860.0	857.8	857.8	856.7	856.7	856.8	856.6	856.5
3775	860.0	857.8	857.8	856.7	856.7	856.8	856.6	856.5
3885	860.0	857.9	857.9	856.8	856.7	856.8	856.6	856.6
3984	860.1	858.0	858.0	856.8	856.8	856.9	856.7	856.6
4127	860.2	858.0	858.0	856.9	856.9	857.0	856.8	856.7
4221	860.2	858.0	858.0	856.9	856.9	857.0	856.8	856.7
4264	860.2	858.0	858.0	856.9	856.9	857.0	856.8	856.7
4384	860.2	858.1	858.1	857.0	856.9	857.0	856.8	856.8
4516	860.2	858.1	858.1	856.9	856.9	857.0	856.8	856.8
4633	860.3	858.3	858.3	857.2	857.2	857.3	857.1	857.1
4737	861.1	859.0	859.0	857.8	857.7	857.9	857.6	857.6
4847	861.6	859.6	859.6	858.4	858.4	858.5	858.2	858.2
4951	861.6	859.6	859.6	858.4	858.4	858.6	858.3	858.2
5066	861.6	859.7	859.7	858.5	858.5	858.7	858.4	858.3
5215	862.2	860.2	860.2	859.0	858.9	859.2	858.8	858.8

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
5343	862.8	860.8	860.8	859.4	859.3	859.7	859.2	859.2
5469	863.0	861.0	861.0	859.5	859.5	859.9	859.4	859.3
5605	863.2	861.2	861.2	859.7	859.7	860.1	859.5	859.5
5718	863.4	861.3	861.3	859.8	859.8	860.3	859.7	859.6
5821	863.5	861.5	861.5	860.0	859.9	860.4	859.8	859.8
5925	863.6	861.6	861.6	860.1	860.1	860.5	859.9	859.9
6039	863.7	861.7	861.7	860.2	860.2	860.7	860.1	860.0
6158	863.9	861.9	861.9	860.4	860.4	860.8	860.3	860.2
6275	864.0	862.1	862.1	860.6	860.6	861.1	860.5	860.5
6390	864.2	862.3	862.3	860.8	860.8	861.3	860.7	860.7
6450	864.2	862.3	862.3	860.9	860.9	861.4	860.8	860.8
6520	864.1	862.2	862.2	861.0	861.0	861.4	860.9	860.9
6564	865.0	863.2	863.2	862.1	862.2	862.4	861.9	862.1
6620	865.3	863.7	863.7	862.3	862.3	862.8	862.2	862.1
6720	865.5	863.9	863.9	862.4	862.3	863.0	862.4	862.1
6822	865.7	864.1	864.1	862.6	862.3	863.3	862.7	862.2
6934	865.9	864.4	864.4	862.8	862.4	863.6	863.0	862.3
7051	866.6	865.5	865.5	863.6	862.9	864.7	864.0	862.7
7167	867.1	866.0	866.0	864.3	863.4	865.3	864.7	863.2
7293	868.2	867.1	867.1	865.1	864.1	866.3	865.5	863.8
7443	868.1	866.9	866.9	865.0	864.0	866.1	865.4	863.7
7551	868.9	868.3	868.3	866.3	865.2	867.5	866.8	864.9
7669	869.7	868.8	868.8	866.7	865.5	868.0	867.2	865.2
7767	869.7	868.9	868.9	866.7	865.5	868.0	867.3	865.2
7879	869.8	868.9	868.9	866.8	865.6	868.1	867.3	865.2
7939	870.1	869.1	869.1	867.0	866.0	868.3	867.5	865.8
8085	870.3	869.4	869.4	867.4	866.2	868.6	867.9	865.9
8173	871.2	870.1	870.1	867.8	866.2	869.3	868.5	865.9
8232	871.3	870.2	870.2	868.1	866.8	869.5	868.7	866.6
8291	872.2	871.0	871.0	868.5	866.9	870.1	869.2	866.7
8407	872.3	871.1	871.1	869.0	867.4	870.3	869.5	867.1
8525	872.5	871.4	871.4	869.6	867.8	870.7	870.0	867.5
8629	872.7	871.6	871.6	869.7	867.8	870.9	870.1	867.5
8697	872.9	871.9	871.9	869.9	868.1	871.1	870.4	867.8
8835	873.4	872.4	872.4	871.3	870.2	872.0	871.6	870.0
8987	874.5	874.0	874.0	872.5	871.1	873.5	872.9	870.8
9052	875.1	874.4	874.4	872.5	871.2	873.8	873.1	870.9
9116	876.3	875.4	875.4	873.6	871.8	874.7	874.0	871.3
9210	878.6	876.7	876.7	875.0	872.5	876.2	875.5	872.1
9288	880.4	879.4	879.4	876.6	874.1	878.2	877.2	873.5
9407	880.7	879.6	879.6	876.7	874.1	878.4	877.4	873.5
9580	881.0	879.8	879.8	876.9	874.2	878.7	877.6	873.6
9696	881.0	879.9	879.9	876.9	874.2	878.7	877.6	873.7
9769	881.2	880.0	880.0	877.0	874.3	878.8	877.7	873.8
9868	881.1	880.0	880.0	877.0	874.2	878.8	877.7	873.8
9967	881.5	880.3	880.3	877.5	874.5	879.1	878.1	874.5

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
10072	881.5	880.3	880.3	877.5	874.9	879.2	878.1	875.0
10175	881.6	880.4	880.4	877.8	876.0	879.3	878.3	876.2
10290	881.7	880.6	880.6	878.3	876.5	879.5	878.6	876.7
10376	881.8	880.8	880.8	878.9	877.1	879.8	879.1	877.3
10499	882.8	881.9	881.9	880.2	877.9	881.1	880.5	878.2
10603	883.1	882.3	882.3	880.5	878.2	881.5	880.8	878.4
10707	883.6	882.7	882.7	880.8	878.3	881.8	881.1	878.6
10815	883.8	882.9	882.9	881.0	878.4	882.0	881.3	878.7
10888	884.0	883.1	883.1	881.1	878.5	882.2	881.4	878.8
10934	884.1	883.2	883.2	881.2	878.6	882.3	881.5	878.9
11039	884.2	883.4	883.4	881.4	878.8	882.5	881.7	879.1
11148	884.0	883.2	883.2	881.5	878.9	882.4	881.8	879.2
11260	885.6	884.6	884.6	881.9	879.0	883.4	882.3	879.3
11370	885.7	884.7	884.7	882.2	879.1	883.7	882.7	879.5
11473	887.7	886.5	886.5	883.3	879.3	885.1	883.8	879.7
11577	887.8	886.6	886.6	883.3	879.4	885.2	883.9	879.8
11693	888.0	886.7	886.7	883.6	880.2	885.4	884.1	880.6
11744	888.3	887.1	887.1	883.9	880.4	885.7	884.4	880.8
11799	888.3	887.1	887.1	883.9	880.5	885.7	884.4	880.8
11853	888.5	887.2	887.2	884.0	880.6	885.8	884.5	880.9
11909	888.5	887.3	887.3	884.0	880.7	885.8	884.5	881.0
12010	888.5	887.2	887.2	884.0	881.3	885.7	884.5	881.5
12124	888.8	887.7	887.7	885.1	881.9	886.6	885.5	882.2
12219	888.7	887.6	887.6	885.2	882.4	886.6	885.6	882.8
12329	890.0	889.2	889.2	886.9	883.4	888.3	887.3	883.8
12440	890.1	889.3	889.3	887.0	883.7	888.4	887.5	884.1
12539	890.1	889.3	889.3	887.1	883.9	888.4	887.5	884.3
12649	890.1	889.4	889.4	887.1	884.1	888.4	887.5	884.5
12745	890.3	889.5	889.5	887.3	884.3	888.6	887.7	884.6
12873	889.7	889.1	889.1	887.3	885.1	888.3	887.6	885.2
12955	891.2	890.8	890.8	889.2	886.6	890.1	889.5	887.0
13069	892.8	892.2	892.2	890.5	887.9	891.5	890.8	888.2
13217	893.3	893.0	893.0	891.5	889.7	892.3	891.7	889.9
13295	894.7	894.3	894.3	893.1	891.4	893.8	893.3	891.5
13358	897.2	896.8	896.8	895.5	893.4	896.2	895.7	893.6
13384	898.2	897.8	897.8	896.5	893.9	897.3	896.8	894.2
13467	899.2	898.6	898.6	896.9	894.0	897.9	897.2	894.4
13526	899.3	898.6	898.6	897.0	894.1	897.9	897.2	894.5
13642	899.3	898.7	898.7	897.0	894.1	898.0	897.3	894.5
13763	899.4	898.8	898.8	897.0	894.2	898.0	897.3	894.5
13866	899.4	898.7	898.7	897.0	893.7	898.0	897.3	894.2
13970	899.4	898.7	898.7	897.0	894.0	898.0	897.3	894.4
14089	899.4	898.8	898.8	897.0	894.4	898.0	897.3	894.7
14199	899.4	898.8	898.8	897.1	894.5	898.0	897.4	894.8
14304	899.4	898.8	898.8	897.1	894.5	898.0	897.4	894.8
14408	899.4	898.8	898.8	897.2	894.8	898.1	897.4	895.1

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Water Surface Elevation (feet)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
14527	899.5	898.9	898.9	897.3	895.3	898.2	897.6	895.5
14610	899.5	898.9	898.9	897.3	895.4	898.2	897.6	895.6
14729	899.5	898.9	898.9	897.4	895.6	898.2	897.6	895.7
14829	899.5	898.9	898.9	897.2	895.2	898.1	897.5	895.4
14939	899.5	898.9	898.9	897.3	895.4	898.2	897.6	895.6
15054	899.5	898.9	898.9	897.4	896.0	898.2	897.7	896.1
15159	899.7	899.1	899.1	897.9	896.8	898.5	898.1	896.9
15261	899.7	899.2	899.2	898.0	897.0	898.6	898.2	897.1
15365	899.8	899.3	899.3	898.1	897.3	898.7	898.3	897.4

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
146	15.4	14.2	14.2	13.6	13.6	13.6	13.6	13.5
298	11.3	10.8	10.8	10.3	10.3	10.2	10.2	10.2
405	13.8	11.9	11.9	11.5	11.5	11.4	11.4	11.3
480	15.5	13.2	13.2	12.3	12.3	12.2	12.1	12.1
571	16.5	13.2	13.2	12.1	12.1	12.2	12.0	11.9
654	14.8	13.3	13.3	11.8	11.8	11.8	11.6	11.6
807	19.0	16.3	16.3	15.4	15.4	15.4	15.2	15.2
947	14.0	12.7	12.7	12.2	12.2	12.2	12.1	12.1
1095	14.7	12.7	12.7	12.8	12.9	13.0	12.9	12.9
1284	12.9	11.1	11.1	9.5	9.4	9.5	9.3	9.2
1419	15.1	13.1	13.1	11.6	11.5	11.6	11.3	11.3
1573	6.2	5.3	5.3	4.8	4.7	4.8	4.7	4.7
1729	8.0	7.5	7.5	7.3	7.3	7.3	7.3	7.2
1845	8.0	7.9	7.9	7.6	7.5	7.6	7.5	7.5
1959	11.2	9.4	9.4	8.3	8.2	8.3	8.1	8.1
2091	15.4	12.3	12.3	10.7	10.6	10.7	10.5	10.4
2186	11.9	11.4	11.4	11.2	11.2	11.3	11.1	11.1
2293	12.8	13.4	13.4	12.8	12.8	12.8	12.7	12.7
2409	8.5	8.0	8.0	7.5	7.5	7.5	7.4	7.4
2531	8.1	7.5	7.5	7.1	7.1	7.1	7.1	7.1
2696	7.1	6.7	6.7	6.5	6.5	6.5	6.5	6.5
2843	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7
2919	6.5	6.5	6.5	6.9	6.9	6.8	6.9	7.0
3078	7.9	8.0	8.0	7.8	7.8	7.9	7.7	7.7
3134	7.5	7.1	7.1	6.7	6.7	6.7	6.7	6.7
3184	7.3	7.4	7.4	7.4	7.4	7.4	7.5	7.5
3252	8.7	8.0	8.0	7.6	7.6	7.6	7.6	7.6
3309	8.4	7.6	7.6	7.2	7.2	7.3	7.2	7.2
3466	5.1	4.5	4.5	4.2	4.2	4.2	4.2	4.2
3540	5.8	5.2	5.2	5.0	5.0	5.0	4.9	4.9
3646	6.5	5.7	5.7	5.3	5.3	5.3	5.3	5.2
3740	3.5	3.1	3.1	2.8	2.8	2.8	2.8	2.8
3775	4.2	3.8	3.8	3.3	3.3	3.5	3.3	3.3
3885	5.1	4.7	4.7	4.3	4.3	4.5	4.3	4.2
3984	3.3	2.9	2.9	2.6	2.5	2.7	2.5	2.5
4127	3.2	2.8	2.8	2.4	2.4	2.5	2.4	2.4
4221	3.1	2.7	2.7	2.4	2.4	2.5	2.4	2.4
4264	4.4	4.1	4.1	3.5	3.5	3.7	3.5	3.5
4384	5.1	4.8	4.8	4.5	4.5	4.6	4.4	4.4
4516	9.2	9.1	9.1	8.5	8.5	8.8	8.4	8.4
4633	9.6	8.8	8.8	7.9	7.9	8.2	7.8	7.8
4737	7.7	7.4	7.4	7.1	7.1	7.3	7.1	7.1
4847	4.6	4.0	4.0	3.7	3.7	3.8	3.7	3.7
4951	6.1	5.7	5.7	4.9	4.8	5.5	4.8	4.8
5066	10.8	9.5	9.5	7.7	7.7	8.7	7.6	7.5
5215	10.5	9.1	9.1	7.2	7.2	8.0	7.1	7.1

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
5343	7.1	5.9	5.9	5.0	5.0	5.4	4.9	4.9
5469	7.5	6.6	6.6	5.6	5.6	6.1	5.5	5.5
5605	7.2	6.3	6.3	5.4	5.3	5.8	5.3	5.3
5718	6.5	5.8	5.8	5.2	5.1	5.5	5.1	5.1
5821	6.1	5.5	5.5	4.8	4.8	5.2	4.8	4.8
5925	6.2	5.5	5.5	5.1	5.1	5.3	5.0	5.0
6039	6.1	5.7	5.7	5.2	5.2	5.5	5.2	5.2
6158	6.3	6.2	6.2	5.6	5.6	6.0	5.6	5.6
6275	6.0	5.8	5.8	5.5	5.5	5.7	5.5	5.5
6390	4.7	4.6	4.6	4.7	4.7	4.7	4.7	4.7
6450	5.8	6.4	6.4	6.9	6.9	6.8	6.9	6.9
6520	10.4	10.1	10.1	9.1	9.1	9.5	9.0	8.9
6564	6.0	6.5	6.5	3.6	1.9	5.9	4.8	1.6
6620	6.0	4.9	4.9	3.1	1.7	4.8	4.1	1.5
6720	8.6	8.5	8.5	5.4	3.0	8.0	6.9	2.6
6822	6.6	6.1	6.1	3.7	2.1	5.5	4.6	1.9
6934	10.8	11.2	11.2	7.8	4.8	10.4	9.2	4.4
7051	9.1	8.8	8.8	7.3	5.7	8.5	8.0	5.5
7167	11.9	11.0	11.0	8.5	6.7	10.2	9.2	6.3
7293	4.4	3.8	3.8	2.7	2.1	3.4	3.0	2.0
7443	11.8	12.3	12.3	10.2	8.8	11.6	11.0	8.5
7551	8.5	7.0	7.0	5.4	4.1	6.6	5.9	3.9
7669	4.0	3.3	3.3	2.2	1.6	2.9	2.5	1.5
7767	6.1	5.1	5.1	3.7	3.0	4.6	4.0	2.7
7879	8.6	7.5	7.5	6.2	5.9	7.0	6.4	6.0
7939	7.6	6.9	6.9	5.6	2.6	6.6	6.0	2.2
8085	12.0	10.7	10.7	8.2	3.7	10.1	9.0	3.2
8173	9.2	8.8	8.8	7.8	6.2	8.6	7.7	6.2
8232	9.2	8.2	8.2	6.8	3.6	7.6	7.0	3.1
8291	6.2	6.0	6.0	6.8	4.9	6.0	6.4	4.3
8407	7.1	7.0	7.0	6.7	4.5	6.9	6.9	4.2
8525	7.9	7.0	7.0	4.5	2.5	6.1	5.2	2.1
8629	8.6	8.3	8.3	6.3	4.2	7.6	6.9	4.0
8697	8.2	7.6	7.6	5.9	4.5	7.0	6.4	4.3
8835	12.9	13.3	13.3	10.3	7.0	12.3	11.1	6.3
8987	8.2	6.7	6.7	4.5	2.7	5.8	5.0	2.5
9052	11.3	10.3	10.3	8.7	4.5	9.5	8.9	4.0
9116	7.9	7.3	7.3	6.5	5.7	6.9	6.8	5.4
9210	12.2	13.6	13.6	9.9	8.6	11.6	10.6	8.2
9288	6.0	5.2	5.2	3.7	2.2	5.0	4.3	2.0
9407	5.2	4.4	4.4	3.3	1.8	4.1	3.7	1.7
9580	4.1	3.8	3.8	3.1	1.3	3.4	3.1	2.3
9696	4.9	4.6	4.6	4.0	1.6	4.2	3.8	2.6
9769	3.3	3.0	3.0	2.5	1.1	2.7	2.5	1.7
9868	6.1	5.8	5.8	5.8	3.1	5.4	5.3	5.3
9967	2.9	2.7	2.7	2.3	1.3	2.4	2.3	1.6

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
10072	4.1	4.1	4.1	4.4	5.1	4.0	4.0	5.7
10175	5.0	4.8	4.8	5.0	2.6	4.7	4.7	2.9
10290	7.1	7.2	7.2	7.8	4.3	7.3	7.5	4.8
10376	11.7	11.5	11.5	9.9	5.3	11.2	10.4	5.7
10499	8.3	7.7	7.7	5.7	3.0	6.8	6.0	3.3
10603	8.3	7.6	7.6	5.7	3.0	6.8	6.0	3.2
10707	6.9	6.4	6.4	4.8	2.2	5.7	5.0	2.4
10815	7.0	6.7	6.7	5.4	2.6	6.1	5.6	2.9
10888	7.1	6.7	6.7	5.8	2.9	6.3	6.0	3.4
10934	7.4	7.0	7.0	6.0	3.2	6.6	6.2	3.6
11039	7.8	7.2	7.2	5.3	2.4	6.5	5.7	2.6
11148	12.5	11.4	11.4	7.7	2.6	9.9	8.5	3.0
11260	9.5	8.8	8.8	7.6	2.6	8.4	7.9	3.0
11370	12.1	10.9	10.9	7.7	2.9	9.6	8.3	3.3
11473	6.6	6.0	6.0	4.4	2.4	5.4	4.7	2.6
11577	7.5	6.9	6.9	5.8	5.1	6.5	6.0	5.4
11693	7.1	6.7	6.7	5.4	3.3	6.3	5.6	3.4
11744	5.1	4.8	4.8	3.7	2.0	4.4	3.9	2.2
11799	5.0	4.6	4.6	3.7	2.4	4.3	3.9	2.6
11853	4.1	3.9	3.9	3.5	2.7	3.7	3.5	2.8
11909	4.2	4.1	4.1	4.3	3.4	4.0	4.2	3.6
12010	6.7	7.2	7.2	7.8	3.5	7.8	7.8	4.2
12124	7.0	6.8	6.8	5.8	3.2	6.1	5.9	3.8
12219	10.9	11.5	11.5	10.3	6.0	11.1	10.6	6.1
12329	4.9	4.4	4.4	4.0	3.4	4.1	4.0	3.6
12440	4.4	4.1	4.1	3.2	2.3	3.6	3.3	2.6
12539	4.2	3.9	3.9	3.3	2.5	3.6	3.3	2.7
12649	5.2	5.0	5.0	4.5	2.0	4.7	4.7	2.3
12745	5.3	5.1	5.1	4.5	1.9	5.0	4.6	2.2
12873	10.3	9.5	9.5	7.4	4.2	8.5	7.7	4.8
12955	11.9	11.1	11.1	8.9	5.8	10.3	9.4	6.2
13069	7.2	6.7	6.7	5.5	2.7	6.1	5.7	2.9
13217	11.4	10.6	10.6	9.1	4.6	10.3	9.5	5.1
13295	10.1	9.3	9.3	7.6	4.1	8.5	7.7	4.6
13358	11.9	10.9	10.9	8.2	5.6	9.7	8.7	6.3
13384	8.5	7.6	7.6	4.9	2.6	6.4	5.4	2.9
13467	4.2	3.9	3.9	3.2	1.8	3.6	3.3	2.1
13526	3.4	3.2	3.2	2.4	1.2	2.8	2.5	1.4
13642	2.5	2.3	2.3	1.6	0.9	2.0	1.7	1.0
13763	1.7	1.5	1.5	0.9	0.2	1.2	1.0	0.2
13866	2.2	2.4	2.4	3.4	7.4	2.8	3.2	6.8
13970	2.4	2.8	2.8	3.8	7.3	3.2	3.6	6.6
14089	2.6	2.8	2.8	3.6	5.6	3.2	3.6	5.3
14199	2.5	2.8	2.8	3.8	5.9	3.2	3.6	5.6
14304	2.7	3.1	3.1	4.3	7.3	3.5	4.1	7.0
14408	2.7	3.0	3.0	4.2	6.7	3.5	4.0	6.4

Attachment 4 - HEC-RAS 0.01 ACE Model Results for Existing Conditions and Alternatives

Cross Section	Velocity (ft/s)							
	Existing Conditions	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6	Alt-7
14527	2.1	2.4	2.4	3.1	4.4	2.7	3.0	4.3
14610	2.2	2.4	2.4	3.2	4.6	2.8	3.1	4.5
14729	2.8	3.0	3.0	3.7	4.6	3.4	3.6	4.5
14829	4.1	4.5	4.5	5.9	8.2	5.1	5.7	8.0
14939	4.3	4.8	4.8	6.6	9.9	5.6	6.3	9.5
15054	5.0	5.6	5.6	7.4	9.3	6.3	7.1	9.3
15159	4.3	4.7	4.7	6.0	7.4	5.2	5.7	7.4
15261	4.5	4.9	4.9	6.4	8.0	5.6	6.1	8.0
15365	4.4	4.8	4.8	6.0	7.0	5.3	5.8	6.9

Attachment 5 - Alternatives HEC-RAS Flow Load Points Including Outlet B

Alternative 1		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	250-Year	500-Year
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	842	2468	4136	6241	8227
J-11	11909.4	5	5	5	5	996	2715	4496	6757	8904
J-10	9407.3	5	5	5	5	930	2555	4260	6489	8654
J-09	7879.3	5	5	5	12	983	2637	4378	6661	8879
J-04	6519.9	5	14	441	1008	1837	3206	5189	7847	10454
J-03	4847.2	5	127	607	1222	2125	3247	5248	7938	10590
J-02	3739.6	5	171	672	1306	2240	3215	5199	7875	10517
J-01	480.2	5	259	802	1477	2475	3359	5268	7975	10659

Alternative 2		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	1107	2983	5379	7625
J-11	11909.4	5	5	5	5	5	1274	3251	5807	8216
J-10	9407.3	5	5	5	5	5	1204	3061	5483	7829
J-09	7879.3	5	5	5	5	165	1262	3149	5619	8019
J-04	6519.9	5	5	325	921	1821	2555	3768	6590	9367
J-03	4847.2	5	5	491	1134	2109	2906	3812	6658	9471
J-02	3739.6	5	5	556	1219	2224	3046	3972	6591	9386
J-01	480.2	5	5	686	1390	2459	3336	4323	6673	9500

Alternative 3		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	1691	4394	6917
J-11	11909.4	5	5	5	5	5	4	1885	4744	7427
J-10	9407.3	5	5	5	5	5	135	1715	4303	6790
J-09	7879.3	5	5	5	5	5	491	1782	4416	6949
J-04	6519.9	5	5	214	818	1736	2526	3369	5178	8078
J-03	4847.2	5	5	380	1031	2024	2878	3784	5224	8150
J-02	3739.6	5	5	445	1116	2139	3018	3950	5246	8051
J-01	480.2	5	5	575	1287	2374	3308	4298	5678	8142

Attachment 5 - Alternatives HEC-RAS Flow Load Points Including Outlet B

Alternative 4		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	5	2381	4764
J-11	11909.4	5	5	5	5	5	5	5	2613	5133
J-10	9407.3	5	5	5	5	5	5	397	2551	4966
J-09	7879.3	5	5	5	5	5	431	859	2631	5087
J-04	6519.9	5	5	163	763	1674	2465	3345	4534	5956
J-03	4847.2	5	5	329	976	1962	2818	3761	5045	6276
J-02	3739.6	5	5	394	1061	2077	2957	3926	5239	6493
J-01	480.2	5	5	524	1231	2312	3248	4275	5669	7011

Alternative 5		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	1301	2935	5124	8806
J-11	11909.4	5	5	5	5	5	1483	3211	5537	8822
J-10	9407.3	5	5	5	5	5	1494	3177	5468	7870
J-09	7879.3	5	5	5	5	5	1558	3271	5606	8075
J-04	6519.9	5	5	176	778	1641	2386	3951	6625	9496
J-03	4847.2	5	5	341	991	1929	2736	4010	6712	9604
J-02	3739.6	5	5	407	1076	2044	2877	4001	6689	9511
J-01	480.2	5	5	537	1247	2279	3167	4165	6780	9633

Alternative 6		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	2030	4338	7588
J-11	11909.4	5	5	5	5	5	5	2248	4692	7490
J-10	9407.3	5	5	5	5	5	5	2231	4608	6918
J-09	7879.3	5	5	5	5	5	610	2307	4726	7090
J-04	6519.9	5	5	132	729	1632	2382	3222	5588	8317
J-03	4847.2	5	5	298	942	1920	2733	3639	5662	8418
J-02	3739.6	5	5	363	1027	2035	2873	3806	5633	8368
J-01	480.2	5	5	493	1197	2270	3163	4156	5712	8476

Attachment 5 - Alternatives HEC-RAS Flow Load Points Including Outlet B

Alternative 7		Event - Peak Discharge (cfs)								
HMS Junction	RAS Station	1	2	5	10	25	50	100	250	500
J-16	15365.4	1331	1732	2489	3234	4369	5350	6458	7983	9559
J-14	14527.0	1485	1933	2770	3595	4835	5899	7100	8754	10447
DP-1	13762.6	5	5	5	5	5	5	5	2111	4267
J-11	11909.4	5	5	5	5	5	5	5	2332	4608
J-10	9407.3	5	5	5	5	5	5	261	2354	4598
J-09	7879.3	5	5	5	5	5	292	693	2434	4714
J-04	6519.9	5	5	5	638	1541	2326	3182	4366	5572
J-03	4847.2	5	5	216	852	1828	2679	3598	4877	6112
J-02	3739.6	5	5	282	937	1943	2818	3763	5071	6330
J-01	480.2	5	5	412	1107	2178	3108	4112	5501	6847

APPENDIX D

GEOTECHINCAL ENGINEERING

APPENDIX D

GEOTECHINCAL ENGINEERING

Blacksnake Creek
Section 205 Feasibility Study

Geotechnical Report

CDM Federal Programs Corporation
Kansas City, MO

Final
May 2013

Stanley Consultants INC.
A Stanley Group Company
Engineering, Environmental and Construction Services - Worldwide

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Section 1

Introduction

Frequent flooding of Blacksnake Creek within the northwest part of the City of St. Joseph, Missouri, has initiated the Blacksnake Creek Section 205 Feasibility Study, which will ultimately determine a preferred design alternative for flood improvements and mitigation within the basin.

Blacksnake Creek is a small tributary of the Missouri River that runs through St. Joseph, flowing in a predominantly south-southwesterly direction to its junction with the river. The Blacksnake Creek basin includes residential, commercial, and industrial property within the city limits and possesses a total drainage area of 8.2 square miles. Basin flows are conveyed by natural, open channels in the upper five square miles of the watershed, where the creek channel has an average capacity of 5,400 cfs and the floodplain is 400 feet wide with 0.008 feet per foot slope. Typical channel dimensions are 40-feet wide by 10-feet deep.

At Karnes Road, the flows are directed into a combined closed sewer system and conveyed to the Missouri River. On many occasions, the capacity of the combined sewer inlet, which is a 12-foot by 12-foot reinforced concrete box culvert, is exceeded, causing flows to travel south over streets and lawns. At least six major flood events have been recorded at this location, each resulting in major property damage. The City of St. Joseph and The United States Army Corps of Engineers have designated improvements to the drainage basin as a high priority.

This Geotechnical Reports summarizes the design and analyses of geotechnical aspects of the Blacksnake Creek Section 205 Feasibility Study project, including erosion protection and slope stability.

Section 2

Geotechnical Analyses

Review of Geological and Geotechnical Data

Subsurface investigation of the Blacksnake Creek project area was performed by the USACE in January 2004, with geotechnical laboratory testing conducted in July 2004 by Geotechnology, Inc. The data available from this investigation is limited; therefore, many assumptions have been made for the current level of design. It is recommended that the final design contract include a more extensive geotechnical investigation and laboratory testing program.

Site soils are predominantly lean clays. Groundwater was encountered in three of six borings and was measured at levels ranging from 5.3 to 18.2 feet depth which correspond to an approximate elevation (EL) range of 894 to 877 National Geodetic Vertical Datum. For the stability analysis, four separate clay layers were assumed from the geotechnical data: Surface clay extending for a depth of three feet; Medium-Stiff Clay extending to EL 876; Soft Clay to EL 859; and a Stiff Clay layer below EL 859. Table 1 below summarizes the subsurface stratification and shear strength properties assumed for the geotechnical analysis.

Table 1. Summary of Subsurface Stratification.

				Total Stress		Effective Stress	
Stratum	Depth (feet)	Elevation	Unit Weight (pcf)	Phi (deg)	c (psf)	Phi (deg)	c (psf)
Surface Clay	0 - 3	897 to 900	124	0	1000	32	0
Med-Stiff Clay	3 - 24	876 to 897	124	0	870	32	0
Soft Clay	24 - 41	859 to 876	124	0	410	24	0
Stiff Clay	41+	Below EL 859	124	0	1000	32	0

The USACE Geological and Geotechnical Conditions report, boring logs, and laboratory testing results are included with Appendix A.

Slope Erosion and Scour Protection

The slopes of the detention basin shall be topsoiled to a minimum depth of four inches and seeded to establish vegetation. Due to the tall height of most of the slopes, temporary erosion control blankets may need to be installed to minimize erosion until the grass is established. Installation of the blankets will be determined by the timing and duration of the slope stabilization. If hydroseeding can be accomplished in a timely manner, blankets would not be necessary. Seed mixture, seeding rates and seeding methods should be coordinated with the City of St. Joseph, with hydroseeding recommended for quicker turf establishment.

Existing soils are typically lean clays, which are considered moderately erodible. Riprap sizing equations used a design velocity of 3.7 feet per second which is the velocity at the bank full condition. The maximum shear stress for the bank full condition on straight reaches of the pilot channel does not exceed the permissible shear stress for a vegetated channel and will therefore not require stone protection. However, the relatively sharp channel bends increase the maximum shear stress in those locations which will require rock riprap on the order of MO-DOT Type II Rock Ditch Liner (D_{50} = 6 inches). A riprap thickness of 2.0 feet is recommended for the pilot channel bends.

On the west side of the proposed detention basin, there are two locations where the basin "juts out" forming a constriction of high flows with power pole islands on the east side of the basin. MO-DOT Type III Rock Ditch Liner Liner (D50 = 12 inches), with a total thickness of 3.5 feet is recommended for armoring these areas.

Riprap is also recommended for downstream of the Savannah Road bridge/culvert. No hydraulic data was available for flowrates and velocities at this location, so a velocity of around 10 feet/second was assumed. Per USACE riprap sizing methodology, this would require a rock with D_{50} around 12 inches (MoDOT Type III Rock Ditch Liner) installed with a thickness of 3.0 feet. The same minimum size riprap and thickness is assumed to protect the existing inlet structure for the proposed detention basin near Karnes Road.

A 6-inch layer of riprap bedding is recommended at all riprap locations. Riprap bedding gradation recommendation is as follows:

- 100% passing 150mm (6 inches)
- 75% to 95% passing 75mm (3 inches)
- 35% to 75% passing 25mm (1 inch)
- 10% to 40% passing 4.75mm (#4)
- 5% to 25% passing 2mm (#10)
- 0% to 10% passing 0.425mm (#40)

Exhibit D-1, which shows the locations and sizes of proposed erosion protection, is included in Appendix D.

Slope Stability Analysis

Excavation slopes for the Blacksnake Creek detention basin areas were analyzed for global stability using GEO-SLOPE SLOPE/W software. Four separate conditions were analyzed. All reflect a single typical basin excavation slope of 3H:1V from EL 900 to EL 876. Analysis conditions and target factors of safety follow recommendations of USACE Design Manual 1110-2-1902 Slope Stability. Results of the analyses are listed below:

Total Stress Condition

Target Factor of Safety (FOS) = 1.30; Actual FOS = 1.30. This condition controls the slope angle. Parameters were assigned based on available unconsolidated-undrained (UU) Q triaxial compression tests, unconfined compression (UC), N-value, and Torvane Shear test data in the 2004 soil boring logs. Cohesive parameters were selected based on a 2/3 rule (2/3 of the data points fall above the assigned value for each stratum). Note that soil borings did indicate data points below the selected parameters, but the 2/3 rule for parameter selection was considered to be a reasonable approach. See Appendix B for additional data on parameter selection.

Effective Stress Condition

Target FOS = 1.50, Actual FOS = 1.73. Effective stress parameters were based on Atterberg Limit correlations (EM 1110-2-2504, Table 3-7). Consolidated-undrained (CU) R-BAR triaxial compression test data was available, however, a review of lab data sheets revealed inconsistencies between the table data and stress/strain plots. The results of test data containing inconsistencies were ignored.

Effective Stress Condition – Rapid Drawdown

Target FOS = 1.1, Actual FOS = 1.20. Rapid Drawdown of the storage pool from EL. 894 to 876 was assumed for the analysis. A staged drawdown with both effective and total stress input conditions was analyzed.

Total Stress – Seismic Loading Condition

Target FOS = 1.10, Actual FOS = 1.21. Horizontal Acceleration of 0.02g was assumed based on USGS Seismic Hazard Map for 10% chance of exceedence in 50 years (peak ground acceleration).

The analyses indicate that 3H:1V is a stable excavation slope based on the available data. If subsequent investigations indicate softer clays than the current data, the slope angle may need to be decreased – at least in localized areas. Since proposed excavation depths will be much less than the assumed 24 feet in most locations, the analysis can be considered conservative. Stability analysis plates are included in Appendix B.

Northwest Parkway Overflow Section

A 100-year design event was assumed for the erosion protection at the south overflow section on Northwest Parkway. The maximum water surface elevation for this event is El. 898.7, which results in an assumed height of water of 1.7 feet over Northwest Parkway. The corresponding

maximum velocity at the 100-year event is 3.5 feet per second. The roadway overflow section, with a low-point elevation of 897.0, will be overtopped by flows that occur at a frequency between the 25-year and 50-year design events.

USBR riprap sizing calculations for overtopping sections call for large riprap, MO-DOT Type IV Rock Ditch Liner, with a minimum D_{50} of 19" and a total thickness of 3.5 feet on a 8H:1V slope which fits the existing topography. Riprap of the same type and thickness was assumed on the upstream slope of the overflow section also. Pavement for the overflow section should be Portland cement concrete, with a minimum thickness of 9 inches. The concrete paved roadway section should extend for a minimum length of 350 feet, which would provide an extra 50 feet on each side of the 100-year overflow area. It is recommended that a toe-wall be added to the downstream edge of the pavement down to a depth of 4.5 feet to protect against undermining of the pavement structure.

If the City has concerns with the safety and aesthetics of large riprap, alternative erosion protection, such as concrete paving or articulated concrete blocks could be installed. Vegetation could be established along the slope with certain articulated concrete block designs.

Secondary Overflow Section

At the south end of the proposed detention basin a secondary overflow section is present at the abandoned railroad right-of-way with a top elevation of 898, which would result in the section being overtopped at a higher design frequency event than the Northwest Parkway overflow section although still between the 25-year and 50-year recurrence intervals. MO-DOT Type IV Rock Ditch Liner is recommended to ensure the structural integrity of the overflow section and adjacent roadway bridge embankment. A thickness of 3.5 feet should be installed along the berm slopes and along the natural ground downstream through the confined bridge opening. Approximate extents of the proposed riprap protection are shown on Exhibit D-1 in Appendix D.

Transmission Towers

For the recommended alternative, the existing electrical transmission poles will be left intact and the excavation will leave berms or "islands" present in the constructed detention basin. The 3H:1V soil slopes are adequate for stability at these locations. Due to the structural importance of the transmission poles, their presence within the detention basin, and their close proximity to the pilot channel, riprap erosion protection should be installed on the berms. The same riprap design assumptions used for sizing erosion protection at the Savannah Road culvert outlet were used in determining the appropriate size and thickness for protecting the power pole islands. A larger riprap size than used on the pilot channel bends, on the order of MO-DOT Type III Rock Ditch Liner (D_{50} = 12 inches), with a total thickness of 3.5 feet should be installed at these locations. Pilot channel slopes within the island areas should also be armored to ensure the channel remains in the established alignment.

Construction / Water Control Plan

For the purposes of estimating, a flow of approximately 385 cfs, which is the capacity of the proposed pilot channel, was assumed necessary to accommodate during construction. Due to using the existing creek alignment for the new pilot channel, a large temporary diversion channel, capable of accommodating this flow will need to be created during construction. Preliminary sizing indicates a 3-foot-deep channel with a 20-foot-wide bottom and 3H:1V sideslopes will be necessary to handle the construction flow for Blacksnake Creek. Erosion control measures including rock check dams will need to be included in the diversion channel. Temporary diversion of the water from the east tributary will also be necessary, although it is assumed that a 24" or 30" pipe could convey that drainage during construction. From previous study information, Blacksnake Creek base flows -- exclusive of storm events -- are assumed to be around 3 cfs.

A staged construction plan was assumed to facilitate soil stabilization in the basin and to handle the base flows in the diversion. The contractor must consider construction staging, haul road access points within the construction site and haul routes outside of the construction area as major components of his construction plan.

In essence, the majority of the excavation should be done while avoiding disturbance to the existing channel. A basic construction sequencing list was developed and included at the end of this section. Vegetated buffer strips, with maximum construction slopes of 1.5H:1V will be used to separate new excavations from the existing creek.

Erosion control is of the utmost importance during the construction of the Blacksnake Creek improvements. Storm water pollution prevention best management practices (BMP's) will need to be utilized for all aspects of the project. Development and adherence to the storm water pollution prevention plan (SWPPP) is critical. The contractor will need to dedicate personnel to perform storm water management activities.

Groundwater was encountered in boring holes at depths ranging from 5 feet to 18 feet below the surface (El. 900 to 877), which is near the level of proposed excavation. Due to the nature of the clay soils present, it is not anticipated that well point systems will need to be employed during construction. Groundwater, and surface runoff, should be directed to sumps preferably in corner locations that can serve as siltation basins. Sump pumps will be used to pump the excess water to the storm sewer system.

Staging and diversions could be facilitated if a significant portion of the excavation could be accomplished during the late fall and winter months of November through February, when average precipitation amounts are lowest. Blacksnake Creek base flows exclusive of storm events are assumed to be around 3 cfs. Therefore construction that avoids the wettest part of the year – typically April through September – would greatly affect the amount of surface water to be handled.

Final design of the detention basin and pilot channel should account for the benefits of constructing the pilot channel on a new alignment, instead of following the existing creek bed.

Minor realignments of the pilot channel could help greatly with construction staging and directing flows away from the power pole islands.

Geotechnical Recommendations for Proposed Box Culverts

Since no new box culvert inlet or outlet structures were included in the recommended alternative, geotechnical recommendations for proposed box culverts were not developed.

Material Quantity Assumptions

- Mo-DOT Type II Rock Ditch Liner – 3,550 CY
- Mo-DOT Type III Rock Ditch Liner – 15,900 CY
- Mo-DOT Type IV Rock Ditch Liner – 10,850 CY

Preliminary Construction Sequencing

A preliminary construction sequence was developed within the constraints of the provided detention basin and pilot channel alignment. It was included to illustrate assumptions and challenges of construction while accommodating Blacksnake Creek flows.

Construction activities will be greatly influenced by the time of year, proposed alignment, and conditions for erosion control stabilization. For the listed plan, construction was split into two different subareas: Subarea 1, which is the detention basin south of Maxwell Road; and Subarea 2, which lies to the north of Maxwell Road. A construction staging exhibit (D-2) is included in Appendix D. Depending upon available staging areas, the portion of Subarea 1 south of Karnes Road could be split into a separate subarea that could be constructed last.

STAGE 1 CONSTRUCTION

1) Install construction signage at road closure locations (Karnes Road, Maxwell Road); warning signs for hauling activities (Karnes Road, St. Joseph Road); and for construction traffic under power lines.
2) Coordinate utility relocations and abandonments in each area of work prior to commencement of construction activities.
3) Establish perimeter erosion control measures, and haul road locations (Karnes Road; Maxwell Road).
4) Establish staging areas: baseball field and parking lot can be utilized until those areas are excavated.
5) Install riprap at the existing combined sewer box culvert inlet as preparation for future diversion discharges.

6) Install stream monitoring gages – upstream of project site for water level; near combined sewer inlet for turbidity and water level.
7) Clear timber & brush from Subarea 1 (below Maxwell Road) and in Creek; Grub only in areas to be graded – do not grub in existing creek. Salvage timber to extent possible.
8) Coordinate dewatering pump locations, conveyances, and discharge locations. Assume ultimate discharge outfall into storm sewer structure.
9) Demolish existing impacted utilities, roadways, parking areas, recreation facilities and related structures in Subarea 1. Leave Maxwell Road grade and culvert intact.
10) Strip topsoil from Subarea 1 detention basin and stockpile on site; stabilize stockpiles if topsoil will be undisturbed for more than 14 days.
11) Excavate Subarea 1 detention basin – keeping a 10-foot wide buffer with 1.5H:1V side slopes between excavations and the existing creek, as well as new pilot channel excavation adjacent to existing creek.
12) Excavate temporary diversion channel to the west of existing Blacksnake Creek; stabilize channel and side-slopes; Preliminary channel sizing calls for a 5-foot-deep channel with a 28-foot-wide bottom and 3H:1V sideslopes. Keep earthen berms between diversion channel and existing creek.
13) Excavate new permanent east tributary channel east of existing Blacksnake Creek; stabilize channel and side-slopes; Keep earthen berms between existing channel and new channel.
14) Stabilize detention basin area and diversion channel area with temporary and permanent erosion control measures. Areas must be stabilized before creek flows are introduced. Tall sloped surfaces may require temporary erosion control blankets.
15) After area is stabilized, divert Blacksnake Creek flows to diversion channel. Install earthen berm at north junction to keep base flows out of existing channel. Do not install separation berm at south junction in order to accommodate east tributary flows.
16) Grub, excavate and grade at new east tributary junction; install pipe crossing across channel to convey and confine east tributary flows across new channel to temporary diversion channel.
17) Install earthen separation berm at existing east tributary to direct flows to new channel and diversion channel.
18) Install earthen separation berm at south junction of existing Blacksnake Creek and diversion channel.
19) Grub, excavate and grade remaining existing/proposed permanent channel.
20) Complete the platforms for power poles; install riprap on upstream slopes and slopes adjacent to the creek channel.
21) Stabilize permanent channel with temporary and permanent erosion control.
22) Remove buffer areas and stabilize.
23) Remove earthen separation berms and divert base flows to the permanent channel location.
24) Fill in diversion channel and stabilize graded area.
25) Remove haul roads to Karnes Road and stabilize graded area.

STAGE 2 CONSTRUCTION

26) Clear timber & brush from Subarea 2 and in Creek; Grub only in areas to be graded – do not grub in existing creek.
27) Coordinate dewatering pump locations, conveyances, and discharge locations. Assume ultimate discharge into storm sewer structure.
28) Demolish existing impacted utilities, and related structures in Subarea 2.
29) Strip topsoil from Subarea 2 detention basin and stockpile on site; stabilize stockpiles if topsoil will be undisturbed for more than 14 days.
30) Excavate Subarea 2 detention basin and new channel areas – keeping a 10-foot wide buffer with 1.5H:1V side slopes between excavations and the existing creek.
31) Excavate temporary diversion channel to the west of existing Blacksnake Creek where necessary; stabilize channel and side-slopes; Preliminary channel sizing calls for a 5-foot-deep channel with a 28-foot-wide bottom and 3H:1V sideslopes. Keep earthen separation berms between new channel/diversion channel and existing creek.
32) Stabilize detention basin area, new channel and diversion channel area with temporary and permanent erosion control measures. Areas must be stabilized before creek flows are introduced.
33) After area is stabilized, divert Blacksnake Creek flows to diversion channel in Subarea 2. Install earthen separation berm at north and south junctions to keep base flows out of existing channel.
34) Grub, excavate and grade remaining existing/proposed permanent channel.
35) Complete the platforms for power poles; install riprap on upstream slopes and slopes adjacent to the creek channel.
36) Stabilize permanent channel with temporary and permanent erosion control.
37) Remove buffer areas and stabilize.
38) Remove earthen separation berms and divert base flows to the permanent channel location.
39) Fill in diversion channel and stabilize graded area.

Recommendations for Additional Geotechnical Investigation

It is recommended that an additional geotechnical investigation and laboratory testing program be conducted to verify the soil stratigraphy and shear strength parameters determined as part of this preliminary feasibility study. Additional investigation into the erodibility of the soils is also recommended as part of the additional investigation.

It is recommended that the geotechnical investigation consist of approximately 15-20 hollow-stem auger borings, each with a depth of 50 feet, or refusal, whichever occurs first. Soil boring locations should be selected based on critical components of the project. For example, transmission tower pads, inlet and outlet locations, overflow embankments, and tall or otherwise critical embankment slopes. Additionally, soil borings should be appropriately spaced around the perimeter of the project to provide adequate information about stratigraphy changes from one end of the project to the other.

It is recommended that soil borings include shelby-tube (for cohesive materials) and split-spoon (for granular materials) sampling at 5-foot intervals for the full depth of the soil borings. A laboratory testing program would then be developed including moisture content testing, Atterberg limit testing, unconfined compression testing, and unconsolidated undrained and consolidated undrained with pore water pressure triaxial compression testing. The tests should be well-distributed throughout the soil boring depth to provide sufficient testing within each encountered stratum.

Since the project involves excavation of material and not placement or embankment construction, there is no anticipated requirement for consolidation testing or standard proctor testing.

Appendix A

USACE Geological and Geotechnical Conditions Report, Boring Logs and Laboratory Testing Results

GEOLOGICAL AND GEOTECHNICAL CONDITIONS

1. Regional geology

The northern Missouri area was glaciated during Nebraskan and Kansan time. Most of the ground cover of the Tertiary and Quaternary Periods consists of alluvial clays, sand and gravels, glacial till and gravels, and clays and loess. Alluvial and eolian deposits from the middle to late Pleistocene are extensive in northern Missouri. Southwest of the project site in Wyeth Park Pleistocene deposits have been measured up to 120 feet thick. The measured section is made up of Bignell Silt, Peoria Silt, Farmdale Silt and Sangamon Soil, underlain by Nebraskan silt.

The Pennsylvanian age bedrock of the Douglas Group is exposed along the river bluffs in St. Joseph. The Douglas Group consists mostly of shale, but includes sandstone and limestone layers. Basal limestones of the Shawnee Group outcrop in the hills of St. Joseph above the Douglas group.

Buried river valleys from ancient drainage formed by several periods of previous glaciation have been mapped by inference in the area by Dreeszen and Burchett. There is buried drainage from a major tributary under the southern part of St. Joseph and one just north near Amazonia that join together east of St. Joseph and continues to the present day Grand River valley. These ancient tributaries are capable of producing large quantities of potable water.

The silts and silts with clay encountered in the overburden were easily compressed either during the push or during the extrusion process. The compressed samples did not have a lot of moisture in the matrix. The Torvane readings taken along the sides of the sample were higher in the compressed samples than the uncompressed samples. The silts and clayey silts that did not compress had a higher water content in the matrix and lower Torvane readings along the sides of the sample. Since water is not compressible, it appears that there are a lot of void spaces in the silts allowing compression. Unconsolidated soils, such as slough from a higher slope, would have more void spaces due to lack of compaction at the time of deposition. Settlement could be inferred from the compressibility of the samples.

2. Topography

The uplands in the area generally are strongly sloping to steep and highly dissected. They slope mainly to the southeast, with the gradient of the slopes decreasing from west to east. The elevations of the uplands are about 950 feet above sea level, and 765 feet of the bottomland. Relief influences soil formation

3. Site Area Soils

The soils on the right riverbank of Blacksnake River consist of Colo silt loams, poorly drained soils in its low areas. These soils formed in silty alluvium and the slopes ranged from 0 to 2 percent. The surface layer is very dark gray, friable silty clay loam, the subsurface layer is black, friable silty clay loam followed by the subsoil layer consisting of very dark, gray, firm silty clay loam. The permeability is moderate and the surface runoff is slow. The surface layer is friable and can be easily tilled throughout a moderate range in moisture content. The shrink-swell potential is high. A seasonal high water table commonly is at a depth of 1 to 3 feet during extended wet period of time.

4. Subsurface Investigation

4.1. Drilling and Sampling.

The subsurface investigation for the Blacksnake Creek project was performed by a drill crew from the Kansas City District Corps of Engineers in January 2004. The investigation consisted of performing a total of 6 (six) borings. The boring locations plan view and the strip logs of the exploratory borings are shown in Enclosure 1.

The borings AD-1 and AD-2 were drilled 15 feet deep in the proposed borrow area using a CME 750 ATV drill rig. A 3-¼ inch I.D. inner split barrel sampler was used to obtain sack and jar samples. Alternating layers of silts and clays with interspersed fine sands were encountered throughout both borings to a depth of 15 feet.

Borings ADU-3 and AD-4 were drilled at the location of the proposed levee, along the Blacksnake Creek to a depth between 15 and 16 feet. Boring ADU-3 was drilled with a CME 750 All Terrain Vehicle (ATV) drill rig using 3 ¾ inch I.D. hollow stem augers to advance the hole and a 1-⅜ inch split spoon for sampling. Boring AD-4 was drilled using a Failing 1500 drill rig using a 5 inch box auger to advance the hole and a 1-⅜ inch split spoon for sampling. Undisturbed samples were collected from the boring ADU-3. Alternating layers of silts and clays with interspersed fine sands were encountered throughout both borings to a depth of 15 feet. Limestone cobbles, cement debris and bricks were seen at the surface near the location of ADU-3, but no construction debris was encountered during drilling.

Borings ADU-5 and ADU-6 were drilled at the location of the proposed Kern Road raise. Boring ADU-5, located on the southeast side of the project site near the concrete channel enclosure north of Karnes road, was drilled to 55.5 feet. Continuous undisturbed samples were taken to 49 feet and sampling then continued with S.P.T. every 2.5 feet to 55.5 feet where bedrock was encountered. At 50.5 feet, augering was halted and the drilling method switched to mud rotary and a tricone bit. Clays and silts with interspersed fine sand and a 1.3-foot thick sand with clay was encountered to 51.5 feet. A 0.6-foot thick layer of gravel was found above the bedrock. The bedrock encountered at 54.6 feet was a mudstone or possibly highly weathered shale. One jar sample was obtained from the bedrock. Boring ADU-6 is located closest to Karnes road on the southeast side of the project area. The boring was drilled to the top of rock at 25.8 feet. Clayey silts with fine sand interspersed were encountered to a depth of 24.4 feet. Beginning at 24.4 feet to the top of rock at 25.8 feet a gravel layer was encountered.

Sand was encountered in only one of the boring locations. At a depth of 6.0 feet in boring ADU- an 1.3-foot thick sand layer was logged and sampled. A layer of clayey-gravelly sand 8.4 feet thick was encountered starting at 46.2 feet. A 1.4 feet thick layer of gravelly fat clay was encountered in ADU-6 starting at a depth of 24.4 feet.

The borings were backfilled with neat cement grout to within 3 feet of the ground surface and topped with cuttings from the boreholes. The grout mix consisted of approximately 7.5 gallons of water to each bag of cement. The grout was tremied through drill pipe to the bottom of the boring.

Boring information are summarized in Table 1:

Table 1 – Borings General Information

Boring No.	Investigative Purpose	Total Depth (feet)	No. of Undisturbed Samples	No. of S.P.T. samples	No. of Sack Samples	Water Level (feet)	Sand or gravel encountered (ft)
AD-1	Borrow	15.0			3	None	
AD-2	Borrow	15.0			3	None	
ADU-3	Levee	15.5	6			None	
AD-4	Levee	16.0		8		5.3	
ADU-5	Road Raise	55.5	18	3		14.2	6.0-7.3, 46.2-54.6
ADU-6	Road Raise	25.8	10	1		18.2	24.4-25.8

4.2. Groundwater.

Groundwater was encountered in 3 of the 6 borings. Water levels were taken at the start of the second day of drilling the 2 deeper borings ADU-5 and ADU-6. Water level in AD-4 was taken 2 hours after drilling was completed.

4.3. Undisturbed Sampling.

Thirty-four (34) undisturbed samples were collected from 3 borings (ADU 3, ADU-5 and ADU-6). Each tube sample was extruded in the field and waxed after torvane strength determinations were run on the top, bottom, and midpoint and a jar sample retained from the base of the sample. Laboratory testing on the undisturbed samples consisted of unconsolidated-undrained triaxial compression tests (Q tests), consolidated undrained triaxial compression tests with pore pressure measurement (R-bar tests), consolidation tests and unconfined compression test. The tests were done on samples collected from borings ADU-3, ADU-5, and ADU-6 to determine the geotechnical characteristics of the foundation soils for the road raise and the levee construction.

4.4. Disturbed Sampling.

Sixty (60) jar samples were collected from all borings. Jar samples were obtained of representative materials encountered between two undisturbed samples, from SPT tests, and at the base of each undisturbed sample. Laboratory testing on the jar samples consisted of determination of the moisture content and Atterberg limits. The jars were grouped based on the visual classifications and Atterberg Limits done on representative sample of each group. The soils will be classified based on Atterberg Limits and visual classification.

4.5. Sac Samples.

Six (6) sacs were collected from the proposed borrow areas. Standard Proctor compaction tests conform ASTM D-698 were performed on the selected sac samples. Unconsolidated-undrained triaxial compression tests (Q tests), consolidated undrained triaxial compression tests with pore pressure measurement (R-bar tests) and were performed on remolded samples compacted to 95% of density as obtained from the Standard Proctor tests.

4.6. Laboratory Testing.

4.6.1. General.

Selected samples of material obtained during the field exploration were tested to determine the engineering and physical properties of the foundation soils and the borrow materials. Laboratory tests were performed by Geotechnology, Inc., Kansas City. The laboratory testing included

Atterberg Limits, natural moisture contents, shear strength parameters of undisturbed soil samples based on unconfined compression tests, unconsolidated undrained (UU) Q triaxial compression tests, and consolidated undrained (CU) R-BAR triaxial compression tests with pore pressure measurements, and consolidation tests. Standard Proctor tests were performed on sac samples collected from the proposed borrow areas. A summary of laboratory testing results is shown in Table 2 "SUMMARY OF LABORATORY TESTING RESULTS".

Table 2 - SUMMARY OF LABORATORY TESTING RESULTS

Boring #	Depth (ft)	Sample #	Classif. Goup #	LABORATORY TEST													
				Moisture Content %	Visual Classif.	Atterberg Limits				Unconfined Compression Strength (psf)	Triaxial					Standard Proctor	
						Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Liquidity Index (LI)		Q Test c (psf)	R-Bar Test				γ_{dmax} (pcf)	Optimum Moisture Content, %
												Total Strength		Effective Strength			
												ϕ (^{0})	c (psf)	ϕ (^{0})	c (psf)		
AD-1	0-2.0	J-1	6	25.4	CL												
	2.0-4.0	S-1		16.3	CL	37	22	15	-38		3080	11.5	1800	34.7	0	107	16
	2.0-4.0	J-2	6	19.9	CL												
	4.0-5.0	J-3	6	30.7	CL												
	5.0-8.0	S-2			CL	32	21	11									
	5.0-8.0	J-4	9	26.3	CL												
	8.0-10.0	J-5	9	27.7	CL	37	23	14	34								
	10.0-12.0	J-6	1	27.9	CL												
	12.0-15.0	J-7	1	29.0	CL												
AD-2	0.0-2.5	J-1	6	26.2	CL	36	21	15	35								
	2.5-5.0	J-2	5	24.3	CL	35	22	13	18								
	2.5-5.0	S-2			CL	32	22	10									
	5.0-7.5	J-3	5	24.2	CL												
	7.5-10.0	J-4	6	28.3	CL												
	10.0-12.5	J-5	6	24.4	CL												
	12.5-15.0	J-6	6	27.7	CL												
ADU-3	2.9-3.0	J-1	5	21.6	CL												
	1.0-3.0	WAX-1		21.7	CL	38	27	11	-48		1000	13.3	1000	32	0		
	5.4-5.5	J-2	6	20.1	CL												
	7.9-6.00	J-3	6	23.5	CL												
	10.4-10.5	J-4	1	27.8	CL												
	12.9-13.0	J-5	1	27.9	CL												
	15.4-15.5	J-6	1	29.1	CL												
AD-4	0.5-1.0	J-1	5	24.6	CL												
	2.5-2.8	J-2	5	15.1	CL												
	4.5-5.7	J-3	3	25.0	CL												

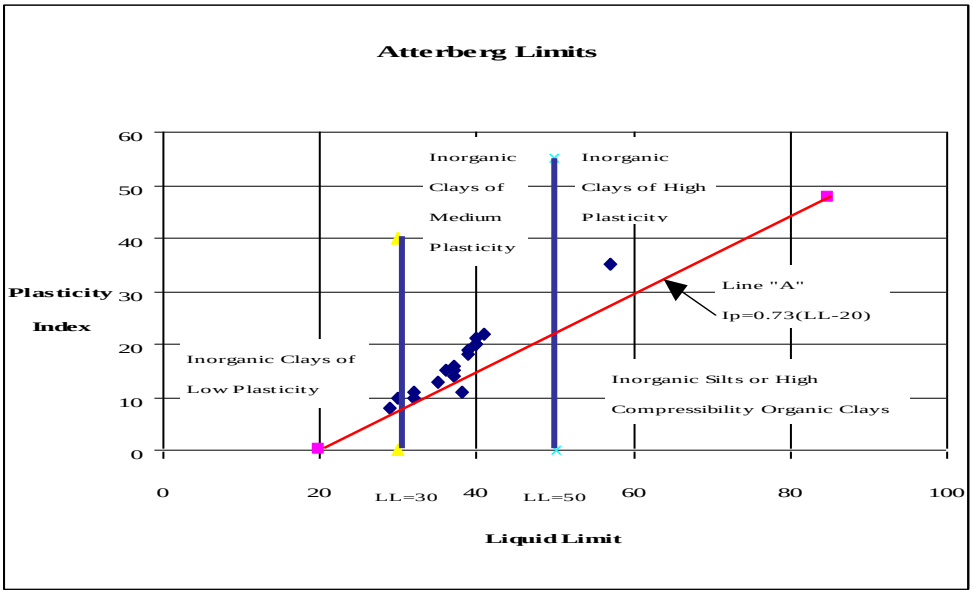
Boring #	Depth (ft)	Sample #	Classif. Goup #	LABORATORY TEST													
				Moisture Content %	Visual Classif.	Atterberg Limits				Unconfined Compression Strength (psf)	Triaxial					Standard Proctor	
						Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Liquidity Index (LI)		Q Test c (psf)	R-Bar Test				γ_{dmax} (pcf)	Optimum Moisture Content, %
												Total Strength		Effective Strength			
												ϕ (^{0})	c (psf)	ϕ (^{0})	c (psf)		
	6.5-8.0	J-4	6	26.6	CL												
	8.5-10.0	J-5	1	29.0	CL												
	10.5-12.0	J-6	1	27.0	CL												
	12.5-14.0	J-7	10	28.5	CL												
	14.5-16.0	J-8	10	29.9	CL												
ADU-5	2.0-3.5	WAX-1		20.1	CL	41	19	22	-2	3920							
	3.5-3.6	J-1	5	18.6	CL												
	4.5-6.5	WAX-2		29.6	CL	40	20	20	18		800	10	780	8.5	960		
	6.4-6.5	J-2	5	23.6	CL												
	7.0-8.9	WAX-3		20.5	CL	40	19	21	14	2160							
	8.9-9.0	J-3	1	21.9	CL	40	20	20	17								
	9.5-11.4	WAX-4		23.3	CL	39	21	18	28	1940							
	11.4-11.5	J-4	4	26.0	CH	57	22	35	29								
	13.9-14.0	J5	6	32.0	CL												
	16.4-16.5	J-6	6	33.2	CL												
	18.9-19.0	J-7	6	32.6	CL												
	21.4-21.5	J-8	1	29.6	CL												
	23.9-24.0	J-9	10	27.1	CL												
	26.4-25.0	J-10	10	28.1	CL												
	28.9-29.0	J-11	10	29.9	CL												
	31.4-35.0	J-12	10	28.3	CL												
	33.9-34.0	J-13	1	26.2	CL												
	36.4-36.5	J-14	10	25.7	CL												
	38.9-39.0	J-15	10	25.8	CL												
	41.4-41.5	J-16	10	23.4	CL												
	43.9-44.0	J-17	2	18.7	CL	Non-plastic											
	46.4-46.5	J-18	2	17.0	CL												
	49.0-49.5	J-19	3	18.7	CL												
	51.5-52.4	J-20	2	20.3	CL												

Boring #	Depth (ft)	Sample #	Classif. Goup #	LABORATORY TEST													
				Moisture Content %	Visual Classif.	Atterberg Limits				Unconfined Compression Strength (psf)	Triaxial					Standard Proctor	
						Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Liquidity Index (LI)		Q Test c (psf)	R-Bar Test				γ_{dmax} (pcf)	Optimum Moisture Content, %
												Total Strength		Effective Strength			
												ϕ (^{0})	c (psf)	ϕ (^{0})	c (psf)		
	54.0-54.6	J-21	2	13.7	CL												
	54.6-55.5	J-22	4	21.7	CH												
ADU-6	0.5-2.4	WAX-1		19.4	CL	40	20	20	19	3900							
	2.4-2.5	J-1	6	23.8	CL												
	4.9-5.0	J-2	5	20.6	CL												
	5.5-7.4	WAX-3		23.0	CL	39	20	19	16	1780							
	7.4-7.5	J-3	10	23.0	CL												
	9.9-10.0	J-4	8	21.2	CL	30	20	10	29								
	12.4-12.5	J-5	10	22.9	CL												
	13.0-14.9	WAX-6		23.2	CL	29	21	8	2								
	14.9-15.0	J-6	10	21.2	CL												
	17.4-17.5	J-7	10	22.5	CL	37	21	16	-6								
	19.9-20.0	J-8	10	20.1	CL												
ADU-6	22.4-22.5	J-9	10	21.5	CL												
	24.9-25.0	J-10	10	22.3	CL												

4.6.2. Soil Classification Tests.

In an attempt to characterize the site and to classify the soils, moisture content and Atterberg limits tests were conducted. Overburden clay material was classified in accordance with ASTM D 2487 as lean clay (CL), except one sample that was determined to be fat clay. The results of the 68 natural moisture content tests performed on disturbed and undisturbed samples show the moisture content ranges between 13.7 and 33.2 percent with the average of 24.4%. The results of the Atterberg Limits tests performed on 18 samples of clay material are presented in Table 2 and on Casagrande's plasticity chart in Figure 1. As shown in Table 2, the soils encountered in the foundation consist of lean clays, with low plasticity index and high water content, except one sample within a thin layer of fat clay with high plasticity encountered in Boring ADU-5 at a depth of 11.5 feet from the surface. The Liquid Limit (LL) varies between 29 and 41 percent with one exception where the LL was found to be 57. The Plastic Limit (PL) varies between19 and 27 with an average of 21.

Figure 1 – Atterberg Limits



4.6.3. Consolidation Tests.

One consolidation test was performed on undisturbed clay samples collected in Boring ADU-5 between 4.5 and 6.5 feet below existing grade. A summary of consolidation test results is shown in Table 3.

TABLE C-8 - CONSOLIDATION TESTS SUMMARY

Boring No.	Sample No.	Depth feet	Elev. ft	Moist. %	LL	PL	PI	LI	C_c	C_r	e_0	P_p tsf
ADU-5	Wax-2	4.5-6.5	890	29.6	40	20	20	18	0.138	0.013	0.9222	1.6

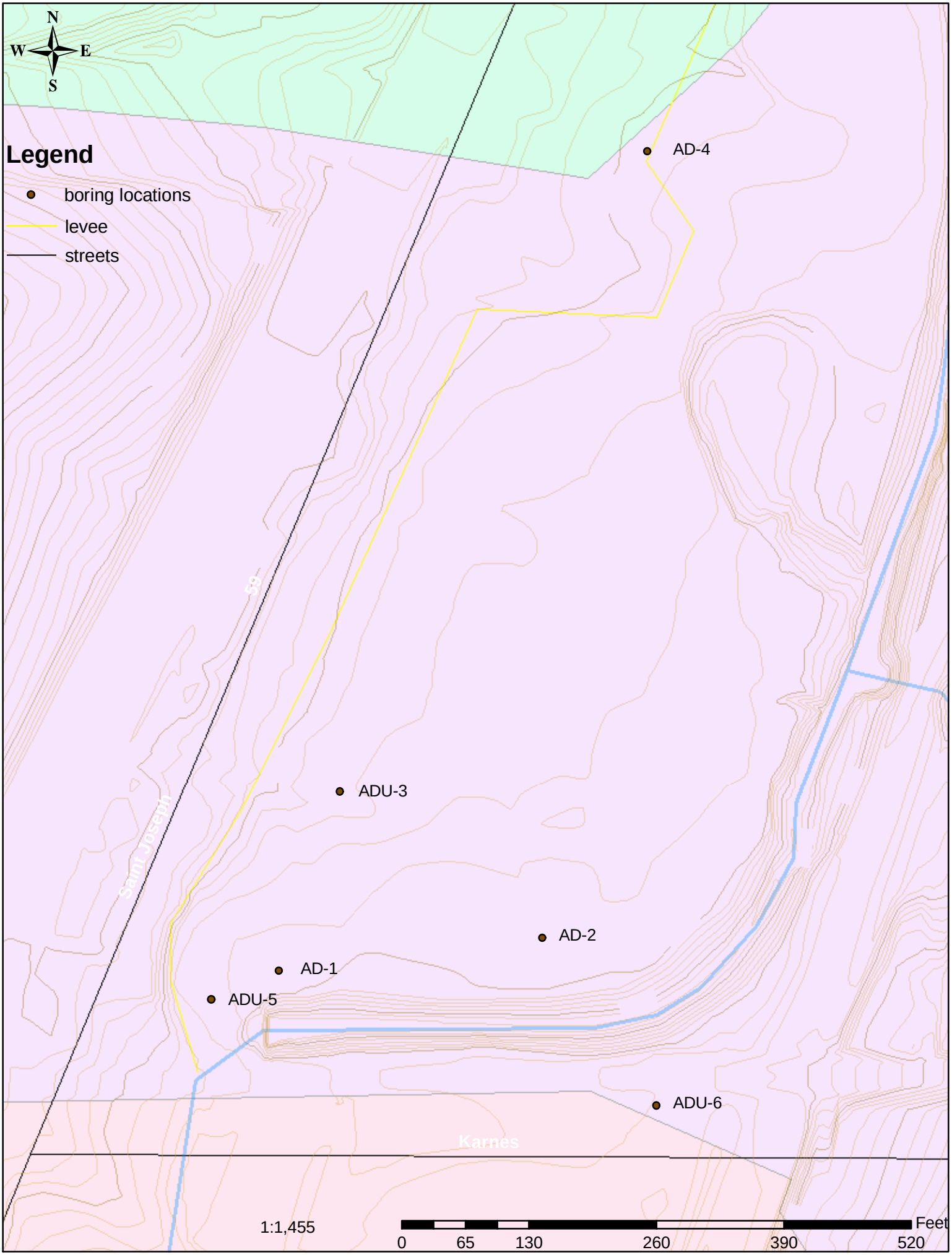
4.6.4. Unconfined Compression Tests

A total of five (5) unconfined compression tests were performed on undisturbed samples collected form the borings ADU-5 and ADU-6 at depth varying between 2 and 15 feet below the existing surface. The results of the unconfined compression tests are shown on Table 2. The soil shear strength varies between 1780 psf and 3900 psf, with strength decreasing with the depth.

4.6.5. Triaxial Compression Tests.

Unconsolidated undrained (UU) Q triaxial compression tests. Three (3) unconsolidated undrained (UU) Q triaxial compression tests were performed, one of them on remolded sample from the borrow area and 2 tests on undisturbed samples collected from borings ADU-3 and ADU-5, at a depth of 1 to 3 feet and 4.5 to 6.5 feet respectively. The remolded sample collected from the proposed borrow area was compacted at approximately 95 percent Standard Proctor maximum density, determined by ASTM D-698-91, adjusted to a range between 2 and 3 percent above optimum moisture content. A series consists of three Q tests conducted on three specimens trimmed from a single Shelby tube sample. The test series were conducted at confining pressures of 1 tsf. Results of the Q triaxial compression tests are provided in Table 2.

Consolidate Undrained (CU) triaxial tests (R-Bar). Two (2) test series of consolidated undrained (CU) triaxial tests with pore water pressure measurements were performed on undisturbed samples collected from SADU-3 and ADU-5 at depths up to 6.5feet below the existing ground surface. One CU test was performed on remolded sample, collected from the proposed borrow area, compacted at approximately 95 percent Standard Proctor maximum density, determined by ASTM D-698-91, adjusted to a range of between 2 to 3 percent above optimum moisture content. A consolidated undrained test series consists of three tests conducted on three specimens trimmed from a single Shelby tube sample, saturated and consolidated at different confining pressures to define the strength envelope. The test series were conducted at confining pressures of 0.5, 1, and 2 tsf. Shear strength in terms of effective strength (S strength) were established from the CU tests by measuring the induced pore water pressures. Results of the CU triaxial tests in terms of effective and total strength parameters are provided in Table 2.


N
W
E
S
Legend
boring locations
levee
streets
AD-4
59
ADU-3
Saint Joseph
AD-2
AD-1
ADU-5
ADU-6
Karnes
1:1,455
0
65
130
260
390
520
Feet

LOG OF BORING AD-1

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323043.27, E 2692161.78
DATE(S) DRILLED: 3/1/04 - 3/1/04

FIELD DATA

DRILLING METHOD(S):
CME 750, 3 3/4" Hollow Stem Auger

GROUNDWATER INFORMATION:
Not encountered

SURFACE ELEVATION: 0

LABORATORY DATA

DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT LL	ATTERBERG LIMITS: PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)		
0–5					FAT CLAY MEDIUM DAMP TO MOIST BROWN TO DARK BROWN -rootlets -contains sparse, occasional very fine sand, < 15%								
5–10					CLAYEY SILT MEDIUM DAMP BROWN TO DARK BROWN -contains sparse occasional very fine sand, < 15%								
10–15					FAT CLAY MEDIUM DAMP TO MOIST BROWN & GREENISH GRAY -contains sparse, occasional very fine sand, < 15%								
15					Bottom of Hole								

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with Portland cement dry bagged to 3.0' BGS and topped with spoils.
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING AD-2

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323077.02, E 2692430.74
DATE(S) DRILLED: 3/1/04 - 3/1/04

DRILLING METHOD(S):
CME 750, 3 3/4" Hollow Stem Auger

GROUNDWATER INFORMATION:
Not encountered

SURFACE ELEVATION: 0

FIELD DATA						LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT LL	ATTERBERG LIMITS: PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)		
					FAT CLAY DAMP TO MOIST MEDIUM BROWN -silty -rootlets -contains <15 % very fine sand								
1 2													
					FAT CLAY MEDIUM DAMP BROWN AND DARK GRAY <contains 15% very fine sand occasionally								
3 4 5 6 7 8 9 10 11 12													
					FAT CLAY MEDIUM MOIST BROWN AND GREENISH GRAY <contains 15% very fine sand occasionally								
13 14													
15					BOH								

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with 2 bags Portland cement dry bagged and topped with spoils.
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING AD-4

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323880.13, E 2692538.1
DATE(S) DRILLED: 2/26/04 - 2/26/04

DRILLING METHOD(S):
Failing 1500, 5 inch box auger, 1 3/8" standard split spoon

GROUNDWATER INFORMATION:
2 hours after drilling

SURFACE ELEVATION: 0

FIELD DATA						LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT LL	ATTERBERG LIMITS: PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)		
1 – 2			X	N = 8	FAT CLAY SOFT DAMP BROWN TO DARK BROWN -rootlets								
3 – 4			X	N = 21	CLAYEY SILT STIFF DAMP BROWN < 15% very fine sand -sparse occasional rootlets								
5 – 6			X	N = 14	FAT CLAY MEDIUM DAMP BROWN - contains < 15 % very fine sand - silty								
7 – 8					FAT CLAY SOFT DAMP TO MOIST BROWN - contains < 15% very fine sand								
9 – 10			X	N = 5									
11 – 12			X	N = 6									
13 – 14			X	N = 6									
15 – 16			X	N = 3									
16					BOH								

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with grout tremied to 2.0' BGS with 2 bags of portland cement, topped with spoils to ground surface
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING ADU-3

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323226.77, E 2692224.11
DATE(S) DRILLED: 3/1/04 - 3/1/04

DRILLING METHOD(S):
CME 750, 3 3/4" Hollow Stem Auger, 5" Shelby Tube

GROUNDWATER INFORMATION:
Not encountered

SURFACE ELEVATION: 0

FIELD DATA						LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT LL	ATTERBERG LIMITS: PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)		
					FAT CLAY MEDIUM DAMP TO MOIST BROWN -rootlets								
1													
2				T = .4, .4, .4	FAT CLAY STIFF DAMP BROWN TO REDDISH BROWN -contains sparse, occasional very fine sand, <15%								
3													
4				T = .35, .9, >1									
5													
6													
7				T = .9, .8, .85									
8													
9				T = .7, .65, .7									
10													
11					FAT CLAY STIFF TO MEDIUM DAMP BROWN -contains sparse, occasional very fine sand, <15%								
12				T = .65, .43, .5									
13					FAT CLAY STIFF TO MEDIUM DAMP BROWN -contains sparse, occasional very fine sand, <15%								
14				T = .65, .6, .5									
15													
					BOTTOM OF HOLE								

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with 2 bags Portland cement dry bagged and topped with spoils.
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING ADU-5

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323014.45, E 2692092.69
DATE(S) DRILLED: 2/24/04 - 2/25/04

FIELD DATA

DRILLING METHOD(S):
Failing 1500, 5 inch box auger, 5" shelby tube, 1 3/8" standard split spoon

GROUNDWATER INFORMATION:
overnight, during drilling 2/25/04 0700

SURFACE ELEVATION: 0

LABORATORY DATA

DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS LIQUID LIMIT LL	ATTERBERG LIMITS PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)
					FAT CLAY MEDIUM DAMP TO MOIST BROWN -rootlets						
1											
2					SILTY LEAN CLAY WITH SAND STIFF TO VERY STIFF DAMP BROWN TO DARK BROWN -fill -contains sparse, occasional fine to coarse limestone gravel up to 2" in size <15% -contains very fine to fine sand, <15%						
3											
4											
5				T = .3, .25, .25	FAT CLAY MEDIUM DAMP BROWN TO LIGHT BROWN -contains occasional very fine sand <15%						
6											
7					CLAYEY SAND DENSE TO MEDIUM DENSE DAMP BROWN TO DARK BROWN -contains very fine to fine sand 45% to 55%						
8				T = .55, .25, .75							
9					FAT CLAY STIFF DAMP BROWN TO DARK BROWN -sparse occasional very fine to fine sand <15%						
10				T = .85, .7, .6							
11					FAT CLAY STIFF DAMP BROWN TO LIGHT BROWN -sparse occasional very fine to fine sand <15%						
12											
13				T = .4, .4, .2	SANDY FAT CLAY MEDIUM TO STIFF DAMP TO MOIST DARK GRAY -contains very fine to fine sand 30% to 40% -poorly laminated						
14											
15				T = .4, .35, .2	SANDY FAT CLAY MEDIUM MOIST DARK GRAY -contains very fine to fine sand 30% to 40% -poorly laminated						
16											
17					SANDY FAT CLAY MEDIUM TO STIFF DAMP TO MOIST DARK GRAY						
18				T = .3, .35, .4							
19											
20											

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with grout tremied to 2.0' BGS with 8 bags of portland cement, topped with spoils
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING ADU-5

US Army Corps of Engineers

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323014.45, E 2692092.69
DATE(S) DRILLED: 2/24/04 - 2/25/04

DRILLING METHOD(S):
Failing 1500, 5 inch box auger, 5" shelby tube, 1 3/8" standard split spoon

GROUNDWATER INFORMATION:
overnight, during drilling 2/25/04 0700

FIELD DATA: DEPTH (FT) | SOIL SYMBOL | BREAKS: bb or mb | SAMPLES | N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %

LABORATORY DATA: USCS SYMBOL | ATTERBERG LIMITS: LIQUID LIMIT (LL), PLASTIC LIMIT (PL) | MOISTURE CONTENT (%) | UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT) | MINUS NO. 200 SIEVE (%)

DEPTH (FT)	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM
		T = .3, .4	-contains very fine to fine sand 30% to 40% -poorly laminated
21			SANDY FAT CLAY MEDIUM DAMP DARK GRAY -contains very fine to fine sand 25% to 35% -poorly laminated
22			
23		T = .2, .2, .2	SILTY LEAN CLAY WITH SAND MEDIUM TO STIFF DAMP DARK GRAY TO DARK GREENISH GRAY -contains 15% to 25% very fine sand
24			
25		T = .2, .3, .25	-20.4' to 20.5' layer containing very fine to medium sand in matrix -20.8' to 21.1' layer containing very fine to coarse sand in matrix
26			SILTY LEAN CLAY WITH SAND MEDIUM TO STIFF MOIST TO WET BROWN TO LIGHT BROWN -contains 15% to 25% very fine sand
27			
28		T = .3, .3, .3	
29			
30		T = .2, .15, .15	
31			
32			
33		T = .3, .4, .4	SILTY LEAN CLAY STIFF DAMP TO MOIST BROWN -contains <15% very fine sand
34			
35		T = .55, .55, .55	
36			
37			
38		T = .6, .6, .6	
39			SANDY FAT CLAY STIFF
40			

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with grout tremied to 2.0' BGS with 8 bags of portland cement, topped with spoils
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING ADU-5

US Army Corps of Engineers

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1323014.45, E 2692092.69
DATE(S) DRILLED: 2/24/04 - 2/25/04

DRILLING METHOD(S):
Failing 1500, 5 inch box auger, 5" shelby tube, 1 3/8" standard split spoon

GROUNDWATER INFORMATION:
overnight, during drilling 2/25/04 0700

FIELD DATA						LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT LL	ATTERBERG LIMITS: PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)		
41				T = .35, .35, .35	MOIST BROWN -with silt -contains 20% to 30% very fine to fine sand								
42													
43				T = .25, .4, .25									
44													
45				T = .25, .15, .2									
46													
47					CLAYEY SAND DENSE WET BROWN -contains 50% to 60% very fine to coarse sand								
48													
49													
50				N = 33									
51													
52				N = 30	CLAYEY SAND MEDIUM SATURATED BROWN -contains 55% to 65% very fine to coarse sand, sparse fine gravel								
53													
54					SANDY GRAVEL MEDIUM SATURATED BROWN -contains 40% to 50% fine to coarse gravel up to 1" diameter, poorly sorted -contains 30% to 40% fine to coarse sand, dominately medium to coarse								
55				N = 52									
					MUDSTONE SOFT DENSE TO VERY FINE GRAINED GREENISH GRAY AND ORANGE -poorly laminated								
					BOH								

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with grout tremied to 2.0' BGS with 8 bags of portland cement, topped with spoils
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING ADU-6

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1322906.04, E 2692547.52
DATE(S) DRILLED: 2/23/04 - 2/24/04

FIELD DATA

DRILLING METHOD(S):
Failing 1500, 5 inch box auger, 5" shelby tube, 1 3/8" standard split spoon

GROUNDWATER INFORMATION:
overnight during drilling 2/24/04 0700

SURFACE ELEVATION: 0

LABORATORY DATA

DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT (LL)	ATTERBERG LIMITS: PLASTIC LIMIT (PL)	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)
0–6				T = .55, .9, .75 T = .55, .6, .5	FAT CLAY MEDIUM TO STIFF DAMP BROWN TO DARK BROWN <15% very fine sand -silty						
6–9				T = .55, .55, .7 T = .85, .9, .65	FAT CLAY STIFF DAMP BROWN TO LIGHT BROWN -<15% very fine to fine sand -silty						
9–13				T = .7, .55, .65	ELASTIC SILT STIFF DAMP BROWN TO LIGHT BROWN <15% very fine to fine sand -clayey						
13–19				T = .4, .35, .55 T = .65, .45, .55	FAT CLAY STIFF DAMP BROWN TO LIGHT BROWN -<15% very fine to fine sand -silty						
19–20				T = .45, .55, .6	FAT CLAY STIFF						

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with grout tremied to 2.0' BGS with 3 bags of portland cement, topped with spoils to ground surface
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

LOG OF BORING ADU-6

US Army Corps of Engineers ®

Department of the Army
Kansas City District
Corps of Engineers
700 Federal Building
Kansas City, MO 64106

INSTALLATION: Blacksnake Creek
PROJECT: Road Raise and Levee Investigation
LOCATION: Saint Joseph, MO
COORDINATES: N 1322906.04, E 2692547.52
DATE(S) DRILLED: 2/23/04 - 2/24/04

DRILLING METHOD(S):
Failing 1500, 5 inch box auger, 5" shelby tube, 1 3/8" standard split spoon

GROUNDWATER INFORMATION:
overnight during drilling 2/24/04 0700

FIELD DATA						LABORATORY DATA							
DEPTH (FT)	SOIL SYMBOL	BREAKS: bb or mb	SAMPLES	N: BLOWS/FT P: TONS/SQ FT T: TORVANE KG/CM SQ R: % RQD: %	DESCRIPTION OF STRATUM	USCS SYMBOL	ATTERBERG LIMITS: LIQUID LIMIT LL	ATTERBERG LIMITS: PLASTIC LIMIT PL	MOISTURE CONTENT (%)	UNCONFINED COMPRESSIVE STRENGTH (TONS/SQ FT)	MINUS NO. 200 SIEVE (%)		
					DAMP LIGHT BROWN TO LIGHT REDDISH BROWN -silty								
21				T = >1, >1,	>1								
22													
23													
24				T = >1, >1,	.6								
					GRAVELLY FAT CLAY STIFF DAMP TO MOIST LIGHT BROWN TO LIGHT REDDISH BROWN -silty -contains fine to 30% to 40% coarse limestone gravel and cobbles up to 6" in diameter								
25													
				N = 50									
					GRAVELLY FAT CLAY STIFF SATURATED LIGHT BROWN TO LIGHT REDDISH BROWN -silty -contains fine to 30% to 40% coarse limestone gravel and cobbles up to 6" in diameter								
					BOH								

N - STANDARD PENETRATION TEST RESISTANCE
P - POCKET PENETROMETER RESISTANCE
T - TORVANE EQUALLY SPACED ALONG SAMPLE
R - ROCK CORE RECOVERY
RQD - ROCK QUALITY DESIGNATION

REMARKS:
Backfill with grout tremied to 2.0' BGS with 3 bags of portland cement, topped with spoils to ground surface
Coordinates Trimble Hand GPS US State Plane MO west 2403 NAD 83 feet.

GEOTECHNOLOGY, INC.
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS • COLLINSVILLE • KANSAS CITY

August 16, 2004

Ms. Mary Perlea
U.S. Army Corps of Engineers
NWK-EC-GD
601 East 12th Street
Kansas City, MO 64106

RECEIVED
OCT 2 2011
STANLEY CONSULTANTS
MINNEAPOLIS

Reference: Indefinite Delivery Contract No. DACA41-03-D-0003

Dear Ms. Perlea:

Please find attached laboratory testing results for the Blacksnake Creek project under the referenced contract. We appreciate the continued opportunity to provide services to the Corps under this contract. Please feel free to call with any questions.

Very truly yours,

Geotechnology, Inc.

STATE OF MISSOURI
YINGWEI WU
NUMBER
PROFESSIONAL ENGINEER

Yingwei Wu, Ph.D. P.E.
Staff Engineer

YAW:yaw

Copies submitted: (2)

Attachments: Laboratory Testing Results

printed on recycled paper

9136 CODY • OVERLAND PARK, KANSAS 66214 • 913/438-1900 • FAX: 913/438-1923

GEOTECHNOLOGY, INC.
ENGINEERING AND ENVIRONMENTAL SERVICES
ST. LOUIS • COLLINSVILLE • KANSAS CITY

SUMMARY OF CLASSIFICATIONS TESTS

Project: Black Snake River

Note: By visual examination and classification, samples not tested were compared and grouped with typical test samples described below:

1)	Lean Clay (CL)	Brown and dark brown clay (LL - 40, PI - 20)
2)	Sand and Gravel	Brown sand and gravel (LL - N/A, PI – Non-Plastic)
3)	Silt (ML)	Brown to light grey clayey sandy silt (LL - N/A, PI - N/A)
4)	Fat Clay (CH)	Grey to dark yellow clay (LL - 57, PI - 22)
5)	Lean Clay (CL)	Dark brown silty clay (LL - 35, PI - 13)
6)	Lean Clay (CL)	Dark brown, sandy silty clay (LL - 36, PI - 15)
7)	Fat Clay (CH)	Brown clay with sand and gravel (LL - N/A, PI - N/A)
8)	Silty Clay (CL)	Light brown silty clay (LL - 30, PI - 10)
9)	Lean Clay (CL)	Dark brown silty clay, trace sand (LL - 37, PI - 14)
10)	Lean Clay (CL)	Light brown to brown silty clay (LL - 37, PI - 16)

BORING NO.	SAMPLE DEPTH (feet)	SAMPLE NUMBER	LABORATORY TESTS								
			Classification Group Number	Moisture Content, %	Atterberg Limit			γ_t (pcf)	Unconfined Compression	Standard Proctor	
					Liquid Limit	Plastic Limit	Plasticity Index		qu, (tsf)	γ_{dmax} (pcf)	Optimum Moisture Content, %
AD-1	0-2.0	Jar-1	6	25.4							
	2.0-4.0	Sack-1		N/T*	37	22	15			107.0	16.0
	2.0-4.0	Jar-2	6	19.9							
	4.0-5.0	Jar-3	6	30.7							
	5.0-8.0	Sack-2		N/T*	32	21	11			Not Enough Materials	
	5.0-8.0	Jar-4	9	26.3							
	8.0-10.0	Jar-5	9	27.7	37	23	14				
	10.0-12.0	Jar-6	1	27.9							
	12.0-15.0	Jar-7	1	29.0							
AD-2	0.0-2.5	Jar-1	6	26.2	36	21	15				
	2.5-5.0	Jar-2	5	24.3	35	22	13				
	2.5-5.0	Sack-2		N/T*	32	22	10			105.5	16.5
	5.0-7.5	Jar-3	5	24.2							
	7.5-10.0	Jar-4	6	28.3							
	10.0-12.5	Jar-5	6	24.4							
	12.5-15.0	Jar-6	6	27.7							
ADU-3	2.9-3.0	Jar-1	5	21.6							
	1.0-3.0	WAX-1		21.7	38	27	11				
	5.4-5.5	Jar-2	6	20.1							
	6.0-7.9	Jar-3	6	23.5							
	10.4-10.5	Jar-4	1	27.8							
	12.9-13.0	Jar-5	1	27.9							
	15.4-15.5	Jar-6	1	29.1							

* Sack samples or disturbed wax samples

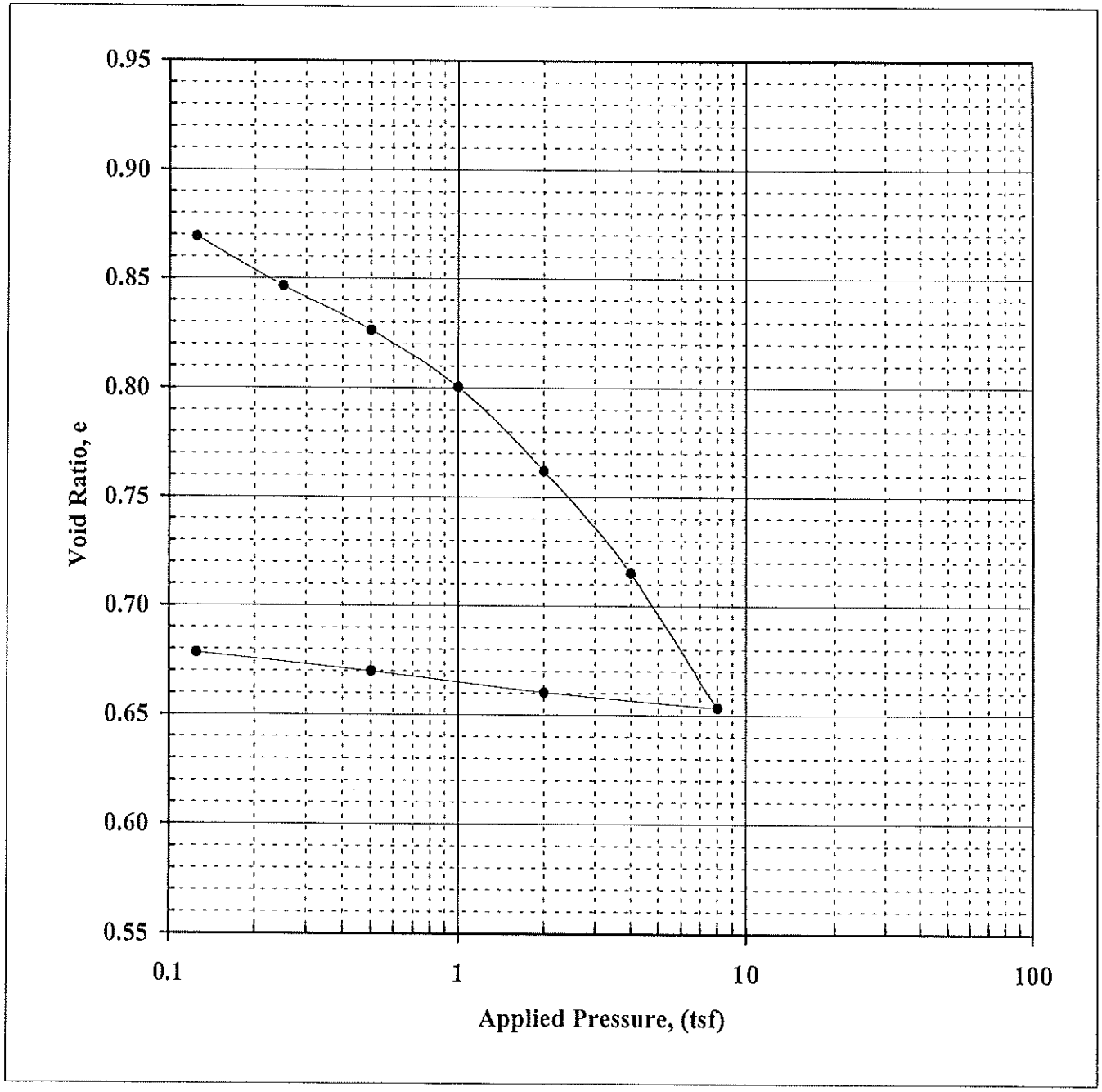
BORING NO.	SAMPLE DEPTH (feet)	SAMPLE NUMBER	LABORATORY TESTS								
			Classification Group Number	Moisture Content, %	Atterberg Limit			γ_t (pcf)	Unconfined Compression	Standard Proctor	
					Liquid Limit	Plastic Limit	Plasticity Index		qu, (tsf)	γ_{dmax} (pcf)	Optimum Moisture Content, %
AD-4	0.5-1.0	Jar-1	5	24.6							
	2.5-2.8	Jar-2	5	15.1							
	4.5-5.7	Jar-3	3	25.0	Not Enough Materials						
	6.5-8.0	Jar-4	6	26.6							
	8.5-10.0	Jar-5	1	29.0							
	10.5-12.0	Jar-6	1	27.9							
	12.5-14.0	Jar-7	10	28.5							
	14.5-16.0	Jar-8	10	29.9							
ADU-5	2.0-3.5	WAX-1		20.1	41	19	22	106.6	1.46		
	3.5-3.6	Jar-1	5	18.6							
	4.5-6.5	WAX-2		29.6	40	20	20	113.6			
	6.4-6.5	Jar-2	5	23.6							
	7.0-8.9	WAX-3		20.5	40	19	21	102.7	0.54		
	8.9-9.0	Jar-3	1	21.9	40	20	20				
	9.5-11.4	WAX-4		23.3	39	21	18	100.2	0.49		
	11.4-11.5	Jar-4	4	26.0	57	22	35				
	13.9-14.0	Jar-5	6	32.0							
	16.4-16.5	Jar-6	6	33.2							
	18.9-19.0	Jar-7	6	32.6							
	21.4-21.5	Jar-8	1	29.6							
	23.9-24.0	Jar-9	10	27.1							
	26.4-26.5	Jar-10	10	28.1							
	28.9-29.0	Jar-11	10	29.9							
	31.4-35.0	Jar-12	10	28.3							
	33.9-34.0	Jar-13	1	26.2							

BORING NO.	SAMPLE DEPTH (feet)	SAMPLE NUMBER	LABORATORY TESTS								
			Classification Group Number	Moisture Content, %	Atterberg Limit			γ_t (pcf)	Unconfined Compression	Standard Proctor	
					Liquid Limit	Plastic Limit	Plasticity Index		qu, (tsf)	γ_{dmax} (pcf)	Optimum Moisture Content, %
	36.4-36.5	Jar-14	10	25.7							
	38.9-39.0	Jar-15	10	25.8							
	41.4-41.5	Jar-16	10	23.4							
	43.9-44.0	Jar-17	2	18.7	Non-plastic						
	46.4-46.5	Jar-18	2	17.0							
	49.0-49.5	Jar-19	3	18.7							
	51.5-52.4	Jar-20	2	20.3							
	54.0-54.6	Jar-21	2	13.7							
	54.6-55.5	Jar-22	4	21.7							
ADU-6	0.5-2.4	WAX-1		19.4	40	20	20	104.2	0.97		
	2.4-2.5	Jar-1	6	23.8							
	4.9-5.0	Jar-2	5	20.6							
	5.5-7.4	WAX-3		23.0	39	20	19	N/T*	N/T*		
	7.4-7.5	Jar-3	10	23.0							
	9.9-10.0	Jar-4	8	21.2	30	20	10				
	12.4-12.5	Jar-5	10	22.9							
	13.0-14.9	WAX-6		23.2	29	21	8	100.5	0.44		
	14.9-15.0	Jar-6	10	21.2							
	17.4-17.5	Jar-7	10	22.5	37	21	16				
	19.9-20.0	Jar-8	10	20.1							
	22.4-22.5	Jar-9	10	21.5							
	24.9-25.0	Jar-10	10	22.3							
	25.5-25.8	Jar-11	7	76.2	Not Enough Materials						

Boring No.	ADU-5	GEOTECHNOLOGY		Job No.	06808.01.32KC
Sample No.	Wax-2	ENGINEERING AND ENVIRONMENTAL SERVICES		Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	SAINT LOUIS, COLLINSVILLE, KANSAS CITY		Sheet No.	
Tested By	SR	**One-Dimensional Consolidation Test**		Test Date	07/19/04
Computed By	yaw	(ASTM D 4546-96-C)		Checked By	ARK

Plot of Void Ratio versus Log of Pressure

Compression Index, C_c =	0.138	**Void Ratio, e_o =**	0.9222	
Recompression Index, C_r =	0.013	**Preconsolidation Pressure =**	1.6	(tsf)



Boring No.	ADU-5	b No.	06808.01.32KC
Sample No.	Wax-2	b Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	ıeet No.	
Tested By	SR	Test Date	07/19/04
Computed By	yaw	Checked B	ARK

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

One-Dimensional Consolidation Test

(ASTM D 4546-96-C)

Summary and Computation Sheet

SAMPLE DESCRIPTION: CL, brown, low plasticity CLAY

Assumed Specific Gravity Gs: 2.70

Ring No. #1	BEFORE TEST	AFTER TEST
Height	1.0000 (in.)	0.8732 (in.)
Diameter	2.5000 (in.)	2.5000 (in.)
Area	4.9087 (sq.in.)	4.9087 (sq.in.)
Volume	4.9087 (cu.in.)	4.2863 (cu.in.)
Wt. (ring + wet soil)	362.84 (gm)	360.12 (gm)
Wt. (ring + dry soil)	329.41 (gm)	329.41 (gm)
Wt. of ring	216.47 (gm)	216.47 (gm)
Wt. of wet soil	146.37 (gm)	143.65 (gm)
Wt. of dry soil	112.94 (gm)	112.94 (gm)
Moisture content	29.6 (%)	27.2 (%)
Wet density	113.6 (pcf)	127.7 (pcf)
Dry density	87.7 (pcf)	100.4 (pcf)
Solids height	0.5203 (in.)	0.5202 (in.)
Ht. of water	0.4157 (in.)	0.3819 (in.)
Saturation	82 (%)	100 (%)

Dial Reading Factor: 0.0001 (in.)
Initial Dial Reading: 13
Method for Final Reading (1. Use D_{100}, 2. D at end of load, 3. D at specific time): 2

Elaspsed Time (min)	Pressure Increment (tsf)	Dial Reading	Correc-tion	Dial Reading Corrected	Change of Reading	Specimen Height (in.)	Void Ratio	Average Pressure (tsf)	Cv (in.^{2}/min)
	0	13	0	13	0	1.0000	0.922		
	0.125	295	7	288	275	0.9725	0.869		
	0.250	427	21	406	118	0.9607	0.847		
	0.500	548	37	511	105	0.9502	0.826		
	1.000	700	54	646	135	0.9367	0.800		
	2.000	922	76	846	200	0.9167	0.762		
	4.000	1192	102	1090	244	0.8923	0.715		
	8.000	1531	119	1412	322	0.8601	0.653		
	2.000	1479	104	1375	-37	0.8638	0.660		
	0.500	1414	89	1325	-50	0.8688	0.670		
	0.125	1348	67	1281	-44	0.8732	0.678		

Boring No.	ADU-5	Job No.	06808.01.32KC
Sample No.	Wax-2	Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'		
Tested By	SR	Test Date	07/19/04
Computed By	yaw	Checked By	AKW

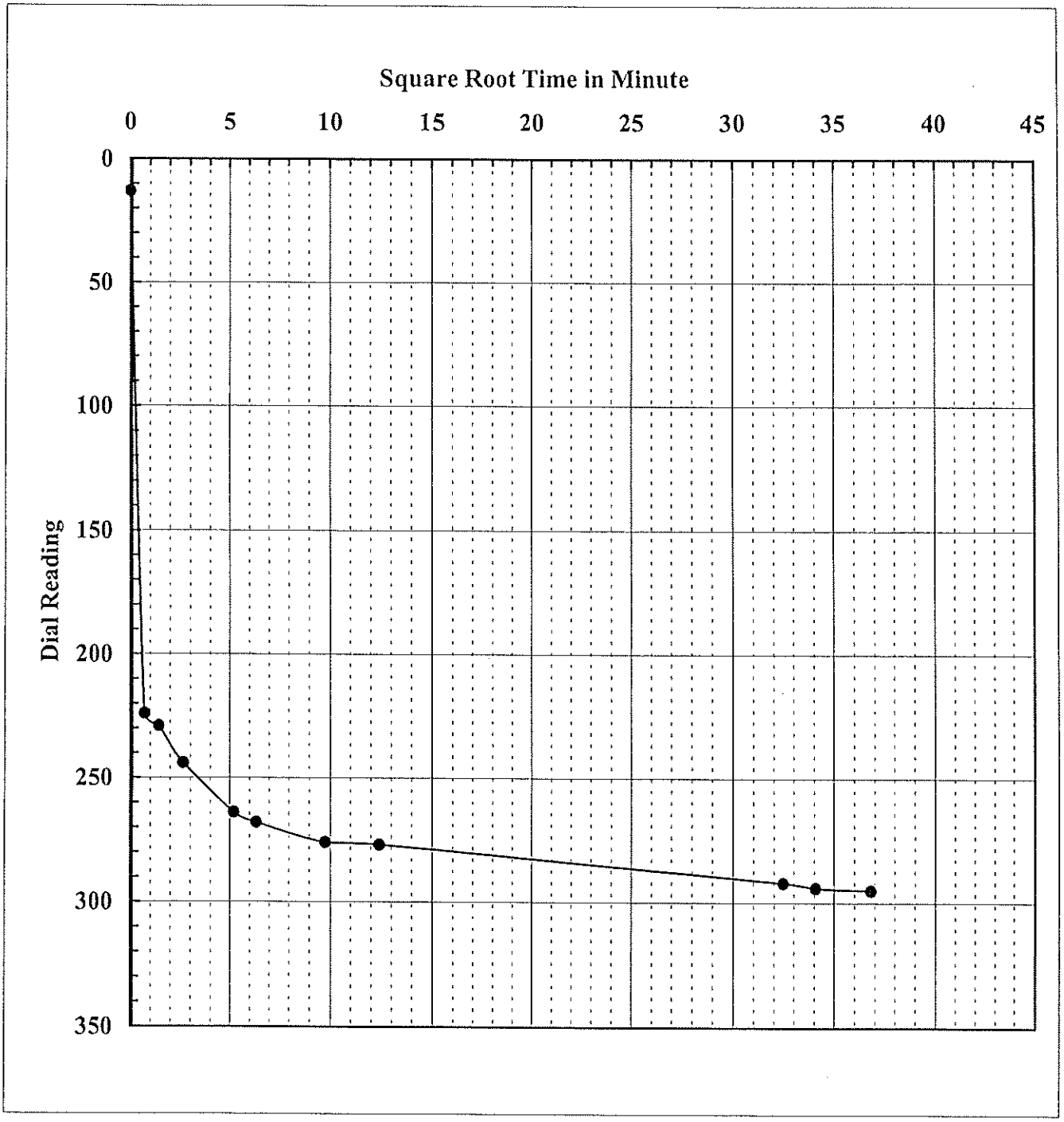
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

One-Dimensional Consolidation Test

(ASTM D 4546-96-C)

Plot of Deformation versus Square Root of Time

Applied Pressure = 0.125 (tsf)



Boring No.	ADU-5	Job No.	06808.01.32KC
Sample No.	Wax-2	Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'		
Tested By	SR	Test Date	07/19/04
Computed By	yaw	Checked By	AKC

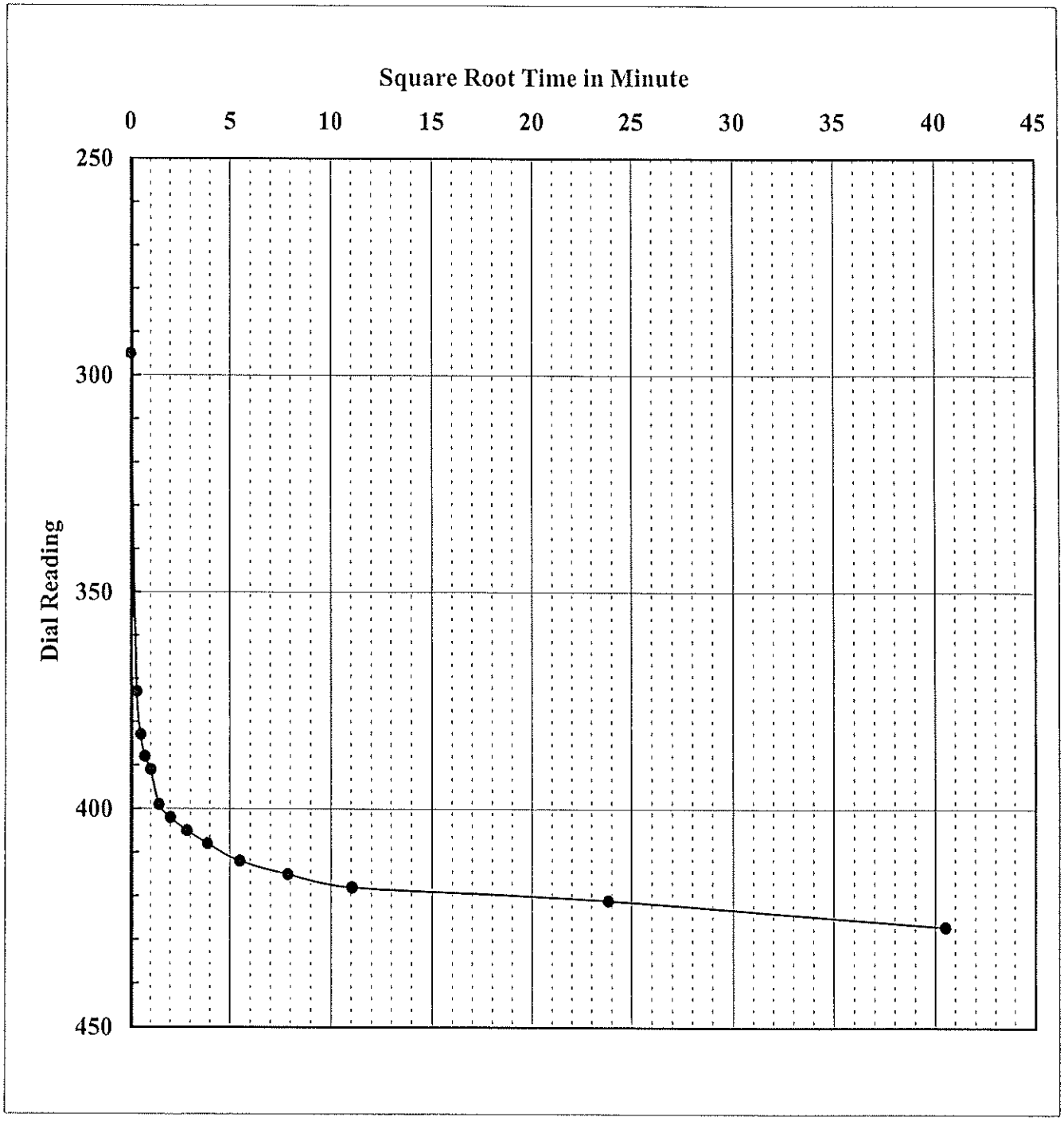
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

One-Dimensional Consolidation Test

(ASTM D 4546-96-C)

Plot of Deformation versus Square Root of Time

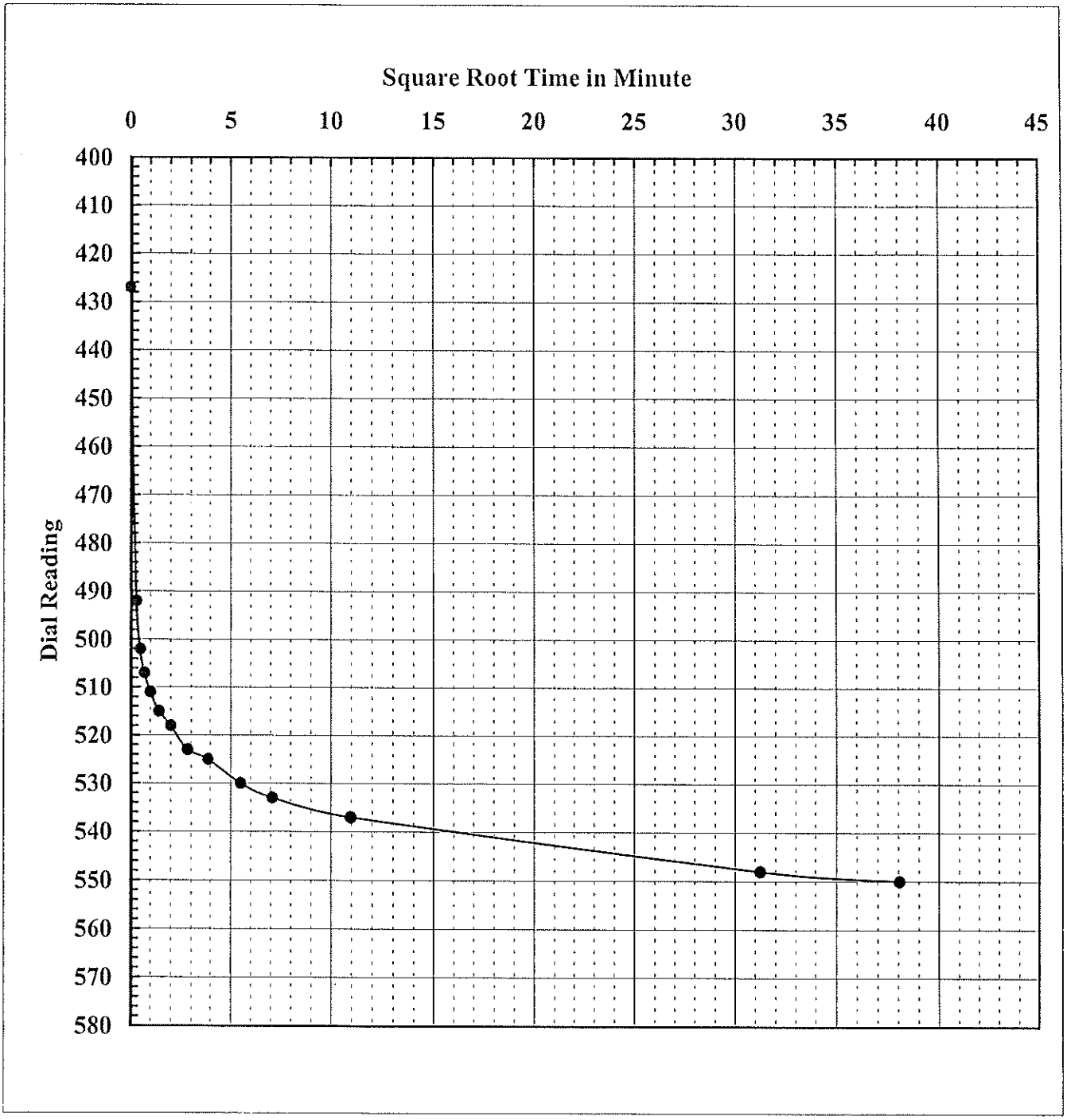
Applied Pressure = 0.25 (tsf)



Boring No.	ADU-5	GEOTECHNOLOGY		Job No.	06808.01.32KC
Sample No.	Wax-2	ENGINEERING AND ENVIRONMENTAL SERVICES		Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	SAINT LOUIS, COLLINSVILLE, KANSAS CITY		Sheet No.	
Tested By	SR	**One-Dimensional Consolidation Test**		Test Date	07/19/04
Computed By	yaw	(ASTM D 4546-96-C)		Checked By	ARK

Plot of Deformation versus Square Root of Time

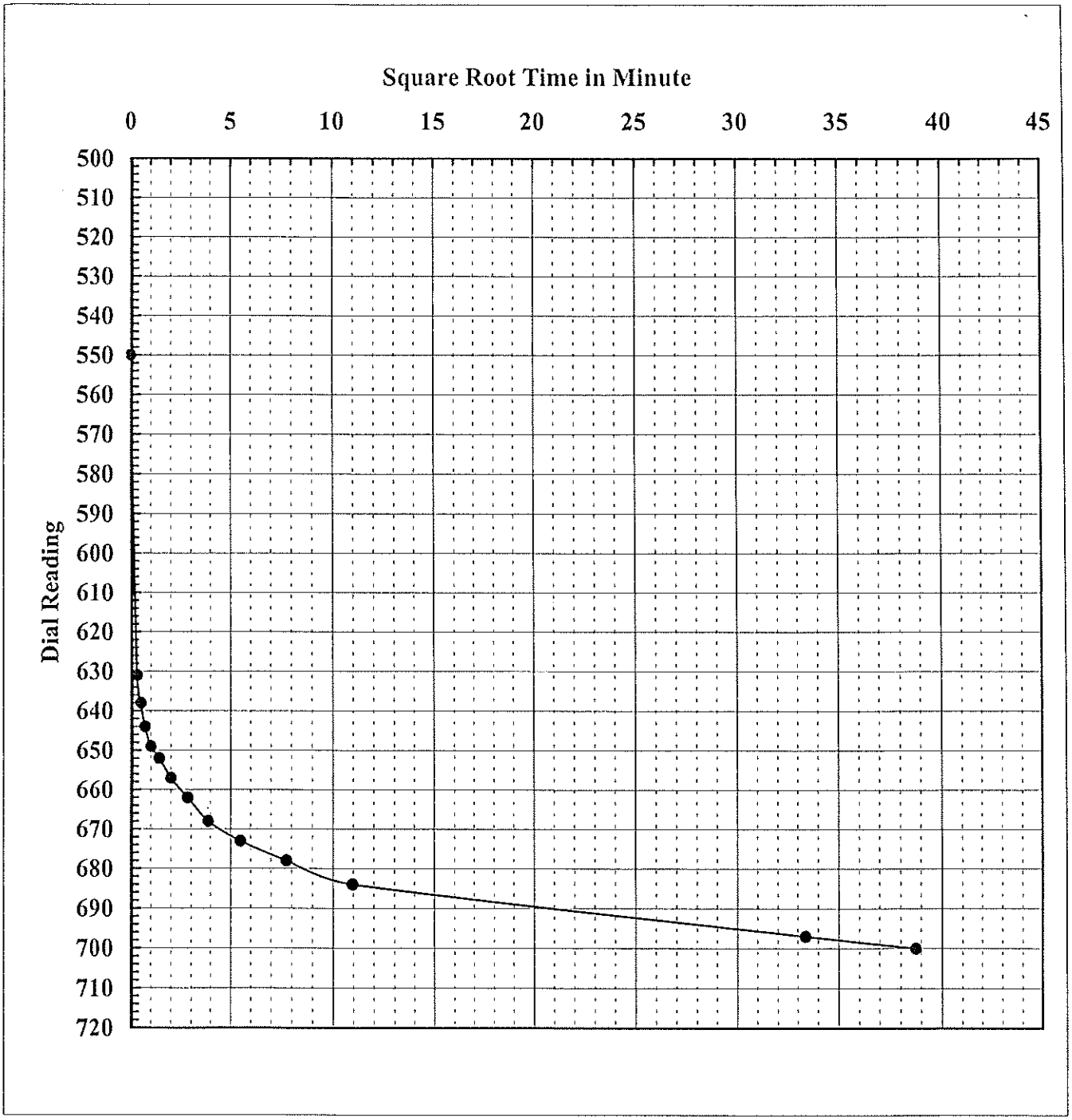
Applied Pressure = 0.5 (tsf)



Boring No.	ADU-5	GEOTECHNOLOGY		Job No.	06808.01.32KC
Sample No.	Wax-2	ENGINEERING AND ENVIRONMENTAL SERVICES		Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	SAINT LOUIS, COLLINSVILLE, KANSAS CITY		Sheet No.	
Tested By	SR	**One-Dimensional Consolidation Test**		Test Date	07/19/04
Computed By	yaw	(ASTM D 4546-96-C)		Checked By	

Plot of Deformation versus Square Root of Time

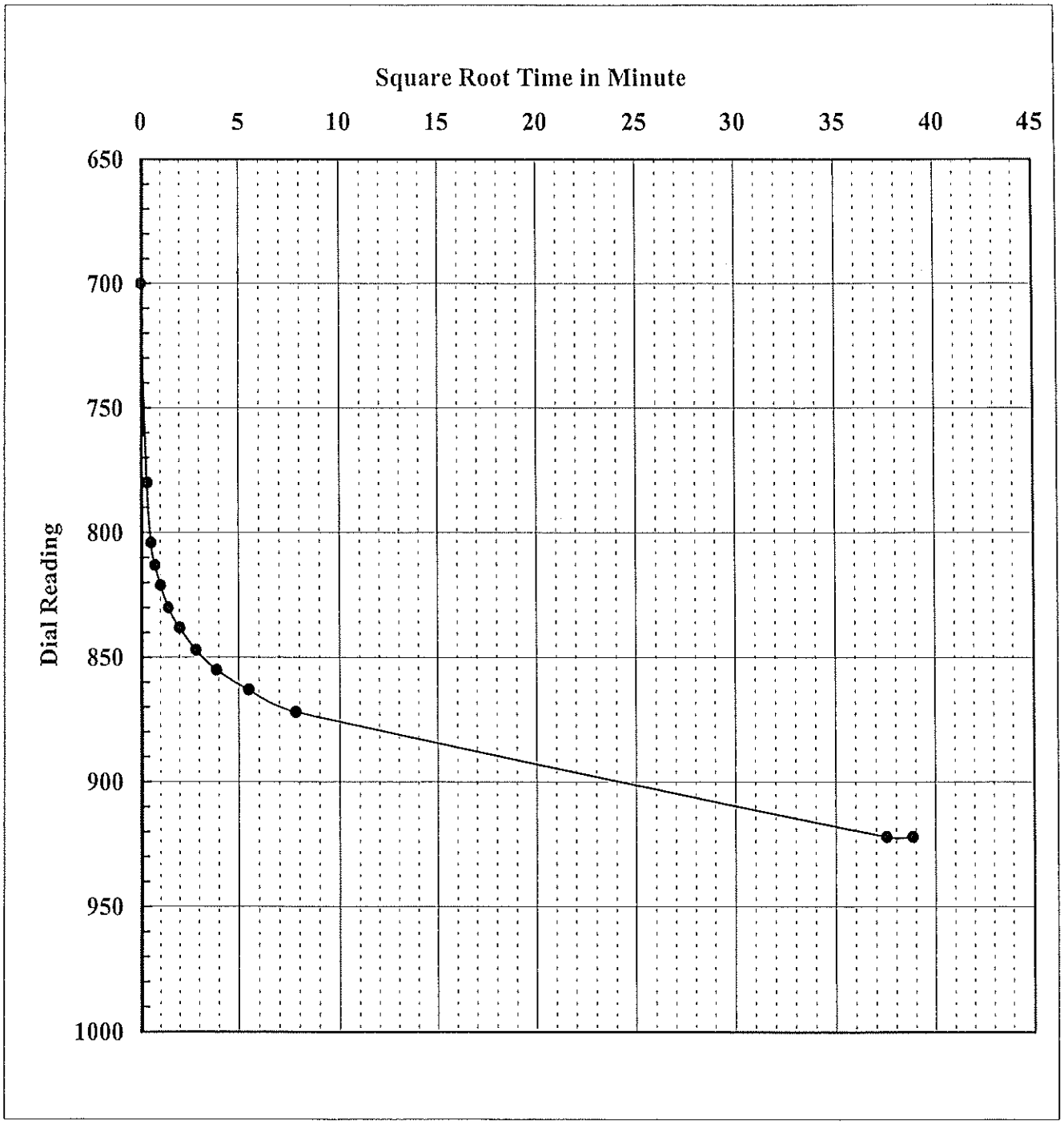
Applied Pressure = 1 (tsf)



Boring No.	ADU-5	GEOTECHNOLOGY		Job No.	06808.01.32KC
Sample No.	Wax-2	ENGINEERING AND ENVIRONMENTAL SERVICES		Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	SAINT LOUIS, COLLINSVILLE, KANSAS CITY		Sheet No.	
Tested By	SR	**One-Dimensional Consolidation Test**		Test Date	07/19/04
Computed By	yaw	(ASTM D 4546-96-C)		Checked By	

Plot of Deformation versus Square Root of Time

Applied Pressure = 2 (tsf)



Boring No.	ADU-5	Job No.	06808.01.32KC
Sample No.	Wax-2	Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	Sheet No.	
Tested By	SR	Test Date	07/19/04
Computed By	yaw	Checked By	Arc

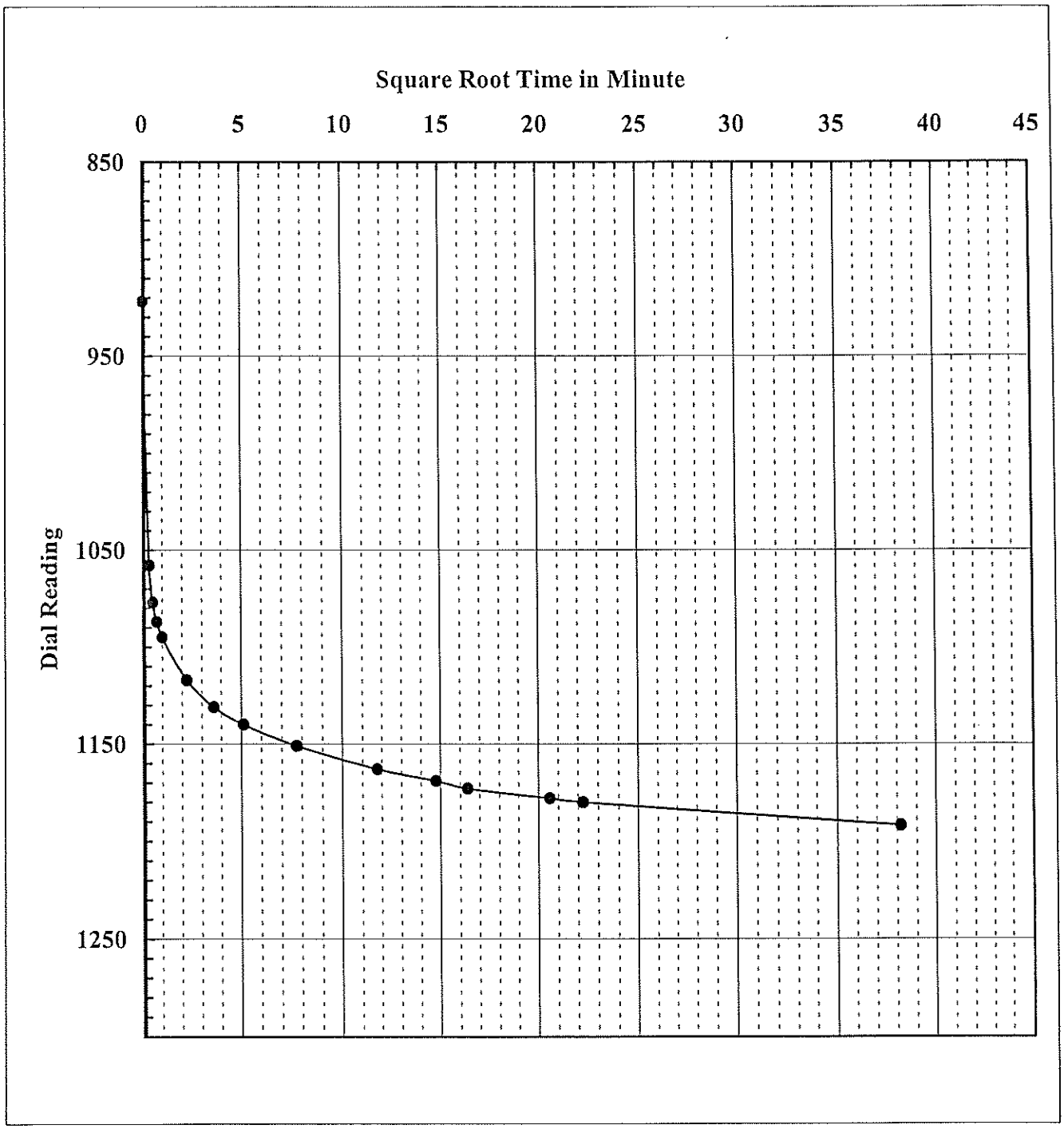
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

One-Dimensional Consolidation Test

(ASTM D 4546-96-C)

Plot of Deformation versus Square Root of Time

Applied Pressure = 4 (tsf)



Boring No.	ADU-5	Job No.	06808.01.32KC
Sample No.	Wax-2	Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	Sheet No.	
Tested By	SR	Test Date	07/19/04
Computed By	yaw	Checked By	AKR

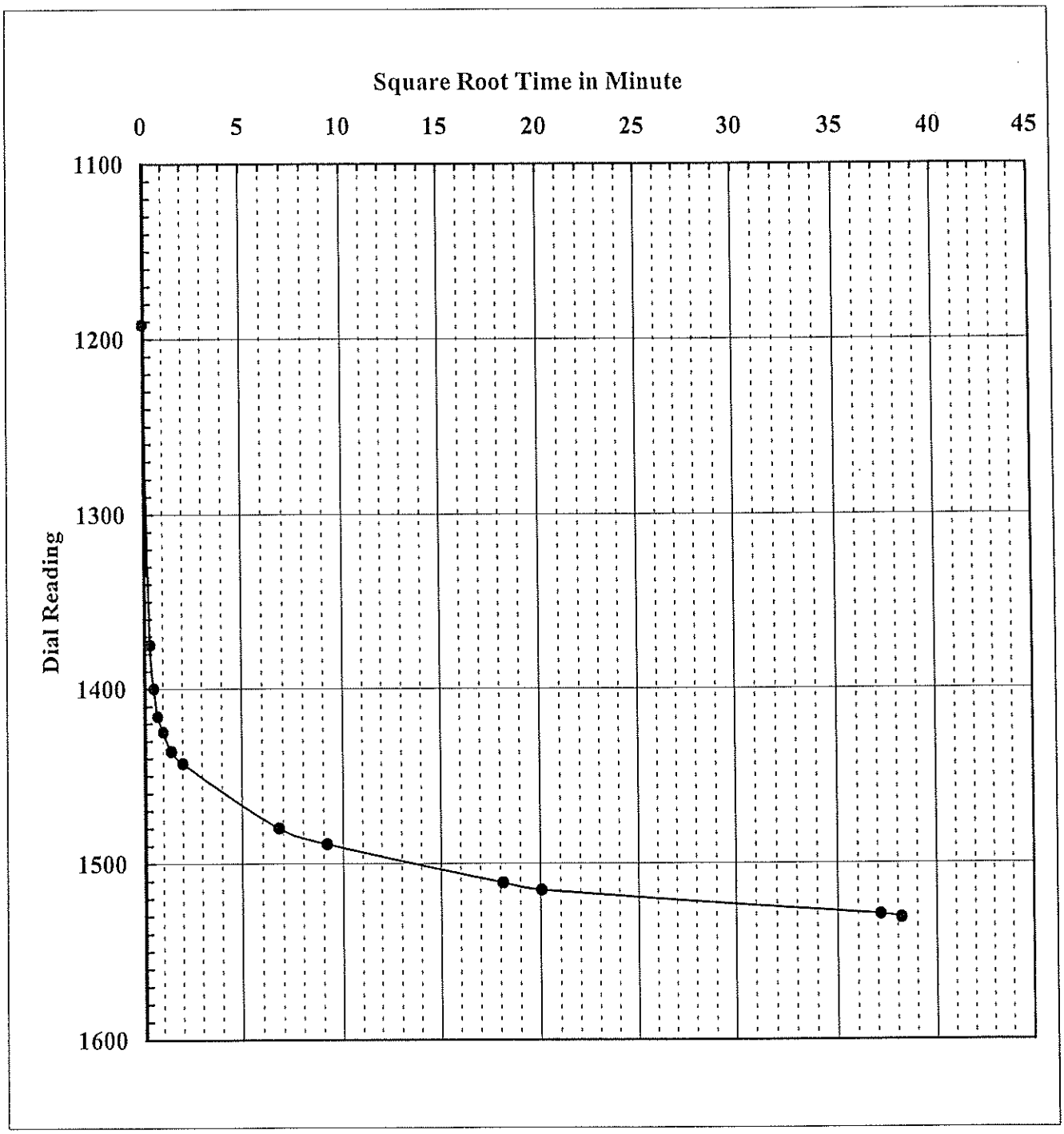
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

One-Dimensional Consolidation Test

(ASTM D 4546-96-C)

Plot of Deformation versus Square Root of Time

Applied Pressure = 8 (tsf)



Boring No.	ADU-5	Job No.	06808.01.32KC
Sample No.	Wax-2	Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	Sheet No.	
Tested By	SR	Test Date	07/19/04
Computed By	yaw	Checked By	AKK

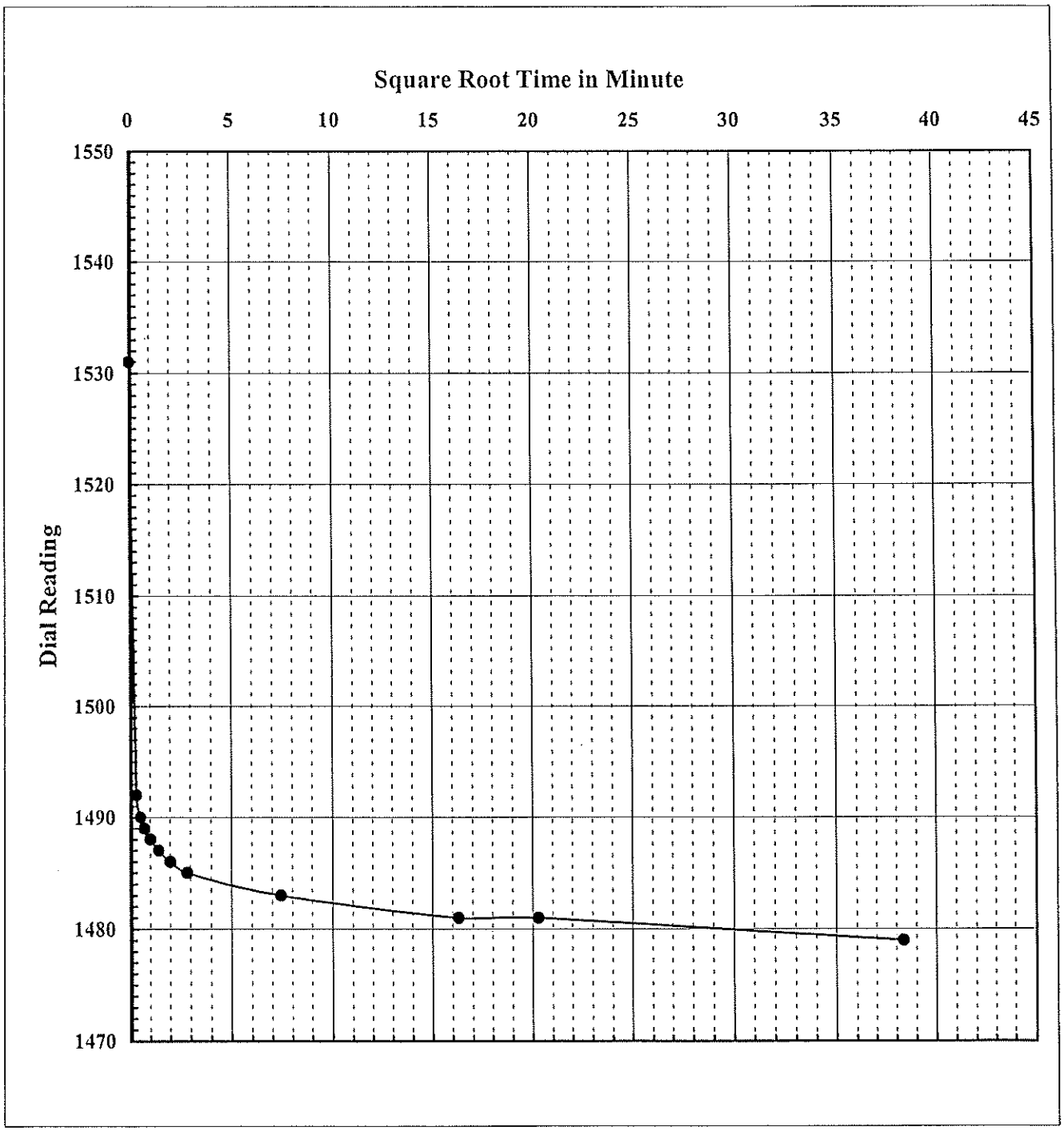
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

One-Dimensional Consolidation Test

(ASTM D 4546-96-C)

Plot of Deformation versus Square Root of Time

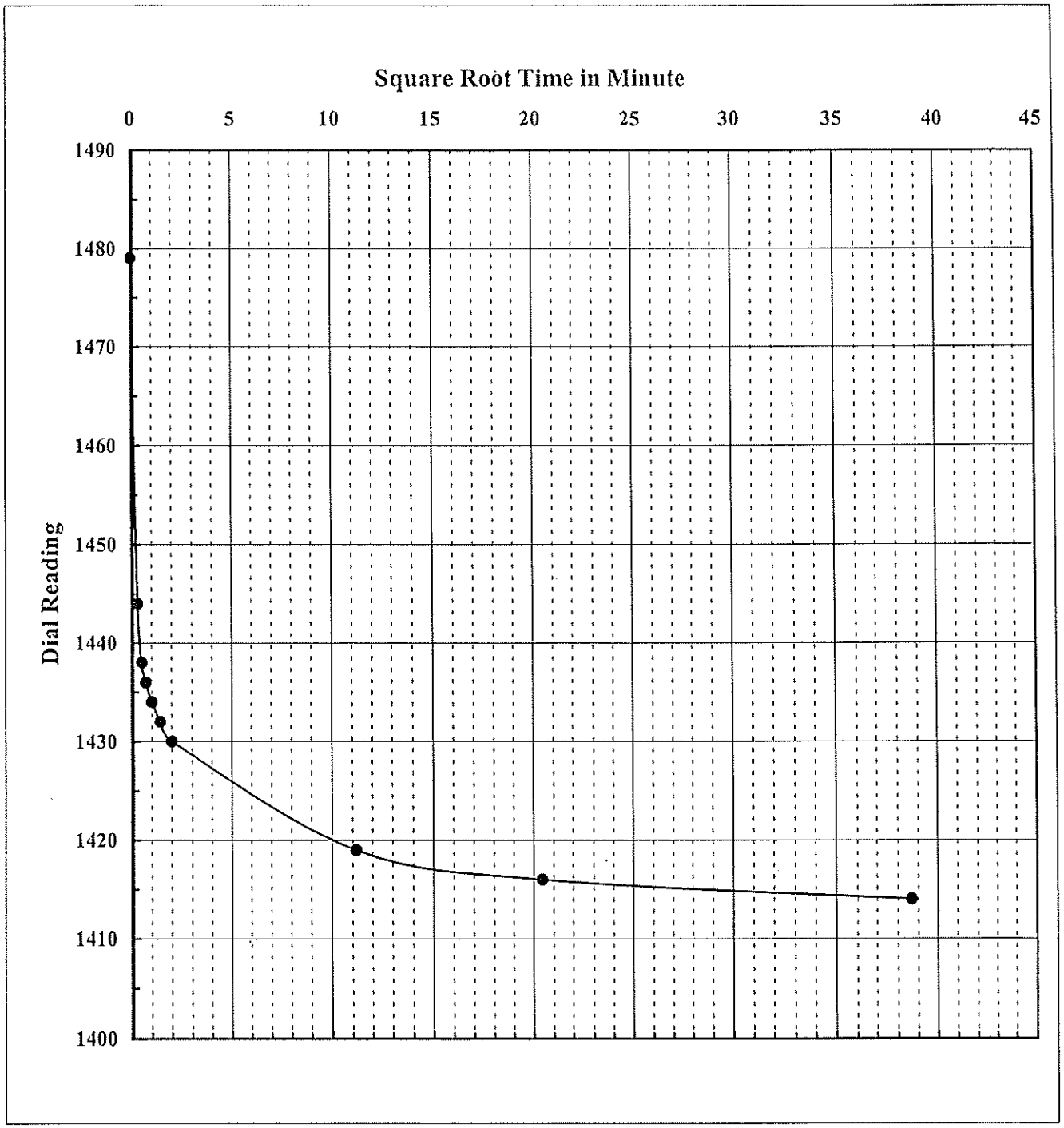
Applied Pressure @ Unloading = 2 (tsf)



Boring No.	ADU-5	GEOTECHNOLOGY		Job No.	06808.01.32KC
Sample No.	Wax-2	ENGINEERING AND ENVIRONMENTAL SERVICES		Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	SAINT LOUIS, COLLINSVILLE, KANSAS CITY		Sheet No.	
Tested By	SR	**One-Dimensional Consolidation Test**		Test Date	07/19/04
Computed By	yaw	(ASTM D 4546-96-C)		Checked By	ARK

Plot of Deformation versus Square Root of Time

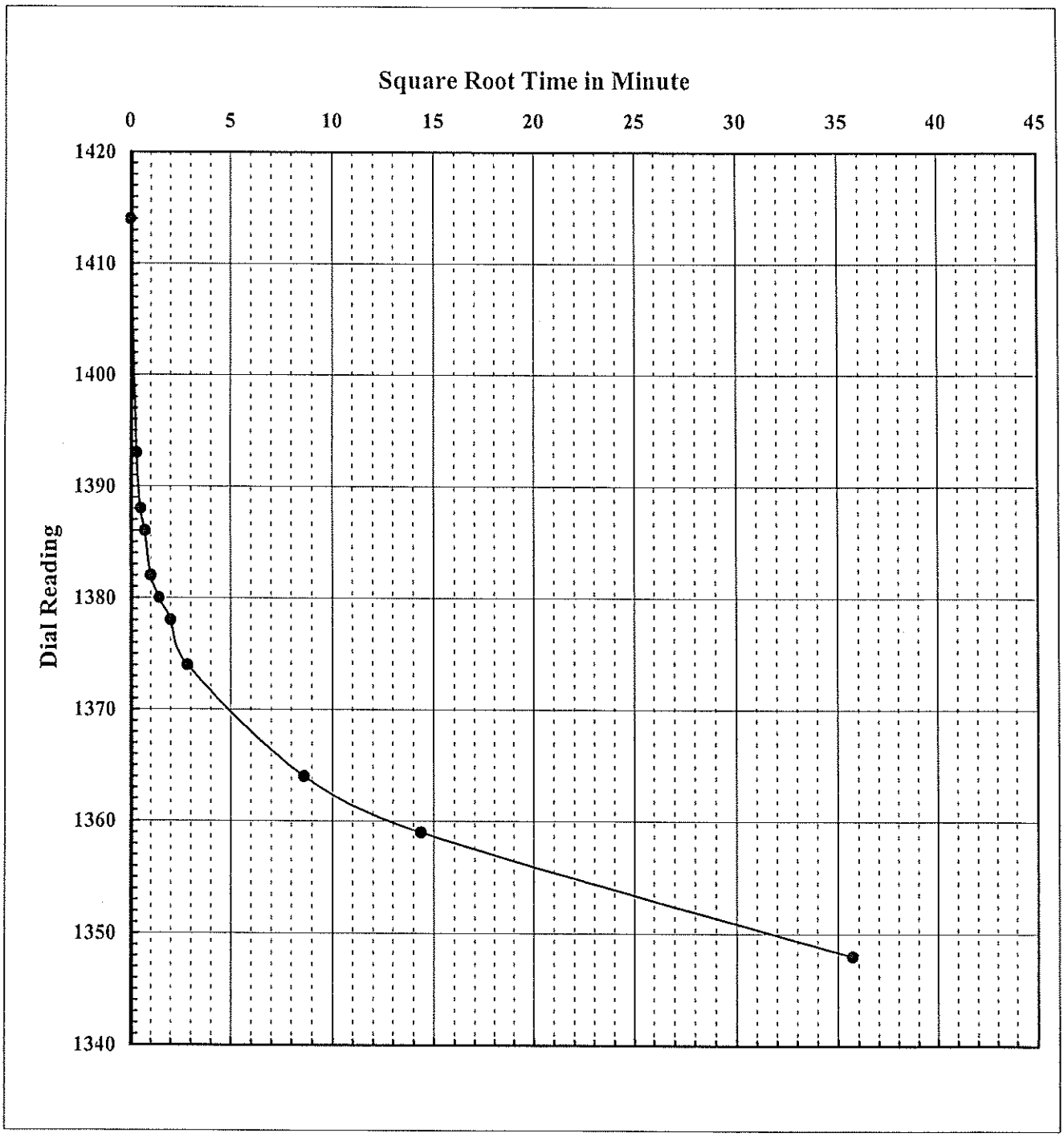
Applied Pressure @ Unloading = 0.5 (tsf)



Boring No.	ADU-5	GEOTECHNOLOGY		Job No.	06808.01.32KC
Sample No.	Wax-2	ENGINEERING AND ENVIRONMENTAL SERVICES		Job Name	Blacksnake Creek
Depth (ft)	4.5-6.5'	SAINT LOUIS, COLLINSVILLE, KANSAS CITY		Sheet No.	
Tested By	SR	**One-Dimensional Consolidation Test**		Test Date	07/19/04
Computed By	yaw	(ASTM D 4546-96-C)		Checked By	AJK

Plot of Deformation versus Square Root of Time

Applied Pressure @ Unloading = 0.125 (tsf)



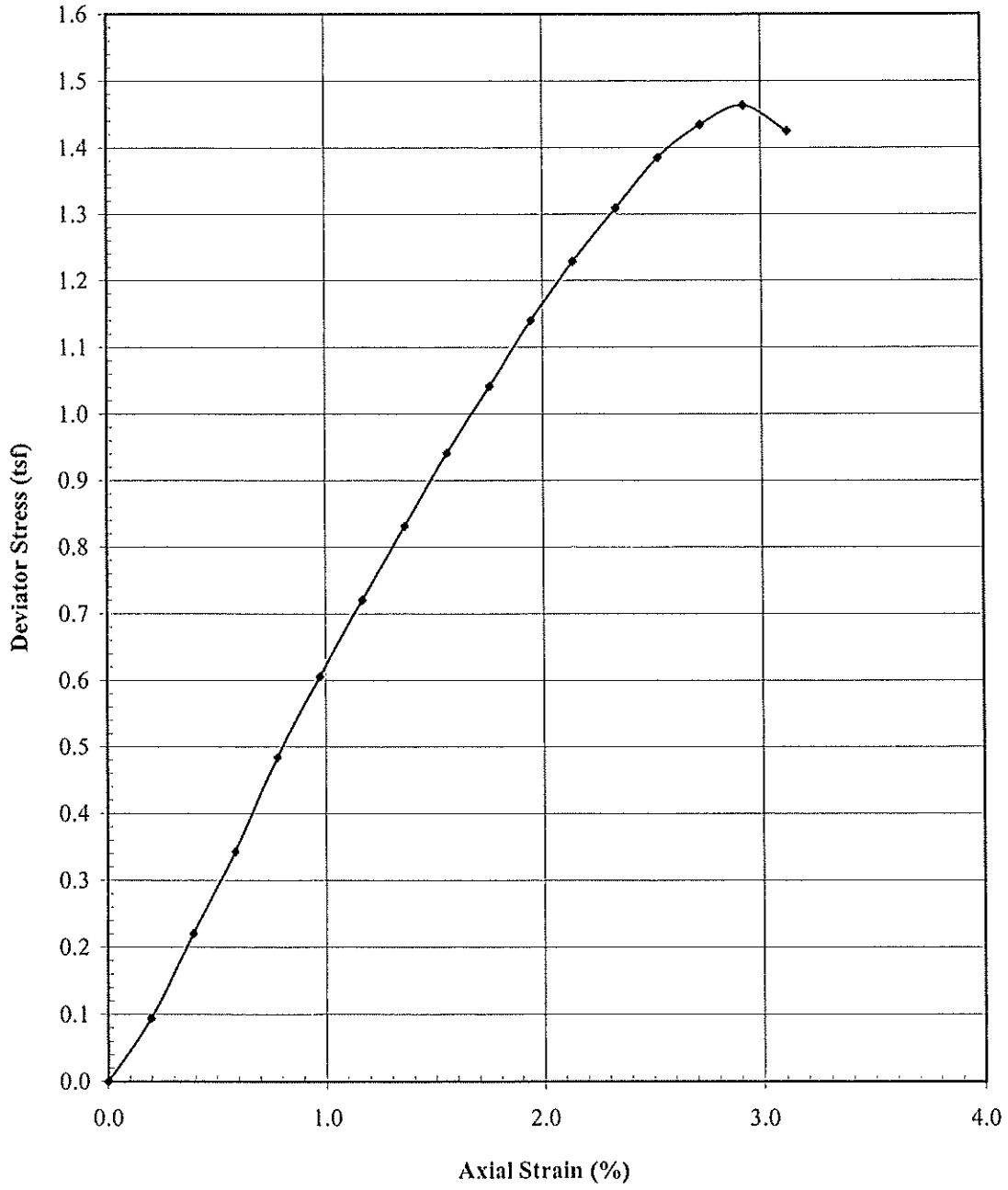
Boring No.	ADU-5
Sample No.	Wax-1
Depth (ft)	2-3.5'
Date	07/09/2004
Sheet No.	

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

UNCONFINED COMPRESSION TEST
ASTM D-2166
Stress-Strain Plot

Job No.	0680801.32KC
Job Name	Black Snake Creek
Tested By	JIU
Calculated By	yaw
Checked By	

Max. Shear Strength =	1.46 tsf	Water Content =	20.1 %
Failure Strain =	2.92 %	Dry Unit Weight =	106.6 pcf



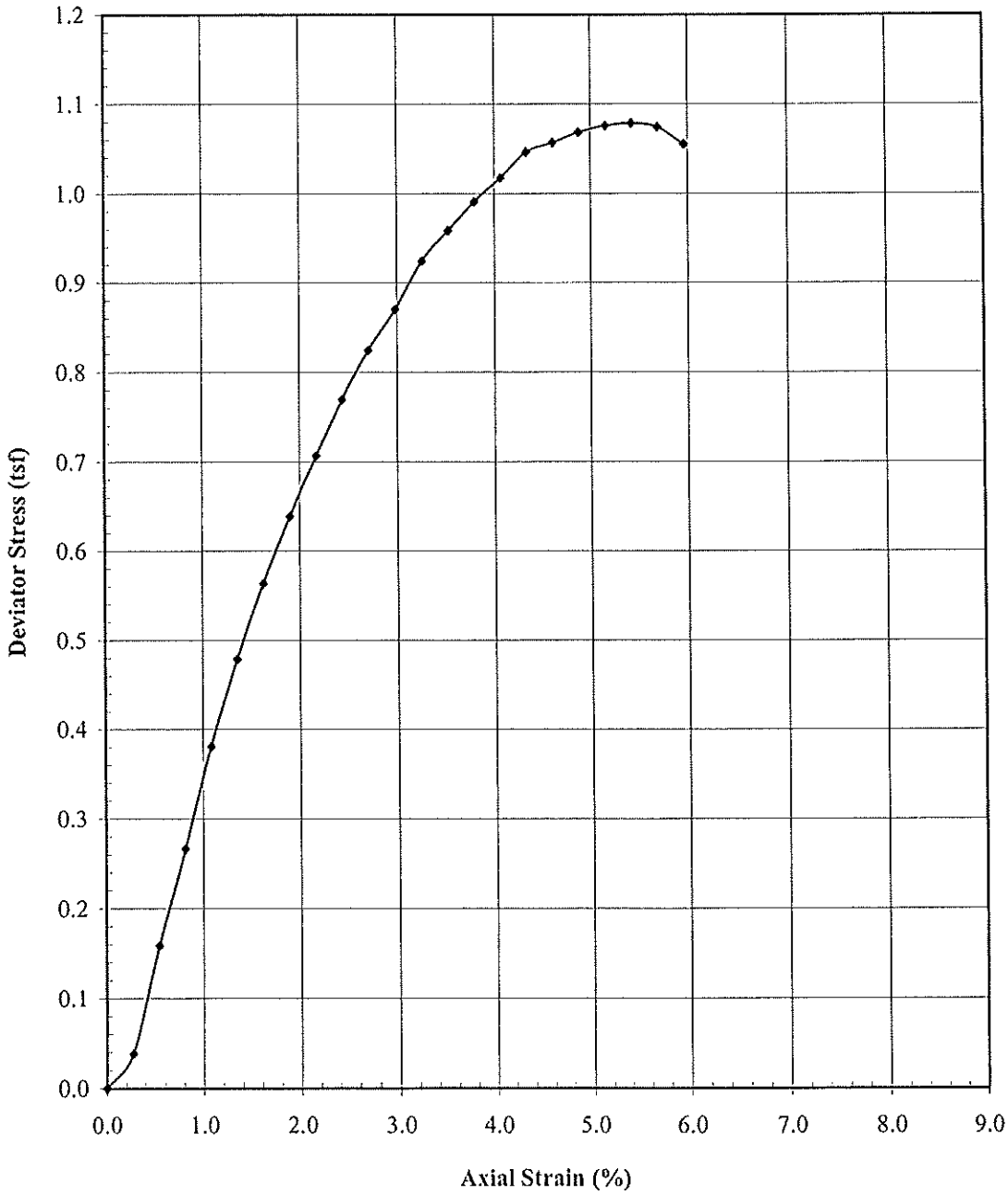
Boring No.	ADU-5
Sample No.	Wax-3
Depth (ft)	7-8.9'
Date	07/09/2004
Sheet No.	

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

UNCONFINED COMPRESSION TEST
ASTM D-2166
Stress-Strain Plot

Job No.	0680801.32KC
Job Name	Black Snake Creek
Tested By	JIU
Calculated By	yaw
Checked By	

Max. Shear Strength =	1.08 tsf	Water Content =	20.5 %
Failure Strain =	5.42 %	Dry Unit Weight =	102.7 pcf



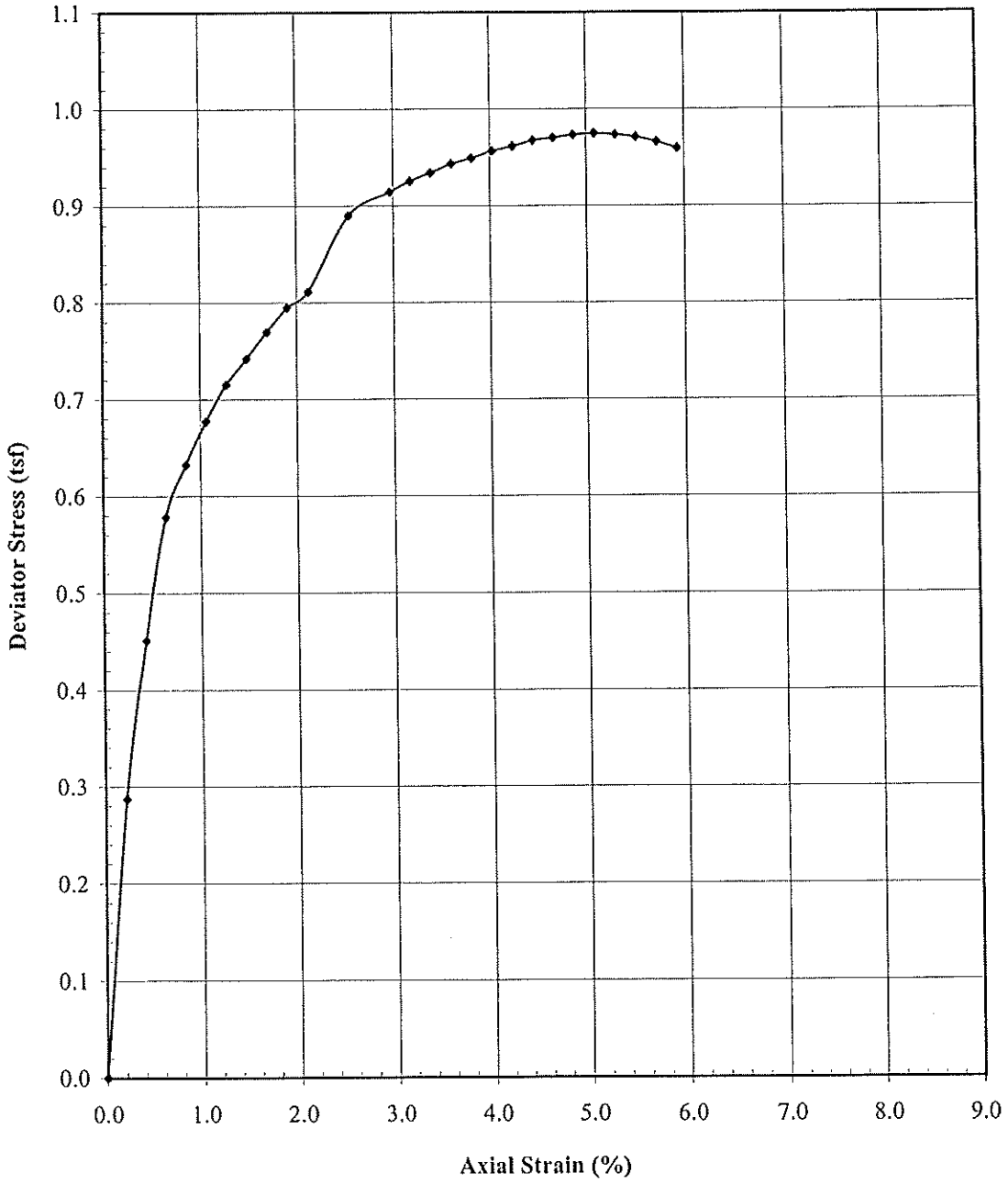
Boring No.	ADU-5
Sample No.	Wax-4
Depth (ft)	9.5-11.4'
Date	06/25/2004
Sheet No.	

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

UNCONFINED COMPRESSION TEST
ASTM D-2166
Stress-Strain Plot

Job No.	0680801.32KC
Job Name	Black Snake Creek
Tested By	JIU
Calculated By	yaw
Checked By	

Max. Shear Strength =	0.97 tsf	Water Content =	23.3 %
Failure Strain =	5.08 %	Dry Unit Weight =	100.2 pcf



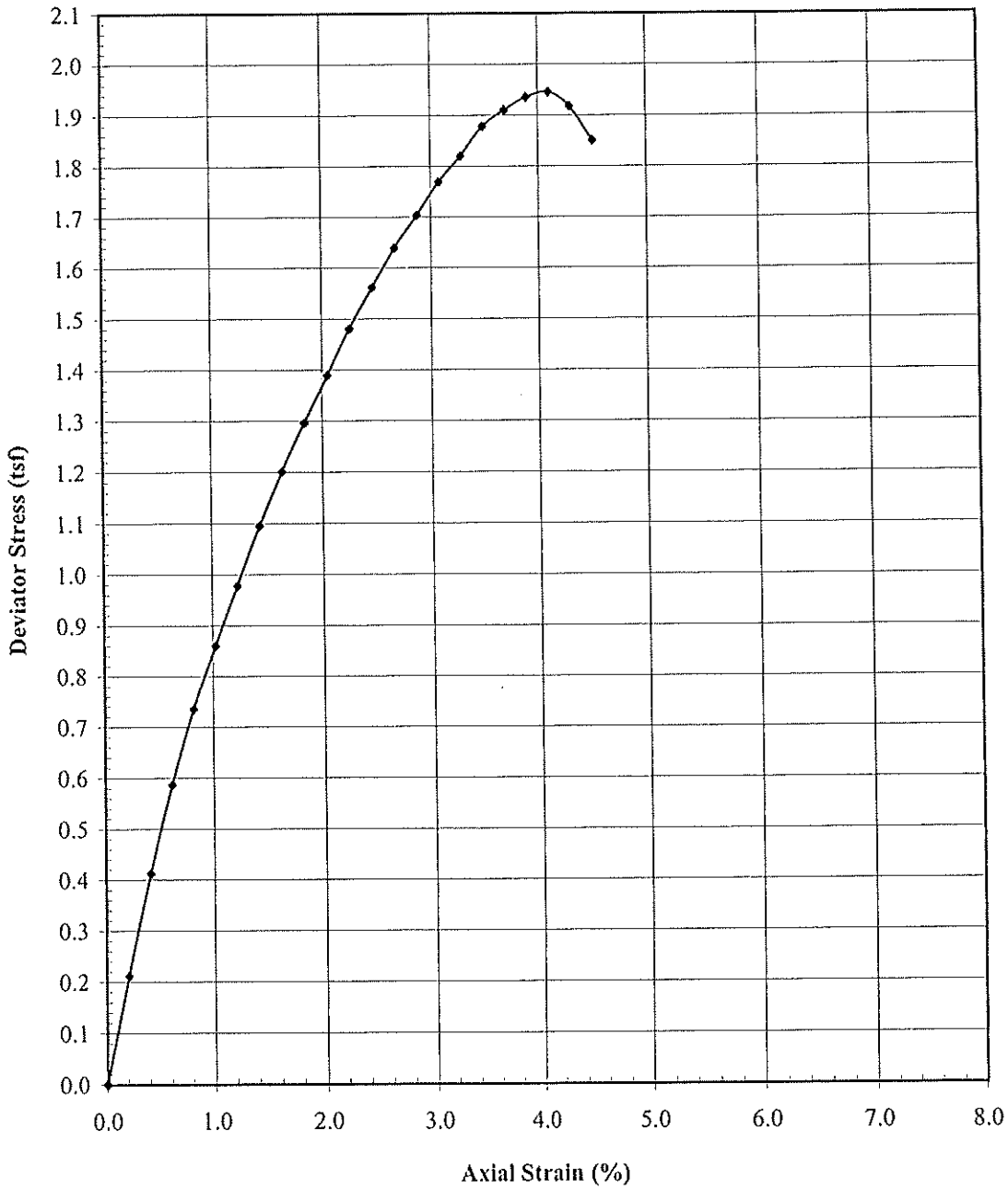
Boring No.	ADU-6
Sample No.	Wax-1
Depth (ft)	0.5-2.4'
Date	06/25/2004
Sheet No.	

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

UNCONFINED COMPRESSION TEST
ASTM D-2166
Stress-Strain Plot

Job No.	0680801.32KC
Job Name	Black Snake Creek
Tested By	JIU
Calculated By	yaw
Checked By	GM

Max. Shear Strength =	1.95 tsf	Water Content =	19.4 %
Failure Strain =	4.10 %	Dry Unit Weight =	104.2 pcf

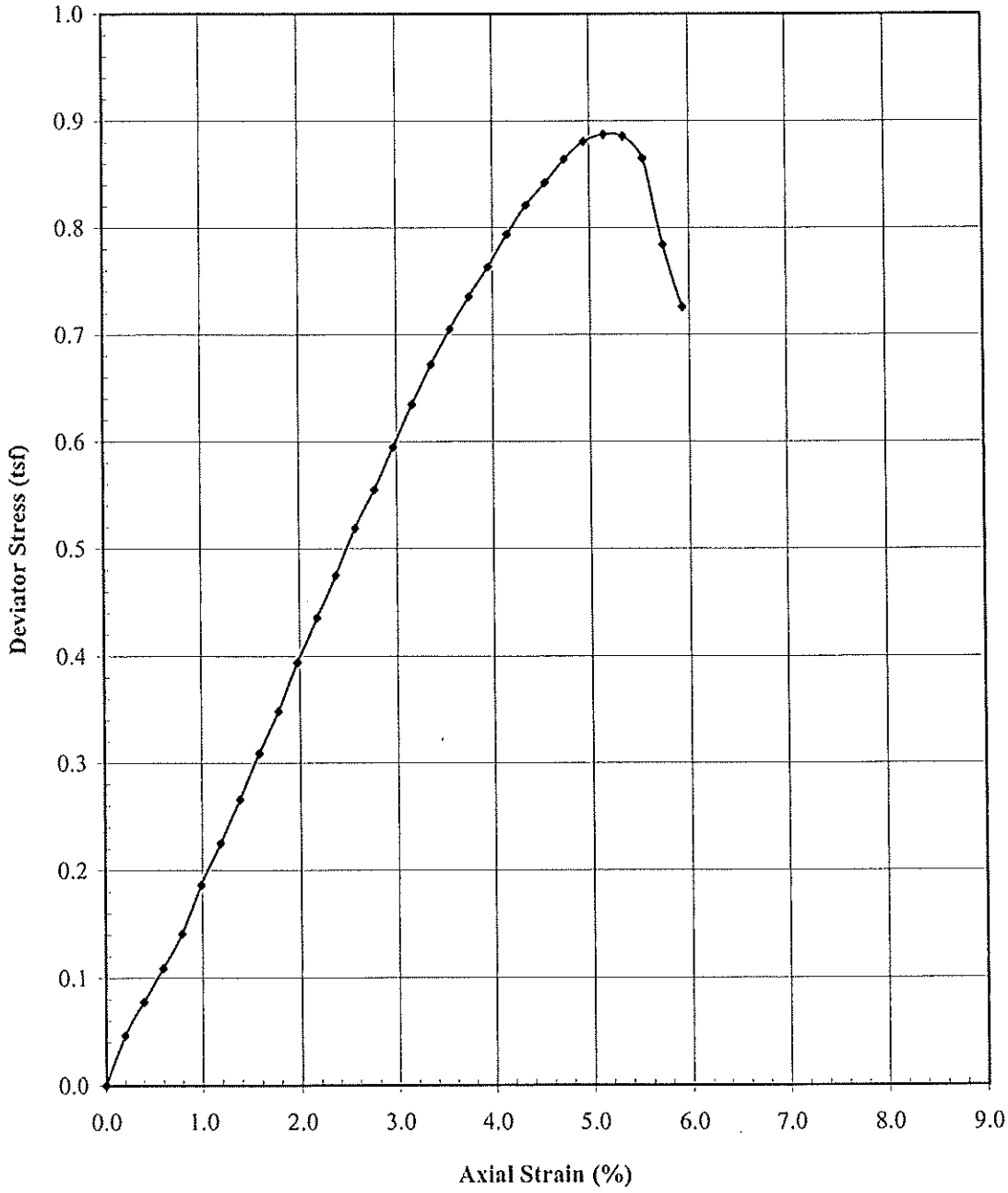


Boring No.	ADU-6	Job No.	0680801.32KC
Sample No.	Wax-6	Job Name	Black Snake Creek
Depth (ft)	13.0-14.9'	Tested By	JB
Date	06/25/2004	Calculated By	yaw
Sheet No.		Checked By	SDM

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

UNCONFINED COMPRESSION TEST
ASTM D-2166
Stress-Strain Plot

Max. Shear Strength =	0.89 tsf	Water Content =	23.2 %
Failure Strain =	5.14 %	Dry Unit Weight =	100.5 pcf

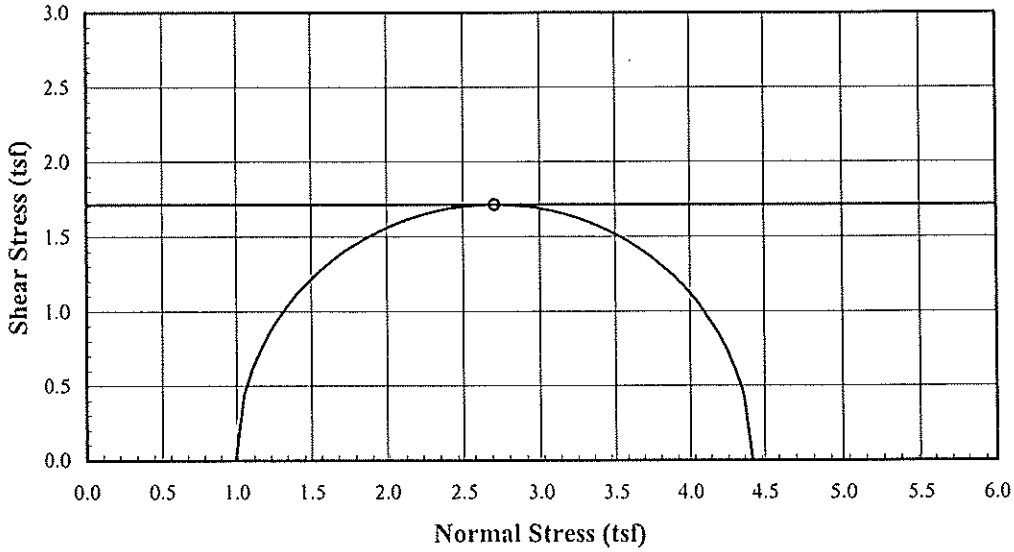


Boring No.	ADU-1
Sample No.	S-1
Depth (ft)	2.0-4.0'
Date	8/13/04
Sheet No.	

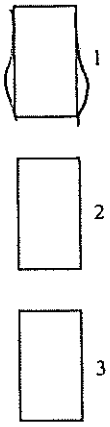
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

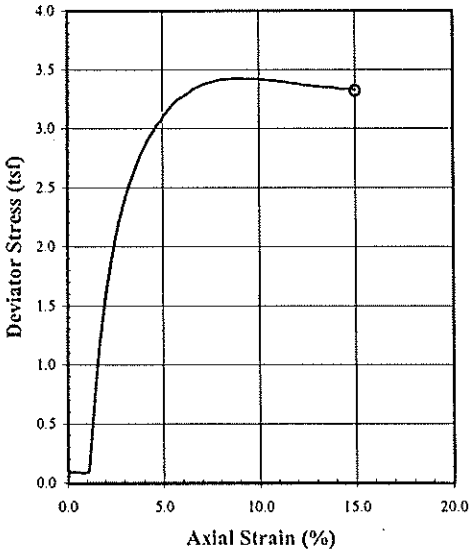
UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D2850

Job No.	0680801.32KM
Job Name	COE-Blacksnake Creek
Tested By	ARK
Calculated By	ARK
Checked By	yaw



Failure Sketch





		Symbol	○	□	△	
		Test No.	1	2	3	4
Initial	Water Content, %	w_0	16.3			
	Dry Density, pcf	γ_d	100.6			
	Void Ratio	e_0	0.66			
	Saturation, %	s_0	65.9			
Back Pressure	Water Content, %	w_0	16.3			
	Dry Density, pcf	γ_d	100.6			
	Void Ratio	e_0	0.66			
	Saturation, %	s_0	65.9			
	Final Back Pressure, psi	u_0	0			
	Minor Prin. Stress, tsf	σ_3	0.99			
	Max. Dev. Stress, tsf	$(\sigma_1 - \sigma_3)_{max}$	3.43			
	Time to Failure, min	t_f				
	Rate of Strain, in/min		0.05			
	Initial Diameter, in	D_0	2.791			
	Initial Height, in	H_0	5.910			

Strain Controlled

Description of Specimens: Brown, low plasticity CLAY

LL=	37		PL=	22		PI=	15		G_s=	2.68	Type of Speciment	Remolded @ 95% optima

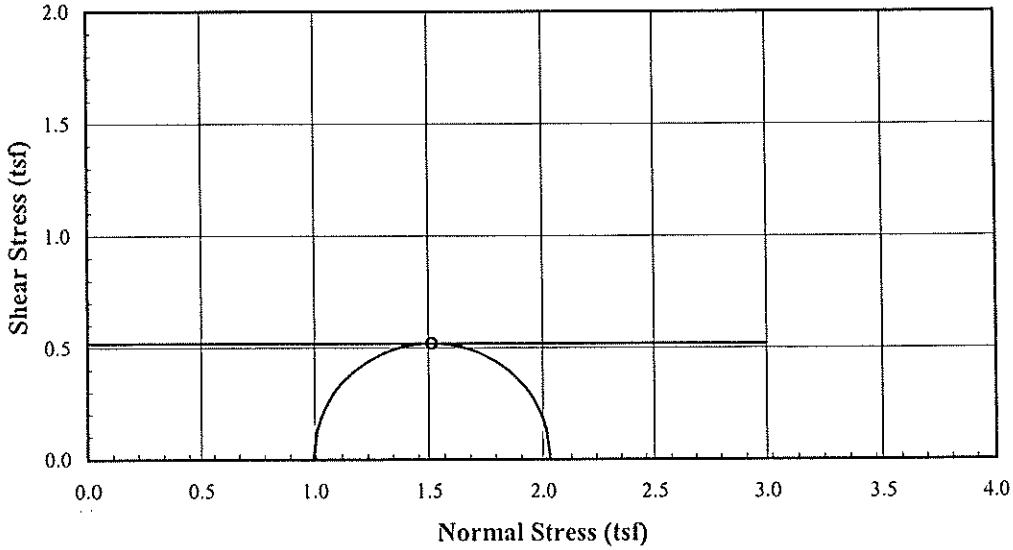
Remarks:

Boring No.	ADU-3
Sample No.	Wax-1
Depth (ft)	1.0-3.0'
Date	8/15/04
Sheet No.	

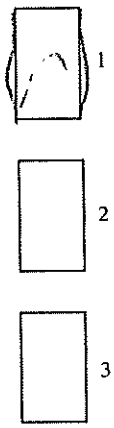
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

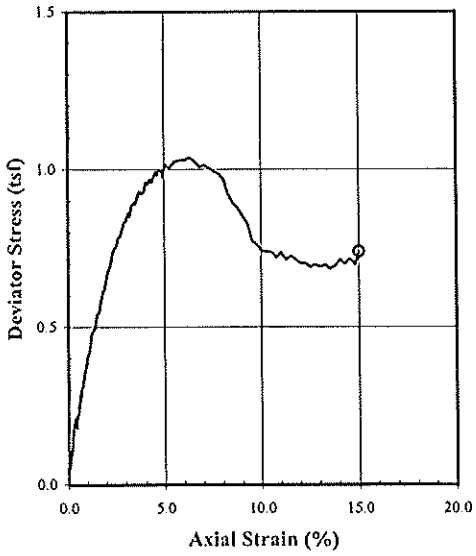
UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D2850

Job No.	0680801.32KM
Job Name	COE-Blacksnake Creek
Tested By	ARK
Calculated By	ARK
Checked By	yaw



Failure Sketch





		Symbol	○	□	△	
		Test No.	1	2	3	4
Initial	Water Content, %	w_0	20.6			
	Dry Density, pcf	γ_d	93.9			
	Void Ratio	e_0	0.78			
	Saturation, %	s_0	70.7			
Back Pressure	Water Content, %	w_0	20.6			
	Dry Density, pcf	γ_d	93.9			
	Void Ratio	e_0	0.78			
	Saturation, %	s_0	70.7			
	Final Back Pressure, psi	u_0	0			
	Minor Prin. Stress, tsf	σ_3	0.99			
	Max. Dev. Stress, tsf	$(\sigma_1 - \sigma_3)_{max}$	1.04			
	Time to Failure, min	t_f				
	Rate of Strain, in/min		0.05			
	Initial Diameter, in	D_0	1.473			
	Initial Height, in	H_0	2.860			

Strain Controlled

Description of Specimens: Dark brown, low plasticity CLAY

LL=	38		PL=	27		PI=	11		G_s=	2.68		Type of Speciment	5" Wax Sample

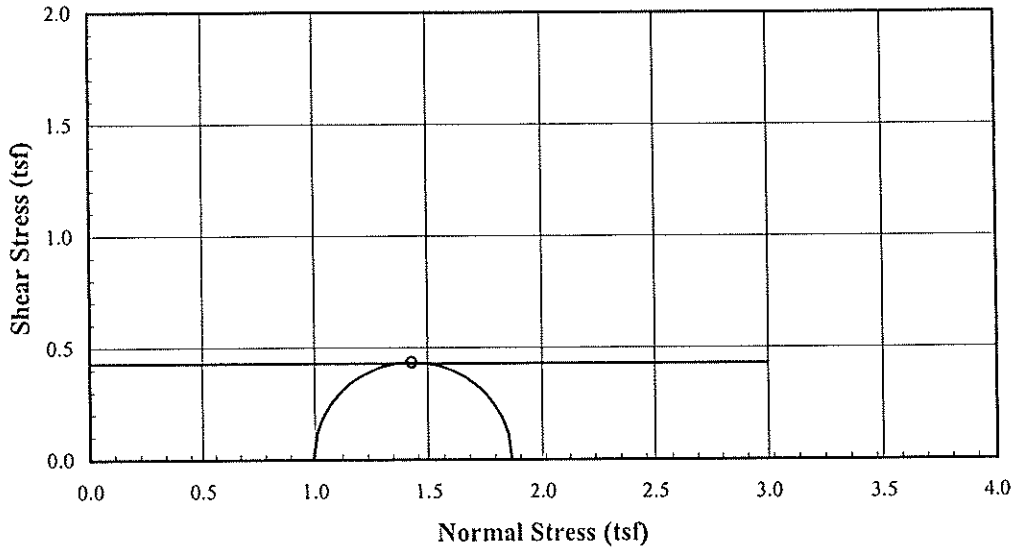
Remarks:

Boring No.	ADU-5
Sample No.	Wax-2
Depth (ft)	4.5-6.5'
Date	8/13/04
Sheet No.	

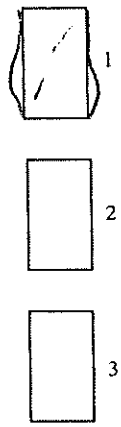
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

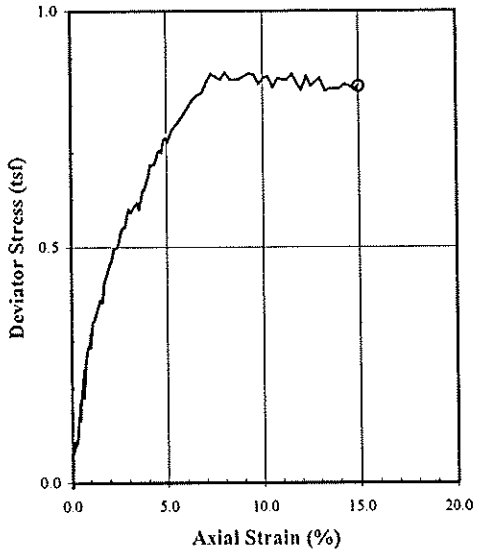
UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ASTM D2850

Job No.	0680801.32KM
Job Name	COE-Blacksnake Creek
Tested By	ARK
Calculated By	ARK
Checked By	yaw



Failure Sketch





		Symbol	○	□	△	
		Test No.	1	2	3	4
Initial	Water Content, %	w_0	26.8			
	Dry Density, pcf	γ_d	96.5			
	Void Ratio	e_0	0.73			
	Saturation, %	s_0	97.9			
Back Pressure	Water Content, %	w_0	26.8			
	Dry Density, pcf	γ_d	96.5			
	Void Ratio	e_0	0.73			
	Saturation, %	s_0	97.9			
	Final Back Pressure, psi	u_0	0			
	Minor Prin. Stress, tsf	σ_3	0.99			
	Max. Dev. Stress, tsf	$(\sigma_1 - \sigma_3)_{max}$	0.87			
	Time to Failure, min	t_f				
	Rate of Strain, in/min		0.05			
	Initial Diameter, in	D_0	1.472			
	Initial Height, in	H_0	3.209			

Strain Controlled

Description of Specimens: Dark brown, low plasticity CLAY

LL=	40		PL=	20		PI=	20		G_s=	2.68		Type of Speciment	5" Wax Sample

Remarks:

Boring No.	ADU-1
Sample No.	S-1
Depth (ft)	
Date	7/28/04
Sheet No.	

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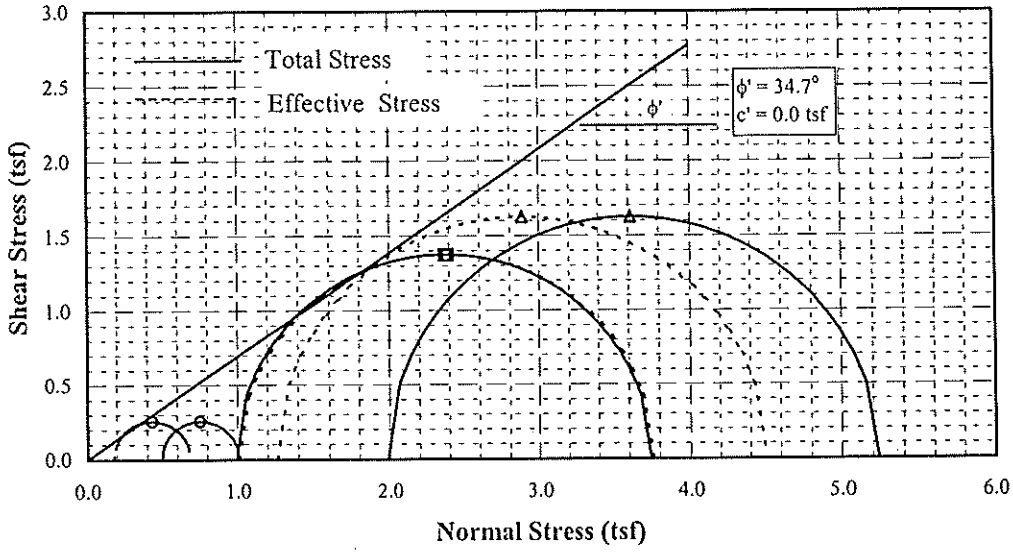
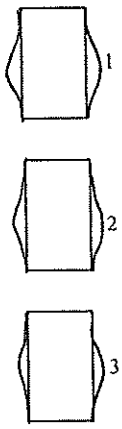
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

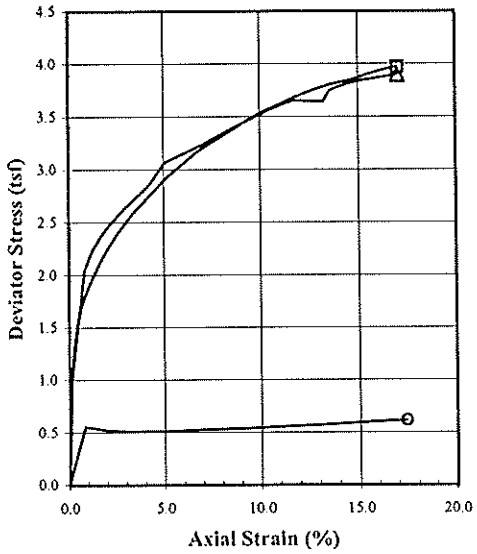
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D4767

Job No.	0680801.32KM
Job Name	Blacksnake Creek
Tested By	SR
Calculated By	yaw
Checked By	ARK



Failure Sketch





		Symbol	○	□	△	
		Test No.	1	2	3	
Initial	Water Content, %	w_0	16.0	16.0	16.0	
	Dry Density, pcf	γ_d	101.4	101.5	101.5	
	Void Ratio	e_0	0.67	0.67	0.67	
	Saturation, %	s_0	64.7	64.8	64.8	
Back Pressure	Water Content, %	w_0	23.1	22.6	22.0	
	Dry Density, pcf	γ_d	104.0	104.9	106.0	
	Void Ratio	e_0	0.63	0.62	0.60	
	Saturation, %	s_0	99.3	99.2	99.7	
	Final Back Pressure, psi	u_0	35.8	35.2	35.3	
	Minor Prin. Stress, tsf	σ_3	0.50	0.99	1.99	
	Max. Dev. Stress, tsf	$(\sigma_1 - \sigma_3)_{max}$	0.51	2.75	3.25	
	Time to Failure, min	t_f				
	Rate of Strain, in/min		0.01	0.01	0.01	
	Initial Diameter, in	D_0	2.823	2.823	2.823	
	Initial Height, in	H_0	5.945	5.945	5.945	
	B-Value		0.98	0.99	0.99	

Strain Controlled

Description of Specimens: Brown, low plasticity CLAY

LL=	37		PL=	22		PI=	15		G_s=	2.72		Type of Speciment	Remolded Sample

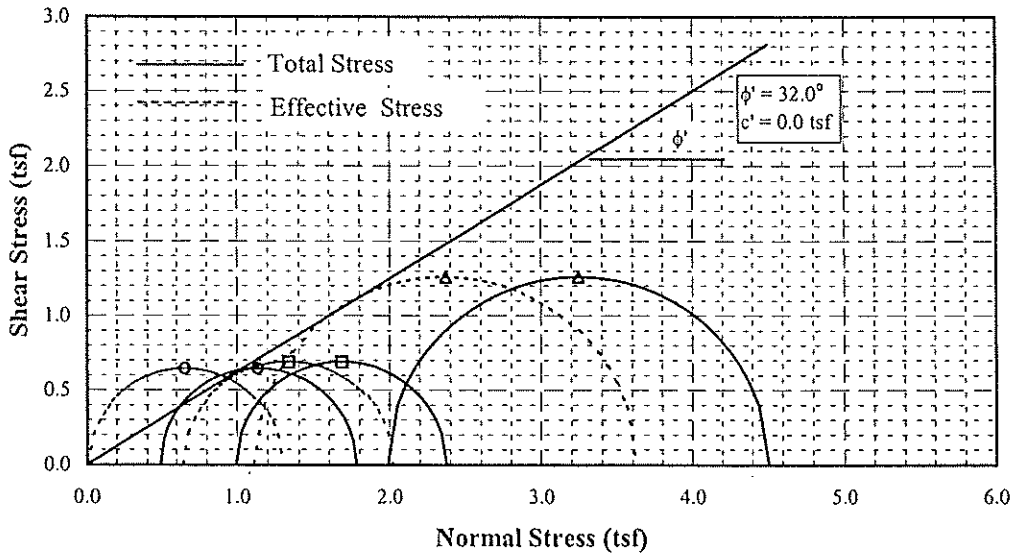
Remarks:

Boring No.	ADU-3
Sample No.	Wax-1
Depth (ft)	1'-3'
Date	8/11/04
Sheet No.	

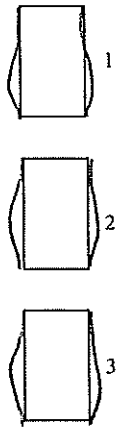
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

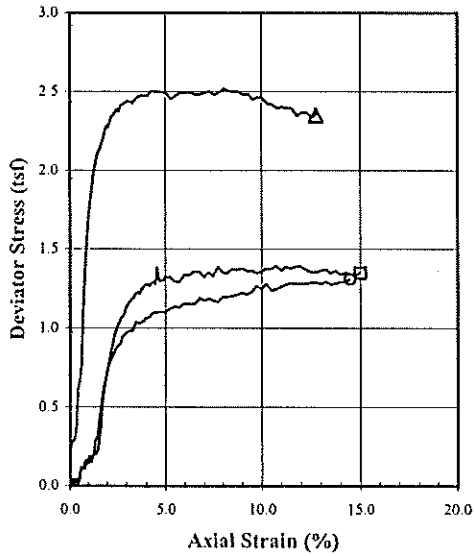
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D4767

Job No.	0680801.32KM
Job Name	COE-Blacksnake Creek
Tested By	ARK
Calculated By	ARK
Checked By	yaw



Failure Sketch





		Symbol	○	□	△	
		Test No.	1	2	3	
Initial	Water Content, %	w_0	21.8	19.8	20.0	
	Dry Density, pcf	γ_d	91.3	92.5	92.8	
	Void Ratio	e_0	0.83	0.81	0.80	
	Saturation, %	s_0	70.5	65.6	66.9	
Back Pressure	Water Content, %	w_0	29.3	27.0	26.2	
	Dry Density, pcf	γ_d	93.6	97.0	98.2	
	Void Ratio	e_0	0.79	0.72	0.70	
	Saturation, %	s_0	100.0	99.8	99.8	
	Final Back Pressure, psi	u_0	35.1	35.7	31.8	
	Minor Prin. Stress, tsf	σ_3	0.49	0.99	1.99	
	Max. Dev. Stress, tsf	$(\sigma_1 - \sigma_3)_{max}$	1.29	1.38	2.52	
	Time to Failure, min	t_f				
	Rate of Strain, in/min		0.01	0.01	0.01	
	Initial Diameter, in	D_0	1.491	1.481	1.486	
	Initial Height, in	H_0	3.001	3.022	2.954	
	B-Value		0.99	0.98	0.98	

Strain Controlled

Description of Specimens: Brown, low plasticity CLAY

LL=	38		PL=	27		PI=	11		G_s=	2.68		Type of Speciment	5" Wax Sample

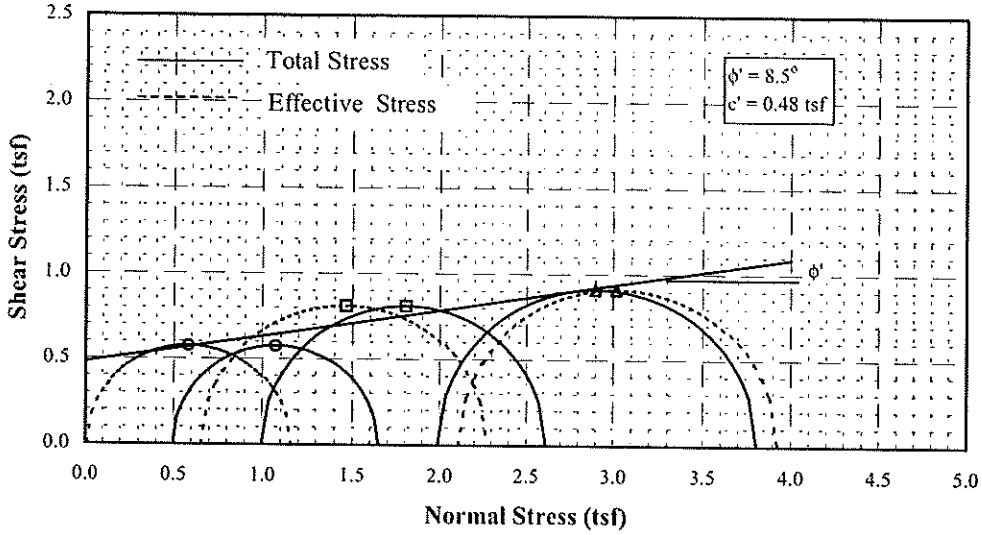
Remarks:

Boring No.	ADU-5
Sample No.	Wax-2
Depth (ft)	4.5-6.5'
Date	8/13/04
Sheet No.	

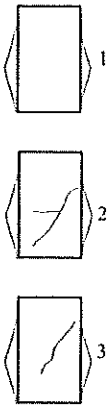
GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, COLLINSVILLE, KANSAS CITY

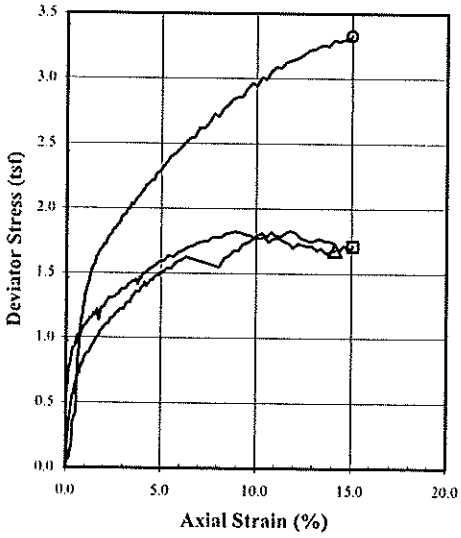
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST
ASTM D4767

Job No.	0680801.32KM
Job Name	COE-Blacksnake Creek
Tested By	ARK
Calculated By	ARK
Checked By	yaw



Failure Sketch





		Symbol	○	□	△	
		Test No.	1	2	3	
Initial	Water Content, %	w_0	27.7	27.3	27.0	
	Dry Density, pcf	γ_d	95.9	96.1	95.7	
	Void Ratio	e_0	0.74	0.74	0.75	
	Saturation, %	s_0	99.7	99.0	96.6	
Back Pressure	Water Content, %	w_0	27.8	27.4	26.9	
	Dry Density, pcf	γ_d	95.9	96.4	97.2	
	Void Ratio	e_0	0.74	0.73	0.72	
	Saturation, %	s_0	100.2	99.9	99.9	
	Final Back Pressure, psi	u_0	30	40.9	30	
	Minor Prin. Stress, tsf	σ_3	0.50	0.99	1.99	
	Max. Dev. Stress, tsf	$(\sigma_1 - \sigma_3)_{max}$	1.15	1.62	1.82	
	Time to Failure, min	t_f				
	Rate of Strain, in/min		0.025	0.025	0.025	
	Initial Diameter, in	D_0	1.483	1.462	1.479	
	Initial Height, in	H_0	3.204	3.227	3.201	
	B-Value		0.97	0.97	0.95	

Strain Controlled

Description of Specimens: Dark brown, low plasticity CLAY

LL=	40		PL=	20		PI=	20		G_s=	2.68		Type of Speciment	5" Wax Sample

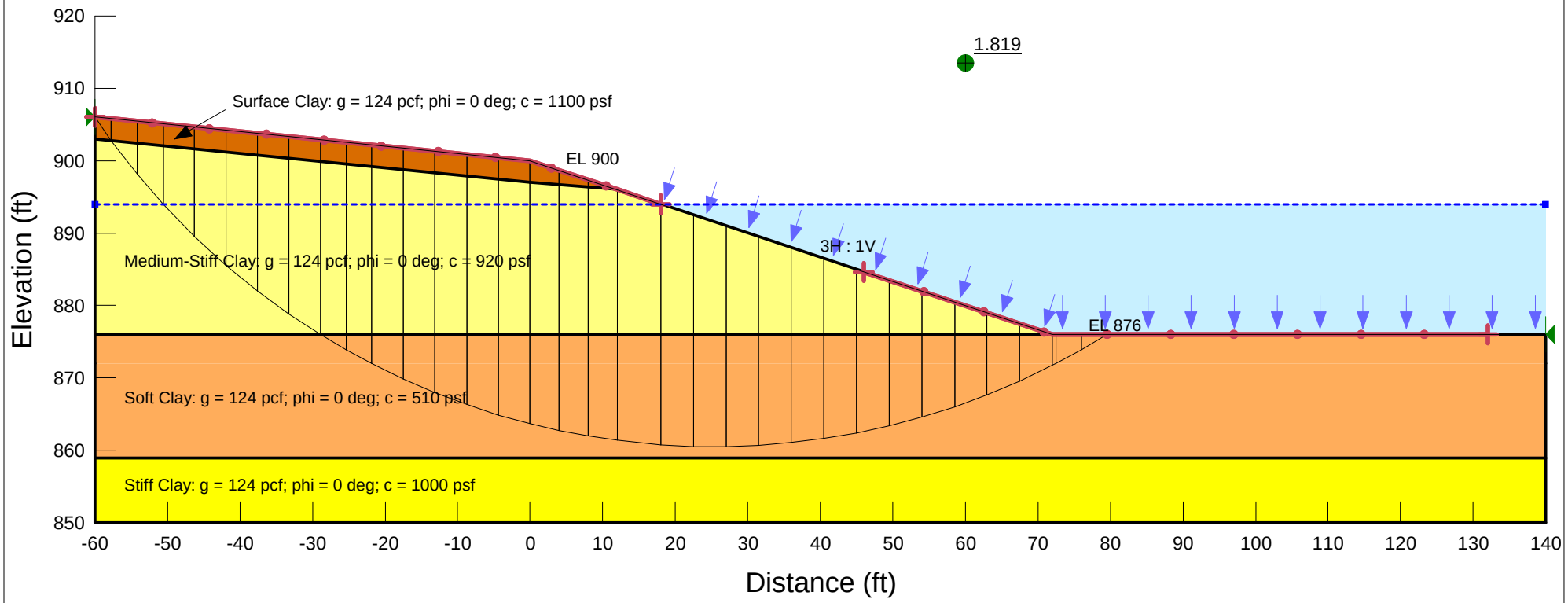
Remarks:

Appendix B

Stability Computations

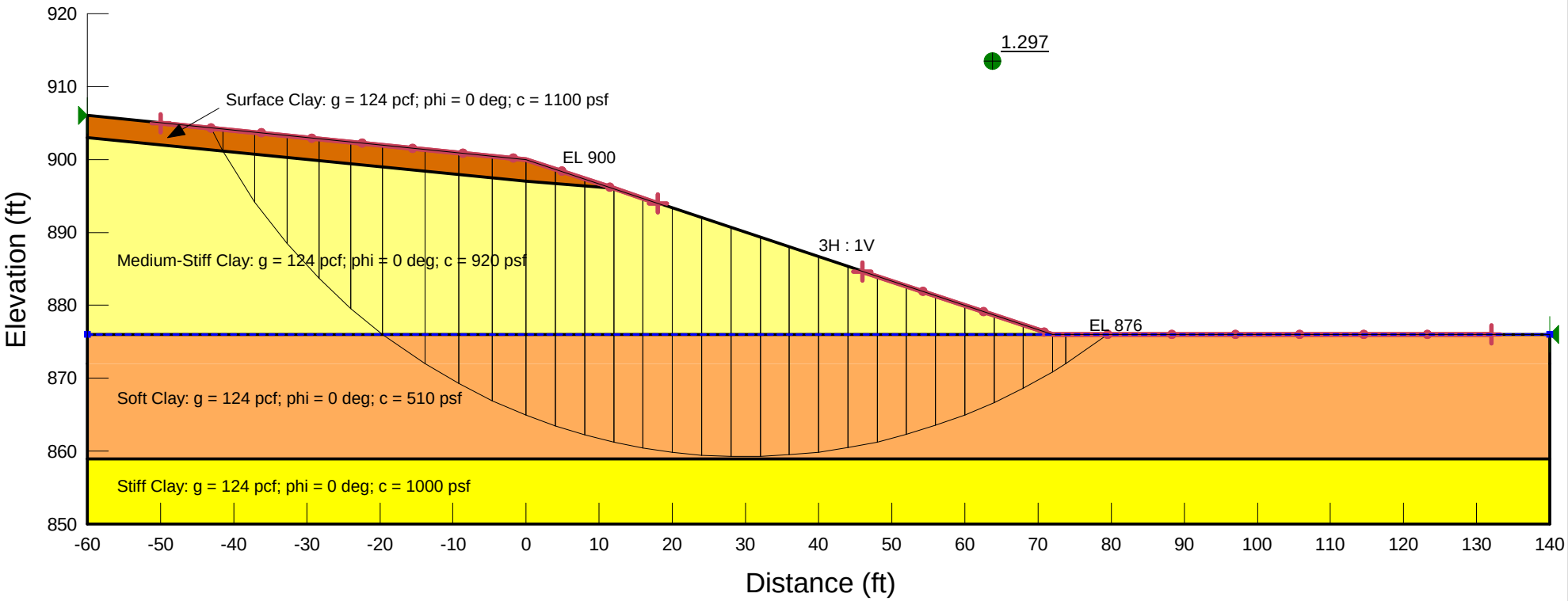
Blacksnake Creek
Excavation Stability Analysis
Total Stress Condition 1

Filename: Blacksnake_02c.gsz
Computed: JRJ Date: 12/10/2012
Checked: LDK Date: 12/20/2012



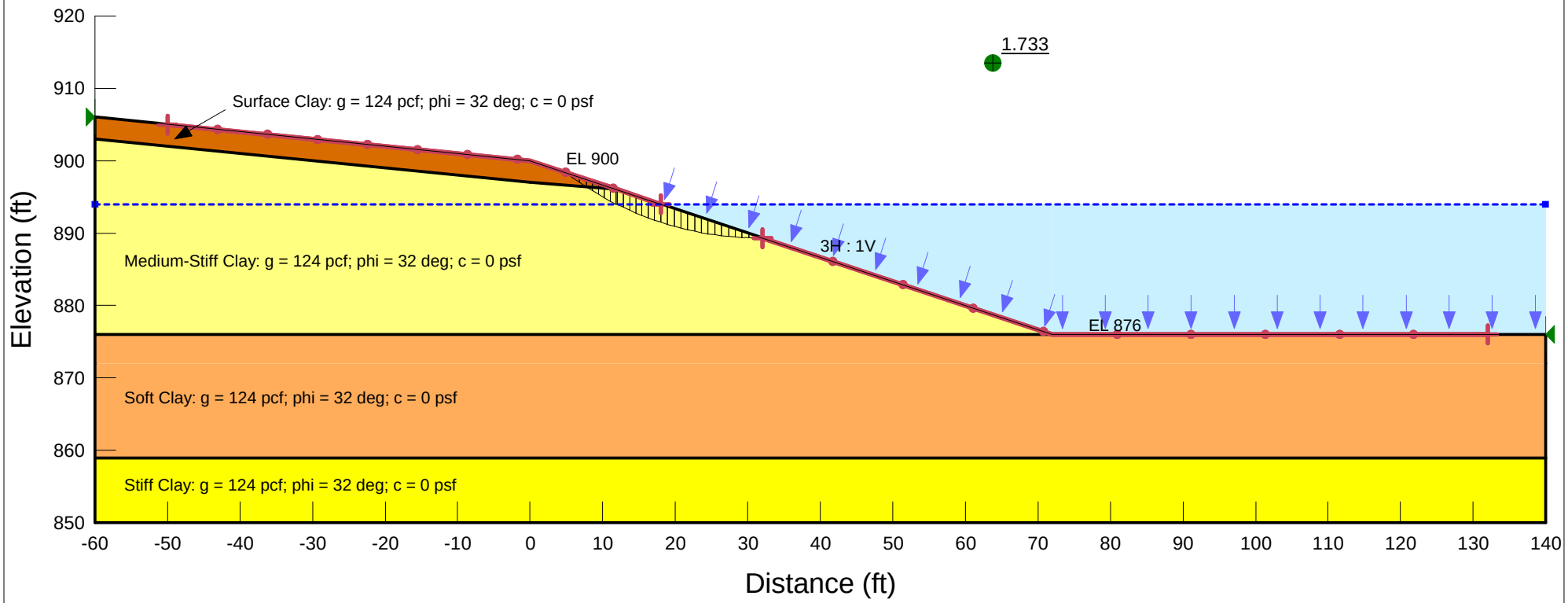
Blacksnake Creek
Excavation Stability Analysis
Total Stress Condition 2

Filename: Blacksnake_02b.gsz
Computed: JRJ Date: 12/10/2012
Checked: LDK Date: 12/20/2012



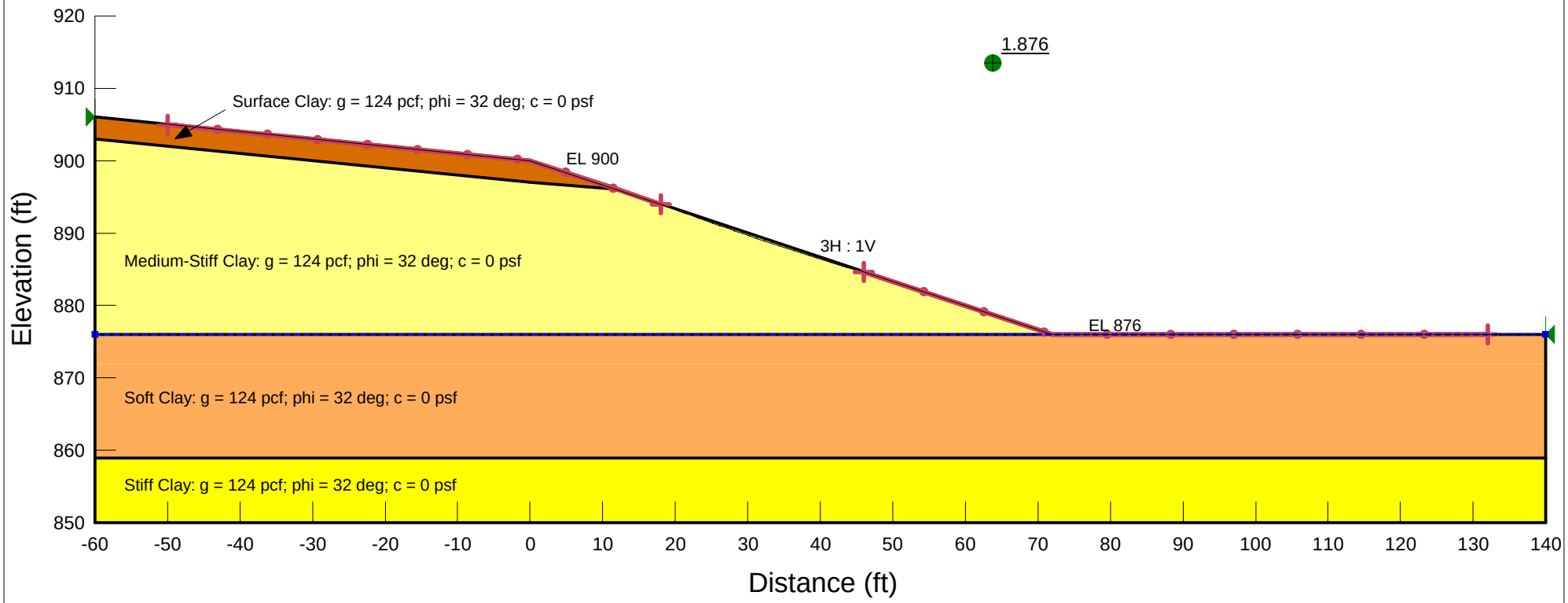
Blacksnake Creek
Excavation Stability Analysis
Effective Stress Condition 1

Filename: Blacksnake_03b.gsz
Computed: JRJ Date: 12/10/2012
Checked: LDK Date: 12/20/2012



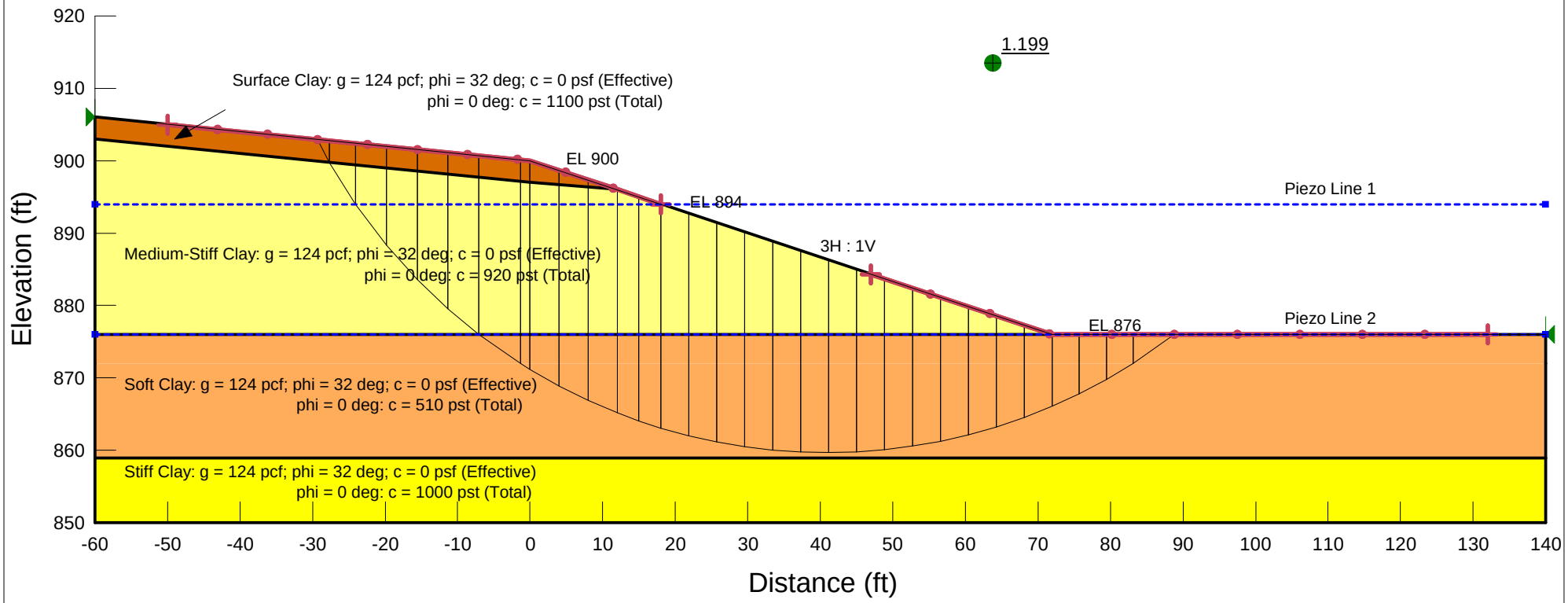
Blacksnake Creek
Excavation Stability Analysis
Effective Stress Condition 2

Filename: Blacksnake_03a.gsz
Computed: JRJ Date: 12/10/2012
Checked: LDK Date: 12/20/2012



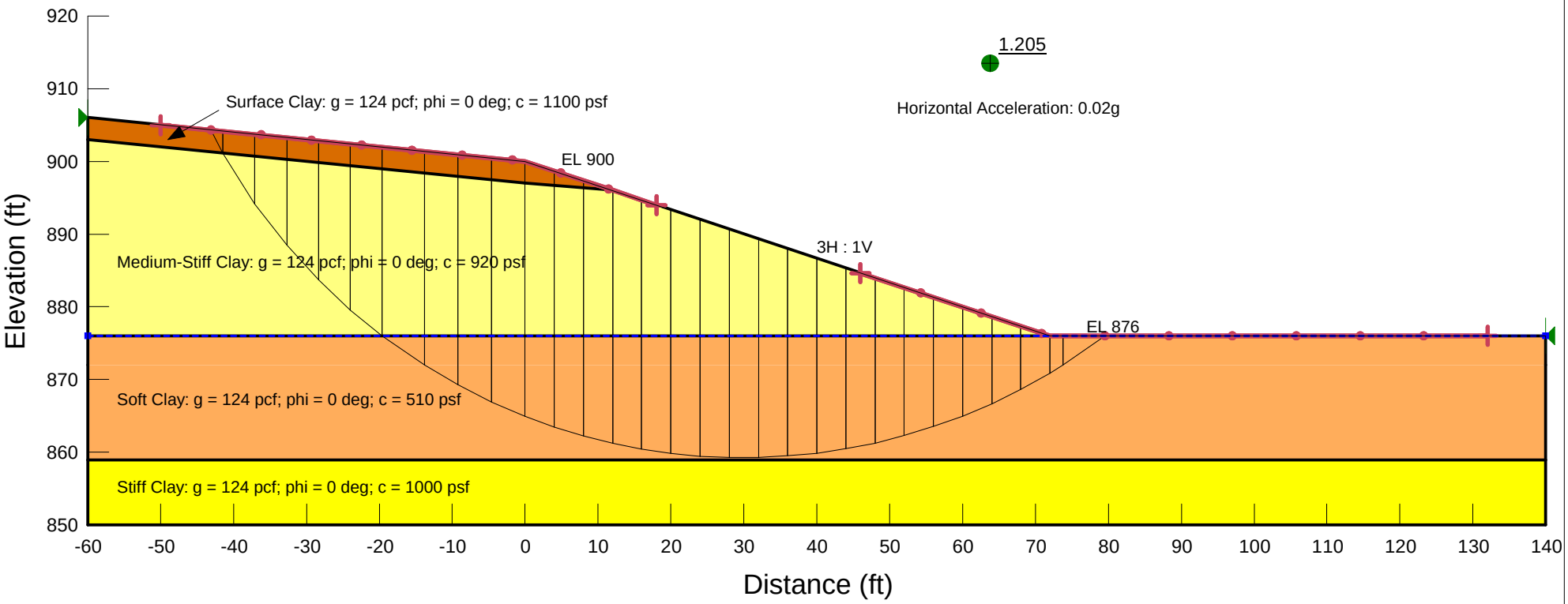
Blacksnake Creek
Excavation Stability Analysis
Rapid Drawdown Condition

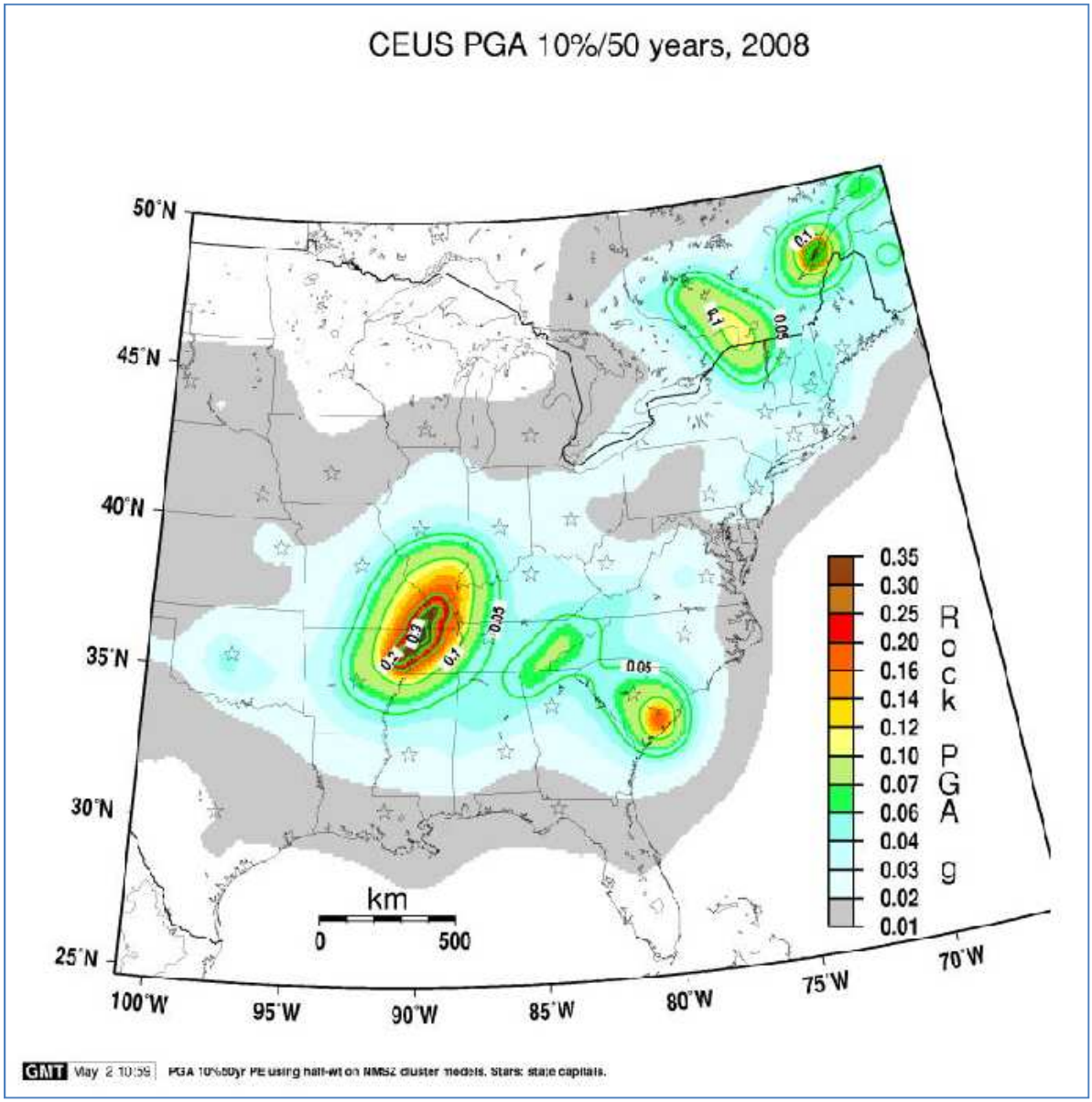
Filename: Blacksnake_04 - Stage Drawdown.gsz
Computed: JRJ Date: 12/10/2012
Checked: LDK Date: 12/20/2012



Blacksnake Creek
Excavation Stability Analysis
Total Stress Condition - Seismic Analysis

Filename: Blacksnake_02f.gsz
Computed: JRJ Date: 12/10/2012
Checked: LDK Date: 12/20/2012




CEUS PGA 10%/50 years, 2008
50°N
45°N
40°N
35°N
30°N
25°N
100°W
95°W
90°W
85°W
80°W
75°W
70°W
0.1
0.05
0.3
0.2
0.1
0.05
0.05
km
0
500
0.35
0.30
0.25
0.20
0.16
0.14
0.12
0.10
0.07
0.06
0.04
0.03
0.02
0.01
Rock PGA g
GMT May 2 10:59
PGA 10%50yr PE using half-wt on NMS2 cluster models. Stars: state capitals.

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Project No. _____ Page No. _____

Subject Black Snake Creek

Computed by JRJ Date 12-10-12

Checked by _____ Date _____

Approved by _____ Date _____

Total Stress Parameters

Sheet No. _____ of _____

Surface Clay: 0-3'

ADU-5 c = 1460 psf (UC)
ADU-3 c = 1040 psf (UU)
ADU-6 c = 1950 psf (UC)

} $\frac{2}{3}$ rule: Assume c = 1100 psf

Medium-Stiff Clay: 3' - 24'

ADU-5: ~~c = 870 psf (UU)~~ * inconsistent test data sheet
c = 1080 psf (UC)
c = 970 psf (UC)
c = 676 psf (Torvane)

ADU-3: c = 819 psf (Torvane)
c = 1331 psf (Torvane)
c = 1024 psf (Torvane)

ADU-6: c = 1126 psf (Torvane)
c = 890 psf (UC)
c = 819 psf (Torvane)

Assume c = 920 psf ($\frac{2}{3}$ of UC Test Data and $\frac{1}{2}$ of Torvane Test Data at or above assumed parameter)

AD-4: N = 21, 14 } N = 14 ⇒ c = 1700 psf

N = 5, 6, 6, 3 } N = 5 ⇒ c = 500 psf (EM 1110-2-2504 Table 3-4)

→ This is likely part of soft clay stratum.

*Med-Stiff clay stratum is thinner or boring elevation is lower.

Soft Clay: 24' - 41'

ADU-5: c = 410 psf
c = 512 psf
c = 614 psf
c = 307 psf
c = 717 psf
} Torvane.

ADU-6: c = 2048 psf (Torvane) — Likely part of stiff clay stratum.

Assume: c = 510 psf

SC 3004 R4 898

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Project No. _____ Page No. _____

Subject BLACK SNAKE CREEK

Computed by JRS Date 12-10-12

Checked by _____ Date _____

Approved by _____ Date _____

Sheet No. _____ of _____

STIFF CLAY:

ADU -5'

c = 1126 psf

c = 1229 psf

c = 717 psf (SANDY)

c = 614 psf (SANDY)

c = 410 psf (SANDY)

ASSUME: c = 1,000 psf

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Project No. _____ Page No. _____

Subject BLACK SNAKE CREEK

Computed by JRS Date 12-10-12

Checked by _____ Date _____

EFFECTIVE STRESS PARAMETERS

Approved by _____ Date _____

Sheet No. _____ of _____

EFFECTIVE STRESS PARAMETERS BASED ON ATTERBERG LIMIT CORRELATIONS.

Typical PI RANGE : 10 → 20

This corresponds to $\phi' = 31° - 33°$

Assume $\phi = 32°$ for all strata.

TRIAXIAL Testing lab data exhibited inconsistencies. This data was ignored.

SC 3004 R4 898

EFFECTIVE STRESS

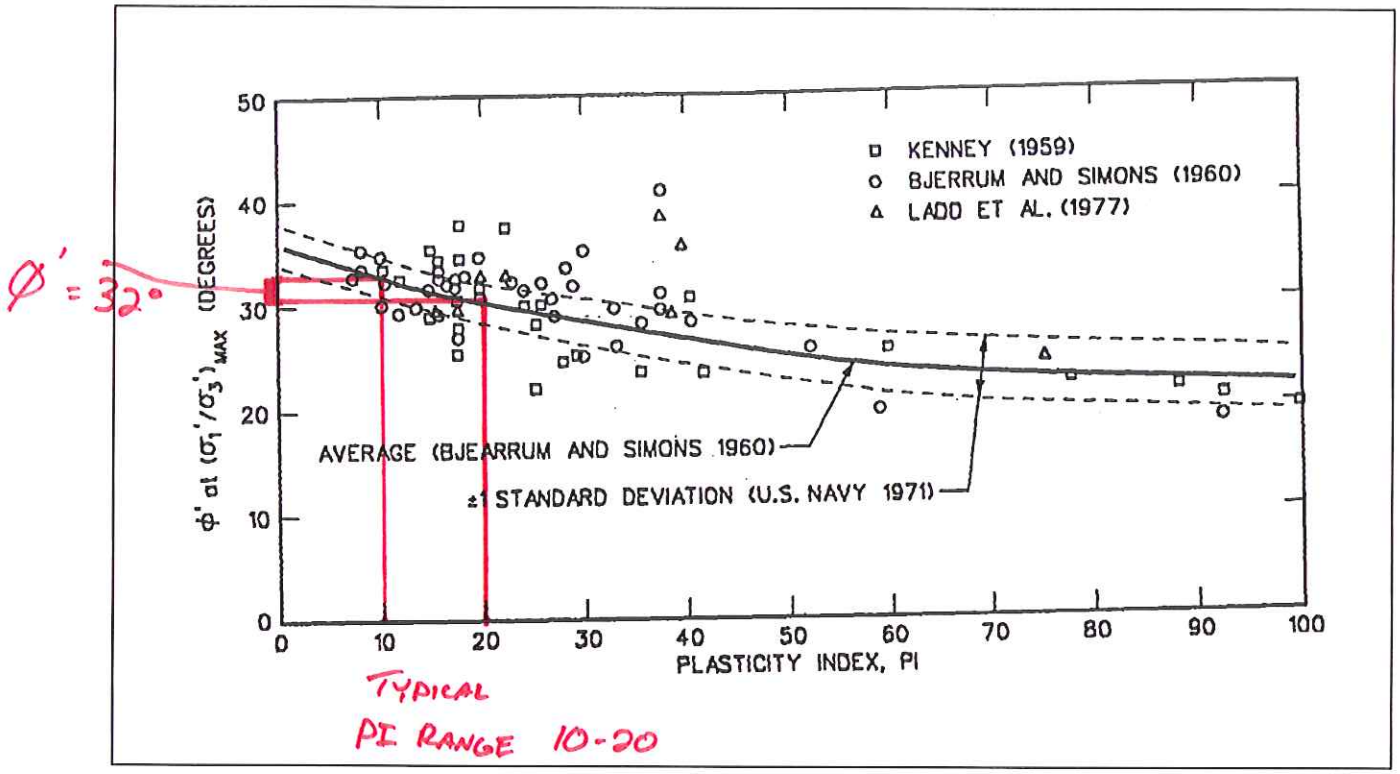

Figure 3-4. Empirical correlation between friction angle and PI from triaxial tests on normally consolidated clays

stress of 1 ton per square foot using an equation of the form:

$$N' = C_N N \tag{3-1}$$

where

N' = corrected resistance

C_N = correction factor

N = measured resistance

Table 3-5 and Figure 3-5 summarize the some most commonly proposed values for C_N. Whitman and Liao (1984) developed the following expression for C_N:

$$C_N = \sqrt{\frac{1}{\sigma'_{vo}}} \tag{3-2}$$

where effective stress due to overburden, σ'_{vo}, is expressed in tons per square foot. The drained friction angle ϕ' can be estimated from N' using Figure 3-6. The relative density of normally consolidated sands can be estimated from the correlation obtained by Marcuson and Bieganousky (1977):

$$D_r = 11.7 + 0.76[|222(N) + 1600 - 53(p'_{vo}) - 50(C_u)^2|]^{1/2} \tag{3-3}$$

where

p'_{vo} = effective overburden pressure in pounds per square inch

C_u = coefficient of uniformity (D_{60}/D_{10})

Correlations have also been proposed between the SPT and the undrained strength of clays (see Table 3-4). However, these are generally unreliable and should be used for very preliminary studies only and for checking the reasonableness of SPT and lab data.

c. Cone penetration test. The CPT (ASTM D 3441-79 (1986a)) is widely used in Europe and is gaining

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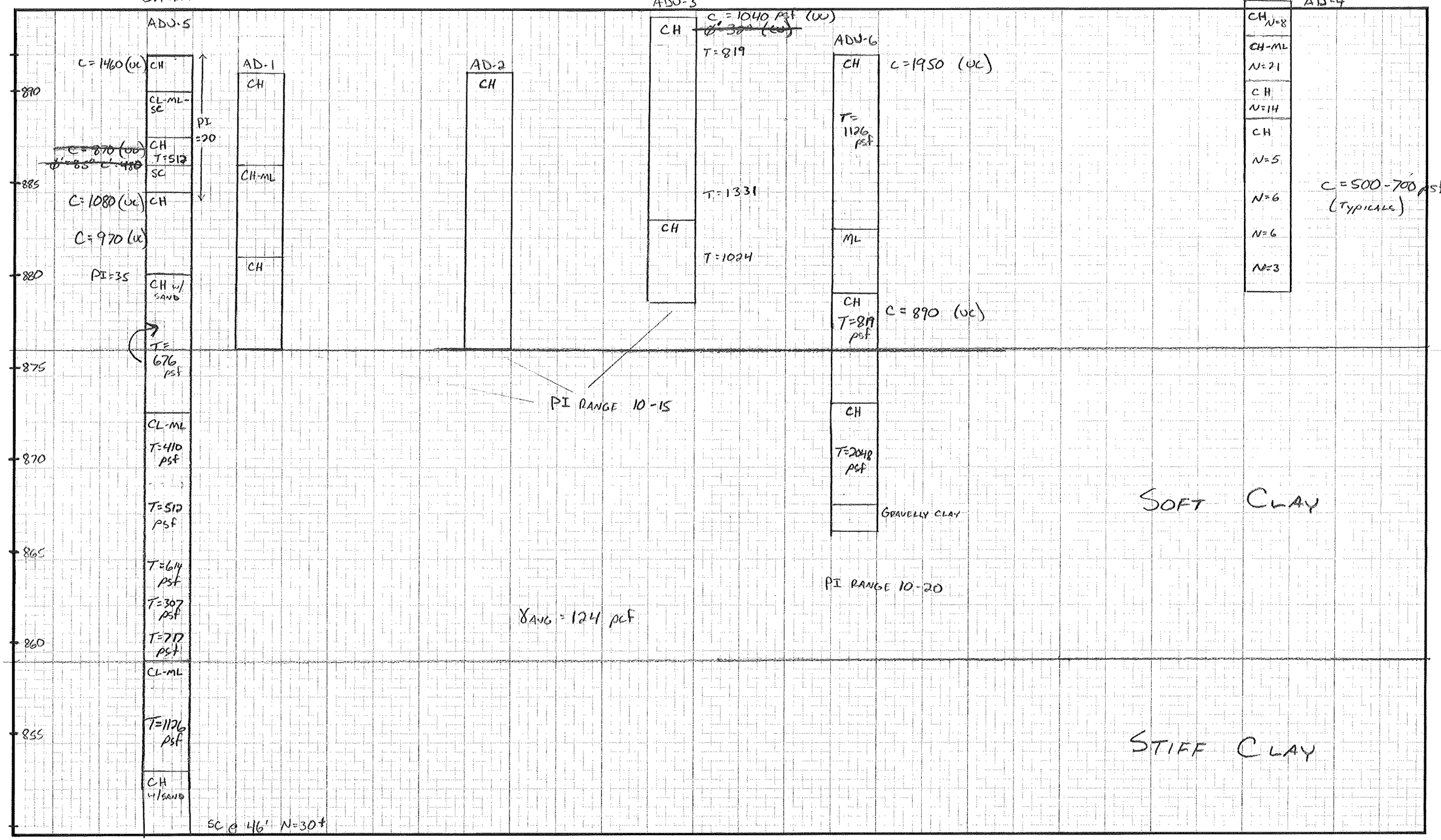
* ELEVATIONS NOT INCLUDED ON SOIL BORINGS
ELEVATIONS ARE APPROXIMATED BASED ON TOPOGRAPHIC DATA.



SC 3006

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Appendix C

Erosion Protection Calculations

Stanley Consultants INC.

Project No.	23842	Page No.	1
Subject	BLACKSNAKE CREEK OVERFLOW SPILLWAY RIPRAP SIZING @ NORTHWEST PARKWAY		
Computed by	ZD	Date	8/27/12
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METRIC UNITS

D/S SIDE SLOPE = 1V : ~~6~~ 8H FITS TOPO BEST

WEIR LENGTH = 249' @ ELEV 898.7 (Q_{100}) 75.90 m

HEIGHT OVER WEIR = 898.7 − ~~896.3~~ 896.3 = ~~2.2'~~ 2.4 0.67 m

↑ FROM CAD FILE PROFILE

OVERTOPPING FLOW FROM WEIR EQN = $Q = CLH^{1.5}$

$C \cong 2.6$

$Q = (2.6)(249)(2.4)^{1.5} = \cancel{2113}$ cfs 2407 60 m³/s

q = FLOW PER UNIT LENGTH $q = \frac{2113 \text{ cfs}}{249 \text{ ft}} = \cancel{8.49}$ cfs/ft 9.67 ~~0.788~~ .898 m³/s / m

RIPRAP SIZING
EQUATIONS PER U.S.B.R "SIMPLIFIED DESIGN GUIDE FOR RIPRAP SUBJECTED TO OVERTOPPING FLOW"
PAP-0790, 1998 (EQUATIONS ARE IN METRIC UNITS)

FROM FIGURE 4 ⇒ $D_{50} C_u^{0.25} = \cancel{0.23}$ 0.20 ✓

$S = \cancel{0.17}$ 0.125 $D_{50} = \frac{\cancel{0.23}\ .20}{(1.95)^{.25}} = \cancel{0.195}$ m 0.169 ✓

$C_u = 1.95$ COEF. OF UNIFORMITY

≅ ROUND TO 0.20 m FOR ITERATION 1

ITERATION #1

INTERSTITIAL VELOCITY

$$V_i = 2.48\, C_u^{-2.22} S^{0.58} \sqrt{g(D_{50})}$$
$$= 2.48\,(1.95)^{-2.22}(\cancel{0.17}\ 0.125)^{.58}\sqrt{(9.81)(0.2)}$$
$$= \cancel{0.282}\ \text{m/s}\ \ 0.236\ \text{m/s}$$ ✓

$$V_{AVE} = V_i \times n_p = (\cancel{0.282}\ .236\ \text{m/s})(.45) = \cancel{0.127}\ 0.106\ \text{m/s}$$ ✓

↑ POROSITY = 0.45

Y = AVG DEPTH OF WATER AT POINT OF INCIPIENT FAILURE $= q / V_{AVE} = \frac{0.788}{\cancel{0.127}\ .106} = \cancel{6.20}$ m 7.42 m

$$Y > 2D_{50}$$

CONTINUE THRU STEPS 5-10

Stanley Consultants INC.

Project No. 23842 Page No. 2

Subject BLACKSNAKE CREEK OVERFLOW SPILLWAY RIPRAP SIZING @ NORTHWEST PARKWAY

Computed by ADP Date 8/27/12

Checked by JRS Date 1-11-13

Approved by Date

Sheet No. of

$$h = \frac{(0.06)(2.65-1.00)(.20)(0.900)}{0.97\ (0.125)} = 0.147$$

$$n = 0.0414\,(D_{50})^{1/6} = 0.0414\,(0.20)^{.17} = 0.0315$$

$$q_1 = \frac{1}{(.0315)}(.147)^{1.67}(.125)^{.5} = 0.456$$

$$q_2 = .\cancel{788}\ .898 - .456 = 0.\cancel{33}\ .442$$

$$h_2 = \frac{0.\cancel{33}\ .442}{0.106} = \cancel{3.13}\ 4.17 \Rightarrow h_2 > 4D_{50}$$

∴ INCREASE D_{50} SIZE AND GO TO ITERATION #2

EXCEL SPREADSHEET ITERATIONS FOR D_{50}

YIELD $D_{50} = 0.28$ m WHICH MEETS CRITERIA

$= 0.92$ FT $= 11''$

THICKNESS SHALL BE BETWEEN $2D_{50}$ & $4D_{50}$

$2D_{50} = 22''$ $3D_{50} = 33''$ $4D_{50} = 44''$

▷ ADD SAFETY FACTOR, BUMP UP TO MODOT - TYPE IV ⇒ $D_{50} = 19''$

MAX SIZE = 28''

$2D_{50} = 38'' = 3.2'$

$3D_{50} = 4.75'$

CHECK $1.5\,D_{100} = 42'' = 3.5'$ ✓

USE 3.5' THICKNESS ✓

Stanley Consultants INC.

Project No. 23842 Page No.

Subject BLACKSNAKE CREEK
OVERFLOW SPILLWAY RIPRAP SIZING
@ NORTHWEST PARKWAY

Computed by GD Date 12/6/12
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Approved by Date

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CHECK RIPRAP SIZING FOR SPILLWAYS

EQUATIONS FOUND IN NRCS STREAM RESTORATION DESIGN HANDBOOK TS-14C

ABT & JOHNSON METHOD

$$D_{50} = (q\ \text{design})^{0.56} \times S^{0.43} \times 5.23 \qquad (TS14C-14)$$

$$= (8.49\ \text{cfs/ft})^{.56} (0.125)^{0.43} (5.23)$$

$$= 7.09 \text{ INCHES}$$

ARS ROCK CHUTES

$$D_{50} = 12\,(0.233 q S^{0.58})^{.529} \qquad (TS14C-17)$$

$$= 12\left[(0.233)(8.49)(.125)^{.58}\right]^{.529}$$

$$= 9.10 \text{ INCHES}$$

USACE STEEP SLOPE RIPRAP (TS14C-12)

$$D_{30} = \frac{1.95\, S^{0.555} (Cq)^{.667}}{g^{.333}} = \frac{1.95\,(.125)^{.555}(1.25 \times \cancel{8.49}\ 9.67)^{.667}}{(32.2)^{.333}}$$

$$= \cancel{0.934'}\ 1.02'$$

$$D_{50} \cong \cancel{1.07'}\ 1.17' = \cancel{12.89}\ 14.08 \text{ INCHES} \checkmark$$

MOST CONSERVATIVE

WITH $\cancel{1.4}$ 1.3 SAFETY FACTOR $\Rightarrow D_{50} = 18$ INCHES ✓

CORRESPONDS TO MO-DOT TYPE IV ROCK DITCH LINER ($D_{50} \cong 19''$)

$$\text{THICKNESS} = 1.5 \times D_{100} = 1.5 \times 28'' = 42''$$

$$= \underline{3.5' \text{ THICKNESS}} \checkmark$$

SC 3020 R2 199

Design Procedure to Predict Stable Stone Size

A new design procedure to predict median stone size for a protective riprap layer has been developed from the test program and compilation of data from previous investigations [2,4,5,6]. A set of curves shown in Figure 4 for different embankment slopes combines the rock properties of the riprap material, discharge, and embankment slope. Each curve represents the point of incipient failure for a particular embankment slope, S, for a design unit discharge, q, and median stone size, D_{50}. C_u on the y-axis is the coefficient of uniformity of the material which is the ratio of the material D_{60} to D_{10}. The curves on figure 4 are based on the riprap material having an angle of internal friction, Φ, of 42˚. The design curves combine empirical data with accepted sediment transport equations and are not simply a best fit of the data. A safety factor is not included in the graph, but left to the judgement of the designer to apply as needed.

Further investigation of the data used to determine these design curves can lead to some simplification of the design, such as eliminating the coefficient of stability, C_s, from previous design information [4]. Plotting the data with the design curves on linear axes shows that there is little difference in D_{50} when the embankment slope is 0.1 or less. Also, determination of the coefficient of uniformity is often difficult. This can lead to concerns by the designer trying to identify rock sizes for use with the design procedure. A sensitivity analysis was performed by varying the coefficient of uniformity from 1.5 to 2.1 and found to produce a ±5 percent difference in the computed median stone size.

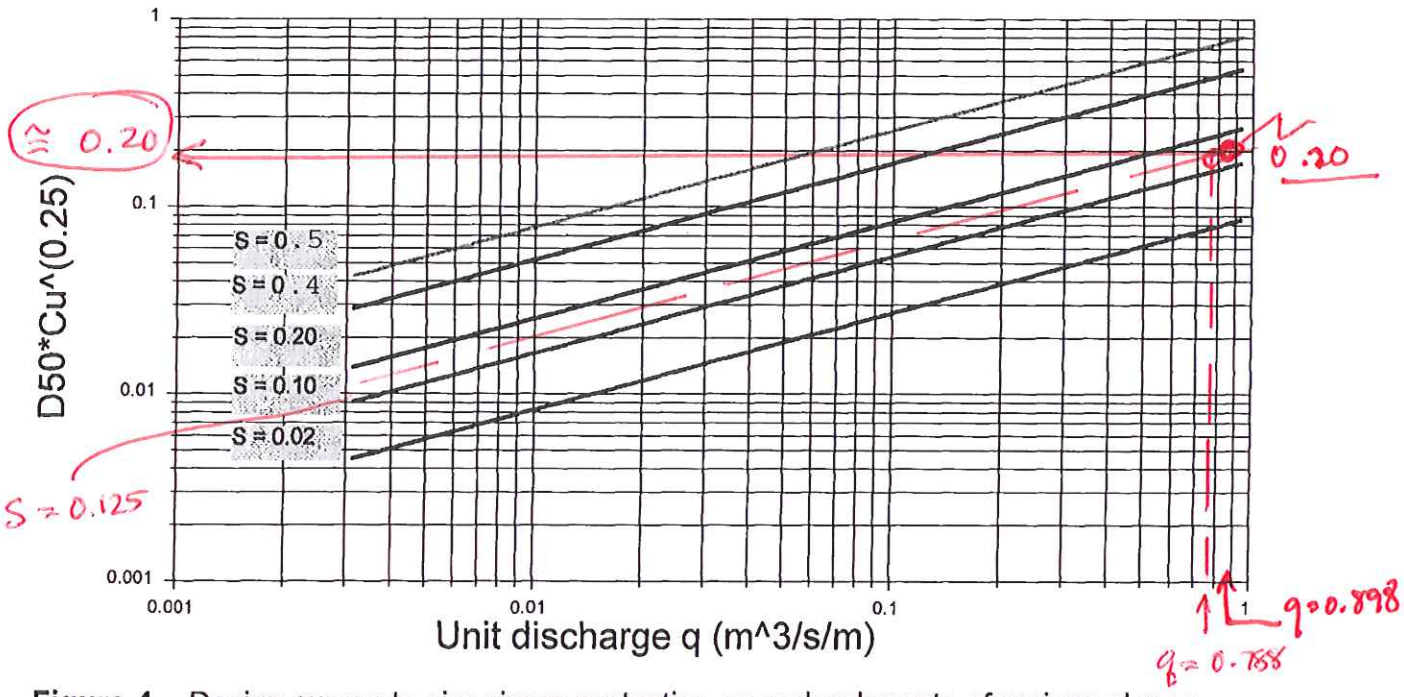

Figure 4. - Design curves to size riprap protection on embankments of various slopes. These curves represent the point of incipient failure as described previously. No safety factor has been included. (Fig4.wpd)

USBR PAP-790, "SIMPLIFIED DESIGN GUIDELINE FOR RIPRAP SUBJECTED TO OVERTOPPING FLOW", 1998 (page 6)

NRCS STREAM RESTORATION DESIGN HANDBOOK

be used for exposed boulders or stones exposed to impinging flow.

U.S. Bureau of Reclamation method

This high-energy technique is outlined in U.S. Bureau of Reclamation (USBR) EM–25 (Peterka 1958) and was developed for sizing riprap below a stilling basin. It was empirically developed using 11 prototype installations with velocities ranging from 1 foot per second to 20 foot per second. The formula is:

$$D_{50} = 0.0122V^{2.06} \qquad \text{(eq. TS14C–9)}$$

where:

D_{50} = median stone diameter (ft)
V = average channel velocity (ft/s)

U.S. Geological Survey method (Blodgett 1981)

This technique is based on analysis of field data of 39 large events from sites in Arizona, Washington, Oregon, Nevada, and California. Riprap protection failed in 14 of the 39 cases. An envelope curve was empirically developed to represent the difference between sites that performed without damage and those that were damaged by particle erosion. The formula is:

$$D_{50} = 0.01V^{2.44} \qquad \text{(eq. TS14C–10)}$$

where:

D_{50} = median stone diameter (ft)
V = average channel velocity (ft/s)

This method typically provides overly conservative results.

Tillatoba model study

This study (Blaisdell 1973) provides an equation for sizing stone to remain stable in the turbulent flow found below stilling basins. This high-energy technique results in an estimate for D_{50}.

$$D_{50} = 0.00116\frac{V^3}{\sqrt{d}} \qquad \text{(eq. TS14C–11)}$$

where:

V = velocity (ft/s)
d = flow depth (ft)
D_{50} = stone diameter (ft)

USACE steep slope riprap design

This high-energy technique is outlined in standard USACE guidance as provided in EM 1110–2–1601. It is designed for use on slopes from 2 to 20 percent. However, the side slopes should be 1V:2.5H or flatter. A typical application would be a rock-lined chute. The formula is:

$$D_{30} = \frac{1.95S^{0.555}(Cq)^{\frac{2}{3}}}{g^{\frac{1}{3}}} \qquad \text{(eq. TS14C–12)}$$

where:

D_{30} = stone size; m percent finer by weight
S = channel slope
q = unit discharge ($q = Q/b$, where b = bottom width of chute and Q is total flow)
C = flow concentration factor (usually 1.25, but can be higher if the approach is skewed)
g = gravitational constant

This equation is applicable to thickness = 1.5 D_{100}, angular rock, unit weight of 167 pounds per cubic foot, D_{85}/D_{15} from 1.7 to 2.7, slopes from 2 to 20 percent, and uniform flow on a downslope with no tailwater. This equation typically predicts conservative sizes.

USACE habitat boulder design

This technique is outlined in USACE guidance provided in EMRRP–SR–11. It is developed for sizing boulder clusters in a channel for habitat enhancement. This high-energy relationship is an incipient motion relation for fully immersed boulders in turbulent flow on a flat bed. This method is for impinging flow. The formula is:

$$D = \frac{18(\text{depth})S_f}{(SG-1)} \qquad \text{(eq. TS14C–13)}$$

where:

D = minimum stone size
depth = channel depth
S_f = channel friction slope
SG = specific gravity of the stone

This equation has also been used to size stones for use in low instream weirs. However, estimating the friction slope across a drop can be difficult.

Abt and Johnson (1991)

Abt and Johnson (1991) conducted near-prototype flume studies to determine riprap stability when subjected to overtopping flows such as in spillway flow or in sloping loose-rock grade control structures. Slopes varied from 2 to 20 percent. Riprap design criteria for overtopping flows were developed for two conditions: stone movement and riprap layer failure. Criteria were

developed as a function of median stone size, unit discharge, and embankment slope. The equation is:

$$D_{50} = \left(q_{design}\right)^{0.56} \times S^{0.43} \times 5.23 \qquad \text{(eq. TS14C–14)}$$

where:

D_{50} = stone size in inches; m percent finer by weight

q_{design} = unit discharge ($ft^3/s/ft$)

S = channel slope (ft/ft) and S between 0.02 and 0.20 ft/ft

$$\left(q_{design}\right) = \frac{\left(q_{failure}\right)}{0.74} = 1.35 q_{failure} \qquad \text{(eq. TS14C–15)}$$

Stone movement occurred at approximately 74 percent of the flow, causing layer failure. It was determined from testing that rounded stone should be oversized by approximately 40 percent to provide the same protection as angular stone.

ARS rock chutes

This design technique (Robinson, Rice, and Kadavy 1998) is primarily targeted at high-energy applications. Loose riprap with a 2 D_{50} blanket thickness composed of relatively uniform, angular riprap was tested to overtopping failure in models and field scale structures. This method applies to bed slopes of 40 percent and less. This technique can be used for low slope, and thus, low-energy applications, but it is particularly useful for slopes greater than 2 percent. A factor of safety appropriate for the project should be applied to the predicted rock size. The equations are:

for S <0.1

$$D_{50} = 12\left(1.923 q S^{1.5}\right)^{0.529} \qquad \text{(eq. TS14C–16)}$$

0.10<S<0.40

$$D_{50} = 12\left(0.233 q S^{0.58}\right)^{0.529} \qquad \text{(eq. TS14C–17)}$$

where:

D_{50} = median stone size (in)

q = highest stable unit discharge ($ft^3/s/ft$)

S = channel slope (ft/ft)

A spreadsheet program (Lorenz, Lobrecht, and Robinson 2000) is available to assist in sizing riprap on steep slopes. A screen capture of this spreadsheet program is shown in figure TS14C–7.

This method is best used in steep slopes for grade control, embankment overtopping, or on side inlets from fields to a major drainage outlet. The spreadsheet provides much additional information related to rock chutes such as guidance on inlet and outlet conditions, quantity estimates, and hydrology.

California Department of Transportation RSP

This technique was developed by the California Department of Transportation (CALTRANS) for designing rock slope protection (RSP) for streams and riverbanks. Unlike most of the other available techniques, it results in a recommended minimum weight of the stone. The equation is:

$$W = \frac{0.00002}{\left(G_S - 1\right)^3} \times \frac{VM \times V^6 \times G_S}{\sin^3\left(r - a\right)} \qquad \text{(eq. TS14C–18)}$$

where:

W = minimum rock weight (lb)

V = velocity (ft/s)

VM = 0.67 if parallel flow

VM = 1.33 if impinging flow

G_S = specific gravity of rock (typically 2.65)

r = angle of repose (70° for randomly placed rock)

a = outside slope face angle to the horizontal (typically a maximum of 33°)

The weight indicated by this method should be used in conjunction with standard CALTRANS specifications and gradations.

Far West states (FWS)—Lane's Method

Vito A. Vanoni worked with the Northwest E&WP Unit to develop the procedure from the ASCE paper entitled "Design of Stable Alluvial Channels" (Lane 1955a). The equation is:

$$D_{75} = \frac{3.5}{C \times K} \times \gamma_w \times D \times S_f \qquad \text{(eq. TS14C–19)}$$

where:

D_{75} = stone size, (in)

C = correction for channel curvature

K = correction for side slope

S_f = channel friction slope (ft/ft)

d = depth of flow (ft)

γ_w = density of water

This is generally considered to be a conservative technique. It assumed that the stress on the sides of the channel were 1.4 times that of the bottom. This

MISSOURI DOT RIPRAP GRADATIONS

609.30.4 Construction Requirements.

609.30.4.1 The curb shall be placed in position on a primed surface by means of an approved automatic curb machine that shapes and compacts the mixture to the specified cross section. The placement temperature of the mixture shall be approximately 260 F. All joints shall be carefully made in such a manner as to ensure a continuous bond between the old and new sections of the curb.

609.30.4.2 The newly laid curb shall be protected from traffic until the heat of the asphalt mixture has dissipated. Immediately after the asphalt curb has hardened, the curb shall be backfilled where required with suitable material.

609.30.4.3 If painting of the asphalt curb is specified in the contract, a primer coat of commercial grade asphalt base aluminum paint shall be applied first.

609.30.5 Method of Measurement. Asphalt curb will be measured to the nearest linear foot.

609.30.6 Basis of Payment. The accepted quantity of asphalt curb will be paid for at the contract unit price. No direct payment will be made for priming prior to placing the curb or for painting the completed curb.

SECTION 609.40 DRAIN BASIN ASPHALT CURB.

609.40.1 Description. This work shall consist of furnishing and constructing a drain basin as shown on the plans or as directed by the engineer.

609.40.2 Material. Drain basins shall consist of a drop inlet of the size and type shown on the plans, grates and bearing plates for drop inlet, Group C pipe in the size shown on plans and concrete slope protection at pipe outlet as shown on plans. These items shall be in accordance Division 1000, Material Details, and specifically as follows:

Item	Section
Rock Ditch Lining	609.60
Grates and Bearing Plates	614
Drop Inlet	1033

609.40.3 Construction Requirements. Excavation and backfilling shall be in accordance with Secs 604 and 725. The adjustment shall be made to the line and grade shown on the plans or as directed by the engineer. The concrete slope protection for the drain basin outlet shall be placed as shown on the plans or as directed by the engineer.

609.40.4 Basis of Payment. Payment for the accepted drain basin, complete in place, will be paid for at the contract unit price per each. Payment for the accepted quantities of Class 3 excavation required for installing the drop inlet for the drain basin will be paid for at the contract unit price.

SECTION 609.50 BLANK.

SECTION 609.60 ROCK DITCH LINER.

609.60.1 Description. This work shall consist of constructing rock ditch liners at locations shown on the plans or as directed by the engineer.

609.60.2 Material. The material for rock ditch liner shall consist of a predominantly one-sized, durable stone, shot rock or broken concrete. Acceptance by the engineer may be made

from "MISSOURI STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION, 2011 EDITION"

by visual inspection. All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section
Geotextile Fabric	1011

609.60.2.1 Type 1 Rock Ditch Liner shall consist of material with a predominant rock size of 3 inches, a maximum rock size of 6 inches and a gradation such that no more than 15 percent will be less than one inch.

609.60.2.2 Type 2 Rock Ditch Liner shall consist of material with a predominant rock size of 6 inches, a maximum rock size of 10 inches and a gradation such that no more than 15 percent will be less than 3 inches. $D_{50} \cong 6''$

609.60.2.3 Type 3 Rock Ditch Liner shall consist of material with a predominant rock size of 12 inches, a maximum rock size of 20 inches and a gradation such that no more than 15 percent will be less than 4 inches. $D_{50} \cong 12''$

609.60.2.4 Type 4 Rock Ditch Liner shall consist of material with a predominant rock size of 19 inches, a maximum rock size of 28 inches and a gradation such that no more than 15 percent will be less than 6 inches. $D_{50} \cong 19''$

609.60.2.5 Bedding material shall be used under Type 3 and Type 4 Rock Ditch Liner. Bedding material shall consist of crushed stone or gravel with a gradation consisting of 100 percent passing the 3-inch sieve, 30 to 70 percent passing the 1 1/2-inch sieve and 0 to 15 percent passing the No. 4 sieve.

609.60.3 Construction Requirements. Rock ditch liner shall be placed to the approximate shape and thickness shown on the plans for the specified ditch or as directed by the engineer. The rock shall be dumped on a subgrade of reasonably uniform density and left in a rough condition meeting the approval from the engineer.

609.60.4 Method of Measurement. Rock ditch liner and bedding material will each be measured to the nearest cubic yard of material.

609.60.5 Basis of Payment.

609.60.5.1 If shown on the plans that the material for rock ditch liner is to be obtained from the right of way or other sources furnished by the Commission, the excavating, including all breaking, loading, and hauling, regardless of distance, to the site of the rock ditch liner will be paid for and considered completely covered under such contract items as Class A Excavation, Class C Excavation, Unclassified Excavation, Excavation for Structures or other applicable items. If payment is made under these conditions, separate payment for furnishing rock ditch liner will not be made.

609.60.5.2 If the plans show material for rock ditch liner to be secured from sources cited in Sec 609.60.5.1 and this material is made unsuitable or unattainable by the contractor's operations, the contractor shall provide suitable material and dispose of any surplus material at the contractor's expense.

609.60.5.3 If the contract documents provide for obtaining material from the right of way or other source furnished by the Commission, but all or part of the required quantity of acceptable material is not available, unless the shortage is due to the contractor's operations, payment for such additional rock base material that the contractor will be required to furnish

USACE RIPRAP DESIGN per EM 1110-2-1601

(USED TO SIZE RIPRAP DOWNSTREAM OF THE SAVANNAH RD CULVERT)

Computed by GD Date 8/30/12

Checked by JRJ Date 1-11-13

$D_{30} = S_f C_s C_v C_t d\,[(\gamma_w / \gamma_s - \gamma_w)^{1/2} * (V / (K_1 g d)^{0.5})]^{2.5}$

$K_1 = [1-(\sin^2\Theta/\sin^2\Phi)]0.5$

V	10	velocity
d	10	depth
K_1	0.952319	
Θ	11.31	
Φ	40	
γ_w	62.4	unit weight of water (weight/volume)
γ_s	165	unit weight of stone (weight/volume)
S_f	1.5	Safety factor
C_s	0.3	Stability coefficient for incipient failure (=.30 for angular rock; 0.375 for rounded rock)
C_t	1	thickness coefficient (=1.0 for thickness - $1D_{100}$ (max) or 1.5 D_{50} (max)
C_v	1.2	vertical velocity distribution coefficient (=1.0 straight channels, inside of bends; 1.283 - 0.2 log (R/W) outside of bends [1 for (R/W) > 26)

D_{30} =	0.714731	Riprap size (FT) of which 30 percent is finer by weight
	8.576768	Riprap size (IN) of which 30 percent is finer by weight

CORRESPONDS TO APPROXIMATE D_{50} = 12"

Stanley Consultants INC.

Project No. 23842 Page No. 1

Subject BLACKSNAKE CREEK
PILOT CHANNEL STREAMBED

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CHANNEL BED - EROSION PROTECTION

EQUATIONS & METHODS FROM HEC-15 - DESIGN OF ROADSIDE CHANNELS WITH FLEXIBLE LININGS, THIRD EDITION, SEPT 2005

DESIGN EVENT → FULL CHANNEL $d = 2.0'$ $Q = 385$ cfs

$V = \frac{385 \text{ cfs}}{104 \text{ SF}} = 3.7'/s$ $S = 0.005'/FT$

CHECK GRASS-LINED VEGETATED CHANNEL

$$\tau_e = \tau_d (1 - C_f)\left[\frac{n_s}{n}\right]^2 \quad \text{(EQN 4.3)}$$

$C_f = 0.70$ $\tau_d = (62.4)(2)(.005) = 0.624 \text{ lb/ft}^2$

$n_s = 0.016$

$n = 0.04$

$$\tau_e = \left[(62.4 \text{ lbs/ft})(2')(0.005)\right](1 - .70)\left[\frac{0.016}{0.04}\right]^2 = 0.030 \text{ lb/ft}^2$$

τ_p = PERMISSIBLE SOIL SHEAR STRESS

SOIL CLASSIFICATION = "CL"

BORING AD-1

$PI = 15$

$e = \cancel{0.80}$ 0.66

$c_1 = 1.07$ $c_5 = -0.57$

$c_2 = 14.3$ $c_6 = 10^{-4}$

$c_3 = 47.7$

$c_4 = 1.48$

$$\tau_{p\,soil} = (c_1 PI^2 + c_2 PI + c_3)(c_4 + c_5 e)^2 c_6$$

(EQN 4.6)

$$= (1.07(15)^2 + (14.3)(15) + 47.7)\left[1.48 + (-0.57)(.66)\right]^2 (.0001)$$

$$= 0.0613 \text{ lbs/ft}^2$$

$$\tau_p = \frac{\tau_{p\,soil}}{(1 - C_f)}\left(\frac{n}{n_s}\right)^2 = \frac{0.0613}{(.30)}\left(\frac{0.04}{0.016}\right)^2 = 1.28 \text{ lb/ft}^2$$

(EQN 4.7)

$$\tau_p > \tau_o \Rightarrow 1.28 \text{ lb/ft}^2 > 0.624 \text{ lb/ft}^2$$

VEGETATED LINING OKAY FOR PILOT CHANNEL

Stanley Consultants INC.

Project No. 23842 Page No. 2

Subject BLACKSNAKE CREEK
PILOT CHANNEL STREAMBED

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DETERMINE STRESS IN CHANNEL BENDS

NORTH BEND RADIUS = 50' = R_c (OTHERS ARE 100' TO 210')

TOP WIDTH OF WATER ≅ 60' = T

$\tau_b = K_b \tau_d$ (EQN 3.6)

τ_b = side shear stress on channel

K_b = RATIO CHANNEL BEND STRESS TO BOTTOM STRESS

τ_d = MAX DEPTH SHEAR STRESS

PER HEC-15 (3.7) ⇒ $K_b = 2.00$ SINCE $\frac{R_c}{T} \leq 2$ FOR MOST BENDS

$\tau_b = (2.0)(.624 \text{ lbs/ft}^2)$

$= 1.248 \text{ lb/ft}^2$

THIS IS LESS THAN VEGETATED LINING τ_p; BUT NO FACTOR OF SAFETY → RECOMMEND SMALL RIPRAP IN BEND AREAS

GRAVEL MULCH (D_{50} = 2 IN) $\tau_p = 0.8$ lbs/ft² NOT OKAY

ROCK RIPRAP (D_{50} = 0.5' = 6 IN) $\tau_p = 2.4$ lbs/ft² OK

TYPE II ROCK DITCH LINER MO-DOT

IN BENDS & AT CONSTRICTIONS

Table 4.4 (SI). Grass Roughness Coefficient, C_n, for SCS Retardance Classes

Retardance Class	A	B	C	D	E
Stem Height, mm	910	610	200	100	40
C_s	390	81	47	33	44
C_n	0.605	0.418	0.220	0.147	0.093

Table 4.4 (CU). Grass Roughness Coefficient, C_n, for SCS Retardance Classes

Retardance Class	A	B	C	D	E
Stem Height, in	36	24	8.0	4.0	1.6
C_s	33	7.1	3.9	2.7	3.8
C_n	0.605	0.418	0.220	0.147	0.093

4.2 MANNING'S ROUGHNESS

Manning's roughness coefficient for grass linings varies depending on grass properties as reflected in the C_n parameter and the shear force exerted by the flow. This is because the applied shear on the grass stem causes the stem to bend, which reduces the stem height relative to the depth of flow and reducing the roughness.

$$n = \alpha C_n \tau_o^{-0.4} \tag{4.2}$$

where,

τ_o = mean boundary shear stress, N/m^2 (lb/ft^2)

α = unit conversion constant, 1.0 (SI), 0.213 (CU)

See Appendix C.2 for the derivation of Equation 4.2.

4.3 PERMISSIBLE SHEAR STRESS

The permissible shear stress of a vegetative lining is determined both by the underlying soil properties as well as those of the vegetation. Determination of permissible shear stress for the lining is based on the permissible shear stress of the soil combined with the protection afforded by the vegetation, if any.

4.3.1 Effective Shear Stress

Grass lining moves shear stress away from the soil surface. The remaining shear at the soil surface is termed the effective shear stress. When the effective shear stress is less than the allowable shear for the soil surface, then erosion of the soil surface will be controlled. Grass linings provide shear reduction in two ways. First, the grass stems dissipate shear force within the canopy before it reaches the soil surface. Second, the grass plant (both the root and stem) stabilizes the soil surface against turbulent fluctuations. This process model (USDA, 1987) for the effective shear at the soil surface is given by the following equation.

$$\tau_e = \tau_d (1 - C_f) \left(\frac{n_s}{n} \right)^2 \tag{4.3}$$

HEC-15

where,

τ_e = effective shear stress on the soil surface, N/m^2 (lb/ft^2)

τ_d = design shear stress, N/m^2 (lb/ft^2) $= \gamma d S_o = 0.624$

C_f = grass cover factor $= 0.70$

n_s = soil grain roughness $= 0.016$

n = overall lining roughness $= 0.04$

Soil grain roughness is taken as 0.016 when D_{75} < 1.3 mm (0.05 in). For larger grain soils, the soil grain roughness is given by:

$$n_s = \alpha (D_{75})^{1/6} \tag{4.4}$$

where,

n_s = soil grain roughness (D_{75} > 1.3 mm (0.05 in))

D_{75} = soil size where 75% of the material is finer, mm (in)

α = unit conversion constant, 0.015 (SI), 0.026 (CU)

Note that soil grain roughness value, n_s, is less than the typical value reported in Table 2.1 for a bare soil channel. The total roughness value for bare soil channel includes form roughness (surface texture of the soil) in addition to the soil grain roughness. However, Equation 4.3 is based on soil grain roughness.

The grass cover factor, C_f, varies with cover density and grass growth form (sod or bunch). The selection of the cover factor is a matter of engineering judgment since limited data are available. Table 4.5 provides a reasonable approach to estimating a cover factor based on (USDA, 1987, Table 3.1). Cover factors are better for sod-forming grasses than bunch grasses. In all cases a uniform stand of grass is assumed. Non-uniform conditions include wheel ruts, animal trails and other disturbances that run parallel to the direction of the channel. Estimates of cover factor are best for good uniform stands of grass and there is more uncertainty in the estimates of fair and poor conditions.

Table 4.5. Cover Factor Values for Uniform Stands of Grass

Growth Form	Cover Factor, C_f				
	Excellent	Very Good	Good	Fair	Poor
Sod	0.98	0.95	0.90	0.84	0.75
Bunch	0.55	0.53	0.50	0.47	0.41
Mixed	0.82	0.79	0.75	0.70	0.62

4.3.2 Permissible Soil Shear Stress

Erosion of the soil boundary occurs when the effective shear stress exceeds the permissible soil shear stress. Permissible soil shear stress is a function of particle size, cohesive strength, and soil density. The erodibility of coarse non-cohesive soils (defined as soils with a plasticity index of less than 10) is due mainly to particle size, while fine-grained cohesive soils are controlled mainly by cohesive strength and soil density.

New ditch construction includes the placement of topsoil on the perimeter of the channel. Topsoil is typically gathered from locations on the project and stockpiled for revegetation work. Therefore, the important physical properties of the soil can be determined during the design by sampling surface soils from the project area. Since these soils are likely to be mixed together, average physical properties are acceptable for design.

The following sections offer detailed methods for determination of soil permissible shear. However, the normal variation of permissible shear stress for different soils is moderate, particularly for fine-grained cohesive soils. An approximate method is also provided for cohesive soils.

4.3.2.1 Non-cohesive Soils

The permissible soil shear stress for fine-grained, non-cohesive soils (D_{75} < 1.3 mm (0.05 in)) is relatively constant and is conservatively estimated at 1.0 N/m^2 (0.02 lb/ft^2). For coarse grained, non-cohesive soils (1.3 mm (0.05 in) < D_{75} < 50 mm (2 in)) the following equation applies.

$$\tau_{p,soil} = \alpha D_{75} \tag{4.5}$$

where,

$\tau_{p,soil}$ = permissible soil shear stress, N/m^2 (lb/ft^2)
D_{75} = soil size where 75% of the material is finer, mm (in)
α = unit conversion constant, 0.75 (SI), 0.4 (CU)

4.3.2.2 Cohesive Soils

Cohesive soils are largely fine grained and their permissible shear stress depends on cohesive strength and soil density. Cohesive strength is associated with the plasticity index (PI), which is the difference between the liquid and plastic limits of the soil. The soil density is a function of the void ratio (e). The basic formula for permissible shear on cohesive soils is the following.

$$\tau_{p,soil} = \left(c_1 PI^2 + c_2 PI + c_3\right)\left(c_4 + c_5 e\right)^2 c_6 \tag{4.6}$$

where,

$\tau_{p,soil}$ = soil permissible shear stress, N/m^2 (lb/ft^2)
PI = plasticity index ≈ 15
e = void ratio ≈ 0.66
c_1, c_2, c_3, c_4, c_5, c_6 = coefficients (Table 4.6)

A simplified approach for estimating permissible soil shear stress based on Equation 4.6 is illustrated in Figure 4.1. Fine grained soils are grouped together (GM, CL, SC, ML, SM, and MH) and coarse grained soil (GC). Clays (CH) fall between the two groups.

Higher soil unit weight increases the permissible shear stress and lower soil unit weight decreases permissible shear stress. Figure 4.1 is applicable for soils that are within 5 percent of a typical unit weight for a soil class. For sands and gravels (SM, SC, GM, GC) typical soil unit weight is approximately 1.6 ton/m^3 (100 lb/ft^3), for silts and lean clays (ML, CL) 1.4 ton/m^3 (90 lb/ft^3) and fat clays (CH, MH) 1.3 ton/m^3 (80 lb/ft^3).

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Table 4.6. Coefficients for Permissible Soil Shear Stress (USDA, 1987)

ASTM Soil Classification(1)	Applicable Range	c_1	c_2	c_3	c_4	c_5	c_6 (SI)	c_6 (CU)
GM	$10 \leq PI \leq 20$	1.07	14.3	47.7	1.42	-0.61	4.8×10^{-3}	10^{-4}
	$20 \leq PI$			0.076	1.42	-0.61	48.	1.0
GC	$10 \leq PI \leq 20$	0.0477	2.86	42.9	1.42	-0.61	4.8×10^{-2}	10^{-3}
	$20 \leq PI$			0.119	1.42	-0.61	48.	1.0
SM	$10 \leq PI \leq 20$	1.07	7.15	11.9	1.42	-0.61	4.8×10^{-3}	10^{-4}
	$20 \leq PI$			0.058	1.42	-0.61	48.	1.0
SC	$10 \leq PI \leq 20$	1.07	14.3	47.7	1.42	-0.61	4.8×10^{-3}	10^{-4}
	$20 \leq PI$			0.076	1.42	-0.61	48.	1.0
ML	$10 \leq PI \leq 20$	1.07	7.15	11.9	1.48	-0.57	4.8×10^{-3}	10^{-4}
	$20 \leq PI$			0.058	1.48	-0.57	48.	1.0
CL	$10 \leq PI \leq 20$	1.07	14.3	47.7	1.48	-0.57	4.8×10^{-3}	10^{-4}
	$20 \leq PI$			0.076	1.48	-0.57	48.	1.0
MH	$10 \leq PI \leq 20$	0.0477	1.43	10.7	1.38	-0.373	4.8×10^{-2}	10^{-3}
	$20 \leq PI$			0.058	1.38	-0.373	48.	1.0
CH	$20 \leq PI$			0.097	1.38	-0.373	48.	1.0

(1) Note:	Typical names
GM	Silty gravels, gravel-sand silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
SM	Silty sands, sand-silt mixtures
SC	Clayey sands, sand-clay mixtures
ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
CH	Inorganic clays of high plasticity, fat clays

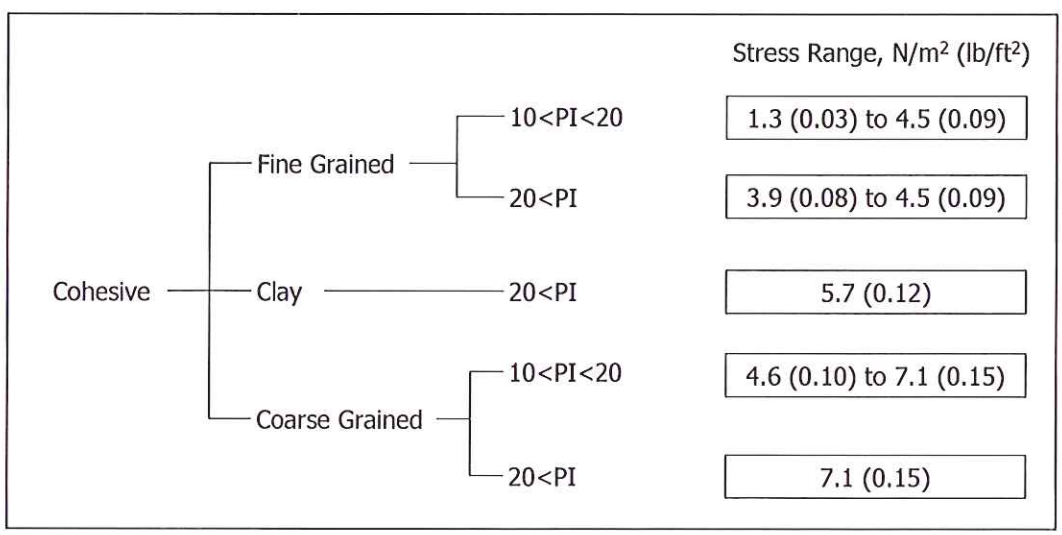

Figure 4.1. Cohesive Soil Permissible Shear Stress

4.3.3 Permissible Vegetation/Soil Shear Stress

The combined effects of the soil permissible shear stress and the effective shear stress transferred through the vegetative lining results in a permissible shear stress for the vegetative lining. Taking Equation 4.3 and substituting the permissible shear stress for the soil for the effective shear stress on the soil, τ_e, gives the following equation for permissible shear stress for the vegetative lining:

$$\tau_p = \frac{\tau_{p,soil}}{(1 - C_f)}\left(\frac{n}{n_s}\right)^2 \tag{4.7}$$

where,

τ_p = permissible shear stress on the vegetative lining, N/m^2 (lb/ft^2)

$\tau_{p,soil}$ = permissible soil shear stress, N/m^2 (lb/ft^2)

C_f = grass cover factor

n_s = soil grain roughness

n = overall lining roughness

Design Example: Grass Lining Design (SI)

Evaluate a grass lining for a roadside channel given the following channel shape, soil conditions, grade, and design flow. It is expected that the grass lining will be maintained in good conditions in the spring and summer months, which are the main storm seasons.

Given:

Shape: Trapezoidal, B = 0.9 m, Z = 3

Soil: Clayey sand (SC classification), PI = 16, e = 0.5

Grass: Sod, height = 0.075 m

Grade: 3.0 percent

Flow: 0.5 m^3/s

Solution

The solution is accomplished using procedure given in Section 3.1 for a straight channel.

Step 1. Channel slope, shape, and discharge have been given.

Step 2. A vegetative lining on a clayey sand soil will be evaluated.

Step 3. Initial depth is estimated at 0.30 m

From the geometric relationship of a trapezoid (see Appendix B):

$$A = Bd + Zd^2 = 0.9(0.3) + 3(0.3)^2 = 0.540 \text{ m}^2$$

$$P = B + 2d\sqrt{Z^2 + 1} = 0.9 + 2(0.3)\sqrt{3^2 + 1} = 2.80 \text{ m}$$

R = A/P = (0.54)/(2.8) = 0.193 m

Step 4. To estimate n, the applied shear stress on the grass lining is given by Equation 2.3

$$\tau_o = \gamma RS_o = 9810(0.193)(0.03) = 56.8 \text{ N/m}^2$$

Determine a Manning's n value from Equation 4.2. From Table 4.3, C_n = 0.142

Concrete is a non-erodible, rigid lining so it has a very high rigid permissible shear stress. By using the techniques in Section 4.3 (Equation 4.7 and Table 4.5) the permissible shear stress of the vegetative portion of the lining is 2.5 lb/ft^2.

A safety factor of 1.0 is chosen for this situation.

Step 7. The maximum shear stress on the channel side slopes (0.67 lb/ft^2) is less than permissible shear stress on the vegetation (2.5 lb/ft^2) so the lining is acceptable. (The concrete bottom lining is non-erodible.)

3.4 STABILITY IN BENDS

Flow around a bend creates secondary currents, which impose higher shear stresses on the channel sides and bottom compared to a straight reach (Nouh and Townsend, 1979) as shown in Figure 3.3. At the beginning of the bend, the maximum shear stress is near the inside and moves toward the outside as the flow leaves the bend. The increased shear stress caused by a bend persists downstream of the bend.

Equation 3.6 gives the maximum shear stress in a bend.

$$\tau_b = K_b \tau_d \tag{3.6}$$

where,

τ_b = side shear stress on the channel, N/m^2 (lb/ft^2)

K_b = ratio of channel bend to bottom shear stress

τ_d = shear stress in channel at maximum depth, N/m^2 (lb/ft^2)

The maximum shear stress in a bend is a function of the ratio of channel curvature to the top (water surface) width, R_C/T. As R_C/T decreases, that is as the bend becomes sharper, the maximum shear stress in the bend tends to increase. K_b can be determined from the following equation from Young, et al., (1996) adapted from Lane (1955):

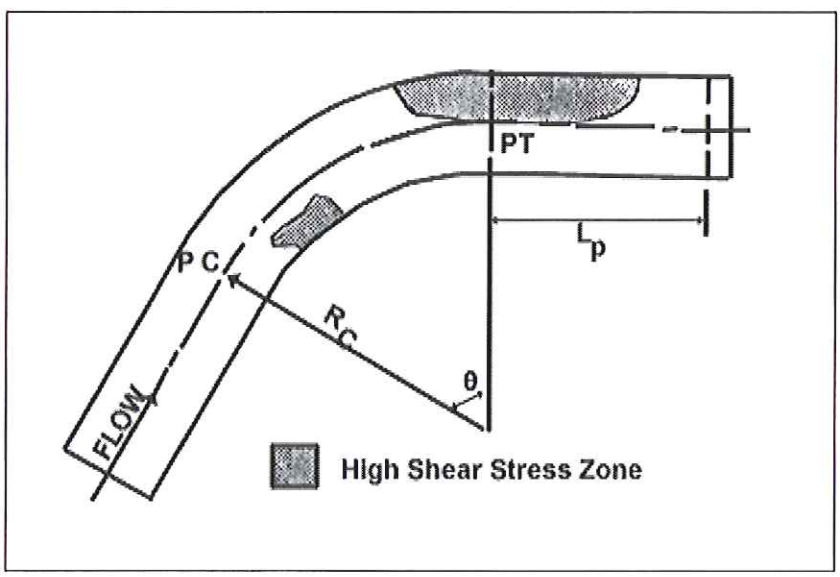

Figure 3.3. Shear Stress Distribution in a Channel Bend (Nouh and Townsend, 1979)

$$K_b = 2.00 \qquad R_C/T \le 2$$

$$K_b = 2.38 - 0.206\left(\frac{R_c}{T}\right) + 0.0073\left(\frac{R_c}{T}\right)^2 \qquad 2 < R_C/T < 10 \qquad (3.7)$$

$$K_b = 1.05 \qquad 10 \le R_C/T$$

where,

R_c = radius of curvature of the bend to the channel centerline, m (ft) = 50

T = channel top (water surface) width, m (ft) = 60

$\frac{R_c}{T} = 0.833$

The added stress induced by bends does not fully attenuate until some distance downstream of the bend. If added lining protection is needed to resist the bend stresses, this protection should continue downstream a length given by:

$$L_p = \alpha\left(\frac{R^{7/6}}{n}\right) \qquad (3.8)$$

where,

L_p = length of protection, m (ft)

R = hydraulic radius of the channel, m (ft)

n = Manning's roughness for lining material in the bend

α = unit conversion constant, 0.74 (SI) and 0.60 (CU)

A final consideration for channel design at bends is the increase in water surface elevation at the outside of the bend caused by the superelevation of the water surface. Additional freeboard is necessary in bends and can be calculated use the following equation:

$$\Delta d = \frac{V^2 T}{g R_c} \qquad (3.9)$$

where,

Δd = additional freeboard required because of superelevation, m (ft)

V = average channel velocity, m/s (ft/s)

T = water surface top width, m (ft)

g = acceleration due to gravity, m/s^2 (ft/s^2)

R_c = radius of curvature of the bend to the channel centerline, m (ft)

The design procedure for channel bends is summarized in the following steps:

Step 1. Determine the shear stress in the bend and check whether or not an alternative lining is needed in the bend.

Step 2. If an alternative lining is needed, select a trial lining type and compute the new hydraulic properties and bend shear stress.

Step 3. Estimate the required length of protection.

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Subject BLACKSNAKE CREEK PRELIMINARY RIPRAP QUANTITIES FOR FEASIBILITY STUDY

Computed by GD Date 12/6/12

Checked by JRJ Date 1-11-13

Approved by Date

Sheet No. of

OVERFLOW SECTIONS

			ADJUST FOR SLOPE
• NORTHWEST PARKWAY –	D/S :	19,346 FT² →	19,900 FT²
	U/S :	39,376 FT² →	43,320 FT²
• RAILROAD OVERFLOW –	D/S :	8,285 FT² →	8,285 FT²
	U/S :	11,578 FT² →	12,200 FT²

83,705 FT²

MO-DOT TYPE IV ROCK/ DITCH LINER → TOTAL →
T=3.5'

× 3.5 FT

292,968 FT³

÷ 27

≅ 10,850 CY

CHANNEL BENDS

		ADJUST FOR SLOPE (5:1)
NORTH →	4129 FT² →	4200 FT²
	8439 FT² →	8610 FT²
	10970 FT² →	11,200 FT²
	9064 FT² →	9250 FT²
	8442 FT² →	8600 FT²
TRIBUTARY →	3402 FT² →	3804 FT² (2:1)
	802 FT² →	897 FT²
	778 FT² →	870 FT²

47,431 FT²

× 2 FT

94,862 FT³

3513 CY

↓ ROUND UP

3550 CY

SC 3020 R2 199

Stanley Consultants INC.

Project No. 23842 Page No. 2

Subject BLACKSNAKE CREEK
PRELIMINARY RIPRAP QUANTITIES

Computed by GD Date 12/6/12

Checked by JRS Date 1-11-13

Approved by Date

Sheet No. of

POWER POLE ISLANDS

1	SOUTHERNMOST	28,538 FT²	→	31,400 FT²
2		37,387 FT²	→	41,125 FT²
3		12,269 FT²	→	13,500 FT²
4		8,051 FT²	→	8,900 FT²
5	NORTHERNMOST (W/OUTLET PROTECTION)	20,153 FT²	→	~~22,200 FT²~~ SD 20,800 FT²
				115,725 FT²

COMBINED SEWER INLET PROTECTION

26,064 FT² → 27,400 FT²

MO-DOT TYPE III ROCK / DITCH LINER → TOTAL → 143,125 FT²

T = 3.0'

× 3 FT

429,375 FT³

÷ 27

≅ 15,900 CY

SC 3020 R2 199

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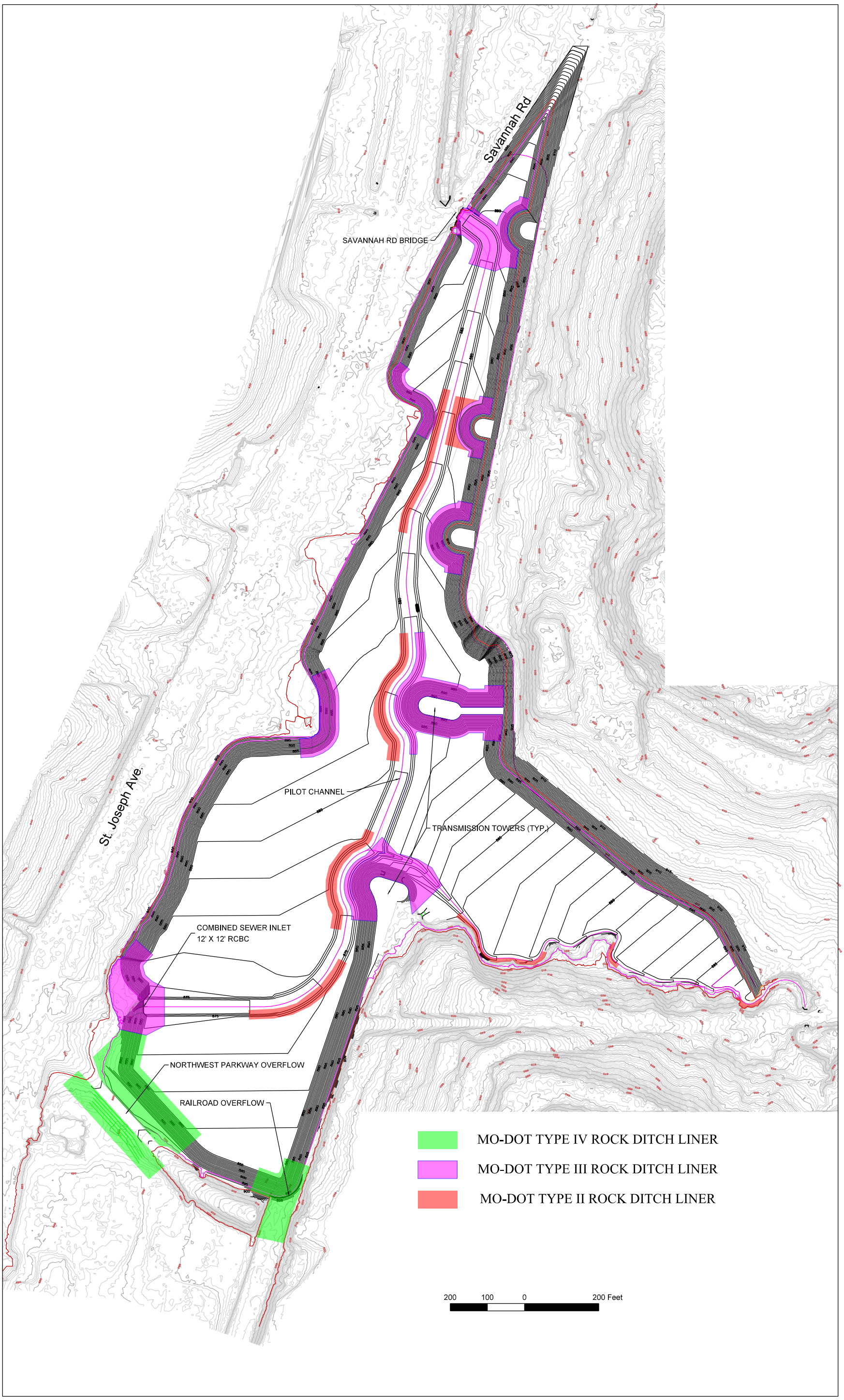
Appendix D

Exhibits



BLACKSNAKE CREEK FEASIBILITY STUDY
EXHIBIT D-1
RIPRAP / EROSION PROTECTION

BLACKSNAKE CREEK FEASIBILITY STUDY
EXHIBIT D-2
CONSTRUCTION STAGING

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Appendix E

Cost Estimate

Detailed Cost Estimates are not issued for Public Release.
Project Costs are described in the main report.

APPENDIX F

Not used for this Report

APPENDIX G

Real Estate Plan

REAL ESTATE PLAN (REP)
BLACKSNAKE CREEK
FLOOD DAMAGE REDUCTION PROJECT
BUCHANAN COUNTY, MISSOURI

1. Purpose: This Real Estate information is developed in support of the Feasibility Report for the subject project under authority of Section 205 of the Flood Control Act of 1948, as amended by the Water Resources Development Act of 1986. The Reconnaissance Report that resulted from the June 9, 1984 flood identifies a potential Federal interest in flood damage reduction measures. The non-Federal sponsor (NFS) for the Feasibility Study is the City of St. Joseph, Missouri. The purpose of this plan is to include information on any real estate activities that may be involved for the identified project. The Blacksnake Creek watershed encompasses an 8.6 square mile basin. Beginning at Karnes Road, the lower 3.2 square miles of the watershed is in an urban setting. The portion of the Blacksnake Creek watershed basin in question is located at Karnes Road and St. Joseph Avenue in the City of St. Joseph, Missouri, in the county of Buchanan.

During storms greater or equal to a 10 year frequency, the capacity of the Karnes Road sewer inlet is exceeded causing water to flow over Karnes Road and inundate over 200 properties. Construction of a dry detention basin north of Northwest Parkway and north of Karnes Road would reduce peak flows entering the sewer system and likely reduce flooding.

The recommended plan will create a detention basin to capture water during flood events. No other flood control structures will be constructed.

The Real Estate Plan is tentative in nature; it is for planning purposes only and both the final real property acquisition lines and the real estate cost estimates provided are subject to change even after approval of the Feasibility Report.

2. Description of Lands, Easements, Rights of Way, Relocation and Disposal (LERRD):

Lands required for the detention basin will be acquired in fee. Lands necessary for disposal of materials will be acquired in temporary work area easements. Lands required for relocation of utilities will be acquired in utility/pipeline easements. Each standard estate is described below.

Estates to be acquired:

a. **FEE.** The fee simple title to (the land described in Exhibit A1 and A2 and Exhibit B) subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

b. **Temporary Work Area Easement.** A temporary easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos. _____, _____ and _____),), for a period not to exceed three (3) years, beginning with date possession of the land is granted to the United States, for use by the United States, its representatives, agents, and contractors as a (borrow area) (work area), including the right to (borrow and/or deposit fill, spoil and waste material thereon) (move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the Blacksnake Creek Project, together with the right to trim, cut, fell and remove therefrom all trees, underbrush,

obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

c. **Utility and/or Pipeline Easement.** A perpetual and assignable easement and right-of-way in, on, over and across (the land described in Exhibit A and Exhibit B) (Tracts Nos. 8, 12, 13, 6, 28, 05.001, 32, 5, 8, 6), for the location, construction, operation, maintenance, alteration; repair and patrol of overhead and underground utilities and pipelines; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

Table 2.1: City of St. Joseph

Estate	Estimated Acres	Estimated Land Value
Fee - Project Footprint	34.852	$296,242
Fee-Mitigation Lands	14.17	$120,445
Utility/Pipeline Easement	7.198	$30,591
Temporary Work Area Easement (3 year period)	20	$51,000
Subtotal		$ 498,278.00
Incremental Costs 25%		$124,569.50
Estimated Total	**61 Parcels 76.22**	**$ 622,847.50**

3. LERRD Owned by Non-Federal Sponsor: The City of St. Joseph owns fee over approximately 3.1 acres along the project area in parcel numbers 152 and 153. These lands are available for the project but not sufficient to cover all improvements, so additional acquisition is necessary.

4. Existing Federal Project in area: There are no Federal Projects in the proposed project area.

5. Non-Standard Estates: No non-standard estates will be proposed for this project area.

6. Federally Owned Land in Project Area: There is no federally owned land in the project area.

7. Navigational Servitude: The Federal Navigational Servitude doctrine arises from two related components: navigation power which is derived from the commerce clause of the U.S. Constitution giving Congress regulatory power over navigable waters; and navigation servitude which provides that certain private property may be taken, without compensation to the landowner, if the taking is necessary

to exercise the navigation power. Private ownership of land below navigable or tidal waters is acquired and held subject to the dominant public right of navigation. This dominant public right may be exercised by Congress without giving rise to a compensable taking. Black Snake Creek is not navigable therefore exercise of Federal Navigational Servitude is not applicable to the project.

8. Real Estate Maps: Project maps are included as EXHIBIT A. Real Estate mapping depicts the project area, tract boundaries required to support the project, and significant utilities and facilities to be relocated. Exhibit A also shows lands where mitigation will take place.

9. Flooding Induced by Project: No takings analysis will be required and no flooding issues will affect the project based upon the acquisition of real estate interests in fee.

10. Baseline Cost Estimate on Acquisition of LERRD:

TABLE 10.1 - Baseline Cost Estimate	
Type of Costs	**Total Costs**
Land Acquisition Costs	
Temporary Construction Easement	$51,000.00
Fee Simple for Project Structures	$296,242.00
Fee Simple for Mitigation lands	$120,445.00
Utility Easement (Permanent)	$30,591.00
Total Real Estate Acquisition Costs	$498,278.00
25% Contingency	$124,569.50
Total Real Estate Acquisition Costs w/ Contingency	**$622,847.50**
Utility/Facility Relocation Costs	
Utility Relocation	$0.00
Total Utility/Facility Relocation w/ Contingency	**$0.00**
LERRD Administrative Costs	
Non-Federal Sponsor Incidental Costs	$564,100.00
Federal Incidental Costs	$10,000.00
Total Incidental Costs	$574,100.00
15% Contingency	$86,115.00
Total Incidental Costs w/ Contingency	**$660,215.00**
Total LERRDS Costs for Project	**$1,283,062.5**

11. Relocation Assistance (P.L. 91-646): The non-federal sponsor has been provided information on P.L. 91-646 and is aware of the obligation to ensure compliance. There are no structures identified for relocation. No persons, businesses or farms shall be displaced.

12. Mineral Activity Impacted Present/Future: There is no current or anticipated mineral activity or timber value impact in the vicinity of the proposed project.

13. Assessment of Non-Federal Sponsor Legal Capability: The Corps has worked with the non-federal sponsor to complete the Assessment of the Non-Federal Sponsor's Real Estate Acquisition Capabilities Checklist, See Exhibit "C'. The non-federal sponsor has the legal authority to acquire and hold title to real property and condemnation authority and is fully capable of contracting for all real estate needs for the project. The sponsor will not require USACE assistance with acquiring real estate. Financial capability is addressed in the main report.

14. Zoning Ordinances Considered in Support of LERRD Requirements: There are no zoning ordinances proposed in connection with the project.

15. Reasonable, Detailed, & Coordinated Timeline for LERRD Acquisition: The project sponsor is responsible for acquiring real estate interests required for the project. The final time frame for land acquisition for the area will be determined once PPA has been executed. The Project Manager and Real Estate Division will finalize the milestone schedule upon project approval to meet dates for advertisement and award of a construction contract.

16. Facility/Utility Relocation: Though there are known utilities, none have provided proof of a compensable interest in the property. This report is done under the assumption the utility relocations will be done at no cost to the project. The NFS is in agreement with this assumption and the risk associated with the unknown of this cost has been identified within the Cost Risk Analysis.

ANY CONCLUSION OR CATEGORIZATION CONTAINED IN THIS REAL ESTATE PLAN, OR ELSEWHERE IN THIS PROJECT REPORT, THAT AN ITEM IS A UTILITY OR FACILITY RELOCATION TO BE PERFORMED BY THE NON-FEDERAL SPONSOR AS PART OF ITS LERRD RESPONSIBILITIES IS PRELIMINARY ONLY. THE GOVERNMENT WILL MAKE A FINAL DETERMINATION OF THE RELOCATIONS NECESSARY FOR THE CONSTRUCTION, OPERATION, OR MAINTENANCE OF THE PROJECT AFTER FURTHER ANALYSIS AND COMPLETION AND APPROVAL OF FINAL ATTORNEY'S OPINIONS OF COMPENSABILITY FOR EACH OF THE IMPACTED UTILITIES AND FACILITIES.

17. Impact of HTRW: There are no known HTRW issues that will impact this project. A Phase I Environmental Assessment was completed in March 2004.

18. Opposition/Support of Project by Local Landowners: The Corps of Engineers is not aware of any public opposition to this project at this time. All comments received during the public review period for the Draft Report will be added to the Public Involvement Appendix of the Final Report. Corrective actions or reconsiderations of alternatives will be implemented as needed based upon the comments received.

19. Notification to Non-Federal Sponsor of Early Acquisition of LERRD: As project alternatives are clearly selected, the non-federal sponsor will be issued a risk letter explaining the risk of acquiring lands prior the execution of the PCA and be advised to wait on coordination of the acquisition plan and notice to proceed with acquisition.

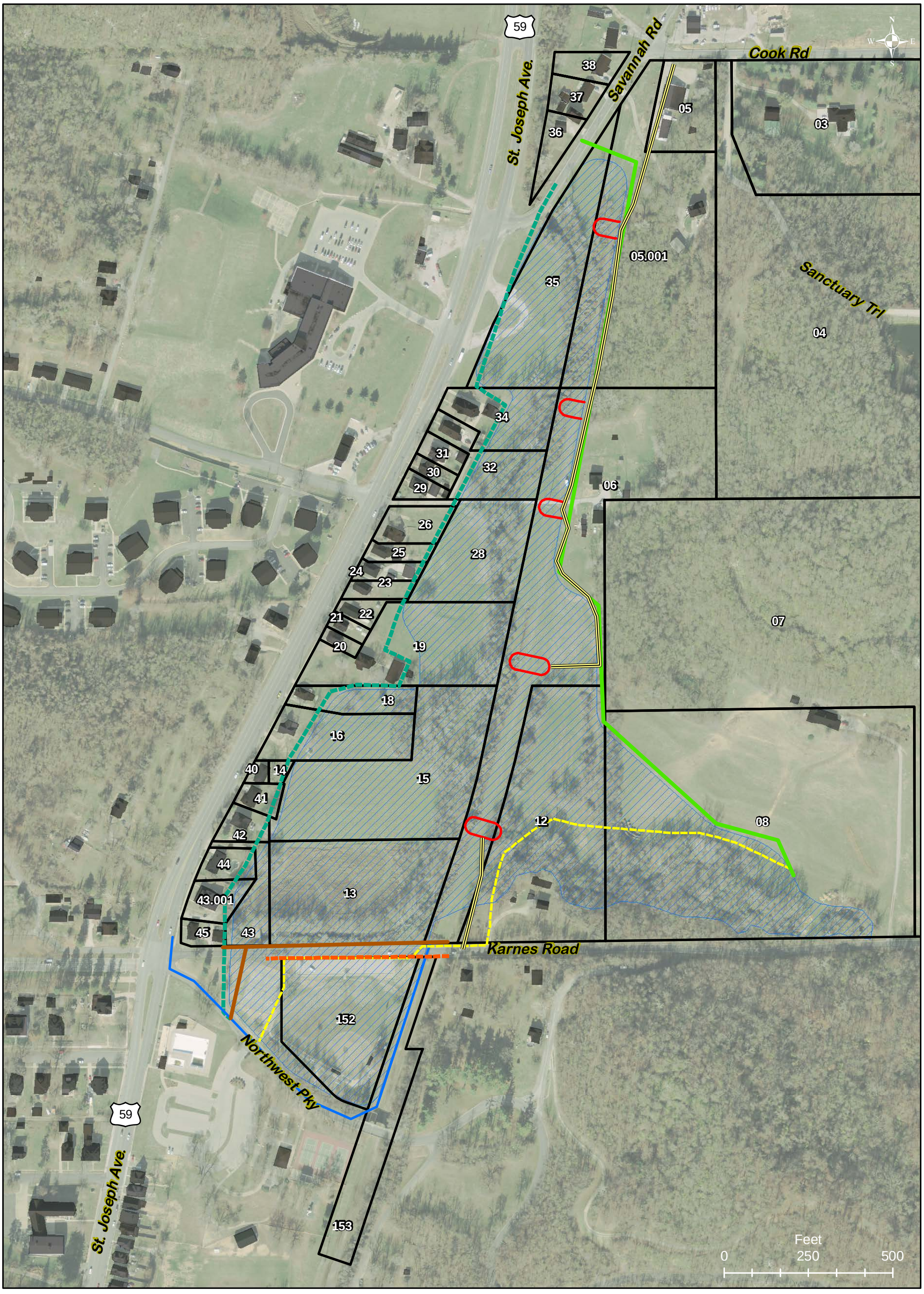
20. All other Real Estate Issues: There is a possibility of discovering unknown utilities and HTRW issues during construction. No other Real Estate issues are known at this time.

Prepared by Meredith Harmon
April 2015

REAL ESTATE PLAN (REP)
BLACKSNAKE CREEK
FLOOD DAMAGE REDUCTION PROJECT
BUCHANAN COUNTY, MISSOURI

PROJECT MAPS

EXHIBIT A



Black Snake Creek: St. Joseph, MO
Proposed Utility Changes
Data: CDM 2013

Note: Parcel data provided by Buchanan County GIS departemnt (September 2012). Easments derivived from CDM Survey Report 2012.

- Access Road
- Comm Line to Bury
- East Sanitary Sewer Allignment
- Electrical Line Demo
- Electric Pads
- Gas Line Mods
- Proposed AT&T Reroute
- San Sewer Alignments
- Parcels
- Building Footprint
- Detention Basin

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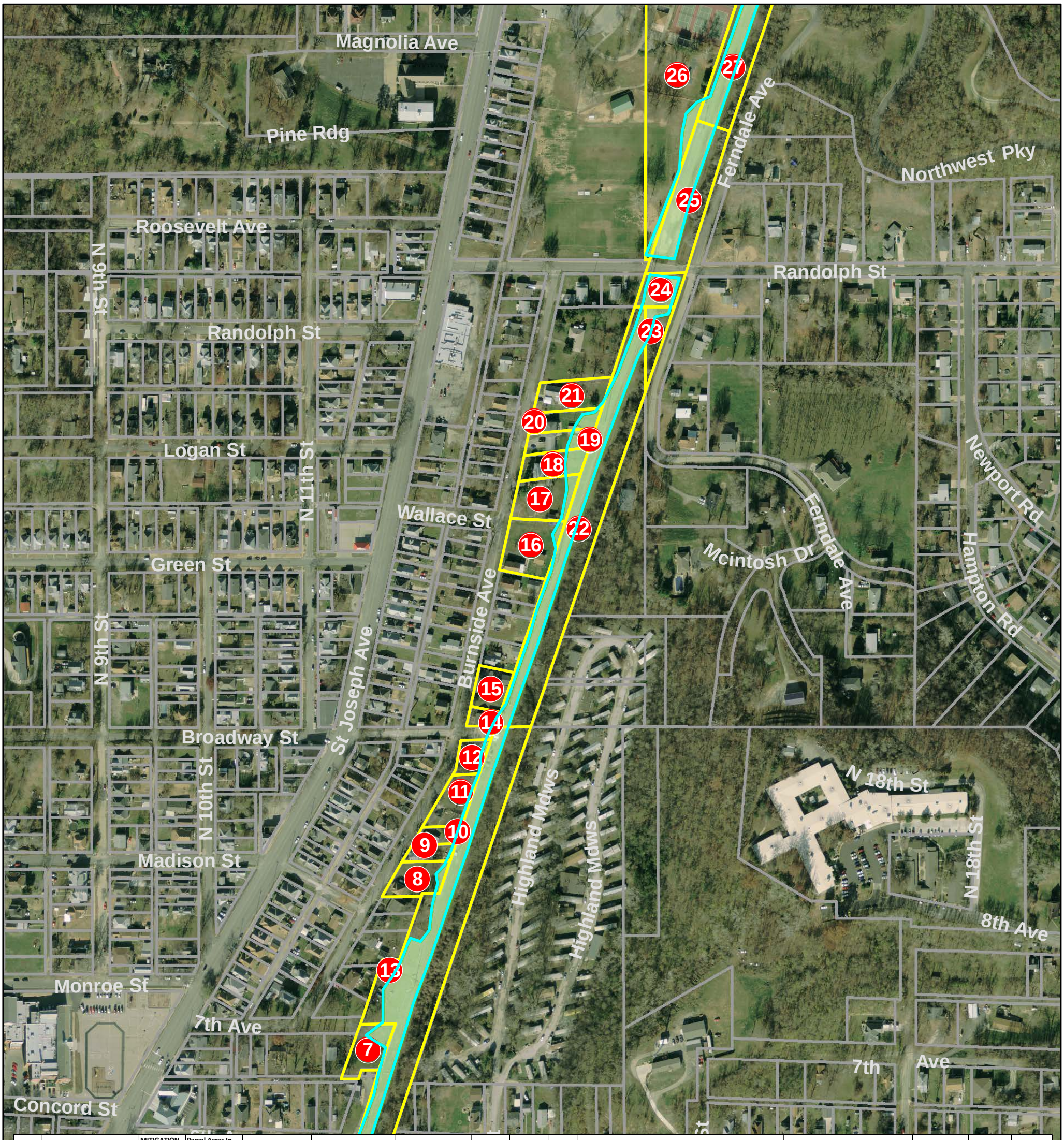


MAP_ID	MITIGATION_AREA	MITIGATION_ ACRES	Parcel Acres In Mitigation Area	TOTAL PARCEL ACRES	PARCEL_ID	SITUSADDRE	SITUS_CITY	SITUS_STAT	SITE_ZIP	NAME1	MAILTO_ADD	MAILTO_CIT	MAILTO_STA	MAILTO_ZIP
7	Blacksnake Potential Area 2	3.38	0.08	0.33	06-3.0-05-001-002-057.000	4502 SAVANNAH RD	ST JOSEPH	MO	64505	KCP&L GREATER MISSOURI OPERATIONS CO PROPERTY TAX DEPT	PO BOX 418679	KANSAS CITY	MO	641419679
8	Blacksnake Potential Area 2	3.38	0.04	0.33	06-3.0-05-001-002-007.000	4426 SAVANNAH RD	ST JOSEPH	MO	64505	CORNELIUS RONALD	5107 SAVANNAH RD	ST JOSEPH	MO	64505
9	Blacksnake Potential Area 2	3.38	0.01	0.15	06-3.0-05-001-002-006.000	4713 ST JOSEPH AVE	ST JOSEPH	MO	64505	PEARL HOLDINGS LLC	17616 S MILLER RD	BELTON	MO	64012
10	Blacksnake Potential Area 2	3.38	0.01	0.14	06-3.0-05-001-002-005.000	4504 SAVANNAH RD	ST JOSEPH	MO	64505	CORNELIUS RONALD	5107 SAVANNAH RD	ST JOSEPH	MO	64505
11	Blacksnake Potential Area 2	3.38	0.02	0.32	06-3.0-05-001-002-002.000	515 MIDDLETON ST	ST JOSEPH	MO	64505	CHAMBERLIN GORDON F TRUST	PO BOX 7578	MISSION HILLS	CA	913467578
12	Blacksnake Potential Area 2	3.38	0.02	0.18	06-3.0-05-001-002-001.000	RICHARDSON ST	ST JOSEPH	MO	64505	O MEARA WILLIAM K	3308 S LEONARD RD	ST JOSEPH	MO	64503
13	Blacksnake Potential Area 2	3.38	1.51	6.85	06-3.0-05-001-001-092.000	607 RICHARDSON ST	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
14	Blacksnake Potential Area 2	3.38	0.01	0.10	03-9.0-32-004-002-004.000	MAPLE LEAF WALKWAY	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
15	Blacksnake Potential Area 2	3.38	0.00	0.26	03-9.0-32-004-002-005.000	615 JEFFERSON ST	ST JOSEPH	MO	64505	MC CORMICK PATRICK	3213 ARBOR LAKE DR	ST JOSEPH	MO	64506
16	Blacksnake Potential Area 2	3.38	0.03	0.54	03-9.0-32-004-002-012.000	2015 ST JOSEPH AVE	ST JOSEPH	MO	64505	DANNAR SUSIE A TRUST/TRUSTEE	3710 MEADOW OAK LN	ST JOSEPH	MO	64503
17	Blacksnake Potential Area 2	3.38	0.07	0.46	03-9.0-32-004-001-207.000	MAPLE LEAF WALKWAY	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
18	Blacksnake Potential Area 2	3.38	0.09	0.31	03-9.0-32-004-001-206.000	7TH AVE	ST JOSEPH	MO	64505	REYNOLDS JERRY FRANKLIN	2913 BURNSIDE AVE	ST JOSEPH	MO	64505
19	Blacksnake Potential Area 2	3.38	0.08	0.24	03-9.0-32-004-001-205.000	3005 BURNSIDE AVE	ST JOSEPH	MO	64505	EVERHART LARRY ALLEN LE	EVERHART,D L;ARN,D L;EVERHART,D L JT	ST JOSEPH	MO	64505
20	Blacksnake Potential Area 2	3.38	0.06	0.26	03-9.0-32-004-001-204.000	3015 BURNSIDE AVE	ST JOSEPH	MO	64505	KAPP HOMES LLC	14505 WOODSON ST	OVERLAND PARK	KS	66223
21	Blacksnake Potential Area 2	3.38	0.00	0.40	03-9.0-32-004-001-203.000	3017 BURNSIDE AVE	ST JOSEPH	MO	64505	LONGORIA ALFREDO & MARY	4318 S STONECREST CIR	ST JOSEPH	MO	64506
22	Blacksnake Potential Area 2	3.38	1.01	2.67	03-9.0-32-004-002-184.000	3019 BURNSIDE AVE	ST JOSEPH	MO	64505	PEARL TERI LEE; INGERSOLL, KELLI ANN	3001 BURNSIDE AVE	ST JOSEPH	MO	64505
23	Blacksnake Potential Area 2	3.38	0.07	0.23	03-8.0-33-003-000-155.000	3029 BURNSIDE AVE	ST JOSEPH	MO	64505	HIHATH RICK	20932 COUNTY RD 386	ST JOSEPH	MO	64505
24	Blacksnake Potential Area 2	3.38	0.17	0.25	03-8.0-33-003-000-153.001	MAPLE LEAF WALKWAY	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
25	Blacksnake Potential Area 1	1.08	0.53	1.06	03-8.0-33-003-000-154.000	3101 BURNSIDE AVE	ST JOSEPH	MO	64505	MC CLAIN SANDRA	3101 BURNSIDE AVE	ST JOSEPH	MO	64505
26	Blacksnake Potential Area 1	1.08	0.16	2.65	03-8.0-33-003-000-151.000	3109 BURNSIDE AVE	ST JOSEPH	MO	64505	NASH GEORGE L & NASH DAVID L JT	9680 SE 28 RD	ST JOSEPH	MO	64507
27	Blacksnake Potential Area 1	1.08	0.39	1.79	03-8.0-33-003-000-153.000	3127 BURNSIDE AVE	ST JOSEPH	MO	64505	PRYOR ROBERT L & WF MARY G	3127 BURNSIDE AVE	ST JOSEPH	MO	64505

BLACKSNAKE CREEK: POTENTIAL MITIGATION AREAS: 1 & 2

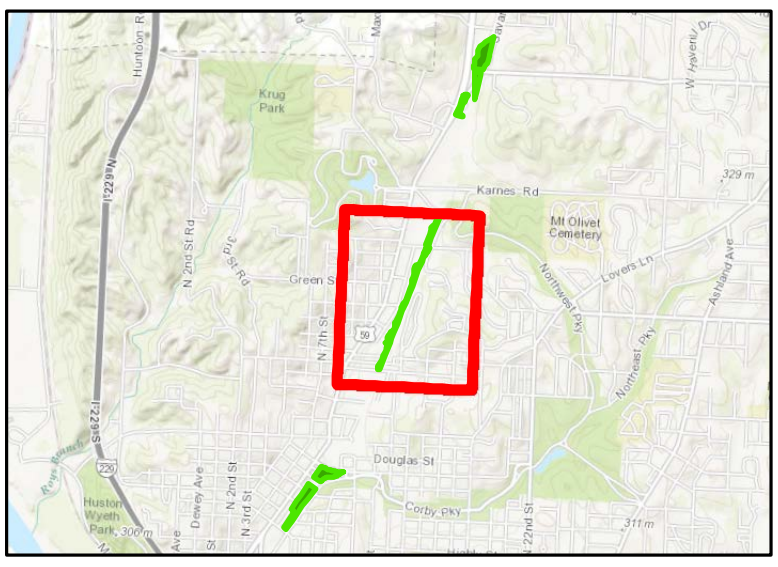
Parcels

Potential Mitigation Areas

Feet

0 375 750 1,500

N W E S



MAP_ID	MITIGATION_AREA	MITIGATION_ ACRES	Parcel Acres In Mitigation Area	TOTAL PARCEL ACRES	PARCEL_ID	SITUSADDRE	SITUS_CITY	SITUS_STAT	SITE_ZIP	NAME1	MAILTO_ADD	MAILTO_CIT	MAILTO_STA	MAILTO_ZIP
0	Blacksnake Potential Area 4	3.62	0.02	0.96	06-3.0-05-003-003-101.000	4209 ST JOSEPH AVE	ST JOSEPH	MO	64505	FLEEMAN RENEE A	4209 ST JOSEPH AVE	ST JOSEPH	MO	64505
1	Blacksnake Potential Area 4	3.62	0.15	0.19	06-3.0-05-003-003-099.000	4215 SAVANNAH RD	ST JOSEPH	MO	64505	HAENNI RANDALL V & MARY ANN	14163 CO RD 339	SAVANNAH	MO	64485
2	Blacksnake Potential Area 4	3.62	0.09	0.11	06-3.0-05-004-002-098.000	4215 SAVANNAH RD	ST JOSEPH	MO	64505	HAENNI RANDALL V & MARY ANN	14163 CO RD 339	SAVANNAH	MO	64485
3	Blacksnake Potential Area 4	3.62	3.30	3.76	06-3.0-05-004-002-103.000	4400 SAVANNAH RD	ST JOSEPH	MO	64505	GRIMM JACK & LUCY	4400 SAVANNAH RD	ST JOSEPH	MO	64505
4	Blacksnake Potential Area 3	2.29	0.39	0.48	06-3.0-05-004-002-099.000	4420 SAVANNAH RD	ST JOSEPH	MO	64505	CATON ALBERT B & JOYCE SUE	4420 SAVANNAH RD	ST JOSEPH	MO	64505
5	Blacksnake Potential Area 3	2.29	0.31	0.33	06-3.0-05-004-002-100.000	4421 SAVANNAH RD	ST JOSEPH	MO	64505	PAULMAN KIRBY I & JANICE K	4421 SAVANNAH RD	ST JOSEPH	MO	64505
6	Blacksnake Potential Area 3	2.29	0.61	0.63	06-3.0-05-004-002-102.000	4422 SAVANNAH RD	ST JOSEPH	MO	64505	CATON ALBERT B & JOYCE SUE	4420 SAVANNAH RD	ST JOSEPH	MO	64505
7	Blacksnake Potential Area 2	3.38	0.08	0.33	06-3.0-05-001-002-057.000	4502 SAVANNAH RD	ST JOSEPH	MO	64505	KCP&L GREATER MISSOURI OPERATIONS CO PROPERTY TAX DEPT	PO BOX 418679	KANSAS CITY	MO	641419679

BLACKSNAKE CREEK: POTENTIAL MITIGATION AREAS: 3 & 4

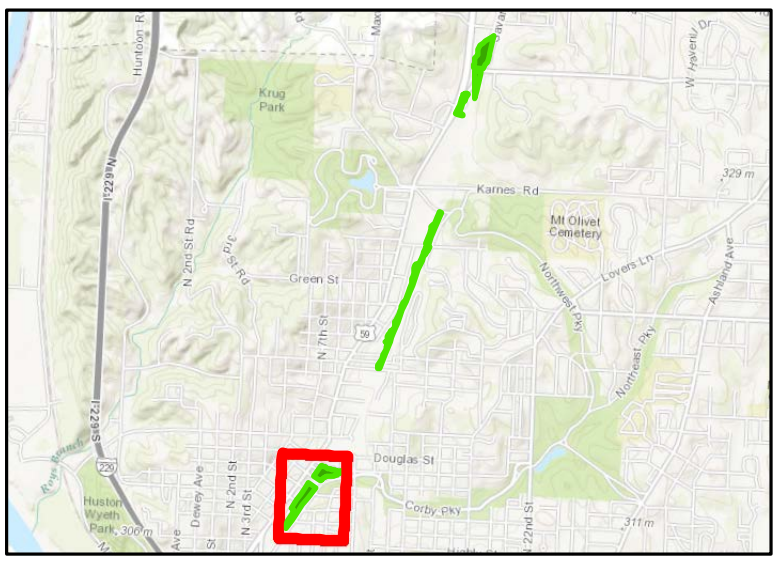
Parcels

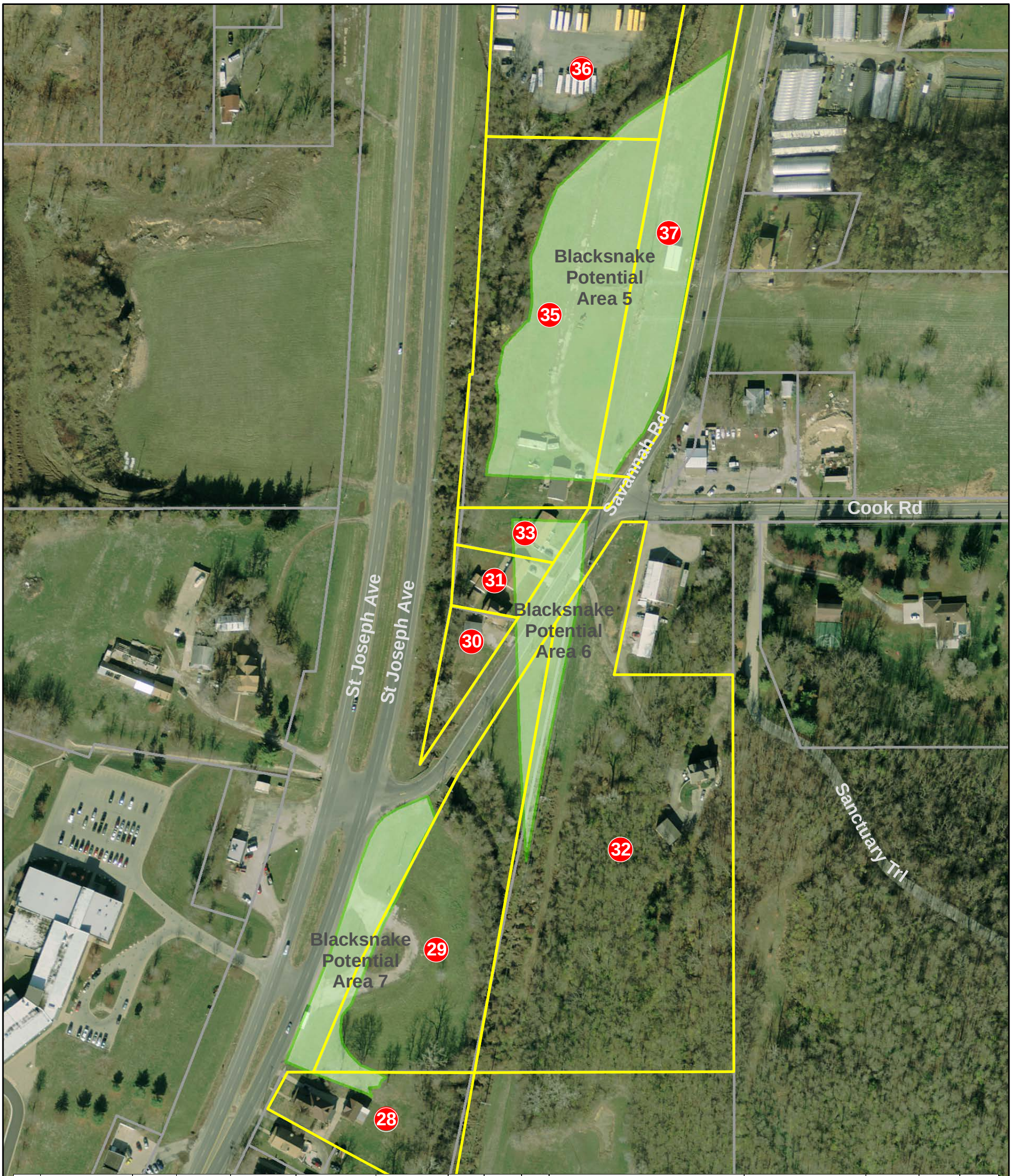
Potential Mitigation Areas

Feet

0 125 250 500

N W E S





MAP_ID	MITIGATION_AREA	MITIGATION_ ACRES	Parcel Acres In Mitigation Area	TOTAL PARCEL ACRES	PARCEL_ID	SITUSADDRE	SITUS_CITY	SITUS_STAT	SITE_ZIP	NAME1	MAILTO_ADD	MAILTO_CIT	MAILTO_STA	MAILTO_ZIP
28	Blacksnake Potential Area 7	0.98	0.06	1.21	03-8.0-33-002-000-034.000	3301 BURNSIDE AVE	ST JOSEPH	MO	64505	MORRIS MARION A & JUDITH ANN	13701 SYCAMORE	OLATHE	KS	66062
29	Blacksnake Potential Area 7	0.98	0.15	2.92	03-8.0-33-002-000-035.000	3303 BURNSIDE AVE	ST JOSEPH	MO	64505	JONES JAMES C	3303 BURNSIDE	ST JOSEPH	MO	64505
29	Blacksnake Potential Area 6	0.98	0.18	2.92	03-8.0-33-002-000-035.000	BURNSIDE AVE	ST JOSEPH	MO	64505	HALCOMB JANICE L	3313 BURNSIDE AVE	ST JOSEPH	MO	64505
30	Blacksnake Potential Area 6	0.98	0.00	0.39	03-8.0-33-002-000-036.000	3313 BURNSIDE AVE	ST JOSEPH	MO	64505	HALCOMB JANICE L	3313 BURNSIDE AVE	ST JOSEPH	MO	64505
31	Blacksnake Potential Area 6	0.98	0.09	0.36	03-8.0-33-002-000-037.000	3317 BURNSIDE AVE	ST JOSEPH	MO	64505	MC GEORGE JENNIFER	3317 BURNSIDE AVE	ST JOSEPH	MO	64505
32	Blacksnake Potential Area 6	0.98	0.25	6.92	03-8.0-33-002-000-005.001	MAPLE LEAF WALKWAY	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
33	Blacksnake Potential Area 6	0.98	0.15	0.39	03-8.0-33-002-000-038.000	MAPLE LEAF WALKWAY	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
34	Blacksnake Potential Area 5	4.03	0.01	0.06	03-8.0-28-003-001-114.002	1318 RANDOLPH ST	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
35	Blacksnake Potential Area 5	4.03	2.45	3.97	03-8.0-28-003-002-066.000	MAPLE LEAF WALKWAY	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
36	Blacksnake Potential Area 5	4.03	0.09	4.61	03-8.0-28-003-002-065.000	FERNDALE AVE	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501
37	Blacksnake Potential Area 5	4.03	1.49	4.40	03-8.0-28-003-001-114.001	1502 KARNES RD	ST JOSEPH	MO	64505	CITY OF ST JOSEPH	1100 FREDERICK AVE	ST JOSEPH	MO	64501

BLACKSNAKE CREEK: POTENTIAL MITIGATION AREAS: 5,6,& 7

Parcels

Potential Mitigation Areas

Feet

0 125 250 500

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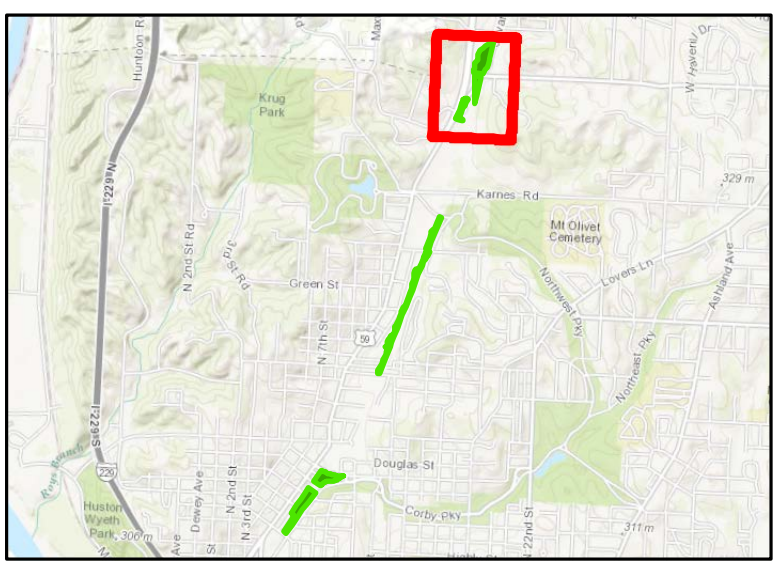

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REAL ESTATE PLAN (REP)
BLACKSNAKE CREEK
FLOOD DAMAGE REDUCTION PROJECT
BUCHANAN COUNTY, MISSOURI

PARCEL OWNERSHIP

EXHIBIT B

Project Footprint Areas

Parcel #	Address	Name	ACRES	Type	Easment	Fee	Temp	Utility
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.112	P	Sewer			0.112
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.334	P	Gas			0.334
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.000	P	Electrical/Sewer			0.000
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.193	P	Sewer			0.193
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.198	P	Gas			0.198
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	4.748	P	Fee	4.748		
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.196	P	Gas			0.196
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	1.050	P	Electrical			1.050
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.260	P	Electrical			0.260
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.673	P	Ingress/Egress			
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.061	P	Electrical			0.061
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.317	P	Electrical/Sewer			0.317
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.260	P	Electrical/Sewer			0.260
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.017	P	Sewer			0.017
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.091	P	Sewer			0.091
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	0.223	P	Ingress/Egress			
012.000	1601 KARNES RD	BUTRICK JOHN F & BUTRICK FRANCIS A	4.049	P	Fee	4.049		
015.000	3903 ST JOSEPH AVE	KLENK VERNON LEE & WF DONNA JUNE	4.118	P	Fee	4.118		
013.000	1502 KARNES RD	ANWAR SOHAIL	0.545	P	Ingress/Egress			
013.000	1502 KARNES RD	ANWAR SOHAIL	0.152	P	Sewer			0.152
013.000	1502 KARNES RD	ANWAR SOHAIL	3.612	P	Fee	3.612		
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.213	P	Ingress/Egress			
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.100	P	Sewer			0.100
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.008	P	Sewer			0.008
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.073	P	Sewer			0.073
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.019	P	Sewer			0.019
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.091	T	Construction		0.091	
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.557	P	Ingress/Egress			
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.027	P	Electrical			0.027
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.025	P	Sewer			0.025
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.992	P	Electrical/Sewer			0.992
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.428	P	Electrical/Sewer			0.428
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.114	P	Sewer			0.114
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.141	P	Ingress/Egress			
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.089	P	Sewer			0.089
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.343	P	Ingress/Egress			
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.050	P	Sewer			0.050
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.535	P	Ingress/Egress			
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	4.457	P	Fee	4.457		
026.000	4125 ST JOSEPH AVE	GMAC MORTGAGE LLC	0.007	P	Fee	0.007		
025.000	4119 ST JOSEPH AVE	ADAMS DAVID B & NICHOLE DEANN	0.003	P	Fee	0.003		
024.000	4115 ST JOSEPH AVE	BURTON JODY LEE	0.004	P	Driveway			
024.000	4115 ST JOSEPH AVE	BURTON JODY LEE	0.003	P	Fee	0.003		
023.000	4111 ST JOSEPH AVE	OROZCO JOHN & BERNARD KAREN	0.003	P	Fee	0.003		

028.000	4200 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.023	P	Driveway			
028.000	4200 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.069	P	Sewer			0.069
028.000	4200 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	1.898	P	Fee	1.898		
022.000	4107 ST JOSEPH AVE	MOON DORIS J	0.001	P	Fee	0.001		
019.000	4101 ST JOSEPH AVE	EVANS DANNY W & WF LOIS E	1.562	P	Fee	1.562		
018.000	4007 ST JOSEPH AVE	HAYNES FRANCES L	0.405	P	Fee	0.405		
016.000	4003 ST JOSEPH AVE	WATTENBARGER CURT E	0.975	P	Fee	0.975		
043.000	3901 A ST JOSEPH AVE	ANWAR SOHAIL	0.493	P	Fee	0.493		
042.000	3903 ST JOSEPH AVE	KLENK VERNON LEE & WF DONNA JUNE	0.000	P	Fee	0.000		
043.001	3809 ST JOSEPH AVE	HALL G MAX & CAROLYN A	0.058	P	Fee	0.058		
044.000	3901 ST JOSEPH AVE	MAAG JAMES T & WF DIANA LEA	0.024	P	Fee	0.024		
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.045	P	Sewer			0.045
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.140	P	Electrical/Sewer			0.140
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.140	P	Electrical/Sewer			0.140
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.209	P	Sewer			0.209
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.882	P	Electrical			0.882
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.192	P	Ingress/Egress			
005.001	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	1.112	P	Fee	1.112		
035.000	4215 SAVANNAH RD	HAENNI RANDALL V & MARY ANN	2.870	P	Fee	2.870		
034.000	4209 ST JOSEPH AVE	FLEEMAN RENEE A	0.665	P	Fee	0.665		
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.039	P	Sewer			0.039
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.003	P	Sewer			0.003
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.031	P	Sewer			0.031
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.003	P	Sewer			0.003
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.021	P	Culvert/Ditch			0.021
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.032	T	Construction		0.032	
032.000	4207 ST JOSEPH AVE	HEBERT REBA M & SHANE R	0.682	P	Fee	0.682		
152.000	KARNES RD	CITY OF ST JOSEPH	2.932	P	Fee	2.932		
153.00	1502 KARNES RD	CITY OF ST JOSEPH	0.173	P	Fee	0.173		
005.000	1814 COOK RD	PAULMAN KIRBY I & JANICE K	0.001	P	Sewer			0.001
005.000	1814 COOK RD	PAULMAN KIRBY I & JANICE K	0.354	P	Electrical			0.354
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.010	P	Gas			0.010
008.000	2001 KARNES RD	ARCHDEKIN JERRY L & JOY C/O JARRETT	0.010	P	Sewer			0.010
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.029	P	Sewer			0.029
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.029	P	Ingress/Egress			
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.024	P	Electrical			0.024
006.000	4133 ST JOSEPH AVE	JUMPS DONALD E & PAMELA G	0.024	P	Ingress/Egress			0.024
		Totals				**34.852**	**0.122**	**7.198**
		Total of Permenant and Temporary Easements*						**42.172**

ne of acres may "Overlap" on the Flowage Easement. For purposes of this report, they are considered to be in addition to other Flowage Easem

Mitigation Area

MAP_ID	Address	NAME	Parcel Acres for Mitigation
0	4209 ST JOSEPH AVE	FLEEMAN RENEE A	0.02
1	4215 SAVANNAH RD	HAENNI RANDALL V & MARY ANN	0.15
2	4215 SAVANNAH RD	HAENNI RANDALL V & MARY ANN	0.09
3	4400 SAVANNAH RD	GRIMM JACK & LUCY	3.30
4	4420 SAVANNAH RD	CATON ALBERT B & JOYCE SUE	0.39
5	4421 SAVANNAH RD	PAULMAN KIRBY I & JANICE K	0.31
6	4422 SAVANNAH RD	CATON ALBERT B & JOYCE SUE	0.61
7	4502 SAVANNAH RD	KCP&L GREATER MISSOURI OPERATIONS CO PROPERTY TAX DEPT	0.08
8	4426 SAVANNAH RD	CORNELIUS RONALD	0.04
9	4713 ST JOSEPH AVE	PEARL HOLDINGS LLC	0.01
10	4504 SAVANNAH RD	CORNELIUS RONALD	0.01
11	515 MIDDLETON ST	CHAMBERLIN GORDON F TRUST	0.02
12	RICHARDSON ST	O MEARA WILLIAM K	0.02
13	607 RICHARDSON ST	CITY OF ST JOSEPH	1.51
14	MAPLE LEAF WALKWAY	CITY OF ST JOSEPH	0.01
15	615 JEFFERSON ST	MC CORMICK PATRICK	0.00
16	2015 ST JOSEPH AVE	DANNAR SUSIE A TRUST/TRUSTEE	0.03
17	MAPLE LEAF WALKWAY	CITY OF ST JOSEPH	0.07
18	7TH AVE	REYNOLDS JERRY FRANKLIN	0.09
19	3005 BURNSIDE AVE	EVERHART LARRY ALLEN LE	0.08
20	3015 BURNSIDE AVE	KAPP HOMES LLC	0.06
21	3017 BURNSIDE AVE	LONGORIA ALFREDO & MARY	0.00
22	3019 BURNSIDE AVE	PEARL TERI LEE; INGERSOLL, KELLI ANN	1.01
23	3029 BURNSIDE AVE	HIHATH RICK	0.07
24	MAPLE LEAF WALKWAY	CITY OF ST JOSEPH	0.17
25	3101 BURNSIDE AVE	MC CLAIN SANDRA	0.53
26	3109 BURNSIDE AVE	NASH GEORGE L & NASH DAVID L JT	0.16
27	3127 BURNSIDE AVE	PRYOR ROBERT L & WF MARY G	0.39
28	3301 BURNSIDE AVE	MORRIS MARION A & JUDITH ANN	0.06
29	3303 BURNSIDE AVE	JONES JAMES C	0.15
29	BURNSIDE AVE	HALCOMB JANICE L	0.18
30	3313 BURNSIDE AVE	HALCOMB JANICE L	0.00
31	3317 BURNSIDE AVE	MC GEORGE JENNIFER	0.09
32	MAPLE LEAF WALKWAY	CITY OF ST JOSEPH	0.25
33	MAPLE LEAF WALKWAY	CITY OF ST JOSEPH	0.15
34	1318 RANDOLPH ST	CITY OF ST JOSEPH	0.01
35	MAPLE LEAF WALKWAY	CITY OF ST JOSEPH	2.45
36	FERNDALE AVE	CITY OF ST JOSEPH	0.09
37	1502 KARNES RD	CITY OF ST JOSEPH	1.49
		Total:	14.17

REAL ESTATE PLAN (REP)
BLACKSNAKE CREEK
FLOOD DAMAGE REDUCTION PROJECT
BUCHANAN COUNTY, MISSOURI

ASSESSMENT OF NON-FEDERAL SPONSOR
REAL ESTATE ACQUISITION CAPABILITY

EXHIBIT C

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE ACQUISITION CAPABILITY

BLACKSNAKE CREEK
SECTION 205
FLOOD DAMAGE REDUCTION PROJECT
BUCHANAN COUNTY, MISSOURI

I. Legal Authority:

a. Does the sponsor have the legal authority to acquire and hold title to real property for project purposes? Yes

b. Does the sponsor have the power of eminent domain for this project? Yes

c. Does the sponsor have "quick take" authority for this project? No

d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? No

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? No

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirement of Federal projects including P.L. 91-646, as amended? No

b. If the answer to II.a. is "yes", has a reasonable plan been developed to provide such training? N/A

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? Yes

d. Is the sponsor's projected in-house staffing level sufficient considering its other workload, if any, and the project schedule? Yes

e. Can the sponsor obtain contractor support, if required, in a timely fashion? Yes

f. Will the sponsor likely request USACE assistance in acquiring real estate? No

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? Yes

b. Has the sponsor approved the project/real estate schedule/milestones? Not at this time. The project is currently in the Feasibility Phase. Coordination will be made with the sponsor once a final schedule is developed.

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? Yes

b. With regard to this project, the sponsor is anticipated to be (Highly, Fully, Moderate, Marginally capable). Fully capable

V. Coordination:

a. Has this assessment been coordinated with the sponsor? Yes

b. Does the sponsor concur with this assessment? Yes

Prepared by: _____
Daniel L. Marsh
Realty Specialist

Reviewed by: _____
Patty Richardson
RE-CM Team Leader

Approved by: _____ 7/16/13
Greg Wilson
Chief, Real Estate Division

APPENDIX H

Not used for this Report

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BLACKSNAKE CREEK FLOOD RISK MANAGEMENT PROJECT
MISSOURI RIVER BASIN
ST. JOSEPH, MISSOURI

APPENDIX I
SOCIOECONOMICS

1.0 INTRODUCTION

1.1 PURPOSE

This feasibility-level economic analysis provides a benefit-cost analysis of the proposed Blacksnake Creek flood risk management project. Demographic data and economic development background pertaining to the community are discussed, and the development of a complete structure inventory is discussed. The inventory serves as the basis for a risk-based analysis which evaluates flood damages in the study area on an annualized equivalent basis and calculates damage reduction project performance by simulating a large number of possible flood events, taking into account all pertinent economic and engineering data including uncertainty factors. This analysis results in several outputs:

- Description and quantification of economic and social flood damage impacts to properties within the study area in the existing condition;
- Statistical estimates of project engineering performance or reliability under existing conditions in the context of a range of possible flood events;
- Estimated economic performance of alternatives formulated to improve project performance, in terms of residual damages, damages prevented, annualized benefits and costs;
- Statistical estimates of enhanced project engineering performance provided by each alternative;
- Economic optimization of alternatives and identification of the most economically efficient alternative;
- Characterization of the selected plan in terms of economic performance (annual damages, benefits, costs and residual damages) and engineering performance (or assurance).

1.2 STUDY GUIDANCE

Pertinent guidance governing economic analysis procedures includes:

- Economic and Environmental Principles and Guidelines for Water and Related Resources Implementation Studies (P&G), dated March 1983;

- Engineering Regulation (ER) 1105-2-100, "Planning Guidance Notebook," dated 22 April 2000 (partially updated subsequently);

- Engineering Regulation (ER) 1105-2-101, Risk-Based Analysis for Flood Damage Reduction Studies, dated 3 January 2006

- Engineer Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, dated 1 August 1996.

- Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures With Basements, dated 10 October 2003.

- EGM 09-04, Generic Depth-Damage Relationships for Vehicles, dated 22 Jun 2009.

- Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies, New Orleans District, Corps of Engineers, May 1997.

- IWR Report 96-R-12, Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, Jack C. Kiefer and J. Scott Willett (Planning & Management Consultants Ltd., Carbondale IL), May 1996.

- Water Resources Development Act (WRDA) of 1990, Section 308.

2.0 STUDY AREA SETTING

2.1 LOCATION

St. Joseph is located in Buchanan County in northwestern Missouri, about 55 miles north of Kansas City, Missouri. The city is situated on the main stem of the Missouri River between river miles 452 and 445. Downtown St. Joseph is at mile 449.5.

Within this broad area, this analysis specifically is concerned with Blacksnake Creek, a tributary to the Missouri River. Blacksnake Creek originates in rural areas just north of the city limits in Andrew County and subsequently flows through the northwestern portion of St. Joseph to its mouth at the Missouri River (mile 449.1). The stream is an open channel above Karnes Road and runs initially through agricultural areas in Andrew County and then through mainly residential areas near the northern edge of St. Joseph. At Karnes Road the stream enters a combined sewer and continues downstream as a covered channel.

Along the 4.3-mile length of the portion of the creek located within the city limits of St. Joseph, Blacksnake generally parallels U.S. Highway 59 (known locally as St. Joseph Avenue) and is located just east of the busy commercial strip lining that street. The covered channel extends all the way to the mouth of the creek, which is located at the foot of Jules Street on the southern edge of downtown St. Joseph.

2.2 SOCIOECONOMIC CONTEXT

2.2.1 Demographic Data - St. Joseph had a population of 76,780 as of the 2010 Census, making it the eighth-largest city in Missouri. Demographic data for the city are displayed in Table I-1, which indicates that the 2010 population total represented an increase of 3.8% over the 2000 Census total of 73,990. Although population increased from 2000 to 2010, the increase was smaller than increases for the same period for Missouri (7.0%) and the U.S. (9.7%). Similarly, for the 20-year period from 1990 to 2010, the population of St. Joseph increased 6.9% - an increase, but well below the increases experienced for Missouri (17.0%) and the U.S. (24.1%) for this time period. The 2013 population estimate for the city had risen to 77,147 (American Community Survey).

The growth of population for Buchanan County overall and for the St. Joseph Metropolitan Statistical Area (MSA) was similar to that of the city. The county's population increased 3.7% from 2000 to 2010 and 7.4% from 1990 to 2010. The MSA, which covers four counties in Missouri and Kansas, had a 2010 population of 127,927, which represented an increase of 4.1% since 2000 and 9.9% since 1990.

In addition to the population data in Table I-1, a number of other points can be gleaned from that table as well as Tables I-2 (social data), which are based on 5-year averages from the American Community Survey. (Note that demographic data in other sections of this report, including the main report, are based on the 2010 Census figures rather than

these 5-year averages through 2012.) These tables indicate that the residents of St. Joseph city, in comparison to Missouri and the nation, are

- Somewhat younger, with a median age of 35.6 vs. 37.9 for Missouri and 37.2 for the U.S.;
- Significantly more likely to be white (88.3% vs. 83.1% for the state and 74.2% for the U.S.);
- Less likely to be Hispanic than the nation (5.7% vs. 16.4%) but more than the state (3.5%);
- Slightly less educated in terms of the number of high school graduates (84.4% vs. 87.2% for Missouri and 85.7% for the U.S.), and significantly less educated in terms of those with bachelor degree or higher (20.4% vs. 25.8% and 28.5%);
- Somewhat more likely to be disabled (4.5% of under 18 and 42.7% of over 65, vs. 4.7% and 38.5% for the state and 4.0% and 36.8% for the nation);
- Much more likely to be natives of the U.S. (96.4%) and to speak English at home (94.1%) than the nation (87.1% and 79.5%), but about the same as the state.

Additional data on housing and economics in St. Joseph are provided in Tables I-3 and I-4. Some points worth noting from these tables:

- Per capita income for St. Joseph ($21,440) is slightly lower than for Buchanan County ($22,184) and the St. Joseph MSA ($22,139), and significantly lower than for the state ($25,546) and the nation ($28,051). The same pattern holds true for median and mean household income and median and mean family income.
- A larger proportion of St. Joseph's residents (18.4%) were below the poverty line than in the state (15.0%) and the U.S. (14.9%).
- St. Joseph has a higher percentage of residents receiving food stamp benefits (16.1%) and cash public assistance (3.1%) than the MSA (13.1% and 2.6%), Missouri (13.1% and 2.4%), and the nation (11.4% and 2.7%).
- The city's unemployment rate of 8.6% was higher than the county's (8.0%) and slightly higher than the state's (8.5%), but lower than the U.S. rate of 9.3%.
- Housing stock in St. Joseph, of which 53.8% was built prior to 1960, is much older than for the state (31.5%) and the nation (30.3%).
- The average St. Joseph home value of $121,234 was significantly lower than the comparable values for the county ($135,418), the MSA ($138,872), and the state ($169,314), and was less than half the national value of $254,710. Median home values in the city also are similarly well behind those for the state and nation.

TABLE I-1 -- DEMOGRAPHIC DATA					
	St. Joseph, MO (city)	**Buchanan County MO**	**St. Joseph, MO-KS Metro Area**	**Missouri**	**U.S.**
POPULATION					
Total population (July 1, 2012 Census estimate)	77,176	89,706	127,927	6,024,552	313,873,685
Total population (2008-12 ACS)	76,729	89,162	127,176	5,982,413	309,138,720
Total population (2010 Census)	76,780	89,201	127,329	5,988,927	308,745,538
Total population (2000 Census)	73,990	85,998	122,336	5,595,211	281,421,906
% increase, 2000-2010	3.8%	3.7%	4.1%	7.0%	9.7%
Total population (1990 Census)	71,852	83,083	115,816	5,117,073	248,709,873
% increase, 1990-2010	6.9%	7.4%	9.9%	17.0%	24.1%
AGE (Universe: Total population)					
Median age in years	35.6	36.6	37.8	37.9	37.2
Under 18 years (%)	23.6	23.5	22.8	23.7	23.9
62 years and over (%)	16.7	16.9	17.4	17.3	16.3
SEX (In percent; universe: Total population)					
Male	49.9	49.9	51.2	49.0	49.2
Female	50.1	50.1	48.8	51.0	50.8
RACE (In percent; universe: Total population)					
One race	96.3	96.7	97.1	97.8	97.3
White alone	88.3	89.7	90.6	83.1	74.2
Black or African American	5.2	4.5	4.3	11.5	12.6
American Indian and Alaska Native	0.4	0.4	0.4	0.4	0.8
Asian	0.9	0.8	0.7	1.6	4.8
Native Hawaiian and Other Pacific Islander	0.2	0.2	0.1	0.1	0.2
Some other race	1.3	1.2	0.9	1.0	4.8
Two or more races	3.7	3.3	2.9	2.2	2.7
White (alone or in combination)	91.8	92.8	93.3	85.1	76.5
Black (alone or in combination)	7.5	6.5	5.9	12.5	13.6
American Indian (alone or in combination)	1.6	1.5	1.7	1.3	1.6
Asian (alone or in combination)	1.3	1.2	1.0	2.0	5.6
Native Hawaiian (alone or in combination)	0.3	0.3	0.2	0.2	0.4
Some other race (alone or in combination)	1.6	1.4	1.2	1.2	5.3
HISPANIC OR LATINO (ANY RACE) (Percent of total population)					
Hispanic or Latino of any race	5.7	5.3	4.2	3.5	16.4

Source: U.S. Census Bureau, American Community Survey (ACS), 5-year estimates 2008-2012, unless otherwise indicated

TABLE I-2 -- SOCIAL DATA					
	St. Joseph, MO (city)	Buchanan County MO	St. Joseph, MO-KS Metro Area	Missouri	U.S.
HOUSEHOLDS					
Total households	33,307	38,416	53,593	2,710,506	131,642,456
HOUSEHOLDS BY TYPE					
Family households (%)	60.9	63.2	64.9	65.5	66.5
Nonfamily households (%)	39.1	36.8	35.1	34.5	33.5
HHs with one or more people under 18 years	30.2	30.6	30.8	31.7	33.3
HHs with one or more people 65 years and over	25.0	25.3	26.3	25.1	24.9
Average household size	2.5	2.5	2.5	2.5	2.6
Average family size	3.2	3.2	3.1	3.0	3.2
PERSONS BY HOUSEHOLD TYPE / GROUP QUARTERS (Percent of total population)					
Living in family households	80.3	81.8	82.8	82.7	83.7
Living in nonfamily households	19.7	18.2	17.2	17.3	16.3
Living alone	32.7	30.9	29.7	28.7	27.5
Living in group quarters	5.3	4.5	6.5	2.9	2.6
EDUCATIONAL ATTAINMENT (Percent of population 25 years and older)					
High school graduate or higher	84.4	85.4	86.1	87.2	85.7
Bachelor degree or higher	20.4	20.3	19.1	25.8	28.5
Graduate degree or higher	7.2	6.9	6.6	9.6	10.6
DISABLED BY AGE (Percent of civilian noninstitutionalized population)					
Persons under 18 with a disability	4.5	4.2	4.7	4.7	4.0
Persons 65 and over with a disability	42.7	41.7	40.6	38.5	36.8
RESIDENCE 1 YEAR AGO (Percent of population 1 year and over)					
In same house 1 year ago	77.3	79.2	81.1	83.6	84.8
PLACE OF BIRTH AND CITIZENSHIP STATUS (Percent of total population)					
U.S. native	96.4	96.9	97.5	96.1	87.1
Foreign born	3.6	3.1	2.5	3.9	12.9
FOREIGN BORN - WORLD REGION OF BIRTH (Percent of foreign-born population)					
Europe	10.8	11.3	13.6	21.8	12.1
Asia	20.7	21.0	21.6	36.0	28.5
Africa	20.0	19.7	17.3	7.9	4.0
Oceania	1.1	1.1	2.0	1.5	0.6
Latin and Central America (includes Mexico)	44.8	44.2	43.1	30.3	52.8
Northern America	2.5	2.7	2.5	2.6	2.1
LANGUAGE SPOKEN AT HOME (Percent of population 5 years and over)					
English only	94.1	94.7	95.6	93.9	79.5

Source: U.S. Census Bureau, American Community Survey (ACS), 5-year estimates 2008-2012

TABLE I-3 -- ECONOMIC DATA					
	St. Joseph, MO (city)	Buchanan County MO	St. Joseph, MO-KS Metro Area	Missouri	U.S.
INCOME					
Median household income	$42,248	$44,181	$45,717	$47,333	$53,046
Mean household income	$53,829	$56,325	$57,286	$63,405	$73,034
Median family income	$53,416	$55,952	$57,576	$59,395	$64,585
Mean family income	$65,212	$67,614	$68,331	$75,484	$85,065
Per-capita income	$21,440	$22,184	$22,139	$25,546	$28,051
Households with food stamp benefits (%)	16.1	15.1	13.1	13.1	11.4
Households with cash public assistance (%)	3.1	2.9	2.6	2.4	2.7
Households with income =/> $200,000 (%)	1.2	1.4	1.4	2.8	4.6
Family HHs with income =/> $200,000 (%)	1.8	2.0	1.9	3.8	6.0
POVERTY STATUS OVER THE LAST 12 MONTHS (Percent of persons for whom poverty status is determined)					
Persons below poverty level	18.4	16.5	14.3	15.0	14.9
Persons under 18 in poverty	25.8	22.7	19.4	20.9	20.8
Persons over 65 in poverty	9.2	8.7	8.7	8.9	9.4
EMPLOYMENT STATUS (Percent of population 16 years and over)					
Civilians employed	91.4	92.0	92.6	91.5	90.7
Civilians unemployed	8.6	8.0	7.4	8.5	9.3
In military	0.2	0.2	0.2	0.4	0.5
COMMUTING TO WORK (Workers 16 years and over)					
Mean travel time to work (minutes)	16.4	17.5	19.1	23.2	25.4
WORKERS BY OCCUPATION (Percent of civilian employed population 16 years and over)					
Management, professional & related	27.3	28.0	28.2	34.3	35.9
Service occupations	20.0	19.4	19.1	17.7	17.8
Sales and office occupations	24.6	24.3	24.0	25.3	24.9
Farming, fishing & forestry	0.3	0.4	0.6	0.6	0.7
Construction, extraction, maintenance & repair	8.0	8.3	9.1	8.7	8.6
Production, transportation & material moving	19.8	19.7	18.9	13.5	12.1
WORKERS BY INDUSTRY (Percent of civilian employed population 16 years and over)					
Agriculture, forestry, fishing, hunting, mining	0.4	1.0	2.0	1.8	1.9
Construction	5.5	5.9	6.7	6.4	6.5
Manufacturing	17.9	18.2	17.0	11.7	10.6
Wholesale trade	2.7	2.6	2.7	2.8	2.8
Retail trade	11.9	11.5	11.3	11.9	11.6
Transportation, warehousing & utilities	5.0	5.0	5.1	5.1	5.0
Information	1.3	1.4	1.3	2.2	2.2
Finance, insurance, real estate, rental, leasing	6.0	5.9	5.6	6.9	6.7
Professional, scientific, management & admin.	6.3	6.2	5.6	9.0	10.7
Educational services, health care, & social assistance	23.9	23.5	24.2	23.8	22.9
Arts, entertainment & recreation, and accommodation & food services	9.5	9.0	8.4	8.9	9.2
Other services, except public administration	5.2	5.4	5.1	4.8	4.9
Public administration	4.3	4.4	5.1	4.7	4.9
CLASS OF WORKER (Percent of civilian employed population 16 years and over)					
Private wage and salary workers	83.5	82.7	79.9	80.4	78.7
Government workers	12.5	12.6	14.3	13.4	14.9
Self-empl. in own unincorporated business	3.9	4.5	5.5	6.0	6.3
Unpaid family workers	0.1	0.2	0.2	0.2	0.1

Source: U.S. Census Bureau, American Community Survey (ACS), 5-year estimates 2008-2012

TABLE I-4 -- HOUSING DATA					
	St. Joseph, MO (city)	Buchanan County MO	St. Joseph, MO-KS Metro Area	Missouri	U.S.
HOUSING UNITS					
Total housing units	33,307	38,416	53,593	2,710,506	131,642,456
Single-family units (% of total)	75.5	77.0	76.9	73.6	67.5
Duplexes (% of total)	4.5	4.0	3.8	3.6	3.8
Mobile homes per 1,000 housing units	32	43	64	67	65
HOUSING OCCUPANCY					
Owner-occupied housing units - %	62.6	65.7	68.1	69.0	65.5
Renter-occupied housing units - %	37.4	34.3	31.9	31.0	34.5
Homeowner vacancy rate (%)	2.7	2.4	2.3	2.5	2.3
Rental vacancy rate (%)	6.6	6.5	5.5	8.0	7.7
YEAR STRUCTURE BUILT (Percent of total housing units)					
Built 2005 or later	0.1	0.1	0.1	0.3	0.3
Built before 1960	53.8	50.3	45.5	31.5	30.3
YEAR HOUSEHOLDER MOVED INTO UNIT (Percent of occupied housing units)					
Moved in 2005 or later	14.0	13.1	11.7	10.9	10.8
Moved in 1969 or earlier	5.9	6.0	5.9	4.4	4.7
VEHICLES AVAILABLE (Percent of occupied housing units)					
No vehicles available	9.5	8.5	7.7	7.3	9.0
1 vehicle available	38.1	35.6	32.6	33.2	33.7
2 vehicles available	37.2	37.4	37.8	38.8	37.6
3 or more vehicles available	15.2	18.4	21.8	20.7	19.7
HOME VALUES (Universe: owner-occupied housing units)					
Median home value	$99,800	$108,300	$110,600	$138,400	$181,400
Average home value	$121,234	$135,418	$138,872	$169,314	$254,710
Value of less than $50,000 (%)	14.6	13.5	14.0	11.5	8.6
Value of $500,000 or more (%)	1.0	1.3	1.9	3.4	10.9

Source: U.S. Census Bureau, American Community Survey (ACS), 5-year estimates 2008-2012

2.2.2 Local Economy - The Blacksnake Creek basin, especially the urbanized portion, is one of the oldest parts of the city, if not the oldest. A fur trading post was established at the mouth of Blacksnake Creek in 1827. The community that developed around this post was known as Blacksnake Hills and was later renamed St. Joseph. Much of the city's notable history as a "jumping-off" point for the Western frontier occurred in the immediate area of the community at the mouth of Blacksnake Creek, including the establishment and operation of the Pony Express in 1860.

After the Civil War, St. Joseph recovered and became a leading wholesaler for westward-bound supplies. This rapidly growing commerce enabled the city to enjoy its most prosperous period in the 1870s and 1880s, and it also began to develop during this period into a meat-packing center. The city's population grew rapidly from nearly 9,000 in 1860 to a peak of 102,979 in 1900. However, after nearby Leavenworth, Kansas, lost to Kansas City the intense competition to build the first Missouri River bridge in northwestern Missouri, rail traffic gradually shifted away from St. Joseph and Leavenworth to Kansas City, and the economy of St. Joseph began to decline . Population fell rapidly from 1900

to 1910 and then stabilized somewhat, and for the last century, the city's population has remained relatively stable at between 71,000 and 81,000.

Today, St. Joseph's economy is dominated by the health care industry and manufacturing. As can be seen in Table 3, the percentage of workers employed in the educational services, health care and social assistance industry is 23.9%, the largest industry by employment in St. Joseph, although the percentage is very comparable to the county, MSA, state and nation. Heartland Health employs more than 3,000 people in St. Joseph. The second largest industry is manufacturing, and the 17.9% of workers in the city employed in manufacturing concerns is significantly more than the comparable percentage in manufacturing statewide (11.7%) and nationwide (10.6%). Leading manufacturers in St. Joseph include Triumph Foods, Johnson Controls, Sara Lee, and Altec Industries. Other items of note in Table 3 are the relatively small share of city residents who work in agriculture and forestry – only 0.4% in St. Joseph, compared to from 1 to 2% in the county, MSA, state and nation – and the percentage of government workers (12.5%), which is somewhat less than for Missouri (13.4%) and the U.S. (14.9%).

A key presence in the city and the region is the animal health and life sciences industry, which accounts for a large share of manufacturing in St. Joseph. The city is one component of the KC Animal Health Corridor, which includes a critical mass of leaders in the business, academic, scientific and government firms located along the east/west axis from Columbia, Missouri through Kansas City to Manhattan, Kansas and also on a second axis from Kansas City to Maryville via St. Joseph. Nearly one-third of the $19 billion global animal health industry is concentrated in this region. In St. Joseph, about 6,200 workers are employed in the veterinary pharmaceutical preparation industry, agricultural chemicals, and blood derivatives. Certain companies that are represented locally in this sector also have a global presence. Nestle Purina's global headquarters for research and development for Friskies dog and cat foods is located in St. Joseph, as is the global headquarters of Boehringer Ingelheim Vetmedica, and the city also hosts the headquarters for the U.S. Animal Health Association.

Narrowing the focus to the Blacksnake Creek study area, there are 43 businesses located along the stream from Karnes Road to the mouth. Table I-5 summarizes the breakdown by industry of companies in this area. Of the 43 businesses, 20 are in either the "other services" category or in retail. Most of the businesses in "other services" are auto repair garages.

TABLE I-5 STUDY AREA INDUSTRIAL STRUCTURE	
Industry	Number of businesses
Utilities	1
Construction	2
Manufacturing	4
Wholesale	3
Retail	8
Transportation & warehousing	3
Financial	2
Rental & leasing	1
Health care & social assistance	1
Arts, entertainment & recreation	1
Accommodation & food services	2
Other services	12
Public administration	2
unidentified	1
Total	43

2.3 HISTORICAL FLOODING ON BLACKSNAKE CREEK

None of the historical floods in the Blacksnake Creek basin has been adequately documented in terms of economic damages. Generally, only anecdotal information is available. Even if more comprehensive estimates were available, any attempt to use these estimates to check or calibrate the type of synthetic annualized estimates presented in Corps economic analyses would be complicated by the absence of gage data for the stream, which limits the ability to apply estimated frequencies or probabilities to the individual events.

In any case, flooding was seen as an issue in the Blacksnake basin as early as a major flash flood in 1849 and has remained one to the present day. Other flash floods are known to have occurred over the following century, including a major one in 1943, but details are not available. In 1959, the Blacksnake basin experienced two significant flash flooding events. The most severe of these events occurred in May and sent a high-velocity wave of water six to eight feet deep down St. Joseph Avenue and the railroad right-of-way. Newspaper accounts indicated significant damage to about 130 homes and 23 businesses. One death also was reported in the flood, at a location central to this study: Karnes Road, where the open stream enters the covered channel. Later flash flood events culminated in a June 1984 event believed to have been a 0.5 to 0.33-chance storm event. One post-flood estimate put the damage at $3.6 million, or about $8.4 million in 2014 dollars. A Corps reconnaissance study followed the 1984 event, culminating in the 1987 report which identified an interest in Federal action. No other major Blacksnake Creek floods have occurred in the interim since 1984, although there have been smaller events for which there is very little documentation.

3.0 DATABASE DEVELOPMENT

3.1 ECONOMIC ANALYSIS PARAMETERS

3.1.1 Index Years, Price Level and Interest Rates - The existing conditions analysis is indexed to conditions of 2014. The base year for the analysis - i.e., the year when the project would be completed and operational - is FY 2018. A future condition is also included in the analysis, indexed to 2038. However, note that all three of these conditions are identically characterized in the risk and uncertainty analysis. That is to say, engineering data, including water surface profiles, and economic development assumptions are considered constant in all respects from 2014 through 2067.

The economic analysis in this report is based on a FY 2015 price level (index: 1 October 2014). The current FY 2015 Federal interest rate for water resource projects of 3.375% is used in annual costs calculations. (Benefits in this analysis are not sensitive to interest rate changes.) The economic period of analysis is 50 years, the maximum allowed by guidance and also the maximum time period that would be reasonable for attempting to project either economic or hydrologic and hydraulic conditions in the basin.

3.1.2 Economic Reaches - For the economic analysis, the study area was originally divided into three reaches. One of these was not carried over into the final stages of the study, and the economic analysis results will be reported in relation to two reaches. The reaches are illustrated on Figure 1 and are discussed below:

Reach 1 – Reach 1 is the most downstream reach, extending from the mouth of Blacksnake Creek upstream to Fillmore/Grand Street just north of downtown St. Joseph. The stream in this area is a covered channel flowing through a primarily industrial portion of the city. This reach has a small amount of residential land use, but is mostly industrial and commercial. As of 2014, Reach 1 included 10 homes and 24 businesses spread between 57 non-residential structures. Wire Rope is a major business presence in this reach, but most of the businesses are small and medium-sized enterprises. Most structures in this reach are older structures in average condition.

Reach 2 – Like Reach 1, Reach 2 is covered channel. Reach 2 runs from Fillmore/Grand Street upstream to Karnes Road, where the open stream enters the covered channel. Reach 2 contains much more residential land use than Reach 1 but also has a commercial/retail strip along St. Joseph Avenue/Highway 59. There are 113 homes and 23 non-residential structures housing 19 businesses in Reach 2.

The other original reach, which was removed from the later stages of the economic analysis, was Reach 3. This reach is the upstream portion of Blacksnake Creek, from Karnes Road upstream to the headwaters in southernmost Andrew County. This segment is an open channel, running through rural areas and residential neighborhoods of northern St. Joseph. Homes in this area are generally newer and larger than further downstream, and the great majority of these homes are near Blacksnake Creek but are on high ground

above the floodplain (with a few exceptions where homes could be affected by the largest potential flood events).

Since the proposed project would be constructed just north of Karnes Road, benefits from less frequent/severe flooding would affect only Reaches 1 and 2. Reach 3 was included in the study to ensure that any adverse induced impacts from the project are fully considered. As the study developed, it became clear that impacts from the project in this area would be negligible and it was dropped from further economic analysis.

3.2 DATA DEVELOPMENT

3.2.1 Initial Database Development - The economic database for the Blacksnake Creek analysis was based initially on data from Buchanan County tax records which included appraised values for structures in the study area along with supporting data in the form of structure characteristics for each property. Kansas City District economics staff subsequently carried out a complete, structure-by-structure field survey of all buildings in the 0.2% floodplain within the study area. The purpose of the survey was to build on the initial data from the county tax records in three areas. First, current occupancy as shown in the tax records was confirmed or updated for each building. Second, where businesses and public facilities were concerned, the nature of the activity was not always obvious from the tax data or the business name, so properties were inspected for additional clues, as well as for the presence of significant outside inventory or equipment. Third, first-floor elevations relative to the ground were estimated by visual inspection and ground elevations were checked for reasonableness, and the presence of basements also was noted. Notes from the completed field survey were subsequently integrated with the tax data to form an adjusted initial structure inventory for the study area.

It is important to note that Section 308 of the Water Resources Development Act (WRDA) of 1990 has been observed in this analysis, and structures built since 1991 in the 1% floodplain with a first-floor elevation lower than the 1% flood elevation are not included in the structure inventory. That said, Section 308 issues are virtually nonexistent in the Blacksnake Creek area since the floodplain has been urbanized and fully developed for many years and there is little opportunity to build new structures in the floodplain. The structures in the Blacksnake structure inventory were built before 1991, and long before 1991 in the vast majority of cases.

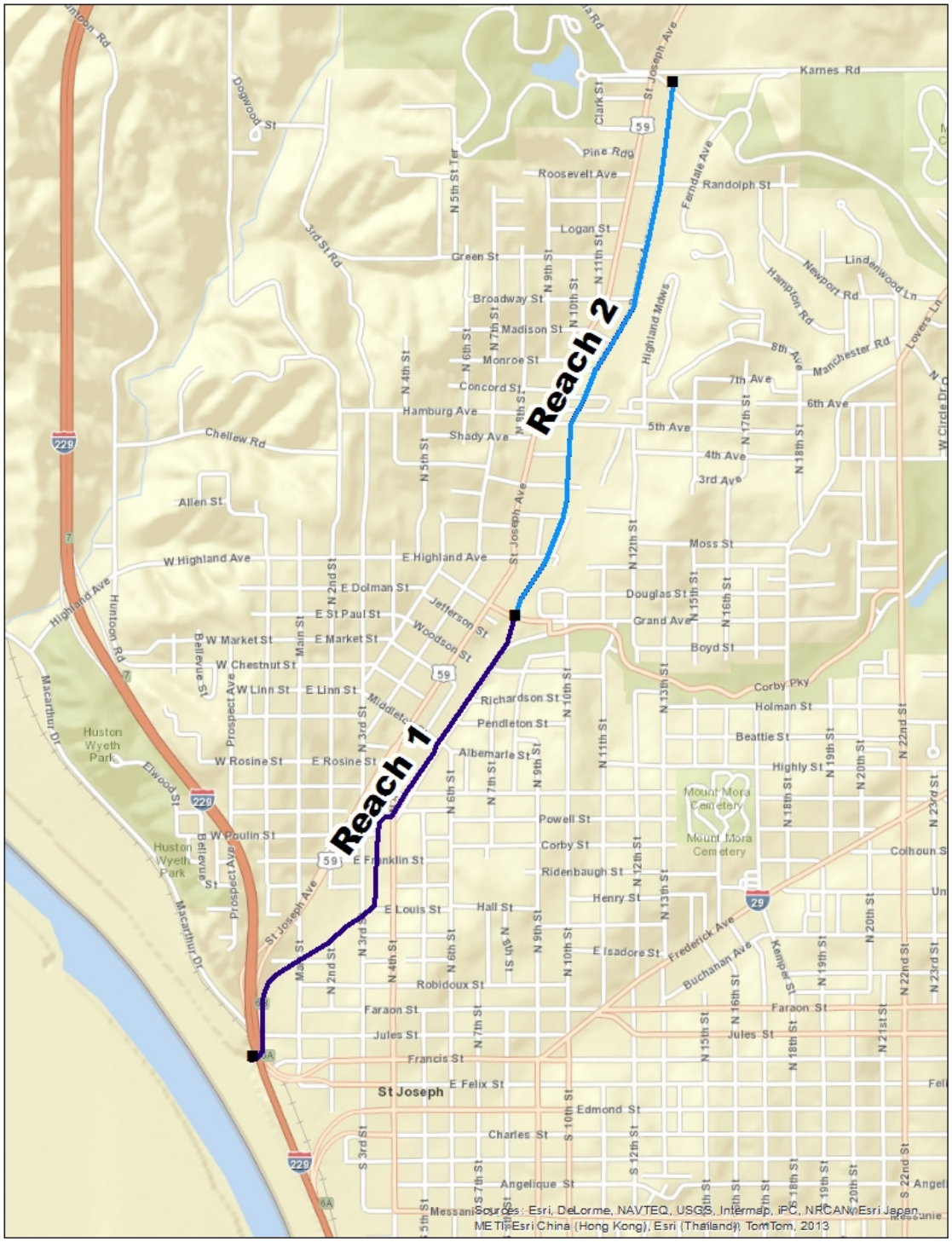

FIGURE 1 – ECONOMIC STUDY REACHES

3.2.2 Elevations and Stationing – Each property in a flood risk management economic analysis is assigned a ground elevation at mean sea level (m.s.l.), as well as a first-floor elevation and a lowest opening elevation if it is different from the first-floor elevation. Properties also are assigned stations positioning them relative to the stream. The elevations and stations are used in the flood damage analysis model to help determine depths of flooding for each flood event evaluated. Ultimately, the first-floor elevations for each type of structure are assigned an uncertainty factor, usually expressed as a standard deviation around a normally distributed variable.

For the Blacksnake analysis, ground elevations were estimated using 2008 GIS mapping with 2-foot contours. During the field survey, these ground elevations were checked for reasonableness and consistency. Foundation heights were also observed during the field survey and were applied to the ground elevations to obtain first floor elevations. To account for uncertainty, all structures were assigned a standard deviation of 0.3 feet in first-floor elevation. This value is based on Table 6-5 of EM 1110-2-1619, which indicates that the uncertainty associated with mapping based on an aerial survey with 2-foot contours is characterized by a standard deviation of 0.3 feet.

3.2.3 Structure Valuation: Residential – Corps of Engineers planning guidance requires property to be valued in terms of depreciated replacement value. Also called current cash value, depreciated replacement value is the cost today to replace an asset (a building, a piece of equipment, etc.) with another object of the same type, function, and condition. Although appraised values of all structures were obtained from Buchanan County, these were not intended to be used in the economic analysis, as these values are not necessarily depreciated replacement values. The appraisal database was useful primarily for the structure characteristics, which are the basis of property tax appraisals and which included exterior wall type, number of stories, area in square feet, construction class/quality, age, and conditions. These characteristics were also utilized by Kansas City District economic staff to estimate depreciated replacement values using a modified Marshall and Swift methodology based on costs per square foot. No information was available for some factors typically used in Marshall and Swift valuation, particularly interior characteristics such as walls, heating and cooling, floor type and other attributes requiring internal inspections of each home. But a valuation process was developed to adapt the detailed Marshall and Swift process to the more limited data generally available for Corps economic analyses. For residential properties, the valuation method enumerated below was used to determine structure depreciated replacement values:

1. Determine type of home: site-built or manufactured, single family or multiple (apartments).

2. Determine quality of construction: low, fair, average, good, very good, or excellent. These standard Marshall and Swift categories were applied to each structure during the field survey using sample photographs of each type provided in the Marshall and Swift reference guides.

3. Identify exterior walls type. Although the basic exterior wall composition types

are in turn divided into multiple sub-categories in the Marshall and Swift data, with each category characterized by a separate set of values per square foot, the valuation for this analysis was based on only the basic material (wood, metal, masonry).

4. Determine basic replacement cost per square foot based on type, construction quality, size, and exterior wall type. Since it was not possible to identify exterior wall types in optimal detail in the field survey, we instead computed an average of the square foot values for all categories listed within each construction type, quality type, and size.

5. Calculate a basic total replacement cost by multiplying the square foot cost by the area in square feet.

6. For homes with basements, add a value to account for the basement. Basement sizes for individual structures were not available, so it was assumed that basement size was equal to 75% of the structure footprint area. Values for unfinished basements were used in an effort to be conservative in assigning values.

7. Add garage value based on map measurement of outbuildings by GIS staff.

8. Calculate total replacement value using the basic cost per square foot plus the additions for basement and garage.

9. Determine typical physical life for each type of home using Marshall/Swift tables.

10. Determine effective age. The field survey evaluated the relative condition of each home using a rating of 1 to 5 (low to very good). These ratings were converted to an average aging factor for each level, from 10% of physical life used for homes in very good condition to 80% of physical life used for homes in poor condition. These age factors based on observed conditions were applied to the typical physical life to obtain an effective age.

11. Select depreciation factor using the effective age and typical physical life. These percentages are available in Marshall and Swift tables.

12. Calculate depreciated replacement value for the structure by applying the depreciation factor to the total replacement value.

Uncertainty factors for residential structure values were developed by assuming that the true rating of construction quality for any given home could be one category higher or lower than our estimate. For example, if a home's construction quality was rated as fair in the field survey, for the uncertainty calculations we assumed that the true rating could instead be low (one category below fair) if we were too optimistic, or average (one category above fair) if we were too pessimistic. Basic square foot values were identified for each condition for 1 and 2 story homes with either wood or masonry walls. Three

typical home sizes were evaluated: 1600, 2400, and 3000 square feet. Within each home type and typical size, the percentage change in square foot value from one construction quality rating to the next was calculated. We then accounted for uncertainty by finding the maximum incremental change between quality ratings in any category or size. The maximum incremental change was approximately 35%. The 35% maximum change was divided by two to obtain an estimated standard deviation of 17.5%. This standard deviation was applied to each residential occupancy type used in the damage analysis.

3.2.4 Structure Valuation: Nonresidential and Infrastructure - As with residential valuation, the appraised county tax values for nonresidential structures were considered but not ultimately used since these depreciated values are not always consistent with depreciated replacement values. An additional shortcoming was that most public facilities do not have values in the tax records. A modified Marshall and Swift method was used to estimate values for nonresidential structures. The process, very similar to the one used for residential structure values, is summarized below:

1. Determine occupancy type, such as garage, church, office building, retail store, motel, etc.

2. Determine construction class. The classes are A, B, C, D, or S as defined in the Marshall and Swift Valuation Service.

3. Determine construction quality: low, fair, average, good, very good, or excellent.

4. Calculate replacement value per square foot based on occupancy type, construction class and quality.

5. Compute total replacement value by multiplying area in square feet by the square foot replacement value selected.

6. Determine typical physical life for the relevant structure type by using Marshall and Swift tables.

7. Determine effective age. As with residences, the field survey evaluated the condition of each business or facility using a relative rating of 1 to 5 (low to very good). These ratings were converted to an average aging factor for each level, from 10% of physical life used for structures in very good condition to 80% of physical life for structures in poor condition. These age factors based on observed conditions were applied to the typical physical life to obtain an effective age.

8. Select depreciation factor from the Marshall and Swift tables using the effective age and typical physical life.

9. Calculate depreciated replacement value for the structure by applying the depreciation factor to the total replacement value.

Uncertainty in the valuation of nonresidential structures is assumed to be normally distributed and is characterized in this analysis by a standard deviation of 15% for all properties. Like the structure value uncertainty for residential properties, this standard deviation assumes that assessment of construction types and qualities is a key source of value uncertainty and reflects the typical differences (an estimated 30%) between successive categories of construction types in Marshall and Swift commercial data.

Streets were valued using typical replacement costs per mile based on an average of available estimates from the transportation departments of Missouri and several other states. The depreciated replacement values used in this analysis are $1,658,000 for major city streets and $995,000 for secondary streets (FY 2015 prices). A standard deviation of 15%t was applied to the street values for uncertainty. It should be noted that streets in the Blacksnake floodplain generally consist only of older side streets that slope down from St. Joseph Avenue into the floodplain, and flood damage potential for streets is minimal.

3.2.5 Contents Valuation: Residential - Residential contents are not valued separately in the damage analysis, since users of standard residential depth-damage functions issued by CEIWR in 2000 and 2003 are directed to enter 100% as the residential content-to-structure value ratio. For purposes of estimating investment only, the residential content-to-structure value ratio used is 50%. For mobile homes, which are not included in the IWR functions, a content-to-structure value ratio of 63.6% is used (see EM 1110-2-1619, 1 Aug. 1996, Table 6-4). There are only two mobile homes in the study area.

An additional component of residential contents that is not accounted for in the IWR depth-damage functions is vehicles and other items external to the home, such as outbuildings and landscaping. Values for outbuildings were estimated directly in this analysis, using the Marshall and Swift data and procedures. It is primarily vehicles and landscaping that remain to be accounted for in this study, and vehicles are the main item in terms of value. Based on 2010 Census data for the block groups in the study area, the analysis assumes an average of 1.6 cars per residence. It is also assumed that 50% of residents will evacuate their cars in cases of flooding with less than six hours warning time (which would be the case with flash-flooding on Blacksnake Creek). This assumption comes from Table 5 in EGM 09-04 (although it may overstate the efficacy of evacuation since it appears to be based only on data for residents who have an opportunity to move their vehicles, and some residents might not have enough warning time in a flash flood to even have an opportunity to evacuate property). The combined effect of these two assumptions is that 1.6 cars would be present in the floodplain during flash flooding at 50% of the homes in the study area – or, what is the same thing, each home is assumed to have 0.8 cars left behind after evacuation is accounted for. The average 2014 sale value for used vehicles, according to the automotive data site TrueCar, was $16,335. Multiplying this value by 0.8, a value of $13,300 is assumed for cars left behind at each of the 48 residences.

3.2.6 Contents Valuation: Nonresidential - One large business in Reach 1, Wire Rope, was interviewed for the analysis. In most cases, however, contents for non-residential

properties, including uncertainty factors, were estimated using generic content-to-structure value ratios (CSVRs). These were taken from a report issued by the New Orleans District Corps of Engineers. The report, and its applicability to this study, are discussed below in section 3.2.8 dealing with nonresidential depth-damage functions. The CSVRs included in the New Orleans dataset include uncertainty factors in the form of standard deviations and minimum/maximum values.

3.2.7 Damage Functions: Residential - Residential damages for most homes in this analysis, shown in Table I-6, are based on depth-damage functions released in Economic Guidance Memorandum (EGM) 04-01, "Generic Depth-Damage Relationships for Residential Structures With Basements," dated 10 October 2003. This EGM summarized data developed by the Institute for Water Resources (IWR) using post-flood residential damage claim records provided by the Federal Emergency Management Agency (FEMA). The functions account for both structural and content damage to homes with and without basements. Based as they are on post-flood damage claims data, the functions should also account for any emergency flood avoidance actions taken by residents such as evacuation or flood proofing. Of the eight residential occupancy types selected for this analysis, four use the IWR functions: 1-story with and without basement and 2-story with and without basement.

Two other functions for one and a half-story homes with and without basement were created by averaging the IWR functions for 1 and 2 story homes. (Although the IWR functions begin as low as 8 feet below the first floor for homes with basements, all homes in this analysis have been assigned beginning damage stages of minus 2 feet. This prevents the software from beginning to read the functions until a depth of minus 2 feet is attained, and then only for homes with basements.)

The remaining two functions are for mobile homes and vehicles. For the three mobile homes in the structure inventory, a depth-damage relationship from the New Orleans District dataset discussed just below in section 3.2.8 was used. For vehicles, the depth-damage function follows the official Corps IWR data released in EGM 09-04.

3.2.8 Damage Functions: Nonresidential and Infrastructure – The depth-damage function used for the largest business in the study area, Wire Rope, was developed based on an interview with representatives of that business. For other businesses, depth-damage relationships for both structures and contents (as well as content-to-structure value ratios) used in this analysis are taken from data developed by the New Orleans District, as published in "Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies," May 1997, and other studies. The depth-damage functions are shown in Table I-6. The New Orleans dataset remains one of the best published sources for commercial and public valuation and flood damage estimates and has been recommended by Corps subject experts for use in NWK flood risk management economic analyses. The functions are based on a wide range of expertise, including panels made up of experienced subject experts on construction and post-flood cleanup, owner/operators of businesses, and FEMA post-flood depth-damage functions

for the same region. One additional function for churches was taken from IWR Report 96-R-12, "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies" (1996), a report based on flooding in the Wyoming Valley of the Susquehanna River basin in Pennsylvania.

It is required in the Planning Guidance Notebook (ER 1105-2-100, Appendix E, para. E-19q(2)) that when "comparable floodplain data" (i.e., generic data) are used, the study must justify the applicability of the data to local conditions. The particular New Orleans dataset used in this analysis (there are several such datasets for different types of conditions, published in at least three reports) is actually quite appropriate for the Blacksnake study area. The data for both depth-damages and content values were based on post-flood surveys with business operators conducted in the aftermath of an urban, freshwater (not saltwater, it should be emphasized) flood event in Louisiana. These characteristics transfer well to the St. Joseph context of flooding. Moreover, the owner/operators interviewed represented many of the same types of businesses and facilities as are found in the St. Joseph structure inventory, including restaurants, grocers, retail and services, professional offices, repairs and home use businesses, warehouses and contractors, and public facilities. The structure damage functions are for masonry, wood, or metal walls and should be applicable to most areas with these types of nonresidential structures (with the possible exception of regions with extreme climate factors that require entirely different building codes). The Wyoming Valley data used for churches are also appropriate for use in this study area. Though they are based on a flood event associated with a tropical storm system, the circumstances are not very different: an inland area (Wilkes-Barre is more than 100 miles inland), characterized by mixed-use urbanized land uses affected by freshwater flooding.

Two other points should be added to this discussion. First, it will be noted that some of the functions assume that damage occurs at an elevation of zero. One reason for this is that surface flows do, in fact, damage some items. Examples include finished goods inventories stored on the floor (particularly items such as food or drugs), inventories that are very sensitive to humidity even if not directly touching the water, or equipment with electrical wiring in the floor. Another reason is that depth-damage functions typically are structured in depth increments of a half-foot, if not a foot. If damage occurs with depths of only two or three inches (as it usually would), these depths would more readily round to zero than to one foot or one half foot. Damage percentages paired with an elevation of zero, therefore, might in actuality be accounting for very shallow flows of greater than zero depth. Second, in this flash-flooding context, there is very little opportunity for businesses to evacuate equipment and inventory (particularly if the flood occurs overnight). Therefore, the nonresidential depth-damage functions have not been further modified to reflect flood damage avoidance measures like evacuation.

Uncertainty factors are included in the New Orleans dataset. The depth-damage functions include median, maximum, and minimum values that serve as the basis for triangular damage uncertainty distributions in the risk analysis. The Wyoming Valley data, on the other hand, included only median values and had to be augmented by assumed uncertainty bounds that were assigned using professional judgment.

For city streets, the depth-damage function used in this analysis was formulated by obtaining typical costs per mile for minor maintenance such as regrading and resurfacing as well as for more major reconstruction to compare against the costs of new construction. In general, it is assumed that lower levels of inundation will result in relatively minor damage requiring repairs amounting to regrading and/or resurfacing, while more severe inundation levels will require much more expensive repairs that would be comparable to reconstruction. The resurfacing and reconstruction costs per mile obtained were divided by the new construction costs per mile to produce the generalized depth-damage percentages.

3.2.9 Non-Physical Costs of Flooding - In addition to the tangible damages to businesses, homes, and other physical property items caused by flood inundation or exposure, the costs of flooding include emergency costs and disaster relief costs. Emergency cost savings can encompass savings related to a wide range of flooding impacts, including emergency personnel costs, flood fighting costs (sandbagging, for example), avoidance costs (raising or evacuation of property), temporary food and housing, debris cleanup, and damage to infrastructure items not otherwise included in the damage analysis such as sewer lines. The city of St. Joseph was contacted to obtain available historical data on emergency costs incurred during previous flood events. However, local governments rarely have this type of data on file, particularly when no serious flood events have occurred recently, with the result that there is a dearth of empirical data. For this reason, we were unable to obtain enough reliable data to estimate this category of impacts based on direct or first-hand data. Yet emergency flood fighting costs are a recognized and significant category of economic impacts from flooding, and accuracy is not served by their absence from the economic analysis.

As an alternative, we consulted several reports published by the Corps pertaining to the 1993 Missouri River basin flood in order to estimate typical emergency costs for a large flood in an urban setting. (The 1993 event was rated as equal to or approximating a 0.2%-chance event in most locations along the Missouri.) These reports included the 1993 Interagency Floodplain Management Review Committee Report (Galloway Report); Impacts of the Great Flood of 1993 (CELMV, May 1996); and the Flood Plain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries (USACE, June 1995). We compared 1993 flood damage estimates for damage centers detailed in these reports with 1993 agency emergency costs as reported in these documents. Based on these data, emergency costs as a percentage of total physical flood damages ranged from a low of 12.4% to a high of 15%, with an average of 13.4% for all states impacted by the 1993 flood. In addition, we also consulted a white paper by a former HQUSACE reviewer who surveyed planning reports submitted to HQUSACE by Corps districts across the nation in recent years. This analysis found that emergency costs claimed in approved Corps reports averaged about 9% of total EAD reduced. Based on the information contained in these sources, we assumed that emergency costs are equivalent to a maximum of 9% of physical flood damages in the largest events and to smaller percentages in lesser events. Preliminary HEC-FDA runs were executed to obtain estimates of total physical damages for the 0.2%-chance event in each study reach, and emergency costs were then entered into the structure inventory as a structure in each

reach with a value equivalent to the 500-year damages from the preliminary HEC-FDA runs. The depth-damage function developed starts at two feet of flooding with 0.5% damage and rises to the maximum of 9% at eight feet of flooding. Uncertainty in the damage function was represented very conservatively by a triangular function in which the maximum or upper uncertainty bound rises to a maximum of 11% at nine feet.

Also included in the data we reviewed from prior studies were estimates of disaster relief costs. However, these costs appeared to overlap with the emergency cost estimates in the same studies, presenting a potential for double-counting damages, and we instead elected to obtain data from the Region VII FEMA office. Their data included typical costs for disaster housing assistance and grant assistance to individuals and families following recent Missouri floods, including the 1993 Missouri River flood. Relocation and reoccupation costs for non-residential occupants were not estimated and were not included in the analysis. The data indicated that residential emergency assistance averaged about $8,900 per home (FY 2015 prices). We multiplied this average household amount by the estimated number of homes damaged in a 0.2%-chance flood, again using preliminary HEC-FDA runs. This total was entered into the HEC-FDA study file for each levee unit area as the maximum emergency costs that could be incurred, with a standard deviation of 10%. A depth-damage function was developed based on the idea that disaster relief would mainly be an issue in the larger flood events. The function therefore begins with 10% damage at 3 feet of flooding and rises to 100% at 10 feet.

(Note that this category of damages is included only in the final FY15 benefit calculations for the NED plan and is not included in the FY11 economic screening.)

TABLE I-6 - DEPTH-DAMAGE FUNCTIONS											
Depth in feet>>	0	1	2	3	4	5	6	8	10	12	16
Residential 1NB struc	13	23	32	40	47	53	59	67	73	77	81
Residential 1NB cont	8	13	18	22	26	29	32	36	38	40	40
Residential 2NB struc	9	15	21	26	31	36	41	49	56	61	69
Residential 2NB cont	5	9	12	16	19	21	24	28	32	35	37
Residential 1WB struc	26	32	39	46	52	59	65	74	80	81	81
Residential 1WB cont	16	19	22	25	27	30	32	36	39	39	39
Residential 2WB struc	18	22	27	32	37	42	47	56	65	71	76
Residential 2WB cont	12	14	16	18	20	22	24	29	34	40	53
Residential 1.5NB struc	11	19	27	33	39	45	50	58	65	69	75
Residential 1.5NB cont	7	11	15	19	22	25	28	32	35	37	39
Residential 1.5WB struc	22	27	33	39	45	50	56	65	73	76	79
Residential 1.5WB cont	14	16	19	21	24	26	28	33	37	40	46
Residential mob home struc	10	45	46	97	97	97	97	97	97	97	97
Residential mob home cont	0	85	95	99	99	99	99	99	99	99	99
Residential - vehicles	0	25	43	59	72	84	93	100	100	100	100
Commercial struc masonry	0	14	26	33	41	48	53	65	72	76	78
Commercial struc metal	0	10	19	21	27	38	47	53	59	60	62
Commercial struc wood	0	18	31	38	43	51	57	69	76	84	91
Commercial cont - warehouse	0	28	45	55	62	72	78	87	93	96	96
Commercial cont retail	0	30	55	65	77	88	96	97	97	97	100
Commercial cont repair	0	30	41	52	65	75	91	93	99	100	100
Commercial cont grocer	0	39	54	66	79	92	97	100	100	100	100
Commercial cont professional	0	31	52	65	73	79	82	86	89	92	98
Commercial cont public	0	25	55	69	79	84	85	85	90	90	94
Commercial cont restaurant	0	26	54	68	83	88	95	98	99	100	100
Commercial cont service station	0	14	26	34	41	46	50	56	59	61	63
Commercial cont salvage yard	0	3	8	15	25	35	45	60	70	70	70
Commercial cont manufacturer	1	10	20	30	40	50	60	80	100	100	100
Streets & roads	1	2	4	6	8	11	15	23	33	43	63
Disaster relief	0	10	20	40	60	80	90	100	100	100	100
Emergency costs	0	3	4	5	6	7	8	9	9	9	9

3.3 FINAL DATABASE – INVESTMENT AND POPULATION AT RISK

Completion of the tasks discussed above ultimately results in an economic structure inventory. The structure inventory is subsequently used for several purposes, but initially it is the basis for estimates of investment in the study area. A determination of population within the study area completes the economic database used in the damage analysis.

3.3.1 Investment – Investment for the Blacksnake Creek study area is summarized in Table I-7. The estimated total investment in the study area, in FY 2015 prices, is $94,012,300. There are 123 homes, 43 businesses, and 80 nonresidential structures. Reach 1, the downstream reach, contains 10 homes and 24 businesses in 57 nonresidential structures. Total investment in Reach 1 is $56,604,600, which is 60.2% of

the total for the study area. Total investment in Reach 2 is estimated at $37,407,700, which is 39.8% of the total for the study area. Reach 2 contains 113 homes and 19 businesses in 23 nonresidential structures.

Residential value accounts for 21.5% of total investment, while 73.5% is nonresidential investment and 5.0% is streets. Structure value represents 54.9% of the combined value of residential and nonresidential properties (streets excluded), while contents, including residential vehicles, makes up the other 45.1%.

These investment totals are assumed to remain constant under base year and future conditions. Therefore, Table I-7 represents investment for the future without-project condition as well as for existing conditions.

3.3.2 Population at Risk – Population at risk (PAR) is the portion of the population living, working, or otherwise temporarily in the study area flood plain. These persons are potentially at risk in the event of flooding.

The resident portion of PAR was estimated using 2010 Census block data for blocks adjoining Blacksnake Creek. The study area includes portions of the following Census tracts and block groups: Andrew County tract 101, block groups 1, 2 and 3; Buchanan County tract 2, block groups 2 and 3; Buchanan County tract 3, block groups 1 and 2; Buchanan County tract 5, block groups 1 and 3; Buchanan County tract 12, block group 1; and Buchanan County tract 30, block group 1. It is estimated that there are 2,525 people residing in the flood plain or adjacent to it (and therefore likely to be in the flood plain frequently).

The second group included in PAR is workers. Data on the number of employees per business are not easily available and were not collected for the study, but based on the number of businesses and their scales of operations, there are believed to be at least 500 workers at the 43 businesses in the study area, bringing the total above 3,000. The third group is comprised of those temporarily in the area, such as customers of area businesses or simply drivers passing through the area. Producing a sensible estimate of this sub-group of PAR is very difficult, but the count here will be based on traffic along Highway 59/St. Joseph Avenue. Data from the Missouri Department of Transportation indicates that the average daily traffic count on Highway 59 near Karnes Road is 10,790. This works out to about 450 per hour. All together, it appears that a reasonable estimate of PAR in the Blacksnake study area would be about 3,500.

TABLE I-7 TOTAL INVESTMENT				
In $1,000s; FY 2015 prices				
	Reach 1 (mouth to Fillmore St.)	**Reach 2** (Fillmore St. to Karnes Rd.)	**Total**	
RESIDENTIAL				
Quantity	10	113	123	
Value - Structures	$393.9	$11,996.2	$12,390.1	
Value - Contents	$328.0	$7,478.4	$7,806.4	
Value - Total	$721.9	$19,474.6	$20,196.5	21.5%
NON-RESIDENTIAL				
# Businesses	24	19	43	
# Structures	57	23	80	
Value - Structures	$26,449.4	$8,099.4	$34,548.8	
Value - Contents	$25,857.1	$8,728.5	$34,585.6	
Value - Total	$52,306.5	$16,827.9	$69,134.4	73.5%
ROADS & STREETS				
Value	$3,576.2	$1,105.2	$4,681.4	5.0%
TOTALS				
Total Value	$56,604.6	$37,407.7	$94,012.3	
Percentage of Overall	60.2%	39.8%		
Total # Structures	67	136	203	
Structures vs. Contents				
Total Value - Structures*	$30,419.5	$21,200.8	$51,620.3	54.9%
Total Value - Contents	$26,185.1	$16,206.9	$42,392.0	45.1%
	60.2%	39.8%		
* Includes value of streets				

4.0 DAMAGE ANALYSIS MODELING

4.1 THE HEC-FDA RISK ANALYSIS PROGRAM

The basic assumption underlying use of a risk analysis program is that data in flood risk studies are based on imperfect knowledge and unpredictable future developments, so that key variables for which median or most likely values are specified could, in reality, take on a range of values above and below the specified values. A program with advanced mathematical capabilities is needed to perform an analysis that reflects risk and uncertainty, and the Blacksnake Creek economic analysis uses the HEC-FDA program to compute damages and benefits. HEC-FDA is the acronym for the Flood Damage Analysis program produced by the Hydrologic Engineering Center. This program is

standard in Corps of Engineers economic risk analyses for flood risk studies. The newest version, 1.2.5a, which is the certified version of the program, is used in this analysis.

In HEC-FDA, key economic input data are first loaded into the program. There are two economic input files for HEC-FDA: a structure inventory file compiling data for all damageable property in the study area, including structure values, ground and first-floor elevations, and stream stationing, and an occupancies file that compiles information for each major occupancy type (1-story homes, retail businesses, government offices, etc.), including content-to-structure value ratios, depth-damage functions, and uncertainty factors for all economic variables. Together, these data files shape the three main economic variables critical to estimating flood damages at each location: elevation, value, and damage susceptibility. Along with the economic data, the hydrologic/hydraulic data for the stream are also entered into the program in the form of water surface profiles for eight selected flood events. All engineering and economic data are entered into the program in terms of median or most likely values and are accompanied by appropriate uncertainty parameters specifying the range of possible values for each variable.

The first phase of the risk analysis produces an economic stage-damage function. The program performs numerous iterations, each combining various possible values for each economic input (elevation, value, and depth-damage) by sampling the uncertainty distributions provided for those variables. Flood damages for each foot of flooding are computed based on the level of investment subject to flooding, the beginning damage elevation, and the estimated damage to that investment with various depths of flooding. The HEC-FDA program references each structure's first floor elevation or beginning damage elevation to the corresponding frequency event elevation at the reach index point. Individual stage-damage relationships at each structure for each investment category are then computed with risk and aggregated to the reach index location specified for integration with the engineering data.

But the ultimate goal is to express damages in an annualized equivalent form, and this is the purpose of the second phase of the risk analysis, which integrates the economic stage-damage function with the engineering data. The HEC-FDA program utilizes a Monte Carlo process to randomly sample multiple probability distribution functions to produce tens of thousands of possible flood events instead of a few discrete scenarios. For each event, the program samples the range of possible values for each variable and determines (a) whether the flood event results in damage, and (b) how much damage occurs. The result is to effectively extend the period of record synthetically to thousands of flood events in a manner that reflects uncertainty in assumptions and the dynamic interaction of variables over long time periods.

The calculation of annual damages conceptually involves a weighted average in which damages computed for each event are multiplied by the incremental probability of that event and the product is summed. This total, referred to as expected annual damages (EAD), represents an estimate of the average damages that would be expected in any given year over the long term. The outcome of the Monte Carlo simulations is a single expected value for annual damages that represents an average of the thousands of

synthetic events. Even though it is a single value, the expected value integrates many variables, including their uncertainty distributions. The average annual damage total can then be compared on an equivalent basis to an annualized cost for the planned project to obtain a benefit-cost ratio. Computations are made for expected annual damages under each condition, existing (or base, since both conditions are equivalent in this analysis) and future. The goal of the economic screening of alternatives is to identify the National Economic Development (NED) plan. The NED plan is the plan with the highest net benefits. This is considered the most economically efficient alternative. EAD is assumed constant in those years of the period of analysis beyond the most likely future condition. An equivalent annual damage also is computed, representing essentially a summation of base and future year conditions with the future year damages expressed as a discounted present worth value which is added to the base year damages.

An additional result of the risk analysis is a set of statistics characterizing project performance or assurance – the probability that a project will successfully contain flood events of varying magnitudes. There are three main assurance outputs. Annual exceedance probability (AEP) is the probability of a damaging flood occurring in any given year. The AEP is calculated with reference not to a single event, but to the entire range of possible events. A second output is long-term risk – the probability that a damaging flood will occur over periods of 10, 30, and 50 years. The third output is conditional nonexceedance probability (CNEP). CNEP is an estimate of the probability that a levee unit will successfully contain certain specified flood events of interest such as the 1% chance event (i.e., the event magnitude with a 1% chance of occurring in any year).

4.2 MODELING FOR BLACKSNAKE CREEK

4.2.1 Basic Modeling - The comprehensive structure inventory for the study area discussed above in section 3 – including elevations, values, and depth-damage functions for each property, accompanied by uncertainty factors – and the set of water surface profiles were entered into the HEC-FDA risk analysis program for damage computations. Damages in this analysis consist of physical inundation damages to commercial, industrial, residential and public/non-profit structures and their contents, as well as damages to roads. Water surface profiles were prepared for eight flood events: 50%, 20%, 10%, 4%, 2%, 1%, 0.4%, and 0.2%, plus invert stages. This analysis uses one set of profiles for all conditions – existing, base year, and future. A standard operating procedure for the effective use of HEC-FDA is the extension of the exceedance frequency and stage-discharge functions with uncertainty to the 0.9999 event (essentially the “1-year” event), and this procedure was followed in the Blacksnake model, with the exceedance frequency functions modified to include the estimated stage for the 0.9999 event.

4.2.2 Special Issues - While the Blacksnake analysis is a typical HEC-FDA analysis in most respects, two aspects merit additional mention. The first concerns integration of the stage-probability-discharge functional relationship within FDA. Early runs of the model resulted in stage-damage functions showing unrealistically high damages at minimal

levels of flooding. Exceedance probability functions with uncertainty also showed extreme values at +/- two standard deviations, which undoubtedly contributed to the distorted stage-damage functions. These shortcomings in the model proved intractable, and ultimately it was decided to attempt to deal with the problem by completely removing discharge data from the calculations. HEC-FDA includes two alternatives for forming the exceedance probability functions: in addition to the commonly-used discharge-frequency relationship, there is a second option to base these functions on water surface profiles formed by stage-frequency relationships. Use of this approach provided much more reasonable and realistic results. (This version of the model, along with earlier versions for comparison, was subsequently presented informally to an advanced HEC-FDA training class for critique. Instructors and students at the course did not identify any significant shortcomings with the stage-frequency form of the model.)

The second issue concerns the extent of flood risk reduction provided under existing conditions by the combined sewer. The sewer does provide some protection against smaller floods. The threshold at which flows begin to exceed the sewer's capacity and escape the underground pipe to flood overbank areas occurs in the range of a nominal 20% to 10% (5 to 10-year) event. The water surface profiles formulated for the modeling reflect this zero damage threshold. In the risk-based context of the HEC-FDA model, the zero damage frequency is higher (i.e., more frequent) than suggested above, with an expected value of about 40% (2.5-year) – in other words, the combined sewer, in a risk-based context, does not perform as well in reducing flood risk as would be expected given the nominal rating. In any case, the actual effect of the existing combined sewer in reducing flood risk is reflected in the economic damage model.

4.2.3 Atlas 14 – Very late in the feasibility study (subsequent to the Alternative Formulation Briefing), the National Oceanic and Atmospheric Administration (NOAA) published a new precipitation-frequency atlas for the U.S., known as Atlas 14. The new precipitation-frequency data potentially affects and alters the hydrology and hydraulics prepared for many Corps flood risk management studies, in many cases indicating significantly higher stages than previously estimated. Although the Atlas 14 data was released very late in the Blacksnake Creek study, the Kansas City District undertook a sensitivity analysis using the new data to find out whether either economic justification or identification of the NED plan could be affected by the new data. Kansas City District engineering staff prepared a new set of water surface profiles reflecting the Atlas 14 estimates for the events considered in the economic analysis. These profiles were entered into the HEC-FDA model and a sensitivity analysis was executed. The results of this sensitivity analysis will be discussed below in section 6.4.

5.0 EXISTING AND FUTURE WITHOUT-PROJECT CONDITIONS

As discussed above, there is no distinction in this analysis between existing, base year and future conditions. Water surface profiles and other hydrologic/hydraulic data are considered stable over the period of analysis, as is the economic structure inventory. The results summarized in this section therefore will represent existing conditions as well as future without-project conditions.

5.1 EXPECTED ANNUAL DAMAGES (EAD)

The EAD calculated for without-project conditions by the HEC-FDA model are summarized in Table I-8. Total EAD is estimated at $3,545,900. This total breaks down into 71.2% in Reach 1 and 28.8% in Reach 2. Nonresidential damages account for 63.8% of total damages, while residential accounts for 25.8%, emergency costs for 8.6%, and streets for 1.8%.

The HEC-FDA program also produces estimates of damages in selected events, and two common reference events are the 1% and 0.2% flood events. In a 1% flood, an estimated $30,596,000 would be expected according to the model. Of the 203 structures in the study area, 148 would be inundated by the 1% event. In a 0.2% event, 165 of the 203 structures would be inundated, and estimated damages would total $39,743,000. Damages in these two events and others, as calculated within the HEC-FDA program, are presented by reach in Table I-9.

TABLE I-8 - FUTURE WITHOUT--PROJECT CONDITION EQUIVALENT ANNUAL DAMAGES

FY15 prices; $1,000s

	Reach 1	Reach 2	Total	
Residential	$ 87.4	$ 828.7	$ 916.1	25.8%
Commercial/Public	$ 2,201.5	$ 60.2	$ 2,261.7	63.8%
Streets & Roads	$ 63.4	$ 0.0	$ 63.4	1.8%
Emergency Costs	$ 171.6	$ 133.1	$ 304.6	8.6%
TOTAL	**$ 2,523.9**	**$ 1,022.0**	**$ 3,545.9**	100.0%
	71.2%	28.8%	100.0%	

TABLE I-9 -- EXCEEDANCE PROBABILITY VS. DAMAGE						
REACH 1	Emergency Costs	Non-Residential	Residential	Streets	Vehicles (Residential)	Total
50.00%	$25.3	$323.4	$7.9	$9.3	$5.2	$371.1
20.00%	$265.0	$3,390.4	$83.2	$97.6	$54.3	$3,890.5
10.00%	$521.4	$6,671.0	$163.7	$192.0	$106.9	$7,655.0
4.00%	$1,010.8	$12,933.5	$317.3	$372.3	$207.3	$14,841.2
2.00%	$1,270.3	$16,252.8	$398.7	$467.8	$260.5	$18,650.1
1.00%	$1,481.1	$18,949.8	$464.8	$545.5	$303.8	$21,745.0
0.50%	$1,663.2	$21,280.5	$522.0	$612.6	$341.1	$24,419.4
0.20%	$1,865.6	$23,870.5	$585.6	$687.1	$382.6	$27,391.4
REACH 2	Emergency Costs	Non-Residential	Residential	Streets	Vehicles (Residential)	Total
50.00%	$9.0	$3.8	$47.1	$0.0	$5.4	$65.3
20.00%	$251.0	$106.9	$1,321.4	$0.0	$152.6	$1,831.9
10.00%	$484.1	$206.3	$2,549.2	$0.1	$294.3	$3,534.0
4.00%	$763.3	$325.2	$4,018.9	$0.1	$464.0	$5,571.5
2.00%	$993.4	$423.2	$5,230.4	$0.2	$603.9	$7,251.1
1.00%	$1,212.6	$516.6	$6,384.4	$0.2	$737.1	$8,850.9
0.50%	$1,429.6	$609.1	$7,527.5	$0.2	$869.1	$10,435.5
0.20%	$1,692.2	$720.9	$8,909.7	$0.3	$1,028.7	$12,351.8
TOTAL	Emergency Costs	Non-Residential	Residential	Streets	Vehicles (Residential)	Total
50.00%	$34.3	$327.2	$55.0	$9.3	$10.6	$436.4
20.00%	$516.0	$3,497.3	$1,404.6	$97.6	$206.9	$5,722.4
10.00%	$1,005.5	$6,877.3	$2,712.9	$192.1	$401.2	$11,189.0
4.00%	$1,774.1	$13,258.7	$4,336.2	$372.4	$671.3	$20,412.7
2.00%	$2,263.7	$16,676.0	$5,629.1	$468.0	$864.4	$25,901.2
1.00%	$2,693.7	$19,466.4	$6,849.2	$545.7	$1,040.9	$30,595.9
0.50%	$3,092.8	$21,889.6	$8,049.5	$612.8	$1,210.2	$34,854.9
0.20%	$3,557.8	$24,591.4	$9,495.3	$687.4	$1,411.3	$39,743.2

5.2 EXCEEDANCE PROBABILITY RATINGS

The probability of the occurrence of damaging flooding in the without-project condition is summarized in Table I-10. The HEC-FDA model's risk-based assessment of without-project conditions in the basin results in an estimated annual exceedance probability (AEP) of approximately 39%. Since the combined sewer has been estimated to contain peak flows for at least a 20% flood event or slightly larger, the risk-based estimate indicates that the sewer's actual performance is lower than previous (non-risk based) estimates. The HEC-FDA results also indicate that there is essentially no chance of containing even a 10% event – much less larger events - under conditions of risk and uncertainty, and that the occurrence of a damaging flood over any long-term period – even 10 years – is almost certain. (This does not mean that a damaging flood would occur in every 10-year time period. The statistic is to be understood as predicting the occurrence of damaging floods about every 10 years, on average, over the long term.)

TABLE I-10 -- WITHOUT-PROJECT EXCEEDANCE PROBABILITY HEC-FDA ESTIMATES			
	REACH 1 (DOWNSTREAM)	**REACH 2 (UPSTREAM)**	**TOTAL PROJECT AREA**
ANNUAL EXCEEDANCE PROBABILITY*			
Median	38.7%	33.4%	38.7%
Expected	38.4%	33.3%	38.4%
LONG-TERM RISK ** (chance of flooding during period)			
over 10 years	99.2%	98.3%	99.2%
over 30 years	100.0%	100.0%	100.0%
over 50 years	100.0%	100.0%	100.0%
CONDITIONAL EXCEEDANCE PROBABILITY PER EVENT (in %)			
10.0%	100.0%	100.0%	100.0%
4.0%	100.0%	100.0%	100.0%
2.0%	100.0%	100.0%	100.0%
1.0%	100.0%	100.0%	100.0%
0.4%	100.0%	100.0%	100.0%
0.2%	100.0%	100.0%	100.0%
CONDITIONAL NON-EXCEEDANCE PROBABILITY PER EVENT (in %)			
10.0%	0.0%	0.0%	0.0%
4.0%	0.0%	0.0%	0.0%
2.0%	0.0%	0.0%	0.0%
1.0%	0.0%	0.0%	0.0%
0.4%	0.0%	0.0%	0.0%
0.2%	0.0%	0.0%	0.0%

* Annual exceedance probability (AEP) is the chance of a damaging flood in any year. The statistic implies nothing about the magnitude of the flood except that it would be large enough to exceed the system's capacity.

** The same is true of the long-term risk of flooding; it is based on the probability of a damaging flood of any magnitude.

6.0 ALTERNATIVES SCREENING

6.1 ALTERNATIVES DEVELOPED FOR ANALYSIS

Eight alternatives ultimately were developed and quantitatively evaluated for this study. All eight alternatives are structural flood risk reduction measures. Alternatives 1-4 form one group of similar (although separate) alternatives, while alternatives 5-8 are a second group of similar alternatives. The pertinent features of the alternatives are summarized below:

- Alternatives 1-4
    - These alternatives are variants of the same basic plan, which involves raising Karnes Road to act as a dry detention dam with an overflow spillway.
    - Alternative 1 involves no excavation for the detention area upstream of Karnes Road, while 2, 3 and 4 involve increasing amounts of excavation.
    - Due to the risk that these alternatives would cause drainage issues on residential properties just upstream of the project, all four alternatives would include a levee/floodwall combination upstream of Karnes Road. This feature was meant to protect homes in that area from any adverse effects of the detention basin and would not reduce flood risk relative to the without-project condition.
    - Alternative 4 extends the detention basin downstream of Karnes Road, removing a short portion of Karnes and adding a second levee.

- Alternatives 5-8
    - These three alternatives are also variants of the same plan.
    - Like alternatives 1-4, these plans involve dry detention upstream of Karnes Road.
    - Unlike alternatives 1-4, they use the natural topography and a lower pool height to avoid the need for the Karnes Road dam and levee/floodwall combination upstream.
    - The dry detention area in alternative 5 is upstream of Karnes Road. Alternatives 6 and 8 extend it a short distance downstream to Northwest Parkway, as in alternative 4. Alternative 7 expands the detention area upstream of Karnes to the west. Thus, project scale increases in moving from alternative 5 to 6 to 7, as it does in moving from 1 to 2, 3 and 4.
    - Alternative 7, unlike the other three alternatives in this group, would require 21 residential property relocations.

In addition to the eight structural alternatives, several non-structural alternatives were also examined (see section 2.5.2 of the main report), although no benefit-cost analysis was performed on these alternatives. In general, non-structural measures are unlikely to be cost-effective in addressing flooding in this area. A buyout plan would be hampered by the dispersal of the at-risk properties over a lengthy area; none of the clusters of structures along the stream are concentrated enough to stand out from the other areas in

terms of flood damage history or potential for future flooding. Buying out all of the properties in the flood plain would be far more expensive than the structural alternatives and would also reduce the city's tax base. Estimated costs for effective flood proofing would amount to a large percentage of the total values of the affected structures. Avoidance measures such as evacuation of property or certain kinds of flood proofing requiring action early in a flood event would likely be of very limited usefulness given the small amount of warning time afforded by flash flooding in this area.

6.2 COSTS

The structural alternatives were costed in 2009 at an equivalent screening level of detail. First costs for the eight alternatives (subsequently updated to FY 2012 prices) ranged from $14.7 million to $25 million, as shown in Table I-11. The first costs were annualized based on the then-current interest rate of 4.125% (subsequently updated to the 3.75% Federal rate for 2013), a period of analysis of 50 years, and an installation period of six years from PED to project completion (used in calculating interest during construction). The first costs accounted for design, real estate, and construction costs.

OMRR&R costs at FY 2012 prices also were estimated at the screening level and added to the annualized first costs. OMRR&R costs were estimated at $130,000 for alternatives 1-4 and $24,000 for alternatives 5-7. Alternatives 5-7 would be expected to have much lower OMRR&R costs because they do not include the Karnes Road detention dam and the levee/floodwall and are designed to work with rather than against the natural topography of the area.

Annualized costs for the eight alternatives were paired with the annual benefits evaluated in HEC-FDA for each alternative to arrive at the screening results for this analysis.

(Note: There is a mismatch between the FY 2013 interest rate and the FY 2012 price level used in the screening. At the time of the last update of the screening in 2013, adjustment of values to FY 2013 prices had not been done and was not planned until the final preparation of this report, so the FY 12 prices were not adjusted. But the FY 2013 interest rate was used in the annual costs calculations to obtain the most accurate estimates available for annual costs at that time. Even though the interest rate and price level are not from the same year, all alternatives are evaluated on the same basis.)

6.3 SCREENING RESULTS

Table I-11 summarizes the main results of the benefit-cost analysis of the eight screening alternatives, while Table I-12 shows the project assurance ratings for each screening alternative (i.e., the likelihood that the project's capacity would be exceeded). The main points emerging from the economic screening analysis were as follows:

- The HEC-FDA analysis estimated EAD (equivalent annual damages) of $2,890,000 (FY 2012 prices) for the without-project condition. (Note that the total EAD of $3,558,000 cited above in section 5.1 is a later post-screening estimate.)

All alternatives reduced these damages by approximately 73% to 87%. All alternatives had benefit-cost ratios exceeding unity, ranging from 1.8 to 3.3.

- Alternatives 5, 6 and 8 were the economically optimal alternatives. Alternative 5 had a small but insignificant margin of superiority in net benefits over alternative 6, but 5 and 6 came in second in the rankings to Alternative 8.
- All alternatives dramatically alleviated long-term flood risk, but by no means would they eliminate it. Not only the largest flood events, but also those of more *modest scale would continue to result in damaging floods; see the annual exceedance probabilities in Table I-11, which show that a 10% annual exceedance probability is about the best that any of the alternatives can achieve in Reach 1.
- The alternatives generally had a much more pronounced effect on preventing damaging floods in Reach 2, which is the location of the entrance to the sewer.
- Alternative 8 was the NED plan, to be discussed further in section 7.

TABLE I-11 -- SCREENING BENEFITS AND COSTS BY ALTERNATIVE

Interest rate: 3.75%
Price level: October 2011

Alternative	Total project costs ($1,000s)	Annual OMRR&R costs	Annual costs ($1,000s)	Annual damages ($1,000s)	Annual benefits ($1,000s)	Benefit-cost ratio	Net benefits ($1,000s)
Existing	n.a.		n.a.	$ 2,890.0	n.a.	n.a.	n.a.
1	$16,093.0	$130.0	$906.4	$657.8	$2,232.2	**2.5**	$1,325.8
2	$22,372.0	$130.0	$1,210.5	$524.0	$2,366.0	**2.0**	$1,155.5
3	$25,032.0	$130.0	$1,337.4	$447.0	$2,443.0	**1.8**	$1,105.5
4	$24,838.0	$130.0	$1,328.2	$480.6	$2,409.4	**1.8**	$1,081.3
5	$14,732.0	$24.0	$739.9	$477.7	$2,412.3	**3.3**	$1,672.3
6	$16,298.0	$24.0	$813.9	$410.2	$2,479.8	**3.0**	$1,665.8
7	$22,950.0	$24.0	$1,134.0	$371.3	$2,518.7	**2.2**	$1,384.7
8	$15,105.1	$24.0	$753.6	$410.2	$2,479.8	**3.3**	**$1,726.2**

TABLE I-12 -- SCREENING PROJECT PERFORMANCE BY ALTERNATIVE						
Alternative	**Annual exceedance probability ***		**Nonexceedance probability in 1% event ****		**Chances of flooding over 10 years**	
	Reach 1	**Reach 2**	**Reach 1**	**Reach 2**	**Reach 1**	**Reach 2**
Existing	0.3893 < 5 year	0.3288 < 5 year	0.0000	0.0000	99.3%	98.1%
1	0.1244 < 10 year	0.0384 ~ 25 year	0.0000	0.0428	73.5%	33.8%
2	0.1128 ~ 10 year	0.0174 > 50 year	0.0000	0.1783	69.8%	16.1%
3	0.1007 ~ 10 year	0.0081 ~ 125 year	0.0000	0.9998	65.4%	7.9%
4	0.1052 ~ 10 year	0.0038 > 250 year	0.0000	0.9998	67.1%	3.7%
5	0.0966 ~ 10 year	0.0213 ~ 50 year	0.0000	0.1816	63.8%	18.8%
6	0.0922 ~ 10 year	0.0118 > 75 year	0.0000	0.0072	62.0%	11.2%
7	0.0841 > 10 year	0.0038 > 250 year	0.0000	0.9998	58.5%	3.8%
8	0.0922 ~ 10 year	0.0118 > 75 year	0.0000	0.0072	62.0%	11.2%

* Annual exceedance probability is the probability that a damaging flood (of whatever magnitude) would occur during any given year.

** Nonexceedance probability in the 1% event is the probability that the project would contain the 1%-chance flood event without significant damage from overtopping or project failure.

6.4 ATLAS 14 SENSITIVITY ANALYSIS

As discussed above in section 4.2.3, a new set of water surface profiles for the eight alternatives was computed based on the new Atlas 14 precipitation-frequency data. The profiles were entered into HEC-FDA along with the economic data used in the 2012 screening analysis, and the screening analysis was redone to determine whether the new data had any material effect on the study's previous conclusions.

The effects of the Atlas 14 profiles were very minimal in the Blacksnake Creek study area. Without-project EAD increased by less than 2%, and residual damages with the alternatives in place increased by less than 3% in most cases. In terms of economic justification, none of the benefit-cost ratios for the alternatives changed by more than a point (i.e., from 3.0 to 3.1), and the benefit-cost ratio for Alternative 8, the NED plan, did

not change at all. The other issue that required investigation was the screening rankings. Although the margin of superiority that Alternative 8 held in net benefits over the other alternatives narrowed somewhat, the screening rankings did not change in any way and Alternative 8 continued to be the NED plan.

Since the effect of the Atlas 14 data on the economic analysis was essentially nonexistent in the sensitivity test, it was decided that no further action was required in response to the new data; i.e., damage and benefit computations previously completed for the study did not need to be revised to reflect the Atlas 14 data. Thus, no change was made in the damages and benefits previously computed for use in the study. All damages and benefits reported in the tables in this appendix are based on the pre-Atlas 14 hydrologic/hydraulic data.

7.0 PLAN SELECTION

7.1 THE NED PLAN

The NED plan emerging from the screening analysis was Alternative 8, which excavates the Blacksnake Creek floodplain both north and south of Karnes Road to create detention capacity during peak flows. The NED plan requires no control structures such as levees, floodwalls, or detention dams and works more in harmony with the natural topography of the area than several of the earlier alternatives. The abandonment of Karnes Road in the area of the creek – a decision made by the city late in the study - is assumed, and this action reduces construction costs that would have been necessitated by raising, reconstructing, and strengthening the road, as well as installing culverts, in order to maintain the operability of Karnes Road. It also eliminates the need to relocate three power poles. The NED plan has a margin of superiority of about 3% in net benefits over the second-ranking alternatives (Alternatives 5 and 6, which were essentially tied in net benefits).

7.2 NED PLAN COSTS

A new and more detailed cost estimate for the NED plan was developed in late 2013. The current estimated total project cost in FY 2015 dollars, summarized in Table I-13, is $13,083,000. This total includes preconstruction engineering and design, real estate requirements, construction and construction management and contingencies.

Annual cost calculations for the NED plan, totaling $586,600, are summarized in Table I-14. Annual costs were calculated at the current FY 2015 Federal water resources interest rate of 3.375%. A 50-year period of analysis is assumed. Interest during construction computations assume project completion in FY 2018.

A new estimate of OMRR&R costs also was prepared for the NED plan in early 2014. The tasks assumed for the new estimate include routine annual costs of $28,300 as well as replacement costs at longer intervals, particularly the replacement of riprap every 20

years at $19,400. The discounted present-worth of the OMRR&R costs is $29,300 at the interest rate of 3.375%, slightly more than but comparable to the 2011 screening-level estimate of $23,000, particularly when the four year difference in price levels is taken into account.

TABLE I-13 -- TOTAL PROJECT COSTS	
$1,000s; FY 15 prices	
Planning, Engineering & Design (PED)	$2,044.0
Lands & Damages	$1,220.0
Construction Management (S&A)	$504.0
Construction	
Relocations	$154.0
Fish & Wildlife Facilities	$84.0
Floodway Control & Diversion Structures	$9,077.0
TOTAL PROJECT COST	**$13,083.0**
Fully-Funded Cost	$13,579.0

TABLE I-14 -- ANNUAL COSTS	
$1,000s; FY 15 prices	
First Costs	$13,083.0
IDC	$289.1
Total Investment Cost	$13,372.1
I&A factor (3.375%, 50 years)	0.04168
Annual Cost subtotal	$557.3
Annual OMRR&R Cost	$29.3
TOTAL ANNUAL COST	**$586.6**

7.3 NED PLAN BENEFITS

Benefits for the NED plan were recalculated most recently in early 2015 to account for price level changes in structure inventory values and other adjustments. The 2015 update had three components: (1) Price levels were updated, using a factor of 1.1465 (ENR Construction Cost Index, October 2008 to October 2014) to adjust structure replacement values to current prices. Depreciation percentages applied to the structure replacement values to produce depreciated replacement values were also updated to reflect the passage of additional time. (2) The method of calculating residential vehicle damages was revised. Previous benefit computations for the project, including the 2011 screening benefits, accounted for vehicle and landscaping values by assuming that the total vehicle and landscaping value for each residence was equal to 5% of the residential structure

value. The revised method used in the 2015 calculations is summarized above in section 3.2.5. This change in methodology was expected to produce, and did produce, only minimal changes in EAD and EAD reduced. (3) Emergency costs avoided, which were not included in EAD and benefit calculations prior to 2015, were added to the analysis. The procedures used for emergency costs are summarized above in section 3.2.9.

Summarized in Table I-15, annual benefits total $3,058,800 in FY 2015 dollars. This total is not affected by interest rate changes. The without-project EAD of $3,545,900 is reduced by about 86% with the NED plan in place. Reach 1 accounts for 69% of the benefits, while Reach 2 contributes the remaining 31%. Nonresidential benefits account for 61.7% of total benefits, while residential accounts for 27.6%, emergency costs for 9.0%, and streets for 1.6%.

Table I-15 also shows probabilistic estimates of the benefits. For example, there is a 25% chance that benefits under conditions of uncertainty would exceed $3,572,400 and a 50% chance that benefits would exceed $3,013,100. The latter total is very close to the expected value of the benefits ($3,058,800).

Finally, the HEC-FDA model estimates that in a 1% flood event, the number of structures inundated would be reduced from 148 without the project to about 50 with the project in place. In a 0.2% event, the project would reduce the number of inundated structures from 165 to 123.

TABLE I-15 -- ANNUAL BENEFITS

FY 15 prices; $1,000s

BENEFITS	Reach 1	Reach 2	Total	
Future without-project EAD	$2,523.9	$1,022.0	$3,545.9	
Residual with-project EAD	$423.0	$64.2	$487.1	
Damage reduction EAD	$2,100.9	$957.8	$3,058.8	
	68.7%	31.3%	100.0%	
BENEFITS BY CATEGORY				
Residential	$69.4	$775.5	$844.8	27.6%
Non-Residential	$1,832.8	$55.7	$1,888.5	61.7%
Streets	$49.9	$0.0	$49.9	1.6%
Non-Physical Costs	$148.9	$126.7	$275.5	9.0%
Total	$2,100.9	$957.8	$3,058.7	91.0%
PROBABILISTIC BENEFITS *			Total	
75% probability that benefits exceed:	$1,722.0	$778.9	$2,500.9	
50% probability that benefits exceed:	$2,075.2	$937.9	$3,013.1	
25% probability that benefits exceed:	$2,456.7	$1,115.7	$3,572.4	
Mean benefits	$2,100.9	$957.8	$3,058.8	

7.4 BENEFIT-COST DATA FOR NED PLAN

As seen in Table I-16, at the 3.375% interest rate, the NED plan for Blacksnake Creek has a very strong benefit-cost ratio of 5.2. Annual benefits total $3,058,800, annual costs are estimated at $584,000, and annual net benefits total $2,474,800.

TABLE I-16 -- BENEFIT-COST DATA	
FY 15 prices; interest rate = 3.375%; in $1,000s	
Annual Benefits	$3,058.8
Annual Costs	$586.6
Benefit-Cost Ratio	5.2
Net Benefits	$2,472.2

7.5 INDUCED DAMAGES AND REGIONAL ECONOMIC IMPACTS

7.5.1 Induced Damages - The feasibility study tasks included investigation of the potential for the NED plan to raise stages upstream or downstream of the project area. The investigation concluded that the project would not raise stages for the 1% flood event over future without-project conditions

7.5.2 Relocations – Although relocations would have been necessary with some alternatives considered during the screening process, the NED plan would necessitate no relocations of businesses or residences either inside or outside of the project area.

7.5.3 Regional Economic Development (RED) Impacts - The benefit evaluation process involves analysis of the economic losses to the subject study area from flooding as well as the potential gains to the study area from the successful prevention of flooding. Some impacts with and without a flood control project may be of major significance to a metropolitan area or community, but may not have any net impact on the national economy. For example, if a flood interrupts production at a given business in one community, that community suffers a loss. However, if the lost production is replaced by production at another plant elsewhere in the country, the loss to the local community does not represent a net loss to the national economy. Regional economic development (RED) impacts of this nature are not included in determining the NED benefits and costs, but do receive consideration in the decision-making process.

In the short term, during construction of the project, temporary increases in employment would be expected. The temporary presence of construction workers in the area for the project could bring a temporary increase in demand for some services in the local area and also in business volume, profits and sales tax receipts at the local retail and service establishments. In the longer term, implementation of the selected plan would contribute to the long-term stability of a large section of central St. Joseph traversed by Blacksnake Creek. Area businesses and residents with flood risk concerns would be expected to

continue their existing occupancy, and new businesses and investment would be more easily attracted to the study area in the future if vacancies occur, resulting in a stronger tax base. The continued deterioration of flood-prone buildings would be prevented, as would any subsequent effects on the resale market. With continued industrial and commercial stability enhanced by the increased reliability against flooding, existing neighborhoods and populations would also be expected to remain relatively stable, barring impacts from other sources. Other undesirable impacts of flooding, such as detours resulting in time costs and extra operating expenses, would also be alleviated.

7.6 ASSURANCE

The estimated performance of a flood risk management project in reducing the chances of occurrence of damaging floods is known as assurance. Assurance can be expressed as a range of statistics, and HEC-FDA, in addition to estimating economic damage and damage reduced, also provides a range of assurance estimates as an output. Table I-16 summarizes assurance statistics for the Blacksnake Creek project. The table displays statistics for both reaches of the project area as well as for the project area as a whole. For example, in Reach 2, the upstream reach, the project has essentially a 100% chance of containing the 10% flood event, but in Reach 1, the downstream reach, the CNEP (conditional nonexceedance probability) is 62.6%. (All probabilities discussed in this section are expressed as percentages.) Given these results, the CNEP for the entire project area is considered to be 62.6% because the rating for the entire project area is based on whichever reach has the lowest performance rating. For the Blacksnake project, performance in the upstream reach, near the project, is lower than in the downstream reach. This can be seen most dramatically in the CNEP results for a 1% flood event, where the HEC-FDA model calculates a 37.9% chance that Reach 2 would avoid significant damage, but no chance that Reach 1 would also avoid damage. Because the assurance ratings for the downstream reach are lower than for the upstream reach, the ratings for the project area as a whole are conservatively based on the downstream ratings.

The annual chance of exceedance (ACE) in the project area is rated at 38.4% under without-project conditions. This means that without the project, there is approximately a 38% chance of a damaging flood in any given year. (The statistic accounts for the entire range of possible floods that would be large enough to result in economic damage and thus encompasses a broad range of smaller, moderate, and larger events.) With implementation of the project, the annual exceedance probability drops from 38% to approximately 9%

The long-term risk calculations displayed in the table indicate the estimated chances of a damaging flood over specified time periods. Like the ACE, these statistics account for floods with a broad range of possible magnitudes. For example, on average over the long-run under without-project conditions, it is essentially certain that a damaging flood would occur during an average 10, 30, or 50-year period. (This is a long-term average and does not necessarily mean that a damaging flood will occur in the next 10 years.) Under with-

project conditions, the chances of flooding over the 10-year drop to 61.2%, and over the 30-year period, the chances are reduced to 94.2%.

7.7 RESIDUAL RISK

Although it might be desirable if a flood risk management project could totally eliminate the consequences of flooding to property and people, the simple fact is that no project that conceivably could be constructed would successfully contain every possible flood. Significant flood risk will continue after the Blacksnake project is implemented. Indeed, another way of looking at the results in Table I-17 is that the chances that a damaging flood will occur in the project area even with the project in place are not really reduced significantly except in the smaller, more frequent floods. Exceedance probability (the chances of flood damage) in a 4% event, which is 100% for without-project conditions, is only reduced to 96% by the project, and is close to 100% for events higher than the 4% with the project in place. A total of $487,000 in residual EAD - about 14% of total without-project EAD – would be expected after project implementation.

The high continuing probability that damaging flood events will occur in the project area does not mean that the project is ineffective. As can be seen in the discussion of benefits above, the project very substantially reduces potential economic damage over the long term. But it accomplishes this not by completely preventing floods from occurring, but by alleviating depths of flooding to much less dangerous and harmful levels when floods do occur. There will be a continuing need, even after project implementation, to monitor potential flood events diligently and take appropriate precautions.

TABLE I-17 -- PROJECT PERFORMANCE (ASSURANCE) HEC-FDA ESTIMATES						
	REACH 1 (DOWNSTREAM)		REACH 2 (UPSTREAM)		TOTAL PROJECT AREA	
	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT	WITHOUT PROJECT	WITH PROJECT
ANNUAL CHANCE OF EXCEEDANCE (ACE)*						
Median	38.7%	9.0%	33.4%	1.2%	38.7%	9.0%
Expected	38.4%	9.0%	33.3%	1.2%	38.4%	9.0%
LONG-TERM RISK** (chance of flooding during period)						
over 10 years	99.2%	61.2%	98.3%	11.3%	99.2%	61.2%
over 30 years	100.0%	94.2%	100.0%	30.3%	100.0%	94.2%
over 50 years	100.0%	99.1%	100.0%	45.2%	100.0%	99.1%
CONDITIONAL EXCEEDANCE PROBABILITY PER EVENT (in %)						
10.0%	100.0%	37.4%	100.0%	0.0%	100.0%	37.4%
4.0%	100.0%	96.0%	100.0%	0.0%	100.0%	96.0%
2.0%	100.0%	99.7%	100.0%	0.0%	100.0%	99.7%
1.0%	100.0%	100.0%	100.0%	99.5%	100.0%	100.0%
0.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
CONDITIONAL NON-EXCEEDANCE PROBABILITY PER EVENT (in %)						
10.0%	0.0%	62.6%	0.0%	100.0%	0.0%	62.6%
4.0%	0.0%	4.0%	0.0%	100.0%	0.0%	4.0%
2.0%	0.0%	0.3%	0.0%	100.0%	0.0%	0.3%
1.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

* Annual chance of exceedance (ACE) is the chance of a damaging flood in any year. The statistic implies nothing about the magnitude of the flood except that it would be large enough to exceed the system's capacity.

** The same is true of the long-term risk of flooding; it is based on the probability of a damaging flood of any magnitude.

8.0 CONCLUSION

The feasibility-level socioeconomics analysis of the Blacksnake Creek Federal flood risk management project in St. Joseph, Missouri, has found that a strong Federal interest exists in the NED plan. The plan, estimated to cost $13,083,000, exhibits very strong economic justification with a benefit-cost ratio of 5.2 at the current Federal interest rate of 3.375%. At the budgetary interest rate of 7%, the benefit-cost ratio is 3.0. With net annual benefits of $2,457,000, the project represents a strong contribution to national economic outputs.

Annual benefits	**$ 3,059,000**
First costs	**$ 13,083,000**
Annual costs	**$ 587,000**
Benefit-cost ratio	**5.2**
Net benefits	**$ 2,472,000**

Supplement to Appendix I: PLAN FOR ECONOMIC UPDATES

ER 1105-2-100, para. D-4, requires a plan for conducting updates of the project economic justification. Economic updates, revisiting estimated damages, benefits, costs, affected population, and residual risk, will be required every three years until the project gains a new construction start, after which the required interval will be five years. Updates are not intended to involve major economic analyses or extensive reworking of the feasibility study analysis. They are intended to verify the continuing validity of important assumptions on which the economic justification is founded as well as to update data to current price levels. It is currently expected that the first economic update would be required in FY 2018.

Under the guidance, several different approaches are available for carrying out an economic update, depending on the nature of the economic base. Total investment and economic damage potential in some study areas are dominated by a few larger companies, and updates can be readily prepared in these cases by reevaluating the benefits of just a few companies that account for a high percentage of project benefits. This approach is not possible for the Blacksnake Creek project because the economic base is distributed among primarily smaller and medium-sized service and retail businesses spread along an approximately 2.3 mile stretch of St. Joseph Avenue. Sampling is another option which can be an acceptable approach in generally residential areas but tends to be far less satisfactory for dealing with commercial and industrial areas with a heterogeneous mix of businesses. Although most of the structures in the Blacksnake Creek study area are residential, 71% of total investment is accounted for by nonresidential structures, so sampling would not be an advisable methodology for an economic update in this area.

The planned approach for updating the Blacksnake Creek study area economic data would be to carry out a 100% field survey to identify land use and occupancy changes, re-calculate structure values in current dollars, and adjust equipment and inventory values for changes in activity and price levels. Local city and Chamber of Commerce staff would be consulted to further help identify major changes of the previous three years pertaining to the economic structure inventory and particularly to major nonresidential properties. Discussions would encompass verification of continuing operations at major properties, identification of significant changes in operational scale at major businesses and facilities, and identification of significant new development including major new businesses, public facilities, residential developments, and roads and streets.

Upon completion of the field survey and discussions (or other research), a decision would be made regarding whether the changes observed since the last report would constitute a significant change in previous economic assumptions and modeling results. If not, the update would be considered a Level 1 economic update and would simply reaffirm the previously reported benefits, which would continue to be the economic data of record for another three years.

Level 1 update labor estimate:
Data gathering and survey – 24 hours
Report preparation – 16 hours
Total – 40 hours

If the changes observed in economic conditions in the study area are more significant, a higher level of economic update would be prepared. Tasks to be completed would depend upon the degree of economic change observed, with more substantial changes requiring higher update levels, but might include the following for a Level 2 update:

1. Economic structure inventory revisions for nonresidential properties – For the first update, these revisions might be a price level adjustment of replacement costs; for subsequent updates, there would be new replacement cost estimates using RS Means data or the equivalent. Depreciation of the structures also would be revisited and recalculated based upon field observations of the conditions of individual structures. Nonresidential contents in this analysis are computed as percentages of structure value and will update automatically when structure values are updated. (16 hours)

2. Economic structure inventory revisions for residential properties – The updating of residential structure values would be based on an update factor determined based on changes in the average and median housing values for the city, count and MSA (or down to the block group level if data are available at that level). The factor would be applied to all residential structure values. Vehicle values would be updated with an up-to-date estimate of the average used vehicle cost in the U.S. (or smaller area if available). (4 hours)

3. Transportation network -- For roads, streets and railroads, updated average replacement costs per mile, as well as average depreciation factors, will be used to bring depreciated replacement values up to date for each type of road. (1 hour)

4. New development -- For significant new additions to the property base, including large businesses and facilities built above the 1% flood elevation, significant new residential projects built above the 1% flood elevation, or major new roads and streets, new depreciated replacement values would be estimated in the same manner in which they have been prepared for the present report. However, major new development in the Blacksnake study area is not really anticipated at this time. (8 hours)

5. Other benefits -- For disaster relief costs, up-to-date data will be obtained from FEMA. For emergency costs, updated values would be driven by new HEC-FDA calculations of residential and nonresidential EAD; the emergency costs are estimated as a percentage of these costs. (2 hours)

6. Damages and benefits analysis - The HEC-FDA program will be loaded with the updated property database and new damage and benefit estimates will be produced. (8 hours)

7. Benefit-cost ratio - An updated cost estimate will be prepared by engineering staff and annualized. Benefit-cost ratios and net benefits will be calculated based on the updated benefits from HEC-FDA and the annual costs. (2 hours)

8. Population -- Estimates of population at risk will be updated if block-level Census data are available for current conditions. (4 hours)

9. Documentation – An update report will be prepared documenting the tasks completed and the results of the updated analysis. (32 hours)

Total estimated labor: 77 hours. This estimate is based on a Level 2 economic update; if higher levels are required, the labor could greatly increase.

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APPENDIX J

Clean Water Act 404(b)(1) Evaluation

CLEAN WATER ACT
SECTION 404(b)(1) EVALUATION (40 CFR 230)

BLACKSNAKE CREEK SECTION 205 FEASIBILITY STUDY

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CLEAN WATER ACT
SECTION 404(b)(1) EVALUATION (40 CFR 230)

BLACKSNAKE CREEK SECTION 205 FEASIBILITY STUDY

PROJECT DESCRIPTION

a. Location

Blacksnake Creek is a small left bank tributary of the Missouri River located in Andrew and Buchanan Counties, Missouri. The creek enters the City about 4.3 miles above its mouth and flows south-southwest through the City of St. Joseph to its confluence with the Missouri River (Figures 1 and 2).

b. General Description

The watershed has a total drainage area of 8.2 square miles. The channel in the lower 3.2 square miles of the basin is enclosed in a combined sewer of varying size up to 17 feet in diameter. The upper 5 square miles of the basin above the combined sewer inlet at Karnes Road is drained by open channel.

Blacksnake Creek is an urbanized stream that flows for about 3,200 linear feet through the project area. The channel was straightened and the bottom concrete lined for the last 530 linear feet of the channel before subverting into an underground channel (combined sewer) through an inlet located immediately north of Karnes Road and conveyed to the Missouri River. The storm system north of Karnes Road consists mostly of open channels, while the system south of Karnes Road is largely piped. The substrate of the unlined portions of the Creek is composed of clay. The Creek is incised and there is a large amount of concrete and asphalt debris in the channel, as well as a variety of litter.

A small ephemeral stream flows into Blacksnake Creek in the southeastern portion of the project area. This tributary is also incised with some litter observed during field observations, although to a lesser degree compared to the Creek. The stream is culverted, but does not contain concrete lined channel, a low water crossing and multiple culverts like the Creek.

During storm events greater than or equal to a 5-year frequency, the capacity of the Karnes Road combined sewer inlet is exceeded, flooding the area downstream of Karnes Road. During intense storm events (greater than or equal to a 5-year frequency), the Karnes Road combined sewer inlet capacity is exceeded. When this occurs, flow from Blacksnake Creek overtops Karnes Road and flows south via streets and yards to flood residential, commercial, and industrial properties within the City, including over 200 residential, commercial, and industrial structures along the St. Joseph Boulevard corridor. At least six major flood events have been recorded at this location, each resulting in major property damage.

c. Authority and Purpose

This study is authorized under Section 205 of the Flood Control Act of 1948, as amended by the Water Resources Development Act of 1986. Section 205, one of several existing authorities in

the Continuing Authorities Program (CAP), gives the U.S. Army Corps of Engineers (USACE) authority to plan, design, and construct small flood control projects that have not been specifically authorized by Congress. Federal participation in Section 205 projects is limited by statute to $10 million.

There have been at least six major flood events in recorded history, each causing major damages to developed property. One of the most damaging floods occurred on June 9, 1984, and caused several million dollars in damages. The remaining five significant storms happened in June 1943, June 1949, May and August of 1959, and May 1962. Ongoing upper basin development and floodplain encroachment are potential factors in continuing flood related damage during larger storm events. Therefore, the purpose of the project is to implement a flood risk management alternative to reduce flood risk and associated impacts to home and businesses along St. Joseph Boulevard. The City is also required to control sewer overflows as regulated by the Clean Water Act. The proposed action would be permitted and conducted under all general and regional conditions specified for regulatory compliance by the Kansas City District, Regulatory Branch. Section 401 Water Quality Certification would be obtained from the State of Missouri prior to construction.

Alternatives

Structural flood mitigation measures reduce flood hazard by keeping floodwaters away from people and damageable property. The structural measures considered included the excavation of a detention basin and construction of a detention dam, levee, and floodwall. Initial plan formulation included the development and engineering review of four dry detention plans for the area north of Karnes Road and east of St. Joseph Avenue, with levels of protection in the range of a 10- to 250-year flood event. The detention plans included:

- Raising Karnes Road to act as a detention dam, with associated drainage and outlet structures.
- Construction of a levee on the west side of the detention basin from Karnes Road to Savannah Road and a floodwall on the east bank of Blacksnake Creek north of Savannah Road to protect existing residences and structures.
- Excavation of the Blacksnake Creek floodplain north of Karnes Road to increase detention.
- Site grading, utility/sewer relocations and other appurtenances.
- Acquisition/buyout of properties.

The four initial dry detention plan alternatives are shown in Figure 3 and described below.

Alternative 1 - Alternative 1 raises Karnes Road to elevation 905 NGVD to act as a detention dam but includes no excavation of the existing basin to increase storage. This alternative also includes construction of a levee and a floodwall upstream of Karnes Road to provide protection to existing residences and structures. The levee would be located to the east of and parallel to St.

Joseph Avenue. The floodwall would be located farther upstream, just to the north of Savannah Road. In this alternative, an overflow spillway at Karnes Road would be the point of overtopping.

Alternative 2 - Alternative 2, in addition to the features of Alternative 1, would excavate the detention basin within the Blacksnake Creek floodplain north of Karnes Road between St. Joseph Avenue and an abandoned railroad right-of-way to increase the detention capacity.

Alternative 3 - Alternative 3 would increase the detention capacity of Alternative 2 by extending the detention area to the east of the abandoned railroad right-of-way. The abandoned railroad right-of-way would be removed to access the additional detention volume to the east.

Alternative 4 - Alternative 4 would increase the detention capacity of Alternative 3 by removing a portion of Karnes Road, extending the levee downstream of Karnes Road to Northwest Parkway, and additional excavation within the basin area. This alternative does not include the replacement of Karnes Road. In this alternative, an overflow spillway at Northwest Parkway would be the point of overtopping.

Based on the initial value engineering review of the alternatives and discussions with the project sponsor, three additional alternatives were developed using the natural topography and a lower pool height to eliminate the need for the traditional and costly structures (detention dam, levee, and floodwall) of Alternatives 1 through 4. The four alternative detention plans are shown in Figure 4 and described below.

Alternative 5 - The Blacksnake Creek floodplain north of Karnes Road between St. Joseph Avenue and an abandoned railroad right-of-way would be excavated to increase the detention capacity. The abandoned railroad right-of-way along the east side of the basin would be removed to access additional detention volume to the east. An overflow spillway would be constructed at an elevation of 895 NGVD on Karnes Road. In this alternative, an overflow spillway at Karnes Road would be the point of overtopping.

Alternative 6 - Alternative 6 would increase the detention capacity of Alternative 5 by excavating the area between Karnes Road and Northwest Parkway. Culverts would be constructed to provide a connection between the areas north and south of the Karnes Road. In this alternative, an overflow spillway constructed at an elevation of 895 NGVD at Northwest Parkway would be the point of overtopping.

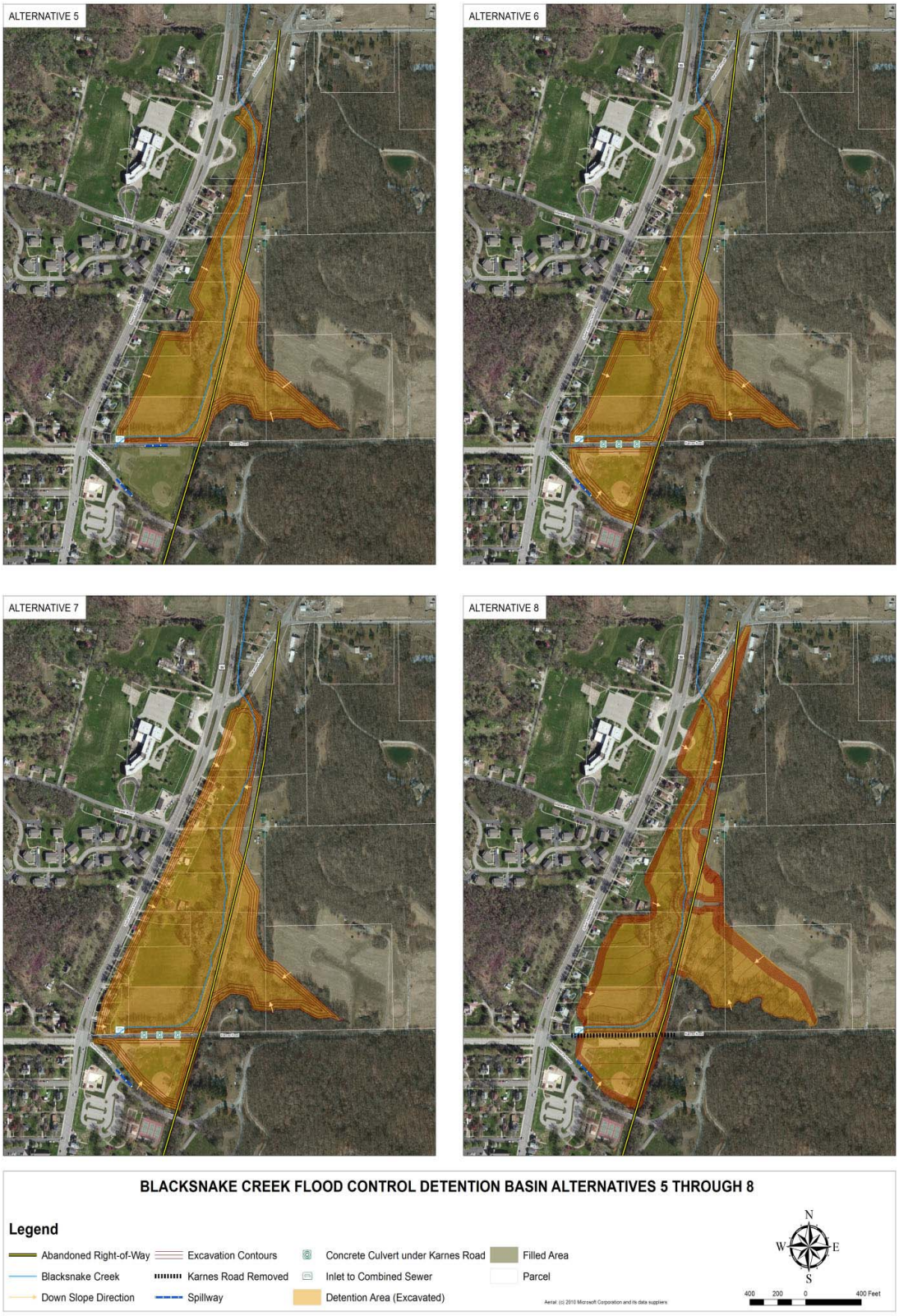
Alternative 7 - Alternative 7 would increase the detention capacity of Alternative 6 by expanding the basin north of Karnes Road to the west. This alternative would require the purchase and demolition of the residences on the west side of the basin along St. Joseph Avenue. In this alternative, an overflow spillway constructed at an elevation of 895 NGVD at Northwest Parkway would be the point of overtopping.

Subsequent to the development of Alternatives 1 through 7, the City approved a transportation plan that included the City's abandonment of the Karnes Road section crossing the basin. Therefore, an additional alternative that excavates the abandoned Karnes Road was formulated.

Alternative 8 - Alternative 8 modifies Alternative 6 by removing Karnes Road. The removal of Karnes Road reduces construction cost by eliminating the need to raise, reconstruct, and armor the road, and for the installation of culverts to provide a hydraulic connection between the basin areas north and south of the road.

Figure 3 – Alternatives 1 through 4

Figure 4 – Alternatives 5 through 8



A nonstructural flood risk management study was completed as a separate task for this project. Nonstructural measures considered during this study include structure acquisition and demolition/relocation, structure elevation, flood proofing, localized flood reduction measures, flood emergency preparedness system, and floodplain regulation.

No Action

The no action alternative is unacceptable as it would not provide a means to decrease combined sewer overflows and flooding along St. Joseph Boulevard. Flooding and adverse socioeconomic impacts would continue to occur. The City would not be in compliance as they are required to control sewer overflows as regulated by the Clean Water Act, Missouri Department of Natural Resources and U.S. Environmental Protection Agency.

Recommended Plan

Due to the large number of homes and businesses in the flood prone area, structure acquisition is not practical. In addition to the acquisition and demolition/relocation cost based on socioeconomic analysis, removal of these structures would significantly reduce the City's tax base. Therefore, nonstructural alternatives were screened out of feasibility. The no action alternative does not beet the basic project purpose of reducing flood risk and compliance with the Clean Water Act. Alternatives 5 through 8 meet the project purpose and do not include the costly structural measures of Alternatives 1 through 4.

Alternatives 1 through 4 are not preferred as these alternatives were formulated with traditional flood risk management structures including detention dam, levee, and floodwall that are typically very expensive to construct and maintain. These alternatives are variants of the same basic plan which include raising Karnes Road to act as a dry detention dam with an overflow spillway. Alternative 1 includes no excavation for the detention area upstream of Karnes Road, while 2, 3 and 4 involve increasing amounts of excavation. All four alternatives would include a levee/floodwall combination upstream of Karnes Road, which is meant to protect homes in that area from any adverse effects of the detention basin. Alternative 4 extends the detention basin downstream of Karnes Road, removing a short portion of Karnes and adding a second levee.

Alternatives 5 through 8 are also variants of the same plan. Like Alternatives 1 through 4, these plans involve dry detention upstream of Karnes Road. Unlike Alternatives 1 through 4, they use the natural topography and a lower pool height to avoid the need for the Karnes Road dam and levee/floodwall combination upstream. The dry detention area in Alternative 5 is upstream of Karnes Road. Alternative 6 extends it a short distance downstream to Northwest Parkway, as in Alternative 4. Alternative 7 expands the detention area upstream of Karnes to the west.

Alternative 8 is similar to Alternative 6 but takes into account the City's plan to abandon the section of Karnes Road crossing the basin as part of its approved area transportation plan. The abandonment of Karnes Roads allows a reduction in cost by eliminating the need to raise, reconstruct, and armor the road, and for the installation of culverts to provide a hydraulic connection between the basin areas north and south of the road. The volume gained by the removal of Karnes Road is used to construct utility pads around three 161 KV power poles that were to be relocated under Alternative 6 while maintaining the same detention volume. The cost

savings associated with removing Karnes Road and not relocating the 161 KV power poles out of the basin is approximately $1 million. Therefore, Alternative 8 is the Preferred Alternative.

d. General Description of Fill Material

The total estimated amount of soil fill to be placed is 2,700 cubic yards. Clean soil fill would be obtained from a commercial borrow source.

Approximately 33,120 tons of riprap for erosion control and 3800 tons of aggregate surfacing would be placed. Rock would be obtained from an approved quarry and meet the criteria specified in Engineering Manual 1110-2-1601, Engineering and Design - Hydraulic Design of Flood Control Channels.

e. Description of the Proposed Fill Placement Sites

Fill material would be placed around the transmission tower pads, inlet and outlet locations, overflow embankments, and at other locations of potential excessive erosion such as creek bends or tall basin side slopes. Fill material will consist of aggregate surfacing for access roads and riprap for erosion control around the transmission tower pads, inlet and outlet locations, overflow embankments, and at other locations that could experience excessive erosion such as creek bends or tall basin side slopes.

Some material excavated from the creek and stream would be combined with fill and moved around to shape the creek and stream channel and banks. It is estimated that about 2,700 cubic yards of soil fill would be used for the Creek and 53 cubic yards of soil fill would be used for the stream.

Of the 2,650 total linear feet of Blacksnake Creek within project area, 1,200 linear feet would be excavated three to four feet deeper than the existing creek substrate. The creek bottom would also be widened an average of 20 feet along its length as it is currently incised. Areas that are realigned for power pole foundations would bump the channel out and function as small meanders. The estimated amount of material to be excavated below the ordinary high water mark (OHWM) totals 44,000 cubic yards and the estimated total amount of fill is approximately 2,700 cubic yards for a net excavation of 41,300 cubic yards. Excavated material will be reused as fill and would be moved around to shape the stream and streambanks. Remaining suitable material would be used to elevate power pole foundations.

Approximately 2,140 tons of riprap would be placed below the ordinary high water mark (OHWM) at creek bends. Approximately 30,980 tons of rock would be placed above the OHWM. Placement of rock above the OHWM includes around power pole pads, at the primary and secondary spillways, and at river bends. Approximately 3,800 tons of aggregate will be used for permanent and temporary access roads.

The ephemeral stream to the east of Blacksnake Creek would be impacted similar to the Creek. The total stream length is 1,380 linear feet, 240 linear feet of stream be realigned and 1,060 linear feet of stream would be shaped to convey flow more efficiently. The estimated amount of material to be excavated below the OHWM totals 284 cubic yards and the total estimated amount

of fill required is 53 cubic yards. Excavation would not occur deeper than the existing streambed and excavated material would be moved around to shape the stream and stream banks. Sixty linear feet of the existing channel would be permanently filled. Flow would be directed into the Creek similar to existing conditions.

f. Description of Disposal Method

Material would be placed at the fill site by mechanical means. Equipment would be standard earthmoving construction equipment.

1. REVIEW OF COMPLIANCE (§230.10[A]-[D])

A review of the proposed activity indicates that:

a. The proposed rock and soil fill and rock placement does not occur in a special aquatic site. Rock and soil placement must be placed within the aquatic ecosystem to fulfill its basic purpose.

b. The activity does not appear to (1) violate applicable state water quality or effluent standards; (2) jeopardize the existence of Federally listed endangered or threatened species or their habitat; and (3) violate requirements of any Federally designated marine sanctuary.

c. The activity will not cause or contribute to significant degradation of a water of the United States including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic, or economic values.

d. Appropriate and practicable steps would be taken to minimize potential adverse impacts of grading and rock placement on the aquatic ecosystem through the use of best management practices (BMPs) incorporated into the construction specifications.

2. TECHNICAL EVALUATION FACTORS (SUBPARTS C-F)

a. Physical and Chemical Characteristics of the Aquatic Ecosystem (Subpart C)

1. Substrate impacts. 1,200 linear feet of the Blacksnake Creek channel substrate would be excavated three to four feet deeper than the existing creek substrate. The creek bottom would also be widened an average of 20 feet along its length as it is currently incised. The estimated amount of material to be excavated below the Creek ordinary high water mark (OHWM) totals 44,000 cubic yards. Excavated material will be reused as fill and would be moved around to shape the stream and streambanks. Remaining suitable material would be used to elevate power pole foundations.

   Approximately 2,140 tons of riprap would be placed below the ordinary high water mark (OHWM) at creek bends. Approximately 30,980 tons of rock would be placed above the OHWM. Placement of rock above the OHWM includes around power pole

pads, at the primary and secondary spillways, and at river bends. Approximately 3,800 tons of aggregate will be used for permanent and temporary access roads.

The ephemeral stream to the east of Blacksnake Creek would be impacted similar to the Creek. 240 linear feet of stream be realigned and 1,060 linear feet of stream would be shaped to convey flow more efficiently. The estimated amount of material to be excavated below the OHWM totals 284 cubic yards and the total estimated amount of fill required is 53 cubic yards. Excavation would not occur deeper than the existing streambed and excavated material would be moved around to shape the stream and stream banks. Sixty linear feet of the existing channel would be permanently filled. Flow would be directed into the Creek similar to existing conditions.

2. Suspended particulates/turbidity impacts. A temporary diversion channel capable of accommodating the Blacksnake Creek base flow would be excavated within the construction footprint to facilitate detention basin. The substrate of the diversion channel would be graded and compacted to minimize increased suspended particulates and associated turbidity.

   Similar to the temporary diversion channel, the Creek and ephemeral stream substrate would be compacted to keep existing soils in place during construction. Sediment that has accumulated behind asphalt, concrete, and miscellaneous trash dumped into the creek, and to a lesser extent the stream, would be removed prior to construction and the substrates would be compacted with existing and fill soils. Best management practices such as trenched silt fencing and staked hay bales would be used to minimize soil entering the Creek from bank shaping and adversely impacting downstream water quality.

   Fill material consisting of aggregate surfacing for access roads and riprap for erosion control would be placed around the transmission tower pads, inlet and outlet locations, overflow embankments, and at other locations that could be eroded such as Creek bends and side slopes. The placement of rock fill in areas of potential erosion would stabilize the Creek and prevent erosion to minimize suspended particulates and turbidity. Therefore, increased suspended particulates and turbidity impacts within and downstream of the project area are anticipated to be short-term, minor and construction related.

   Construction activities are not expected to produce any significant change in suspended particulate matter or turbidity of the Missouri River, or other drainages located within the vicinity of the project area. No noticeable impacts to dissolved oxygen levels, toxic metals, organics or pathogens are anticipated as debris would be removed from the Creek prior to construction. Daylighting the creek and stream as a result of riparian corridor removal is anticipated to increase water temperatures. Water temperature would decrease with underground flow and dissolved oxygen would increase with water mixing at the Missouri River outfall. Photosynthetic, filter feeder, and sight feeder impacts are expected to be minimal as the existing aquatic ecosystem viability is very limited.

3. Water column impacts. Water chemistry, clarity, color, odor, taste, dissolved gas levels, nutrients, and eutrophication would not be anticipated to be affected by a temporary stream diversion, detention basin excavation, soil fill and rock placement for erosion control. A short-term, minor construction related impact to water clarity could occur following construction and stabilization of the creek and stream channels and banks. Best management practices would be used to prevent water quality impacts during and post construction.
4. Alteration of current patterns and water circulation. The Creek is channelized with no rock and riffle, and very minimal pool due to very low base flows. No adverse effects to current patterns or water circulation were identified. The creek is channelized and slight meandering around transmission tower pads for an approximate length of 900 feet is incorporated into the project design. Debris removal from the creek channel and banks, broadening of the creek channel, and the incorporation of slight meanders along the creek would positively alter current patterns and water circulation.
5. Alteration of normal water fluctuations/hydroperiod. The project as designed is anticipated to decrease fluctuation and increase hydroperiod during heavy precipitation events. Increasing hydroperiod would provide for settling of particulates prior to flowing downstream and would benefit water quality. No adverse effects to normal water fluctuations/hydroperiod were identified.
6. Alteration of salinity gradients. Salinity determinations are not applicable to the area.

b. Biological Characteristics of the Aquatic Ecosystem (Subpart D)

1. Effect on threatened/endangered species and their habitat. No threatened or endangered species occur within or adjacent to the stream. The Federally endangered pallid sturgeon (*Scaphirhynchus albus*) inhabits the Missouri River downstream. A potential minor, short-term construction related increase in suspended particluates and turbidity would not be anticipated to adversely affect the pallid sturgeon as this species is adapted to large, turbid rivers.
2. Effect on the aquatic food web. The proposed action should have no significant effect on the aquatic food web. No significant impacts to benthos, plankton, or nekton are anticipated as the aquatic food web is minimal and already severely impacted by channelization, culverts and concrete lined channel, a low water crossing and debris dumped into and adjacent to the creek.
3. Effect on wildlife (mammals, birds, reptiles, and amphibians). Construction is anticipated to have a long-term, minor impact to wildlife due to removal of riparian corridor and daylighting the stream. Wildlife would be expected to use adjacent habitat during construction. Areas of similar habitat occur upstream of the proposed detention basin. Tree removal would be mitigated by replacing impacted trees within the watrershed. The Recommended Plan would result in positive impacts to water quality as combined sewer overflows and overland flooding would decrease.

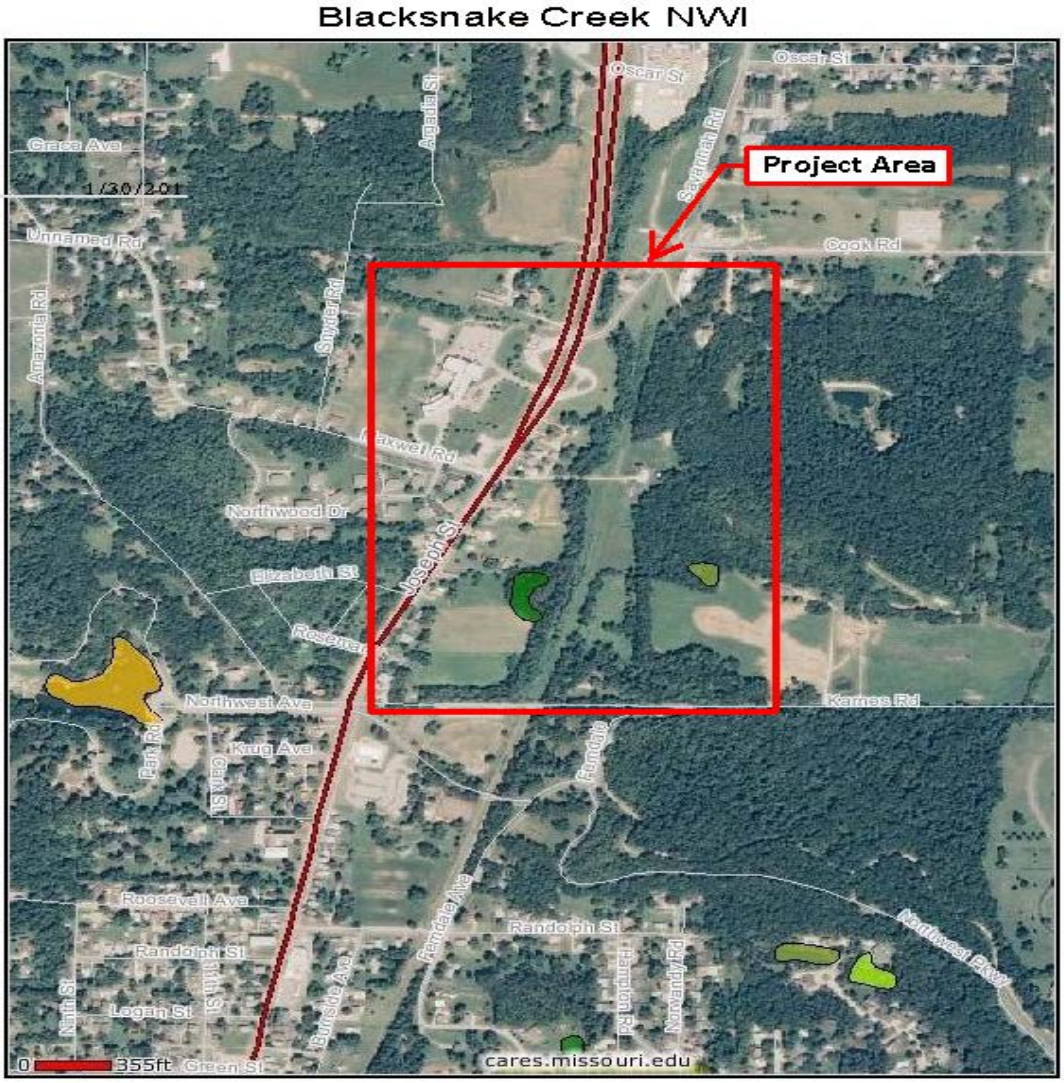
c. Special Aquatic Sites (Subpart E)

1. Sanctuaries

2. Wetlands
3. Mud flats
4. Vegetated shallows
5. Coral reefs
6. Riffle and pool complexes

The proposed action would have no adverse effect on sanctuaries, wetlands, mud flats, vegetated shallows, or riffle and pool complexes as none exist within the vicinity of detention basin excavation. Although an NWI-mapped wetland is located within the area of detention basin excavation, this mapped wetland is riparian corridor and not wetland due to a lack of wetland hydrology, as verified during field reconnaissance (Figure 5).

Figure 5 – Blacksnake Creek NWI



d. Human Use Characteristics (Subpart F)

1. Effects on municipal and private water supplies
2. Recreational and commercial fisheries impacts
3. Effects on water related recreation
4. Aesthetic impacts
5. Effects on parks, national and historical monuments, national seashores, wilderness areas, research sites, and similar preserves.

The proposed action would have no substantial adverse effect on municipal and private water supplies, recreational or commercial fisheries, water-related recreation, parks, national and historical monuments, national seashores, wilderness areas, research sites, or similar preserves. A moderate, long-term adverse impact to aesthetics would occur due to the removal of riparian corridor and excavation for detention, particularly to residents along St. Joseph Avenue whose property faces the Creek, and those who drive along the roads in the vicinity of Blacksnake Creek. Similar habitat occurs upstream of the proposed detention basin. Tree mitigation would occur in areas upstream of the impacted riparian corridor.

3. EVALUATION OF FILL MATERIAL (SUBPART G)

a. The following information has been considered in evaluating the biological availability of possible contaminants in fill material: physical characteristics. Soil fill material would be obtained from a CENWK approved commercial source and local quarry, and rock would be obtained from an existing quarry located in Missouri or Kansas that meets the criteria specified in Engineering Manual 1110-2-1601, Engineering and Design - Hydraulic Design of Flood Control Channels. Construction material would be chemically stable and non-contaminating. Neither the rock or soil fill nor its placement would cause relocation or increases of contaminants in the aquatic system.

4. DISPOSAL SITE DELINEATION (§230.11[F])

a. The following factors, as appropriate, have been considered in evaluating the disposal site: depth of water at the disposal site, current velocity, direction, variability at disposal site, and the degree of turbulence. The project area and disposal site have also been evaluated for the presence of special aquatic sites and waters of the U.S. No special aquatic sites are located within the vicinity of construction or disposal.

A total of 660,000 bank cubic yards are estimated to be excavated for the detention basin. Spoil separation and disposal is to occur at the existing softball complex (Complex), located approximately 1.9 miles west of the proposed detention basin excavation. Soil unsuitable for levee construction, estimated at 160,000 bank cubic yards, is to be graded into the existing ground. Rock and debris would be disposed in an appropriate landfill. Approximately 500,000 bank cubic yards would be stockpiled at Elwood Bottoms, located approximately 2.9 miles south of the Complex and used as fill for the MRLS 471-460 levee raise located approximately 0.3 miles west of the Complex. A buffer of at least 100 feet

would be used at the Complex to prevent spoil from entering the Missouri River. Stockpiled soil would be covered and/or seeded to prevent erosion and contained by silt fencing.

The Complex and Elwood Bottoms contain NWI-mapped wetlands. Wetlands mapped in the vicinity of the Complex are primarily located in the southern portion of the Complex, and adjacent to the Missouri River. Some wetland acreage is mapped adjacent to the ball fields (Figure 6 Softball Complex NWI). Elwood Bottoms has been severely disturbed due to tree clearing, earthmoving, and agricultural activity. One emergent wetland is NWI-mapped within the area of proposed spoil placement (Figure 7 Elwood Spoil Area NWI). This wetland was not observed to exist during field reconnaissance. Construction specifications would preclude the placement of spoil would not be placed within or adjacent to existing wetlands or in areas where runoff could enter existing wetlands. All areas of borrow and spoil placement will be assessed for changed conditions prior to construction.

Figure 6 – Softball Complex NWI

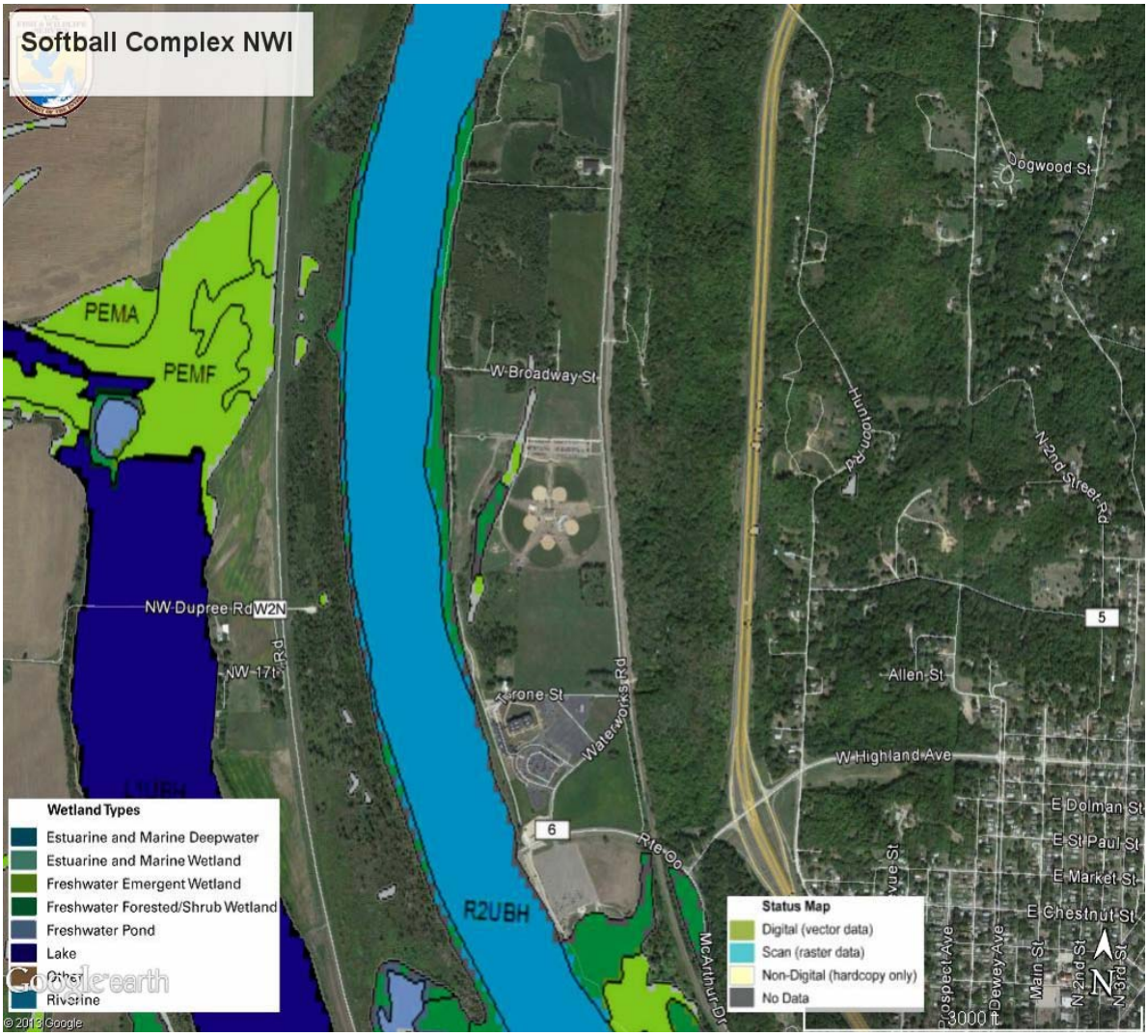
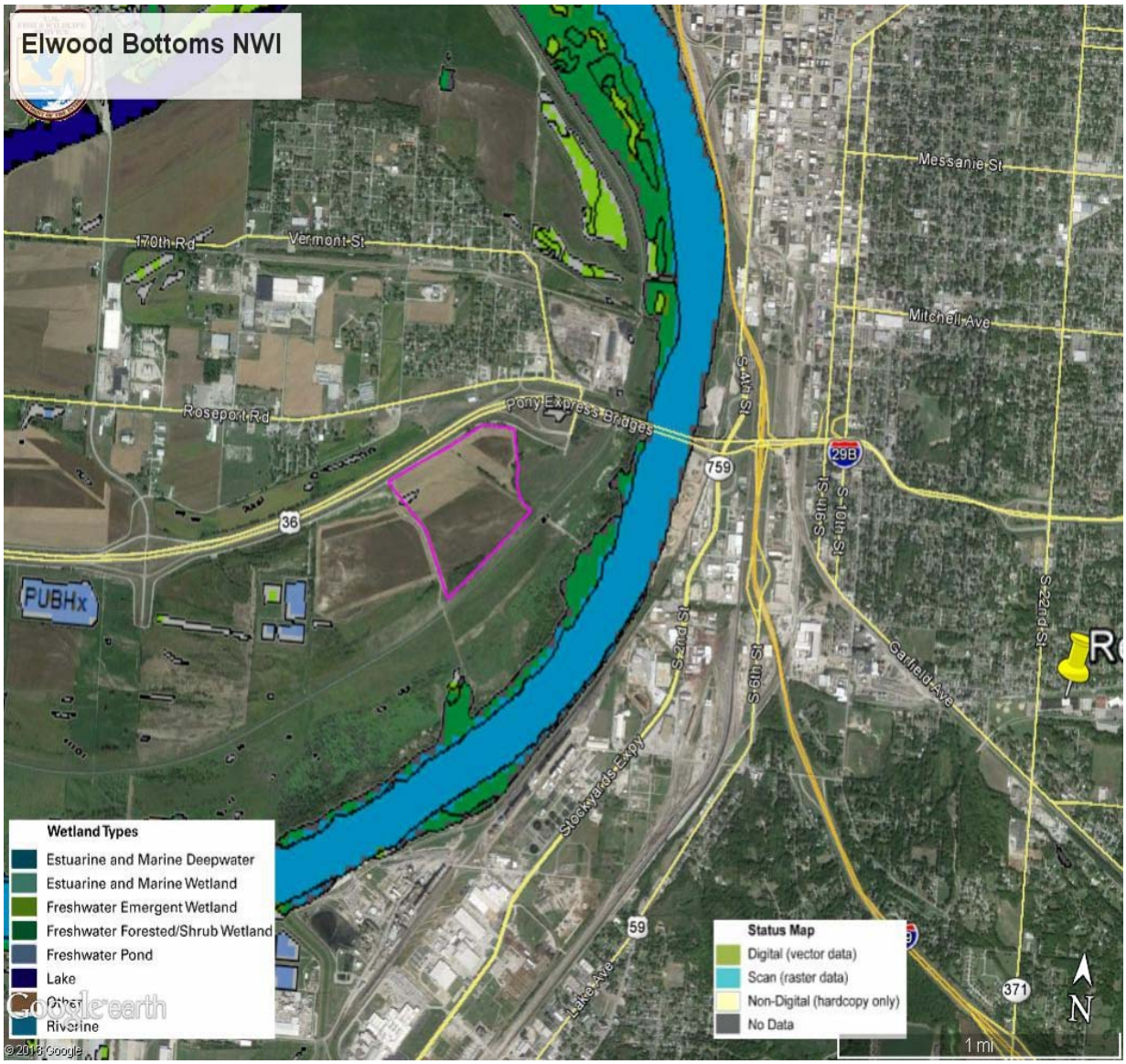


Figure 7 - Elwood Spoil Area NWI



b. Mixing Zone Determination: An evaluation of the appropriate factors in 4a above indicates that the disposal site and/or size of mixing zone are appropriate.

5. ACTIONS TO MINIMIZE ADVERSE EFFECTS (SUBPART H)

All appropriate and practicable steps, as warranted, would be taken through application of recommendations of §230.70-230.77 to ensure minimal adverse effects of the proposed fill placement. These actions include the following:

a. In order to minimize and/or avoid adverse effects on the aquatic ecosystem, the Corps will minimize impacts to the terrestrial and aquatic environment and use uncontaminated fill material. All activities will comply with standard Corps measures, directives, and policies to ensure environmental protection during construction and minimize construction-related pollution. The following lists some of the environmental protection measures and policies.
(1) Temporary erosion control measures (silt fences, berms, dikes, drains, etc.) will be provided and maintained.

(2) The Contractor will obtain all applicable construction permits including an NPDES permit from MDNR for stormwater discharges from the project's construction work areas. Contractors shall adhere to all requirements of the NPDES stormwater discharge permit and all additional permit requirements.

(3) Dust will be reduced in work areas by sprinkling with water or other methods that are permitted to reduce hazard and nuisance.

(4) Disturbed areas area shall be graded, filled and seeded.

(5) Contractors will employ machinery of appropriate size for the fill placement activities.

(6) Fuel, chemical and other materials stored at the project site shall be stored in a manner that minimizes the discharge of product to waters of the state.

(7) Deleterious material removed from the stream and separated from suitable soil at the Complex would not be used as fill material and disposed in an appropriate landfill.

6. FACTUAL DETERMINATIONS (§230.11)

A review of the appropriate information as identified in items 2-5 above indicates that there are short-term and long-term environmental effects of the proposed detention excavation as related to: a. Physical substrate disposal site; Water circulation, fluctuation, and salinity; c. Suspended particulates/turbidity; d. Contaminant availability; e. Aquatic ecosystem structure and function; and f. Disposal site.

Although soil would be stockpiled for later reuse, the physical substrate would be graded upon soil removal. Therefore, a minor, short-term adverse impact would occur due to the stockpiling of soils and grading upon soil removal. The creek is channelized and incized with no rock and

riffle, and very minimal pool due to very low base flows. The existing condition of the ephemeral stream is impacted similar to the creek, but to a lesser degree. No adverse effects to water circulation were identified. Slight meandering around transmission tower pads for an approximate length of 900 feet within the creek is incorporated into the project design. Debris removal from the creek channel and banks, broadening of the creek and stream channel, and the incorporation of slight meanders along the creek would positively impact water circulation. The project as designed is anticipated to decrease fluctuation and increase hydroperiod during heavy precipitation events. There would be no anticipated change in the salinity of the freshwater system. A short-term, construction related adverse impact may occur to water quality due to an increase in suspended particulates/turbidity during construction. Best management practices would be incorporated into the project construction specifications to avoid, or otherwise minimize a potential increase in suspended particulates/turbidity. Construction of the Recommended Plan would decrease the frequency of combined sewer overflows, decrease flood risk and increase hydroperiod, which would provide for settling of particulates prior to flowing downstream and provide a long-term positive impact to downstream water quality. Clean soil and rock would be obtained from commercial sources to prevent the potential availability of contaminants.

The aquatic ecosystem structure and function of both Blacksnake Creek and the ephemeral stream would be impacted by the Recommended Plan. The Kansas City District Regulatory Branch (OD-R) conducted an impact using the 2013 Missouri Stream Mitigation Method (Attachment 1). For all of the action alternatives proposed including the Recommended Plan, there would be a net overall minor, long-term positive impact to Blacksnake Creek. Aquatic habitat adverse impacts result in 3,648 debits. These debits are offset by 4,008 credits that result from positive impacts to the stream and primarily include concrete lined channel removal, culvert and low water crossing removal. However, tree removal and daylighting the Creek would still result in a moderate, long-term adverse project impact although the existing aquatic community is very limited.

The no action alternative would leave the creek in its current state and result in minor, short-term and moderate, long-term adverse impacts as selective clearing, littering, increased incision and erosion would be anticipated to continue.

The ephemeral stream is not as severely impacted by incision and littering as the creek and does not contain concrete lined channel, a low water crossing, or multiple culvert removal and functions more as a natural system. Aquatic habitat adverse impacts result in 803.52 debits. Positive impacts to the stream primarily include stream widening and bank shaping, which would prevent future increased incision and is considered a long-term, moderate positive impact with credits totaling 342. Therefore, all of the action alternatives proposed including the Recommended Plan would result in minor, long-term positive impacts to the stream and overall moderate, long-term adverse impacts to the stream due to direct impacts resulting from construction, tree removal and daylighting the stream. The no action alternative would be anticipated to result in short-term and long-term adverse impacts to the

stream and downstream water quality due to litter accumulation, increased incision and erosion.

Based on the stream impact assessment conducted by OD-R, the Recommended Plan results in a net debit of 101.52. In-kind stream mitigation would be conducted using a mitigation bank located as near as practicable to the Blacksnake Creek watershed.

The City's future maintenance of the both the Creek and the stream to convey flow is also considered a long-term, minor positive impact as they would remove litter and deleterious material that impedes flow. Post construction operation and maintenance would primarily include periodic mowing and debris removal from the channel, combined sewer inlet, and spillway, riprap replacement, and reseeding of erosion prone areas. Therefore, operation and maintenance activities are not anticipated to result in appreciable post construction adverse impacts to aquatic habitat as they would function to convey flow and prevent erosion.

A minor, short-term adverse would occur at the disposal site due to the separation of deleterious material from soil and the stockpiling of soil. Deleterious material would be removed from the Complex and properly disposed. Any soil incidentally left at the Complex would be graded into existing soil to existing conditions elevation. Stockpiling of soil at Elwood Bottoms is also considered a minor, short-term impact as grading to existing conditions would occur upon soil removal.

Determination of Cumulative Impacts on the Aquatic Ecosystem. As determined by OD-R's stream impact assessment, there would be a long-term, minor overall adverse impact to the aquatic ecosystem as a result of the Recommended Plan. Stream disturbance coupled with riparian tree removal and daylighting the creek and stream is considered a moderate, long-term adverse impact as although the aquatic ecosystem is very limited and low quality under existing conditions, the project will likely change the aquatic community that is currently present within the project area.

Determination of Secondary Impacts on the Aquatic Ecosystem. No short-term or long-term secondary impacts to the aquatic ecosystem are anticipated. The purpose of the project is to decrease combined sewer overflows and increase flood risk management in compliance with the Clean Water Act.

7. EVALUATION RESPONSIBILITY:

Prepared by: _____

Mr. Richard A. Skinker – Biologist DATE
Plan Formulation Section

Reviewed by: _____

Mr. Jason W. Farmer, Chief DATE
Environmental Resources Section