FEASIBILITY REPORT
MISSOURI RIVER LEVEE SYSTEM UNITS R471-460 AND L-455
MISSOURI AND KANSAS

APPENDIX A

PUBLIC INVOVLEMENT

SEPTEMBER 2006

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

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APPENDIX A
MISSOURI RIVER LEVEE SYSTEM (MRLS)
UNITS R471-460 AND L-455
FEASIBILITY STUDY

Public meetings were held on October 29 and 30, 2002, in Elwood and Wathena, Kansas. These meetings were jointly presented by the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers. The purpose of these meetings was to present to the public the increased risk of flooding in the area, decertification of the unit R471-460 by FEMA, the consequences of decertification, and the status of the feasibility study. Flyers used to advertise these meetings are included in this appendix.

A meeting was held on May 4, 2005, at Rosecrans Airport between representatives of the Missouri Air National Guard, the City of St. Joseph, the Corps, and Senator Christopher Bond. The purpose of the meeting was for the Guard to present to the Senator their plans for future expansion of the facilities at Rosecrans Airport that are being hindered by the decertification of the right bank levee. The Corps presented the current status of the feasibility study. The meeting was well documented in the St. Joseph News-Press newspaper the next day.

A public meeting was held August 28, 2006 in Elwood, Kansas to present the recommendations of the feasibility report and obtain public comment. Notice of the meeting was distributed to potentially interested parties and published in the newspapers of St. Joseph, MO and Doniphan County, KS. Copies of the notice letter, press release, affidavits of publication, and meeting agenda are included in this appendix. Twenty-six attendees were present at the meeting representing the local sponsors, land owners in the study area, local municipal and elected officials, levee districts upstream and downstream of the project area, and state agencies. Comments received, with responses by the Corps of Engineers, are included in this appendix.

FLOOD RISK ALERT

Residents living in the Elwood-Gladden and French Bottoms area of Doniphan County, Kansas and Buchanan County, Missouri are invited to attend a public meeting hosted by the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers (USACE), and your community to explain the increased risk of flooding in the area.

Meeting Locations and Times

OCTOBER 29, 2002 at 7:00 p.m.
City of Elwood Community Center
803 Massachusetts Street
Elwood, Kansas

OCTOBER 30, 2002 at 7:00 p.m.
City of Wathena Community Center
303 East St. Joseph Street
Wathena, Kansas

For further information, contact your community floodplain official.

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Flood Risk Alert

- If you are a resident living in the Elwood-Gladden and French Bottoms area of Doniphan County, Kansas and Buchanan County, Missouri you need to know you have an increased flood risk.
- The levee along the west side of the Missouri River no longer provides as much protection as it once did. As a result, much of the Elwood-Gladden and French Bottoms area will now be designated in the floodplain.
- Your community officials are working on a plan to restore the levee to its full protection level.
- What should you do?
  - ✓ Come to one of the public meetings (see other side) scheduled to explain your risk and options.
  - ✓ Contact your local community to determine whether your property is affected.
  - ✓ Contact your local insurance agent to see about adding or reviewing your flood insurance coverage.

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DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT, CORPS OF ENGINEERS
700 FEDERAL BUILDING
KANSAS CITY, MISSOURI 64106-2896
August 1, 2006

REPLY TO
ATTENTION OF:

Planning, Programs and Project Management Division
Planning Branch

Dear Interested Party:

In accordance with provisions of the National Environmental Policy Act of 1969, we are notifying you of the availability of the Draft Environmental Assessment and Draft Feasibility Report (DEA/DFR) for the MRLS Units R471-460 and L-455, Flood Damage Reduction Study, St. Joseph, Missouri. The document is available for review on the Kansas City District web page at: http://www.nwk.usace.army.mil/projects/R471-L455/. Also, in accordance with Section 404 of the Clean Water Act, a Public Notice (PN) of the proposed project is available for review and comment on our Regulatory Branch web page at: www.nwk.usace.army.mil/regulatory/public_notices/200501489.pdf

This DEA is prepared pursuant to NEPA to assess the environmental and social impacts associated with improving the level of flood damage reduction for the two levee units in the Saint Joseph metropolitan area. The DEA examines impacts with and without the proposed alternatives. Written comments on the DEA/DFR or PN should be directed to the individual identified below no later than August 31, 2006.

Christopher M. White, Ph.D.
St. Joseph Levees Project
Kansas City District, Corps of Engineers
601 E. 12th Street
Kansas City, Missouri 64106-2896

The Corps of Engineers will respond to comments received as a result of issuance of the DEA/DFR and PN during final review and preparation of the Final Environmental Assessment and Feasibility Report.

Sincerely,

David L. Combs
Chief, Planning Branch

Enclosure

News Release

US Army Corps of Engineers
Kansas City District

601 E. 12th Street
Kansas City, Missouri 64106-2896

Contact: Tom O'Hara
Phone: (816) 389-3486

For immediate release

Date: August 10, 2006

U.S. Army Corps of Engineers sets Aug. 28 public meeting for St. Joseph levees study, environmental assessment

ELWOOD, Kan. – Officials from the Kansas City District, U.S. Army Corps of Engineers will meet with the public to discuss a Draft Environmental Assessment and Feasibility Study on the R460-471 & L455 Flood Damage Reduction Projects at 6:30 p.m. Aug. 28, 2006 in the Elwood Community Center, 803 Massachusetts Street, Elwood, Kan.

The Draft Environmental Assessment and Feasibility Study examines alternatives and recommends a proposed plan for improvements to the existing levee system aimed at reducing flood risk and improving levee reliability for the communities of St. Joseph, Elwood, and Wathena, as well as the Rosecrans Memorial Airport / Missouri Air National Guard Base. The levees provide flood protection to about 21,000 acres of rural agriculture and urban residential and commercial development.

Individuals, organizations, and agencies may participate by attending the public meeting or by emailing comments on the document before Aug. 31, 2006.

All comments must be postmarked or sent by August 31, 2006. Email: Matthew D. Vandenberg at matthew.d.vandenberg@nwk02.usace.army.mil; mail: Kansas City District, Corps of Engineers, 601 E. 12th Street - Room 843, Attn: Christopher M. White, Kansas City, Missouri 64106-2896; or phone 816-389-3158. The document may also be reviewed at local libraries or downloaded at http://www.nwk.usace.army.mil/regulatory/public_notices/200501489.pdf

-30-

Editor's Note: Public email comments on the Draft Environmental Assessment may be sent to matthew.d.vandenberg@nwk02.usace.army.mil. Media inquiries may be addressed to the Kansas City District Public Affairs Office at (816) 389-3486. Questions concerning the Draft Environmental Assessment should be addressed to Matthew D. Vandenberg at matthew.d.vandenberg@nwk02.usace.army.mil.

PUBLIC NOTICE

(Published in the Kansas Chief, Thursday, August 17, 2006)

LEGAL NOTICE

Notice of Public Meeting for U.S. Army Corps of Engineers Draft Environmental Assessment and Feasibility Study on the R460-471 & L455 Levee Flood Damage Reduction Projects on August 28th 2006, starting at 6:30 p.m. at the Elwood Community Center, 803 Massachusetts Street, Elwood, Kansas 66024

The Draft Environmental Assessment and Feasibility Study examines alternatives and recommends a proposed plan for improvements to the existing levee system aimed at reducing flood risk and improving levee reliability for the communities of St. Joseph, Elwood and Wathena, as well as the Rosecrans Memorial Airport / Missouri Air National Guard Base. These levee units provide flood protection to about 21,000 acres of rural agricultural and urban residential and commercial development.

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AFFIDAVIT OF PUBLICATION

STATE OF KANSAS, DONIPHAN COUNTY, SS:

Dana D. Foley, being first duly sworn, deposes and says: That he is publisher of *The Kansas Chief* a weekly newspaper printed in the State of Kansas, and published in and of general circulation in Doniphan County, Kansas, with a general paid circulation on a yearly basis in Doniphan County, Kansas, and that said newspaper is not a trade, religious or fraternal publication.

Said newspaper is weekly published at least weekly 50 times a year; has been so published continuously and uninterruptedly in said county and state for a period of more than five years prior to the first publication of said notice; and has been admitted at the post office of Wathena, Kansas, in said County as periodicals postage paid.

That the attached notice is a true copy thereof and was published in the regular and entire issue of said newspaper for One consecutive weeks, the first publication thereof being made as aforesaid on the 17 day of August, 2006, with subsequent publications being made on the following dates:

_____, 20___

_____, 20___

_____, 20___

Publisher

Subscribed and sworn to before me this 17 day of August, 2006.

LORI VERTIN
NOTARY PUBLIC
STATE OF KANSAS

Notary Public

My commission expires 7-6-07

Printer's fee/ Affidavit fee $ 37.92

AFFIDAVIT OF PUBLICATION

St. Joseph News-Press, 825 Edmond St, St. Joseph, MO 64501

Reference: 163518 P.O. :
Ad ID: 5215773 DESC. :Levee Flood Damage Reduction Projects

MATTHEW VANDENBERG
ENVIRONMENTAL RESOURCES SPECIALIST
601 EAST 12TH STREET
KANSAS CITY, MO 64106

County of Buchanan
State of Missouri

I, Leona Gillenwater, being duly sworn according to law, state that I am the Legal Advertising Coordinator of the St. Joseph News-Press, a daily newspaper of general circulation in the county of Buchanan, where located; which has been admitted to the Post Office as second class matter in the city of St. Joseph, the city of publication; where newspaper has been published regularly and consecutively for a period of three years and has a list of bona fide subscribers voluntarily engaged to pay a stated price for a subscription for a definite period of time, and that such newspaper has complied with the provisions of Section 493.050 Revised Statutes of Missouri, 1949. The affixed notice appeared in said newspaper on the following date:

Run Dates:	08/17/06	to	08/17/06
Appearances:	1		
AD SPACE:	75		
TOTAL COST:	$135.00		
FILED ON	08/21/06		

(Signed) Leona Gillenwater

Subscribed and sworn before me this 25th day of August 2006
Heather Sturtz Notary Public

(Published in the St. Joseph News-Press Thurs., 08/17/06)

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Heather Sturtz
Notary Public Notary Seal
State of Missouri County of Buchanan
My Commission Expires 01/30/2010
Commission #06831729

US Army Corps of Engineers®

St. Joseph Levees Feasibility Study and Environmental Assessment

Public Meeting Agenda
August 28, 2006

Meeting Location: Elwood, Kansas, Community Center
Meeting Time: 6:30pm

This meeting is presented by the Kansas City District Corps of Engineers in Cooperation with the Local Governing Boards for the St. Joseph Area Flood Protection System

LEVEE UNIT/SECTION	Non-Federal Owner/Operator
MRLS R471-460	St. Joseph Airport Levee District (MO portions) Elwood-Gladden Drainage District (KS portions)
MRLS L-455	South St. Joseph Levee District

Introductions and Meeting Overview -- *Corps of Engineers*
(approx. 10 minutes)
- Levee owners/operators.
- Format and guidelines for tonight's session.
- Recording of formal comments (leave written comment forms at sign-up table).
- Informal question and answer period during the Information Table segment.

Brief Slide Presentation on Feasibility Study and the Environmental Assessment-- *Corps of Engineers*
(approx. 20 minutes)
Background, levee descriptions, objectives of the feasibility study, recommended plan, and normal steps toward implementation of a Federal Civil Works project

Statements by the Levee Sponsors
(approx. 10 minutes)

Information Tables Segment
(approx. 1 hour)
- Information Tables and presentation boards are located around the meeting area.
- Attendees are welcome to ask informal questions to Corps & levee sponsors at the tables.

Meeting Adjournment

The Draft Feasibility Study and Environmental Assessment, along with the slides from this evening's presentation are available on the project website at:

http://www.nwk.usace.army.mil/projects/r471&l455

A summary of the written comments received at tonight's meeting will be posted to the website when available.

The following comments were received during, or in response to, the 28 August 2006 public meeting.

Public Meeting Comment 1

Submitted by: James Rader
Mayor, City of Elwood

Comment: I have lived in Elwood for 69 ½ years. I have been here through the flood of 1952 and also 1993. We have had extensive commercial development here since 1973. I feel this will stop without the recommended work done on the levees. Also the personal trauma of going through a flood and the cleaning and repairs afterward more than justify the cost of these extensions. Thank you for your work, Jim Rader.

Response: Comment noted and appreciated.

Public Meeting Comment 2

Submitted by: John Osborne

Comment: I was here in "93" and along with my friends & neighbors, listened to State & Federal official pacify Elwood residents. All I ask for myself and all Elwood resident is "Do what you say you'll do & don't say you will & then don't." Most people who have had any dealing with FEMA or the Corp, are very skeptical of everything the say & do. We all want to live in a safe community, & I for one support your efforts. Thank you, John Osborne.

Response: Comment noted and appreciated.

Public Meeting Comment 3

Submitted by: Doug Shepherd
President, South St. Joseph Levee & Drainage District

Comment: Why is there proposed work for levee between 205+00 to 295+00 when our trouble spot in 1993 was in the area of 107+70. Where we had to sandbag the levee to contain flood water. In the proposed work area we didn't have any problem.

Response: Appendix B of the Feasibility Study has identified the reach of the levee in the vicinity of station 107+70 as a reach requiring additional field surveys during Preconstruction, Engineering, and Design (PED). A little over 300-feet of levee in this area has been identified as suspect and may require a levee cap approximately a minimum of 0.6 of a foot thickness. Your comment of your first hand experience during the flood of 1993 and the additional field surveys during PED will most likely result in a short length the levee at this location receiving fill on its crown sufficient to remove the low spot.

Public Meeting Comment 4

Submitted by: Laipple Farms

Comment: If the improvements to the existing levee system is carried out we are concerned where the borrow area or dirt will be obtained? We are not willing to give any borrow areas or dirt for these improvements. There have been several borrow areas given on this land through the years. We depend on this land for our living. There is no difference between this business and any other business. There is no drainage for the three (3) creeks that drain into the old river channel, that drain through Gladden Bottom. The channel is about filled up. It should be dredged out going East, to the tubes that are there. If the old channel would be cleaned out, this material could be used for the improvements on the existing levee.

Response: Potential borrow areas are currently designated as those areas adjacent to the levee on the river side. Generally, borrow locations are chosen nearest to the project site to offset additional haul distances and cost and/or processing cost, if any. Furthermore, areas of significant tree growth and wildlife habitat are avoided. This is in accordance with Corps guidance. However, final locations and quantities that will be taken from each site are not finalized. During the Pre-Construction Engineering and Design (PED) phase, alternative locations and the use of dredged material will be considered. . If you are aware of borrow sources capable of producing acceptable fill material in the quantities necessary for construction of the selected plan, those locations should be provided to this office for consideration during PED.

Public Meeting Comment 5

Submitted by: John Cox
Airport Levee member

Comment: Since the Mo Air National Guard 139th AW has the greatest investment protected by the R471-460 levee system. Why can't the DOD fund the O&M and/or levee system improvements?

Response: Cost-sharing requirements for Civil Works projects were established by Congress in the Water Resources Development Act of 1986. For a project of this type, a 65/35 split between the Federal government and local interests is required, without regard to the value or nature of investment within the existing system.

Public Meeting Comment 6

Submitted by: Gary Laipple
Farmer

Comment: Our family farm runs along the river from north of river mile 454 then south to river mile 452. We went through the construction of the levee with all the right of way and borrow area. We filled the borrow areas and deep plowed the haul roads. We have also been through various floods, including the "1993 flood" which was devastating to our family farm. So perhaps you can understand why our family is against any destruction of our farm, which includes the borrow areas and right of ways. Here are several alternatives for borrow areas. (1) Government Land along the river south of our farm which is river mile #451. (2) Dredge the old river channel. This would provide dirt plus drainage for the bottom. (3) Haul dirt from the bluff. (4) Dredge dirt out of the Missouri river. Please consider an alternative for the borrow areas other than our farm. Also if berms are extended we should be allowed to farm them instead of taking the ground out of production.

Response: Same response as Public Meeting Comment 4 with the addition that extension of underseepage berms will be conducted using temporary easements and the ground will revert back to the property owner after completion of construction. Farming of underseepage berm areas is allowed.

Public Meeting Comment 7

Submitted by: Jan B. Laipple

Comment: I am opposed to giving any dirt (borrow areas) or material of any kind, concerning stations 100+00 – 120+00 – 140+00 – 160+00 – 180+00 – 200+00 – 220+00. I am also against parting with any additional land. Create the borrow areas South of the above stations. (Stations – 240+00 – 260+00 – 280+00 – 300+00 – 320+00.) This land is not being farmed. Dredge the material out of the present river channel. Material could also be obtained out of the old river channel prior to 1952. A levee could be constructed East and West to the North of Rosecrans Airport. The obstructions and bottleneck at stations 400+00 – 420+00 – 440+00 could be corrected. This would help the flow of the river and help prevent flooding. The river should be maintained for navigation, not for preservation of wildlife. Dikes should be maintained to keep the river channel navigable. Moving products up and down the river is a much cheaper way of moving them. We have spent a lifetime building and paying for this farm. The land affected is priceless. This is how my families' livelihood is obtained. Thank you.

Response: See response to Public Meeting Comment 4 regarding borrow locations and evaluation of possible alternative sources. Levee realignment and setback is significantly more expensive than a raise in the existing location. The cost would outweigh the benefits of the project and cause a greater financial impact to the local levee districts.

Federal laws and regulations require the Corps of Engineers to examine the environmental impacts of proposed actions and propose alternatives to minimize or mitigate those impacts. The management of the Missouri River for various purposes and the maintenance of the channel dikes is beyond the scope of this study.

Public Meeting Comment 8

Submitted by: Pat Higdon

Comment: The public meeting in Elwood, KS, was informative and I understand the plan and necessity of improving the levee. I currently farm ground on both sides of the levee. It was not made clear how the construction of the levee will affect my acreage economically and what expected length of time. Where will the dirt (ground) come from for the project? Will I lose acreage? Will I be compensated for the loss of crop production effected during the project? Please respond – Pat Higdon

Response: Borrow (soil) material for the levee raise is currently proposed to come from the areas between the levee and the river. Specific locations and quantities from each location have not been fully developed. Construction of the entire project is estimated to take three years, however, impacts to specific location within the project should be less than that. Permanent loss of acreage may occur and will be compensated through the negotiation and purchase of a permanent right-of-way easement. Similarly, temporary impacts during construction will be compensated through the negotiation of temporary easements. Impacts to specific parcels will be refined during the Pre-Construction Engineering and Design (PED) phase and, when available, will be coordinated with each individual affected property owner.

FEASIBILITY REPORT
MISSOURI RIVER LEVEE SYSTEM L-455 & R 471-460
MISSOURI AND KANSAS

APPENDIX B

ENGINEERING

SEPTEMBER 2006

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

FEASIBILITY REPORT
Missouri River Levee System L-455 & R 471-460
Missouri and Kansas

Section 1 **Introduction**

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1.4	Existing Condition	1-2
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Section 2 **Hydrology and Hydraulics**

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2.5	Existing Conditions	2-8
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Section 3 **Geotechnical**

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3.8	Selected Plan	3-32

Tables 1 Through 3 are Incorporated Within the Text. Tables 4A, 4B, & 5 Precede the Drawing Sheets at the End of Appendix B

Figures 1 Through 22 are Incorporated Within the Text

Section 4 **Civil**

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4.3	Road and Railway Levee Crossings	4-1
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Section 4 **Civil (continued)**

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Section 5 **Structural**

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Tables

Tables 1 thru 3 are Incorporated Within the Text of Section 3, Geotechnical

Table 4A	MRLS R 471-460 Seepage Schedule
Table 4B	MRLS R 471-460 Seepage Schedule
Table 5	MRLS L-455 Seepage Schedule

Drawings

Sheet 1	MRLS R 471-460; Location/Vicinity
Sheet 2	MRLS L-455; Location/Vicinity
Sheet 3	Levee Section Schedule
Sheet 4	Typical Levee Sections
Sheet 5	Typical Levee Sections; Fill Zones; Levee Raise Less Than 3 Feet
Sheet 6	Typical Levee Section; Fill Zones; Levee Raise 3-Feet or Greater
Sheet 7	MRLS R 471-460; Pressure Relief Wells
Sheet 8	Typical Levee Sections; Quantity Computations; Levee Raise Less Than 3 Feet
Sheet 9	Typical Levee Section; Quantity Computations; Levee Raise 3-Feet or Greater
Sheet S-1	MRLS R 471-460; Drainage Structure No. 4; Sta. 325+00; Levee Removal and Temp. Flood Protection
Sheet S-2	MRLS R 471-460; Drainage Structure No. 4; Sta. 325+00; Replacement Structure Profile and Details
Sheet S-3	MRLS R 471-460; Drainage Structure Details; Gatewell And Pipe Extensions

1.1 GENERAL

The purpose of the Engineering Appendix is to document engineering efforts completed during the Missouri River Levee Systems (MRLS) L-455 and R 471-460 Feasibility Study development.

1.2 PROJECT LOCATION AND LIMITS

MRLS R 471-460 (see drawing sheet number 1) is located on the right bank of the Missouri River in the vicinity of St. Joseph, Missouri and Elwood, Kansas. MRLS L-455 (see drawing sheet number 2) is located on the left bank of the Missouri River. The upstream levee limit along the Missouri River and the lower end tie-back levee upstream limit along Contrary Creek are located within the City of St. Joseph, Missouri. Sheet numbers 1 and 2 also include the limits of the respective top of levee raises for the selected plan.

1.3 ENGINEERING EFFORTS

1.3.1 Overview

This study utilized the following engineering disciplines: Hydrology and Hydraulics, Geotechnical, Civil, and Structural. Information presented in the Engineering Appendix focuses on establishing the existing condition and developing the selected plan as part of the study's plan formulation. Detailed documentation is included within the separately bound document, "Missouri River Levee Systems (MRLS) L-455 & R 471-460, Design Documentation Report (DDR)". The DDR is intended to span the processes from the reconnaissance study through engineering and design during construction (EDC). The DDR will be updated as data, analyses, and designs supersede previous efforts. The DDR will be dated according to the date each final product (i.e., reconnaissance study, feasibility study, pre-construction engineering and design, and EDC).

1.3.2 Existing Condition

The Hydrology and Hydraulics and Geotechnical disciplines provided input to the flood control works' existing condition. At the time the existing condition was being established it was decided since there were no floodwalls, the Structural discipline would not have a part in establishing the flood control works' existing condition.

1.3.3 Selected Plan

The selected plan is the National Economic Development Plan (NED) that maximizes the net benefits while providing a favorable benefit to cost ratio. The selected plan also provides for MRLS R 471-460 to obtain FEMA certification. The MRLS L-455 water surface profile and top of levee were set to eliminate impacts from work proposed on the right bank. The Hydrology and Hydraulics disciplines provided the water surface corresponding to the proposed top of levee. The Civil discipline provided the limits of the top of levee raise as well information on utility crossings within the limits of the top of levee raise. Although the Structural discipline did not establish an existing condition for either of the levee units, they did consider structures' existing condition in the sense of the respective structure meeting current design criteria with no

top of levee raise. The Structural disciplines only considered gatewell structures and pipes when the structure or pipe fell within the limits of the top of levee raise. The impacts of the raise to the structures or pipes were also addressed. The Geotechnical discipline provided soil parameter support to other disciplines as well as developing the levee section necessary to accommodate the raise while at the same time ensuring levee stability.

1.3.4 Alternative Screening

The engineering disciplines provided input for alternative screening. Alternative screening primarily considered various top of levee raises. Alternative screening is addressed in more detail within the main body of the study. Realignment was also considered at a screening level of effort and is addressed in more detail within the main body of the study.

1.4 EXISTING CONDITION

The Hydrology and Hydraulic discipline as well as the Geotechnical discipline used risk and uncertainty to establish the existing condition for MRLS L-455 and MRLS R 471-460. The existing condition established the base condition for the Economics efforts as well as identifying potential problem areas with the levee to be addressed as part of the plan formulation process and the selected plan development.

1.5 SELECTED PLAN

The selected plan includes raising the top of the levee for selected reaches of MRLS L-455 and R 471-460. See Sheet numbers 1 and 2 for levee limits subject to a top of levee raise. As part of the top of levee raise the following features were addressed: add fill to the levee crest and landward slope and resurfacing the levee crown with aggregate; thickening and widening berms to ensure seepage control and stability; abandoning existing pressure relief wells that no longer can withstand the increased hydrostatic pressures; incorporating pressure relief wells where real estate will not accommodate underseepage berm widths; modifying utility crossings where the levee is subject to raise; modifying gatewell drainage structures to accommodate the additional levee fill; and replacing a gatewell drainage structure that no longer meets the minimum load safety factors.

2.1 INTRODUCTION

A hydraulic analysis was performed on the Missouri River by the U.S. Army Corps of Engineers (USACE), Kansas City District (KCD). The hydraulic computations are based on the USACE HEC-RAS step-backwater computer software program (HEC-RAS 3.1.3). Calibration was performed to produce water surface profiles for the Missouri River near St. Joseph, Missouri. The study area consists of approximately 56 river miles on the Missouri River, from RM 428 to RM 484. The HEC-RAS model was developed using the latest available floodplain mapping for the Missouri and the latest hydrographic survey data. The existing conditions model was calibrated to the Upper Mississippi River System Flow Frequency Study (UMRSFFS) flood profiles for the study reach.

This section of the Engineering Appendix documents development of water surface profiles through the existing St. Joseph reach and evaluates alternatives for improving the integrity of the existing flood control system. The HEC-RAS model developed in this study was used to model existing conditions, future conditions without project, and future conditions with project alternatives.

In addition to the hydraulic analysis performed on the Missouri River, results from other studies are presented that characterize the existing conditions. These additional studies include: an analysis of levee tiebacks; development of interior floodwater/exterior water surface elevation relationships; impacts due to any proposed improvements; and an evaluation of the adequacy of the original levee design.

2.2 STREAM AND VALLEY CHARACTERISTICS

The Missouri River natural valley floodplain is approximately 3½ to 4 miles wide, while the main channel averages about 700 to 1,000 feet wide throughout the project reach. Bank-full discharge is approximately 140,000 cubic feet per second (cfs) for this reach of the Missouri River. This discharge corresponds to a flood event between the 50% chance of exceedance (2-year) and the 20% chance of exceedance (5-year) event. The average bed slope through the project reach is approximately 1 foot per mile. The drainage area of the Missouri River at the St. Joseph Gage is 420,100 square miles.

There is one stream gage located on the Missouri River within the project reach. The St. Joseph Gage is on the Union Pacific Railroad Bridge, at RM 448.2. The datum of the gage is 788.19 feet above mean sea level (msl) (NGVD 1929). The flood stage for the Kansas City Gage is 17 feet, which corresponds to an elevation of 805.19 feet. The period of record for this gage extends from 1897 to present. Exhibit 2.1 shows the latest rating curve, USGS curve #9, at the St. Joseph Gage.

2.3 HYDROLOGY

The overall hydrology and flow frequencies on the Missouri River in the St. Joseph area have been estimated in three major studies. These are: the *Missouri River Levees, Sioux*

City, Iowa to the Mouth (1947); the *Missouri River Agriculture Levee Restudy Program* (1962); and the *Upper Mississippi River System Flow Frequency Study* (2003). A discussion of each of those study results is provided below.

2.3.1 Missouri River Levees, Sioux City, Iowa to the Mouth (1947)

The original design discharge for R460-471 and L455 was 325,000 cfs as reported in Appendix I, Hydrology of the 1947 report. There was no design frequency assigned to the 325,000 cfs design flow. However, the 1947 report did identify a reservoir controlled 100-yr discharge of 250,000 cfs. The design top of levee profile was based on a backwater profile developed for the 325,000 cfs through the St. Joseph reach with an additional two feet of freeboard added. An additional one foot of freeboard was added in certain locations due to flow dynamics along the studied reach.

2.3.2 Missouri River Agricultural Levee Restudy Program (1962)

Hydrology for the Missouri River in the Kansas City District was developed and published in a Hydrology Report dated March, 1962. The data presented in that report has been used by the Kansas City District to estimate flood flows for subsequent flood control studies, Federal Emergency Management Agency (FEMA) Flood Insurance Studies, and similar purposes since that time**.** Table 1 summarizes these flows at the St. Joseph Gage.

Table 1. Flow Frequency from March, 1962 Hydrology Report

Frequency in Percent Chance of Exceedance	Return Interval (years)	Missouri River Discharge at St. Joseph Gage (cfs)
0.2%	500	330,000
1%	100	270,000
2%	50	246,000
10%	10	185,000

2.3.3 Upper Mississippi River System Flow Frequency Study (2003)

Recently, a new discharge-frequency relationship on the Missouri River was produced. The Upper Mississippi River System Flow Frequency Study (UMRSFFS) (KCD 2003) is a large, complex evaluation of the regulated and unregulated flows on the Mississippi, lower Illinois, and Missouri River Basins. This study produced a detailed analysis of the effects of reservoir regulation on the main stem of the Missouri River. Table 2 summarizes the regulated flow frequency estimates published in UMRSFFS, as applicable to the St. Joseph Feasibility Study. These discharges have been used to establish the existing conditions flow frequency data used in this study.

Table 2. Flow Frequency Data as Developed in UMRSFFS (2001)

Frequency in Percent Chance of Exceedance	Missouri River at St. Joseph Gage (cfs)
0.2%	324,000
0.5%	287,000
1%	261,000
2%	233,000
5%	199,000
10%	174,000
20%	147,000
50%	109,000

Note: Expressing discharge probability in percent chance exceedance (occurrence) is currently used in lieu of a flood return interval expressed in years. Percent chance exceedance expresses the probability of the discharge occurring each year. A return interval is the period of time over which, on average, one flood event will equal or exceed that discharge. For example, a 1% chance exceedance flood event has a one-in-one-hundred chance of being equaled or exceeded in any given year. If a 1% chance exceedance flood event were to occur this year, the probability of occurring next year and the year after is still the same, 1%. On average, only one flood event would equal or exceed the 1% chance event during a 100-year time period, thus the term a 100-year flood event. For this document, discharge will be expressed as a percent chance of exceedance followed by the equivalent return interval. All profiles presented herein represent the "most probable" or "nominal" estimates of water surface elevations. It is possible that actual water surface elevations may be higher or lower than those shown.

2.3.4 Traditional Analysis vs. Risk Based Analysis

To account for uncertainties in discharge-frequency estimates, stage-discharge functions, and engineering parameters (geotechnical and structural), the traditional analysis allowed for freeboard (a factor-of-safety) to be added to the top-of-levee design. In other words, if 325,000 cfs were the design discharge, the levee would be designed to pass this flow with a certain degree of freeboard, typically 2 feet on agricultural levees. Therefore, when describing the project performance (or level of protection) one would assign it an average return period in years of the largest flood that can be accommodated by the project, with a high degree of assurance. This assurance came from the freeboard. Therefore, if the design discharge of 325,000 cfs had a frequency of 0.2% chance of exceedance, the levee could be characterized as a "500-year levee."

Currently, the Corps of Engineers uses Risk Based Analysis (RBA) for formulating flood damage reduction projects. This method considers all of the same engineering parameters as the traditional method, but accounts for the uncertainties in these parameters during the analysis in lieu of using freeboard. Project performance is measured in terms of how a given plan will function when exposed to a full range of floods that could occur. Under this new method, the project performance will be

expressed as the chance in any year of a flow exceeding the largest flood that can be accommodated by the plan under study, with a conditional non-exceedance probability of 90%. The concept of freeboard in plan formulation is no longer used.

2.3.5 Hydrologic Uncertainty

The use of the new RBA methodology requires a characterization of the hydrologic uncertainty of the flow estimates used. This uncertainty is used in the Monte Carlo algorithms built into the Flood Damage Analysis (FDA) computer program as developed by the Hydrologic Engineering Center (HEC). The uncertainty bands used in this program are based on the effective record lengths used to develop the flow frequency estimates. For this study, the effective record length is governed by the gage histories of the main stem Missouri River gages. The effective record length used in the HEC-FDA for the discharge-frequency curve is 70 years. The graphical method was used by entering the range of discharges reported in the UMRSFFS.

2.4 HYDRAULICS

The basis for the hydraulic analysis was the development of an existing and future conditions HEC-RAS model. HEC-RAS, version 3.1.3, as developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, was used in the analysis. This model was used in an attempt to calibrate to the flood event of 1993 from measured high-water marks and corresponding instantaneous discharge estimates. Since, the St. Joseph reach was subject to a large levee failure on R471-460, the steady state HEC-RAS model could not be satisfactorily calibrated to the 1993 profile. However, the UMRFFS included the use of an unsteady hydraulic model, UNET, for generation of flood profiles calibrated to the 1993 high water marks. The unsteady UNET model is capable of modeling the significant flow lost through the R471-460 breach in 1993 to be able to reproduce the 1993 flood profile through the St. Joseph study reach. Therefore, the HEC-RAS model used for the current St. Joseph study was calibrated to the UNET profiles generated for UMRFFS. Once the model was calibrated, a series of steady flow water surface profiles was created based on the flood discharges in Table 2. The first step in the model development was to enter all applicable geometric data, including a schematic of the river system, cross-section data, bridge data, and other geometric data.

2.4.1 River System Schematic and Cross-Section Data

The Missouri River centerline was established by the Kansas City District and is based on the navigation sailing line and the 1960 adjusted river mileage. All of the mapping and cross section production work was part of the Mississippi Basin Modeling System (MBMS) project. The Missouri River mapping of the floodplain from bluff-to-bluff was accomplished under contracts with Horizons, Inc. The mapping is based on aerial photography from 1995 and 1998. Digital format for this mapping data is in the form of a digital terrain model, or DTM. Data files are in Universal Transverse Mercator (UTM)

Zone 15, North American Datum (NAD) 83, National Geodetic Vertical Datum (NGVD) 29, with units in feet. Mapping in the St. Joseph area is from the 1998 data.

Hydrographic survey of the Missouri River channel was accomplished via channel soundings performed by the Kansas City District in 1998. The channel soundings and the DTM data were merged into one continuous surface in DTM format to represent the Missouri River and its floodplain from bluff-to-bluff. Using the DTMs of the merged data, geo-referenced, bluff-to-bluff cross sections based were produced. On average, there are about three cross-sections per river mile with a higher density in the vicinity of the bridges.

The River System Schematic was imported into the HEC-RAS model using ArcView Geographic Information System (GIS) software. The Missouri River model begins near Atchison at RM 428.61 and extends upstream to RM 484.11. The downstream end of the model was extended far enough (RM 428.61) to account for uncertainties in starting water surface elevations. That is, any instability would be eliminated before the water surface profile reached the downstream end of the project reach. The upstream end was extended far enough (RM 484.11) to assess project impacts upstream from the study area. See Exhibit 2.2 for a plan view HEC-RAS schematic of the Missouri River model.

2.4.2 Bridge Data

Two bridges are located in the reach of the Missouri River used in the model. The U.S. Highway 36 Bridge is located at RM 447.84. The low chord elevation of this bridge (830 feet msl) is well above the water surface elevations during low frequency flood events. Therefore, only the piers of this bridge were included in the model. The Union Pacific Railroad Bridge is located at RM 448.16. This bridge is a rotating bridge and usually kept in the open position (the bridge structure in parallel with the current). It is closed only a few times a year and then only while a train crosses over it. Therefore, this bridge was modeled in the open position. The model used both the energy and momentum methods to calculate energy loss. The method that has the highest energy loss is used to determine the water surface elevations.

The data for the railroad bridge was taken from the As-built drawings of the bridge obtained from the Union Pacific Railroad. The drawings were dated 1917 and reference the Mean Gulf Tide at Biloxi, Mississippi as the vertical datum. This datum could not be correlated to the control used for the Missouri River Mapping. The As-built drawings for levee R471-460 indicated the low chord for the Union Pacific Railroad Bridge is 819.7 feet msl. This was verified by the U.S. Coast Guard. Therefore, a low chord elevation of 819.7 feet msl was used. All other elevations were taken from the Union Pacific As-built drawings and adjusted to correlate to the low chord elevation. As a test, the model was run with the low chord elevation of the bridge at lower elevations (up to three feet lower). This evaluation indicated that there was very little effect on the water surface elevations.

2.4.3 Other Geometric Data

Ineffective flow areas were entered into the HEC-RAS model to account for areas of quiescent water that do not contribute to the discharge calculations.

Contraction and expansion coefficients were entered into the model according to the guidance distributed by HEC (HEC-RAS 2001). These parameters account for losses associated with flows expanding and contracting across the flood plain. For areas with gradual transitions between cross sections, contraction and expansion coefficients were set at 0.1 and 0.3, respectively. In the vicinity of bridges of the Union Pacific Railroad Bridge the contraction and expansion coefficients were increased to 0.3 and 0.5, respectively.

Initial Manning's n-values were entered based on land cover from field investigation and aerial photography. These roughness coefficients were modified during the calibration, which will be discussed further in this chapter.

The existing top-of-levee elevations were surveyed for both levee units to more accurately define the levee profiles. The R471-460 data were collected by the Kansas City District Survey Section in 2003. The L455 data were collected by the Kansas City District Survey Section in 2002.

2.4.4 1993 Flow Data

Efforts were made to calibrate the HEC-RAS model to the 1993 high water mark data. However, this was not successful due to the unknowns in flow along the St. Joseph reach in the 1993 flood event and the unsteady nature of the 1993 flood in St. Joseph. Three flow rates were used in the RAS model calibration because two breaches occurred in the right bank levee:

RM 484.11	305,000 cfs
RM 452.80	228,050 cfs
RM 441.88	305,000 cfs

The upstream breach occurred at RM 452.80. The downstream breach occurred at RM 441.88. The USGS gauging station is located at RM 448.20. The peak stage of 32.69 feet was measured at this gauge at 0300 on 26 July 1993. At 1300 on 26 July 1993 the discharge at this gauge was measured to be 227,000 cfs by the USGS. At the time of this discharge measurement the stage was at 32.54 feet, 0.15 feet less than the peak. Based on the rating curve and these measurements, the peak discharge at the gauge was found to be 228,050 cfs.

It is difficult to determine the exact peak discharge of the Missouri River above the upstream breach and below the downstream breach. The upstream breach in the right bank levee occurred approximately 24 hours before the peak stage occurred. The

downstream breach did not occur until after the peak stage occurred. The area behind the levee was filling with water at the time the peak stage was measured. The amount of water flowing through the upstream breach was unknown because the flow behind the levee was not in equilibrium.

2.4.5 Calibration

Due to the significant unsteady aspects of the 1993 flows through the St. Joseph reach, the calibration of the steady state HEC-RAS model to the 1993 high water mark data produced unsatisfactory results. The 1993 high water marks provided the best opportunity to calibrate for high flows as the existing geometry should be a fairly accurate representation of the geometry during the 1993 flood. The UMRFFS was occurring concurrently with the development of the HEC-RAS model for this study. The unsteady UNET model used in UMRFFS was calibrated to the 1993 flood hydrograph for the entire length of the Missouri River between Rulo, Nebraska, and St. Louis, Missouri. The UNET model was able to be calibrated as described in the following excerpt from the *Upper Mississippi River System Flow Frequency Study – Appendix E*:

> "Another aspect of the UNET calibration process that was extremely important in the Kansas City District was the simulation of the performance of the Missouri River levees. A unique routine, known as the Kansas City Levee Algorithm, has been built into UNET for this purpose. That algorithm allows the user to first specify the upstream and downstream limits of a particular levee, which allows UNET to compute the floodplain storage within that levee. Next it allows the modeler to specify the point of levee rupture and the water surface elevation causing that rupture. This allows UNET to divert a portion of the passing flood wave into floodplain storage. Finally, the modeler is allowed to specify the channel discharge that will mobilize overbank flow in the behind-the-levee area. Because levees line almost the entire bank of the Missouri River, and many of these levees fail during great floods, the model calibration process in the Kansas City District required careful modeling of levee performance as well as careful estimation of channel roughness elements.
>
> The year 1993 was chosen as the calibration standard for this study. The data is recent, multiple measurements by USGS were made close to the peak flow of that year, and high water marks from the July-August flood of that year are well documented. The initial calibration using the automated calibration techniques of UNET were not fully satisfactory because the computed profile did not reproduce the high water marks between the gages. A second calibration more closely reproduced those marks, but was not used because the model did not properly reproduce the rupture and measured back-of-levee flow in the L-471-460 levee (St. Joseph area), and could not trace the multiple high water marks in the Kansas City area. These automated calibration techniques were then abandoned. The model was calibrated by manually adjusting resistance coefficients and levee

characteristics until the peak flow profile for 1993, and the observed flow and stage hydrographs at the gages, closely matched the observed data."

Once calibrated, the UNET model was then used to model the profiles as based on the frequency flows as defined in UMRFFS and documented in the Hydrology section of this report. The HEC-RAS model was then calibrated to reproduce the UNET model water surface profile for the 1% (100-year) chance event, as the profiles near this frequency are of primary concern in this study. Manning's n-values were adjusted in an attempt to match the resulting HEC-RAS water surface elevations with the UNET water surface elevations. The final Manning's n-values range from 0.025-0.030 for the channel and 0.030-0.100 in the overbank areas. Exhibit 2.3 displays the comparison of the water surface profiles for the 1% (100-year) chance event water surface profile as modeled by both the HEC-RAS model and the UNET model.

The model calibration has been verified with readings taken from USGS Gage 06818000 for field-measured discharges. The gage is located on the railroad bridge at River Mile 448.16 in the HEC-RAS model. The Exhibit 2.4 displays the model water surface profile along with gage readings from USGS field measured discharges. Only discharge measurements/gage readings since 1980 were used in this comparison to minimize the effects of any long-term stage trends in this reach. The data from 1980 to the present provides 856 discharge measurements/gage readings for this comparison. Exhibit 2.4 displays that the modeled water-surfaces are at the top edge of the data collected from the USGS gage. This result is expected, as HEC-RAS provides a complete backwater simulation, and the modeled water surfaces should lie along the top edge (the falling limb) of the hysteresis displayed in the gage data.

2.5 EXISTING CONDITIONS

2.5.1 Missouri River Water Surface Profiles

Once the model was calibrated, existing conditions water surface profiles were generated for the 50% (2-year), 20% (5-year), 10% (10-year), 5% (20-year), 2% (50-year), 1% (100-year), 0.5% (200-year), and 0.2% (500-year) chance of exceedance flood events. The starting water surface elevations for each of the profiles were calculated using the water surface elevation from the UMRFFS for RM 428.61.

For each of these flood events, an assumption was made about overbank flows. As levees begin to overtop, it was assumed in HEC-RAS that the protected areas would be considered ineffective flow areas. That is, the profiles will reflect a confined cross-sectional area from levee to levee and will not compute the protected areas as flowing. This was assumed to avoid trying to predict where a levee would fail. HEC-RAS is a one-dimensional steady state model. It is beyond the limitations for HEC-RAS to predict the overbank flow scenarios or to model multi-dimensional flow. The HEC-RAS results for the Missouri River are presented in Exhibit 2.5. The 0.2% and 0.5% chance event profiles are listed as 'confined' because the actual existing conditions profiles exceed the

existing top of levee elevations but are confined by ineffective flow areas. Levee-Unit-specific water surface profiles showing the 2% (50-year), 1% (100-year), 0.5% (200-year), and 0.2% (500-year) chance of exceedance flood events in relation to the surveyed top-of-levee were created for the both R471-460 and L455 (Exhibits 2.6 and 2.7). The engineering performance of the levees in the existing condition can be found in Appendix C – Economic Appendix as this output comes from the economist's HEC-FDA analysis.

2.5.2 Hydraulic Uncertainty

Uncertainties in computed water surface elevations are a result of imperfect knowledge and lack of appropriate data. Uncertainties in water surface elevation result from a number of physical factors such as bed forms, debris and other obstructions, channel scour or deposition, sediment transport, and waves. In hydraulic modeling, other factors such as hydraulic roughness variation with season, inexact geometry and loss coefficients, and error in setting high-water marks result in errors in computed water surface elevations. Estimating these uncertainties in water surface elevation is based on sensitivity analyses, analytical studies of gage readings, and interpretation of the success of model adjustments following traditional procedures presented in USACE Engineering Manual (EM) No. 1110-2-1619 (EM 1996).

Stage uncertainty is expressed in the Risk Based Analysis as a standard deviation (in feet). To obtain a total standard deviation the formula below, taken from EM 1110-2-1619, was applied:

$$\text{Total Standard Deviation} = \text{SQRT}\left((S_{natural})^2 + (S_{model})^2\right)$$

where SQRT = square root mathematical function
$S_{natural}$ = standard deviation based on historical data and gage readings
S_{model} = standard deviation based on mapping detail and reliability of estimating Manning's n values

$S_{natural}$, is calculated by comparing observed data with the latest rating curve at the gage in the project reach. To avoid potential problems due to shifts in the rating curve over time, only observed data going back to 1978 were used. Only data for floods exceeding elevation 806 at the St. Joseph gage were analyzed. The following formula is used to calculate $S_{natural}$.

$$S_{natural} = \text{SQRT}\left((\Sigma(X-M)^2)/(N-1)\right)$$

where SQRT = square root mathematical function
X = stage corresponding to measured Q
M = best fit curve estimate of stage corresponding to Q
N = number of stage-discharge observations in the range being analyzed

The standard deviation based on historical data and gage readings, $S_{natural}$, was computed as 1.24 feet.

The second component in quantifying standard deviation is S_{model}. S_{model} is obtained by estimating the confidence in the cross-section data from topographic mapping efforts and in estimating the reliability of the Manning's n-value. Table 5-2 in EM 1110-2-1619 quantifies an S_{model}, based on these two factors. A standard deviation of 0.3 foot was chosen from EM 1110-2-1619 Table 5-2 since the cross-sections were based on current aerial mapping and the Manning's n-values were assumed to be reliable.

Once $S_{natural}$ and S_{model} are known, a total standard deviation can be computed. Following traditional procedures presented in EM 1110-2-1619, a total standard deviation of 1.28 feet was computed for the entire discharge set.

2.6 LEVEE TIEBACK ANALYSIS

2.6.1 Introduction

At some locations, landward extensions of the main stem levee protect interior areas from backwater and/or tributary headwater flooding. These extensions are called levee tiebacks. Additional hydraulic analysis is required to characterize existing conditions relative to a levee tieback.

For this study, purposes for analyzing levee tiebacks include determining their impacts on interior floodwater and exterior water surface elevation relationships, and identifying the longitudinal extent of backwater-control on water surface elevations along a levee tieback.

Three levee tiebacks were analyzed for existing conditions hydraulics. Summarized in Table 4 are each levee tieback analyzed as part of the St. Joseph Feasibility Study.

Table 4. St. Joseph Study Levee Tiebacks

Missouri River Levee Unit	Levee Tieback Headwater Source Area	Missouri River HEC-RAS River Station
L455	Contrary Creek	437.30
L455	Browns Branch	445.73
R471-460	Peters Creek	441.73

2.6.3 Contrary Creek

Contrary Creek is the downstream tieback for levee L455. A HEC-RAS model of Contrary Creek was developed by HDR in 1999. This model provided the basis of the Contrary Creek model used in this study. The HDR model was modified to reflect survey elevations along the tieback levee collected as part of the L455 top of levee survey conducted in 2002. The Manning's n-values in the HEC-RAS model were also modified

to reflect the tree growth along the channel banks. A channel n-value of 0.050 was used in the current model along with a n-value of 0.030 for the grassy overbank areas. A HEC-1 hydrologic model for the 26.2 sq. mi. Contrary Creek Watershed was used to determine the Contrary Creek design flows. The HEC-1 model was developed by HDR and documented in the report "Missouri River Levees L455 and R460-471: Interior Drainage Study, Task 3: Contrary Creek Watershed Model", (2001). Table 5 displays the results from the HEC-1 model.

Table 5. St. Joseph Study Levee Tiebacks Contrary Creek Flows

Frequency in Percent Chance of Occurrence	Contrary Creek Design Flow (cfs)
50%	4,070
20%	6,180
10%	7,830
4%	9,510
2%	11,200
1%	12,900
0.5%	14,900
0.2%	17,400

A headwater flood profile for each recurrence interval was calculated for Contrary Creek. This assumed that a flood event on Contrary Creek was completely independent of flooding on the Missouri River. This assumption is based on the relative size of the small Contrary Creek watershed to the Missouri River watershed at this location. The Contrary Creek watershed responds quickly to a storm event and the peak will pass quickly, whereas the Missouri River responds slowly to a prolonged weather pattern or snowmelt in the upstream tributary area. Therefore, downstream starting elevations were based on a normal depth within Contrary Creek.

The backwater elevations for each flood event on the Missouri River at the mouth of Contrary Creek was superimposed over the headwater flood profiles for the respective flood event on Contrary Creek. The final profile for Contrary Creek is the maximum of the headwater flood within Contrary Creek and the Missouri River backwater elevation for each flood event (Exhibit 2.8).

The possible effects due to a coincident event over the Contrary Creek watershed along with flood stages along the Missouri River were analyzed. This limited analysis provides a check as to whether further coincident analysis would be justified. The 1% chance Contrary Creek headwater event flood profile was calculated using a downstream starting elevation equal to the backwater from a 2% chance flood event on the Missouri River. This combination was viewed as a conservative scenario, providing an upper limit to coincident effects, as a coincident occurrence of two such low probability events would be rare. The coincident analysis showed despite the coincidence of occurrence between

the Missouri River and Contrary Creek floods that the 1% chance Contrary Creek profile was not increased over that modeled using a normal depth starting elevation.

The Contrary Creek tieback levee is adequate to protect from overtopping by a 1% chance Missouri River flood event. However, the levee is not adequate to protect against Contrary Creek flooding events. The majority of the levee is inadequate to protect against the 1% chance Contrary Creek flood event and significant portions are adequate for only the 4% chance flood event. These areas can be addressed further at the request of the local sponsors, but are outside of the scope of the current feasibility study.

2.6.4 Browns Branch

Browns Branch is an internal tieback for levee L455. A HEC-RAS model of Browns Branch was developed by HDR in 1999. This model provided the basis of the Contrary Creek model used in this study. A HEC-1 model was developed by HDR and documented in the report "Tributary Hydraulics, Missouri River Levee System, Unit L-455 and Unit R-460-471", (2000). The hydrologic model assumed a freely discharging watershed to Browns Branch. Table 6 displays the results from the HEC-1 model.

Table 6. Browns Branch Flows

Frequency in Percent Chance of Occurrence	Browns Branch Design Flow (cfs)
50%	1,975
20%	2,850*
10%	3,500*
4%	4,500*
2%	5,350*
1%	6,150*
0.4%	7,500*
0.2%	8,600*

*Exceeds Capacity of 9'x9' RCB at beginning of Browns Branch

Browns Branch is protected from overland flow into the channel by the presence of L455 tieback levees on either side of the channel. The only discharge point into Browns Branch is a dual 9'x9' RCB at the extreme upstream end of the channel. This box culvert conveys surface runoff from the tributary watershed to Browns Branch. Therefore, the capacity of this box culvert limits the amount of runoff from the watershed that can be introduced to Browns Branch. The hydraulic capacity of this box culvert was analyzed. Information provided by the City of St. Joseph, indicated that the slope of the Dbl. 9'x9' RCB is 0.00179 ft/ft. The hydraulic capacity of the culvert was calculated to be 1,634 cfs. For this analysis, the culvert capacity was figured as 110% of the hydraulic capacity or 1,797 cfs. From the above table, the culvert capacity is less than the 2-Yr Flood Event from the contributing watershed. Therefore, the culvert capacity (1,797 cfs) is the design flow for each headwater flood profile within Browns Branch.

A headwater flood profile for the design flow was calculated for Browns Branch. This assumed that a flood event on Browns Branch was completely independent of flooding on the Missouri River. This assumption is based on the relative size of the small Browns Branch watershed to the Missouri River watershed at this location. The Browns Branch watershed responds quickly to a storm event and the peak will pass quickly, whereas the Missouri River responds slowly to a prolonged weather pattern or snowmelt in the upstream tributary area. Therefore, downstream starting elevations were based on a normal depth within Browns Branch. As stated previously, the headwater flood profile was the same for each Flood Event 2-yr through 500-yr.

The backwater elevations for each flood event on the Missouri River at the mouth of Browns Branch was superimposed over the headwater flood profiles for the respective flood event on Browns Branch. The final profile for Browns Branch is the maximum of the headwater flood within Browns Branch and the Missouri backwater elevation for each flood event (Exhibit 2.9).

The possible effects due to a coincident event over the Browns Branch watershed along with flood stages along the Missouri River were analyzed (Exhibit 2.9). Since the maximum flow within Browns Branch is achieved in a frequent event (>50% annual chance of occurrence), it is quite possible that this event could occur coincident with low frequency events on the Missouri River. The maximum Browns Branch headwater event flood profile was calculated using a downstream starting elevation equal to the backwater from a 1% chance flood event on the Missouri River. This combination was viewed as a conservative scenario, providing an upper limit to coincident effects.

The minimum difference between the lowest levee elevation and the 1% chance elevation from the Missouri River backwater exceeds 3 feet with the water surface elevation always lower. The Browns Branch coincident event headwater flood profile comes within 1.15 feet of the top of the tieback levee. Thus the most likely form of overtopping would be headwater flooding.

2.6.5 Peters Creek

Peters Creek is the downstream tieback for levee R471-460. A HEC-RAS model of Peters Creek was developed by HDR in 1999. This model provided the basis of the Contrary Creek model used in this study. A HEC-1 model was developed by HDR and documented in the report “Tributary Hydraulics, Missouri River Levee System, Unit L-455 and Unit R-460-471”, (2000). Table 7 displays the results from the HEC-1 model.

Table 7. Peters Creek Flows

Frequency in Percent Chance of Occurrence	Peters Creek Design Flow (cfs)
50%	1,950
20%	3,150
10%	4,375
4%	6,300
2%	8,000
1%	10,000
0.4%	13,000
0.2%	15,500

A headwater flood profile for each recurrence interval was calculated for Peters Creek. This assumed that a flood event on Peters Creek was completely independent of flooding on the Missouri River. This assumption is based on the relative size of the small Peters Creek watershed to the Missouri River watershed at this location. The Peters Creek watershed responds quickly to a storm event and the peak will pass quickly, whereas the Missouri River responds slowly to a prolonged weather pattern or snowmelt in the upstream tributary area. Therefore, downstream starting elevations were based on a normal depth within Peters Creek.

The starting water surface elevation for each headwater flood profile began at normal depth at the downstream end of Peters Creek. However, the lower 2000 feet of Peters Creek in the model has a flat invert at elevation 792.50. A slope of 0.0005 ft/ft was used as the downstream boundary condition since a zero slope can not be used in normal depth calculations. This assumption was tested by using various starting slopes ranging from 0.0002-0.002 and examining the resultant water surface profiles. The profiles for the various assumed downstream slopes were nearly identical at points more than 1700 feet upstream of the mouth of Peters Creek. These differences at the lower end of the tributary are insignificant as the flood profiles near the mouth of Peters Creek are controlled by Missouri River backwater and not headwater flooding in Peters Creek.

The backwater elevation for each flood event on the Missouri River at the mouth of Peters Creek was superimposed over the headwater flood profiles for the respective flood event on Peters Creek. The final profile for Peters Creek is the maximum of the headwater flood within Peters Creek and the Missouri backwater elevation for each flood event (Exhibit 2.10).

The possible effects due to a coincident event over the Peters Creek watershed along with flood stages along the Missouri River were analyzed. This limited analysis provides a check as to whether further coincident analysis would be justified. The 1% chance Peters Creek headwater event flood profile was calculated using a downstream starting elevation equal to the backwater from a 2% chance flood event on the Missouri River. This

combination was viewed as a conservative scenario, providing an upper limit to coincident effects, as a coincident occurrence of two such low probability events would be rare.

The minimum difference between the lowest levee elevation and the 1% chance elevation from the Missouri River backwater exceeds 3 feet and has no effect on FEMA certification for this levee. Exhibit 2.10 also displays the results of the limited analysis of coincident events. The coincident event profile remained well below the top of levee along the length of the tieback for this worst-case scenario. Therefore, it was determined that a coincident event was not critical in the analysis of the Peters Creek tieback.

2.7 INTERIOR FLOODWATER/EXTERIOR WATER SURFACE ELEVATION RELATIONSHIPS

2.7.1 Introduction

For each levee unit, an analysis was performed for estimating a land-side (interior) floodwater elevation at a given river-side (exterior) water surface elevation. Interior flooding attributed to levee failure or levee overtopping was considered for developing interior/exterior water surface relationships. Results of this analysis will be used as input to the HEC-FDA model. To provide a means of economic analysis, damages to the protected area for a given flood event must be calculated. Interior flood profiles, assuming a breach of the studied levee, need to be analyzed for each flood event in the existing conditions model. These profiles must then be associated with the same probability flood in a confined channel exterior to the studied levee.

2.7.2 Approach

The proposed methodology used in the analysis of the interior flood profiles is based in part on the breach and subsequent flooding of R460-471 during the July 1993 flood. The reason for choosing this method is that past performance is the best predictor of future performance. In 1993 the levee breach occurred near the upstream end of the studied levee. The subsequent interior flood traveled from the breach location and ponded behind the lower end of the levee. This pond behind the downstream levee continued to rise until the downstream levee breached, returning the interior flood flow back to the river channel. The following timeline, summarizing the sequence of events occurring in July 1993, was assembled based upon information from Levee District eyewitness accounts as verified by Situation Report entries on file within the Kansas City District's Emergency Management Branch.

Date	Hour	Event
24 July 1993	1600	Overtopping begins near river mile 453
25 July	0200	Catastrophic failure near river mile 453
26 July	1400	Overtopping begins near river mile 442

27 July	2200	---
		Catastrophic failure takes place within this period near river mile 442
28 July	0200	----

The proposed methodology is based on a combination of past performance of the levee, combined with a logical modification of the FEMA delineation process. This approach was developed, in part, because of the delineation of an AR zone by FEMA utilized this same procedure. This same procedure was also applied to L455, even though that levee did not fail during the 1993 flood.

The Interior Floodwater Analysis assumes a complete breach of the upper limits of the levee system allowing uncontained flow through the protected area. This condition did occur with a breach in the upper portion of the levee during the 1993 flood event. The analyzed channel consists of the main channel geometry and the flooded protected area. Since the majority of the protected area behind the studied levee is row cropped agricultural land, n-values appropriate for such land use have been assigned to the flood plains landward of the levee. The Interior Floodwater Analysis model allows flow within the main channel and behind the studied levee, creating a family of interior flood profiles for the full valley. The most upstream section used in generating interior flood profiles for R471-460 was River Mile 453.44. The levee does extend to River Mile 456.24, but the portion from 453.44 to 456.24 flows from west to east. This results in the interior flood profile being distorted, showing an excessive rise in the profiles, by considering these cross-sections which flow perpendicular to the direction of interior flood flow. It is likely that the limited agricultural damage in the upper end of the protected area can be represented by the long North-South leg of the Missouri River. The same occurs at the downstream end of the levee, but it is inconsequential due to the interior flood profiles being overridden by the ponding elevation at the downstream end.

The levee low point is the minimum elevation of the interior floodwater prior to overtopping the levee and returning to the main channel. The levee low point elevation is 816.12 and 813.28 for R471-460 and L455, respectively. This creates a level pool at the lower portions of the interior floodwater profile. However, the level pool elevation cannot exceed the water surface elevation of the most upstream section of the confined channel flood profile adjacent to the studied levee, as there would not be adequate head to fill the protected area. Therefore, the minimum elevation of the interior flood profile will be the lesser of the levee low point or the confined channel water surface elevation for the most upstream section. It should also be noted that HEC-FDA, cannot accept flood profile data when the elevation of a more severe flood is not greater than that for a lesser flood. Therefore, the ponding elevation was incremented by 0.10 foot for each flood event. The final interior flood profile consists of a level pool behind the downstream portion of the levee extending to a point of intersection with the interior flood profile as discussed in the previous step.

The interior flood profile is assosciated with an exterior confined water surface profile to determine the interior/exterior relationship for each levee unit. The exterior confined profile is created by taking the accepted existing conditions model and not allowing any flow over the studied levee or within the protected area. This is achieved by setting ineffective flow limits on the studied levee to such a height that there are no areas of effective flow within the protected area, regardless of flood event probability. Thus there is an exterior profile and an associated interior profile for each flood frequency used in this study.

General discussions of the methods and results for all levee geotechnical and structural failure analyses can be found in the relevant Geotechnical and Structural chapters of this appendix. For each levee unit, exterior water surface and levee failure elevation data were translated to an index point along the top-of-levee.

The approach used for estimating interior floodwater elevations was dependent upon the cause of interior flooding (levee failure or levee overtopping) and the elevation of the lowest point along the top-of-levee. To identify the location and translate the elevation of initial levee overtopping to the index point, the existing conditions 1% chance of exceedance (100-year) flood event water surface profile was adjusted (equally raised or lowered) to intersect the top-of-levee at the initial point of overtopping. For levee failures below both the lowest top-of-levee and the elevation of initial levee overtopping, it was assumed that the interior floodwater would equilibrate to the elevation of the levee failure. When levee failure is above the lowest top-of-levee-elevation, but below the initial levee overtopping elevation, it was assumed that the interior floodwater elevation would equate to the lowest top-of-levee elevation. Once the levee is overtopped, it is assumed that the interior floodwater elevation would initially equate to lowest top-of-levee elevation. Once the exterior surface water exceeds the lowest top-of-levee elevation, it is assumed that the interior water surface elevation would then equal the exterior water surface elevation at that location.

2.7.3 Results

Results of categorizing interior floodwater and exterior water surface relationships and associated probabilities were tabulated and provided for input into the HEC-FDA analysis of the St. Joseph Levees. Figures showing the interior water surface profiles are provided for each levee unit (Exhibits 2.11 and 2.12). Figures showing the interior floodwater/exterior water surface relationship entered into HEC-FDA for each index point used in this study are provided (Exhibits 2.13 and 2.14).

2.8 FUTURE CONDITIONS WITHOUT PROJECT (BASELINE)

The future conditions without project represents the probable stage-discharge relationship at a selected future date based on the best available current data, the incorporation of any definite projects planned to be completed within the study reach, and any long term natural river processes that may affect future stages. For the purposes of this study, the

future conditions have been defined as conditions reasonably expected to be present in 2038. A critical assumption in the future conditions analysis is that hydrologic conditions along the Missouri River are relatively static and that flows used in the existing conditions study will be used in the future conditions analysis. The assumption was also implemented in the development of the recently released *Upper Mississippi River System Flow Frequency Study* (UMRFFS), 2003, which was based on the study of 100 years of gage records along the Missouri River. The UMRFFS superseded the previous Missouri River hydrology published in 1962 in the report titled *Missouri River Agricultural Levee Restudy Program*. It is therefore reasonable to assume that the newly published flows in the UMRFFS will still be applicable at the future conditions date.

2.8.1 Future Changes to Missouri River Model

The USACE Northwest Division-Missouri River Basin Reservoir Control Center in Omaha, Nebraska published *Missouri River Stage Trends, RCC Technical Report A-04* in April 2004. This report provided some long-term trend data for the St. Joseph gage on the Missouri River. The stage trends at the St. Joseph Gage for low frequency flows are shown in Exhibit 2.15. The 70,000 cfs and100,000 cfs data series reflects a significant rise in stages from 1928 to 2003.

A likely contributor to the flood flow stage changes along the Missouri River is accretion behind dikes placed for navigation channel confinement. Flows deposit sediment in the quiescent area downstream of the navigation dike structures. This sediment builds over time and encroaches further into the channel. As time passes, vegetation has grown on this newly accreted land. The vegetation stabilizes this accreted land from future erosion and allows the cycle to continue further into the channel. This cycle produces the tall stands of timber present in the accreted land behind the dikes along the riverward side of the levees. The accreted land tree growth then leads to higher stages for a given flow as conveyance area is decreased and overbank roughness is significantly increased.

Overgrowth of the foreshores can contribute to continued rising stages in the Missouri River along the studied reach. The right foreshore is primarily farmed north of the Missouri Department of Conservation Property. The Missouri Department of Conservation Property is composed of dense mature trees and extends north from the railroad bridge to approximately River Mile 452. Scattered portions of the left foreshore are being farmed currently, but much of the left foreshore has fully overgrown with mature trees. The area experiencing the most new growth is an area extending along the right foreshore from the Highway 36 Bridge to the downstream end of R460-471. This area is being allowed to experience natural tree growth as part of the Wetlands Conservation Program. This area will transition from grassland with small scrub trees to a mature stand of trees. This overgrowth will be considered as a condition affecting future Missouri River water surface profiles within the studied reach. For this study, land that is currently farmed will be assumed to continue to be farmed in the future and land overgrown with mature trees will be assumed to remain as mature tree growth.

Therefore, the only land use to change in the future conditions model is the land along the right foreshore in the Wetlands Conservation Program.

2.8.2 Future Conditions Water Surface Profiles

Future conditions water surface profiles were generated for the 50% (2-year), 20% (5-year), 10% (10-year), 5% (20-year), 2% (50-year), 1% (100-year), 0.5% (200-year), and 0.2% (500-year) chance of exceedance flood events (Exhibit 2.16). For each of these flood events, a similar assumption as used in the existing conditions model was made concerning overbank flows. As levees begin to overtop, the protected areas behind are considered ineffective flow areas. The profiles reflect flow in the area from levee to levee and do not consider the protected areas as conveying flow. Thus the 0.2% and 0.5% profiles are labeled "confined" to reflect this approximation. Levee unit-specific water surface profiles showing the 1% (100-year) chance of exceedance flood event in relation to the top-of-levee were created for both R471-460 (Exhibit 2.17) and L455 (Exhibit 2.18). The engineering performance of the levees in the future without project condition can be found in Appendix C – Economic Appendix as this output comes from the economist's HEC-FDA analysis.

2.8.3 Hydraulic Uncertainty

As discussed in the existing conditions section, stage uncertainty is expressed in Risk Based Analysis as a standard deviation (in feet). Per USACE Engineering Manual (EM) No. 1110-2-1619 (EM 1996), a total standard deviation was obtained by applying the formula below:

$$\text{Total Standard Deviation} = \text{SQRT}\left((S_{natural})^2 + (S_{model})^2\right)$$

where SQRT = square root mathematical function
$S_{natural}$ = standard deviation based on historical data and gage readings
S_{model} = standard deviation based on mapping detail and reliability of estimating Manning's n values

The $S_{natural}$ will remain unchanged, as that portion of the uncertainty is due to the agreement between historical gage readings and modeled water surface elevations. $S_{natural}$ is a function of calibration accuracy and does not change from existing conditions to future conditions. However, due to additional assumptions in the development of the future conditions model, S_{model} will increase. Due to the uncertainty of future channel morphology and vegetation growth, the reliability of the cross-section data and Manning's n-value was decreased. S_{model} is obtained by estimating the confidence in the cross-section data from topographic mapping efforts and in estimating the reliability of the Manning's n-value. Table 5-2 in EM 1110-2-1619 quantifies S_{model}, based on these two factors. A standard deviation of 0.7 feet was chosen since the cross-sections were

based on current aerial mapping and the Manning's n-values were assumed to be less reliable than existing conditions.

Once $S_{natural}$ and S_{model} are known, a total standard deviation can be computed. Following traditional procedures presented in EM 1110-2-1619, a total standard deviation of 1.42 feet was estimated for the entire discharge set in the future conditions.

2.9 FUTURE CONDITIONS WITH PROJECT

2.9.1 Studied Alternative Raises

The future conditions with project represents the probable stage-discharge relationship at a selected future date (2038) reflecting any proposed alternatives from the current feasibility study. The basis of this hydraulic model is the future conditions without project model modified to reflect any proposed alternatives.

Four alternatives have been identified for the St. Joseph Levee Units levee raise. The alternatives include raising the levee to 1.5 feet above the nominal future conditions without project 1% (100-year) chance of exceedance flood profile (referred to as the n100+1.5 alternative), raising the levee to 3 feet above the nominal future conditions without project 1% (100-year) chance of exceedance flood profile (referred to as the n100+3 alternative), raising the levee to 1.5 feet above the future conditions without project "confined" 0.2% (500-year) chance of exceedance flood event (referred to as the 500+1.5 alternative), and raising the levee to 3 feet above the future conditions without project "confined" 0.2% (500-year) chance of exceedance flood event (referred to as the 500+3 alternative). Freeboard does not explicitly enter into this set of alternatives. A typical spread of four raises is examined for purposes of allowing economic optimization. This spread was chosen based on practical experience and expected costs. The n100+3 alternative analysis was conducted in detail with the other three alternatives receiving a cursory analysis as a means of developing a net benefits curve. Therefore, the with project analysis is focused on the n100+3 preferred alternative (Exhibit 2.19).

2.9.2 Performance of Alternatives

The preferred alternative, the n100+3 raise, increases the R471-460 conditional nonexceedance probability for the 1% (100-year) flood event profile from 41.8% in the future without project condition to 91.6% in the future with project condition. Please refer to Table 8 for a summary of HEC-FDA engineering performance results for the various alternatives. The detailed HEC-FDA results can be found in Appendix C – Economic Appendix. Appendix C contains the reliability data for all studied alternatives and for both the existing and future conditions.

Table 8. Engineering Performance Data from HEC-FDA
1% (100-yr) Conditional Nonexceedance Probability

ANALYSIS YEAR/ ALTERNATIVE	R471-460	L-455
2013 without-project	51.3%	93.6%
2013 overtopping only	67.8%	95.0%
2013 Alternative 4 (100+1.5)	84.3%	93.6%
2013 Alternative 1 (100+3)	95.8%	95.0%
2013 Alternative 2 (500+1.5)	99.8%	99.2%
2013 Alternative 3 (500+3)	100.0%	100.0%
2038 without-project	41.8%	92.8%
2038 overtopping only	56.6%	94.0%
2038 Alternative 4 (100+1.5)	75.7%	92.8%
2038 Alternative 1 (100+3)	91.6%	94.0%
2038 Alternative 2 (500+1.5)	99.3%	98.9%
2038 Alternative 3 (500+3)	99.9%	99.9%

Both existing levees currently pass the nominal 1% (100-year) chance of exceedance flood profile without overtopping. Therefore, there are no impacts to the profile for the 1% (100-year) chance of exceedance event for any raise alternative. This is an important designation as there are no impacts to the FEMA Base Flood Elevations along the Missouri River at any point as a result of any raise alternative. However, the preferred alternative would remove the FEMA AR Zone designation for the R471-460 protected area. The impacts due to the proposed alternatives impact only profiles for events larger than the 1% (100-year) chance of exceedance event.

2.9.3 Impacts to Others

As stated previously, the HEC-RAS model assumed a confined channel with no conveyance through the protected area in the event of overtopping. Therefore, the HEC-RAS model would not identify any impacts to the Missouri River profile as a result of levee raises. The largest impact to the profile is due to the delaying or preventing of the overtopping as seen in the 1993 flood event on R471-460. This unsteady flow problem called for the use of the UNET model to capture the impacts to the Missouri River profile as a result of the proposed n100+3 alternative. The impacts for this alternative were analyzed for the 1993 flood event as modeled in the UMRFFS UNET model.

The UMRFFS UNET model used for calibration in this study was modified to reflect the proposed R471-460 raise. The UNET “include file” contains the levee designations for all Federal Levees and significant private levees along the Missouri River in the studied reach. The ZBLV variable, the river elevation when the breach in the levee initiates, in the LV record for Levee R471-460 was edited to reflect the raised breach elevation. In the existing conditions, ZBLV = 825.50, an elevation one foot below the existing top of

levee. The proposed improvements to the levee will set the crest elevation at the 1% chance flood event plus 3-feet. The modeled breach elevation will account for increased reliability at stages below the crest elevation, as well as the physical top of levee elevation increase (1.5 feet at the breach location), and therefore the proposed model will use ZBLV = 828.00. The modification of the ZBLV value for R471-460 was the only modification to the existing UNET data.

The proposed "with project" condition was run in UNET. The output provided a daily maximum water surface elevation profile along the river, which displays the impacts of the R471-460 improvements. It should be noted that while the top of levee elevation has been increased, the UNET model still shows that R471-460 fails due to the Flood of 1993. It should also be noted that this analysis assumes that the breach in an event similar to 1993 would occur in the same location at the upstream end of R471-460 as it occurred in 1993. The results of this analysis would vary if the initial levee overtopping and subsequent breach occurred at the downstream end of the R471-460 Levee Unit. The with and without project profiles for this analysis were plotted together to identify locations where the daily water surface was increased due to the improvements to R471-460.

Exhibits 2.20 and 2.21 tabulate and display the differences in the existing and proposed conditions maximum water surfaces along the studied reach. It is evident that the improvements to R471-460 have a significant effect to the maximum water surface profiles seen in the 1993 Flood event. By delaying the breaching of R471-460 in the 1993 Flood event and the subsequent flow loss to storage, greater peak flows are seen in the reaches adjacent to and downstream of R471-460. This increased peak flow causes increases in the maximum water surface seen adjacent to and downstream of R471-460. The maximum rise in the water surface profile, 0.82 feet, is seen at RM 433.44. Levees L448-443 and R440 are located near the location of the maximum rise. Each of these levees has significant freeboard (minimum freeboard approximately 3.5 feet) above the maximum water surface calculated in the UNET model for the Flood of 1993. The increase in maximum water surface elevations adjacent to L455 range from approximately 0.40-feet at the upstream end of the levee to approximately 0.60-feet at the downstream end of L455. All Federal levees should perform in a 1993 flood event similar to their respective performance in 1993. Levees that overtopped in the 1993 flood event would still overtop and those levees which were elevated above the maximum 1993 water surface elevation would continue to be above the 1993 maximum water surface with the proposed R471-460 and L455 raise.

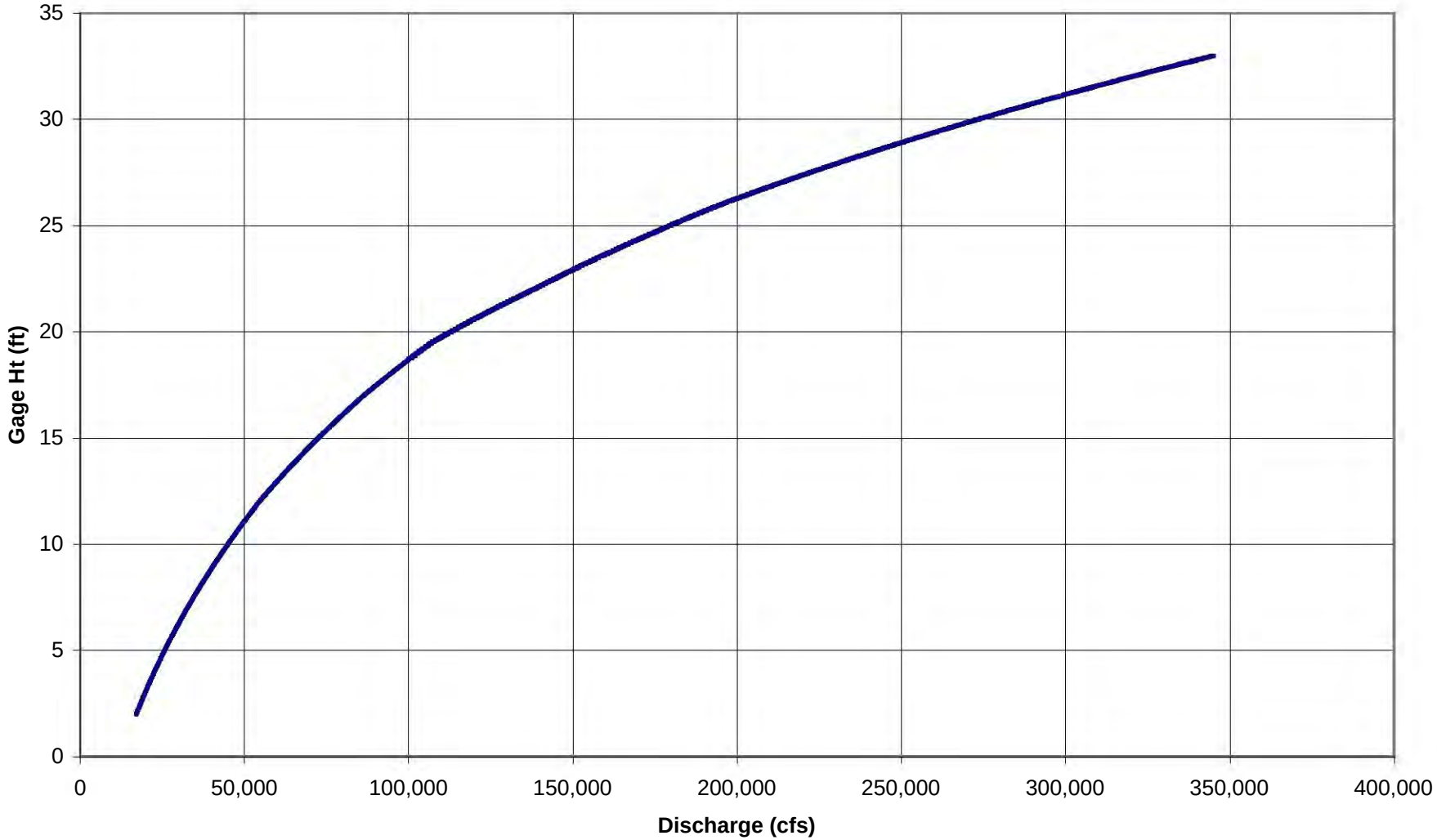
2.10 EVALUATION OF THE ADEQUACY OF THE ORIGINAL DESIGN

Unit R471-460 was overtopped by a flow of approximately 268,000 cfs during the Flood of 1993. This overtopping flow was approximately 60,000 cfs less than the design flow, 325,000 cfs, for R471-460. The original levee design, completed in 1965, also accounted for two feet of freeboard above the design flow profile. The relatively low overtopping flow as compared to design has brought into question the adequacy of the original design

and the subsequent top of levee profile. Upon review of the original design, the cause for the current recommended alternative and inadequacy of the existing levee unit has been deemed a design deficiency in the original design of R471-460. Please refer to the attached Memorandum for Record (Exhibit 2-22) for a detailed summary of the design deficiency analysis.

Exhibit 2.1

St. Joseph Gage Rating Curve
Rating Curve #9, Retrieved 20 Jun 2006



Designed by: EDS
Checked by: MMW
Date: 7/22/2006

Exhibit 2.2
HEC-RAS Schematic of Study Reach

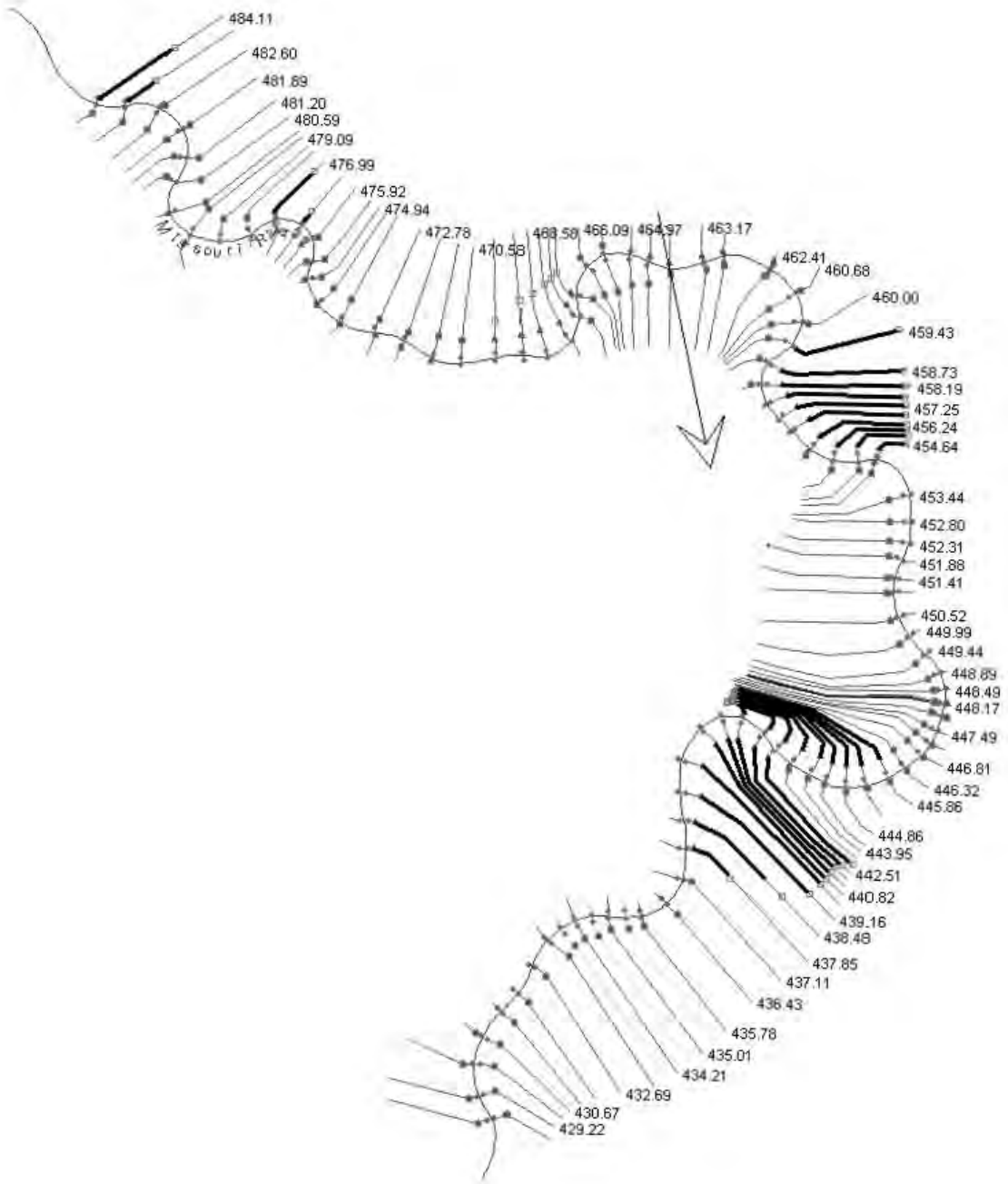
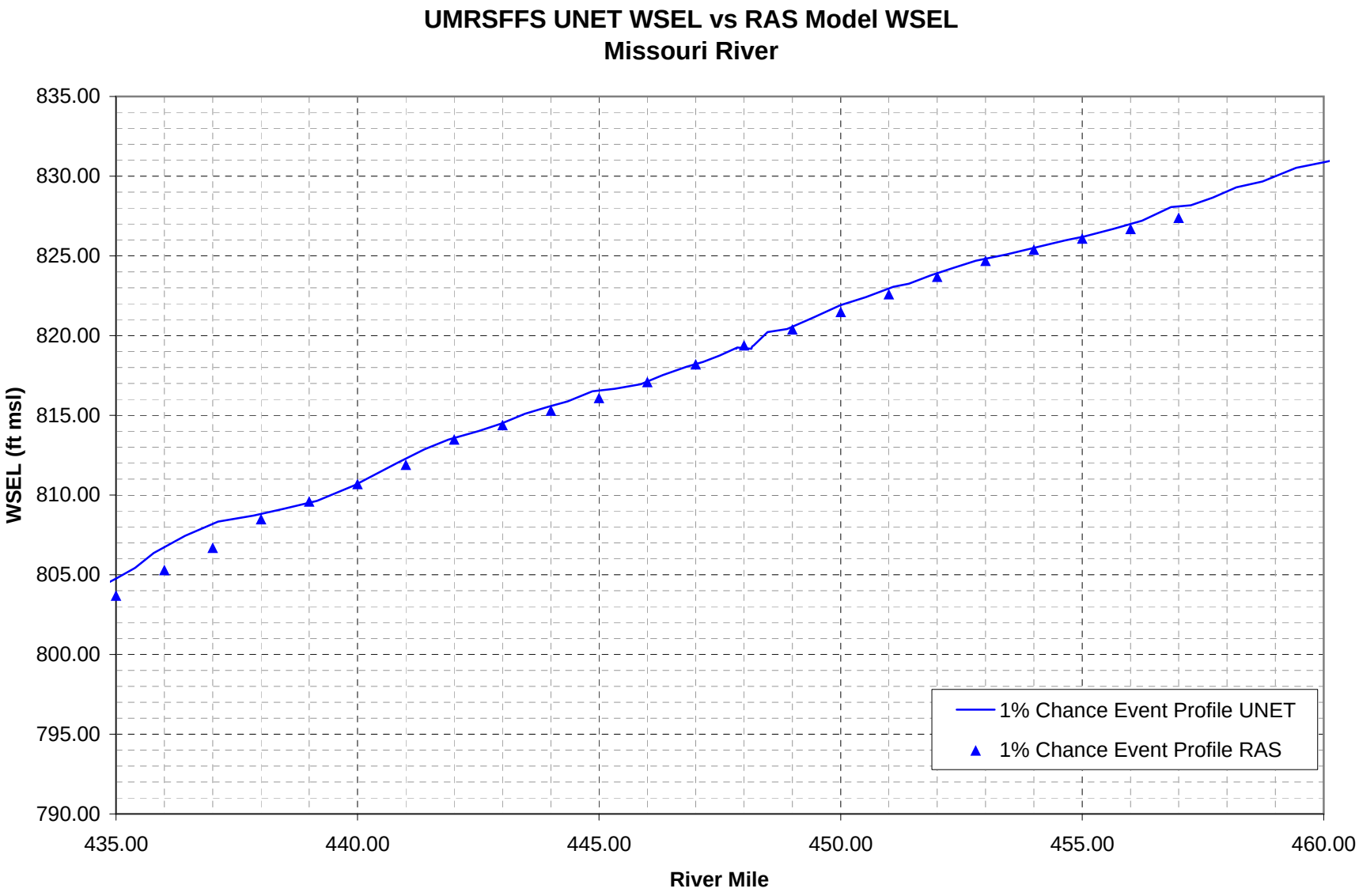
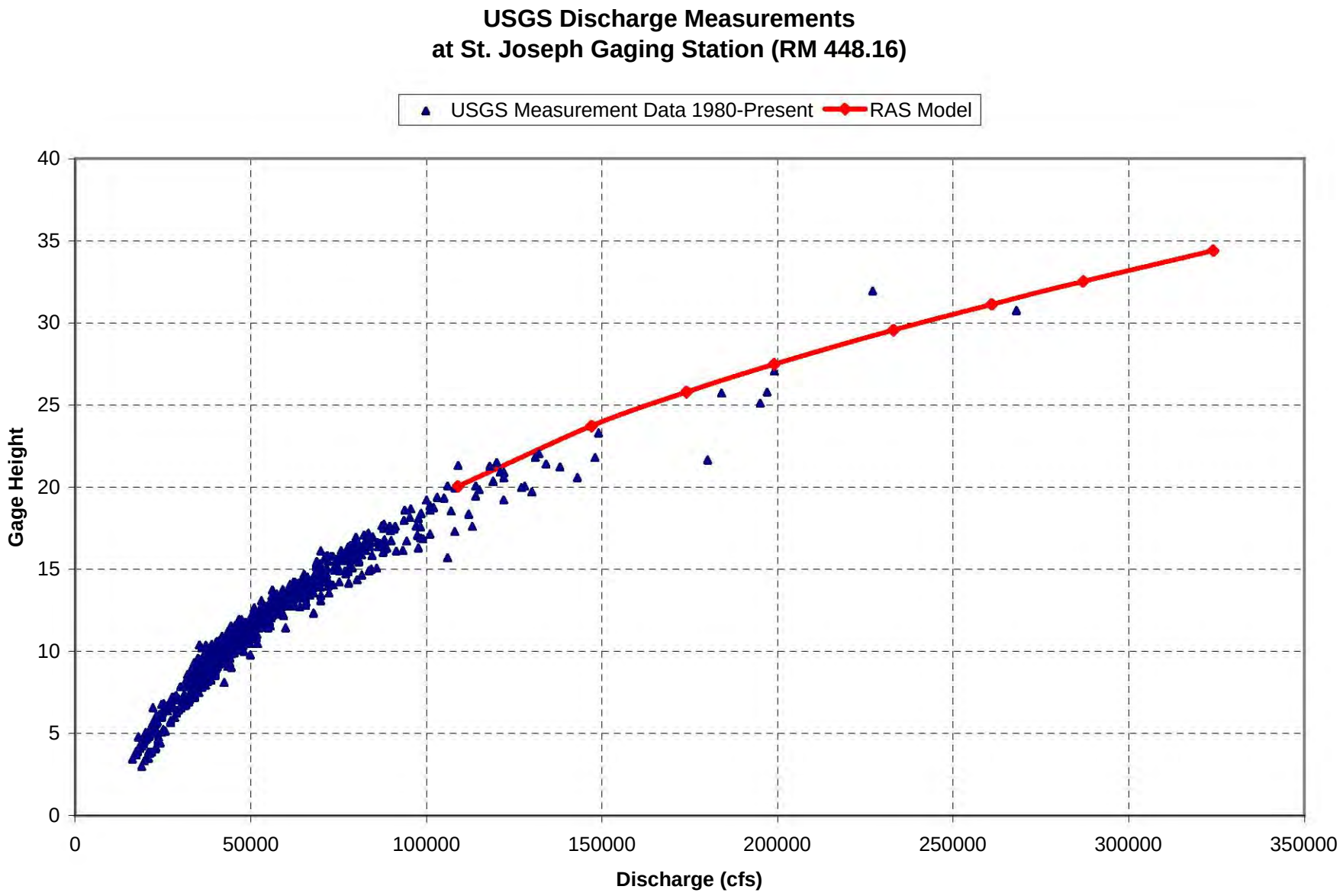


Exhibit 2.3



Designed by: EDS
Checked by: MMW
Date: 7/22/2006

Exhibit 2.4



Designed: EDS
Checked: MMW
Date: 7/22/2006

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
428.61	50%	2	109000	750.79	789.5	772.59	789.88	0.000106	4.98	0.18
428.61	20%	5	147000	750.79	791.2	774.41	791.78	0.000152	6.19	0.22
428.61	10%	10	174000	750.79	792.8	775.58	793.46	0.000166	6.69	0.23
428.61	5%	20	199000	750.79	793.9	776.6	794.64	0.000182	7.17	0.24
428.61	2%	50	233000	750.79	795.1	777.95	795.96	0.000207	7.82	0.26
428.61	1%	100	261000	750.79	796.2	778.99	797.13	0.000218	8.2	0.27
428.61	0.5% (Confined)	200	287000	750.79	797.1	779.94	798.09	0.000228	8.57	0.27
428.61	0.2% (Confined)	500	324000	750.79	798.3	781.21	799.38	0.000241	9.04	0.28
429.22	50%	2	109000	758.58	789.83	775.38	790.32	0.000154	5.64	0.21
429.22	20%	5	147000	758.58	791.68	777.31	792.38	0.000205	6.83	0.25
429.22	10%	10	174000	758.58	793.33	778.52	794.1	0.000215	7.26	0.26
429.22	5%	20	199000	758.58	794.49	779.57	795.32	0.000228	7.67	0.27
429.22	2%	50	233000	758.58	795.78	780.93	796.7	0.000245	8.21	0.28
429.22	1%	100	261000	758.58	796.92	781.99	797.88	0.000249	8.51	0.28
429.22	0.5% (Confined)	200	287000	758.58	797.86	782.91	798.86	0.000255	8.8	0.29
429.22	0.2% (Confined)	500	324000	758.58	799.15	784.22	800.19	0.000266	9.12	0.3
429.99	50%	2	109000	746.8	790.46	769.37	790.74	0.000067	4.27	0.15
429.99	20%	5	147000	746.8	792.53	771.23	792.94	0.000091	5.21	0.17
429.99	10%	10	174000	746.8	794.23	772.4	794.7	0.0001	5.65	0.18
429.99	5%	20	199000	746.8	795.44	773.51	795.97	0.00011	6.05	0.19
429.99	2%	50	233000	746.8	796.8	774.88	797.4	0.000123	6.59	0.2
429.99	1%	100	261000	746.8	797.97	775.98	798.62	0.000132	6.91	0.21
429.99	0.5% (Confined)	200	287000	746.8	798.96	776.95	799.64	0.000142	7.16	0.22
429.99	0.2% (Confined)	500	324000	746.8	800.29	778.32	801.01	0.000151	7.48	0.23
430.67	50%	2	109000	760.18	790.64	776.52	791.16	0.000161	5.8	0.22
430.67	20%	5	147000	760.18	792.77	778.32	793.51	0.000209	7	0.25
430.67	10%	10	174000	760.18	794.48	779.52	795.32	0.000226	7.55	0.27
430.67	5%	20	199000	760.18	795.71	780.56	796.65	0.000244	8.05	0.28
430.67	2%	50	233000	760.18	797.11	781.92	798.15	0.000264	8.6	0.29
430.67	1%	100	261000	760.18	798.3	782.98	799.39	0.000271	8.92	0.3
430.67	0.5% (Confined)	200	287000	760.18	799.32	783.94	800.45	0.000276	9.19	0.3
430.67	0.2% (Confined)	500	324000	760.18	800.67	785.25	801.85	0.00028	9.54	0.3
431.4	50%	2	109000	762.29	791.39	774.79	791.78	0.000153	5.05	0.18
431.4	20%	5	147000	762.29	793.75	776.56	794.32	0.000198	6.09	0.21
431.4	10%	10	174000	762.29	795.55	777.72	796.19	0.000211	6.54	0.22
431.4	5%	20	199000	762.29	796.88	778.73	797.57	0.000225	6.93	0.23
431.4	2%	50	233000	762.29	798.38	780.06	799.15	0.000244	7.39	0.26
431.4	1%	100	261000	762.29	799.62	781.09	800.41	0.00025	7.62	0.26
431.4	0.5% (Confined)	200	287000	762.29	800.67	782.01	801.49	0.000255	7.82	0.26
431.4	0.2% (Confined)	500	324000	762.29	802.05	783.31	802.9	0.000258	8.07	0.27
431.97	50%	2	109000	762.1	791.8	776.72	792.32	0.000188	5.81	0.22
431.97	20%	5	147000	762.1	794.29	778.66	795	0.000233	6.84	0.25
431.97	10%	10	174000	762.1	796.12	779.96	796.9	0.000242	7.27	0.25
431.97	5%	20	199000	762.1	797.5	781.08	798.33	0.00026	7.62	0.26
431.97	2%	50	233000	762.1	799.06	782.52	799.96	0.000277	8.07	0.28
431.97	1%	100	261000	762.1	800.31	783.66	801.25	0.000284	8.36	0.28
431.97	0.5% (Confined)	200	287000	762.1	801.36	784.65	802.34	0.000291	8.61	0.28
431.97	0.2% (Confined)	500	324000	762.1	802.74	786.05	803.78	0.000296	8.96	0.29
432.69	50%	2	109000	762.83	792.53	775.81	793.01	0.000171	5.61	0.21
432.69	20%	5	147000	762.83	795.2	777.8	795.87	0.000218	6.62	0.24
432.69	10%	10	174000	762.83	797.06	779.11	797.81	0.000229	7.07	0.25
432.69	5%	20	199000	762.83	798.47	780.25	799.29	0.000238	7.46	0.26
432.69	2%	50	233000	762.83	800.07	781.73	800.97	0.000251	7.97	0.27
432.69	1%	100	261000	762.83	801.34	782.93	802.29	0.000257	8.31	0.27
432.69	0.5% (Confined)	200	287000	762.83	802.41	783.94	803.41	0.000264	8.61	0.28
432.69	0.2% (Confined)	500	324000	762.83	803.8	785.4	804.88	0.000273	9.02	0.28

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
433.4	50%	2	109000	766.99	793.25	780.1	793.67	0.000175	5.25	0.21
433.4	20%	5	147000	766.99	796.17	781.76	796.61	0.00017	5.63	0.21
433.4	10%	10	174000	766.99	798.12	782.82	798.54	0.000156	5.67	0.2
433.4	5%	20	199000	766.99	799.61	783.77	800.03	0.000149	5.75	0.2
433.4	2%	50	233000	766.99	801.31	785.01	801.73	0.000144	5.89	0.2
433.4	1%	100	261000	766.99	802.64	785.96	803.04	0.000139	5.96	0.2
433.4	0.5% (Confined)	200	287000	766.99	803.77	786.83	804.17	0.000134	6.02	0.2
433.4	0.2% (Confined)	500	324000	766.99	805.24	788.03	805.64	0.00013	6.12	0.19
433.805*	50%	2	109000	762.08	793.8	780.33	794.23	0.000178	5.34	0.21
433.805*	20%	5	147000	762.08	796.68	782.04	797.19	0.000186	5.91	0.22
433.805*	10%	10	174000	762.08	798.58	783.14	799.07	0.000175	6.01	0.22
433.805*	5%	20	199000	762.08	800.05	784.12	800.53	0.000167	6.09	0.21
433.805*	2%	50	233000	762.08	801.74	785.47	802.21	0.000162	6.23	0.21
433.805*	1%	100	261000	762.08	803.05	786.45	803.51	0.000155	6.3	0.21
433.805*	0.5% (Confined)	200	287000	762.08	804.16	787.32	804.62	0.000151	6.38	0.21
433.805*	0.2% (Confined)	500	324000	762.08	805.62	788.49	806.08	0.000147	6.5	0.21
434.21	50%	2	109000	757.17	794.43	780.11	794.83	0.000196	5.14	0.2
434.21	20%	5	147000	757.17	797.37	781.8	797.8	0.000193	5.52	0.2
434.21	10%	10	174000	757.17	799.24	782.9	799.65	0.00018	5.57	0.2
434.21	5%	20	199000	757.17	800.69	783.87	801.08	0.000173	5.65	0.2
434.21	2%	50	233000	757.17	802.35	785.13	802.75	0.000169	5.8	0.19
434.21	1%	100	261000	757.17	803.63	786.09	804.03	0.000165	5.9	0.19
434.21	0.5% (Confined)	200	287000	757.17	804.73	787	805.13	0.000162	6	0.19
434.21	0.2% (Confined)	500	324000	757.17	806.17	788.2	806.58	0.00016	6.15	0.19
434.61*	50%	2	109000	761.57	795.08	781.13	795.62	0.000285	5.96	0.24
434.61*	20%	5	147000	761.57	797.98	783.61	798.6	0.000293	6.56	0.25
434.61*	10%	10	174000	761.57	799.8	785.49	800.41	0.000276	6.68	0.24
434.61*	5%	20	199000	761.57	801.23	786.77	801.81	0.000261	6.73	0.24
434.61*	2%	50	233000	761.57	802.88	788.06	803.44	0.000244	6.79	0.23
434.61*	1%	100	261000	761.57	804.15	789.11	804.69	0.00023	6.8	0.23
434.61*	0.5% (Confined)	200	287000	761.57	805.25	790.02	805.77	0.00022	6.83	0.22
434.61*	0.2% (Confined)	500	324000	761.57	806.68	791.27	807.19	0.00021	6.89	0.22
435.01	50%	2	109000	765.96	795.92	780.42	796.37	0.000199	5.49	0.21
435.01	20%	5	147000	765.96	798.84	782.34	799.4	0.000221	6.21	0.22
435.01	10%	10	174000	765.96	800.58	783.59	801.2	0.000231	6.62	0.23
435.01	5%	20	199000	765.96	801.95	784.69	802.61	0.000239	6.95	0.23
435.01	2%	50	233000	765.96	803.54	786.13	804.25	0.000246	7.33	0.24
435.01	1%	100	261000	765.96	804.77	787.25	805.49	0.000247	7.55	0.24
435.01	0.5% (Confined)	200	287000	765.96	805.83	788.24	806.56	0.000247	7.71	0.24
435.01	0.2% (Confined)	500	324000	765.96	807.23	789.64	807.98	0.000245	7.92	0.24
435.395*	50%	2	109000	765.51	796.51	780.98	796.99	0.000202	5.54	0.21
435.395*	20%	5	147000	765.51	799.48	782.91	800.12	0.000237	6.47	0.23
435.395*	10%	10	174000	765.51	801.24	784.18	801.96	0.000253	6.97	0.24
435.395*	5%	20	199000	765.51	802.63	785.31	803.41	0.000265	7.37	0.25
435.395*	2%	50	233000	765.51	804.22	786.69	805.11	0.000287	7.95	0.26
435.395*	1%	100	261000	765.51	805.43	787.78	806.38	0.000296	8.3	0.26
435.395*	0.5% (Confined)	200	287000	765.51	806.48	788.78	807.46	0.000303	8.58	0.27
435.395*	0.2% (Confined)	500	324000	765.51	807.86	790.1	808.9	0.000312	8.96	0.27
435.78	50%	2	109000	765.05	797.14	781.2	797.58	0.000187	5.38	0.2
435.78	20%	5	147000	765.05	800.24	783.34	800.8	0.000209	6.14	0.21
435.78	10%	10	174000	765.05	802.06	784.54	802.69	0.000222	6.6	0.22
435.78	5%	20	199000	765.05	803.48	785.6	804.18	0.000233	6.99	0.23
435.78	2%	50	233000	765.05	805.16	786.95	805.93	0.000248	7.49	0.24
435.78	1%	100	261000	765.05	806.37	788	807.23	0.000265	7.95	0.25
435.78	0.5% (Confined)	200	287000	765.05	807.43	788.96	808.34	0.000275	8.27	0.26
435.78	0.2% (Confined)	500	324000	765.05	808.82	790.27	809.81	0.000288	8.71	0.26

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
436.43	50%	2	109000	764.81	797.83	782.36	798.19	0.000163	4.87	0.18
436.43	20%	5	147000	764.81	801.03	784.01	801.47	0.000178	5.48	0.2
436.43	10%	10	174000	764.81	802.92	785.11	803.4	0.000182	5.81	0.2
436.43	5%	20	199000	764.81	804.39	786.05	804.91	0.000187	6.11	0.2
436.43	2%	50	233000	764.81	806.14	787.28	806.71	0.000196	6.51	0.21
436.43	1%	100	261000	764.81	807.44	788.26	808.05	0.000203	6.82	0.22
436.43	0.5% (Confined)	200	287000	764.81	808.54	789.11	809.19	0.00021	7.1	0.22
436.43	0.2% (Confined)	500	324000	764.81	810	790.32	810.7	0.00022	7.48	0.23
437.11	50%	2	109000	767.88	798.38	781.01	798.76	0.000152	5.12	0.18
437.11	20%	5	147000	767.88	801.73	783.04	802.05	0.000141	5.07	0.18
437.11	10%	10	174000	767.88	803.67	784.27	803.96	0.000127	5	0.17
437.11	5%	20	199000	767.88	805.19	785.4	805.46	0.000121	5	0.16
437.11	2%	50	233000	767.88	806.99	786.78	807.26	0.000115	5.06	0.16
437.11	1%	100	261000	767.88	808.34	787.92	808.61	0.000111	5.13	0.16
437.11	0.5% (Confined)	200	287000	767.88	809.48	788.96	809.76	0.000109	5.2	0.16
437.11	0.2% (Confined)	500	324000	767.88	810.99	790.34	811.28	0.000108	5.32	0.16
437.85	50%	2	109000	770.79	798.98	782.5	799.38	0.000164	5.14	0.19
437.85	20%	5	147000	770.79	802.24	784.28	802.67	0.000164	5.55	0.19
437.85	10%	10	174000	770.79	804.11	785.45	804.55	0.000159	5.7	0.19
437.85	5%	20	199000	770.79	805.6	786.5	806.04	0.000155	5.83	0.19
437.85	2%	50	233000	770.79	807.38	787.8	807.82	0.000153	6.01	0.19
437.85	1%	100	261000	770.79	808.71	788.89	809.16	0.000151	6.15	0.19
437.85	0.5% (Confined)	200	287000	770.79	809.84	789.83	810.3	0.000151	6.28	0.19
437.85	0.2% (Confined)	500	324000	770.79	811.34	791.11	811.82	0.000151	6.47	0.19
438.48	50%	2	109000	764.52	799.54	779.43	799.82	0.000101	4.31	0.15
438.48	20%	5	147000	764.52	802.77	781.23	803.15	0.00012	5.02	0.17
438.48	10%	10	174000	764.52	804.6	782.39	805.03	0.000132	5.44	0.17
438.48	5%	20	199000	764.52	806.07	783.44	806.54	0.00014	5.77	0.18
438.48	2%	50	233000	764.52	807.82	784.76	808.35	0.000149	6.19	0.19
438.48	1%	100	261000	764.52	809.14	785.81	809.71	0.000156	6.49	0.19
438.48	0.5% (Confined)	200	287000	764.52	810.26	786.71	810.87	0.000163	6.78	0.2
438.48	0.2% (Confined)	500	324000	764.52	811.75	788.02	812.41	0.000171	7.14	0.21
439.16	50%	2	109000	752.48	799.89	776.93	800.19	0.0001	4.36	0.15
439.16	20%	5	147000	752.48	803.19	778.91	803.59	0.000124	5.15	0.17
439.16	10%	10	174000	752.48	805.05	780.21	805.53	0.000139	5.65	0.18
439.16	5%	20	199000	752.48	806.54	781.37	807.09	0.000156	6.07	0.19
439.16	2%	50	233000	752.48	808.32	782.83	808.96	0.000173	6.62	0.2
439.16	1%	100	261000	752.48	809.64	784	810.36	0.000186	7.04	0.21
439.16	0.5% (Confined)	200	287000	752.48	810.77	785	811.56	0.000197	7.42	0.22
439.16	0.2% (Confined)	500	324000	752.48	812.27	786.44	813.16	0.000213	7.93	0.23
439.93	50%	2	109000	772.31	800.33	786.42	800.91	0.000284	6.25	0.24
439.93	20%	5	147000	772.31	803.76	788.51	804.37	0.000267	6.62	0.24
439.93	10%	10	174000	772.31	805.71	789.9	806.32	0.000257	6.81	0.24
439.93	5%	20	199000	772.31	807.29	791.02	807.9	0.00025	6.96	0.24
439.93	2%	50	233000	772.31	809.17	792.65	809.79	0.000243	7.16	0.24
439.93	1%	100	261000	772.31	810.6	793.86	811.22	0.000237	7.3	0.23
439.93	0.5% (Confined)	200	287000	772.31	811.82	794.95	812.45	0.000234	7.44	0.23
439.93	0.2% (Confined)	500	324000	772.31	813.44	797.2	814.08	0.00023	7.63	0.23
440.82	50%	2	109000	768.93	801.96	784.09	802.36	0.000152	5.1	0.18
440.82	20%	5	147000	768.93	805.33	786.08	805.86	0.000176	5.91	0.2
440.82	10%	10	174000	768.93	807.22	787.31	807.83	0.000191	6.42	0.21
440.82	5%	20	199000	768.93	808.77	788.41	809.46	0.000203	6.85	0.22
440.82	2%	50	233000	768.93	810.62	789.79	811.4	0.00022	7.42	0.23
440.82	1%	100	261000	768.93	812.01	790.9	812.88	0.000233	7.84	0.24
440.82	0.5% (Confined)	200	287000	768.93	813.21	791.91	814.14	0.000244	8.21	0.24
440.82	0.2% (Confined)	500	324000	768.93	814.79	793.25	815.83	0.000259	8.72	0.25

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
441.39	50%	2	109000	766.92	802.44	787.1	802.88	0.000195	5.4	0.2
441.39	20%	5	147000	766.92	805.92	788.99	806.43	0.000208	5.92	0.21
441.39	10%	10	174000	766.92	807.88	790.18	808.42	0.000207	6.22	0.21
441.39	5%	20	199000	766.92	809.49	791.19	810.06	0.000207	6.48	0.22
441.39	2%	50	233000	766.92	811.42	792.59	812.04	0.000211	6.84	0.22
441.39	1%	100	261000	766.92	812.88	793.62	813.53	0.000214	7.11	0.22
441.39	0.5% (Confined)	200	287000	766.92	814.14	794.61	814.82	0.000217	7.34	0.23
441.39	0.2% (Confined)	500	324000	766.92	815.81	795.9	816.54	0.000221	7.67	0.23
441.88	50%	2	109000	770.62	802.97	788.88	803.39	0.000201	5.28	0.2
441.88	20%	5	147000	770.62	806.48	790.59	806.94	0.000193	5.7	0.2
441.88	10%	10	174000	770.62	808.44	791.71	808.92	0.000191	5.96	0.21
441.88	5%	20	199000	770.62	810.05	792.67	810.56	0.00019	6.19	0.21
441.88	2%	50	233000	770.62	812	793.93	812.54	0.000191	6.5	0.21
441.88	1%	100	261000	770.62	813.47	794.93	814.03	0.000193	6.74	0.21
441.88	0.5% (Confined)	200	287000	770.62	814.73	795.84	815.32	0.000195	6.96	0.22
441.88	0.2% (Confined)	500	324000	770.62	816.42	797.05	817.04	0.000198	7.26	0.22
442.51	50%	2	109000	774.45	803.63	787.81	804.03	0.000182	5.14	0.2
442.51	20%	5	147000	774.45	807.11	789.64	807.59	0.000203	5.75	0.21
442.51	10%	10	174000	774.45	809.04	790.85	809.59	0.000209	6.15	0.22
442.51	5%	20	199000	774.45	810.64	791.88	811.24	0.000216	6.51	0.22
442.51	2%	50	233000	774.45	812.56	793.24	813.25	0.000226	6.98	0.23
442.51	1%	100	261000	774.45	814.02	794.31	814.77	0.000235	7.35	0.24
442.51	0.5% (Confined)	200	287000	774.45	815.27	795.25	816.08	0.000243	7.68	0.24
442.51	0.2% (Confined)	500	324000	774.45	816.94	796.55	817.83	0.000254	8.12	0.25
442.97	50%	2	109000	770.48	803.99	786.19	804.43	0.000143	5.31	0.19
442.97	20%	5	147000	770.48	807.5	788.54	808.03	0.000155	6	0.21
442.97	10%	10	174000	770.48	809.45	789.96	810.05	0.000162	6.44	0.21
442.97	5%	20	199000	770.48	811.06	791.23	811.71	0.000169	6.81	0.22
442.97	2%	50	233000	770.48	813.01	793.07	813.74	0.000178	7.3	0.23
442.97	1%	100	261000	770.48	814.48	794.27	815.28	0.000185	7.67	0.23
442.97	0.5% (Confined)	200	287000	770.48	815.75	795.25	816.61	0.000191	8	0.24
442.97	0.2% (Confined)	500	324000	770.48	817.45	796.6	818.38	0.0002	8.44	0.25
443.46	50%	2	109000	772.82	804.38	787.17	804.81	0.000146	5.3	0.2
443.46	20%	5	147000	772.82	807.95	789.46	808.43	0.000148	5.81	0.2
443.46	10%	10	174000	772.82	809.94	790.87	810.46	0.000151	6.16	0.21
443.46	5%	20	199000	772.82	811.58	792.16	812.14	0.000154	6.45	0.21
443.46	2%	50	233000	772.82	813.58	793.97	814.19	0.000159	6.84	0.22
443.46	1%	100	261000	772.82	815.09	795.08	815.74	0.000162	7.14	0.22
443.46	0.5% (Confined)	200	287000	772.82	816.4	796.08	817.09	0.000166	7.41	0.22
443.46	0.2% (Confined)	500	324000	772.82	818.13	797.44	818.88	0.000171	7.78	0.23
443.95	50%	2	109000	777.34	804.79	791.54	805.24	0.000187	5.51	0.22
443.95	20%	5	147000	777.34	808.36	793.37	808.85	0.000174	5.91	0.22
443.95	10%	10	174000	777.34	810.36	794.52	810.88	0.000173	6.22	0.22
443.95	5%	20	199000	777.34	812.01	795.54	812.56	0.000174	6.5	0.22
443.95	2%	50	233000	777.34	814.02	796.87	814.62	0.000177	6.87	0.22
443.95	1%	100	261000	777.34	815.54	797.92	816.18	0.000179	7.16	0.23
443.95	0.5% (Confined)	200	287000	777.34	816.85	798.86	817.53	0.000182	7.43	0.23
443.95	0.2% (Confined)	500	324000	777.34	818.6	801.28	819.34	0.000186	7.78	0.24
444.35	50%	2	109000	770.31	805.14	789.01	805.61	0.000166	5.56	0.21
444.35	20%	5	147000	770.31	808.69	791.84	809.2	0.000163	6.04	0.21
444.35	10%	10	174000	770.31	810.68	793.06	811.23	0.000165	6.38	0.21
444.35	5%	20	199000	770.31	812.33	794.17	812.91	0.000166	6.66	0.22
444.35	2%	50	233000	770.31	814.35	795.56	814.98	0.000169	7.02	0.22
444.35	1%	100	261000	770.31	815.87	796.69	816.54	0.000172	7.31	0.22
444.35	0.5% (Confined)	200	287000	770.31	817.19	797.67	817.9	0.000174	7.56	0.23
444.35	0.2% (Confined)	500	324000	770.31	818.95	799.04	819.7	0.000178	7.9	0.23

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
444.86	50%	2	109000	770.16	805.7	786.54	805.97	0.000103	4.29	0.15
444.86	20%	5	147000	770.16	809.25	788.35	809.56	0.000104	4.68	0.15
444.86	10%	10	174000	770.16	811.26	789.51	811.59	0.000106	4.94	0.16
444.86	5%	20	199000	770.16	812.93	790.54	813.28	0.000108	5.16	0.16
444.86	2%	50	233000	770.16	814.97	791.89	815.34	0.000111	5.45	0.16
444.86	1%	100	261000	770.16	816.51	792.91	816.91	0.000113	5.67	0.17
444.86	0.5% (Confined)	200	287000	770.16	817.85	793.87	818.27	0.000115	5.86	0.17
444.86	0.2% (Confined)	500	324000	770.16	819.64	795.15	820.09	0.000118	6.12	0.17
445.33	50%	2	109000	775.29	805.9	789.41	806.29	0.000128	5.01	0.18
445.33	20%	5	147000	775.29	809.44	791.38	809.88	0.000132	5.54	0.19
445.33	10%	10	174000	775.29	811.44	792.56	811.92	0.000135	5.87	0.19
445.33	5%	20	199000	775.29	813.1	793.57	813.62	0.000138	6.16	0.2
445.33	2%	50	233000	775.29	815.13	794.92	815.7	0.000142	6.53	0.2
445.33	1%	100	261000	775.29	816.67	795.99	817.27	0.000145	6.81	0.21
445.33	0.5% (Confined)	200	287000	775.29	818.01	796.91	818.64	0.000148	7.07	0.21
445.33	0.2% (Confined)	500	324000	775.29	819.79	798.2	820.47	0.000152	7.4	0.22
445.86	50%	2	109000	776.53	806.23	791.26	806.76	0.000183	5.84	0.22
445.86	20%	5	147000	776.53	809.75	793.21	810.38	0.000194	6.54	0.23
445.86	10%	10	174000	776.53	811.74	794.48	812.44	0.000202	6.98	0.24
445.86	5%	20	199000	776.53	813.39	795.59	814.15	0.000207	7.34	0.24
445.86	2%	50	233000	776.53	815.41	796.99	816.25	0.000213	7.78	0.25
445.86	1%	100	261000	776.53	816.95	798.14	817.84	0.000217	8.12	0.25
445.86	0.5% (Confined)	200	287000	776.53	818.28	799.15	819.22	0.000221	8.42	0.26
445.86	0.2% (Confined)	500	324000	776.53	820.06	800.49	821.07	0.000227	8.83	0.26
446.32	50%	2	109000	776.46	806.68	791.59	807.23	0.000206	6.07	0.23
446.32	20%	5	147000	776.46	810.23	794.19	810.87	0.000212	6.68	0.24
446.32	10%	10	174000	776.46	812.24	795.58	812.94	0.000214	7.05	0.24
446.32	5%	20	199000	776.46	813.92	796.72	814.66	0.000218	7.38	0.25
446.32	2%	50	233000	776.46	815.97	798.15	816.77	0.000225	7.78	0.25
446.32	1%	100	261000	776.46	817.52	799.32	818.37	0.000229	8.09	0.26
446.32	0.5% (Confined)	200	287000	776.46	818.87	800.34	819.76	0.000232	8.37	0.26
446.32	0.2% (Confined)	500	324000	776.46	820.66	801.75	821.61	0.000235	8.74	0.26
446.81	50%	2	109000	773.96	807.24	789.5	807.68	0.000141	5.38	0.19
446.81	20%	5	147000	773.96	810.78	791.61	811.35	0.000162	6.14	0.21
446.81	10%	10	174000	773.96	812.79	792.95	813.44	0.000175	6.61	0.22
446.81	5%	20	199000	773.96	814.46	794.11	815.17	0.000182	7.01	0.23
446.81	2%	50	233000	773.96	816.49	795.62	817.3	0.000192	7.53	0.24
446.81	1%	100	261000	773.96	818.04	796.82	818.92	0.000199	7.91	0.24
446.81	0.5% (Confined)	200	287000	773.96	819.38	797.86	820.33	0.000205	8.25	0.25
446.81	0.2% (Confined)	500	324000	773.96	821.17	799.3	822.2	0.000213	8.7	0.26
447.15	50%	2	109000	772.65	807.46	790.74	807.97	0.000161	5.7	0.21
447.15	20%	5	147000	772.65	811.04	792.79	811.67	0.000176	6.48	0.22
447.15	10%	10	174000	772.65	813.06	794.12	813.77	0.000185	6.96	0.23
447.15	5%	20	199000	772.65	814.74	795.33	815.52	0.000192	7.37	0.24
447.15	2%	50	233000	772.65	816.79	796.86	817.66	0.000201	7.87	0.24
447.15	1%	100	261000	772.65	818.35	798.05	819.29	0.000208	8.26	0.25
447.15	0.5% (Confined)	200	287000	772.65	819.7	799.1	820.71	0.000214	8.6	0.25
447.15	0.2% (Confined)	500	324000	772.65	821.51	800.57	822.6	0.000222	9.05	0.26
447.49	50%	2	109000	776.69	807.82	790	808.24	0.000134	5.23	0.19
447.49	20%	5	147000	776.69	811.41	791.99	811.97	0.000153	6.03	0.21
447.49	10%	10	174000	776.69	813.44	793.28	814.1	0.000164	6.57	0.22
447.49	5%	20	199000	776.69	815.12	794.38	815.85	0.000173	7.01	0.22
447.49	2%	50	233000	776.69	817.18	795.87	818.01	0.000184	7.54	0.23
447.49	1%	100	261000	776.69	818.75	797.03	819.65	0.00019	7.91	0.24
447.49	0.5% (Confined)	200	287000	776.69	820.12	798.03	821.08	0.000195	8.22	0.24
447.49	0.2% (Confined)	500	324000	776.69	821.95	799.46	822.98	0.000201	8.62	0.25

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
447.83	50%	2	109000	773	808.15	783.47	808.43	0.000061	4.21	0.13
447.83	20%	5	147000	773	811.8	785.47	812.19	0.000074	5.02	0.15
447.83	10%	10	174000	773	813.87	786.78	814.34	0.000085	5.56	0.16
447.83	5%	20	199000	773	815.56	787.92	816.11	0.000094	6.03	0.17
447.83	2%	50	233000	773	817.63	789.39	818.29	0.000106	6.64	0.18
447.83	1%	100	261000	773	819.2	790.56	819.94	0.000115	7.1	0.19
447.83	0.5% (Confined)	200	287000	773	820.55	791.62	821.38	0.000124	7.51	0.2
447.83	0.2% (Confined)	500	324000	773	822.36	793.03	823.3	0.000134	8.04	0.21
447.84	50%	2	109000	773	808.14	783.87	808.44	0.00008	4.39	0.14
447.84	20%	5	147000	773	811.79	785.95	812.21	0.000099	5.23	0.16
447.84	10%	10	174000	773	813.85	787.31	814.35	0.000114	5.79	0.17
447.84	5%	20	199000	773	815.54	788.49	816.13	0.000127	6.28	0.18
447.84	2%	50	233000	773	817.61	790.04	818.31	0.000145	6.9	0.19
447.84	1%	100	261000	773	819.17	791.21	819.97	0.000159	7.38	0.2
447.84	0.5% (Confined)	200	287000	773	820.52	792.3	821.41	0.000172	7.79	0.21
447.84	0.2% (Confined)	500	324000	773	822.32	793.77	823.33	0.000188	8.35	0.22
447.85	50%	2	109000	773	808.17	783.47	808.45	0.000061	4.21	0.13
447.85	20%	5	147000	773	811.83	785.47	812.22	0.000074	5.02	0.15
447.85	10%	10	174000	773	813.9	786.78	814.37	0.000084	5.55	0.16
447.85	5%	20	199000	773	815.6	787.92	816.14	0.000093	6.02	0.17
447.85	2%	50	233000	773	817.67	789.39	818.33	0.000105	6.63	0.18
447.85	1%	100	261000	773	819.24	790.56	819.99	0.000115	7.09	0.19
447.85	0.5% (Confined)	200	287000	773	820.6	791.62	821.43	0.000123	7.5	0.2
447.85	0.2% (Confined)	500	324000	773	822.41	793.03	823.35	0.000134	8.03	0.21
447.86	50%	2	109000	771.61	808.16	787.96	808.46	0.000081	4.34	0.15
447.86	20%	5	147000	771.61	811.82	789.73	812.22	0.000097	5.1	0.17
447.86	10%	10	174000	771.61	813.89	790.89	814.38	0.000107	5.61	0.18
447.86	5%	20	199000	771.61	815.59	791.9	816.15	0.000116	6.05	0.19
447.86	2%	50	233000	771.61	817.67	793.22	818.34	0.000128	6.62	0.2
447.86	1%	100	261000	771.61	819.25	794.23	820	0.000137	7.05	0.2
447.86	0.5% (Confined)	200	287000	771.61	820.61	795.16	821.44	0.000145	7.44	0.21
447.86	0.2% (Confined)	500	324000	771.61	822.42	796.44	823.36	0.000156	7.95	0.22
448.15	50%	2	109000	773.29	808.19	789.42	808.7	0.000152	5.73	0.2
448.15	20%	5	147000	773.29	811.83	791.73	812.52	0.000178	6.68	0.22
448.15	10%	10	174000	773.29	813.88	793.21	814.71	0.000195	7.32	0.24
448.15	5%	20	199000	773.29	815.57	794.51	816.52	0.00021	7.87	0.25
448.15	2%	50	233000	773.29	817.63	796.2	818.74	0.000229	8.58	0.26
448.15	1%	100	261000	773.29	819.18	797.51	820.44	0.000244	9.13	0.27
448.15	0.5% (Confined)	200	287000	773.29	820.52	798.65	821.91	0.000258	9.62	0.28
448.15	0.2% (Confined)	500	324000	773.29	822.3	800.27	823.88	0.000277	10.29	0.29
448.16			Bridge							
448.17	50%	2	109000	773.29	808.24	789.42	808.75	0.000151	5.71	0.2
448.17	20%	5	147000	773.29	811.91	791.73	812.59	0.000177	6.66	0.22
448.17	10%	10	174000	773.29	813.97	793.21	814.79	0.000193	7.29	0.23
448.17	5%	20	199000	773.29	815.67	794.51	816.61	0.000207	7.84	0.25
448.17	2%	50	233000	773.29	817.75	796.2	818.85	0.000226	8.55	0.26
448.17	1%	100	261000	773.29	819.31	797.51	820.55	0.000241	9.1	0.27
448.17	0.5% (Confined)	200	287000	773.29	820.71	798.65	822.08	0.000253	9.57	0.28
448.17	0.2% (Confined)	500	324000	773.29	822.58	800.27	824.12	0.00027	10.2	0.29
448.2	50%	2	109000	773.29	808.27	789.41	808.78	0.000151	5.71	0.2
448.2	20%	5	147000	773.29	811.94	791.73	812.62	0.000184	6.65	0.23
448.2	10%	10	174000	773.29	814.01	793.21	814.82	0.000202	7.26	0.24
448.2	5%	20	199000	773.29	815.72	794.5	816.64	0.000215	7.79	0.25
448.2	2%	50	233000	773.29	817.8	796.2	818.89	0.000233	8.47	0.26
448.2	1%	100	261000	773.29	819.38	797.51	820.6	0.000247	9	0.27
448.2	0.5% (Confined)	200	287000	773.29	820.79	798.67	822.13	0.000258	9.45	0.28

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
448.2	0.2% (Confined)	500	324000	773.29	822.66	800.27	824.17	0.000273	10.07	0.29
448.49	50%	2	109000	775.4	808.69	791.55	809.01	0.000107	4.61	0.17
448.49	20%	5	147000	775.4	812.47	793.19	812.9	0.000119	5.32	0.18
448.49	10%	10	174000	775.4	814.62	794.29	815.13	0.000129	5.8	0.19
448.49	5%	20	199000	775.4	816.39	795.24	816.98	0.000138	6.22	0.2
448.49	2%	50	233000	775.4	818.57	796.49	819.26	0.000149	6.75	0.21
448.49	1%	100	259000	775.4	820.23	797.4	820.99	0.000154	7.11	0.21
448.49	0.5% (Confined)	200	287000	775.4	821.69	798.33	822.54	0.000163	7.52	0.22
448.49	0.2% (Confined)	500	324000	775.4	823.66	799.52	824.61	0.000171	7.98	0.23
448.89	50%	2	109000	774.34	808.84	791.81	809.34	0.000161	5.71	0.21
448.89	20%	5	147000	774.34	812.63	793.96	813.27	0.000175	6.51	0.22
448.89	10%	10	174000	774.34	814.79	795.59	815.53	0.000186	7.04	0.23
448.89	5%	20	199000	774.34	816.57	796.74	817.4	0.000197	7.51	0.24
448.89	2%	50	233000	774.34	818.75	798.22	819.71	0.00021	8.11	0.25
448.89	1%	100	259000	774.34	820.41	799.33	821.46	0.00022	8.49	0.26
448.89	0.5% (Confined)	200	287000	774.34	821.9	800.46	823.04	0.000236	8.93	0.27
448.89	0.2% (Confined)	500	324000	774.34	823.88	801.88	825.13	0.000244	9.42	0.27
449.44	50%	2	109000	782.5	809.33	794.8	809.91	0.000227	6.14	0.24
449.44	20%	5	147000	782.5	813.16	796.95	813.85	0.000225	6.78	0.24
449.44	10%	10	174000	782.5	815.36	798.36	816.12	0.000226	7.18	0.25
449.44	5%	20	199000	782.5	817.18	799.57	818.01	0.000228	7.53	0.25
449.44	2%	50	233000	782.5	819.44	801.13	820.35	0.000232	7.98	0.26
449.44	1%	100	259000	782.5	821.15	802.25	822.11	0.000232	8.26	0.26
449.44	0.5% (Confined)	200	287000	782.5	822.7	803.4	823.72	0.000237	8.6	0.26
449.44	0.2% (Confined)	500	324000	782.5	824.73	804.86	825.84	0.000239	8.99	0.27
449.99	50%	2	109000	779.32	810.02	793.39	810.46	0.000147	5.35	0.2
449.99	20%	5	147000	779.32	813.87	795.6	814.42	0.000156	6.05	0.21
449.99	10%	10	174000	779.32	816.07	797	816.7	0.000164	6.5	0.21
449.99	5%	20	199000	779.32	817.91	798.09	818.6	0.000168	6.86	0.22
449.99	2%	50	233000	779.32	820.19	799.47	820.95	0.000174	7.31	0.23
449.99	1%	100	259000	779.32	821.9	800.47	822.72	0.000175	7.6	0.23
449.99	0.5% (Confined)	200	287000	779.32	823.47	801.51	824.35	0.00018	7.95	0.23
449.99	0.2% (Confined)	500	324000	779.32	825.52	802.84	826.47	0.000185	8.34	0.24
450.52	50%	2	109000	779.55	810.44	795.49	810.91	0.000171	5.5	0.21
450.52	20%	5	147000	779.55	814.3	797.31	814.9	0.000182	6.23	0.22
450.52	10%	10	174000	779.55	816.52	798.54	817.21	0.000191	6.7	0.23
450.52	5%	20	199000	779.55	818.37	799.61	819.12	0.000196	7.06	0.23
450.52	2%	50	233000	779.55	820.68	800.98	821.48	0.000201	7.4	0.24
450.52	1%	100	259000	779.55	822.42	801.96	823.23	0.000193	7.55	0.24
450.52	0.5% (Confined)	200	287000	779.55	824.03	803	824.87	0.00019	7.74	0.24
450.52	0.2% (Confined)	500	324000	779.55	826.14	804.3	826.99	0.000184	7.93	0.24
451.09	50%	2	109000	776.43	810.94	794.06	811.38	0.00014	5.32	0.19
451.09	20%	5	147000	776.43	814.83	795.94	815.41	0.000155	6.12	0.21
451.09	10%	10	174000	776.43	817.09	797.17	817.74	0.000162	6.54	0.21
451.09	5%	20	199000	776.43	818.99	798.24	819.66	0.000162	6.77	0.22
451.09	2%	50	233000	776.43	821.33	799.65	822.02	0.000157	7	0.21
451.09	1%	100	259000	776.43	823.06	800.65	823.75	0.000152	7.12	0.21
451.09	0.5% (Confined)	200	287000	776.43	824.68	801.74	825.37	0.00015	7.28	0.21
451.09	0.2% (Confined)	500	324000	776.43	826.78	803.1	827.48	0.000145	7.44	0.21
451.41	50%	2	109000	777.14	811.16	795.7	811.65	0.000166	5.62	0.21
451.41	20%	5	147000	777.14	815.08	797.55	815.7	0.000178	6.37	0.22
451.41	10%	10	174000	777.14	817.35	798.78	818.04	0.000182	6.78	0.23
451.41	5%	20	199000	777.14	819.24	799.83	819.97	0.000181	7.07	0.23
451.41	2%	50	233000	777.14	821.56	801.22	822.33	0.00018	7.39	0.23
451.41	1%	100	259000	777.14	823.26	802.25	824.05	0.000177	7.6	0.23
451.41	0.5% (Confined)	200	287000	777.14	824.86	803.32	825.68	0.000177	7.84	0.23
451.41	0.2% (Confined)	500	324000	777.14	826.94	804.65	827.79	0.000175	8.08	0.23

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
451.88	50%	2	109000	784.26	811.57	797.61	812.15	0.000218	6.15	0.24
451.88	20%	5	147000	784.26	815.54	799.58	816.19	0.000211	6.65	0.24
451.88	10%	10	174000	784.26	817.84	800.84	818.52	0.000204	6.88	0.24
451.88	5%	20	199000	784.26	819.74	801.96	820.45	0.000198	7.08	0.24
451.88	2%	50	233000	784.26	822.08	803.4	822.79	0.000189	7.29	0.23
451.88	1%	100	259000	784.26	823.8	804.43	824.51	0.000178	7.35	0.23
451.88	0.5% (Confined)	200	287000	784.26	825.42	805.51	826.13	0.000172	7.46	0.23
451.88	0.2% (Confined)	500	324000	784.26	827.52	806.89	828.23	0.000162	7.54	0.22
452.31	50%	2	109000	778.18	812.13	795.08	812.59	0.000167	5.46	0.21
452.31	20%	5	147000	778.18	816.04	797.06	816.64	0.000179	6.2	0.22
452.31	10%	10	174000	778.18	818.3	798.35	818.96	0.000184	6.58	0.22
452.31	5%	20	199000	778.18	820.19	799.43	820.87	0.000181	6.79	0.23
452.31	2%	50	233000	778.18	822.52	800.94	823.2	0.000175	6.97	0.22
452.31	1%	100	259000	778.18	824.22	801.97	824.9	0.000168	7.06	0.22
452.31	0.5% (Confined)	200	287000	778.18	825.82	803.09	826.51	0.000163	7.2	0.22
452.31	0.2% (Confined)	500	324000	778.18	827.88	804.47	828.58	0.000156	7.33	0.22
452.8	50%	2	109000	775.07	812.58	792.7	812.94	0.000105	4.85	0.17
452.8	20%	5	147000	775.07	816.54	794.66	817.02	0.000117	5.59	0.18
452.8	10%	10	174000	775.07	818.84	795.97	819.35	0.000119	5.89	0.19
452.8	5%	20	199000	775.07	820.73	797.11	821.26	0.000119	6.11	0.19
452.8	2%	50	233000	775.07	823.03	798.52	823.58	0.000119	6.35	0.19
452.8	1%	100	259000	775.07	824.7	799.63	825.27	0.000117	6.5	0.19
452.8	0.5% (Confined)	200	287000	775.07	826.29	800.74	826.87	0.000118	6.66	0.19
452.8	0.2% (Confined)	500	324000	775.07	828.34	802.12	828.93	0.000117	6.83	0.19
453.44	50%	2	109000	780.74	812.95	796.38	813.35	0.000134	5.11	0.19
453.44	20%	5	147000	780.74	816.95	798.22	817.47	0.000144	5.8	0.2
453.44	10%	10	174000	780.74	819.25	799.41	819.81	0.000145	6.1	0.2
453.44	5%	20	199000	780.74	821.14	800.46	821.71	0.000144	6.31	0.2
453.44	2%	50	233000	780.74	823.43	801.8	824.03	0.000142	6.56	0.2
453.44	1%	100	259000	780.74	825.09	802.8	825.71	0.000139	6.72	0.2
453.44	0.5% (Confined)	200	287000	780.74	826.68	803.83	827.31	0.000138	6.91	0.2
453.44	0.2% (Confined)	500	324000	780.74	828.72	805.14	829.37	0.000136	7.11	0.2
454.64	50%	2	109000	786.19	813.81	797.51	814.18	0.000126	4.87	0.18
454.64	20%	5	147000	786.19	817.88	799.25	818.34	0.00013	5.48	0.19
454.64	10%	10	174000	786.19	820.18	800.39	820.68	0.000131	5.77	0.19
454.64	5%	20	199000	786.19	822.05	801.37	822.56	0.000129	5.96	0.19
454.64	2%	50	233000	786.19	824.32	802.66	824.85	0.000126	6.19	0.19
454.64	1%	100	259000	786.19	825.97	803.6	826.51	0.000124	6.34	0.19
454.64	0.5% (Confined)	200	287000	786.19	827.54	804.56	828.1	0.000123	6.51	0.19
454.64	0.2% (Confined)	500	324000	786.19	829.57	805.76	830.14	0.000121	6.69	0.19
455.05	50%	2	109000	769.11	814.1	800.55	814.53	0.00018	5.28	0.21
455.05	20%	5	147000	769.11	818.17	802.25	818.68	0.000175	5.81	0.21
455.05	10%	10	174000	769.11	820.46	803.33	821.02	0.000172	6.1	0.21
455.05	5%	20	199000	769.11	822.32	804.3	822.9	0.000169	6.31	0.22
455.05	2%	50	233000	769.11	824.58	805.52	825.19	0.000164	6.56	0.21
455.05	1%	100	259000	769.11	826.22	806.44	826.83	0.000158	6.68	0.21
455.05	0.5% (Confined)	200	287000	769.11	827.79	807.38	828.42	0.000154	6.82	0.21
455.05	0.2% (Confined)	500	324000	769.11	829.81	808.56	830.45	0.000149	6.97	0.21
455.65	50%	2	109000	784.46	814.65	801.15	815.1	0.000181	5.43	0.21
455.65	20%	5	147000	784.46	818.7	802.88	819.24	0.000176	5.95	0.22
455.65	10%	10	174000	784.46	821	803.98	821.56	0.000171	6.22	0.22
455.65	5%	20	199000	784.46	822.84	804.97	823.43	0.000166	6.41	0.22
455.65	2%	50	233000	784.46	825.09	806.23	825.7	0.000161	6.66	0.22
455.65	1%	100	259000	784.46	826.7	807.13	827.33	0.000158	6.82	0.21
455.65	0.5% (Confined)	200	287000	784.46	828.26	808.1	828.91	0.000156	7.02	0.22
455.65	0.2% (Confined)	500	324000	784.46	830.26	809.32	830.93	0.000153	7.23	0.22

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
456.24	50%	2	109000	781.09	815.2	799.36	815.63	0.000154	5.23	0.2
456.24	20%	5	147000	781.09	819.25	801.38	819.76	0.000154	5.8	0.2
456.24	10%	10	174000	781.09	821.53	802.59	822.08	0.000158	6.1	0.21
456.24	5%	20	199000	781.09	823.37	803.62	823.93	0.000153	6.28	0.21
456.24	2%	50	233000	781.09	825.6	805	826.18	0.000148	6.5	0.21
456.24	1%	100	259000	781.09	827.21	805.96	827.8	0.000144	6.63	0.21
456.24	0.5% (Confined)	200	287000	781.09	828.78	806.99	829.38	0.000142	6.79	0.21
456.24	0.2% (Confined)	500	324000	781.09	830.77	808.3	831.39	0.000139	6.97	0.21
456.84	50%	2	109000	780.28	815.69	796.31	816.04	0.000111	4.74	0.17
456.84	20%	5	147000	780.28	819.74	798.45	820.19	0.00012	5.4	0.18
456.84	10%	10	174000	780.28	822.07	799.88	822.56	0.00012	5.71	0.18
456.84	5%	20	199000	780.28	823.99	800.99	824.49	0.000117	5.89	0.18
456.84	2%	50	233000	780.28	826.36	802.44	826.87	0.000114	6.09	0.18
456.84	1%	100	259000	780.28	828.06	803.51	828.57	0.000111	6.22	0.18
456.84	0.5% (Confined)	200	287000	780.28	829.7	804.63	830.23	0.000109	6.36	0.18
456.84	0.2% (Confined)	500	324000	780.28	831.8	805.98	832.34	0.000107	6.52	0.18
457.25	50%	2	109000	783.2	815.86	800.5	816.43	0.000207	6.11	0.23
457.25	20%	5	147000	783.2	819.92	802.8	820.6	0.000206	6.73	0.24
457.25	10%	10	174000	783.2	822.23	804.3	822.97	0.000207	7.1	0.24
457.25	5%	20	199000	783.2	824.14	805.56	824.91	0.000204	7.38	0.24
457.25	2%	50	233000	783.2	826.49	807.09	827.29	0.000199	7.67	0.24
457.25	1%	100	259000	783.2	828.18	808.22	828.99	0.000193	7.82	0.24
457.25	0.5% (Confined)	200	287000	783.2	829.84	809.38	830.66	0.000189	7.99	0.24
457.25	0.2% (Confined)	500	324000	783.2	831.93	810.85	832.77	0.000183	8.18	0.24
457.7	50%	2	109000	770.55	816.34	800.07	816.89	0.000181	5.99	0.22
457.7	20%	5	147000	770.55	820.38	802.13	821.07	0.000196	6.77	0.23
457.7	10%	10	174000	770.55	822.7	803.48	823.44	0.000196	7.13	0.23
457.7	5%	20	199000	770.55	824.6	804.67	825.37	0.000192	7.37	0.23
457.7	2%	50	233000	770.55	826.96	806.18	827.74	0.000185	7.59	0.23
457.7	1%	100	259000	770.55	828.65	807.31	829.43	0.000179	7.72	0.23
457.7	0.5% (Confined)	200	287000	770.55	830.3	808.47	831.08	0.000175	7.87	0.23
457.7	0.2% (Confined)	500	324000	770.55	832.39	809.93	833.18	0.00017	8.03	0.23
458.19	50%	2	109000	782.85	816.86	804.3	817.43	0.000237	6.1	0.24
458.19	20%	5	147000	782.85	820.95	806.28	821.62	0.000225	6.65	0.24
458.19	10%	10	174000	782.85	823.31	807.45	823.97	0.000208	6.77	0.24
458.19	5%	20	199000	782.85	825.25	808.47	825.88	0.000191	6.79	0.23
458.19	2%	50	233000	782.85	827.61	809.77	828.21	0.000171	6.8	0.22
458.19	1%	100	259000	782.85	829.3	810.76	829.87	0.000159	6.81	0.21
458.19	0.5% (Confined)	200	287000	782.85	830.95	811.76	831.51	0.00015	6.85	0.21
458.19	0.2% (Confined)	500	324000	782.85	833.03	813.03	833.58	0.00014	6.89	0.21
458.73	50%	2	109000	788.99	817.49	803.3	818.06	0.000202	6.05	0.23
458.73	20%	5	147000	788.99	821.55	805.16	822.23	0.000204	6.71	0.23
458.73	10%	10	174000	788.99	823.86	806.39	824.56	0.0002	6.97	0.23
458.73	5%	20	199000	788.99	825.73	807.47	826.44	0.000191	7.11	0.23
458.73	2%	50	233000	788.99	828.03	808.86	828.73	0.00018	7.27	0.23
458.73	1%	100	259000	788.99	829.67	809.88	830.37	0.000173	7.37	0.22
458.73	0.5% (Confined)	200	287000	788.99	831.29	810.94	831.99	0.000168	7.49	0.22
458.73	0.2% (Confined)	500	324000	788.99	833.34	812.29	834.04	0.000162	7.63	0.22
459.43	50%	2	109000	789.08	818.33	805.55	818.83	0.000216	5.67	0.23
459.43	20%	5	147000	789.08	822.45	807.3	822.96	0.000186	5.89	0.22
459.43	10%	10	174000	789.08	824.79	808.45	825.25	0.000171	5.83	0.21
459.43	5%	20	199000	789.08	826.65	809.48	827.08	0.000158	5.75	0.21
459.43	2%	50	233000	789.08	828.91	810.76	829.31	0.000139	5.72	0.2
459.43	1%	100	259000	789.08	830.52	811.71	830.91	0.000128	5.72	0.19
459.43	0.5% (Confined)	200	287000	789.08	832.12	812.71	832.51	0.00012	5.74	0.19
459.43	0.2% (Confined)	500	324000	789.08	834.14	813.94	834.53	0.000111	5.78	0.18

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
460	50%	2	109000	786.06	818.96	805.75	819.48	0.000209	5.78	0.23
460	20%	5	147000	786.06	822.98	807.79	823.54	0.000195	6.18	0.23
460	10%	10	174000	786.06	825.27	808.93	825.79	0.000192	6.16	0.22
460	5%	20	199000	786.06	827.08	809.92	827.56	0.000171	6.08	0.22
460	2%	50	233000	786.06	829.28	811.2	829.73	0.000154	5.99	0.21
460	1%	100	259000	786.06	830.87	812.1	831.28	0.000141	5.9	0.2
460	0.5% (Confined)	200	287000	786.06	832.45	813.05	832.84	0.000129	5.86	0.19
460	0.2% (Confined)	500	324000	786.06	834.45	814.36	834.83	0.000116	5.82	0.18
460.68	50%	2	109000	785.22	819.71	802.44	820.13	0.000145	5.21	0.19
460.68	20%	5	147000	785.22	823.7	804.4	824.18	0.000151	5.69	0.2
460.68	10%	10	174000	785.22	825.98	805.71	826.43	0.000163	5.67	0.21
460.68	5%	20	199000	785.22	827.69	806.85	828.12	0.00015	5.71	0.2
460.68	2%	50	233000	785.22	829.8	808.3	830.21	0.000137	5.75	0.19
460.68	1%	100	259000	785.22	831.32	809.38	831.73	0.000129	5.78	0.19
460.68	0.5% (Confined)	200	287000	785.22	832.85	810.47	833.25	0.000122	5.82	0.19
460.68	0.2% (Confined)	500	324000	785.22	834.81	811.89	835.2	0.000114	5.86	0.18
461.5	50%	2	109000	792.68	820.33	804.82	820.85	0.000172	5.77	0.21
461.5	20%	5	147000	792.68	824.29	806.73	824.97	0.000188	6.62	0.23
461.5	10%	10	174000	792.68	826.51	807.98	827.31	0.000203	7.19	0.24
461.5	5%	20	199000	792.68	828.12	809.06	829.03	0.000218	7.7	0.25
461.5	2%	50	233000	792.68	830.14	810.5	831.15	0.000239	8.25	0.26
461.5	1%	100	259000	792.68	831.58	811.56	832.67	0.000245	8.61	0.27
461.5	0.5% (Confined)	200	287000	792.68	833.03	812.65	834.2	0.00025	8.96	0.27
461.5	0.2% (Confined)	500	324000	792.68	834.9	814.03	836.15	0.000254	9.36	0.28
462.41	50%	2	109000	779.67	821.16	804.35	821.6	0.000142	5.34	0.19
462.41	20%	5	147000	779.67	825.22	806.23	825.79	0.000153	6.08	0.2
462.41	10%	10	174000	779.67	827.57	807.48	828.21	0.000169	6.52	0.22
462.41	5%	20	199000	779.67	829.35	808.56	830.06	0.000204	6.87	0.24
462.41	2%	50	233000	779.67	831.47	809.97	832.25	0.000214	7.29	0.24
462.41	1%	100	259000	779.67	832.95	811	833.79	0.000216	7.59	0.25
462.41	0.5% (Confined)	200	287000	779.67	834.44	812.04	835.33	0.000219	7.89	0.25
462.41	0.2% (Confined)	500	324000	779.67	836.34	813.4	837.3	0.000221	8.25	0.25
462.66	50%	2	109000	787.54	821.39	802.18	821.79	0.000125	5.06	0.18
462.66	20%	5	147000	787.54	825.47	804.24	825.99	0.000136	5.78	0.19
462.66	10%	10	174000	787.54	827.83	805.68	828.43	0.000144	6.24	0.2
462.66	5%	20	199000	787.54	829.64	806.89	830.31	0.00017	6.63	0.22
462.66	2%	50	233000	787.54	831.77	808.44	832.53	0.000195	7.11	0.23
462.66	1%	100	259000	787.54	833.24	809.57	834.07	0.000202	7.44	0.24
462.66	0.5% (Confined)	200	287000	787.54	834.72	810.86	835.62	0.000207	7.79	0.25
462.66	0.2% (Confined)	500	324000	787.54	836.6	812.36	837.59	0.000213	8.21	0.25
463.17	50%	2	104000	782.36	821.71	803.73	822.11	0.000121	5.08	0.18
463.17	20%	5	141000	782.36	825.83	805.64	826.35	0.000138	5.85	0.19
463.17	10%	10	167000	782.36	828.21	806.88	828.81	0.000147	6.29	0.2
463.17	5%	20	191000	782.36	830.07	807.94	830.74	0.000153	6.68	0.21
463.17	2%	50	225000	782.36	832.23	809.41	833.01	0.000165	7.23	0.22
463.17	1%	100	256000	782.36	833.7	810.66	834.59	0.000181	7.79	0.23
463.17	0.5% (Confined)	200	285000	782.36	835.18	811.79	836.17	0.000191	8.23	0.24
463.17	0.2% (Confined)	500	323000	782.36	837.07	813.24	838.17	0.000201	8.74	0.25
463.97	50%	2	104000	786.19	822.24	805.81	822.75	0.000167	5.77	0.21
463.97	20%	5	141000	786.19	826.39	807.85	827.08	0.000183	6.63	0.22
463.97	10%	10	167000	786.19	828.79	809.29	829.6	0.000196	7.21	0.23
463.97	5%	20	191000	786.19	830.65	810.52	831.57	0.000207	7.7	0.24
463.97	2%	50	225000	786.19	832.84	812.1	833.91	0.000224	8.38	0.26
463.97	1%	100	256000	786.19	834.35	813.4	835.59	0.000245	9.04	0.27
463.97	0.5% (Confined)	200	285000	786.19	835.86	814.59	837.23	0.000259	9.55	0.28
463.97	0.2% (Confined)	500	323000	786.19	837.77	816.08	839.3	0.000274	10.17	0.29

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
464.51	50%	2	104000	789.56	822.74	805.2	823.18	0.000136	5.35	0.19
464.51	20%	5	141000	789.56	827	807.17	827.53	0.00014	5.99	0.2
464.51	10%	10	167000	789.56	829.53	808.45	830.07	0.000135	6.15	0.2
464.51	5%	20	191000	789.56	831.52	809.56	832.05	0.000128	6.25	0.19
464.51	2%	50	225000	789.56	833.9	811.08	834.42	0.000122	6.37	0.19
464.51	1%	100	256000	789.56	835.59	812.4	836.13	0.000121	6.57	0.19
464.51	0.5% (Confined)	200	285000	789.56	837.25	813.57	837.78	0.000118	6.67	0.19
464.51	0.2% (Confined)	500	323000	789.56	839.34	815.05	839.87	0.000114	6.78	0.19
464.97	50%	2	104000	792.41	823.09	808.6	823.56	0.000175	5.48	0.21
464.97	20%	5	141000	792.41	827.41	810.43	827.9	0.000158	5.74	0.21
464.97	10%	10	167000	792.41	829.97	811.61	830.4	0.000133	5.63	0.19
464.97	5%	20	191000	792.41	831.97	812.64	832.35	0.000116	5.52	0.18
464.97	2%	50	225000	792.41	834.34	814.02	834.69	0.000103	5.47	0.17
464.97	1%	100	256000	792.41	836.04	815.23	836.4	0.000099	5.55	0.17
464.97	0.5% (Confined)	200	285000	792.41	837.7	816.3	838.04	0.000093	5.57	0.17
464.97	0.2% (Confined)	500	323000	792.41	839.78	817.66	840.12	0.000087	5.59	0.16
465.6	50%	2	104000	793.92	823.69	809.9	824.17	0.000189	5.58	0.22
465.6	20%	5	141000	793.92	827.94	811.7	828.42	0.000159	5.75	0.21
465.6	10%	10	167000	793.92	830.45	812.86	830.82	0.000124	5.41	0.18
465.6	5%	20	191000	793.92	832.39	813.85	832.7	0.000103	5.15	0.17
465.6	2%	50	225000	793.92	834.72	815.24	834.99	0.000086	4.96	0.16
465.6	1%	100	256000	793.92	836.42	816.41	836.67	0.000079	4.93	0.15
465.6	0.5% (Confined)	200	285000	793.92	838.06	817.49	838.29	0.000073	4.88	0.15
465.6	0.2% (Confined)	500	323000	793.92	840.13	818.83	840.35	0.000066	4.82	0.14
466.09	50%	2	104000	790.5	824.18	809.77	824.65	0.000187	5.49	0.22
466.09	20%	5	141000	790.5	828.39	812.18	828.81	0.00015	5.5	0.2
466.09	10%	10	167000	790.5	830.79	813.36	831.13	0.000133	5.21	0.19
466.09	5%	20	191000	790.5	832.67	814.36	832.96	0.000112	5.01	0.17
466.09	2%	50	225000	790.5	834.94	815.73	835.2	0.000095	4.89	0.16
466.09	1%	100	256000	790.5	836.61	816.91	836.87	0.000089	4.91	0.16
466.09	0.5% (Confined)	200	285000	790.5	838.23	817.97	838.47	0.000082	4.89	0.15
466.09	0.2% (Confined)	500	323000	790.5	840.28	819.3	840.51	0.000074	4.86	0.15
466.82	50%	2	104000	794.85	824.9	809.34	825.42	0.000193	5.78	0.22
466.82	20%	5	141000	794.85	828.92	811.45	829.52	0.0002	6.34	0.23
466.82	10%	10	167000	794.85	831.21	812.84	831.82	0.000204	6.51	0.23
466.82	5%	20	191000	794.85	832.97	814.04	833.58	0.000197	6.61	0.23
466.82	2%	50	225000	794.85	835.15	815.63	835.76	0.000191	6.76	0.23
466.82	1%	100	256000	794.85	836.78	817	837.41	0.000188	6.97	0.23
466.82	0.5% (Confined)	200	285000	794.85	838.35	818.22	838.99	0.000182	7.1	0.23
466.82	0.2% (Confined)	500	323000	794.85	840.34	819.75	840.99	0.000173	7.24	0.22
467.31	50%	2	104000	798.59	825.43	812.74	826.05	0.000283	6.32	0.26
467.31	20%	5	141000	798.59	829.44	814.85	830.14	0.000258	6.81	0.26
467.31	10%	10	167000	798.59	831.74	816.19	832.41	0.000249	6.84	0.26
467.31	5%	20	191000	798.59	833.49	817.37	834.13	0.000227	6.87	0.25
467.31	2%	50	225000	798.59	835.65	818.93	836.26	0.000204	6.89	0.24
467.31	1%	100	256000	798.59	837.28	820.26	837.88	0.000192	6.96	0.23
467.31	0.5% (Confined)	200	285000	798.59	838.86	821.44	839.44	0.000178	6.95	0.23
467.31	0.2% (Confined)	500	323000	798.59	840.86	822.87	841.42	0.000162	6.94	0.22
467.9	50%	2	104000	794.04	826.31	814.04	826.84	0.000245	5.87	0.24
467.9	20%	5	141000	794.04	830.22	815.96	830.87	0.000236	6.5	0.25
467.9	10%	10	167000	794.04	832.42	817.18	833.1	0.000227	6.76	0.25
467.9	5%	20	191000	794.04	834.08	818.36	834.78	0.00022	6.96	0.24
467.9	2%	50	225000	794.04	836.19	819.71	836.88	0.000228	7.09	0.25
467.9	1%	100	256000	794.04	837.78	820.83	838.48	0.000221	7.27	0.25
467.9	0.5% (Confined)	200	285000	794.04	839.31	821.88	839.99	0.000207	7.3	0.24
467.9	0.2% (Confined)	500	323000	794.04	841.27	823.19	841.92	0.000189	7.29	0.23

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
468.58	50%	2	104000	790.75	827.04	809.66	827.66	0.000196	6.34	0.23
468.58	20%	5	141000	790.75	830.91	812.03	831.77	0.000226	7.42	0.25
468.58	10%	10	167000	790.75	833.04	813.6	834.04	0.000246	8.08	0.26
468.58	5%	20	191000	790.75	834.66	814.92	835.74	0.000258	8.51	0.27
468.58	2%	50	225000	790.75	836.76	816.71	837.87	0.000274	8.88	0.28
468.58	1%	100	256000	790.75	838.32	818.26	839.45	0.00028	9.15	0.28
468.58	0.5% (Confined)	200	285000	790.75	839.81	819.66	840.92	0.000276	9.26	0.28
468.58	0.2% (Confined)	500	323000	790.75	841.71	821.4	842.77	0.000266	9.32	0.28
469.14	50%	2	104000	799.64	827.79	811.29	828.2	0.000154	5.14	0.2
469.14	20%	5	141000	799.64	831.84	813.19	832.36	0.00016	5.82	0.21
469.14	10%	10	167000	799.64	834.08	814.42	834.69	0.000172	6.27	0.22
469.14	5%	20	191000	799.64	835.73	815.49	836.41	0.000185	6.68	0.23
469.14	2%	50	225000	799.64	837.79	816.91	838.57	0.000195	7.2	0.24
469.14	1%	100	256000	799.64	839.29	818.18	840.16	0.000207	7.67	0.24
469.14	0.5% (Confined)	200	285000	799.64	840.67	819.29	841.62	0.000215	8.06	0.25
469.14	0.2% (Confined)	500	323000	799.64	842.41	820.73	843.46	0.000224	8.51	0.26
469.77	50%	2	104000	797.49	828.26	811.91	828.78	0.000178	5.77	0.21
469.77	20%	5	141000	797.49	832.37	813.95	833	0.000211	6.41	0.23
469.77	10%	10	167000	797.49	834.69	815.25	835.36	0.000226	6.72	0.24
469.77	5%	20	191000	797.49	836.38	816.36	837.11	0.000229	7.04	0.25
469.77	2%	50	225000	797.49	838.49	817.92	839.28	0.000233	7.45	0.25
469.77	1%	100	256000	797.49	840.05	819.27	840.91	0.000243	7.86	0.26
469.77	0.5% (Confined)	200	285000	797.49	841.47	820.46	842.4	0.000248	8.19	0.26
469.77	0.2% (Confined)	500	323000	797.49	843.26	822.1	844.26	0.000252	8.59	0.27
470.58	50%	2	104000	799.2	829.09	815.33	829.54	0.000178	5.41	0.21
470.58	20%	5	141000	799.2	833.29	817.06	833.82	0.000171	5.91	0.21
470.58	10%	10	167000	799.2	835.63	818.18	836.18	0.000164	6.15	0.21
470.58	5%	20	191000	799.2	837.36	819.09	837.94	0.000163	6.39	0.21
470.58	2%	50	225000	799.2	839.51	820.45	840.12	0.000162	6.7	0.21
470.58	1%	100	256000	799.2	841.13	821.61	841.78	0.000164	6.97	0.22
470.58	0.5% (Confined)	200	285000	799.2	842.6	822.63	843.27	0.000164	7.19	0.22
470.58	0.2% (Confined)	500	323000	799.2	844.45	823.92	845.15	0.000163	7.44	0.22
471.28	50%	2	104000	794.31	829.73	813.72	830.21	0.000177	5.6	0.21
471.28	20%	5	141000	794.31	833.89	816.38	834.47	0.000176	6.19	0.22
471.28	10%	10	167000	794.31	836.21	817.78	836.81	0.000169	6.4	0.22
471.28	5%	20	191000	794.31	837.94	818.97	838.55	0.000165	6.59	0.22
471.28	2%	50	225000	794.31	840.09	820.45	840.72	0.000163	6.86	0.22
471.28	1%	100	256000	794.31	841.71	821.73	842.37	0.000163	7.11	0.22
471.28	0.5% (Confined)	200	285000	794.31	843.19	822.85	843.86	0.000162	7.31	0.22
471.28	0.2% (Confined)	500	323000	794.31	845.03	824.3	845.72	0.000161	7.53	0.22
472.06	50%	2	104000	798.32	830.47	816.4	830.92	0.000171	5.38	0.21
472.06	20%	5	141000	798.32	834.66	818.1	835.22	0.000189	6	0.22
472.06	10%	10	167000	798.32	836.93	819.25	837.54	0.000191	6.34	0.23
472.06	5%	20	191000	798.32	838.62	820.23	839.29	0.000193	6.66	0.23
472.06	2%	50	225000	798.32	840.73	821.56	841.47	0.000197	7.1	0.24
472.06	1%	100	256000	798.32	842.34	822.7	843.15	0.000205	7.51	0.24
472.06	0.5% (Confined)	200	285000	798.32	843.78	823.74	844.66	0.00021	7.85	0.25
472.06	0.2% (Confined)	500	323000	798.32	845.59	825.03	846.55	0.000216	8.26	0.25
472.78	50%	2	104000	790.23	831.09	813.12	831.48	0.000125	5.01	0.18
472.78	20%	5	141000	790.23	835.33	815.08	835.82	0.000135	5.69	0.19
472.78	10%	10	167000	790.23	837.61	816.34	838.16	0.000141	6.08	0.2
472.78	5%	20	191000	790.23	839.32	817.41	839.92	0.000146	6.42	0.2
472.78	2%	50	225000	790.23	841.45	818.88	842.13	0.000153	6.86	0.21
472.78	1%	100	256000	790.23	843.1	820.18	843.84	0.000161	7.26	0.22
472.78	0.5% (Confined)	200	285000	790.23	844.57	821.33	845.38	0.000166	7.6	0.22
472.78	0.2% (Confined)	500	323000	790.23	846.41	822.77	847.29	0.000172	8	0.23

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
473.62	50%	2	104000	802.97	831.69	817.59	832.19	0.000187	5.69	0.22
473.62	20%	5	141000	802.97	835.95	819.42	836.57	0.000188	6.32	0.22
473.62	10%	10	167000	802.97	838.26	820.62	838.91	0.000186	6.62	0.23
473.62	5%	20	191000	802.97	840	821.66	840.65	0.000177	6.74	0.22
473.62	2%	50	225000	802.97	842.21	823.05	842.84	0.000166	6.86	0.22
473.62	1%	100	256000	802.97	843.94	824.26	844.57	0.000161	7	0.22
473.62	0.5% (Confined)	200	285000	802.97	845.48	825.34	846.11	0.000156	7.1	0.22
473.62	0.2% (Confined)	500	323000	802.97	847.39	826.7	848.02	0.000149	7.22	0.21
474.29	50%	2	104000	795.31	832.34	817.04	832.87	0.000185	5.87	0.22
474.29	20%	5	141000	795.31	836.61	819.06	837.23	0.000182	6.45	0.22
474.29	10%	10	167000	795.31	838.92	820.36	839.55	0.000173	6.64	0.22
474.29	5%	20	191000	795.31	840.61	821.5	841.26	0.000171	6.86	0.22
474.29	2%	50	225000	795.31	842.76	823.03	843.43	0.000169	7.15	0.22
474.29	1%	100	256000	795.31	844.45	824.32	845.15	0.00017	7.42	0.22
474.29	0.5% (Confined)	200	285000	795.31	845.95	825.52	846.68	0.00017	7.64	0.23
474.29	0.2% (Confined)	500	323000	795.31	847.83	827	848.59	0.00017	7.9	0.23
474.94	50%	2	104000	794.58	833	816.45	833.47	0.000163	5.53	0.21
474.94	20%	5	141000	794.58	837.27	818.59	837.81	0.00016	6.04	0.21
474.94	10%	10	167000	794.58	839.53	820.3	840.1	0.000159	6.31	0.21
474.94	5%	20	191000	794.58	841.19	821.41	841.8	0.000161	6.61	0.21
474.94	2%	50	225000	794.58	843.3	822.91	843.97	0.000165	7	0.22
474.94	1%	100	256000	794.58	844.97	824.18	845.7	0.00017	7.35	0.22
474.94	0.5% (Confined)	200	285000	794.58	846.46	825.34	847.24	0.000173	7.65	0.23
474.94	0.2% (Confined)	500	323000	794.58	848.32	826.87	849.15	0.000177	8	0.23
475.38	50%	2	104000	802.02	833.32	820.14	834.01	0.000264	6.65	0.26
475.38	20%	5	141000	802.02	837.58	822.2	838.34	0.000248	7.13	0.26
475.38	10%	10	167000	802.02	839.84	823.55	840.6	0.000242	7.32	0.26
475.38	5%	20	191000	802.02	841.51	824.72	842.3	0.000237	7.56	0.26
475.38	2%	50	225000	802.02	843.63	826.29	844.46	0.000233	7.88	0.26
475.38	1%	100	256000	802.02	845.31	827.64	846.19	0.000234	8.18	0.26
475.38	0.5% (Confined)	200	285000	802.02	846.82	828.86	847.73	0.000233	8.43	0.26
475.38	0.2% (Confined)	500	323000	802.02	848.68	830.37	849.65	0.000231	8.73	0.26
475.92	50%	2	104000	800.78	834.18	819.96	834.63	0.000175	5.39	0.21
475.92	20%	5	141000	800.78	838.38	821.71	838.94	0.000177	6.05	0.22
475.92	10%	10	167000	800.78	840.56	822.84	841.21	0.000183	6.5	0.22
475.92	5%	20	191000	800.78	842.17	823.82	842.91	0.000193	6.94	0.23
475.92	2%	50	225000	800.78	844.23	825.16	845.08	0.000205	7.5	0.24
475.92	1%	100	256000	800.78	846.07	826.33	846.74	0.000167	7.04	0.22
475.92	0.5% (Confined)	200	285000	800.78	847.58	827.35	848.28	0.000168	7.29	0.22
475.92	0.2% (Confined)	500	323000	800.78	849.44	828.67	850.19	0.000169	7.58	0.23
476.34	50%	2	104000	800.67	834.54	818.99	834.95	0.000146	5.16	0.19
476.34	20%	5	141000	800.67	838.75	820.78	839.27	0.000151	5.82	0.2
476.34	10%	10	167000	800.67	840.95	821.89	841.55	0.000158	6.28	0.21
476.34	5%	20	191000	800.67	842.59	822.92	843.27	0.000167	6.71	0.22
476.34	2%	50	225000	800.67	844.68	824.25	845.46	0.00018	7.27	0.23
476.34	1%	100	256000	800.67	846.38	825.43	847.06	0.000159	7.08	0.22
476.34	0.5% (Confined)	200	285000	800.67	847.88	826.49	848.61	0.000162	7.37	0.22
476.34	0.2% (Confined)	500	323000	800.67	849.74	827.82	850.52	0.000165	7.7	0.22
476.99	50%	2	104000	798.83	834.96	819.21	835.54	0.000193	6.11	0.22
476.99	20%	5	141000	798.83	839.15	821.32	839.9	0.000208	6.95	0.24
476.99	10%	10	167000	798.83	841.36	822.68	842.21	0.000217	7.48	0.25
476.99	5%	20	191000	798.83	843.02	823.89	843.97	0.000228	7.97	0.25
476.99	2%	50	225000	798.83	845.21	825.49	846.11	0.000211	8.03	0.25
476.99	1%	100	256000	798.83	846.75	826.93	847.72	0.00022	8.44	0.25
476.99	0.5% (Confined)	200	285000	798.83	848.26	828.24	849.27	0.000222	8.73	0.26
476.99	0.2% (Confined)	500	323000	798.83	850.12	829.79	851.19	0.000223	9.07	0.26

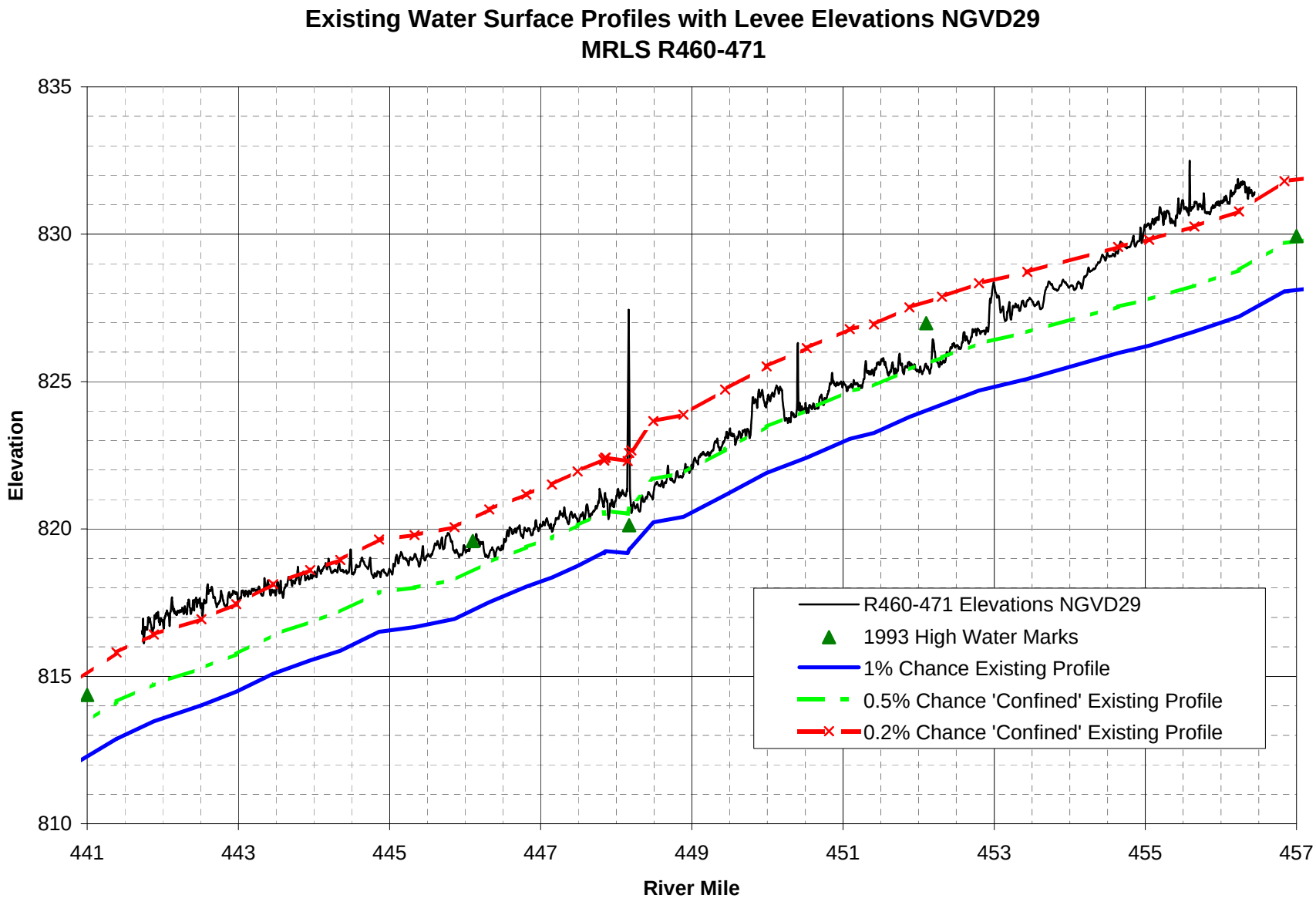
Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
477.64	50%	2	104000	800.29	835.78	820.48	836.16	0.000157	5.16	0.2
477.64	20%	5	141000	800.29	840.14	822.7	840.54	0.00015	5.41	0.2
477.64	10%	10	167000	800.29	842.43	823.98	842.84	0.000138	5.53	0.19
477.64	5%	20	191000	800.29	844.18	825.08	844.61	0.000134	5.7	0.19
477.64	2%	50	225000	800.29	846.25	826.49	846.71	0.000134	5.99	0.2
477.64	1%	100	256000	800.29	847.9	827.82	848.29	0.000115	5.76	0.18
477.64	0.5% (Confined)	200	285000	800.29	849.44	829.16	849.84	0.000112	5.88	0.18
477.64	0.2% (Confined)	500	323000	800.29	851.34	831.69	851.75	0.000109	6.02	0.18
478.4	50%	2	104000	806.35	836.36	821.67	836.81	0.000163	5.4	0.21
478.4	20%	5	141000	806.35	840.66	823.5	841.12	0.000146	5.68	0.2
478.4	10%	10	167000	806.35	842.9	824.72	843.37	0.000139	5.86	0.2
478.4	5%	20	191000	806.35	844.64	825.76	845.11	0.000135	6	0.2
478.4	2%	50	225000	806.35	846.71	827.18	847.2	0.000133	6.25	0.2
478.4	1%	100	256000	806.35	848.25	828.36	848.78	0.000136	6.52	0.2
478.4	0.5% (Confined)	200	285000	806.35	849.77	829.44	850.32	0.000135	6.7	0.2
478.4	0.2% (Confined)	500	323000	806.35	851.65	830.8	852.22	0.000134	6.9	0.2
479.09	50%	2	104000	810.08	837.01	824.25	837.44	0.000187	5.41	0.22
479.09	20%	5	141000	810.08	841.26	826.05	841.64	0.000146	5.37	0.2
479.09	10%	10	167000	810.08	843.51	827.22	843.84	0.000124	5.22	0.18
479.09	5%	20	191000	810.08	845.24	828.2	845.54	0.000109	5.12	0.17
479.09	2%	50	225000	810.08	847.32	829.54	847.6	0.000098	5.09	0.17
479.09	1%	100	256000	810.08	848.89	830.75	849.17	0.000093	5.15	0.16
479.09	0.5% (Confined)	200	285000	810.08	850.42	832.61	850.69	0.000088	5.16	0.16
479.09	0.2% (Confined)	500	323000	810.08	852.31	833.98	852.58	0.000082	5.19	0.16
479.81	50%	2	103000	800.46	837.74	823.01	838.18	0.000226	5.57	0.23
479.81	20%	5	140000	800.46	841.78	825.81	842.15	0.000164	5.41	0.21
479.81	10%	10	166000	800.46	843.92	828.05	844.25	0.000139	5.28	0.19
479.81	5%	20	190000	800.46	845.58	829.3	845.89	0.000127	5.27	0.18
479.81	2%	50	224000	800.46	847.61	830.73	847.91	0.000118	5.34	0.18
479.81	1%	100	255000	800.46	849.16	832.07	849.46	0.000116	5.47	0.18
479.81	0.5% (Confined)	200	284000	800.46	850.66	833.82	850.97	0.000111	5.55	0.18
479.81	0.2% (Confined)	500	322000	800.46	852.53	835.67	852.84	0.000106	5.65	0.18
480.59	50%	2	103000	809.61	838.58	823.55	839.06	0.000216	5.64	0.21
480.59	20%	5	140000	809.61	842.38	825.51	842.86	0.000193	5.84	0.21
480.59	10%	10	166000	809.61	844.42	826.78	844.88	0.000186	5.97	0.2
480.59	5%	20	190000	809.61	846.03	827.89	846.48	0.000179	6	0.2
480.59	2%	50	224000	809.61	848.02	829.38	848.45	0.000169	6.07	0.2
480.59	1%	100	255000	809.61	849.55	830.66	849.98	0.000166	6.2	0.2
480.59	0.5% (Confined)	200	284000	809.61	851.03	831.83	851.46	0.000159	6.26	0.19
480.59	0.2% (Confined)	500	322000	809.61	852.88	833.28	853.3	0.000151	6.34	0.19
481.2	50%	2	103000	809.33	839.31	825.88	839.76	0.000224	5.45	0.21
481.2	20%	5	140000	809.33	843	827.63	843.48	0.000207	5.8	0.21
481.2	10%	10	166000	809.33	844.99	828.78	845.48	0.0002	6.01	0.21
481.2	5%	20	190000	809.33	846.56	829.79	847.07	0.000198	6.22	0.21
481.2	2%	50	224000	809.33	848.5	831.12	849.04	0.000199	6.54	0.21
481.2	1%	100	255000	809.33	850	832.31	850.58	0.000204	6.85	0.22
481.2	0.5% (Confined)	200	284000	809.33	851.44	833.37	852.05	0.000204	7.07	0.22
481.2	0.2% (Confined)	500	322000	809.33	853.25	834.7	853.89	0.000204	7.32	0.22
481.89	50%	2	103000	810.32	840.11	826.31	840.59	0.000248	5.66	0.22
481.89	20%	5	140000	810.32	843.71	828.5	844.29	0.000252	6.3	0.23
481.89	10%	10	166000	810.32	845.66	829.83	846.29	0.000255	6.68	0.24
481.89	5%	20	190000	810.32	847.21	830.95	847.88	0.000258	6.99	0.24
481.89	2%	50	224000	810.32	849.13	832.98	849.85	0.000258	7.33	0.24
481.89	1%	100	255000	810.32	850.65	834.33	851.39	0.00026	7.62	0.25
481.89	0.5% (Confined)	200	284000	810.32	852.09	835.41	852.85	0.000256	7.8	0.25
481.89	0.2% (Confined)	500	322000	810.32	853.89	836.67	854.67	0.000251	8.01	0.25

Exhibit 2.5
Missouri River Existing Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
482.6	50%	2	103000	809.27	841.02	828.07	841.51	0.000265	5.69	0.23
482.6	20%	5	140000	809.27	844.62	829.92	845.19	0.000258	6.24	0.23
482.6	10%	10	166000	809.27	846.61	831.11	847.17	0.000242	6.35	0.23
482.6	5%	20	190000	809.27	848.18	832.16	848.73	0.000227	6.43	0.22
482.6	2%	50	224000	809.27	850.13	833.85	850.67	0.000215	6.56	0.22
482.6	1%	100	255000	809.27	851.66	834.99	852.2	0.000209	6.72	0.22
482.6	0.5% (Confined)	200	284000	809.27	853.09	836.01	853.64	0.000202	6.81	0.22
482.6	0.2% (Confined)	500	322000	809.27	854.88	837.37	855.43	0.000194	6.93	0.21
483.45	50%	2	103000	809.53	842.16	827.66	842.76	0.000297	6.22	0.25
483.45	20%	5	140000	809.53	845.76	830.32	846.55	0.000353	7.11	0.27
483.45	10%	10	166000	809.53	847.64	831.83	848.56	0.000384	7.7	0.29
483.45	5%	20	190000	809.53	849.1	833.16	850.13	0.000401	8.2	0.29
483.45	2%	50	224000	809.53	850.92	834.9	852.07	0.000416	8.77	0.3
483.45	1%	100	255000	809.53	852.39	836.18	853.61	0.000421	9.15	0.31
483.45	0.5% (Confined)	200	284000	809.53	853.76	837.25	855.01	0.000415	9.4	0.31
483.45	0.2% (Confined)	500	322000	809.53	855.48	838.72	856.76	0.000405	9.65	0.31
484.11	50%	2	103000	813.88	843.16	828.65	843.62	0.000209	5.44	0.21
484.11	20%	5	140000	813.88	846.93	830.48	847.5	0.000218	6.17	0.22
484.11	10%	10	166000	813.88	848.93	831.69	849.57	0.000224	6.59	0.22
484.11	5%	20	190000	813.88	850.48	832.73	851.19	0.000232	6.96	0.23
484.11	2%	50	224000	813.88	852.39	834.11	853.19	0.000245	7.48	0.24
484.11	1%	100	255000	813.88	853.88	835.33	854.76	0.000259	7.93	0.25
484.11	0.5% (Confined)	200	284000	813.88	855.22	836.39	856.17	0.000268	8.3	0.25
484.11	0.2% (Confined)	500	322000	813.88	856.89	837.75	857.93	0.000278	8.74	0.26

Exhibit 2.6



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Checked By: MMW
Date: 7/22/2006

Exhibit 2.7

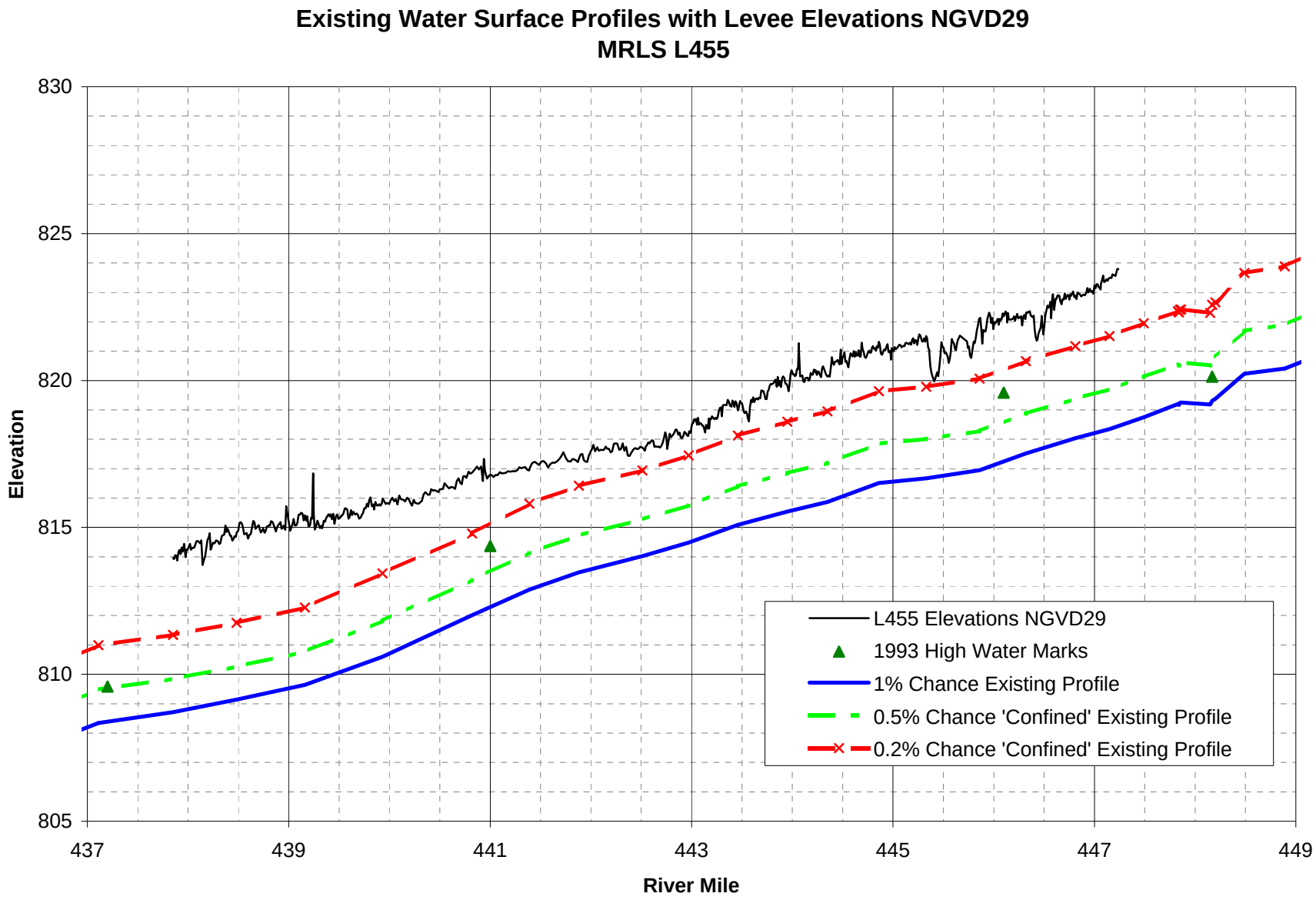

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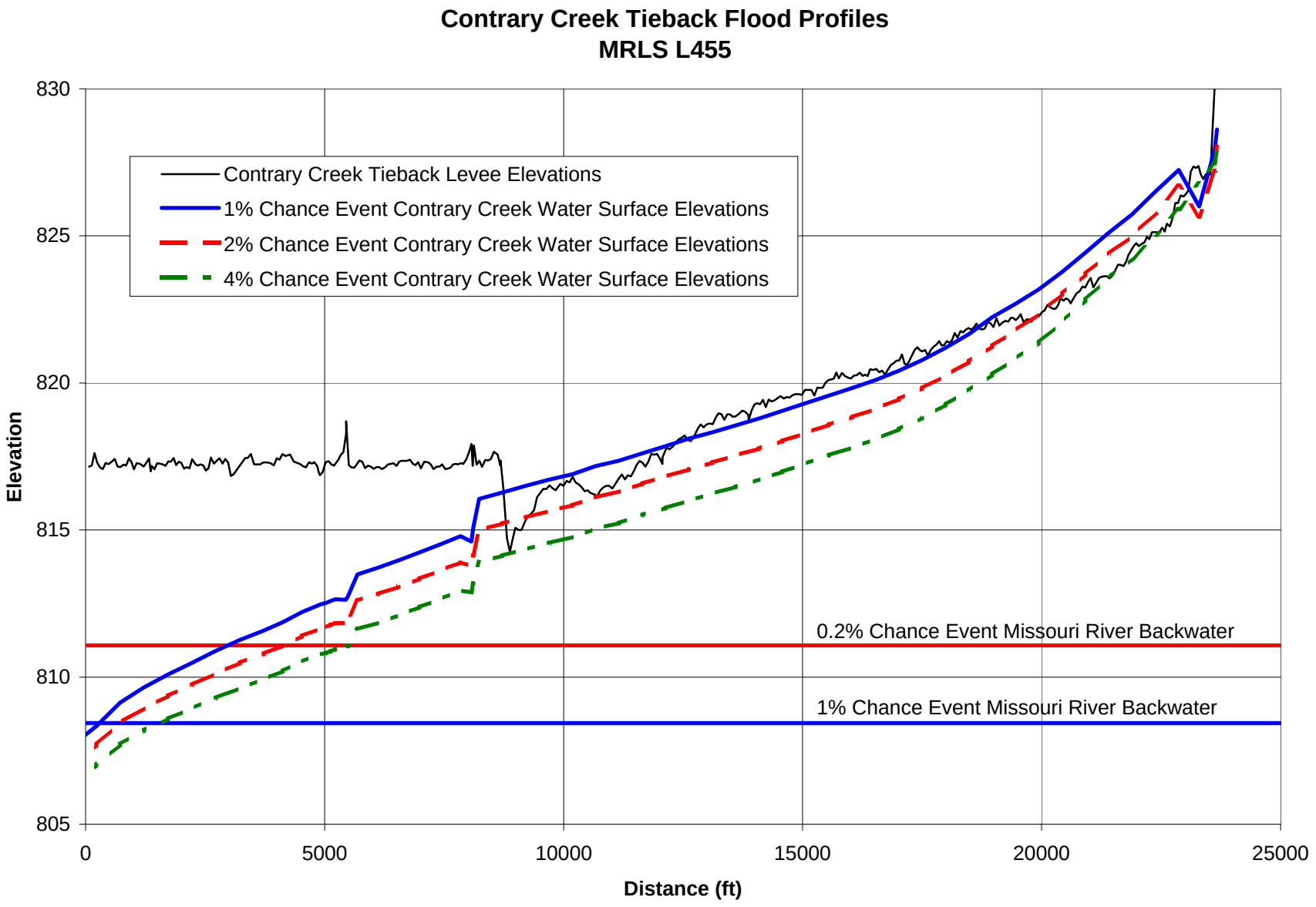
Exhibit 2.8



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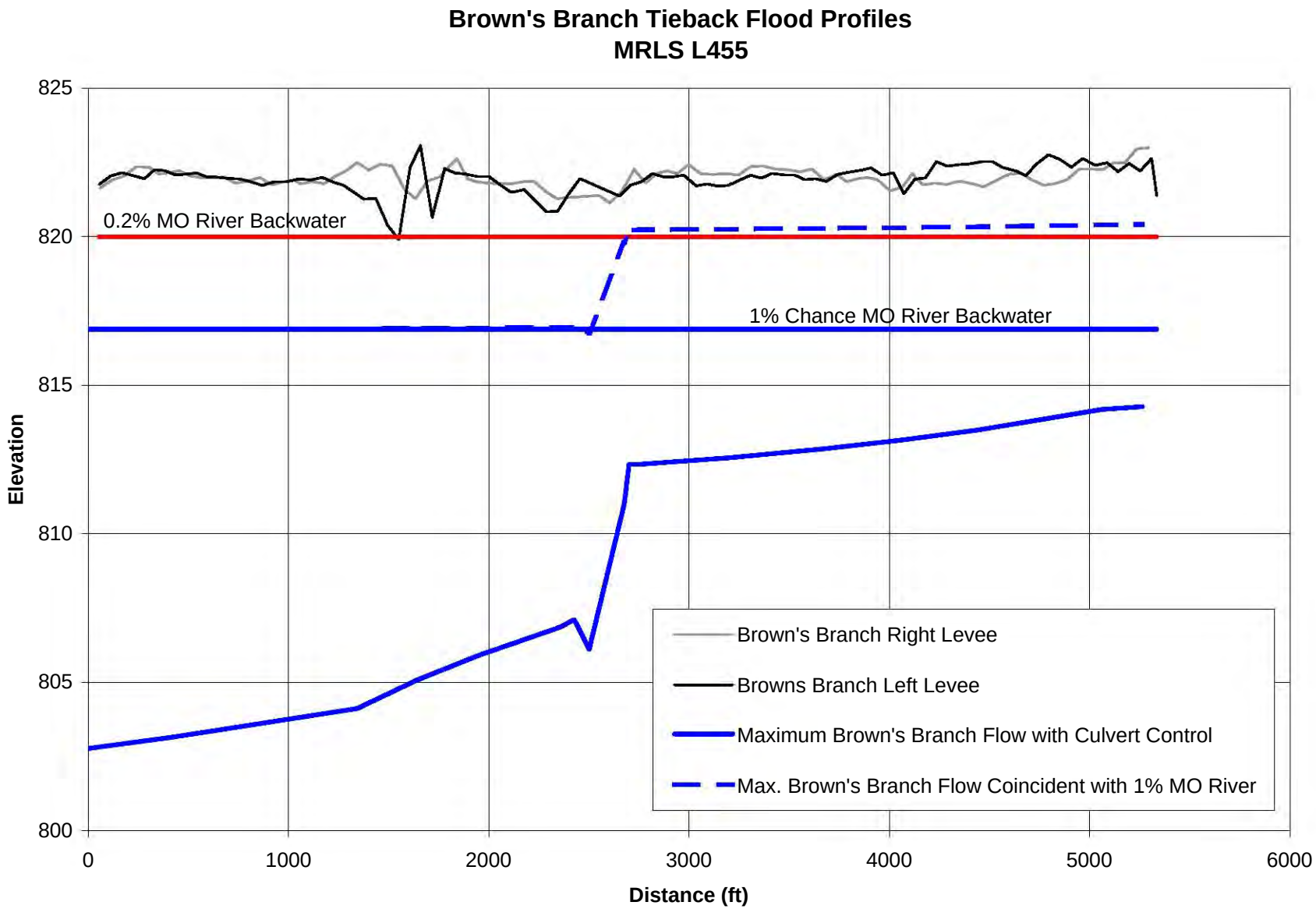

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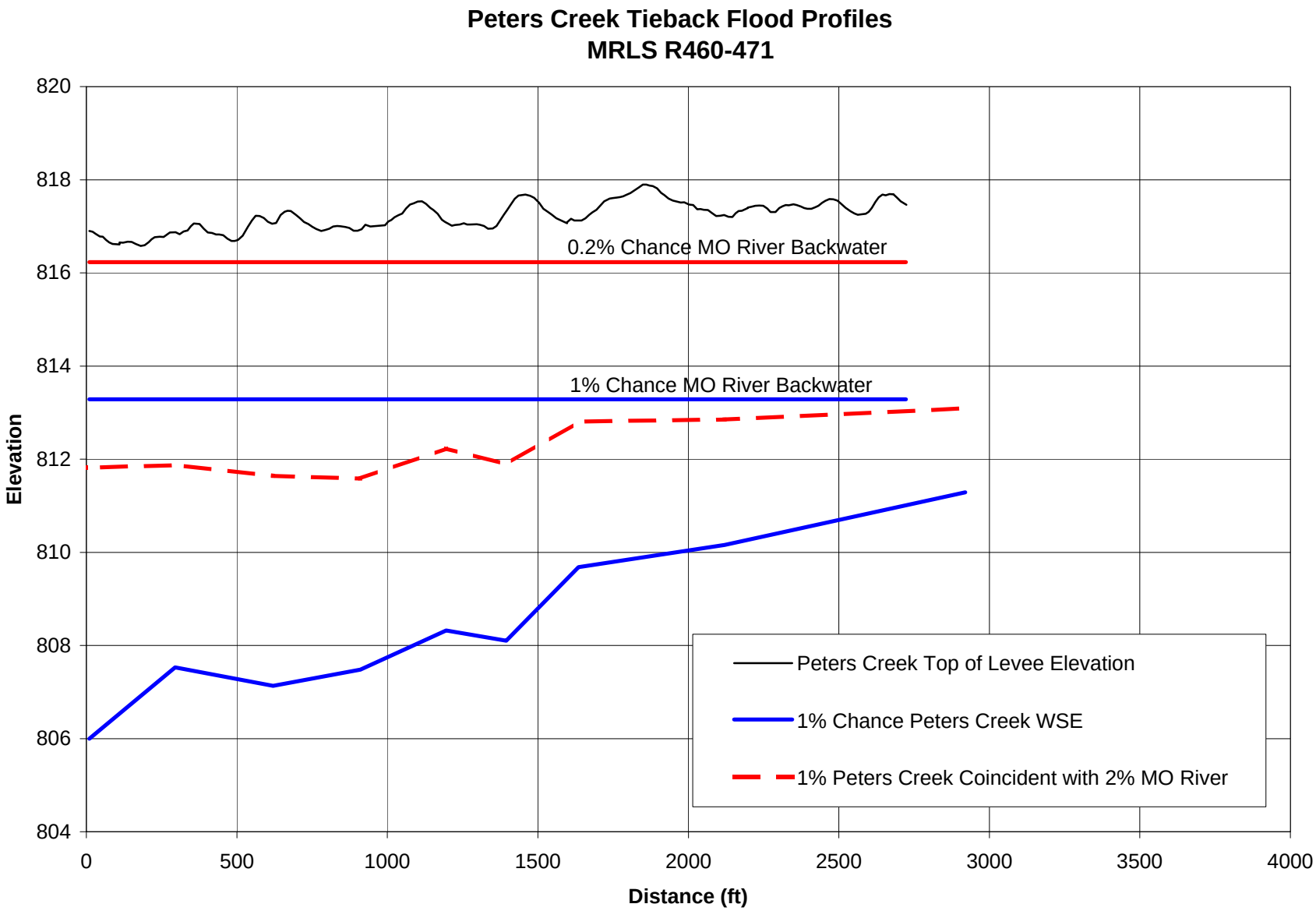
Exhibit 2.10



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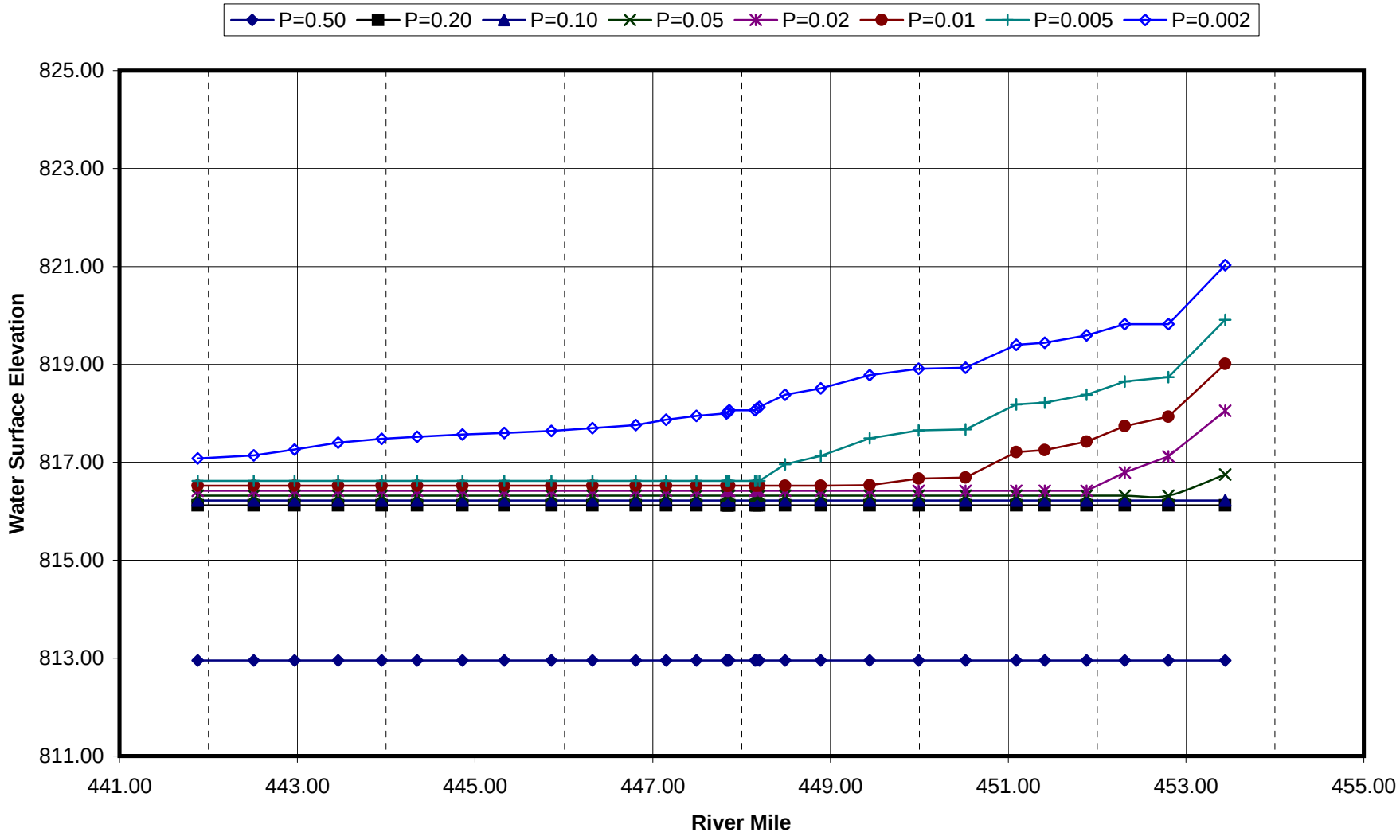
Date: 7/22/2006

Exhibit 2.11

Interior Flood Profiles With Ponding
MRLS R460-471



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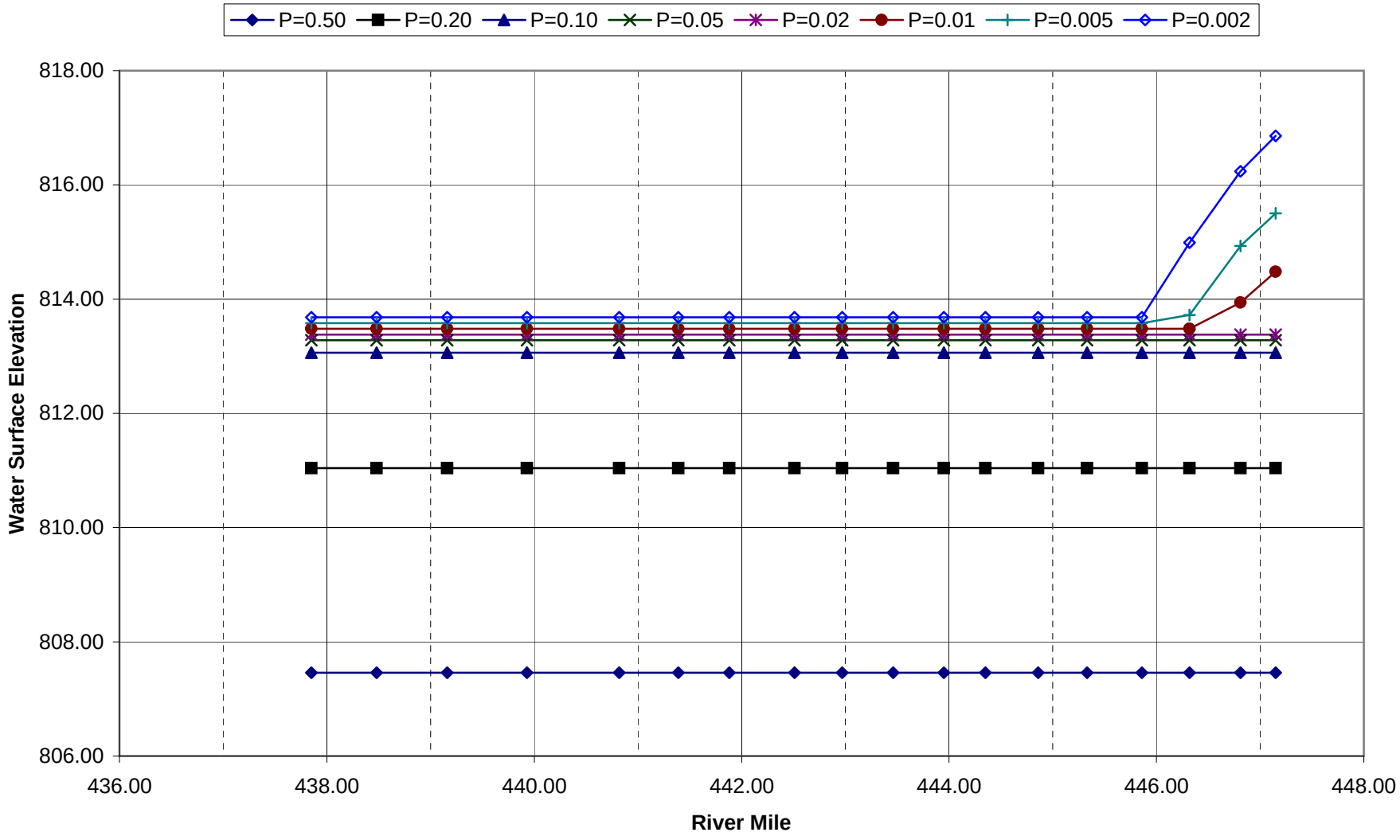
Date: 7/22/2006

Exhibit 2.12

Interior Flood Profiles With Ponding Behind Downstream Levee
MRLS L455



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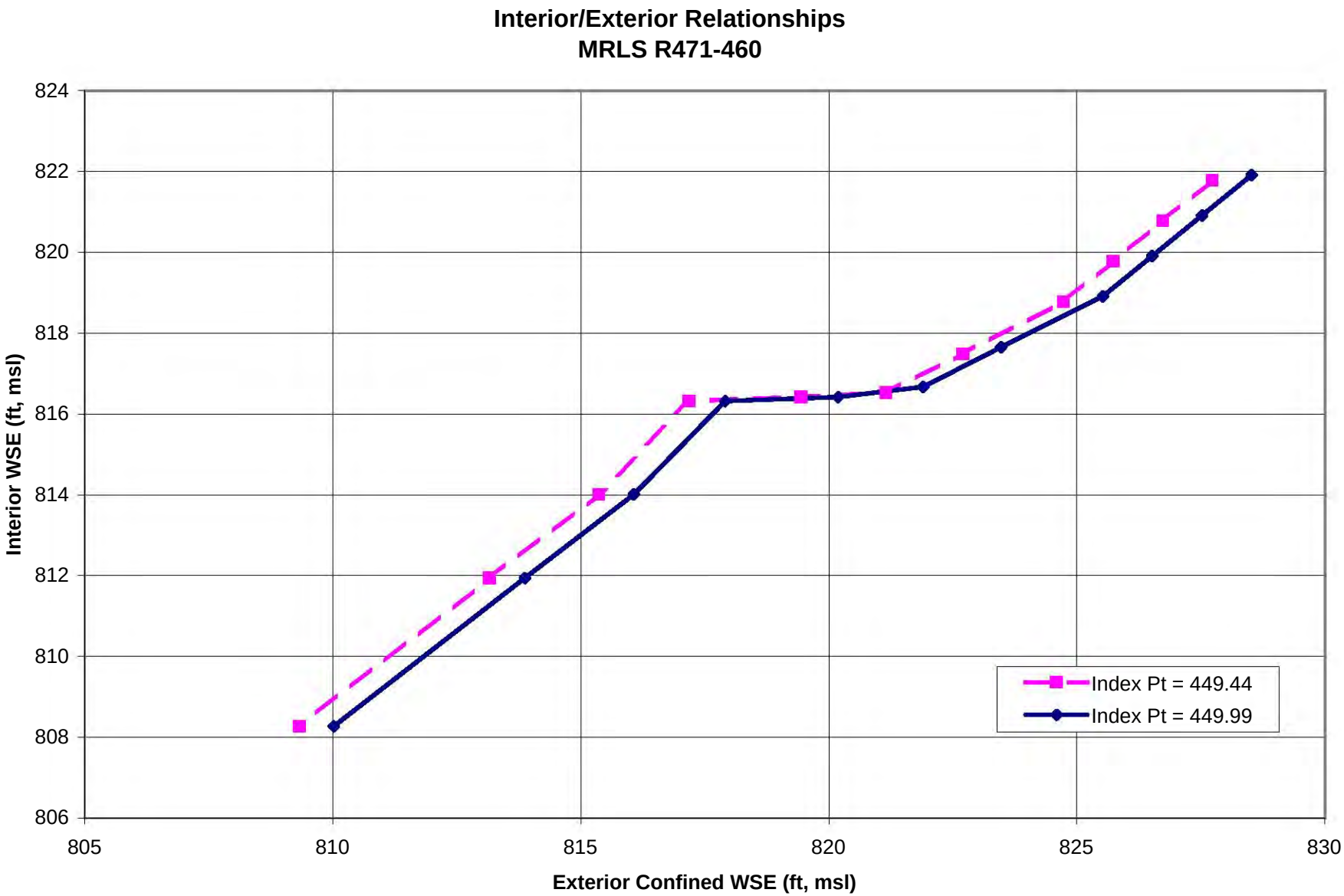
Date: 7/22/2006

Exhibit 2.13



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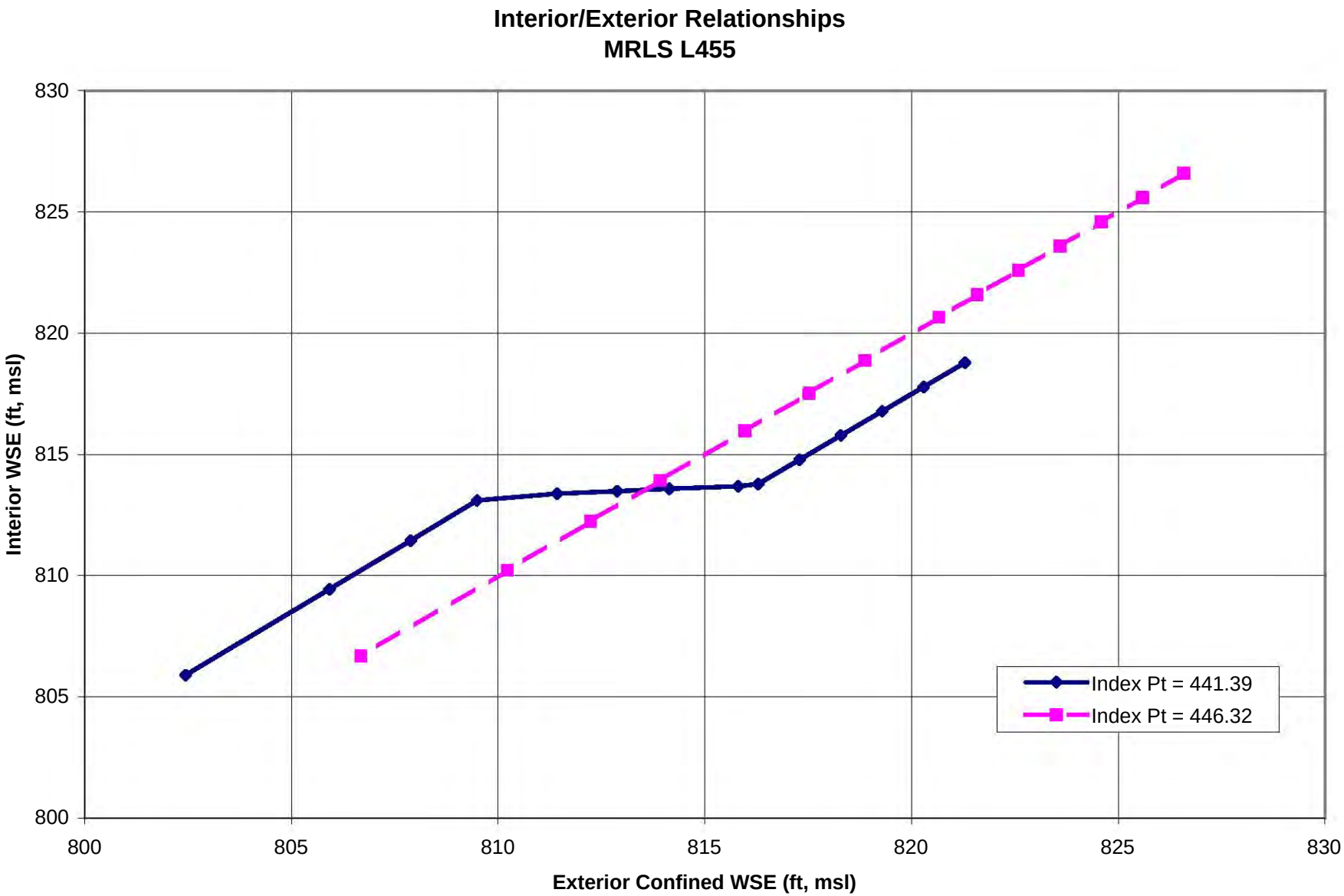
Date: 7/22/2006

Exhibit 2.14



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Checked: MMW
Date: 7/22/2006

Exhibit 2.15

Taken From the *Missouri River Stage Trends, RCC Technical Report A-04*

By USACE Northwest Division-Missouri River Basin Reservoir Control Center in Omaha, Nebraska

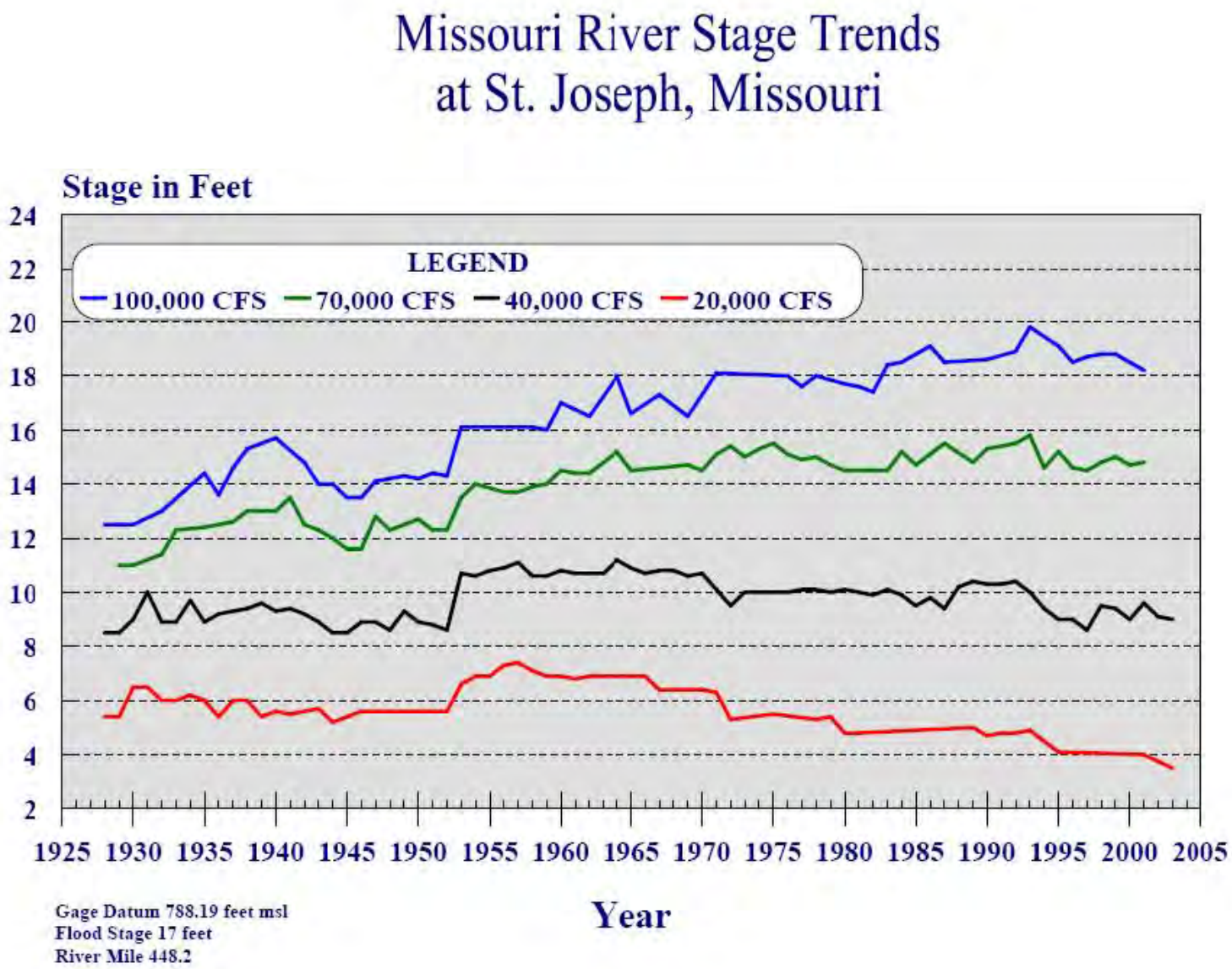


Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
428.61	50%	2	109000	750.79	789.5	772.59	789.88	0.000106	4.98	0.18
428.61	20%	5	147000	750.79	791.2	774.41	791.78	0.000152	6.19	0.22
428.61	10%	10	174000	750.79	792.3	775.58	793	0.000179	6.88	0.24
428.61	5%	20	199000	750.79	793.9	776.6	794.64	0.000182	7.17	0.24
428.61	2%	50	233000	750.79	795.1	777.95	795.96	0.000207	7.82	0.26
428.61	1%	100	261000	750.79	796.2	778.99	797.13	0.000218	8.2	0.27
428.61	0.5% (Confined)	200	287000	750.79	797.1	779.94	798.09	0.000228	8.57	0.27
428.61	0.2% (Confined)	500	324000	750.79	798.3	781.21	799.38	0.000241	9.04	0.28
429.22	50%	2	109000	758.58	789.83	775.38	790.32	0.000154	5.64	0.21
429.22	20%	5	147000	758.58	791.68	777.31	792.38	0.000205	6.83	0.25
429.22	10%	10	174000	758.58	792.87	778.52	793.69	0.000234	7.49	0.27
429.22	5%	20	199000	758.58	794.49	779.57	795.32	0.000228	7.67	0.27
429.22	2%	50	233000	758.58	795.78	780.93	796.7	0.000245	8.21	0.28
429.22	1%	100	261000	758.58	796.92	781.99	797.88	0.000249	8.51	0.28
429.22	0.5% (Confined)	200	287000	758.58	797.86	782.91	798.86	0.000255	8.8	0.29
429.22	0.2% (Confined)	500	324000	758.58	799.15	784.22	800.19	0.000266	9.12	0.3
429.99	50%	2	109000	746.8	790.46	769.37	790.74	0.000067	4.27	0.15
429.99	20%	5	147000	746.8	792.53	771.23	792.94	0.000091	5.21	0.17
429.99	10%	10	174000	746.8	793.85	772.4	794.34	0.000106	5.76	0.19
429.99	5%	20	199000	746.8	795.44	773.51	795.97	0.00011	6.05	0.19
429.99	2%	50	233000	746.8	796.8	774.88	797.4	0.000123	6.59	0.2
429.99	1%	100	261000	746.8	797.97	775.98	798.62	0.000132	6.91	0.21
429.99	0.5% (Confined)	200	287000	746.8	798.96	776.95	799.64	0.000142	7.16	0.22
429.99	0.2% (Confined)	500	324000	746.8	800.29	778.32	801.01	0.000151	7.48	0.23
430.67	50%	2	109000	760.18	790.64	776.52	791.16	0.000161	5.8	0.22
430.67	20%	5	147000	760.18	792.77	778.32	793.51	0.000209	7	0.25
430.67	10%	10	174000	760.18	794.11	779.52	795	0.000239	7.7	0.27
430.67	5%	20	199000	760.18	795.71	780.56	796.65	0.000244	8.05	0.28
430.67	2%	50	233000	760.18	797.11	781.92	798.15	0.000264	8.6	0.29
430.67	1%	100	261000	760.18	798.3	782.98	799.39	0.000271	8.92	0.3
430.67	0.5% (Confined)	200	287000	760.18	799.32	783.94	800.45	0.000276	9.19	0.3
430.67	0.2% (Confined)	500	324000	760.18	800.67	785.25	801.85	0.00028	9.54	0.3
431.4	50%	2	109000	762.29	791.39	774.79	791.78	0.000153	5.05	0.18
431.4	20%	5	147000	762.29	793.75	776.56	794.32	0.000198	6.09	0.21
431.4	10%	10	174000	762.29	795.25	777.72	795.91	0.000221	6.65	0.23
431.4	5%	20	199000	762.29	796.88	778.73	797.57	0.000225	6.93	0.23
431.4	2%	50	233000	762.29	798.38	780.06	799.15	0.000244	7.39	0.26
431.4	1%	100	261000	762.29	799.62	781.09	800.41	0.00025	7.62	0.26
431.4	0.5% (Confined)	200	287000	762.29	800.67	782.01	801.49	0.000255	7.82	0.26
431.4	0.2% (Confined)	500	324000	762.29	802.05	783.31	802.9	0.000258	8.07	0.27
431.97	50%	2	109000	762.1	791.8	776.72	792.32	0.000188	5.81	0.22
431.97	20%	5	147000	762.1	794.29	778.66	795	0.000233	6.84	0.25
431.97	10%	10	174000	762.1	795.85	779.96	796.66	0.000253	7.39	0.26
431.97	5%	20	199000	762.1	797.5	781.08	798.33	0.00026	7.62	0.26
431.97	2%	50	233000	762.1	799.06	782.52	799.96	0.000277	8.07	0.28
431.97	1%	100	261000	762.1	800.31	783.66	801.25	0.000284	8.36	0.28
431.97	0.5% (Confined)	200	287000	762.1	801.36	784.65	802.34	0.000291	8.61	0.28
431.97	0.2% (Confined)	500	324000	762.1	802.74	786.05	803.78	0.000296	8.96	0.29
432.69	50%	2	109000	762.83	792.53	775.81	793.01	0.000171	5.61	0.21
432.69	20%	5	147000	762.83	795.2	777.8	795.87	0.000218	6.62	0.24
432.69	10%	10	174000	762.83	796.83	779.11	797.6	0.000237	7.17	0.25
432.69	5%	20	199000	762.83	798.47	780.25	799.29	0.000238	7.46	0.26
432.69	2%	50	233000	762.83	800.07	781.73	800.97	0.000251	7.97	0.27
432.69	1%	100	261000	762.83	801.34	782.93	802.29	0.000257	8.31	0.27
432.69	0.5% (Confined)	200	287000	762.83	802.41	783.94	803.41	0.000264	8.61	0.28
432.69	0.2% (Confined)	500	324000	762.83	803.8	785.4	804.88	0.000273	9.02	0.28

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
433.4	50%	2	109000	766.99	793.25	780.1	793.67	0.000175	5.25	0.21
433.4	20%	5	147000	766.99	796.17	781.76	796.61	0.00017	5.63	0.21
433.4	10%	10	174000	766.99	797.93	782.82	798.36	0.000163	5.76	0.21
433.4	5%	20	199000	766.99	799.61	783.77	800.03	0.000149	5.75	0.2
433.4	2%	50	233000	766.99	801.31	785.01	801.73	0.000144	5.89	0.2
433.4	1%	100	261000	766.99	802.64	785.96	803.04	0.000139	5.96	0.2
433.4	0.5% (Confined)	200	287000	766.99	803.77	786.83	804.17	0.000134	6.02	0.2
433.4	0.2% (Confined)	500	324000	766.99	805.24	788.03	805.64	0.00013	6.12	0.19
433.805*	50%	2	109000	762.08	793.8	780.33	794.23	0.000178	5.34	0.21
433.805*	20%	5	147000	762.08	796.68	782.04	797.19	0.000186	5.91	0.22
433.805*	10%	10	174000	762.08	798.41	783.14	798.92	0.000182	6.1	0.22
433.805*	5%	20	199000	762.08	800.05	784.12	800.53	0.000167	6.09	0.21
433.805*	2%	50	233000	762.08	801.74	785.47	802.21	0.000162	6.23	0.21
433.805*	1%	100	261000	762.08	803.05	786.45	803.51	0.000155	6.3	0.21
433.805*	0.5% (Confined)	200	287000	762.08	804.16	787.32	804.62	0.000151	6.38	0.21
433.805*	0.2% (Confined)	500	324000	762.08	805.62	788.49	806.08	0.000147	6.5	0.21
434.21	50%	2	109000	757.17	794.43	780.11	794.83	0.000196	5.14	0.2
434.21	20%	5	147000	757.17	797.37	781.8	797.8	0.000193	5.52	0.2
434.21	10%	10	174000	757.17	799.09	782.9	799.51	0.000186	5.64	0.2
434.21	5%	20	199000	757.17	800.69	783.87	801.08	0.000173	5.65	0.2
434.21	2%	50	233000	757.17	802.35	785.13	802.75	0.000169	5.8	0.19
434.21	1%	100	261000	757.17	803.63	786.09	804.03	0.000165	5.9	0.19
434.21	0.5% (Confined)	200	287000	757.17	804.73	787	805.13	0.000162	6	0.19
434.21	0.2% (Confined)	500	324000	757.17	806.17	788.2	806.58	0.00016	6.15	0.19
434.61*	50%	2	109000	761.57	795.08	781.13	795.62	0.000285	5.96	0.24
434.61*	20%	5	147000	761.57	797.98	783.61	798.6	0.000293	6.56	0.25
434.61*	10%	10	174000	761.57	799.67	785.49	800.29	0.000285	6.76	0.25
434.61*	5%	20	199000	761.57	801.23	786.77	801.81	0.000261	6.73	0.24
434.61*	2%	50	233000	761.57	802.88	788.06	803.44	0.000244	6.79	0.23
434.61*	1%	100	261000	761.57	804.15	789.11	804.69	0.00023	6.8	0.23
434.61*	0.5% (Confined)	200	287000	761.57	805.25	790.02	805.77	0.00022	6.83	0.22
434.61*	0.2% (Confined)	500	324000	761.57	806.68	791.27	807.19	0.00021	6.89	0.22
435.01	50%	2	109000	765.96	795.92	780.42	796.37	0.000199	5.49	0.21
435.01	20%	5	147000	765.96	798.84	782.34	799.4	0.000221	6.21	0.22
435.01	10%	10	174000	765.96	800.48	783.59	801.1	0.000235	6.67	0.23
435.01	5%	20	199000	765.96	801.95	784.69	802.61	0.000239	6.95	0.23
435.01	2%	50	233000	765.96	803.54	786.13	804.25	0.000246	7.33	0.24
435.01	1%	100	261000	765.96	804.77	787.25	805.49	0.000247	7.55	0.24
435.01	0.5% (Confined)	200	287000	765.96	805.83	788.24	806.56	0.000247	7.71	0.24
435.01	0.2% (Confined)	500	324000	765.96	807.23	789.64	807.98	0.000245	7.92	0.24
435.395*	50%	2	109000	765.51	796.51	780.98	796.99	0.000202	5.54	0.21
435.395*	20%	5	147000	765.51	799.48	782.91	800.12	0.000237	6.47	0.23
435.395*	10%	10	174000	765.51	801.15	784.18	801.88	0.000257	7.01	0.24
435.395*	5%	20	199000	765.51	802.63	785.31	803.41	0.000265	7.37	0.25
435.395*	2%	50	233000	765.51	804.22	786.69	805.11	0.000287	7.95	0.26
435.395*	1%	100	261000	765.51	805.43	787.78	806.38	0.000296	8.3	0.26
435.395*	0.5% (Confined)	200	287000	765.51	806.48	788.78	807.46	0.000303	8.58	0.27
435.395*	0.2% (Confined)	500	324000	765.51	807.86	790.1	808.9	0.000312	8.96	0.27
435.78	50%	2	109000	765.05	797.14	781.2	797.58	0.000187	5.38	0.2
435.78	20%	5	147000	765.05	800.24	783.34	800.8	0.000209	6.14	0.21
435.78	10%	10	174000	765.05	801.98	784.54	802.61	0.000225	6.63	0.22
435.78	5%	20	199000	765.05	803.48	785.6	804.18	0.000233	6.99	0.23
435.78	2%	50	233000	765.05	805.16	786.95	805.93	0.000248	7.49	0.24
435.78	1%	100	261000	765.05	806.37	788	807.23	0.000265	7.95	0.25
435.78	0.5% (Confined)	200	287000	765.05	807.43	788.96	808.34	0.000275	8.27	0.26
435.78	0.2% (Confined)	500	324000	765.05	808.82	790.27	809.81	0.000288	8.71	0.26

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
436.43	50%	2	109000	764.81	797.83	782.36	798.19	0.000163	4.87	0.18
436.43	20%	5	147000	764.81	801.03	784.01	801.47	0.000178	5.48	0.2
436.43	10%	10	174000	764.81	802.84	785.11	803.33	0.000185	5.84	0.2
436.43	5%	20	199000	764.81	804.39	786.05	804.91	0.000187	6.11	0.2
436.43	2%	50	233000	764.81	806.14	787.28	806.71	0.000196	6.51	0.21
436.43	1%	100	261000	764.81	807.44	788.26	808.05	0.000203	6.82	0.22
436.43	0.5% (Confined)	200	287000	764.81	808.54	789.11	809.19	0.00021	7.1	0.22
436.43	0.2% (Confined)	500	324000	764.81	810	790.32	810.7	0.00022	7.48	0.23
437.11	50%	2	109000	767.88	798.38	781.01	798.76	0.000152	5.12	0.18
437.11	20%	5	147000	767.88	801.73	783.04	802.05	0.000141	5.07	0.18
437.11	10%	10	174000	767.88	803.6	784.27	803.9	0.000129	5.03	0.17
437.11	5%	20	199000	767.88	805.19	785.4	805.46	0.000121	5	0.16
437.11	2%	50	233000	767.88	806.99	786.78	807.26	0.000115	5.06	0.16
437.11	1%	100	261000	767.88	808.34	787.92	808.61	0.000111	5.13	0.16
437.11	0.5% (Confined)	200	287000	767.88	809.48	788.96	809.76	0.000109	5.2	0.16
437.11	0.2% (Confined)	500	324000	767.88	810.99	790.34	811.28	0.000108	5.32	0.16
437.85	50%	2	109000	770.79	798.98	782.5	799.38	0.000164	5.14	0.19
437.85	20%	5	147000	770.79	802.24	784.28	802.67	0.000164	5.55	0.19
437.85	10%	10	174000	770.79	804.05	785.45	804.49	0.00016	5.72	0.19
437.85	5%	20	199000	770.79	805.6	786.5	806.04	0.000155	5.83	0.19
437.85	2%	50	233000	770.79	807.38	787.8	807.82	0.000153	6.01	0.19
437.85	1%	100	261000	770.79	808.71	788.89	809.16	0.000151	6.15	0.19
437.85	0.5% (Confined)	200	287000	770.79	809.84	789.83	810.3	0.000151	6.28	0.19
437.85	0.2% (Confined)	500	324000	770.79	811.34	791.11	811.82	0.000151	6.47	0.19
438.48	50%	2	109000	764.52	799.54	779.43	799.82	0.000101	4.31	0.15
438.48	20%	5	147000	764.52	802.77	781.23	803.15	0.00012	5.02	0.17
438.48	10%	10	174000	764.52	804.55	782.39	804.98	0.000133	5.45	0.18
438.48	5%	20	199000	764.52	806.07	783.44	806.54	0.00014	5.77	0.18
438.48	2%	50	233000	764.52	807.82	784.76	808.35	0.000149	6.19	0.19
438.48	1%	100	261000	764.52	809.14	785.81	809.71	0.000156	6.49	0.19
438.48	0.5% (Confined)	200	287000	764.52	810.26	786.71	810.87	0.000163	6.78	0.2
438.48	0.2% (Confined)	500	324000	764.52	811.75	788.02	812.41	0.000171	7.14	0.21
439.16	50%	2	109000	752.48	799.89	776.93	800.19	0.0001	4.36	0.15
439.16	20%	5	147000	752.48	803.19	778.91	803.59	0.000124	5.15	0.17
439.16	10%	10	174000	752.48	805	780.21	805.48	0.00014	5.66	0.18
439.16	5%	20	199000	752.48	806.54	781.37	807.09	0.000156	6.07	0.19
439.16	2%	50	233000	752.48	808.32	782.83	808.96	0.000173	6.62	0.2
439.16	1%	100	261000	752.48	809.64	784	810.36	0.000186	7.04	0.21
439.16	0.5% (Confined)	200	287000	752.48	810.77	785	811.56	0.000197	7.42	0.22
439.16	0.2% (Confined)	500	324000	752.48	812.27	786.44	813.16	0.000213	7.93	0.23
439.93	50%	2	109000	772.31	800.33	786.42	800.91	0.000284	6.25	0.24
439.93	20%	5	147000	772.31	803.76	788.51	804.37	0.000267	6.62	0.24
439.93	10%	10	174000	772.31	805.67	789.9	806.28	0.00026	6.83	0.24
439.93	5%	20	199000	772.31	807.29	791.02	807.9	0.00025	6.96	0.24
439.93	2%	50	233000	772.31	809.17	792.65	809.79	0.000243	7.16	0.24
439.93	1%	100	261000	772.31	810.6	793.86	811.22	0.000237	7.3	0.23
439.93	0.5% (Confined)	200	287000	772.31	811.82	794.95	812.45	0.000234	7.44	0.23
439.93	0.2% (Confined)	500	324000	772.31	813.44	797.2	814.08	0.00023	7.63	0.23
440.82	50%	2	109000	768.93	801.96	784.09	802.36	0.000152	5.1	0.18
440.82	20%	5	147000	768.93	805.33	786.08	805.86	0.000176	5.91	0.2
440.82	10%	10	174000	768.93	807.19	787.31	807.8	0.000192	6.43	0.21
440.82	5%	20	199000	768.93	808.77	788.41	809.46	0.000203	6.85	0.22
440.82	2%	50	233000	768.93	810.62	789.79	811.4	0.00022	7.42	0.23
440.82	1%	100	261000	768.93	812.01	790.9	812.88	0.000233	7.84	0.24
440.82	0.5% (Confined)	200	287000	768.93	813.21	791.91	814.14	0.000244	8.21	0.24
440.82	0.2% (Confined)	500	324000	768.93	814.79	793.25	815.83	0.000259	8.72	0.25

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
441.39	50%	2	109000	766.92	802.44	787.1	802.88	0.000195	5.4	0.2
441.39	20%	5	147000	766.92	805.92	788.99	806.43	0.000208	5.92	0.21
441.39	10%	10	174000	766.92	807.85	790.18	808.39	0.000208	6.23	0.21
441.39	5%	20	199000	766.92	809.49	791.19	810.06	0.000207	6.48	0.22
441.39	2%	50	233000	766.92	811.42	792.59	812.04	0.000211	6.84	0.22
441.39	1%	100	261000	766.92	812.88	793.62	813.53	0.000214	7.11	0.22
441.39	0.5% (Confined)	200	287000	766.92	814.14	794.61	814.82	0.000217	7.34	0.23
441.39	0.2% (Confined)	500	324000	766.92	815.81	795.9	816.54	0.000221	7.67	0.23
441.88	50%	2	109000	770.62	802.97	788.88	803.4	0.000201	5.28	0.2
441.88	20%	5	147000	770.62	806.47	790.59	806.94	0.000195	5.72	0.21
441.88	10%	10	174000	770.62	808.4	791.71	808.9	0.000194	6	0.21
441.88	5%	20	199000	770.62	810.04	792.67	810.56	0.000193	6.24	0.21
441.88	2%	50	233000	770.62	811.98	793.93	812.54	0.000195	6.56	0.21
441.88	1%	100	261000	770.62	813.45	794.93	814.04	0.000197	6.82	0.22
441.88	0.5% (Confined)	200	287000	770.62	814.71	795.84	815.33	0.0002	7.05	0.22
441.88	0.2% (Confined)	500	324000	770.62	816.39	797.05	817.05	0.000204	7.36	0.22
442.51	50%	2	109000	774.45	803.63	787.81	804.03	0.000182	5.14	0.2
442.51	20%	5	147000	774.45	807.11	789.64	807.6	0.000204	5.77	0.21
442.51	10%	10	174000	774.45	809.02	790.85	809.57	0.000212	6.19	0.22
442.51	5%	20	199000	774.45	810.63	791.88	811.25	0.000218	6.55	0.22
442.51	2%	50	233000	774.45	812.56	793.24	813.26	0.00023	7.03	0.23
442.51	1%	100	261000	774.45	814.02	794.31	814.78	0.000239	7.41	0.24
442.51	0.5% (Confined)	200	287000	774.45	815.27	795.25	816.1	0.000247	7.74	0.24
442.51	0.2% (Confined)	500	324000	774.45	816.94	796.55	817.85	0.000258	8.2	0.25
442.97	50%	2	109000	770.48	803.99	786.19	804.43	0.000144	5.32	0.19
442.97	20%	5	147000	770.48	807.5	788.54	808.05	0.000157	6.04	0.21
442.97	10%	10	174000	770.48	809.42	789.96	810.04	0.000166	6.52	0.22
442.97	5%	20	199000	770.48	811.05	791.23	811.74	0.000173	6.91	0.22
442.97	2%	50	233000	770.48	813	793.07	813.78	0.000184	7.42	0.23
442.97	1%	100	261000	770.48	814.47	794.27	815.32	0.000192	7.82	0.24
442.97	0.5% (Confined)	200	287000	770.48	815.74	795.25	816.65	0.000199	8.17	0.25
442.97	0.2% (Confined)	500	324000	770.48	817.43	796.6	818.43	0.000209	8.64	0.25
443.46	50%	2	109000	772.82	804.37	787.17	804.82	0.000152	5.41	0.2
443.46	20%	5	147000	772.82	807.91	789.46	808.47	0.000166	6.14	0.21
443.46	10%	10	174000	772.82	809.85	790.87	810.5	0.000176	6.62	0.22
443.46	5%	20	199000	772.82	811.5	792.16	812.21	0.000183	7.03	0.23
443.46	2%	50	233000	772.82	813.47	793.97	814.28	0.000195	7.57	0.24
443.46	1%	100	261000	772.82	814.96	795.08	815.85	0.000204	7.98	0.25
443.46	0.5% (Confined)	200	287000	772.82	816.24	796.08	817.2	0.000212	8.35	0.25
443.46	0.2% (Confined)	500	324000	772.82	817.95	797.44	819.02	0.000223	8.84	0.26
443.95	50%	2	109000	777.34	804.79	791.54	805.28	0.000199	5.69	0.22
443.95	20%	5	147000	777.34	808.36	793.37	808.94	0.000196	6.28	0.23
443.95	10%	10	174000	777.34	810.34	794.52	810.98	0.000201	6.71	0.23
443.95	5%	20	199000	777.34	812.01	795.54	812.71	0.000206	7.07	0.24
443.95	2%	50	233000	777.34	814.02	796.87	814.8	0.000213	7.56	0.25
443.95	1%	100	261000	777.34	815.53	797.92	816.39	0.00022	7.93	0.25
443.95	0.5% (Confined)	200	287000	777.34	816.85	798.86	817.77	0.000226	8.27	0.26
443.95	0.2% (Confined)	500	324000	777.34	818.59	800.12	819.6	0.000234	8.73	0.27
444.35	50%	2	109000	770.31	805.18	789.01	805.66	0.000171	5.65	0.21
444.35	20%	5	147000	770.31	808.74	791.84	809.34	0.00018	6.36	0.22
444.35	10%	10	174000	770.31	810.72	793.06	811.39	0.000189	6.84	0.23
444.35	5%	20	199000	770.31	812.39	794.17	813.14	0.000196	7.25	0.24
444.35	2%	50	233000	770.31	814.41	795.56	815.25	0.000207	7.78	0.24
444.35	1%	100	261000	770.31	815.93	796.69	816.86	0.000215	8.18	0.25
444.35	0.5% (Confined)	200	287000	770.31	817.26	797.67	818.25	0.000222	8.54	0.26
444.35	0.2% (Confined)	500	324000	770.31	819.01	799.04	820.1	0.000232	9.03	0.27

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
444.86	50%	2	109000	770.16	805.75	786.54	806.05	0.00011	4.42	0.16
444.86	20%	5	147000	770.16	809.36	788.35	809.75	0.000122	5.07	0.17
444.86	10%	10	174000	770.16	811.39	789.51	811.83	0.000131	5.5	0.17
444.86	5%	20	199000	770.16	813.1	790.54	813.59	0.000138	5.86	0.18
444.86	2%	50	233000	770.16	815.17	791.89	815.74	0.000148	6.33	0.19
444.86	1%	100	261000	770.16	816.74	792.91	817.36	0.000156	6.68	0.2
444.86	0.5% (Confined)	200	287000	770.16	818.1	793.87	818.77	0.000163	7	0.2
444.86	0.2% (Confined)	500	324000	770.16	819.9	795.15	820.65	0.000172	7.43	0.21
445.33	50%	2	109000	775.29	805.98	789.41	806.37	0.00013	5.06	0.19
445.33	20%	5	147000	775.29	809.61	791.38	810.1	0.00014	5.73	0.2
445.33	10%	10	174000	775.29	811.65	792.56	812.21	0.000149	6.18	0.2
445.33	5%	20	199000	775.29	813.37	793.57	813.99	0.000155	6.56	0.21
445.33	2%	50	233000	775.29	815.45	794.92	816.16	0.000164	7.05	0.22
445.33	1%	100	261000	775.29	817.03	795.99	817.8	0.000171	7.43	0.23
445.33	0.5% (Confined)	200	287000	775.29	818.39	796.91	819.23	0.000177	7.77	0.23
445.33	0.2% (Confined)	500	324000	775.29	820.21	798.2	821.14	0.000185	8.22	0.24
445.86	50%	2	109000	776.53	806.31	791.26	806.84	0.000182	5.83	0.22
445.86	20%	5	147000	776.53	809.96	793.21	810.61	0.000194	6.59	0.23
445.86	10%	10	174000	776.53	812	794.48	812.75	0.000205	7.08	0.24
445.86	5%	20	199000	776.53	813.73	795.59	814.55	0.000213	7.5	0.25
445.86	2%	50	233000	776.53	815.83	796.99	816.75	0.000222	8.02	0.25
445.86	1%	100	261000	776.53	817.41	798.14	818.41	0.000229	8.42	0.26
445.86	0.5% (Confined)	200	287000	776.53	818.79	799.15	819.86	0.000235	8.78	0.27
445.86	0.2% (Confined)	500	324000	776.53	820.62	800.49	821.79	0.000244	9.26	0.27
446.32	50%	2	109000	776.46	806.75	791.59	807.32	0.000207	6.1	0.23
446.32	20%	5	147000	776.46	810.43	794.19	811.11	0.000215	6.78	0.24
446.32	10%	10	174000	776.46	812.51	795.58	813.26	0.000222	7.22	0.25
446.32	5%	20	199000	776.46	814.26	796.72	815.08	0.000228	7.6	0.25
446.32	2%	50	233000	776.46	816.4	798.15	817.3	0.000239	8.07	0.26
446.32	1%	100	261000	776.46	818.01	799.32	818.98	0.000244	8.44	0.27
446.32	0.5% (Confined)	200	287000	776.46	819.41	800.34	820.44	0.000249	8.77	0.27
446.32	0.2% (Confined)	500	324000	776.46	821.27	801.75	822.39	0.000254	9.2	0.28
446.81	50%	2	109000	773.96	807.33	789.5	807.77	0.00014	5.36	0.19
446.81	20%	5	147000	773.96	811.03	791.61	811.6	0.000161	6.11	0.21
446.81	10%	10	174000	773.96	813.12	792.95	813.77	0.000171	6.59	0.22
446.81	5%	20	199000	773.96	814.88	794.11	815.6	0.000178	7	0.23
446.81	2%	50	233000	773.96	817.02	795.62	817.84	0.000188	7.52	0.23
446.81	1%	100	261000	773.96	818.64	796.82	819.54	0.000195	7.92	0.24
446.81	0.5% (Confined)	200	287000	773.96	820.05	797.86	821.01	0.000201	8.27	0.25
446.81	0.2% (Confined)	500	324000	773.96	821.92	799.3	822.98	0.000209	8.73	0.25
447.15	50%	2	109000	772.65	807.55	790.74	808.05	0.00016	5.71	0.21
447.15	20%	5	147000	772.65	811.27	792.79	811.92	0.000177	6.54	0.22
447.15	10%	10	174000	772.65	813.36	794.12	814.12	0.000188	7.08	0.23
447.15	5%	20	199000	772.65	815.13	795.33	815.97	0.000197	7.52	0.24
447.15	2%	50	233000	772.65	817.28	796.86	818.23	0.000208	8.09	0.25
447.15	1%	100	261000	772.65	818.9	798.05	819.94	0.000217	8.53	0.26
447.15	0.5% (Confined)	200	287000	772.65	820.3	799.1	821.43	0.000225	8.92	0.26
447.15	0.2% (Confined)	500	324000	772.65	822.17	800.57	823.42	0.000235	9.43	0.27
447.49	50%	2	109000	776.69	807.91	790	808.33	0.000133	5.21	0.19
447.49	20%	5	147000	776.69	811.68	791.99	812.23	0.000149	6	0.2
447.49	10%	10	174000	776.69	813.8	793.28	814.45	0.00016	6.52	0.21
447.49	5%	20	199000	776.69	815.58	794.38	816.31	0.000167	6.95	0.22
447.49	2%	50	233000	776.69	817.77	795.87	818.59	0.000176	7.47	0.23
447.49	1%	100	261000	776.69	819.43	797.03	820.32	0.000182	7.83	0.23
447.49	0.5% (Confined)	200	287000	776.69	820.88	798.03	821.83	0.000186	8.14	0.24
447.49	0.2% (Confined)	500	324000	776.69	822.81	799.46	823.83	0.00019	8.53	0.24

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
447.83	50%	2	109000	773	808.24	783.47	808.51	0.00006	4.2	0.13
447.83	20%	5	147000	773	812.06	785.47	812.44	0.000072	4.98	0.15
447.83	10%	10	174000	773	814.22	786.78	814.68	0.000082	5.5	0.16
447.83	5%	20	199000	773	816.03	787.92	816.56	0.00009	5.94	0.17
447.83	2%	50	233000	773	818.23	789.39	818.86	0.0001	6.52	0.18
447.83	1%	100	261000	773	819.89	790.56	820.6	0.000108	6.96	0.19
447.83	0.5% (Confined)	200	287000	773	821.33	791.62	822.12	0.000115	7.34	0.19
447.83	0.2% (Confined)	500	324000	773	823.25	793.03	824.13	0.000124	7.83	0.2
447.84	50%	2	109000	773	808.22	783.87	808.52	0.000079	4.38	0.14
447.84	20%	5	147000	773	812.05	785.95	812.46	0.000097	5.19	0.15
447.84	10%	10	174000	773	814.2	787.31	814.7	0.00011	5.73	0.17
447.84	5%	20	199000	773	816.01	788.49	816.58	0.000122	6.19	0.18
447.84	2%	50	233000	773	818.21	790.04	818.89	0.000138	6.78	0.19
447.84	1%	100	261000	773	819.86	791.21	820.63	0.00015	7.23	0.19
447.84	0.5% (Confined)	200	287000	773	821.3	792.3	822.14	0.000161	7.62	0.2
447.84	0.2% (Confined)	500	324000	773	823.21	793.77	824.17	0.000175	8.14	0.21
447.85	50%	2	109000	773	808.26	783.47	808.53	0.00006	4.2	0.13
447.85	20%	5	147000	773	812.09	785.47	812.47	0.000072	4.97	0.15
447.85	10%	10	174000	773	814.25	786.78	814.71	0.000081	5.49	0.16
447.85	5%	20	199000	773	816.06	787.92	816.59	0.000089	5.94	0.17
447.85	2%	50	233000	773	818.27	789.39	818.9	0.0001	6.51	0.18
447.85	1%	100	261000	773	819.93	790.56	820.64	0.000108	6.95	0.19
447.85	0.5% (Confined)	200	287000	773	821.38	791.62	822.16	0.000115	7.33	0.19
447.85	0.2% (Confined)	500	324000	773	823.3	793.03	824.18	0.000124	7.82	0.2
447.86	50%	2	109000	771.61	808.25	787.96	808.54	0.00008	4.32	0.15
447.86	20%	5	147000	771.61	812.08	789.73	812.48	0.000094	5.05	0.16
447.86	10%	10	174000	771.61	814.25	790.89	814.72	0.000103	5.54	0.17
447.86	5%	20	199000	771.61	816.06	791.9	816.6	0.00011	5.96	0.18
447.86	2%	50	233000	771.61	818.27	793.22	818.91	0.00012	6.49	0.19
447.86	1%	100	261000	771.61	819.93	794.23	820.65	0.000128	6.91	0.2
447.86	0.5% (Confined)	200	287000	771.61	821.38	795.16	822.17	0.000135	7.27	0.21
447.86	0.2% (Confined)	500	324000	771.61	823.31	796.44	824.19	0.000143	7.73	0.21
448.15	50%	2	109000	773.29	808.27	789.42	808.78	0.000151	5.71	0.2
448.15	20%	5	147000	773.29	812.09	791.73	812.76	0.000173	6.62	0.22
448.15	10%	10	174000	773.29	814.24	793.21	815.04	0.000187	7.22	0.23
448.15	5%	20	199000	773.29	816.04	794.51	816.95	0.000199	7.74	0.24
448.15	2%	50	233000	773.29	818.22	796.2	819.29	0.000215	8.41	0.25
448.15	1%	100	261000	773.29	819.87	797.51	821.07	0.000228	8.93	0.26
448.15	0.5% (Confined)	200	287000	773.29	821.3	798.65	822.61	0.000239	9.4	0.27
448.15	0.2% (Confined)	500	324000	773.29	823.19	800.27	824.68	0.000255	10.02	0.28
448.16			Bridge							
448.17	50%	2	109000	773.29	808.33	789.42	808.83	0.00015	5.69	0.2
448.17	20%	5	147000	773.29	812.16	791.73	812.83	0.000171	6.6	0.22
448.17	10%	10	174000	773.29	814.32	793.21	815.12	0.000185	7.2	0.23
448.17	5%	20	199000	773.29	816.13	794.51	817.04	0.000197	7.72	0.24
448.17	2%	50	233000	773.29	818.33	796.2	819.39	0.000213	8.38	0.25
448.17	1%	100	261000	773.29	820.02	797.51	821.2	0.000224	8.89	0.26
448.17	0.5% (Confined)	200	287000	773.29	821.49	798.65	822.79	0.000235	9.34	0.27
448.17	0.2% (Confined)	500	324000	773.29	823.47	800.27	824.93	0.000248	9.94	0.28
448.2	50%	2	109000	773.29	808.35	789.41	808.85	0.000149	5.69	0.2
448.2	20%	5	147000	773.29	812.19	791.73	812.86	0.00018	6.58	0.22
448.2	10%	10	174000	773.29	814.36	793.21	815.15	0.000193	7.16	0.23
448.2	5%	20	199000	773.29	816.18	794.5	817.07	0.000204	7.66	0.24
448.2	2%	50	233000	773.29	818.39	796.2	819.43	0.000218	8.3	0.25
448.2	1%	100	261000	773.29	820.08	797.51	821.24	0.000229	8.79	0.26
448.2	0.5% (Confined)	200	287000	773.29	821.56	798.67	822.84	0.000239	9.23	0.27

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
448.2	0.2% (Confined)	500	324000	773.29	823.55	800.27	824.98	0.000251	9.81	0.28
448.49	50%	2	109000	775.4	808.76	791.55	809.09	0.000106	4.59	0.17
448.49	20%	5	147000	775.4	812.71	793.19	813.14	0.000116	5.27	0.18
448.49	10%	10	174000	775.4	814.95	794.29	815.45	0.000124	5.73	0.19
448.49	5%	20	199000	775.4	816.82	795.24	817.39	0.000131	6.12	0.19
448.49	2%	50	233000	775.4	819.11	796.49	819.78	0.00014	6.63	0.2
448.49	1%	100	259000	775.4	820.88	797.4	821.61	0.000144	6.96	0.21
448.49	0.5% (Confined)	200	287000	775.4	822.41	798.33	823.22	0.000152	7.35	0.21
448.49	0.2% (Confined)	500	324000	775.4	824.49	799.52	825.39	0.000158	7.79	0.22
448.89	50%	2	109000	774.34	808.92	791.81	809.42	0.000159	5.69	0.2
448.89	20%	5	147000	774.34	812.86	793.96	813.49	0.00017	6.45	0.22
448.89	10%	10	174000	774.34	815.11	795.59	815.83	0.000179	6.95	0.23
448.89	5%	20	199000	774.34	816.99	796.74	817.79	0.000187	7.39	0.23
448.89	2%	50	233000	774.34	819.28	798.22	820.2	0.000199	7.95	0.24
448.89	1%	100	259000	774.34	821.06	799.33	822.05	0.000209	8.3	0.25
448.89	0.5% (Confined)	200	287000	774.34	822.6	800.46	823.68	0.000219	8.71	0.26
448.89	0.2% (Confined)	500	324000	774.34	824.68	801.88	825.87	0.000225	9.17	0.26
449.44	50%	2	109000	782.5	809.4	794.8	809.98	0.000224	6.12	0.24
449.44	20%	5	147000	782.5	813.38	796.95	814.06	0.000218	6.7	0.24
449.44	10%	10	174000	782.5	815.66	798.36	816.4	0.000217	7.08	0.24
449.44	5%	20	199000	782.5	817.58	799.57	818.37	0.000216	7.4	0.25
449.44	2%	50	233000	782.5	819.94	801.13	820.8	0.000218	7.81	0.25
449.44	1%	100	259000	782.5	821.76	802.25	822.66	0.000216	8.06	0.25
449.44	0.5% (Confined)	200	287000	782.5	823.35	803.4	824.32	0.000219	8.39	0.26
449.44	0.2% (Confined)	500	324000	782.5	825.47	804.86	826.51	0.00022	8.76	0.26
449.99	50%	2	109000	779.32	810.08	793.39	810.52	0.000146	5.33	0.2
449.99	20%	5	147000	779.32	814.06	795.6	814.61	0.000153	6.01	0.2
449.99	10%	10	174000	779.32	816.34	797	816.95	0.000158	6.43	0.21
449.99	5%	20	199000	779.32	818.27	798.09	818.93	0.000161	6.76	0.21
449.99	2%	50	233000	779.32	820.64	799.47	821.37	0.000164	7.18	0.22
449.99	1%	100	259000	779.32	822.45	800.47	823.23	0.000165	7.45	0.22
449.99	0.5% (Confined)	200	287000	779.32	824.06	801.51	824.9	0.000169	7.78	0.23
449.99	0.2% (Confined)	500	324000	779.32	826.2	802.84	827.1	0.000173	8.16	0.23
450.52	50%	2	109000	779.55	810.5	795.49	810.97	0.00017	5.49	0.21
450.52	20%	5	147000	779.55	814.49	797.31	815.08	0.000177	6.18	0.22
450.52	10%	10	174000	779.55	816.77	798.54	817.45	0.000184	6.63	0.23
450.52	5%	20	199000	779.55	818.71	799.61	819.43	0.000187	6.95	0.23
450.52	2%	50	233000	779.55	821.11	800.98	821.87	0.000189	7.25	0.23
450.52	1%	100	259000	779.55	822.94	801.96	823.71	0.00018	7.36	0.23
450.52	0.5% (Confined)	200	287000	779.55	824.6	803	825.39	0.000177	7.55	0.23
450.52	0.2% (Confined)	500	324000	779.55	826.79	804.3	827.59	0.000169	7.7	0.23
451.09	50%	2	109000	776.43	811	794.06	811.43	0.000139	5.3	0.19
451.09	20%	5	147000	776.43	815	795.94	815.57	0.000152	6.07	0.2
451.09	10%	10	174000	776.43	817.33	797.17	817.96	0.000157	6.46	0.21
451.09	5%	20	199000	776.43	819.3	798.24	819.95	0.000155	6.67	0.21
451.09	2%	50	233000	776.43	821.72	799.65	822.38	0.000149	6.86	0.21
451.09	1%	100	259000	776.43	823.54	800.65	824.19	0.000142	6.95	0.21
451.09	0.5% (Confined)	200	287000	776.43	825.2	801.74	825.86	0.000139	7.1	0.21
451.09	0.2% (Confined)	500	324000	776.43	827.38	803.1	828.04	0.000134	7.24	0.2
451.41	50%	2	109000	777.14	811.21	795.7	811.7	0.000165	5.61	0.21
451.41	20%	5	147000	777.14	815.25	797.55	815.86	0.000174	6.33	0.22
451.41	10%	10	174000	777.14	817.58	798.78	818.25	0.000176	6.71	0.22
451.41	5%	20	199000	777.14	819.54	799.83	820.24	0.000174	6.96	0.22
451.41	2%	50	233000	777.14	821.93	801.22	822.67	0.000171	7.26	0.22
451.41	1%	100	259000	777.14	823.73	802.25	824.48	0.000167	7.44	0.22
451.41	0.5% (Confined)	200	287000	777.14	825.37	803.32	826.15	0.000166	7.66	0.22
451.41	0.2% (Confined)	500	324000	777.14	827.52	804.65	828.33	0.000163	7.89	0.22

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
451.88	50%	2	109000	784.26	811.62	797.61	812.2	0.000216	6.13	0.24
451.88	20%	5	147000	784.26	815.7	799.58	816.34	0.000205	6.58	0.24
451.88	10%	10	174000	784.26	818.06	800.84	818.72	0.000197	6.8	0.23
451.88	5%	20	199000	784.26	820.02	801.96	820.7	0.00019	6.98	0.23
451.88	2%	50	233000	784.26	822.43	803.4	823.11	0.000178	7.15	0.23
451.88	1%	100	259000	784.26	824.24	804.43	824.91	0.000167	7.18	0.22
451.88	0.5% (Confined)	200	287000	784.26	825.9	805.51	826.57	0.00016	7.27	0.22
451.88	0.2% (Confined)	500	324000	784.26	828.07	806.89	828.73	0.00015	7.33	0.21
452.31	50%	2	109000	778.18	812.18	795.08	812.64	0.000166	5.45	0.21
452.31	20%	5	147000	778.18	816.19	797.06	816.77	0.000175	6.16	0.22
452.31	10%	10	174000	778.18	818.5	798.35	819.14	0.000179	6.52	0.22
452.31	5%	20	199000	778.18	820.45	799.43	821.11	0.000174	6.69	0.22
452.31	2%	50	233000	778.18	822.85	800.94	823.5	0.000167	6.84	0.22
452.31	1%	100	259000	778.18	824.62	801.97	825.27	0.000158	6.91	0.21
452.31	0.5% (Confined)	200	287000	778.18	826.26	803.09	826.92	0.000153	7.04	0.21
452.31	0.2% (Confined)	500	324000	778.18	828.4	804.47	829.06	0.000146	7.14	0.21
452.8	50%	2	109000	775.07	812.62	792.7	812.99	0.000104	4.84	0.17
452.8	20%	5	147000	775.07	816.68	794.66	817.15	0.000115	5.55	0.18
452.8	10%	10	174000	775.07	819.02	795.97	819.53	0.000116	5.84	0.18
452.8	5%	20	199000	775.07	820.97	797.11	821.48	0.000115	6.03	0.18
452.8	2%	50	233000	775.07	823.33	798.52	823.87	0.000114	6.26	0.18
452.8	1%	100	259000	775.07	825.08	799.63	825.62	0.000112	6.38	0.18
452.8	0.5% (Confined)	200	287000	775.07	826.71	800.74	827.26	0.000112	6.53	0.19
452.8	0.2% (Confined)	500	324000	775.07	828.83	802.12	829.39	0.00011	6.68	0.19
453.44	50%	2	109000	780.74	812.99	796.38	813.39	0.000134	5.1	0.19
453.44	20%	5	147000	780.74	817.08	798.22	817.59	0.000142	5.76	0.2
453.44	10%	10	174000	780.74	819.43	799.41	819.97	0.000142	6.04	0.2
453.44	5%	20	199000	780.74	821.36	800.46	821.92	0.000139	6.24	0.2
453.44	2%	50	233000	780.74	823.71	801.8	824.29	0.000136	6.47	0.2
453.44	1%	100	259000	780.74	825.45	802.8	826.04	0.000132	6.6	0.2
453.44	0.5% (Confined)	200	287000	780.74	827.07	803.83	827.68	0.000131	6.78	0.2
453.44	0.2% (Confined)	500	324000	780.74	829.18	805.14	829.81	0.000128	6.97	0.2
454.64	50%	2	109000	786.19	813.85	797.51	814.22	0.000125	4.86	0.18
454.64	20%	5	147000	786.19	817.99	799.25	818.44	0.000128	5.45	0.19
454.64	10%	10	174000	786.19	820.33	800.39	820.82	0.000128	5.72	0.19
454.64	5%	20	199000	786.19	822.24	801.37	822.74	0.000125	5.9	0.19
454.64	2%	50	233000	786.19	824.57	802.66	825.09	0.000122	6.12	0.19
454.64	1%	100	259000	786.19	826.28	803.6	826.81	0.000118	6.24	0.19
454.64	0.5% (Confined)	200	287000	786.19	827.9	804.56	828.44	0.000117	6.4	0.19
454.64	0.2% (Confined)	500	324000	786.19	829.98	805.76	830.54	0.000114	6.57	0.19
455.05	50%	2	109000	769.11	814.13	800.55	814.56	0.000179	5.27	0.21
455.05	20%	5	147000	769.11	818.27	802.25	818.78	0.000172	5.77	0.21
455.05	10%	10	174000	769.11	820.6	803.33	821.16	0.000168	6.06	0.21
455.05	5%	20	199000	769.11	822.51	804.3	823.08	0.000164	6.25	0.21
455.05	2%	50	233000	769.11	824.82	805.52	825.41	0.000158	6.48	0.21
455.05	1%	100	259000	769.11	826.52	806.44	827.12	0.000151	6.57	0.21
455.05	0.5% (Confined)	200	287000	769.11	828.14	807.38	828.74	0.000147	6.71	0.21
455.05	0.2% (Confined)	500	324000	769.11	830.22	808.56	830.83	0.000141	6.84	0.2
455.65	50%	2	109000	784.46	814.68	801.15	815.13	0.00018	5.42	0.21
455.65	20%	5	147000	784.46	818.8	802.88	819.33	0.000174	5.92	0.22
455.65	10%	10	174000	784.46	821.13	803.98	821.68	0.000167	6.17	0.21
455.65	5%	20	199000	784.46	823.01	804.97	823.59	0.000162	6.35	0.21
455.65	2%	50	233000	784.46	825.31	806.23	825.9	0.000156	6.59	0.21
455.65	1%	100	259000	784.46	826.99	807.13	827.59	0.000152	6.73	0.21
455.65	0.5% (Confined)	200	287000	784.46	828.58	808.1	829.21	0.00015	6.91	0.21
455.65	0.2% (Confined)	500	324000	784.46	830.64	809.32	831.29	0.000146	7.11	0.21

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
456.24	50%	2	109000	781.09	815.23	799.36	815.66	0.000153	5.22	0.2
456.24	20%	5	147000	781.09	819.34	801.38	819.84	0.000152	5.77	0.2
456.24	10%	10	174000	781.09	821.65	802.59	822.19	0.000155	6.06	0.21
456.24	5%	20	199000	781.09	823.52	803.62	824.07	0.00015	6.23	0.21
456.24	2%	50	233000	781.09	825.81	805	826.37	0.000144	6.43	0.2
456.24	1%	100	259000	781.09	827.48	805.96	828.05	0.000139	6.54	0.2
456.24	0.5% (Confined)	200	287000	781.09	829.07	806.99	829.66	0.000137	6.7	0.2
456.24	0.2% (Confined)	500	324000	781.09	831.13	808.3	831.73	0.000133	6.86	0.2
456.84	50%	2	109000	780.28	815.72	796.31	816.07	0.000111	4.73	0.17
456.84	20%	5	147000	780.28	819.82	798.45	820.27	0.000118	5.38	0.18
456.84	10%	10	174000	780.28	822.18	799.88	822.66	0.000118	5.67	0.18
456.84	5%	20	199000	780.28	824.14	800.99	824.64	0.000115	5.85	0.18
456.84	2%	50	233000	780.28	826.55	802.44	827.05	0.000111	6.03	0.18
456.84	1%	100	259000	780.28	828.3	803.51	828.81	0.000107	6.14	0.18
456.84	0.5% (Confined)	200	287000	780.28	829.98	804.63	830.5	0.000105	6.28	0.18
456.84	0.2% (Confined)	500	324000	780.28	832.13	805.98	832.65	0.000103	6.42	0.18
457.25	50%	2	109000	783.2	815.88	800.5	816.46	0.000206	6.1	0.23
457.25	20%	5	147000	783.2	820	802.8	820.67	0.000203	6.7	0.24
457.25	10%	10	174000	783.2	822.34	804.3	823.07	0.000203	7.06	0.24
457.25	5%	20	199000	783.2	824.28	805.56	825.04	0.0002	7.32	0.24
457.25	2%	50	233000	783.2	826.68	807.09	827.46	0.000194	7.6	0.24
457.25	1%	100	259000	783.2	828.43	808.22	829.22	0.000186	7.72	0.24
457.25	0.5% (Confined)	200	287000	783.2	830.11	809.38	830.91	0.000182	7.88	0.23
457.25	0.2% (Confined)	500	324000	783.2	832.26	810.85	833.07	0.000176	8.06	0.23
457.7	50%	2	109000	770.55	816.36	800.07	816.91	0.00018	5.99	0.22
457.7	20%	5	147000	770.55	820.45	802.13	821.14	0.000194	6.75	0.23
457.7	10%	10	174000	770.55	822.8	803.48	823.54	0.000193	7.09	0.23
457.7	5%	20	199000	770.55	824.74	804.67	825.5	0.000188	7.31	0.23
457.7	2%	50	233000	770.55	827.14	806.18	827.9	0.00018	7.52	0.23
457.7	1%	100	259000	770.55	828.88	807.31	829.63	0.000174	7.63	0.23
457.7	0.5% (Confined)	200	287000	770.55	830.55	808.47	831.31	0.000169	7.77	0.22
457.7	0.2% (Confined)	500	324000	770.55	832.7	809.93	833.46	0.000163	7.92	0.22
458.19	50%	2	109000	782.85	816.88	804.3	817.45	0.000236	6.09	0.24
458.19	20%	5	147000	782.85	821.02	806.28	821.68	0.000223	6.63	0.24
458.19	10%	10	174000	782.85	823.41	807.45	824.06	0.000205	6.73	0.24
458.19	5%	20	199000	782.85	825.37	808.47	825.99	0.000187	6.74	0.23
458.19	2%	50	233000	782.85	827.78	809.77	828.36	0.000166	6.73	0.22
458.19	1%	100	259000	782.85	829.51	810.76	830.06	0.000154	6.72	0.21
458.19	0.5% (Confined)	200	287000	782.85	831.18	811.76	831.73	0.000145	6.76	0.21
458.19	0.2% (Confined)	500	324000	782.85	833.32	813.03	833.85	0.000135	6.79	0.2
458.73	50%	2	109000	788.99	817.51	803.3	818.08	0.000202	6.04	0.23
458.73	20%	5	147000	788.99	821.61	805.16	822.29	0.000202	6.68	0.23
458.73	10%	10	174000	788.99	823.94	806.39	824.64	0.000197	6.94	0.23
458.73	5%	20	199000	788.99	825.84	807.47	826.54	0.000187	7.07	0.23
458.73	2%	50	233000	788.99	828.18	808.86	828.86	0.000176	7.21	0.23
458.73	1%	100	259000	788.99	829.87	809.88	830.55	0.000168	7.29	0.22
458.73	0.5% (Confined)	200	287000	788.99	831.51	810.94	832.19	0.000163	7.41	0.22
458.73	0.2% (Confined)	500	324000	788.99	833.6	812.29	834.29	0.000156	7.53	0.22
459.43	50%	2	109000	789.08	818.35	805.55	818.85	0.000215	5.67	0.23
459.43	20%	5	147000	789.08	822.51	807.3	823.01	0.000184	5.86	0.22
459.43	10%	10	174000	789.08	824.86	808.45	825.32	0.000169	5.79	0.21
459.43	5%	20	199000	789.08	826.74	809.48	827.17	0.000155	5.71	0.2
459.43	2%	50	233000	789.08	829.03	810.76	829.43	0.000135	5.67	0.19
459.43	1%	100	259000	789.08	830.69	811.71	831.08	0.000124	5.65	0.19
459.43	0.5% (Confined)	200	287000	789.08	832.31	812.71	832.69	0.000116	5.68	0.18
459.43	0.2% (Confined)	500	324000	789.08	834.38	813.94	834.76	0.000107	5.71	0.18

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
460	50%	2	109000	786.06	818.98	805.75	819.5	0.000209	5.77	0.23
460	20%	5	147000	786.06	823.03	807.79	823.59	0.000195	6.16	0.23
460	10%	10	174000	786.06	825.33	808.93	825.85	0.000189	6.13	0.22
460	5%	20	199000	786.06	827.16	809.92	827.64	0.000168	6.03	0.21
460	2%	50	233000	786.06	829.4	811.2	829.84	0.00015	5.93	0.2
460	1%	100	259000	786.06	831.03	812.1	831.43	0.000137	5.83	0.2
460	0.5% (Confined)	200	287000	786.06	832.63	813.05	833.02	0.000125	5.79	0.19
460	0.2% (Confined)	500	324000	786.06	834.68	814.36	835.05	0.000112	5.74	0.18
460.68	50%	2	109000	785.22	819.73	802.44	820.15	0.000144	5.21	0.19
460.68	20%	5	147000	785.22	823.75	804.4	824.22	0.000152	5.67	0.2
460.68	10%	10	174000	785.22	826.03	805.71	826.48	0.000161	5.65	0.21
460.68	5%	20	199000	785.22	827.76	806.85	828.19	0.000148	5.68	0.2
460.68	2%	50	233000	785.22	829.9	808.3	830.31	0.000134	5.71	0.19
460.68	1%	100	259000	785.22	831.47	809.38	831.86	0.000125	5.72	0.19
460.68	0.5% (Confined)	200	287000	785.22	833.02	810.47	833.41	0.000118	5.76	0.18
460.68	0.2% (Confined)	500	324000	785.22	835.02	811.89	835.41	0.00011	5.79	0.18
461.5	50%	2	109000	792.68	820.34	804.82	820.86	0.000172	5.77	0.21
461.5	20%	5	147000	792.68	824.33	806.73	825.01	0.000187	6.61	0.23
461.5	10%	10	174000	792.68	826.56	807.98	827.36	0.000201	7.18	0.24
461.5	5%	20	199000	792.68	828.19	809.06	829.09	0.000216	7.68	0.25
461.5	2%	50	233000	792.68	830.23	810.5	831.24	0.000236	8.21	0.26
461.5	1%	100	259000	792.68	831.71	811.56	832.79	0.000241	8.56	0.26
461.5	0.5% (Confined)	200	287000	792.68	833.19	812.65	834.34	0.000245	8.9	0.27
461.5	0.2% (Confined)	500	324000	792.68	835.11	814.03	836.33	0.000248	9.28	0.27
462.41	50%	2	109000	779.67	821.17	804.35	821.61	0.000142	5.34	0.19
462.41	20%	5	147000	779.67	825.26	806.23	825.83	0.000152	6.07	0.2
462.41	10%	10	174000	779.67	827.61	807.48	828.25	0.000169	6.51	0.22
462.41	5%	20	199000	779.67	829.41	808.56	830.11	0.000204	6.85	0.24
462.41	2%	50	233000	779.67	831.55	809.97	832.33	0.000212	7.27	0.24
462.41	1%	100	259000	779.67	833.06	811	833.89	0.000213	7.55	0.25
462.41	0.5% (Confined)	200	287000	779.67	834.57	812.04	835.45	0.000215	7.85	0.25
462.41	0.2% (Confined)	500	324000	779.67	836.51	813.4	837.46	0.000217	8.2	0.25
462.66	50%	2	109000	787.54	821.4	802.18	821.8	0.000125	5.06	0.18
462.66	20%	5	147000	787.54	825.51	804.24	826.03	0.000135	5.77	0.19
462.66	10%	10	174000	787.54	827.87	805.68	828.46	0.000143	6.23	0.2
462.66	5%	20	199000	787.54	829.7	806.89	830.36	0.000169	6.62	0.22
462.66	2%	50	233000	787.54	831.85	808.44	832.6	0.000193	7.08	0.23
462.66	1%	100	259000	787.54	833.35	809.57	834.16	0.000199	7.41	0.24
462.66	0.5% (Confined)	200	287000	787.54	834.85	810.86	835.74	0.000204	7.76	0.24
462.66	0.2% (Confined)	500	324000	787.54	836.77	812.36	837.75	0.000209	8.17	0.25
463.17	50%	2	104000	782.36	821.73	803.73	822.12	0.000121	5.07	0.18
463.17	20%	5	141000	782.36	825.87	805.64	826.39	0.000138	5.84	0.19
463.17	10%	10	167000	782.36	828.25	806.88	828.85	0.000147	6.28	0.2
463.17	5%	20	191000	782.36	830.12	807.94	830.79	0.000152	6.66	0.21
463.17	2%	50	225000	782.36	832.3	809.41	833.07	0.000163	7.21	0.22
463.17	1%	100	256000	782.36	833.8	810.66	834.68	0.000179	7.77	0.23
463.17	0.5% (Confined)	200	285000	782.36	835.3	811.79	836.28	0.000188	8.2	0.24
463.17	0.2% (Confined)	500	323000	782.36	837.22	813.24	838.31	0.000198	8.7	0.25
463.97	50%	2	104000	786.19	822.25	805.81	822.76	0.000167	5.76	0.21
463.97	20%	5	141000	786.19	826.43	807.85	827.11	0.000182	6.63	0.22
463.97	10%	10	167000	786.19	828.83	809.29	829.63	0.000195	7.2	0.23
463.97	5%	20	191000	786.19	830.7	810.52	831.61	0.000206	7.69	0.24
463.97	2%	50	225000	786.19	832.91	812.1	833.97	0.000222	8.36	0.26
463.97	1%	100	256000	786.19	834.44	813.4	835.67	0.000243	9.01	0.27
463.97	0.5% (Confined)	200	285000	786.19	835.97	814.59	837.33	0.000256	9.52	0.28
463.97	0.2% (Confined)	500	323000	786.19	837.91	816.08	839.43	0.00027	10.12	0.29

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
464.51	50%	2	104000	789.56	822.74	805.2	823.19	0.000136	5.35	0.19
464.51	20%	5	141000	789.56	827.03	807.17	827.57	0.00014	5.97	0.2
464.51	10%	10	167000	789.56	829.57	808.45	830.1	0.000134	6.14	0.2
464.51	5%	20	191000	789.56	831.57	809.56	832.1	0.000127	6.23	0.19
464.51	2%	50	225000	789.56	833.96	811.08	834.47	0.00012	6.35	0.19
464.51	1%	100	256000	789.56	835.67	812.4	836.2	0.00012	6.54	0.19
464.51	0.5% (Confined)	200	285000	789.56	837.35	813.57	837.88	0.000116	6.64	0.19
464.51	0.2% (Confined)	500	323000	789.56	839.47	815.05	839.99	0.000112	6.74	0.19
464.97	50%	2	104000	792.41	823.1	808.6	823.56	0.000175	5.47	0.21
464.97	20%	5	141000	792.41	827.45	810.43	827.93	0.000157	5.73	0.21
464.97	10%	10	167000	792.41	830.01	811.61	830.43	0.000132	5.61	0.19
464.97	5%	20	191000	792.41	832.01	812.64	832.4	0.000115	5.5	0.18
464.97	2%	50	225000	792.41	834.39	814.02	834.75	0.000102	5.45	0.17
464.97	1%	100	256000	792.41	836.12	815.23	836.47	0.000097	5.52	0.17
464.97	0.5% (Confined)	200	285000	792.41	837.79	816.3	838.13	0.000092	5.54	0.17
464.97	0.2% (Confined)	500	323000	792.41	839.9	817.66	840.23	0.000085	5.55	0.16
465.6	50%	2	104000	793.92	823.7	809.9	824.18	0.000188	5.58	0.22
465.6	20%	5	141000	793.92	827.98	811.7	828.45	0.000158	5.74	0.21
465.6	10%	10	167000	793.92	830.48	812.86	830.85	0.000124	5.39	0.18
465.6	5%	20	191000	793.92	832.44	813.85	832.74	0.000102	5.13	0.17
465.6	2%	50	225000	793.92	834.78	815.24	835.04	0.000085	4.93	0.16
465.6	1%	100	256000	793.92	836.49	816.41	836.74	0.000078	4.91	0.15
465.6	0.5% (Confined)	200	285000	793.92	838.15	817.49	838.38	0.000071	4.85	0.15
465.6	0.2% (Confined)	500	323000	793.92	840.24	818.83	840.46	0.000064	4.79	0.14
466.09	50%	2	104000	790.5	824.19	809.77	824.66	0.000186	5.49	0.22
466.09	20%	5	141000	790.5	828.41	812.18	828.83	0.000149	5.49	0.2
466.09	10%	10	167000	790.5	830.82	813.36	831.16	0.000132	5.19	0.19
466.09	5%	20	191000	790.5	832.71	814.36	833	0.000111	5	0.17
466.09	2%	50	225000	790.5	834.99	815.73	835.25	0.000094	4.88	0.16
466.09	1%	100	256000	790.5	836.68	816.91	836.93	0.000088	4.88	0.16
466.09	0.5% (Confined)	200	285000	790.5	838.31	817.97	838.56	0.000081	4.86	0.15
466.09	0.2% (Confined)	500	323000	790.5	840.39	819.3	840.62	0.000073	4.83	0.15
466.82	50%	2	104000	794.85	824.9	809.34	825.42	0.000193	5.78	0.22
466.82	20%	5	141000	794.85	828.94	811.45	829.54	0.000199	6.33	0.23
466.82	10%	10	167000	794.85	831.23	812.84	831.84	0.000203	6.5	0.23
466.82	5%	20	191000	794.85	833.01	814.04	833.61	0.000196	6.6	0.23
466.82	2%	50	225000	794.85	835.2	815.63	835.8	0.00019	6.74	0.23
466.82	1%	100	256000	794.85	836.84	817	837.47	0.000186	6.95	0.23
466.82	0.5% (Confined)	200	285000	794.85	838.43	818.22	839.06	0.000179	7.07	0.23
466.82	0.2% (Confined)	500	323000	794.85	840.45	819.75	841.09	0.000171	7.2	0.22
467.31	50%	2	104000	798.59	825.44	812.74	826.06	0.000283	6.32	0.26
467.31	20%	5	141000	798.59	829.46	814.85	830.16	0.000257	6.8	0.26
467.31	10%	10	167000	798.59	831.76	816.19	832.43	0.000248	6.83	0.25
467.31	5%	20	191000	798.59	833.52	817.37	834.16	0.000225	6.85	0.25
467.31	2%	50	225000	798.59	835.69	818.93	836.3	0.000202	6.87	0.24
467.31	1%	100	256000	798.59	837.34	820.26	837.94	0.000189	6.93	0.23
467.31	0.5% (Confined)	200	285000	798.59	838.93	821.44	839.51	0.000176	6.92	0.22
467.31	0.2% (Confined)	500	323000	798.59	840.96	822.87	841.51	0.00016	6.9	0.22
467.9	50%	2	104000	794.04	826.31	814.04	826.85	0.000245	5.87	0.24
467.9	20%	5	141000	794.04	830.24	815.96	830.89	0.000235	6.5	0.25
467.9	10%	10	167000	794.04	832.44	817.18	833.12	0.000226	6.75	0.24
467.9	5%	20	191000	794.04	834.11	818.36	834.81	0.000219	6.94	0.24
467.9	2%	50	225000	794.04	836.23	819.71	836.92	0.000227	7.07	0.25
467.9	1%	100	256000	794.04	837.84	820.83	838.53	0.000219	7.24	0.25
467.9	0.5% (Confined)	200	285000	794.04	839.38	821.88	840.06	0.000204	7.27	0.24
467.9	0.2% (Confined)	500	323000	794.04	841.37	823.19	842.01	0.000186	7.24	0.23

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
468.58	50%	2	104000	790.75	827.04	809.66	827.66	0.000196	6.34	0.23
468.58	20%	5	141000	790.75	830.93	812.03	831.78	0.000226	7.42	0.25
468.58	10%	10	167000	790.75	833.06	813.6	834.06	0.000246	8.07	0.26
468.58	5%	20	191000	790.75	834.68	814.92	835.76	0.000257	8.5	0.27
468.58	2%	50	225000	790.75	836.79	816.71	837.9	0.000273	8.86	0.28
468.58	1%	100	256000	790.75	838.37	818.26	839.49	0.000278	9.12	0.28
468.58	0.5% (Confined)	200	285000	790.75	839.87	819.66	840.97	0.000273	9.22	0.28
468.58	0.2% (Confined)	500	323000	790.75	841.79	821.4	842.85	0.000262	9.27	0.27
469.14	50%	2	104000	799.64	827.79	811.29	828.2	0.000154	5.14	0.2
469.14	20%	5	141000	799.64	831.85	813.19	832.37	0.00016	5.81	0.21
469.14	10%	10	167000	799.64	834.09	814.42	834.7	0.000172	6.27	0.22
469.14	5%	20	191000	799.64	835.75	815.49	836.43	0.000185	6.68	0.23
469.14	2%	50	225000	799.64	837.82	816.91	838.59	0.000194	7.19	0.23
469.14	1%	100	256000	799.64	839.33	818.18	840.2	0.000206	7.66	0.24
469.14	0.5% (Confined)	200	285000	799.64	840.72	819.29	841.67	0.000214	8.04	0.25
469.14	0.2% (Confined)	500	323000	799.64	842.48	820.73	843.52	0.000222	8.49	0.26
469.77	50%	2	104000	797.49	828.26	811.91	828.78	0.000178	5.77	0.21
469.77	20%	5	141000	797.49	832.39	813.95	833.01	0.000211	6.41	0.23
469.77	10%	10	167000	797.49	834.7	815.25	835.37	0.000225	6.71	0.24
469.77	5%	20	191000	797.49	836.4	816.36	837.13	0.000228	7.04	0.25
469.77	2%	50	225000	797.49	838.52	817.92	839.3	0.000232	7.44	0.25
469.77	1%	100	256000	797.49	840.08	819.27	840.94	0.000241	7.85	0.26
469.77	0.5% (Confined)	200	285000	797.49	841.52	820.46	842.44	0.000247	8.17	0.26
469.77	0.2% (Confined)	500	323000	797.49	843.33	822.1	844.32	0.00025	8.56	0.27
470.58	50%	2	104000	799.2	829.09	815.33	829.55	0.000178	5.4	0.21
470.58	20%	5	141000	799.2	833.3	817.06	833.83	0.000171	5.9	0.21
470.58	10%	10	167000	799.2	835.64	818.18	836.2	0.000164	6.15	0.21
470.58	5%	20	191000	799.2	837.38	819.09	837.95	0.000162	6.38	0.21
470.58	2%	50	225000	799.2	839.53	820.45	840.14	0.000162	6.7	0.21
470.58	1%	100	256000	799.2	841.16	821.61	841.81	0.000163	6.96	0.22
470.58	0.5% (Confined)	200	285000	799.2	842.64	822.63	843.31	0.000163	7.17	0.22
470.58	0.2% (Confined)	500	323000	799.2	844.5	823.92	845.2	0.000162	7.42	0.22
471.28	50%	2	104000	794.31	829.73	813.72	830.22	0.000177	5.6	0.21
471.28	20%	5	141000	794.31	833.9	816.38	834.48	0.000175	6.18	0.22
471.28	10%	10	167000	794.31	836.22	817.78	836.82	0.000168	6.4	0.22
471.28	5%	20	191000	794.31	837.95	818.97	838.56	0.000165	6.59	0.22
471.28	2%	50	225000	794.31	840.11	820.45	840.73	0.000162	6.85	0.22
471.28	1%	100	256000	794.31	841.74	821.73	842.39	0.000162	7.1	0.22
471.28	0.5% (Confined)	200	285000	794.31	843.22	822.85	843.89	0.000161	7.29	0.22
471.28	0.2% (Confined)	500	323000	794.31	845.08	824.3	845.77	0.00016	7.51	0.22
472.06	50%	2	104000	798.32	830.48	816.4	830.93	0.000171	5.38	0.21
472.06	20%	5	141000	798.32	834.67	818.1	835.23	0.000189	6	0.22
472.06	10%	10	167000	798.32	836.94	819.25	837.55	0.00019	6.34	0.23
472.06	5%	20	191000	798.32	838.64	820.23	839.3	0.000192	6.66	0.23
472.06	2%	50	225000	798.32	840.75	821.56	841.48	0.000197	7.09	0.23
472.06	1%	100	256000	798.32	842.36	822.7	843.17	0.000204	7.5	0.24
472.06	0.5% (Confined)	200	285000	798.32	843.81	823.74	844.69	0.00021	7.84	0.25
472.06	0.2% (Confined)	500	323000	798.32	845.63	825.03	846.59	0.000215	8.25	0.25
472.78	50%	2	104000	790.23	831.09	813.12	831.48	0.000125	5.01	0.18
472.78	20%	5	141000	790.23	835.34	815.08	835.83	0.000135	5.69	0.19
472.78	10%	10	167000	790.23	837.62	816.34	838.17	0.000141	6.07	0.2
472.78	5%	20	191000	790.23	839.33	817.41	839.93	0.000146	6.41	0.2
472.78	2%	50	225000	790.23	841.47	818.88	842.14	0.000152	6.85	0.21
472.78	1%	100	256000	790.23	843.12	820.18	843.86	0.00016	7.26	0.22
472.78	0.5% (Confined)	200	285000	790.23	844.6	821.33	845.4	0.000166	7.59	0.22
472.78	0.2% (Confined)	500	323000	790.23	846.45	822.77	847.33	0.000172	7.99	0.23

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
473.62	50%	2	104000	802.97	831.69	817.59	832.19	0.000187	5.69	0.22
473.62	20%	5	141000	802.97	835.96	819.42	836.57	0.000188	6.32	0.22
473.62	10%	10	167000	802.97	838.27	820.62	838.92	0.000186	6.61	0.23
473.62	5%	20	191000	802.97	840.01	821.66	840.66	0.000177	6.73	0.22
473.62	2%	50	225000	802.97	842.23	823.05	842.85	0.000166	6.86	0.22
473.62	1%	100	256000	802.97	843.96	824.26	844.58	0.00016	6.99	0.22
473.62	0.5% (Confined)	200	285000	802.97	845.5	825.34	846.13	0.000155	7.09	0.21
473.62	0.2% (Confined)	500	323000	802.97	847.43	826.7	848.05	0.000149	7.2	0.21
474.29	50%	2	104000	795.31	832.34	817.04	832.87	0.000185	5.87	0.22
474.29	20%	5	141000	795.31	836.62	819.06	837.24	0.000182	6.45	0.22
474.29	10%	10	167000	795.31	838.92	820.36	839.55	0.000173	6.64	0.22
474.29	5%	20	191000	795.31	840.62	821.5	841.26	0.000171	6.86	0.22
474.29	2%	50	225000	795.31	842.77	823.03	843.44	0.000169	7.14	0.22
474.29	1%	100	256000	795.31	844.46	824.32	845.17	0.00017	7.41	0.22
474.29	0.5% (Confined)	200	285000	795.31	845.98	825.52	846.7	0.00017	7.63	0.23
474.29	0.2% (Confined)	500	323000	795.31	847.87	827	848.62	0.000169	7.89	0.23
474.94	50%	2	104000	794.58	833	816.45	833.47	0.000163	5.53	0.21
474.94	20%	5	141000	794.58	837.28	818.59	837.82	0.00016	6.03	0.21
474.94	10%	10	167000	794.58	839.53	820.3	840.1	0.000159	6.31	0.21
474.94	5%	20	191000	794.58	841.2	821.41	841.81	0.000161	6.61	0.21
474.94	2%	50	225000	794.58	843.31	822.91	843.98	0.000165	6.99	0.22
474.94	1%	100	256000	794.58	844.99	824.18	845.71	0.00017	7.34	0.22
474.94	0.5% (Confined)	200	285000	794.58	846.48	825.34	847.26	0.000173	7.64	0.23
474.94	0.2% (Confined)	500	323000	794.58	848.35	826.87	849.18	0.000177	7.99	0.23
475.38	50%	2	104000	802.02	833.33	820.14	834.01	0.000264	6.65	0.26
475.38	20%	5	141000	802.02	837.58	822.2	838.34	0.000247	7.13	0.26
475.38	10%	10	167000	802.02	839.85	823.55	840.61	0.000242	7.31	0.26
475.38	5%	20	191000	802.02	841.52	824.72	842.31	0.000237	7.56	0.26
475.38	2%	50	225000	802.02	843.64	826.29	844.47	0.000233	7.88	0.26
475.38	1%	100	256000	802.02	845.33	827.64	846.21	0.000233	8.18	0.26
475.38	0.5% (Confined)	200	285000	802.02	846.84	828.86	847.75	0.000232	8.42	0.26
475.38	0.2% (Confined)	500	323000	802.02	848.71	830.37	849.67	0.000231	8.72	0.26
475.92	50%	2	104000	800.78	834.18	819.96	834.64	0.000175	5.39	0.21
475.92	20%	5	141000	800.78	838.38	821.71	838.95	0.000177	6.04	0.22
475.92	10%	10	167000	800.78	840.56	822.84	841.21	0.000183	6.5	0.22
475.92	5%	20	191000	800.78	842.18	823.82	842.91	0.000192	6.93	0.23
475.92	2%	50	225000	800.78	844.24	825.16	845.09	0.000205	7.5	0.24
475.92	1%	100	256000	800.78	846.09	826.33	846.76	0.000166	7.04	0.22
475.92	0.5% (Confined)	200	285000	800.78	847.59	827.35	848.3	0.000167	7.28	0.22
475.92	0.2% (Confined)	500	323000	800.78	849.47	828.67	850.22	0.000168	7.57	0.22
476.34	50%	2	104000	800.67	834.54	818.99	834.95	0.000146	5.16	0.19
476.34	20%	5	141000	800.67	838.75	820.78	839.27	0.000151	5.82	0.2
476.34	10%	10	167000	800.67	840.95	821.89	841.55	0.000158	6.28	0.21
476.34	5%	20	191000	800.67	842.59	822.92	843.27	0.000167	6.71	0.22
476.34	2%	50	225000	800.67	844.68	824.25	845.47	0.000179	7.27	0.23
476.34	1%	100	256000	800.67	846.39	825.43	847.08	0.000159	7.08	0.22
476.34	0.5% (Confined)	200	285000	800.67	847.89	826.49	848.62	0.000162	7.36	0.22
476.34	0.2% (Confined)	500	323000	800.67	849.77	827.82	850.55	0.000165	7.69	0.22
476.99	50%	2	104000	798.83	834.96	819.21	835.54	0.000193	6.11	0.22
476.99	20%	5	141000	798.83	839.16	821.32	839.9	0.000208	6.95	0.24
476.99	10%	10	167000	798.83	841.37	822.68	842.22	0.000217	7.48	0.25
476.99	5%	20	191000	798.83	843.03	823.89	843.98	0.000228	7.96	0.25
476.99	2%	50	225000	798.83	845.22	825.49	846.12	0.000211	8.03	0.25
476.99	1%	100	256000	798.83	846.76	826.93	847.73	0.000219	8.44	0.25
476.99	0.5% (Confined)	200	285000	798.83	848.27	828.24	849.28	0.000221	8.73	0.26
476.99	0.2% (Confined)	500	323000	798.83	850.15	829.79	851.21	0.000223	9.06	0.26

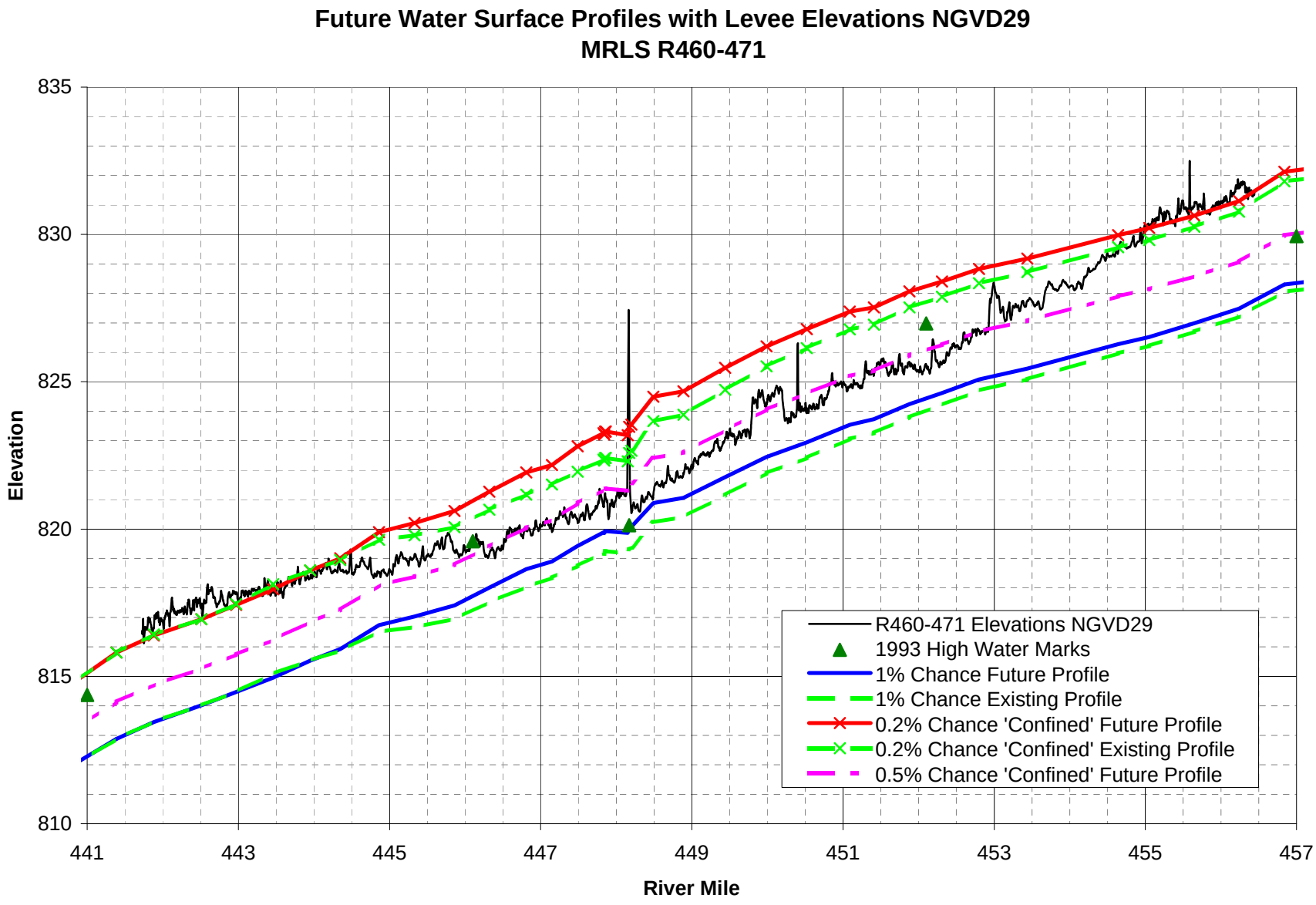
Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
477.64	50%	2	104000	800.29	835.78	820.48	836.17	0.000157	5.16	0.2
477.64	20%	5	141000	800.29	840.14	822.7	840.54	0.00015	5.4	0.2
477.64	10%	10	167000	800.29	842.43	823.98	842.84	0.000138	5.53	0.19
477.64	5%	20	191000	800.29	844.19	825.08	844.61	0.000134	5.7	0.19
477.64	2%	50	225000	800.29	846.26	826.49	846.72	0.000134	5.99	0.2
477.64	1%	100	256000	800.29	847.91	827.82	848.3	0.000115	5.76	0.18
477.64	0.5% (Confined)	200	285000	800.29	849.45	829.16	849.85	0.000112	5.87	0.18
477.64	0.2% (Confined)	500	323000	800.29	851.36	831.69	851.77	0.000109	6.01	0.18
478.4	50%	2	104000	806.35	836.36	821.67	836.81	0.000163	5.4	0.21
478.4	20%	5	141000	806.35	840.66	823.5	841.12	0.000145	5.68	0.2
478.4	10%	10	167000	806.35	842.91	824.72	843.38	0.000139	5.86	0.2
478.4	5%	20	191000	806.35	844.64	825.76	845.12	0.000135	6	0.2
478.4	2%	50	225000	806.35	846.71	827.18	847.21	0.000133	6.25	0.2
478.4	1%	100	256000	806.35	848.26	828.36	848.79	0.000136	6.52	0.2
478.4	0.5% (Confined)	200	285000	806.35	849.78	829.44	850.33	0.000135	6.69	0.2
478.4	0.2% (Confined)	500	323000	806.35	851.67	830.8	852.24	0.000133	6.9	0.2
479.09	50%	2	104000	810.08	837.01	824.25	837.44	0.000187	5.41	0.22
479.09	20%	5	141000	810.08	841.26	826.05	841.64	0.000146	5.37	0.2
479.09	10%	10	167000	810.08	843.51	827.22	843.84	0.000124	5.22	0.18
479.09	5%	20	191000	810.08	845.24	828.2	845.54	0.000109	5.12	0.17
479.09	2%	50	225000	810.08	847.33	829.54	847.61	0.000098	5.09	0.17
479.09	1%	100	256000	810.08	848.9	830.75	849.18	0.000093	5.15	0.16
479.09	0.5% (Confined)	200	285000	810.08	850.43	832.61	850.7	0.000088	5.16	0.16
479.09	0.2% (Confined)	500	323000	810.08	852.33	833.98	852.6	0.000082	5.18	0.16
479.81	50%	2	103000	800.46	837.74	823.01	838.18	0.000226	5.57	0.23
479.81	20%	5	140000	800.46	841.78	825.81	842.15	0.000164	5.41	0.2
479.81	10%	10	166000	800.46	843.93	828.05	844.25	0.000139	5.28	0.19
479.81	5%	20	190000	800.46	845.59	829.3	845.9	0.000127	5.27	0.18
479.81	2%	50	224000	800.46	847.62	830.73	847.92	0.000118	5.34	0.18
479.81	1%	100	255000	800.46	849.17	832.07	849.47	0.000115	5.47	0.18
479.81	0.5% (Confined)	200	284000	800.46	850.67	833.82	850.98	0.000111	5.54	0.18
479.81	0.2% (Confined)	500	322000	800.46	852.54	835.67	852.85	0.000106	5.64	0.18
480.59	50%	2	103000	809.61	838.58	823.55	839.07	0.000216	5.64	0.21
480.59	20%	5	140000	809.61	842.39	825.51	842.86	0.000193	5.84	0.21
480.59	10%	10	166000	809.61	844.42	826.78	844.88	0.000186	5.97	0.2
480.59	5%	20	190000	809.61	846.04	827.89	846.48	0.000179	5.99	0.2
480.59	2%	50	224000	809.61	848.02	829.38	848.45	0.000169	6.07	0.2
480.59	1%	100	255000	809.61	849.56	830.66	849.99	0.000165	6.2	0.2
480.59	0.5% (Confined)	200	284000	809.61	851.04	831.83	851.47	0.000158	6.26	0.19
480.59	0.2% (Confined)	500	322000	809.61	852.89	833.28	853.32	0.000151	6.33	0.19
481.2	50%	2	103000	809.33	839.31	825.88	839.76	0.000224	5.45	0.21
481.2	20%	5	140000	809.33	843.01	827.63	843.48	0.000207	5.79	0.21
481.2	10%	10	166000	809.33	845	828.78	845.48	0.0002	6.01	0.21
481.2	5%	20	190000	809.33	846.57	829.79	847.07	0.000198	6.22	0.21
481.2	2%	50	224000	809.33	848.5	831.12	849.04	0.000199	6.54	0.21
481.2	1%	100	255000	809.33	850.01	832.31	850.59	0.000204	6.84	0.22
481.2	0.5% (Confined)	200	284000	809.33	851.45	833.37	852.06	0.000204	7.06	0.22
481.2	0.2% (Confined)	500	322000	809.33	853.26	834.7	853.9	0.000204	7.32	0.22
481.89	50%	2	103000	810.32	840.11	826.31	840.59	0.000248	5.66	0.22
481.89	20%	5	140000	810.32	843.72	828.5	844.29	0.000252	6.3	0.23
481.89	10%	10	166000	810.32	845.66	829.83	846.29	0.000255	6.68	0.24
481.89	5%	20	190000	810.32	847.21	830.95	847.88	0.000258	6.99	0.24
481.89	2%	50	224000	810.32	849.14	832.98	849.85	0.000258	7.32	0.24
481.89	1%	100	255000	810.32	850.65	834.33	851.4	0.00026	7.61	0.25
481.89	0.5% (Confined)	200	284000	810.32	852.1	835.41	852.86	0.000256	7.8	0.25
481.89	0.2% (Confined)	500	322000	810.32	853.9	836.67	854.68	0.00025	8.01	0.25

Exhibit 2.16
Missouri River Future Conditions Water Surface Elevations

HEC-RAS River Mile	Profile Frequency Percent	Profile Frequency Year	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Average Vel Chnl (ft/s)	Channel Froude #
482.6	50%	2	103000	809.27	841.02	828.07	841.52	0.000265	5.69	0.23
482.6	20%	5	140000	809.27	844.62	829.92	845.2	0.000258	6.24	0.23
482.6	10%	10	166000	809.27	846.61	831.11	847.17	0.000241	6.35	0.23
482.6	5%	20	190000	809.27	848.19	832.16	848.73	0.000227	6.42	0.22
482.6	2%	50	224000	809.27	850.13	833.85	850.67	0.000215	6.56	0.22
482.6	1%	100	255000	809.27	851.66	834.99	852.21	0.000209	6.71	0.22
482.6	0.5% (Confined)	200	284000	809.27	853.1	836.01	853.64	0.000202	6.81	0.22
482.6	0.2% (Confined)	500	322000	809.27	854.89	837.37	855.44	0.000193	6.92	0.21
483.45	50%	2	103000	809.53	842.16	827.66	842.76	0.000297	6.22	0.25
483.45	20%	5	140000	809.53	845.76	830.32	846.55	0.000353	7.11	0.27
483.45	10%	10	166000	809.53	847.64	831.83	848.56	0.000384	7.7	0.29
483.45	5%	20	190000	809.53	849.1	833.16	850.13	0.000401	8.2	0.29
483.45	2%	50	224000	809.53	850.92	834.9	852.08	0.000416	8.77	0.3
483.45	1%	100	255000	809.53	852.39	836.18	853.61	0.00042	9.15	0.31
483.45	0.5% (Confined)	200	284000	809.53	853.77	837.25	855.02	0.000415	9.39	0.31
483.45	0.2% (Confined)	500	322000	809.53	855.5	838.72	856.76	0.000404	9.64	0.31
484.11	50%	2	103000	813.88	843.16	828.65	843.62	0.000209	5.44	0.21
484.11	20%	5	140000	813.88	846.93	830.48	847.51	0.000218	6.17	0.22
484.11	10%	10	166000	813.88	848.93	831.69	849.57	0.000224	6.59	0.22
484.11	5%	20	190000	813.88	850.49	832.73	851.19	0.000232	6.96	0.23
484.11	2%	50	224000	813.88	852.39	834.11	853.19	0.000245	7.47	0.24
484.11	1%	100	255000	813.88	853.88	835.33	854.76	0.000259	7.93	0.25
484.11	0.5% (Confined)	200	284000	813.88	855.23	836.39	856.18	0.000268	8.3	0.25
484.11	0.2% (Confined)	500	322000	813.88	856.9	837.75	857.93	0.000278	8.73	0.26

Exhibit 2.17



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Date: 7/22/2006

Exhibit 2.18

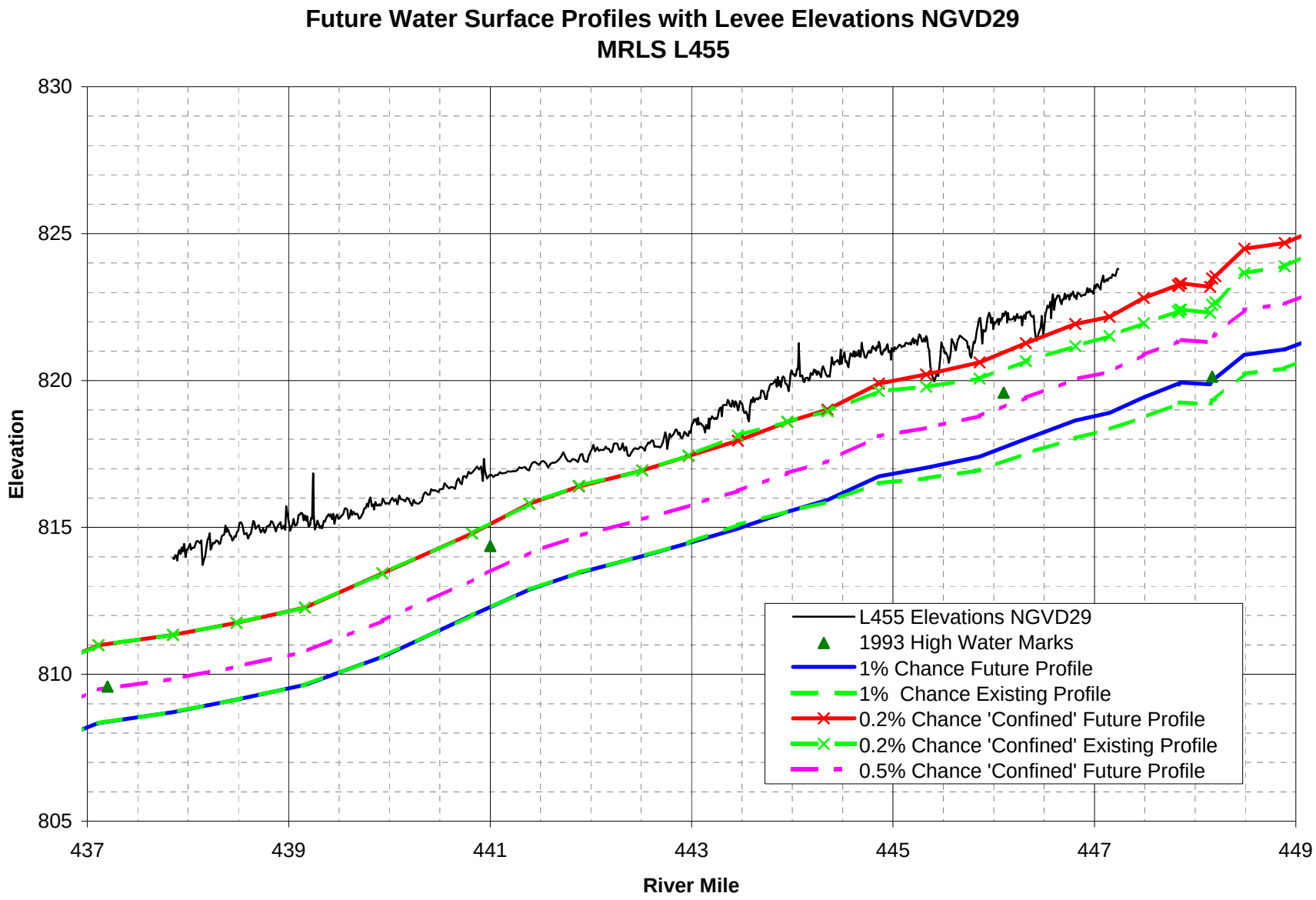

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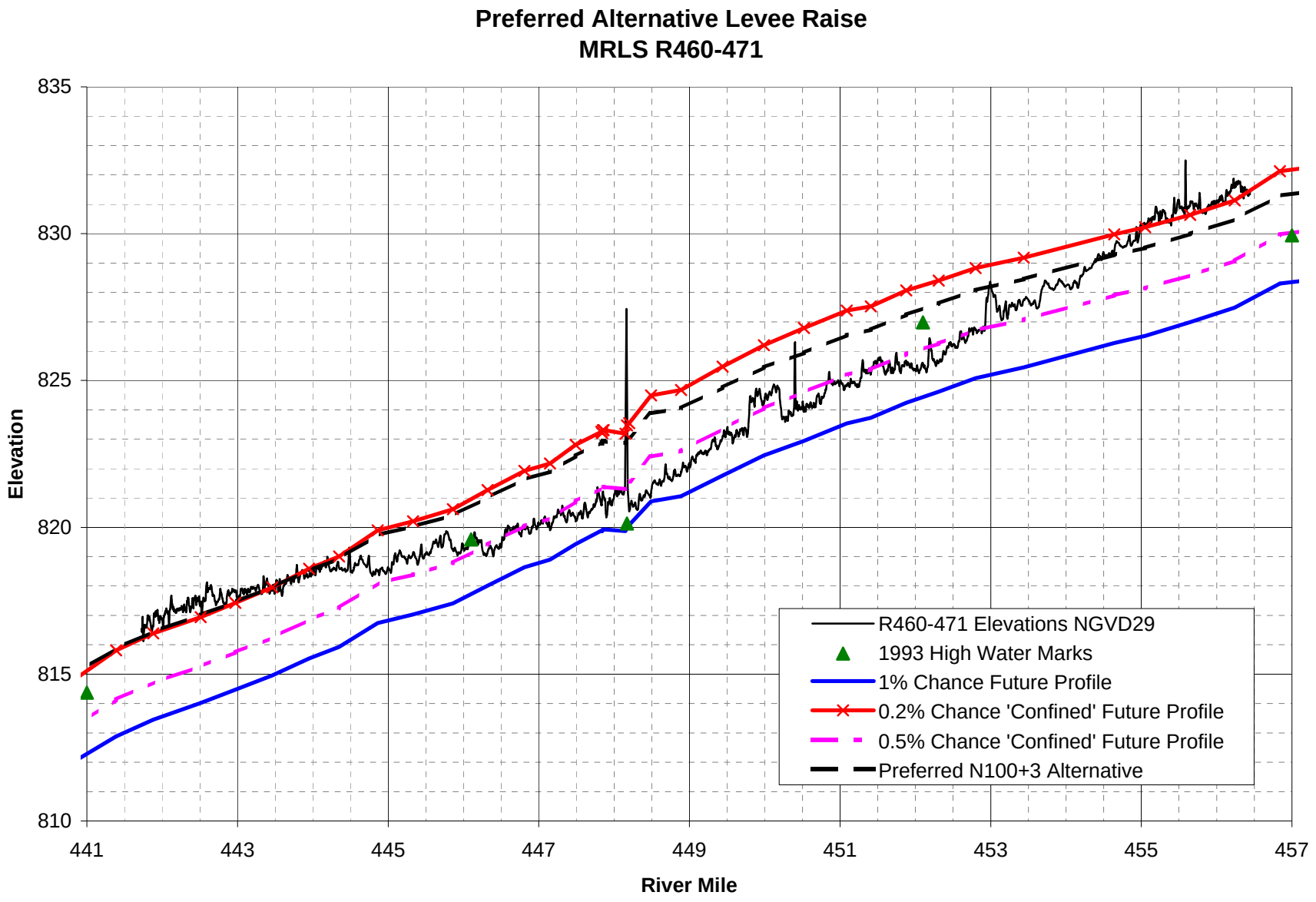
Exhibit 2.19



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Date: 7/22/2006

Exhibit 2.20

Future Conditions With Project Impacts to 1993 Flood Water Surface Elevations

River Mile	1993 Maximum WS Elev		Δ Max WS Elev (Ft)
	Without Project (Ft)	With Project (Ft)	
481.89	853.28	853.34	0.06
481.20	852.71	852.77	0.06
480.59	852.03	852.10	0.07
480.00	851.84	851.90	0.06
479.81	851.78	851.85	0.07
479.09	851.52	851.59	0.07
478.40	850.67	850.75	0.08
477.64	850.18	850.27	0.09
476.99	849.58	849.68	0.10
476.70	849.55	849.65	0.10
476.34	849.43	849.54	0.11
475.92	849.12	849.23	0.11
475.38	848.57	848.70	0.13
475.34	848.55	848.69	0.14
474.94	848.08	848.21	0.13
474.29	847.48	847.62	0.14
473.62	846.91	847.06	0.15
472.78	846.24	846.41	0.17
472.06	845.51	845.70	0.19
471.28	844.43	844.65	0.22
470.58	843.72	843.97	0.25
469.77	843.03	843.27	0.24
469.14	842.44	842.65	0.21
468.58	840.94	841.00	0.06
468.40	841.03	841.11	0.08
467.90	840.71	840.76	0.05
467.31	840.47	840.50	0.03
466.82	839.92	839.91	-0.01
466.09	839.32	839.26	-0.06
465.60	838.82	838.74	-0.08
465.18	838.59	838.50	-0.09
464.97	838.48	838.39	-0.09
464.51	838.05	837.95	-0.10
463.97	837.64	837.52	-0.12
463.17	836.98	836.84	-0.14
462.66	836.23	836.08	-0.15
462.41	835.94	835.79	-0.15
462.02	835.55	835.41	-0.14
461.50	834.88	834.74	-0.14
461.00	834.61	834.48	-0.13
460.68	834.44	834.32	-0.12
459.97	833.82	833.70	-0.12
459.40	833.47	833.38	-0.09
458.72	832.50	832.44	-0.06
458.18	832.11	832.08	-0.03
458.00	831.84	831.82	-0.02
457.68	831.30	831.33	0.03
457.23	830.84	830.90	0.06

Exhibit 2.20

Future Conditions With Project Impacts to 1993 Flood Water Surface Elevations

River Mile	1993 Maximum WS Elev		Δ Max WS Elev (Ft)
	Without Project (Ft)	With Project (Ft)	
456.82	830.89	830.95	0.06
456.50	830.65	830.73	0.08
456.22	830.41	830.52	0.11
455.64	829.95	830.08	0.13
455.05	829.38	829.56	0.18
454.63	829.16	829.35	0.19
454.00	828.69	828.92	0.23
453.44	828.19	828.46	0.27
452.80	827.82	828.10	0.28
452.31	827.31	827.63	0.32
451.88	826.62	826.99	0.37
451.41	826.18	826.56	0.38
451.09	825.78	826.18	0.40
450.52	825.04	825.45	0.41
450.00	824.59	825.00	0.41
449.44	823.59	823.98	0.39
448.89	822.76	823.22	0.46
448.49	822.62	822.95	0.33
448.30	822.12	822.61	0.49
448.26	822.07	822.56	0.49
448.21	822.03	822.51	0.48
448.21	822.02	822.51	0.49
448.21	822.02	822.51	0.49
447.79	821.89	822.29	0.40
447.78	822.12	822.44	0.32
447.71	821.85	822.22	0.37
447.60	821.90	822.22	0.32
447.51	821.64	822.00	0.36
447.16	821.13	821.55	0.42
446.83	820.63	821.10	0.47
446.33	820.08	820.53	0.45
445.88	819.64	820.06	0.42
445.60	819.42	819.84	0.42
445.33	819.24	819.66	0.42
444.86	819.04	819.45	0.41
444.36	818.82	819.23	0.41
443.98	818.60	819.02	0.42
443.49	818.25	818.66	0.41
442.99	817.89	818.30	0.41
442.53	817.54	817.95	0.41
441.92	816.76	817.17	0.41
441.80	816.61	817.02	0.41
441.42	815.93	816.36	0.43
440.85	815.02	815.47	0.45
439.96	812.28	812.83	0.55
439.19	812.01	812.56	0.55
438.53	811.26	811.82	0.56
437.88	810.27	810.90	0.63

Exhibit 2.20

Future Conditions With Project Impacts to 1993 Flood Water Surface Elevations

River Mile	1993 Maximum WS Elev		Δ Max WS Elev (Ft)
	Without Project (Ft)	With Project (Ft)	
437.64	809.90	810.53	0.63
437.60	809.84	810.47	0.63
437.14	809.15	809.79	0.64
436.46	808.70	809.35	0.65
435.82	807.29	807.99	0.70
435.15	806.49	807.22	0.73
434.21	805.86	806.65	0.79
433.44	805.00	805.82	0.82
432.73	803.86	804.66	0.80
432.00	802.24	802.97	0.73
431.44	802.14	802.90	0.76
431.00	801.51	802.24	0.73
430.71	800.98	801.68	0.70
430.04	801.68	802.42	0.74
429.27	800.19	800.87	0.68
428.65	800.25	800.98	0.73
428.00	799.78	800.53	0.75
427.92	799.74	800.50	0.76
427.90	799.70	800.46	0.76
427.13	798.87	799.57	0.70
426.48	798.08	798.82	0.74
425.87	797.54	798.28	0.74
425.22	797.36	798.08	0.72
424.66	797.02	797.76	0.74
424.30	796.16	796.87	0.71
424.24	795.81	796.53	0.72
423.77	794.58	795.14	0.56
423.20	795.24	795.86	0.62
422.57	794.86	795.44	0.58
422.53	794.52	795.06	0.54
422.44	794.31	794.89	0.58
421.93	794.33	794.90	0.57
421.35	793.47	794.01	0.54
420.75	792.98	793.49	0.51
420.04	793.22	793.79	0.57
419.24	792.78	793.35	0.57
418.70	792.04	792.56	0.52
418.44	791.61	792.11	0.50
418.20	791.80	792.35	0.55
418.00	791.90	792.47	0.57
417.73	791.96	792.55	0.59
417.09	789.70	790.16	0.46
416.90	790.02	790.52	0.50
416.70	790.28	790.80	0.52
416.55	790.43	790.97	0.54
416.07	789.42	789.92	0.50
415.50	789.71	790.24	0.53
415.00	789.70	790.23	0.53

Exhibit 2.20
Future Conditions With Project Impacts to 1993 Flood Water Surface Elevations

River Mile	1993 Maximum WS Elev		Δ Max WS Elev (Ft)
	Without Project (Ft)	With Project (Ft)	
414.90	789.70	790.23	0.53
414.20	789.32	789.84	0.52
413.47	788.03	788.48	0.45
412.80	787.62	788.09	0.47
412.00	787.69	788.13	0.44
411.50	787.02	787.45	0.43
411.39	786.85	787.27	0.42
410.68	785.49	785.89	0.40
410.01	785.41	785.86	0.45
409.49	785.15	785.62	0.47
408.79	783.53	784.09	0.56
408.26	784.07	784.54	0.47
407.74	784.02	784.48	0.46
407.19	783.15	783.57	0.42
406.75	783.11	783.52	0.41
406.50	783.21	783.66	0.45
406.25	783.44	783.90	0.46
405.60	782.39	782.83	0.44
405.01	782.24	782.70	0.46
404.36	782.09	782.55	0.46
403.81	781.87	782.35	0.48
403.50	781.83	782.30	0.47
403.14	781.77	782.24	0.47
403.00	781.71	782.19	0.48
402.47	781.41	781.88	0.47
401.86	781.12	781.60	0.48
401.41	780.91	781.41	0.50
401.30	780.82	781.32	0.50
400.76	780.32	780.81	0.49
400.15	779.70	780.16	0.46
399.53	779.12	779.56	0.44
399.30	778.80	779.24	0.44
398.86	778.04	778.46	0.42
398.31	778.40	778.84	0.44
397.60	776.93	777.35	0.42
397.57	777.23	777.65	0.42
397.48	777.56	777.99	0.43
396.71	776.25	776.66	0.41
396.04	775.69	776.09	0.40
395.50	775.45	775.87	0.42
394.54	775.23	775.64	0.41
394.00	774.70	775.13	0.43
393.74	774.36	774.80	0.44
393.18	773.74	774.17	0.43
392.59	773.08	773.50	0.42
391.93	772.84	773.26	0.42
391.50	772.69	773.15	0.46
391.29	772.58	773.01	0.43

Exhibit 2.20

Future Conditions With Project Impacts to 1993 Flood Water Surface Elevations

River Mile	1993 Maximum WS Elev		Δ Max WS Elev (Ft)
	Without Project (Ft)	With Project (Ft)	
391.21	772.50	772.96	0.46
391.00	772.31	772.77	0.46
390.57	771.38	771.80	0.42
389.75	771.12	771.54	0.42
389.00	770.76	771.18	0.42
388.51	770.98	771.41	0.43
388.20	770.83	771.26	0.43
387.86	770.72	771.15	0.43
387.32	769.74	770.18	0.44
386.62	769.54	769.99	0.45
386.20	769.29	769.74	0.45
385.66	769.00	769.45	0.45
385.15	768.76	769.21	0.45
385.00	768.61	769.06	0.45
384.40	767.92	768.35	0.43
383.65	767.16	767.58	0.42
383.00	767.24	767.67	0.43
382.89	767.24	767.67	0.43
381.89	766.86	767.29	0.43
381.20	766.63	767.05	0.42
380.87	766.53	766.95	0.42
380.28	766.32	766.74	0.42
379.53	766.04	766.46	0.42
379.00	765.88	766.30	0.42
378.85	765.69	766.11	0.42
378.70	765.63	766.05	0.42
378.26	765.42	765.83	0.41
377.43	764.35	764.71	0.36
376.76	763.37	763.70	0.33
376.11	762.95	763.28	0.33
376.00	763.13	763.47	0.34
375.71	763.15	763.49	0.34
375.33	763.08	763.42	0.34
375.07	763.00	763.34	0.34
374.76	762.94	763.28	0.34
374.43	762.82	763.16	0.34
374.14	762.73	763.06	0.33
374.11	762.69	763.03	0.34
374.02	762.68	763.02	0.34
374.00	762.68	763.01	0.33
373.79	762.63	762.96	0.33
373.46	762.53	762.86	0.33
373.40	762.51	762.85	0.34
373.15	762.43	762.76	0.33
372.86	762.31	762.64	0.33
372.61	762.17	762.50	0.33
372.58	761.92	762.24	0.32
372.47	762.05	762.37	0.32

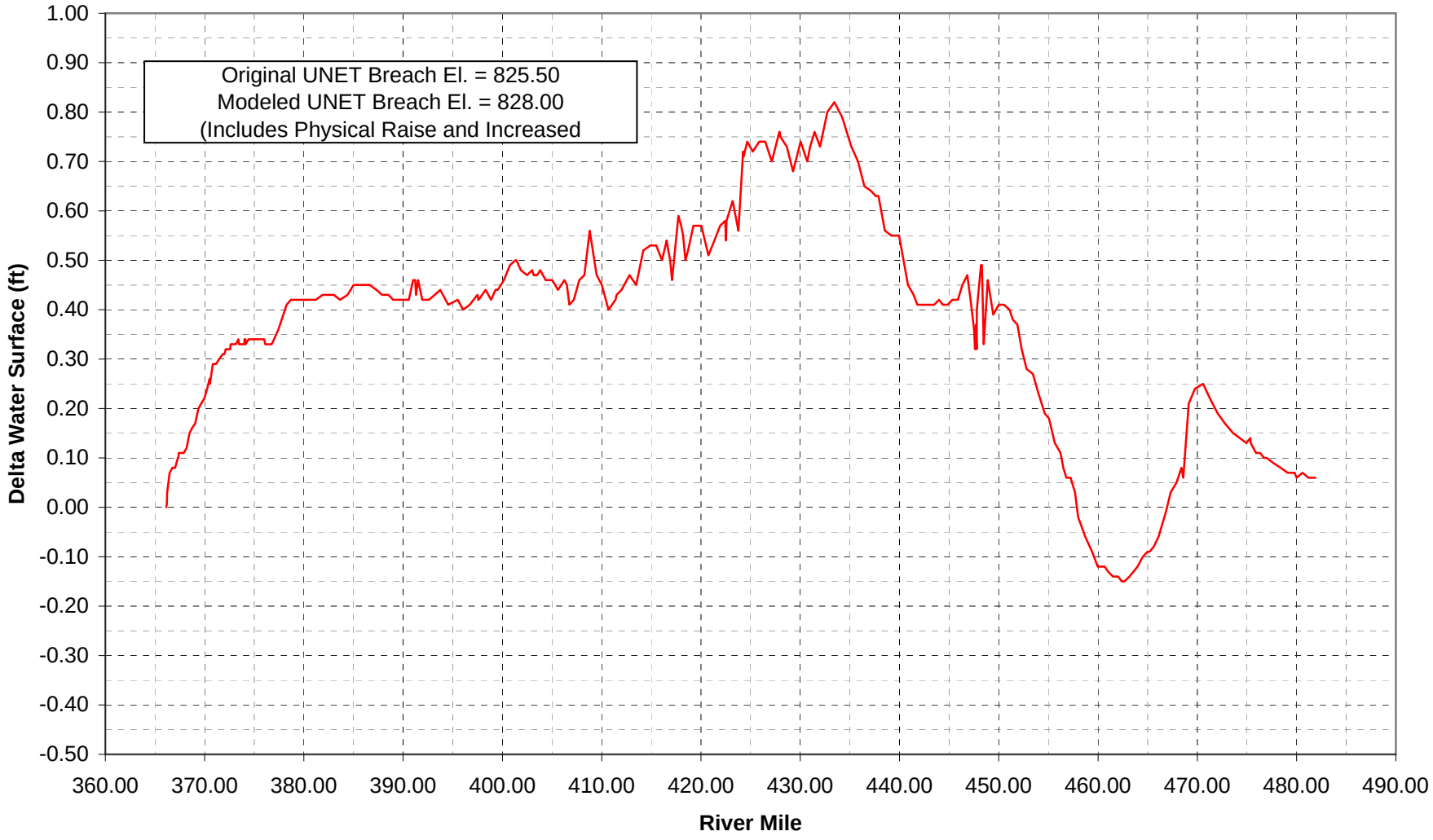
Exhibit 2.20

Future Conditions With Project Impacts to 1993 Flood Water Surface Elevations

River Mile	1993 Maximum WS Elev		Δ Max WS Elev (Ft)
	Without Project (Ft)	With Project (Ft)	
372.13	761.89	762.21	0.32
372.00	761.79	762.10	0.31
371.83	761.57	761.88	0.31
371.47	761.40	761.70	0.30
371.14	761.10	761.39	0.29
370.83	760.86	761.15	0.29
370.54	760.33	760.58	0.25
370.50	760.27	760.53	0.26
370.26	759.91	760.15	0.24
369.96	759.46	759.68	0.22
369.66	759.29	759.50	0.21
369.38	758.95	759.15	0.20
369.05	758.56	758.73	0.17
368.73	758.41	758.57	0.16
368.48	758.09	758.24	0.15
368.19	757.59	757.71	0.12
367.89	757.33	757.44	0.11
367.57	757.39	757.50	0.11
367.50	757.34	757.45	0.11
367.40	757.30	757.41	0.11
367.36	757.28	757.38	0.10
367.30	757.25	757.35	0.10
367.03	756.76	756.84	0.08
366.75	756.72	756.80	0.08
366.48	756.60	756.67	0.07
366.23	755.63	755.66	0.03
366.20	755.44	755.45	0.01
366.15	755.20	755.20	0.00

Exhibit 2.21

Missouri River Delta Maximum Water Surface from 1993 Conditions Using Unet Model for 1993 Flow Data



Designed: EDS
Checked: MMW
Date: 7/22/2006

CENWK-EC-HH **6 Sep 2006**

MEMORANDUM FOR RECORD

SUBJECT: MRLS R471-460 Design Deficiency Investigation

1. Purpose of this MFR. The purpose of this MFR is to document the procedures that have led to a determination of design deficiency of the original MRLS R471-460 design.

2. Background. The St. Joseph Levees Feasibility Study is addressing the need for improved reliability for levees L455 and R471-460 of the Missouri River Levee System in the vicinity of St. Joseph, Missouri. The existing conditions investigation has identified that Unit R471-460 is currently performing at a reliability much lower than designed in 1965. The USACE Headquarters Policy Compliance Review Letter dated 31 August 2006 has brought into question the original design adequacy of the subject levee.

3. Problem. As stated in the 1947 *Missouri River Agricultural Levees Definite Project Report - Appendix I, Hydrology* the design discharge at St Joseph was 325,000 cfs. This was a design flow and was not associated with any frequency at that time. MRLS Unit R471-460 was overtopped in the 1993 Flood along the Missouri River. The exact flow that overtopped R460-471 in 1993 is unknown. However, from timelines kept by USACE liaisons and the local drainage district it is documented that overtopping began at 1600 on 7/24/1993. Catastrophic failure is estimated to have occurred at 0200 on 7/25/1993. The USGS recorded an actual stream measurement at the St Joseph Gage location as 268,000 cfs at 1445 on 7/24/1993. Thus a recorded flow of 268,000 cfs was recorded approximately 1 hour and 15 minutes prior to initial overtopping. This flow, much lower than the stated design flow, is a good estimate of the maximum flow that the levee could pass before overtopping and subsequent failure.

4. Design Flow History of MRLS R471-460. As stated in the 1947 *Missouri River Agricultural Levees Definite Project Report - Appendix I, Hydrology* the design discharge at St Joseph was 325,000 cfs. *Appendix I, Hydrology* was submitted to the Chief of Engineers for approval in August 1946 recommending a design flood discharge at St. Joseph of 293,000 cfs, with 2 ft of freeboard. In a letter to Missouri River Division (MRD) dated 17 Dec 1946, the Chief's office recommended a revised design flow of 355,000 cfs. On 19 March 1947, MRD responded by letter proposing a design flow of 325,000 cfs. The Chief's office approved this design discharge by letter dated 18 Apr 1947. This was a design flow and was not associated with any frequency at that time. However, Enclosure 2 of *Appendix I* in the 1947 DPR identified the natural 100-yr discharge as 255,000 cfs and the 100-yr discharge modified by Fort Peck as 250,000 cfs. No 500-year frequencies were reported in this enclosure to *Appendix I*. However, these numbers included within the hydrology appendix to the 1947 DPR indicate that the project was originally authorized for a discharge (325,000 cfs) that was well above the known 100-yr discharge at the time. The 1965 R471-460 General Design Memorandum (GDM) also included the design discharge of 325,000 cfs.

By the time the two St Joseph projects (R460-471 and L455) were constructed in 1962-1968, the *Missouri River Agricultural Levee Restudy Program – Hydrology Report* was published (March 1962). This report re-addressed flood frequencies on the Missouri River. The flood frequencies generated in the 1962 Restudy provided the basis for Flood Control Studies, Flood Insurance Studies, and FEMA maps for the next 40 years. The 1962 Restudy, taking into account the Missouri River Mainstem Reservoirs, reported that at the St. Joseph gage the 500-year discharge was 330,000 cfs and the 100-year discharge was 270,000 cfs. Thus before the projects were constructed the anticipated level of protection was nearly 500-year. The recent Upper Mississippi River System Flow Frequency Study (UMRSFFS, 2003) results indicate that flow frequencies in the St. Joseph area have not changed much from the 1962 study. The UMRFFS discharges are 324,000 cfs for the 0.2% chance (500-year) event and 260,000 cfs for the 1% chance (100-year) event. Thus with hydrology remaining fairly constant over the past 60 years, the focus of design deficiency analysis has been on hydraulic modeling.

5. Outline of Investigation Process. The R471-460 design profile assumptions were attempted to be re-created using available data and design information from the Levee Unit R471-460 General Design Memorandum (GDM) dated December 1965. Exhibit I of the GDM outlines the process used to develop the top of levee profile and alignment. The alignment was chosen such that the minimum floodway width adjacent the length of the levee should not be less than 3000 feet. The top of levee profile was computed by a backwater computation using Manning's n-values of 0.025 and 0.050 for channel and overbank areas, respectively. Cross-section and channel geometry data used in these computations were not located. However, detailed mapping of the Missouri River created in 1974 (six years following levee construction) was located. This 1974 mapping was used for the Missouri River Restudy completed in 1976, which resulted in FEMA mapping of the Missouri River.

Cross-sections from the 1976 Missouri River Restudy were entered into HEC-RAS for a reach extending from RM 425.44 – RM 465.59. The 1976 Missouri River Restudy cross-sections included dike geometry within the model. It was assumed that the design channel n-value, 0.025, used in the 1965 GDM was slightly high for the Missouri River channel and must have accounted for a composite n-value that included dikes as additional channel roughness. Therefore, the dike geometry was removed from the 1976 cross-section data in an attempt to reproduce 1965 design assumptions. The 1965 n-values were then applied to the HEC-RAS model to best re-create the design assumptions of 1965.

The design top of levee profile elevations taken from the 1965 GDM were compared to current surveyed elevations taken from a field survey conducted by the Kansas City District Survey Section in 2003 to ensure that the existing levee is built to design criteria. The surveyed top of levee elevations are slightly above the design top of levee elevations

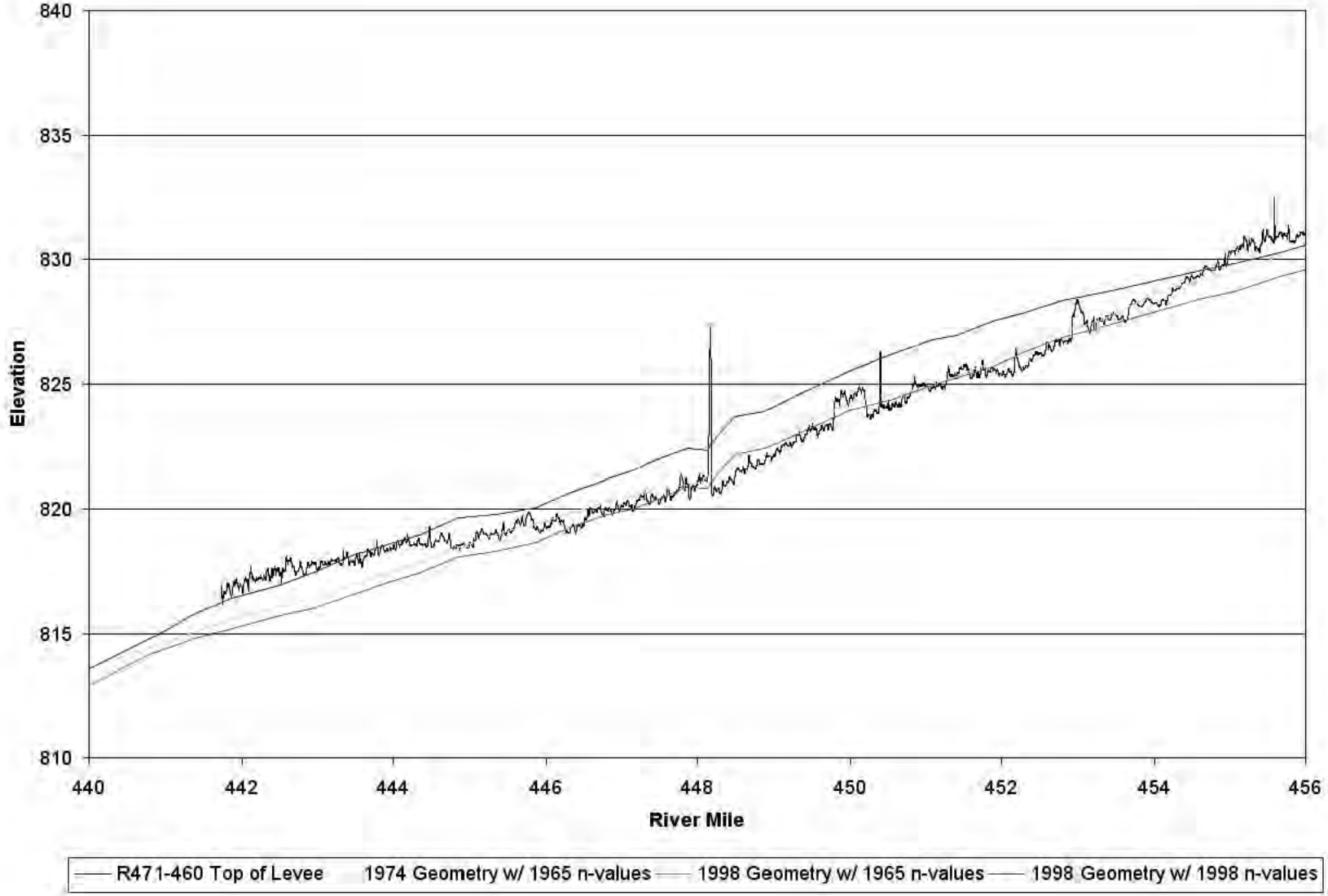
along the length of Unit R471-460. Therefore, the existing levee meets or exceeds the design top of levee profile.

Plate 1 displays the HEC-RAS modeled design flow water surface profile using geometry from 1974 and design n-values from 1965. This profile, which lies above the top of levee, is the best attempt to model the assumptions used for design in 1965. The design flow was also modeled using the existing conditions geometry generated for the St. Joseph Feasibility Study using 1998 Missouri River Mapping with n-values from the 1965 GDM. The close agreement between the profiles for the 1974 geometry and the 1998 geometry with the 1965 n-values indicate that changed channel geometry has not been a significant contributor to the inadequacy of the existing levee. For comparison purposes, the design flow was run using the existing conditions geometry and n-values generated for the St. Joseph Feasibility Study. The 1998 existing conditions n-values were calibrated to the UMRSFFS UNET unsteady flow hydraulic model profiles which were calibrated to 1993 high water marks and gage data.

6. Results. A flow of approximately 268,000 cfs overtopped MRLS Unit R471-460 during the 1993 Flood. This flow was approximately 60,000 cfs less than the design flow of 325,000 cfs used in the 1965 design profile for Unit R471-460. The design top of levee was set at an elevation between two and three feet above the design water surface profile to allow for two feet of freeboard along the length of the levee and up to one foot of dynamic effects at certain locations along the levee. This low overtopping flow raises concerns as to the original design top of levee elevation. In an attempt to recreate the original design assumptions, historical cross section data (1974) gathered shortly after the time of levee construction (1968) was combined with n-value assumptions from the original design documentation. This modeling produced a water surface profile for the design flow that is above the top of the constructed levee without any consideration of freeboard. The modeled design flow profile coupled with the 1993 overtopping at a flow much lower than the design flow has led to the determination of design deficiency in the top of levee profile for MRLS Unit R471-460.

Eric Shumate, P.E.
Hydraulic Engineer
CENWK-EC-HH

Plate 1. MRLS R471-460 Historical Profile Comparisons Using Original Design Discharge = 325,000 cfs



3.1 INTRODUCTION

The Geotechnical support to the Missouri River Levee Systems (MRLS) L-455 and R 471-460 Feasibility Study focused on establishing the geotechnical existing condition and developing the selected plan. The selected plan provides flood protection against the 100-year plus 3-feet flood profile. Geotechnical input was also provided for alternative screening. Alternative screening is addressed in more detail within the main body of the study.

3.2 EXISTING FLOOD CONTROL WORKS DESCRIPTION

Both MRLS L-455 and R 471-460 levees are about 13 miles in length. MRLS L-455 protects a portion of St. Joseph. MRLS R 471-460 protects Elwood, KS and the Rosecrans Memorial Airport. Both flood control units protect large agricultural areas. The project features most relevant to geotechnical concerns are listed in Table 1. Both levees have a combination of stability berms (both riverside and landside) and landside seepage berms.

Table 1. Project Features

Item	L-455	R 471-460
Levee (linear feet)	71,644	72,800
Height (feet), Range	5 – 22	7 – 18 (17 – 26 at Relief Wells)
Height, Typical	13.5	14.2
Relief Wells	34	20
Typical side slopes	3H:1V	3H:1V
Top Width (feet)	10	10
Pumping Plant	2 cfs	-
Drainage Structures	27	12
Sand bag closures	4	0

3.3 PROJECT SITE CONDITIONS

The project site over most of the levee alignments consists of relatively level to slightly undulating agricultural fields situated in the Missouri River flood plain. Most of the foreshore areas, riverside of the levee, are wooded. Some of these foreshore areas were previously cultivated, but have recently been converted to natural floodplain woodlands, through the wetlands reserve program. The majority of the levee length is located in these agricultural fields with relatively typical heights.

There are numerous areas where previous channels have been filled in the levee foundation. The most significant is the MRLS R 471-460 crossing of the old oxbow that forms Browning Lake. This reach includes 20 relief wells. Locations where smaller tributary channels have been filled are shown on the drawings. Near Contrary Lake, the levee passes through a narrow section that subdivides the river from the lake. There are also two filled scour holes on MRLS R 471-460 from the breach that occurred during the 1993 flood. The upstream breach removed about 1100 feet of levee, scouring a hole about

1000 feet landward, and up to about 45 feet maximum depth. Tributary inlets include Contrary Creek and Browns Branch on MRLS L-455, and Peters Creek on MRLS R471-460.

3.4 PROJECT SITE GEOLOGY

St. Joseph, MO lies within the Dissected Till Plains of the Central Lowlands physiographic province of Missouri. The overlying soils in the upland areas consist of glacial till and loess of Pleistocene age. The Nebraskan and Kansan glacial advances (1.5 to 3 million years ago) leveled the topography of northern Missouri. The last two ice advances, the Illinoisan and Wisconsinian had no direct physical presence in northwestern Missouri, but added a thick layer of loess to the deposits of glacial till already present. The loess deposits are highly erodible soils that contribute sediment to low gradient and turbid prairie streams that are typical of the region.

MRLS L-455 and R 471-460 levees are founded on more recent alluvial sediments within meander belts of the Missouri River. Alluvial deposition and erosion that occurred during the changing course of the river has formed a complex system of soil conditions within the Missouri River floodplain at the project vicinity. Landform features in the project area are indicative of the active meander activity of the Missouri River, before revetments and channelization of the river stabilized it. Contrary Lake (on the L-455 levee) and Browning Lake (on the R 471-460 levee) were both formed by segments of abandoned channel. Past river meanders have left a system of buried channels, oxbow lakes, and sloughs. The meander activity also creates uncertainty in geologic interpretation of soil stratigraphy, since channel erosion and infilling creates discontinuities in the horizontal bedding of soils.

The predominant soil conditions on both levees consist of a typical alluvial plain that includes a thick deposit of pervious sand overlain by a surficial blanket of clay or plastic silt. Bedrock within the basin consists primarily of shale beds, limestone, and sandstone. The underlying bedrock forms a relatively impervious boundary influencing groundwater flow that affects levee underseepage. These predominant soil conditions are conducive to levee distress from underseepage during flood events; and also conform to the basic model for underseepage analysis. There are also some areas where weak cohesive soils directly underlay the foundation of the levee, requiring stability berms that were incorporated into the existing levee, and prompting concern regarding adequacy of slope stability.

3.5 LEVEE PERFORMANCE DURING PAST FLOOD EVENTS

There is a USGS gage (#06818000) located in St. Joseph, just upstream of the railroad bridge. The top 5 historical crests are listed in Table 2. Data was obtained during the flood of 1952 from the existing private levees at the time, and was used during design of the present levees. The 1993 flood is the most recent of the top 5 crests, and exceeded the 1973 and 1979 floods by over 6 feet. Performance of the levees during the Flood of 1993 provides a performance record with water essentially at or near the top of levee.

Table 2. Historical Crests for Missouri River at St. Joseph

Date	Stage
07/26/1993	32.07
04/29/1881	27.20
04/22/1952	26.82
03/03/1979	25.78
10/13/1973	25.63

3.5.1 MRLS R 471-460—Flood of 1993

Overtopping of MRLS R 471-460 levee occurred over a reach of about 5 miles, beginning at and extending upstream of the railroad crossing (at Station 404+30). The freeboard was not consistent, so the depth of overtopping varied from no overtopping to about ½ feet depth through this 5-mile reach. Air photographs show that much of the levee was completely submerged after the upstream breach flooded the interior areas landside of the levee.

The MRLS R 470-460 levee reportedly performed satisfactorily until it was overtopped. The St. Joseph Airport Levee District indicated there were no observations of sand-boils. In particular, the Levee District indicated there were no observations of piping or stability problems near the upstream breach area. The breach occurred during the night, and there were no witnesses that observed exactly how the levee unraveled. The evidence suggests that levee breach resulted entirely from erosion of the earth fill from water passing over it.

There was one area of heavy seepage where sheet-flow drained away from the levee, located on the north side of the levee access road at Station 270+00. A photograph of this area is shown on Figure 7. Gravel is present on the surface of the recently disked agricultural field in a zone from about Station 266+00 through station 270+00, and extending about 50 to 100 feet from the landside levee toe. There was about ¾ inch rainfall in the area the night prior to the inspection. The gravelly zone was lighter in color from less moisture, indicating a difference in soil texture and/or a thin topsoil stratum in this area. The GIS air photograph also shows a light colored area at this location over about a 900 feet reach.

There are no readings from the piezometers, observations of relief well discharges, or freeboard gage records from the 1993 flood.

Several photographs showed erosion of a channel (estimated at its maximum to be about 3 feet deep) along the levee centerline and leaving turf-covered slopes intact. Water was running in the erosion channel parallel to the levee and exiting down field access ramps. The field access ramps were also eroded, similar to the levee crown.

Figure 7. Heavy Seepage Area at R 471-460, Sta. 270+00.

3.5.2 MRLS L-455—Flood of 1993

MRLS L-455 levee had two areas of sand boil activity. The first area occurred in the Lake Contrary lakebed, and was not known until several years after the flood event. The local farmers observed circular depressions in the lakebed at the West end of Lake Contrary. The depressions were dish shaped, about 1-1/5 feet deep and 10 - 12 feet in diameter. These are thought to be remnants of significant sand boil activity. However, they occur about 1000 feet from the levee, and are not considered to provide a threat to the levee.

Some small sand boils were observed near the east end of Lake Contrary during the Flood of 1993. The boils first developed near a stage of 24, and the intensity did not seem to increase as the river level crested at stage 32.1. The boils were ringed with a single course of sand bags. It appears that the sand boils initially blew out some material from the blanket and then developed into concentrated seeps. The area of the sand boils is indicated in the two photographs (Figures 8 and 9), shot from the same approximate location. The levee is about 200 – 300 feet from the sandboils, and curves away from the lakeshore off the left side of the photographs.

The South St. Joseph Levee and Drainage District noted a soft wet area along the levee toe near the access ramp at Levee Station 137+43. An area about 200 –300 feet to the southwest was reported as very soft. It is likely that many other soft areas similar to this occurred, but were not observed in areas without traffic.

In 1993, two storm sewer outfalls on Brown's Branch had rubber valves. The rubber valve on a 30" RCP at Sta. 26+66 turned inside out during the flood. These were replaced with flap gates.

Figure 8. Ringed Sand-boils during Flood of 1993.

Figure 9. Vicinity of 1993 Sand-boils, as photographed in 2004.

The South St. Joseph Levee and Drainage District took freeboard readings daily during the Flood of 1993, but did not read piezometers or monitor relief well discharge. However, the relief wells discharge plenty of water to the point that it is a concern for interior drainage.

3.5.3 Contrary Creek Slide Failure

MRLS L-455 levee ends just below a railroad overpass on Contrary Creek at Station 716+44. A total of 12.62 inches of rainfall at St. Joseph was recorded on 7 - 10 June 1984, with over 7 inches on 8 June. High flows in Contrary Creek eroded the channel bank downstream of the railroad bridge. The toe scour initiated a deep-seated slide of the cohesive bank that encroached on the lower portion of the levee prism. The slide was repaired under PL 84-99 funding. The repair included riprap to prevent future scour, but the slope failed again following a 2.24 inch rainfall event on 17 May 1986. The second failure was likely due to rapid drawdown conditions in remolded soils in a weakened condition from the initial failure. The slope was again repaired with PL 84-99 funding. The second repair included 3 “baffle dikes” that consisted of rock filled trenches excavated into the slope (transverse to the levee alignment).

3.5.4 Peters Creek Scour Repairs

There have been at least 2 instances where scour has been a concern at Peters Creek, on Levee MRLS R 471-460. The bank was restored at Stations 7+65 to 8+50 under contract DACW41-85-Q-0191, issued 20 Feb 1985. This work placed 100 CY of fill and 780 TN of rockfill. Another concern regarding bank scour was documented in a request of PL 84-99 assistance from the Elwood-Gladden Drainage District on 19 August 1987. This concern was located at Sta. 708+00 to 711+00. The request was denied since the distress was documented in periodic inspection reports, and was considered to be operations and maintenance related.

3.6 POTENTIAL MODES OF FAILURE

The National Academy of Science[1] has noted that the Corps has many years of experience with levee performance (including levee failures), and that much of this experience is accessible. However, this experience is difficult to quantify. The Flood of 1993 provides an ideal case history potential because it met or exceeded the design flood of many levees, it covered a large region, and it is relatively recent. Yet, the post flood report provided no direct interpretation for the cause of levee failures. In most cases the cause of the breach was not listed. Non-federal levees, where most of the failures occurred, were summarized in lesser detail than the Federal levees. In many cases, perhaps most cases, the actual breach of the levees occurred at night and/or without observation. Post mortem speculation on the cause of breaches lead to controversy, and in some cases far-fetched scenarios. The only conclusion that can be drawn from the 1993 flood is that the case

[1] Risk Analysis and Uncertainty in Flood Damage Reduction Studies, National Academy Press (2000).

histories do not discredit long-standing engineering assumptions regarding levee performance.

In spite of shortcomings, there is some information available for the 1993 flood:

a. Within the St. Louis District, 39 federal levees were breached/overtopped out of a total of 229. Ten federal levees were severely damaged by floodwaters. Of these ten, "eight were overtopped and two were breached while the river was above the design flood flowline, but within the levee freeboard." It is not clear how the levees could overtop if the water level was within the freeboard. About 80% of the private levees were overtopped or breached.[2]

b. Within the Rock Island District, boils were observed at nearly all of the sand levee projects. The boils were concentrated at berm toes inside curves, and at groves of trees. Sinkholes developed on berms typically at distances of 10 to 75 feet riverward of berm toe boils. Some sinkholes progressed up the levee slope. The report indicates, "Many levee districts experienced inundation as a result of overtopping or breaks in the levees." It lists 15 federal levees and 10 non-federal levees, but does not resolve the cause of inundation.[3]

c. Within the Kansas City District, sandboils were observed landward of five levee units. "Six of the MRLS units were substantially overtopped resulting in four of them being completely breached by erosion of the levee embankment by overtopping scour". Four levee units incurred sloughing, which was attributed to rapid drawdown conditions. Sinkholes, caused by pipe joint leakage and subsequent piping of the adjacent soils, were observed at six levee units.[4]

In spite of a large number of levees with observed sandboil activity, levees seldom fail from underseepage. The Kansas City and Omaha Districts recognized this in a meeting on underseepage in 1962[5]. During the Flood of 1993, there was only one breach on Federal levees definitely linked to seepage distress (Kaskaskia Island).[6, 7] Flood fight efforts are usually successful in identifying problems and stabilizing the distress. Minor sandboils sometimes occur if a landside blanket heaves and cracks; and these may heal over time. Also, levees are resilient since they tend to display signs of underseepage distress before they reach a collapse state.

It is clear that the predominant cause of inundation behind levees is overtopping. Nevertheless, premature levee failures due occur. In cases where geotechnical levee failure observations and/or data are available, post mortem failure analyses frequently link

[2] The Great Flood of 1993 Post-Flood Report, Appendix C, September 1994.
[3] The Great Flood of 1993 Post-Flood Report, Appendix B, September 1994.
[4] The Great Flood of 1993 Post-Flood Report, Appendix E, September 1994.
[5] Meeting at MRD on Underseepage Control on Agricultural Levees, CENWK files, 27 Nov. 1962, 11pp.
[6] The Great Flood of 1993 Post-Flood Report, USACE, Sept. 1994.
[7] Mansur, C. , G. Postol & J. Salley, Performance of Relief Well Systems Along Mississippi River Levees, J. of Geot. & Geoenv. Eng, ASCE, Aug. 2000.

failures to multiple causes. In many cases, the failure mode is complex and the predominant cause is speculative.

3.7 EXISTING CONDITIONS

3.7.1 General

The feasibility study will assess the economics of raising these levees. Potential projects will be considered by selection of an optimal NED (National Economic Development) plan, which seeks to optimize the benefit/cost ratio. The economics analysis will consider the baseline conditions by preparation of a river stage-flood damage analysis for the existing levees in their present condition. This analysis considers the potential for the levee to breach before it is overtopped.

In order to assess the potential for premature levee failure (other than by overtopping), a risk-based analysis of levee reliability has been made in conformance with ER 1105-2-101. The risk-based analysis is based on an engineering analysis with a probabilistic approach using likely failure modes, as described in ETL 1110-2-556. The reliability analysis has been based on failure modes of underseepage and slope stability. Most of the risk is associated with underseepage. Likewise, most of the emphasis of the analysis herein is placed on underseepage.

The results have been presented in a format of charting the probability of failure as a function of the remaining levee freeboard. These results are included in the Results section of the report. In general, the levees have a low probability of failure, as demonstrated by adequate performance during the flood of 1993.

ER 1105-2-101 states “the ultimate goal is a comprehensive approach in which the values of all key variables, parameters, and components of flood damage reduction studies are subject to probabilistic analysis.” This report has used judgment to eliminate unlikely causes and focus on those failure modes considered most significant. For this reliability analysis, two predominant failure modes have been analyzed independently. These failure modes include underseepage and slope stability. Other common failure modes include through-seepage and settlement.

3.7.1.1 Underseepage

The presence of a deep pervious stratum and overlying blanket of fine, cohesive soils makes the levee susceptible to underseepage. Underseepage was a significant concern of the designers, and its relevance is apparent by identification of the typical site geology. Based on the analysis, the most likely geotechnical failure mode (other than by overtopping) of these levees would be initiated by a condition of severe piping.

3.7.1.2 Through Seepage

Through-seepage is categorized as seepage primarily passing through the levee as opposed to passing beneath it. Through-seepage distress is characteristic of sand levees. The L-455 and R 471-460 levees are constructed from clay soils, and are not prone to through-seepage problems. This is substantiated by observations during the 1993 flood. The only area where seepage was observed near the face or toe of the levee was near Station 270+00 on R 471-460. The landside blanket is known to be nearly absent in this area, leading to a prognosis of underseepage. Through seepage was not analyzed as part of the reliability analysis.

3.7.1.3 Slope Stability

Slide failures occurred during construction of the neighboring downstream levee unit L 448-443, just on the opposite side of Contrary Creek. These slide failures were attributed to presence of soft alluvial clays in the levee foundation and channel excavation combined with end-of-construction loading conditions. This area of soft foundation soils at L 448-443 extends across the Contrary Creek channel into the L-455 levee. The relief well fields on both projects are also situated in areas with soft foundation clays. Another slide failure occurred at Station 713+00 of L-455 that was initiated by erosion. Portions of the levee foundations are situated on soft alluvial clays that are a concern for stability of the levee.

The soft alluvial clays are most susceptible to slope failure during end-of-construction conditions due to rapid loading. The pore pressures dissipate over time, resulting in strength gain and increased stability of these levees. The end-of-construction condition is not a concern for the existing levees. However, it may be a concern that would require further analysis if the levees were raised a substantial amount.

Rapid drawdown increases loading conditions on the levee due to saturated soils in the embankment. The saturated soils increase the weight of the embankment and form seepage forces as it drains. Rapid drawdown is manifested by riverward slides. These forces are not activated until the river level recedes from its crest. The risk of inundation and property damage decreases as the river level recedes. Since the purpose of the levee reliability analysis is linked to economic damages, rapid drawdown was not considered as a failure mode.

Steady state seepage conditions peak as the river level crests. Steady state seepage is manifested by landward slides. Softening of the landward blanket caused by uplift and piping activity along the levee toe, may also contribute to sliding instability. The steady state seepage failure mode was investigated by reliability methods.

3.7.1.4 Settlement

The top of levee profile indicates that overtopping does not occur uniformly, and does not show superiority at the upstream end. The inconsistent levee profile is due to a number of sources. It may be related in part to settlement at select locations. Since the levees have been in place for over 40 years, and the foundation soils susceptible to consolidation are generally less than 20 feet in thickness, future settlement should be small in proportion to

that which has already occurred. The existing levee profile is being addressed by overtopping analysis, and was not considered as a geotechnical failure mode.

3.7.1.5 Other Risks

Experience on the Upper Mississippi River – Illinois Waterway System Navigation Study has shown that many geotechnical failures, or unsatisfactory performance events that require repair or cause damages, result from unanticipated failure modes that were not analyzed in the design. There are other series of events (not captured in the probabilistic analysis) that could potentially result in levee failures. Some of these additional risks that compromise levee reliability are discussed.

a. Closures. There are gaps in the levees that require sandbag closures. There is risk associated with proper and timely placement of sandbag closures.

b. Outlet Gates. There are outlet structures in the levees for storm runoff and sanitary sewage. The outlets consist of reinforced concrete pipe with flap gates or sluice gates. There is risk that a flap gate may be lodged with debris and leak, or that a sluice gate may seize or not close securely. For the large ponding areas behind these levees, leaking gates would have minor consequences.

c. Piping at Outlets. Piping problems tend to be exacerbated at structures since the interface disrupts the soil fabric, the structure alters the stress state in the ground, the pipes allow roofing or formation of voids due to settlement or piping action, and compaction of soils is difficult around pipes and structures. Leaking pipe joints due to settlement or concrete degradation can result in loss of material around the pipe. There is no available performance function for assessing the potential for piping at the outlets, as the problem seems to have characteristics of random events. In most cases the outlets will be present with or without the levee project, so the consequences of failure would cancel out in the economic analysis.

d. Scour. Numerous areas were repaired subsequent to the 1993 flood where the grass vegetation had been eroded. Scour areas on the levee tended to occur near perturbations in the flow, such as near field access ramps or ditches/spoil piles. Several scour areas about 5 feet deep occurred in open fields. Changed conditions between the 1993 flood and the next flood event may result in changes of scour manifestation. The 1993 flood crested (Figure 1) in late July when the upper portions of the levee riverward slope had healthy turf cover. The turf cover during a spring flood may not be as resistant to erosion. New wooded areas in the foreshore that have been diverted into the wetlands reserve program could alter flow velocities or current patterns near the levee. Debris or ice jams could also cause localized scour by damaging the grass cover or redirecting the current. Pump outwash improperly spilled over the levee crest could initiate erosion of the levee. There is risk that a scour area below the water level could go undetected until it causes a slide, or collapse of the levee crown.

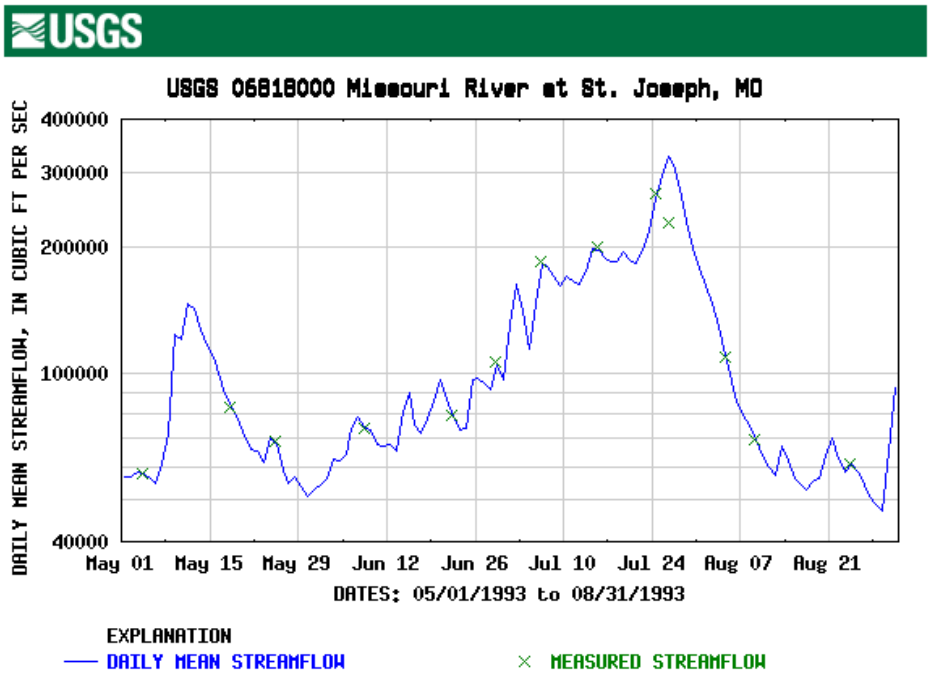


FIGURE 1. HYDROGRAPH AT ST. JOSEPH FOR 1993 FLOOD

e. Power Poles. Present design guidance strongly discourages power poles located within the levee prism, including berms. There are a series of large power poles for a high voltage line near the downstream end of the L-455 levee. The power poles may interfere with flood fight efforts, they tend to concentrate seepage and the formation of boils if located near the landside toe, and they are prone to instability during floods due to saturated ground and upward gradients. The enigma of power poles and trees in levees is that the only time they become unstable is when the river crests – the very time that their toppling failure poses a flood threat. There is risk that overturned power poles could lead to a levee breach.

3.7.2 Analysis Methodology

3.7.2.1 Reliability Analysis

The reliability analysis followed concepts described in ETL 1110-2-556. The reliability analysis proceeds by using a conventional engineering analysis. A failure mode is assumed; and the critical state of impending failure is expressed as a factor of safety, or ratio of capacity/demand. The reliability analyses conducted in this study used the first-order second-moment (FOSM). The FOSM method uses a first order Taylor's series expansion to calculate derivatives of the performance function, and only uses the first two moments of the normal distribution. The first moment is the mean, and the second moment is the variance (or standard deviation).

A probabilistic analysis must be based on a performance function. The performance function defines the failure criteria by either a factor of safety, or capacity-demand ratio. For slope stability, the limit state is taken at a factor of safety of 1. For underseepage, the capacity – demand ratio is used. The demand is defined by the calculated upward gradient. The capacity has been adjusted beyond the critical gradient to provide an estimation of failure that is more closely associated with conditions incipient to a levee breach.

The capacity for underseepage is based on a value linked to severe sand boil activity incipient to levee failure. If the capacity were based on the critical gradient, the performance function would predict the occurrence of (at a minimum) a low consequent event defined by initiation of sand boil activity. This would lead to an event tree, whereby some probability of events could be linked to high, medium or low consequences resulting from the occurrence of sandboil activity. An event tree could also be applied to estimate high or medium consequences resulting from severe sandboil activity incipient to levee failure, but it has been neglected from this analysis.

3.7.2.2 Underseepage Analysis

3.7.2.2.1 Factors of Safety

There are two factors of safety applicable to underseepage. These are the uplift factor of safety and the gradient factor of safety. These two factors of safety are defined here since they are both mentioned in subsequent discussions.

The uplift factor of safety (FS_g) is derived by analyzing forces acting on the base of the blanket layer,

$$FS_{up} = W/u, \tag{1}$$

where W is the total weight of the overlying blanket layer, and u is the uplift pressure acting on the base of the blanket. The gradient factor of safety is derived as the ratio of the critical gradient (i_{cr}) to the calculated gradient (i),

$$FS_g = i_{cr}/i. \tag{2}$$

If the piezometric level above the ground surface (H_g) and the blanket layer thickness (Z_{bl}) are known, as indicated in Figure 2, then the factors of safety are:

$$FS_g = \frac{\gamma_{sat} \cdot Z_{bl} - \gamma_w \cdot Z_{bl}}{\gamma_w \cdot H_g}, \tag{3}$$

$$FS_{up} = \frac{\gamma_{sat} \cdot Z_{bl}}{\gamma_w \cdot H_g + \gamma_w \cdot Z_{bl}}, \tag{4}$$

where γ_{sat} is the saturated unit weight of the blanket soil, and γ_w is the unit weight of water.

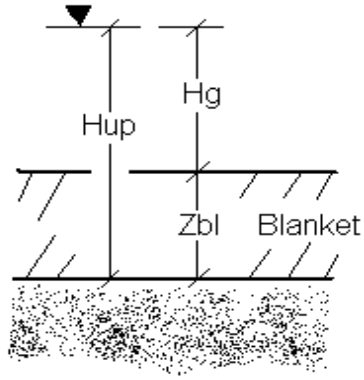


FIGURE 2. Uplift Pressure
on Bottom of Blanket Layer

These two factors of safety have different characteristics:

a. For a uniform blanket layer at limit state conditions, $FS_{up} = FS_g = 1$. Since the factors of safety converge at the limit state, recent Corps practice has been to only address the gradient factor of safety if the blanket layer is relatively uniform.

b. The gradient factor of safety is more responsive, since as $H_g \rightarrow 0$, FSup $\rightarrow (\gamma_{sat}/\gamma_w) \cong 2$, but $FS_g \rightarrow$ infinity.

c. The factors of safety diverge if the layer thickness is transformed as appropriate for variable stratigraphy within the blanket layer.

3.7.2.2.2 Underseepage Calculation Procedure

Underseepage analysis was performed by the methods in EM 1110-2-1913, Appendix B. The equations were completely included within an Excel spreadsheet. The equations to calculate the head at the toe were modified based on an assumed impervious berm. The levee cross sections of the idealized seepage model is shown in Figure 3. The resulting equations are:

$$ho = \frac{X3}{X1 + L2 + X3}(H + H_{TOL} - h_{tw}) + h_{tw} \quad , \qquad i_o = \frac{h_o - h_{TW}}{Z_{bl}}, \quad (5)$$

$$h_1 = \frac{X3 + W_{SP} + W_{SB}}{X1 + (L2 - 3Z_{B1}) + W_{SB} + W_{SP} + X3}(H + H_{TOL} - h_{tw}) + h_{tw}\ , \qquad i_1 = \frac{h_1 - h_{TW}}{Z_{bl} + Z_{B1}}, \quad (6)$$

$$h_2 = \frac{X3 + W_{SP}}{X1 + (L2 - 3Z_{B1}) + W_{SB} + W_{SP} + X3}(H + H_{TOL} - h_{tw}) + h_{tw}\ , \qquad i_2 = \frac{h_2 - h_{TW}}{Z_{bl} + Z_{B2}}, \quad (7)$$

$$h_3 = \frac{X3}{X1 + (L2 - 3Z_{B1}) + W_{SB} + W_{SP} + X3}(H + H_{TOL} - h_{tw}) + h_{tw}\ , \qquad i_3 = \frac{h_3 - h_{TW}}{Z_{bl}}. \quad (8)$$

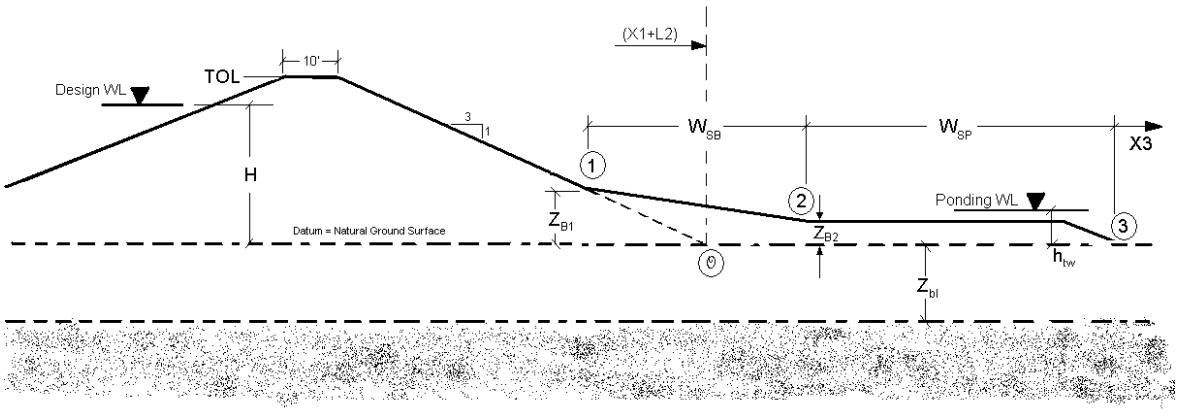


Figure 3. Model for Underseepage Analysis

Reliability was analyzed for all of the original seepage design sections where the data was reported. This was done for several reasons. The first is that the original design sections encompass the critical sections known to the designers, and thus should avoid overlooking critical reaches. The second is that the data was readily available and easily added to an automated spreadsheet. The third is that analysis of a comprehensive set of sections provides additional information on the overall performance of the levee system. Providing a comprehensive analysis of the levee system, rather than just focusing on the critical reaches, has been recommended by the National Academy of Science.[8]

3.7.2.2.3 Extrapolation of the Critical Gradient

The estimation of soil parameters for seepage analysis is complicated by the phenomenon that the effective permeability of the blanket layer over a large area tends to be orders of magnitude higher than the permeability of small samples of soil. Furthermore, the effective permeability of the landside blanket is not constant, but increases as uplift pressure may cause heave and cracking. Heavy seepage will flush out defects and preferential seepage paths in the blanket layer, either existing or introduced from blanket floatation response to uplift pressure.

Flotation factor of safety over a large area cannot be less than 1. If it did, the blanket layer would rise up as a membrane over a bed of water. This cannot occur to any appreciable amount without the blanket cracking and releasing water through concentrated seeps. As the river level raises further, the volumetric seepage quantities increase, and the sandboils are exacerbated by this increase in seepage flow. Increased sandboil activity could be correlated with increase in effective blanket permeability. However, the conventional mathematical model uses constant blanket permeability. Maintaining a constant blanket

[8] Risk Analysis and Uncertainty in Flood Damage Reduction Studies, National Academy Press (2000).

permeability leads to extrapolation of the gradient. This extrapolation is a hypothetical state, and is sometimes emphasized by referring to the "calculated gradient."

3.7.2.2.4 Design Values for Underseepage Analysis

The effective blanket permeability values are influenced primarily by spatial variation and geologic discontinuities that are obscured from direct observation. These are, for practicable purposes, impossible to detect and quantify. For this reason, design parameters have been based on back calculation of blanket permeability values correlated with piezometer readings. These correlations have evolved into design values in EM 1110-2-1913, and ETL 1110-2-555. Based on TM 3-424 Table 37 and 38, the amount of scatter in back calculated values varies widely, so it is difficult to question the original author's judgment in selecting design values. Collective consideration of various design value schemes and physical laws suggests that the following trends are generally applicable to underseepage analysis:

a. The effective permeability can be categorized by soil plasticity, where SM, ML, CL and CH soils have consecutively lower permeability.

b. The effective permeability is related to layer thickness. For moderate permeability soils (SM), the layer thickness affect is moderate. For low permeability soils (CL and CH), the layer thickness affect is more pronounced.

c. The variation (design value uncertainty) is higher for thin blankets, and becomes more consistent for thick layers.

The point at which piezometer readings are taken provides a baseline. The piezometer correlations were generally taken during sand boil activity, or at high river levels close to boil activity. Inconsistency in boil activity during piezometer readings may be responsible in part for the large amount of scatter.

3.7.2.2.5 Surcharge Factor

There are 5 sources that lead to an approximate surcharge factor to estimate a condition of severe sand boil activity incipient to levee failure. This surcharge factor is taken as the ratio (i_{cr}/i_f), where i_{cr} is the critical gradient and i_f is the gradient at "failure."

a. Many of the levees in Rock Island District (prior to 1962) were designed assuming a significant flood fight is justified.[9] The design anticipated that major boils, and hundreds of minor boils, would develop. This was confirmed by significant sandboil activity during the 1993 flood at the Rock Island District. The Rock Island criteria for berms was a calculated gradient factor of safety of 0.7 ($i_c/i = 0.7$). Assuming the factor of safety at failure is $i_f/i = 1$, leads to a surcharge factor of (i_{cr}/i_f) = 0.7.

[9] Rock Island District Levee Practices, MRKED-F Memorandum for Branch File, 25 October 1962.

b. Kansas District experience from the 1952 flood was that seepage was tolerable and near critical state indicated by distributed seepage and pin boils, for computed gradient factors of safety of 0.8. At computed gradient factors of safety of 0.55, the seepage conditions were objectionable, considered dangerous, and required a major flood fight. Adjusting the critical gradient to the field observations, the surcharge factor is $(i_{cr}/i_f) = 0.55/0.8 = 0.6875 \cong 0.7$.

c. St. Louis District back calculated a gradient of 1.35 for the Bois Brule and Kaskaskia Island levee failures that occurred during the Flood of 1993.[10] Both these failures were due to underseepage, and resulted in an actual breach of the levee. In a recent existing conditions report, St. Louis District used this calculated gradient to estimate the occurrence of a high consequence event (defined as a levee breach). Based on a critical gradient of 0.85, the surcharge factor is $(i_{cr}/i_f) = 0.85/1.35 = 0.63$.

d. Considering the TM 3-424 chart of observed seepage conditions (in Figure 9), the severity of seepage, described as light, medium, heavy, and sandboils, is shown to increase for calculated gradients. Extrapolating this chart to a higher level, the factor of $(i_{cr}/i_f) = 0.7$ seems reasonable.

e. Design of berms for MRLS projects in the time frame when L-455 and R 471-460 were designed and constructed using factor of safety criteria dependent on past observations.[11,12] Where major boil activity had occurred during past flood conditions, berms were proportioned to develop a gradient factor of safety of 1 at the berm toe and 1.5 at the levee toe. Although the logic is a little indirect, it can be inferred that the 1.5 factor of safety approximately shifts the boil activity from failure state back to critical state. Using this assumption, the surcharge factor is $(i_{cr}/i_f) = 1/1.5 = 0.6667 \cong 0.7$.

f. Using a value for the surcharge factor of 0.7 produces reasonable results when calibrating to the 1993 flood conditions at L-455 and R 471-460. Calibration to the 1993 flood is shown in Figures 4 and 5. The probabilities of failure at L-455 are less than 5%, so it is expected that no major seepage concerns were reported during 1993. At R 471-460, there were a few sections with higher probabilities of failure, but since the levee overtopped, there were not reliable observations of seepage conditions at design flood elevation.

[10] Private communication with Mr. Edward Demsky, CEMVS, 19 July 2004.
[11] Design Memorandum No. 1 - Underseepage Control – Levee Unit 400-L, including Appendices I and II, 20 November 1953.
[12] Design Memorandum No. 1 - Underseepage Control – Levee Unit 476-L, revised 24 March 1954.

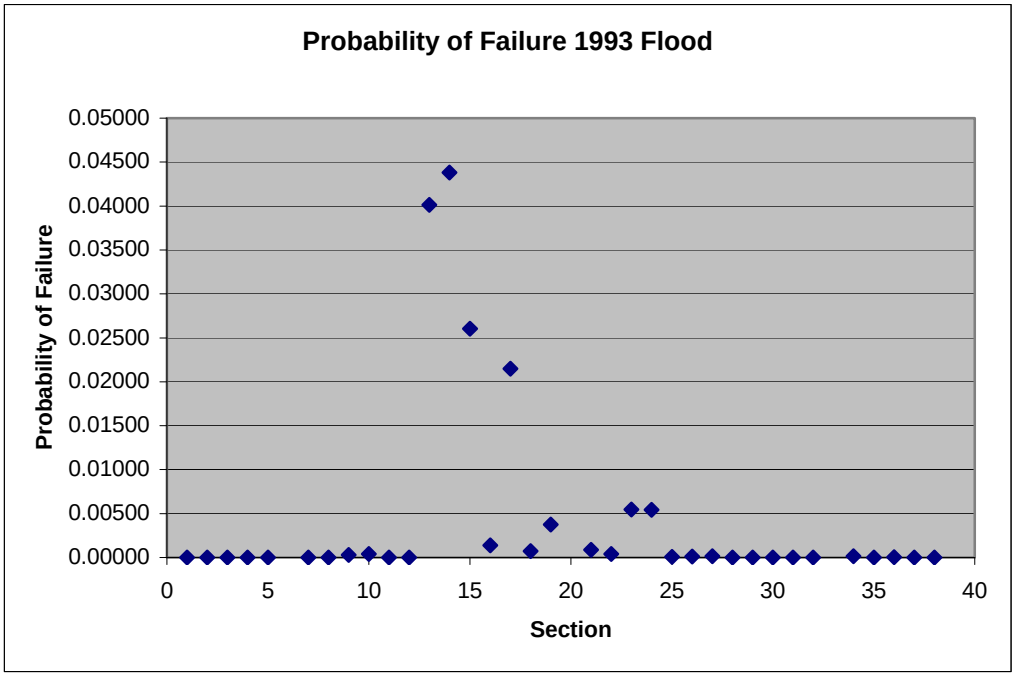


FIGURE 4. Probability of Failure Calculated for 1993 Flood at L455

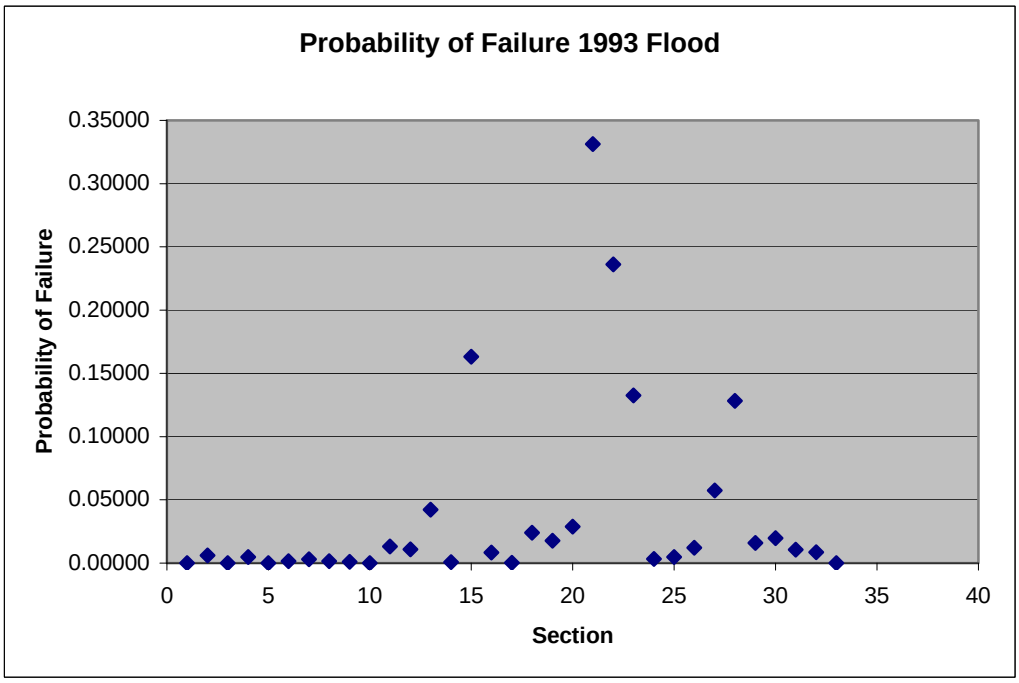


FIGURE 5. Probability of Failure Calculated for 1993 Flood at R471-460

3.7.2.3 Slope Stability Analysis

The slope stability analysis was performed with Utexas4. Factors of safety calculated from Utexas4 were inserted in the FOSM analysis to calculate the probability of failure. A typical section was used to determine if more detailed analysis is justified. Rather than

proceeding with a number of detailed cross sections in various reaches, one typical section was analyzed with the FOSM method. Conservative assumptions were made, including a 20 feet levee height, a 15 feet foundation layer of soft clay, a fully developed phreatic surface extending from the riverside crest to the landside toe, and seepage entrance/exit length that maximizes the phreatic surface in the underlying sand without uplift at the berm toe.

3.7.3 Levee Dimension Information

Recent dimensions of the levee and surrounding topography are based on a 4-foot contour interval. This was not considered sufficient to construct levee cross sections; so seepage cross sections were based on the original tabulated design calculations. The original tabulated design calculations are in agreement with the as-built cross sections of the levees as indicated in typical design sections in the Operations and Maintenance manual.

Several sources were investigated for the purpose of verifying site conditions. Comparison of levee crest and toe elevations is shown in Figure 6. The recent top of levee profile survey shows elevations consistently above the as-built elevations in the O & M manual. The elevations of the berm are indicated as points 1 and 2. There are no recent surveys of the berms. To provide a consistent relation of the berm elevations to the top of levee, the O & M manual dimensions (including top of levee) were used in the reliability calculations.

The levee toe elevations were calculated from the O & M manual top of levee elevations, minus the levee heights in the design calculations.

On levee L-455, the design calculations were based on a design water surface 1 foot below top of levee. On levee R 471-460, the design calculations were based on a design water surface at the top of levee. Occasionally, levees are raised during flood events, such as by sand bags or flash boards. The 13-mile reach of levee for both projects makes it unlikely that the overall level of protection could be raised during flood fight operations. An exception may be pushing the landside slopes up to peak the crest; but this is not considered since it damages the levee and significantly increases seepage problems. The reliability calculations used a freeboard analysis referenced to the top of levee.

Interior ponding levels were assumed from a variety of abstract data. A booklet containing the original design calculations for L-455 included a note that assumed a ponding elevation of 799.5 at the reach at Sta. 445+00 to 465+00. However, this ponding level was not consistent in other reaches. The reliability analysis assumed a ponding elevation of 800.0-feet at the reach from Sta. 248+00 to 480+00. This generates ponding depths typically about 2 feet, which corresponds to the 1993 flood observations indicated by the local sponsor.

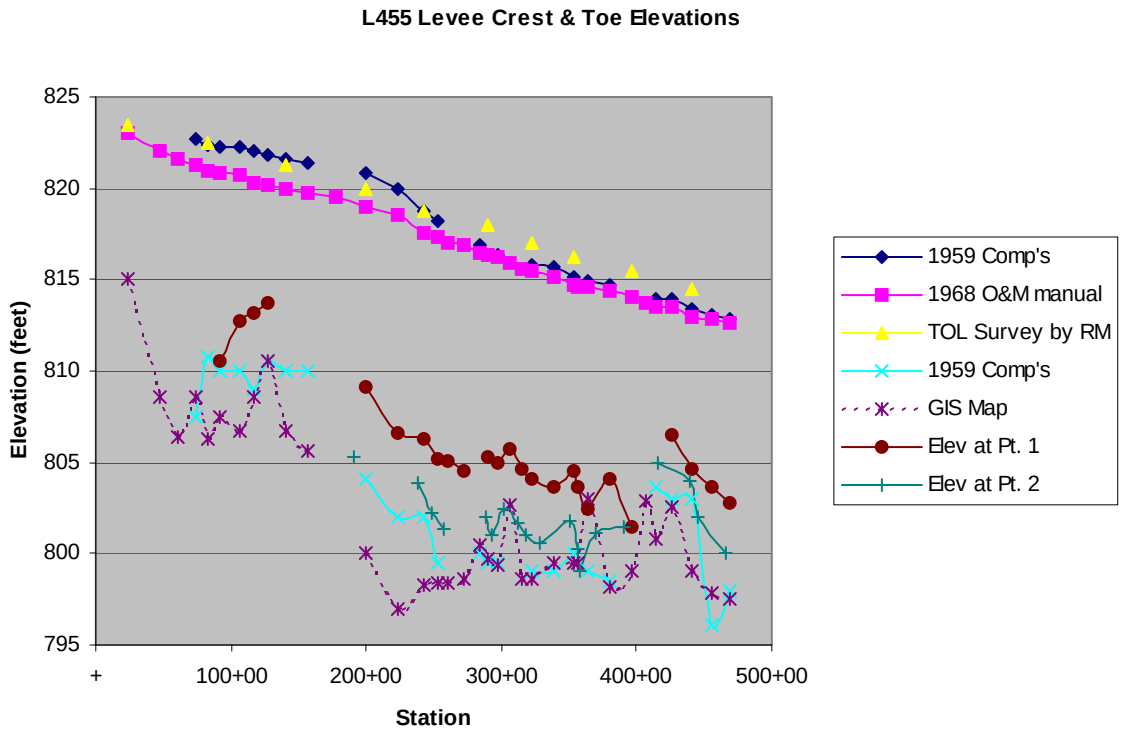


FIGURE 6. L-455 LEVEE CREST AND TOE ELEVATIONS

3.7.4 Soil Parameters for Reliability Analysis

3.7.4.1 Uncertainty in Soil Parameters

Measures of uncertainty of soil parameters are included in the reliability analysis. The uncertainty is expressed either as standard deviation, or coefficient of variation (COV). The standard deviation is used directly in the calculations. The COVs are relatively more consistent from project to project than the standard deviation, and are used for comparative purposes. Comparing COVs is a reality check. Some commonly accepted COVs for geotechnical parameters are:

Parameter	Coefficient of Variation	Source
Unit Weight	3 %	Harr[13] (After Hammitt)
Unit Weight (density)	5 - 10 %	Baecher & Christian[14] (After others)
Specific Gravity	2 %	Harr (After Padilla & Vanmarcke)
Porosity	10 %	Harr (After Schultz)
Friction Angle in Sand	12 %	Harr (After Schultz)
Friction Angle in Sand	2 - 5 %	Baecher & Christian (After others)
Cohesion	40 %	Harr (After Fredlund & Dahlman)
Cohesion	20 - 50 %	Baecher & Christian (After others)
Permeability, saturated	90 %	Harr (After Nielsen)

[13] Harr, Milton, Reliability-Based Design in Civil Engineering, McGraw-Hill, 1987.
[14] Baecher, Gregory and John Christian, Reliability and Statistics in Geotechnical Engineering, Wiley, 2003.

Although the original studies may have been specific as to how these COVs were derived, the tabulation of general values does not differentiate between different sources of error. Christian et al.[15] categorized four general categories for sources of error:

a. Spatial variation due to real changes in soil characteristics (aleatory)

b. Random testing errors (perceived as spatial error)

c. Statistical uncertainty arising from limited testing (epistemic)

d. Test Bias, such as sample disturbance (epistemic)

Spatial variation can be used to justify very high uncertainty. Averaging data from different geologic stratigraphy is not realistic for a probabilistic analysis, if it were detected and separated in conventional analysis. Similarly, statistical error from limited testing can be shown to be very high if based on an assumption of complete random sampling. However, there is intelligence in selection of boring locations, and selection of samples for testing. Combined with geologic interpretation, the subsurface information for confidence in soil parameters become subjective.

A subjective analysis (or expert opinion) method for determining parameter uncertainty can be approximated from the 4-Sigma or 6-Sigma rule. Inclusion of error should be based on representative values for analysis. The random testing errors (Category 2) should be subtracted out. Spatial variation and statistical uncertainty (Categories 1 and 3) can be estimated through engineering judgment by confidence in predicting test values if further testing were conducted.

Predicted test values should be thought of as weighted-average test values as they would affect the analysis. For example, when test values are obtained in a zone where spatial averaging affects the analysis, the standard error of the mean(σ_μ) is more appropriate in place of the standard deviation (σ), where N is the number of data values.

$$\sigma_\mu = \frac{\sigma}{\sqrt{N}}$$

3.7.4.2 Critical Gradient

The critical gradient is a measure of when the upward percolation of water begins to carry soil particles with it. The critical gradient is characterized by the soil and the water, not by other factors in the underseepage analysis. The critical gradient is calculated as

$$i_c = \gamma_b / \gamma_{h2o} \quad \text{, or} \qquad 1a$$

[15] Christian, J., C. Ladd & G. Baecher, "Reliability Applied to Slope Stability Analysis", J. of Geotech. Eng., ASCE, Dec. 1994.

$$i_c = (G_s - 1)/(1+e) \qquad 1b$$

Typical soil parameters for L-455 include a saturated unit weight for the top blanket soil of γ_{sat} = 114 pcf and a dry unit weight of γ_d = 80 pcf. Other soil properties calculated from these unit weights include: buoyant unit weight, γ_b = 51.5 pcf, saturated water content, w = 42.5 %, void ratio, e = 1.19, porosity, n = .54, and specific gravity of solids, G_s = 2.81. Based on these properties, the expected value for the typical critical gradient is calculated by either eqn. 1a or 1b as i_c = 0.84. Berm calculations for both levees listed critical gradients used in the original analyses. These ranged from 0.70 to 0.85, with a typical value of 0.80. Since the critical gradients reported in the original analyses are based on superior knowledge of soil conditions known at the time, they were used in the reliability analysis.

The uncertainty in the critical gradient was estimated from published field observations on the Lower Mississippi River, and correlation with typical uncertainty for the porosity. Figure 10 shows the field observations. The field observations were confirmed with piezometers, and not based on seepage calculations. Based on the reported gradients in the Sand Boils category, and deleting the two low values as outliers, the COV for the critical gradient is 15.8%. As a reality check, the COV is calculated from the porosity. Substituting e = n/(1-n) in Eqn. 1b,

$$i_c = (G_s - 1)(1-n) \qquad 1c$$

Based on a typical COV for the porosity of 10%, mean values of Gs=2.8 and n=0.54, the FOSM method and Eqn. 1c was used to determine a corresponding COV for the critical gradient of 11.7%. Wolff and Demsky[16] used a COV for the critical gradient of 9.5%, based on a point estimate analysis centered on assumed uncertainty in the unit weight of the blanket soil.

A COV for the critical gradient of 15% was used in the analyses. The uncertainty is primarily due to spatial variation of soil characteristics. The probability density function for the critical gradient (using a mean of 0.82 for L-455) is shown in Figure 11.

[16] Wolf, T., E. Demsky, J. Schauer & E. Perry, "Reliability Assessment of Dike and Levee Embankments for Water-Resources Planning", Uncertainty in the Geologic Environment: From Theory to Practice, ASCE Geotechnical Publication No. 58, Madison, WI, July 31 – Aug. 3, 1996.

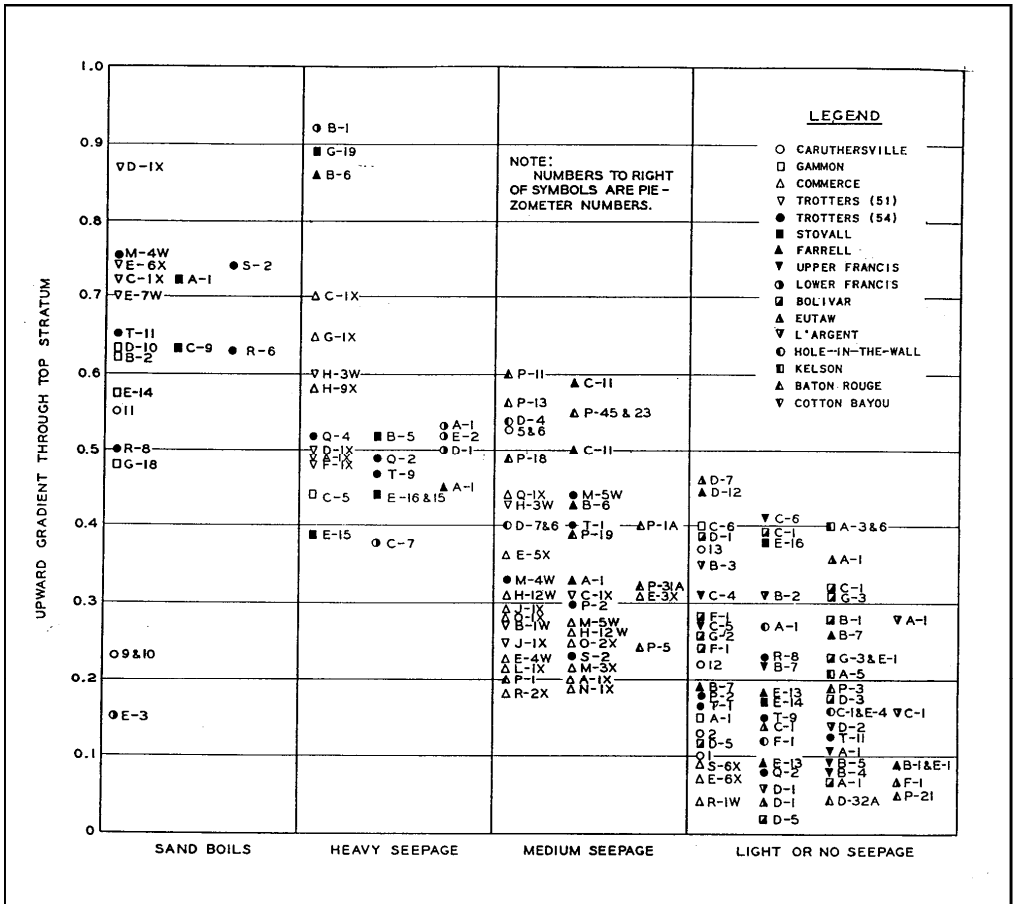


FIGURE 10. Seepage Observations on the Lower Mississippi River (From ETL 1110-2-555 Fig. 2-1, After WES Technical Memo 3-424 Fig 47 (1956))

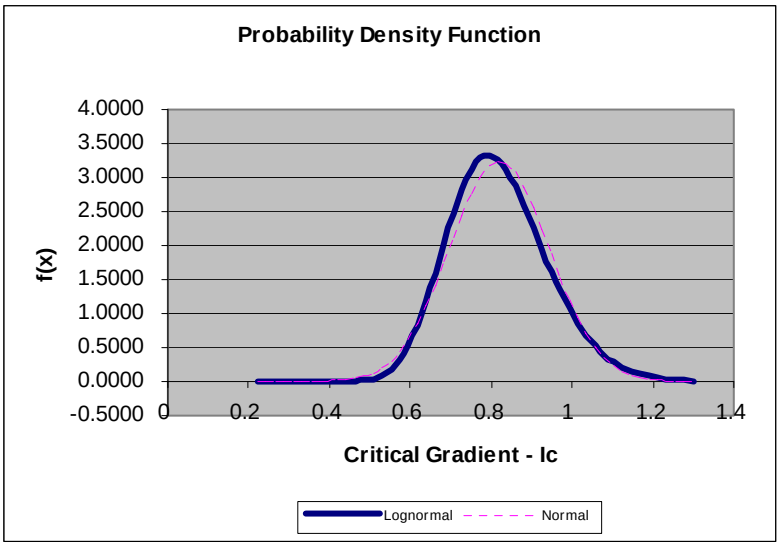


FIGURE 11. Critical Gradient, $E(i_c)$ Varies (0.82 shown for illustration), COV = 15%

3.7.4.3 Blanket Layer Thickness

Blanket layer thicknesses reported in the original analyses are based on superior knowledge of soil conditions known at the time, and these values were used in the reliability analysis. A COV of 10% used selected, based on subjective consideration of the 6-sigma rule. A typical distribution is shown in Figure 12.

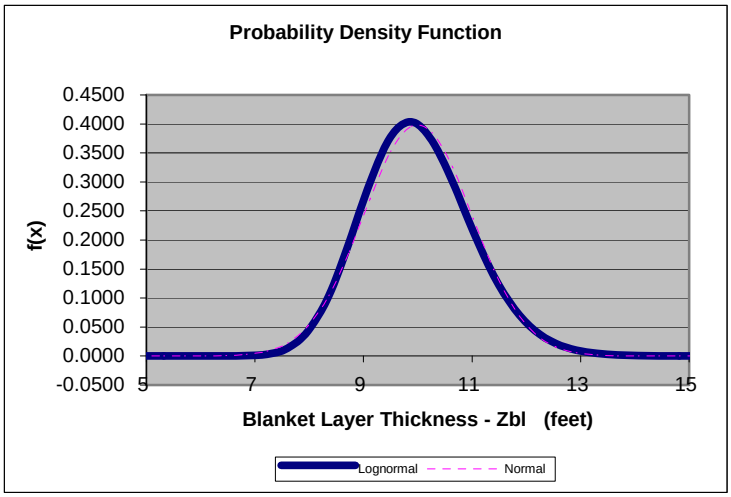


FIGURE 12. Blanket Layer Thickness, $E(Z_{bl})$ Varies (10' shown for illustration), COV = 10%

3.7.4.4 Permeability Ratio

The permeability ratios were recalculated based on soil type and layer thickness as shown in the calculations. A COV of 30% was used based on engineering judgment, and in consideration of inherent variation in design values (see charts shown in the calculations).

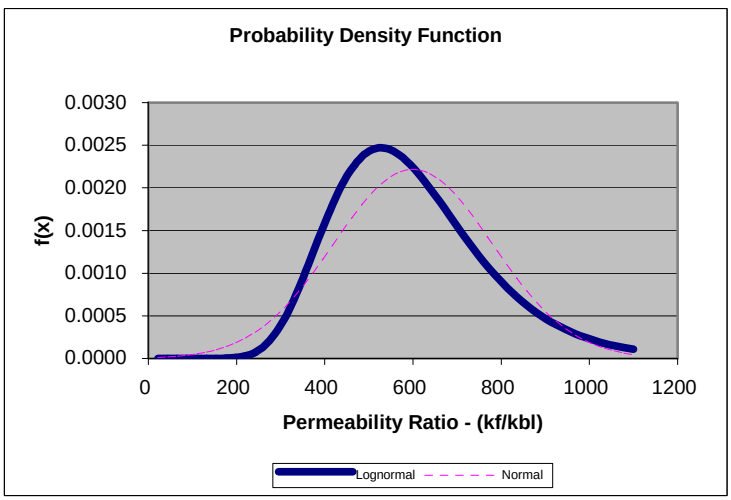


FIGURE 13. Permeability Ratio, $E(k_f/k_{bl})$ Varies (600 shown for illustration), COV = 30%

3.7.4.5 Aquifer Thickness

There were 7 borings that showed depth to rock on L-455. These included borings D-1, 2, 3, 4, 19, 55 and 142. The depth to rock was typically about 75 to 80 feet in the midsection of the project, ranging to about 70 feet near the upstream end and about 100 feet at the downstream end. The analysis was based on a mean depth of 80 feet with a 20% coefficient of variation. This uncertainty may somewhat include known variation through the project alignment, but the aquifer depth did not have a significant impact on the total variance for the factor of safety.

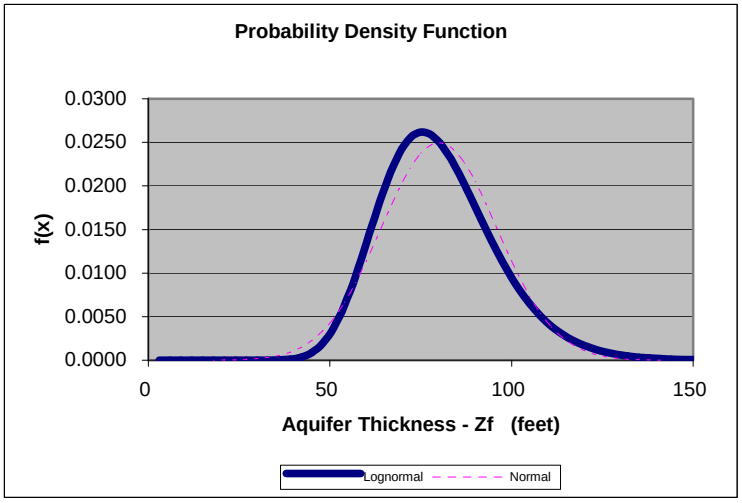


FIGURE 14. Aquifer Thickness, $E(Z_f)$ =80', COV = 20%

3.7.4.6 Effective Seepage Entrance

The effective seepage entrance is variable, dependent on the soil type and the layer thickness. The values are dependent on layer thickness since defects and spatial variation have a more pronounced affect in thin layers. This results in the field permeability of the blanket layer being much higher than the laboratory permeability of a small sample. Design values for effective seepage entrance provided in EM 1110-2-1913, Table C-1 are shown in Figure 15. These values are the same as those published in TM 3-424, Table 37. The trends in Figure 15 show that there is a significant uncertainty in selecting values for X1.

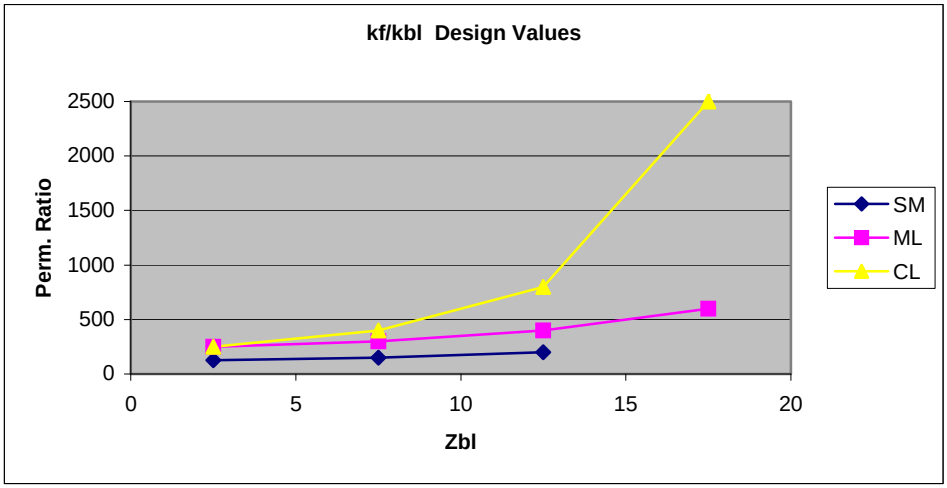


Figure 15. Design Values for Effective Seepage Entrance

The COV for the effective seepage entrance was analyzed by considering the COVs for the permeability ratio, thickness of the pervious stratum and the blanket layer, and the model correlation. The total variance was calculated based on typical values of $E(k_f/k_{bl}) = 600$, $E(Z_f) = 60$, $E(Z_{br}) = 10$, $COV(k_f/k_{bl}) = 30\%$, $COV(Z_f) = 20\%$, and $COV(Z_{br}) = 10\%$. The parameter X3 in the table represents $(1/c) = sqrt(Z_f * Z_{br} * k_f/k_{br})$. The parameter L1/X3 represents model error in the design values, with a COV of 30%. Based on this analysis, the COV for effective seepage entrance is 25.3%. A value of COV(X1) = 25% was used in the analysis.

Table 3. Variance of Effective Seepage Entrance

VARIABLES				Computations			
Kf/Kbl -	Zf (feet)	Zb (feet)	L1/X3 -	X3 (feet)	X1	var(X1)	PERCENT OF TOTAL VARIATION
600	60	10	1	600	457.0		
420	60	10	1	502	382.3		
780	60	10	1	684	521.0	4808.96	35.9%
600	48	10	1	537	408.7		
600	72	10	1	657	500.6	2109.402	15.7%
600	60	9	1	569	433.5		
600	60	11	1	629	479.3	523.3347	3.9%
600	60	10	0.7	600	362.6		
600	60	10	1.3	600	517.0	5960.861	44.5%

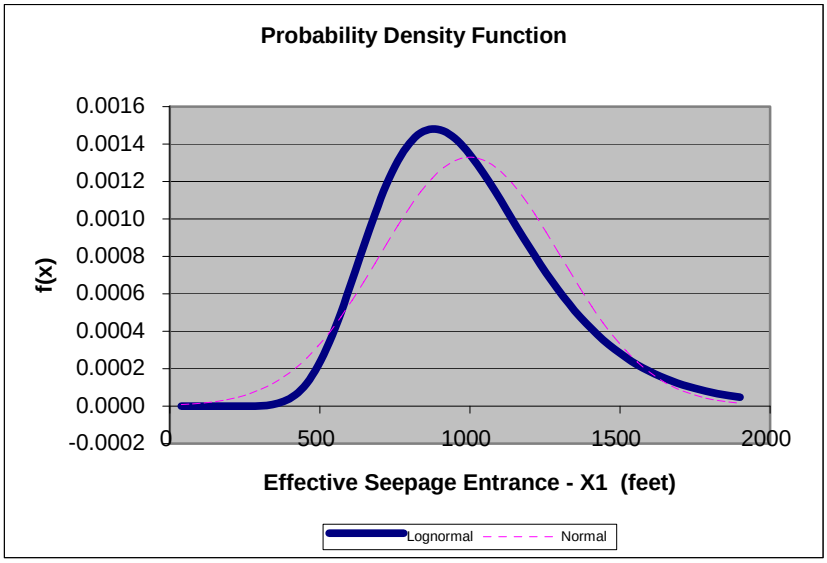


FIGURE 16. Effective Seepage Entrance Length, E(X1) = 1000', COV = 30%

Head loss at Relief Wells

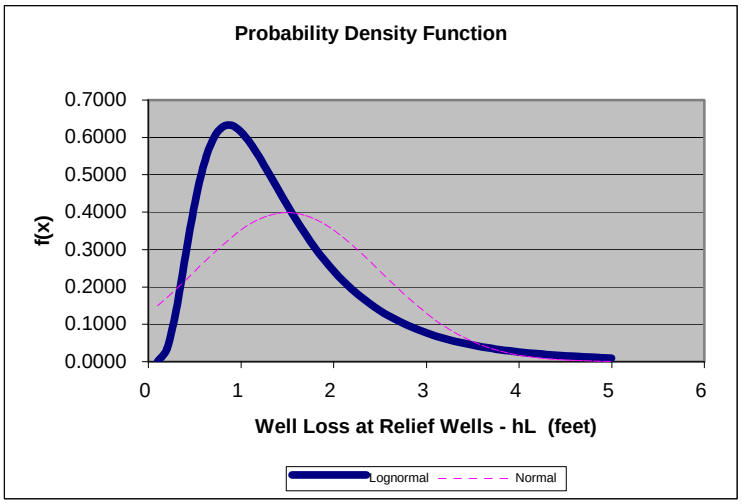


FIGURE 17. Head Loss at Relief Wells, E(h_L) = 1.5', COV = 67%

3.7.4.7 Shear Strength

Figure 18 shows shear strength data obtained for R 471-460, correlated with the plasticity index. Strength correlations for lower and upper Mississippi River alluvial clays are also show. The strength correlation for the lower Mississippi is shown in EM 1110-2-1913 figure 3.2, and is taken from a WES report.[17] The strength correlation for the upper Mississippi is from 66 consolidated-undrained triaxial tests with pore pressure measurements (R-bar tests) from Mississippi River Locks and Dams 3 through 9. Borings

[17] Engineering Properties of Fine-Grained Mississippi Valley Alluvial Soils Meander Belt and Backwater Deposits, Technical Report No. 3-604, WES, June 1962.

were located to detect the worst soil conditions. The project samples from R 471-460 more closely match the correlation from the lower Mississippi. The softer clays found at the project sites likely exhibit shear strength near the lower range of the data shown. A mean shear strength of 19 degrees was used in the analysis, with a coefficient of variation of 10%.

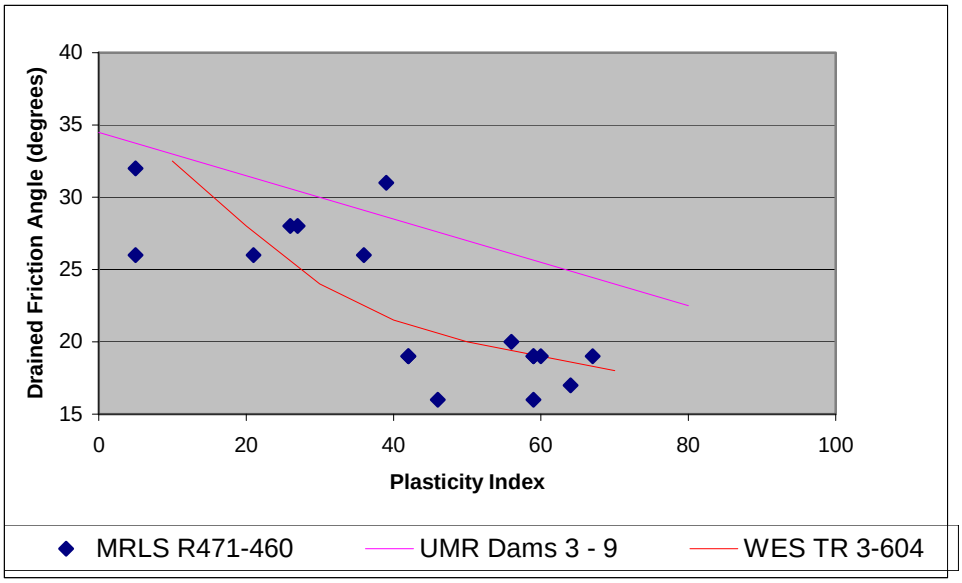


FIGURE 18. Shear Strength Data from R 471-460

3.7.5 Conclusions

a. Figures 19 and 20 shows probability of failure vs. freeboard traces for 38 sections on L-455 and 33 sections on R 471-460. Most traces are clustered near zero probability of failure. Significant probability of failure is limited to a few select sections. This means that the majority of the levee is expected to have good performance, and distress should be limited to isolated locations.

b. Combined underseepage and slope stability probability of failure vs. freeboard for the critical sections are shown in Figures 21 and 22.

c. The berms on the levees have a tendency to equalize the factors of safety along the levee alignment, which would be expected since they were designed to consistent standards.

d. Reduced interior ponding (such as by extensive interior drainage or a more rapid river stage rise time) could increase seepage related distress.

e. The paragraph on Underseepage Calculation Procedure includes equations for calculation of the exit gradient at four locations: (0) the theoretical levee toe, (1) the stability berm crest, (2) the stability berm toe, and (3) the seepage berm toe. (These locations are shown on Figure 3). The spreadsheets likewise calculate the probability of

failure for these four locations. Only location (2) was used for the reported results. Reasons for selecting location (2) are that location (0) does not actually exist where berms are constructed, location (2) is consistently more critical than location (1), and design criteria for berm width dictates that location (3) is at a sufficient distance that boils beyond the seepage berm toe should not threaten the levee.

f. No attempts have been made to quantitatively separate out spatial (aleatory) uncertainty from systemic (epistemic) errors. However, the majority of the uncertainty is attributable to epistemic errors, which is related to the limits of what is known. These errors are incorporated in a systematic manner in the engineering analysis to provide an uncertain measure of levee stability. This means that the reported probabilities of failure are a measure of the chance for a levee breach to occur within the analyzed section given a flood event of the given magnitude. This is consistent with economic assumptions. The economic models may be based on a breach at any of the reported sections analyzed to search for the optimum breach location. However, to be consistent with the source of uncertainty assumptions, the economic damages must be based on only one breach location.

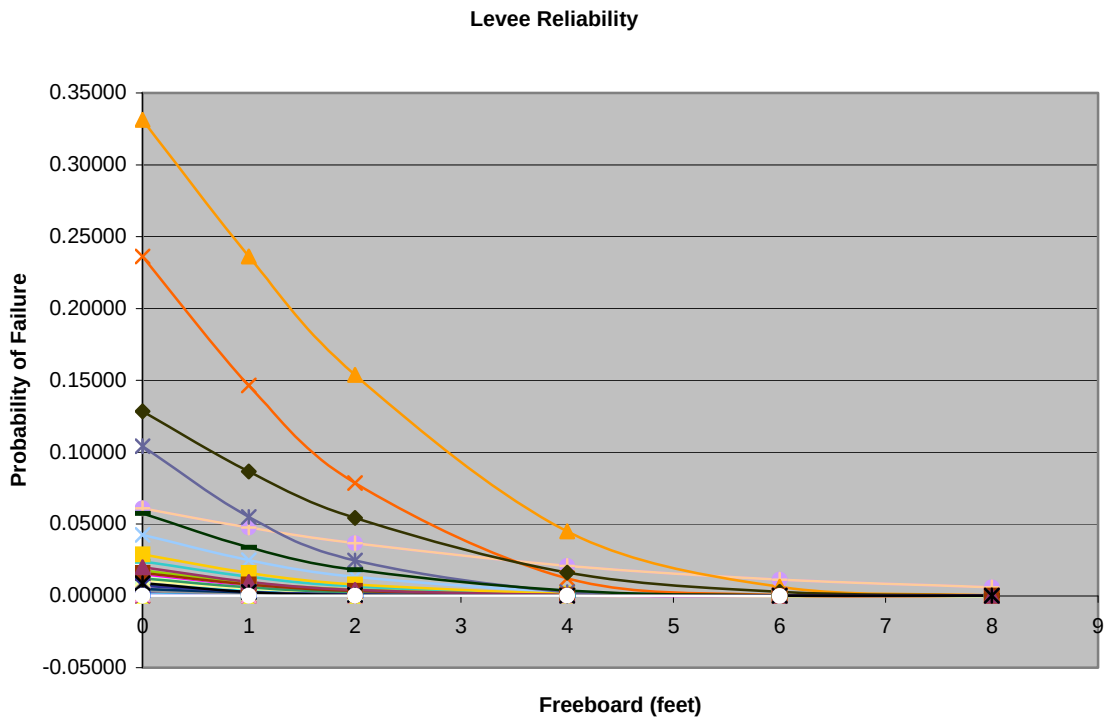


FIGURE 19. UNDERSEEPAGE RELIABILITY FOR R471-460

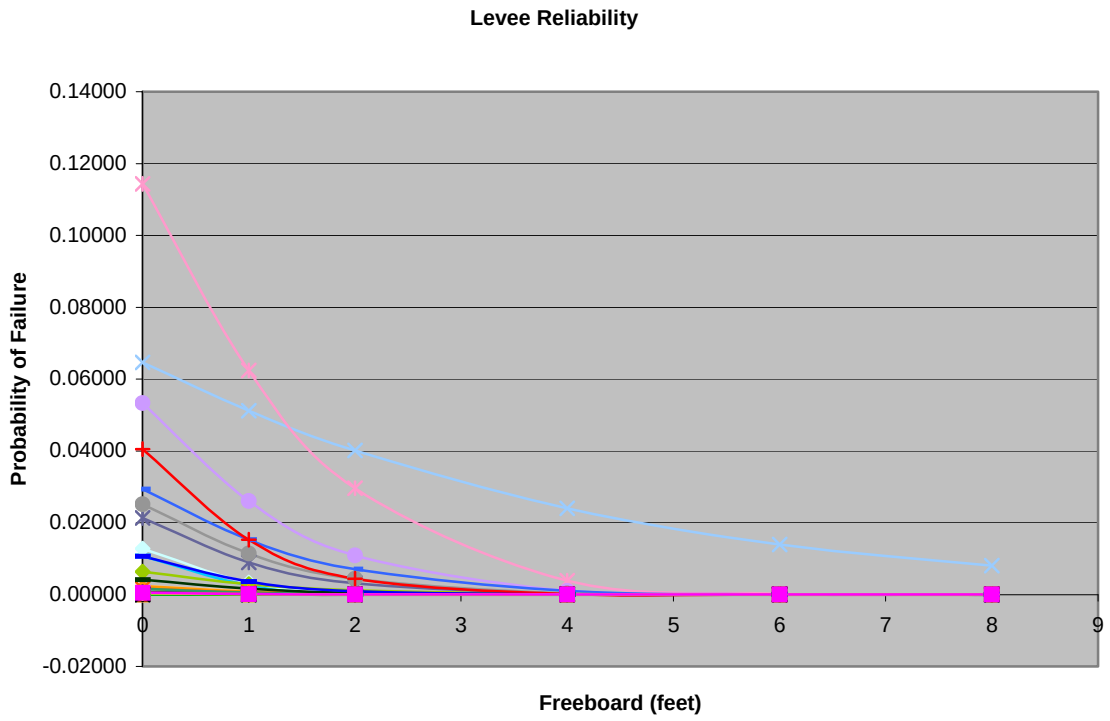


FIGURE 20. UNDERSEEPAGE RELIABILITY FOR L455

Critical Sections	Failure Mode	Levee Station:			Probability of Failure					
					Freeboard 0 (feet)	Freeboard 1 (feet)	Freeboard 2 (feet)	Freeboard 4 (feet)	Freeboard 6 (feet)	Freeboard 8 (feet)
10	Underseepage	123+00	to	131+00	1.28%	0.34%	0.06%	0.00%	0.00%	0.00%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				2.27%	1.08%	0.56%	0.00%	0.00%	0.00%
13	Underseepage	165+00	to	190+00	6.46%	5.12%	4.01%	2.40%	1.40%	0.81%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				7.40%	5.83%	4.49%	2.40%	1.40%	0.81%
14	Underseepage	191+00	to	209+00	11.44%	6.24%	2.96%	0.39%	0.02%	0.00%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				12.32%	6.94%	3.45%	0.39%	0.02%	0.00%
24	Underseepage	312+00	to	317+00	2.52%	1.14%	0.44%	0.04%	0.00%	0.00%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				3.49%	1.88%	0.94%	0.04%	0.00%	0.00%

FIGURE 21. MRLS L-455 Critical Sections

Critical Sections	Failure Mode	Levee Station:			Probability of Failure					
					Freeboard 0 (feet)	Freeboard 1 (feet)	Freeboard 2 (feet)	Freeboard 4 (feet)	Freeboard 6 (feet)	Freeboard 8 (feet)
13	Underseepage	229+00	to	251+00	4.23%	2.48%	1.33%	0.28%	0.03%	0.00%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				5.19%	3.21%	1.83%	0.28%	0.03%	0.00%
16	Underseepage	302+00	to	331+00	0.85%	0.66%	0.52%	0.31%	0.19%	0.11%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				1.84%	1.41%	1.01%	0.31%	0.19%	0.11%
21	Underseepage	395+00	to	404+00	33.12%	23.62%	15.38%	4.50%	0.63%	0.02%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				33.79%	24.19%	15.80%	4.50%	0.63%	0.02%
28	Underseepage	545+00	to	600+00	12.83%	8.66%	5.43%	1.61%	0.28%	0.02%
	Slope Stability				1.00%	0.75%	0.50%	0.00%	0.00%	0.00%
	Total				13.71%	9.35%	5.90%	1.61%	0.28%	0.02%

FIGURE 22. MRLS R 471-460 Critical Sections

3.8 SELECTED PLAN

3.8.1 General

The feasibility study selected plan provides flood protection against the 100-year plus 3-feet flood profile. Both urban and rural areas are protected by these two levee units and failure at any location of the levee will result in at least some urban areas being subjected to flooding.

The limits of the selected plan top of levee raise are addressed within Section 4, Civil and are also indicated within the drawings, Sheet 1 and 2. Within Section 4, Civil the magnitude of the raise represents the maximum value for the levee reach indicated. Since the top of levee raise is not parallel to the existing levee profile within the limits defined by Section 4, the Geotechnical effort refined the raise into representative levee reaches.

The Geotechnical effort is relying on available information and will not utilize a drill, sampling, and testing program as part of the study. A literature search was conducted of in-house files as well as the Records Holding facility. It is apparent the best information available is included within the respective levee unit's General Design Memorandum (GDM) documents, as-built drawings, and operation and maintenance manuals. These documents will serve as the sources for site characterization, establishing soil parameters, making engineering recommendations, considering original designs, and the basis for recommending efforts necessary during Preconstruction Engineering and Design (PED). For the most part, previous levee unit project summaries will be used for this study.

Both levee units were originally constructed with limited piezometric instrumentation. However, piezometric readings could not be located from a search of the project files. Discussions with the local non-Federal sponsors concluded readings were not obtained during the Great Flood of 1993.

Both units were subjected to a full and lengthy performance test from the Great Flood of 1993. As addressed earlier in this Section, all indications are both levees performed adequately with minimal, if any, signs of stress. Not only is this an acknowledgement the structural integrity of the levee under its current state is sound, but the procedures and designs used for the original project are sufficient and appropriate for the selected plan's minimal top of levee raise.

Where the levee is subject to a raise, criteria will follow current day Federal Levee criteria. The sources of criteria will be the Corps of Engineers' Engineering Manuals as well as the Kansas City District Website, http://www.nwk.usace.army.mil/local_protection/levees.html A deterministic approach, with adopted safety factors, will be used for the plan formulation.

3.8.2 Levee Section

Drawing Sheet Number 4 shows the two typical levee sections used for this study. The top of levee raise builds off of the existing levee cross section maintaining previously designed levee slopes. For the most part levee slopes are 1 vertical on 3 horizontal except for a few instances where the levee slopes are 1 vertical on 4 horizontal. The flatter slopes are generally located where the levee crosses the Missouri River oxbow legs. The levee slopes are included within the table on Sheet Number 3. If the top of levee raise is 1-foot or less, then the raise is accounted for with a levee crown raise using 1 vertical on 2 horizontal slopes intercepting the existing slopes. If the top of levee raise is more than 1-foot, then the raise includes building off of the landward slope to support the raise. The landward slope is the same slope as currently exists. MRLS R 471-460 includes the maximum top of levee raise of 3.37-feet. The MRLS R 471-460 original GDM indicates embankment stability is not an issue except where the levee crosses the Missouri River oxbow legs. In addition, MRLS R 471-460 performance during the Great Flood of 1993 did not result in embankment slides or discoveries of embankment stress. The 3.37 feet maximum raise is not anticipated to induce instability. The landside is supported by additional fill at the levee toe since the minimum underseepage berm thickness at the levee toe is 5-feet. However, design and contingency did account for fill to construct limited stability berms, most likely riverward, if at all. Stability analysis will be completed during PED to verify berm locations. MRLS L-455 includes the maximum top of levee raise of 0.94 of a foot. MRLS L-455 did include stability berms as part of original design. The distance from the top of the levee to the berm-levee slope intercept was maintained. In addition, MRLS L-455 performance during the Great Flood of 1993 did not result in embankment slides or discoveries of embankment stress.

3.8.3 Underseepage Analysis

Underseepage analysis was performed for both units: L-455 and R 471-460. The analysis was completed using Excel spreadsheets and a hand check was included to verify the spreadsheets. An underseepage berm summary is presented within the drawings, Sheet Numbers 3 and 4. The analysis and support are included within the DDR documentation.

Both EM 1110-2-1913 and the Kansas City District Website, http://www.nwk.usace.army.mil/local_protection/pdf/underseepage.pdf were used in performing the analysis. The key considerations were as follows:

a. For this study, current Kansas City District criteria (regardless of original design) were applied to levee sections subject to a raise. The seepage criteria used for this study was coordinated with Kansas City District management. The Kansas City District agreed the criteria are appropriate for this study. However, it was acknowledged the criteria is evolving spurred by relatively recent major flood events and will be revisited during PED.

b. Floodwater at the top of the levee was considered when assessing if underseepage control is necessary. A 1.1 minimum gradient safety factor at the levee toe is necessary to warrant no underseepage control. (KCD Website)

c. Floodwater 3-feet below top of levee was considered when designing underseepage control. Design requires a 1.5 gradient safety factor at the levee/berm contact (levee toe) and a 1.1 gradient safety factor at the underseepage berm toe. (KCD Website)

d. If underseepage control is necessary and an underseepage berm is selected for the control, the minimum width of the berm is 150-feet, the minimum berm thickness at the levee is 5-feet, and the underseepage berm toe is 2-feet thick at the berm design width unless the landward natural blanket rises allowing the berm to terminate before achieving the design width. (EM 1110-2-1913)

e. The landward blanket is considered semi-pervious and infinite in extent unless features demonstrate otherwise.

Tables 4A, 4B, and 5 include summaries of underseepage analysis parameters and results.

Both levee units include a pressure relief well field. The R 471-460's pressure relief well field is included within the levee reach subject to a raise, therefore, only the R 471-460 pressure relief well field will be included as part of this study and is addressed within this Section and drawing, Sheet Number 7. The R 471-460 pressure relief wells are in a line approximately 100 feet landward of the levee toe. A berm was constructed between the levee and the relief wells and provides for both stability and underseepage control (supplementing the pressure relief wells especially at the levee toe). The underseepage analysis assumed a finite landward blanket ending at the pressure relief well line and Browning Lake. This reach does not require additional fill between the levee and the pressure relief well field.

During Preconstruction, Engineering, and Design (PED), additional field work will be conducted including mapping, surveys, and drilling/sampling to support a refined underseepage berm analysis and design as well as pressure relief field analysis and design.

3.8.4 MRLS R 471-460 Pressure Relief Wells

The twenty original pressure relief wells located between MRLS R 471-460 levee stations 292+00 and 327+00 form a line parallel to the levee about 100-feet out from the levee. Pressure relief wells are necessary at this location because there is insufficient area between the levee and Browning Lake for an underseepage berm.

During the Great Flood of 1993 this reach of levee was subjected to overtopping. The full hydrostatic head on the levee did not produce sand boils indicating the landward berm and the pressure relief wells are adequate to counter excessive underseepage activity.

The existing pressure relief wells are 8-inch diameter assembled wood stave screens and risers wrapped with stainless steel wire. Current day pressure relief well construction materials no longer include wood assemblies and have been replaced with the more reliable and durable steel riser and screen assemblies. Wood stave well assemblies cannot withstand aggressive pressure relief well testing, development, and treatments. The MRLS

R 471-460 pressure relief wells were installed in 1967 and all indications are that individual well efficiencies have decreased requiring development and treatment efforts the wood stave well assemblies may not be able to withstand. Throughout the pressure relief well field there will be a 1.5 to a 2.7 feet increase in differential hydrostatic head across the levee attributed to the top of levee raise. This will provide additional stress to the existing pressure relief well wooden assemblies of uncertain structural integrity. The recommendation included in the feasibility study is to abandon in-place the existing 20 pressure relief wells and replace as indicated through analysis and design. A thorough subsurface investigation, analysis, and design will be completed during Pre-construction, Engineering, and Design (PED).

For feasibility study estimating purposes, 22 pressure relief wells will be assumed necessary to replace the existing 20. The extra 2 will account for offsetting the replacement pressure relief wells, the additional hydrostatic head, and the uncertainty with the conditions landward within Browning Lake.

As part of the Federal project, the 20 pressure relief wells constructed with wood staves will be abandoned in-place by filling with aggregate materials to the base of the blanket and grouting throughout the thickness of the blanket. The abandonment will not occur until a replacement pressure relief well field has been constructed, pump tested, and developed. The pressure relief well field layout will be based upon subsurface investigation, seepage analysis and modeling, and design. The current pressure relief well layout follows the perimeter of Browning Lake where it approximately parallels the levee alignment. Additional pressure relief wells were located adjacent the drainage ditch discharging Browning Lake through the levee and into the Missouri River. Between the levee and the pressure relief well field, a berm was constructed as part of the original contract. It is anticipated a similar pressure relief well field layout as what currently exists will be necessary when laying out the replacement pressure relief wells. Within the drawings, Sheet Number 7 shows the existing pressure relief well field. During Preconstruction Engineering and Design (PED) the pressure relief well field analysis and design will be developed utilizing additional subsurface investigation and sampling and laboratory testing. Pilot borings' sampling as well as laboratory gradation testing of the subsurface formation at each pressure relief well location will be completed during PED to facilitate pressure relief well screen design. Pressure relief well assemblies will be stainless steel screen and risers. Each pressure relief well will include a discharge into Browning Lake consisting of a manhole, horizontal pipe with flap gate, and ditch, where necessary. A gravity plunger valve will be inserted into the top of each pressure relief well to provide necessary redundancy to preventing backflow into the pressure relief well should Browning Lake rise and the discharge pipe flap gate fail. Each pressure relief well manhole access will be secured with a lid and locking mechanism.

3.8.5 Stability

The selected plan's maximum top of levee raise is 3.37-feet over a 600-feet length of levee embankment. The magnitude of the top of levee raise decreases in both directions out from this 600-feet reach. Because of the limited magnitude of the top of levee raise, the

favorable performance during the Great Flood of 1993, and the original levee design GDM indicating stability is not a problem for these units within the feasibility study limits, stability berms were addressed by maintaining the distance from the top of the levee to the berm and levee intercept where a berm currently exists. In addition, consideration was given to similar projects already constructed. Typically for a levee taller than the levees of this study and with similar foundation conditions, design provides for a distance of 17-feet from the top of the levee to the berm and levee intercept. The selected plan's landside underseepage berm includes a minimum 5-feet thickness at the levee. The maximum distance from the top of the levee to the berm and levee intercept is 15-feet. This is believed to be adequate. On the riverside of the levee, the distance from the top of the levee to the berm and levee intercept was maintained, if not decreased.

3.8.6 Settlement

The selected plan maximum top of levee raise is 3.37-feet over a 600-feet length of levee embankment. The magnitude of the top of levee raise decreases in both directions out from this 600-feet reach. Top of levee raises greater than 1-foot place fill on the levee crown and the levee landward slope. A 3.37 top of levee raise is results in slightly less than a 7-feet fill thickness on the landward slope. A 7-feet thickness is far less than the height of the original levee embankment. Settlement attributed to the additional fill is anticipated to be minimal or even insignificant and well within the range of fill finish grade allowances.

Search of the available project documentation determined consolidation testing had not been completed for this levee unit. Settlement analysis from the original design is not available and the soil investigation and testing completed at the time of original design is limited in value for computing settlement. It is apparent the designers for the original construction anticipated settlement as camber requirements were specified for each major pipe profile beneath the levee. The camber for the pipe profiles of this study ranged from 1.1 inches to 4.4 inches. However, this may have been nothing more than built in redundancy to eliminate any damage risk should there be settlement attributed to foundation conditions or questionable construction practices.

Review of the soils information within the levee limits subject to a top of levee raise indicates relatively thin zones of fine material that would be subject to the more typical consolidation processes. The thicker subsurface fine material zones where the risk of consolidation is relatively greater, are located outside the study reach. Zones beneath the upper fine materials tend to be fine to medium sand and settlement would tend to be instantaneously if any settlement at all for the magnitude of fill.

An empirical analysis using correlations is not recommended for the magnitude of the fill thickness for the selected plan. An empirical analysis will tend to deliver conservative results that are not realistic for the magnitude of fill to be placed as part of the selected plan.

Recent field surveys indicate there is no evidence of excessive settlement. However, the settlement magnitudes indicated may not be readily identifiable without a more detailed survey and uncertainty would remain since there is not 100 percent confidence in the as-built elevations at the time of original construction. Settlement in general should be revisited during the Preconstruction Engineering and Design (PED) Phase. The drainage structures' settlement investigation level of effort during PED should not be decided until the following has occurred and considered in the decision:

a. Investigate the pipe profile camber to determine if pipe settlement has occurred since original construction and if camber remains for additional settlement.

b. Inspect the pipe joints to determine if additional articulation is possible to accommodate additional settlement.

c. Complete precise field surveys documenting drainage structures key features' current elevations and compare these elevations to the available as-built details.

During PED it is recommended subsurface zones be identified, sampled, and performed consolidation testing. Consideration will be given to the magnitude of the additional loading, engineering assessment of ongoing consolidation (if any), and soil compressible tendencies (classification and thickness). Further settlement of the levee embankment is easily resolved with additional levee crown raise (overbuild). However, structural concerns should be coordinated, considered in design, and documented.

3.8.7 Rock Slope Protection

Within the limits of the levee raise, R 471-460 existing rock slope protection is limited to the railroad abutment (approximately Sta. 404+20) and beneath Highway 36 Bridge (over the levee and the Missouri River) (approximately Sta. 421+00). L-455 does have rock slope protection. Both of these units did not exhibit signs of levee slope erosion or river attack following the Flood of 1993 (flood of record). It is anticipated significant quantities of rock will not be required for the levee raise. Rock quantities provided to Cost Estimating allow for adding rock where rock currently exists to account for the levee subjected to a raise.

Modeling river attack and velocities for levee embankment erosion has improved since these levees were originally designed. During Preconstruction, Engineering, and Design (PED), analysis and modeling should be completed to determine if levee reaches currently rock faced could be replaced with sod cover. This would be a project cost savings and a future operations and maintenance savings. As part of the analysis and modeling process, a thorough coordinated review of the levees and possibly analysis should be completed to verify rock is not needed at locations currently sod covered.

3.8.8 Soil Quantity

The levee and underseepage berm quantity computations were completed with Excel spreadsheets and are maintained within the DDR and are to be used in conjunction with drawings, Sheet Numbers 8 and 9. The spreadsheets utilized a very simplistic approach breaking the section up into easily computed areas and assuming the cross section was applicable for length of levee.

During Preconstruction, Engineering, and Design (PED) accurate surveys and mapping will be necessary to refine quantity estimates.

3.8.9 Material Sources

3.8.9.1 General

Materials required for constructing the selected plan include concrete for the gatewell structures; pipe, conduit, valves, and manholes for utility relocations and pressure relief well construction; aggregate for levee surfacing; riprap to supplement the limited levee armoring disturbed by the construction; and earthen fill to construct the levee and berms. Manufactured items and materials, such as concrete, pipe, and valves, will be supplied by area vendors.

3.8.9.2 Aggregate and Riprap

Aggregate and riprap may be obtained from locally approved quarries. There is an approved quarry located north of St. Joseph in the area of Amazonia, Missouri. The relatively short haul distance and already identified as an approved source, is likely to result in the quarry used for this project.

3.8.9.3 Earthen Fill

3.8.9.3.1 Land Based Borrow Areas

EM 1110-2-1923, Design and Construction of Levees (30 April 2000), Chapter 4, Borrow Areas notes that generally the most economical borrow areas are those located parallel and adjacent the levee. Borrow area selection consideration not only much consider the most economical source of acceptable material, but other considerations must be addressed, such as cultural and environmental concerns. Two types of earthen fill necessary for constructing the selected plan are: impervious material and random material (pervious or impervious). Impervious material is needed for the levee cap, riverward fill, and to a limited extent the levee landward slope. Random fill is necessary for the levee landward slope and the wide underseepage berms. Top soil for covering the random will be obtained from stripping the borrow areas and the underseepage berms. The greatest percentage of the fill will be random material. Because the greater share of the fill requirements is random material, the concern is not as great in what material types will be discovered within the riverward borrow areas. Limited sorting during excavation will be practiced so as to preserve the impervious material for use in the applicable zone areas.

Riverward borrow bays between the river and the levee were identified as borrow sources for the selected plan. Sheet Numbers 1 and 2 include the borrow area levee station limits. MRLS L-455 borrow areas begin a minimum of 450-feet riverward of the levee and extend out to 100-feet of the Missouri River high bank. MRLS R 471-460 borrow areas begin a minimum of 300-feet riverward of the levee and extend out to 100-feet of the Missouri River high bank. Underseepage analysis accounted for the reduced riverward entrance for both units. Borrow areas for the selected plan are at the same locations as the borrow areas that were made available for original construction. Borrow area borings were not completed as part of this study. In addition, since documentation was not located indicating what areas have historically been borrowed, there is uncertainty as to what type of material exists within the borrow areas. However, as addressed above, the bulk of borrow will be used for landward underseepage berms and the landward face of the levee. Both of these fill zones allow random material. Random material is defined as sand, silt, clay, or combinations of sand, silt, or clay. Only the levee crown or fill placed riverward requires the use of impervious fill. The risk of unacceptable material from the borrow areas is minimal. However, during PED a drill and sampling program should be conducted for the borrow areas.

Based on the observation of the river stages, it appears excavations within the borrow areas riverward of the levee could be as deep as 10-feet towards the upstream borrow limits and 7-feet towards the downstream borrow limits before reaching the river stage. These depths will more than adequately allow for the estimated fill quantities.

There have been inquiries about dredging from Contrary Lake and Browning Lake. This study did not consider dredging Lake Contrary or Browning Lake as sources of fill because there are concerns with the probable organic content at the bottom of the lake and the likelihood the dredged material would not be free draining material. The borings in the vicinity of the levee adjacent Lake Contrary indicate zones of silty sands as well as zones of silt and clay materials. Some borings indicate poorly graded sands which would work well with a dredging and fill operation for the underseepage berms, however, it would be difficult to separate the free draining sands from the zones that are not free draining. Organic material is not recommended as a levee structural fill or a fill other than topsoil, which has a limited thickness. Placement of saturated material that is not free draining precludes proper compaction and will introduce instability and long term consolidation (settlement).

3.8.9.3.2 Dredge Operations

Since a considerable portion of the fill to construct the selected plan will be random material, dredging from the Missouri River would likely prove more economical than a land based borrow operation. Gradations from the Missouri River sediment indicate free draining fine to medium sands with less than 1% fine material (passing the #200 sieve). For this study, dredging from the Missouri River was not considered as a source of fill material as there are concerns that will require attention, such as cultural issues and issues with declining river sediment load. During PED it is recommended dredging be

considered in greater depth. A river sedimentation study will most like be necessary to resolve some of the concerns.

3.8.10 Levee Gages and Instrumentation

Although some instrumentation and gages would be ideal as part of the selected plan construction, historically there has not been much success with local sponsors protecting, maintaining, and reading the instrumentation during a flood event. The lack of awareness and use may be attributed to the limited involvement from the Corps of Engineers, infrequent flood events, and the fact that generally there are different local board members from flood event to flood event. These levees have been tested and proven during the Great Flood of 1993. In addition, with the minimal raise, the benefits of additional instrumentation would not be significant.

The selected plan will include the following levee freeboard gages:

MRLS R 471-460:

FB-2……Station 115+60
FB-3……Station 230+00
FB-4……Station 325+00
FB-5……Station 398+00
FB-6……Station 420+35
FB-7……Station 497+60
FB-8……Station 558+50

MRLS L-455:

No additional freeboard gages or modifications to freeboard gages will be included as part of the selected plan.

4.1 INTRODUCTION

The Civil Design support to the Missouri River Levee Systems (MRLS) L-455 and R 471-460 Feasibility Study focused on the selected plan. The selected plan provides flood protection against the 100-year + 3-feet flood profile. The Civil Design efforts included managing and developing project area surveys and mapping, establishing the levee study project limits, developing alignment and levee stationing, addressing impacts to roads and railways, and addressing impacts to utilities. Civil Design efforts also provided input to the alternative screening process. Alternative screening is addressed in more detail within the main body of the study.

4.2 STUDY'S LEVEE LIMITS

4.2.1 General

The selected plan includes top of levee raises only and does not include levee realignments. Civil Design determined the limits of the top of levee raises for each unit of this study. Top of levee raises 1-foot or less will have earth fill placed on the levee crown with 1 vertical on 2 horizontal slopes intersecting both the existing riverward and landward levee slopes. In this case the levee centerline will remain at its current alignment. Top of levee raises greater than 1 foot will have earth fill placed on the levee crown and the landward levee slope. The landward levee fill slope will be the same as the existing landward slope. Top of levee raises greater than 1-foot will result in a landward shift of the levee centerline. The magnitude of the shift landward will depend on the top of levee raise value as well as the riverward and landward levee slopes. The limits and maximum raised considered as part of the study's selected plan are addressed within the paragraphs that follow. Additional information is located within the Surveys and Mapping paragraphs herein Section Four.

4.2.2 MRLS R 471-460

The study's selected plan for MRLS R 471-460 will include a top of levee raise from levee station 93+09 through levee station 639+84. The maximum top of levee raise will be 3.37-feet.

4.2.3 MRLS L-455

The study's selected plan for MRLS L-455 will include a top of levee raise from levee station 205+64 (Part 1) through levee station 294+93 (Part 1). The maximum top of levee raise will be 0.94-foot.

4.3 ROAD AND RAILWAY LEVEE CROSSINGS

4.3.1 MRLS R 471-460

4.3.1.1 Union Pacific Railway Crossing

The Union Pacific Railway levee crossing occurs at approximately MRLS R 471-460 levee station 402+60. Travel on the levee crown terminates at the railway levee crossing. Levee ramps are provided north and south of the railway embankment; however, each is located

riverward of the levee centerline and will not be effective as a vehicle turn-a-round to reverse direction during a flood event. A turn-a-round or landward ramp would be beneficial both upstream and downstream of the railway embankment. Pre-construction, Engineering, and Design (PED) will revisit locations of ramps, turn-outs, and turn-a-rounds. The current top of levee is below the top of the railway embankment at the tie-in points. An impervious blanket lines the railway abutment face that projects riverward of the levee alignment. The levee's selected plan's proposed raise elevates the levee crown to about elevation 823.08. The top of the railway embankment is approximately elevation 827.2 or about 4-feet higher than the proposed top of levee at the levee tie-in points to the railway embankment. Additional impervious facing to account for the levee raise should be anticipated on the railway abutment projecting riverward of the levee alignment.

4.3.1.2 U.S. Highway 36 Crossing

U.S. Highway 36 spans both the levee and Missouri River approximately at MRLS R 471-460 levee station 421+00. Sufficient clearance lies between the top of levee raise and the U.S. Highway 36 low steel to allow for construction equipment and levee access equipment necessary for levee operation and maintenance.

4.3.2 MRLS L-455

The MRLS L-455 selected plan limits do not include existing road or railway crossings of the levee.

4.4 UTILITY RELOCATIONS

4.4.1 General

Utility relocations for the purpose of the Civil Design efforts do not include storm sewer drainage structures through the levee. Storm sewer drainage structures through the levee which are considered a feature of the flood control works are addressed within Section Five, Structural. Civil Design efforts included site visits to identify utilities crossing or in the vicinity of the levee unit and a literature search to supplement the site visit. During Pre-construction Engineering and Design (PED) contacts will be made with utility locator services as well as city and county agencies to verify a complete list of utilities crossing the levee or in the vicinity of the levee and to obtain additional information of each utility, such as vertical and horizontal alignment, size, utility material, utility use, and other utility features of concern with flood control.

4.4.2 MRLS R 471-460

4.4.2.1 General

A study of utilities crossing MRLS R 471-460 was conducted to estimate costs for relocation or removal of functioning or abandoned utilities. MRLS R 471-460 has six utilities crossing the levee. Of the six, three utilities are outside the limits of the raise. The three utilities within the limits of the raise will be relocated over the top of levee raise. During PED structural uplift will be addressed for the utility lengths landward of the levee. PED will also address the need for temporary flood control protection or not as part of each utility's relocation. The following

paragraphs addresses disposition of the utilities crossing through the levee and specific items of interest for estimation of relocation cost.

4.4.2.2 Williams Brothers Pipeline

The Williams Brothers pipeline is identified as UL1 within the MRLS R 471-460 Operations and Maintenance Manual. The crossing occurs at levee station 53+38.3. The pipeline is a16-inch steel pipe (SP) and includes a gate valve. The line crosses the levee at about elevation 828.1. No action is required since this crossing is outside the limits of the top of levee raise.

4.4.2.3 St. Joseph Waterline

The St. Joseph Water Company maintains a 16-inch diameter ductile iron pipe (DIP) waterline that crosses MRLS R 471-460 at levee station 300+00. The waterline is identified as UL2 within the MRLS R 471-460 Operations and Maintenance Manual. The waterline crosses the levee at about elevation 821.6, and the line includes one butterfly valve 156-feet landward and one butterfly valve 132-feet riverward of the levee centerline. The waterline will be relocated over the top of levee raise with the new pipe invert elevation of 825.8 at the levee crossing. The crossing will include 3.5-feet of earthen overbuild. An air release valve and gate valve will be installed on the riverward edge of the levee crest. Information for cost estimating purposes is provided as follows:

a. Overbuild quantity: 3.5-feet of cover; 1,400 compacted cubic yards
b. Excavation: 714 cubic yards to expose the line and excavation of borrow for overbuild
c. Backfill: 17 compacted cubic yards of impervious fill to supplement the excavation quantity
d. Manhole: 4-feet diameter standard shallow pre-cast manhole placed on concrete base
e. Valves: one air/vacuum valve and one gate valve
f. Relocation Length: 300-feet. Existing butterfly valves to remain
g. Pipe Type: 16-inch diameter DIP standard water service pipe, class 50 rated at 350 pounds per square inch
h. Pipe Bends: four 22.5 degree bends and two 11.25 degree bends
i. Remove and dispose off site replaced existing pipe

4.4.2.4 Gas Line

The 8-inch diameter SP gas line crosses MRLS R 471-460 at levee station 417+65. The gas line is identified as UL3 within the MRLS R 471-460 Operations and Maintenance Manual. The existing line crosses the levee at about elevation 799.0. The gas line will be relocated over the top of levee raise. The top of levee raise elevation in this area is approximately 823.0. Information for cost estimating purposes is provided as follows:

a. Overbuild quantity: 2-feet of cover; 450 compacted cubic yards
b. Excavation: 3,760 cubic yards to expose the line and excavation of borrow for overbuild
c. Backfill: 1.5 compacted cubic yards of impervious fill to supplement the excavation quantity
d. Relocation Length: 288-feet
e. Pipe Type: 8-inch diameter schedule 40 welded SP, black pipe
f. Pipe Bends: six 90 degree bends and two 45 degree bends
g. Remove and dispose off site replaced existing pipe

4.4.2.5 Telephone Cable

The telephone cable line crosses MRLS R 471-460 at levee station 418+15. The cable line is identified as UL4 within the MRLS R 471-460 Operations and Maintenance Manual. The existing line crosses the levee at about elevation 816.5 buried approximately 3.5-feet deep. The cable line will be relocated over the top of levee raise. Information for cost estimating purposes is provided as follows:

a. Overbuild quantity: 2-feet of cover; 450 compacted cubic yards
b. Excavation: 295 cubic yards to expose the cable and excavation of borrow for overbuild
c. Backfill: 5 compacted cubic yards of impervious fill to supplement the excavation quantity
d. Relocation Length: 191-feet
e. Break Points: two splice points with splice box
f. Cable Type: 1200 pair cable
g. Remove and dispose off site replaced existing cable

4.4.2.6 Sanitary Sewer Line

The 12-inch diameter sanitary sewer line is identified as UL5 within the MRLS R 471-460 Operations and Maintenance Manual. The Peter's Creek and levee crossing occurs at levee station 709+40. The pipeline crosses the levee at about elevation 806.8 and is plugged and abandoned. No action is required during the feasibility phase since this crossing is outside the limits of the top of levee raise.

4.4.2.7 Sanitary Sewer Line

The 8-inch diameter sanitary sewer vitrified clay pipe (VCP) is identified as UL6 within the MRLS R 471-460 Operations and Maintenance Manual. The line crosses at Peter's Creek channel station 5+1.47. No action is required during the feasibility phase since this crossing is outside the limits f the top of levee raise.

4.4.2.8 Overhead Power Lines

Two power lines cross or are in the vicinity of MRLS R 471-460 within the limits of the top of levee raise. At approximately levee station 301+20 there is a major transmission line, however, the current lines are elevated well above the top of levee raise sufficiently to avoid clearance issues. At approximately levee station 300+00 there is a smaller single-phase power line adjacent to the landside levee toe. No modifications are necessary for the feasibility study. However, this area will be revisited during PED to ensure no interference with the selected plan's levee footprint.

4.4.3 MRLS L-455

The MRLS L-455 selected plan limits do not include utility crossings of the levee.

4.5 SURVEYS AND MAPPING

4.5.1 General

Sources of surveys and mapping include relative recent top of levee field surveys, the original topographic mapping available from the levee as-built drawings, and the 1998 Missouri River Mapping.

4.5.2 Mapping

4.5.2.1 General

Since the original levee topographic mapping pre-dates the mid 1960s and the contours are not complete, it is in question. This topography is used to supplement surveys and more recent mapping. The 1998 Missouri River Mapping is on 4-feet contour intervals and meets National Mapping Standards for accuracy. This mapping is primarily used to determine floodplain tendencies and obtain elevations where no other information is available.

4.5.2.2 Mapping Use and Limitations

The stationing for the levees should be considered approximate since stationing was applied to current topographic mapping by visual methods. Raster images from the levee as-built drawings were lined up with the 1998 Missouri River Mapping and the stationing was transposed from those raster images. The stationing is estimated to be accurate to within 50 feet based on professional judgment.

The cross section by H&H used river miles to determine predicted water elevation on the levee. This information was later converted to stationing and adjusted visually using professional judgment to account for difference between the curvature of the river and the curvature of the levee. Based on professional judgment, cross section stationing is estimated to be accurate to within 50 feet.

4.5.3 Surveys

4.5.3.1 General

The survey of MRLS L-455 was conducted in September 2002. The survey of MRLS R 471-460 was conducted in March 2003. Both surveys were done in State Plane coordinate System (SPS) zone Missouri West and US survey feet. The original required vertical accuracy for these surveys was ±0.1 feet and later changed to ±0.2 feet.

Two methods were used to conduct the survey: GPS and differential leveling. The GPS method used a base and receiver system. The base is put on a known control point and the coordinates for that point are programmed in. The control points for MRLS L-455 were BM-12 and BM-7; and the points for MRLS R 471-460 were BM T-216 and ROSE. The receiver is mounted on an All Terrain Vehicle (ATV), and then data is broadcasted from the receiver to base as the ATV moves on the line to be surveyed.

The second method was differential leveling. MRLS L-455 was measured in the fall of 2002 and a limited reach of MRLS R 471-460 was measured in December of 1996. This method is used for vertical surveys only.

The mapping standards on this project require 90% of spot elevations to meet standards, ±0.2 feet, which was met. "The certainty of accuracy for each station is not 100% dependable. Collecting GPS data continuously over extended time duration will inevitably produce outliers." (Greg Shamberger, Survey Memo, May 2003)

4.5.3.2 Limitations of the Survey; Vertical Accuracy

Quality control for the "surveyed top of levee" stated that 90% of the points were within the allowable limits of +/- 0.2-foot, which conceivably leaves up to 10% of the points with a lower level of accuracy. It is impossible to know how far off an outlier may be, as well as which specific points are outliers, however, relatively very small top of levee raises (i.e. less than 1-foot and some areas less than 0.2-foot) were calculated based upon the top of levee survey coupled with levee as-built information. Follow-up field checks and comparisons with structures and the levee centerline indicate the levee as-built elevations were generally accurate, though detailed field survey checks were not conducted. The information at hand gives a representation of the magnitude of the top of levee raises as well as the levee station limits. The top of levee raises will be further investigated during PED with detailed field surveys.

4.6 RAISE DETERMINATIONS

To determine top of levee raises the following method was used: if both the record drawings and the survey were above the predicted water level then there is clearly need for a raise. In other words, for a clearly needed levee raise, the design water surface elevation is higher than both the surveyed top of levee minus 0.5-foot (to account for aggregate surfacing) and the levee as-built drawings' top of levee elevation.

There are other areas, however, that are considered "inconclusive" that will require further screening during PED. There are areas where the surveyed top of levee minus 0.5-foot may be below the design water surface elevation, but by less than 0.2-foot (the stated accuracy of the survey), or the levee as-built information in the area indicates top of levee elevations above the design water surface elevation.

The table below indicates where a raise is required, how high, and whether the need for the raise is clear or inconclusive (requiring further investigation during PED). An additional column is also provided to indicate whether the UNET model (induced damages assuming raise to 1% + 3-feet on opposing bank) or the HEC-RAS model water surface elevations controls the identified need for a raise. Backwater elevations were considered for tiebacks on Browns Branch & Peters Creek.

MRLS R 471-460

Station Limits	Linear Feet	Raise (feet)	Clear or Inconclusive	Which Model Controls
064+53 - 064+78	25	0.003	Inconclusive	RAS
087+73 - 088+85	112	0.3	Inconclusive	RAS
089+35 - 092+62	327	0.3	Inconclusive	RAS
093+09 - 639+84	54,675	3.3	Clear (Inconclusive on ends)	RAS
639+84 - 717+00	7,716	0.5	Inconclusive	RAS & Backwater (Peters Creek)

MRLS L-455

Station Limits	Linear Feet	Raise (feet)	Clear of Inconclusive	Which Model Controls
047+81 - 048+44	63	0.2	Inconclusive	RAS
050+35 - 052+92	257	0.3	Inconclusive	RAS
084+38 - 084+56	18	0.1	Inconclusive	RAS
088+78 - 089+14	36	1.2	Inconclusive	RAS
089+46 - 089+55	9	0.5	Inconclusive	RAS
090+90 - 091+21	31	0.3	Inconclusive	RAS
104+83 - 110+02	519	0.6	Inconclusive	RAS
205+64 - 294+93	8,929	0.9	Clear	UNET

No raise required for Browns Branch tiebacks.

5.1 MRLS R 471-460 STRUCTURAL OVERVIEW AND SUMMARY

5.1.1 Introduction

The Structural support to the Missouri River Levee Systems (MRLS) L-455 and R 471-460 Feasibility Study focused on the selected plan. The selected plan provides flood protection against the 100-year plus 3-feet flood profile. Structural input was also provided for alternative screening. Alternative screening is addressed in more detail within the main body of the study. The documentation as follows provides a structural overview and summary for the MRLS R 471-460 selected plan.

5.1.2 Overview

The Kansas City District's Structural Section, EC-DS, performed the structural analysis. Technical reviews were completed by in-house staff and the St. Paul District. The 100-year plus 3-feet flood profile for the selected plan was established by the Hydrology/Hydraulics and Civil Design Project Development Team (PDT) disciplines. Only those structures within a levee reach subject to a raise were considered as part of the structural effort. The structural features within the MRLS R 471-460 top of levee raise limits included drainage pipes and a box culver as well as the drainage systems' gatewell structures. The documentation addresses the following:

a. Levee and structural analysis references
b. Feasibility study Scope of Work (SOW)
c. Documentation
d. Drainage systems identified for study
e. Utility lines identified for study
f. Stability analysis methodology
g. Stability analysis results
h. Strength analysis methodology
i. Strength analysis results
j. Recommendations

Detailed documentation is included within the separately bound document, "Missouri River Levee System (MRLS) L-455 & R 471-460, Design Documentation Report (DDR)" and is available for viewing upon request. The following project information can be found within the DDR:

a. Structural Overview and Summary (similar to this document)
b. Scope of Work
c. Conduit Analysis
d. Gatewell Analysis
e. EC-GD Hydraulic Grade Line and Settlement Estimates

5.1.3 Levee and Structural Analysis References

Levee reference material in Table 1 below provided information used to analyze the drainage structures, including specifications for construction of MRLS R 471-460. The structural criteria used to complete structural support to the feasibility study are listed in Table 2 below. Army Corps of Engineers (COE) and private industry criteria were used to conduct the structural analysis.

Table 1. References.

ID	Publication Title	Pub Date
R1*	Operation and Maintenance Manual, Appendix I (As-Builts)	10/13/69
R2	Plans for Construction of Unit No R471-460	04/66
R3*	MRLS R471 460 Photos	11/04
R4*	MRLS R471 L455 Photos	01/05
R5	Specifications for Construction of Unit No R471-460	1966
R6*	R471 L455 Binded Documents (Periodic Inspection Reports, Levee Repair, etc)	10/15/04
R7	Unit R-471-460 Operation and Maintenance Manual	12/86
R8	L455 & R471-460 Feasibility Study Drawings	04/05
R9	R471-460 Design Computations	1966

*Documents located within the DDR.

Table 2. Structural and Stability Criteria References

ID#	Publication Title	Pub Date
	Army Corps of Engineers (COE):	
S1	EM-1110-2-2104 Strength Design for Reinforced-Concrete Hydraulic Structures, Change 1	08/20/03
S2	EM 1110-2-2902 Conduits, Culverts, and Pipes, Change 1	03/31/98
S3	EC 1110-2-6058 Stability Analysis of Concrete Structures	11/30/03
S4	Kansas City District Local Protection Guidance. Web address: http://www.nwk.usace.army.mil/Local_Protection/guidance.html	Varies
S5	ETL 1110-2-307 Flotation Stability Criteria for Concrete Hydraulic Structures	08/20/87
	American Concrete Institute (ACI):	
S11	318-02 Building Code Requirements for Structural Concrete	2002
S12	340R-97 ACI Design Handbook	1997
S13	ACI 350-01 Code Requirements for Environmental Engineering Concrete Structures	2001
	American Concrete Pipe Association (ACPA):	
S21	Design Method for Reinforced Concrete Pipe and Concrete Sections, Prepared for Technical Committee for the American Concrete Pipe Association, Frank J. Heger	12/82
S22	Pipe Design Manual, (Revised to Include Standard Installations edition)	06/00
	Federal Emergency Management Agency	
S23	NEHRP Guidelines for the Seismic Rehabilitation of Buildings, FEMA 310	1997

5.1.4 Structures (EC-DS) Feasibility Study Scope of Work (SOW)

The MRLS L-455 and R 471-460 Feasibility Study Structural SOW is located within the Project Management Plan (PMP) located within PM-PF files and within the DDR. The SOW has undergone modifications and clarifications since its creation in September 2003. The following information represents modifications/clarification of the original SOW:

a. The feasibility study will address only those structures lying in areas requiring a top of levee raise.
b. The top of levee raise affects the drainage systems located from levee station 115+60 to levee station 610+00. The corresponding river miles are from 454.1 to 443.4 (plus or minus 0.2 miles).
c. Flap gates will not be used on the drainage systems.
d. This feasibility study utilized an alternatives' screening approach to determine the selected plan. The selected plan is the levee raise required to provide protection for the 100-year + 3-feet flood event. All references made to "Future Design" in this report refer to the design required to meet the 100-year +3 feet flood event level of protection.
e. The gatewells will not require electrical utilities.
f. The levee footprint change will require replacement of the drainage systems inlets listed in Table 3 below.

5.1.5 Project Management Plan and Quality Control Plan

The feasibility study Project Management Plan (PMP) and Quality Control Plan (QCP) are located within PM-PF files and within the DDR.

5.1.6 Drainage Systems Identified for Study

Only those drainage systems located in areas where a top of levee raise is necessary to fulfill the 100-year + 3-feet flood protection requirement were chosen for study. Through coordination with the Hydrology/Hydraulics and Civil Design disciplines, a total of 8 MRLS R 471-460 drainage systems were identified for this feasibility study. The 8 drainage systems are listed in Table 3 below. The drainage system identification number corresponds to the numbers given in the drawings of Reference R7 (Table 1 above). The top of gatewell elevation values obtained from Reference R1 (Table 1 above) was verified in the field by Civil Design in March 2005. Note that the existing top of levee elevation value is higher than the existing top of gatewell elevation value for all drainage systems. The higher elevation is due to aggregate added to the top of levee since initial construction. Except for drainage system 4, each drainage system is composed of an inlet, outlet, pipe, and gatewell each constructed of reinforced concrete. Drainage system 4 consists of an inlet, outlet, box culvert, and gatewell each constructed of reinforced concrete. None of these drainage systems have a flap gate.

Table 3. Drainage Systems Analyzed.

Drain Sys	Conduit Size, (in) / Type[A]	Levee STA[B]	River Mile[C]	100 year + 3 Feet Flood Elev., (ft)[D]	Existing Top of Gatewell Elev., (ft)[B] / Conduit Invert Elev., (ft)[E]	Proposed Top of Gatewell Elev. (ft)[F]	Proposed Gatewell Raise, (ft)[G]	Existing Top of Levee Elev., (ft)[H]	Proposed Top of Levee Elev., (ft)[J]	Proposed Levee Raise, (ft)[K]
2	48 / RCP	115+60	454.1	828.96	828.1 / 809.7	828.96	0.86	828.6	828.96	0.86
3	48 / RCP	186+00	452.5	827.73	825.7 / 807.7	827.73	2.03	826.2	827.73	2.03
4	72 x 60 / RCB	325+00	449.9	825.34	823.3 / 797.2	825.34	2.04	823.8	825.34	2.04
5	36 / RCP	398+00	448.4	823.47	821.2 / 801.2	823.47	2.27	821.7	823.47	2.27
7	24 / RCP	420+35	447.9	822.90	820.5 / 803.2	822.90	2.40	821.0	822.90	2.40
8	66 / RCP	497+60	446.1	820.68	819.3 / 797.2	820.68	1.38	819.8	820.68	1.38
9	48 / RCP	558+50	444.5	819.25	818.4 / 796.7	819.25	0.85	818.9	819.25	0.85
10	54 / RCP	610+00	443.4	817.88	817.7 / 795.2	817.88	0.18	818.2	817.88	0.18

[A] Precast Reinforced Concrete Pipe (RCP); Reinforced Concrete Box Culvert (RCB)
[B] Reference: R1
[C] Approximate, plus or minus 0.2 miles
[D] Reference: R8
[E] Reference: R1. Invert elevation at gatewell sluice gate thimble connection. The outlet invert elevation at the gatewell connection is 1 foot lower than the invert elevation at gatewell sluice gate thimble connection for each drainage system.
[F] Equal to the 100 year+3 feet flood elevation
[G] Proposed Top of Gatewell Elev. – Existing Top of Gatewell Elev.
[H] Does include the existing aggregate material placed on levee crown. The aggregate thickness is approximately 0.5 feet
[J] Levee crown elevation prior to placement of aggregate material. The aggregate thickness is assumed to be 0.5 feet
[K] Proposed Top of Levee Elev. – Existing Top of Levee Elev. + 0.5 feet

5.1.7 Utility Lines

The utility lines shown in Table 4 below are located where a top of levee raise is necessary to fulfill the 100-year + 3-feet flood protection requirement.

Table 4. Utility Lines.

Utility ID	Levee Station	River Mile	Utility
UL01	53+38.3	~455.7	Petroleum
UL02	300+00	~450.4	Water
Ulxx	3xx+xx	xxx.x	Electric, above ground, adjacent to protected side levee toe. Not on O&MM drawings
UL03	417+65	447.9	Natural Gas
UL04	418+15	447.9	Natural Gas

5.1.8 Stability Analysis Methodology

5.1.8.1 Flotation

The criterion posted in Chapter 3 of Reference S3 (Table 2 above) was used to determine if the structures studied met the required safety factors for uplift. Table 5 below lists the minimum flotation factors of safety for various types of events. For this feasibility study, an extreme event is considered the 100-year + 3-feet top of levee event, which has a minimum safety factor of 1.1. A 3-feet below top of levee event is considered an unusual event and has a minimum safety factor of 1.2.

Table 5. Required Factors of Safety for Flotation-All Structures.

Load Condition	Factor of Safety (FS)
Usual	1.3
Unusual	1.2
Extreme	1.1

5.1.8.1.1 Uplift

The uplift force (U) is an input variable used in calculating the FS for flotation value. Two methods were used to determine the U value. The weight of the water displaced by the structure represented the U value in the first method, referred herein as Method "A". The second method of analysis used the equation posted in Reference S4 (Table 2 above), titled *Uplift*. This method of analysis is referred herein as Method "B" and its associated equation is presented below:

$$U = p_3 A=(H_1/H_2)*H_3 G_w \qquad \text{EQN 1}$$

Where; U=uplift force acting on the structure

p_3=uplift pressure acting on the structure

A =area of the structure over which the uplift force acts

H_1=vertical distance from the impervious blanket base to the hydraulic grade line at the structure location (HGL)

H_2=impervious blanket thickness
H_3=vertical distance from the base of the structure to the top of the blanket
G_w=density of water

The value of U was calculated for Methods A and B. The largest value was carried forward in calculating the FS for flotation value.

5.1.8.1.2 Gatewells

Except for drainage system 4, each drainage system gatewell has an 8-inch base slab heel extension located on the inlet and outlet sides of the gatewell. Drainage system 4 does not have heel extensions. Instead, the drainage system 4 RCB structure is cast integrally with the gatewell walls. None of the drainage systems have flap gates. It was assumed that flap gates would not be required in the future design. Therefore, it is also assumed that the gatewell sluice gate will be closed and each of the gatewells will fill with water during a Missouri River flood event. The gatewell uplift was calculated in a rapid drawdown situation. In this situation the gatewells are assumed dry. The weight of water displaced by the gatewell adjusted by the weight of water in the soil located above the gatewell heels was calculated to determine the uplift force acting on the gatewell (Method A). This value of uplift force was compared to the uplift value calculated using the impervious blanket thickness value (Method B) and EQN 1. The largest value of uplift computed using the two above described methods was used to determine the resulting FS for flotation. The gatewell FS for flotation was calculated using Reference S5 (Table 2 above), equation 1.

5.1.8.1.3 Conduits

To determine the drainage system conduit factor of safety for flotation values, the hydraulic grade line (HGL) profiles and impervious blanket elevation values provided by the Geotechnical discipline were used. Conduit uplift was calculated at the levee/berm srpingline location (near the conduit inlet headwall) using the guidance provided in Reference S4 (Table 2 above) and the blanket/grade line parameter located in the DDR. By observation, it was determined that the governing conduit factor of safety for flotation would occur near the conduit inlet because of the minimum conduit earth cover and the conduit being dry during a flood event at this location.

5.1.8.2 Bearing Capacity and Settlement

An overview of the bearing and settlement analysis for the gatewells and conduits are located in the DDR.

5.1.9 Stability Analysis Results

5.1.9.1 Flotation

5.1.9.1.1 Gatewells

The gatewell flotation stability calculations are located in the DDR. The Method A calculated values of uplift force governed. All drainage system gatewells studied met the minimum safety factor against uplift for the future design (top of levee) and 3-feet below top of levee flood events. The evaluated gatewell factors of safety values (FS) are tabulated in Table 6 below.

Table 6. Gatewell Future Design Factors of Safety (FS) For Flotation.

Drainage System Gatewell	FS For An Unusual Event (3 Feet Below Top of Levee Flood Event)	Required FS Met For An Unusual Event? (Min SF=1.2)	FS For An Extreme Event (Top of Levee Flood Event)	Required FS Met For An Extreme Event? (Min SF=1.1)
2	1.7	YES	1.4	YES
3	1.7	YES	1.4	YES
4	1.2	YES	1.1	YES
5	1.8	YES	1.5	YES
7	1.9	YES	1.6	YES
8	1.5	YES	1.3	YES
9	1.6	YES	1.4	YES
10	1.5	YES	1.3	YES

5.1.9.1.2 Conduits

The conduit FS for flotation values are shown in Table 6A below and represent the FS for conduit flotation at the levee/berm springline during the design event. The values of uplift (U) calculated by Method B as described above governed the FS for flotation values. FS for flotation values that did not meet the minimum requirements are associated with drainage systems 3, 8 and 10.

Table 6A. Conduit Future Design Factors of Safety (FS) For Flotation.

Drainage System Conduit	Conduit Size, (in)	FS For An Unusual Event (3 Feet Below Top of Levee Flood Event)	Required FS Met For An Unusual Event? (Min SF=1.2)	FS For An Extreme Event (Top of Levee Flood Event)	Required FS Met For An ExtremeEvent? (Min SF=1.1)
2	48	1.4	YES	1.2	YES
3	48	1.0	NO	0.83	NO
4	72 x 60	>1.2	YES	>1.1	YES
5	36	1.7	YES	1.5	YES
7	24	2.2	YES	1.7	YES
8	66	1.3	YES	1.0	NO
9	48	1.3	YES	1.3	YES
10	54	1.3	YES	1.0	NO

5.1.9.2 Settlement

The gatewells' estimated settlement values determined by the Geotechnical discipline are shown in Table 7 below.

Table 7. Estimated Settlement Due to Additional Fill Required for the Future Design

Drainage System	Fill On Levee Crown, (ft)	Estimated Settlement, (in)
2	1.0	<0.5
3	2.0	<0.5
4	2.0	<0.5
5	3.5	<0.5
7	3.0	<0.5
8	2.0	<0.5
9	1.5	<0.5
10	0.5	<0.5

5.1.10 Strength Analysis Methodology

Strength analysis was conducted on the gatewells, reinforced concrete pipe (RCP) and reinforced concrete box (RCB) culvert. The RCB and gatewell center-to-center span length was used to compute the moment capacity and demand values. The shear demand values were taken at distance "d" equal to the reinforcement depth away from the support. The capacity (R) and demand (Q) values were calculated with both the load factor and strength reduction factor equal to 1. The resulting R/Q values were compared to the minimum acceptable safety factors shown in Table 8 below. Information on the concrete strength (f_c) and steel reinforcement strength (f_y) was not posted in the drawings or specifications. The Reference R9 (Table 1 above) design calculations used a concrete compression strength value of f_c equal to 1050 psi and an f_s value of 20 ksi. These values are based upon the working stress method of design whereby f_c=f'c(0.35) and f_s=20 ksi. This results in an f'_c value of 3 ksi. For the reinforcement, Reference R5 (Table 1 above) states *All bent bars and dowels #6 and larger shall be intermediate grade billet steel. Straight bars may be intermediate grade billet-steel, hard grade billet-steel or rail steel.* Table 6-2 of Reference S23 (Table 2 above) states that the yield strength of Intermediate Steel is 40 ksi, Hard steel 50 ksi and rail steel is 60 ksi. Based on the specification information posted in Reference R5 (Table 1 above), f_c=3ksi and f_y=40ksi values were used for the initial analysis of the gatewells and RCB. Additional analysis was conducted on the RCB, drainage system 4 and 8 gatewells using a concrete compressive strength equal to f'_c=3 x 1.25ksi=3.75 ksi.

Table 8. Minimum Acceptable Strength Safety Factors (SF) for Existing Structures.

Structure	Load Factor, LF	Strength Reduction Factor, SR	SF= LF/SR	Minimum Acceptable SF= 0.85*SF	Reference
RCP	Dependant upon the D-load strength value. Range: 1.5 to 1.25	0.9	1.67 to 1.39	Dependant upon the D-load strength value. Range: **1.28 to 1.06**	S21, S22
RCB & Gatewell Moment	1.7	0.9	1.89	**1.61**	S1, Single Load Factor Method

RCB & Gatewell Shear	1.7	0.85	2.0	**1.70**	S1, Single Load Factor Method

5.1.10.1 RCP

To determine the class of RCP present in the levee, the direct design equation 3.10 found in Reference S21 (Table 2 above) was used to calculate the $D_{0.01}$ capacity value. This equation was used because the class of RCP placed in the levee was not specified in the MRLS R 471-460 specifications or drawings. The capacity (R) value obtained from the Reference S21 (Table 2 above) equation 3.10 was compared to the demand (Q) value obtained from equation 3-2 found in Reference S22 (Table 2 above) to determine if the RCP met the minimum strength requirements. For RCP demand, the embankment condition was used. No live loads were placed on the RCP because the contribution of live loading on RCP is negligible when the pipe depth exceeds 10 feet (Figure 5-2 of Reference R5 (Table 1 above)). For strength analysis, it was assumed that the RCP would be full of water. A bedding factor (B_f) of 2.23 and a vertical arching factor (VAF) equal to 1.4 were used to determine the RCP loading. The VAF=1.4 was determined by using Illustration 4.3 located in Reference S22 (Table 2 above) for a "Type 3" pipe installation. The bedding factor value was determined by using equation 3-1 located in Reference S2 (Table 2 above) for a projection ratio of 0.7. This projection ratio was determined from information extrapolated from Reference R5 (Table 1 above). Section 8 of Reference R5 (Table 1) (levee specifications) stating *"The bed shall fit the contour of the pipe over a width of not less than 0.6 of the pipe diameter."* The calculated 2.23 bedding factor is comparable to the "Type 3" installation bedding factor value posted in Reference S22 (Table 2 above). The Type 3 installation is based upon the Standard Installation Direct Design (SIDD) procedure developed and recommended by the ACPA for the design of RCP. This method replaces the historical Marston/Spangler design procedure used in Reference S2 (Table 2 above).

5.1.10.2 RCB

The RCB was evaluated for the existing and future design load cases using the embankment condition, Case I and Case II as outlined in Reference S2 (Table 2 above). For Case I, the VAF=1.5 and the horizontal arching factor, HAF=0.5. For Case II, the VAF=1.0 and HAF=1.0. The coefficient of lateral at rest earth pressure used was K_o=0.7. The RCB was assumed dry (sluice gate closed) for all load cases and lateral load due to water pressure during a flood event would be present on the RCB sidewalls. Thrust loading was taken into account in determining the moment and shear capacity (R) values for all four RCB walls. The shear capacity (R) values were calculated using Reference S11 (Table 2 above), section 11.3.2 criteria. A section of the RCB located just landward of the sluice gate was chosen for analysis. The RCB at this location is referred to as the Type B RCB in Reference R1 (Table 1 above).

5.1.10.3 Gatewells

The gatewell wall sections chosen for analysis were determined by the locations where the reinforcement sizing changed and the conduit crown locations. These wall sections were analyzed for moment and shear capacity versus demand. For this feasibility study, the top of proposed levee (future design), 100-year + 3-feet flood event load case was analyzed. The at-rest coefficient of earth pressure, K_o=0.7 was used. Each gatewell was assumed to contain water at the same elevation as the flood event because none of the gatewells are expected to have flap gates installed. Therefore the net lateral loading on the gatewell walls due to water pressure would be zero. The moment capacity (R) values were calculated using Reference S1 (Table 2 above) equation D1, taking into account the benefit of lateral thrust acting on the gatewell wall sections. The shear capacity (R) values were calculated using Reference S11 (Table 2 above), section 11.3.2 criteria which also takes into account the benefit of lateral thrust acting on the wall sections. The moment demand (Q) values were computed using the moment distribution method. The moment distribution factors were obtained using the Deflection guidance provided in Reference S12 (Table 2 above) to obtain the wall section effective moment of inertia values.

5.1.10.4 Required Safety Factor (SF) Values

5.1.11.1 RCP

The hydraulic load factor of 1.3 that is based on environmental structure durability given in References S13 and S1 (Table 2 above) was not used in this feasibility study. This factor addresses durability and structure longevity versus strength. The American Concrete Pipe Association does not apply the hydraulic factor when determining the RCP demand. The strength reduction value R=0.9 is based on Reference S21 (Table 2 above) for the direct design of RCP. Reference S22 (Table 2 above) was used to determine the RCP D-load safety factors. The relationship between ultimate D-load and 0.01-inch crack D-load is 1.5 for 0.01-inch crack D-loads of 2,000 or less; 1.25 for 0.01 inch crack D loads of 3,000 or more; and a linear reduction from 1.5 to 1.25 for 0.01 inch crack D-loads between more than 2,000 and less than 3,000. For example, if the D-load 0.01 crack strength is calculated to be 2300, the resulting safety factor SF= 1.5 – (300/1000)(1.5-1.25)=1.425. The resulting safety factors were reduced by 15% to account for the fact that no reports of distress have been reported for the RCP included in this feasibility study. For the example given above, the minimum acceptable safety factor = 1.425(0.85)=1.21. The 15% reduction factor has been used on previous feasibility studies such as the Kansas City 7 Levees feasibility study.

5.1.11.2 RCB and Gatewells

The Single Load Factor Method (SLFM) and strength reduction factors from Reference S1 (Table 2 above) were used to determine the minimum SF. Note that the hydraulic factor = 1.3 required in Reference S1 (Table 2 above) for concrete hydraulic structures was not applied for reasons outlined in paragraph 9.4.1. For existing RCB and gatewell structures, it is recommended that the minimum SF = 1.61 be used for moment loads. The

recommended minimum acceptable SF for shear loads is SF = 1.70. These SF values were determined by taking 85% of the load factor divided by strength reduction value. The resulting safety factors were reduced by 15% to account for the fact that no reports of distress have been reported for the RCB and gatewells in this feasibility study. The reduction is used only for the acceptance of existing structures that have no signs of distress. If modification is required, the structure will be required to adhere to the Corps criteria without reduction to applicable safety factors. Regardless of the calculated SF, all RCB and gatewell structures should be visually inspected prior to making a final decision on whether replacement is necessary.

5.1.11 Strength Analysis Results

5.1.11.1 RCB

Results of the RCB analysis are shown in Tables 9, 10 and 11 below. Analysis was conducted on the existing design for a top of levee flood event and for the future design top of levee flood event. For both load cases where VAF=1.5 and HAF=0.5, (Case I) the RCB negative sidewall moment controlled. For both load cases where VAF=HAF=1.0, the positive sidewall moment controlled (Case II). Additional analysis of the RCB was done in light of the R/Q values shown in Table 9 below. The RCB was analyzed using a concrete compressive strength, f'_c=3.75 ksi. The 3.75 ksi value was obtained by multiplying the 3 ksi by 1.25. This factor was obtained from Reference S23 (Table 2 above), and is an expected value (versus lower bound) for concrete compressive strength as the concrete continues to hydrate and strengthen with age. The minimum acceptable SF shown in Table 10 below was obtained in part from Reference S1 (Table 2 above). Reference S1 (Table 2 above) defines the Modified ACI 318 Method, where the SF =[(1.7)1.3(0.75)]/0.9 = 1.84. The resulting 1.84 value was then multiplied by 0.85 to get the 1.5 SF. Note that the 1.5 value is less conservative than the flexure SF=1.61 used in the initial analysis. The 0.85 coefficient stated above was incorporated because the structures analyzed for this feasibility study have not exhibited signs of distress, thus permitting a minimum acceptable SF equal to 1.5. Also, the maximum loads the structures may be exposed to are highly predictable relative to conventional building structures exposed to live loads. The herein described Modified ACI Method using a minimum acceptable SF of 1.5 was also used in the Kansas City District's Seven Levees and Topeka Feasibility Studies. Results of the analysis using the Modified ACI Method are posted in Table 10 below. The RCB still did not meet the minimum required SF for bending moment for f'_c=3.75 ksi.

5.1.11.2 Gatewells

Results of the gatewell strength analysis are shown in Tables 12, 13 and 14 below. Drainage system 4, 8 and 10 gatewells failed to meet the minimum SF for bending moment at the lower wall elevations. Additional analysis was performed using the same methodology outlined in Paragraph 5.1.11.1 Drainage system 4 and 8 gatewells failed to

meet the minimum SF for bending moment at the lower wall elevations using a concrete compressive strength of 3.75 ksi.

Table 9. RCB Moment SF, Existing and Future Design Top of Levee Flood Events.

Load Case	Positive Moment R, (Kip*ft)	Positive Moment Q, (Kip*ft)	Positive Moment R/Q	Negative Moment R, (Kip*ft)	Negative Moment Q, (Kip*ft)	Negative Moment R/Q	Min. Acceptable SF	Meets Minimum Moment Capacity SF Requirement?
ET_I	11.3	4.7	2.40	14	10.4	1.35	1.61	NO
ET_II	10.3	7.8	1.32	13.0	10	1.30	1.61	NO
FT_I	11.9	5.2	2.29	14.6	12.2	1.20	1.61	NO
FT_II	10.8	8.6	1.26	13.5	10.8	1.25	1.61	NO

ET_I: Top of levee flood event, existing design, VAF=1.5 and HAF=0.5
ET_II: Top of levee flood event, existing design, VAF=1.0 and HAF=1.0
FT_I: Top of levee flood event, future design, VAF=1.0 and HAF=1.0
FT_II: Top of levee flood event, future design, VAF=1.0 and HAF=1.0

Table 10. RCB Moment SF, Future Design Top of Levee Flood Event, Concrete f'_c***=3.75 ksi***

Load Case	Positive Moment R, (Kip*ft)	Positive Moment Q, (Kip*ft)	Positive Moment R/Q	Negative Moment R, (Kip*ft)	Negative Moment Q, (Kip*ft)	Negative Moment R/Q	Min. Acceptable SF*	Meets Minimum Moment Capacity SF Requirement?
FT_I	12.0	4.9	2.45	14.8	11.1	1.33	1.5	NO
FT_II	10.9	8.6	1.27	13.7	10.9	1.26	1.5	NO

ET_I: Top of levee flood event, existing design, VAF=1.5 and HAF=0.5
ET_II: Top of levee flood event, existing design, VAF=1.0 and HAF=1.0
FT_I: Top of levee flood event, future design, VAF=1.0 and HAF=1.0
FT_II: Top of levee flood event, future design, VAF=1.0 and HAF=1.0
* Based on the Modified ACI Method, reduced by 15%

Table 11. RCB Shear SF, Future Design Top of Levee Flood Event.

Load Case	Shear R, (Kip)	Shear Q, (Kip)	Shear R/Q	Min. Acceptable SF	Meets Minimum Shear Capacity SF Requirement?
FT_I	15.5	7.4	2.09	1.70	YES
FT_II	11.5	5.3	2.17	1.70	YES

Table 12. Gatewell Wall Moment SF, Top of Levee Flood Event-Future Design. Moment values based upon a section width b = 1 foot unless noted otherwise.

DS	STA & Depth[A], (ft)	Positive Moment			Negative Moment			Min. Accept. SF	Meets Minimum Moment Capacity SF Requirement?
		R, (Kip*ft)	Q, (Kip*ft)	R/Q	R, (Kip*ft)	Q, (Kip*ft)	R/Q		
2	115+60 15.3	11.5	3.6	3.19	8.0	4.1	1.95	1.61	YES
2	115+60 14.5	7.9	3.4	2.32	7.9	3.8	2.08	1.61	YES
2	115+60 19.3	9.8	5.0	1.96	C	C		1.61	YES
3	186+00 16.0	8.0	3.8	2.11	8	4.3	1.86	1.61	YES
3	186+00 20.0	9.8	5.2	1.88	C	C		1.61	YES
4	325+00 12.0	7.7	4.9	1.57	7.7	5.1	1.51	1.61	NO
4	325+00 17.0	11.8	7.0	1.69	8.3	7.2	1.15	1.61	NO
4	325+00 21.0	16.2	7.6	2.13	8.5	8.3	1.02	1.61	NO
5	398+00 19.0	8.3	3.0	2.77	8.3	4.1	2.02	1.61	YES
7	420+35 17.7	8.2	1.5	5.47	8.2	3.1	2.65	1.61	YES
8	497+60 13.7	7.9	5	1.58	7.9	5.3	1.49	1.61	NO
8	497+60 16.1[B]	43.0	22.2	1.94	32.4	23.5	1.38	1.61	NO
8	497+60 25.0[B]	14.3	7.8	1.83	C	C		1.61	YES
9	558+50 18.5	8.3	4.4	1.89	8.3	5.0	1.66	1.61	YES
9	558+50 22.6	9.82	5.8	1.69	C	C		1.61	YES
10	610+00 16.0	8.2	4.3	1.91	8.2	5.0	1.64	1.61	YES
10	610+00 16.9	16.5	9.1	1.81	16.5	10.5	1.57	1.61	NO
10	610+00 22.0	14.3	6.9	2.07	C	C		1.61	YES

[A] Measured from top of levee, future design elevation, including the 0.5 ft aggregate material thickness.
[B] Section width b=3.8 ft.
[C] Gatewell wall section located orthogonal of the walls with pipe openings. Negative moment cannot be developed in these wall areas.

Table 13. Gatewell Wall Moment SF, Top of Levee Flood Event-Future Design. Moment values based upon a section width b = 1 foot and concrete *f'$_c$=3.75 ksi*

DS	STA & Depth[A], (ft)	Positive Moment			Negative Moment			Min. Accept. SF*	Meets Minimum Moment Capacity SF Requirement?
		R, (Kip*ft)	Q, (Kip*ft)	R/Q	R, (Kip*ft)	Q, (Kip*ft)	R/Q		
4	325+00 19.0	16.4	7.8	2.10	8.5	8.1	1.05	1.5	NO
8	497+60 13.7	8.0	5.0	1.60	8.0	5.3	1.51	1.5	YES
8	497+60 16.1[B]	43.2	22.2	1.95	32.5	23.5	1.38	1.5	NO

[A] Measured from top of levee, future design elevation, including the 0.5 ft aggregate material thickness.
[B] Section width b=3.8 ft.
* Based on the Modified ACI Method, reduced by 15%

Table 14. Gatewell Wall Shear SF, Top of Levee Flood Event-Future Design. Based on section width b= 1 foot unless noted otherwise.

DS	STA & Depth[A], (ft)	Shear			Min. Acceptable SF	Meets Minimum Shear Capacity SF Requirement?
		R, (Kip)	Q, (Kip)	R/Q		
2	115+60 15.3	13.1	2.7	4.85	1.70	YES
3	186+00 16.0	12.9	2.9	4.45	1.70	YES
4	325+00 13.0	13.2	5.0	2.64	1.70	YES
5	398+00 19.0	12.9	2.6	4.96	1.70	YES
7	420+35 17.7	12.9	1.7	7.59	1.70	YES
8	497+60 24.0	13.0	5.8	2.24	1.70	YES
9	558+50 18.5	12.9	3.3	3.91	1.70	YES
10	610+00 16.9[B]	25.7	6.8	3.78	1.70	YES

[A] Measured from top of levee, future design elevation, including the 0.5 ft aggregate material thickness.
[B] Section width b=2 ft

5.1.11.3 RCP

The calculated RCP SF is shown in Table 15 below. All RCP studied met the minimum capacity requirements. All of the RCP analyzed meet the minimum capacity requirements.

Table 15. RCP Evaluated Safety Factors For Future Design Levee.

DS	Dia, (in)	Depth[A], (ft)	Capacity, R,(plf)	Demand, Q, (plf)	R/Q	Min. SF Allowed	Meets Minimum Capacity Requirement?
2	48	15.3	2236	1532	1.46	1.22	YES
3	48	16.1	2236	1602	1.4	1.22	YES
5	36	19.4	2395	1893	1.27	1.19	YES
7	24	17.9	2680	1761	1.52	1.13	YES
8	66	17.9	2934	1803	1.63	1.10	YES
9	48	18.6	2236	1832	1.22	1.22	YES
10	54	18.2	2262	1805	1.25	1.22	YES

[A] Measured from top of levee, future design elevation (including 0.5 ft of aggregate material on levee crown) to RCP crown.

5.1.12 Recommendations

5.1.12.1 Gatewells

Based on the strength analysis, it is recommended that testing be accomplished on the drainage systems 4 and 8 gatewell concrete and reinforcement steel per ACI guidance for the testing of existing structures. Based on the material properties obtained from testing, an analysis should be reaccomplished to determine if the structure meets the minimum strength requirements. Regardless of the calculated SF for any of the structures, the physical condition of the gatewells should undergo a through visual examination prior to making a final decision as to whether replacement or rehabilitation action is necessary. If flap gates are installed on drainage system 4, 8, 9 and 10 outlet pipes, the respective gatewells should be reanalyzed for strength. Drainage systems 2, 3, 5 and 7 gatewell walls have a bending moment R/Q value equal to or greater than the acceptable SF for the Future Design event and would not require replacement if flap gates were installed on the outlets.

5.1.12.2 Conduits

It is recommended that the drainage system 4 RCB be replaced. The drainage system 4 RCB sidewalls were not designed for the lateral loads incurred by water pressure during a flood event per the 1966 design calculations (Reference R9). This has resulted in a 38% increase in the lateral load on the RCB sidewalls for Case I. A 21% increase in the lateral load on the RCB sidewalls resulted for Case II. Please refer to the hand calculations in Section III of this document for details comparing the original RCB design load cases versus the RCB load cases used in this feasibility study. This has resulted in the RCB sidewalls not meeting the minimum moment strength requirements. The 1966 design calculations used a fill height of 18 feet whereas the existing fill height at the levee crown is 20 feet. The fill height for the Future Design event at the levee crown is approximately

22 feet. The minimum FS for flotation was not met for the drainage system 3, 8 and 10 conduits. It is recommended that the levee berm be raised approximately 1.25 feet at drainage system 3 and 1.0 feet at drainage systems 8 and 10 to provide the minimum FS for flotation during the design event.

5.1.12.3 Preliminary Design

Sheet S-01, "MRLS R 471-460, Drainage Structure No. 4, Sta. 325+00, Levee Removal and Temp. Flood Protection" of the Engineering Appendix includes details for removal of Drainage Structure No. 4 including temporary flood protection. The temporary flood protection is for a level currently provided by the existing levee system. Sheet S-02, "MRLS R 471-460, Drainage Structure No. 4, Sta. 325+00, Replacement Structure Profile and Details" of the Engineering Appendix includes preliminary designs for the replacement drainage structure. Sheet S-03, "MRLS R 471-460, Drainage Structure Details, Gatewell and Pipe Extensions" of the Engineering Appendix includes preliminary design for the gatewell top extensions, the inlet extensions, and the inlet treatments. Final detailed design will be completed during PED.

5.2 MRLS L-455 STRUCTURAL OVERVIEW AND SUMMARY

5.2.1 Introduction

The Structural support to the Missouri River Levee System (MRLS) L-455 and R 471-460 Feasibility Study focused on the selected plan. The selected plan provides flood protection against the 100 year plus 3-feet flood profile. Structural input was also provided for alternative screening. Alternative screening is addressed in more detail within the main body of the study. The documentation as follows provides a structural overview and summary for the MRLS L-455 selected plan.

5.2.2 Overview

The Kansas City District's Structural Section, EC-DS, performed the structural analysis. Technical reviews were completed by in-house staff and the St. Paul District. The 100-year plus 3-feet flood profile for the selected plan was established by the Hydrology/Hydraulics and Civil Design Project Development Team (PDT) disciplines. Only those structures within a levee reach subject to a raise were considered as part of the structural effort. The structural features within the MRLS L-455 top of levee raise limits included drainage pipes as well as the drainage systems' gatewell structures. The documentation addresses the following:

a. Levee and structural analysis references
b. Feasibility study Scope of Work (SOW)
c. Documentation
d. Drainage systems identified for study

e. Utility lines identified for study
f. Stability analysis methodology
g. Stability analysis results
h. Strength analysis methodology
i. Strength analysis results and recommendations

Detailed documentation is included within the separately bound document, "Missouri River Levee System (MRLS) L-455 & R 471-460, Design Documentation Report (DDR)" and is available for viewing upon request. The following project information can be found within the DDR:

a. Structural Overview and Summary (similar to this document)
b. Scope of Work
c. Corrugated Metal Pipe (CMP) Analysis
d. Gatewell Analysis

5.2.3 Levee and Structural Analysis References

Levee reference material in Table 1 below provided information used to analyze the drainage structures. The structural criteria used to complete structural support to the feasibility study are listed in Table 2 below. Army Corps of Engineers (COE) and private industry criteria were used to conduct the structural analysis.

Table 1. References.

ID	Publication Title	Pub Date
R1*	Operation and Maintenance Manual, Appendix I (As-Builts)	03/23/66
R4*	MRLS R471 L455 Photos	01/05
R5*	Unit L-455 Operation and Maintenance Manual, Appendix III, Periodic Inspection Report No. 1	02/74
R6*	R471 L455 Binded Documents (Periodic Inspection Reports, Levee Repair, etc)	10/15/04
R8	L455 & R471-460 Feasibility Study Drawings	04/05
R9	Specifications for Construction of Levee Unit 455-L, Part I	1962
R10	Specifications for Construction of Levee Unit 455-L, Part II	1963
R11	FEMA 356 Prestandard and Commentary for The Seismic Rehabilitation of Buildings	11/00

*Documents located within the DDR.

Table 2. Structural and Stability Criteria References

ID#	Publication Title	Pub Date
	Army Corps of Engineers (COE):	
S1	EM-1110-2-2104 Strength Design for Reinforced-Concrete Hydraulic Structures, Change 1	08/20/03
S2	EM 1110-2-2902 Conduits, Culverts, and Pipes, Change 1	03/31/98
S3	EC 1110-2-6058 Stability Analysis of Concrete Structures	11/30/03
S4	Kansas City District Local Protection Guidance. Web address: http://www.nwk.usace.army.mil/Local_Protection/guidance.html	Varies
S5	ETL 1110-2-307 Flotation Stability Criteria for Concrete Hydraulic Structures	08/20/87
	American Concrete Institute (ACI):	

S11	318-02 Building Code Requirements for Structural Concrete	2002
S12	340R-97 ACI Design Handbook	1997
S13	ACI 350-01 Code Requirements for Environmental Engineering Concrete Structures	2001
	ASTM	
S20	A796-04a Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications	2004
	FHWA	
S30	Corrugated Metal Pipe, Structural Design Criteria and Recommended Installation Practice	04/1976

5.2.4 Structures (EC-DS) Feasibility Study Scope of Work (SOW)

The MRLS L-455 and R 471-460 Feasibility Study Structural SOW is located within the Project Management Plan (PMP) located within the PM-PF files and within the DDR. The SOW has undergone modifications and clarifications since its creation in September 2003. The following information represents modifications/clarification of the original SOW:

a. The feasibility study will address only those structures lying in areas requiring a levee raise.
b. The levee raise affects the drainage systems located at levee stations 232+00 and 312+36. The river mile locations are 443.2 and 440.9 respectively (plus or minus 0.2 miles).
c. Flap gates will not be used on the drainage systems.
d. This feasibility study utilized an alternatives' screening approach to determine the selected plan. The selected plan is the levee raise required to provide protection for the 100-year + 3-feet flood event.
e. The gatewells will not require electrical utilities.

5.2.5 Project Management Plan and Quality Control Plan

The feasibility study Project Management Plan (PMP) and Quality Control Plan (QCP) are located within PM-PF files and within the DDR.

5.2.6 Drainage Systems Identified for Study

Through coordination with the Hydrology/Hydraulics and Civil Design disciplines, a total of 2 MRLS L-455 drainage systems were identified for this feasibility study. The 2 drainage systems are listed in Table 3 below. Note that the reference documents in Table 1 above do not specify drainage system identification numbers. The top of gatewell elevation values obtained from reference R1 (Table 1 above) were verified in the field by Civil Design in March 2005. Both drainage systems are composed of an inlet, outlet, and gatewell constructed of reinforced concrete. Corrugated metal pipe (CMP) provide the drainage path at both drainage systems. The water surface elevations shown in Table 3 below indicate that a top of gatewell raise will not be necessary at levee stations 232+00

Table 3. Drainage Systems Analyzed.

Conduit Size, (in) / Type[A]	Levee STA[B]	River Mile[C]	100 year + 3 Feet Flood Elev., (ft)[D]	Existing Top of Gatewell Elev., (ft)[B] / Conduit Invert Elev., (ft)[E]	Proposed Top of Gatewell Elev. (ft)[F]	Proposed Gatewell Raise, (ft)[G]	Existing Top of Levee Elev., (ft)[H]	Proposed Top of Levee Elev., (ft)[J]	Proposed Levee Raise, (ft)[K]
24 / CMP	232+00	443.2	817.67	817.8 / 796.4	817.8	0	818.3	817.8	0
24 / CMP	312+36	440.9	815.19	815.7 / 794.0	815.7	0	816.2	815.7	0

[A] Precast Reinforced Concrete Pipe (RCP); Reinforced Concrete Box Culvert (RCB), Corrugated (Circular) Metal Pipe (CMP)
[B] Reference: R1
[C] Approximate, plus or minus 0.2 miles
[D] Reference: R8
[E] Reference: R1. Invert elevation at gatewell sluice gate thimble connection.
[F] Equal to the 100 year+3 feet flood elevation or existing top of gatewell elevation, whichever is greater
[G] Proposed Top of Gatewell Elev. – Existing Top of Gatewell Elev.
[H] Does include the existing aggregate material placed on levee crown. The aggregate thickness is approximately 0.5 feet
[J] Levee crown elevation prior to placement of aggregate material. The aggregate thickness is assumed to be 0.5 feet
[K] Proposed Top of Levee Elev. – Existing Top of Levee Elev. + 0.5 feet

and 312+36. Therefore, for this feasibility study, the drainage system analysis will be for existing conditions.

5.2.7 Utility Lines Identified for Study

No utility lines have been identified as impacted by this feasibility study.

5.2.8 Stability Analysis Methodology

5.2.8.1 Flotation

The criteria posted in Chapter 3 of reference S3 (Table 2 above) was used to determine if the structures met the required safety factors for uplift. Table 4 below lists the minimum flotation factors of safety for various types of events. For this feasibility study, an extreme event is considered the 100-year + 3-feet top of levee event, which has a minimum safety factor of 1.1. Three feet below top of levee event is considered an unusual event and has a minimum safety factor of 1.2.

Table 4. Required Factors of Safety for Flotation-All Structures.

Load Condition	Factor of Safety (FS)
Usual	1.3
Unusual	1.2
Extreme	1.1

5.2.8.1.1 Gatewells

The gatewells studied do not have a heel extension. None of the drainage systems have flap gates. It was assumed that flap gates would not be required in the future design. Therefore, it is also assumed that the gatewell sluice gate will be closed and each of the gatewells will fill with water during a Missouri River flood event. The gatewell uplift was calculated in a rapid drawdown situation. In this situation the gatewells are assumed dry. The uplift force acting on a gatewell was calculated to equal the weight of water displaced by the gatewell. It is not expected that the uplift force using the method posted in reference S4 (Table 2 above) will control the factor of safety against flotation.

5.2.8.1.2 Conduits

By observation, it was determined that the minimum factor of safety for flotation would occur at the conduit inlet because of the minimum conduit earth cover and the pipe being dry during a flood event at this location. Conduit flotation analysis was not completed for this study.

5.2.8.2 Bearing Capacity and Settlement

The gatewells' bearing analysis and settlement were not completed for this study.

5.2.9 Stability Analysis Results

5.2.9.1 Flotation

5.2.9.1.1 Gatewells

The gatewell flotation stability calculations are located in the DDR. All of the drainage system gatewells studied met the minimum safety factor against uplift for the existing top of levee and three feet below top of levee flood events. The evaluated gatewell factor of safety values (FS) is tabulated in Table 5 below.

Table 5. Gatewell Existing Design Factors of Safety For Flotation.

Factors of Safety, (FS)				
Levee Station	**FS For Event A: 3 Feet Below Top of Levee Flood Event**	**Required FS Met For Event A? Min FS=1.2**	**FS For Event B: Top of Levee Flood Event**	**Required FS Met For Event B? Min FS=1.1**
232+00	1.6	YES	1.4	YES
312+36	1.6	YES	1.4	YES

5.2.9.1.2 Conduits

The conduits flotation analysis was not completed for this study.

5.2.9.2 Bearing Capacity and Settlement

5.2.9.2.1 Gatewells

The gatewells' bearing capacity and settlement were not completed for this study.

5.2.9.2.2 Conduits

The conduit settlement was not completed for this study.

5.2.10 Strength Analysis Methodology

Strength analysis was conducted on the drainage system corrugated metal pipe (CMP) and gatewell structures. For the gatewells, the center-to-center span length was used to compute the moment capacity and demand values. The shear demand values were taken at distance "d" equal to the reinforcement depth away from the support. The capacity (R) and demand (Q) values were calculated with a load factor and strength reduction factor equal to one for the two gatewell structures. The resulting R/Q values were compared to the minimum acceptable safety factors shown in Table 7 below. The concrete reinforcement yield strength fy=40 ksi was obtained from References R9 and R11 (Table 1 above) (ASTM A615 Intermediate Billet Steel). Information pertaining to the concrete

strength (f_c) could not be found. Based on the time period the structures were built (1960s) and Table 6-3 in Reference R11 (Table 1 above), f_c=3ksi was used in the gatewell analysis. The CMP strength was checked using the Load Resistance Factor Design (LRFD) method found in Reference S20 (Table 2 above).

Table 6. Minimum Acceptable Strength Factor of Safety (FS) Values for Existing Structures.

Structure	Load Factor, LF	Strength Reduction Factor, SR	FS= LF/SR	Minimum Acceptable FS= 0.85*FS	Reference
CMP	1.95 for Earth Loads 1.75 for Live and Impact Loads	1.0 for Wall Area and Buckling 0.67 for Seam Strength	1.95 for Wall Area and Buckling 2.61 for Seam Strength	No reduction allowed.	S20
RCB & Gatewell Moment	1.7	0.9	1.89	**1.61**	S1, Single Load Factor Method
RCB & Gatewell Shear	1.7	0.85	2.0	**1.70**	S1, Single Load Factor Method

5.2.10.1 CMP

The CMP was analyzed using the LRFD design provisions in Reference S20 (Table 2 above). The load factors (LF) and factor of safety (FS) values were incorporated in the design equations. An embankment loading condition was used. A soil stiffness factor k equal to 0.44 was used to determine the critical buckling stress. The k value was obtained from Reference S30 (Table 2 above). Reference S30 (Table 2 above) recommends a k=0.44 value when the quality of side fill material and compaction required for k=0.22 are not obtainable. The available pipe corrugation material property information is limited. Reference R1 (Table 1 above) stated only *14 gauge CMP*. 14 gauge steel corresponds to a thickness of 0.079 inches. Based on pictures taken during the January 2005 site visit, the CMP was assumed to have annular 2 $^2/_3$ x ½ corrugations. A single line of $^5/_{16}$-in diameter rivets was assumed to be present.

5.2.10.2 Gatewells

The gatewell wall sections were analyzed for moment and shear capacity versus demand. For this feasibility study, the top of proposed levee 100-year + 3-feet flood event load case was analyzed. Note that the proposed design does not dictate a raise in the gatewell or levee height. The at-rest coefficient of earth pressure, K_o=1.0 was used. The moment capacity (R) values were calculated using reference S1 (Table 2 above) equation D1, taking into account the benefit of lateral thrust acting on the gatewell wall sections. The shear capacity (R) values were calculated using reference S11 (Table 2 above), section 11.3.2 criteria which also takes into account the benefit of lateral thrust acting on the wall

sections. The moment demand (Q) values were computed using the moment distribution method. The moment distribution factors were obtained using the Deflection guidance provided in reference S12 (Table 2 above) to obtain the wall section effective moment of inertia values. For the 95% Feasibility Study Report, the gatewell wall sections located at the pipe crown and lower elevations will be evaluated for moment strength capacity using plate analysis.

5.2.10.3 Required Factor of Safety (FS) Values

5.2.10.3.1 CMP

The CMP was required to meet the design standards of Reference S20 (Table 2 above) which include the LF and FS posted in Table 6 above. Reference S20 (Table 2 above) is referenced in Corps Reference S2 (Table 2 above) for the design of CMP.

5.2.10.3.2 Gatewells

The Single Load Factor Method (SLFM) and strength reduction factors from Reference S1 (Table 2 above) were used to determine the minimum FS. The hydraulic load factor of 1.3 that is based on environmental structure durability given in Reference S13 and S1 (Table 2 above) was not used in this feasibility study. This factor addresses durability and structure longevity versus strength. For existing RCB and gatewell structures, it is recommended that the minimum FS = 1.61 be used for moment loads. The recommended minimum acceptable FS for shear loads is FS = 1.70. These FS values were determined by taking 85% of the load factor divided by strength reduction value. The resulting factor of safety values were reduced by 15% to account for the fact that no reports of distress have been reported for the gatewells in this feasibility study.

5.2.11 Strength Analysis Results and Recommendations

5.2.11.1 Gatewells

Results of the gatewell strength analysis are shown in Tables 7 and 8 below. Based upon the moment strength analysis, the gatewells meet the minimum moment and shear safety factors for an existing structure. Regardless of the calculated FS, the physical condition of the gatewells should be examined prior to making a final decision as to whether replacement or modification is necessary.

Table 7. Gatewell Wall Moment FS, Top of Levee Flood Event-Existing Design.

	Positive Moment			Negative Moment				
STA & Depth[A], (ft)	R, (Kip*ft)	Q, (Kip*ft)	R/Q	R, (Kip*ft)	Q, (Kip*ft)	R/Q	Min. Accept. FS	Meets Minimum Moment Capacity FS Requirement?
232+00 19.9	9.3	2.5	3.72	9.3	5.0	1.86	1.61	YES
312+36 20.2	9.3	2.5	3.72	9.3	5.1	1.82	1.61	YES

[A] Measured from top of levee, future design elevation, including the 0.5 ft aggregate material thickness.

Table 8. Gatewell Wall Shear FS, Top of Levee Flood Event-Existing Design.

[A] Measured from top of levee, future design elevation, including the 0.5 ft aggregate material thickness.

	Shear				
STA & Depth[A], (ft)	R, (Kip*ft)	Q, (Kip*ft)	R/Q	Min. Acceptable FS	Meets Minimum Shear Capacity FS Requirement?
232+00 19.9	12.9	2.8	4.61	1.70	YES
312+36 20.2	12.9	2.8	4.61	1.70	YES

5.2.11.2 CMP

The factored demand and capacity values are posted in Table 9 below. The CMP met the Reference S20 (Table 2 above) strength requirements.

5.2.11.2.1 Corps Criteria for CMP Use

Reference S2 (Table 2 above) states that CMP cannot be used as an option in agricultural levees where the levee embankment is greater than 12 feet above the pipe invert. The CMP do not meet this criterion. As shown in Table 9 below, the pipe depth at both levee locations is in excess of 20 feet.

5.2.11.2.2 CMP Perforation Life

Figure 4-1 in Reference S2 (Table 2 above) was used to evaluate the CMP perforation life. Using a pH value of 7.0 (neutral) and a resistivity of 4000-ohm cm for a clay soil, the years to perforation value is approximately 40 years for galvanized CMP. A recent site visit revealed that the protective bituminous coating on the CMP located at Levee Station 312+36 is peeling off of the interior surfaces of the pipe. The pipe invert was filled with wooden debris and could not be inspected. The CMP at Levee Station 232+00 was completely silted in and could not be inspected as of January 2005. The South St. Joseph Levee and Drainage District has been advised of the operations and maintenance issues and the need to remove obstructions from the pipes.

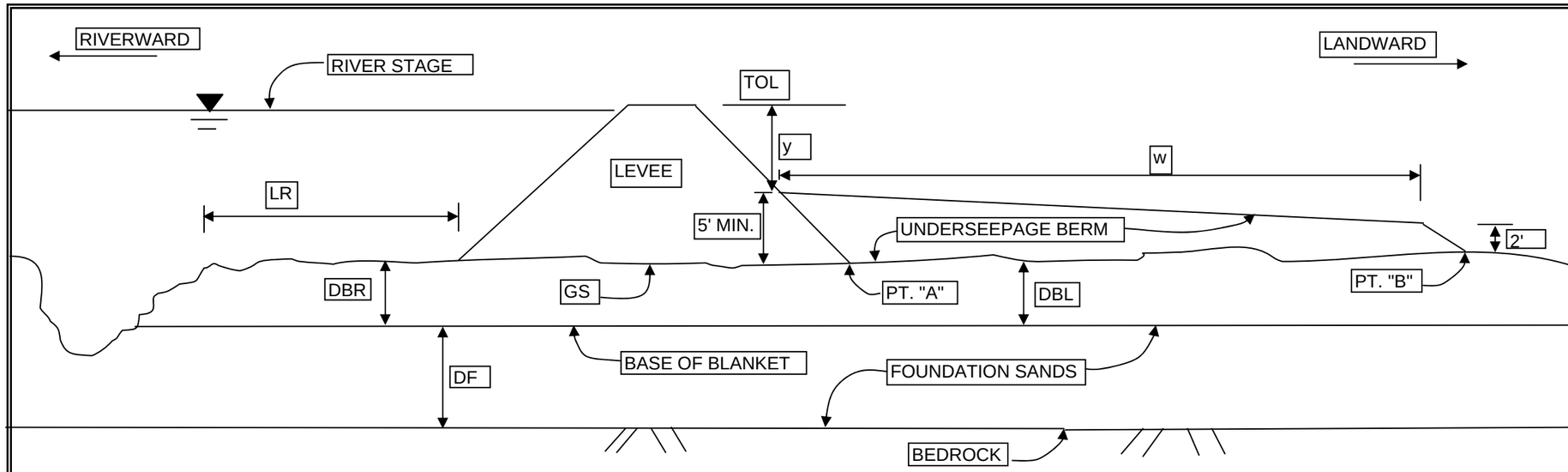
5.2.11.2.3 CMP Recommendations

The calculated life expectancy of the CMP has been exceeded. It is likely that the CMP at Levee Station 232+00 has significant corrosion given the silt buildup. If the pipe is perforated, piping of levee material will occur during flood events. This condition will jeopardize the levee's integrity during a significant Missouri river flood event. It is recommended that the silt be removed from the CMP located at Levee Station 232+00 and conduct a complete visual inspection of the CMP. Similarly, the wooded debris in the Levee Station 312+36 drainage system should be removed and conduct a visual inspection of the CMP. Based on the inspection results and a life cycle study, the CMP should be rehabilitated or replaced with reinforced concrete pipe. Possible rehabilitation alternatives include Cured In Place Pipe (CIPP) or a rigid HDPE pipe inlay.

Table 9. CMP Evaluated Safety Factors For Existing Design Levee.

STA / Dia, (in)	Depth[A], (ft)	Factored Capacity, (plf)	Factored Demand, (plf)	Meets Minimum Capacity Requirement?
232+00 / 24	19.9	12194	4657	YES
312+36 / 24	20.2	12194	4727	YES

[A] Measured from top of levee, future design elevation (including 0.5 ft of aggregate material on levee crown) to CMP crown.



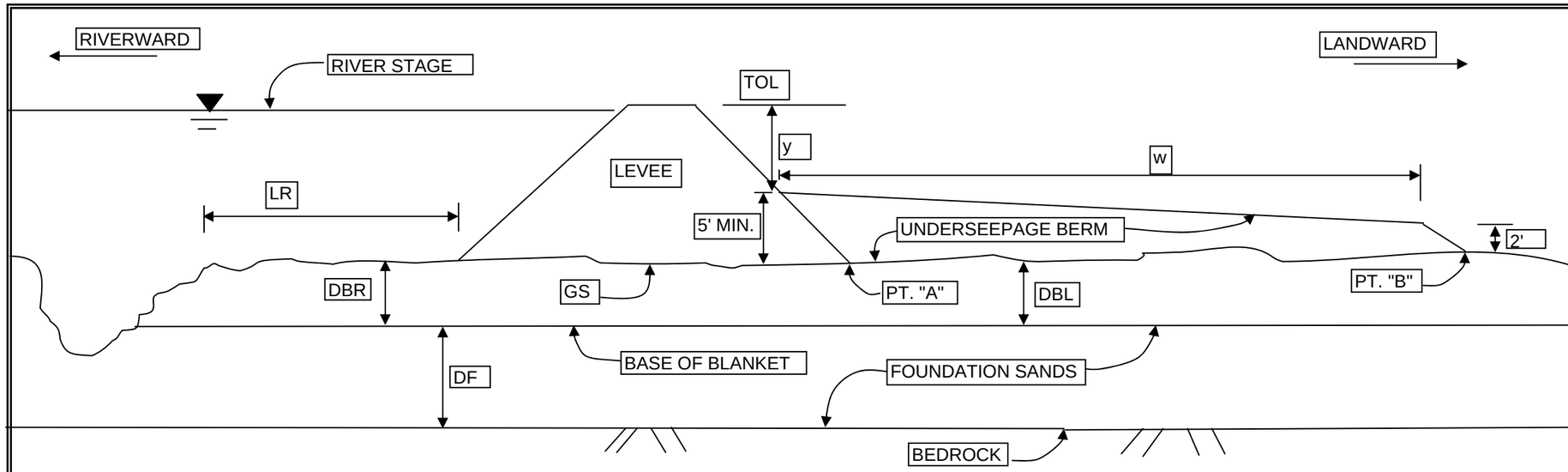
MRLS L-455 & R 471-460
FEASIBILITY STUDY

TABLE 4A

MRLS R 471-460
SEEPAGE SCHEDULE
September 7, 2006

NOTES: 1. L2 is the levee base width without an underseepage berm and is the levee base plus 1/2 the seepage berm width when there is a seepage berm.
2. Water surface elevation: check for seepage control use TOL - GS and a safety factor of 1.1 at PT. "A". Design seepage control use TOL - 3'- GS and safety factors of 1.5 at PT. "A" & 1.1 at PT. "B"

MRLS R 471-460 LEVEE REACH STATION	STATION	GROUND SURFACE ELEVATION GS (FT)	TOP OF LEVEE ELEVATION TOL (FT)	RIVERWARD NATURAL BLANKET THICKNESS DBR (FT)	LANDWARD NATURAL BLANKET THICKNESS DBL (FT)	RIVERWARD BLANKET SOIL TYPE (USCS)	LANDWARD BLANKET SOIL TYPE (USCS)	RIVERWARD HYDRAULIC CONDUCTIVITY RATIO kf/kbr	LANDWARD HYDRAULIC CONDUCIVITY RATIO kf/kbl	RIVERWARD ENTRANCE LR (FT)	FOUNDATION SANDS THICKNESS DF (FT)	IMPERVIOUS BASE WIDTH NO SEEP. BERM L2 (FT)	IMPERVIOUS BASE WIDTH W/ SEEP. BERM L2 (FT)	NATURAL BLANKET CRITICAL VERTICAL GRADIENT	VERTICAL GRADIENT THRU BLANKET PT. "A"	UNDERSEEPAGE BERM DISTANCE "Y" (FT)	DISTANCE "w" (150' MIN.) (FT)	VERTICAL GRADIENT BLNKT/BERM PT. "A"	VERTICAL GRADIENT BLANKET PT. "B"
93+09	99+00	815.00	829.41	11	11	CL	CL	800	600	900	90	94	94	0.80	0.65	NO BERM REQUIRED			
100+00	114+00	814.50	828.97	11.5	11.5	CH	CH	1000	800	1000	90	91	91	0.75	0.65	NO BERM REQUIRED			
115+00	132+00	815.50	828.73	11	11	CH	CH	800	600	300	90	89	164	0.80	0.81	8.0	150	0.13	0.53
132+00	150+00	814.50	828.32	11	11	CH	CH	800	600	300	90	93	168	0.80	0.84	9.0	150	0.15	0.56
151+00	156+00	815.50	828.28	4	4	CL-ML	CL-ML	400	200	300	90	87	172	0.80	1.42	7.5	170	0.00	0.69
156+00	161+50	816.00	828.25	4	4	CL-ML	CL-ML	400	200	300	90	84	159	0.80	1.37	7.0	150	0.03	0.69
162+00	165+00	815.00	828.12	4	4	CL-ML	CL-ML	400	200	300	90	89	174	0.80	1.45	8.0	170	0.02	0.71
166+00	228+00	812.00	827.40	4.5	4.5	CL-CH	CL-CH	500	300	300	85	102	247	0.80	1.65	10.5	290	0.22	0.72
229+00	251+00	806.00	826.65	10.5	10.5	ML	ML	600	400	600	75	134	209	0.80	0.94	15.5	150	0.26	0.66
252+00	281+00	816.50	826.08	6	6	CL-ML	CL-ML	600	400	500	85	67	67	0.80	0.79	NO BERM REQUIRED			
282+00	295+50	807.00	825.97	4.5	4.5	CH	CH	600	400	700	75	124	309	0.80	1.72	14.0	370	0.33	0.72
296+50	299+00	808.00	825.79	4.5	4.5	CH	CH	600	400	700	75	117	282	0.80	1.62	12.5	330	0.26	0.73
300+00	307+00	800.00	825.74	6	6	CH	CH	900	700	1000	60	190	190	0.70		PRESSURE RELIEF WELLS			
308+00	313+00	800.00	825.60	6	6	CH	CH	900	700	1000	60	215	215	0.70		PRESSURE RELIEF WELLS			
314+00	331+00	802.00	825.48	6	6	CH	CH	900	700	1000	60	198	198	0.70		PRESSURE RELIEF WELLS			
332+00	341+00	810.00	825.22	9	9	ML	ML	500	300	1000	65	101	101	0.80	0.68	NO BERM REQUIRED			
342+00	351+00	804.00	824.07	5	5	ML	ML	500	300	1000	65	130	265	0.80	1.49	15.0	270	0.28	0.71
352+00	375+00	804.00	824.07	9	9	CH	CH	1000	800	1000	65	130	285	0.70	1.03	15.0	310	0.27	0.63
376+00	394+00	804.00	823.56	6	6	CH	CH	700	500	1000	65	127	292	0.75	1.35	14.5	330	0.29	0.68
395+00	397+00	804.00	823.56	6	6	OL	OL	700	500	500	65	127	302	0.80	1.50	14.5	350	0.37	0.72
398+00	404+00	805.00	823.52	6	6	OL	OL	700	500	500	65	121	276	0.80	1.43	13.5	310	0.31	0.73
405+00	419+00	808.00	823.01	4	4	ML	ML	400	200	500	75	100	185	0.80	1.40	10.0	170	0.04	0.70
420+00	439+00	806.00	822.49	8	8	CL	CL	700	500	400	65	109	184	0.80	1.08	11.5	150	0.20	0.71
440+00	466+00	805.00	821.72	6	6	CL	CL	700	500	1000	65	110	205	0.80	1.17	11.5	190	0.13	0.71



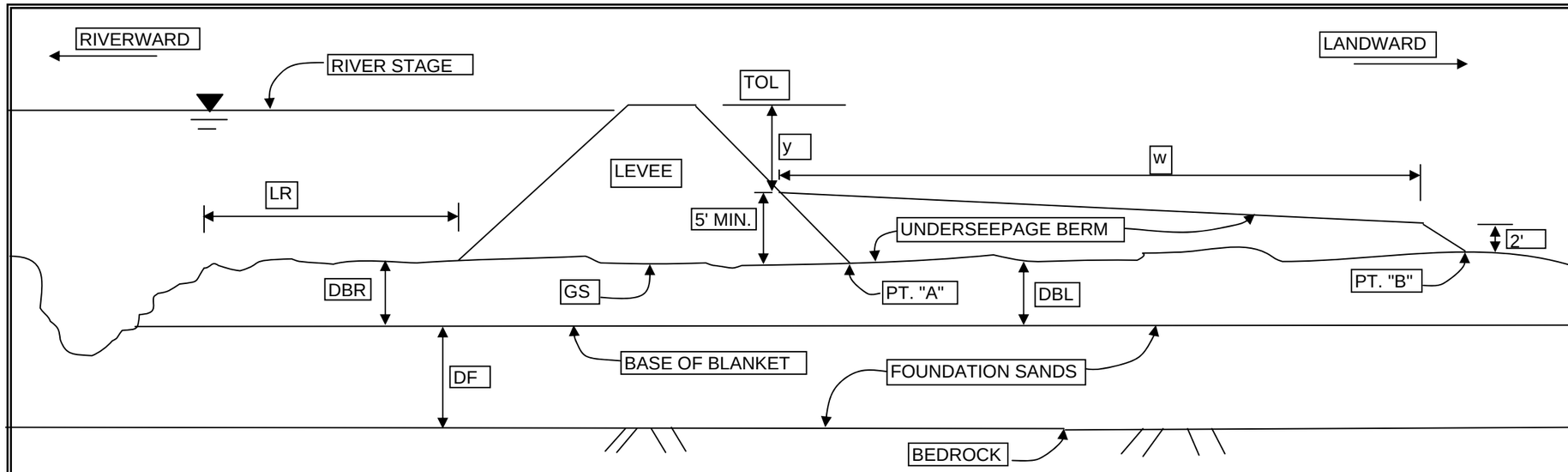
MRLS L-455 & R 471-460
FEASIBILITY STUDY

TABLE 4A

MRLS R 471-460
SEEPAGE SCHEDULE
September 7, 2006

NOTES: 1. L2 is the levee base width without an underseepage berm and is the levee base plus 1/2 the seepage berm width when there is a seepage berm.
2. Water surface elevation: check for seepage control use TOL - GS and a safety factor of 1.1 at PT. "A". Design seepage control use TOL - 3'- GS and safety factors of 1.5 at PT. "A" & 1.1 at PT. "B"

MRLS R 471-460 LEVEE REACH STATION	STATION	GROUND SURFACE ELEVATION GS (FT)	TOP OF LEVEE ELEVATION TOL (FT)	RIVERWARD NATURAL BLANKET THICKNESS DBR (FT)	LANDWARD NATURAL BLANKET THICKNESS DBL (FT)	RIVERWARD BLANKET SOIL TYPE (USCS)	LANDWARD BLANKET SOIL TYPE (USCS)	RIVERWARD HYDRAULIC CONDUCTIVITY RATIO kf/kbr	LANDWARD HYDRAULIC CONDUCIVITY RATIO kf/kbl	RIVERWARD ENTRANCE LR (FT)	FOUNDATION SANDS THICKNESS DF (FT)	IMPERVIOUS BASE WIDTH NO SEEP. BERM L2 (FT)	IMPERVIOUS BASE WIDTH W/ SEEP. BERM L2 (FT)	NATURAL BLANKET CRITICAL VERTICAL GRADIENT	VERTICAL GRADIENT THRU BLANKET PT. "A"	UNDERSEEPAGE BERM DISTANCE "Y" (FT)	DISTANCE "w" (150' MIN.) (FT)	VERTICAL GRADIENT BLNKT/BERM PT. "A"	VERTICAL GRADIENT BLANKET PT. "B"
467+00	492+00	806.00	821.12	7.5	7.5	ML	ML	700	500	300	65	101	176	0.80	1.14	10.0	150	0.18	0.72
493+00	506+50	803.50	820.65	5	5	ML	ML	500	300	300	70	113	258	0.80	1.60	12.0	290	0.29	0.70
506+50	516+00	804.00	820.48	5	5	ML	ML	500	300	300	70	109	244	0.80	1.55	11.5	270	0.25	0.70
517+00	544+00	801.00	819.87	4	4	CL	CL	500	300	300	70	123	308	0.80	2.07	14.0	370	0.43	0.72
545+00	550+50	802.00	819.75	3	3	CL-ML	CL-ML	500	300	300	70	117	312	0.80	2.46	12.5	390	0.40	0.71
550+50	564+00	802.00	819.19	3	3	CL-ML	CL-ML	500	300	300	70	113	298	0.80	2.40	12.0	370	0.36	0.72
564+00	600+00	802.00	818.17	3	3	CL-ML	CL-ML	500	300	300	70	107	282	0.80	2.28	11.0	350	0.29	0.71
601+00	622+00	803.00	818.02	8	8	CL-ML	CL-ML	600	400	800	65	95	170	0.80	0.82	10.0	150	0.05	0.52
623+00	628+00	802.00	817.56	9	9	ML	ML	600	400	600	60	100	175	0.80	0.80	10.5	150	0.09	0.51
629+00	639+84	801.00	817.33	9	9	ML	ML	600	400	600	60	130	205	0.80	0.81	11.0	150	0.10	0.53



MRLS L-455 & R 471-460
FEASIBILITY STUDY

TABLE 5

MRLS L-455
SEEPAGE SCHEDULE
September 7, 2006

NOTES: 1. L2 is the levee base width without an underseepage berm and is the levee base plus 1/2 the seepage berm width when there is a seepage berm.
2. Water surface elevation: check for seepage control use TOL - GS and a safety factor of 1.1 at PT. "A". Design seepage control use TOL - 3'- GS and safety factors of 1.5 at PT. "A" & 1.1 at PT. "B"

MRLS L-455 LEVEE REACH STATION	STATION	GROUND SURFACE ELEVATION GS (FT)	TOP OF LEVEE ELEVATION TOL (FT)	RIVERWARD NATURAL BLANKET THICKNESS DBR (FT)	LANDWARD NATURAL BLANKET THICKNESS DBL (FT)	RIVERWARD BLANKET SOIL TYPE (USCS)	LANDWARD BLANKET SOIL TYPE (USCS)	RIVERWARD HYDRAULIC CONDUCTIVITY RATIO kf/kbr	LANDWARD HYDRAULIC CONDUCIVITY RATIO kf/kbl	RIVERWARD ENTRANCE LR (FT)	FOUNDATION SANDS THICKNESS DF (FT)	IMPERVIOUS BASE WIDTH NO SEEP. BERM L2 (FT)	IMPERVIOUS BASE WIDTH W/ SEEP. BERM L2 (FT)	NATURAL BLANKET CRITICAL VERTICAL GRADIENT	VERTICAL GRADIENT THRU BLANKET PT. "A"	UNDERSEEPAGE BERM DISTANCE "Y" (FT)	DISTANCE "w" (150' MIN.) (FT)	VERTICAL GRADIENT BLNKT/BERM PT. "A"	VERTICAL GRADIENT BLANKET PT. "B"
205+64	209+00	802.00	818.77	15	7.5	CL	ML	500	400	200	70	111	236	0.80	1.34	11.5	250	0.32	0.72
210+00	237+00	802.00	818.46	13	13	CL	OL	600	600	350	70	104	179	0.80	0.80	11.5	150	0.21	0.56
238+00	247+00	800.00	818.03	7.5	7.5	CH	CH	800	800	900	70	113	278	0.75	1.17	13.0	330	0.25	0.67
248+00	257+00	800.00	818.03	10	5	CH	CH	800	700	450	70	113	358	0.80	1.77	13.0	490	0.39	0.72
258+00	262+00	800.00	818.03	9	9	CH	CH	800	800	450	65	113	268	0.75	1.15	13.0	310	0.31	0.68
263+00	280+00	800.00	817.78	7	11	CL	CL	800	800	900	65	112	187	0.80	0.86	12.5	150	0.20	0.62
280+00	288+00	800.00	817.13	7.5	9.5	CH-CL	CH-CL	800	800	800	65	110	185	0.80	0.94	12.0	150	0.19	0.66
288+00	292+00	800.00	816.78	8	8	CH	CH	800	800	700	70	111	206	0.80	1.08	11.5	190	0.20	0.72
293+00	294+93	800.00	816.78	8	10	OL	ML	600	600	450	65	111	186	0.80	0.95	11.5	150	0.21	0.65

MRLS L-455 & R 471-460
FEASIBILITY STUDY

MRLS R 471-460

LOCATION/VICINITY

SHEET REFERENCE NO. 1

STA. 93+09
BEGIN RW
BORROW

STA. 215+00
END RW
BORROW

STA. 471+20
BEGIN RW
BORROW

STA. 93+09
BEGIN RAISE

STA. 639+84
END RAISE

STA. 610+00
END RW
BORROW

℄ OF LEVEE
UNIT NO. R471-460

STA. -(2+25) UPSTREAM
LIMIT OF LEVEE

STA. 728+00± DOWNSTREAM
LIMIT OF LEVEE

PETERS CREEK CHANNEL IMPROVEMENT

LANDSIDE DRAINAGE
DITCH STA. 172+00 ±
TO STA. 191+30 ±

RIVERSIDE DRAINAGE
DITCH STA. 4+00 ±
TO STA. 41+50 ±

LANDSIDE DRAINAGE
DITCH STA. 558+50
TO STA. 593+20 ±

LANDSIDE DRAINAGE
DITCH STA. 610+00
TO STA. 633+30 ±

LANDSIDE DRAINAGE
DITCH STA. 632+00
TO STA. 682+50

LANDSIDE DRAINAGE
DITCH STA. 701+00
TO STA. 704+80

16" O.D. STEEL PIPE LINE
BY WILLIAMS BROS. PIPE-
LINE CO.

RELIEF WELL
AREA
(SEE SHEET NO. 13)

WATHENA WASTE
STABILIZATION PONDS

WATHENA WATER WORKS

UNDER
CONTRUCTION

MRLS UNIT
NO. L-455

ST. JOSEPH

SOUTH
ST. JOSEPH

ST. JOSEPH GAGE

ELWOOD

WATHENA

ROSECRANS
MEMORIAL AIRPORT

GLADDEN

FRENCH

BOTTOMS

MISSOURI

KANSAS

DONIPHAN CO.

BUCHANAN CO.

LAKE CONTRARY

OLD MISSOURI RIVER

BROWNING

Peters Cr.

SHEET NO. 6

SHEET NO. 7

SHEET NO. 8

SHEET NO. 9

SHEET NO. 10

SHEET NO. 11

FB-1

FB-2

FB-3

FB-4

FB-5

FB-6

FB-7

FB-8

FB-9

154,000N

148,000N

142,000N

136,000N

130,000N

124,000N

118,000N

12,000E

6,000E

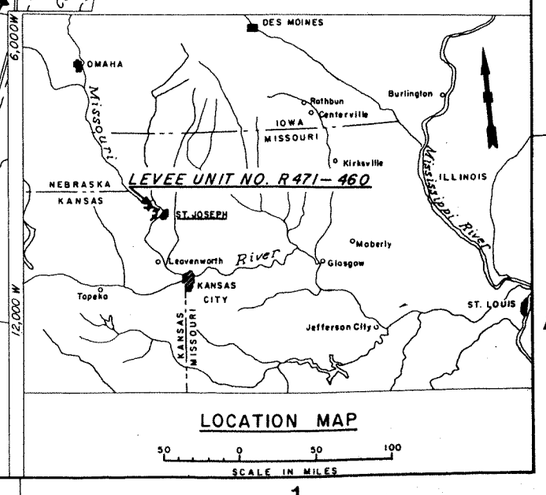
ZERO

12,000W

18,000W

VICINITY

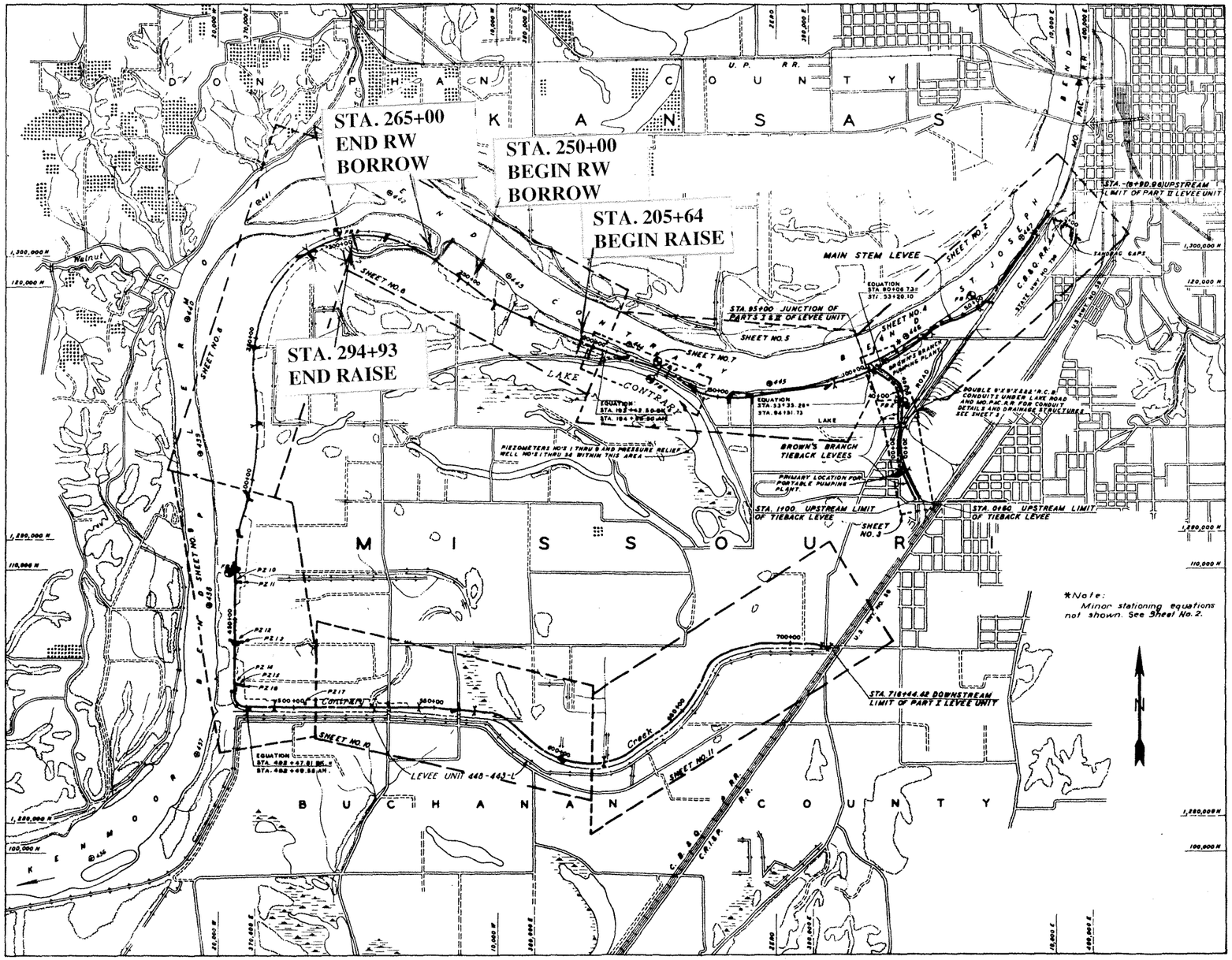
1500 0 1500 3000 4500
SCALE IN FEET



LOCATION MAP

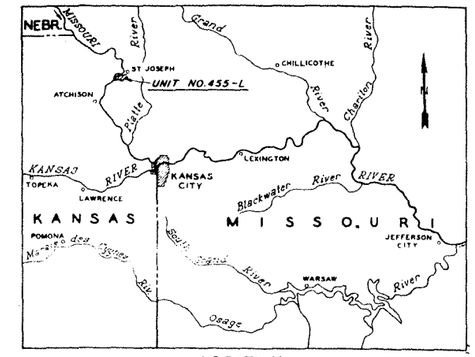
50 0 50 100
SCALE IN MILES

~~INCLOSURE 2~~ ~~SHEET NO. 1~~



VICINITY

1600 0 1600 3200 4800
SCALE IN FEET



LOCATION

20 0 20 40
SCALE IN MILES

GENERAL NOTES

Planimetry from Corps of Engineers Aerial Survey of 1952.

Topography of plan sheets from U.S.C. of E. plane-table surveys of 1954, 1955 and 1958.

Elevations referred to mean sea level are based on the U.S.C. & G.S. 1929 general adjustment.

Alinements based on plane co-ordinate system with Missouri River Commission triangulation station "WESTON" as origin.

Weston grid system

Mercator (Missouri, west zone) grid system

Missouri River Mile based on 1960 Adjustment.

LEGEND

Levee Unit No. L 455
Other levees
New or improved channel
Drainage structure
Ramp
Riprap slope protection
Freeboard gage
Forecasting gage
Pumping plant
Piezometer
Pressure relief wells
Miles above mouth of Missouri River — 456
Underseepage control berm

MRLS L-455 & R 471-460
FEASIBILITY STUDY

MRLS L 455

LOCATION/VICINITY

SHEET REFERENCE NO. 2

NOTES:

1. SEE SHEET NO. 4 FOR TYPICAL LEVEE SECTIONS.
2. RAISE 1-FOOT OR LESS WILL HAVE 1 VERTICAL ON 2 HORIZONTAL LEVEE FILL SLOPE UNTIL IT INTERCEPTS EXISTING SLOPE.
3. WHERE THERE IS A GAP IN LEVEE STATIONS, PROVIDE A SMOOTH TRANSITION BETWEEN LEVEE SECTIONS. SMOOTH TRANSITION BETWEEN LEVEE SECTINS WITHOUT STATION GAP.
4. BERM SLOPES ARE APPROXIMATE.

LEVEE SECTION SCHEDULE

LEVEE STATION LIMITS FROM	LEVEE STATION LIMITS TO	LEVEE SECTION A OR B	LEVEE RAISE (FT)	LANDWARD LEVEE SLOPE (1 V ON "x" H)	PROPOSED LANDSIDE BERM SPRINGLINE y (FT)	PROPOSED LANDSIDE BERM WIDTH w (FT)	PROPOSED LANDSIDE BERM SLOPE (1 V ON "s" H)
MRLS R 471-460							
93+09	99+00	A	0.33	N/A			
100+00	114+00	A	0.94	N/A			
115+00	132+00	B	1.14	3.0	8.0	150.0	50.0
132+00	150+00	B	1.71	3.0	9.0	150.0	50.0
151+00	156+00	B	1.71	3.0	7.5	170.0	55.0
156+00	161+50	B	1.39	3.0	7.0	150.0	50.0
162+00	165+00	B	2.00	3.0	8.0	170.0	55.0
166+00	228+00	B	2.66	3.0	10.5	290.0	100.0
229+00	251+00	B	2.36	3.0	15.5	150.0	50.0
252+00	281+00	B	2.47	3.0			
282+00	295+50	B	2.52	3.0	14.0	370.0	125.0
296+50	299+00	B	2.49	3.0	12.5	330.0	110.0
300+00	307+00	B	2.67	4.0			
308+00	313+00	B	1.50	4.0			
314+00	331+00	B	1.87	4.0			
332+00	341+00	B	2.60	3.0			
342+00	351+00	B	2.66	3.0	15.0	270.0	90.0
352+00	375+00	B	2.66	3.0	15.0	310.0	100.0
376+00	394+00	B	3.11	3.0	14.5	330.0	110.0
395+00	397+00	B	3.11	3.0	14.5	350.0	115.0
398+00	404+00	B	3.37	3.0	13.5	310.0	100.0
405+00	419+00	B	3.12	3.0	10.0	170.0	55.0
420+00	439+00	B	2.73	3.0	11.5	150.0	50.0

LEVEE STATION LIMITS FROM	LEVEE STATION LIMITS TO	LEVEE SECTION A OR B	LEVEE RAISE (FT)	LANDWARD LEVEE SLOPE (1 V ON "x" H)	PROPOSED LANDSIDE BERM SPRINGLINE y (FT)	PROPOSED LANDSIDE BERM WIDTH w (FT)	PROPOSED LANDSIDE BERM SLOPE (1 V ON "s" H)
MRLS R 471-460 (CON'T)							
440+00	466+00	B	2.43	3.0	11.5	190.0	60.0
467+00	492+00	B	2.56	3.0	10.0	150.0	50.0
493+00	506+50	B	2.00	3.0	12.0	290.0	95.0
506+50	516+00	B	1.75	3.0	11.5	270.0	90.0
517+00	544+00	B	1.95	3.0	14.0	370.0	120.0
545+00	550+50	B	1.88	3.0	12.5	390.0	130.0
550+50	564+00	B	1.15	3.0	12.0	370.0	120.0
564+00	600+00	B	1.02	3.0	11.0	350.0	115.0
601+00	622+00	A	0.78	N/A	10.0	150.0	50.0
623+00	628+00	A	0.56	N/A	10.5	150.0	50.0
629+00	639+84	A	0.49	N/A	11.0	150.0	50.0
MRLS L-455							
205+64	209+00	A	0.02	N/A	11.5	250.0	80.0
210+00	237+00	A	0.73	N/A	11.5	150.0	50.0
238+00	247+00	A	0.94	N/A	13.0	330.0	110.0
248+00	257+00	A	0.94	N/A	13.0	490.0	160.0
258+00	262+00	A	0.94	N/A	13.0	310.0	100.0
263+00	280+00	A	0.82	N/A	12.5	150.0	50.0
280+00	288+00	A	0.39	N/A	12.0	150.0	50.0
288+00	292+00	A	0.01	N/A	11.5	190.0	60.0
293+00	294+93	A	0.01	N/A	11.5	150.0	50.0

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DATE: 15-Feb-20 07:14

US Army Corps of Engineers
Kansas City District

Symbol	Description	Date	Appr.

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Drawn by:
Checked by:
Submitted by:
Date: X
File no.
Plot scale: 100 : 1
CADD File Name: XSECT03.DGN

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

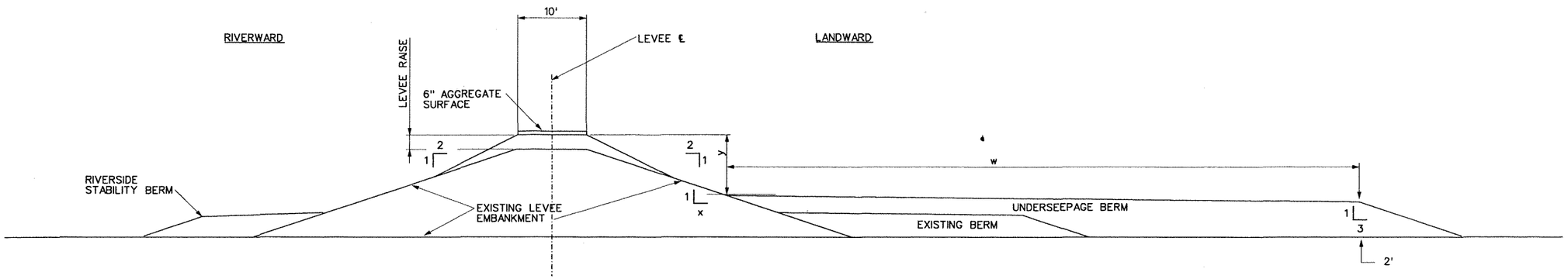
MRLS L-455 AND R 471-460
FEASIBILITY STUDY

LEVEE SECTION SCHEDULE

Sheet reference number:
3

NOTES:

1. TOP OF LEVEE REFERENCES ARE TO BELOW AGGREGATE SURFACE.
2. RIVERSIDE STABILITY BERM ONLY WHERE DESIGN REQUIRES.
3. SECTION A FOR RAISES 1' OR LESS. SECTION B FOR RAISES GREATER THAN 1'.
4. SEE SHEET NO. 3, "LEVEE SECTION SCHEDULE" FOR LANDWARD LEVEE SLOPE AND LANDWARD BERM DIMENSIONS.



A SECTION
X X
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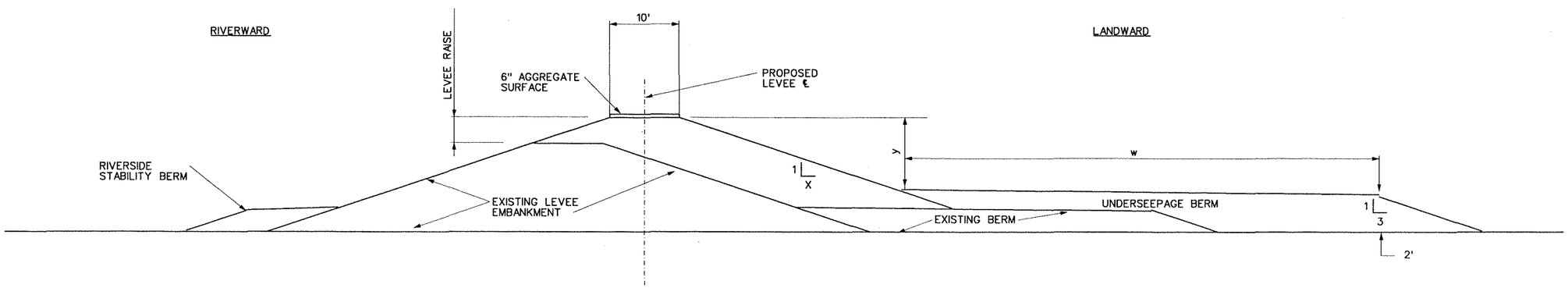

B SECTION
X X
SCALE: NOT TO SCALE

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DATE: 15-Feb-20 07-15

US Army Corps of Engineers
Kansas City District

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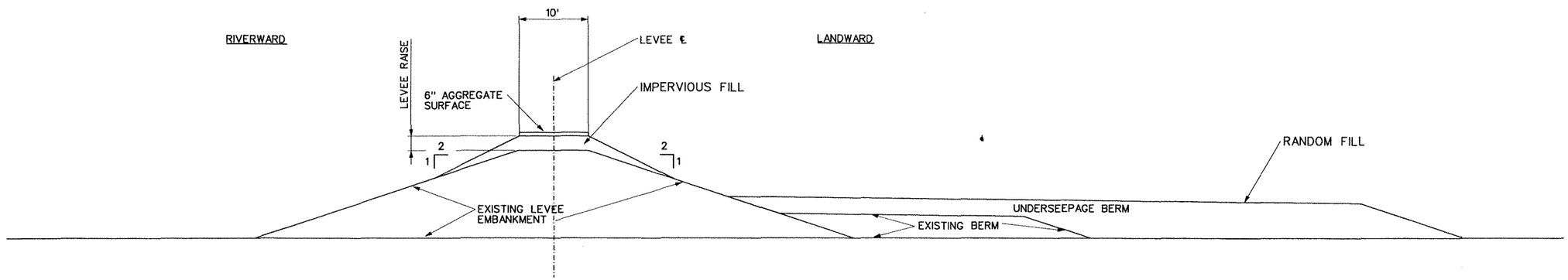
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

MRLS L-455 AND R 471-460
FEASIBILITY STUDY

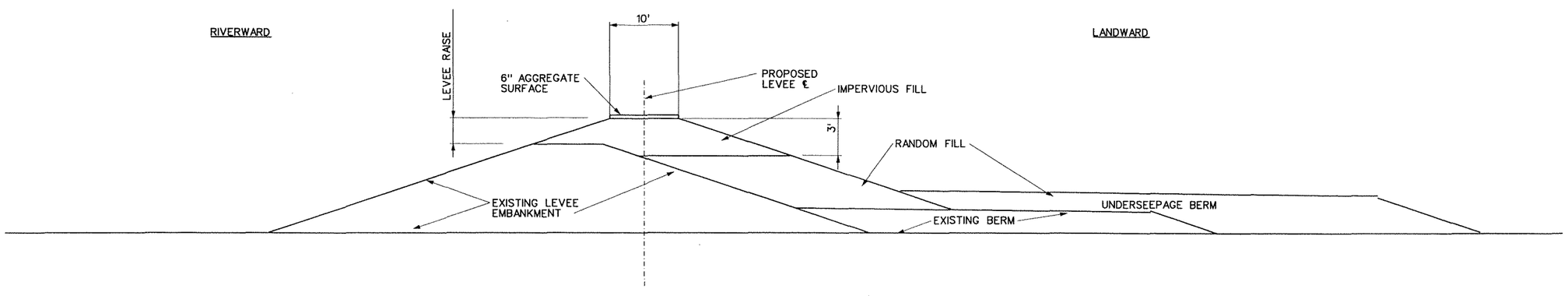
TYPICAL LEVEE SECTIONS

Sheet reference number:
4



LEVEE RAISE UP TO 1-FOOT

SCALE: NOT TO SCALE



LEVEE RAISE GREATER THAN 1-FOOT AND LESS THAN 3-FEET

SCALE: NOT TO SCALE

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DATE: 15-Feb-20 07:16

US Army Corps of Engineers
Kansas City District

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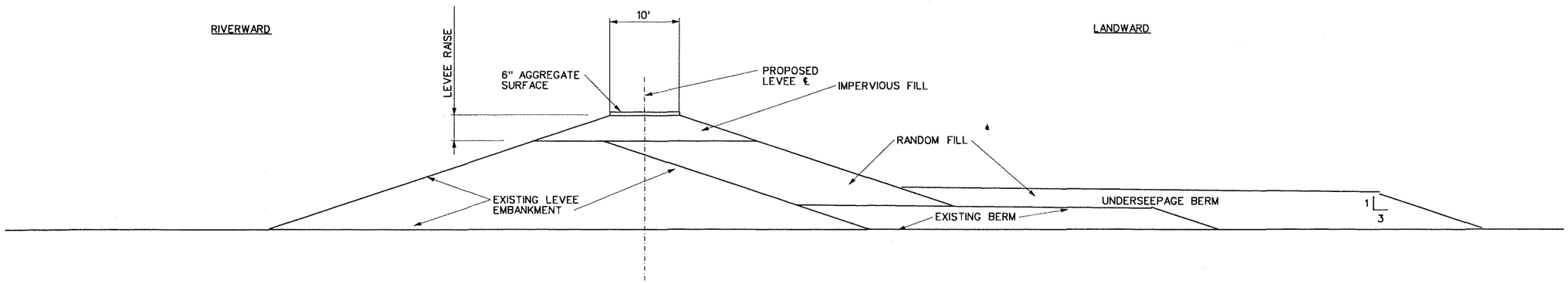
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

MRLS L-455 AND R 471-460
FEASIBILITY STUDY

TYPICAL LEVEE SECTIONS
FILL ZONES
LEVEE RAISE LESS THAN 3 FEET

Sheet reference number:
5



LEVEE RAISE 3'-FEET OR GREATER

SCALE: NOT TO SCALE

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DATE: 15-Feb-20 07:16

US Army Corps of Engineers
Kansas City District

Symbol	Description	Date	Appr.

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Drawn by:
Checked by:
Submitted by:

Date: X
File no.
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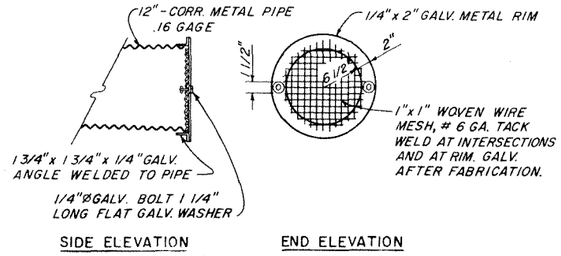
CADD File Name: XSECT06.DGN

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

MRLS L-455 AND R 471-460
FEASIBILITY STUDY

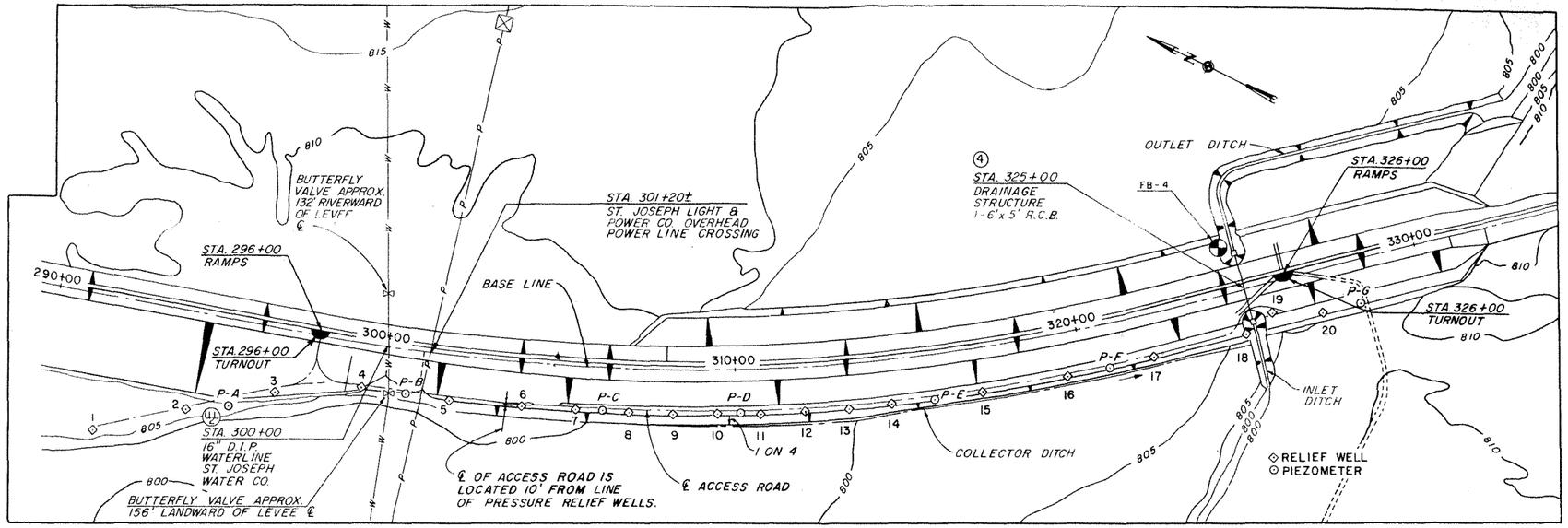
TYPICAL LEVEE SECTION
FILL ZONES
LEVEE RAISE 3-FEET OR GREATER

Sheet reference number:
6



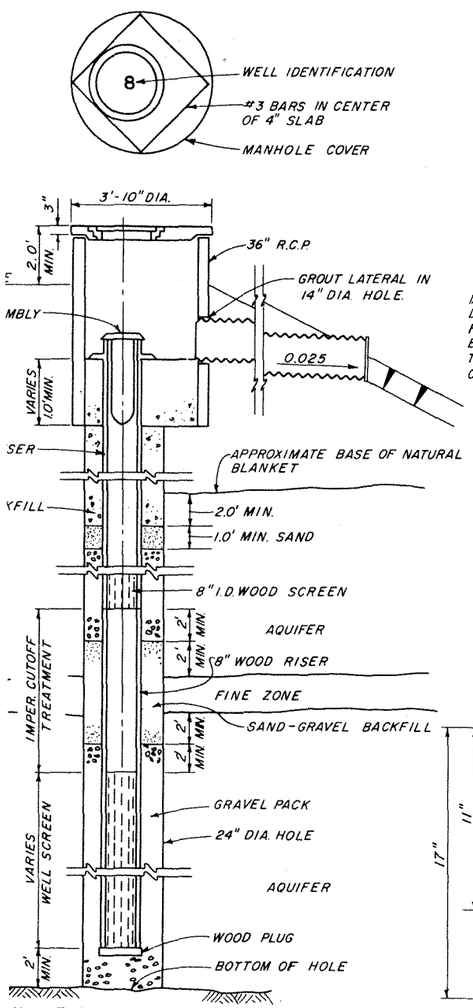
LATERAL GUARD SCREEN

NOT TO SCALE



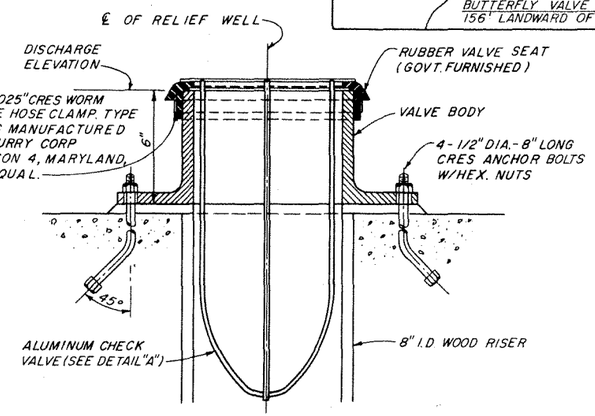
PLANS-PIEZOMETERS & RELIEF WELLS

200 0 200 400
SCALE IN FEET



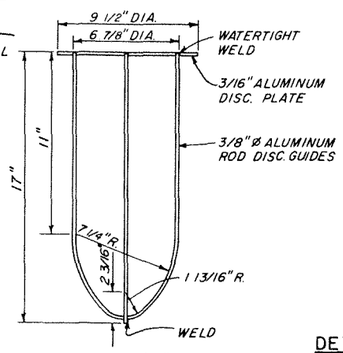
IL OF GRAVEL PACKED WELL AND WELL MANHOLE

NOT TO SCALE



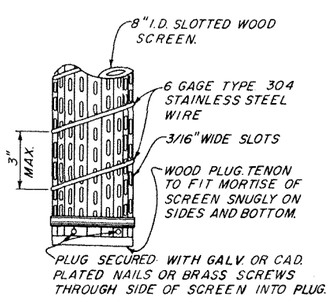
DISCHARGE ASSEMBLY DETAIL

NOT TO SCALE



DETAIL "A"

NOT TO SCALE



DETAIL OF WOOD SCREEN WITH BOTTOM PLUG

NOT TO SCALE

RELIEF WELL SCHEDULE

NO.	LOCATION STATION	LOCATION RANGE	DISCH. ELEV.	BOT. ELEV. HOLE	BOT. ELEV. WELL	SCREEN ELEVATIONS UPPER SEC. TOP	SCREEN ELEVATIONS UPPER SEC. BOT.	SCREEN ELEVATIONS LOWER SEC. TOP	SCREEN ELEVATIONS LOWER SEC. BOT.	TOTALS (EST.) QUANTITY IN LINEAR FEET SCREEN	RISER	SAND-GRAVEL	GRAVEL PACK	CONC.	M.H.	LATERALS
1	292+00	385 R.	803	715.5	717.5	769.5	717.5			52	33	1	72.5	13.5	11	17.5
2	294+50	280 R.	803	713.0	716.0	770.0	754.0	744.0	716.0	44	42.5	7	65	13.5	11	17.5
3	297+00	190 R.	803	713.0	716.0	760.0	716.0			44	42.5	1	76	13.5	11	17.5
4	299+50	130 R.	804	714.0	716.0	768.0	764.5	752.0	716.0	40	47.5	9	67	13.5	11	13.0
5	302+00	130 R.	804	714.0	718.0	758.0	718.0			40	45.5	1	75	13.5	9	13.0
6	304+00	130 R.	804	714.0	716.0	772.0	760.0	748.0	716.0	44	41.5	9	67	13.5	9	13.0
7	305+50	130 R.	803	714.0	719.0	767.0	763.0	747.0	719.0	32	51.5	13	63	12.5	9	17.5
8	307+00	130 R.	802	714.0	718.0	774.0	762.0	746.0	718.0	40	43.5	13	61	12.5	11	21.5
9	308+25	130 R.	802	714.0	718.0	778.0	762.0	742.0	718.0	40	43.5	17	57.0	12.5	11	21.5
*10	309+50	130 R.	802	716.0	718.0	782.0	778.0	746.0	718.0	40	43.5	18.5	53.5	12.5	11	21.5
11	310+75	130 R.	802	715.0	720.0	784.0	780.0	752.0	720.0	36	45.5	24.5	50.5	12.5	11	21.5
12	312+00	130 R.	802	716.0	720.0	776.0	768.0	744.0	720.0	32	49.5	21.5	52.5	12.5	11	21.5
*13	313+25	130 R.	802	716.0	720.0	780.0	776.0	744.0	720.0	32	49.5	20.5	47.5	12.5	11	21.5
14	314+50	130 R.	804	718.0	721.0	781.0	777.0	745.0	721.0	28	54.5	29	44.0	12.5	9	13.0
15	317+00	130 R.	805	721.0	725.0	777.0	761.0	749.0	725.0	40	39.5	10.5	60.5	12.5	8	8.5
16	319+50	130 R.	805	721.4	724.0	780.0	764.0	752.0	724.0	44	36.5	10	60.6	12.5	8	8.5
17	322+00	130 R.	805	727.0	729.0	777.0	761.0	745.0	729.0	32	43.5	14	51.0	12.5	8	8.5
18	324+71	130 R.	802	728.0	731.5	775.5	763.5	755.5	731.5	36	34.0	6	55.0	12.5	11	13.5
19	325+29	90 R.	802	727.0	731.0	779.0	771.0	747.0	731.0	24	46.5	21	42.0	12.5	11	20.0
20	327+00	130 R.	805	729.0	730.5	766.5	758.5	746.5	730.5	24	50.0	91.5	52.0	13.5	9	8.5

* WELL NO. 10 HAS MIDDLE SECTION OF SCREEN EL. 762.0 TO EL. 754.0
WELL NO. 13 HAS MIDDLE SECTION OF SCREEN EL. 764.0 TO EL. 760.0

NOTES:

1. Details show existing pressure relief wells. Existing pressure relief wells to be abandoned in-place.

2. Replacement pressure relief wells located the same distance out from the levee but offset 5-feet from the existing pressure relief well.

3. Replacement pressure relief wells will be 8-inch diameter stainless steel assemblies. Outfall will be similar to the existing details.

MRLS L-455 & R 471-460
FEASIBILITY STUDY

MRLS R 471-460

PRESSURE RELIEF WELLS

SHEET REFERENCE NO. 7

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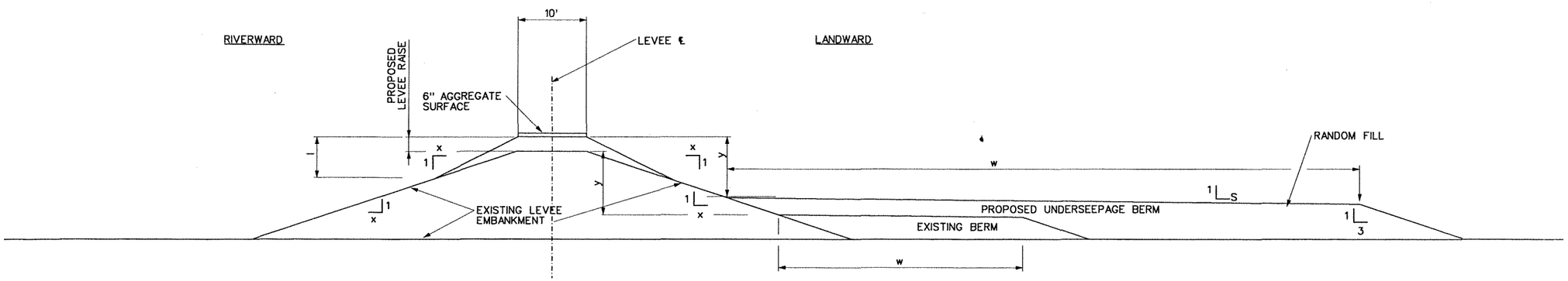

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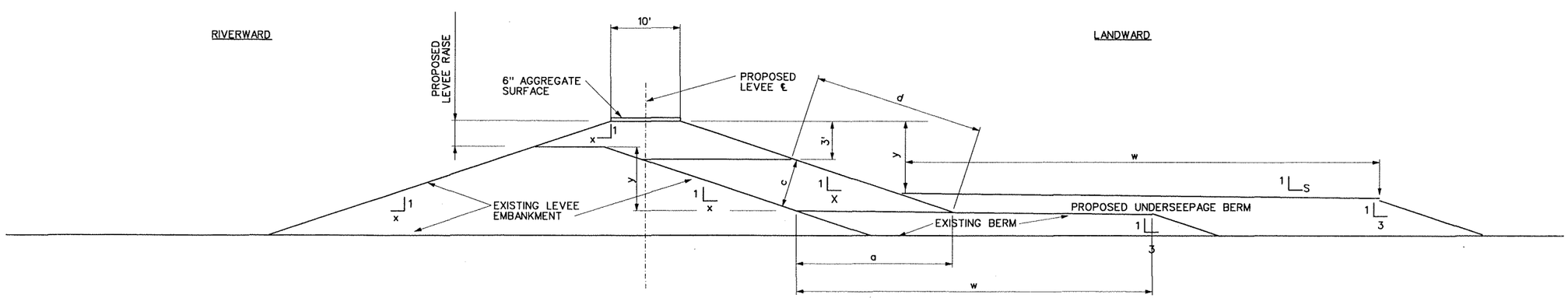

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MRLS L-455 AND R 471-460
FEASIBILITY STUDY

TYPICAL LEVEE SECTIONS
QUANTITY COMPUTATIONS
LEVEE RAISE LESS THAN 3 FEET

Sheet reference number:
8

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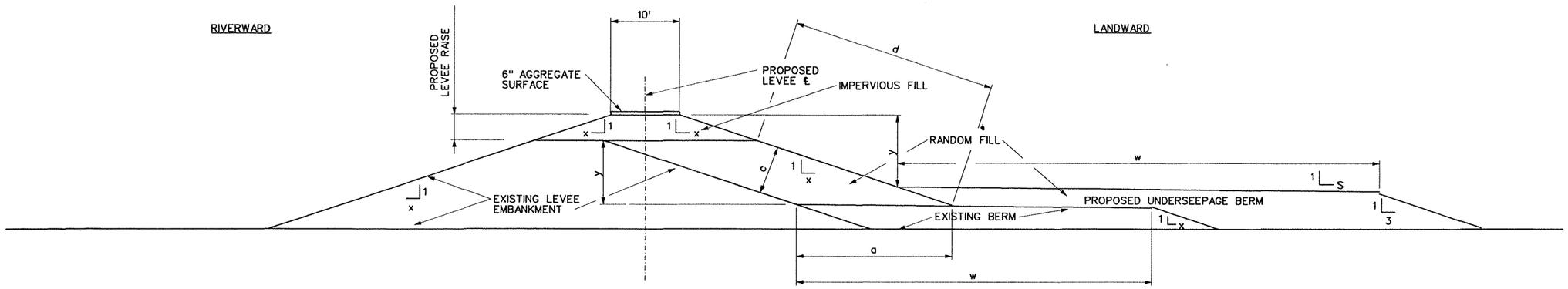
3. LEVEE HEIGHT ADJUSTED WITHIN THE QUANTITY COMPUTATION SPREADSHEET REFERS TO TOP OF EXISTING BERM TO TOP OF PROPOSED LEVEE.



LEVEE RAISE 3'-FEET OR GREATER

SCALE: NOT TO SCALE

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MRLS L-455 AND R-471-460
FEASIBILITY STUDY

TYPICAL LEVEE SECTION
QUANTITY COMPUTATIONS
LEVEE RAISE 3-FEET OR GREATER

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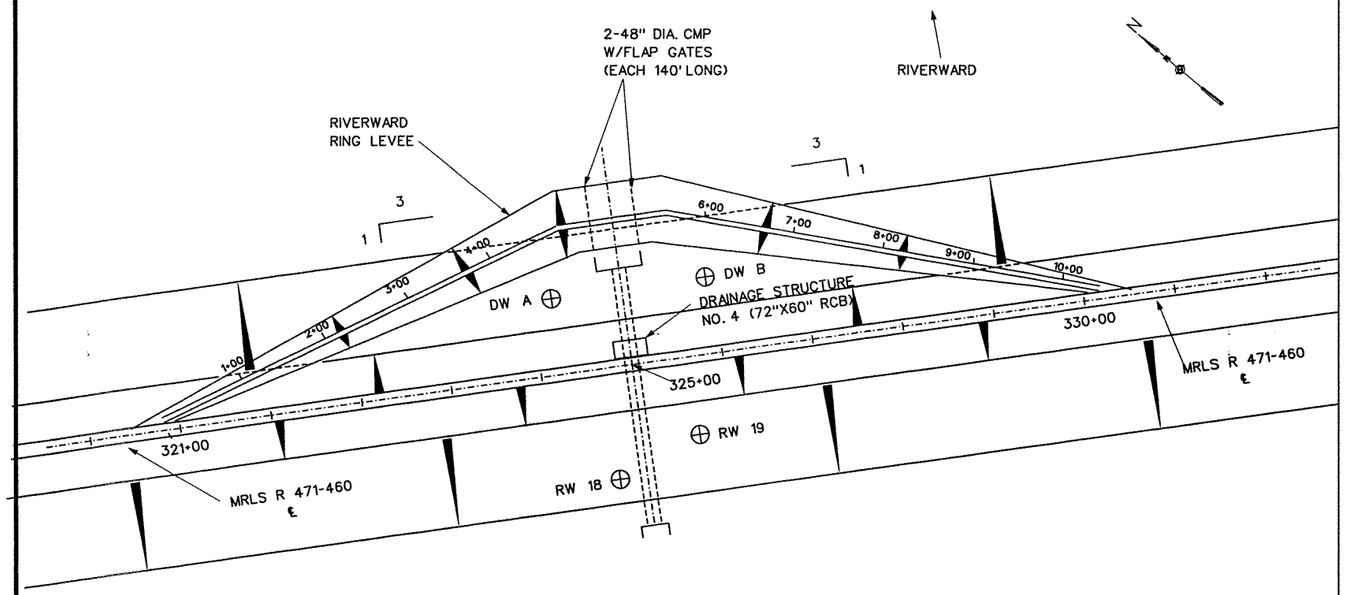
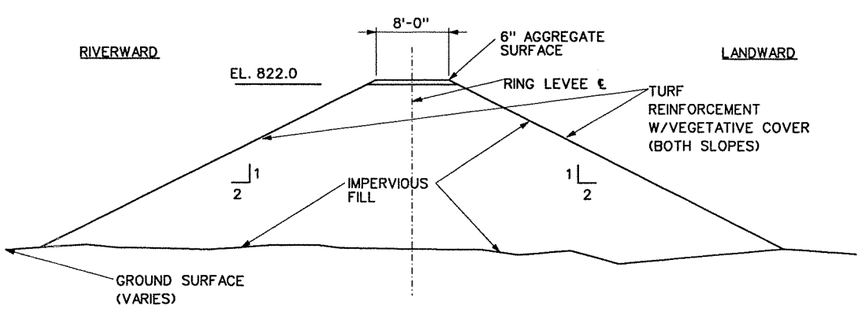


MRLS R 471-460--DRAINAGE STRUCTURE NO. 4
PLAN VIEW-- TEMPORARY FLOOD PROTECTION

SCALE: NOT TO SCALE

NOTES:

1. DRAWINGS REPRESENT THE 100-YR.+ 3-FT.
2. PRESSURE RELIEF WELLS, DEWATERING WELLS (DW), AND RIVERWARD RING LEVEE IN-PLACE AND OPERATIONAL PRIOR TO EXCAVATING MRLS R 471-460 LEVEE EMBANKMENT.
3. PRESSURE RELIEF WELLS (RW) 18 & 19 REPLACED AND USED AS DEWARTERING WELLS DURING CONSTRUCTION.
4. DW A & B SHALL BE REMOVED POST CONSTRUCTION.
5. RIVERWARD RING LEVEE SHALL BE REMOVED ONCE MRLS R 471-460 IS RECONSTRUCTED.
6. TWO 48" DIAMETER CMP SHALL BE CONTINUOUS FROM RING LEVEE TO LANDWARD OF MRLS R 471-460.



B RIVERWARD RING LEVEE

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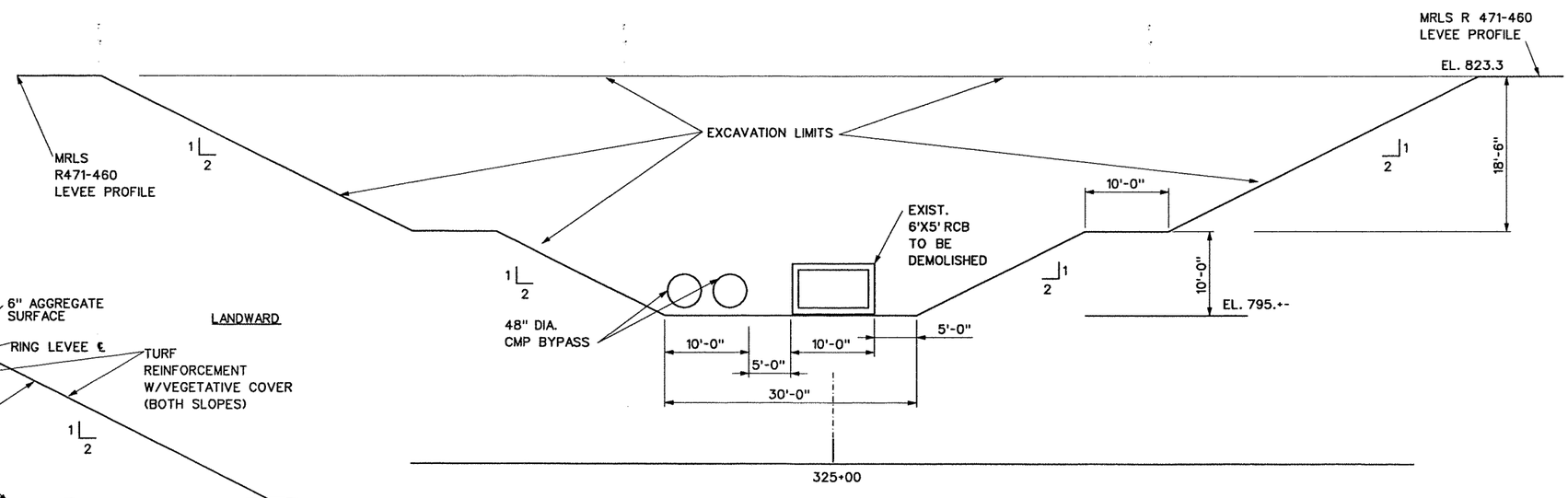

B MRLS R 471-460 - PROFILE

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MRLS L455 AND R471 - 460
FEASIBILITY STUDY
MRLS R 471-460
DRAINAGE STRUCTURE NO. 4
STA. 325+00; LEVEE REMOVAL AND
TEMP. FLOOD PROTECTION

Sheet reference number:
S-01

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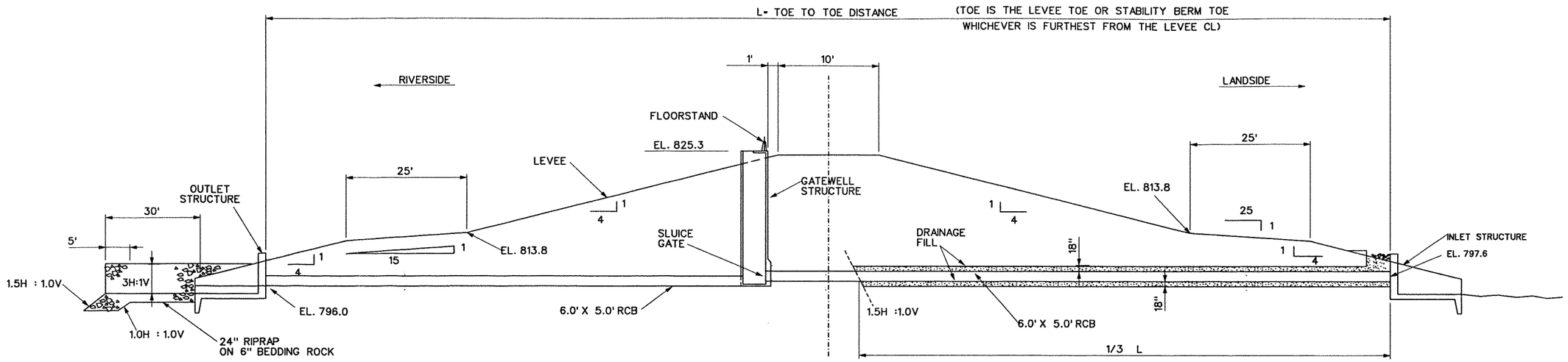

DRAINAGE STRUCTURE NO. 4 - PROFILE--STA.325+00

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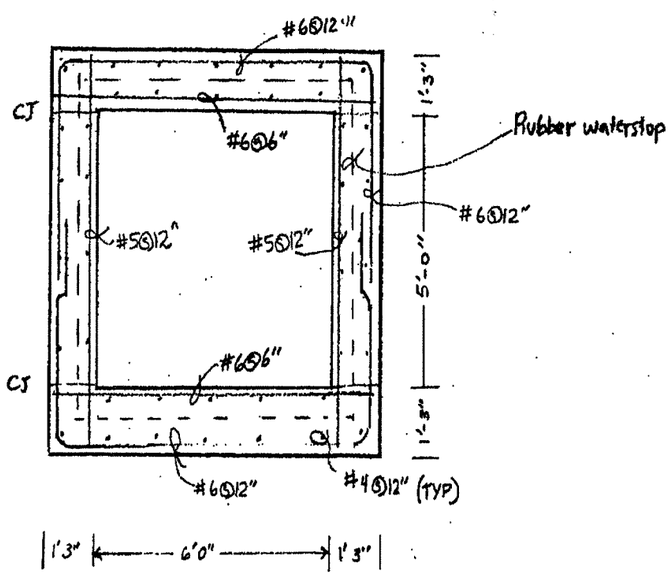

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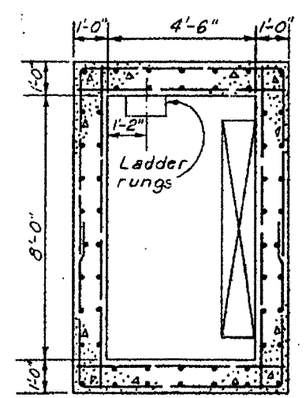

HORIZONTAL SECTION THRU GATEWELL

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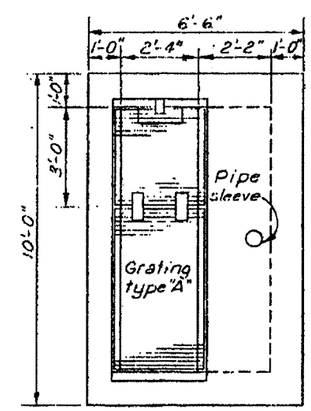

GATEWELL DECK- PLAN VIEW

SCALE: NOT TO SCALE

NOTES:

1. DRAWINGS REPRESENT THE 100-YR.+ 3-FT.
2. DETAILS INDICATED ARE SUBJECT TO DESIGN DURING PRE-CONSTRUCTION, ENGINEERING AND DESIGN (PED) FOLLOWING SITE INVESTIGATION AND STRUCTURAL TESTS. DETAILS ARE INDICATIVE OF THE INFORMATION AVAILABLE AT THE TIME OF THE STUDY.
3. SAND DRAIN IS A FINE TO MEDIUM POORLY GRADED SAND. UNIFIED SOIL CLASSIFICATION IS AN SP. THE SAND DRAIN OUTLET SHALL BE AT THE INLET HEADWALL. THE SAND OUTLET WILL BE PROTECTED WITH NON-WOVEN GEOTEXTILE FABRIC LAID OVER THE SAND SURFACE AT GRADE. EIGHTEEN INCH RIPRAP ON TOP OF 6-INCH BEDDING ROCK WILL BE PLACED ON THE GEOTEXTILE FABRIC. THE AREA WILL BE SHAPED SO DRAINAGE IS NOT INTO THE SAND DRAIN EXIT AREA.

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MRLS L455 AND R471- 460
FEASIBILITY STUDY
MRLS R 471 - 460
DRAINAGE STRUCTURE NO. 4
STA. 325+00: REPLACEMENT
STRUCTURE PROFILE AND DETAILS

Sheet reference number:
S-02

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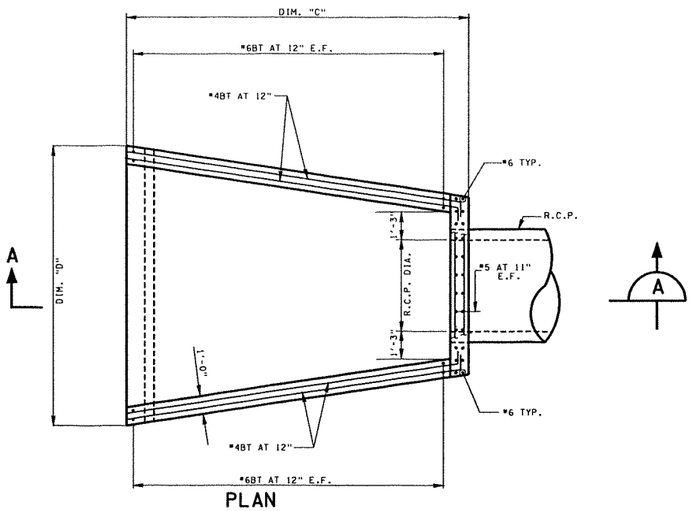

PLAN

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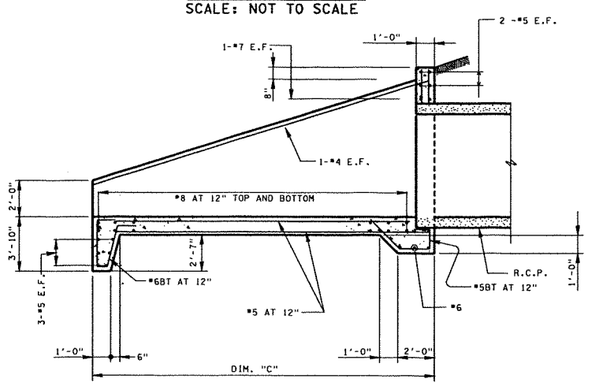
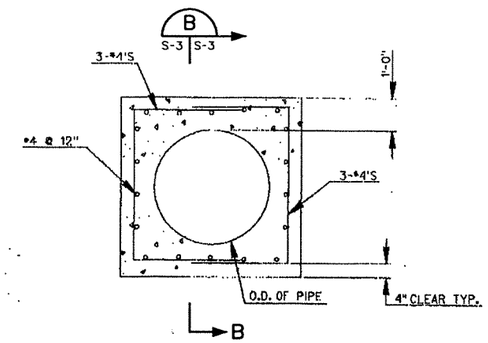


A SECTION

SCALE: NOT TO SCALE

REPLACEMENT INLET FOR PIPE EXTENSIONS



A SECTION

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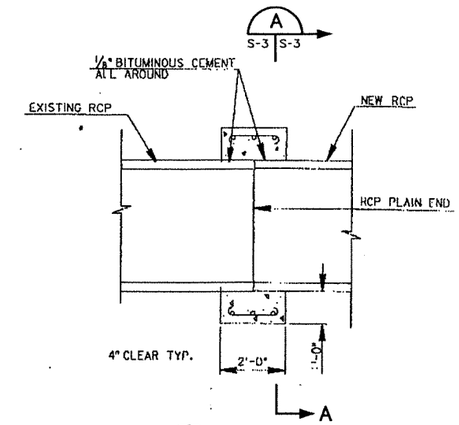

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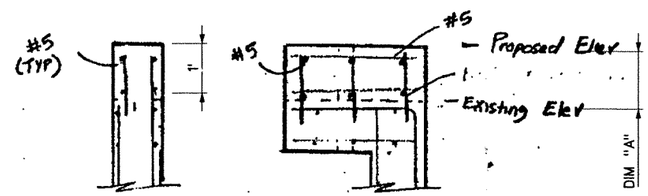
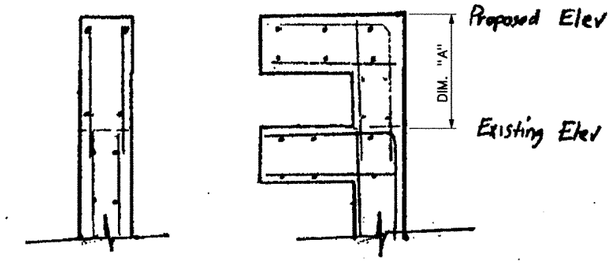
CONCRETE COLLAR DETAILS



CASE 1: RAISE EQUAL TO OR LESS THAN DECK THICKNESS



CASE 2: RAISE GREATER THAN DECK THICKNESS

TOP OF GATEWELL RAISE

SCALE: NOT TO SCALE

NOTES:

1. DRAWINGS REPRESENT THE 100-YR.+ 3-FT.
2. DETAILS INDICATED ARE SUBJECT TO DESIGN DURING PRE-CONSTRUCTION, ENGINEERING, AND DESIGN (PED) FOLLOWING SITE INVESTIGATION AND STRUCTURAL TESTS. DETAILS ARE INDICATIVE OF THE INFORMATION AVAILABLE AT THE TIME OF THE STUDY.
3. REFER TO THE TABLE FOR DRAINAGE STRUCTURES SUBJECT TO AN INLET EXTENSION OR A GATEWELL TOP RAISE. INLETS SUBJECT TO AN EXTENSION ARE TO HAVE THE EXISTING INLET DEMOLISHED AND REMOVED FROM THE SITE. PIPE EXTENSION INSIDE DIAMETER SHALL BE EQUAL TO THE EXISTING PIPE INSIDE DIAMETER. THE SLOPE OF THE PIPE EXTENSION SHALL BE EQUAL TO THE EXISTING PIPE SLOPE.

MRLS R 471-460 DRAINAGE STRUCTURES
GATEWELL TOP RAISES AND INLET EXTENSIONS

DRAINAGE STRUCTURE (DS)	LEVEE STATION	PIPE DIAMETER (INCHES)	TOP OF GATEWELL RAISE DIM. A (FEET)	INLET PIPE EXTENSION (FEET)	INLET STRUCTURE DIM. C (FT-INCHES)	INLET STRUCTURE DIM. D (FT-INCHES)
DS NO. 2	115+60	48	1.00	8	14'-0"	15'-11"
DS NO. 3	186+00	48	2.00	16	14'-0"	15'-11"
DS NO. 5	398+00	36	2.25	24	11'-0"	12'-11"
DS NO. 7	420+35	24	2.33	16	8'-5"	10'-6"
DS NO. 8	497+60	66	1.33	16	17'-6"	18'-6"
DS NO. 9	558+50	48	1.00	8	14'-0"	15'-11"
DS NO. 10	610+00	54	0.00	0	N/A	N/A

US Army Corps of Engineers
Kansas City District

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KANSAS CITY, MISSOURI

MRLS L455 AND R471 - 460
FEASIBILITY STUDY

MRLS R471 - 460
DRAINAGE STRUCTURE DETAILS
GATEWELL AND PIPE EXTENSIONS

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MISSOURI RIVER LEVEE SYSTEM
UNITS R471-460 AND L455
ST. JOSEPH, MISSOURI / ELWOOD, KANSAS

FEASIBILITY REPORT
AND
ENVIRONMENTAL ASSESSMENT

APPENDIX C

Socioeconomics Analysis

September 2006

MISSOURI RIVER LEVEE SYSTEM
UNITS L-455 AND R471-460
ST. JOSEPH, MISSOURI / ELWOOD, KANSAS

FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX C
SOCIOECONOMICS ANALYSIS

September 2006

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MISSOURI RIVER LEVEE SYSTEM
UNITS L-455 AND R471-460
ST. JOSEPH, MISSOURI / ELWOOD, KANSAS

FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX C
SOCIOECONOMICS ANALYSIS

September 2006

1.0 INTRODUCTION

1.1 SCOPE OF ANALYSIS

This feasibility-level economic analysis will provide an accounting of all properties protected by the L-455 and R471-460 levee units: This inventory will serve as the database for a risk-based analysis that will produce several outputs:

- Description and quantification of economic flood damage impacts in the existing condition to properties within the study area;
- Statistical estimates of the projects' existing condition engineering performance (reliability) in the context of a range of possible flood events;
- 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;
- Identification of the most economically efficient alternative;
- Characterization of the selected plan in terms of economic performance (annual benefits and costs, residual damages) and engineering performance.

1.2 GUIDANCE

The economic analysis is accomplished under standard Corps of Engineers guidance for economic analysis and other Federal guidance for water resources projects, including:

- 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 with subsequent revisions;

- Engineer Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, dated 1 August 1996;

- ER 1105-2-101, Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies, dated 13 January 2006;

- Engineering Technical Letter (ETL) 1110-2-556, Engineering and Design, Risk-Based Analysis in Geotechnical Engineering For Support of Planning Studies, dated 28 May 1999.

2.0 PROJECT AND STUDY AREA DESCRIPTION

2.1 FEDERAL PROJECT

Both the L-455 and R471-460 levee units were authorized as part of the comprehensive Missouri River Levee System in the 1944 Flood Control Act. Construction of both units began in 1962 and was completed in 1967-68.

2.1.1 L-455

The L-455 levee is located in Buchanan County, Missouri, along the left bank of the Missouri River. The levee extends approximately 15.6 miles from the mouth of Contrary Creek at Missouri River mile 437.4 to the mouth of Whitehead Creek at mile 447.3, about three-quarters of a mile south of downtown St. Joseph.

2.1.2 R471-460

The R471-460 levee is located along the right bank of the Missouri River, primarily in Doniphan County, Kansas, but also partly in Buchanan County, Missouri, a section of which is on the Kansas side of the river. The levee is across the river and slightly upstream from the L-455 unit, extending 13.8 miles from the mouth of Peters Creek at Missouri River mile 441.8 to the tieback at Treece Road at mile 456.5.

2.2 STUDY AREA DESCRIIPTION

The study area is located along the Missouri River in Buchanan County, Missouri, and Doniphan

County, Kansas. The entire study area is part of the St. Joseph MSA (Metropolitan Statistical Area). St. Joseph is about 50 miles north of Kansas City. Figure 1 displays a map of the study area.

2.2.1 L-455 Area

The area of 7,519 acres includes the southwestern portion of the city of St. Joseph (2000 pop. 73,990) as well as an unincorporated area. Within the protected area are several distinct areas.

- Stockyards – The Stockyards district is the old central industrial district of St. Joseph. It is home to a number of very large companies and public facilities and contains the lion's share of investment in the L-455 area. As an old stockyards hub area, it is naturally home to an active network of railroad lines. Although the old stockyards are long gone, the traditional identity has been revived recently by the opening of a massive new pork processing plant.

- King Hill – This neighborhood begins on the east edge of the protected area and is partially on high ground beyond the floodplain. It has a significant retail and commercial area along U.S. Highway 59/Lake Avenue as well as numerous small, older homes.

- Kirschner-Purtell – This older community with its own identity is southwest of the Stockyards area at the city limits. It is mainly residential with small, older homes and a small retail component along Highway 752.

- Lake Contrary – Lake Contrary is an unincorporated rural area west of Kirschner-Purtell. The lake is lined by dozens of residences. Land uses in the areas surrounding the lake are primarily agricultural. A small residential area with a few newer and relatively high quality homes also is located near Contrary Creek at the southern edge of the protected area.

2.2.2 R471-460 Area

This levee protects a total area of 13,424 acres and includes the following areas:

- Elwood, Kansas – Elwood (2000 pop. 1,145) is primarily residential, with nearly 500 homes. Many of the homes are newer manufactured homes purchased with flood insurance reimbursement to replace homes destroyed in the devastating 1993 flood. Several retail, industrial and public facilities are located along or near U.S. Highway 36 at the south edge of town.

- Rosecrans Airport – This area, known traditionally as the French Bottoms, is located within the Browning Lake oxbow and is part of St. Joseph, Missouri, despite being on the Kansas side of the river. The area originally was on the opposite bank of the river with the rest of St. Joseph, but was cut off when the river changed course during the 1952 flood. In addition to Rosecrans Airport, the 139th Airlift Wing of the Missouri Air National Guard also is located here. These two

facilities, and especially the huge Air Guard base, dominate the overall river economic picture in the R471-460 area. This area was heavily damaged in both the 1993 and 1952 floods. A number of residences also are located to the north and east of the airport and base areas, particularly along Browning Lake.

- Wathena, Kansas (2000 pop. 1,348) – This town is at the far western edge of the protected area. It is mostly beyond the river bottoms and only the southeast corner of the town is in the floodplain. This section of the town mostly contains businesses and homes along and near Highway 36.

- Gladden Bottoms - This is a large unincorporated area north of Rosecrans Airport that is almost entirely farmed and planted in crops.

2.3 STUDY AREA ECONOMY

2.3.1 Economic Development and Land Use

Perhaps the main focus of economic development in the contemporary study area is a cluster of life science manufacturing concerns located in the St. Joseph Stockyards and extending across the river into the Elwood area. This cluster of firms ties into other such firms elsewhere in St. Joseph and in Kansas City to the south. Major life science companies in the study area include Triumph Foods, the huge new pork processing facility in St. Joseph's Stockyards, as well as AGP (soybean processing), Boehringer Ingelheim Vetmedica (veterinary drug manufacturing), Albaugh and Omnium (herbicide manufacturers), Biozyme and Friskies-Nestle Purina (animal food and supplements manufacturers), and Prime Tanning (leather manufacturing), among others.

Other major companies and facilities located in the L-455 area include Silgan and Cryovac (food container and packaging manufacturers), Johnson Controls (battery manufacturing), and VP Buildings (steel building frame manufacturers). Major utilities include the St. Joseph Water Pollution Control facility and Aquila (electric power utility), both located in the St. Joseph Stockyards.

In the R471-460 area, Rosecrans Airport and the Missouri Air Guard base are key economic components. Major companies in the right bank area include Affiliated Foods (grocery wholesaler), BMS Management (warehousing and storage), Porters Building Center (home supply retail), Snorkel (boom manufacturing), Herzog Construction, and Sellyer Industries (truck chassis and components manufacturing).

Agriculture is a major land use in the study area. Farmed crop acreage accounts for about 5,100 of 7,219 total acres in the L-455 area (71% of the total) and about 7,200 of 13,424 total acres in the R471-460 area (54%). Agricultural land uses are found primarily in the western portion of L-455 and the northern portion of R471-460.

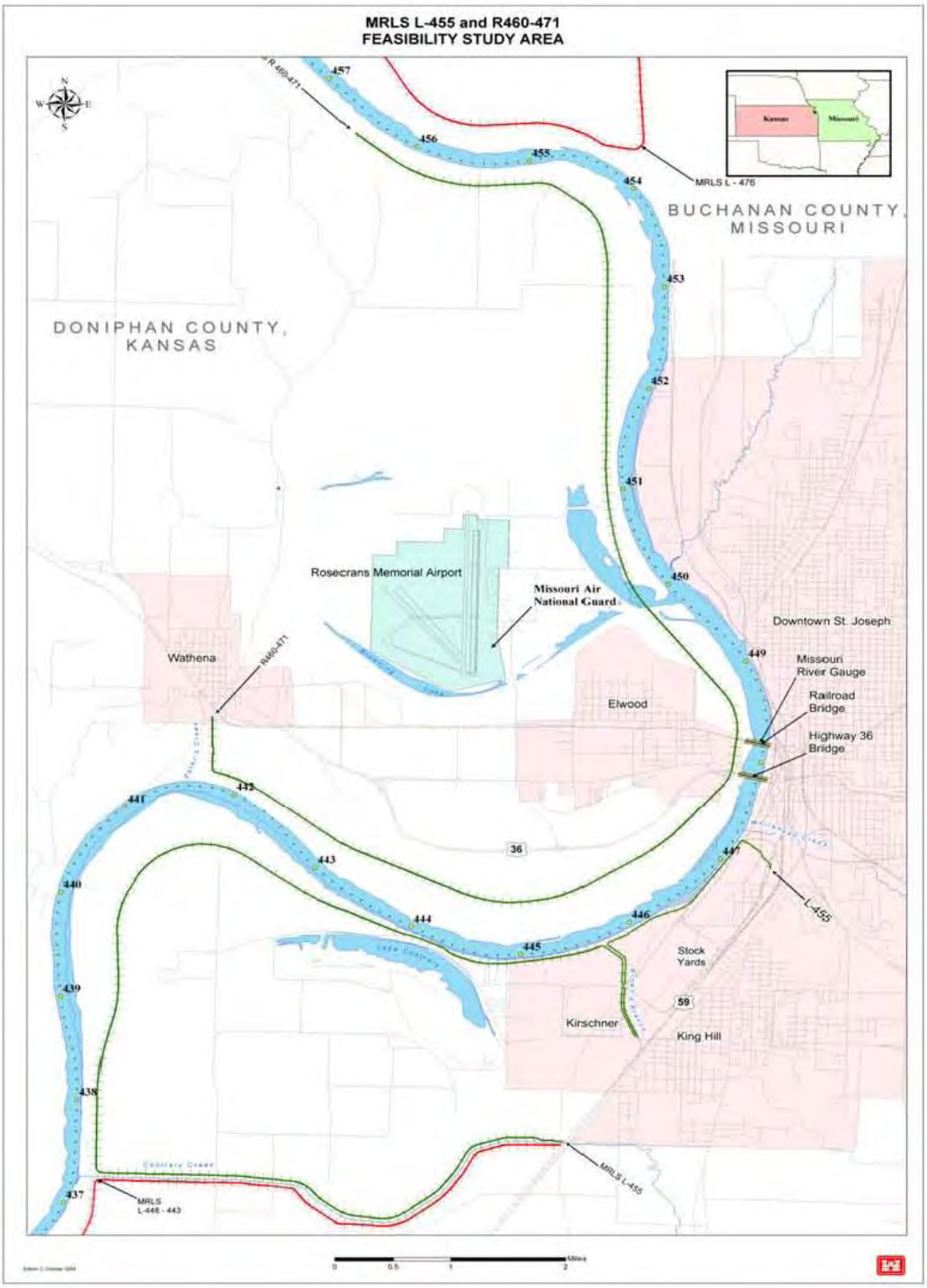

FIGURE 1
L-455 & R471-460 STUDY AREA

2.3.2 Access

Primary north-south road access in the study area is provided by Interstate Highway 229. I-229 links to I-29, providing a fast connection with Kansas City International Airport as well as with Omaha and points north and south from Canada to Mexico. State Highway 759, also known as the Stockyards Expressway; and U.S. Highway 59, also known as Lake Avenue, provide north-south routes in the L-455 area. These routes also serve the R471-460 area, which contains no major north-south routes. East-west access through the study area is provided by U.S. Highway 36, connecting St. Joseph, Elwood, and Wathena with other towns to the east and west. Highway 36 runs through the R471-460 area and is accessed by L-455 area commuters about a half-mile north of the upstream end of the levee.

Air transportation needs are served locally by Rosecrans Airport, located in the R471-460 area, and by Kansas City International Airport, which is located about 35 miles south of the study area. Rail service is provided in the L-455 area, primarily in the Stockyards area, by Union Pacific and Burlington Northern-Santa Fe Railroads. The Port of St. Joseph is situated at Missouri River mile 448 on the left bank, less than a mile from the upstream end of L-455, allowing easy access to river barge transportation.

2.4 FLOOD HISTORY

2.4.1 Early St. Joseph Floods

Major Missouri River flood events occurred in 1844 and 1881. Peak discharges were an estimated 350,000 cfs in 1844, the second largest in history, and 370,000 in 1881, the third largest. No damage estimates are available for these floods, but the impact presumably would have been sharply limited because development along the river was minimal at those early stages of St. Joseph history.

2.4.2 The 1952 Flood

One of the two largest flood events in modern history at St. Joseph was the flood of April 1952. The peak discharge of 397,000 cfs on April 23 was the greatest ever recorded at the St. Joseph gage, previously or subsequently. The flood crest reached an estimated stage of 26.8, nearly 10 feet above flood stage. The study area was still unprotected by Federal levees at that time, although the two study area levee units had been authorized as part of the comprehensive Missouri River Levee System in 1944. More than $2 million in damage was recorded in St. Joseph and another $450,000 in the Elwood and Wathena areas. In today's prices, the approximately $2.5 million in 1952 damages would have amounted to about $23 million. This is believed to be a very incomplete accounting of damages from the flood, however. Corps county damage estimates at the time showed almost $15 million of damage in Buchanan and Doniphan Counties ($140 million in FY 2006 prices), most of which would have been in the St. Joseph area.

In any event, damages incurred were limited by the location of the damage center at Rosecrans Airport, which at that time consisted mostly of low-quality temporary World War II-era

buildings, as well as by the successful flood fight in some districts of the city. All men in the city were drafted into an emergency flood-fighting effort. Temporary levees were constructed at Rosecrans Airport and other sites. Many portions of the city were spared flood damage due to these efforts, but the temporary levee at Rosecrans Airport failed and the airport area was inundated by 10 feet of flooding. Lake Contrary, at that time the site of a resort area with an amusement park, race track and summer homes, was also inundated to depths of 5 feet. In Wathena, backwater from the Missouri River caused Peters Creek to overflow, damaging a few blocks at the southeast corner of the town including a mobile home park. The Stockyards area was affected by sewer backflows, high water table and shallow flooding, as was the nearby Kirschner-Purtell community. About 800 residents were evacuated from Elwood, which was severely damaged.

Prior to the flood, the French Bottoms area of St. Joseph that is home to Rosecrans Airport was encompassed in a horseshoe bend of the river. But the 1952 flood scoured a new channel that bypassed the horseshoe bend, leaving Rosecrans Airport on the Kansas side of the river. (The Missouri River serves as the Missouri-Kansas state line in this region.) In the aftermath of the flood, the Corps constructed a new bypass channel parallel to the one scoured by the river, confirming the shift in geography. For this reason, the R471-460 levee protects areas in both Kansas and Missouri. The old channel was made into Browning Lake.

The main legacy of the 1952 flood was a heightened sense of urgency supporting construction of the L-455 and R471-460 units. Construction finally began in 1962 and was completed in 1967-68. Rosecrans Airport was also rebuilt and greatly modernized in the years succeeding the flood.

2.4.3 The 1993 Flood

The great Missouri and upper Mississippi River flood event of mid-1993 produced the flood of record in the study area in terms of peak stage. Although the peak discharge of 335,000 cfs was not as high as the 1952, 1881, or 1844 floods, the peak stage of 32.1 on July 26 was a new record for the St. Joseph gage. The R471-460 levee overtopped on July 26, one of the few Federal levees in the entire Midwest that failed during the 1993 flood. Most of the protected right bank area was subsequently inundated for several weeks. The nearly 1,300 residents of Elwood were evacuated in advance of flooding that reached 9 feet in the town and the adjacent Rosecrans Airport area, including the Missouri Air National Guard base. Interior overflows from Browning Lake already were threatening the same area even before the levee breach. More than 400 homes and several dozen businesses in Elwood were damaged, and about a third of the homes were ruined. The Air Guard base and Rosecrans Airport also were inundated by up to 9 feet of water. Sophisticated new avionics technology and training equipment at the Air Guard base were particularly hard hit, and a number of aircraft at the base and the airport were lost. Sherwood Medical, a medical supplies manufacturer with more than 700 local employees, was flooded to almost 4.5 feet. Damages at Sherwood reportedly topped $30 million. Snorkel, a work platforms manufacturer and large local employer, sustained severe damage from about 7 feet of flooding. Payless Cashways, now the site of Porter Building Center, was flooded by two feet of water.

Across the river, the L-455 levee threatened to overtop but ultimately held, probably because the

right bank breach reduced pressure on it. Had floodwaters overtopped or breached the L-455 unit, catastrophic damages would have occurred in an industrial area estimated to contain assets of over $1 billion and an annual payroll in excess of $50 million. Nevertheless, significant damage was sustained even as the levee held. The water pump system on the Missouri River water intake was flooded, eliminating the water source to the city's water treatment plant (upstream of the protected area) for nearly a week and impacting about 80,000 customers, including many large corporate customers in the L-455 area. Early in the flood event, the city's sewage treatment plant, located within the L-455 area, was forced to shut down and begin discharging raw sewage into the Missouri River. Many L-455 area businesses closed for an extended period because of concern for the safety of the levee, resulting in lost wages, productivity, and sales. Many Stockyards businesses, as well as a number of homes and small businesses in the Kirschner-Purtell and Lake Contrary areas, were damaged by sewer backup, high water table and surface flows. A number of large businesses lost inventories in the hundreds of thousands of dollars due to business and water supply interruptions.

A systematic and comprehensive post-flood damage survey was not undertaken, partly because of the large scale of the damage. But available information on quantified damages indicated at least $115 million in damage in the R471-460 area and $4 million in the L-455 area. This total reflects October 1993 prices; at current price levels, it would be about $190 million. Please note that this total is not a complete accounting of damages in the Elwood area and the actual total would have been significantly larger in the context of complete information.

In the flood's aftermath, Sherwood Medical Corporation closed its local operation permanently, laying off more than 700 employees. Corporate management reportedly was skeptical that the building ever again could be sterilized well enough to meet Federal standards .

The R471-460 levee subsequently was decertified by FEMA in 1999, and the recent flood history has created difficulties for local economic development staff attempting to interest businesses in locating in the area. Nevertheless, the Elwood area has rebounded fairly well since 1993 and remains a viable community, the population level having almost returned to the pre-flood total.

2.5 DEMOGRAPHICS

2.5.1 Census Data Areas

The entire study area is contained in the St. Joseph Metropolitan Statistical Area (MSA). The following data on population and households, housing, income, age, and education were drawn from 2000 Census data. The specific block groups and blocks comprising the study area were identified for analysis of social characteristics. The study area contains portions of seven Census tracts and all or part of 11 block groups. The relevant tracts and block groups are summarized in Table 1. Table 2 summarizes selected socioeconomic indicators.

2.5.2 Population and Households

Key population and households data from the 2000 Census are summarized below for each relevant area from the county level down to the study area.

- Buchanan County, Missouri – 2000 population was 85,998, an increase of 3.5% over the 1990 population of 83,083. There were 33,557 households in 2000.

- Doniphan County, Kansas – 2000 population was 8,249, an increase of 1.4% over the 1990 total of 8,134. There were 3,173 households in 2000.

- St. Joseph Metropolitan Statistical Area (MSA) – 2000 population was 102,490. The MSA contains the entire study area. As of 2004, the metro area was ranked 296th in the U.S. and is approximately the same size as Harrisburg, Virginia; Dover, Delaware; or Bend, Oregon. There were 39,830 households in 2000.

- St. Joseph, Missouri (city) - 2000 population was 73,990, an increase of 3.0% over the 1990 population of 71,852. There were 29,026 households in 2000.

- Elwood, Kansas – 2000 population was 1,145, an increase of 6.1% over the 1990 population of 1,079. There were 446 households in 2000.

- Wathena, Kansas – 2000 population was 1,348, an increase of 16.2% over the 1990 population of 1,160. There were 524 households in 2000.

- Study area – 2000 population was 5,469. There were 2,301 households in 2000.

- L-455 protected area – 2000 population of 3,838. There were 1,573 households in 2000.

- R471-460 protected area – 2000 population of 1,631. There were 728 households in 2000.

2.5.3 Age

The median age for Buchanan County in 2000 was 36.1 years, which is identical to the Missouri state median age. The Doniphan County median age was 36.8, somewhat older than the Kansas state median of 35.2. The St. Joseph MSA showed a median age of 36.4. The median was 35.6 for St. Joseph city, 32.3 for Elwood, and 36.4 for Wathena.

TABLE 1
STUDY AREA CENSUS TRACTS & BLOCK GROUPS (2000 CENSUS)

L-455 PROTECTED AREA

COUNTY	*TRACT*	*BLOCK GROUP*	*BLOCKS*	*AREAS WITHIN STUDY AREA INCLUDED*	*BOUNDARIES*
BUCHANAN (MO)	20	1	1111-1119, 1130-1138	St. Joseph - Stockyards, Kirschner-Purtell neighborhood	Alabama (S) to downtown, Missouri River (W) to RR tracks (E)
BUCHANAN (MO)	21	3	3001-3007	St. Joseph - King Hill neighborhood northern edge	Russell (N) to Cherokee/Blake (S), RR tracks (W) to 3rd (E)
BUCHANAN (MO)	24	1	1001-1007, 1010-1018, 1022-1031, 1033-1035	St. Joseph - King Hill neighborhood	Cherokee (N) to Alabama (S), RR tracks (W) to King Hill (E)
BUCHANAN (MO)	25	1	1003-1016	St. Joseph - King Hill neighborhood	Alabama (N) to Cliff/Brown/Valley (S), Lake (W) to King Hill (E)
BUCHANAN (MO)	25	2	ALL	St. Joseph - King Hill neighborhood southern edge	Cliff/Brown/Valley (N) to Joseph/Washington /Elizabeth (S) , Lake (W) to King Hill (E)
BUCHANAN (MO)	29	1	ALL	Unincorporated Lake Contrary & surrounding ag area	Missouri River (N) to Janston (S), Missouri River (W) to Diagonal (E)
BUCHANAN (MO)	29	2	2001-2005	Unincorporated Contrary Creek area	Janston (N) to Contrary Creek (S), Missouri River (W) to Diagonal (E)

R471-460 PROTECTED AREA

COUNTY	*TRACT*	*BLOCK GROUP*	*BLOCKS*	*AREAS WITHIN STUDY AREA INCLUDED*	*BOUNDARIES*
BUCHANAN (MO)	3	6	ALL	Missouri portion of right bank area - Rosecrans Airport & Air Guard base	Missouri River (E) & Browning Lake (N, S, & W)
DONIPHAN (KS)	203	1	1045-1049, 1052	Ag area above Wathena and Browning Lake	Missouri River (N) to 210th Rd/ Runnymede Rd/ 200th Rd/ Saratoga Rd/ 190th Rd/ Hwy 36/ Joseph St (S), Peck Rd (W) to Missouri River/ creek/ Treece Rd (E)
DONIPHAN (KS)	203	3	ALL	Elwood northern half and lower Browning Lake	Unnamed creek/ Browning Lake (N) to St. Joseph St/ 175th St/ 170th St/ Vermont/ Old Hwy 238/ Hwy 36 (S), Treece Rd (W) to Missouri River (E)
DONIPHAN (KS)	203	4	ALL	Elwood southern half; SE portion of Wathena	175th Rd/ 170th Rd/ Vermont/ Old Hwy 238/ Hwy 36 (N) to Missouri River (S), Peters Creek (W) to Missouri River (E)

TABLE 2 STUDY AREA SOCIOECONOMIC CHARACTERISTICS									
From 2000 Census data All dollars in $1,000s									
Place	**Buchanan County**	**Doniphan County**	**St. Joseph MSA**	**St. Joseph**	**Elwood**	**Wathena**	**State of Missouri**	**State of Kansas**	**U.S.**
Population	85,998	8,249	102,490	73,990	1,145	1,348	5,595,211	2,688,418	281,421,906
Households	33,557	3,173	39,830	29,026	446	524	2,194,594	1,037,891	105,480,101
Housing Units	36,574	3,489	43,236	31,752	494	566	2,442,017	1,131,200	115,904,641
Median Value of Owner Units	72.7	54.7	75.4	69.6	45.5	65.5	89.9	83.5	119.6
Median Household Income	$34.7	$32.5	$35.7	$32.7	$29.0	$34.0	$37.9	$40.6	$42.0
Per-Capita Income	$17.9	$14.8	$18.1	$17.4	$12.6	$15.4	$19.9	$20.5	$21.6
Individuals Below Poverty Level	12.2%	11.9%	11.6%	13.0%	17.0%	9.8%	11.7%	9.9%	12.4%
% Adults (25+) with High School Diploma	81.5%	80.2%	82.0%	80.9%	72.3%	78.2%	81.3%	86.0%	80.4%
% Adults (25+) with Bachelors Degree	16.9%	14.8%	17.2%	17.1%	50.0%	18.4%	21.6%	25.8%	24.4%
% of People Over 65	15.0%	16.2%	14.9%	15.4%	11.2%	15.2%	13.5%	13.3%	12.4%
% of People Under 18	24.3%	25.3%	24.6%	24.1%	30.9%	27.3%	25.5%	26.5%	25.7%

Median age for the study area block groups ranged from 30.3 in the block group containing Wathena to 38.3 in the Contrary Creek area southwest of St. Joseph.

Approximately 14.9% of the population of the St. Joseph MSA was 65 years of age or older in 2000. The comparable rates at the county level were 15.0% for Buchanan and 16.2% for Doniphan. All of these rates exceed the state averages of 13.5% for Missouri and 13.3% for Kansas. About 24.6% of the 2000 population of the St. Joseph MSA was below 18 years of age. It was 24.3% for Buchanan County and 25.3% for Doniphan County. These figures are slightly lower than the statewide averages of 25.5 for Missouri and 26.5 for Kansas.

2.5.4 Education

Buchanan County's 2000 Census results showed 81.5% of the adult population (over 25) with at least a high school diploma and 16.9% with at least a bachelor's degree. The high school diploma total is slightly better than the Missouri state average of 81.3%, but the bachelor's degree total is below the statewide average of 21.6%. For Doniphan County, 80.2% of the population had high school diplomas, significantly less than the Kansas state average of 86%.

14.8% had bachelor's degrees, again well below the Kansas state average of 25.8. For the St. Joseph MSA, 82.0% had high school diplomas and 17.2% had bachelor's degrees or higher..

2.5.5 Income and Poverty

In general, the study area population is characterized by lower incomes and greater poverty than the state and national averages. In 2000, Buchanan County's median household income was $34,704, well below the Missouri state average of $37,934. Doniphan County's median household income was $32,537, again well below the Kansas state average of $40,624. The St. Joseph MSA had a median household income of $35,675 in 2000. The figures for the cities in the study area were $32,663 for St. Joseph, $28,950 for Elwood, and $34,046 for Wathena. Among study area block groups, median household income ranged from $25,000 for the Stockyards and Kirschner-Purtell areas of St. Joseph to $36,509 for the nearby Contrary Creek area. The national median household income was $41,994, considerably above all portions of the study area.

In terms of per capita income, the St. Joseph MSA figure was $18,123 in 2000. The Buchanan County total of $17,882 was well below the Missouri state average of $19,936. The Doniphan County figure was $14,849, well below the Kansas state average of $20,506. The per capita income in 2000 was $17,445 for St. Joseph, $12,601 for Elwood, and $15,440 for Wathena. The study area block groups range from $11,491 for the northern portion of the King Hill neighborhood in St. Joseph and $11,755 for the northern portion of Elwood to $21,181 in the Contrary Creek area. The latter figure is an outlier representing a block group with a very small population which skews the overall range. The next highest figure is $17,509 in the southern portion of the King Hill neighborhood. All of the study area is well below the national 2000 per capita income of $21,587.

The 2000 poverty level was 11.6% for the St. Joseph MSA. It was 12.2% for Buchanan County, somewhat more than the Missouri state level of 11.7%. Doniphan County's poverty rate was 11.9%, well above the Kansas state average of level of 9.9%. The national rate was 12.4%. The poverty rate was 13% for St. Joseph, 17.0% for Elwood, and 9.8% for Wathena. The highest poverty rate among study area block groups was 25.9% in the northern portion of the King Hill neighborhood. The Lake Contrary area and the Rosecrans Airport area also were at or above 25%. The lowest rates were 6.2% in the Contrary Creek area and 8.9% in the rural area north of Rosecrans Airport.

2.5.6 Employment

Approximately 5.5% of the St. Joseph MSA labor force was unemployed in 2000. The unemployment rate of 5.9% in Buchanan County was above the Missouri state rate of 5.3%. The Doniphan County rate of 7.0% was well above the Kansas state unemployment rate of 4.2%. The national rate was 5.8%. The rate was 6.4% for St. Joseph, 5.2 % for Elwood, and 4.1% for Wathena. Among study area block groups, the unemployment rate ranged from zero in one King Hill neighborhood area and in the Rosecrans Airport area to 16.6% in the Stockyards and Kirschner-Purtell areas of St. Joseph.

The largest portions of the St. Joseph MSA labor force, with a total of 47,184 workers in 2000, are employed in education, health and social services (21.1%), manufacturing (17.0%), and retail (11.5%). Labor force percentages for other industries include recreation and hospitality (7.7%), construction (7.1%), financial, insurance and real estate (6.9%), transportation, warehousing and utilities (6.3%), professional and scientific (6.2%), public administration (5.1%), other services (4.3%), wholesale trade (3.2%), information (1.9%), and agriculture, forestry and mining (1.7%).

2.5.7 Housing

The 2000 Census showed a total of 36,574 housing units in Buchanan County and 3,489 in Doniphan County. The St. Joseph MSA had 43,236 units. There were 31,752 units in the city of St. Joseph, 494 units in Elwood, and 566 units in Wathena in 2000. Missouri block groups in the study area had 2,610 units, while the Kansas block groups had 728 units for a total of 3,338 total housing units in the study area in 2000.

The 2000 median value of owner-occupied housing was $72,700 for Buchanan County, well below the Missouri state median value of $89,900. The Doniphan County total of $54,700 similarly was well below the Kansas state median of $83,500. For the St. Joseph MSA, the median value was $75,400. For the cities in the study area, the 2000 median value was $69,600 in St. Joseph, $45,500 in Elwood, and $65,500 in Wathena. In terms of block groups contained in the study area, the 2000 median value ranged from $29,700 in northern sections of the King Hill neighborhood in St. Joseph and in Elwood to $137,500 in the Missouri portion of the R471-460 area adjacent to Elwood. The latter value is again an outlier since there are only 27 homes in the area and a few very expensive newer homes appear to have skewed the total. The next highest block group median value is $86,700 for the Lake Contrary area.

Buchanan County's 2000 vacancy rate of 8.2% is below the Missouri state rate of 10.1%. The Doniphan County rate of 9.1% was higher than the Kansas state vacancy rate of 8.2%. The St. Joseph MSA vacancy rate was 7.9%. The rate was 8.6% in St. Joseph city, 9.7% in Elwood, and 7.4% in Wathena. Within the study area block groups, the highest vacancy rate, 22.2%, was found in the Rosecrans Airport area.

3.0 DAMAGE ANALYSIS MODEL CONSTRUCTION

3.1 STUDY CONFIGURATION

3.1.1 Analysis Years

The analysis evaluates without and with project conditions based on a 50-year period of analysis, the standard assumption for a Federal levee. In addition to the existing conditions analysis which represents conditions as of 2006, the analysis also assumes a base year of 2013, the approximate year any project would become operational, and a future condition year of 2038, which is the midpoint of the 50-year period beginning in 2013. The analysis years represent static time periods or years relative to which the engineering and economic data are developed.

No additional, separate analysis was prepared for the base condition. There are no known differences between 2006 existing and 2013 base year conditions in terms of either economic development or hydrologic/hydraulic conditions. Therefore, the analysis for 2006 existing conditions should adequately portray base year conditions as well.

3.1.2 Interest Rate and Price Level

The price level for this analysis is October 2005. The current Federal interest rate of 5.125 percent is used in annualizing costs and benefits over the 50-year period of analysis.

3.1.3 Study Reaches

As summarized in Table 3, the study area was divided into four reaches for the economic analysis, including two on each bank. The purpose of the divisions is to facilitate the reporting of economic damages and benefits for distinct subareas of the study area, as well as to ensure accurate computation of damages by heading off problems that could occur in translating property or water surface elevations at remote locations to common index points. The reach selection was made on the basis of distinct land uses, political subdivisions, hydrologic features such as Browning Lake and Brown's Branch, and hydraulic data. The reach delineations were not intended to affect, and do not affect, plan formulation or selection in this study.

3.1.3.1 L-455 Reaches The L-455 protected area extends from the downstream end at Contrary Creek at Missouri RM (River Mile) 437.35 to the upstream end at Whitehead Creek at RM 447.3. This area is divided into two reaches by the tiebacks along Brown's Branch at RM 445.7. The upstream reach is a densely developed urban area which includes the central industrial district in the old Stockyards as well as part of the King Hill neighborhood. This reach is almost completely within the city limits of St. Joseph. The more rural downstream reach is dominated by Lake Contrary and includes an extension of the central industrial district along Lower Lake Road, the Kirschner-Purtell neighborhood, the homes surrounding Lake Contrary, some scattered homes near Contrary Creek, and farmed land to the west and south of Lake Contrary. Most of the downstream area is to the southwest of the St. Joseph city limits and is unincorporated.

The two L-455 reaches are not hydraulically independent, inasmuch as flooding in the upstream

reach could enter the downstream reach. However, flooding that begins downstream cannot back up into the upstream reach, and the overtopping point and critical geotechnical section for L-455 both are on the downstream segment of the levee.

3.1.3.2 R471-460 Reaches On the right bank, the protected area extends from Peters Creek at RM 441.8 to the upstream tieback near Treece Road at RM 456.5. Like the L-455 area, this area is divided into two reaches. The dividing point is at RM 449.5, just downstream of the upstream entrance to Browning Lake and near levee station 250+00. This point was chosen to highlight differences in the water surface profiles affecting the upstream and downstream portions of the levied area as well as differing land uses and political subdivisions. The downstream right bank area features mainly small town urban land uses including the town of Elwood, Kansas, a portion of the town of Wathena, Kansas, and the commercial and industrial area along U.S. Highway 36 connecting the two towns. The upstream reach, in contrast, is mainly industrial and agricultural. It includes the Rosecrans Airport area, the Missouri Air National Guard base, a large farming region north of the airport, and a number of rural residences. The airport and Air Guard base are in the Missouri portion of the reach, while the farmed areas are primarily in the Kansas portions. If a breakout of damage or benefit totals for the Missouri portion of R471-460 is needed, the totals for the upstream reach can be regarded as rough estimates for Missouri since the farmed Kansas portions of the reach are overwhelmed in value by the large public facilities in the Missouri portion.

TABLE 3
ECONOMIC ANALYSIS REACHES

All stations are Missouri River miles

Reach	Levee unit	Downstream end station	Upstream end station	Econ index station	Areas included
LB-US	L-455	445.70	447.30	446.32	Urban SW portion of St. Joseph, including Stockyards & King Hill neighborhood
LB-DS	L-455	437.35	445.70	441.39	Unincorporated Lake Contrary & surrounding ag areas; Kirschner-Purtell neighborhood
RB-US	R471-460	449.50	456.50	449.99	Rosecrans Airport; Air Guard base; ag area
RB-DS	R471-460	441.80	449.50	449.44	Town of Elwood; town of Wathena (portion); Hwy. 36

3.1.4 Economic Categories

The economic structure inventory in this study utilizes four categories of basic land uses: residential, non-residential (including businesses, non-profit institutions such as churches and schools, public facilities and utilities), roads and streets, and agriculture (crops – farm sets are

categorized in residential). Physical inundation damage and benefit estimates produced by the risk analysis are reported in terms of totals for these four categories.

3.2 DATA COLLECTION METHODOLOGY

3.2.1 Tax Records

Initial data collection for the economic analysis included obtaining 2003 county tax records from Buchanan County, Missouri, and Doniphan County, Kansas. The then-current state of the counties' databases allowed only minimal outputs, but information obtained for each structure included address, owner name, appraised value, land use, and parcel numbers.

3.2.2 Mapping

1998 GIS mapping was obtained from the city of St. Joseph and the Corps Missouri River floodplain mapping. The available maps were contoured at intervals of 4 feet and also contained many spot elevations. In addition, areas for each building in square feet were estimated by Corps GIS staff from the footprint of each building in the protected areas.

3.2.3 Field Survey

The somewhat rudimentary outputs available from county tax records in the study area were complemented and, eventually, largely replaced by a structure-by-structure field survey carried out in May-August 2004. Each structure in the protected areas within the 0.2% floodplain (and slightly beyond, in some areas) was surveyed, accounting for approximately 2,400 structures. Information noted for each structure included address; identification of business/facility and industry at non-residential properties; type of home (single, duplex, multiple, mobile home); construction type and quality; with or without basement; number of stories; first floor elevations relative to ground elevations; condition; and estimated age. Significant outbuildings and outdoor inventory or equipment also were noted.

The field survey was updated periodically during preparation of the analysis. The economic database used in this analysis reflects 2006 conditions.

3.2.4 Corporate Interviews

The other major data collection task involved extensive, on-site interviews with major companies and facilities in the study area for the purpose of collecting detailed values and depth-damage data. It was not realistic within the study budget and schedule to interview all or most businesses in the study area. Therefore, we emphasized those businesses and facilities with the largest investments in the protected areas. In this study area, a large percentage of total property value is accounted for by a few very large facilities. These facilities were identified with the help of values from the 1997 reconnaissance study and discussions with St. Joseph Chamber of Commerce staff. Ultimately, 20 extensive interviews were carried out, including 14 in the L-455 area and 6 in the R471-460 area, accounting for the majority of non-residential investment in both areas.

Interviews with representatives of these facilities resulted in site-specific data broken out by each individual building within the plant or facility. For each building, we noted the following information: functions of building (office, manufacturing, warehouse, etc.); first floor elevation; any uses of basement or second floors; estimated replacement values of assets, including ranges of values whenever possible; estimated remaining life and condition of assets; key depth-damage elevations for each major contents item; and any known flood history. Values of buildings and major equipment were estimated in terms of depreciated replacement value, while inventory and smaller equipment estimates were based on replacement values.

3.3 DATA DEVELOPMENT

3.3.1 Ground Elevations

All structures surveyed were assigned a ground elevation from the topographic mapping and a station positioning them relative to the river. Foundation heights observed during the field survey were applied to the ground elevations to obtain first floor elevations. Roads and street lengths were assigned elevations on a block-by-block basis using the topographic mapping. Crop acreage was divided into small areas and each area was broken down into a range of elevations.

To account for uncertainty, a standard deviation of 0.5 feet was assigned to each ground elevation based on the topographic mapping with 4-foot contours. Table 6-5 of EM 1110-2-1619, which gives standard deviations for various methods of determining stages, was consulted to determine the correct standard deviation.

3.3.2 Residential Values and Damage Susceptibility

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3.3.2.1 Residential Structures Valuation - Corps of Engineers 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.

Appraised residential values from county tax records initially were considered, but these values were not ultimately used in the final feasibility study computations, primarily because of difficulties in matching up the tax records with available field survey mapping. Instead, a modified Marshall and Swift methodology based on costs per square foot was used to value all homes using data collected during the field survey. No information was available for some of the factors 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. A valuation process was developed to adapt the detailed Marshall and Swift process to the more limited data available for this study. The valuation method enumerated below was used to determine depreciated replacement values for all residential structures.

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. Determine size of home in square feet, using the footprint measurements provided by GIS staff and also referring to the number of stories.

4. Identify exterior walls type. We noted whether the walls were wood or masonry. Although these basic wall composition types are in turn divided into multiple categories in the Marshall and Swift data, with each category characterized by a separated set of values per square foot, we noted only the basic material.

5. 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.

6. Calculate a basic total replacement cost by multiplying the square foot cost by the area in square feet.

7. 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.

8. Add garage value based on map measurement of outbuildings by GIS staff.

9. Calculate total replacement value using the basic cost per square foot plus the additions for basement and garage.

10. Determine typical physical life for each type of home by using Marshall and Swift tables.

11. 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.

12. Select depreciation factor using the effective age and typical physical life. These percentages are available in Marshall and Swift tables.

13. Calculate depreciated replacement value for the structure by applying the depreciation

factor to the total replacement value.

14. Calculate adjusted depreciated replacement value for structure by applying Marshall and Swift multipliers to reflect current cost and locality adjustments.

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 we rated a home's construction quality 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 38%. The 38% maximum change was divided by 2 to obtain an estimated standard deviation of 19%. This standard deviation was applied to each residential occupancy type used in the damage analysis.

3.3.2.2 Residential Contents Valuation - Because residential depth-damage functions developed by the Institute for Water Resources were used in the analysis, the contents-to-structure-value ratio for homes was set to 1.0 in the HEC-FDA risk analysis model (see section 3.5 below) in accordance with guidance for the use of these functions. In estimating investment, it was assumed that residential contents value is equal to 50% of the structure value. This assumption is purely for estimating investment and does not influence the estimates of damages and benefits. Mobile homes are not covered by the IWR functions. A content-to-structure value ratio of 63.6% was assumed for mobile homes based on FEMA flood insurance claims data referred to in Table 6-4 of EM 1110-2-1619.

The standard deviation used for mobile home contents is 37.8%, again from Table 6-4 of EM 11102-1619. For other residential occupancy types covered by IWR depth-damage functions, no uncertainty factor is included for contents value in HEC-FDA based on IWR guidance.

In addition to contents, an "other" category was added to all residential properties to account for both vehicles and landscaping. Most families today own more than one vehicle, and with imminent threat of flooding, it is likely that they would load belongings into one vehicle and evacuate the area. Therefore, vehicles subject to flood damage were limited to one per home. At the same time, warning times associated with levee failure (as opposed to overtopping) are not generally sufficient to allow comprehensive evacuations, so it is assumed that each home would have one vehicle that would not be evacuated. Most homes in the protected areas have typical shrub plantings, lawns, and gardens that would also be damaged by flooding. The "other" value accounting for the sum of vehicle and landscaping value was assumed to be equivalent to 20% of residential structure value with a standard deviation of 5%. Since the "other" category amounts to about 16.7% of total residential value (20% / (100% + 20%) = 16.7%) and residential value accounts for about 9% of total investment (see Table 4 below), vehicles and landscaping can be seen to account for about 1.5% of total property value in the analysis.

3.3.2.3 Residential Depth-Damage Relationships - The depth-damage functions applied to homes in this analysis were developed by the Institute for Water Resources (IWR) based on post-flood data from thousands of flood insurance claims. The functions are for 1 story with or without basement, 2 story with or without basement, and split level with or without basement. Structure and contents functions are provided for each structure type. The split level functions were not used in this analysis since there are few such homes in the study area, but a pair of unofficial functions for 1.5 story with or without basement were produced by averaging the 1 and 2 story functions. The 1 story functions also were used to evaluate both single family homes and apartments. The only other depth-damage functions not included in the IWR data were the mobile home and vehicle functions, which came from New Orleans District data (see section 3.3.3.2 below).

One consideration in the preparation of depth-damage functions is the likelihood and extent of effective avoidance measures. Avoidance measures could include raising of contents, evacuation, flood proofing and other measures that would lessen property damages in a flood event. No specific data were available concerning residential avoidance measures in this analysis. However, the standard IWR residential depth-damage functions used in this study purportedly were based on flood insurance claims emanating from actual flood events, and these depth-damage relationships are assumed to at least indirectly reflect avoidance measures.

All IWR depth-damage functions are equipped with standard deviations per foot of flooding in addition to the most likely values. The New Orleans functions are accompanied by minimum and maximum percentages for each foot of flooding for use as a triangular uncertainty distribution.

3.3.3 Non-Residential Values and Damage Susceptibility

3.3.3.1 Non-Residential Structure Valuation - As with residential valuation, the appraised county tax values for businesses were considered but not ultimately used to determine depreciated replacement values since matching tax records with field survey mapping could not be accomplished in a reliable manner. An additional shortcoming was that most public facilities did not have values in the tax records.

For interviewed firms and facilities, depreciated replacement value was estimated for the relevant structures during the interviews. In all other cases, an adapted Marshall and Swift methodology for commercial valuation was employed based on costs per square foot. These computations relied on attributes gathered during the field survey. The process, 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. Identify 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.

10. Calculate adjusted depreciated replacement value for the structure by applying Marshall and Swift multipliers to account for necessary current cost and locality adjustments.

3.3.3.2 Non-Residential Contents Valuation

For interviewed firms and facilities, content values were estimated directly from interview data and then converted to content-to-structure value ratios. Interview subjects were asked about the value of each major type of contents in each area or building. These line items were aggregated into a single contents value for use in the HEC-FDA risk analysis model. Major equipment items were characterized in terms of replacement cost and estimated remaining useful life, which facilitated computation of depreciated replacement values. Inventories were valued in terms of replacement value. In addition to a most likely value, maximum and minimum values for each line item were developed which served as the basis for a triangular uncertainty distribution for contents value.

Relative to the final structure inventory database that went into the damage analysis, about 57% of non-residential investment in the study area and about 47% of total investment value is accounted for by the 20 interviewed firms and facilities, indicating that the bulk of the value assumed within the economic structure inventory is backed by primary sources and detailed analysis.

For other firms and facilities that were not interviewed, content-to-structure value ratios published by the New Orleans and Baltimore Districts of the Corps of Engineers were used in most cases. The New Orleans District working in conjunction with Gulf Engineers and Consultants (G.E.C.) of Baton Rouge, Louisiana has developed a great deal of analysis over several studies concerning valuation and depth-damage relationships of flood-prone properties under various conditions, and three reports have been published documenting their methods and results. These reports collectively are one of the few sources of published information on commercial contents valuation and depth-damage functions. The content-to-structure value ratios as published also are accompanied by standard deviations to account for uncertainty. The three reports use slightly different methodologies that produce slightly different datasets. The one used here is the set developed from post-flood owner-operator interviews for the May 1997 report "Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) In Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies." This dataset was based on a mid-1990s canal flooding event in the Baton Rouge area. The context of inland, freshwater, long duration flooding, as well as similarity of construction and occupancy types, suggested the data could be appropriately transferred to the problem area in the present study.

A few ratios also were obtained from an IWR report (originally Baltimore District data) on the Wyoming Valley of the Susquehanna River basin in Pennsylvania. Like the New Orleans data, the Wyoming Valley data also were based on long duration, main stem, inland, freshwater flooding and additionally involved a context of existing levees, all of which strengthens the relevance of the data to the present study. In some cases where little information was available about a business property or industry, a content-to-structure value ratio of 1.0 was assumed.

3.3.3.3 Non-Residential Depth-Damage Relationships

Non-residential depth-damage functions were largely taken from the New Orleans District and Baltimore District data referenced above. All non-residential structures, including interviewed companies, were evaluated using New Orleans functions for commercial wood, masonry and metal buildings. The functions include median, minimum and maximum values, allowing expression of damage uncertainty as a triangular distribution.

Non-residential contents damage functions for interviewed firms or facilities were developed in each case based on data obtained from the interview concerning elevations, values, and damage potential. Depth-damage functions, values, and elevations were assigned for each major line item of property, including uncertainty factors. A total depth-damage function for contents was then developed by computing a weighted average of depth-damage curves for all contents items, with each item weighted by its value as a percentage of total contents value for the company. For example, if office equipment was valued at $10,000 for a given facility, and total equipment and inventory for the facility was valued at $200,000, the depth-damage curve for office equipment would get 5% of the weight in determining the total depth-damage curve for contents.

Flood avoidance measures were factored into the depth-damage relationships where appropriate. The economic interviews, which covered key facilities accounting for approximately 57% of

total non-residential investment value in the study area, included discussion of evacuation, raising, and other avoidance measures that could be employed in a typical Missouri River flood event. Most of the large plants or warehouses evaluated in this study would be unable to relocate very much of their massive inventories in the warning time provided, and most of the facilities would be unable to move or raise their equipment regardless of warning time. One exception would be the aircraft at Rosecrans Airport and the adjacent Missouri Air National Guard base, where we assumed evacuation of nearly all aircraft, although it was assumed that a few aircraft could be damaged in the largest flood events.

For non-residential contents damage estimates at other businesses and facilities that were not interviewed, most of the depth-damage functions used are from the New Orleans data. These functions include median, minimum and maximum values to support a triangular uncertainty distribution. A few contents functions for specific occupancy types not covered by the New Orleans data came from the Wyoming Valley data. The Wyoming Valley functions as published were not accompanied by uncertainty factors. In these cases, uncertainty was developed as a triangular distribution with minimum and maximum percentages assigned as appropriate for each increment of flooding based on professional judgment. In cases where no generalized depth-damage curve was available based on similar businesses or not enough information existed concerning the nature of the business, one of three generalized depth-damage curves was used based on high, medium or low damage potential. Vacant businesses were evaluated using a depth-damage curve that assigned damage to the structure but only minimal damage to contents. (Contents value for vacant buildings, while minimal, is not completely zeroed out since a 50-year period of analysis is assumed and it is likely that a currently vacant building would be occupied for at least a portion of that period.)

3.3.4 Roads and Streets

Roads, streets, highways and railroads were valued in terms of typical construction costs per mile. These costs were obtained by averaging typical costs from a variety of sources, including consulting private sector engineers who have worked on road projects, previous Corps projects, and state Departments of Transportation. The new (replacement) construction costs per mile were converted to depreciated replacement values by assuming a depreciation factor of 35%. Depreciated replacement values per miles used in this analysis include railroads, $1,122,000; highways (4-lane rural), $3,487,000; major arterials, $4,190,000; connector streets, $2,287,000; neighborhood streets, $1,715,000; and county roads, $1,143,000.

Depth-damage functions used for roads in this analysis were 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 depth-damage percentages.

3.3.5 Agriculture – Crop Damage

Crop damages in the analysis are expressed as a value per representative acre. A value per acre was prepared for each county in the study area, Buchanan and Doniphan, using a weighted average that accounts for a number of factors. Initially, a typical crop pattern or distribution is established for river bottoms in the relevant area. Standard, widely available county and district crop data are not useful for this purpose since they reflect all farms, not just those in river bottom areas, and crop patterns and yields in river bottom areas usually differ significantly from other farms. Instead, Farm Service Agency county staff and Natural Resource Conservation Service state staff are consulted for their estimates of local crop patterns and yields in floodplain areas. Virtually all river bottom farming in the study area involves corn and soybeans, with a very small amount of wheat and bean double-cropping in Kansas counties. Crop budgets available from state university extension offices are used to determine annual production costs per acre for each crop, including planting costs per input and harvest costs. Crop calendars for each crop are used to determine the typical monthly schedule for planting, growing and harvesting. Yields per acre for each crop are obtained from the FSA and NRCS sources. For prices per bushel, Corps economic analyses are required to use normalized prices updated each year by the U.S. Department of Agriculture for all basic crops.

These data inputs are integrated to determine on a monthly basis the extent to which each crop is in the ground, mature, and harvested. These calculations in turn determine the value per acre that can be lost to flooding at any given time during the year. Potential monthly losses for each crop are then integrated with monthly flooding probabilities to determine actual losses. Finally, the losses for each crop are combined with crop distribution data to determine the overall crop value lost per acre in a flood. The damage per acre values used in this analysis are $140 for Buchanan County, Missouri, and $162 for Doniphan County, Kansas.

To determine an uncertainty factor for these values, the FSA staff consulted on local crop distribution and yields were asked to estimate yields per acre in an average year, a very good year, and a poor year. The value per acre computations that had been done using the yields per average year were repeated using the very good and poor year values. These computations established a maximum and minimum value. The maximum was 14 to 16% greater than the average, while the minimum was 19 to 22% less than the average. The value uncertainty for crops is therefore expressed using a triangular distribution, with a minimum of 78% and a maximum of 116%.

The depth-damage function used for crop damages assumes that one foot of water ruins a crop.

3.3.6 Base vs. Future Year Adjustments

Separate modules were developed for base and future year conditions to be used in the risk analysis. Each module is a complete economic property inventory reflecting a particular set of conditions. The base and future modules in this analysis include the same data with one exception. The Missouri Air National Guard base on the right bank, which was heavily damaged in the 1993 flood, plans to relocate to higher ground within the protected area. The new site for the base at the north end of Rosecrans Airport would be about nine feet higher than the present

site, which would not entirely remove the base from the floodplain but would greatly reduce the damage potential. (The 1993 flood depth at the base was 9 feet.) The elevation of the new facilities is expected to be 11 feet higher than at the current site. Although the move originally was planned to be completed by 2010, the current timeline is unclear because of wartime Federal funding exigencies and because the decertification of the levee unit reportedly has caused enough uncertainty in the military's planning horizon to delay most funding for the project. The relocation by the base year of the analysis would barely be completed before the base year even if the projected funding schedule proves valid, and any funding delays probably would push forward the date of completion to well past the base year. The economic analysis assumes that the base will have been relocated for the future (2038) without-project condition but not for the base year (2013) condition.

The relocation of the Air Guard base is the only change in the economic database between the base year and future year conditions. No other economic changes are assumed in going from the 2013 to the 2038 condition. However, all properties in the future module are affected by increased Missouri River water surface profiles summarized later in this appendix in Table 11.

3.4 STUDY AREA INVESTMENT TOTALS

The economic structure inventory for this analysis, as defined in the field survey and developed and refined subsequently, resulted in a database that is summarized in Table 4. This database was used in the subsequent risk analysis simulations for computation of damages and benefits. Highlights of the investment data include the following:

- Total investment in homes, businesses and facilities, roads, and crop acreage in the study area is just under $2 billion ($1,997,175,000).

- There are 1,968 homes and 290 businesses and facilities in the study area, as well as almost 80 miles of roads and streets and 12,300 crop acres.

- The L-455 area accounts for 71% of total investment, or about $1.43 billion.

- The L-455 area contains 1,301 homes, two-thirds of the study area total; 165 businesses and facilities), 5,100 crop acres, and almost 53 miles of roads and streets.

- 57% of study area non-residential properties are in the L-455 area, but L-455 accounts for 73% of total non-residential investment.

- R471-460 area investment is an estimated $572 million, accounting for 29% of the study area total.

- The R471-460 area contains 667 homes and 125 non-residential properties, as well as 27 miles of roads and 7,200 crop acres (58.5% of the study area total).

The residential category, about 9% of total study area investment, includes homes and their contents as well as vehicles and landscaping. The non-residential category includes business,

non-profit and public facility structures along with their equipment, inventory and furnishings. Non-residential investment comprises 82.2% of total study area investment. The roads category, which includes streets, county roads, highways and railroads, accounts for 7.9% of total investment. Crops account for the remaining 0.9% of total investment.

TABLE 4
STUDY AREA INVESTMENT TOTALS

In $1,000s

	L-455		R471-460		TOTAL	
RESIDENTIAL						
# Homes	**1,301**	66.1%	**667**	33.9%	**1,968**	
Structure Value	$68,066.5		$37,905.3		$105,971.8	
Contents Value	$47,646.5		$26,533.7		$74,180.2	
Total Value	$115,713.0	64.2%	$64,439.0	35.8%	$180,152.0	9.0%
NON-RESIDENTIAL						
# Businesses / Facilities	**166**	57.2%	**124**	42.8%	**290**	
Structure Value	$322,262.8		$196,012.3		$518,275.1	
Contents Value	$877,551.2		$245,813.5		$1,123,364.7	
Total Value	$1,199,814.0	73.1%	$441,825.8	26.9%	$1,641,639.0	82.2%
ROADS						
Miles	52.9	66.4%	26.8	33.6%	79.7	
Total Value	$102,698.9	65.4%	$54,235.1	34.6%	$156,934.0	7.9%
CROPS						
Acres	5,100	41.5%	7,200	58.5%	12,300	
Total Value	$7,650.0	41.5%	$10,800.0	58.5%	$18,450.0	0.9%
GRAND TOTAL	**$1,427,888.0**	71.4%	**$571,299.9**	28.6%	**$1,997,175.8**	100.0%

3.5 RISK ANALYSIS MODEL

3.5.1 HEC-FDA Software

The ultimate goal of the data collection, development and refinement phase is the compilation of economic data files for import into the HEC-FDA program. HEC-FDA is the Hydrologic Engineering Center's Flood Damage Reduction Analysis program, a risk analysis software product that is the Corps standard for flood damage reduction analyses. HEC-FDA integrates economic data with hydraulic/hydrologic and geotechnical/ structural engineering data, including uncertainty factors for each type of data, to produce estimates of project economic and engineering performance under existing without-project conditions and alternatives. The current HEC-FDA version 1.2 is used in this analysis.

3.5.2 Economic Data Inputs

The economic input files for HEC-FDA include a structure inventory file compiling data for all damageable property in the study area, including structure values, ground elevations and foundation heights (which are added to the ground elevations to produce first-floor elevations), and stream stationing. The structure inventory file is accompanied by an occupancies file that compiles information for each major occupancy type (1-story homes, retail businesses, government offices, etc.) such as content-to-structure value ratios, depth-damage functions, and uncertainty factors for all economic variables. Together, these data files contain the three main factors critical to estimating flood damages at each location: elevation, value, and damage susceptibility.

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 and crops.

3.5.3 Engineering Data Inputs

Engineering inputs for the model include water surface profiles with stages and discharges for a range of eight selected flood events: 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2%-chance events, plus invert stages. Sets of profiles were prepared for both the 2013 and 2038 analysis years. The exceedance probability relationships for each reach and each analysis year were evaluated using the graphical method, which involves specifying a discharge-probability relationship (including a discharge for the 0.999 probability event) for each index point along with the equivalent record length (70 years) for the Missouri River. A stage-discharge relationship also was entered for each of the four index points and two analysis years, with the addition of a standard deviation of 1.28 feet for 2013 conditions and 1.42 feet for 2038 conditions.

Top of levee stages based on critical levee low points were identified and translated to each index point, as were exterior-interior stage relationships. The exterior/interior relationships tell the HEC-FDA program the depth of flooding that affects property inside the levee when a given stage is reached on the river side of the levee. The exterior and interior stages can be identical, as they are for the upstream reach of L-455. In other cases, the interior stages can be slightly less (about 2 feet less for the downstream L-455 reach) or significantly less (about 5 feet for the R471-460 reaches).

Geotechnical probability of failure curves were developed for one critical section on each levee and then adjusted to the appropriate index points. Geotechnical concerns are more significant relative to the R471-460 levee, where probability of failure reaches 34% before overtopping. For the L-455 levee, probability of failure reaches only 7% before overtopping in the downstream reach, and the upstream reach has no probability of failure function. No probable failure points (PFP) were prepared for the analysis since none of the probability of failure curves reach 85% significantly below top of levee.

More information on the methodologies used in developing the geotechnical probability of failure functions and the hydrologic and hydraulic data can be found in the sections corresponding to these disciplines in Appendix B to this report.

3.5.4 Risk Analysis

Upon completion of the economic and engineering data entry, 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.

The second and final phase of the risk analysis integrates the economic stage-damage function with the engineering data. A Monte Carlo process is used to simulate up to a half-million individual flood events in each analysis. Each event samples the engineering and economic variables within their specified ranges of uncertainty to determine whether flood damage occurs and if so, how much. Computations are made for expected annual damages under each condition, existing (or base, since both condition are equivalent in this analysis) and future. Expected annual damage 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 (see Tables 7 and 10 below), with the future year damages expressed as a discounted present worth value which is added to the base year damages.

Results of the risk analysis are described in the following section.

4.0 DAMAGE ANALYSIS – WITHOUT-PROJECT CONDITION

4.1 EXISTING AND BASE YEAR CONDITIONS

Results in this study for existing (2006) and base year conditions (2013) are identical, as there are no differences in property inventories, water surface profiles or other data.

4.1.1 Beginning Damage Frequencies and Key Flood Events

This section summarizes results of the economic analysis as they pertain to beginning damage points and selected flood events. Table 5 summarizes the damages and impacts that would be expected in each of three selected flood events. Like many areas protected by main stem levees, both the L-455 and the R471-460 protected areas essentially form "bowls" behind the levees, so

there is almost no difference in the number of homes and businesses flooded in the three events that are enumerated here. The main difference is in depth of flooding. Table 6 compiles many of the key elevations in this study, including top of levee elevations, water surface profiles for selected flood events for 2013 and 2038 conditions, historical flood peaks, and important properties. Hydraulic data prepared for this study includes a set of water surface profiles for the existing and base year conditions and a second set of profiles for future conditions that reflects stage increases. Both sets of data are summarized in Table 6.

It should be emphasized that the damages summarized in this section are risk-based, and the results obtained in the risk analysis can seem at odds with data that do not reflect the uncertainties involved. As an example, it is stated elsewhere in this report that the R471-460 levee unit can, under existing conditions, contain a 1% flood. This is true inasmuch as the current top of levee elevation for R471-460 exceeds the nominal or most likely 1% flood elevation. However, that does not mean that the 1%-chance flood would cause no damage to R471-460 in the context of a Monte Carlo-based risk analysis simulation. (Witness the existing decertification of the right bank levee for failing to meet certain standards of protection against the 1%-chance flood.) Within the risk analysis, the standard-deviation of 1.28 feet for the stage-frequency relationship under existing conditions means that the elevation reached by a 1%-chance flood could be over 2.5 feet above or below the nominal elevation at two standard deviations from the mean. The 1%-chance flood elevation, in other words, could assume a value anywhere within a range of about 5.1 feet. (The range increases to 5.7 feet under 2038 future conditions.) If a top of levee elevation contains a nominal flood elevation by a margin of 0.9 feet, while the uncertainty factors assumed would allow the risk-based elevation for the same flood to exceed the nominal elevation by 2.6 feet, it is clear that the risk-based flood event could actually exceed top of levee by as much as 1.7 feet.

An additional factor that distinguishes damage potential in the risk context from data based on nominal top of levee and flood event elevations is that the risk model assumes that a flood can occur from geotechnical or structural failure as well as by overtopping.

4.1.1.1 Beginning Damage Frequencies - Results of the risk analysis indicate that, under existing conditions of 2006 or base year conditions of 2013, the R471-460 area could suffer flood damage in an event smaller than the 1% flood – specifically, in a 1.5% (67 year) event. The frequencies involved are approximate since the risk analysis outputs are relative to only a few selected events. Therefore, it would perhaps be more accurate to characterize the beginning damage frequency for R471-460 as being in the range of 2%-chance (50-year) to 1.33%-chance (75-year).

Damage to the L-455 area would require a flood of a 0.2% chance magnitude under existing or base year conditions.

4.1.1.2 The 1% Chance Flood - A 1%-chance (100-year) flood under existing conditions would be associated with a discharge of 261,000 cubic feet per second (cfs). A flood of this magnitude would result in damages of $304.3 million, all in the R471-460 area. L-455 would not be flooded. All but 4 of the 667 homes in the R471-460 area and all but 4 of the 125 businesses and facilities would be affected. Depths in the flooded areas would average 6.7 feet

and would reach as much as 17.7 feet.

4.1.1.3 The 0.5% Chance Flood - A 0.5%-chance or 200-year flood under existing conditions would be associated with a discharge of 287,000 cfs. The L-455 area would not be flooded, but the R471-460 area would suffer damages of $343.4 million. All but one of the 125 businesses and facilities and all but 1 of the 667 homes in the right bank area would be affected by depths averaging 8.1 feet and reaching as much as 19 feet.

4.1.1.4 The 0.2% Chance Flood - A 0.2% or 500-year flood, under existing conditions, would be characterized by a discharge of 324,000 cfs. Damages in the R471-460 area would total $369.5 million, or 54% of total damage in the study area. An estimated 666 homes and 124 businesses and facilities in the right bank area would be damaged by depths of up to 20.8 feet and averaging about 10 feet. The L-455 area's downstream reach would experience similar depths, resulting in damage of $316 million, or 46% of the total study area damage. An estimated 23 businesses and facilities and 590 homes would be affected, all in the downstream left bank area. The upstream reach of L-455 would not flood. Damage in the study area overall would total $685.5 million.

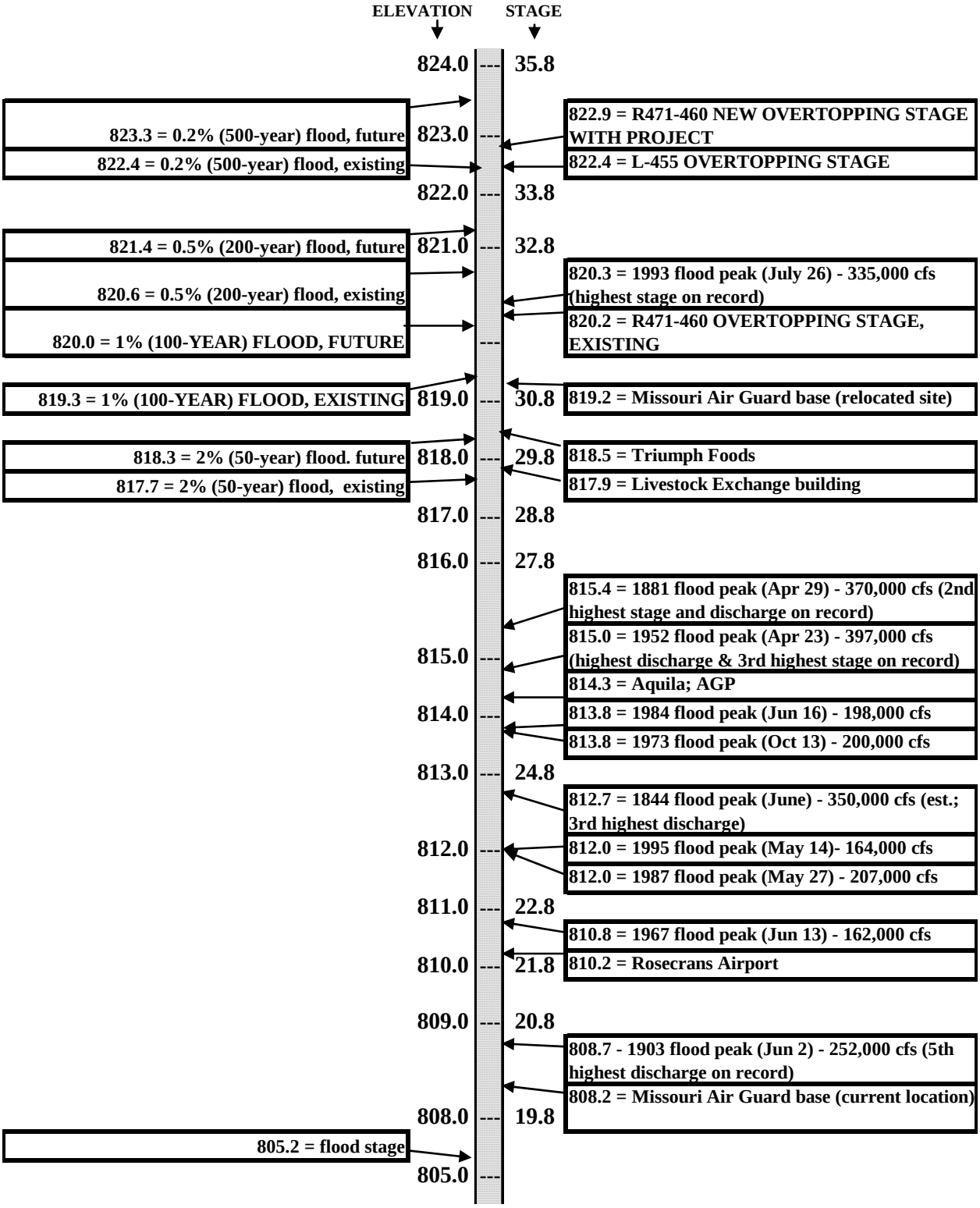
TABLE 5
SINGLE EVENT DAMAGES FOR SELECTED FLOODS

Based on existing conditions (2006)

	L-455	R471-460	Total
1% (100-Year) Event			
Total Damage	$0.0	$304,332.8	$304,332.8
Homes Affected	0	663	663
Businesses Affected	0	121	121
Average Depths	0.0	6.7	
Maximum Depths	0.0	17.7	
0.5% (200-Year) Event			
Total Damage	$0.0	$343,429.5	$343,429.5
Homes Affected	0	666	666
Businesses Affected	0	124	124
Average Depths	0.0	8.1	
Maximum Depths	0.0	19.0	
0.2% (500-Year) Event			
Total Damage	$316,015.1	$369,501.6	$685,516.7
Homes Affected	590	666	1,256
Businesses Affected	23	124	147
Average Depths	9.8	10	
Maximum Depths	20.8	20.8	

TABLE 6 - KEY ELEVATIONS

***** Index point - St. Joseph USGS Missouri River gage - RM 448.16**
Datum = 788.19



4.1.2 Expected Annual Damages for Existing and Base Years

Expected annual damages (EAD) under existing and base year conditions are summarized in Table 7. For the total study area, EAD is an estimated $7.84 million. About 77% of this total, or $6.07 million, is associated with the R471-460 area. The L-455 area accounts for the remaining EAD of $1.77 million.

Although the L-455 area contains a large and valuable property base, EAD potential is limited by the absence of serious geotechnical or hydraulic issues affecting the levee. The decertified R471-460 unit has much more significant concerns in both areas, resulting in greater EAD than the L-455 area despite a much smaller property base.

Total study area EAD is 85.1% non-residential, 11% residential, 3.6% roads, and 0.3% crops.

TABLE 7
EXPECTED ANNUAL DAMAGES BY CATEGORY
EXISTING / BASE YEAR CONDITIONS - WITHOUT PROJECT

Damage in $1,000's

	Residential	Non-Residential	Roads	Crops	Total	
L-455						
Downstream	$101.5	$1,078.8	$40.5	$2.3	$1,223.1	
Upstream	$2.3	$542.5	$5.9	$0.0	$550.7	
L-455 Total	$103.8	$1,621.3	$46.4	$2.3	$1,773.8	22.6%
	5.8%	91.4%	2.6%	0.1%	100.0%	
R471-460 Total						
Downstream	$738.4	$2,726.0	$232.8	$5.1	$3,702.3	
Upstream	$20.5	$2,319.3	$4.3	$18.2	$2,362.4	
R471-460 Total	$758.9	$5,045.3	$237.2	$23.3	$6,064.7	77.4%
	12.5%	83.2%	3.9%	0.4%	100.0%	
Study Area Total	$862.7	$6,666.6	$283.6	$25.6	$7,838.5	
	11.0%	85.1%	3.6%	0.3%	100.0%	

4.1.3 Nonexceedance Probability Ratings for Existing Conditions

In addition to estimating economic performance of the levees, the HEC-FDA risk analysis also characterizes their engineering performance in terms of computed nonexceedance probabilities. Some key results for the existing and base year conditions are summarized below and in Table 8.

4.1.3.1 R471-460 Performance - The main results of the risk analysis pertaining to the right bank levee in existing or base year conditions are as follows:

- The R471-460 unit has only a 51.3% chance of containing a 1%-chance flood event, compared to the 90% or better chance required for certification. This nonexceedance probability accounts for damage due to either overtopping or levee failure.

- R471-460 has a margin above the nominal 1% chance flood elevation of less than one foot (0.9 feet), compared to the margin of three feet that is a standard criterion for levee certification.

- If overtopping alone is considered without geotechnical or structural considerations, the R471-460 unit has a 67.8% chance of containing the 1% flood, still well below the 90% standard even without adding geotechnical risk factors.

- In the levee's current condition, a 0.2%-chance flood would exceed the top of levee by 2.7 feet.

- Over 10 years, the chance of overtopping or failure would be 16%; over 25 years, 36%; over 50 years, 58%.

4.1.3.2 L-455 Performance – Results of the risk analysis pertaining to the left bank unit in the context of existing or base year conditions are as follows:

- The L-455 levee would have a 93.6% chance of containing a 1% chance flood event under existing conditions, considering risk of both overtopping and failure.

- If geotechnical considerations are left aside, L-455 would have a 95% chance of containing a 1% chance overtopping event.

- The levee has a margin of 3.1 feet over the nominal 1% chance flood elevation.

- The top of levee exceeds the nominal 0.2% chance flood elevation, although only by 0.2 feet.

- Long term risk of overtopping or failure is about 2.5% over 10 years; 6% over 25 years; and 12% over 50 years.

4.1.4 Benefits of Existing Project

One additional result of the risk analysis is an estimated annual benefit for each levee. Benefits of the existing levees were determined by deleting the top of levee elevations, geotechnical probability of failure relationships, and interior-exterior stage relationships

TABLE 8 LEVEE ENGINEERING PERFORMANCE RATINGS EXISTING / BASE WITHOUT-PROJECT CONDITION						
	R471-460			L-455		
	overall	Downstream	Upstream	Overall	downstream	Upstream
Top of levee elevations						
Reference river mile		449.4	450.0		441.4	446.3
Existing (without-project) TOL		822.1	822.8		816.0	821.2
Annual Exceedance Probability						
Median (as %)	1.4%	1.4%	1.4%	0.1%	0.1%	0.1%
Expected (as %)	1.7%	1.7%	1.7%	0.1%	0.3%	0.1%
Long-Term Risk (years)						
10 years						
Exceedance probability	16.1%	16.2%	16.1%	2.5%	2.5%	1.2%
Exceedance chance over period	1 in 6.2	1 in 6.2	1 in 6.2	1 in 39.8	1 in 39.8	1 in 83.3
25 years						
Exceedance probability	35.6%	35.6%	35.6%	6.2%	6.2%	3.0%
Exceedance chance over period	1 in 2.8	1 in 2.8	1 in 2.8	1 in 16	1 in 16	1 in 38.5
50 years						
Exceedance probability	58.5%	58.6%	58.5%	12.1%	12.0%	5.9%
Exceedance chance over period	1 in 1.7	1 in 1.7	1 in 1.7	1 in 8.4	1 in 8.4	1 in 17.1
1%-chance flood event context						
Levee height superiority (feet)						
Reference flood elevation		821.2	821.9		812.9	817.5
Levee height superiority	0.9	0.9	0.9	3.1	3.1	3.7
Nonexceedance probability (as %)						
Without-project	51.3%	51.4%	51.3%	93.6%	93.6%	97.3%
Overtopping only	67.8%	67.9%	67.8%	95.0%	95.0%	97.3%
0.2%-chance flood event context						
Reference flood elevation Levee height superiority (ft.)		824.7	825.5		815.8	820.7

TABLE 9 BENEFITS OF EXISTING LEVEES			
	L-455	**R471-460**	**Total**
Annual damages without existing levee	$90,114.5	$60,404.3	$150,518.8
Annual damages with existing levee	$2,074.5	$6,378.3	$8,452.8
Benefits of existing levee	$88,040.0	$54,026.0	$142,066.1

for each levee in the HEC-FDA model and then re-running the analysis. The resulting damage total represents the amount of annual damages that would occur if no levees or other structural flood damage reduction measures existed. Taken together with the EAD from Table 6, which are essentially residual damages that continue to occur even with the levees in place, the difference is the annual benefit of each levee in its existing conditions, as summarized in Table 9.

The analysis indicated that the L-455 area would suffer equivalent annual damages of about $90.1 million if there were no levee in place. Computed EAD for L-455, from Table 7, amounts to $2.1 million, which is essentially a residual damage that continues to occur even with the existing levee in place. Therefore, the existing L-455 unit can be said to have an annual benefit of $88 million. For the R471-460 levee, equivalent annual damages of $60.4 million would occur in the absence of a levee, and EAD with the levee in place totals $6.4 million, so the annual benefit of the existing R471-460 levee is an estimated $54 million.

4.2 FUTURE WITHOUT-PROJECT CONDITION

The primary distinction between existing/base and future conditions in this study involves increases in Missouri River stages. Water surface profiles prepared for the future condition in this study reflect stage increases over existing/base year conditions for all events analyzed. Table 10 summarizes the increases for each event elevation in each study reach (except for the downstream L-455 reach, where no stage increases are slated to occur). Stages increase by up to 0.7 feet in the largest events. The stage increases, based on published historical analysis of Missouri River stages over time, are believed to be caused by the effects of sedimentation. More information on the hydraulic data and its assumptions can be found in section B-2.8 of Appendix B to this report.

A secondary distinction between base and future conditions concerns the relocation of the Missouri Air National Guard base, which is discussed in section 4.2.2.1 below.

4.2.1 Beginning Damage Frequencies and Key Flood Events

Under 2038 conditions, the beginning damage frequency for L-455 remains the 0.2%-chance event. This is because there is no stage increase from existing/base year conditions to the future year in the L-455 downstream reach. The downstream reach would overtop in a slightly smaller event than the upstream reach, so the downstream reach is the benchmark for the L-455 unit as a whole. For R471-460, the beginning frequency becomes a 2%-chance (50-year) event.

These frequencies take into account both overtopping and failure, and again, these frequencies are very approximate due to the limited number of risk analysis event outputs.

In a 1% chance flood event, 2038 damages would be expected to total $267.9 million. This is a 13.6% decrease from 2006 and 2013 conditions due to the relocation of the Air Guard base, discussed below in section 4.2.2.1. No left bank flooding would occur.

In a 0.5% chance event, 2038 damages would total $305.2 million, a decrease of about 12.5% from existing and base year conditions. Again, all of this damage would occur in the R471-460 area as there would be no flooding at L-455.

In a 0.2% chance event under 2038 conditions, flooding would occur in both units. Damages would top $1 billion, almost two-thirds of which would be sustained in the L-455 area.

TABLE 10 WATER SURFACE ELEVATIONS, EXISTING & FUTURE						
	River Mile	Frequency	Discharge	Water Surface Elevations		
				2006 & 2013	2038	Increase
L-455 downstream	441.39	50.0%	109000	802.4	802.4	0.0
	441.39	20.0%	147000	805.9	805.9	0.0
	441.39	10.0%	174000	807.9	807.9	0.0
	441.39	5.0%	199000	809.5	809.5	0.0
	441.39	2.0%	233000	811.4	811.4	0.0
	441.39	1.0%	261000	812.9	812.9	0.0
	441.39	0.5%	287000	814.1	814.1	0.0
	441.39	0.2%	324000	815.8	815.8	0.0
L-455 upstream	446.32	50.0%	109000	806.7	806.8	0.1
	446.32	20.0%	147000	810.2	810.4	0.2
	446.32	10.0%	174000	812.2	812.5	0.3
	446.32	5.0%	199000	813.9	814.3	0.3
	446.32	2.0%	233000	816.0	816.4	0.4
	446.32	1.0%	261000	817.5	818.0	0.5
	446.32	0.5%	287000	818.9	819.4	0.5
	446.32	0.2%	324000	820.7	821.3	0.6
R471-460 downstream	449.44	50.0%	109000	809.3	809.4	0.1
	449.44	20.0%	147000	813.2	813.4	0.2
	449.44	10.0%	174000	815.4	815.7	0.3
	449.44	5.0%	199000	817.2	817.6	0.4
	449.44	2.0%	233000	819.4	819.9	0.5
	449.44	1.0%	259000	821.2	821.8	0.6
	449.44	0.5%	287000	822.7	823.4	0.6
	449.44	0.2%	324000	824.7	825.5	0.7
R471-460 upstream	449.99	50.0%	109000	810.0	810.1	0.1
	449.99	20.0%	147000	813.9	814.1	0.2
	449.99	10.0%	174000	816.1	816.4	0.3
	449.99	5.0%	199000	817.9	818.3	0.4
	449.99	2.0%	233000	820.2	820.6	0.4
	449.99	1.0%	259000	821.9	822.5	0.6
	449.99	0.5%	287000	823.5	824.1	0.6
	449.99	0.2%	324000	825.5	826.2	0.7

4.2.2 Expected Annual Damages

As shown in Table 11, EAD for the total study area increases from $7.84 million in the existing and base conditions to $9.03 million in the future conditions of 2038. This is an increase of 15% which is driven by the growth in river stages from the base to the future condition.

The increase in EAD is disproportionately due to L-455, where EAD increases almost 33%. The increase in the R471-460 area is only about 10%, which is discussed in the next section. The significant increase in the L-455 area is due to the stage increases. In existing and base year conditions, the upstream L-455 does not flood in even the largest events evaluated, but by the future year, the upstream reach would flood in a 0.2%-chance event. Since this reach contains a heavy concentration of large companies and facilities with nearly $1 billion in total investment, any flooding, even in rare events, results in quickly accumulating EAD.

4.2.2.1 Effect of Air Guard Base Relocation

The difference in base and future condition EAD in the R471-460 area is the result of assumptions made for the analysis concerning the Missouri Air Guard base and their relocation schedule as well as increases in river stages. The key assumption concerning the future condition is that the Air Guard base will have been relocated to higher ground by 2038, which in itself would substantially reduce EAD for the future condition in the R471-460 upstream reach. Damages for the 1% chance event at the Air Guard base drop from $78.8 million in existing and base year conditions at the current base location to $17.2 million in the future condition following the relocation. Yet expected annual damages still show an increase. This anomaly is due to the increased stages and increased stage-discharge uncertainty factors in the future condition. The stage increases of 0.6 to 0.7 feet in the largest events in the upstream R471-460 reach prop up the annual damages even when the property inventory for the future condition is significantly reduced (i.e., by raising the Air Guard base elevation by 11 feet).

Another important assumption regarding the Air Guard base relocation and the base vs. future conditions is that the relocation to high ground will not have been completed by the base year of 2013. Since the base has such a central role in the right bank area's economy, that assumption is potentially important. We tested the assumption by alternately assuming that the relocation would be completed by the base year of 2013. Thus, both the base and future year conditions would have the Air Guard base at a site 11 feet higher than its present location. An additional run of the HEC-FDA model was executed based on this assumption, and the results showed that the assumption is considerably less critical to the analysis than expected. EAD for the R471-460 area were reduced only by about 5.8% despite the large drop in primary or single event damages due to the base relocation.

TABLE 11 EXPECTED ANNUAL DAMAGES FUTURE WITHOUT-PROJECT CONDITION				
Damage in $1,000's; Oct. 2005 prices				
	2013	**2038**	**% Change**	**Equiv Ann Dmg**
L-455				
Downstream				
Residential	$101.5	$109.3	7.7%	$105.5
Non-Residential	$1,078.8	$1,159.5	7.5%	$1,120.6
Roads	$40.5	$44.7	10.4%	$42.7
Crops	$2.3	$2.4	6.1%	$2.4
Total	$1,223.1	$1,315.9	7.6%	$1,271.1
Upstream				
Residential	$2.3	$5.1	120.3%	$3.8
Non-Residential	$542.5	$1,022.9	88.6%	$790.9
Roads	$5.9	$11.5	94.2%	$8.8
Crops	$0.0	$0.0	0.0%	$0.0
Total	$550.7	$1,039.4	88.7%	$803.4
L-455 TOTAL	**$1,773.8**	**$2,355.3**	**32.8%**	**$2,074.5**
R471-460				
Downstream				
Residential	$738.4	$919.1	24.5%	$831.9
Non-Residential	$2,726.0	$3,415.8	25.3%	$3,082.7
Roads	$232.8	$294.2	26.3%	$264.5
Crops	$5.1	$6.0	19.6%	$5.6
Total	$3,702.3	$4,635.1	25.2%	$4,184.6
Upstream				
Residential	$20.5	$34.6	68.2%	$27.8
Non-Residential	$2,319.3	$1,964.1	-15.3%	$2,135.6
Roads	$4.3	$7.4	71.0%	$5.9
Crops	$18.2	$30.0	64.4%	$24.3
Total	$2,362.4	$2,036.0	-13.8%	$2,193.6
R471-460 TOTAL	**$6,064.7**	**$6,671.1**	**10.0%**	**$6,378.3**
STUDY AREA TOTAL	**$7,838.5**	**$9,026.5**	**15.2%**	**$8,452.8**

4.2.3 Nonexceedance Probabilities for Future Condition

The engineering performance of both levees is reduced in the future condition because of the increased stages in the 2038 condition (see Table 10). Under 2038 conditions, the R471-460 unit's chance of containing a 1% flood event drops from 51.3% to 41.8%, and the levee has a mere 0.3 feet of margin above the 1% event. If only overtopping events are considered, the nonexceedance probability would be 56.6%. The L-455 levee has a nonexceedance probability

of 92.8%, down from the 2013 estimate of 93.6%. Engineering performance statistics for both levees in the future without-project condition are summarized in Table 12.

4.2.4 Other Impacts

It is considered likely that the Missouri Air Guard base would be relocated from the St. Joseph area if the flood threat and subsequent levee decertification becomes protracted. This loss would significantly harm the St. Joseph area in general and would be a severe impact in the Elwood area. St. Joseph could be forced to relocate their main airport if another major flood occurred. The right bank area in general would be faced with difficulties in attracting new businesses and maintaining their existing economic base.

TABLE 12
LEVEE ENGINEERING PERFORMANCE RATINGS
FUTURE WITHOUT-PROJECT CONDITION (2038)

	R471-460			L-455		
	overall	downstream	Upstream	overall	downstream	upstream
Top of levee elevations						
Reference river mile		449.4	450.0		441.4	446.3
Existing (without-project) TOL		822.1	822.8		816.0	821.2
Annual Exceedance Probability						
Median (%)	1.70%	1.70%	1.70%	0.10%	0.10%	0.20%
Expected (%)	2.10%	2.10%	2.10%	0.30%	0.30%	0.30%
Long-Term Risk (years)						
10 years	19.38%	19.38%	19.03%	2.68%	2.68%	2.51%
25 years	41.64%	41.64%	41.01%	6.56%	6.56%	6.15%
50 years	65.94%	65.94%	65.20%	12.69%	12.69%	11.92%
1%-chance flood event context						
Levee height superiority (feet)						
Reference flood elevation		821.8	822.5		812.9	818.0
Without-project	0.3	0.3	0.4	3.1	3.1	3.7
Nonexceedance probability (as %)						
Without-project	41.8%	41.8%	42.9%	92.8%	92.8%	94.0%
Overtopping only	56.6%	56.6%	57.6%	94.0%	94.1%	94.0%
0.2%-chance flood event context						
Levee height superiority (feet)						
Reference flood elevation		825.5	826.2		815.8	821.3
Without-project	-3.4	-3.4	-3.4	0.2	0.2	0.6

5.0 ALTERNATIVES SCREENING ANALYSIS

5.1 ALTERNATIVES EVALUATED

This study presents a relatively narrow range within which it is possible to formulate alternatives that are potentially feasible in terms of economics and engineering. The two levee units on the ground right now, in their existing conditions, represent a floor or minimum for the formulation of any range of alternatives. Even in the less than satisfactory conditions characterizing the R471-460 levee currently, these levees still offer considerable existing protection which serves to truncate most of the lower range in which alternatives normally could be formulated. This lower range is truncated even more by the fact that some smaller raises apparently would not even be technically feasible and would present extremely high costs while yielding small benefit totals.

On the other hand, formulation of larger-scaled alternatives also is limited by the prospects of sharp cost increases as well as induced stage increases and damages. Hydraulic data developed for this study indicated that new construction would begin to produce a significant increase in induced stages at almost 4 feet above the nominal 1%-chance flood elevation, while another flex point would be reached at 5 feet. In formulating the larger alternatives, we were mindful of these considerations as well as the expressed views of our non-Federal sponsors, who are mainly interested in regaining levee certification for R471-460 as well as heading off any comparable potential concerns for the L-455 levee. The local sponsors indicated their interest in a plan no larger in scale than needed to regain or maintain certification, and they also indicated that even if a larger plan emerged as the NED plan, they would exercise their right to choose the smaller plan that met their objectives.

A number of theoretical alternatives were proposed but screened out prior to economic analysis; see the main report for more details. Four alternatives ultimately were evaluated in the economic screening analysis. All are different scales of levee raises focused on the decertified R471-460 unit, and the alternatives include any L-455 raises necessary to avoid induced damages on the left bank. All differ only in scale and protect essentially the same land and properties as most of the floodplain in the study area is clearly delineated by marked increases in elevation.

The raises required for each alternative are described below in terms of the raise required at the economic index points. The exact amount of the raise will vary along different sections of the levee.

- Alternative 1 is a levee raise of about 2 and 2/3 feet for the R471-460 unit, bringing it up to a level 3 feet above the nominal 1%-chance flood elevation. (This elevation is essentially identical to the 0.2%-chance flood elevation, negating any need to formulate an additional alternative accounting for that scale.) No raise would be required at the economic index point for the L-455 unit in this alternative, although minor raises of less than one foot would be implemented at certain levee stations in order to offset small anticipated increases in water surface profiles for extreme events due to the R471-460 work

- Alternative 2 is a levee raise bringing R471-460 up to an elevation 1.5 feet above the nominal 0.2%-chance flood, requiring a raise of almost 5 feet. L-455 would be raised approximately 1.5 feet.

- Alternative 3, the largest in scale of the alternatives, raises R471-460 about 6.5 feet, with a 3 foot raise for L-455. The raise would bring the top of levee elevations to about 3 feet above the nominal 0.2%-chance flood.

- Alternative 4, the smallest alternative, raises R471-460 to a level 1.5 feet above the nominal 1%-chance flood elevation. A raise of about 1.1 feet is required. L-455 would not be modified in any way under this alternative.

5.2 ECONOMIC SCREENING PROCESS

5.2.1 Screening Costs

Screening-level costs were obtained for the four alternatives. Interest during construction (IDC) was computed for these costs assuming a design and construction period ending in mid-2012. Costs including IDC were then annualized over a 50-year period of analysis. The current FY 06 Federal interest rage of 5.125% is used in the computations, which are summarized in Table 13.

First costs range from $18.9 million for the smallest alternative (Alternative 4), to $30.8 million for Alternative 1, to $94.1 million and $124.0 million for Alternatives 2 and 3. These are broken down in Table 13 by preconstruction engineering and design (PED) costs, real estate costs, and construction and construction management (S & A) costs. IDC also is shown.

OMRR&R costs are not included in this analysis due to a determination by geotechnical and operations staff that no additional such costs over and above present levels would be incurred for any of the alternatives under consideration; i.e., OMRR&R costs associated with any of the alternatives would continue at the current levels. Even if new OMRR&R costs did exist, they would be on far too small a scale to affect economic justification and would not differ enough among alternatives to affect the rankings from this analysis.

5.2.2 Optimization of Alternatives

Each alternative was entered into the HEC-FDA risk analysis model. The Monte Carlo analysis in HEC-FDA was then employed to determine residual damages – i.e., damages that would continue to occur in the with-project condition even with implementation of that alternative – and damages prevented for each alternative.

NED (National Economic Development) analysis involves computation of benefits and costs and subsequent identification of the most economically efficient plan. Economic efficiency is defined in terms of net annual benefits (annual benefits minus annual costs) added to the national economy by the project. The NED optimization process for the four alternatives emphasizes a "systems" approach that focuses primarily on the combined benefits and costs for the two levee units rather than their individual outputs. The NED plan in the systems approach would be the

TABLE 13 NED SCREENING COSTS FOR ALTERNATIVES								
October 2005 prices; 5.125% interest rate In $1,000s Note: no annual O&M costs are added since none of the alternatives would produce additional O&M costs beyond existing without-project levels.								
ALTERNATIVE	**FIRST COSTS**	**FIRST COSTS BREAKDOWN**				**ANNUAL COSTS BREAKDOWN**		
		PED	**LERRD**	**Constr.**	**S & A**	**IDC**	**Economic Costs**	**Annual Costs (subtotal)**
ALTERNATIVE 4 – R471 RAISE TO 1% EVENT + 1.5 FT.								
L455	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
R471	$18,917.6	$1,395.8	$3,012.1	$13,603.8	$905.9	$1,982.9	$20,900.5	$1,167.0
Total	**$18,917.6**					$1,982.9	$20,900.5	$1,167.0
ALTERNATIVE 1 – R471 RAISE TO 1% EVENT + 3 FT.								
L455	$3,051.9	$244.2	$207.5	$2,441.7	$158.5	$300.1	$3,352.0	$187.2
R471	$27,793.7	$2,151.6	$3,083.8	$21,161.9	$1,396.4	$2,819.4	$30,613.1	$1,709.4
Total	**$30,845.6**					$3,119.5	$33,965.1	$1,896.6
ALTERNATIVE 2 – R471 RAISE TO 0.2% EVENT + 1.5 FT.								
L455	$44,389.9	$3,663.7	$2,093.5	$36,254.9	$2,377.8	$4,307.5	$48,697.4	$2,719.2
R471	$49,742.9	$4,002.3	$3,677.9	$39,465.2	$2,597.5	$4,919.5	$54,662.4	$3,052.2
Total	**$94,132.8**					$9,227.0	$103,359.8	$5,771.4
ALTERNATIVE 3 – R471 RAISE TO 0.2% EVENT + 3 T.								
L455	$58,929.0	$4,886.8	$2,385.4	$48,485.3	$3,171.5	$5,689.7	$64,618.7	$3,608.2
R471	$65,075.0	$5,315.5	$3,712.2	$52,597.5	$3,449.8	$5,798.0	$70,873.0	$3,957.4
Total	**$124,004.0**					$11,487.7	$135,491.7	$7,565.6

alternative with the highest combined net benefits for the two levee units. However, the benefit-cost analysis also is presented for each unit individually within each alternative, and the eventual NED plan would be expected to show economic feasibility (i.e., a benefit-cost ratio of at least 1) for each unit as well as the highest net benefits for the two units combined.

Benefits estimated in the screening process do not account for any damages induced by the alternatives. Hydraulic impacts of the alternatives were quantified, but economic impacts were not since it was clear that the stage increases involved would have had no significant effect on the NED plan selection or economic justification. Increased stages across the river at L-455 that would be induced by the R471-460 raises are accommodated by corresponding improvements to the L-455 levee in each alternative (except Alternative 4). Stage increases downstream of the project area would primarily affect agricultural land uses and would occur only in the largest flood events. These factors combined would necessarily result in annualized induced damages that would be more than zero but could only be extremely minimal if quantified. Moreover, the alternatives that would cause the most significant downstream impacts would be the two largest alternatives. These alternatives are the third and fourth ranking alternatives in the NED analysis, and if induced damages were quantified and subtracted from their benefits, it would

serve only to make these alternatives even less economically efficient and thereby reinforce the existing ranking of alternatives.

Screening benefits are based on physical inundation reduction and do not include other benefits such as reduced emergency costs, emergency assistance, or flood insurance administration savings. These categories were not estimated for the screening analysis because we judged that they would not impact the net benefit rankings, but they will be added to the NED plan for the final project benefit-cost ratio. Thus, the benefits for the NED plan in this section will not match those for the NED plan in section 6.

5.3 SCREENING RESULTS

Residual damages for each alternative are detailed by category and study reach in Table 14. The residual damages that would continue to occur in the with-project condition are expressed as equivalent annual damages that account for both the base year condition and the discounted present-worth of the future year condition. The difference between the without-condition EAD and the residual EAD for each alternative represents the benefits for the alternative.

The resulting benefits and benefit-cost results for the screening are summarized in Table 15, while Table 16 summarizes engineering performance data for without and with-project conditions. Four main results emerged from the risk-based screening analysis:

- The NED plan - the plan with the greatest net benefits - is Alternative 1, which consists of a raise of the R471-460 unit to 3 feet above the 1%-chance flood elevation. This plan has estimated net benefits of $4.11 million and a benefit-cost ratio of 3.2.

- The NED plan has a margin of superiority of 15% in net benefits over the second-ranking alternative, Alternative 4. Alternative 4, the smallest alternative, has net benefits of $3.58 million. The NED plan has an 89% margin of superiority over Alternative 2 and a 391% margin over Alternative 3. These are the two largest alternatives. Therefore, Alternative 1, as the NED plan, is bracketed by both smaller and larger-scaled alternatives over which the NED plan has clear superiority in economic efficiency. See Figure 2 for a graphical summary of the net benefits by alternative.

- All alternatives are economically justified. Benefit-cost ratios are strong for Alternatives 1 (3.2) and 4 (4.1), while the justification for Alternatives 2 and 3 would be more marginal with benefit-cost ratios of 1.4 and 1.1 respectively.

- Benefit-cost ratios for R471-460 by itself would be at least fairly strong in all four alternatives. In contrast, Alternative 1 is the only alternative that produces positive net benefits for the L-455 unit by itself.

TABLE 14 EQUIVALENT ANNUAL DAMAGES BY ALTERNATIVE					
Damages shown for alternatives are residual damages that continue to occur with the alternative in place. Damage in $1,000's; Oct. 2005 prices					
	WITHOUT CONDITION	**ALT 4 RESIDUAL**	**ALT 1 RESIDUAL**	**ALT 2 RESIDUAL**	**ALT 3 RESIDUAL**
L-455 Downstream					
Residential	$105.5	$105.5	$71.0	$17.8	$1.7
Non-Residential	$1,120.6	$1,120.6	$749.8	$183.0	$16.8
Roads	$42.7	$42.7	$29.4	$8.1	$0.8
Crops	$2.4	$2.4	$1.6	$0.4	$0.0
Total	$1,271.1	$1,271.1	$851.7	$209.3	$19.4
L-455 Upstream					
Residential	$3.8	$3.8	$3.8	$1.6	$0.3
Non-Residential	$790.9	$790.9	$790.9	$181.8	$19.1
Roads	$8.8	$8.8	$8.8	$2.3	$0.3
Crops	$0.0	$0.0	$0.0	$0.0	$0.0
Total	$803.4	$803.4	$803.4	$185.6	$19.7
L-455 TOTAL	**$2,074.5**	**$1,655.1**	**$1,655.1**	**$394.9**	**$39.0**
R471-460 Downstream					
Downstream					
Residential	$831.9	$202.3	$99.4	$14.2	$1.4
Non-Residential	$3,082.7	$764.7	$385.9	$56.5	$5.7
Roads	$264.5	$67.6	$34.6	$5.6	$0.6
Crops	$5.6	$1.1	$0.5	$0.1	$0.0
Total	$4,184.6	$1,035.6	$520.3	$76.3	$7.8
R471-460 Upstream					
Residential	$27.8	$8.3	$4.2	$0.6	$0.1
Non-Residential	$2,135.6	$577.3	$260.0	$31.2	$3.3
Roads	$5.9	$2.0	$1.0	$0.2	$0.0
Crops	$24.3	$6.2	$2.8	$0.3	$0.0
Total	$2,193.6	$593.8	$268.1	$32.3	$3.4
R471-460 TOTAL	**$6,378.3**	**$1,629.3**	**$788.5**	**$108.6**	**$11.1**
STUDY AREA TOTAL	**$8,452.8**	**$3,284.4**	**$2,443.6**	**$503.4**	**$50.2**

TABLE 15
NED SCREENING BENEFIT-COST DATA FOR ALTERNATIVES

October 2005 prices; 5.125% interest rate
In thousands of dollars

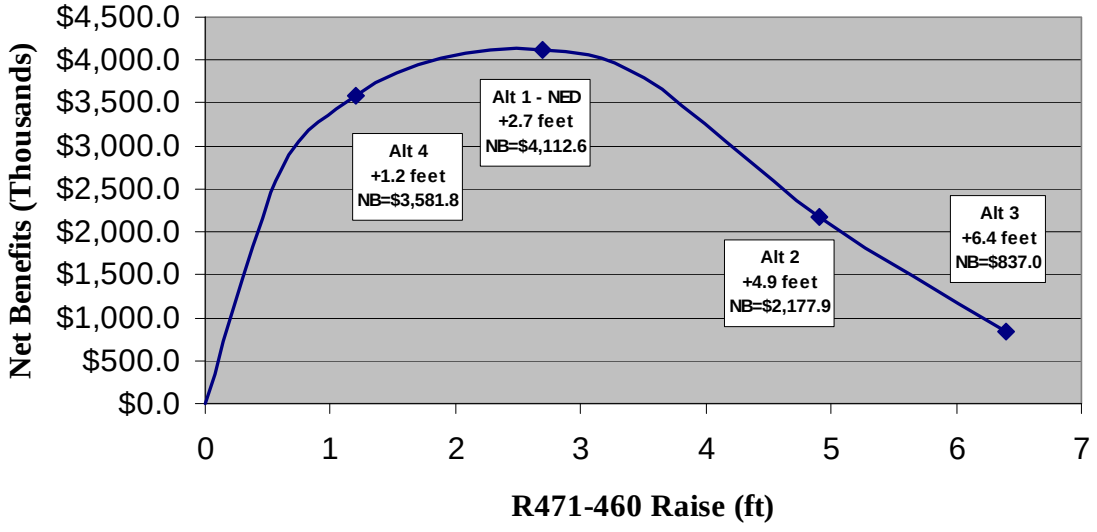
Alternative	First cost	Total annual costs	Total annual damages	Residual annual damage	Total benefits	BCR	Net benefits	Superiority of NED plan
ALTERNATIVE 4 – R471 RAISE TO 1% EVENT + 1.5 FT.								
L455								
Reach 1			$1,271.1	$1,271.1				
Reach 2			$803.4	$803.4				
Total L455	$0.0	$0.0	$2,074.5	$2,074.5	$0.0	0.0	$0.0	
R471								
Reach 1			$4,184.6	$1,035.6				
Reach 2			$2,193.6	$593.8				
Total R471	$18,917.6	$1,167.0	$6,378.3	$1,629.4	$4,748.9	4.1	$3,581.9	
Total	**$18,917.6**	**$1,167.0**	**$8,452.8**	**$3,703.9**	**$4,748.8**	**4.1**	**$3,581.8**	14.8%
ALTERNATIVE 1 – R471 RAISE TO 1% EVENT + 3 FT.								
L455								
Reach 1			$1,271.1	$851.7				
Reach 2			$803.4	$803.4				
Total L455	$3,051.9	$187.2	$2,074.5	$1,655.1	$419.4	2.2	$232.2	
R471								
Reach 1			$4,184.6	$520.3				
Reach 2			$2,193.6	$268.1				
Total R471	$27,793.7	$1,709.4	$6,378.3	$788.4	$5,589.8	3.3	$3,880.4	
Total	**$30,845.6**	**$1,896.6**	**$8,452.8**	**$2,443.5**	**$6,009.2**	**3.2**	**$4,112.6**	*NED*
ALTERNATIVE 2 – R471 RAISE TO 0.2% EVENT + 1.5 FT.								
L455								
Reach 1			$1,271.1	$209.3				
Reach 2			$803.4	$185.6				
Total L455	$44,389.9	$2,719.2	$2,074.5	$394.8	$1,679.6	0.6	$1,039.6	
R471								
Reach 1			$4,184.6	$76.3				
Reach 2			$2,193.6	$32.2				
Total R471	$49,742.9	$3,052.2	$6,378.3	$108.6	$6,269.7	2.1	$3,217.5	
Total	**$94,132.8**	**$5,771.4**	**$8,452.8**	**$503.4**	**$7,949.3**	**1.4**	**$2,177.9**	88.8%
ALTERNATIVE 3 – R471 RAISE TO 0.2% EVENT + 3 FT.								
L455								
Reach 1			$1,271.1	$19.4				
Reach 2			$803.4	$19.7				
Total L455	$58,929.0	$3,608.2	$2,074.5	$39.0	$2,035.5	0.6	$1,572.7	
R471								
Reach 1			$4,184.6	$7.8				
Reach 2			$2,193.6	$3.4				
Total R471	$65,075.0	$3,957.4	$6,378.3	$11.1	$6,367.1	1.6	$2,409.7	391.3%
Total	**$124,004.0**	**$7,565.6**	**$8,452.8**	**$50.1**	**$8,402.6**	**1.1**	**$837.0**	

TABLE 16 LEVEE ENGINEERING PERFORMANCE - WITHOUT PROJECT AND ALTERNATIVES						
	R471-460			L-455		
	OVERALL	downstream	upstream	OVERALL	downstream	upstream
Top of levee elevations						
ref. river mile		449.4	450.0		441.4	446.3
Existing (without-project) TOL		822.1	822.8		816.0	821.2
Alternative 4 TOL (1% + 1.5 ft.)		823.3	824.0		816.0	821.2
Raise required (feet)		1.2	1.1		0.0	0.0
Alternative 1 TOL (1%t + 3 ft.)		824.8	825.5		816.0	821.2
Raise required (feet)		2.7	2.6		0.0	0.0
Alternative 2 TOL (0.2% + 1.5 ft.)		827.0	827.7		817.3	822.8
Raise required (feet)		4.9	4.9		1.3	1.5
Alternative 3 TOL (0.2% + 3 ft.)		828.5	829.2		818.8	824.3
Raise required (feet)		6.4	6.4		2.8	3.0
1%-chance flood context						
Levee height superiority (feet)						
2013 ref. flood elevation		821.2	821.9		812.9	817.5
2013 without-project	0.9	0.9	0.9	3.1	3.1	3.7
2013 Alternative 4	1.1	1.2	1.1	0.0	0.0	0.0
2013 Alternative 1	3.6	3.6	3.6	3.1	3.1	3.7
2013 Alternative 2	5.8	5.8	5.8	4.4	4.4	5.3
2013 Alternative 3	7.3	7.3	7.3	5.9	5.9	6.8
2038 ref. flood elevation		821.8	822.5		812.9	818.0
2038 without-project	0.3	0.3	0.4	3.1	3.1	3.2
2038 Alternative 4	1.5	1.5	1.5	3.1	3.1	3.2
2038 Alternative 1	3.0	3.0	3.0	3.1	3.1	3.2
2038 Alternative 2	5.2	5.2	5.3	4.4	4.4	4.8
2038 Alternative 3	6.7	6.7	6.8	5.9	5.9	6.3
Nonexceedance probability						
2013 without-project	51.3%	51.4%	51.3%	93.6%	93.6%	97.3%
2013 overtopping only	67.8%	67.9%	67.8%	95.0%	95.0%	97.3%
2013 Alternative 4	84.3%	85.1%	84.3%	93.6%	93.6%	97.3%
2013 Alternative 1	95.8%	96.2%	95.8%	95.0%	95.0%	97.3%
2013 Alternative 2	99.8%	99.9%	99.8%	99.2%	99.2%	99.7%
2013 Alternative 3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2038 without-project	41.8%	41.8%	42.9%	92.8%	92.8%	94.0%
2038 overtopping only	56.6%	56.6%	57.6%	94.0%	94.1%	94.0%
2038 Alternative 4	75.7%	75.9%	75.7%	92.8%	92.8%	94.0%
2038 Alternative 1	91.6%	91.7%	91.6%	94.0%	94.1%	94.0%
2038 Alternative 2	99.3%	99.3%	99.3%	98.9%	98.9%	99.0%
2038 Alternative 3	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%

(Table continued on next page)

TABLE 16 (continued) LEVEE ENGINEERING PERFORMANCE - WITHOUT PROJECT AND ALTERNATIVES						
	R471-460			L-455		
0.2%-chance flood context	OVERALL	downstream	upstream	OVERALL	downstream	upstream
Levee height superiority (feet)						
2013 ref. flood elevation		824.7	825.5		815.8	820.7
2013 without-project	-2.7	-2.7	-2.7	0.2	0.2	0.6
2013 Alternative 4	-1.6	-1.5	-1.6	0.2	0.2	0.6
2013 Alternative 1	-0.1	0.0	-0.1	0.2	0.2	0.6
2013 Alternative 2	2.2	2.2	2.2	1.5	1.5	2.1
2013 Alternative 3	3.7	3.7	3.7	3.0	3.0	3.6
2038 ref. flood elevation		825.5	826.2		815.8	821.3
2038 without-project	-3.4	-3.4	-3.4	0.0	0.2	0.0
2038 Alternative 4	-2.6	-2.5	-2.6	-3.6	-3.0	-3.6
2038 Alternative 1	-0.8	-0.7	-0.8	0.0	0.2	0.0
2038 Alternative 2	1.5	1.5	1.5	1.5	1.5	1.5
2038 Alternative 3	3.0	3.0	3.0	3.0	3.0	3.0

FIGURE 2
NET BENEFITS FOR ALTERNATIVES



6.0 NED PLAN

6.1 PLAN DESCRIPTION

The NED plan emerging from the economic screening is Alternative 1. The plan raises the R471-460 levee to an elevation 3 feet above the nominal 1% chance flood elevation. A raise of about 2.6 feet would be required at the economic index point, and the raise required at other points along the levee would be up to 3.4 feet. Seven structures would be modified or replaced. Modifications also would be made to the L-455 levee at certain stations in order to offset small increases in water surface profiles for the most extreme events resulting from the R471-460 construction. The first cost of the NED plan is $32,685,700 in October 2005 prices.

6.2 DAMAGE REDUCTION

By far the largest portion of NED annual benefits is based on prevention of flood damages to homes, businesses and facilities, roads, and crops. The HEC-FDA model credits the NED plan with $6,009,300 in annual benefits based on damage reduction. This total includes $5,589,900 in damages reduced by the R471-460 unit, or 93% of the damage reduction by the total project, and an additional $419,400 in damages reduced by the L-455 unit.

A more probabilistic assessment of damage reduction by the NED plan is shown in Table 17. The most likely value of damages reduced as produced by the risk analysis is $6,009,300. There is a 75% probability that the true benefits exceed $2,470,000, a 50% probability that they exceed $4,550,000, and a 25% probability that they exceed $7,576,000.

TABLE 17
DAMAGE REDUCED BY NED PLAN

Damage in $1,000's

Unit / Damage Reach	Total Without Project	Total With Project	Damage Reduced	Probability Damage Reduced Exceeds Indicated Values		
				0.75	0.50	0.25
L-455						
Left Bank - Downstream	$1,271.1	$851.7	$419.4	$57.6	$70.4	$251.1
Left Bank - Upstream	$803.4	$803.4	$0.0	$0.0	$0.0	$0.0
L-455 Total	$2,074.5	$1,655.1	**$419.4**	$57.6	$70.4	$251.1
R471-460						
Right Bank - Downstream	$4,184.6	$520.3	$3,664.3	$1,572.5	$2,932.3	$4,811.5
Right Bank - Upstream	$2,193.6	$268.1	$1,925.5	$840.0	$1,547.4	$2,513.6
R471-460 Total	$6,378.3	$788.4	**$5,589.8**	$2,412.4	$4,479.7	$7,325.1
Total	$8,452.8	$2,443.5	**$6,009.2**	$2,470.1	$4,550.1	$7,576.2

6.3 OTHER BENEFIT CATEGORIES

Although reduction of physical inundation damages is the main source of benefits for the alternatives analyzed, a number of much smaller benefit categories also exist. These categories of benefits were not large enough to influence plan selection, so they were computed only for the NED plan. The computations were done outside the risk program and are not risk-based as are the damage reduction benefits.

The additional benefit categories considered significant enough to quantify in the context of this study include emergency costs reduced, relocation and reoccupation costs reduced, and flood insurance administrative cost savings. Advance replacement benefits for structures that would be replaced for the project were considered but were not included because there are very few such structures in this analysis.

6.3.1 Emergency Cost Savings

Emergency cost savings can encompass savings related to a wide range of flooding impacts, including emergency personnel costs, floodfighting 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 cities of St. Joseph, Elwood, and Wathena were contacted to obtain available historical data on emergency costs incurred during the 1993 flood. This is the only flood event that has occurred recently enough to provide useful information since the last previous flood was in 1952. Although the cities provided some anecdotal information on their 1993 costs, we were unable to obtain enough reliable data to estimate this category of impacts based on direct or first-hand data. Yet emergency floodfighting 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 flood in order to estimate typical emergency costs for a large flood (the 1993 event was approximately a 0.2%-chance event) in an urban setting. 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 an informal analysis 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 assume that emergency costs are equivalent to 9% of flood damage reduction benefits for the NED plan. This is a somewhat more

conservative assumption than the 13.4% gleaned from the 1993 post-flood reports. Based on EAD reduced in the two protected areas, annual emergency cost savings due to the NED plan are estimated to total $503,100 for R471-460 and $37,700 for L-455.

6.3.2 Relocation and Reoccupation Cost Savings

The Kansas City District obtained data from the Region VII FEMA office regarding typical costs for disaster housing assistance and grant assistance to individuals and families following recent Missouri floods, including the great 1993 Missouri River flood. The data indicated that these types of emergency assistance average about $7,500 per home. We used the estimated number of homes affected in the 1%, 0.5%, and 0.2-chance events (see Table 6) to calculate costs associated with each of these events and then annualize the results. Relocation and reoccupation cost savings total $61,300 for R471-460 and $16,700 for L-455.

6.3.3 Flood Insurance Administrative Cost Savings

When a levee provides sufficient protection against a 1%-chance flood event to be certified by FEMA, that action removes vulnerable structures from the putative "100-year" floodplain and allows occupants holding flood insurance policies to give them up. The estimated savings per policy in administrative costs when a policy is not renewed is $192 per policy in current Corps guidance. Approximately 40 occupants of the floodplain in the R471-460 area hold current flood insurance policies and would have the option of discontinuing them, which would result in an annual benefit of $7,700 for the NED plan. This benefit is applied to the R471-460 portion of the NED plan.

6.4 BENEFITS AND COSTS

As summarized in Table 18, the NED plan shows strong economic justification with a benefit-cost ratio of 3.3 and net benefits of $4,626,900. The annualized cost of the plan is $2,008,900, based on the first cost of $32,685,700. Annual benefits total $6,635,800, of which about 90.6% are based on physical flood damage reduction. (Note that these totals will not match the benefit and cost totals for the NED plan as computed in the screening process and displayed in Table 15. The screening estimate of benefits did not include benefits discussed above in section 6.3, and the estimated first costs of the project were revised for the final benefit-cost estimates.)

Table 18 also shows that, if the project is evaluated as two elements (i.e., R471-460 vs. L-455), both portions are economically justified. For R471-460, the first cost of the selected plan is $29,633,400 and the annual cost is $1,821,700. Benefits total $6,162,000. The resulting benefit-cost ratio is 3.4 and net benefits total $4,343,300. For the L-455 project, first costs of $3,052,300 result in annual costs of $187,200, which, when set against the annual benefits of $473,800, result in a benefit-cost ratio of 2.5 and net benefits of $286,600. It can be seen from these breakouts that there is strong economic justification for each portion of the project as well as for the total project.

TABLE 18 BENEFIT-COST RATIO FOR NED PLAN			
In $1,000s; Oct. 2005 prices Equivalent annual damages			
	PROJECT	**R471-460**	**L-455**
BENEFITS			
EAD without-project	$8,452.8	$6,378.3	$2,074.5
EAD with project (residual)	$2,443.5	$788.4	$1,655.1
EAD reduced	$6,009.3	$5,589.9	$419.4
Emergency cost savings	$540.8	$503.1	$37.7
Relocation and reoccupation cost savings	$78.0	$61.3	$16.7
Flood insurance administrative cost savings	$7.7	$7.7	$0.0
TOTAL ANNUAL BENEFITS	**$6,635.8**	**$6,162.0**	**$473.8**
% by unit		92.9%	7.1%
COSTS			
First cost	$32,685.7	$29,633.4	$3,052.3
IDC	$3,291.9	$2,991.8	$300.1
Economic cost	$35,977.6	$32,625.2	$3,352.4
Interest & amortization factor	0.05584	0.05584	0.05584
Annual cost	$2,008.9	$1,821.7	$187.2
Annual O & M costs	$0.0	$0.0	$0.0
TOTAL ANNUAL COSTS	**$2,008.9**	**$1,821.7**	**$187.2**
% by unit		90.1%	9.9%
BENEFIT-COST RATIO	**3.3**	**3.4**	**2.5**
NET BENEFITS	**$4,626.9**	**$4,340.3**	**$286.6**
% by unit		94.0%	6.0%

6.5 ENGINEERING PERFORMANCE

The NED plan would restore a margin of at least 3 feet above the nominal 1% chance flood elevation for both levee units. Under future conditions of 2038, the nonexceedance probability for R471-460 would rise to 91.6% compared to its nonexceedance probability of 51.3% under existing condition without project. The R471-460 unit would have a 1 in 30.1 chance of overtopping or failing over a 10-year period, and a 1 in 6.4 chance over a 50-year period. The L-455 unit would have a 1 in 39.8 chance of overtopping or failing over a 10-year period and a 1 in 8.4 chance over 50 years. See Table 19 for statistics describing various aspects of the engineering performance of the NED plan.

6.6 INDUCED DAMAGES

Hydraulic investigations for this study concluded that the project is not expected to have any significant impact in terms of raising water surface profiles. The water surface profile for the

1%-chance event is not affected by the project. The profiles for events larger than the 1%-chance event would be somewhat increased downstream of the project area as well as across the river at the L-455 area. The purpose of the L-455 portion of the project is to offset the increases at that location. However, as discussed above, the L-455 portion of the project is economically justified on its own independent terms - i.e., it is justified by the damages it would prevent within the L-455 area under without-project conditions, even without additional consideration of its efficacy in alleviating incremental damage potential contributed by the project. Downstream economic damages were not quantified for this analysis but would necessarily be minimal since the increased stages occur only in the most infrequent events and affect downstream areas with primarily agricultural impacts. Although minimal, the induced damages, if quantified, would be greater than zero and would serve to slightly reduce the estimated annual benefits for the project. Economic justification would not be affected.

6.7 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. These regional (RED) impacts are not included in determining the NED benefits and costs, but do receive consideration in the decision-making process.

Construction of the selected plan would contribute to the long-term stability of both the R471-460 and L-455 areas. Plans considered do not require acquisition or relocation of residents or businesses. There would be no impacts to the local tax bases due to demolition or removal of structures. With increased levee unit reliability and performance, existing businesses 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. 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. Temporary increases in employment would be expected during construction. The temporary presence of construction workers for the project could bring a temporary increase in demand for some services in the local area, but also a temporary increase in business volume, profits and sales tax receipts at the local retail and service establishments.

During the later stages of this study, a massive new pork processing facility was constructed and opened in the St. Joseph stockyards area. There has not been an opportunity to assess the likely consequences of prolonged business interruption regarding this very new business, but it will be one of the largest such plants in the U.S. and at least some business losses during flood events could be NED losses. These losses could be significant in relation to the overall benefits of the project.

6.8 RESIDUAL RISK

Although floodplain users and occupants may desire total protection from flooding, this is an unachievable goal. No flood damage reduction project can guarantee total elimination of flooding. The selected plan has substantial economic benefits and reduces equivalent annual damages in the study area by about 71% over without project conditions. But this means that there remains a significant residual equivalent annual damage in excess of $2.4 million. There still would be a 10% to 16% chance of exceedance over a 50-year period under 2038 conditions (see Table 19).

With any flood damage reduction project, it is important for floodplain users and occupants to be aware of the level of flood risk that remains even after implementation of a recommended project (see Table 19). The probability and occurrence of flooding will be much less frequent with the implementation of the recommended plan in the study area However, during major flood events, residents and other floodplain occupants may still be ordered to evacuate and move to higher ground. And in rare large events, the Federal levees could be overwhelmed, resulting in flood depths inside the levied areas could reach 20 feet. Because the areas within the levee units are relatively flat, most of the study area could be affected. It has been said that a flood damage reduction project designed relative to a 1%-chance flood event (the event that is critical to certification criteria) is an especially dangerous project, in that an event of historical magnitude is not necessarily required to overwhelm the project and cause catastrophic damage, yet many floodplain tenants will feel that they have near-total protection against flooding and give up their flood insurance policies. They might find it advantageous to keep their policies, which usually are fairly inexpensive in areas with certified levees. Meanwhile, local leadership and emergency operations staff will need to design plans for these flood events which may be infrequent, but would hold the potential for catastrophe if they occurred. Effective emergency planning in advance is the best way to protect communities and minimize the damage from these rare flood events.

TABLE 19 ENGINEERING PERFORMANCE RATINGS FOR NED PLAN						
For future conditions (2038)						
	R471-460			L-455		
	OVERALL	downstream	upstream	OVERALL	downstream	upstream
Top of levee elevations						
Reference river mile		449.4	450.0		441.4	446.3
New TOL		824.8	825.5		816.0	821.2
Annual Exceedance Probability						
Median (as %)	0.30%	0.30%	0.30%	0.10%	0.10%	0.20%
Expected (as %)	0.30%	0.30%	0.30%	0.20%	0.20%	0.30%
Long-Term Risk (years)						
10 years						
Exceedance probability	3.32%	3.14%	3.32%	2.51%	2.26%	2.51%
Exceedance chance over period	1 in 30.1	1 in 31.9	1 in 30.1	1 in 39.8	1 in 44.3	1 in 39.8
25 years						
Exceedance probability	8.09%	7.67%	8.09%	6.15%	5.55%	6.15%
Exceedance chance over period	1 in 12.4	1 in 13.0	1 in 12.4	1 in 16.2	1 in 18.0	1 in 16.2
50 years						
Exceedance probability	15.53%	14.75%	15.53%	11.92%	10.80%	11.92%
Exceedance chance over period	1 in 6.4	1 in 6.8	1 in 6.4	1 in 8.4	1 in 9.3	1 in 8.4
1% Event Context						
Levee height margin						
Reference flood elevation		821.8	822.5		812.9	818.0
Margin (ft.)	3.0	3.0	3.0	3.1	3.1	3.2
Nonexceedance probability (as %)	91.6%	91.7%	91.6%	94.0%	94.1%	94.0%
0.2% Event Context						
Levee height margin						
Reference flood elevation		825.5	826.2		815.8	821.3
Margin (ft.)	-0.7	-0.7	-0.7	-0.1	0.2	-0.1

FEASIBILITY REPORT

MISSOURI RIVER LEVEE SYTEM UNITS R471-460 AND L-455
SAINT JOSEPH, MISSOURI / ELWOOD, KANSAS

APPENDIX D

REAL ESTATE PLAN

September 2006

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

REAL ESTATE PLAN
For
MISSOURI RIVER LEVEE SYSTEM (MRLS)
L-455 AND R471-460
FLOOD DAMAGE REDUCTION PROJECT

BUCHANAN COUNTY, MISSOURI &
DONIPHAN COUNTY, KANSAS

This Real Estate Plan (REP) information is developed in support of the Feasibility Study for the subject project. The authority for this feasibility study is the continuing authority of Section 216 of the 1970 Flood Control Act. The Reconnaissance Report published in May 1996 identifies a potential Federal interest in flood damage reduction measures. The non-Federal sponsors (NFS) for the Feasibility Study are the South St. Joseph Levee District, the Elwood-Gladden Drainage District, and the Airport Levee District. The purpose of this plan is to include information on any real estate activities that may be involved for the identified project. The project is located on the Missouri River in Buchanan County, Missouri and Doniphan County, Kansas. The project is currently estimated to involve approximately 92 acres, six (6) landowners and eleven (11) parcels on the left bank (South St. Joseph Levee District, L-455), approximately 1285 acres, twenty-one (17) landowners and thirty five (35) parcels on the Kansas right bank portion (Elwood-Gladden Drainage District) and approximately 45 acres, five (5) landowners and eight (8) parcels on the Missouri right bank portion (St. Joseph Airport Levee District). See Page 3, Tables 2.1- 2.3.

1. **PROJECT PURPOSE:** To raise the level of protection to provide greater protection against rare flood events as identified in the Reconnaissance Study and in support of the Feasibility Study. No other REP has been developed for this project. The alternatives provide protection against flood events of the 1-percent and 0.2-percent chance of occurrence. To the extent that accepted techniques permit, the analysis of protection will account for the rising stage trend of the Missouri River to assure that an alternative will be designed to accomplish the stated protection under future conditions up to 25 years after the project is constructed.

2. **DESCRIPTION OF LANDS, EASEMENT, RIGHTS-OF-WAY, RELOCATION, DISPOSAL (LERRD):** Project purposes require acquisition at a minimum of permanent and temporary easements that will include borrow area sites and temporary access easements.

Estates to be acquired by the NFS(s) are explained below and further detailed in Table 2.1 -2.3:

a. Fee Simple: No Fee Simple acquisition is required for levee right-of-way (r-o-w) on this project. Plus, a disposal site is not required as the project plan is for all aggregates to be used as fill, all trees and branches to be burned on site and all top soils to be used on the new surfaces.

b. Flood Protection Levee Easements:

A perpetual and assignable right and easement in (the lands to be described) to construct, maintain, repair, operate, patrol and replace a flood protection levee, including all appurtenances thereto; reserving, however, to the owners, their heirs and assigns, all such rights and privileges in the land 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. Temporary Work Area Construction Easement:

A temporary easement and right-of-way in, on, over and across (the land to be described) 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 construction area, borrow area and work area, including the right to borrow, 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 Missouri River Levee System, L-455 and R471-460, Flood Damage Reduction 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.

NOTE: Temporary Work Area Easements are proposed for the under seepage berms to be constructed along the levee system. This proposed temporary easement does not prove to be a risk to the project stability as the under seepage berms fall outside of the critical zone of the main levee protection. All stability berms which fall within the critical zone will require permanent flood control easements. At a range of 1’ on 50’-100’ slope, there will be a gradual change in the grade of the fields that is beneficial to the drainage and allows owners to return to farming the areas at no risk to the project. Our levee inspection program is very active and monitors activity on and near the levees on a regular basis.

b. Temporary Work Area Access Easement:

A temporary easement and right-of-way in, on, over and across (the land to be described) 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 temporary ingress and egress route, 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 Missouri River Levee System, L-455 and R471-460, Flood Damage Reduction 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.

Below is a summary of estate to be acquired, estimated acres and estimated land values for each of the Non-Federal sponsors.

Table 2.1: South St. Joseph Levee District (Missouri Left Bank)		
ESTATE/Project Feature	**ESTIMATED ACRES**	**ESTIMATED LAND VALUE**
Permanent Levee Easements $1900.00 per acre	6.0	$11,000.00
Temporary Work Area Sites (3- year period) 10% FMV inflated for 3 years	44.0	$25,000.00
Temporary Work Area Sites Borrow (3- year period) *100% FMV $1900 per acre	42.0	$80,000.00
Estimated TOTAL	11 parcels 92.0	$116,000.00

Table 2.2: Elwood-Gladden Drainage District, Kansas (Kansas Right Bank Portion)		
ESTATE/Project Feature	**ESTIMATED ACRES**	**ESTIMATED LAND VALUE**
Permanent Levee Easements $2000.00 per acre	41.0	$ 82,000.00
Temporary Work Area Sites (3- year period) 10% FMV inflated for 3 years	244.0	$ 160,000.00
Temporary Work Area Sites Borrow (3- year period) *100% FMV $2000 per acre	1000.0	$2,000,000.00
Estimated TOTAL	35 parcels 1285.0	$2,242,000.00

Table 2.3: St. Joseph Airport Levee District, Missouri (Missouri Right Bank Portion)		
ESTATE/Project Feature	**ESTIMATED ACRES**	**ESTIMATED LAND VALUE**
Permanent Levee Easements $2000.00 per acre	16.0	$ 33,000.00
Temporary Work Area Sites (3- year period) 10% FMV inflated for 3 years	29.0	$ 4,000.00
Temporary Work Area Sites Borrow (3- year period) *100% FMV $2000 per acre	0.0	0.00
Estimated TOTAL	5 parcels 45.0	$ 37,000.00

***Note**: Borrow is 100% FMV due to the extent of top soil removal, up to 6 feet in some locations which will leave the land unusable for its current agricultural purposes. Only a few areas are suitable for borrow and preliminary meetings with the landowners have indicated that there is opposition to this borrow area. At the start of the project if there is still opposition, the land may

need to be condemned or bought in fee. A safe assumption for planning purposes is to expect paying nearly 100% of FMV for this property. Final locations and quantities that will be taken from each site have not been finalized. During the Pre-Construction Engineering and Design (PED) phase, alternative locations and the use of dredged material will be considered to lower borrow area costs. Given these circumstances it would be irrelevant to estimate a residual value of the lands after the borrow has been removed without the assistance of a timely appraisal.

3. **NON-FEDERAL OWNED LANDS:** There are three State Chartered Levee/Drainage Districts whom own lands or hold easements along the MRLS L-455 & R471-460 Levee System. In addition to the three levee Districts (also NFS), there are two state agencies that own or manage land along the levee, Kansas Department of Wildlife and Parks (KDWP) and Missouri Department of Conservation (MDC). The Missouri Air National Guard and the City of St. Joseph, Missouri own approximately 1950 acres near the area (Rosecrans Memorial Airport) but this area will not be affected by the levee project. For Kansas Department of Wildlife and Parks, approximately 1.2 acres of permanent easement will be required to extend the berm. For MDC, approximately 10 acres of permanent easement and 14 acres of temporary easement will be required for berm extension and under seepage berm placement.

South St. Joseph Levee District: Holds a permanent flood control easement over the South St. Joseph Levee Unit project area, Stations 00+00 to 717+44, and the lands are sufficient and available for the project. L-455 is a federal levee and it is assumed that the sponsor has previously provided these lands as an item of local cooperation. Further research of the original project O&M Manuals during PED will help to identify any existing lands the sponsor may have provided outside the existing easement indicated on the RE Mapping.

Elwood-Gladden Drainage District: Holds a permanent flood control easement over the Elwood/Gladden Levee Unit project area, Levee Stations 12+25 to 240+00 and Stations 321+00 to 728+00 and the lands are sufficient and available for the project. R471-460 is a federal levee so the sponsor has previously provided these lands as an item of local cooperation. Further research of the original project O&M Manuals during PED will help to identify any existing lands the sponsor may have provided outside the existing easement indicated on the RE Mapping.

St. Joseph Airport Levee District: Holds a permanent flood control easement over the Airport Levee Unit project area, Levee Stations approximately 240+00 to 320+00, and the lands are sufficient and available for the project. R471-460 is a federal levee so the sponsor has previously provided these lands as an item of local cooperation. Further research of the original project O&M Manuals during PED will help to identify any existing lands the sponsor may have provided outside the existing easement indicated on the RE Mapping.

4. **NON-STANDARD ESTATES**: There will be no non-standard estates required for this project.

5. **EXISTING FEDERAL PROJECT IN AREA**: The current Missouri River Levee System (MRLS) Units R471-460 and L-455 (Figure 1) are existing Federal projects and are located on opposite sides of the Missouri River and provide local flood protection for the metropolitan area of St. Joseph, Missouri, and surrounding communities. The MRLS was authorized by the Flood Control Act of 1944 (P.L. 534, 72nd Congress). These Units were designed by the Corps of Engineers, Kansas City District, and constructed between 1962 and 1968. The LERRD that

supports the current project was previously provided as an item of local cooperation during the original levee construction project. The levee is now being raised to a new level of protection and the sponsors will only receive credit of the newly provided lands.

Since the levee has been in place for many years, there is established access for required O&M needs. The raise of the system will not affect the established access nor will it add a need for more access. The current routes will be used for hauling materials and access to the levee construction areas. All routes have been noted on the real estate plates.

6. **FEDERALLY OWNED LAND IN PROJECT AREA**: Recently, the Corps has purchased agricultural property along the Elwood/Gladden Levee. It was purchased under the authority of the Missouri River Fish and Wildlife Mitigation Program, which is a federally funded "willing seller" program that returns property along the Missouri River to the flood plain for fish and wildlife mitigation. The lands purchased do encompass parts of the proposed St. Joseph Levee Project and any use for this land for the project will be coordinated with the Missouri River Mitigation Project Manager to make sure it does not interfere with the intended mitigation project purposes. At this time we feel the areas will be a benefit to the levee raise project.

7. **NAVIGATIONAL SERVITUDE**: Navigational Servitude does not apply on this project.

8. **REAL ESTATE MAPPING**: Maps of the proposed project areas are attached as EXHIBIT "A" and EXHIBIT "B", Pages 1 – 6. Mapping is consistent with the preferred alternative footprint. Mapping contains a vicinity map with sectioning, ingress and egress routes, ownership, utilities to be relocated, and a note describing the difficulty if establishing Sections, Township and Range due to vicinity to a major river.

9. **FLOODING INDUCED BY PROJECT**: The feasibility study requires the analysis of any induced damages due to raises in the water surface profile caused by raises of the studied levee unit. The H & H analysis conducted shows no induced damages to the 1% (100-yr) flood event. Induced damages do not begin until we reach a flood event that is greater than the 1% (100-year) flood event. A Preliminary Takings Analysis has not been performed at this point due to the determination of "no induced damages" up to the 100 year event. Implementation of any right bank raise alternative will cause some limited amount of increased damages to Unit L-455, located just across the river and slightly downstream. The Baseline Event (100+3) alternative includes a minimal raise to the left bank to mitigate these damages. Even though a similar situation on the Kansas City Levees Feasibility established a "no taking opinion" it was decided that during PED, as further defining of the Hydrology and Hydraulics occurs, a preliminary taking analysis or Attorneys Opinion of no taking will need to be accomplished.

Water surface profiles will be affected upstream of St. Joseph and possibly as far downstream as Kansas City. An H & H analysis was conducted to determine potential impacts to other levee units in those areas. It was determined that the 100+3 alternative raise does not significantly affect these other units.

10. **BASELINE COST ESTIMATE FOR REAL ESTATE**: Below are summary tables of the Real Estate Baseline Cost Estimate for LERRD, NFS incidental costs, In-House Labor costs and Contingencies by Sponsor. A rollup of all costs is included as Table 10.4. LERRD values are based on tract appraisals obtained in 2006 for the Missouri River Mitigation Program. A Cost

Estimate covering the area was created by St. Louis District Review Appraiser, Tim Nelson. The MRLS L-455 and L471-460 Levee System Project fall directing in the appraised area.

TABLE 10.1: SOUTH ST. JOSEPH LEVEE DISTRICT (LEFT BANK L-455)	
LERRD Costs:	
Perm. Easement - Stability berm	$ 11,000.00
Temp. Easement - Underseepage berm	$ 25,000.00
Temp. Easement - Borrow Area	$ 80,000.00
Contingencies (15%)	$ 17,000.00
	$133,000.00
Non Federal Sponsor Incidental Costs:	$ 44,000.00
Contingencies (15%)	$ 7,000.00
	$ 51,000.00
In-house Government Costs:	$ 20,000.00
Contingencies (15%)	$ 3,000.00
	$ 23,000.00
Total	$207,000.00

TABLE 10.2: ELWOOD/ GLADDEN DRAINAGE DISTRICT (RIGHT BANK R470-460)	
LERRD Costs:	
Perm. Easement - Stability berm	$ 82,000.00
Temp. Easement - Underseepage berm	$ 160,000.00
Temp. Easement - Borrow Area	$2,000,000.00
Contingencies (15%)	$ 336,000.00
	$2,578,000.00
Non Federal Sponsor Incidental Costs:	$ 61,000.00
Contingencies (15%)	$ 9,000.00
	$ 70,000.00
In-house Government (Federal)Costs:	$ 21,000.00
Contingencies (15%)	$ 3,000.00
	$ 24,000.00
Total	$2,672,000.00

TABLE 10.3 ST. JOSEPH AIRPORT LEVEE DISTRICT (RIGHT BANK R471-460)	
LERRD Costs:	
Perm. Easement - Stability berm	$ 33,000.00
Temp. Easement - Underseepage berm	$ 4,000.00
Temp. Easement - Borrow Area	$ 0.00
Contingencies (15%)	$ 6,000.00
	$ 43,000.00
Non Federal Sponsor Incidental Costs:	$ 4,000.00
Contingencies	$ 1,000.00
	$ 5,000.00
In-house Government Costs:	$ 9,000.00
Contingencies	$ 1,000.00
	$ 10,000.00
Estimated Total	$ 58,000.00

Table 10.4 : Rollup of Estimated Total Land Costs for Total Project	
Land Values w/contingency	$2,754,000.00
Non Federal Sponsor Cost w/contingency	$ 125,000.00
In House Federal Costs w/contingency	$ 57,000.00
Total Estimated Project RE Costs	$2,936,000.00

Note: Utility LERRD Values will be determined in PED due to lack of information on compensable rights of the utility owners. See Section 16, paragraph 1.

11. **RELOCATION ASSISTANCE (P.L. 91-646)**: The non-federal sponsors have been advised of the Uniform Relocation Assistance and Real Property Acquisitions Policies Act of 1948, as amended (Public Law 91-646). There are no families or businesses that will temporarily or permanently require displacement as a result of this project, so there is no resettlement or relocation activity anticipated.

12. **MINERAL ACTIVITY IMPACTED PRESENT/FUTURE**: At this time the COE is not aware of any outstanding mineral interests that need to be acquired or subordinated in the project area.

13. **ASSESSMENT OF NON-FED SPONSOR(S) LEGAL/PROFESSIONAL CAPABILITY**: The non-Federal sponsors had land acquisition capabilities either through contract or in-house personnel and are fully capable of acquiring any lands necessary for the project. See Exhibit "C" for the Assessment of Non-Federal Sponsor's RE Acquisition Capabilities Checklist. Financial capability is addressed in the main report.

14. **ZONING ORDINANCES CONSIDERED IN LIEU OR/SUPPORT OF LERRD REQUIREMENTS**: There are no zoning ordinances proposed in connection with the project.

15. **REASONABLE, DETAILED, & COORDINATED TIMELINE FOR LERRD ACQUISITION**: The following are proposed milestones for project implementation:

Activity	Project TimeLine
Feasibility Complete	*July 2006*
Div. & HQ Review and Approval	*September 2006*
WRDA 2006	*Unknown*
PED (2 years)	*August 2006 – 2008*
Acquisition Plan to Sponsor	*August 2008*
Acquisition (18 months)	*September 2008 – March 2010*
LERRD Certification	*2010*
Construction (2 years)	*2010 - 2012*

16. **FACILITY/UTILITY RELOCATION**: A study of utilities crossing the St Joseph Levee Units R471-460 and L455 were conducted to estimate costs for relocation or removal of functioning or abandoned utilities. For Unit R471-460, six (6) utilities cross the levee. Of the six, three (3) utilities are outside the limits of the raise and three utilities within the limits of the raise will be relocated up and over the levee (modified in place). Documents for the three public utilities are being sought at this time; however sufficient information is not available for a Preliminary Attorney's Opinion of Compensability for the three public utilities.

Attorney's Opinion's of Compensability Interest, as required by paragraph 12-22 of Engineering Regulation 405-1-12 for the three utility relocations will be completed in the next project phase. Based on preliminary information utility relocation costs are estimated at approx. $350,000.00. A small percent of the total project costs. Therefore, delaying completion of the Opinions of Compensable Interest to the next project phase when more specific information will be available poses a negligible risk due to the comparatively small cost for the relocation work in relation to TPC.

Further, any conclusion or categorization contained in this report that an item is a utility or facility relocation to be performed is at the cost of the non-federal sponsor as part of LERRD responsibilities and is preliminary only. The federal Government will make a final determination of the relocations necessary for the construction, operation or maintenances 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**: The land in the project is not known or suspected to contain hazardous and/or toxic wastes. The Kansas City District of the US Army Corps of Engineers did complete the Feasibility Study (FS) Hazardous, Toxic, and Radiological Waste (HTRW) assessment of levee units L-455 and R-460-471 in St. Joseph, Missouri and Elwood, Kansas, in September 1999. Based on site visits and data search information, the known or suspected contaminant areas located in, on, under, or adjacent to the land required for the construction, operation and maintenance of the project where concluded as no further action or consideration required.

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. Many public meeting have been held and the consensus of the input is “fix the levee and fix it now”. A public meeting was held on August 28, 2006 to take comments on the Feasibility Plan. One area of opposition is the borrow areas. Landowners affected by the proposed areas are greatly concerned at the number of acres to be acquired for borrow sites and the extent of the soil removal. See attached RE Mapping for areas of concern.

19. **NOTIFICATION TO NON-FEDERAL SPONSOR OF EARLY ACQUISITION OF LERRD**: During PED the construction limit will be clearly defined and an acquisition schedule set. The non federal sponsors will be issued risk letters explaining the risk of acquiring lands prior to execution of the PCA.

20. **OTHER RE ISSUES:**

The land areas identified in the project footprint have been reviewed by environmental staff to identify Wetland Reserve Program (WRP) and Conservation Reserve program (CRP) lands within its reaches.

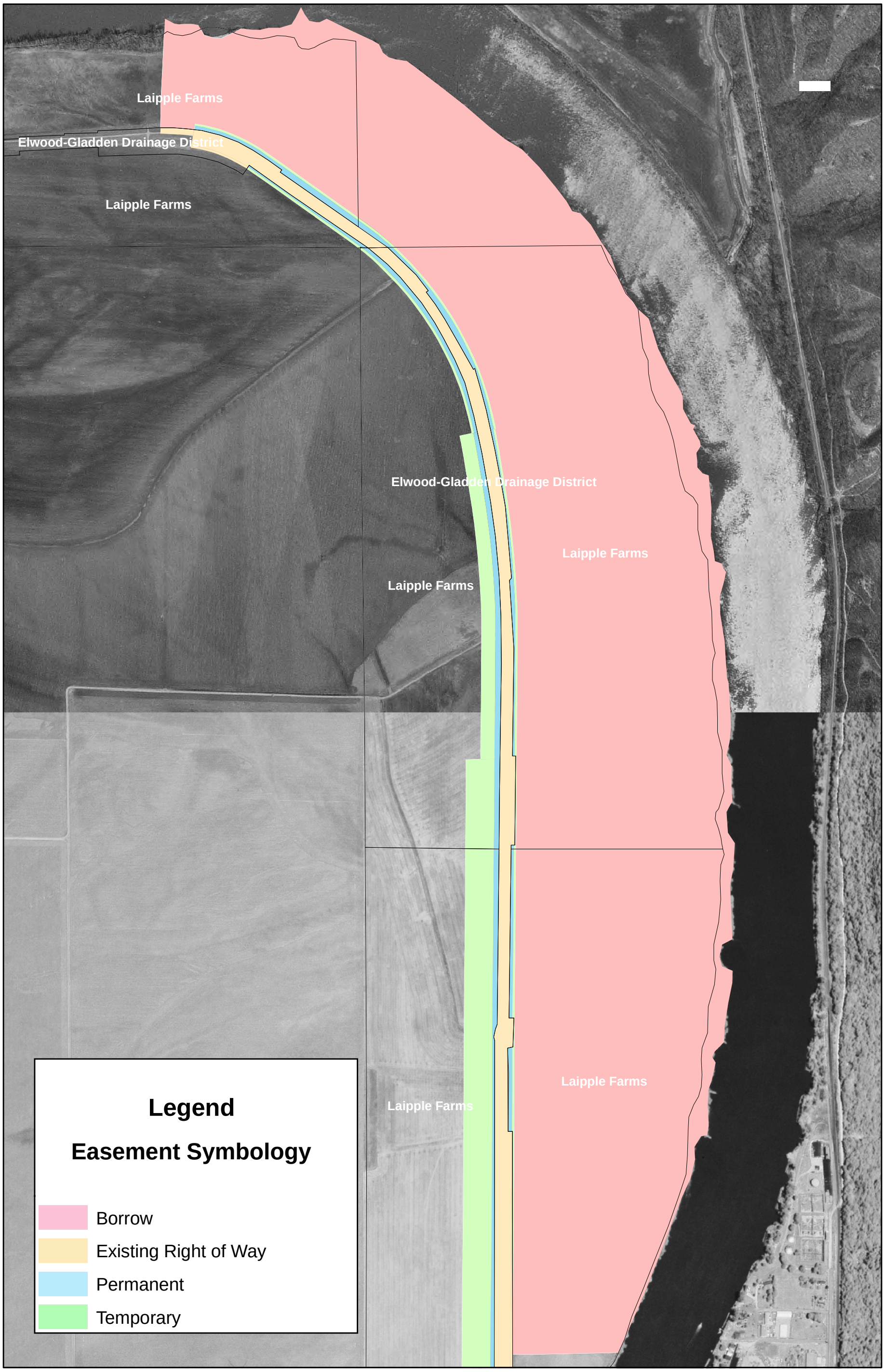
Lands purchase by the Corps of Engineers Missouri River Mitigation sites along the Elwood/ Gladden Levee Unit could be suitable for borrow and access to the project. This could create a saving on cost of proposed permanent easement for borrow.

Missouri River Levee System, L-455 Real Estate Site Plan

0 1,250 2,500 5,000 Feet

Exhibit A

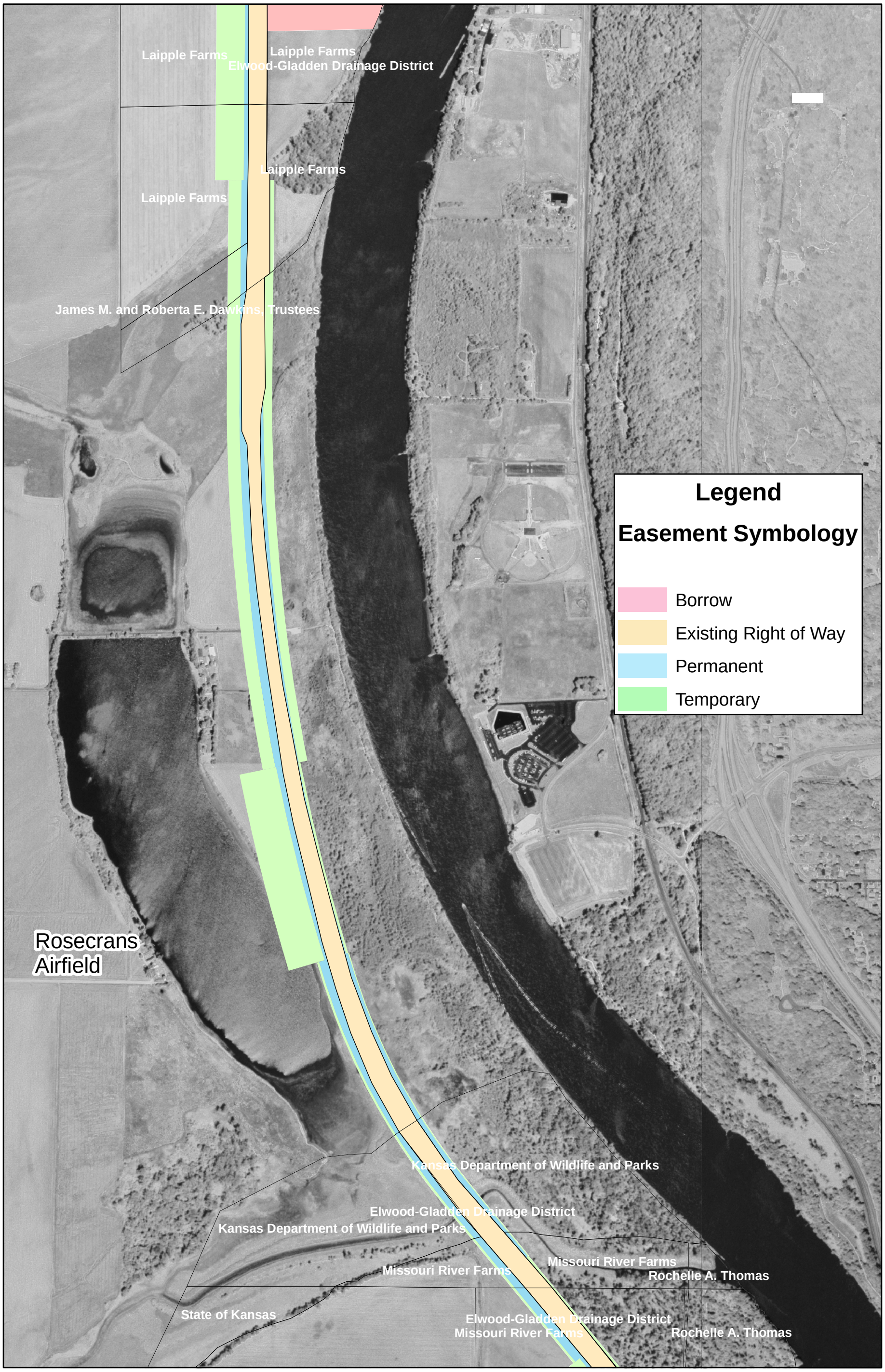
Missouri River Levee System, R-471-460 Real Estate Site Plan



0 0.1 0.2 0.4 Miles

Exhibit B

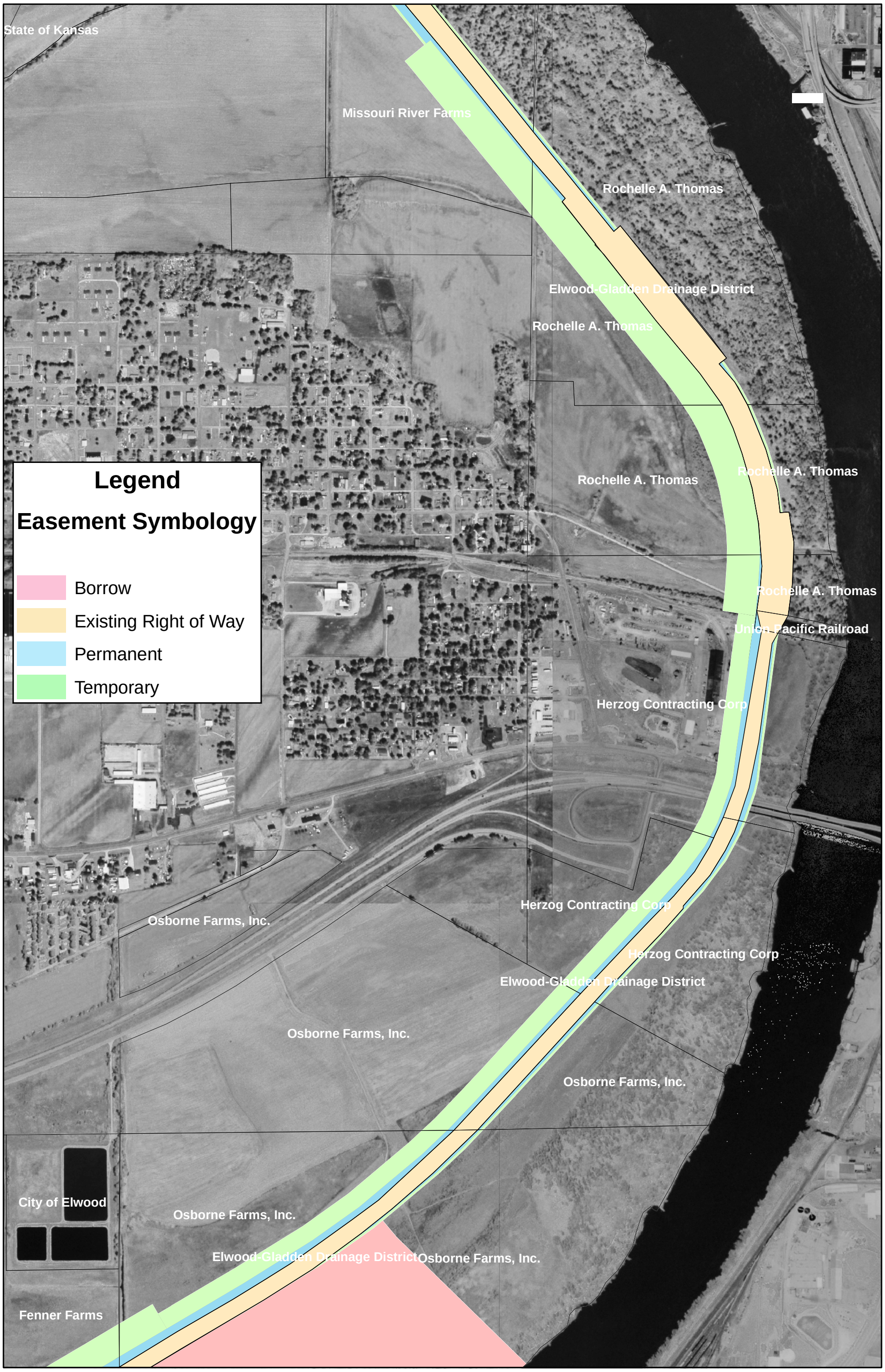
Missouri River Levee System, R-471-460 Real Estate Site Plan



0 0.125 0.25 0.5 Miles

Exhibit B

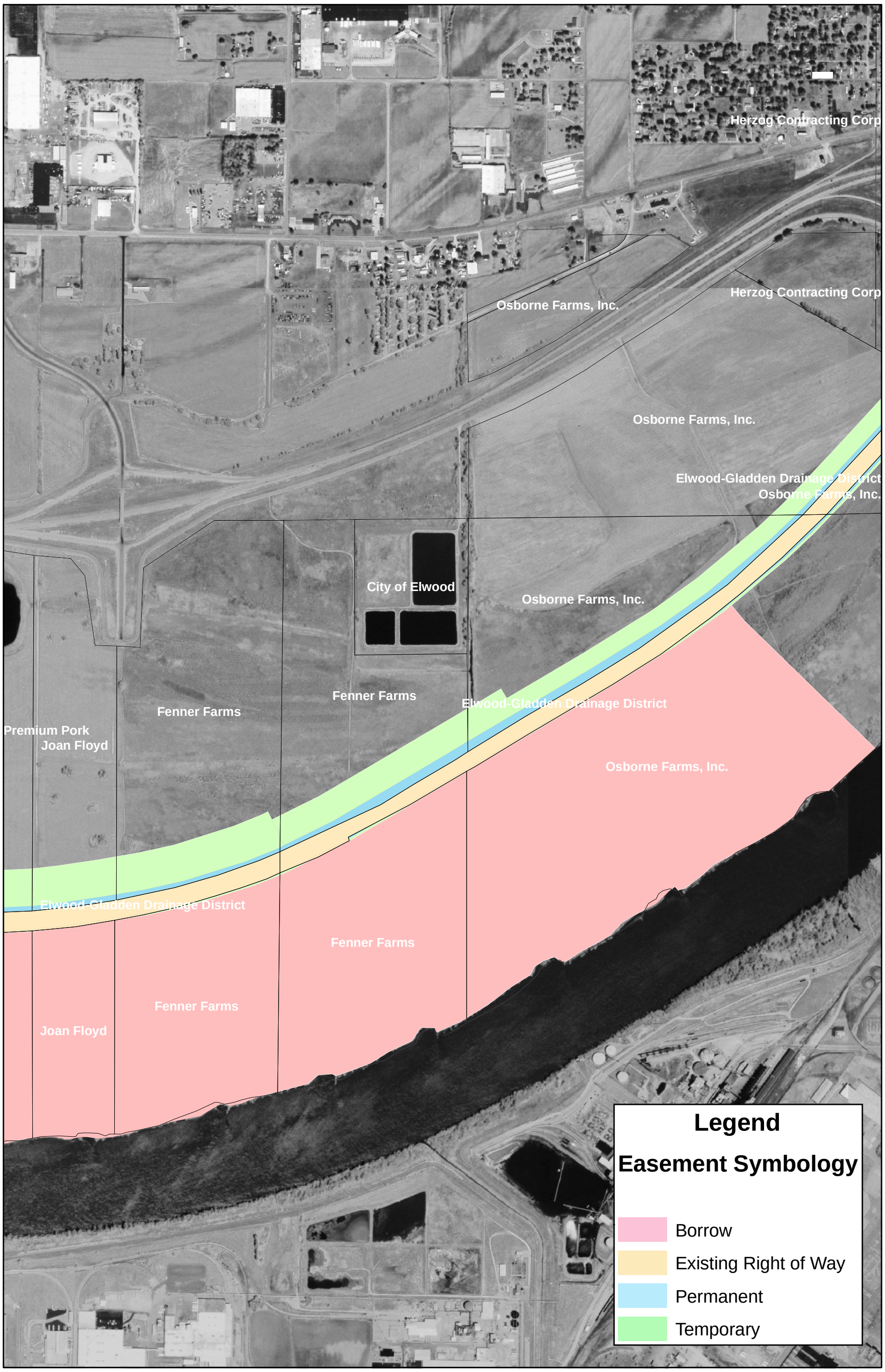
Missouri River Levee System, R-471-460 Real Estate Site Plan



0 0.125 0.25 0.5 Miles

Exhibit B

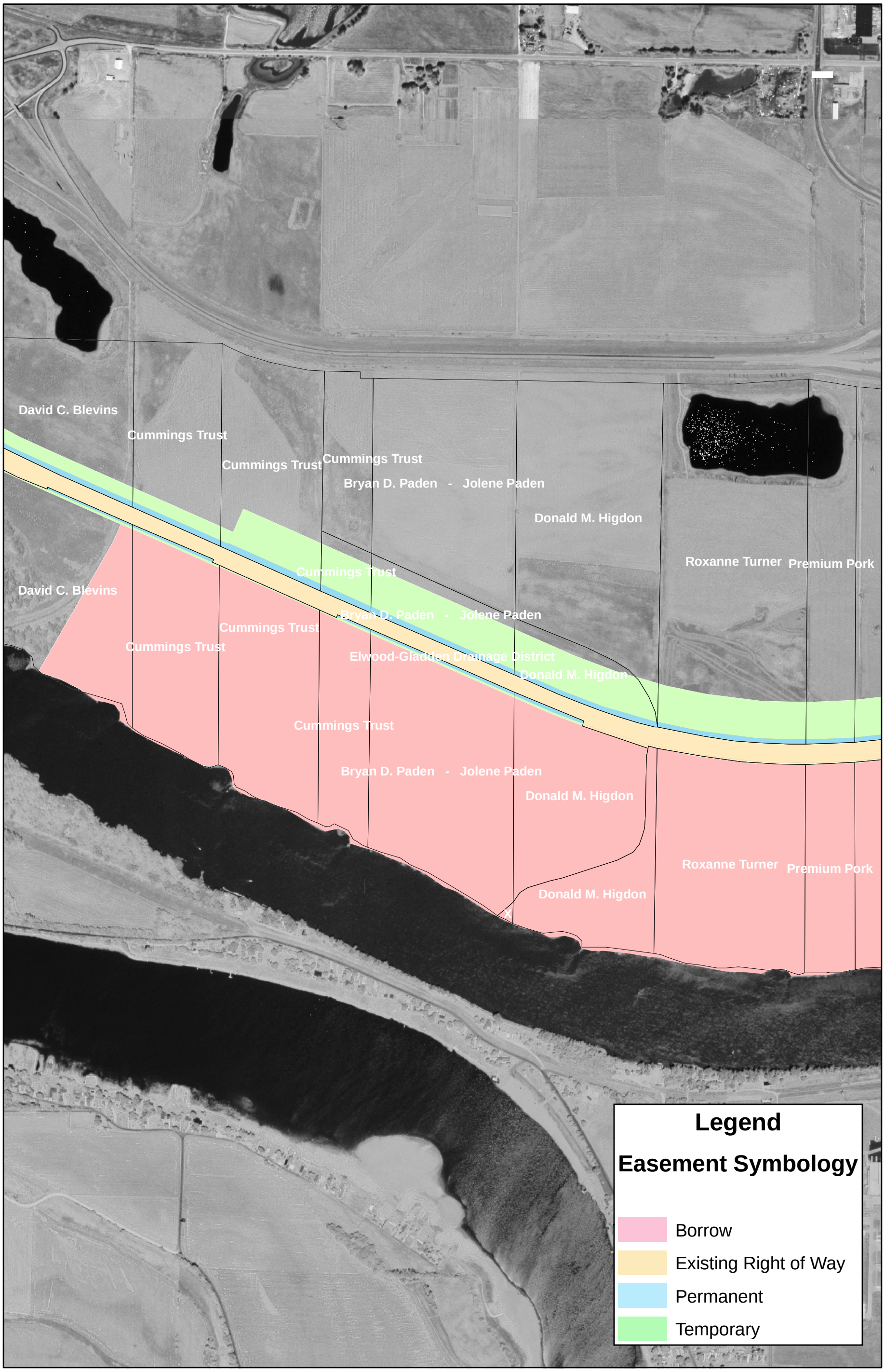
Missouri River Levee System, R-471-460 Real Estate Site Plan



0 0.125 0.25 0.5 Miles

Exhibit B

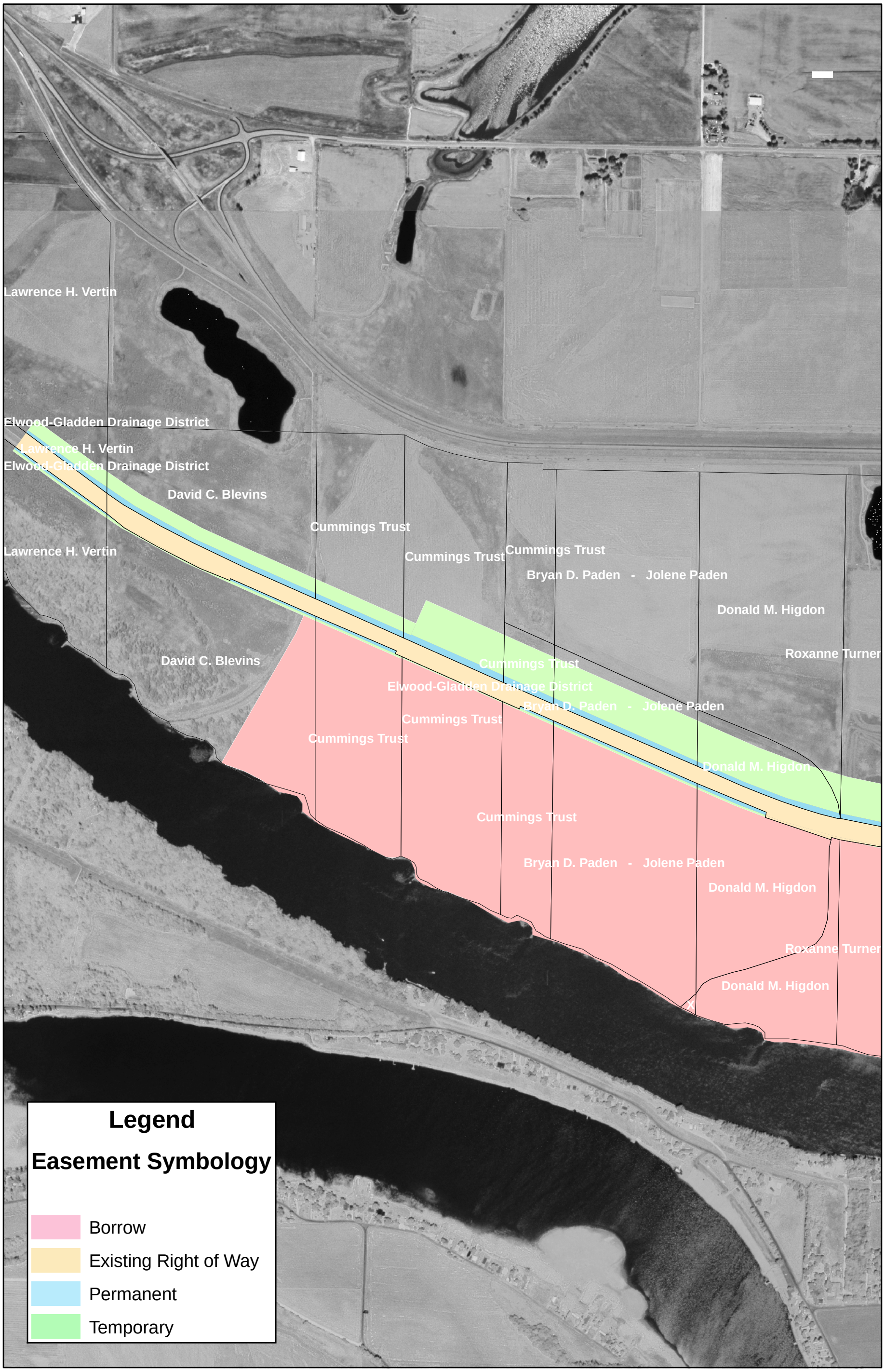
Missouri River Levee System, R-471-460 Real Estate Site Plan



0 0.125 0.25 0.5 Miles

Exhibit B

Missouri River Levee System, R-471-460 Real Estate Site Plan



0 0.125 0.25 0.5 Miles

Exhibit B

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE ACQUISITION CAPABILITY

South Saint Joseph Drainage and Levee District, MRLS R471-460
Elwood-Gladden Drainage District, MRLS L-455

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, Coordination meetings where held with sponsors to explain process and requirements.**

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**

Exhibit “C”

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? Review of Milestones and acquisition schedule will come during PED.

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 **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:

Lora E. Vacca
Real Estate Specialist

Exhibit "C"

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE ACQUISITION CAPABILITY

St. Joseph Airport Drainage District
Missouri River Levee System (MRLS) L455, R471-460

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, Coordination meetings where held with sponsors to explain process and requirements.**

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**

Exhibit “C”

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 but once a final alternative is selected, all will re-look at schedules.**

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 **fully capable**.

V. Coordination:

a. Has this assessment been coordinated with the sponsor? Not at this time.

b. Does the sponsor concur with this assessment? N/A

Prepared by:

Lora E. Vacca
Real Estate Specialist

Exhibit "C"

FEASIBILITY REPORT
MISSOURI RIVER LEVEE SYSTEM UNITS R471-460 AND L-455
SAINT JOSEPH, MISSOURI / ELWOOD, KANSAS

APPENDIX E

HAZARDOUS AND TOXIC WASTE

SEPTEMBER 2006

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers

Kansas City, Missouri

FEASIBILITY STUDY HTRW ASSESSMENT
ST. JOSPEH, MISSOURI AND ELWOOD, KANSAS
MISSOURI RIVER LEVEE SYSTEM UNITS L-455 AND R-460-471

22 September 1999

1 INTRODUCTION

The Kansas City District of the US Army Corps of Engineers has completed the Feasibility Study (FS) Hazardous, Toxic, and Radiological Waste (HTRW) assessment of levee units L-455 and R-460-471 in St. Joseph, Missouri and Elwood, Kansas, respectively. This assessment includes:

1. Review of database search report covering the St. Joseph and Elwood corridors, and

2. Documentation of the site visit.

This document includes a summary of the database search report and the site visit. The database search results can be found in Attachment 1 at the end of this document.

Before the FS phase of this project, a complete Reconnaissance Report that included HTRW evaluation was performed by HDR Engineering, Inc. for the US Army Corps of Engineers in May 1996. This FS phase HTRW Assessment was performed to re-examine the levee areas and further investigate the following areas outlined in the Feasibility Study Scope of Work:

1. Union Carbide Ag. Products – former lagoon with dioxin
2. Farmland/BN Railroad – former insecticide plant
3. FMGP/KCPBL – manufacturing gas plant
4. Gilmore Chemical- agricultural chemicals
5. Former St. Joseph Landfill
6. Elwood dri, drum found after the 1993 flood.

2 STUDY AREA

The study area comprises of two levee units: L-455 in Missouri and R-460-471 in Kansas and Missouri. The corridor encompassing these areas is defined as 500 feet either side of levee centerline and can be seen in Attachment 1.

3 ENVIRONMENTAL DATABASE SEARCH

The Corps of Engineers Kansas City District commissioned VISTA Information Solutions, Inc. to conduct the environmental database search. CENWK-EC-ED reviewed the VISTA report for indications of environmental concern in the vicinity of the subject area.

Listed in table 1 below are the databases that were searched. The table includes the acronym of the database, the database name, date of last data release, and number of "hits" (the number of sites within the corridor that registered during a search of that particular database).

Table 1. Databases Searched

Database Acronym	Database Description	Last Data Release Date	No. of Hits
NPL	National Priorities List	July 1999	0
SPL	Superfund Section of Department of Natural Resources (DNR) Missouri Priorities List	October 1998	0
CERCLIS	Sites proposed or on the NPL	May 1999	0
NFRAP	Sites originally considered for NPL, but where action is complete, or it was decided no action was necessary because contamination was not found, quickly removed, or not serious	May 1999	3
SCL	Kansas identified disposal sites list confirmed abandoned or uncontrolled	July 1999	0
CORRACTS	RCRA facilities undergoing "Corrective Action"	May 1999	1
ERNS	Emergency Response Notification System reported releases of oil and hazardous substances	December 1998	3[A]
RCRA-TSD	Resource Conservation and Recovery Act (RCRA) Transport, Storage, and Disposal Facilities	May 1999	1
RCRA-LgGen	RCRA Facilities generating at least 1000 kg/month of non-acutely hazardous waste or 1 kg/month of acutely hazardous waste	May 1999	1
RCRA-SmGen	RCRA Facilities generating less than 1000 kg/month of non-acutely hazardous waste	May 1999	2
SWLF	Solid Waste Landfills, Incinerators, and Transfer Stations Provided by the Missouri DNR	July 1995	0
LUST	Registered Leaking Underground Storage Tanks provided by KDHE	July 1999	0
LUST	Registered Leaking Underground Storage Tanks provided by the Waste Mgmt. Div. of Missouri DNR	March 1999	0
UST	Registered Underground Storage Tanks provided by Missouri DNR	June 1999	1
UST	Registered Underground Storage Tanks provided by the Kansas Bureau of Environmental Remediation	July 1999	0
SWLF	Solid waste landfills, incinerators and transfer stations provided by USGS	July 1995	
SPILL	Equivalent to ERNS database for Kansas	June 1999	0
AST	Registered Above Ground Storage Tanks provided by the Kansas Bureau of Environmental Remediation	July 1999	0

[A] - All three hits were for the same event

Database survey results are classified into two types of sites: mapped sites and unmapped sites. Mapped sites were located on a map in the database search report. Unmapped sites are listed as possibly in the search corridor since VISTA mapping was apparently unable to accurately map the addresses supplied. Table 2 below summarizes the seven sites, five mapped and two unmapped, registered from the database search:

Table 2. Sites Registered in Database Searches

Property	Database Hits	Summary of Events
<u>Mapped Sites</u> Omnium LLC 1417A Lower Lake Road St. Joseph, MO 64504	CORRACTS RCRA-LgGen RCRA-TSD	Completed RCRA Facility Assessment with no RCRA Facility Investigation imposed
Farmland Industries, Inc. 1417 Lower Lake Road St. Joseph, MO 64504	UST-MO	Removed 2, 20,000 gal tanks; 2, 1000 gal tanks; and 2, 5000 gal tanks
St. Joseph Light and Power Lake Road Plant 1413 Lower Lake Road St. Joseph, MO 64504	RCRA-SmGen	Small generator of waste
Lake Road Warehouse Company 1400 Lower Lake Road St. Joseph, MO 64504	RCRA-SmGen NFRAP	Not on NPL, incident type unknown
Larry Helfry 1613 Vernon St. Joseph, MO 64504	ERNS (3 hits from same address)	Spilled 30 gallons of diesel fuel 26 July 1992 into soil and storm sewers
<u>Unmapped Sites</u> Old Fanning Dump Sec 13 T56N R36W St. Joseph, MO 64504	NFRAP	Described as a 7.3 acre site used as an open dump containing many open and rusty 55 gallon drums, preliminary assessment 2 January 1988
St. Joseph Light Power Company NW ¼ NE ¼ SEC 36 T57N R36W St. Joseph, MO 64504	NFRAP	Described as a 2 to 3 acre fly ash landfill in wet land area, preliminary assessment 2 January 1988

4 SITE VISIT

The 12 August 1999 site visit is documented in Attachment 2. During the visit, a local member of the levee board was questioned about some of the sites mentioned in the FS Scope of Work. He had no knowledge of the dioxin pits and the St. Joseph Landfill sites mentioned in the FS Scope of Work.

On levee R-460-471, the only potential HTRW concern is at the Herzog Hot Mix Plant north of Highway 36. Stockpiles of what appears to be recycled asphalt are in contact with the landside toe of the levee.

On levee L-455, three potential HTRW concerns exist. One is the proximity of underground gas pipelines near station 55+00 to station 85+00. The second concern is industrial sewage pipes crossing the west side of the levee along Brown's Branch Creek. The third concern is sediment ponds near station 110+00. Although the ponds are within 500 feet of the levee centerline, they are at least 100 feet from the toe of the levee. This distance makes it unlikely they would be disturbed for a levee raise of 5 feet or less, but the existence of the ponds should be considered.

5 CONCLUSIONS

Potential sites of concern can be separated into three categories: sites from the FS Scope of Work, sites from the 12 August 1999 field visit, and sites highlighted in the database search.

All sites mentioned in the FS Scope of Work (listed in part 1) were eliminated as items of concern. No additional information was obtained despite an interview with a levee board member, a site visit, and a thorough database search. Below is a summary of how each potential site outlined in the FS Scope of Work was addressed for this report:

Table 3. FS Scope of Work Sites Summary and Conclusions

FS Scope of Work Potential Site	Findings	Conclusion/ Recommended Action
Union Carbide Ag. Products – former lagoon with dioxin	• No database search hits • No information from levee board member • Nothing noticed during site visit	No further consideration
Farmland/BN Railroad – former insecticide plant	• No markings noticed during site visit • No database search hits	No further consideration
FMGP/KCPBL – manufacturing gas plant	• Manufacturing plants noticed during site visit, but none adjacent to the levee	No further consideration
Gilmore Chemical- agricultural chemicals	• Manufacturing plants noticed during site visit, but none adjacent to the levee	No further consideration
Former St. Joseph Landfill	• No database search hits • No information from levee board member	No further consideration
Elwood dri, drum found after the 1993 flood	• No database search hits • Assumed anomaly from 1993	No further consideration

flood

Four items were highlighted as potential concerns during the 12 August site visit. Table 4 below summarizes the findings and recommendations for each:

Table 4. Field Site Visit Sites Summary and Conclusions

Field Visit Site of Potential Concern	Findings	Conclusion/ Recommended Action
Levee R-460-471 Herzog Hot Mix Plant at Highway 36 and Levee	• Recycled asphalt material stockpiled against levee toe	Remove pile from toe now and move pile farther from toe during construction
LeveeL-455 Williams Gas Pipelines	• Running along toe from station 55+00 to 85+00	Maintain utility awareness all along the levees and do not disturb
Industrial Sewage Pipes crossing levee	• at Brown's Branch Creek portion of levee	Maintain awareness and do not disturb
Sediment ponds	• near station 110+00	Do not disturb

No follow-up action is necessary for any of the database search sites. Potential concerns from the database search are summarized in Table 5 below:

Table 5. Database Search Sites Summary and Conclusions

Database Search Sites of Potential Concern	Database Findings	Conclusion/ Recommended Action
Omnium LLC	• CORRACTS • RCRA-LgGen • RCRA-TSD	No RCRA investigation necessary, no action necessary
Farmland Industries, Inc.	• UST-MO	Removal action complete, no action necessary
St. Joseph Light and Power Lake Road Plant	• RCRA-SmGen • Registered UST	no action necessary
Lake Road Warehouse	• RCRA-SmGen • NFRAP	No information provided for contamination , no action necessary
Larry Helfry	• ERNS	30 gal. diesel fuel spill over 7 years ago, no action necessary
Old Fanning Dump	• NFRAP	Site estimated to be greater than 2.5 miles from nearest levee, no action necessary[B]
St. Joseph Light and Power Co.	• NFRAP	Fly ash landfill found to be approximately 0.5 miles from Brown's Branch Levee, no action necessary[B]

[B]- See attachment 3 for maps

FEASIBILITY REPORT
MISSOURI RIVER LEVEE SYSTEM UNITS R471-460 AND L-455
SAINT JOSEPH, MISSOURI / ELWOOD, KANSAS

APPENDIX F

COST ESTIMATING

SEPTEMBER 2006

DEPARTMENT OF THE ARMY
Kansas City District, U.S. Army Corps of Engineers
Kansas City, Missouri

* * * * TOTAL CONTRACT COST SUMMARY * * * *

TOTAL - ALL CONTRACTS

Date: 18 July 2006

PROJECT: MRLS L-455 & R-471-460 Feasibility Study

DISTRICT: Kansas City District Corps of Engineers

LOCATION: St. Joseph, Missouri

P.O.C.: Patrick J. Miramontez, Cost Engineering Section

	CURRENT MCACES ESTIMATE PREPARED: JUL 2006 EFFECTIVE PRICING LEVEL: 1 OCT 05					AUTHORIZ./BUDGET YEAR: EFFECT. PRICING LEVEL: 1 OCT 05			*** FULLY FUNDED ESTIMATE ***		
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	COST ($K)	CNTG ($K)	TOTAL ($K)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES										
0603- -	WILDLIFE FACILITIES & SANCTUARIES	500	0	0%	500	500	0	500	549	0	549
11- - -	LEVEES & FLOODWALLS										
1101- -	LEVEES	18,509	4,595	25%	23,104	18,508	4,595	23,103	20,336	5,048	25,384
1102- -	FLOODWALLS	0	0	0%	0	0	0	0	0	0	0
13- - -	PUMPING PLANTS										
1300- -	PUMPING PLANTS	0	0	0%	0	0	0	0	0	0	0
	TOTAL CONSTRUCTION COSTS ===>	19,009	4,595	24%	23,604	19,008	4,595	23,603	20,885	5,048	25,933
01 - - -	LANDS AND DAMAGES										
0101- -	LAND VALUES	2395.1	359.27	15%	2,754	2,395	359	2,754	2,539	380	2,919
0102- -	LABOR	158.58	23.787	15%	182	159	24	182	170	25	195
02 - - -	RELOCATIONS	295.41	59.082	20%	354	295	59	354	325	65	390
30 - - -	PLANNING, ENGINEERING & DESIGN	1,930	465.48	24%	2,396	1,930	465	2,396	2,067	499	2,566
31 - - -	CONSTRUCTION MANAGEMENT	1253	302.1	24%	1,555	1,253	302	1,555	1,430	345	1,775
	TOTAL PROJECT COSTS ========>	25,041	5,805	23%	30,846	25,041	5,804	30,845	27,416	6,362	33,778

TOTAL FEDERAL COSTS (65%)====> $ 21,956 K

TOTAL NON-FEDERAL COSTS (35%)====> $ 11,822 K

TOTAL FULLY FUNDED ESTIMATE =======> $ 33,778 K

APPROVED:

* * * * TOTAL CONTRACT COST SUMMARY * * * *

CONTRACT A - R471-460 (100 year + 3ft)

Date: 18 July 2006

PROJECT: MRLS L-455 & R-471-460 Feasibility Study

DISTRICT: Kansas City District Corps of Engineers

LOCATION: St. Joseph, Missouri

P.O.C.: Patrick J. Miramontez, Cost Engineering Section

	CURRENT MCACES ESTIMATE PREPARED: JUL 2006					AUTHORIZ./BUDGET YEAR:								
	EFFECTIVE PRICING LEVEL: 1 OCT 05					EFFECT. PRICING LEVEL: 1 OCT 05				* * * FULLY FUNDED ESTIMATE * * *				
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES													
0603- -	WILDLIFE FACILITIES & SANCTUARIES	500	0	0%	500	0.0%	500	0	500	Jun-2010	9.88%	549	0	549
11- - -	LEVEES & FLOODWALLS													
1101- -	LEVEES	16,606	4,056	24%	20,662	0.0%	16,606	4,056	20,662	Jun-2010	9.88%	18,246	4,456	22,702
1102- -	FLOODWALLS	0	0	0%	0	0.0%	0	0	0		0.00%	0	0	0
13- - -	PUMPING PLANTS													
1300- -	PUMPING PLANTS	0	0	0%	0	0.0%	0	0	0		0.00%	0	0	0
	TOTAL CONSTRUCTION COSTS ===>	17,106	4,056	24%	21,162		17,106	4,056	21,162			18,795	4,456	23,251
01 - - -	LANDS AND DAMAGES													
0101- -	LAND VALUES	2278.8	341.8	15%	2,621	0.0%	2,279	342	2,621	Jun-2008	6.00%	2,416	362	2,778
0102- -	LABOR	94	14	15%	109	0.0%	94	14	109	Jun-2008	7.10%	101	15	116
02 - - -	RELOCATIONS	295	59	20%	354	0.0%	295	59	354	Jun-2010	9.88%	325	65	390
30 - - -	PLANNING, ENGINEERING & DESIGN	1740	411	24%	2,152	0.0%	1,740	411	2,152	Oct-2007	7.10%	1,864	441	2,305
31 - - -	CONSTRUCTION MANAGEMENT	1129	267	24%	1,396	0.0%	1,129	267	1,396	Jun-2010	14.10%	1,289	305	1,594
	TOTAL PROJECT COSTS ========>	22,644	5,149	23%	27,794		22,644	5,149	27,794			24,790	5,644	30,434

* * * * TOTAL CONTRACT COST SUMMARY * * * *

CONTRACT B - L455 (100 Year + 3ft)

Date: 18 July 2006

PROJECT: MRLS L-455 & R-471-460 Feasibility Study

DISTRICT: Kansas City District Corps of Engineers

LOCATION: St. Joseph, Missouri

P.O.C.: Patrick J. Miramontez, Cost Engineering Section

CURRENT MCACES ESTIMATE PREPARED: JUL 2006

EFFECTIVE PRICING LEVEL: 1 OCT 05

AUTHORIZ./BUDGET YEAR:

EFFECT. PRICING LEVEL: 1 OCT 05

ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	* * * FULLY FUNDED ESTIMATE * * * FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
06 - - -	FISH & WILDLIFE FACILITIES													
0603- -	WILDLIFE FACILITIES & SANCTUARIES	0	0	0%	0	0.0%	0	0	0	Jun-2010	9.88%	0	0	0
11- - -	LEVEES & FLOODWALLS													
1101- -	LEVEES	1,902	539	28%	2,442	0.0%	1,902	539	2,441	Jun-2010	9.88%	2,090	592	2,682
1102- -	FLOODWALLS	0	0	0%	0	0.0%	0	0	0		0.00%	0	0	0
13- - -	PUMPING PLANTS													
1300- -	PUMPING PLANTS	0	0	0%	0	0.0%	0	0	0		0.00%	0	0	0
	TOTAL CONSTRUCTION COSTS ===>	1,902	539	28%	2,442		1,902	539	2,441			2,090	592	2,682
01 - - -	LANDS AND DAMAGES													
0101- -	LAND VALUES	116.29	17.44	15%	134	0.0%	116	17	134	Jun-2008	6.00%	123	18	141
0102- -	LABOR	64.12	9.618	15%	74	0.0%	64	10	74	Jun-2008	7.10%	69	10	79
02 - - -	RELOCATIONS	0	0	0%	0	0.0%	0	0	0	Jun-2010	9.88%	0	0	0
30 - - -	PLANNING, ENGINEERING & DESIGN	190	54	28%	244	0.0%	190	54	244	Oct-2007	7.10%	203	58	261
31 - - -	CONSTRUCTION MANAGEMENT	124	35.05	28%	159	0.0%	124	35	159	Jun-2010	14.10%	141	40	181
	TOTAL PROJECT COSTS ========>	2,397	655	27%	3,052		2,396	655	3,052			2,626	718	3,344

Feasibility Study Estimate For:
St. Joseph Feasibility Study -
L455
Nominal 100 Yr + 3ft Levee Raise
dated 18 Jul 2006

Designed By: CENWK
Estimated By: CENWK-EC-DC

Prepared By: Patrick Miramontez 816-983-3322
LATEST ESTIMATE AS OF 18 Jul 06

Preparation Date: 01/10/06
Effective Date of Pricing: 10/01/05

Sales Tax: 0.00%

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01- Lands & Damages - The costs include the acquisition of Permanent Right-of-Way, Temporary Right-of-Way, and borrow areas. Also included, where necessary, is the relocation cost of businesses that infringe on the footprint of the raised levee. These costs include Non Federal Sponsors cost to perform the Legal work, Title Work, Tract appraisals, and land surveys, as well as Federal labor costs.

02 - Relocations - This item currently includes only utility relocations. There are two types of utility relocations: 1) Utilities crossing the levee - These are utilities identified as having to be removed from their current location and placed up and over the new levee raise. This will require a fill zone that will be evident above the levee projected lines. All abandoned pipes crossing the levee will be removed. No Utilities have been identified for this reach. 2) Utilities impacted by Uplift - None identified.

06 - Fish & Wildlife Facilities - NOT USED.

11 - Levees
This item consists of 4 different components. These components include: 1) Relief Wells, 2) Borrow Site, 3) Levee Raise (including Levee Cut, Levee Raise, Stability (Riverside Berms) and Underseepage berms), and 4) Drainage System Modifications.

- Relief Wells - NOT USED.

- Borrow Site - It is currently assumed one borrow site will be utilized. It is assumed 100% of the material will come from the borrow sites located a maximum of .66 miles from the levee centroid. The costs include the preparation of the borrow site, and the final grading of the borrow site when completed.

- Levee Cut - Quantities for the levee cut were based on the removal of the aggregate surfacing on top of the levee, and the stripping of topsoil from the landside of the existing levee. It was assumed this material will be dozed off and windrowed next to the levee.

- Levee Raise (including Stability/Underseepage Berms) - Quantities for the levee raise was calculated by using In-Roads CAD software and then hand manipulated. Haul distances were hand calculated based on the borrow site locations and the quantities required. Haul distances vary from 0.51 miles to .66 miles. The material is to be excavated, loaded, and hauled using off-highway dump trucks over the existing ramps and new ramps and low water crossings where needed. A cost is also included for new aggregate surfacing and seeding and mulching.

- Drainage System Modifications - NOT USED.

-Estimated Engineering and Design Costs = 10% of project implementation (less lands & damages) cost. To be refined.

-Estimated Construction Supervision & Administration = 6.5% of project implementation (less lands & damages) cost. To be refined.

Areas of Cost Sensitivity
- Estimate does not include any costs for sampling/testing for HTRW.
- Estimate does not include any costs for the hauling and disposal of HTRW.
- Estimate does not include O&M costs. Only project implementation (construction, real-estate and associated) costs.
- Estimate based on borrow source located at Approx Left Bank Levee Station 250+00 to 265+00. If this borrow is not available for use additional costs will have to be considered.

General Cost Information
- The quantities have been calculated by EC-GD, EC-DC, and EC-DS. A contingency determination meeting will be held with all of the designers to apply the appropriate amount of contingency to each line item.
- No tax has been included for the state of Missouri.
- The source for the labor rates used in the estimate is the Dec 2005 Department of Labor Wage rates for Buchanon County, Missouri.
- The national 2001 Unit Price Book is used to price minor items. Quotes were received for major cost items. An adjustment factor is added to bring the rates to the appropriate price level date.
- 2005 equipment rates were used.
- Once all of the databases are normalized to the appropriate price level date an escalation factor will be added to the owner level to bring the estimate to the appropriate price level date. The escalation factors used were derived from the Civil Works Construction Cost Index System (CWCCIS) EM1110-2-1304.

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** PROJECT OWNER SUMMARY - Feature **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
01 Lands and Damages	1.00	EA	180,410	27,061	0	0	0	207,471	207470.93
11 Levees and Floodwalls	1.00	EA	1,902,490	539,252	0	244,174	158,469	2,844,385	2844385
TOTAL Feasibility Study Estimate For:	1.00	EA	2,082,899	566,313	0	244,174	158,469	3,051,856	3051856

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Borrow Area-Sta 250+00 to 265+00	42.00	ACR	79,800	11,970	0	0	0	91,770	2185.00
01.23.01.01.02 Sta 205+50 to 209+50	2.65	ACR	2,043	306	0	0	0	2,349	886.37
01.23.01.01.03 Sta 209+50 to 237+50	10.75	ACR	7,790	1,169	0	0	0	8,959	833.35
01.23.01.01.04 Sta 237+50 to 257+50	19.00	ACR	12,825	1,924	0	0	0	14,749	776.25
01.23.01.01.05 Sta 257+50 to 262+50	3.85	ACR	2,660	399	0	0	0	3,059	794.55
01.23.01.01.06 Sta 262+50 to 288+50	10.60	ACR	8,702	1,305	0	0	0	10,007	944.08
01.23.01.01.07 Sta 288+50 to 292+50	2.05	ACR	1,634	245	0	0	0	1,879	916.63
01.23.01.01.08 Sta 292+50 to 295+00	1.00	ACR	836	125	0	0	0	961	961.40
TOTAL Land Values	1.00	EA	116,290	17,443	0	0	0	133,733	133732.93
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.09 NFS Costs	1.00	EA	44,400	6,660	0	0	0	51,060	51060.00
TOTAL Non Federal Sponsors Costs	1.00	EA	44,400	6,660	0	0	0	51,060	51060.00
01.23.01.03 Federal Costs									
01.23.01.03.10 Federal Costs	1.00	EA	19,720	2,958	0	0	0	22,678	22678.00
TOTAL Federal Costs	1.00	EA	19,720	2,958	0	0	0	22,678	22678.00
TOTAL Land Values	1.00	EA	180,410	27,061	0	0	0	207,471	207470.93
TOTAL Land Values	1.00	EA	180,410	27,061	0	0	0	207,471	207470.93
TOTAL Lands and Damages	1.00	EA	180,410	27,061	0	0	0	207,471	207470.93
02 Relocations									
02.01 Utility Relocations									
02.01.03 Cemetery, Utilities, & Structure									
02.01.03.18 Utilities Crossing Levee									
02.01.03.18.11 Utilities Crossing Levee - NONE									
02.01.03.20 Utilities Affected by Uplift									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
02.01.03.20.12 Util affected by uplift - NONE									
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Relief Wells									
11.01.02 Borrow Sites & Site Prep									
11.01.02.01 Site Prep Sta 250+00 to 265+00									
11.01.02.01.13 Stripping/Windrow Material	13889.00	CY	20,148	4,030	0	2,418	1,569	28,165	2.03
TOTAL Site Prep Sta 250+00 to 265+00	13889.00	CY	20,148	4,030	0	2,418	1,569	28,165	2.03
11.01.02.02 Low Water Crossing - Sta 232+00									
11.01.02.02.14 Low Water Crossing - Sta 232+00									
11.01.02.02.14.01 Low Water Crossing - Sta 232+00	1.00	EA	6,233	1,247	0	748	485	8,713	8713.08
TOTAL Low Water Crossing - Sta 232+00	1.00	EA	6,233	1,247	0	748	485	8,713	8713.08
TOTAL Low Water Crossing - Sta 232+00	1.00	EA	6,233	1,247	0	748	485	8,713	8713.08
11.01.02.10 Final Grade Site									
11.01.02.10.15 Final Grade Sta 250+00 to 265+00	13889.00	CY	20,115	4,023	0	2,414	1,567	28,118	2.02
TOTAL Final Grade Site	1.00	EA	20,115	4,023	0	2,414	1,567	28,118	28118.26
TOTAL Borrow Sites & Site Prep	1.00	EA	46,496	9,299	0	5,580	3,621	64,996	64995.88
11.01.03 Stripping Levee									
11.01.03.05 Remove Aggr Sta 205+64 to 294+93									
11.01.03.05.16 Excavate Aggregate from Levee	1654.00	BCY	1,140	228	0	137	89	1,594	0.96
TOTAL Remove Aggr Sta 205+64 to 294+93	1654.00	BCY	1,140	228	0	137	89	1,594	0.96
11.01.03.06 Strip Levee-Less than 1' Raise									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.03.06.17 Strip Topsoil from Levee	3065.35	BCY	2,776	555	0	333	216	3,880	1.27
11.01.03.06.18 Windrow Material	3065.35	BCY	1,409	282	0	169	110	1,970	0.64
TOTAL Strip Levee-Less than 1' Raise	3.80	ACR	4,185	837	0	502	326	5,850	1539.39
11.01.03.09 Strip Berm-Less than 1' Raise									
11.01.03.09.19 Strip Topsoil from Levee	38800.83	BCY	66,177	13,235	0	7,941	5,154	92,508	2.38
11.01.03.09.20 Windrow Material	38800.83	BCY	18,658	3,732	0	2,239	1,453	26,082	0.67
TOTAL Strip Berm-Less than 1' Raise	48.10	ACR	84,836	16,967	0	10,180	6,607	118,590	2465.50
TOTAL Stripping Levee	43519.00	BCY	90,161	18,032	0	10,819	7,022	126,034	2.90
11.01.04 Levee Raise (Impervious)									
11.01.04.01 Exc/Haul Matl-Sta 205+64-257+50									
11.01.04.01.21 Exc/Haul	3001.25	BCY	13,341	2,668	0	1,601	1,039	18,649	6.21
TOTAL Exc/Haul Matl-Sta 205+64-257+50	3001.25	BCY	13,341	2,668	0	1,601	1,039	18,649	6.21
11.01.04.02 Exc/Haul Matl-Sta 257+50-294+93									
11.01.04.02.22 Exc/Haul	2486.25	BCY	11,052	2,210	0	1,326	861	15,449	6.21
TOTAL Exc/Haul Matl-Sta 257+50-294+93	2486.25	BCY	11,052	2,210	0	1,326	861	15,449	6.21
11.01.04.03 Place Material									
11.01.04.03.23 Scarify Existing Surface	133935.00	SF	426	85	0	51	33	596	0.00
11.01.04.03.24 Place	5487.50	BCY	8,863	1,773	0	1,064	690	12,390	2.26
TOTAL Place Material	5487.50	BCY	9,289	1,858	0	1,115	723	12,986	2.37
TOTAL Levee Raise (Impervious)	4390.00	CCY	33,682	6,736	0	4,042	2,623	47,084	10.73
11.01.07 Underseepage Berm (Random)									
11.01.07.02 Exc/Haul Matl-Sta 205+64- 257+00									
11.01.07.02.25 Exc/Haul	162793.75	BCY	723,641	217,092	0	94,073	61,054	1,095,861	6.73
TOTAL Exc/Haul Matl-Sta 205+64- 257+00	162793.75	BCY	723,641	217,092	0	94,073	61,054	1,095,861	6.73

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.07.03 Exc/Haul Matl-Sta 257+00- 294+93									
11.01.07.03.26 Exc/Haul	83327.50	BCY	370,403	111,121	0	48,152	31,251	560,927	6.73
TOTAL Exc/Haul Matl-Sta 257+00- 294+93	83327.50	BCY	370,403	111,121	0	48,152	31,251	560,927	6.73
11.01.07.53 Place Material									
11.01.07.53.27 Scarify Existing Surface	1785800	SF	5,685	1,137	0	682	443	7,947	0.00
11.01.07.53.28 Place	244467.25	BCY	367,550	110,265	0	47,782	31,010	556,607	2.28
11.01.07.53.29 Spread Aggregate Surfacing Matl	1654.00	BCY	978	196	0	117	76	1,366	0.83
TOTAL Place Material	246121.25	BCY	374,213	111,598	0	48,581	31,529	565,920	2.30
TOTAL Underseepage Berm (Random)	196897.00	CCY	1,468,257	439,811	0	190,807	123,834	2,222,708	11.29
11.01.27 Seeding & Mulching									
11.01.27.01 Seeding & Mulching									
11.01.27.01.30 Seeding & Mulching									
11.01.27.01.30.01 Seeding & Mulching	14.70	ACR	27,488	5,498	0	3,299	2,141	38,425	2613.92
TOTAL Seeding & Mulching	14.70	ACR	27,488	5,498	0	3,299	2,141	38,425	2613.92
TOTAL Seeding & Mulching	14.70	ACR	27,488	5,498	0	3,299	2,141	38,425	2613.92
TOTAL Seeding & Mulching	14.70	ACR	27,488	5,498	0	3,299	2,141	38,425	2613.92
11.01.28 Replace Aggregate Surfacing									
11.01.28.27 Replace Aggregate Surfacing									
11.01.28.27.31 Replace Aggregate Surfacing									
11.01.28.27.31.01 Replace Aggregate Surfacing	3143.00	TON	64,734	12,947	0	7,768	5,041	90,491	28.79
TOTAL Replace Aggregate Surfacing	3143.00	TON	64,734	12,947	0	7,768	5,041	90,491	28.79
TOTAL Replace Aggregate Surfacing	3143.00	TON	64,734	12,947	0	7,768	5,041	90,491	28.79
TOTAL Replace Aggregate Surfacing	1654.00	CCY	64,734	12,947	0	7,768	5,041	90,491	54.71
11.01.29 Replace Stripped Material									
11.01.29.06 Repl Lev w/ less than 1' Raise									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.29.06.32 Push Topsoil to Levee	3065.35 BCY	2,776	555	0	333	216	3,880	1.27
11.01.29.06.33 Finish Grade Lev for TS Placemnt	3.80 ACR	4,701	940	0	564	366	6,571	1729.22
TOTAL Repl Lev w/ less than 1' Raise	3.80 ACR	7,476	1,495	0	897	582	10,451	2750.28
11.01.29.09 Repl Berm-Less than 1' Raise								
11.01.29.09.34 Push Topsoil to Berm	36542.15 BCY	66,177	13,235	0	7,941	5,154	92,508	2.53
11.01.29.09.35 Finish Grade Lev for TS Placemnt	45.30 ACR	56,038	11,208	0	6,725	4,364	78,334	1729.22
TOTAL Repl Berm-Less than 1' Raise	45.30 ACR	122,215	24,443	0	14,666	9,518	170,842	3771.35
TOTAL Replace Stripped Material	41865.00 CY	129,691	25,938	0	15,563	10,100	181,293	4.33
11.01.30 Slope Protection								
11.01.30.27 Place Bedding Material								
11.01.30.27.36 Place Bedding Material								
11.01.30.27.36.01 Place Bedding Material	350.00 TON	9,603	4,801	0	1,440	935	16,780	47.94
TOTAL Place Bedding Material	350.00 TON	9,603	4,801	0	1,440	935	16,780	47.94
TOTAL Place Bedding Material	350.00 TON	9,603	4,801	0	1,440	935	16,780	47.94
11.01.30.28 Place Riprap Protection								
11.01.30.28.37 Place Riprap Protection								
11.01.30.28.37.01 Place Riprap Protection	1000.00 TON	32,378	16,189	0	4,857	3,152	56,576	56.58
TOTAL Place Riprap Protection	1000.00 TON	32,378	16,189	0	4,857	3,152	56,576	56.58
TOTAL Place Riprap Protection	1000.00 TON	32,378	16,189	0	4,857	3,152	56,576	56.58
TOTAL Slope Protection	1.00 EA	41,981	20,990	0	6,297	4,087	73,355	73355.18
11.01.31 Drainage Systems								
TOTAL Levees	1.00 EA	1,902,490	539,252	0	244,174	158,469	2,844,385	2844385
11.02 Floodwalls - NONE								
TOTAL Levees and Floodwalls	1.00 EA	1,902,490	539,252	0	244,174	158,469	2,844,385	2844385
TOTAL Feasibility Study Estimate For:	1.00 EA	2,082,899	566,313	0	244,174	158,469	3,051,856	3051856

** PROJECT INDIRECT SUMMARY - Feature **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages	1.00	EA	180,410	0	0	0	0	180,410	180409.50
11 Levees and Floodwalls	1.00	EA	1,526,127	0	183,135	170,926	22,302	1,902,490	1902490
TOTAL Feasibility Study Estimate For:	1.00	EA	1,706,536	0	183,135	170,926	22,302	2,082,899	2082899
Contingency								566,313	
SUBTOTAL								2,649,212	
Engineering & Design								244,174	
SUBTOTAL								2,893,387	
Supervision & Administration								158,469	
TOTAL INCL OWNER COSTS								3,051,856	

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Borrow Area-Sta 250+00 to 265+00	42.00	ACR	79,800	0	0	0	0	79,800	1900.00
01.23.01.01.02 Sta 205+50 to 209+50	2.65	ACR	2,043	0	0	0	0	2,043	770.75
01.23.01.01.03 Sta 209+50 to 237+50	10.75	ACR	7,790	0	0	0	0	7,790	724.65
01.23.01.01.04 Sta 237+50 to 257+50	19.00	ACR	12,825	0	0	0	0	12,825	675.00
01.23.01.01.05 Sta 257+50 to 262+50	3.85	ACR	2,660	0	0	0	0	2,660	690.91
01.23.01.01.06 Sta 262+50 to 288+50	10.60	ACR	8,702	0	0	0	0	8,702	820.94
01.23.01.01.07 Sta 288+50 to 292+50	2.05	ACR	1,634	0	0	0	0	1,634	797.07
01.23.01.01.08 Sta 292+50 to 295+00	1.00	ACR	836	0	0	0	0	836	836.00
TOTAL Land Values	1.00	EA	116,290	0	0	0	0	116,290	116289.50
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.09 NFS Costs	1.00	EA	44,400	0	0	0	0	44,400	44400.00
TOTAL Non Federal Sponsors Costs	1.00	EA	44,400	0	0	0	0	44,400	44400.00
01.23.01.03 Federal Costs									
01.23.01.03.10 Federal Costs	1.00	EA	19,720	0	0	0	0	19,720	19720.00
TOTAL Federal Costs	1.00	EA	19,720	0	0	0	0	19,720	19720.00
TOTAL Land Values	1.00	EA	180,410	0	0	0	0	180,410	180409.50
TOTAL Land Values	1.00	EA	180,410	0	0	0	0	180,410	180409.50
TOTAL Lands and Damages	1.00	EA	180,410	0	0	0	0	180,410	180409.50
02 Relocations									
02.01 Utility Relocations									
02.01.03 Cemetery, Utilities, & Structure									
02.01.03.18 Utilities Crossing Levee									
02.01.03.18.11 Utilities Crossing Levee - NONE									
02.01.03.20 Utilities Affected by Uplift									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
02.01.03.20.12 Util affected by uplift - NONE									
06 Fish & Wildlife Facilities									
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Relief Wells									
11.01.02 Borrow Sites & Site Prep									
11.01.02.01 Site Prep Sta 250+00 to 265+00									
11.01.02.01.13 Stripping/Windrow Material	13889.00	CY	16,162	0	1,939	1,810	236	20,148	1.45
TOTAL Site Prep Sta 250+00 to 265+00	13889.00	CY	16,162	0	1,939	1,810	236	20,148	1.45
11.01.02.02 Low Water Crossing - Sta 232+00									
11.01.02.02.14 Low Water Crossing - Sta 232+00									
11.01.02.02.14.01 Low Water Crossing - Sta 232+00	1.00	EA	5,000	0	600	560	73	6,233	6233.07
TOTAL Low Water Crossing - Sta 232+00	1.00	EA	5,000	0	600	560	73	6,233	6233.07
TOTAL Low Water Crossing - Sta 232+00	1.00	EA	5,000	0	600	560	73	6,233	6233.07
11.01.02.10 Final Grade Site									
11.01.02.10.15 Final Grade Sta 250+00 to 265+00	13889.00	CY	16,136	0	1,936	1,807	236	20,115	1.45
TOTAL Final Grade Site	1.00	EA	16,136	0	1,936	1,807	236	20,115	20114.93
TOTAL Borrow Sites & Site Prep	1.00	EA	37,298	0	4,476	4,177	545	46,496	46496.04
11.01.03 Stripping Levee									
11.01.03.05 Remove Aggr Sta 205+64 to 294+93									
11.01.03.05.16 Excavate Aggregate from Levee	1654.00	BCY	915	0	110	102	13	1,140	0.69
TOTAL Remove Aggr Sta 205+64 to 294+93	1654.00	BCY	915	0	110	102	13	1,140	0.69
11.01.03.06 Strip Levee-Less than 1' Raise									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.03.06.17 Strip Topsoil from Levee	3065.35	BCY	2,227	0	267	249	33	2,776	0.91
11.01.03.06.18 Windrow Material	3065.35	BCY	1,130	0	136	127	17	1,409	0.46
TOTAL Strip Levee-Less than 1' Raise	3.80	ACR	3,357	0	403	376	49	4,185	1101.23
11.01.03.09 Strip Berm-Less than 1' Raise									
11.01.03.09.19 Strip Topsoil from Levee	38800.83	BCY	53,086	0	6,370	5,946	776	66,177	1.71
11.01.03.09.20 Windrow Material	38800.83	BCY	14,967	0	1,796	1,676	219	18,658	0.48
TOTAL Strip Berm-Less than 1' Raise	48.10	ACR	68,053	0	8,166	7,622	994	84,836	1763.74
TOTAL Stripping Levee	43519.00	BCY	72,324	0	8,679	8,100	1,057	90,161	2.07
11.01.04 Levee Raise (Impervious)									
11.01.04.01 Exc/Haul Matl-Sta 205+64-257+50									
11.01.04.01.21 Exc/Haul	3001.25	BCY	10,702	0	1,284	1,199	156	13,341	4.45
TOTAL Exc/Haul Matl-Sta 205+64-257+50	3001.25	BCY	10,702	0	1,284	1,199	156	13,341	4.45
11.01.04.02 Exc/Haul Matl-Sta 257+50-294+93									
11.01.04.02.22 Exc/Haul	2486.25	BCY	8,865	0	1,064	993	130	11,052	4.45
TOTAL Exc/Haul Matl-Sta 257+50-294+93	2486.25	BCY	8,865	0	1,064	993	130	11,052	4.45
11.01.04.03 Place Material									
11.01.04.03.23 Scarify Existing Surface	133935.00	SF	342	0	41	38	5	426	0.00
11.01.04.03.24 Place	5487.50	BCY	7,110	0	853	796	104	8,863	1.62
TOTAL Place Material	5487.50	BCY	7,452	0	894	835	109	9,289	1.69
TOTAL Levee Raise (Impervious)	4390.00	CCY	27,019	0	3,242	3,026	395	33,682	7.67
11.01.07 Underseepage Berm (Random)									
11.01.07.02 Exc/Haul Matl-Sta 205+64- 257+00									
11.01.07.02.25 Exc/Haul	162793.75	BCY	580,486	0	69,658	65,014	8,483	723,641	4.45
TOTAL Exc/Haul Matl-Sta 205+64- 257+00	162793.75	BCY	580,486	0	69,658	65,014	8,483	723,641	4.45

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.07.03 Exc/Haul Matl-Sta 257+00- 294+93									
11.01.07.03.26 Exc/Haul	83327.50	BCY	297,127	0	35,655	33,278	4,342	370,403	4.45
TOTAL Exc/Haul Matl-Sta 257+00- 294+93	83327.50	BCY	297,127	0	35,655	33,278	4,342	370,403	4.45
11.01.07.53 Place Material									
11.01.07.53.27 Scarify Existing Surface	1785800	SF	4,560	0	547	511	67	5,685	0.00
11.01.07.53.28 Place	244467.25	BCY	294,839	0	35,381	33,022	4,309	367,550	1.50
11.01.07.53.29 Spread Aggregate Surfacing Matl	1654.00	BCY	784	0	94	88	11	978	0.59
TOTAL Place Material	246121.25	BCY	300,183	0	36,022	33,621	4,387	374,213	1.52
TOTAL Underseepage Berm (Random)	196897.00	CCY	1,177,796	0	141,336	131,913	17,212	1,468,257	7.46
11.01.27 Seeding & Mulching									
11.01.27.01 Seeding & Mulching									
11.01.27.01.30 Seeding & Mulching									
11.01.27.01.30.01 Seeding & Mulching	14.70	ACR	22,050	0	2,646	2,470	322	27,488	1869.92
TOTAL Seeding & Mulching	14.70	ACR	22,050	0	2,646	2,470	322	27,488	1869.92
TOTAL Seeding & Mulching	14.70	ACR	22,050	0	2,646	2,470	322	27,488	1869.92
TOTAL Seeding & Mulching	14.70	ACR	22,050	0	2,646	2,470	322	27,488	1869.92
11.01.28 Replace Aggregate Surfacing									
11.01.28.27 Replace Aggregate Surfacing									
11.01.28.27.31 Replace Aggregate Surfacing									
11.01.28.27.31.01 Replace Aggregate Surfacing	3143.00	TON	51,928	0	6,231	5,816	759	64,734	20.60
TOTAL Replace Aggregate Surfacing	3143.00	TON	51,928	0	6,231	5,816	759	64,734	20.60
TOTAL Replace Aggregate Surfacing	3143.00	TON	51,928	0	6,231	5,816	759	64,734	20.60
TOTAL Replace Aggregate Surfacing	1654.00	CCY	51,928	0	6,231	5,816	759	64,734	39.14
11.01.29 Replace Stripped Material									
11.01.29.06 Repl Lev w/ less than 1' Raise									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.29.06.32 Push Topsoil to Levee	3065.35	BCY	2,227	0	267	249	33	2,776	0.91
11.01.29.06.33 Finish Grade Lev for TS Placemnt	3.80	ACR	3,771	0	452	422	55	4,701	1237.03
TOTAL Repl Lev w/ less than 1' Raise	3.80	ACR	5,997	0	720	672	88	7,476	1967.47
11.01.29.09 Repl Berm-Less than 1' Raise									
11.01.29.09.34 Push Topsoil to Berm	36542.15	BCY	53,086	0	6,370	5,946	776	66,177	1.81
11.01.29.09.35 Finish Grade Lev for TS Placemnt	45.30	ACR	44,952	0	5,394	5,035	657	56,038	1237.03
TOTAL Repl Berm-Less than 1' Raise	45.30	ACR	98,038	0	11,765	10,980	1,433	122,215	2697.90
TOTAL Replace Stripped Material	41865.00	CY	104,035	0	12,484	11,652	1,520	129,691	3.10
11.01.30 Slope Protection									
11.01.30.27 Place Bedding Material									
11.01.30.27.36 Place Bedding Material									
11.01.30.27.36.01 Place Bedding Material	350.00	TON	7,703	0	924	863	113	9,603	27.44
TOTAL Place Bedding Material	350.00	TON	7,703	0	924	863	113	9,603	27.44
TOTAL Place Bedding Material	350.00	TON	7,703	0	924	863	113	9,603	27.44
11.01.30.28 Place Riprap Protection									
11.01.30.28.37 Place Riprap Protection									
11.01.30.28.37.01 Place Riprap Protection	1000.00	TON	25,973	0	3,117	2,909	380	32,378	32.38
TOTAL Place Riprap Protection	1000.00	TON	25,973	0	3,117	2,909	380	32,378	32.38
TOTAL Place Riprap Protection	1000.00	TON	25,973	0	3,117	2,909	380	32,378	32.38
TOTAL Slope Protection	1.00	EA	33,676	0	4,041	3,772	492	41,981	41980.82
11.01.31 Drainage Systems									
TOTAL Levees	1.00	EA	1,526,127	0	183,135	170,926	22,302	1,902,490	1902490
11.02 Floodwalls - NONE									
TOTAL Levees and Floodwalls	1.00	EA	1,526,127	0	183,135	170,926	22,302	1,902,490	1902490
TOTAL Feasibility Study Estimate For:	1.00	EA	1,706,536	0	183,135	170,926	22,302	2,082,899	2082899

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
Contingency								566,313	
SUBTOTAL								2,649,212	
Engineering & Design								244,174	
SUBTOTAL								2,893,387	
Supervision & Administration								158,469	
TOTAL INCL OWNER COSTS								3,051,856	

No errors detected...

* * * END OF ERROR REPORT * * *

Feasibility Study Estimate for:
R470-461
St. Joseph, Missouri
Nominal 100 Yr +3ft Levee Raise
dated 18 Jul 2006

Designed By: CENWK
Estimated By: CENWK-EC-DC

Prepared By: Patrick Miramontez 816-983-3322
LATEST ESTIMATE AS OF 18 Jul 06

Preparation Date: 01/10/06
Effective Date of Pricing: 10/01/05

Sales Tax: 0.00%

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01- Lands & Damages - The costs include the acquisition of Permanent Right-of-Way, Temporary Right-of-Way, and borrow areas. Also included, where necessary, is the relocation cost of businesses that infringe on the footprint of the raised levee. These costs include Non Federal Sponsors cost to perform the Legal work, Title Work, Tract appraisals, and land surveys, as well as Federal labor costs.

02 - Relocations - This item currently includes only utility relocations. There are two types of utility relocations:

1) Utilities crossing the levee - These are utilities identified as having to be removed from their current location and placed up and over the new levee raise. This will require a fill zone that will be evident above the levee projected lines. All abandoned pipes crossing the levee will be removed.

2) Fences, Gates, and Power Poles - These structures/utilities are currently in or near the levee. They will be impacted in the levee raise, and therefore will need to be relocated.

06 - Fish & Wildlife Facilities - An allowance of $500,000 was included to allow for mitigation of the borrow areas. Specifics of the plan are currently not known.

11 - Levees & Floodwalls- The levees cost consists of 4 different components. These components include: 1) Relief Wells, 2) Borrow Site, 3) Levee Raise (including Levee Cut, Levee Raise, Stability (Riverside Berms) and Underseepage berms), and 4) Drainage System Modifications.

- Relief Wells - Relief Wells are placed in areas of tight congestion to avoid the costly displacement of businesses. The costs are based on 10" stainless steel wells. It is assumed 22 new wells will be required at varying depths based on current analysis. To be refined in final plan.

- Borrow Site - It is currently assumed two borrow sites will be utilized. It is assumed 100% of the material will come from the borrow sites located a maximum of 4.2 miles from the levee centroid. The costs include the preparation of the borrow site, and the final grading of the borrow site when completed. Also included is additional clearing of trees in the levee ROW.

- Levee Cut - Quantities for the levee cut were based on the removal of the aggregate surfacing on top of the levee, and the stripping of topsoil from the landside of the existing levee. It was assumed this material will be dozed off and windrowed next to the levee.

- Levee Raise (including Stability/Underseepage Berms) - Quantities for the levee raise was calculated by using In-Roads CAD software and then hand manipulated. Haul distances were hand calculated based on the borrow site locations and the quantities required. Haul distances vary from 0.55 miles to 4.22 miles. The material is to be excavated, loaded, and hauled using off-highway dump trucks over the existing ramps and new ramps and low water

crossings where needed. A cost is also included for new aggregate surfacing and seeding and mulching.

- Drainage System Modifications - This item includes costs to raise existing platforms on gatewells due to levee raises and the complete replacement of one gatewell.

- Floodwalls - None in this contract.

30 - Estimated Engineering & Design Cost = 10% of project implementation (less lands & damages) cost. To be refined.

31 - Estimated Construction Supervision & Administration = 6.5% of project implementation (less lands & damages) cost. To be refined.

Areas of Cost Sensitivity

- Estimate does not include any costs for sampling/testing for HTRW.
- Estimate does not include any costs for the hauling and disposal of HTRW.
- Estimate does not include O&M costs. Only project implementation (construction, real-estate and associated) costs.
- Estimate based on borrow source located at Approx Right Bank Levee Stations 93+09 to 215+00, and Sta 471+20 to 610+00. If this borrow is not available for use additional costs will have to be considered.

General Cost Information

- The quantities have been calculated by EC-GD, EC-DC, and EC-DS. A contingency determination meeting will be held with all of the designers to apply the appropriate amount of contingency to each line item.
- No tax has been included for the state of Missouri.
- The source for the labor rates used in the estimate is the Dec 2005 Department of Labor Wage rates for Buchanon County, Missouri.
- The national 2001 Unit Price Book is used to price minor items. Quotes were received for major cost items. An adjustment factor is added to bring the rates to the appropriate price level date.
- 2005 equipment rates were used.
- Once all of the databases are normalized to the appropriate price level date an escalation factor will be added to the owner level to bring the estimate to the appropriate price level date. The escalation factors used were derived from the Civil Works Construction Cost Index System (CWCCIS) EM1110-2-1304.

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No Backup Reports...

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** PROJECT OWNER SUMMARY - Feature **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
01 Lands and Damages	1.00	EA	2,373,298	355,995	0	0	0	2,729,293	2729293
02 Relocations	1.00	EA	295,409	59,082	0	35,449	23,006	412,947	412946.67
06 Fish & Wildlife Facilities	1.00	EA	500,000	0	0	50,000	32,450	582,450	582450.00
11 Levees and Floodwalls	1.00	EA	16,606,176	4,055,680	0	2,066,186	1,340,954	24,068,996	24068996
TOTAL Feasibility Study Estimate for:	1.00	EA	19,774,883	4,470,756	0	2,151,635	1,396,411	27,793,685	27793685

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Borrow Area	1000.00	ACR	2,000,000	300,000	0	0	0	2,300,000	2300.00
01.23.01.01.02 Sta 93+00 to 132+00	9.13	ACR	13,262	1,989	0	0	0	15,251	1670.46
01.23.01.01.03 Sta 132+00 to 161+50	14.47	ACR	15,164	2,275	0	0	0	17,439	1205.16
01.23.01.01.04 Sta 161+50 to 228+50	48.84	ACR	38,460	5,769	0	0	0	44,229	905.59
01.23.01.01.05 Sta 228+50 to 281+50	26.46	ACR	19,768	2,965	0	0	0	22,733	859.15
01.23.01.01.06 Sta 281+50 to 299+50	14.72	ACR	8,832	1,325	0	0	0	10,157	690.00
01.23.01.01.07 Sta 299+50 to 331+50	9.43	ACR	10,684	1,603	0	0	0	12,287	1302.93
01.23.01.01.08 Sta 331+50 to 341+50	2.67	ACR	4,052	608	0	0	0	4,660	1745.24
01.23.01.01.09 Sta 341+50 to 404+50	46.35	ACR	31,086	4,663	0	0	0	35,749	771.28
01.23.01.01.10 Sta 404+50 to 492+50	45.15	ACR	41,706	6,256	0	0	0	47,962	1062.28
01.23.01.01.11 Sta 492+50 to 516+50	19.07	ACR	17,042	2,556	0	0	0	19,598	1027.70
01.23.01.01.12 Sta 516+50 to 600+50	77.09	ACR	60,618	9,093	0	0	0	69,711	904.28
01.23.01.01.13 Sta 600+50 to 639+84	17.58	ACR	18,164	2,725	0	0	0	20,889	1188.20
TOTAL Land Values	1.00	EA	2,278,838	341,826	0	0	0	2,620,664	2620664
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.14 NFS Costs	1.00	EA	64,900	9,735	0	0	0	74,635	74635.00
TOTAL Non Federal Sponsors Costs	1.00	EA	64,900	9,735	0	0	0	74,635	74635.00
01.23.01.03 Federal Costs									
01.23.01.03.15 Federal Costs	1.00	EA	29,560	4,434	0	0	0	33,994	33994.00
TOTAL Federal Costs	1.00	EA	29,560	4,434	0	0	0	33,994	33994.00
TOTAL Land Values	1.00	EA	2,373,298	355,995	0	0	0	2,729,293	2729293
TOTAL Land Values	1.00	EA	2,373,298	355,995	0	0	0	2,729,293	2729293
TOTAL Lands and Damages	1.00	EA	2,373,298	355,995	0	0	0	2,729,293	2729293
02 Relocations									
02.01 Utility Relocations									
02.01.03 Cemetery, Utilities, & Structure									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
02.01.03.18 Utilities Crossing Levee									
02.01.03.18.16 UL1- Sta 53+38 - 16" SP - No Act									
02.01.03.18.17 UL2- Sta 300+00-16" DIP waterlin									
02.01.03.18.17.01 Excavation for Bypass	355.00	CY	8,475	1,695	0	1,017	660	11,848	33.37
02.01.03.18.17.02 16" Ductile Iron Pipe	300.00	LF	36,272	7,254	0	4,353	2,825	50,704	169.01
02.01.03.18.17.03 16" Ductile Iron Fittings	6.00	EA	16,808	3,362	0	2,017	1,309	23,496	3915.99
02.01.03.18.17.04 Air Release Valve/Chamber	1.00	EA	6,578	1,316	0	789	512	9,195	9195.24
02.01.03.18.17.05 Final Cutover Connection	6.00	HR	3,679	736	0	441	286	5,142	857.04
02.01.03.18.17.24 Excavation for Demolition	714.00	CY	8,475	1,695	0	1,017	660	11,848	16.59
02.01.03.18.17.25 Removal of Existing Waterline	284.00	LF	4,506	901	0	541	351	6,298	22.18
02.01.03.18.17.26 Excavate & Haul BF Material	2022.00	BCY	17,201	3,440	0	2,064	1,340	24,045	11.89
02.01.03.18.17.27 Backfill/Compaction	3108.00	CY	12,996	2,599	0	1,560	1,012	18,167	5.85
TOTAL UL2- Sta 300+00-16" DIP waterlin	1.00	EA	114,990	22,998	0	13,799	8,955	160,742	160742.40
02.01.03.18.18 UL3- Sta 417+65 - 8" Gas Pipe									
02.01.03.18.18.01 Excavation for Bypass	804.00	CY	8,475	1,695	0	1,017	660	11,848	14.74
02.01.03.18.18.02 8" Dia Gas Line	300.00	LF	20,126	4,025	0	2,415	1,567	28,134	93.78
02.01.03.18.18.03 8" Gas Line Fittings	6.00	EA	5,628	1,126	0	675	438	7,868	1311.28
02.01.03.18.18.04 Final Cutover Connection	4.00	HR	2,466	493	0	296	192	3,447	861.82
02.01.03.18.18.05 Excavation for Demolition	3760.00	BCY	21,189	4,238	0	2,543	1,650	29,619	7.88
02.01.03.18.18.06 Removal of Existing Gas Line	120.00	LF	1,408	282	0	169	110	1,968	16.40
02.01.03.18.18.07 Excavate & Haul BF Material	600.00	BCY	6,450	1,290	0	774	502	9,017	15.03
02.01.03.18.18.08 Backfill/Compaction	5264.00	BCY	28,505	5,701	0	3,421	2,220	39,846	7.57
02.01.03.18.18.09 Contingency plan	1.00	EA	25,000	5,000	0	3,000	1,947	34,947	34947.00
TOTAL UL3- Sta 417+65 - 8" Gas Pipe	1.00	EA	119,247	23,849	0	14,310	9,287	166,693	166693.12
02.01.03.18.19 UL4- Sta 418+15 - Telephone Cbl									
02.01.03.18.19.02 New Telephone Cable incl Exc	200.00	LF	12,469	2,494	0	1,496	971	17,431	87.15
02.01.03.18.19.05 Splice Connection & Testing	1.00	EA	4,094	819	0	491	319	5,723	5722.69
02.01.03.18.19.24 Excavation for Demolition	295.00	CY	3,798	760	0	456	296	5,309	18.00
02.01.03.18.19.27 Backfill/Compaction	300.00	CY	2,661	532	0	319	207	3,720	12.40
TOTAL UL4- Sta 418+15 - Telephone Cbl	1.00	EA	23,022	4,604	0	2,763	1,793	32,183	32182.53
02.01.03.18.21 UL6- Sta 5+1.47 - 8" VCP-No Act									
TOTAL Utilities Crossing Levee	1.00	EA	257,260	51,452	0	30,871	20,035	359,618	359618.05
02.01.03.20 Fencing, Gates, & Power Poles									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
02.01.03.20.22 Fencing, Gates, and Power Poles									
02.01.03.20.22.01 Sta 269+12-Rem/Repl Wood Post/Gt	2.00	EA	1,918	384	0	230	149	2,681	1340.46
02.01.03.20.22.02 Sta 269+12-Rem/Repl Barbed Wire	1000.00	LF	4,315	863	0	518	336	6,032	6.03
02.01.03.20.22.03 Sta 269+12-Relocate Power Poles	6.00	EA	12,000	2,400	0	1,440	935	16,775	2795.76
02.01.03.20.22.04 Sta 269+12-Clearing for Poles	1.00	EA	1,226	245	0	147	96	1,714	1714.35
02.01.03.20.22.05 Sta 404+00 - Clearing	1.00	EA	1,745	349	0	209	136	2,439	2438.91
02.01.03.20.22.06 Sta 404+00-Rem CLF/gate	140.00	LF	718	144	0	86	56	1,004	7.17
02.01.03.20.22.07 Sta 404+00-New CLF/gate	1.00	EA	2,718	544	0	326	212	3,800	3799.89
02.01.03.20.22.08 Sta 418+00-Rem gate	1.00	EA	359	72	0	43	28	502	501.96
02.01.03.20.22.09 Sta 418+00-New gate	1.00	EA	589	118	0	71	46	823	823.32
02.01.03.20.22.10 Sta 418+00-Rem/Repl Barbed Wire	130.00	LF	561	112	0	67	44	784	6.03
02.01.03.20.22.11 Remove/Replace Additional Gates	6.00	EA	12,000	2,400	0	1,440	935	16,775	2795.76
TOTAL Fencing, Gates, and Power Poles	1.00	EA	38,150	7,630	0	4,578	2,971	53,329	53328.62
TOTAL Fencing, Gates, & Power Poles	1.00	EA	38,150	7,630	0	4,578	2,971	53,329	53328.62
TOTAL Cemetery, Utilities, & Structure			295,409	59,082	0	35,449	23,006	412,947	
TOTAL Utility Relocations	1.00	EA	295,409	59,082	0	35,449	23,006	412,947	412946.67
TOTAL Relocations	1.00	EA	295,409	59,082	0	35,449	23,006	412,947	412946.67
06 Fish & Wildlife Facilities									
06.03 Fish & Wildlife Fac/Sanc									
06.03.99 Associated General Items									
06.03.99.01 Environmental Enhancement									
06.03.99.01.23 Environmental Enhancement	1.00	EA	500,000	0	0	50,000	32,450	582,450	582450.00
TOTAL Environmental Enhancement	1.00	EA	500,000	0	0	50,000	32,450	582,450	582450.00
TOTAL Associated General Items	1.00	EA	500,000	0	0	50,000	32,450	582,450	582450.00
TOTAL Fish & Wildlife Fac/Sanc	1.00	EA	500,000	0	0	50,000	32,450	582,450	582450.00
TOTAL Fish & Wildlife Facilities	1.00	EA	500,000	0	0	50,000	32,450	582,450	582450.00
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Relief Wells									
11.01.01.01 Sta 292+00 to 327+00									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.01.01.24 New Relief Wells									
11.01.01.01.24.01 RW Sta 292+00 to 327+00	22.00	EA	899,755	179,951	0	107,971	70,073	1,257,750	57170.46
TOTAL New Relief Wells	22.00	EA	899,755	179,951	0	107,971	70,073	1,257,750	57170.46
11.01.01.01.25 Abandon Existing Relief Wells									
11.01.01.01.25.01 RW Sta 292+00 to 327+00	20.00	EA	19,149	3,830	0	2,298	1,491	26,768	1338.38
TOTAL Abandon Existing Relief Wells	20.00	EA	19,149	3,830	0	2,298	1,491	26,768	1338.38
TOTAL Sta 292+00 to 327+00	22.00	EA	918,904	183,781	0	110,268	71,564	1,284,518	58387.16
TOTAL Relief Wells	1.00	EA	918,904	183,781	0	110,268	71,564	1,284,518	1284518
11.01.02 Borrow Sites & Site Prep									
11.01.02.01 Site Prep Sta 93+09 to 215+00									
11.01.02.01.26 Stripping/Windrow Material	112880.00	CY	147,269	29,454	0	17,672	11,469	205,864	1.82
TOTAL Site Prep Sta 93+09 to 215+00	112880.00	CY	147,269	29,454	0	17,672	11,469	205,864	1.82
11.01.02.05 Site Prep Sta 471+20 to 610+00									
11.01.02.05.27 Site Prep New Borrow Site	159.00	ACR	16,403	3,281	0	1,968	1,277	22,930	144.21
11.01.02.05.28 Clearing and Grub Site	159.00	ACR	388,146	97,037	0	48,518	31,488	565,189	3554.65
11.01.02.05.29 Push Cleared Material to Piles	106.00	PIL	27,771	5,554	0	3,332	2,163	38,820	366.23
11.01.02.05.30 Maintain Burning Piles	106.00	PIL	19,648	3,930	0	2,358	1,530	27,466	259.11
TOTAL Site Prep Sta 471+20 to 610+00	159.00	ACR	451,968	109,801	0	56,177	36,459	654,405	4115.75
11.01.02.06 Additional Clearing & Grubbing									
11.01.02.06.2A Sta 496+00 to Sta 558+50	50.70	ACR	52,282	13,071	0	6,535	4,241	76,129	1501.56
11.01.02.06.2B Sta 558+50 to 610+00 (landward)	23.70	ACR	127,852	31,963	0	15,981	10,372	186,168	7855.19
11.01.02.06.2C Sta 610+00 to 639+84 (landward)	11.10	ACR	59,880	14,970	0	7,485	4,858	87,193	7855.19
11.01.02.06.2D Push Cleared Material to Piles	57.00	PIL	14,933	3,733	0	1,867	1,211	21,745	381.49
11.01.02.06.2E Maintain Burning Piles	57.00	PIL	10,566	2,641	0	1,321	857	15,385	269.91
TOTAL Additional Clearing & Grubbing	85.50	ACR	265,512	66,378	0	33,189	21,540	386,619	4521.86
11.01.02.10 Final Grade Both Sites									
11.01.02.10.31 Final Grade Sta 93+09 to 215+00	112880.00	CY	162,771	32,554	0	19,532	12,677	227,534	2.02

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.02.10.32 Final Grade Sta 471+20 to 610+00	159.00	ACR	137,565	27,513	0	16,508	10,714	192,299	1209.43
TOTAL Final Grade Both Sites	2.00	EA	300,335	60,067	0	36,040	23,390	419,833	209916.47
11.01.02.15 Ramps for Levee Crossings									
11.01.02.15.33 Ramps for Levee Crossings	4200.00	CY	28,055	5,611	0	3,367	2,185	39,218	9.34
TOTAL Ramps for Levee Crossings	7.00	EA	28,055	5,611	0	3,367	2,185	39,218	5602.55
11.01.02.20 Remove Ramps at Project End									
11.01.02.20.34 Remove Ramps at Project End	4200.00	CY	23,976	4,795	0	2,877	1,867	33,516	7.98
TOTAL Remove Ramps at Project End	7.00	EA	23,976	4,795	0	2,877	1,867	33,516	4788.03
11.01.02.25 Low Water Crossings									
11.01.02.25.35 Low Water Crossings									
11.01.02.25.35.01 Low Water Crossings	13.00	EA	80,678	16,136	0	9,681	6,283	112,779	8675.27
TOTAL Low Water Crossings	13.00	EA	80,678	16,136	0	9,681	6,283	112,779	8675.27
TOTAL Low Water Crossings	13.00	EA	80,678	16,136	0	9,681	6,283	112,779	8675.27
TOTAL Borrow Sites & Site Prep	1.00	EA	1,297,795	292,242	0	159,004	103,193	1,852,234	1852234
11.01.03 Stripping Levee									
11.01.03.05 Remove Aggr Sta 93+09 to 639+84									
11.01.03.05.36 Excavate Aggregate from Levee	10125.00	BCY	6,951	1,390	0	834	541	9,716	0.96
TOTAL Remove Aggr Sta 93+09 to 639+84	10125.00	BCY	6,951	1,390	0	834	541	9,716	0.96
11.01.03.06 Strip Levee-Less than 1' Raise									
11.01.03.06.37 Strip Topsoil from Levee	2178.01	BCY	1,768	354	0	212	138	2,471	1.13
11.01.03.06.38 Windrow Material	2178.01	BCY	997	199	0	120	78	1,393	0.64
TOTAL Strip Levee-Less than 1' Raise	2.70	ACR	2,765	553	0	332	215	3,865	1431.30
11.01.03.07 Strip Levee - > than 1' < 3' Rse									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.03.07.39 Strip Topsoil from Levee	37590.82	BCY	30,510	6,102	0	3,661	2,376	42,649	1.13
11.01.03.07.40 Windrow Material	37590.82	BCY	17,204	3,441	0	2,064	1,340	24,049	0.64
TOTAL Strip Levee - > than 1' < 3' Rse	46.60	ACR	47,714	9,543	0	5,726	3,716	66,698	1431.29
11.01.03.08 Strip Levee - > than </= 3' Rse									
11.01.03.08.41 Strip Topsoil from Levee	3226.68	BCY	2,619	524	0	314	204	3,661	1.13
11.01.03.08.42 Windrow Material	3226.68	BCY	1,477	295	0	177	115	2,064	0.64
TOTAL Strip Levee - > than </= 3' Rse	4.00	ACR	4,096	819	0	491	319	5,725	1431.29
11.01.03.09 Strip Berm-Less than 1' Raise									
11.01.03.09.43 Strip Topsoil from Levee	12100.05	BCY	19,641	4,910	0	2,455	1,593	28,600	2.36
11.01.03.09.44 Windrow Material	12100.05	BCY	5,538	1,384	0	692	449	8,064	0.67
TOTAL Strip Berm-Less than 1' Raise	15.00	ACR	25,179	6,295	0	3,147	2,043	36,664	2444.28
11.01.03.10 Strip Berm- > than 1' > 3' Raise									
11.01.03.10.45 Strip Topsoil from Levee	182710.76	BCY	296,586	74,147	0	37,073	24,061	431,867	2.36
11.01.03.10.46 Windrow Material	182710.76	BCY	83,621	20,905	0	10,453	6,784	121,762	0.67
TOTAL Strip Berm- > than 1' > 3' Raise	226.50	ACR	380,207	95,052	0	47,526	30,844	553,629	2444.28
11.01.03.11 Strip Berm- >/= 3' Raise									
11.01.03.11.47 Strip Topsoil from Levee	23312.76	BCY	37,843	9,461	0	4,730	3,070	55,104	2.36
11.01.03.11.48 Windrow Material	23312.76	BCY	10,670	2,667	0	1,334	866	15,536	0.67
TOTAL Strip Berm- >/= 3' Raise	28.90	ACR	48,512	12,128	0	6,064	3,936	70,640	2444.28
TOTAL Stripping Levee	271244.00	BCY	515,423	125,780	0	64,120	41,614	746,937	2.75
11.01.04 Levee Raise (Impervious)									
11.01.04.01 Exc/Haul Matl-Sta 93+09 - 114+00									
11.01.04.01.49 Exc/Haul	1166.25	BCY	5,162	1,032	0	619	402	7,215	6.19
TOTAL Exc/Haul Matl-Sta 93+09 - 114+00	1166.25	BCY	5,162	1,032	0	619	402	7,215	6.19
11.01.04.02 Exc/Haul Matl-Sta 600+00- 639+84									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.04.02.50 Exc/Haul	2061.25	BCY	9,123	1,825	0	1,095	710	12,753	6.19
TOTAL Exc/Haul Matl-Sta 600+00- 639+84	2061.25	BCY	9,123	1,825	0	1,095	710	12,753	6.19
11.01.04.03 Exc/Haul Matl-Sta 114+00- 228+00									
11.01.04.03.51 Exc/Haul	23696.25	BCY	104,876	20,975	0	12,585	8,168	146,604	6.19
TOTAL Exc/Haul Matl-Sta 114+00- 228+00	23696.25	BCY	104,876	20,975	0	12,585	8,168	146,604	6.19
11.01.04.04 Exc/Haul Matl-Sta 228+00- 375+00									
11.01.04.04.52 Exc/Haul	34861.25	BCY	219,156	43,831	0	26,299	17,068	306,354	8.79
TOTAL Exc/Haul Matl-Sta 228+00- 375+00	34861.25	BCY	219,156	43,831	0	26,299	17,068	306,354	8.79
11.01.04.05 Exc/Haul Matl-Sta 419+00- 467+00									
11.01.04.05.53 Exc/Haul	11558.75	BCY	51,157	10,231	0	6,139	3,984	71,512	6.19
TOTAL Exc/Haul Matl-Sta 419+00- 467+00	11558.75	BCY	51,157	10,231	0	6,139	3,984	71,512	6.19
11.01.04.06 Exc/Haul Matl-Sta 467+00- 600+00									
11.01.04.06.54 Exc/Haul	23607.50	BCY	104,483	20,897	0	12,538	8,137	146,055	6.19
TOTAL Exc/Haul Matl-Sta 467+00- 600+00	23607.50	BCY	104,483	20,897	0	12,538	8,137	146,055	6.19
11.01.04.07 Exc/Haul Matl-Sta 375+00- 398+00									
11.01.04.07.55 Exc/Haul	6402.50	BCY	48,192	9,638	0	5,783	3,753	67,366	10.52
TOTAL Exc/Haul Matl-Sta 375+00- 398+00	6402.50	BCY	48,192	9,638	0	5,783	3,753	67,366	10.52
11.01.04.08 Exc/Haul Matl-Sta 398+00- 419+00									
11.01.04.08.56 Exc/Haul	6093.75	BCY	38,308	7,662	0	4,597	2,983	53,551	8.79
TOTAL Exc/Haul Matl-Sta 398+00- 419+00	6093.75	BCY	38,308	7,662	0	4,597	2,983	53,551	8.79
11.01.04.52 Place Material									
11.01.04.52.57 Scarify Existing Surface	2187000	SF	6,932	1,386	0	832	540	9,690	0.00

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.04.52.58 Place	109447.50	BCY	176,006	35,201	0	21,121	13,707	246,035	2.25
TOTAL Place Material	109447.50	BCY	182,938	36,588	0	21,953	14,247	255,726	2.34
TOTAL Levee Raise (Impervious)	87558.00	CCY	763,396	152,679	0	91,608	59,453	1,067,136	12.19
11.01.05 Levee Raise (Random)									
11.01.05.03 Exc/Haul Matl-Sta 114+00- 228+00									
11.01.05.03.59 Exc/Haul	54895.00	BCY	242,957	48,591	0	29,155	18,922	339,625	6.19
TOTAL Exc/Haul Matl-Sta 114+00- 228+00	54895.00	BCY	242,957	48,591	0	29,155	18,922	339,625	6.19
11.01.05.04 Exc/Haul Matl-Sta 228+00- 375+00									
11.01.05.04.60 Exc/Haul	124602.50	BCY	783,318	156,664	0	93,998	61,005	1,094,984	8.79
TOTAL Exc/Haul Matl-Sta 228+00- 375+00	124602.50	BCY	783,318	156,664	0	93,998	61,005	1,094,984	8.79
11.01.05.05 Exc/Haul Matl-Sta 419+00- 467+00									
11.01.05.05.61 Exc/Haul	29440.00	BCY	130,297	26,059	0	15,636	10,148	182,140	6.19
TOTAL Exc/Haul Matl-Sta 419+00- 467+00	29440.00	BCY	130,297	26,059	0	15,636	10,148	182,140	6.19
11.01.05.06 Exc/Haul Matl-Sta 467+00- 600+00									
11.01.05.06.62 Exc/Haul	64110.00	BCY	283,741	56,748	0	34,049	22,098	396,637	6.19
TOTAL Exc/Haul Matl-Sta 467+00- 600+00	64110.00	BCY	283,741	56,748	0	34,049	22,098	396,637	6.19
11.01.05.07 Exc/Haul Matl-Sta 375+00- 398+00									
11.01.05.07.63 Exc/Haul	20798.75	BCY	156,552	31,310	0	18,786	12,192	218,841	10.52
TOTAL Exc/Haul Matl-Sta 375+00- 398+00	20798.75	BCY	156,552	31,310	0	18,786	12,192	218,841	10.52
11.01.05.08 Exc/Haul Matl-Sta 398+00- 419+00									
11.01.05.08.64 Exc/Haul	15510.00	BCY	97,504	19,501	0	11,700	7,594	136,299	8.79
TOTAL Exc/Haul Matl-Sta 398+00- 419+00	15510.00	BCY	97,504	19,501	0	11,700	7,594	136,299	8.79

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.05.52 Place Material									
11.01.05.52.65 Scarify Existing Surface	2187000	SF	6,932	1,386	0	832	540	9,690	0.00
11.01.05.52.66 Place	309356.25	BCY	497,486	99,497	0	59,698	38,744	695,425	2.25
TOTAL Place Material	309356.25	BCY	504,418	100,884	0	60,530	39,284	705,116	2.28
TOTAL Levee Raise (Random)	247485.00	CCY	2,198,787	439,757	0	263,854	171,242	3,073,641	12.42
11.01.06 Riverward Berm									
11.01.06.01 Exc/Haul Matl-Sta 166+00- 398+00									
11.01.06.01.67 Exc/Haul	161111.25	BCY	1,012,831	253,208	0	126,604	82,166	1,474,809	9.15
TOTAL Exc/Haul Matl-Sta 166+00- 398+00	161111.25	BCY	1,012,831	253,208	0	126,604	82,166	1,474,809	9.15
11.01.06.02 Exc/Haul Matl-Sta 398+00- 550+00									
11.01.06.02.68 Exc/Haul	105555.00	BCY	532,639	133,160	0	66,580	43,210	775,589	7.35
TOTAL Exc/Haul Matl-Sta 398+00- 550+00	105555.00	BCY	532,639	133,160	0	66,580	43,210	775,589	7.35
11.01.06.56 Place Material									
11.01.06.56.69 Scarify Existing Surface	1344000	SF	4,260	852	0	511	332	5,955	0.00
11.01.06.56.70 Place	266666.25	BCY	428,835	107,209	0	53,604	34,789	624,437	2.34
TOTAL Place Material	266666.25	BCY	433,095	108,061	0	54,116	35,121	630,392	2.36
TOTAL Riverward Berm	213333.00	CCY	1,978,565	494,428	0	247,299	160,497	2,880,789	13.50
11.01.07 Underseepage Berm (Random)									
11.01.07.02 Exc/Haul Matl-Sta 600+00- 639+84									
11.01.07.02.71 Exc/Haul	80203.75	BCY	354,970	106,491	0	46,146	29,949	537,556	6.70
TOTAL Exc/Haul Matl-Sta 600+00- 639+84	80203.75	BCY	354,970	106,491	0	46,146	29,949	537,556	6.70
11.01.07.03 Exc/Haul Matl-Sta 114+00- 228+00									
11.01.07.03.72 Exc/Haul	275548.75	BCY	1,219,538	365,862	0	158,540	102,892	1,846,832	6.70
TOTAL Exc/Haul Matl-Sta 114+00- 228+00	275548.75	BCY	1,219,538	365,862	0	158,540	102,892	1,846,832	6.70

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.07.04 Exc/Haul Matl-Sta 228+00- 375+00									
11.01.07.04.73 Exc/Haul	97012.50	BCY	609,872	182,962	0	79,283	51,455	923,572	9.52
TOTAL Exc/Haul Matl-Sta 228+00- 375+00	97012.50	BCY	609,872	182,962	0	79,283	51,455	923,572	9.52
11.01.07.05 Exc/Haul Matl-Sta 419+00- 467+00									
11.01.07.05.74 Exc/Haul	64632.50	BCY	286,054	85,816	0	37,187	24,134	433,192	6.70
TOTAL Exc/Haul Matl-Sta 419+00- 467+00	64632.50	BCY	286,054	85,816	0	37,187	24,134	433,192	6.70
11.01.07.06 Exc/Haul Matl-Sta 467+00- 600+00									
11.01.07.06.75 Exc/Haul	317035.00	BCY	1,403,151	420,945	0	182,410	118,384	2,124,889	6.70
TOTAL Exc/Haul Matl-Sta 467+00- 600+00	317035.00	BCY	1,403,151	420,945	0	182,410	118,384	2,124,889	6.70
11.01.07.07 Exc/Haul Matl-Sta 375+00- 398+00									
11.01.07.07.76 Exc/Haul	58356.25	BCY	439,247	131,774	0	57,102	37,059	665,182	11.40
TOTAL Exc/Haul Matl-Sta 375+00- 398+00	58356.25	BCY	439,247	131,774	0	57,102	37,059	665,182	11.40
11.01.07.08 Exc/Haul Matl-Sta 398+00- 419+00									
11.01.07.08.77 Exc/Haul	52578.75	BCY	330,538	99,161	0	42,970	27,887	500,557	9.52
TOTAL Exc/Haul Matl-Sta 398+00- 419+00	52578.75	BCY	330,538	99,161	0	42,970	27,887	500,557	9.52
11.01.07.53 Place Material									
11.01.07.53.78 Scarify Existing Surface	10935000	SF	34,660	6,932	0	4,159	2,699	48,451	0.00
11.01.07.53.79 Place	935242.50	BCY	1,400,011	420,003	0	182,001	118,119	2,120,134	2.27
11.01.07.53.80 Spread Aggregate Surfacing Matl	10125.00	BCY	5,958	1,192	0	715	464	8,328	0.82
TOTAL Place Material	945367.50	BCY	1,440,629	428,127	0	186,876	121,282	2,176,914	2.30
TOTAL Underseepage Berm (Random)	756295.00	CCY	6,083,999	1,821,138	0	790,514	513,043	9,208,694	12.18
11.01.08 Seeding & Mulching									
11.01.08.01 Seeding & Mulching									
11.01.08.01.81 Seeding & Mulching									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.08.01.81.01 Seeding & Mulching	120.00	ACR	223,417	44,683	0	26,810	17,400	312,310	2602.58
TOTAL Seeding & Mulching	120.00	ACR	223,417	44,683	0	26,810	17,400	312,310	2602.58
TOTAL Seeding & Mulching	120.00	ACR	223,417	44,683	0	26,810	17,400	312,310	2602.58
TOTAL Seeding & Mulching	120.00	ACR	223,417	44,683	0	26,810	17,400	312,310	2602.58
11.01.09 Replace Aggregate Surfacing									
11.01.09.27 Replace Aggregate Surfacing									
11.01.09.27.82 Replace Aggregate Surfacing									
11.01.09.27.82.01 Replace Aggregate Surfacing	19238.00	TON	403,272	80,654	0	48,393	31,407	563,726	29.30
TOTAL Replace Aggregate Surfacing	19238.00	TON	403,272	80,654	0	48,393	31,407	563,726	29.30
TOTAL Replace Aggregate Surfacing	19238.00	TON	403,272	80,654	0	48,393	31,407	563,726	29.30
TOTAL Replace Aggregate Surfacing	10125.00	CCY	403,272	80,654	0	48,393	31,407	563,726	55.68
11.01.10 Replace Stripped Material									
11.01.10.06 Repl Lev w/ less than 1' Raise									
11.01.10.06.84 Push Topsoil to Levee	2178.01	BCY	1,964	393	0	236	153	2,745	1.26
11.01.10.06.85 Finish Grade Lev for TS Placemnt	2.70	ACR	3,325	665	0	399	259	4,649	1721.72
TOTAL Repl Lev w/ less than 1' Raise	2.70	ACR	5,289	1,058	0	635	412	7,394	2738.35
11.01.10.07 Repl Lev w/ > than 1' < 3' Rse									
11.01.10.07.86 Push Topsoil to Levee	37590.82	BCY	33,891	6,778	0	4,067	2,639	47,375	1.26
11.01.10.07.87 Finish Grade Lev for TS Placemnt	46.60	ACR	57,396	11,479	0	6,887	4,470	80,232	1721.72
TOTAL Repl Lev w/ > than 1' < 3' Rse	46.60	ACR	91,286	18,257	0	10,954	7,109	127,607	2738.35
11.01.10.08 Repl Lev w/ > than </= 3' Rse									
11.01.10.08.88 Push Topsoil to Levee	3226.68	BCY	2,909	582	0	349	227	4,067	1.26
11.01.10.08.89 Finish Grade Lev for TS Placemnt	4.00	ACR	4,927	985	0	591	384	6,887	1721.72
TOTAL Repl Lev w/ > than </= 3' Rse	4.00	ACR	7,836	1,567	0	940	610	10,953	2738.35
11.01.10.09 Repl Berm-Less than 1' Raise									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.10.09.90 Push Topsoil to Berm	12100.05	ACR	21,818	4,364	0	2,618	1,699	30,499	2.52
11.01.10.09.91 Finish Grade Lev for TS Placemnt	15.00	ACR	18,475	3,695	0	2,217	1,439	25,826	1721.72
TOTAL Repl Berm-Less than 1' Raise	15.00	ACR	40,293	8,059	0	4,835	3,138	56,325	3754.98
11.01.10.10 Repl Berm- > than 1' > 3' Raise									
11.01.10.10.92 Push Topsoil to Berm	182710.76	BCY	329,451	65,890	0	39,534	25,658	460,534	2.52
11.01.10.10.93 Finish Grade Lev for TS Placemnt	226.50	ACR	278,972	55,794	0	33,477	21,726	389,970	1721.72
TOTAL Repl Berm- > than 1' > 3' Raise	226.50	ACR	608,424	121,685	0	73,011	47,384	850,503	3754.98
11.01.10.11 Repl Berm- >/= 3' Raise									
11.01.10.11.94 Push Topsoil to Berm	23312.76	BCY	42,036	8,407	0	5,044	3,274	58,761	2.52
11.01.10.11.95 Finish Grade Lev for TS Placemnt	28.90	ACR	35,595	7,119	0	4,271	2,772	49,758	1721.72
TOTAL Repl Berm- >/= 3' Raise	28.90	ACR	77,631	15,526	0	9,316	6,046	108,519	3754.98
TOTAL Replace Stripped Material	261119.00	CY	830,759	166,152	0	99,691	64,699	1,161,301	4.45
11.01.11 Slope Protection									
11.01.11.27 Place Bedding Material									
11.01.11.27.96 Place Bedding Material									
11.01.11.27.96.01 Place Bedding Material	40.00	TON	1,500	750	0	225	146	2,621	65.53
TOTAL Place Bedding Material	40.00	TON	1,500	750	0	225	146	2,621	65.53
TOTAL Place Bedding Material	40.00	TON	1,500	750	0	225	146	2,621	65.53
11.01.11.28 Place Riprap Protection									
11.01.11.28.97 Place Riprap Protection									
11.01.11.28.97.01 Place Riprap Protection	120.00	TON	5,429	2,715	0	814	529	9,487	79.06
TOTAL Place Riprap Protection	120.00	TON	5,429	2,715	0	814	529	9,487	79.06
TOTAL Place Riprap Protection	120.00	TON	5,429	2,715	0	814	529	9,487	79.06
TOTAL Slope Protection	1.00	EA	6,929	3,465	0	1,039	675	12,108	12107.91
11.01.12 Freeboard Gages									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.12.01 Freeboard Gages									
11.01.12.01.98 Freeboard Gages									
11.01.12.01.98.01 Freeboard Gages	7.00	EA	173,769	8,688	0	18,246	11,841	212,544	30363.45
TOTAL Freeboard Gages	7.00	EA	173,769	8,688	0	18,246	11,841	212,544	30363.45
TOTAL Freeboard Gages	7.00	EA	173,769	8,688	0	18,246	11,841	212,544	30363.45
TOTAL Freeboard Gages	7.00	EA	173,769	8,688	0	18,246	11,841	212,544	30363.45
11.01.13 Drainage Systems									
11.01.13.16 Drainage System 2 - Sta 115+60									
11.01.13.16.99 Platform Raise - 1 foot									
11.01.13.16.99. 1 Sand Blasting	28.00	SF	97	19	0	12	8	136	4.87
11.01.13.16.99.10 Vertcl Drilg Holes -1.5"X 6"Deep	60.00	EA	1,376	275	0	165	107	1,924	32.06
11.01.13.16.99.15 Grouting of vertical holes	60.00	EA	829	166	0	99	65	1,159	19.31
11.01.13.16.99.30 Hole Layout	3.00	HR	311	62	0	37	24	435	144.95
11.01.13.16.99.45 Concrete -Slab	1.14	CY	750	150	0	90	58	1,048	919.15
11.01.13.16.99.50 Forms for Slab	98.00	SF	706	141	0	85	55	987	10.07
11.01.13.16.99.55 Reinforcing Steel for Slab	201.00	LB	349	70	0	42	27	488	2.43
11.01.13.16.99.60 Replace Stem	1.00	EA	3,275	655	0	393	255	4,578	4578.44
TOTAL Platform Raise - 1 foot	1.00	EA	7,693	1,539	0	923	599	10,754	10754.45
11.01.13.16.A0 Drainage Structure Extension									
11.01.13.16.A0.01 Excavate and Remove Existing End	1.00	EA	1,152	230	0	138	90	1,610	1610.01
11.01.13.16.A0.02 Place RCP Extension	1.00	EA	1,869	374	0	224	146	2,612	2612.05
11.01.13.16.A0.03 Replace Flared End Section	1.00	EA	2,278	456	0	273	177	3,184	3184.27
11.01.13.16.A0.04 Place Concrete Collars	1.00	EA	2,431	486	0	292	189	3,398	3398.23
11.01.13.16.A0.05 Additional Compaction Labor	1.00	EA	352	70	0	42	27	492	491.53
11.01.13.16.A0.06 Riprap Removal and Replacement	1.00	EA	3,199	640	0	384	249	4,472	4472.43
TOTAL Drainage Structure Extension	1.00	EA	11,280	2,256	0	1,354	879	15,769	15768.52
TOTAL Drainage System 2 - Sta 115+60	1.00	EA	18,974	3,795	0	2,277	1,478	26,523	26522.97
11.01.13.17 Drainage System 3 - Sta 186+00									
11.01.13.17.A1 Platform Raise - 2 foot									
11.01.13.17.A1. 1 Sand Blasting	28.00	SF	97	19	0	12	8	136	4.87
11.01.13.17.A1.10 Vertcl Drilg Holes -1.5"X 6"Deep	48.00	EA	1,101	220	0	132	86	1,539	32.06

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.13.17.A1.15 Grouting of vertical holes	48.00	EA	666	133	0	80	52	932	19.41
11.01.13.17.A1.30 Hole Layout	3.00	HR	311	62	0	37	24	435	144.95
11.01.13.17.A1.45 Concrete -Slab	2.28	CY	962	192	0	115	75	1,345	589.70
11.01.13.17.A1.50 Forms for Slab	123.00	SF	865	173	0	104	67	1,209	9.83
11.01.13.17.A1.55 Reinforcing Steel for Slab	186.00	LB	350	70	0	42	27	489	2.63
11.01.13.17.A1.60 Replace Stem	1.00	EA	3,351	670	0	402	261	4,684	4684.10
TOTAL Platform Raise - 2 foot	1.00	EA	7,703	1,541	0	924	600	10,768	10768.20
11.01.13.17.A2 Drainage Structure Extension									
11.01.13.17.A2.01 Excavate and Remove Existing End	1.00	EA	1,152	230	0	138	90	1,610	1610.01
11.01.13.17.A2.02 Place RCP Extension	1.00	EA	2,684	537	0	322	209	3,752	3752.33
11.01.13.17.A2.03 Replace Flared End Section	1.00	EA	2,278	456	0	273	177	3,184	3184.27
11.01.13.17.A2.04 Place Concrete Collars	1.00	EA	2,431	486	0	292	189	3,398	3398.23
11.01.13.17.A2.05 Additional Compaction Labor	1.00	EA	352	70	0	42	27	492	491.53
11.01.13.17.A2.06 Riprap Removal and Replacement	1.00	EA	3,199	640	0	384	249	4,472	4472.43
TOTAL Drainage Structure Extension	1.00	EA	12,096	2,419	0	1,452	942	16,909	16908.80
TOTAL Drainage System 3 - Sta 186+00	1.00	EA	19,799	3,960	0	2,376	1,542	27,677	27676.99
11.01.13.18 Drainage System 4 - Sta 325+00									
11.01.13.18.A3 Dewatering									
11.01.13.18.A3.01 Drill Well & Set Casing	2.00	EA	73,659	14,732	0	8,839	5,737	102,967	51483.31
11.01.13.18.A3.02 Pilot Hole	1.00	EA	11,449	2,290	0	1,374	892	16,004	16003.64
11.01.13.18.A3.03 Dewatering Labor	30.00	DAY	12,053	2,411	0	1,446	939	16,848	561.62
11.01.13.18.A3.04 Abandon Wells	2.00	EA	9,930	1,986	0	1,192	773	13,880	6940.22
TOTAL Dewatering	1.00	EA	107,090	21,418	0	12,851	8,340	149,699	149699.15
11.01.13.18.A4 Exc/Haul Imp Fill for Ring Levee	21717.50	BCY	149,998	30,000	0	18,000	11,682	209,679	9.65
11.01.13.18.A5 Place Imp Fill for Ring Levee	21717.50	BCY	34,925	6,985	0	4,191	2,720	48,820	2.25
11.01.13.18.A6 48" Dia CMP for Ring Lev/Bypass									
11.01.13.18.A6.01 48" Dia CMP for Ring Levee	280.00	LF	37,809	7,562	0	4,537	2,945	52,852	188.76
11.01.13.18.A6.02 48" Dia CMP for Bypass	700.00	LF	48,390	9,678	0	5,807	3,769	67,643	96.63
TOTAL 48" Dia CMP for Ring Lev/Bypass	980.00	LF	86,198	17,240	0	10,344	6,713	120,495	122.95
11.01.13.18.A7 Seeding/Mulching for Ring Levee									
11.01.13.18.A7.01 Seeding and Mulching	1.30	ACR	1,129	226	0	136	88	1,579	1214.54
TOTAL Seeding/Mulching for Ring Levee	1.30	ACR	1,129	226	0	136	88	1,579	1214.54

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.13.18.A8 Turf Reinforcement Mat									
11.01.13.18.A8.01 Delivery of Reinforcement Mat	55215.00	SF	124	25	0	15	10	174	0.00
11.01.13.18.A8.02 Reinforcement Mat	63000.00	SF	27,019	5,404	0	3,242	2,104	37,769	0.60
11.01.13.18.A8.03 Trenching	19.26	CY	2,467	493	0	296	192	3,449	179.05
11.01.13.18.A8.04 Placement of Reinforcement Mat	6135.00	SY	6,208	1,242	0	745	483	8,677	1.41
11.01.13.18.A8.05 Backfill Trench & Reseed	19.26	CY	2,715	543	0	326	211	3,796	197.07
TOTAL Turf Reinforcement Mat	55215.00	SF	38,533	7,707	0	4,624	3,001	53,864	0.98
11.01.13.18.B0 Exc/Stockpile Exist Levee	16250.00	BCY	47,736	9,547	0	5,728	3,718	66,729	4.11
11.01.13.18.B1 Gatewell Structure									
11.01.13.18.B1.01 Demo Exist Gatewell Str/RCB	1.00	EA	30,014	6,003	0	3,602	2,337	41,956	41955.77
11.01.13.18.B1.02 Structural Excavation	1.00	EA	3,201	640	0	384	249	4,474	4474.03
11.01.13.18.B1.03 Base Slab	2.81	CY	5,073	1,015	0	609	395	7,091	2523.53
11.01.13.18.B1.04 1st Lift	17.22	CY	22,405	4,481	0	2,689	1,745	31,319	1818.76
11.01.13.18.B1.05 2nd Lift	17.22	CY	23,274	4,655	0	2,793	1,813	32,535	1889.35
11.01.13.18.B1.06 3rd Lift	9.98	CY	17,772	3,554	0	2,133	1,384	24,843	2489.23
11.01.13.18.B1.07 Elevated Slab	2.96	CY	5,268	1,054	0	632	410	7,364	2487.99
11.01.13.18.B1.08 Concrete Collars (allowance)	2.00	EA	2,482	496	0	298	193	3,470	1735.05
11.01.13.18.B1.15 Metals - Ladders	1.00	EA	3,681	736	0	442	287	5,145	5145.43
11.01.13.18.B1.16 Metals - Landings	1.00	EA	4,065	813	0	488	317	5,682	5682.39
11.01.13.18.B1.17 Metals - Labor	1.00	EA	8,351	1,670	0	1,002	650	11,674	11674.13
11.01.13.18.B1.30 Metals - Hydraulic Structures	1.00	EA	70,574	14,115	0	8,469	5,496	98,654	98653.66
TOTAL Gatewell Structure	1.00	EA	196,159	39,232	0	23,539	15,277	274,207	274207.37
11.01.13.18.B2 Inlet Structure For 6'x5' RCB									
11.01.13.18.B2.01 Toe	0.54	CY	220	44	0	26	17	307	569.25
11.01.13.18.B2.03 Slab	4.15	CY	4,315	863	0	518	336	6,032	1453.59
11.01.13.18.B2.04 Wingwall	4.01	CY	11,139	2,228	0	1,337	868	15,572	3883.18
11.01.13.18.B2.05 Headwall	1.88	CY	6,135	1,227	0	736	478	8,576	4561.61
11.01.13.18.B2.06 Concrete Collars (allowance)	1.00	EA	1,241	248	0	149	97	1,735	1735.05
11.01.13.18.B2.07 Free Draining Material Behind HW	1.30	CY	973	195	0	117	76	1,361	1046.55
TOTAL Inlet Structure For 6'x5' RCB	1.00	EA	24,024	4,805	0	2,883	1,871	33,583	33582.75
11.01.13.18.B3 Outlet Structure for 6'x5' RCB									
11.01.13.18.B3.01 Toe	1.70	CY	456	91	0	55	36	637	374.83
11.01.13.18.B3.03 Slab	6.30	CY	2,745	549	0	329	214	3,837	608.97
11.01.13.18.B3.04 Wingwall	5.53	CY	11,252	2,250	0	1,350	876	15,729	2844.38
11.01.13.18.B3.05 Headwall	3.09	CY	5,102	1,020	0	612	397	7,132	2307.98
11.01.13.18.B3.07 Concrete Collars	1.30	CY	1,529	306	0	183	119	2,138	1644.30
TOTAL Outlet Structure for 6'x5' RCB	1.00	EA	21,084	4,217	0	2,530	1,642	29,472	29472.41

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.13.18.B4 6'x5' RCB									
11.01.13.18.B4.33 Earthwork for 5'x6' RCB	190.00	LF	1,975	395	0	237	154	2,760	14.53
11.01.13.18.B4.34 Base Slab for 6'x5' RCB	74.77	CY	57,489	11,498	0	6,899	4,477	80,363	1074.80
11.01.13.18.B4.35 Walls for 6'x5' RCB	87.96	CY	124,188	24,838	0	14,903	9,672	173,600	1973.62
11.01.13.18.B4.36 Elevated Slab for 6'x5' RCB	74.77	CY	61,049	12,210	0	7,326	4,755	85,340	1141.37
TOTAL 6'x5' RCB	190.00	LF	244,701	48,940	0	29,364	19,057	342,062	1800.33
11.01.13.18.B6 Replace Exist Levee/Compact	16250.00	BCY	115,532	23,106	0	13,864	8,998	161,501	9.94
11.01.13.18.B7 Seeding/Mulching for RS of Levee									
11.01.13.18.B7.01 Seeding and Mulching	2.30	ACR	1,998	400	0	240	156	2,793	1214.54
TOTAL Seeding/Mulching for RS of Levee	2.30	ACR	1,998	400	0	240	156	2,793	1214.54
TOTAL Drainage System 4 - Sta 325+00	1.00	EA	1,069,108	213,822	0	128,293	83,262	1,494,485	1494485
11.01.13.19 Drainage System 5 - Sta 398+00									
11.01.13.19.B9 Platform Raise - 2.25 foot									
11.01.13.19.B9. 1 Sand Blasting	26.00	SF	90	18	0	11	7	127	4.87
11.01.13.19.B9.10 Vertcl Drilg Holes -1.5"X 6"Deep	44.00	EA	1,009	202	0	121	79	1,411	32.06
11.01.13.19.B9.15 Grouting of vertical holes	44.00	EA	601	120	0	72	47	840	19.09
11.01.13.19.B9.30 Hole Layout	3.00	HR	311	62	0	37	24	435	144.95
11.01.13.19.B9.45 Concrete -Slab	2.65	CY	1,081	216	0	130	84	1,511	570.17
11.01.13.19.B9.50 Forms for Slab	117.00	SF	827	165	0	99	64	1,155	9.88
11.01.13.19.B9.55 Reinforcing Steel for Slab	182.00	LB	345	69	0	41	27	483	2.65
11.01.13.19.B9.60 Replace Stem	1.00	EA	3,786	757	0	454	295	5,293	5292.58
TOTAL Platform Raise - 2.25 foot	1.00	EA	8,051	1,610	0	966	627	11,254	11254.12
11.01.13.19.C0 Drainage Structure Extension									
11.01.13.19.C0.01 Excavate and Remove Existing End	1.00	EA	1,152	230	0	138	90	1,610	1610.01
11.01.13.19.C0.02 Place RCP Extension	1.00	EA	2,461	492	0	295	192	3,441	3440.57
11.01.13.19.C0.03 Replace Flared End Section	1.00	EA	1,930	386	0	232	150	2,698	2698.46
11.01.13.19.C0.04 Place Concrete Collars	1.00	EA	2,291	458	0	275	178	3,203	3202.86
11.01.13.19.C0.05 Additional Compaction Labor	1.00	EA	352	70	0	42	27	492	491.53
11.01.13.19.C0.06 Riprap Removal and Replacement	1.00	EA	3,199	640	0	384	249	4,472	4472.43
TOTAL Drainage Structure Extension	1.00	EA	11,386	2,277	0	1,366	887	15,916	15915.86
TOTAL Drainage System 5 - Sta 398+00	1.00	EA	19,437	3,887	0	2,332	1,514	27,170	27169.98
11.01.13.20 Drainage System 7 - Sta 420+35									

** PROJECT OWNER SUMMARY - Assembly **

	QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.13.20.C1 Platform Raise - 2.5 foot									
11.01.13.20.C1. 1 Sand Blasting	24.00	SF	84	17	0	10	7	117	4.87
11.01.13.20.C1.10 Vertcl Drilg Holes -1.5"X 6"Deep	40.00	EA	917	183	0	110	71	1,283	32.06
11.01.13.20.C1.15 Grouting of vertical holes	40.00	EA	561	112	0	67	44	784	19.61
11.01.13.20.C1.30 Hole Layout	3.00	HR	311	62	0	37	24	435	144.95
11.01.13.20.C1.45 Concrete -Slab	2.22	CY	992	198	0	119	77	1,387	624.84
11.01.13.20.C1.50 Forms for Slab	116.00	SF	809	162	0	97	63	1,130	9.74
11.01.13.20.C1.55 Reinforcing Steel for Slab	198.00	LB	362	72	0	43	28	506	2.56
11.01.13.20.C1.60 Replace Stem	1.00	EA	3,612	722	0	433	281	5,048	5048.46
TOTAL Platform Raise - 2.5 foot	1.00	EA	7,648	1,530	0	918	596	10,691	10690.55
11.01.13.20.C2 Drainage Structure Extension									
11.01.13.20.C2.01 Excavate and Remove Existing End	1.00	EA	1,152	230	0	138	90	1,610	1610.01
11.01.13.20.C2.02 Place RCP Extension	1.00	EA	1,482	296	0	178	115	2,072	2071.96
11.01.13.20.C2.03 Replace Flared End Section	1.00	EA	1,610	322	0	193	125	2,251	2250.81
11.01.13.20.C2.04 Place Concrete Collars	1.00	EA	2,338	468	0	281	182	3,268	3267.75
11.01.13.20.C2.05 Additional Compaction Labor	1.00	EA	352	70	0	42	27	492	491.53
11.01.13.20.C2.06 Riprap Removal and Replacement	1.00	EA	3,199	640	0	384	249	4,472	4472.43
TOTAL Drainage Structure Extension	1.00	EA	10,133	2,027	0	1,216	789	14,164	14164.50
TOTAL Drainage System 7 - Sta 420+35	1.00	EA	17,781	3,556	0	2,134	1,385	24,855	24855.05
11.01.13.21 Drainage System 8 - Sta 497+60									
11.01.13.21.C3 Platform Raise - 1 foot 5 inches									
11.01.13.21.C3. 1 Sand Blasting	32.00	SF	111	22	0	13	9	156	4.87
11.01.13.21.C3.10 Vertcl Drilg Holes -1.5"X 6"Deep	80.00	EA	2,018	404	0	242	157	2,822	35.27
11.01.13.21.C3.15 Grouting of vertical holes	80.00	EA	1,227	245	0	147	96	1,715	21.44
11.01.13.21.C3.30 Hole Layout	3.00	HR	311	62	0	37	24	435	144.95
11.01.13.21.C3.45 Concrete -Slab	2.46	CY	1,042	208	0	125	81	1,456	591.91
11.01.13.21.C3.50 Forms for Slab	147.00	SF	918	184	0	110	72	1,284	8.73
11.01.13.21.C3.55 Reinforcing Steel for Slab	293.00	LB	445	89	0	53	35	621	2.12
11.01.13.21.C3.60 Replace Stem	1.00	EA	3,606	721	0	433	281	5,041	5041.17
TOTAL Platform Raise - 1 foot 5 inches	1.00	EA	9,679	1,936	0	1,161	754	13,530	13529.83
11.01.13.21.C4 Drainage Structure Extension									
11.01.13.21.C4.01 Excavate and Remove Existing End	1.00	EA	2,914	583	0	350	227	4,073	4073.28
11.01.13.21.C4.02 Place RCP Extension	1.00	EA	4,057	811	0	487	316	5,671	5670.88
11.01.13.21.C4.03 Place Conc Collars for RCP Ext	1.00	EA	2,431	486	0	292	189	3,398	3398.23
11.01.13.21.C4.04 Toe	0.54	CY	220	44	0	26	17	307	569.25
11.01.13.21.C4.05 Slab	4.15	CY	4,315	863	0	518	336	6,032	1453.59

** PROJECT OWNER SUMMARY - Assembly **

		QUANTITY	UOM	CONTRACT	CONTING	ESCALATN	E&D	S&A	TOTAL COST	UNIT COST
11.01.13.21.C4.06	Wingwall	4.01	CY	11,139	2,228	0	1,337	868	15,572	3883.18
11.01.13.21.C4.07	Headwall	1.88	CY	6,135	1,227	0	736	478	8,576	4561.61
11.01.13.21.C4.08	Concrete Collars (allowance)	1.00	EA	1,241	248	0	149	97	1,735	1735.05
11.01.13.21.C4.09	Free Draining Material Behind HW	1.30	CY	973	195	0	117	76	1,361	1046.55
11.01.13.21.C4.10	Additional Compaction Labor	1.00	EA	352	70	0	42	27	492	491.53
11.01.13.21.C4.11	Riprap Removal and Replacement	1.00	EA	3,199	640	0	384	249	4,472	4472.43
TOTAL	Drainage Structure Extension	1.00	EA	36,977	7,395	0	4,437	2,880	51,689	51689.10
TOTAL	Drainage System 8 - Sta 497+60	1.00	EA	46,656	9,331	0	5,599	3,634	65,219	65218.92
11.01.13.22	Drainage System 9 - Sta 558+50									
11.01.13.22.C5	Platform Raise - 1 foot									
11.01.13.22.C5. 1	Sand Blasting	28.00	SF	97	19	0	12	8	136	4.87
11.01.13.22.C5.10	Vertcl Drilg Holes -1.5"X 6"Deep	60.00	EA	1,376	275	0	165	107	1,924	32.06
11.01.13.22.C5.15	Grouting of vertical holes	60.00	EA	829	166	0	99	65	1,159	19.31
11.01.13.22.C5.30	Hole Layout	3.00	HR	311	62	0	37	24	435	144.95
11.01.13.22.C5.45	Concrete -Slab	1.14	CY	750	150	0	90	58	1,048	919.15
11.01.13.22.C5.50	Forms for Slab	98.00	SF	706	141	0	85	55	987	10.07
11.01.13.22.C5.55	Reinforcing Steel for Slab	201.00	LB	349	70	0	42	27	488	2.43
11.01.13.22.C5.60	Replace Stem	1.00	EA	3,709	742	0	445	289	5,185	5185.10
TOTAL	Platform Raise - 1 foot	1.00	EA	8,127	1,625	0	975	633	11,361	11361.11
11.01.13.22.C6	Drainage Structure Extension									
11.01.13.22.C6.01	Excavate and Remove Existing End	1.00	EA	1,152	230	0	138	90	1,610	1610.01
11.01.13.22.C6.02	Place RCP Extension	1.00	EA	1,869	374	0	224	146	2,612	2612.05
11.01.13.22.C6.03	Replace Flared End Section	1.00	EA	2,278	456	0	273	177	3,184	3184.27
11.01.13.22.C6.04	Place Concrete Collars	1.00	EA	2,431	486	0	292	189	3,398	3398.23
11.01.13.22.C6.05	Additional Compaction Labor	1.00	EA	352	70	0	42	27	492	491.53
11.01.13.22.C6.06	Riprap Removal and Replacement	1.00	EA	3,199	640	0	384	249	4,472	4472.43
TOTAL	Drainage Structure Extension	1.00	EA	11,280	2,256	0	1,354	879	15,769	15768.52
TOTAL	Drainage System 9 - Sta 558+50	1.00	EA	19,408	3,882	0	2,329	1,511	27,130	27129.63
TOTAL	Drainage Systems	1.00	EA	1,211,161	242,232	0	145,339	94,325	1,693,058	1693058
TOTAL	Levees	1.00	EA	16,606,176	4,055,680	0	2,066,186	1,340,954	24,068,996	24068996
11.02	Floodwalls - NONE									
TOTAL	Levees and Floodwalls	1.00	EA	16,606,176	4,055,680	0	2,066,186	1,340,954	24,068,996	24068996
TOTAL	Feasibility Study Estimate for:	1.00	EA	19,774,883	4,470,756	0	2,151,635	1,396,411	27,793,685	27793685

** PROJECT INDIRECT SUMMARY - Feature **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages	1.00	EA	2,373,298	0	0	0	0	2,373,298	2373298
02 Relocations	1.00	EA	295,409	0	0	0	0	295,409	295409.24
06 Fish & Wildlife Facilities	1.00	EA	500,000	0	0	0	0	500,000	500000.00
11 Levees and Floodwalls	1.00	EA	13,379,088	0	1,605,491	1,498,458	123,140	16,606,176	16606176
TOTAL Feasibility Study Estimate for:	1.00	EA	16,547,795	0	1,605,491	1,498,458	123,140	19,774,883	19774883
Contingency								4,470,756	
SUBTOTAL								24,245,640	
Engineering & Design								2,151,635	
SUBTOTAL								26,397,274	
Supervision & Administration								1,396,411	
TOTAL INCL OWNER COSTS								27,793,685	

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
01 Lands and Damages									
01.23 Land Values									
01.23.01 Land Values									
01.23.01.01 Land Values									
01.23.01.01.01 Borrow Area	1000.00	ACR	2,000,000	0	0	0	0	2,000,000	2000.00
01.23.01.01.02 Sta 93+00 to 132+00	9.13	ACR	13,262	0	0	0	0	13,262	1452.57
01.23.01.01.03 Sta 132+00 to 161+50	14.47	ACR	15,164	0	0	0	0	15,164	1047.96
01.23.01.01.04 Sta 161+50 to 228+50	48.84	ACR	38,460	0	0	0	0	38,460	787.47
01.23.01.01.05 Sta 228+50 to 281+50	26.46	ACR	19,768	0	0	0	0	19,768	747.09
01.23.01.01.06 Sta 281+50 to 299+50	14.72	ACR	8,832	0	0	0	0	8,832	600.00
01.23.01.01.07 Sta 299+50 to 331+50	9.43	ACR	10,684	0	0	0	0	10,684	1132.98
01.23.01.01.08 Sta 331+50 to 341+50	2.67	ACR	4,052	0	0	0	0	4,052	1517.60
01.23.01.01.09 Sta 341+50 to 404+50	46.35	ACR	31,086	0	0	0	0	31,086	670.68
01.23.01.01.10 Sta 404+50 to 492+50	45.15	ACR	41,706	0	0	0	0	41,706	923.72
01.23.01.01.11 Sta 492+50 to 516+50	19.07	ACR	17,042	0	0	0	0	17,042	893.65
01.23.01.01.12 Sta 516+50 to 600+50	77.09	ACR	60,618	0	0	0	0	60,618	786.33
01.23.01.01.13 Sta 600+50 to 639+84	17.58	ACR	18,164	0	0	0	0	18,164	1033.22
TOTAL Land Values	1.00	EA	2,278,838	0	0	0	0	2,278,838	2278838
01.23.01.02 Non Federal Sponsors Costs									
01.23.01.02.14 NFS Costs	1.00	EA	64,900	0	0	0	0	64,900	64900.00
TOTAL Non Federal Sponsors Costs	1.00	EA	64,900	0	0	0	0	64,900	64900.00
01.23.01.03 Federal Costs									
01.23.01.03.15 Federal Costs	1.00	EA	29,560	0	0	0	0	29,560	29560.00
TOTAL Federal Costs	1.00	EA	29,560	0	0	0	0	29,560	29560.00
TOTAL Land Values	1.00	EA	2,373,298	0	0	0	0	2,373,298	2373298
TOTAL Land Values	1.00	EA	2,373,298	0	0	0	0	2,373,298	2373298
TOTAL Lands and Damages	1.00	EA	2,373,298	0	0	0	0	2,373,298	2373298
02 Relocations									
02.01 Utility Relocations									
02.01.03 Cemetery, Utilities, & Structure									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
02.01.03.18 Utilities Crossing Levee									
02.01.03.18.16 UL1- Sta 53+38 - 16" SP - No Act									
02.01.03.18.17 UL2- Sta 300+00-16" DIP waterlin									
02.01.03.18.17.01 Excavation for Bypass	355.00	CY	8,475	0	0	0	0	8,475	23.87
02.01.03.18.17.02 16" Ductile Iron Pipe	300.00	LF	36,272	0	0	0	0	36,272	120.91
02.01.03.18.17.03 16" Ductile Iron Fittings	6.00	EA	16,808	0	0	0	0	16,808	2801.38
02.01.03.18.17.04 Air Release Valve/Chamber	1.00	EA	6,578	0	0	0	0	6,578	6577.99
02.01.03.18.17.05 Final Cutover Connection	6.00	HR	3,679	0	0	0	0	3,679	613.10
02.01.03.18.17.24 Excavation for Demolition	714.00	CY	8,475	0	0	0	0	8,475	11.87
02.01.03.18.17.25 Removal of Existing Waterline	284.00	LF	4,506	0	0	0	0	4,506	15.86
02.01.03.18.17.26 Excavate & Haul BF Material	2022.00	BCY	17,201	0	0	0	0	17,201	8.51
02.01.03.18.17.27 Backfill/Compaction	3108.00	CY	12,996	0	0	0	0	12,996	4.18
TOTAL UL2- Sta 300+00-16" DIP waterlin	1.00	EA	114,990	0	0	0	0	114,990	114990.13
02.01.03.18.18 UL3- Sta 417+65 - 8" Gas Pipe									
02.01.03.18.18.01 Excavation for Bypass	804.00	CY	8,475	0	0	0	0	8,475	10.54
02.01.03.18.18.02 8" Dia Gas Line	300.00	LF	20,126	0	0	0	0	20,126	67.09
02.01.03.18.18.03 8" Gas Line Fittings	6.00	EA	5,628	0	0	0	0	5,628	938.05
02.01.03.18.18.04 Final Cutover Connection	4.00	HR	2,466	0	0	0	0	2,466	616.52
02.01.03.18.18.05 Excavation for Demolition	3760.00	BCY	21,189	0	0	0	0	21,189	5.64
02.01.03.18.18.06 Removal of Existing Gas Line	120.00	LF	1,408	0	0	0	0	1,408	11.73
02.01.03.18.18.07 Excavate & Haul BF Material	600.00	BCY	6,450	0	0	0	0	6,450	10.75
02.01.03.18.18.08 Backfill/Compaction	5264.00	BCY	28,505	0	0	0	0	28,505	5.42
02.01.03.18.18.09 Contingency plan	1.00	EA	25,000	0	0	0	0	25,000	25000.00
TOTAL UL3- Sta 417+65 - 8" Gas Pipe	1.00	EA	119,247	0	0	0	0	119,247	119247.09
02.01.03.18.19 UL4- Sta 418+15 - Telephone Cbl									
02.01.03.18.19.02 New Telephone Cable incl Exc	200.00	LF	12,469	0	0	0	0	12,469	62.35
02.01.03.18.19.05 Splice Connection & Testing	1.00	EA	4,094	0	0	0	0	4,094	4093.83
02.01.03.18.19.24 Excavation for Demolition	295.00	CY	3,798	0	0	0	0	3,798	12.87
02.01.03.18.19.27 Backfill/Compaction	300.00	CY	2,661	0	0	0	0	2,661	8.87
TOTAL UL4- Sta 418+15 - Telephone Cbl	1.00	EA	23,022	0	0	0	0	23,022	23022.39
02.01.03.18.21 UL6- Sta 5+1.47 - 8" VCP-No Act									
TOTAL Utilities Crossing Levee	1.00	EA	257,260	0	0	0	0	257,260	257259.60
02.01.03.20 Fencing, Gates, & Power Poles									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
02.01.03.20.22 Fencing, Gates, and Power Poles									
02.01.03.20.22.01 Sta 269+12-Rem/Repl Wood Post/Gt	2.00	EA	1,918	0	0	0	0	1,918	958.93
02.01.03.20.22.02 Sta 269+12-Rem/Repl Barbed Wire	1000.00	LF	4,315	0	0	0	0	4,315	4.32
02.01.03.20.22.03 Sta 269+12-Relocate Power Poles	6.00	EA	12,000	0	0	0	0	12,000	2000.00
02.01.03.20.22.04 Sta 269+12-Clearing for Poles	1.00	EA	1,226	0	0	0	0	1,226	1226.40
02.01.03.20.22.05 Sta 404+00 - Clearing	1.00	EA	1,745	0	0	0	0	1,745	1744.72
02.01.03.20.22.06 Sta 404+00-Rem CLF/gate	140.00	LF	718	0	0	0	0	718	5.13
02.01.03.20.22.07 Sta 404+00-New CLF/gate	1.00	EA	2,718	0	0	0	0	2,718	2718.32
02.01.03.20.22.08 Sta 418+00-Rem gate	1.00	EA	359	0	0	0	0	359	359.09
02.01.03.20.22.09 Sta 418+00-New gate	1.00	EA	589	0	0	0	0	589	588.98
02.01.03.20.22.10 Sta 418+00-Rem/Repl Barbed Wire	130.00	LF	561	0	0	0	0	561	4.32
02.01.03.20.22.11 Remove/Replace Additional Gates	6.00	EA	12,000	0	0	0	0	12,000	2000.00
TOTAL Fencing, Gates, and Power Poles	1.00	EA	38,150	0	0	0	0	38,150	38149.64
TOTAL Fencing, Gates, & Power Poles	1.00	EA	38,150	0	0	0	0	38,150	38149.64
TOTAL Cemetery, Utilities, & Structure			295,409	0	0	0	0	295,409	
TOTAL Utility Relocations	1.00	EA	295,409	0	0	0	0	295,409	295409.24
TOTAL Relocations	1.00	EA	295,409	0	0	0	0	295,409	295409.24
06 Fish & Wildlife Facilities									
06.03 Fish & Wildlife Fac/Sanc									
06.03.99 Associated General Items									
06.03.99.01 Environmental Enhancement									
06.03.99.01.23 Environmental Enhancement	1.00	EA	500,000	0	0	0	0	500,000	500000.00
TOTAL Environmental Enhancement	1.00	EA	500,000	0	0	0	0	500,000	500000.00
TOTAL Associated General Items	1.00	EA	500,000	0	0	0	0	500,000	500000.00
TOTAL Fish & Wildlife Fac/Sanc	1.00	EA	500,000	0	0	0	0	500,000	500000.00
TOTAL Fish & Wildlife Facilities	1.00	EA	500,000	0	0	0	0	500,000	500000.00
11 Levees and Floodwalls									
11.01 Levees									
11.01.01 Relief Wells									
11.01.01.01 Sta 292+00 to 327+00									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.01.01.24 New Relief Wells									
11.01.01.01.24.01 RW Sta 292+00 to 327+00	22.00	EA	724,905	0	86,989	81,189	6,672	899,755	40897.97
TOTAL New Relief Wells	22.00	EA	724,905	0	86,989	81,189	6,672	899,755	40897.97
11.01.01.01.25 Abandon Existing Relief Wells									
11.01.01.01.25.01 RW Sta 292+00 to 327+00	20.00	EA	15,428	0	1,851	1,728	142	19,149	957.43
TOTAL Abandon Existing Relief Wells	20.00	EA	15,428	0	1,851	1,728	142	19,149	957.43
TOTAL Sta 292+00 to 327+00	22.00	EA	740,333	0	88,840	82,917	6,814	918,904	41768.37
TOTAL Relief Wells	1.00	EA	740,333	0	88,840	82,917	6,814	918,904	918904.06
11.01.02 Borrow Sites & Site Prep									
11.01.02.01 Site Prep Sta 93+09 to 215+00									
11.01.02.01.26 Stripping/Windrow Material	112880.00	CY	118,650	0	14,238	13,289	1,092	147,269	1.30
TOTAL Site Prep Sta 93+09 to 215+00	112880.00	CY	118,650	0	14,238	13,289	1,092	147,269	1.30
11.01.02.05 Site Prep Sta 471+20 to 610+00									
11.01.02.05.27 Site Prep New Borrow Site	159.00	ACR	13,215	0	1,586	1,480	122	16,403	103.16
11.01.02.05.28 Clearing and Grub Site	159.00	ACR	312,717	0	37,526	35,024	2,878	388,146	2441.17
11.01.02.05.29 Push Cleared Material to Piles	106.00	PIL	22,374	0	2,685	2,506	206	27,771	261.99
11.01.02.05.30 Maintain Burning Piles	106.00	PIL	15,830	0	1,900	1,773	146	19,648	185.36
TOTAL Site Prep Sta 471+20 to 610+00	159.00	ACR	364,137	0	43,696	40,783	3,351	451,968	2842.57
11.01.02.06 Additional Clearing & Grubbing									
11.01.02.06.2A Sta 496+00 to Sta 558+50	50.70	ACR	42,122	0	5,055	4,718	388	52,282	1031.21
11.01.02.06.2B Sta 558+50 to 610+00 (landward)	23.70	ACR	103,006	0	12,361	11,537	948	127,852	5394.58
11.01.02.06.2C Sta 610+00 to 639+84 (landward)	11.10	ACR	48,243	0	5,789	5,403	444	59,880	5394.58
11.01.02.06.2D Push Cleared Material to Piles	57.00	PIL	12,031	0	1,444	1,348	111	14,933	261.99
11.01.02.06.2E Maintain Burning Piles	57.00	PIL	8,512	0	1,021	953	78	10,566	185.36
TOTAL Additional Clearing & Grubbing	85.50	ACR	213,915	0	25,670	23,959	1,969	265,512	3105.41
11.01.02.10 Final Grade Both Sites									
11.01.02.10.31 Final Grade Sta 93+09 to 215+00	112880.00	CY	131,139	0	15,737	14,688	1,207	162,771	1.44

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.02.10.32 Final Grade Sta 471+20 to 610+00	159.00	ACR	110,832	0	13,300	12,413	1,020	137,565	865.19
TOTAL Final Grade Both Sites	2.00	EA	241,971	0	29,037	27,101	2,227	300,335	150167.73
11.01.02.15 Ramps for Levee Crossings									
11.01.02.15.33 Ramps for Levee Crossings	4200.00	CY	22,603	0	2,712	2,532	208	28,055	6.68
TOTAL Ramps for Levee Crossings	7.00	EA	22,603	0	2,712	2,532	208	28,055	4007.89
11.01.02.20 Remove Ramps at Project End									
11.01.02.20.34 Remove Ramps at Project End	4200.00	CY	19,317	0	2,318	2,164	178	23,976	5.71
TOTAL Remove Ramps at Project End	7.00	EA	19,317	0	2,318	2,164	178	23,976	3425.21
11.01.02.25 Low Water Crossings									
11.01.02.25.35 Low Water Crossings									
11.01.02.25.35.01 Low Water Crossings	13.00	EA	65,000	0	7,800	7,280	598	80,678	6206.02
TOTAL Low Water Crossings	13.00	EA	65,000	0	7,800	7,280	598	80,678	6206.02
TOTAL Low Water Crossings	13.00	EA	65,000	0	7,800	7,280	598	80,678	6206.02
TOTAL Borrow Sites & Site Prep	1.00	EA	1,045,594	0	125,471	117,106	9,624	1,297,795	1297795
11.01.03 Stripping Levee									
11.01.03.05 Remove Aggr Sta 93+09 to 639+84									
11.01.03.05.36 Excavate Aggregate from Levee	10125.00	BCY	5,600	0	672	627	52	6,951	0.69
TOTAL Remove Aggr Sta 93+09 to 639+84	10125.00	BCY	5,600	0	672	627	52	6,951	0.69
11.01.03.06 Strip Levee-Less than 1' Raise									
11.01.03.06.37 Strip Topsoil from Levee	2178.01	BCY	1,424	0	171	160	13	1,768	0.81
11.01.03.06.38 Windrow Material	2178.01	BCY	803	0	96	90	7	997	0.46
TOTAL Strip Levee-Less than 1' Raise	2.70	ACR	2,227	0	267	249	20	2,765	1023.91
11.01.03.07 Strip Levee - > than 1' < 3' Rse									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.03.07.39 Strip Topsoil from Levee	37590.82	BCY	24,581	0	2,950	2,753	226	30,510	0.81
11.01.03.07.40 Windrow Material	37590.82	BCY	13,861	0	1,663	1,552	128	17,204	0.46
TOTAL Strip Levee - > than 1' < 3' Rse	46.60	ACR	38,442	0	4,613	4,305	354	47,714	1023.90
11.01.03.08 Strip Levee - > than </= 3' Rse									
11.01.03.08.41 Strip Topsoil from Levee	3226.68	BCY	2,110	0	253	236	19	2,619	0.81
11.01.03.08.42 Windrow Material	3226.68	BCY	1,190	0	143	133	11	1,477	0.46
TOTAL Strip Levee - > than </= 3' Rse	4.00	ACR	3,300	0	396	370	30	4,096	1023.90
11.01.03.09 Strip Berm-Less than 1' Raise									
11.01.03.09.43 Strip Topsoil from Levee	12100.05	BCY	15,825	0	1,899	1,772	146	19,641	1.62
11.01.03.09.44 Windrow Material	12100.05	BCY	4,462	0	535	500	41	5,538	0.46
TOTAL Strip Berm-Less than 1' Raise	15.00	ACR	20,286	0	2,434	2,272	187	25,179	1678.62
11.01.03.10 Strip Berm- > than 1' > 3' Raise									
11.01.03.10.45 Strip Topsoil from Levee	182710.76	BCY	238,950	0	28,674	26,762	2,199	296,586	1.62
11.01.03.10.46 Windrow Material	182710.76	BCY	67,371	0	8,084	7,546	620	83,621	0.46
TOTAL Strip Berm- > than 1' > 3' Raise	226.50	ACR	306,321	0	36,759	34,308	2,819	380,207	1678.62
11.01.03.11 Strip Berm- >/= 3' Raise									
11.01.03.11.47 Strip Topsoil from Levee	23312.76	BCY	30,489	0	3,659	3,415	281	37,843	1.62
11.01.03.11.48 Windrow Material	23312.76	BCY	8,596	0	1,032	963	79	10,670	0.46
TOTAL Strip Berm- >/= 3' Raise	28.90	ACR	39,085	0	4,690	4,377	360	48,512	1678.62
TOTAL Stripping Levee	271244.00	BCY	415,261	0	49,831	46,509	3,822	515,423	1.90
11.01.04 Levee Raise (Impervious)									
11.01.04.01 Exc/Haul Matl-Sta 93+09 - 114+00									
11.01.04.01.49 Exc/Haul	1166.25	BCY	4,159	0	499	466	38	5,162	4.43
TOTAL Exc/Haul Matl-Sta 93+09 - 114+00	1166.25	BCY	4,159	0	499	466	38	5,162	4.43
11.01.04.02 Exc/Haul Matl-Sta 600+00- 639+84									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.04.02.50 Exc/Haul	2061.25	BCY	7,350	0	882	823	68	9,123	4.43
TOTAL Exc/Haul Matl-Sta 600+00- 639+84	2061.25	BCY	7,350	0	882	823	68	9,123	4.43
11.01.04.03 Exc/Haul Matl-Sta 114+00- 228+00									
11.01.04.03.51 Exc/Haul	23696.25	BCY	84,496	0	10,139	9,463	778	104,876	4.43
TOTAL Exc/Haul Matl-Sta 114+00- 228+00	23696.25	BCY	84,496	0	10,139	9,463	778	104,876	4.43
11.01.04.04 Exc/Haul Matl-Sta 228+00- 375+00									
11.01.04.04.52 Exc/Haul	34861.25	BCY	176,568	0	21,188	19,776	1,625	219,156	6.29
TOTAL Exc/Haul Matl-Sta 228+00- 375+00	34861.25	BCY	176,568	0	21,188	19,776	1,625	219,156	6.29
11.01.04.05 Exc/Haul Matl-Sta 419+00- 467+00									
11.01.04.05.53 Exc/Haul	11558.75	BCY	41,216	0	4,946	4,616	379	51,157	4.43
TOTAL Exc/Haul Matl-Sta 419+00- 467+00	11558.75	BCY	41,216	0	4,946	4,616	379	51,157	4.43
11.01.04.06 Exc/Haul Matl-Sta 467+00- 600+00									
11.01.04.06.54 Exc/Haul	23607.50	BCY	84,179	0	10,101	9,428	775	104,483	4.43
TOTAL Exc/Haul Matl-Sta 467+00- 600+00	23607.50	BCY	84,179	0	10,101	9,428	775	104,483	4.43
11.01.04.07 Exc/Haul Matl-Sta 375+00- 398+00									
11.01.04.07.55 Exc/Haul	6402.50	BCY	38,826	0	4,659	4,349	357	48,192	7.53
TOTAL Exc/Haul Matl-Sta 375+00- 398+00	6402.50	BCY	38,826	0	4,659	4,349	357	48,192	7.53
11.01.04.08 Exc/Haul Matl-Sta 398+00- 419+00									
11.01.04.08.56 Exc/Haul	6093.75	BCY	30,864	0	3,704	3,457	284	38,308	6.29
TOTAL Exc/Haul Matl-Sta 398+00- 419+00	6093.75	BCY	30,864	0	3,704	3,457	284	38,308	6.29
11.01.04.52 Place Material									
11.01.04.52.57 Scarify Existing Surface	2187000	SF	5,585	0	670	626	51	6,932	0.00

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.04.52.58 Place	109447.50	BCY	141,803	0	17,016	15,882	1,305	176,006	1.61
TOTAL Place Material	109447.50	BCY	147,388	0	17,687	16,507	1,357	182,938	1.67
TOTAL Levee Raise (Impervious)	87558.00	CCY	615,045	0	73,805	68,885	5,661	763,396	8.72
11.01.05 Levee Raise (Random)									
11.01.05.03 Exc/Haul Matl-Sta 114+00- 228+00									
11.01.05.03.59 Exc/Haul	54895.00	BCY	195,743	0	23,489	21,923	1,802	242,957	4.43
TOTAL Exc/Haul Matl-Sta 114+00- 228+00	54895.00	BCY	195,743	0	23,489	21,923	1,802	242,957	4.43
11.01.05.04 Exc/Haul Matl-Sta 228+00- 375+00									
11.01.05.04.60 Exc/Haul	124602.50	BCY	631,095	0	75,731	70,683	5,809	783,318	6.29
TOTAL Exc/Haul Matl-Sta 228+00- 375+00	124602.50	BCY	631,095	0	75,731	70,683	5,809	783,318	6.29
11.01.05.05 Exc/Haul Matl-Sta 419+00- 467+00									
11.01.05.05.61 Exc/Haul	29440.00	BCY	104,976	0	12,597	11,757	966	130,297	4.43
TOTAL Exc/Haul Matl-Sta 419+00- 467+00	29440.00	BCY	104,976	0	12,597	11,757	966	130,297	4.43
11.01.05.06 Exc/Haul Matl-Sta 467+00- 600+00									
11.01.05.06.62 Exc/Haul	64110.00	BCY	228,602	0	27,432	25,603	2,104	283,741	4.43
TOTAL Exc/Haul Matl-Sta 467+00- 600+00	64110.00	BCY	228,602	0	27,432	25,603	2,104	283,741	4.43
11.01.05.07 Exc/Haul Matl-Sta 375+00- 398+00									
11.01.05.07.63 Exc/Haul	20798.75	BCY	126,129	0	15,135	14,126	1,161	156,552	7.53
TOTAL Exc/Haul Matl-Sta 375+00- 398+00	20798.75	BCY	126,129	0	15,135	14,126	1,161	156,552	7.53
11.01.05.08 Exc/Haul Matl-Sta 398+00- 419+00									
11.01.05.08.64 Exc/Haul	15510.00	BCY	78,556	0	9,427	8,798	723	97,504	6.29
TOTAL Exc/Haul Matl-Sta 398+00- 419+00	15510.00	BCY	78,556	0	9,427	8,798	723	97,504	6.29

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.05.52 Place Material									
11.01.05.52.65 Scarify Existing Surface	2187000	SF	5,585	0	670	626	51	6,932	0.00
11.01.05.52.66 Place	309356.25	BCY	400,809	0	48,097	44,891	3,689	497,486	1.61
TOTAL Place Material	309356.25	BCY	406,394	0	48,767	45,516	3,740	504,418	1.63
TOTAL Levee Raise (Random)	247485.00	CCY	1,771,496	0	212,579	198,408	16,305	2,198,787	8.88
11.01.06 Riverward Berm									
11.01.06.01 Exc/Haul Matl-Sta 166+00- 398+00									
11.01.06.01.67 Exc/Haul	161111.25	BCY	816,007	0	97,921	91,393	7,510	1,012,831	6.29
TOTAL Exc/Haul Matl-Sta 166+00- 398+00	161111.25	BCY	816,007	0	97,921	91,393	7,510	1,012,831	6.29
11.01.06.02 Exc/Haul Matl-Sta 398+00- 550+00									
11.01.06.02.68 Exc/Haul	105555.00	BCY	429,131	0	51,496	48,063	3,950	532,639	5.05
TOTAL Exc/Haul Matl-Sta 398+00- 550+00	105555.00	BCY	429,131	0	51,496	48,063	3,950	532,639	5.05
11.01.06.56 Place Material									
11.01.06.56.69 Scarify Existing Surface	1344000	SF	3,432	0	412	384	32	4,260	0.00
11.01.06.56.70 Place	266666.25	BCY	345,499	0	41,460	38,696	3,180	428,835	1.61
TOTAL Place Material	266666.25	BCY	348,931	0	41,872	39,080	3,212	433,095	1.62
TOTAL Riverward Berm	213333.00	CCY	1,594,069	0	191,288	178,536	14,672	1,978,565	9.27
11.01.07 Underseepage Berm (Random)									
11.01.07.02 Exc/Haul Matl-Sta 600+00- 639+84									
11.01.07.02.71 Exc/Haul	80203.75	BCY	285,989	0	34,319	32,031	2,632	354,970	4.43
TOTAL Exc/Haul Matl-Sta 600+00- 639+84	80203.75	BCY	285,989	0	34,319	32,031	2,632	354,970	4.43
11.01.07.03 Exc/Haul Matl-Sta 114+00- 228+00									
11.01.07.03.72 Exc/Haul	275548.75	BCY	982,545	0	117,905	110,045	9,043	1,219,538	4.43
TOTAL Exc/Haul Matl-Sta 114+00- 228+00	275548.75	BCY	982,545	0	117,905	110,045	9,043	1,219,538	4.43

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.07.04 Exc/Haul Matl-Sta 228+00- 375+00									
11.01.07.04.73 Exc/Haul	97012.50	BCY	491,355	0	58,963	55,032	4,522	609,872	6.29
TOTAL Exc/Haul Matl-Sta 228+00- 375+00	97012.50	BCY	491,355	0	58,963	55,032	4,522	609,872	6.29
11.01.07.05 Exc/Haul Matl-Sta 419+00- 467+00									
11.01.07.05.74 Exc/Haul	64632.50	BCY	230,465	0	27,656	25,812	2,121	286,054	4.43
TOTAL Exc/Haul Matl-Sta 419+00- 467+00	64632.50	BCY	230,465	0	27,656	25,812	2,121	286,054	4.43
11.01.07.06 Exc/Haul Matl-Sta 467+00- 600+00									
11.01.07.06.75 Exc/Haul	317035.00	BCY	1,130,475	0	135,657	126,613	10,405	1,403,151	4.43
TOTAL Exc/Haul Matl-Sta 467+00- 600+00	317035.00	BCY	1,130,475	0	135,657	126,613	10,405	1,403,151	4.43
11.01.07.07 Exc/Haul Matl-Sta 375+00- 398+00									
11.01.07.07.76 Exc/Haul	58356.25	BCY	353,888	0	42,467	39,635	3,257	439,247	7.53
TOTAL Exc/Haul Matl-Sta 375+00- 398+00	58356.25	BCY	353,888	0	42,467	39,635	3,257	439,247	7.53
11.01.07.08 Exc/Haul Matl-Sta 398+00- 419+00									
11.01.07.08.77 Exc/Haul	52578.75	BCY	266,304	0	31,957	29,826	2,451	330,538	6.29
TOTAL Exc/Haul Matl-Sta 398+00- 419+00	52578.75	BCY	266,304	0	31,957	29,826	2,451	330,538	6.29
11.01.07.53 Place Material									
11.01.07.53.78 Scarify Existing Surface	10935000	SF	27,925	0	3,351	3,128	257	34,660	0.00
11.01.07.53.79 Place	935242.50	BCY	1,127,946	0	135,354	126,330	10,381	1,400,011	1.50
11.01.07.53.80 Spread Aggregate Surfacing Matl	10125.00	BCY	4,800	0	576	538	44	5,958	0.59
TOTAL Place Material	945367.50	BCY	1,160,671	0	139,280	129,995	10,683	1,440,629	1.52
TOTAL Underseepage Berm (Random)	756295.00	CCY	4,901,692	0	588,203	548,989	45,115	6,083,999	8.04
11.01.08 Seeding & Mulching									
11.01.08.01 Seeding & Mulching									
11.01.08.01.81 Seeding & Mulching									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.08.01.81.01 Seeding & Mulching	120.00	ACR	180,000	0	21,600	20,160	1,657	223,417	1861.81
TOTAL Seeding & Mulching	120.00	ACR	180,000	0	21,600	20,160	1,657	223,417	1861.81
TOTAL Seeding & Mulching	120.00	ACR	180,000	0	21,600	20,160	1,657	223,417	1861.81
TOTAL Seeding & Mulching	120.00	ACR	180,000	0	21,600	20,160	1,657	223,417	1861.81
11.01.09 Replace Aggregate Surfacing									
11.01.09.27 Replace Aggregate Surfacing									
11.01.09.27.82 Replace Aggregate Surfacing									
11.01.09.27.82.01 Replace Aggregate Surfacing	19238.00	TON	324,904	0	38,988	36,389	2,990	403,272	20.96
TOTAL Replace Aggregate Surfacing	19238.00	TON	324,904	0	38,988	36,389	2,990	403,272	20.96
TOTAL Replace Aggregate Surfacing	19238.00	TON	324,904	0	38,988	36,389	2,990	403,272	20.96
TOTAL Replace Aggregate Surfacing	10125.00	CCY	324,904	0	38,988	36,389	2,990	403,272	39.83
11.01.10 Replace Stripped Material									
11.01.10.06 Repl Lev w/ less than 1' Raise									
11.01.10.06.84 Push Topsoil to Levee	2178.01	BCY	1,582	0	190	177	15	1,964	0.90
11.01.10.06.85 Finish Grade Lev for TS Placemnt	2.70	ACR	2,679	0	322	300	25	3,325	1231.66
TOTAL Repl Lev w/ less than 1' Raise	2.70	ACR	4,261	0	511	477	39	5,289	1958.93
11.01.10.07 Repl Lev w/ > than 1' < 3' Rse									
11.01.10.07.86 Push Topsoil to Levee	37590.82	BCY	27,305	0	3,277	3,058	251	33,891	0.90
11.01.10.07.87 Finish Grade Lev for TS Placemnt	46.60	ACR	46,242	0	5,549	5,179	426	57,396	1231.67
TOTAL Repl Lev w/ > than 1' < 3' Rse	46.60	ACR	73,547	0	8,826	8,237	677	91,286	1958.93
11.01.10.08 Repl Lev w/ > than </= 3' Rse									
11.01.10.08.88 Push Topsoil to Levee	3226.68	BCY	2,344	0	281	262	22	2,909	0.90
11.01.10.08.89 Finish Grade Lev for TS Placemnt	4.00	ACR	3,969	0	476	445	37	4,927	1231.66
TOTAL Repl Lev w/ > than </= 3' Rse	4.00	ACR	6,313	0	758	707	58	7,836	1958.93
11.01.10.09 Repl Berm-Less than 1' Raise									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.10.09.90 Push Topsoil to Berm	12100.05	ACR	17,578	0	2,109	1,969	162	21,818	1.80
11.01.10.09.91 Finish Grade Lev for TS Placemnt	15.00	ACR	14,885	0	1,786	1,667	137	18,475	1231.67
TOTAL Repl Berm-Less than 1' Raise	15.00	ACR	32,463	0	3,896	3,636	299	40,293	2686.20
11.01.10.10 Repl Berm- > than 1' > 3' Raise									
11.01.10.10.92 Push Topsoil to Berm	182710.76	BCY	265,429	0	31,851	29,728	2,443	329,451	1.80
11.01.10.10.93 Finish Grade Lev for TS Placemnt	226.50	ACR	224,759	0	26,971	25,173	2,069	278,972	1231.67
TOTAL Repl Berm- > than 1' > 3' Raise	226.50	ACR	490,188	0	58,823	54,901	4,512	608,424	2686.20
11.01.10.11 Repl Berm- >/= 3' Raise									
11.01.10.11.94 Push Topsoil to Berm	23312.76	BCY	33,867	0	4,064	3,793	312	42,036	1.80
11.01.10.11.95 Finish Grade Lev for TS Placemnt	28.90	ACR	28,678	0	3,441	3,212	264	35,595	1231.67
TOTAL Repl Berm- >/= 3' Raise	28.90	ACR	62,545	0	7,505	7,005	576	77,631	2686.20
TOTAL Replace Stripped Material	261119.00	CY	669,317	0	80,318	74,964	6,160	830,759	3.18
11.01.11 Slope Protection									
11.01.11.27 Place Bedding Material									
11.01.11.27.96 Place Bedding Material									
11.01.11.27.96.01 Place Bedding Material	40.00	TON	1,209	0	145	135	11	1,500	37.50
TOTAL Place Bedding Material	40.00	TON	1,209	0	145	135	11	1,500	37.50
TOTAL Place Bedding Material	40.00	TON	1,209	0	145	135	11	1,500	37.50
11.01.11.28 Place Riprap Protection									
11.01.11.28.97 Place Riprap Protection									
11.01.11.28.97.01 Place Riprap Protection	120.00	TON	4,374	0	525	490	40	5,429	45.24
TOTAL Place Riprap Protection	120.00	TON	4,374	0	525	490	40	5,429	45.24
TOTAL Place Riprap Protection	120.00	TON	4,374	0	525	490	40	5,429	45.24
TOTAL Slope Protection	1.00	EA	5,583	0	670	625	51	6,929	6929.30
11.01.12 Freeboard Gages									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.12.01 Freeboard Gages									
11.01.12.01.98 Freeboard Gages									
11.01.12.01.98.01 Freeboard Gages	7.00	EA	140,000	0	16,800	15,680	1,289	173,769	24824.08
TOTAL Freeboard Gages	7.00	EA	140,000	0	16,800	15,680	1,289	173,769	24824.08
TOTAL Freeboard Gages	7.00	EA	140,000	0	16,800	15,680	1,289	173,769	24824.08
TOTAL Freeboard Gages	7.00	EA	140,000	0	16,800	15,680	1,289	173,769	24824.08
11.01.13 Drainage Systems									
11.01.13.16 Drainage System 2 - Sta 115+60									
11.01.13.16.99 Platform Raise - 1 foot									
11.01.13.16.99. 1 Sand Blasting	28.00	SF	79	0	9	9	1	97	3.48
11.01.13.16.99.10 Vertcl Drilg Holes -1.5"X 6"Deep	60.00	EA	1,109	0	133	124	10	1,376	22.94
11.01.13.16.99.15 Grouting of vertical holes	60.00	EA	668	0	80	75	6	829	13.81
11.01.13.16.99.30 Hole Layout	3.00	HR	251	0	30	28	2	311	103.70
11.01.13.16.99.45 Concrete -Slab	1.14	CY	604	0	72	68	6	750	657.53
11.01.13.16.99.50 Forms for Slab	98.00	SF	569	0	68	64	5	706	7.20
11.01.13.16.99.55 Reinforcing Steel for Slab	201.00	LB	281	0	34	31	3	349	1.74
11.01.13.16.99.60 Replace Stem	1.00	EA	2,639	0	317	296	24	3,275	3275.27
TOTAL Platform Raise - 1 foot	1.00	EA	6,198	0	744	694	57	7,693	7693.40
11.01.13.16.A0 Drainage Structure Extension									
11.01.13.16.A0.01 Excavate and Remove Existing End	1.00	EA	928	0	111	104	9	1,152	1151.75
11.01.13.16.A0.02 Place RCP Extension	1.00	EA	1,505	0	181	169	14	1,869	1868.58
11.01.13.16.A0.03 Replace Flared End Section	1.00	EA	1,835	0	220	206	17	2,278	2277.93
11.01.13.16.A0.04 Place Concrete Collars	1.00	EA	1,959	0	235	219	18	2,431	2430.99
11.01.13.16.A0.05 Additional Compaction Labor	1.00	EA	283	0	34	32	3	352	351.62
11.01.13.16.A0.06 Riprap Removal and Replacement	1.00	EA	2,578	0	309	289	24	3,199	3199.44
TOTAL Drainage Structure Extension	1.00	EA	9,088	0	1,091	1,018	84	11,280	11280.31
TOTAL Drainage System 2 - Sta 115+60	1.00	EA	15,287	0	1,834	1,712	141	18,974	18973.71
11.01.13.17 Drainage System 3 - Sta 186+00									
11.01.13.17.A1 Platform Raise - 2 foot									
11.01.13.17.A1. 1 Sand Blasting	28.00	SF	79	0	9	9	1	97	3.48
11.01.13.17.A1.10 Vertcl Drilg Holes -1.5"X 6"Deep	48.00	EA	887	0	106	99	8	1,101	22.94

** PROJECT INDIRECT SUMMARY - Assembly **

		QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.17.A1.15	Grouting of vertical holes	48.00	EA	537	0	64	60	5	666	13.88
11.01.13.17.A1.30	Hole Layout	3.00	HR	251	0	30	28	2	311	103.70
11.01.13.17.A1.45	Concrete -Slab	2.28	CY	775	0	93	87	7	962	421.86
11.01.13.17.A1.50	Forms for Slab	123.00	SF	697	0	84	78	6	865	7.03
11.01.13.17.A1.55	Reinforcing Steel for Slab	186.00	LB	282	0	34	32	3	350	1.88
11.01.13.17.A1.60	Replace Stem	1.00	EA	2,700	0	324	302	25	3,351	3350.86
	TOTAL Platform Raise - 2 foot	1.00	EA	6,206	0	745	695	57	7,703	7703.23
11.01.13.17.A2	Drainage Structure Extension									
11.01.13.17.A2.01	Excavate and Remove Existing End	1.00	EA	928	0	111	104	9	1,152	1151.75
11.01.13.17.A2.02	Place RCP Extension	1.00	EA	2,163	0	260	242	20	2,684	2684.30
11.01.13.17.A2.03	Replace Flared End Section	1.00	EA	1,835	0	220	206	17	2,278	2277.93
11.01.13.17.A2.04	Place Concrete Collars	1.00	EA	1,959	0	235	219	18	2,431	2430.99
11.01.13.17.A2.05	Additional Compaction Labor	1.00	EA	283	0	34	32	3	352	351.62
11.01.13.17.A2.06	Riprap Removal and Replacement	1.00	EA	2,578	0	309	289	24	3,199	3199.44
	TOTAL Drainage Structure Extension	1.00	EA	9,745	0	1,169	1,091	90	12,096	12096.03
	TOTAL Drainage System 3 - Sta 186+00	1.00	EA	15,952	0	1,914	1,787	147	19,799	19799.26
11.01.13.18	Drainage System 4 - Sta 325+00									
11.01.13.18.A3	Dewatering									
11.01.13.18.A3.01	Drill Well & Set Casing	2.00	EA	59,345	0	7,121	6,647	546	73,659	36829.56
11.01.13.18.A3.02	Pilot Hole	1.00	EA	9,224	0	1,107	1,033	85	11,449	11448.51
11.01.13.18.A3.03	Dewatering Labor	30.00	DAY	9,711	0	1,165	1,088	89	12,053	401.76
11.01.13.18.A3.04	Abandon Wells	2.00	EA	8,000	0	960	896	74	9,930	4964.82
	TOTAL Dewatering	1.00	EA	86,279	0	10,354	9,663	794	107,090	107090.13
11.01.13.18.A4	Exc/Haul Imp Fill for Ring Levee	21717.50	BCY	120,848	0	14,502	13,535	1,112	149,998	6.91
11.01.13.18.A5	Place Imp Fill for Ring Levee	21717.50	BCY	28,138	0	3,377	3,151	259	34,925	1.61
11.01.13.18.A6	48" Dia CMP for Ring Lev/Bypass									
11.01.13.18.A6.01	48" Dia CMP for Ring Levee	280.00	LF	30,461	0	3,655	3,412	280	37,809	135.03
11.01.13.18.A6.02	48" Dia CMP for Bypass	700.00	LF	38,986	0	4,678	4,366	359	48,390	69.13
	TOTAL 48" Dia CMP for Ring Lev/Bypass	980.00	LF	69,447	0	8,334	7,778	639	86,198	87.96
11.01.13.18.A7	Seeding/Mulching for Ring Levee									
11.01.13.18.A7.01	Seeding and Mulching	1.30	ACR	910	0	109	102	8	1,129	868.84
	TOTAL Seeding/Mulching for Ring Levee	1.30	ACR	910	0	109	102	8	1,129	868.84

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.18.A8 Turf Reinforcement Mat									
11.01.13.18.A8.01 Delivery of Reinforcement Mat	55215.00	SF	100	0	12	11	1	124	0.00
11.01.13.18.A8.02 Reinforcement Mat	63000.00	SF	21,768	0	2,612	2,438	200	27,019	0.43
11.01.13.18.A8.03 Trenching	19.26	CY	1,988	0	239	223	18	2,467	128.09
11.01.13.18.A8.04 Placement of Reinforcement Mat	6135.00	SY	5,001	0	600	560	46	6,208	1.01
11.01.13.18.A8.05 Backfill Trench & Reseed	19.26	CY	2,188	0	263	245	20	2,715	140.98
TOTAL Turf Reinforcement Mat	55215.00	SF	31,045	0	3,725	3,477	286	38,533	0.70
11.01.13.18.B0 Exc/Stockpile Exist Levee	16250.00	BCY	38,460	0	4,615	4,307	354	47,736	2.94
11.01.13.18.B1 Gatewell Structure									
11.01.13.18.B1.01 Demo Exist Gatewell Str/RCB	1.00	EA	24,181	0	2,902	2,708	223	30,014	30013.85
11.01.13.18.B1.02 Structural Excavation	1.00	EA	2,579	0	309	289	24	3,201	3200.59
11.01.13.18.B1.03 Base Slab	2.81	CY	4,087	0	490	458	38	5,073	1805.26
11.01.13.18.B1.04 1st Lift	17.22	CY	18,051	0	2,166	2,022	166	22,405	1301.08
11.01.13.18.B1.05 2nd Lift	17.22	CY	18,751	0	2,250	2,100	173	23,274	1351.59
11.01.13.18.B1.06 3rd Lift	9.98	CY	14,318	0	1,718	1,604	132	17,772	1780.72
11.01.13.18.B1.07 Elevated Slab	2.96	CY	4,245	0	509	475	39	5,268	1779.83
11.01.13.18.B1.08 Concrete Collars (allowance)	2.00	EA	2,000	0	240	224	18	2,482	1241.20
11.01.13.18.B1.15 Metals - Ladders	1.00	EA	2,966	0	356	332	27	3,681	3680.88
11.01.13.18.B1.16 Metals - Landings	1.00	EA	3,275	0	393	367	30	4,065	4065.00
11.01.13.18.B1.17 Metals - Labor	1.00	EA	6,728	0	807	754	62	8,351	8351.31
11.01.13.18.B1.30 Metals - Hydraulic Structures	1.00	EA	56,859	0	6,823	6,368	523	70,574	70573.77
TOTAL Gatewell Structure	1.00	EA	158,040	0	18,965	17,700	1,455	196,159	196159.45
11.01.13.18.B2 Inlet Structure For 6'x5' RCB									
11.01.13.18.B2.01 Toe	0.54	CY	177	0	21	20	2	220	407.22
11.01.13.18.B2.03 Slab	4.15	CY	3,477	0	417	389	32	4,315	1039.85
11.01.13.18.B2.04 Wingwall	4.01	CY	8,975	0	1,077	1,005	83	11,139	2777.91
11.01.13.18.B2.05 Headwall	1.88	CY	4,943	0	593	554	45	6,135	3263.23
11.01.13.18.B2.06 Concrete Collars (allowance)	1.00	EA	1,000	0	120	112	9	1,241	1241.20
11.01.13.18.B2.07 Free Draining Material Behind HW	1.30	CY	784	0	94	88	7	973	748.67
TOTAL Inlet Structure For 6'x5' RCB	1.00	EA	19,355	0	2,323	2,168	178	24,024	24024.05
11.01.13.18.B3 Outlet Structure for 6'x5' RCB									
11.01.13.18.B3.01 Toe	1.70	CY	367	0	44	41	3	456	268.14
11.01.13.18.B3.03 Slab	6.30	CY	2,211	0	265	248	20	2,745	435.64
11.01.13.18.B3.04 Wingwall	5.53	CY	9,066	0	1,088	1,015	83	11,252	2034.78
11.01.13.18.B3.05 Headwall	3.09	CY	4,110	0	493	460	38	5,102	1651.06
11.01.13.18.B3.07 Concrete Collars	1.30	CY	1,232	0	148	138	11	1,529	1176.28
TOTAL Outlet Structure for 6'x5' RCB	1.00	EA	16,986	0	2,038	1,902	156	21,084	21083.65

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.18.B4 6'x5' RCB									
11.01.13.18.B4.33 Earthwork for 5'x6' RCB	190.00	LF	1,591	0	191	178	15	1,975	10.39
11.01.13.18.B4.34 Base Slab for 6'x5' RCB	74.77	CY	46,317	0	5,558	5,188	426	57,489	768.88
11.01.13.18.B4.35 Walls for 6'x5' RCB	87.96	CY	100,054	0	12,007	11,206	921	124,188	1411.87
11.01.13.18.B4.36 Elevated Slab for 6'x5' RCB	74.77	CY	49,186	0	5,902	5,509	453	61,049	816.50
TOTAL 6'x5' RCB	190.00	LF	197,148	0	23,658	22,081	1,815	244,701	1287.90
11.01.13.18.B6 Replace Exist Levee/Compact	16250.00	BCY	93,081	0	11,170	10,425	857	115,532	7.11
11.01.13.18.B7 Seeding/Mulching for RS of Levee									
11.01.13.18.B7.01 Seeding and Mulching	2.30	ACR	1,610	0	193	180	15	1,998	868.84
TOTAL Seeding/Mulching for RS of Levee	2.30	ACR	1,610	0	193	180	15	1,998	868.84
TOTAL Drainage System 4 - Sta 325+00	1.00	EA	861,348	0	103,362	96,471	7,928	1,069,108	1069108
11.01.13.19 Drainage System 5 - Sta 398+00									
11.01.13.19.B9 Platform Raise - 2.25 foot									
11.01.13.19.B9. 1 Sand Blasting	26.00	SF	73	0	9	8	1	90	3.48
11.01.13.19.B9.10 Vertcl Drilg Holes -1.5"X 6"Deep	44.00	EA	813	0	98	91	7	1,009	22.94
11.01.13.19.B9.15 Grouting of vertical holes	44.00	EA	484	0	58	54	4	601	13.66
11.01.13.19.B9.30 Hole Layout	3.00	HR	251	0	30	28	2	311	103.70
11.01.13.19.B9.45 Concrete -Slab	2.65	CY	871	0	105	98	8	1,081	407.88
11.01.13.19.B9.50 Forms for Slab	117.00	SF	666	0	80	75	6	827	7.06
11.01.13.19.B9.55 Reinforcing Steel for Slab	182.00	LB	278	0	33	31	3	345	1.90
11.01.13.19.B9.60 Replace Stem	1.00	EA	3,050	0	366	342	28	3,786	3786.15
TOTAL Platform Raise - 2.25 foot	1.00	EA	6,486	0	778	726	60	8,051	8050.85
11.01.13.19.C0 Drainage Structure Extension									
11.01.13.19.C0.01 Excavate and Remove Existing End	1.00	EA	928	0	111	104	9	1,152	1151.75
11.01.13.19.C0.02 Place RCP Extension	1.00	EA	1,983	0	238	222	18	2,461	2461.28
11.01.13.19.C0.03 Replace Flared End Section	1.00	EA	1,555	0	187	174	14	1,930	1930.39
11.01.13.19.C0.04 Place Concrete Collars	1.00	EA	1,846	0	222	207	17	2,291	2291.23
11.01.13.19.C0.05 Additional Compaction Labor	1.00	EA	283	0	34	32	3	352	351.62
11.01.13.19.C0.06 Riprap Removal and Replacement	1.00	EA	2,578	0	309	289	24	3,199	3199.44
TOTAL Drainage Structure Extension	1.00	EA	9,173	0	1,101	1,027	84	11,386	11385.71
TOTAL Drainage System 5 - Sta 398+00	1.00	EA	15,659	0	1,879	1,754	144	19,437	19436.56
11.01.13.20 Drainage System 7 - Sta 420+35									

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.20.C1 Platform Raise - 2.5 foot									
11.01.13.20.C1. 1 Sand Blasting	24.00	SF	67	0	8	8	1	84	3.48
11.01.13.20.C1.10 Vertcl Drilg Holes -1.5"X 6"Deep	40.00	EA	739	0	89	83	7	917	22.94
11.01.13.20.C1.15 Grouting of vertical holes	40.00	EA	452	0	54	51	4	561	14.03
11.01.13.20.C1.30 Hole Layout	3.00	HR	251	0	30	28	2	311	103.70
11.01.13.20.C1.45 Concrete -Slab	2.22	CY	799	0	96	90	7	992	446.99
11.01.13.20.C1.50 Forms for Slab	116.00	SF	651	0	78	73	6	809	6.97
11.01.13.20.C1.55 Reinforcing Steel for Slab	198.00	LB	292	0	35	33	3	362	1.83
11.01.13.20.C1.60 Replace Stem	1.00	EA	2,910	0	349	326	27	3,612	3611.51
TOTAL Platform Raise - 2.5 foot	1.00	EA	6,162	0	739	690	57	7,648	7647.69
11.01.13.20.C2 Drainage Structure Extension									
11.01.13.20.C2.01 Excavate and Remove Existing End	1.00	EA	928	0	111	104	9	1,152	1151.75
11.01.13.20.C2.02 Place RCP Extension	1.00	EA	1,194	0	143	134	11	1,482	1482.22
11.01.13.20.C2.03 Replace Flared End Section	1.00	EA	1,297	0	156	145	12	1,610	1610.16
11.01.13.20.C2.04 Place Concrete Collars	1.00	EA	1,883	0	226	211	17	2,338	2337.65
11.01.13.20.C2.05 Additional Compaction Labor	1.00	EA	283	0	34	32	3	352	351.62
11.01.13.20.C2.06 Riprap Removal and Replacement	1.00	EA	2,578	0	309	289	24	3,199	3199.44
TOTAL Drainage Structure Extension	1.00	EA	8,164	0	980	914	75	10,133	10132.84
TOTAL Drainage System 7 - Sta 420+35	1.00	EA	14,325	0	1,719	1,604	132	17,781	17780.53
11.01.13.21 Drainage System 8 - Sta 497+60									
11.01.13.21.C3 Platform Raise - 1 foot 5 inches									
11.01.13.21.C3. 1 Sand Blasting	32.00	SF	90	0	11	10	1	111	3.48
11.01.13.21.C3.10 Vertcl Drilg Holes -1.5"X 6"Deep	80.00	EA	1,626	0	195	182	15	2,018	25.23
11.01.13.21.C3.15 Grouting of vertical holes	80.00	EA	989	0	119	111	9	1,227	15.34
11.01.13.21.C3.30 Hole Layout	3.00	HR	251	0	30	28	2	311	103.70
11.01.13.21.C3.45 Concrete -Slab	2.46	CY	839	0	101	94	8	1,042	423.43
11.01.13.21.C3.50 Forms for Slab	147.00	SF	740	0	89	83	7	918	6.25
11.01.13.21.C3.55 Reinforcing Steel for Slab	293.00	LB	358	0	43	40	3	445	1.52
11.01.13.21.C3.60 Replace Stem	1.00	EA	2,905	0	349	325	27	3,606	3606.30
TOTAL Platform Raise - 1 foot 5 inches	1.00	EA	7,798	0	936	873	72	9,679	9678.82
11.01.13.21.C4 Drainage Structure Extension									
11.01.13.21.C4.01 Excavate and Remove Existing End	1.00	EA	2,348	0	282	263	22	2,914	2913.90
11.01.13.21.C4.02 Place RCP Extension	1.00	EA	3,268	0	392	366	30	4,057	4056.77
11.01.13.21.C4.03 Place Conc Collars for RCP Ext	1.00	EA	1,959	0	235	219	18	2,431	2430.99
11.01.13.21.C4.04 Toe	0.54	CY	177	0	21	20	2	220	407.22
11.01.13.21.C4.05 Slab	4.15	CY	3,477	0	417	389	32	4,315	1039.85

** PROJECT INDIRECT SUMMARY - Assembly **

		QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
11.01.13.21.C4.06	Wingwall	4.01	CY	8,975	0	1,077	1,005	83	11,139	2777.91
11.01.13.21.C4.07	Headwall	1.88	CY	4,943	0	593	554	45	6,135	3263.23
11.01.13.21.C4.08	Concrete Collars (allowance)	1.00	EA	1,000	0	120	112	9	1,241	1241.20
11.01.13.21.C4.09	Free Draining Material Behind HW	1.30	CY	784	0	94	88	7	973	748.67
11.01.13.21.C4.10	Additional Compaction Labor	1.00	EA	283	0	34	32	3	352	351.62
11.01.13.21.C4.11	Riprap Removal and Replacement	1.00	EA	2,578	0	309	289	24	3,199	3199.44
TOTAL	Drainage Structure Extension	1.00	EA	29,791	0	3,575	3,337	274	36,977	36976.78
TOTAL	Drainage System 8 - Sta 497+60	1.00	EA	37,589	0	4,511	4,210	346	46,656	46655.59
11.01.13.22	Drainage System 9 - Sta 558+50									
11.01.13.22.C5	Platform Raise - 1 foot									
11.01.13.22.C5. 1	Sand Blasting	28.00	SF	79	0	9	9	1	97	3.48
11.01.13.22.C5.10	Vertcl Drilg Holes -1.5"X 6"Deep	60.00	EA	1,109	0	133	124	10	1,376	22.94
11.01.13.22.C5.15	Grouting of vertical holes	60.00	EA	668	0	80	75	6	829	13.81
11.01.13.22.C5.30	Hole Layout	3.00	HR	251	0	30	28	2	311	103.70
11.01.13.22.C5.45	Concrete -Slab	1.14	CY	604	0	72	68	6	750	657.53
11.01.13.22.C5.50	Forms for Slab	98.00	SF	569	0	68	64	5	706	7.20
11.01.13.22.C5.55	Reinforcing Steel for Slab	201.00	LB	281	0	34	31	3	349	1.74
11.01.13.22.C5.60	Replace Stem	1.00	EA	2,988	0	359	335	28	3,709	3709.26
TOTAL	Platform Raise - 1 foot	1.00	EA	6,548	0	786	733	60	8,127	8127.38
11.01.13.22.C6	Drainage Structure Extension									
11.01.13.22.C6.01	Excavate and Remove Existing End	1.00	EA	928	0	111	104	9	1,152	1151.75
11.01.13.22.C6.02	Place RCP Extension	1.00	EA	1,505	0	181	169	14	1,869	1868.58
11.01.13.22.C6.03	Replace Flared End Section	1.00	EA	1,835	0	220	206	17	2,278	2277.93
11.01.13.22.C6.04	Place Concrete Collars	1.00	EA	1,959	0	235	219	18	2,431	2430.99
11.01.13.22.C6.05	Additional Compaction Labor	1.00	EA	283	0	34	32	3	352	351.62
11.01.13.22.C6.06	Riprap Removal and Replacement	1.00	EA	2,578	0	309	289	24	3,199	3199.44
TOTAL	Drainage Structure Extension	1.00	EA	9,088	0	1,091	1,018	84	11,280	11280.31
TOTAL	Drainage System 9 - Sta 558+50	1.00	EA	15,636	0	1,876	1,751	144	19,408	19407.69
TOTAL	Drainage Systems	1.00	EA	975,796	0	117,095	109,289	8,981	1,211,161	1211161
TOTAL	Levees	1.00	EA	13,379,088	0	1,605,491	1,498,458	123,140	16,606,176	16606176
11.02	Floodwalls - NONE									
TOTAL	Levees and Floodwalls	1.00	EA	13,379,088	0	1,605,491	1,498,458	123,140	16,606,176	16606176
TOTAL	Feasibility Study Estimate for:	1.00	EA	16,547,795	0	1,605,491	1,498,458	123,140	19,774,883	19774883

** PROJECT INDIRECT SUMMARY - Assembly **

	QUANTITY	UOM	DIRECT	OVERHEAD	% OVRHD	PROFIT	BOND	TOTAL COST	UNIT COST
Contingency								4,470,756	
SUBTOTAL								24,245,640	
Engineering & Design								2,151,635	
SUBTOTAL								26,397,274	
Supervision & Administration								1,396,411	
TOTAL INCL OWNER COSTS								27,793,685	

No errors detected...

* * * END OF ERROR REPORT * * *