UPPER MISSISSIPPI RIVER SYSTEM FLOW FREQUENCY STUDY

Missouri River at Rulo, Nebraska

APPENDIX E

KANSAS CITY DISTRICT

MISSOURI RIVER HYDROLOGY AND HYDRAULIC ANALYSIS

NOVEMBER 2003

INTRODUCTION

Hydrology of the Missouri River
and
Missouri River Flood Profiles

Background

The Kansas City District was one of the five Corps of Engineer Districts that participated in the Upper Mississippi River System Flow Frequency Study. This study commenced in 1997 and was completed in the summer of 2003. The first objective of this study was to review and revise flood flow estimates on the Upper Mississippi River downstream of St Paul Minnesota, the Illinois River downstream of Lockport, Illinois, and the Missouri River downstream of Gavins Point, South Dakota. The second major objective was to provide water surface profiles for major floods on these rivers. The unsteady flow computer program UNET was selected to produce those profiles. This effort considers the rivers in their present configurations, and the effect and presence of all flood control reservoirs and levees within the respective river basins.

The Kansas City District's area of responsibility consists of the main stem of the Missouri River from its mouth to Rulo, Nebraska, at river mile 498. During the course of the overall study it was necessary to conduct ancillary studies on some of the Missouri River tributaries, notably the Kansas and Osage River basins.

Purpose of this Appendix

The purpose of this Appendix is to describe the various studies conducted by the Kansas City District, or by consultants to the District, and to present the results of those studies. Comparisons with previous studies are provided.

Organization of this Appendix

This Appendix is divided into two major parts, Hydrology and Hydraulics. These two studies were carried out sequentially, with work on the Hydrology phase commencing in 1997. The work on this phase of the study was substantially complete in December of 2001, with some minor revisions in September of 2002 and again in May of 2003. The independent technical review of this phase was provided by the Hydrologic Engineering Center (HEC).

Initial independent work on the Hydraulic modeling phase of this study began in the fall of 1998 with the signing of a contract with Dr. Robert L. Barkau. Dr Barkau's contract initiated the development of the UNET model that was used by the District in this study. Work on the calibrated UNET model, and the ancillary models necessary to define historic ungaged lateral inflow, began in earnest in late 1999 and was completed in the spring of 2003. The independent technical review of this phase was provided by the Mississippi Valley Division. These two phases were completed in sequence.

The Hydrology portion of this document is freestanding, and may be used without reference to the Hydraulics portion. The flow estimates from the Hydrology study were used as input into the Hydraulics study, so these two studies are compatible in all respects. It should be noted that the flood flow estimates developed in the Hydrology phase were verified in the Hydraulics phase.

EXECUTIVE SUMMARY

The floods in the summer of 1993 in the upper Midwest focused attention on the subject of the magnitude and frequency of flood flows on the major rivers of the area. In response to this concern, a cooperative study was launched by the five U.S. Army Corps of Engineers (USACE) districts in the upper Midwest. This study was supported by other Federal agencies and seven states in the basin. This study appendix covers the Missouri River from its mouth to Rulo, Nebraska, which is the reach of the Missouri River within the jurisdiction of the Kansas City District. The overall study has two principal objectives: first, to investigate and establish the best possible estimates of the flood flows for the Upper Mississippi, Lower Missouri, and Lower Illinois Rivers, giving full consideration to the present day basin development; and secondly, to develop flood profiles for these streams. Part I of this Appendix covers the present day hydrology of the lower Missouri River, and Part II presents the flood profiles.

Part I - Hydrology

Previous Hydrology Reports

The hydrology of the Lower Missouri River in the Kansas City District was developed and published in a March 1962 report entitled *Missouri River Agricultural Levee Restudy Program – Hydrology Report.* The data presented in that report have been used to estimate flood flows for all flood control studies, Flood Insurance Studies, and similar purposes since that time. The estimated discharges for the six Missouri River gaging stations as presented in that report are listed below.

Missouri River Agricultural Levee Restudy *
Kansas City District Gages

% Chance Flood	Hermann	Boonville	Waverly	Kansas City	St. Joseph	Rulo[1]
0.2	820,000	700,000	-	540,000	330,000	-
1	620,000	550,000	445,000	425,000	270,000	241,000
2	555,000	485,000	395,000	380,000	246,000	220,000
10	405,000	365,000	285,000	270,000	185,000	170,000

*Discharges in cubic feet per second (cfs)

Present Study

The bulk of the Kansas City District's efforts in this study involved data retrieval, manipulation of that data, and basin modeling. Historical stage data was converted to flow for the periods prior to the onset of USGS discharge publication. An unregulated record for the years 1898-1997 was developed by removing the effects of the present system of flood control reservoirs from the record. Also, a regulated period of record was created by simulating the effects of that system of reservoirs. A frequency analysis for unregulated conditions was developed, and then translated into regulated flow estimates using unregulated vs regulated flow relationships. These efforts are described in detail in the Part I of this Appendix. Flow estimates for all points on the River were developed. Flow estimates for the six main stem gaging stations on the River are listed below.

[1] Interpolated data from Plate 12, *Missouri River Agricultural Levee Restudy Program, Hydrology Report,* March 1962

Regulated Flow Frequencies and Discharges*
Kansas City District Gages

% Chance Flood	Hermann	Boonville	Waverly	Kansas City	St. Joseph	Rulo
0.2	833,000	753,000	561,000	532,000	324,000	320,000
1	673,000	573,000	423,000	401,000	260,000	251,000
2	604,000	503,000	370,000	351,000	234,000	218,000
10	439,000	352,000	258,000	245,000	175,000	159,000

*Discharge in cubic feet per second (cfs)

Part II – Hydraulics

Previous Study

The previous development of estimated profiles for various frequency floods was accomplished in the late 1970's and early 1980's using an in-house, one dimensional, steady state computer program known as KCD Backwater. This program is no longer used or supported by the District. The profiles provided by this study have been used for flood plain management purposes since their publication.

Present Study

The Kansas City District study provides flood profiles for the Missouri River from its mouth to Rulo, Nebraska. These profiles are based on an unsteady flow analysis of 100 years of data using a specially modified version of the computer program UNET. The geometry model was calibrated to the hydrograph for the year 1993, including the high water profile for the great flood of that year. Modern topographic and hydrographic data were used to describe the present conditions on the river. The results of the hydrology phase of this study were used to provide flows for the various frequency floods. Variations in elevation estimates for the 1% chance flood from the previously published values ranged from + 6 feet to – 6 feet, with the bulk of the differences within +/- 1.5 feet. Differences in elevation estimates for the six main stem gaging stations are listed below.

Missouri River Flood Profile Comparison

Gage	Percent Chance Flood	Elevation (feet, msl)		
		1976 Profile	2003 Profile	Difference (feet)
Rulo NE	10	861.2	860.1	-1.1
	1.0	861.6	863.0	+1.4
St. Joseph MO	10	811.3	813.5	+2.2
	1.0	815.1	819.4	+4.3
Kansas City MO	10	741.2	740.1	-1.1
	1.0	748.5	749.5	+1.0
Waverly MO	10	674.4	674.4	0.0
	1.0	677.6	677.5	-0.1
Boonville MO	10	596.6	594.7	-1.9
	1.0	599.9	601.9	+1.0
Hermann MO	10	513.7	512.5	-1.2
	1.0	518.4	519.6	+1.2

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PART I

HYDROLOGY

UPPER MISSISSIPPI RIVER SYSTEM
FLOW FREQUENCY STUDY

APPENDIX E

KANSAS CITY DISTRICT

INTRODUCTION

PURPOSE

The purpose of the hydrology phase of the Upper Mississippi River System Flow Frequency Study (UMRSFFS) is to update the discharge frequency relationships, and subsequently the water surface profiles, on the Mississippi River and Illinois River above Cairo, Illinois, and the Missouri River downstream from Gavins Point Dam. This study was initiated by the Rock Island District with five participating U.S. Army Corps of Engineers districts. These were the Omaha, Kansas City, St. Paul, Rock Island, and St. Louis Districts. The purpose of this document is to describe the work accomplished by the Kansas City District as part of the Upper Mississippi, Lower Missouri, and Illinois Rivers flow frequency study. Plate E-1 is a map of the Kansas City District.

Study technical coordination included the periodic coordination and meetings with the Upper Mississippi Flow Frequency Task Force, internal coordination within the Kansas City District throughout the course of the study, and special coordination with other agencies and entities for data gathering, guidance and decision making throughout the study. Extensive coordination was required with all Corps of Engineers districts for data transfer and modeling. Quality control and review was implemented for the study and managed by the Hydrologic Engineering Center (HEC) and the Corps of Engineers districts.

OBJECTIVE

The overall objective of the Kansas City District's effort is to provide a definition of the flood hazards along the main stem of the Missouri River within the Kansas City District. This portion of the appendix covers the initial step in that process, which is the definition of the flood frequency regime on the river, considering the present (1999) state of water resource development in the basin.

PREVIOUS STUDIES

The most recent definitive studies of the Missouri River Hydrology in the Kansas City District under both unregulated and regulated conditions is contained in *Missouri River Agricultural Levee Restudy Program*, published in March 1962. This study included consideration of the existing and proposed reservoir systems on both the main stem and the principal tributaries of the Missouri River. The study also took into account the effect of loss of floodplain storage by routing several large floods down the river under conditions associated with various degrees of levee development.

The flood profiles corresponding to this hydrology were developed in 1979-1981 using an in-house one-dimensional standard step backwater program called KCD Backwater. Since the algorithms incorporated into this program are similar to those used by HEC-RAS, it is believed that these profiles are consistent with results that would have been obtained with the USACE standard backwater program HEC-2 and its successor program, HEC-RAS. The geometry used in the 1979-1981 study was based on 1977 overbank conditions and 1975 channel geometry. Since the publication of that data, these profiles have been used as the basis of all Flood Insurance Studies and other water resource studies on the Missouri River.

ACKNOWLEDGEMENTS
This appendix is one of five district appendices describing the present day hydrology of the Upper Mississippi, Lower Missouri, and Illinois Rivers. This has been a cooperative effort of the St. Paul, Rock Island, St. Louis, Omaha and Kansas City Districts. Credit is due to the Hydrologic Engineering Center (HEC) of Davis, California, for the technical guidance provided to study participants. Consulting services associated with the complex modeling of the Kansas and Osage River basins were provided by the Kansas City office of HNTB, Inc. Also, support dealing with the subject of stream flow depletions was provided by the Great Plains Regional Office of the U.S. Bureau of Reclamation.

MISSOURI RIVER BASIN DESCRIPTION

WATERSHED CHARACTERISTICS

The Missouri River basin is situated in the northern portion of west-central United States. It has a drainage area of about 524,110 square miles, which constitutes approximately 1/6 of the continental United States. From its origin in the headwaters of Red Rock Creek in Montana, it flows for a distance of 2,315 miles to its mouth just upstream of St. Louis, Missouri, making it the longest single waterway in the continental United States. The river has its origins in the Rocky Mountains. From a point near Wolf Point, Montana, the river begins its descent at a steady slope of about 0.90 feet/mile until it empties into the Mississippi River at St. Louis. The Missouri River basin contains all or parts of ten states and minor portions of the Canadian providences of Alberta and Saskatchewan. In its native state, the lower reaches of the Missouri River were described as an unruly river, with a constantly shifting, braided channel. Early valley residents described it as a "transient", meaning it seldom slept in the same bed two nights in a row. Banks were constantly collapsing, launching tree trunks into the river, which became the notorious snags that proved deadly to the early steamboats.

The Kansas City District (subsequently referred to as "the District") covers the lower 498 miles of the River from its mouth to Rulo, Nebraska. The total area of the District is about 109,200 square miles. The principal tributaries of the Missouri River within the District's boundaries are the Kansas and Osage Rivers, with drainage areas of 60,580 square miles and 15,088 square miles, respectively. Other significant tributaries are the Platte, Grand and Chariton Rivers on the left bank, and the Nemaha, Blue, Lamine, and Gasconade Rivers on the right bank. The escarpments which form the edges of the Missouri River floodplain in the district are generally about three miles in width, but they balloon out to widths of 12 to 18 miles in the area of Waverly, Missouri, and Rulo, Nebraska. Plate E-1 is a map of the District. Plates E-2, E-3, and E-4 are diagrams of the Missouri, Kansas and Osage Rivers showing the principal stream gaging stations, flood control lakes, and tributaries.

CLIMATOLOGY

Significant variations in climate occur within the District. The eastern portion lies within the humid climatic zone, with average annual rainfalls up to 40 inches in some places in the Ozark plateau. The western portion of the District lies in the semi-arid High Plains Region, with annual rainfalls as low as 16 inches. Generally, summers are hot and winters are comparatively moderate. The climate is classified as continental, characterized by wide ranges in temperature, and irregular annual and seasonal precipitation. Most precipitation occurs as rainfall during the growing season, but the Missouri River has experienced heavy flows in the past due to snowmelt in the High Plains. Peak flows in streams generally occur in the spring, and to some extent in the fall. Natural stream flow in the summer and winter months is generally lower. Summer time flows on the lower Missouri River are supplemented by releases from the Main Stem Reservoir System in the Omaha District. The mean annual runoff from the Missouri River Basin is 55.6 Million Acre-Feet, or about 2 inches over the entire basin.

FLOOD HISTORY

The Missouri River has been ravaged by floods throughout its history. The earliest great Missouri River flood for which records are available is the Great Flood of 1844. It is not possible to provide an accurate estimate of the magnitude of this flood. Other significant nineteenth century floods occurred in 1876, 1881 and 1883. An extended record of all floods at six Missouri River stream gages for the period 1898 to 1997 was developed as part of this study. A listing of the top ten floods based on either USGS published discharges or flow estimates derived from stage records is listed in Table E-1.

Table E-1
Top Ten Floods
Missouri River Stream Gaging Stations

Rank	Rulo	St. Joseph	Kansas City	Waverly	Boonville	Hermann
1	1952	1952	1951	1993	1993	1993
2	1993	1993	1903	1951	1903	1903
3	1984	1903	1993	1952	1951	1951
4	1947	1908	1952	1944	1944	1995
5	1949	1917	1908	1943	1947	1944
6	1944	1909	1943	1965	1909	1943
7	1950	1912	1915	1947	1908	1986
8	1943	1987	1974	1915	1927	1973
9	1960	1920	1944	1995	1943	1947
10	1951	1929	1909	1929	1995	1935

WATER RESOURCES DEVELOPMENT

The major river in the District is the Missouri River. The largest tributaries to the Missouri within the District are the Kansas River and the Osage-Marais de Cygnes River. Other direct tributaries of the Missouri are the Platte (in Missouri and Iowa), the Grand and the Chariton Rivers. Principal tributaries of the Kansas River are the Republican, Smoky Hill, Big Blue and the Delaware Rivers. Water resources in the District have been extensively developed through the programs of the U. S. Army Corps of Engineers and the Bureau of Reclamation.

Flood Control Reservoirs. The District has eighteen lake projects which are operated for flood control and other purposes. All of these projects are on various tributaries of the Missouri River. A list of these lakes is given in Table E-2.

Table E-2
Corps of Engineers Lakes – Kansas City District

Blue Springs	Clinton	Harlan County
Hillsdale	Kanopolis	Long Branch
Longview	Milford	Melvern
Tuttle Creek	Pomona	Pomme de Terre
Rathbun	Smithville	Stockton
Harry S Truman	Perry	Wilson

The Bureau of Reclamation operates eleven lake projects within the District. The principal purpose of these lakes is to store and distribute water for irrigation in the dryer western portion of the District. When floods threaten the region, the Kansas City District assumes temporary control of these projects and operates them for flood control purposes. A list of these lakes is given in Table E-3.

Table E-3
Bureau of Reclamation Lakes

Bonny	Hugh Butler	Cedar Bluff
Enders	Kirwin	Lovewell
Keith Sebelius	Harry Strunk	Swanson
Waconda	Webster	

Pertinent data for the flood control reservoir projects in the Kansas City District can be found on Plates E-21 through E-25**.**

Navigation. A commercial navigation channel has been established on the Missouri River by the Corps of Engineers. This channel was developed using the principle of confining the flow of the river into a specified channel through the use of groins, various types of dikes, and stone revetments. Construction of these facilities caused the Missouri River to develop and maintain a channel of proper navigation depth through natural scour processes. Releases from the main stem reservoirs are made during the navigation season in support of navigation. Total traffic on the system was 8.3 million tons in 1998. The bulk of this traffic is from Kansas City to the mouth. The largest single commodity moved in the system is classified as construction materials (sand, gravel and stone). The head of navigation is at Sioux City, Iowa, at river mile 734.8. There are no other commercially navigable waterways in the District.

Levees. By two separate Flood Control Acts (1941 and 1944), the Federal government authorized a comprehensive system of eighty-five Missouri River levees in the Kansas

City District. Included in this authorization were five urban levees in the Kansas City metropolitan area. This levee system was intended to protect most of the productive floodplains along the river. The plan also provided for a floodway along the Missouri River. Twenty of these Federal levee projects have been completed to date. Construction of one additional levee is now underway, and a General Reevaluation Report (GRR) is in progress on one additional levee. In addition to these twenty levees, there is one very small urban levee at New Haven, Missouri, in the Federal system. Five Federal levees are in the immediate area of Kansas City, two are downstream of Kansas City, and the remainder are located between Kansas City and Rulo. The five Kansas City levees are considered urban levees and the remainder are agricultural. In aggregate, this system of Federal levees provides protection for about 153,000 acres.

In addition to this system of Federal levees, there are about 97 systems of non-Federal levees of 100 acres or more along the Missouri River within the District. These levees vary with respect to maintenance standards and levels of protection. In general they provide protection from the 20% to 4% chance floods. These levees provide protection to at least 476,000 acres of agricultural lands.

Missouri River Valley/Floodplain Characteristics. The present character of the Missouri River and its floodplains in the Kansas City District is influenced both by the natural physiographic and geological character of the river, and the works of man. The river floodplain is sharply defined by bluff lines. These bluff lines lie far back from the river in two significant reaches. These are the Rulo, Nebraska, area and the reach of river between the mouth of the Little Blue River and Glasgow, Missouri. The more confined reach of river from about RM 466 to the mouth of the Little Blue River (RM 340) has a bluff-to-bluff distance of about 3 miles and contains most of the Federal levees in the District. The flows associated with significant events are generally contained by the levees in this reach. From the Mouth of the Little Blue River to Glasgow (RM 266), the left bank bluff line retreats to open up a floodplain that is 18 miles wide in places. The levees along this reach are non-Federal agricultural levees, which provide a moderate degree of flood protection. Waters associated with great flood events can overspread most of these very extensive floodplains. The bluff lines narrow to about 1.5 to 2 miles in width in the reach from Glasgow to St. Charles (RM 28.1). Except for the small Federal levee around New Haven, the levees in this reach are all non-Federal, and subject to overtopping. Because of the proximity of the bluff lines, the waters of great floods are reasonably confined in this narrow valley. Below St. Charles, the left bank of the Missouri River opens up allowing flood flows to spill over into the floodplain of the Mississippi River. Because of the Missouri River's much greater slope, flood spillage is always from the Missouri River into the Mississippi, never the reverse.

Irrigation. Irrigation is necessary to support modern high-volume agriculture in the arid and semi-arid portions of the Missouri River basin. The latest estimate of irrigated acreage in the entire Missouri River basin is 13,200,000 acres, which is about 4% of the total basin area. Most of this acreage is located upstream of the Kansas City District, but there is a significant irrigated acreage in the western portion of the Kansas River basin. Water withdrawals for irrigation reduce flows. The total estimated annual water consumption is now approaching 12 million acre-feet (MAF), most of which is irrigation water. The present level of outflow from the Missouri River basin is about 55.6 MAF.

Missouri River Drainage Areas. The Kansas City District's tabulation of the drainage areas and of the river mileages of the various tributaries dates from 1962. In order to expand the tabulation of tributary streams, a revised tabulation of Missouri River tributaries, the Missouri River river mileage at their mouths, and their drainage areas was produced. The 2003 USGS Huc11 and Huc14 data were used for the drainage areas. The latest Missouri River hydrographic survey was used for the river mileages. The basic Missouri River mileage for 1962 was used to determine the mile points on the Missouri River sailing line, with some minor adjustments in the absolute distance between those mile points. Since the drainage areas derived in this study differed slightly from those in the 1962 report, and an overall redefinition of drainage areas for the Missouri River basin was not in order, the area listed by USGS at the gage at Rulo, Nebraska, was used as published. The cumulative drainage areas on the Missouri River downstream from Rulo varied slightly from previously published values. This study therefore reports slightly different values than those appearing in the Omaha District report (Appendix F) for Missouri River drainage areas at the five gaging stations downstream of Rulo. These minor differences do not affect the computations used in the overall hydrology of the Missouri River.

HYDROLOGICAL ANALYSIS

METHODOLOGY

The following is a brief description of the work performed to estimate the frequency data for points along the Missouri River.

1.) The existing stream flow records for the main stem stream gaging stations were compiled for the periods when flow readings were collected at the gages. Prior to those periods, stage records at gage sites were translated into estimated flow records using old rating curves. The total time period covered by this extended record is 1898 to 1997.

2.) Watershed computer models were created for the Kansas and Osage River basins. These models were used to estimate the natural discharges for the period of record by removing the effects of the existing system of flood control reservoirs. Simpler models were created to remove the effects of the Smithville project on the Platte River in Missouri. These models were calibrated to observed records.

3.) The results from these studies were furnished to the Omaha District, where they were combined with depletions from the Bureau of Reclamation and routed down the Missouri River, producing an unregulated data set covering the period of analysis at each of the six main stem stream gaging stations within the District. The routing procedure is described in Appendix F.

4.) Data for gages upstream of the Kansas River were found to be subject to two independent flood series: a snowmelt series and a summer rainfall series. A combined probability analysis was performed on the gages at St. Joseph and Rulo.

5.) Data from the unregulated data sets was used to develop unregulated frequency curves using the program HEC-FFA. The statistics of the unregulated flows were regionalized based on a regional shape estimation method that was devised in joint discussions by the Corps and the Interagency Technical Advisory Group (see Hydrologic Engineering Center 1999 and 2000).

6.) Another series of watershed models was created for the Kansas and Osage River basins, with the objective to represent probable basin outflows, assuming that the present system of flood control reservoirs was in place for the applicable period of analysis, and further assuming these structures were operated in compliance with current reservoir operating guidelines. Present level depletions were used in this analysis. Because the reservoir simulation models had to rely on gage records in these tributary streams, and these tributary records did not exist for the entire period of analysis, the reliable portion of this data set is shorter than the unregulated data set.

7.) These outflows were provided to the Omaha District for processing as described above. A data set of regulated flows for each of the six main stem gages was produced.

8.) Annual peak discharges from this data set were arrayed against the corresponding values from the unregulated data set for the valid period of overlapping data. Both data set columns were independently ranked by flow in descending order, and a relationship between regulated and unregulated flows was developed for each gage. This ranking procedure was recommended by HEC. Due to the paucity of data points on the right side of these graphs, it was necessary to supplement these data points with data from a series of synthetic floods developed by the Omaha District.

9.) The relationship developed in step 8 was applied to the unregulated frequency curves to develop a regulated flow frequency curve at each stream gaging station.

10.) These flood flow estimates at the gaging stations were extended to ungaged locations on the Missouri River using a relationship based on stream drainage area.

DATA BASE

The data bases necessary for the development and application of the various computer models that were used to develop the main stem hydrology of the Missouri River fell into three broad categories. These are:

1.) Gaging station data for main stem Missouri River gages.

2.) Gaging station data for key stream gages in the Kansas and Osage River basins.

3.) Meteorological data to support Kansas and Osage basin models.

All stream flow information generated and used in this study was stored and/or manipulated in the USACE data storage system known as DSS. All computer files containing this type of data are stored using a .dss extension on the file name. These data sets are available in the District files.

<u>Main Stem Missouri River Stream Gages</u>. There are six principal main stem gages used in this analysis. These stations are located at Hermann, Boonville, Waverly, Kansas City and St. Joseph in Missouri, and at Rulo, Nebraska. Currently continuous records of both stage and discharge are maintained for these stations. There are numerous other stage-only stations on the river, which were not used for the hydrologic analysis but were used in the calibration of flood profiles (see Hydraulics, the following section).

The overall study objectives required the use of a uniform set of flow records for a 100-year period for all principal stream gaging stations on the main stem of the Upper

Mississippi and Lower Missouri Rivers. The period selected was 1898 to 1997 (see HEC 2000). The data sources for these stations are as follows:

a.) Missouri River Commission (MRC) Stage Data. The MRC was created late in the nineteenth century to develop and install a navigation system on the Missouri River. As part of its duties it maintained daily gage records at a number of staff gages on the river. The MRC was disbanded in 1903.

b.) National Weather Service (NWS) Stage Data. The NWS essentially took over the maintenance and data publication duties for many of the MRC staff gages upon the demise of the MRC.

c.) U.S. Army Corps of Engineers (USACE) Stage Data. The USACE maintained a file on the staff gage at Rulo for a period of time.

d.) United States Geological Survey (USGS) Flow Data. The USGS assumed maintenance of the lower five gaging stations in the mid to late 1920's, and on the gage at Rulo, Nebraska, in 1949. The USGS data sets include both stage and flows.

The USGS flow records were taken as published and used in the study. The problem with the earlier stage-only data was to transform the older records of stage into flow records to complement and extend the USGS records. The first step in this process was to compile as complete a list as possible of daily stage records at each of the six stations prior to the commencement of the USGS records. This process was complicated by shifts in the gage datums used, and by shifts in the location of the staff gages. Once the stage record was compiled, then the oldest credible rating curve was applied to the data to translate stages into discharges. This process required considerable judgment. Since the focus of this study was on flood flows, care was taken to tailor the high flow portions of these records and a lesser scrutiny was applied to the lower discharges. There are multi-year periods where neither stage nor flow data exist for the gages at Waverly and Rulo. These gaps were filled by routing studies conducted by the Omaha District. The data sources for these main stem gages are given in Table E-4.

Table E- 4
Missouri River Main Stem Gaging Stations
Data Sources and Periods of Record

Gaging Station	MRC Stages	NWS Stages	COE Stages	USGS Flows	Routing Model Fill-in
Hermann	1873-1899	1900-1928		1928-Date	
Boonville	1883-1899	1900-1925		1925-Date	
Waverly	1883-1899	1915-1928		1928-Date	1900-1915
Kansas City	1873-1899	1900-1929		1929-Date	
St. Joseph	1873-1899	1900-1929		1929-Date	
Rulo	1886-1899		1929-1949	1949-Date	1900-1929

<u>Kansas River Basin Gages</u>. This study required a continuous record of outflows from the Kansas River basin for observed, unregulated, and regulated conditions. The work necessary to complete this work element was done under contract with the Kansas City office of HNTB Architects Engineers Planners (HNTB). The contractor developed an HEC-HMS model of the basin, and then adjusted that model to reflect the appropriate level

of water resource development in the basin. The HEC-HMS model was based on a series of stream gaging station records within the Kansas River Basin. The stream gaging records (USGS) at several of the key stations dated back to 1919. Many of the other key stations, however, had shorter records. This necessitated the use of some techniques for lengthening the shorter records until a uniform length set of daily flow data sets for the period 1919 to 1997 was developed.

The HEC-HMS models developed for the Kansas and Osage River Basins were used exclusively to route flows from a series of tributary gages that are located upstream of the major reservoirs in these basins. These models were used to simulate the response of the principal flood control reservoirs in the Kansas and Osage River Basins to the historic inflows to those reservoirs. This enabled the District to provide an estimate of historic basin outflows for the pre-reservoir period. Also, these same models were used to remove the effects of reservoir operations from that part of the record when the reservoirs were in service. This was used to construct the unregulated data sets for the main stem gages. These models were used for routing purposes only and are not runoff models.

There were three techniques used to extend record lengths. All are based on the use of daily flow data sets from other, longer record gaging stations in the vicinity of the short record station. The technique of choice was multiple regression. The “missing” data was filled in by use of the following formula:

$D_s = B_0 + B_2 D_2 + B_3 D_3 + B_4 D_4 + ...$ where

D_s = Daily discharge at short record station

B_0 = A coefficient

$B_2, B_3....$ = A coefficient applied to one (of several) long term stations

$D_2, D_3....$ = Daily discharge at the same long term station

The appropriate coefficients were determined by applying standard statistical techniques to periods of time when the records from the short record station overlapped records from the longer record stations. If sufficient gage data was not available to support a multiple regression analysis, then one of two computational techniques known as MOVE procedures was applied. MOVE is an acronym for “Maintenance of Variance Extension”. These are procedures that are based on the use of the statistical means of flows for overlapping periods of gaging station records as modified by the ratios of the standard deviations of those records, the length of the various records, and the sample estimate of product-moment correlation coefficients. These methods have been developed to extend short term records while maintaining the variance and hydrologic extremes of the short record station. Information on the specific MOVE procedure used in this study for the various gages is available in District files. An alternate procedure was sometimes required to extend the data sets at the reservoir sites. The technique used involved the ratio of the drainage areas of the long and short record gages raised to the ¾ power.

There are a number of reservoirs in the far upper reaches of the Republican, Solomon and Smoky Hill Rivers that were not directly modeled, but their effects were incorporated into the inflow data sets for the lower tier of reservoirs.

Table E -5 is a listing of the key gaging stations in the Kansas River basin used in this study, showing both the observed and extended period of record. The principal flood control reservoirs in the basin were also used in the model, thereby requiring extensions of their records. Table E -6 is a list of these reservoirs. Table E -7 is a list of Kansas River basin stream gages used in the extension process.

A schematic diagram of the Kansas River basin is presented on Plate E- 3 of this report. The physical positions of these gages relative to the main stem of the river and to the reservoir system can be seen on this diagram.

Table E- 5
Kansas River Basin
Gaging Stations used in HEC-HMS Routing Model
Observed Conditions

Gage Name	River	Drainage Area (SM)*	River Mile	Observed Period	Extended Period
Desoto	Kansas	59,756	31	10/01/19 – Date	
Lecompton	Kansas	58,400	63.8	3/16/36 – Date	9/30/19 - 3/15/36
Topeka	Kansas	56,720	83.1	10/01/19 – Date	
Wamego	Kansas	55,280	126.9	10/01/19 – Date	
Ft Riley	Kansas	44,870	168.9	12/19/63 – Date	9/30/19 - 12/18/63
Enterprise	Smoky Hill	19,260	43.3	10/01/34 – Date	10/01/19 - 9/30/34
New Cambria	Smoky Hill	11,730	86.6	10/01/62 – Date	10/01/19 - 9/30/62
Near Mentor	Smoky Hill	8,358	101.7	12/01/23 - 6/30/32 10/01/47-Date	10/01/19 - 11/30/23 7/01/32 - 9/30/47
Niles	Solomon	6,770	21.6	10/01/19 – Date	
Tescott	Saline	2,820	68.5	10/01/19 – Date	

* SM = square miles

Table E- 6
Kansas River Basin
Flood Control Reservoirs used in HEC-HMS Routing Model
Observed Conditions

Reservoir Project	River	Date Storage Began	Drainage Area (SM)*	Observed Period	Extended Period
Kanopolis	Smoky Hill	17-Feb-48	7,857	3/01/48 – Date	10/01/19 - 2/29/48
Wilson	Saline	29-Dec-64	1,917	9/04/63 – Date	10/01/19 - 9/03/63
Waconda	Solomon	24-Jul-68	5,076	10/018/67 - Date	10/01/19 - 10/17/67
Harland County	Republican	14-Nov-52	13,500	11/14/52 - Date	10/01/19 - 11/13/52
Milford	Republican	16-Jan-67	24,890	8/24/64 – Date	10/01/19 - 8/23/64
Tuttle Creek	Big Blue	7-Mar-62	9,628	7/20/59 – Date	10/01/19 - 7/19/59
Perry	Delaware	15-Jan-69	1,117	8/01/66 – Date	6/17/22 - 7/31/66
Clinton	Wakarusa	30-Nov-77	367	12/01/77 – Date	4/27/29 – 11/30/77

* SM = square miles

Table E- 7
Kansas River Basin Gaging Stations used to Extend / Correlate Records
Observed Conditions

River	Gage Location	Drainage Area (SM)*	Observed Period
Wakarusa	near Lawrence, KS	425	4/01/20 – Date
Delaware	Valley Falls, KS	922	6/01/22 - 9/30/67
Soldier Creek	near Topeka, KS	290	5/23/29 – 9/30/32; 7/27/35 – Date
Big Blue	Manhattan, KS	9,640	10/01/50 – Date
Big Blue	Randolph, NE	9100	4/01/18 – 9/30/60
Smoky Hill	near New Cambria, KS	11,730	12/01/48 – 9/30/53
Smoky Hill	Lindsborg, KS	8,110	3/01/20 – 7/05/22; 2/01/30 - 9/30/65
Smoky Hill	Langley, KS	7,857	10/01/40 – Date
Smoky Hill	Ellsworth, KS	7,580	10/01/19 – 7/04/25; 8/01/28 – Date
S. F. Solomon	Osborne, KS	2,012	3/28/46 – Date
N. F. Solomon	Portis, KS	2,315	9/17/45 – Date
Saline	near Wilson, KS	1,900	5/11/29 - 9/03/63
Republican	Milford, KS	24,900	10/01/50 – 3/31/64
Republican	below Milford Dam, KS	24,890	10/01/93 – Date
Republican	Clay Center, KS	24,542	10/01/19 – Date
Republican	Scandia, KS	22,903	8/27/19 – 9/30/72
Republican	near Bloomington, KS	21,020	10/01/28 – 9/30/57

* SM = square miles

Osage River Basin Gages. The Osage River basin portion of this study also required a continuous record of outflows from the Osage River basin for observed, unregulated, and regulated conditions. As in the Kansas River basin, this requirement was met by developing an HEC-HMS model of the basin, and then adjusting that model to reflect the appropriate level of water resource development in the basin. The HEC-HMS model was based on a series of stream gaging station records within the Osage River Basin. The available stream gaging records (USGS) in the basin did not permit the overall effective record of the key basin gaging stations to extend back beyond September 1931. As in the Kansas River basin, several key gaging stations had shorter records, necessitating the use of the record lengthening techniques. A uniform set of daily flow data sets for the period 1931 to 1997 was developed. The same three techniques used in the Kansas Basin were used in this basin except the record for the Osage River at Osceola, Missouri, which was extended using one of the HEC-HMS models.

There were two basic HEC-HMS models required for the Osage River basin. Truman Reservoir changed a significant reach of the Osage River from a normal stream to a lake. The normal routing techniques that are applicable for channel routing can no longer be applied to the lake. Therefore, a channel routing model with the Osceola gage as a node point was developed for the pre-Truman conditions. A lake routing model was developed for the post-Truman conditions. The overall schematic for the Osage River basin is shown on Plate E-4.

There are a several smaller flood control reservoirs in the upper portion of the Osage River basin. These reservoirs were not directly modeled, but their effects were incorporated into the inflow data sets for Truman Reservoir. The storage available at Truman is large enough to mask any effects these reservoirs may have on Missouri River flows. The second item of special interest is that an alternate procedure was sometimes required to extend the data sets at the reservoir sites. Because the correlation between gaging stations was too small to use the MOVE methodology, the technique used involved the ratio of the drainage areas of the long and short record gages raised to the ¾ power.

Table E- 8 is a listing of the key gaging stations and flood control reservoirs in the Osage River basin as used in this study, showing both the observed and extended period of record. Table E- 9 is a list of Osage River basin stream gages used in the extension process.

Table E- 8
Osage River Basin
Stream Gaging Stations and Flood Control Reservoirs used in
HEC-HMS Routing Model

	River	Drainage Area (SM)*	River Mile	Observed Period	Extended Period
Stream Gaging Stations:					
Trading Post	Marais de Cygnes	3,230	313.5	9/01/31 – 9/30/58	10/01/58 – Date
Osceola	Osage	8,220	230.9	9/01/31 – 6/31/77	7/01/77 – 9/29/97[2]
Brownington	South Grand	1,660	31.5	9/01/31 – 9/30/71	10/01/71-6/31/77
St. Thomas	Osage	14, 584	34.5	9/01/31 – Date	
Bagnell	Osage	14,000	80.5	6/11/31 - Date	
Flood Control Reservoirs:					
Stockton Lake	Sac	1,292	44.9	10/01/68 – Date	9/01/31 - 9/30/68
Pomme de Terre Lake	Pomme de Terre	611	43.4	6/30/60 – Date	9/01/31 - 6/29/60
Truman Lake	Osage	11,500	175	8/01/77 – Date	

* SM = square miles

[2] Extended using HEC-HMS model.

Table E- 9
Osage River Basin Gaging Stations used to
Extend and/or Correlate Principal Model Routing Gages
Observed Conditions

River	Gage Location	Drainage Area (SM)*	Observed Period
Little Osage	Fulton, KS	295	11/09/48 – Date
South Grand	Archie, MO	256	10/01/69 – 10/09/86
Big Creek	near Blairstown, MO	414	8/01/60 - 10/08/74
Marais de Cygnes	near State Line, KS	3,230	10/01/58 – Date
Sac	near Stockton, MO	1,292	7/21/21 – Date
Osage	near Bagnell, MO	14,000	6/01/25 - Date
Pomme de Terre	Hermitage, MO	655	10/01/21 – 9/30/65
Pomme de Terre	near Hermitage, MO	611	9/30/60 – Date

* SM = square miles

Meteorological Data. Precipitation and evaporation data were necessary components of the HEC-HMS models developed for the Kansas and Osage River basins. This data was used to compute changes in storage in the flood control lakes due to evaporation from the surface of the lake or precipitation falling directly on the lake. All of these flood control lakes have on-site weather stations that collect this type of data. These station records usually precede the effective onset of storage by a few years. Precipitation data for time periods prior to the installation of these project weather stations was derived from the closest available U.S. Weather Bureau (NOAA) station. These sources were also used to fill in gaps in the records of the Corps weather stations. The pan evaporation data was used to predict lake evaporation with the consequent loss of water from the system. It was necessary to apply a derived coefficient to the observed pan evaporation data to account for the observed differences between pan evaporation and lake evaporation. When pan evaporation data was not available, monthly average evaporation rates were used.

Depletions. Much of the western portion of the Missouri River Basin is in the area of the semi-arid western high plains province, where irrigation is widely practiced. Water for irrigation comes from both surface water and ground water sources. Although there is some return flow from irrigated land, much of the water used for irrigation is lost to evapotranspiration and is no longer a component of the surface water flow. Although there are other consumptive uses of water in the basin, irrigation is the largest single consumptive use. The Bureau of Reclamation (BOR) conducted a study of historic consumptive uses in the Missouri River Basin as part of this overall hydrology study. The BOR study results were incorporated into the models used in this study. An expanded discussion of depletions may be found in the Omaha District Appendix F.

UNREGULATED FLOW

The unregulated data sets for each of the six principal Missouri River USGS gaging stations were developed in the following manner. It was first necessary to adapt an existing Missouri River routing model for use in this study. Next, routing models for the two large tributaries in the Kansas City District were developed. These two basins both contain flood control reservoirs that have a significant effect on basin outflows. These models were necessary to be able to reflect the behavior of the flood control system for pre-reservoir conditions, and to remove the effects of the flood control system from the post-reservoir record. Finally, the effects of reservoir regulation were removed from the flow records for the upper Missouri River upstream of Gavins Point, South Dakota, and from the outflows of the Kansas and Osage Basins in NWK. These revised flows were routed down the Missouri River by the Omaha District, providing daily flow records for each of the six USGS gaging stations in the Kansas City District.

Missouri River Routing Models. The daily computed records of reservoir holdouts, tributary inflows, historic depletions, and ungaged local inflows were routed down the main stem of the Missouri River from Gavins Point, South Dakota, to the mouth using a computer model developed and used by the Reservoir Control Center (RCC) in the Northwestern Division Regional Office in Omaha, Nebraska. For a description of this model the reader is referred to the Omaha District Appendix F.

Kansas/Osage River Basin Models. Under its contract with the Kansas City District, HNTB, Inc. developed watershed models of the middle and lower portions of the Osage and Kansas River basins. The main purpose of these models was to compute basin outflows for the entire study period. Two separate models were constructed for each basin to reflect unregulated and regulated conditions. Both sets of models were calibrated to observed conditions prior to the production runs. The principal computer model used to simulate the movement of water through these basins was the Corps' program HEC-HMS. This program is the Corps' principal active hydrology model, capable of developing flow hydrographs at index points in a watershed, accumulating those hydrographs, routing those hydrographs, and a wide variety of other hydrological tasks such as floodwater storage, dam breaks, etc. The Muskingum-Cunge routing option was used in these studies.

Routing reaches and certain routing reach characteristics, including reach length and slope for the Kansas River basin, are given below in Table E-10. It is noted that several of these reaches are quite long, approaching 200 miles. As part of its calibration process, HNTB broke several of these longer reaches into short sections. No significant differences in outflow were noted, so these longer reaches were left in the model to increase its computational efficiency.

Table E- 10
Kansas River Basin
Stream Reaches used in HEC-HMS Routing Model

Upstream Location*	Downstream Location*	River	Stream Slope (feet / mile)	Length (miles)
Kanopolis Lake	Mentor	Smoky Hill	2.4	81.2
Mentor	New Cambria	Smoky Hill	1.8	15.1
Wilson Lake	Tescott	Saline	1.8	84.9
Tescott	New Cambria	Saline	1.6	68.5
New Cambria	Junction Solomon	Smoky Hill	1.6	18.1
Waconda Lake	Niles	Solomon	1.6	147.2
Niles	Junction Smoky Hill	Solomon	1.2	21.6
Junction	Enterprise	Smoky Hill	1.4	25.2
Enterprise	Ft Riley	Smoky Hill	1.4	43.3
Harlan County Lake	Milford Lake	Republican	3.4	195.8
Milford Lake	Ft Riley	Republican	2.5	7.7
Ft Riley	Junction Big Blue	Kansas	2.1	26.4
Tuttle Creek Lake	Junction Kansas	Big Blue	2.1	7.5
Junction	Wamego	Kansas	2.0	15.6
Wamego	Topeka	Kansas	2.2	43.8
Topeka	Lecompton	Kansas	1.6	19.3
Perry Lake	Lecompton	Delaware	1.2	5.8
Lecompton	Junction Wakarusa	Kansas	1.7	23.2
Clinton Lake	Junction Kansas	Wakarusa	1.6	16.3
Junction	Desoto	Kansas	1.6	9.6
Desoto	Mouth	Kansas	1.5	31

* Upstream and downstream locations are all in Kansas, except for Harlan County Lake, Nebraska.

As previously noted, there were two models of the Osage River basin required for this study. The need for these models was driven by the change in basin response when the Truman project was completed. The reach characteristics for the Osage River basin models are given in Table E-11.

Table E- 11
Osage River Basin
Stream Reaches used in HEC-HMS Routing Model

Upstream Location*	Downstream Location*	River	Stream Slope (feet / mile)	Length (miles)
Stockton Lake	Osceola	Sac	1.7	53.9
Stockton Lake	Truman Lake	Sac	1.7	31.5
Trading Post	Osceola	Marais de Cygnes/Osage	0.84	86
Trading Post	Truman Lake	Marais de Cygnes/Osage	0.84	40
Osceola	Lake of the Ozarks	Osage	0.95	46.6
Warsaw	Bagnell	Osage	0.90	94.5
Brownington	Lake of the Ozarks	South Grand	1.1	39
Pomme de Terre	Lake of the Ozarks	Pomme de Terre	2.4	52.4
Pomme de Terre	Truman Lake	Pomme de Terre	2.4	22
Bagnell	St. Thomas	Osage	0.80	37.4
St. Thomas	Mouth	Osage	0.69	43.1

* Upstream and downstream locations are all in Missouri, except for Trading Post, Kansas.

The models were calibrated by adjusting the Manning's resistance coefficients in the model until the routed hydrographs reasonably matched the observed hydrographs at the downstream end of the reach in question. It was necessary to subdivide the record, both by time period and then by discharge to develop a satisfactory set of coefficients to cover the entire period of record. Once these calibrated coefficients were determined, they were used in all subsequent phases of the study. A sensitivity analysis was performed on the model by comparing routed flows with observed flows.

Once these models were calibrated, the first task was to determine the incremental flow which entered the stream system between gages for the period of record. The term applied to this flow is ungaged lateral inflow. This flow was computed for each downstream gage location by routing an observed flow record from an upstream gage down to the gage in question. Next this routed data was subtracted from the observed data at the downstream gage. The resultant record is a daily estimate of the inflow between those two gages for the entire period of record. The ungaged lateral inflows computed by this process were used for both the unregulated and regulated flow versions of these models. The ungaged lateral inflow records were added into the flow stream of the models at the appropriate downstream gages.

The final step prior to running the models for the unregulated data sets was to compute the holdouts for each of the flood control reservoirs for their periods of active service. In its simplest form, a "holdout" can be considered to be the effects of the reservoir, or water that is either removed or added to the downstream flow. Holdouts are treated as flow sources in the computational process and can be positive or negative, and can be used to either add reservoir effects into the record, or to remove the effects of one or more reservoirs. The computation of holdouts is based on the premise that the water surface of the pre-impounded stream is 15% of the water surface of the lake. This 15% estimate is based on the ratio of the impounded lake surface to the surface area of the stream prior to the construction of the dam. These daily unregulated flow data sets were routed to the Missouri River using the appropriate HMS model.

Due to the length of record for tributary gages, the outflow from the Kansas River basin could not be simulated prior to 1919 using the process described above. Because the records of the key tributary gages in the Osage River basin are even shorter, this process could not be used for data prior to 1930. For the years prior to 1919, flow from the Kansas River basin was treated computationally as a component of the ungaged local inflow in the reach between the St. Joseph and Kansas City gages. Appropriate corrections were made for estimated Kansas River basin depletions. In like manner, the outflow of the Osage River basin prior to 1930 was estimated as a component of the ungaged local inflow between the Boonville and Hermann gages, but adjustments for depletions in that basin were not warranted. This computational procedure permitted the construction of unregulated flow data sets for the main stem gages extending back to 1898. This, in turn, allowed the data sets used in the unregulated flow frequency analysis to include the entire 1898–1997 period.

Since the regulated flow data sets in the Kansas City District are heavily dependent on the reservoir effects within the Kansas and Osage River basins, and, because the effectiveness of those systems of reservoirs depend upon the footprints of severe rainfall events, those effects could not be reliably simulated prior to the dates listed above. Therefore, the extended regulated record is only valid from 1920 on for the Kansas City, Waverly and Boonville gages, and from 1930 on for the gage at Hermann. A full "regulated" data set for all of the Kansas City gages was produced using the Daily Routing Model (DRM), but it used various "fill in" techniques for the outflows of these two basins. The data produced for regulated flows in this early period is not of the same quality or validity as the data produce after these tributary models became functional, and should not be used.

Minor Tributary Models. Models of the Platte, Chariton, and Little Chariton Rivers were required due to the presence of the Smithville, Rathbun and Long Branch flood control reservoirs. The models developed for this purpose were spreadsheet models relying on lag routing processes. These same lag routing methods are used on a daily basis by the water control unit in the Kansas City District. These reservoirs only control minor portions of the overall drainage area, and do not have a significant effect on flood peaks on the main stem of the Missouri River.

Final Unregulated Data Sets. The unregulated data sets from the models described above were combined with the ungaged local inflow data sets and depletions, and routed down the river by the Omaha District using the DRM. This produced a simulated daily flow record for each of the six principal Missouri River USGS gaging stations for the period 1898-1997. The annual maximum peak discharges were extracted from these records, and used as an annual series to develop the unregulated flow frequency curves.

REGULATED FLOW

Regulated flows are considered to be those discharges one would expect to encounter on the Missouri River with the present system of flood control reservoirs in place. The regulated flow data set is the series of peak annual discharges that would have occurred over the 1898-1997 period with those flood control reservoirs in place and functioning as designed. In order to construct a simulated flow record for regulated conditions, it was necessary to construct a series of regulated flow models.

Flows upstream of reservoir sites are considered to be historical inflows into those reservoirs. When simulating regulated flow conditions, allowances were made for evaporation from flood control lakes, and precipitation on those lakes. Flow modifications caused by flood control reservoirs can be broadly grouped into two categories, those attributable to the main stem projects, and those attributable to the flood control reservoirs on Missouri River tributaries in the Kansas City District. A description of the main stem reservoirs and the techniques used to model their effects can be found in Appendix F. This Appendix contains a description of the development of regulated data sets for the Kansas, Osage and Platte River (Missouri) basins.

<u>Missouri River Routing Model</u>. The model used for routing estimated reservoir holdouts, upstream flows, tributary flows, present level depletions, and ungaged local inflows down the Missouri River was the Daily Routing Model, or DRM. This is a model developed in the Reservoir Control Center in the Omaha Regional Office of the Northwestern Division. A thorough discussion of this model and its capabilities can be found in Appendix F.

<u>Kansas/Osage River Basin Models</u>. The regulated outflows from the Kansas and Osage River basins were computed with the aid of a complex watershed modeling system. Initially it was thought possible to describe the effect of the reservoir system using an EXCEL spreadsheet model. These reservoir effects would then be routed through the system using essentially the same HEC-HMS model that was used for the development of the unregulated data sets. The reservoir effects proved to be too complex for an EXCEL spreadsheet, so a model based on Microsoft Access, supported by the Visual Basic programming language, was chosen. The computational sequence was as follows and is described in detail in the following paragraphs. First, the input data was analyzed, and the individual reservoir operations were determined using the Access model. A series of reservoir outflow data files was generated by these operations. These operations involved routing reservoir outflows downstream in the Access models. The final regulated data sets were generated by the appropriate HEC-HMS model, using the reservoir outflow data sets and the observed lateral inflows computed previously.

<u>Regulation Manuals</u>. The first step in the process of developing the Access operating models for the basins was to read and digest the regulation manuals for the major flood control reservoirs in the two basins. All District reservoirs have three different pools. These are generally known as the multipurpose pool, the flood control pool, and the surcharge pool. The multipurpose pool resides at the lowest elevation in a reservoir of all the pools. When in this pool, a reservoir is operated for recreation, fish and wildlife, low flow augmentation, water supply, and other similar purposes as authorized. The controlling factors on a project's releases are downstream minimum release rates. As stormwater inflow causes lake levels to rise, a project moves into the flood control pool and the operational scenarios become much more complex. The overall operational

objective becomes one of providing the maximum degree of flood control benefits consistent with the need to insure the integrity of the project. When flood control storage is distributed among several projects, coordination of releases with adjacent projects is required. Releases are governed by a seasonally adjusted schedule that is divided into three distinct phases. These phases are based on the amount of impounded storage and the non-damage capacity of the downstream channel. When a reservoir's pool has risen through the flood control pool, the project is said to be in surcharge storage. The operational objective at this point is simply to release inflow and deplete stored floodwaters in the interest of protecting the structural integrity of the project. Surcharge levels are reached only on rare occasions.

A decision was made early in the study process to structure the Access model to reflect reservoir operations as they are specified in the regulation manuals. Many past operations have been conducted under authorized exceptions to the rules specified in the manuals.

Kansas River Basin Model. Of the 18 flood control reservoirs in the Kansas River basin, only 8 are used directly in the regulated flow analysis. The other ten projects are in the remote upper reaches of the Kansas River basin. These projects provide local flood control benefits and are operated with those ends in mind. The effects of the operations of these remote projects has been accounted for by the Bureau of Reclamation in their development of the inflow data sets for the eight major downstream projects.

Two separate Access models for the Kansas River basin were required. These models were labeled the Upper Kansas River Basin model and the Lower Kansas River Basin model, with the stream gage at Enterprise, Kansas, forming the demarcation line. The upper basin model incorporates Kanopolis, Wilson and Waconda Lakes which have a combined flood control storage of 1,621,000 Acre Feet (AF). These three reservoirs provide control over 76% of the river basin upstream of the Enterprise gage. This model is operated to produce an outflow record set at that gage. The second model, known as the Lower Kansas River Basin model, used the outflow from the upper model as input, and incorporated the effects of the Harland County, Milford, Tuttle Creek, Perry and Clinton flood control reservoirs. In addition to operations in the interest of flood control in the Kansas River basin, this system of reservoirs is operated for flood control on the main stem Missouri River using the Waverly gage as the target index point.

Upper Basin Operating Algorithm. There are three different reservoirs in this model, each having three different possible pools (multipurpose, flood control and surcharge). For each day in the record, the model algorithm first determined a tentative release for each project as if that project were operating alone. If the project were in the multipurpose pool, the project releases were simply in accordance with a predetermined low flow release schedule. Operations in the flood control pool were more complicated. Lake stages in the lower range of the flood control pool, called minor impoundments, triggered a process of pool evacuation in a ten-day target period. Greater levels of flood control storage called for releases depending on the stage of the water levels in the reservoir. All flood control releases, of course, are subject to the physical capacity of the outlet works. After the tentative project releases from each project were determined, then these flows were routed to controlling gages where the ungaged local inflow is added into the flow stream. The sum of the outflows is then checked against the allowable or target flow at this station. If the summed flows are less than the target flow, the tentative flows were accepted and the computation proceeded to the next day. If the summation of flows was greater than the gage target, then the outflow was allocated among the three reservoirs based on a formula using the present level of storage in each reservoir, a factor known as the lake character (a function of the lake's 25 year flood volume), its minimum release at ½ surcharge pool, its surcharge storage capacity, and the Phase II release from the project. (The Phase II release is the maximum non-damaging flow, or essentially bankfull flow.) The physical capacity of the various outlet works and the flood control phases of the several projects are also factors in determining the final releases from each of the three projects.

The algorithm began with an analysis of the upstream two projects, Kanopolis and Wilson and operated them against the gage at New Cambria, Kansas, (see Plate E-3 for a diagram of the Kansas River basin). The computation then proceeded downstream to include those operations and the operation of Waconda, and operated all three projects against the gage at Enterprise, Kansas. If one or more of these projects was in a surcharge pool, then discharges from that project could not be throttled, and appropriate adjustments were made in the discharges from the other projects, if possible. The final flows from each of the three reservoirs were determined by this specified balancing procedure.

The next step was to use the computed daily release for each project, together with reservoir inflow, evaporation and precipitation data to compute the change in storage (and lake level) at each project. This storage level would serve as the starting point for the next day's computation. The final step was to route these releases to the gage at Enterprise, Kansas, and the computation proceeded to the next day.

<u>Lower Basin Operating Algorithm</u>. The analysis of the lower Kansas River basin was similar to that of the upper basin except that the computed discharge from the gage at Enterprise, Kansas, was used in the model without modification. There are four flood control reservoirs in the Lower Kansas River basin – Harlan County, Milford, Perry and Clinton. While this adds an order of magnitude to the complexity of the computations, it does not change the basic analytical procedure. The Harlan County reservoir is on the Republican River about 200 miles upstream of the Milford Reservoir. Hence all computed outflows from the Milford project are based on the storage status of these two reservoirs. The computations proceeded in an upstream to downstream order. First, the tentative releases from the Harlan County and Milford projects were taken with the previously computed discharge at Enterprise and routed to the gage on the Kansas River at Ft. Riley, Kansas, and checked. Next, the tentative releases from the Tuttle Creek project were added and these routed discharges were checked at the Kansas River gages at Wamego, Kansas, and Topeka, Kansas. Next the Perry releases were added to the flow stream and checked at the gage at Lecompton, Kansas. The final increment involved adding the Clinton releases and checking at the Kansas River gage at Desoto, Kansas, and the Missouri River gage at Waverly, Missouri. As the model cascaded through this process, intermediate checks were made at the key gages. If any of these checks proved unsatisfactory, then the specified flow balancing procedure was initiated, appropriate

adjustments were made to the project outflows, and the computations started over again with the Ft. Riley gage. As with the upper basin model, once the final daily outflows for each project were determined, the change in storage was computed and the computations proceeded to the next day.

It should be noted that the computations performed in the Access model involved routing flows down the various streams in the Kansas River basin. A special routing algorithm was incorporated into that model for that purpose. However, once the project outflows were estimated by the Access model, these outflows were transferred to the same HEC-HMS model used to route the observed and unregulated data sets. The final routings were performed by the HEC-HMS model, providing a compatible output data set

Osage River Basin Model. The Osage River basin model was much simpler than the Kansas River model. The effects of the reservoirs west of the Missouri-Kansas state line are inconsequential to Missouri River flows, and were dealt with by minor modifications to the inflow records at the Trading Post, Kansas, gage. The model was essentially a four reservoir model, namely Stockton, Pomme de Terre, Truman, and Bagnell (Lake of the Ozarks). The bulk of the storage in this basin in behind the Truman Dam. The model algorithm started with an analysis of the status and outflows from Stockton and Pomme de Terre projects, with appropriate adjustments as specified in the regulation manuals. These inflows were combined with the unregulated inflows into Truman Lake. The Truman project was operated against the discharge at the Osage River gage at St. Thomas, Missouri. The Lake of the Ozarks has no flood control storage and appears as a simple routing reach in the model. A secondary control target which overrides the St. Thomas, Missouri, gage during significant Missouri River flooding is the gage at Hermann, Missouri. As previously noted, the regulated record provided by this model began in September 1931.

Limitations on Regulated Flow Determinations for the Kansas and Osage River Basins. Because of the limitations imposed by the lack of tributary gage data for the early part of the 20th century, the regulated outflows form the Kansas River Basin could not be simulated prior to 1919 by the above-described process. Likewise, the regulated Osage River Basin outflows prior to 1930 could not be simulated. As described above, a “fill in” process was used in the DRM to estimate regulated basin outflows, but this process does not provide information of the same quality as that described above. In practical terms, this means that the regulated record at the Hermann gage prior to 1930 was not used, and the regulated records for the gages at Boonville, Waverly and Kansas City prior to 1919 were not used. The regulated records for the gages at St. Joseph and Rulo, which were not subject to the limitations of tributary gage records, were usable for the entire 100 year study period.

Minor Tributary Models. Holdouts were also needed for the Platte (Missouri), Chariton, and Little Chariton Rivers for use in the unregulated and regulated analysis of the main stem Missouri River. Each minor tributary has one USACE flood control reservoir authorized to provide flood control benefits along the tributary downstream as well as on the main stem Missouri River. Smithville Lake is located on the Little Platte tributary of the Platte River upstream of Sharps Station, Missouri. Rathbun Lake is located in the headwaters area on the main stem of the Chariton River. Long Branch Lake is located on the main stem of the Little Chariton River. The locations of the reservoirs are shown on Plate E-1. The tributary holdouts were computed as the difference between the unregulated flows and the observed flows. The reservoir storage effects from Smithville Lake and the Kansas River basin reservoirs are lumped in the holdout file at the Kansas City gage. The storage effects from Rathbun and Long Branch Lakes are lumped in the holdout file for the gage at Boonville, Missouri. The District used a spreadsheet analysis to determine both the unregulated and regulated flows from the three tributaries. Both the unregulated and the regulated analysis of the Platte River were carried in one spreadsheet. The analysis of the Chariton and Little Chariton Rivers were combined in a second spreadsheet. The holdouts determined by these spreadsheet analyses were routed down to the Missouri River, and combined with the appropriate input files for use in the main Missouri River routing models.

Regulated Data Sets. A “first cut” run of the outflows from these basins was made using estimated flows at the downstream Missouri River target gages. Then the Omaha District performed an initial routing with the DRM to obtain Missouri River estimated outflows. This initial routing produced a better estimate of the flows at the Missouri River target gages. A “second pass” was then made for the tributary models using these new target flows. This produced an improved set of basin outflows that was furnished to Omaha for a final run using the DRM model. This final run produced a simulated daily flow record for each of the six main stem gaging stations. The annual maximum peak discharges were extracted from these records. These regulated data sets were used to develop the unregulated versus regulated flow frequency relationships in a process described below in the paragraph titled *Regulated Flow Estimates.*

DATA SUMMARIES

Plates E-5 through E-10 are a series of summaries of the various observed and computed peak annual instantaneous flows for each of the Kansas City District Missouri River gaging stations for the period 1898 through 1997. The flows presented are the USGS observed flows, the unregulated flows (both with and without depletions), and the regulated flows (both with and without depletions).

FREQUENCY ANALYSIS

HYDROLOGIC DATA ANALYSIS

Studies conducted by the Omaha District found that the upper reaches of the Missouri River are subject to two independent flood sources. These two periods are defined as the snowmelt season (1 January to 30 April) and the rainfall season (1 May to 31 December). This conclusion was supported by the independent review of the Technical Advisory Group for this study (HEC 2000). The reaches affected extend through the Omaha District down into the upper reaches of the Missouri River in the Kansas City District. For the purposes of this Appendix, the stream gages at Rulo and St. Joseph are affected, but no evidence of a mixed population could be found downstream of the mouth of the Kansas

River. The computational techniques used in these circumstances are different from those used for the normal single source flood records. This split the analysis in the Kansas City District into two separate analyses – a standard analysis of the four gaging stations downstream of the Kansas River, and a mixed population analysis for the two gages upstream of the Kansas River. The frequency analysis for the Kansas City, Waverly, Boonville and Hermann gages presented in this report are standard analysis of annual peak data using the methods outlined in *Guidelines For Determining Flood Flow Frequency*. The analysis of the gages at Rulo and St. Joseph followed the procedures for the analysis of mixed populations as specified in Chapter 10 of EM 1110-2-1415 *Hydrologic Frequency Analysis*.

Peak annual flows for each of the six Missouri River gages in the District are given on Plates E-5 through E-10 in this report. These listed flows include regulated and unregulated flows with depletions as defined above, regulated and unregulated flows without depletions, the USGS gage records, and the pre-USGS stage-based records. Records of daily flows at each of the six gages in DSS format are maintained in the Kansas City District office.

Before processing the daily flow data, it was necessary to convert these daily flow values to instantaneous peak discharges for use in the frequency analyses. This was done by comparing the daily flow values from the extended "observed" data set with the published USGS peak flows. A series of simple equations, all with high (>0.99) correlation coefficients (r^2), were developed for these gages. The equations derived for the six Missouri River gages in the Kansas City District are given in Table E-12.

Table E-12
Conversion of Peak Daily Flow to Instantaneous Flow
Missouri River Gages

Gage	Equation	r^2
Hermann	Q = 1.0253D + 1022	0.99
Boonville	Q = 1.0275D + 1436	0.99
Waverly	Q = 1.0163D + 2344	0.99
Kansas City	Q = 1.0231D + 2636	0.99
St. Joseph	Q = 1.0002D + 5765	0.99
Rulo	Q = 1.0313D + 2519	0.99

Where: Q = Peak Instantaneous Flow
D = Peak Daily Flow

UNREGULATED FREQUENCY ANALYSES

Missouri River Gages Downstream of the Kansas River. The unregulated data sets as described above were analyzed using the computer program HEC-FFA. A regionalization process was employed to reduce statistical sampling error and promote consistency in the frequency curve estimates (HEC 2000). The station statistics from the analyses of these gages, and the regional skew assigned to this reach of the river by the TAG are given on Table E-13.

Table E-13
Missouri River Gages Downstream of the Kansas River
Station Statistics for Unregulated Frequencies

	Hermann	Boonville	Waverly	Kansas City
Drainage Area*	524,200	501,700	487,200	485,200
Mean	5.5337	5.4577	5.4141	5.4139
Std Deviation	0.1658	0.1554	0.1430	0.1430
Regional Skew	0.17	0.17	0.17	0.17

*Drainage Area in square miles

The Waverly gage is located in a reach of the Missouri River where the bluff lines have widened out to provide a floodplain which is as much as 18 miles in width. The Grand River, which is in the prehistoric valley of the Missouri River, enters the Missouri in this reach. The Grand River also has an extremely wide floodplain. These floodplains are mostly in agriculture uses. While there are two large Federal levees in the area providing a high degree of flood protection, most of the area is protected by lower level private levees. As great floods overtop these levees, large amounts of overbank flood storage become available. As great flood waves move through this reach, the actual flow in the river channel tends to reach a certain level and then plateau. Additional water from a rising upstream hydrograph will contribute some water to the flow in the channel and its immediate overbanks, but most of this additional water goes into active or passive overbank storage. The proper method to account for the effects of great floods is to evaluate the floodplain using unsteady flow modeling techniques. The second phase of the Upper Mississippi River System Flow Frequency Study used a modified version of the unsteady flow model UNET to establish daily flows for the entire period of record at all cross sections on the Missouri River. This modified version incorporated a special algorithm which accounts for levee rupture, floodwater storage within failed levees, and floodplain flow landward of those failed levees. The results of the UNET analysis was used to verify the flow estimates for infrequent floods at the Waverly gage.

Plots of the HEC-FFA frequency versus discharge relationships for these four gages are found on Plates E- 11 to E-14.

Missouri River Gages Upstream of the Kansas River. There are two main stem gages upstream of the mouth of the Kansas River in the Kansas City District. Each of the records at these stations was analyzed individually, and the gages were also analyzed as a unit for the purpose of regional frequency analysis. Computer program HEC-FFA was used for this purpose

As noted above, these two gages were evaluated using a mixed distribution (or split season) analysis. Each calendar year was divided into two seasons, referred to herein as the snowmelt season and the rainfall season. The first four months of the calendar year are considered to be the snowmelt season, with the remainder of the year as the rainfall season. The combined probability theorem is described in Chapter 10 of EM 1110-2-1415 *Hydrologic Frequency Analysis*. The regionalization process for the estimation of skews for the two independent seasons involved the use of the gaging station at Nebraska City, Nebraska. Since that gage lies in the Omaha District, no data will be presented herein for that gage. The reader is referred to Appendix F for a discussion of that gage. The data derived for unregulated flows at the St. Joseph and Rulo gages is presented in Table E-14. HEC-FFA plots for the unregulated rainfall and snowmelt seasons for the St. Joseph gage are shown on Plates E-15 and E-16. Plate E-17 is a plot of the combined frequency curve at St. Joseph.

Table E- 14
Missouri River Gages Upstream of the Kansas River
Station Statistics for Unregulated Frequencies

	St. Joseph		**Rulo**	
Drainage Area*	420,300		414,900	
Season	**Snowmelt**	**Rainfall**	**Snowmelt**	**Rainfall**
Mean	5.101	5.320	5.084	5.306
Std Deviation	0.225	0.121	0.223	0.117
Regional Skew	0.077	-0.9	0.077	-0.9

*Drainage Area in square miles

Because of the physiographic characteristics of the Missouri River floodplain in the vicinity of the Rulo gage, which are similar to those at the Waverly gage, flow estimates for floods greater than the 1% chance flood were established via the UNET unsteady flow analysis.

REGULATED FLOW ESTIMATES

The methodology adopted by the UMRSFFS study team involved developing a relationship between the unregulated peak discharges and the regulated peak discharges at each gage. This process is described in Paragraph 3-9 of EM 1110-2-1415 *Hydrologic Frequency Analysis*. For this study, the peak annual unregulated and regulated flows were each listed in separate columns in a spreadsheet. Each column was ranked independently in descending order. The ranked columns were then plotted with the unregulated flow on the abscissa axis versus the regulated flows as the ordinate. A mathematical relationship between unregulated and regulated discharges was then derived based on the plotted data. Ideally this process should yield a meaningful mathematical relationship, but this was not possible due to the paucity of large flood events necessary to define the high discharge portion of the relationship. To provide data points for the high discharge portion of these curves, a series of synthetic large flood events was employed. These floods were developed by the Omaha District, and a description of their derivation can be found in Appendix F. It was not possible to develop an acceptable mathematical relationship for these graphs, so graphical relationships, focusing on large floods, were developed and utilized. This graphical process was recommended to the District by HEC and Northwestern Division, USACE. Plots of these graphs can be found on Plates E-18 and E-19.

The final step in the process was to apply the relationships between unregulated and regulated flows to the unregulated frequency estimates to determine regulated frequency estimates. The final regulated frequency estimates from this process are given in Table E-15.

Table E-15
Regulated Flow Frequencies and Discharges*
Kansas City District Gages

% Chance of Occurrence	Hermann	Boonville	Waverly	Kansas City	St. Joseph	Rulo
0.2	833,000	753,000	561,000	530,000	324,000	320,000
0.5	742,000	648,000	480,000	454,000	287,000	281,000
1	673,000	573,000	424,000	401,000	261,000	250,000
2	604,000	503,000	371,000	351,000	233,000	220,000
5	511,000	415,000	305,000	289,000	199,000	184,000
10	439,000	352,000	258,000	245,000	174,000	158,000
20	363,000	289,000	212,000	210,000	147,000	132,000
50	248,000	203,000	150,000	142,000	109,000	96,100

*Discharge in cubic feet per second (cfs)

These estimates have been verified in the UNET period-of-record hydraulic analysis of the Missouri River. Since that process is computationally independent of the statistical process described herein, these discharges are considered to be reasonable. Because of the truncated records on the Kansas and Osage Rivers, and the limitations they placed on the simulation of the tributary reservoirs, the full 100 year period should not be used for the effective record length at any of these gages. A record length of 70 years is recommended. There are minor differences between the above listed estimates for rare floods at the gage at Rulo and the estimates for the same location published by the Omaha District. These differences are due to the slightly different techniques used by the two Districts. When the UNET period-of-record analysis was conducted by the two districts, no significant differences in water surface profiles were noted.

The final step in this process was to estimate flood flows at ungaged locations on the Missouri River. In order to accomplish this task, it was first necessary to update the 1965 estimates of Missouri River drainage areas in the Kansas City District. That process was described earlier in this Appendix under the topic, “Missouri River Drainage Areas”. The next step was to develop DA versus Q relationships for each frequency flood. The Missouri River was divided into two reaches at the mouth of the Kansas River for this purpose. These relationships were then applied at ungaged areas using the drainage area as the independent variable. The results of this study are given on Plate E-20. These flows were used as input for the UNET period-of-record profile development in the hydraulics phase of this study. The discharges presented in Plate E-20 were verified by a Pearson III analysis conducted as part of the hydraulics study.

PART II

HYDRAULICS

UPPER MISSISSIPPI RIVER SYSTEM
FLOW FREQUENCY STUDY

APPENDIX E

KANSAS CITY DISTRICT

INTRODUCTION

STUDY DESCRIPTION

One of the products of the Upper Mississippi River System Flow Frequency Study (UMRSFFS) is a set of water surface profiles for various frequency floods on the upper Mississippi, lower Missouri, and lower Illinois Rivers. The Kansas City District is responsible for those profiles for that portion of the lower Missouri River extending from Rulo, Nebraska, at River Mile (RM) 498, downstream to the Missouri River's confluence with the Mississippi River. Hydraulic modeling based on the computer program UNET was used in this process. The Qmodel in the Kansas City District covered of 498 river miles of the main stem of the Missouri River and 360 river miles of tributaries. Figure E-1 is a schematic of the Missouri River in the Kansas City District. The schematic shows key stream gaging stations on the Missouri River and some of the tributaries, stream junctions (by river mile), and some limited data on stream drainage areas.

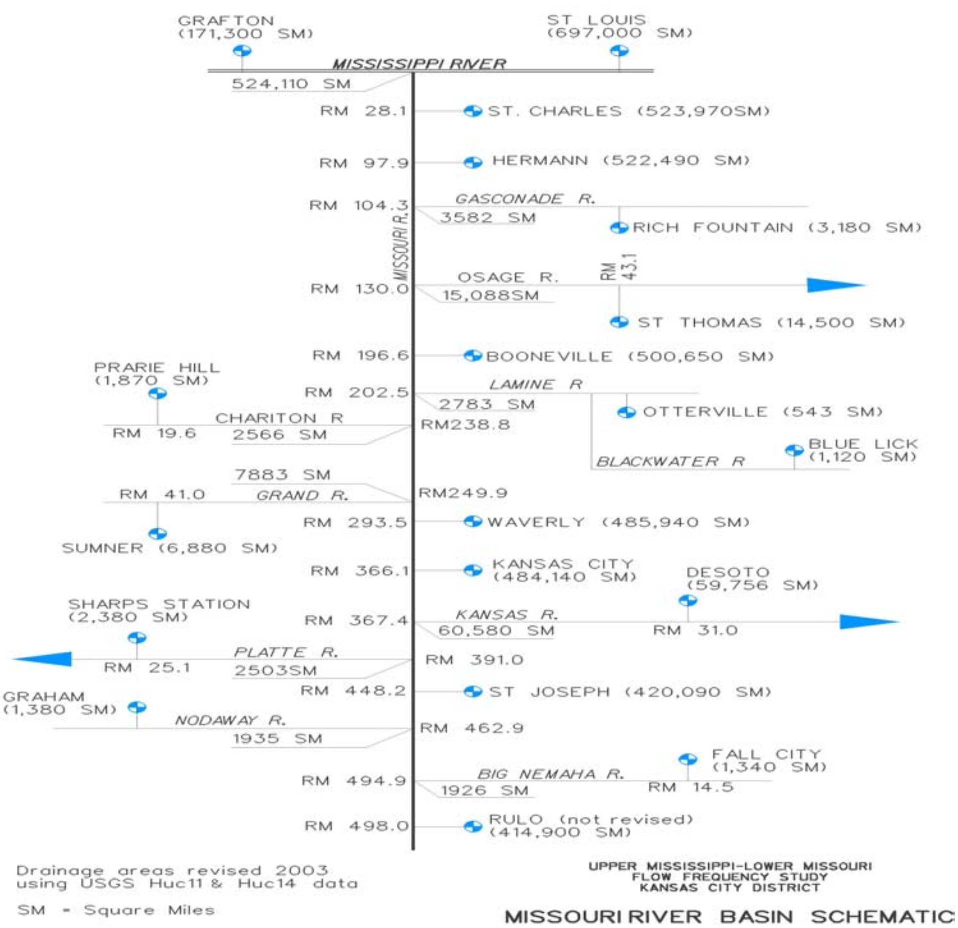

Figure E-1.

UNET HYDRAULIC MODEL

UNET is the hydraulic analysis computer program selected for use in the Upper Mississippi River System Flow Frequency Study (UMRSFFS). UNET is a one-dimensional, unsteady open-channel flow computer model program that can simulate flow in single reaches or complex networks of interconnected reaches. Another capability of UNET is the simulation of storage areas, which is used to simulate the interaction of the river with levees. Storage areas are lake-like regions that can either divert water from, or provide water to, a river or channel. See referenced UNET Users Manual (Apr 2001) and Barkau (1992). The present study is the first time this type of unsteady flow model has been used to produce water surface profiles for various flood frequencies on a major river.

Dr. Robert L. Barkau is the author and developer of the UNET computer program. The USACE Hydrologic Engineering Center (HEC) maintains, distributes, and supports the standard version of UNET for Corps of Engineers' offices. In order to deal with the unique problems of the Missouri River in the Kansas City District, particularly the levee systems, Dr. Barkau developed a customized version of UNET for this study.

STUDY AREA DESCRIPTION

MISSOURI RIVER BASIN

The Missouri River Basin comprises 74 percent of the total upper Mississippi River Basin. The total drainage area of the Missouri River Basin is 524,110 square miles. The Missouri River drainage area within the Kansas City District is about 109,200 square miles.

The Missouri River rises in the northern Rocky Mountains along the continental divide, and flows generally south and eastwardly to join the Mississippi River about 15 miles upstream of St. Louis, Missouri. At 2,315 miles (1960 mileage), it is the longest river in the United States. The Kansas City District encompasses approximately 109,200 square miles of the Missouri River drainage basin from Rulo, Nebraska, downstream to the mouth. The Missouri River basin contains numerous reservoirs and impoundments constructed by different interests for flood control, irrigation, power production, recreation, and water supply.

From Rulo to Kansas City, the Missouri River flows through the dissected till plains of the central lowlands. Downstream of Kansas City, the river flows along the northern border of the Osage Plains and the Ozark Plateau to a point near St. Charles, Missouri, where it re-enters the central lowlands to join the Mississippi River. The Missouri River contributes 42 percent of the long-term average annual flow of the Mississippi River at St. Louis, and is the major contributor of sediment in the upper Mississippi River Basin.

Between Rulo, Nebraska, and the mouth at St. Louis, the Missouri River has a total fall of about 451 feet and the average slope varies from 0.8 to 1.0 foot per mile. The river within this reach contains approximately 865 miles of bankline in Missouri, 140 miles in Kansas, and eight miles in Nebraska. The fringe area along the river is covered with willows and other trees. The floodplains are comparatively wide and for the most part are under cultivation. The width of the floodplain varies from a maximum of approximately thirteen miles to a minimum of approximately 1.5 miles. The actual floodway decreases to less than 0.5 mile in reaches with urban levees at St. Joseph, Kansas City, and St. Charles.

MISSOURI RIVER BASIN RESERVOIRS

The Missouri River Basin contains numerous reservoirs and impoundments. The Corps of Engineers has constructed six large upstream Missouri River multipurpose dams on the main stem of the Missouri River in the Omaha District. All reservoirs within the Kansas City District are constructed on tributaries of the Missouri River. These include eighteen multiple-purpose lake projects constructed by the Corps and eleven lake projects constructed by the Bureau of Reclamation (Bureau). The eleven Bureau lake projects are all in the Republican and Smoky Hill River Basins. These rivers are tributaries to the Kansas River. The Bureau operates these lake projects primarily for the storage and distribution of water for irrigation, while the Kansas City District assumes operational responsibility for flood control. These lakes then become part of the Kansas River flood control system. The Corps projects are listed on Table E-2, and the Bureau projects are listed on Table E-3 in "*Part I: Hydrology*" of this Appendix. Detailed data on these reservoir projects are presented in Plates E-21 through E-25.

MISSOURI RIVER TRIBUTARIES

Major tributaries of the Missouri River are included as separate routing reaches in the UNET hydraulic model. Tributary cross section data was obtained from United States Geological Survey (USGS) 7.5 minute series quadrangle topographic maps. Tributary modeling is of limited detail and intended for inflow routing only. Tributaries are modeled from the last downstream USGS gaging station on the tributary to the tributary's confluence with the Missouri River. The twelve major tributaries to the Missouri River from Rulo, Nebraska, to the confluence with the Mississippi River are described in the following paragraphs. There are two more tributaries, which are located upstream of Rulo, in the Kansas City District UNET model for this study. Descriptions of these two tributaries may be found in the Omaha District Appendix F.

<u>Big Nemaha River – Enters Missouri River at RM 494.9.</u> The Big Nemaha River is a right bank tributary of the Missouri River that drains 1926 square miles in southeastern Nebraska and northeastern Kansas, of which 1315 square miles lie in Nebraska. Basin elevations range from about 840 feet at the mouth of the Big Nemaha River to a maximum of 1535 feet. Stream slopes vary from two feet per mile in the lower reaches to over twenty feet per mile on some tributaries of the Big Nemaha River. There no major impoundments in the Big Nemaha River basin.

<u>Nodaway River – Enters Missouri River at RM 462.9.</u> The Nodaway River is a left bank tributary of the Missouri River that rises in the low, flat divide of southwest Iowa between the Missouri and Mississippi River basins. It flows southwesterly through Iowa, and then southerly through the northwest corner of Missouri to its confluence with the Missouri

River. The Nodaway River is considered to be a small stream with a relatively low average discharge of 524 cfs despite its relatively large drainage area of 1935 square miles.

Platte River – Enters Missouri River at RM 391. The Platte River is a left bank tributary of the Missouri River that rises in the low, flat divide of southwest Iowa. It flows in a generally southerly direction through Iowa and Missouri. The Platte River basin drains an area of 2503 square miles, of which 32% is in Missouri and 68% is in Iowa. The major impoundment in the basin is a Corps reservoir, Smithville Lake, which is on the Little Platte River.

Kansas River – Enters Missouri River at RM 367.4. The Kansas River is a right bank tributary of the Missouri River formed at the confluence of the Smoky Hill and Republican Rivers near Junction City, Kansas. From this junction the river flows eastward for about 170 miles to its confluence with the Missouri River at Kansas City. The floodplain of the Kansas River from Junction City downstream varies in width from approximately 1.5 to 5.0 miles and averages approximately two miles in width. The channel, which is generally 800 to 850 feet wide, meanders in this floodplain. The entire Kansas River drainage basin lies within the Interior Plains physographic region and is approximately 480 miles long and 140 miles wide. Elevations in the river basin vary from 750 feet at the mouth to approximately 5500 feet at the extreme western end of the basin.

The Kansas River basin constitutes approximately one-tenth of the drainage area of the Missouri River and drains the northern half of Kansas, much of southern Nebraska, and a part of northeastern Colorado. The total drainage area of the Kansas River basin is 60,580 square miles of which 15% is in Colorado, 28% is in Nebraska, and 57% is in Kansas. The Kansas River basin contains numerous major impoundments including seven Corps reservoirs and all eleven Bureau reservoirs.

Big Blue River – Enters Missouri River at RM 358.0. The Big Blue River is a right bank tributary of the Missouri River in the eastern Kansas City urban area. The Big Blue River is 43.8 miles long and drains a basin that encompasses a total area of 307 square miles. Approximately 56% of the basin lies in Kansas and 44% lies in Missouri. The Big Blue River basin measures approximately 31 miles in length and 17 miles at its maximum width. The topography of the basin is predominately rolling to gently undulating with fairly steep slopes adjacent to the larger streams. There are numerous urban channel improvement projects scattered throughout the length of the Big Blue River. There are no major impoundments in the basin.

Little Blue River – Enters Missouri River at RM 339.5. The Little Blue River is a right bank tributary of the Missouri River which rises in west-central Missouri and flows in a generally northeasterly direction to join the Missouri River about 20 miles downstream of Kansas City. The Little Blue River basin lies along the southeastern edge of the Kansas City metropolitan area and drains an area of 409 square miles. The basin is approximately 33 miles long, with a maximum width of 13 miles. Major impoundments in the basin include two Corps reservoirs and Lake Jacomo, a Jackson County, Missouri, public recreation lake.

Grand River – Enters Missouri River at RM 249.9. The Grand River is a left bank tributary of the Missouri River that rises in the low, flat divide of south-central Iowa and flows generally in a south-southeasterly direction. The topography of the Grand River basin ranges from rolling to gently undulating glacial plains divided by deeply eroded valleys. The Grand River basin drains an area of 7883 square miles, of which 78 percent is in Missouri and 22 percent is in Iowa. The main stem of the Grand River is about 210 miles in length, which includes the West Fork as part of the main stem. There are no major impoundments in the basin.

Chariton River – Enters Missouri River at RM 238.8. The Chariton River is a left bank tributary of the Missouri River that rises in the low, flat divide of south-central Iowa. It flows southeasterly through Iowa and then southerly through Missouri to join the Missouri River after flowing through a four-mile cutoff. Beginning in 1949, this flood control cutoff diverted the Chariton River directly into the Missouri River at a point approximately 12 miles upstream from its natural mouth. This cutoff separated the Chariton River from its tributary, the Little Chariton River, which is now an independent basin and tributary of the Missouri River. The Chariton River is approximately 170 miles long and drains an area of 2566 square miles. Approximately 925 square miles lie in Iowa and the remainder are in Missouri. The only major impoundment in the basin is Rathbun Lake, a Corps reservoir located in the upper basin in Iowa, approximately 140 river miles above the mouth of the Chariton River.

Little Chariton River – Enters Missouri River at RM 227.2. The Little Chariton River is a left bank tributary of the Missouri River which drains an area of approximately 761 square miles in north-central Missouri. The Little Chariton River was originally a part of the Chariton River basin (see above). The Little Chariton River is formed by the confluence of Middle Fork and East Fork at a point 17 miles above its mouth. It flows into the Missouri River through the old, natural Chariton River channel. The Little Chariton River basin has two major impoundments – Thomas Hill Reservoir on Middle Fork (privately owned), and Long Branch Lake on East Fork (USACE).

Blackwater/Lamine River – Enters Missouri River at RM 202.5. The Lamine River is a right bank tributary of the Missouri River. The Lamine River with its major tributary, the Blackwater River, drains an area of 2783 square miles in west-central Missouri. The Lamine River, flowing in a northerly direction, is joined about ten miles upstream from its mouth by the Blackwater River, flowing in an easterly direction. The mouth of the Lamine is about five miles upstream from Boonville, Missouri. Exclusive of the Blackwater basin, the Lamine River drains an area of about 1100 square miles. The Blackwater River and its tributaries drain about 1550 square miles of the north and west part of the joint basin. There are no major impoundments in the Blackwater/Lamine River basin.

Osage River – Enters Missouri River at RM 130.1. The Osage River is a right bank tributary of the Missouri River which rises in east-central Kansas and flows eastward through west-central Missouri to join the Missouri River near Jefferson City, Missouri. The upper Osage River is called the Marais des Cygnes River. The Osage River drains an area of 15,088 square miles, of which 28% is in Kansas and 72% is in Missouri. There are seven major impoundments in the Osage–Marais des Cygnes River basin. The Lake of the

Ozarks is a hydroelectric power project of the Union Electric Company of Missouri and has a normal power-pool area of 60,000 acres. Also, there are six Corps reservoirs in the basin, including the largest flood control project in the Kansas City District, the Harry S. Truman Reservoir, which has a full flood-control pool area of 209,300 acres.

Gasconade River – Enters Missouri River at RM 104.4. The Gasconade River is a right bank tributary of the Missouri River that rises in south-central Missouri and follows a northeasterly course. The river drains an area of 3582 square miles. There are no major impoundments in the basin.

MISSOURI RIVER NAVIGATION AND BANK STABILIZATION PROJECT

There are seven pertinent Federal statutes providing for the construction, operation and maintenance of a navigation channel and bank stabilization works on the Missouri River. The most recent was a 1945 Act that provided for bank stabilization combined with a nine-foot deep, 300-foot wide navigation channel. The authorized navigation project for the Missouri River extends from its confluence with the Mississippi River at St. Louis, Missouri, to Sioux City, Iowa, a total distance of about 734 river miles. This project was accomplished through revetment of banks, construction of permeable dikes, cutoff of oxbows, closing minor channels, removal of snags, and dredging.

In order to meet the project objectives of bank stabilization and navigation, the river planform was shaped into a series of smoothly curved bends of the appropriate radii and channel width. In areas where the natural river channel did not conform to the design alignment, canals were excavated and natural channels blocked in order to force the river to flow along the design alignment. Bank revetments and dikes have been used to provide a free-flowing navigation channel. Stabilization of the bank along the concave alignment of the design curve used wooden pile and stone fill revetments. Dike fields were constructed along the convex bank perpendicular to the flow. These dikes were designed to prevent bank erosion and to promote accretion, forcing the Missouri River to develop and maintain the design alignment.

A dike field is a system of dikes, which are rock embankments or timber structures that protrude from the bank. The dikes concentrate the flow in the navigation channel. Dikes are generally located on the "inside" of a river bend. A special algorithm has been incorporated into the custom version of UNET used by the Kansas City District in order to reflect the presence of any complex of dike structures protruding from the Missouri River bank.

MISSOURI RIVER LEVEES

Levees line the Missouri River banks, on one or both sides of the river, for virtually the entire length of the river from Rulo, Nebraska, to the mouth of the Missouri River near St. Louis, Missouri.

Federal Levees. The Missouri River Levee System (MRLS) was authorized in the Flood Control Acts of 1941 and 1944 to provide protection to agricultural lands and communities along the Missouri River from Sioux City, Iowa, to the mouth at St. Louis, Missouri. The MRLS levees were designed to operate in conjunction with the six upstream Missouri River dams, which are in the Omaha District, to reduce flood damages as part of the Pick-Sloan Plan. The extent of the Federal levee system within the Kansas City District consists mainly of levee units on both banks from Rulo, Nebraska, to Kansas City, Missouri. Although many Federal levees were proposed downstream of Kansas City, only a few have been built. The majority of the area planned for protection by Federal levees downstream of Kansas City is protected by private or non-Federal levees with varying degrees of level of protection.

Construction of the Federal levees began in the 1950's. The Kansas City District has constructed seventeen Federal levees along the Missouri River as part of the MRLS. All but four of the completed MRLS units are upstream of Kansas City. These units protect mostly agricultural lands plus some small towns. A combination of urban and agricultural land is protected in the St. Joseph, Missouri, vicinity by Levee Units R471-460 and L455. Flood protection in the Kansas City, urban area is provided by seven Federal levee units constructed by the Kansas City District along the Missouri and Kansas Rivers. The units along the Missouri River are the Fairfax/Jersey Creek, Central Industrial District (CID), and East Bottoms Levee Units along the right bank, and the North Kansas City and Birmingham Levee Units along the left bank. Table E-16 lists Federal levees and their locations.

Table E-16
Missouri River Federal Levees

Levee Unit	**Location along the Missouri River** (U/S RM - D/S RM)*	**Levee Unit**	**Location along the Missouri River** (U/S RM - D/S RM)*
R-513	497.5 - 495	L-400	391 – 385
R-500	484.4 - 480	Fairfax-Jersey Creek	374 - 367.5
L-497	482.4 – 476.7	North Kansas City	370.5 - 363.5
L-488	475.3 – 465.2	Central Industrial District (CID)	367.4 - 365.7
R-482	468.4 - 458	East Bottoms	365.7 - 357.5
L-476	461.0 – 454.0	Birmingham	360.3 – 354.0
R-471-460	456.5 – 441.8	R-351	350 - 339.7
L-455	445.6 – 437.6	L-246	250 – 239
L-448-443	437.6 - 428	Chariton River Main Stem	238.8 - 227.3
R-440	431 - 424.3	New Haven	81.7 – 81.4
L-408	401.3 – 391.5		

*U/S = upstream, D/S = downstream

Non-Federal or Private Levees. Non-Federal levees are private levees which are funded and constructed by locally organized levee districts, or which are constructed and owned by one or more individual landowners. Within the Kansas City District, the Missouri River is almost totally leveed from the mouth upstream to Rulo, Nebraska, by Federal and non-Federal levees. Non-Federal levees protect the majority of the agricultural lands from the mouth to Kansas City. However, three non-Federal levees downstream of Kansas City protect urban areas on the lower end of the river. They are the Chesterfield-Monarch, Riverport, and Earth City Levee Districts, all located downstream from RM 45. Upstream of Kansas City, non-Federal levees fill in where there are unprotected areas around the MRLS units. There are approximately one hundred non-Federal levee systems modeled as storage cells in Kansas City's Missouri River UNET model. Many of these levee systems are aggregates of several levee and drainage districts where the levees are contiguous along the river.

Non-Federal levees along the Missouri River were devastated by the 1993 Flood. Except for several non-Federal levees in the St. Louis metropolitan area, all non-Federal levees were breached from Brownsville, Nebraska, to the mouth, a distance of 535 river miles.

HYDRAULIC ANALYSIS COMPUTER MODELING

FLOODPLAIN AND CHANNEL GEOMETRY

Digital Terrain Data

New mapping data was acquired and assembled under the auspices of the Mississippi Basin Modeling System project. The new mapping data was used to develop cross sections for the Missouri River UNET model. In developing the new mapping, digital terrain models (DTMs), which cover the Missouri River floodplain from bluff to bluff, were produced from a combination of 1995 and 1998/1999 aerial photography. Source of the 1995 aerial photography is the USGS. The 1998/1999 aerial photography was provided by a private contractor. Ground surface elevations developed by the aerial mapping are accurate to within 1.33 feet. DTMs with soundings were produced by merging the DTMs with 1998 hydrographic survey data. Kansas City District performed the 1998 hydrographic survey of the Missouri River and supplied this data to a mapping contractor. That contractor produced the DTMs with soundings, and then used this data to produce the cross sections. The horizontal datum for this mapping is NAD 83. The projection is UTM Zone 15. The vertical datum is NGVD 29, and the units of measurement are feet.

Missouri River Cross Sections

Locations of the Missouri River cross sections were determined by the Kansas City District on USGS 1:24,000 scale quadrangle maps and USGS 1:100,000 scale maps. Cross sections were laid out based on the geomorphology of the channel, capturing locations of features such as pools and crossings. The cross sections averaged 0.7 to 0.8 miles apart in rural areas. In urban areas, cross sections averaged 0.2 to 0.3 miles apart. The contractor-furnished cross sections were edited using the editing capabilities of the HEC-RAS computer program. Then the geometry files were translated into UNET geometry files using the computer program RAS2UNET. Some additional editing of the Missouri River cross sections was done within UNET.

Tributary River Cross Sections

Cross section geometry is included in the UNET model for 14 major tributaries of the Missouri River. Tributary cross section geometry was developed from USGS 7.5 minute series quadrangle topographic maps. The tributary cross section data is suitable for flow routing only. Each of the tributary streams is modeled as a single routing reach with a USGS gaging station at the upstream end of the modeled reach. These gaging stations serve as point sources of inflow to the UNET hydraulic model. The tributary reaches range from 10 to 50 miles in length.

FLOW DATA

Streamflow Gages

Flow data is required by the Kansas City UNET model at all tributary inflow locations and at the upstream end of the model. This data is required on a daily basis to produce the period-of-record runs. In addition, stage data and flow data are required at all main stem gages on the Missouri River within the District. Stage data is required from the available stage-only gages on the Missouri River. This data is needed for inflow, boundary conditions, estimation of ungaged inflow, calibration, and verification. A listing of the gages used on the Missouri River is given below in Table E-17, and a listing of the tributary gages is given in Table E-18.

Table E-17
Missouri River Mainstem Gaging Stations

Station	River Mile Location	Type of Data	Use in UNET Model
Nebraska City NE	562.2	Flow and Stage	Flow Input and Calibration
Rulo NE	498.0	Flow and Stage	Calibration
St. Joseph MO	448.2	Flow and Stage	Calibration
Atchison KS	422.5	Stage	Calibration
Kansas City MO	366.1	Flow and Stage	Calibration
Napoleon MO	329	Stage	Calibration
Waverly, MO	293.5	Flow and Stage	Calibration
Glasgow MO	226.2	Stage	Calibration
Boonville MO	196.6	Flow and Stage	Calibration
Jefferson City MO	143.9	Stage	Calibration
Hermann MO	97.9	Flow and Stage	Calibration
St. Charles MO	28.1	Stage	Model Tailwater

Table E-18
Tributary USGS Stream Gaging Stations

Tributary	Station	Tributary River Miles	USGS Flow Record	Missouri River RM at Confluence
Big Nemaha River	Falls City NE	14.5	4/1/44 - Date	494.9
Nodaway River	Graham MO	28.0	4/1/22 – Date	462.9
Platte River	Sharps Station MO	25.1	12/1/78 – Date	391
Kansas River	Desoto KS	31.0	7/8/17 – Date	367.4
Blue River	nr Kansas City MO	23.2	5/1/30 – Date	358.0
Little Blue River	Lake City MO	10.5	4/1/48 – Date	339.5
Grand River	Sumner MO	41.0	10/1/24 – Date	249.9
Chariton River	Prairie Hill MO	19.6	10/1/21 – Date	238.8
East Fork Little Chariton River	Huntsville MO	42.1	10/1/62 – Date	227.2
Lamine/ Blackwater River	Blue Lick MO	30.3	7/1/22 – Date	202.5
Osage River	St. Thomas MO	43.1	6/1/25 - Date	130.1
Gasconade River	Rich Fountain MO	51.3	11/1/21 – Date	104.5

UNET HYDRAULIC MODEL DEVELOPMENT

UNET Models of Missouri River Historic Conditions

1998 UNET Model. The 1998 Missouri River UNET model was developed under the auspices of the Mississippi Basin Model System project for use in water management. Development of this model began with the Floodplain Management Assessment Study of 1994. 1994 hydrographic data and overbank data from the 1970s were used for this model.

Historic UNET Model. The Missouri River has undergone major changes in its planform and length in the 20th century. In order to conduct a period-of-record UNET analysis, it was necessary to be able to estimate the ungaged local inflow to the river for the entire period. Since the hydraulic characteristics of the river changed during the century, it was necessary to develop several UNET geometry models of the Missouri River to simulate historic hydraulic routings for the entire study period. A Missouri River historic UNET model was developed expressly for the purpose of computing the ungaged inflow for the early 1900's. The geometry of this model reflects the natural conditions of the Missouri River before canalization, and the construction of dikes and levees. The natural channel was wide, braided, and shallow, and meandered freely back and forth across the floodplain. Early 20th century topographic maps were used for channel geometry.

UNET Model of Missouri River Present Conditions

A "present condition" Missouri River UNET model was created based on the latest available floodplain and channel geometry (see discussion above). The model consists of about 800 Missouri River cross sections and about 500 cross sections of tributary streams. As originally created, the model had 35 model reaches with 15 of these as main stem Missouri River reaches. Two special reaches were incorporated into the model structure to attempt to model the wide floodplain area in the vicinity of Waverly, but that study strategy proved unsatisfactory and these two reaches were disabled. These two reaches remain in the model however. All Missouri River cross sections are full valley cross sections. A schematic of this model is shown on Plate E-26.

This UNET geometry model, and its accompanying boundary condition file, were configured and calibrated for the required 100-year period of record runs. An enhanced version of the UNET program which incorporated many additional features and capacities necessary for this effort was used by the Kansas City District, as well as all of the other four participating Districts. These special features such as the null internal boundary condition, ungaged lateral inflow computation, etc. are described elsewhere in this overall document and will not be discussed herein. However, computation and calibration processes unique to the Kansas City District will be discussed below.

The boundary condition file was set up to deal with average daily inflow data. The time step for the computations was set at three hours, however a routine in UNET will automatically decrease the time step if necessary to contribute to computational stability.

Extent of UNET Model and Coordination with Adjacent Districts

The upstream end of the UNET model used for these studies by the Kansas City District is at the USGS stream gaging station at Nebraska City, Nebraska, (RM 562.6). This location is 64.2 miles upstream of the gaging station at Rulo, Nebraska, (RM 498), which is the boundary between the Kansas City and Omaha Districts. Nebraska City was chosen because of the utility of using a long record USGS gage as the upstream inflow point, and the fact that most of the inevitable computational anomalies inherent in unsteady flow models would be smoothed out by the time the flows entered the Kansas City District. Also, the selection of the Nebraska City gage allowed the extensive overflow area near Rulo to appear in a single reach. The Omaha District used the USGS stream gaging station at St. Joseph, Missouri, (RM 448.2) as their tailwater gage in order to "overlap" with the Kansas City District at Rulo. The modeled stages for the various frequency floods at Rulo were within the computational accuracy that could be expected of this type of unsteady flow analysis.

The downstream limit of the District's model was the stage-only gage at St. Charles, Missouri, (RM 28.1). This location, while under the backwater influence of the Mississippi River, was the most downstream practical location for use in the District model without modeling the Missouri-Mississippi crossover (see discussion below). The UNET model used by the St. Louis District treats the Missouri River as an inflow tributary, with its head at the USGS stream gage at Hermann, Missouri, (RM 97.9). The inflow at

Hermann used flow and stage data furnished by the Kansas City District. The St. Louis model does incorporate the Missouri-Mississippi overflow in their model, and thereby provides for the full effects of Mississippi River backwaters and Missouri overflow on the lower Missouri River. The lower Missouri River profiles generated by the St. Louis District were "feathered into" the Kansas City profiles provided in this study.

Calibration of UNET Present Condition Model

There are several self-calibrating techniques built into UNET that will not be described in detail here. These techniques are built around a series of iterative computations of daily flow records from one reach translated to the next downstream gage. Initial estimates of channel and overbank roughness coefficients are made, but these are adjusted in the several iterations required for automatic calibration. Seasonal adjustments of stream conveyance, and vertical adjustments in conveyance are also permitted.

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.

Three roughness coefficients were assigned to each cross section. No attempt was made to disaggregate the overbank areas into separate channels. There are 43 reaches identified on the Missouri River main stem. Channel roughness coefficients (as Manning's "n"s) ranged from a low of 0.014 to a high of 0.035, with the majority of the river channel in the 0.023

to 0.028 range. Considerable effort was expended working with the reaches with low "n" values, but it was not possible to reproduce the high water profile and levee performance with higher values. The overbank value used throughout the District was 0.080. Because of the use of the levee algorithm, the Missouri River cross sections isolate the back-of-levee areas from the active flow area (the channel and its immediate overbanks). Since these levees are close to the river, the overbank area in the active portion of a cross section is small with limited conveyance. Changes in the overbank "n" values had almost no effect on the flood profiles.

UNET provides a mechanism to adjust the conveyance of a particular cross section on a seasonal basis and on a flow basis. Adjustment of conveyance is not quite the same as adjusting resistance coefficients, but it has the same effects. Using this capability, the geometry file was first adjusted to reproduce the observed high water marks for the 1993 Flood. This process reproduced the high discharge stage and flow portions of the observed 1993 gage record, but did not reproduce the lower flow portions of those hydrographs. Next, the vertical and seasonal conveyance adjustment factors were used to bring the reproduction of the entire year 1993 as close as possible to the observed hydrographs. In general, flow adjustments were made for discharges below 300,000 cfs, with decreases in conveyance (analogous to increasing "n" values) ranging up to 60%. Dr. Barkau found a seasonal adjustment of about 10% occurs on the Missouri River, so this value was incorporated into the model for the months of May to December.

<u>Computation of Ungaged Lateral Inflow</u>

Ungaged lateral inflow is the observed increment in discharge that occurs between stream gaging stations. That increment can come from tributary outflows, ground water seepage, or from overland flow into the river. There are techniques built into the expanded versions of UNET that facilitate the computation of these ungaged inflows, using the historical gage records. Once a record of ungaged inflows is constructed from the observed records, there are also techniques available which incorporate these flows as inputs in a period of record analysis. The basic techniques in UNET will not be presented here, but the special applications to the Kansas City model will be discussed below.

Since the major tributaries have their own records (albeit shorter than the 100 year period used for this study), it is possible to determine what portion of the ungaged lateral inflow can be assigned to each tributary. Flow unassigned to tributaries is then incorporated into the UNET model as evenly spread along the thread of the stream. Using the data from the period when the tributary gage is active as a guide, lateral inflow was assigned to that tributary for the period preceding the activation of the tributary gage. Using this process, an artificial gage record was constructed for the entire 100 year period for each tributary inflow point. Because of the differences in daily data and instantaneous data, the time step used, and the stream distances involved, there were periods in these created records that indicated negative inflow. In a few isolated cases, these negative inflows were large enough to destabilize the UNET period of record computations. Some editing of these records was therefore necessary.

PERIOD OF RECORD ANALYSIS

Study Strategy

The analytical methods employed by the Kansas City District differs from that employed by some of the other Districts. That process is described in some detail below. The Kansas City District's Missouri River UNET model was used in this analysis. The model consists of three files. The geometry file was calibrated to the 1993 Flood high water marks, and adjusted to reproduce the lower flows and stages of the gage records for the year 1993. The boundary conditions file consists of the daily inflows at the gage at Nebraska City at the upstream end of the model, daily inflows from each of the 14 tributary gages, daily ungaged lateral inflow files (and the guidance for the lateral distribution of these inflows), and seasonal and discharge conveyance adjustment features. The ".inc" file, known as the "include" file, is the performance file for the 104 levee units in the overall model. This include file was an integral part of the overall calibration process for the year 1993.

Because the strategy used by the Kansas City District is keyed to the development of rating curves for each cross section, the 100 year period used to construct these rating curves does not necessarily have to conform to the period used for the development of the regulated flow estimates (see Hydrology). The period 1/1/1900 to 9/30/2000 was used for the period of record runs in the District. This period was selected because the actual flow data for the tributary gages is considered superior to the derived inflows for these stations as described above.

WATER SURFACE PROFILES

Development of UNET-Based Flood Frequency Profiles

In order to develop the required water surface profiles, a unique version of UNET was developed by Dr Barkau for the Kansas City District. Dr Barkau supplemented this version of UNET with a EXCEL spreadsheet file which contained some specialized Macros. When the period-of-record flows are run in this special version of UNET, a trigger in the boundary conditions file causes the following steps to be initiated within the UNET program for each main stem cross section:

a.) A tabulation of annual maximum flow for the period of record, and its associated stage (from that same day) is produced at each cross section. Also, a tabulation of maximum annual stage and its associated discharge is also created at that cross section.

b.) These two data sets are combined into a single file and then plotted. A polynomial curve is passed through the data cluster, and the coefficients for this equation are read out into the referenced EXCEL file. A standard error between the "observed" discharges and discharges computed from the equations is provided. These estimated discharges-vs.-stage points are then read as paired data points into an DSS file, and the pathname of this rating curve becomes a part of an EXCEL importable file.

c.) In addition to the data provided for the rating curves, additional data was generated in the UNET file to estimate peak discharges on a frequency basis and peak stages, also on a frequency basis. These discharge and elevation data were analyzed using both Weibull and Pearson III techniques. Polynomial equations were developed for each of these curves, from which computed ordinates from each curve can be created. These curves are read into DSS files as paired data points, and their DSS pathnames are exported to an EXCEL readable file.

In the case of the Missouri River, the observed period-of-record contains some historic high peak flood flows, so a full definition of the rating curve is produced using this flow set for most reaches of the river. On the other hand, the regulated flow set, because it contains the effects of the flood control reservoir system, provides better estimates of current stage-probability and discharge-probability curves. The frequency curve plots for the Missouri River cross sections appear to be reasonably regular except upstream of the mouth of tributary streams, where a wide scatter of data points are observed.

After the UNET runs were made for the period-of-record, the rating curves for each cross section, in the form of coefficients for polynomial equations, were exported to the special EXCEL spreadsheet. The flow discharges from the Hydrology study phase were listed on this spreadsheet. Each sheet in this EXCEL file was allocated to a single flood frequency. Upon execution of the spreadsheet Macro, the elevation at each cross section for each frequency flood was determined. These elevations were exported to another EXCEL spreadsheet for further editing. Additional editing was required upstream of major river junctions, in the "crossover" area on the lower river at the junction of the St. Louis and Kansas City Districts, and in the Rulo area at the junction of the Omaha and Kansas City Districts. The use of this second spreadsheet allowed profiles to be smoothly merged at District junctions by overlaying the profile data from the two Districts and "cutting and pasting" until a smooth and reasonable joint profile was constructed. A few profiles required some minor adjustments in elevations, but these adjustments were less than 0.5 ft. This effort was coordinated with the appropriate boundary District, and concurrence on the final profiles was secured. These smoothed profiles were then interpolated from cross section locations to locations at even river miles, which is the standard reporting format that has been used in the Kansas City District.

Large River Confluences

Development of UNET-based flood frequency profiles presents a special problem at the junctions of large tributaries. This is due to the backwater effects built into the historic record at that junction. It is noteworthy that the rating curves downstream of the junction are quite smooth, with all of the data points closely clustered around a fitted rating curve. The plotted rating curves upstream of the junction exhibit a wide scatter, with the fitted curve drawn through the middle of the data cluster. Plates E-27 and E-28, which are based on some early period of record runs, illustrate this phenomena. However stage-probability curves both downstream and upstream of the junction exhibit data points tightly clustered around the computed curve, with no appreciable data scatter. Smooth profile surfaces at these junctions are an observed physical phenomena, and are expected in the final publication of these profiles. Therefore a supplemental methodology was used for the junction areas.

If a discharge with a specific probability of occurrence is experienced upstream of the junction of a major tributary, the likelihood of a coincident flow of with the same probability occurring downstream of that junction is small. For example, if an upstream discharge has a probability of 0.10, then the downstream discharge for that specific event might have a probability of 0.08 or 0.12. However, when publishing flood profiles in Flood Insurance Studies, Water Resource Decision Documents, etc., it is the common practice to provide profiles based on the same probability discharge both upstream and downstream of that junction. In this example, one might expect to see the profile for the 0.10 probability flood both upstream and downstream of the junction of the major tributary. Since the chance of coincident flows of the same probability are small, the flows generated by a period of record analysis study are not expected to contain these types of events. This practice of reporting for flows of coincident probabilities on both sides of a tributary junction is artificial, requiring the use of the supplemental methodology.

The period of record analysis produced rating curves on either side of major stream junctions that exhibited the characteristics shown on Plates E-27 and E-28. The data points for the downstream rating curves were tightly clustered about a reasonable rating curve (see Plate E-27), while the data points for the upstream cross section exhibited a wide scatter. (Note: This scatter decreased as one moved upstream of that junction.) For example, viewing Plate E-28, the historic record shows that a discharge of 120,000 cfs can be associated with elevations as low as 738 and as high as 750. The curve on Plate E-28 was generated by UNET and should be regarded simply a representative curve. While these backwater effects manifested themselves upstream of most of the major tributaries, they were particularly severe upstream of the mouths of the Kansas and Osage Rivers. Flood profiles created by simply connecting the predicted elevations downstream of the junctions with those upstream of these junctions were unsatisfactory.

The first supplemental strategy developed to deal with this problem was to use the stage-probability curves produced by UNET to bridge over the junctions. This involved some hand editing of the upstream rating curves within the UNET program, and recomputation of the equations for the upstream rating curves. This process proved to be cumbersome and time consuming.

The second process, which proved to be much faster and provided more reasonable profiles, was based on the fact that the Kansas City District has detailed, recently developed HEC-RAS models available in the vicinities of the mouths of the Osage and Kansas Rivers. These models all use the same geometry and discharges that were used in the UNET period-of-record analysis, and were also calibrated to the 1993 high water marks. Coincident flow studies had been conducted for these studies in order to provide profiles for the same probability flood across the mouths of these tributaries. The downstream profiles for both the UNET and HEC-RAS profiles were in close agreement. Therefore, the HEC-RAS files were used to estimate the profiles in these upstream reaches. The upstream profiles generated “revised” rating curves at the upstream cross sections. These “revised” rating curves were spot checked with the plots for the upstream cross sections to insure that the revised curves plotted within the “cloud” of data points for each cross section. These modifications were made in the second spreadsheet.

Missouri/Mississippi River Crossover

The area along the left bank of the Missouri River, from RM 28 (St. Charles, Missouri) to the confluence with the Mississippi River, is known as the crossover. This area is an extensive peninsula of land that separates the Missouri and Mississippi Rivers. Along this reach the Missouri River channel is perched at elevations above the Mississippi River. Therefore, during times of flooding when the Missouri River overtops its levees, flood water spills out of the left bank of the Missouri River, across this broad, sloping floodplain, and into the Mississippi River. The difference in stream gradients (Missouri steeper, Mississippi flatter) means that the Missouri River spills into the Mississippi, never the other way around. When there is sufficient flow in the Missouri River for these diversions to occur, the diverted flows actually result in lower discharges in the Missouri River and its immediate overbanks as one proceeds downstream from St. Charles, Missouri. Of course, these diverted Missouri River waters enter the Mississippi River upstream from the confluence of the two streams. This is probably one of the most complex hydrological areas in the world, presenting a unique hydraulic modeling problem.

The Kansas City UNET hydraulic model was not used to model this crossover flow. The complex flow patterns in this area involve not only Missouri River discharges, but also must consider inflow from the Upper Mississippi River and the discharge from the Illinois River. This area has traditionally been modeled by the St. Louis District with input from the Kansas City and Rock Island Districts. From the perspective of the Missouri River, a model of this nature is required to properly account for Mississippi River backwater effects on the lower Missouri River. The actual crossover flow has been modeled as a series of levee cells that cascade water from the perched Missouri River channel to the lower, more gently sloping Mississippi River floodplain. The St. Louis District's model contains a short reach of the Missouri River from the gage at Hermann, Missouri, (RM 97.9) to the mouth. This geometry has been taken from the Kansas City UNET model. The Hermann gage discharge information for the St. Louis District model was furnished by the Kansas City District. The Kansas City UNET model used the historic stage record at St. Charles, Missouri, for the tailwater for its period-of-record runs. Once both Districts had completed their models, the two sets of profiles were found to converge near RM 50. The St. Louis profile data downstream of that point was incorporated into the Kansas City profiles.

Interface at Rulo, Nebraska

The stream gage at Rulo, Nebraska, forms the boundary between the Kansas City and Omaha Districts. Both Districts developed UNET models. Both UNET models, because of the nature of the UNET process, had considerable overlap into the adjacent District. The downstream boundary of the Omaha model was at St. Joseph, Missouri, while the upstream boundary of the Kansas City model was at the gage at Nebraska City, Nebraska. Because the high water calibration of the UNET model would have involved considerable work in the adjacent District, which may have not been compatible with the other's efforts, an effort was made to smoothly merge the flood profiles at Rulo. This effort was successful, so smooth profiles through this reach are now available.

FINAL PROFILE PROCESSING

The final two steps in processing the flood profiles was to utilize a five-point distance-weighted profile smoothing technique developed by the Rock Island District, and then to interpolate these profiles to even miles. This latter step was undertaken due to the precedent set by the previous set of high water profiles (1976).

The final profiles are published herein, together with a tabular listing of the final profile elevations. There are three distinct "bulges" in these profiles. One is near St. Charles, one is in the Kansas City area, and one is upstream of RM 440. These are the areas where the main line levees did not fail during the 1993 Flood.

SUMMARY AND CONCLUSIONS

COMPARISON WITH PREVIOUS STUDIES

The Hydrology phase of this study supercedes the Missouri River hydrology originally published in 1962 in the report titled *Missouri River Agricultural Levee Restudy Program*. A table comparing the 1962 discharges at the Missouri River gages with flow estimates from the present study is presented in the Hydrology Appendix.

The Hydraulics study described herein supercedes the water surface profiles produced by the Kansas City District in 1976. The 1976 profiles were produced by an in-house one-dimensional steady state computer program known as KCD Backwater. This program is no longer in use. A comparison of the predicted water surface elevations at the six Missouri River gaging stations is given below.

Table E-19
Profile Comparison

Gage	Percent Chance Flood	Elevation (feet, msl)		
		1976 Profile	2003 Profile	Difference (feet)
Rulo NE	10	861.2	860.1	-1.1
	1.0	861.6	863.0	+1.4
St. Joseph MO	10	811.3	813.5	+2.2
	1.0	815.1	819.4	+4.3
Kansas City MO	10	741.2	740.1	-1.1
	1.0	748.5	749.5	+1.0
Waverly MO	10	674.4	674.4	0.0
	1.0	677.6	677.5	-0.1
Boonville MO	10	596.6	594.7	-1.9
	1.0	599.9	601.9	+1.0
Hermann MO	10	513.7	512.5	-1.2
	1.0	518.4	519.6	+1.2

STUDY LIMITATIONS

This study represents the best overall estimates available at this time of the water surface elevations that are associated with the various frequency floods on the Missouri River. It is subject to the uncertainties normally associated with these types of profiles. These Kansas City District profiles are heavily predicated on the performance of the various Federal and non-Federal levees that line the river throughout the District. When, where, and how these individual levees perform during high flow events has a major local influence on these profiles.

RECOMMENDATIONS

These profiles are recommended for all uses relating to water surface elevations on the Missouri River except for the applications related to the ongoing (2003) levee studies/projects at Kansas City, St. Joseph, and Jefferson City.

FUTURE APPLICATIONS

Although the use of this data for floodway analysis is beyond the scope of this study, these profiles could serve as the basis for remapping the floodplains of the Missouri River under the auspices of the National Flood Insurance Program. However, the UNET model cannot be used for floodway determinations, because there is no recognized method to develop a FEMA-compatible floodway using UNET. Other standard methodologies, such as HEC-RAS, should be used for the floodway determinations, with these profiles used to provide overall guidance for those studies.

FINAL ADOPTED RESULTS

The final profiles are presented in graphical form on Plates E-29 through E-38, and in tabular form in Table E-20, which, because of its size, is located at the end of the Plates.

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GLOSSARY

AF Acre-Foot or Acre-Feet. A volume of water equal to one foot of water spread over one acre of surface area. The water discharged in one day at the rate of one cfs is equal to 1.9835 acre-feet.

Cfs Cubic feet per second. Refers to a rate of discharge representing a volume of one cubic foot of water passing a given point in one second. It is equal to 7.48 gallons per second, 449 gallons per minute, or 646,000 gallons per day. Cfs is often used to mean the same as cfs-day or second-foot-day to denote a volume of water.

Cfs-day Cubic feet per second times one day. This is a unit of measure for volume. One cfs-day is the volume of water equal to one cfs flowing past a given point in one day. An older term no longer used for cfs-day is second-foot-day. It is equivalent to 1.9835 acre-feet of water.

Current flows See regulated flows.

DA Drainage area (see below).

Depletion A reduction in stream flow due to human activity or interference, such as water used for irrigation, electric power generation, or municipal/industrial uses. This also includes water evaporated from man-made ponds and lakes.

Discharge Rating Curve A relationship between stage measurements at a stream gage and the corresponding instantaneous stream discharge at that point.

District Kansas City District, U.S. Army Corps of Engineers.

Drainage Area All lands where runoff of stormwater contributes flow to a common point on a stream or waterway. There are some large portions of the Kansas River Basin that do not actually contribute directly to outflow because of the lack of a developed surface drainage system.

Drainage Basin The entire area drained by a discrete waterway system.

DRM Daily Routing Model. Hydrologic routing model developed in the Reservoir Control Center, Omaha Regional Office of the Northwestern Division.

DSS Data Storage System. This is the computer data storage system developed by HEC for use in the many hydrologic and hydraulic analysis computer programs utilized by the Corps of Engineers. Data stored in this system can be manipulated and analyzed using several available ancillary programs.

Flood Flow Frequency The probability that a discharge of a given magnitude will be equaled or exceeded in any given year. Can be expressed as a probability (i.e., Probability of Occurrence = 0.01, etc.), or as a percent chance (i.e., Percent Chance of Exceedance = 1%, etc.). In the past, the concept of recurrence interval was used, where the recurrence interval was the reciprocal of the probability of occurrence (i.e., 100-Year Flood)

Gaging Station A site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained. The data may include water stages, stream discharges, water quality information, or any combination of the above.

HEC Hydrologic Engineering Center, U.S. Army Corps of Engineers, which is located in Davis, California.

HEC-HMS Hydrologic Modeling System, a computer program developed by the Hydrologic Engineering Center (HEC). This program has the capacity to estimate basin runoff and route flows down a waterway.

HEC-RAS River Analysis System, a computer program developed by the Hydrologic Engineering Center (HEC). This software performs one-dimensional steady flow and unsteady flow calculations.

Holdouts The daily storage effects of a reservoir, generally computed as the inflow minus the total releases (or outflow).

KAF Thousand Acre-Feet. See AF.

Kcfs Thousand cubic feet per second. See cfs.

Local Contributing Area Also called local drainage area. This is the portion of the drainage basin below one gaging station or reservoir and above the next downstream point of interest. .

MAF Million Acre-Feet. See AF.

National Geodetic Vertical Datum of 1929 (NGVD) This is a geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada.

Nodes Special points of interest within hydrologic models, usually points at which discharges are calculated.

NWS National Weather Service, an agency of NOAA, the National Oceanic and Atmospheric Administration in the Department of Commerce; formerly called the United States Weather Bureau (U.S.W.B.).

Q Discharge or flow.

Recurrence Interval See Flood Flow Frequency.

Regulated Flow As used in this study, that flow which would have occurred during the study period with all current basin developments in place.

Reservoir A man-made lake.

River Mile or **RM** The distance above the mouth of the river or stream, measured along the centerline of that waterway. In the case of the Missouri River, or other commercially navigable streams, the measurement is made along the sailing line of the navigation channel.

Second-foot-day Same as cfs-day.

Sq. Mi. or **SM** Square Miles, used primarily as units of measure for basin drainage areas.

Std deviation Standard deviation.

Subbasin A sub-drainage area of a larger drainage basin. A drainage basin may be subdivided into two or more subbasins.

UMRSFFS Upper Mississippi River System Flow Frequency Study, the acronym used for the title of this study.

U.S.W.B. See NWS

UNET Computer program developed by Dr. Robert L. Barkau, which simulates one-dimensional unsteady flow through a network of open channels.

Unregulated Flow As used in this study, that flow which would have occurred during the study period with none of the current basin developments in place.

USBR United States Bureau of Reclamation, Department of Interior. USBR is a cooperating agency with the Upper Mississippi River System Flow Frequency Study.

USGS United States Geological Survey, Department of the Interior.

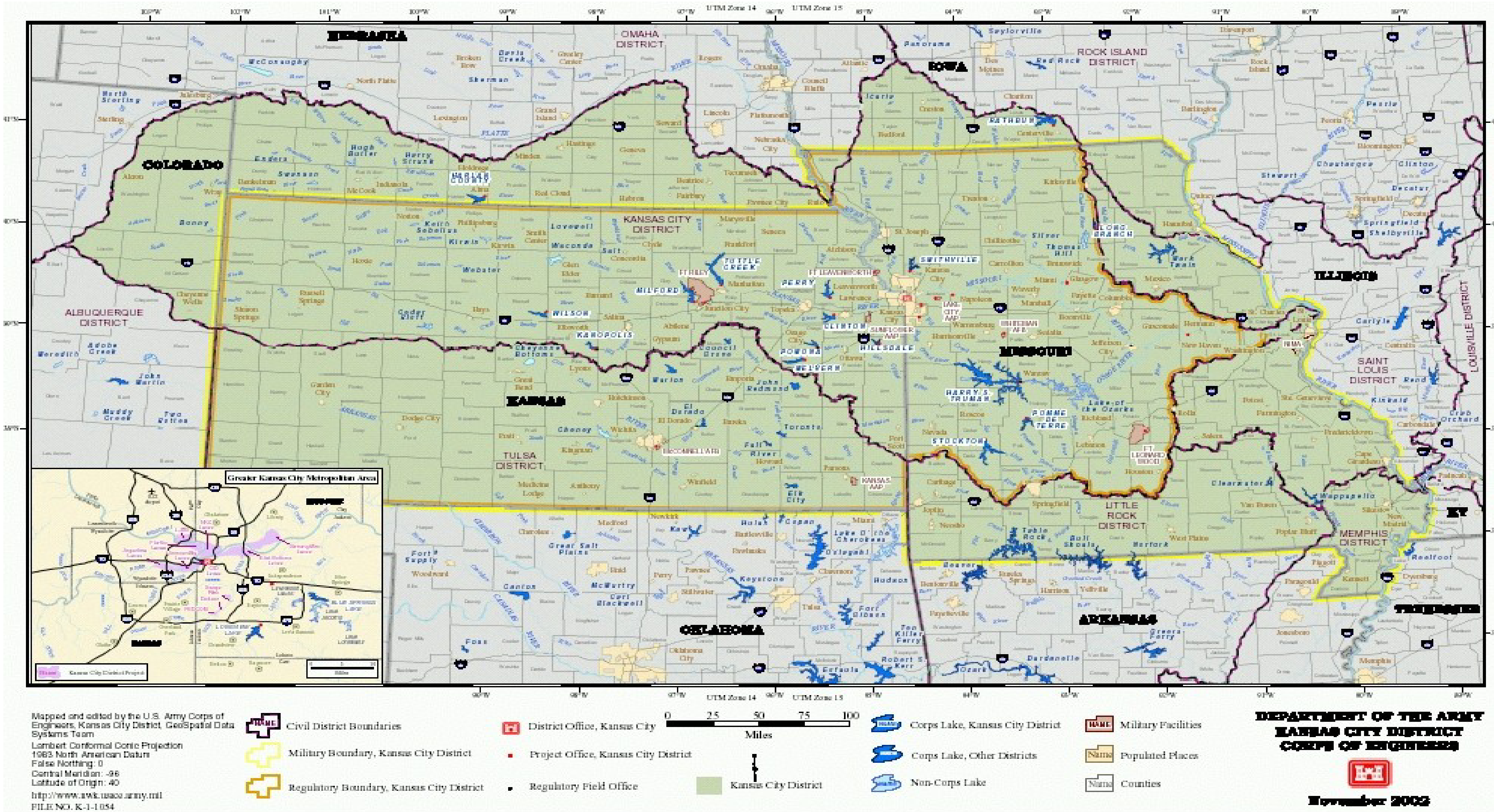

NEBRASKA
IOWA
COLORADO
KANSAS
MISSOURI
ILLINOIS
OKLAHOMA
ARKANSAS
TENNESSEE
KY
OMAHA DISTRICT
ROCK ISLAND DISTRICT
KANSAS CITY DISTRICT
ALBUQUERQUE DISTRICT
TULSA DISTRICT
LITTLE ROCK DISTRICT
MEMPHIS DISTRICT
SAINT LOUIS DISTRICT
LOUISVILLE DISTRICT
UTM Zone 14
UTM Zone 15
Greater Kansas City Metropolitan Area
Mapped and edited by the U.S. Army Corps of Engineers, Kansas City District, GeoSpatial Data Systems Team
Lambert Conformal Conic Projection
1983 North American Datum
False Northing: 0
Central Meridian: -96
Latitude of Origin: 40
http://www.nwk.usace.army.mil
FILE NO. K-1-1054
Civil District Boundaries
Military Boundary, Kansas City District
Regulatory Boundary, Kansas City District
District Office, Kansas City
Project Office, Kansas City District
Regulatory Field Office
0 25 50 75 100
Miles
Kansas City District
Corps Lake, Kansas City District
Corps Lake, Other Districts
Non-Corps Lake
Military Facilities
Populated Places
Counties
DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT
CORPS OF ENGINEERS
November 2002

Plate E-1

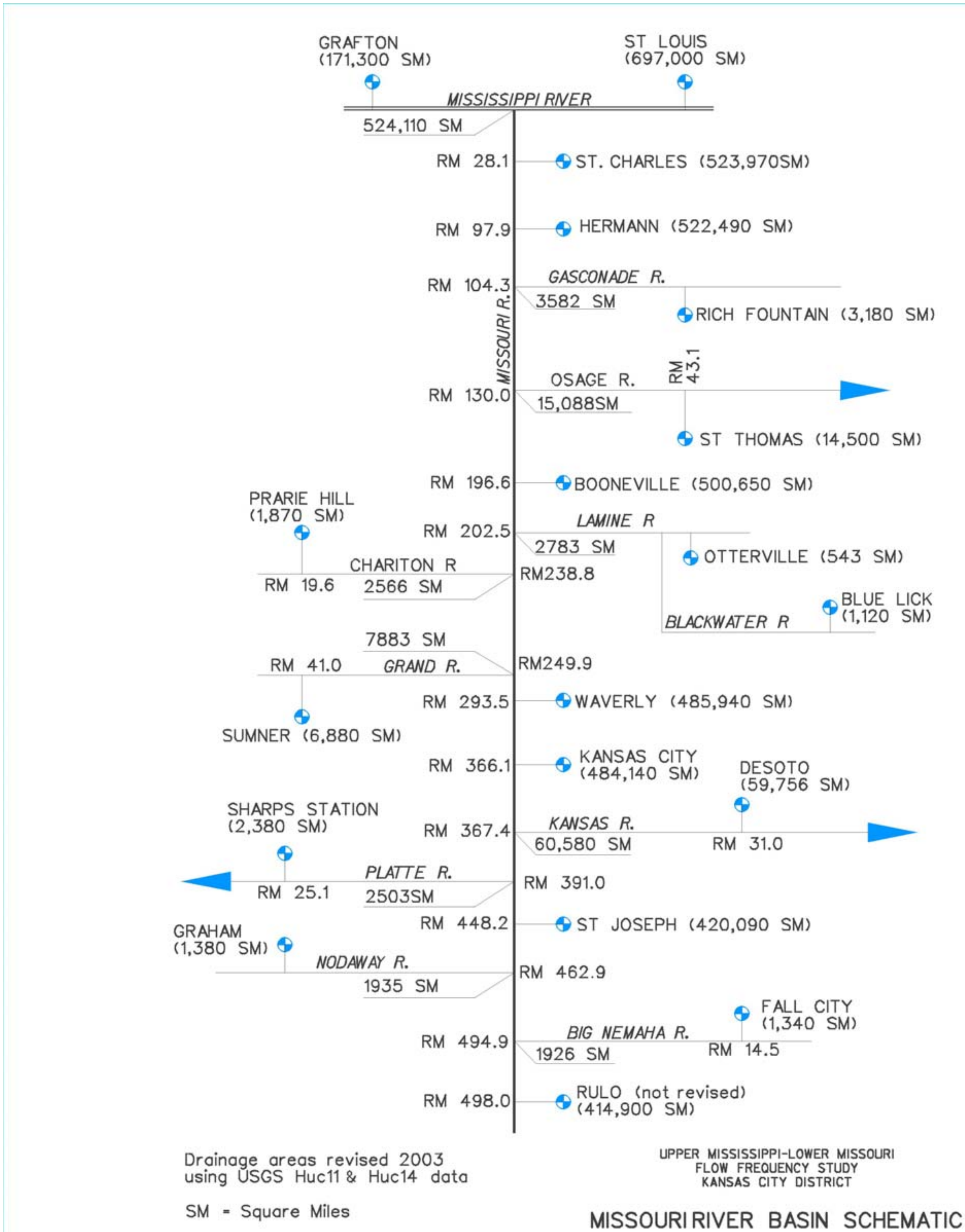
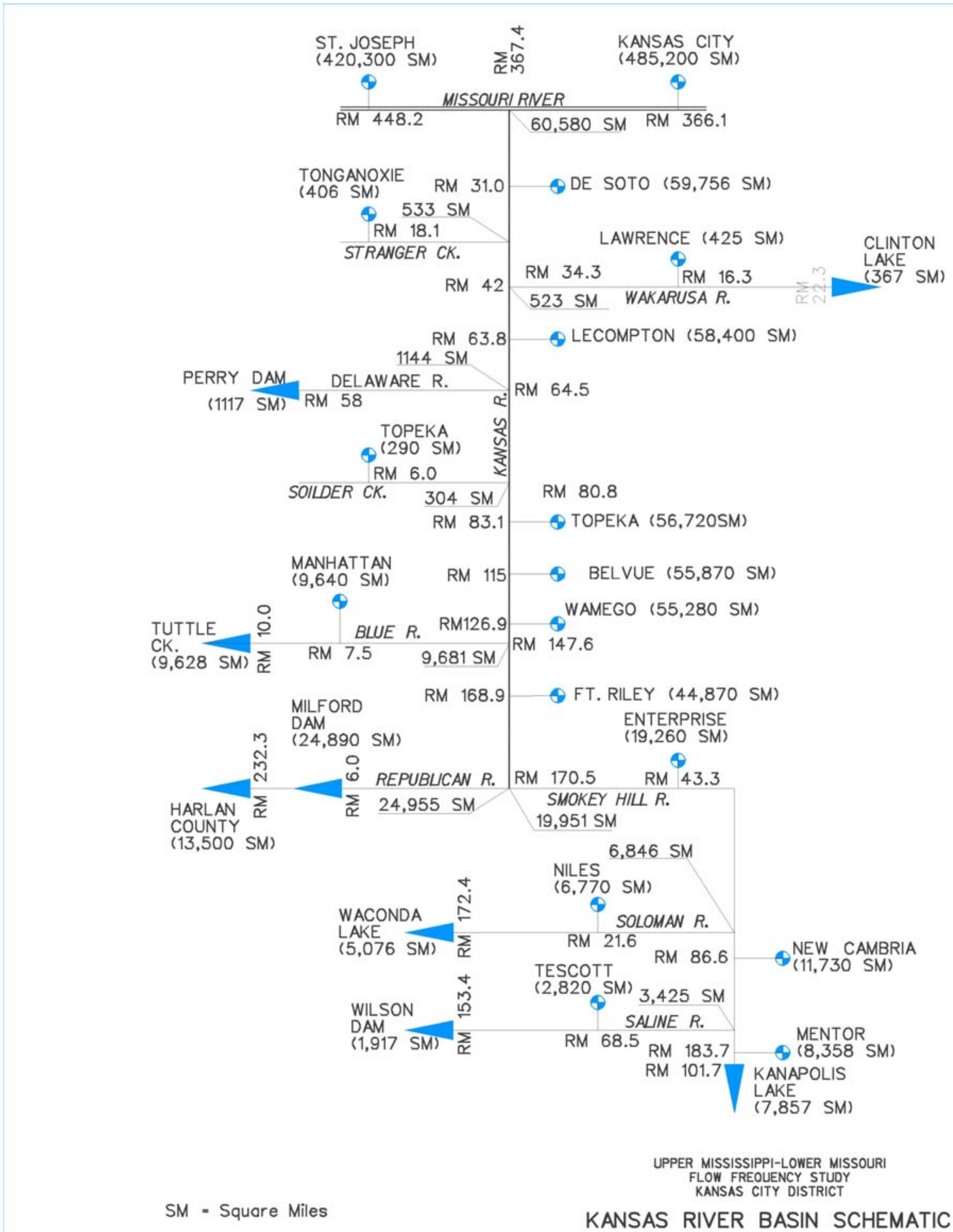

GRAFTON
(171,300 SM)
ST LOUIS
(697,000 SM)
MISSISSIPPI RIVER
524,110 SM
RM 28.1
ST. CHARLES (523,970SM)
RM 97.9
HERMANN (522,490 SM)
RM 104.3
GASCONADE R.
3582 SM
RICH FOUNTAIN (3,180 SM)
MISSOURI R.
OSAGE R.
RM 43.1
RM 130.0
15,088SM
ST THOMAS (14,500 SM)
RM 196.6
BOONEVILLE (500,650 SM)
PRARIE HILL
(1,870 SM)
RM 202.5
LAMINE R
2783 SM
OTTERVILLE (543 SM)
CHARITON R
RM 19.6
2566 SM
RM238.8
BLUE LICK
(1,120 SM)
BLACKWATER R
7883 SM
RM 41.0
GRAND R.
RM249.9
RM 293.5
WAVERLY (485,940 SM)
SUMNER (6,880 SM)
RM 366.1
KANSAS CITY
(484,140 SM)
DESOTO
(59,756 SM)
SHARPS STATION
(2,380 SM)
RM 367.4
KANSAS R.
60,580 SM
RM 31.0
PLATTE R.
RM 25.1
2503SM
RM 391.0
RM 448.2
ST JOSEPH (420,090 SM)
GRAHAM
(1,380 SM)
NODAWAY R.
RM 462.9
1935 SM
FALL CITY
(1,340 SM)
RM 494.9
BIG NEMAHA R.
RM 14.5
1926 SM
RM 498.0
RULO (not revised)
(414,900 SM)
Drainage areas revised 2003
using USGS Huc11 & Huc14 data
SM = Square Miles
UPPER MISSISSIPPI-LOWER MISSOURI
FLOW FREQUENCY STUDY
KANSAS CITY DISTRICT
MISSOURI RIVER BASIN SCHEMATIC

Plate E-2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KANSAS CITY
(485,200 SM)
MISSOURI RIVER
RM 448.2
60,580 SM
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TONGANOXIE
(406 SM)
RM 31.0
DE SOTO (59,756 SM)
533 SM
RM 18.1
STRANGER CK.
LAWRENCE (425 SM)
CLINTON
LAKE
(367 SM)
RM 34.3
RM 16.3
RM 22.3
RM 42
523 SM
WAKARUSA R.
RM 63.8
LECOMPTON (58,400 SM)
1144 SM
PERRY DAM
DELAWARE R.
(1117 SM)
RM 58
RM 64.5
KANSAS R.
TOPEKA
(290 SM)
RM 6.0
SOILDER CK.
304 SM
RM 80.8
RM 83.1
TOPEKA (56,720SM)
MANHATTAN
(9,640 SM)
RM 115
BELVUE (55,870 SM)
WAMEGO (55,280 SM)
TUTTLE
CK.
(9,628 SM)
RM 10.0
BLUE R.
RM126.9
RM 7.5
9,681 SM
RM 147.6
RM 168.9
FT. RILEY (44,870 SM)
MILFORD
DAM
(24,890 SM)
ENTERPRISE
(19,260 SM)
RM 232.3
RM 6.0
REPUBLICAN R.
RM 170.5
RM 43.3
HARLAN
COUNTY
(13,500 SM)
24,955 SM
SMOKEY HILL R.
19,951 SM
6,846 SM
NILES
(6,770 SM)
WACONDA
LAKE
(5,076 SM)
RM 172.4
SOLOMAN R.
RM 21.6
RM 86.6
NEW CAMBRIA
(11,730 SM)
TESCOTT
(2,820 SM)
3,425 SM
WILSON
DAM
(1,917 SM)
RM 153.4
SALINE R.
RM 68.5
RM 183.7
MENTOR
(8,358 SM)
RM 101.7
KANAPOLIS
LAKE
(7,857 SM)
UPPER MISSISSIPPI-LOWER MISSOURI
FLOW FREQUENCY STUDY
KANSAS CITY DISTRICT
SM = Square Miles
KANSAS RIVER BASIN SCHEMATIC

Plate E-3

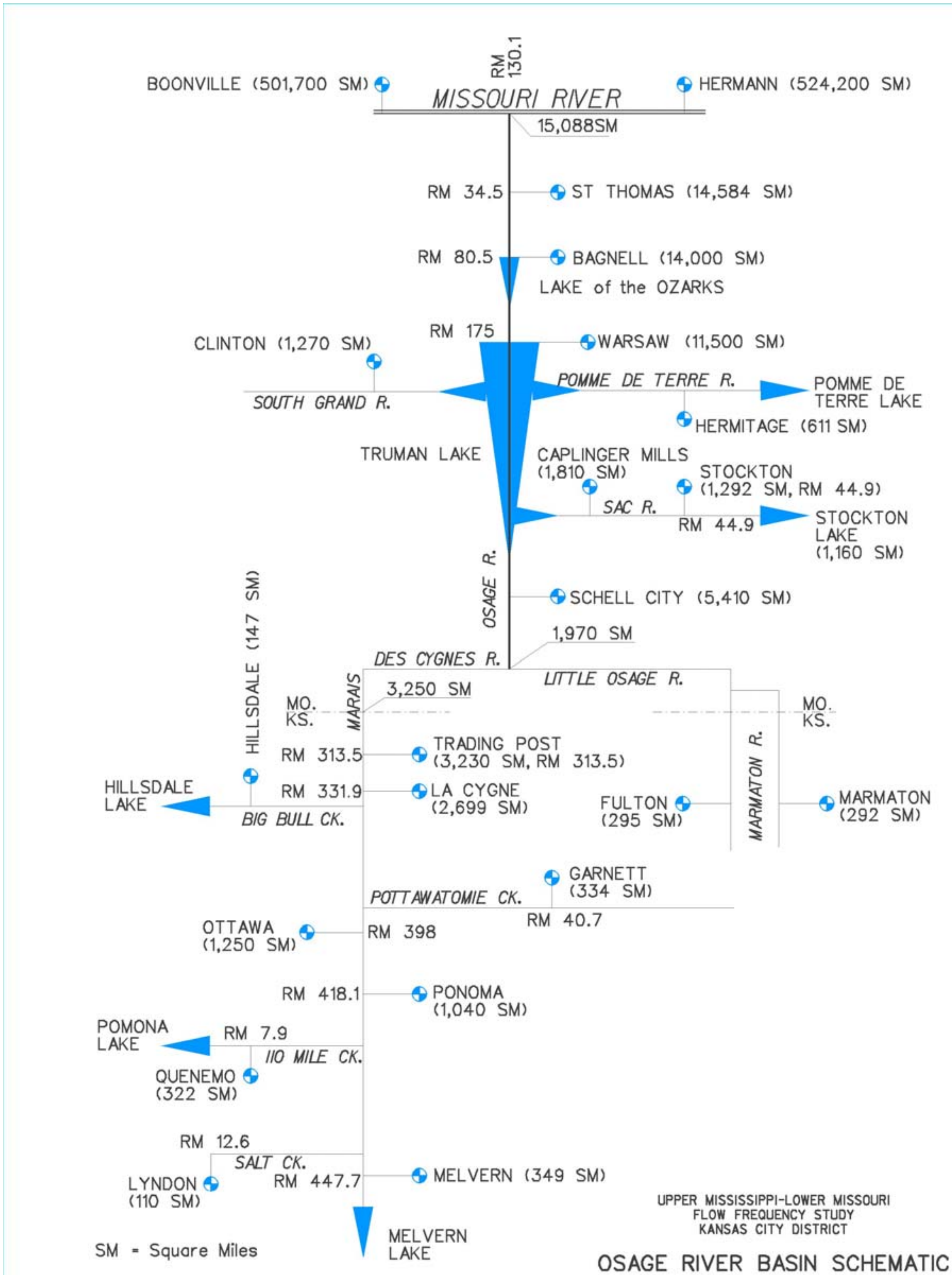

RM 130.1
BOONVILLE (501,700 SM)
MISSOURI RIVER
HERMANN (524,200 SM)
15,088SM
RM 34.5
ST THOMAS (14,584 SM)
RM 80.5
BAGNELL (14,000 SM)
LAKE of the OZARKS
RM 175
WARSAW (11,500 SM)
CLINTON (1,270 SM)
POMME DE TERRE R.
POMME DE TERRE LAKE
SOUTH GRAND R.
HERMITAGE (611 SM)
TRUMAN LAKE
CAPLINGER MILLS (1,810 SM)
STOCKTON (1,292 SM, RM 44.9)
SAC R.
RM 44.9
STOCKTON LAKE (1,160 SM)
OSAGE R.
SCHELL CITY (5,410 SM)
HILLSDALE (147 SM)
1,970 SM
DES CYGNES R.
LITTLE OSAGE R.
MARAIS
3,250 SM
MO.
KS.
MO.
KS.
RM 313.5
TRADING POST (3,230 SM, RM 313.5)
MARMATON R.
HILLSDALE LAKE
RM 331.9
LA CYGNE (2,699 SM)
FULTON (295 SM)
MARMATON (292 SM)
BIG BULL CK.
GARNETT (334 SM)
POTTAWATOMIE CK.
RM 40.7
OTTAWA (1,250 SM)
RM 398
RM 418.1
PONOMA (1,040 SM)
POMONA LAKE
RM 7.9
110 MILE CK.
QUENEMO (322 SM)
RM 12.6
SALT CK.
LYNDON (110 SM)
RM 447.7
MELVERN (349 SM)
UPPER MISSISSIPPI-LOWER MISSOURI
FLOW FREQUENCY STUDY
KANSAS CITY DISTRICT
MELVERN LAKE
SM = Square Miles
OSAGE RIVER BASIN SCHEMATIC

Plate E-4

Missouri River at Rulo

1898-1997

Year	Discharge (cfs)									
	1	2	3	4	5	6	7	8	9	10
1898					183000	108000	205000	111000	74600	66500
1899					182000	264000	207000	267000	110200	110000
1900					137000	108000	163000	108000	72100	63500
1901					159000	92000	177000	92700	69400	69200
1902					147000	95000	173000	96000	84100	74900
1903					241000	113000	257000	112000	159200	155000
1904					165000	169000	190000	170000	70600	68600
1905					206000	111000	228000	111000	85500	83200
1906					171000	117000	193000	118000	73200	73400
1907					219000	95000	246000	94400	115300	111000
1908					257000	73000	278000	77000	133900	125000
1909					224000	141000	255000	140000	149500	117000
1910					102000	215000	127000	215000	93600	93600
1911					130000	82000	168000	81500	69500	69300
1912					151000	242000	188000	242000	145700	146000
1913					136000	215000	171000	216000	101800	102000
1914					197000	87000	229000	87400	89000	88800
1915					208000	196000	234000	197000	103800	97400
1916					183000	156000	218000	158000	88300	75000
1917					226000	220000	251000	221000	114600	115000
1918					155000	166000	209000	167000	71200	66600
1919					116000	153000	153000	154000	70400	71400
1920					249000	194000	264000	194000	129400	131000
1921					235000	91000	277000	91600	106500	107000
1922					164000	144000	211000	144000	69100	65000
1923					201000	113000	235000	114000	100700	92400
1924					186000	173000	220000	174000	116100	117000
1925					172000	151000	214000	153000	88900	86000
1926					105000	94000	145000	93700	75900	76300
1927					230000	159000	247000	161000	127500	123000
1928					147000	137000	196000	136000	105800	104000
1929					215000	168000	244000	167000	89300	87700
1930					107000	91000	128000	90500	74600	76800
1931					62000	52000	132000	53900	54900	54800
1932			91000	61000	150000	87000	183000	86500	72600	65800
1933			72000	67000	104000	95000	146000	95300	45400	45700
1934			65000	77000	64000	71000	139000	70300	43900	43200
1935			138000	61000	118000	47000	159000	47400	91600	94200
1936			90000	127000	70000	111000	113000	111000	69400	69500
1937			132000	83000	112000	76000	141000	78500	47000	47100
1938			155000	121000	147000	113000	211000	112000	65000	59000
1939			93000	147000	85000	147000	125000	149000	73200	73700
1940			69000	41000	79000	44000	152000	46500	66600	66000
1941			150000	83000	113000	68000	141000	69900	48600	48900
1942			148000	77000	184000	90000	224000	90000	75500	75500
1943			167000	181000	178000	199000	236000	201000	76300	76300
1944			185000	176000	214000	175000	276000	175000	111800	112000
1945			129000	111000	171000	123000	189000	123000	103300	102000
1946			90000	58000	120000	77000	163000	79400	87900	85000
1947			199000	145000	208000	191000	246000	193000	119300	120000
1948			136000	148000	176000	133000	220000	134000	93000	92700
1949			140000	197000	129000	196000	167000	199000	105600	106000
1950	170000	192000			174000	221000	179000	223000	145800	135000
1951	179000	166000			210000	170000	250000	170000	162000	162000
1952	137000	360000			155000	440000	204000	447000	161400	162000
1953	121000	83000			249000	92000	285000	91700	92900	91400
1954	123000	48000			150000	91000	199000	95600	106700	105000
1955	54000	58000			84000	78000	134000	77900	54800	55400
1956	57000	52000			124000	71000	180000	71400	49500	48600
1957	120000	40000			219000	51000	274000	51100	116800	117000

Plate E-5

Missouri River at Rulo 1898-1997										
Year	Discharge (cfs)									
	1	2	3	4	5	6	7	8	9	10
1958	100000	75000			149000	110000	183000	112000	98300	98000
1959	104000	53000			131000	146000	210000	148000	104500	106000
1960	92000	187000			111000	357000	183000	360000	180600	182000
1961	77000	54000			93000	64000	148000	63900	83300	83400
1962	126000	146000			203000	217000	231000	219000	174900	176000
1963	93000	70000			210000	106000	283000	106000	96800	94300
1964	109000	52000			216000	55000	270000	57800	110400	110000
1965	103000	99000			239000	128000	294000	134000	118000	110000
1966	86900	87000			73000	145000	127000	146000	87400	87800
1967	157000	45000			306000	77000	329000	78600	164500	164000
1968	76000	50000			168000	69000	242000	69100	75400	74900
1969	102000	112000			151000	235000	190000	240000	108700	109000
1970	66000	53000			151000	81000	207000	84100	67300	62000
1971	105000	131000			155000	164000	217000	166000	137900	139000
1972	97000	64000			158000	250000	202000	252000	100200	94300
1973	128000	119000			141000	146000	185000	147000	125000	127000
1974	93100	62000			141000	77000	213000	81600	91600	91300
1975	86600	87000			186000	125000	232000	128000	86700	87400
1976	73800	59000			126000	87000	185000	89000	68900	70400
1977	83000	48000			68000	58000	119000	67800	74700	75800
1978	106000	168000			182000	324000	228000	330000	171300	172000
1979	82000	142000			219000	182000	228000	186000	140100	142000
1980	78000	64000			98000	68000	177000	70100	77100	77600
1981	60000	49000			160000	47000	210000	47500	58500	59400
1982	127000	82000			190000	129000	244000	132000	130500	130000
1983	127000	110000			214000	133000	292000	135000	146200	146000
1984	225000	122000			300000	148000	359000	150000	239700	241000
1985	83000	91000			89000	100000	136000	112000	85900	86600
1986	135000	105000			171000	251000	247000	252000	155800	157000
1987	139000	147000			150000	273000	181000	275000	135500	137000
1988	55000	50000			61000	57000	123000	58100	54500	55300
1989	120000	51000			106000	78000	155000	81600	115800	116000
1990	124000	37000			155000	50000	261000	50900	122400	122000
1991	100000	55000			215000	50000	251000	52400	102300	105000
1992	85000	56000			101000	57000	151000	56900	126100	126000
1993	301000	118000			369000	163000	411000	164000	310300	312000
1994	94000	96000			123000	168000	183000	169000	89600	90400
1995	124000	88000			236000	148000	284000	151000	137400	156000
1996	153000	67000			255000	126000	323000	128000	144000	145000
1997	118000	127000			218000	307000	275000	309000	127300	127000

No.	Type of Data
1	USGS Record - Rainfall Season
2	USGS Record - Snowmelt Season
3	Stage Record - Rainfall Season
4	Stage Record - Snowmelt Season
5	Unregulated Data from NWO Model without Depletions - Rainfall Season
6	Unregulated Data from NWO Model without Depletions - Snowmelt Season
7	Unregulated Data from NWO Model with Depletions - Rainfall Season
8	Unregulated Data from NWO Model with Depletions - Snowmelt Season
9	Regulated Data from NWO Model without Depletions
10	Regulated Data from NWO Model with Depletions

Plate E-5 (cont)

Missouri River at St. Joseph

1898-1997

Year	Discharge (cfs)									
	1	2	3	4	5	6	7	8	9	10
1898					179000	108000	200000	110000	73200	67200
1899					179000	258000	203000	260000	131000	131000
1900			104000	83000	125000	98000	151000	98000	79100	66000
1901			128000	74000	161000	85000	178000	85000	75600	75500
1902			124000	76000	156000	87000	180000	87000	97100	88300
1903			264000	90000	332000	108000	348000	107000	250200	246000
1904			139000	141000	176000	179000	200000	180000	85400	82500
1905			168000	99000	217000	119000	238000	118000	106500	99700
1906			155000	101000	197000	121000	220000	122000	85000	80800
1907			194000	89000	252000	106000	277000	105000	150300	145000
1908			228000	48000	293000	51000	308000	56000	171200	166000
1909			215000	118000	277000	145000	307000	145000	199500	163000
1910			80000	181000	98000	236000	127000	236000	133500	125000
1911			101000	65000	125000	72000	161000	72000	57900	58500
1912			116000	204000	146000	267000	181000	268000	154800	157000
1913			102000	174000	126000	231000	159000	233000	147600	148000
1914			152000	65000	199000	75000	230000	76000	93500	93400
1915			186000	148000	240000	188000	266000	188000	136800	136000
1916			152000	150000	194000	193000	228000	193000	104900	105000
1917			225000	189000	294000	248000	318000	249000	180400	181000
1918			121000	130000	157000	165000	209000	165000	74200	68500
1919			97000	135000	118000	171000	153000	171000	108900	109000
1920			199000	168000	267000	219000	284000	219000	161300	163000
1921			152000	69000	197000	77000	239000	77000	103600	99000
1922			123000	126000	154000	160000	200000	160000	82000	81700
1923			159000	90000	204000	109000	237000	111000	126900	112000
1924			157000	124000	203000	158000	235000	159000	130900	132000
1925			137000	119000	176000	150000	217000	152000	98800	97800
1926			79000	81000	96000	97000	135000	97000	92100	92500
1927			179000	124000	240000	158000	256000	160000	150300	146000
1928			121000	102000	153000	124000	200000	124000	125100	122000
1929	202000	160000			205000	160000	240000	160000	152500	148000
1930	112000	92000			118000	93000	136000	93000	82400	85000
1931	70000	53000			69000	56000	137000	58000	77300	77300
1932	155000	93000			161000	95000	193000	95000	88500	82100
1933	112000	102000			117000	104000	147000	105000	55900	56700
1934	82000	82000			82000	83000	150000	82000	61100	60500
1935	122000	50000			128000	51000	168000	52000	99000	101000
1936	74000	112000			79000	113000	123000	113000	76100	76100
1937	105000	75000			110000	79000	149000	82000	61800	54900
1938	128000	111000			151000	114000	204000	113000	83200	78200
1939	95000	144000			92000	160000	129000	162000	102800	103000
1940	69000	44000			82000	48000	159000	51000	71100	70700
1941	120000	67000			127000	72000	159000	75000	85500	85800
1942	138000	80000			197000	92000	234000	92000	104200	104000
1943	154000	158000			182000	186000	237000	188000	114500	115000
1944	166000	167000			186000	175000	237000	177000	111600	112000
1945	154000	140000			177000	146000	195000	145000	135200	134000
1946	109000	79000			125000	89000	165000	91000	109800	107000
1947	185000	156000			208000	212000	244000	213000	135500	133000
1948	123000	160000			180000	169000	223000	169000	127700	128000
1949	144000	174000			174000	187000	209000	190000	147400	148000
1950	161000	181000			182000	209000	184000	210000	137200	126000
1951	195000	167000			215000	170000	254000	170000	158900	159000
1952	166000	386000			183000	460000	207000	467000	177700	179000
1953	123000	81000			244000	90000	278000	90000	88900	87500
1954	103000	48000			129000	91000	176000	96000	104100	102000
1955	83000	53000			106000	73000	146000	74000	84700	84600
1956	58000	49000			125000	70000	178000	71000	50400	49200
1957	127000	42000			234000	58000	286000	58000	112200	112000

Plate E-6

Missouri River at St. Joseph
1898-1997

Year	Discharge (cfs)									
	1	2	3	4	5	6	7	8	9	10
1958	132000	76000			180000	107000	204000	109000	128000	128000
1959	130000	59000			143000	146000	210000	148000	127000	128000
1960	100000	180000			120000	350000	184000	353000	182100	191000
1961	105000	73000			98000	79000	146000	80000	109900	110000
1962	132000	140000			205000	214000	229000	217000	169000	170000
1963	91000	82000			205000	116000	271000	117000	94300	92000
1964	110000	59000			220000	63000	272000	66000	111000	110000
1965	164000	133000			266000	155000	317000	155000	163400	164000
1966	82000	88000			79000	146000	135000	147000	88100	88500
1967	164000	49000			301000	79000	323000	80000	160900	161000
1968	82000	55000			170000	71000	238000	71000	80600	80500
1969	115000	118000			161000	236000	198000	239000	116500	117000
1970	71000	54000			158000	84000	204000	86000	72100	72500
1971	111000	129000			154000	162000	216000	163000	140800	142000
1972	114000	64000			157000	247000	200000	249000	115500	110000
1973	201000	158000			194000	184000	203000	184000	197000	199000
1974	112000	81000			141000	96000	212000	101000	110600	111000
1975	96000	86000			185000	129000	233000	132000	88900	88700
1976	88000	95000			136000	91000	187000	96000	87300	88100
1977	117000	51000			104000	61000	128000	70000	111300	113000
1978	150000	178000			184000	330000	262000	335000	183800	185000
1979	94000	172000			225000	197000	237000	199000	170100	172000
1980	102000	79000			112000	82000	175000	84000	101100	101000
1981	73000	53000			160000	51000	208000	51000	73000	73900
1982	160000	114000			218000	128000	253000	130000	162000	162000
1983	147000	132000			218000	155000	293000	156000	151600	152000
1984	201000	136000			274000	158000	328000	159000	226400	228000
1985	89000	90000			96000	108000	137000	118000	87600	88100
1986	155000	124000			185000	266000	251000	268000	175800	177000
1987	208000	155000			218000	265000	247000	268000	204800	206000
1988	60000	54000			63000	61000	124000	63000	59300	60100
1989	167000	59000			155000	77000	188000	82000	146300	147000
1990	140000	44000			170000	60000	270000	60000	137500	138000
1991	117000	67000			227000	61000	265000	64000	117000	119000
1992	127000	71000			140000	72000	183000	73000	141900	142000
1993	334000	136000			404000	184000	464000	185000	346800	348000
1994	108000	106000			135000	170000	192000	171000	103700	104000
1995	155000	107000			237000	166000	312000	169000	161200	170000
1996	161000	69000			257000	126000	323000	127000	160900	162000
1997	135000	138000			220000	299000	277000	301000	138500	142000

No.	Type of Data
1	USGS Record - Rainfall Season
2	USGS Record - Snowmelt Season
3	Stage Record - Rainfall Season
4	Stage Record - Snowmelt Season
5	Unregulated Data from NWO Model without Depletions - Rainfall Season
6	Unregulated Data from NWO Model without Depletions - Snowmelt Season
7	Unregulated Data from NWO Model with Depletions - Rainfall Season
8	Unregulated Data from NWO Model with Depletions - Snowmelt Season
9	Regulated Data from NWO Model without Depletions
10	Regulated Data from NWO Model with Depletions

Plate E-6 (cont)

Missouri River at Kansas City

1898-1997

Year	Discharge (cfs)						Year	Discharge (cfs)					
	1	2	3	4	5	6		1	2	3	4	5	6
1898		203000	226000	241000	118000	115000	1948	208000		222000	264000	132000	140000
1899		232000	256000	264000	142000	142000	1949	195000		225000	260000	154000	161000
1900		141000	163000	190000	123000	122000	1950	198000		236000	282000	139000	133000
1901		167000	190000	207000	129000	130000	1951	573000		593000	621000	349000	321000
1902		231000	255000	281000	191000	182000	1952	400000		469000	477000	173000	171000
1903	548000	531000	558000	574000	466000	464000	1953	128000		243000	279000	100000	98500
1904		266000	292000	317000	220000	213000	1954	122000		151000	202000	121000	120000
1905		225000	250000	272000	186000	183000	1955	111000		120000	165000	92900	91100
1906		172000	194000	219000	94600	94600	1956	71300		125000	179000	67000	61300
1907		238000	262000	289000	155000	149000	1957	143000		245000	302000	124000	123000
1908		386000	414000	428000	280000	283000	1958	193000		239000	271000	172000	172000
1909		304000	331000	361000	249000	208000	1959	155000		169000	246000	132000	138000
1910		179000	203000	203000	148000	146000	1960	251000		392000	416000	227000	229000
1911		94800	117000	155000	106000	106000	1961	178000		140000	169000	156000	160000
1912		231000	258000	259000	174000	177000	1962	182000		261000	282000	182000	184000
1913		211000	241000	242000	132000	133000	1963	96600		218000	279000	102000	98700
1914		199000	228000	260000	117000	116000	1964	158000		264000	297000	144000	145000
1915		357000	383000	408000	289000	287000	1965	225000		331000	387000	213000	200000
1916		173000	195000	230000	116000	118000	1966	213000		150000	170000	98700	100000
1917		297000	327000	351000	210000	210000	1967	255000		424000	450000	260000	249000
1918		164000	187000	236000	114000	117000	1968	120000		170000	236000	110000	111000
1919		191000	213000	214000	155000	155000	1969	183000		261000	266000	163000	160000
1920		221000	255000	273000	149000	151000	1970	134000		192000	223000	115000	118000
1921		203000	229000	272000	124000	125000	1971	126000		172000	236000	133000	133000
1922		203000	228000	230000	149000	149000	1972	122000		246000	248000	124000	117000
1923		206000	237000	268000	127000	119000	1973	313000		400000	405000	314000	304000
1924		213000	239000	273000	160000	160000	1974	184000		208000	225000	180000	161000
1925		178000	203000	243000	118000	126000	1975	109000		217000	277000	115000	114000
1926		121000	136000	163000	122000	122000	1976	120000		141000	196000	108000	110000
1927		262000	290000	293000	190000	189000	1977	206000		216000	244000	192000	190000
1928		136000	159000	208000	147000	145000	1978	192000		357000	362000	186000	188000
1929	254000		265000	294000	188000	187000	1979	220000		278000	282000	189000	192000
1930	149000		154000	172000	120000	121000	1980	169000		214000	215000	159000	160000
1931	64000		143000	138000	131000	134000	1981	131000		171000	224000	129000	128000
1932	178000		186000	219000	96200	96100	1982	201000		302000	327000	186000	185000
1933	109000		116000	149000	53400	53600	1983	192800		288000	322000	174000	176000
1934	87100		74000	146000	55700	54800	1984	125000		360000	418000	289000	294000
1935	230000		232000	262000	158000	159000	1985	212000		253000	254000	200000	200000
1936	117000		120000	130000	81700	82200	1986	196000		285000	327000	196000	197000
1937	102000		112000	157000	84000	77000	1987	224000		314000	312000	213000	212000
1938	137000		161000	202000	95000	83700	1988	68300		73000	127000	69400	70100
1939	135000		155000	158000	102000	101000	1989	200000		222000	258000	166000	166000
1940	68100		82000	160000	71100	70000	1990	133000		194000	290000	133000	134000
1941	215000		221000	254000	128000	119000	1991	113000		228000	266000	117000	119000
1942	206000		255000	294000	148000	143000	1992	167000		208000	264000	161000	162000
1943	366000		364000	420000	198000	185000	1993	541000		641000	705000	525000	534000
1944	311000		320000	325000	220000	225000	1994	103000		175000	196000	101000	101000
1945	242000		266000	285000	180000	184000	1995	220000		328000	357000	241000	236000
1946	123000		138000	170000	122000	119000	1996	168000		253000	322000	163000	165000
1947	261000		295000	322000	186000	181000	1997	190000		357000	360000	199000	199000

No.	Type of Data
1	USGS Record
2	Stage Record
3	Unregulated Data from NWO Model without Depletions
4	Unregulated Data from NWO Model with Depletions
5	Regulated Data from NWO Model without Depletions
6	Regulated Data from NWO Model with Depletions

NOTE: Regulated discharges could not be simulated prior to 1919 in the Kansas River Basin using the ACCESS model described in this report.

Plate E-7

Missouri River at Waverly
1898-1997

Year	Discharge (cfs)						Year	Discharge (cfs)					
	1	2	3	4	5	6		1	2	3	4	5	6
1898			224000	239000	119000	115000	1948	215000		229000	253000	132000	135000
1899			254000	262000	155000	155000	1949	187000		210000	244000	150000	155000
1900			162000	190000	122000	121000	1950	197000		231000	277000	134000	127000
1901			188000	206000	129000	129000	1951	549000		568000	599000	371000	358000
1902			253000	279000	191000	182000	1952	369000		429000	439000	186000	184000
1903			554000	571000	469000	466000	1953	126000		236000	272000	95000	93500
1904			290000	315000	223000	216000	1954	119000		144000	195000	112000	111000
1905			248000	270000	176000	173000	1955	106000		127000	171000	92000	90900
1906			193000	218000	96000	94400	1956	67500		122000	176000	60000	55400
1907			260000	288000	154000	150000	1957	142000		244000	300000	119000	119000
1908			410000	425000	274000	278000	1958	184000		226000	256000	161000	162000
1909			329000	358000	251000	208000	1959	154000		168000	241000	130000	134000
1910			201000	201000	146000	143000	1960	249000		389000	407000	225000	225000
1911			116000	153000	105000	105000	1961	216000		184000	210000	204000	207000
1912			256000	257000	176000	178000	1962	185000		281000	302000	176000	178000
1913			239000	241000	166000	166000	1963	98000		219000	281000	98000	94200
1914			226000	257000	116000	113000	1964	162000		259000	292000	142000	144000
1915		270000	398000	424000	302000	300000	1965	276000		348000	389000	252000	229000
1916		112000	193000	228000	119000	112000	1966	128000		147000	194000	96000	97500
1917		219000	326000	350000	208000	209000	1967	256000		420000	445000	244000	229000
1918		98300	181000	233000	116000	119000	1968	124000		163000	233000	106000	106000
1919		114000	219000	220000	143000	143000	1969	189000		265000	270000	163000	163000
1920		146000	246000	264000	146000	148000	1970	136000		197000	227000	117000	119000
1921		140000	232000	274000	128000	131000	1971	123000		171000	235000	126000	126000
1922		138000	228000	228000	154000	154000	1972	252000		245000	248000	121000	121000
1923		179000	228000	259000	141000	125000	1973	262000		377000	381000	269000	267000
1924		188000	242000	275000	165000	167000	1974	208000		252000	268000	218000	204000
1925		162000	210000	249000	123000	133000	1975	108000		208000	267000	112000	112000
1926		105000	132000	155000	121000	121000	1976	110000		140000	194000	105000	107000
1927		257000	294000	297000	191000	192000	1977			249000	277000	205000	203000
1928		144000	150000	196000	172000	168000	1978	180000		353000	359000	183000	184000
1929	263000		273000	301000	213000	212000	1979	193000		266000	270000	185000	191000
1930	146000		154000	168000	117000	117000	1980	174000		220000	221000	160000	160000
1931	65500		149000	144000	131000	130000	1981	139000		174000	226000	116000	117000
1932	167000		176000	208000	91000	89900	1982	208300		311000	337000	184000	185000
1933	111000		115000	154000	56000	56200	1983	213500		271000	307000	182000	183000
1934	82600		81000	145000	53000	52700	1984	245000		367000	424000	283000	282000
1935	215000		225000	254000	155000	157000	1985	213000		251000	253000	191000	189000
1936	120000		126000	133000	82000	81500	1986	179000		272000	330000	187000	188000
1937	105000		114000	158000	77000	69100	1987	196000		312000	312000	198000	197000
1938	137000		161000	195000	94000	83100	1988	69000		71000	124000	68000	68500
1939	133000		151000	153000	98000	97400	1989	197000		214000	251000	162000	163000
1940	70800		83000	158000	69000	68000	1990	202000		222000	295000	188000	189000
1941	185000		196000	229000	118000	112000	1991	125000		237000	277000	122000	124000
1942	200000		263000	298000	146000	141000	1992	180000		220000	268000	168000	168000
1943	310000		342000	397000	204000	183000	1993			715000	778000	608000	612000
1944	347000		355000	359000	217000	217000	1994	123000		171000	195000	125000	126000
1945	240000		254000	265000	180000	179000	1995	267000		362000	382000	264000	281000
1946	116000		130000	165000	111000	109000	1996	192000		260000	328000	182000	183000
1947	273000		301000	326000	188000	182000	1997	222441		370000	373000	216000	215000

No.	Type of Data
1	USGS Record
2	Stage Record
3	Unregulated Data from NWO Model without Depletions
4	Unregulated Data from NWO Model with Depletions
5	Regulated Data from NWO Model without Depletions
6	Regulated Data from NWO Model with Depletions

NOTE: Regulated discharges could not be simulated prior to 1919 in the Kansas River Basin using the ACCESS model described in this report.

Plate E-8

Missouri River at Boonville
1898-1997

Year	Discharge (cfs)						Year	Discharge (cfs)					
	1	2	3	4	5	6		1	2	3	4	5	6
1898		188000	255000	270000	160000	161000	1948	247000		262000	284000	175000	167000
1899		204000	271000	274000	152000	151000	1949	196000		226000	260000	169000	167000
1900		117000	164000	164000	163000	163000	1950	209000		251000	289000	158000	148000
1901		117000	164000	182000	125000	126000	1951	550000		569000	600000	436000	411000
1902		168000	231000	256000	167000	158000	1952	360000		425000	435000	191000	190000
1903	612000	625000	521000	539000	446000	442000	1953	150000		246000	281000	113000	112000
1904		248000	311000	336000	241000	234000	1954	132000		145000	195000	114000	111000
1905		246000	309000	326000	321000	318000	1955	128000		151000	196000	124000	126000
1906		105000	148000	174000	76700	74900	1956	89200		126000	190000	70000	64900
1907		214000	281000	308000	172000	167000	1957	145000		250000	310000	122000	122000
1908		403000	421000	435000	283000	287000	1958	252000		283000	314000	245000	239000
1909		407000	423000	454000	338000	300000	1959	175000		194000	245000	157000	156000
1910		149000	209000	212000	181000	180000	1960	332000		460000	495000	311000	312000
1911		94600	128000	152000	126000	126000	1961	267000		247000	278000	261000	264000
1912		214000	281000	281000	221000	221000	1962	199000		293000	315000	185000	186000
1913		149000	214000	216000	124000	124000	1963	118000		213000	280000	108000	106000
1914		139000	200000	232000	122000	122000	1964	184000		285000	320000	170000	170000
1915		341000	380000	403000	310000	312000	1965	261000		369000	424000	256000	246000
1916		178000	244000	244000	196000	188000	1966	187000		195000	253000	159000	160000
1917		301000	359000	383000	239000	240000	1967	275000		475000	500000	282000	262000
1918		123000	180000	234000	103000	107000	1968	133000		168000	235000	117000	114000
1919		151000	212000	237000	174000	177000	1969	223000		326000	333000	238000	234000
1920		180000	255000	272000	164000	165000	1970	213000		228000	258000	203000	188000
1921		151000	215000	257000	127000	130000	1971	158000		184000	241000	165000	167000
1922		162000	225000	233000	149000	149000	1972	137000		248000	250000	142000	142000
1923		156000	219000	251000	127000	119000	1973	334000		414000	417000	322000	324000
1924		193000	263000	296000	184000	185000	1974	280000		307000	327000	268000	257000
1925		160000	224000	262000	136000	145000	1975	195000		233000	294000	185000	183000
1926	175000		176000	182000	171000	170000	1976	161000		181000	198000	159000	160000
1927	381000		396000	399000	309000	308000	1977	246000		262000	291000	228000	229000
1928	224000		349000	346000	370000	368000	1978	259000		413000	419000	254000	254000
1929	344000		357000	387000	299000	297000	1979	238000		321000	325000	234000	236000
1930	150000		160000	180000	121000	121000	1980	190000		223000	224000	171000	172000
1931	221000		229000	223000	222000	219000	1981	238000		265000	324000	222000	222000
1932	180000		185000	217000	124000	123000	1982	278000		388000	413000	258000	258000
1933	105000		114000	162000	86100	87700	1983	317700		374000	375000	279000	279000
1934	77000		88000	145000	72300	72000	1984	285000		395000	444000	303000	309000
1935	306000		317000	337000	262000	267000	1985	292000		337000	338000	291000	295000
1936	134000		138000	138000	107000	108000	1986	334000		365000	384000	306000	309000
1937	123000		121000	177000	123000	122000	1987	125000		312000	315000	210000	210000
1938	142000		167000	202000	133000	132000	1988	104000		104000	125000	99400	100000
1939	170000		177000	187000	132000	133000	1989	223000		239000	276000	187000	188000
1940	76700		90000	166000	81900	75000	1990	294000		332000	345000	290000	289000
1941	201000		213000	246000	143000	138000	1991	133000		236000	277000	135000	136000
1942	312000		376000	411000	268000	262000	1992	205000		262000	306000	240000	239000
1943	366000		402000	442000	291000	283000	1993	755000		827000	883000	737000	733000
1944	504000		518000	522000	397000	391000	1994	208000		225000	229000	210000	211000
1945	280000		299000	317000	247000	236000	1995	361000		477000	485000	380000	376000
1946	150000		156000	186000	157000	154000	1996	296000		377000	399000	286000	288000
1947	448000		481000	504000	353000	349000	1997	281000		447000	449000	290000	290000

No.	Type of Data
1	USGS Record
2	Stage Record
3	Unregulated Data from NWO Model without Depletions
4	Unregulated Data from NWO Model with Depletions
5	Regulated Data from NWO Model without Depletions
6	Regulated Data from NWO Model with Depletions

NOTE: Regulated discharges could not be simulated prior to 1919 in the Kansas River Basin using the ACCESS model described in this report.

Plate E-9

Missouri River at Hermann

1898-1997

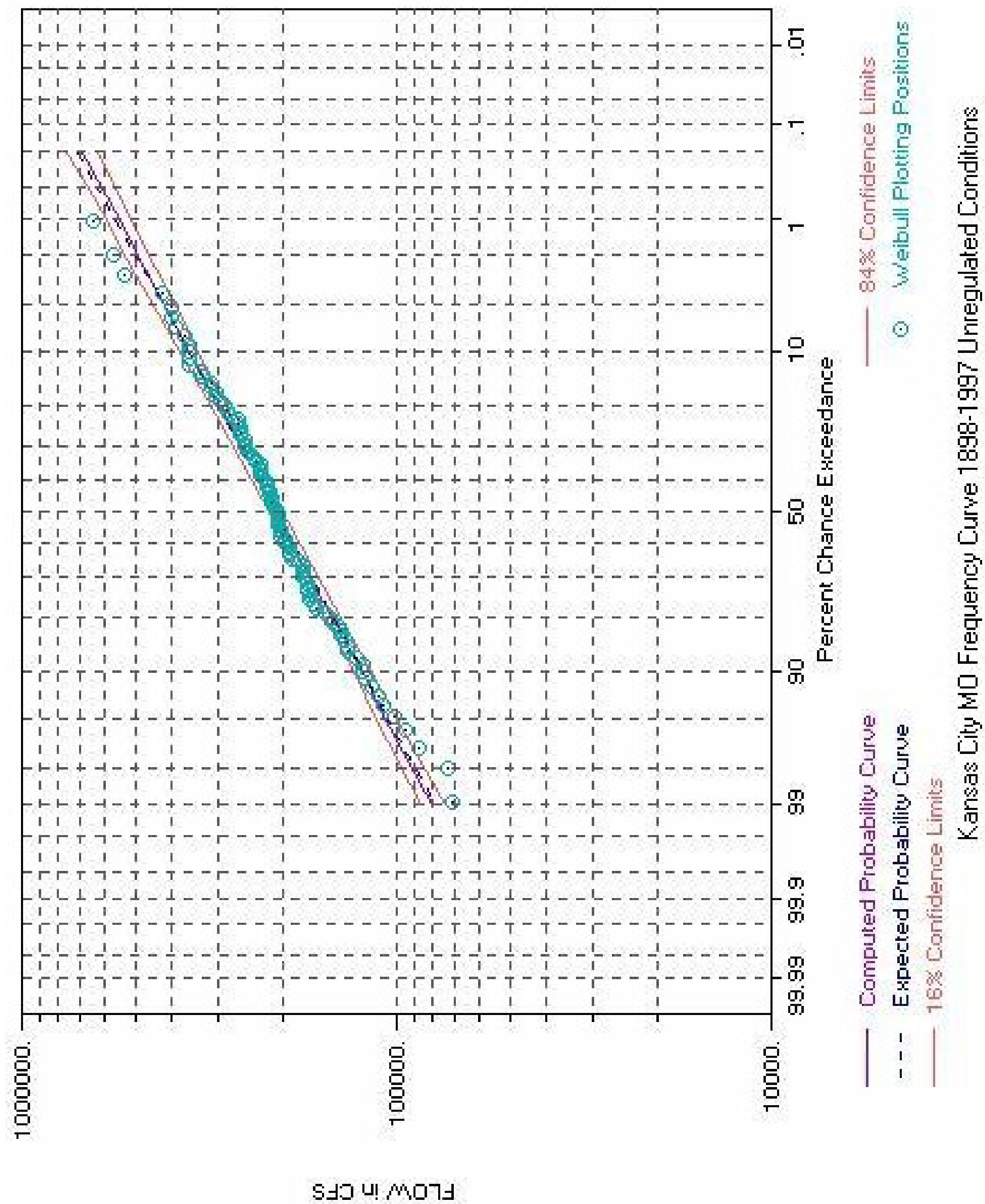
Year	Discharge (cfs)					
	1	2	3	4	5	6
1898		195000	281000	296000	208000	208000
1899		186000	269000	273000	152000	149000
1900		142000	192000	192000	189000	189000
1901		132000	176000	176000	158000	159000
1902		169000	245000	267000	193000	194000
1903	676000	654000	555000	573000	482000	478000
1904		327000	403000	407000	344000	342000
1905		396000	451000	470000	471000	468000
1906		147000	204000	220000	205000	203000
1907		197000	284000	311000	175000	171000
1908		375000	440000	455000	305000	309000
1909		432000	471000	501000	386000	348000
1910		212000	304000	336000	271000	269000
1911		115000	145000	145000	143000	144000
1912		283000	370000	370000	310000	310000
1913		182000	269000	270000	207000	202000
1914		150000	215000	246000	200000	196000
1915		421000	468000	487000	402000	403000
1916		240000	331000	358000	293000	286000
1917		364000	435000	460000	315000	315000
1918		139000	193000	246000	145000	138000
1919		178000	261000	296000	242000	243000
1920		221000	312000	312000	249000	248000
1921		212000	306000	349000	248000	251000
1922		364000	433000	433000	371000	372000
1923		218000	316000	347000	209000	207000
1924		252000	343000	376000	267000	269000
1925		167000	246000	285000	171000	169000
1926		206000	297000	295000	303000	299000
1927		468000	493000	496000	409000	408000
1928		327000	405000	443000	371000	373000
1929	407000		420000	450000	394000	398000
1930	164000		171000	216000	136000	138000
1931	269000		277000	272000	256000	255000
1932	179000		196000	228000	161000	160000
1933	183000		216000	224000	132000	186000
1934	85000		123000	146000	86000	100000
1935	473000		470000	495000	339000	344000
1936	145000		145000	145000	137000	150000
1937	194000		197000	234000	135000	158000
1938	231000		240000	254000	188000	193000
1939	247000		274000	276000	179000	236000
1940	111000		127000	196000	101000	116000
1941	256000		285000	285000	223000	226000
1942	435000		493000	530000	333000	323000
1943	550000		545000	558000	374000	391000
1944	577000		591000	596000	440000	439000
1945	398000		404000	406000	301000	298000
1946	209000		220000	231000	172000	209000
1947	487000		524000	550000	344000	356000

Year	Discharge (cfs)					
	1	2	3	4	5	6
1948	333000		373000	400000	213000	225000
1949	239000		274000	308000	205000	213000
1950	265000		291000	339000	238000	211000
1951	618000		643000	677000	574000	499000
1952	368000		435000	444000	221000	244000
1953	177000		246000	282000	153000	140000
1954	145000		154000	203000	122000	117000
1955	186000		192000	195000	144000	180000
1956	89000		140000	203000	71000	89200
1957	196000		283000	327000	165000	178000
1958	339000		362000	401000	284000	283000
1959	190000		212000	245000	178000	189000
1960	330000		471000	502000	295000	298000
1961	405000		397000	409000	274000	316000
1962	278000		290000	311000	231000	230000
1963	139000		215000	282000	122000	120000
1964	202000		306000	341000	208000	202000
1965	306000		390000	442000	281000	274000
1966	188000		206000	263000	166000	166000
1967	372000		572000	595000	311000	330000
1968	187000		177000	246000	148000	159000
1969	360000		368000	403000	304000	332000
1970	293000		303000	332000	255000	272000
1971	207000		224000	245000	213000	216000
1972	179000		250000	253000	174000	195000
1973	500000		503000	505000	420000	435000
1974	325000		316000	334000	265000	266000
1975	278000		287000	312000	254000	262000
1976	199000		219000	225000	202000	197000
1977	250000		266000	294000	241000	241000
1978	348000		455000	461000	305000	329000
1979	289000		374000	377000	252000	265000
1980	201000		262000	263000	176000	199000
1981	282000		402000	453000	261000	255000
1982	298900		441000	466000	328000	371000
1983	394600		530000	532000	297000	369000
1984	314000		403000	459000	289000	323000
1985	415000		542000	542000	311000	440000
1986	549000		872000	876000	292000	508000
1987	185000		361000	364000	245000	240000
1988	166000		209000	210000	126000	162000
1989	214000		226000	262000	185000	180000
1990	381000		447000	460000	334000	379000
1991	164000		241000	281000	159000	163000
1992	249000		374000	370000	264000	319000
1993	750000		876000	931000	724000	749000
1994	445000		564000	566000	294000	447000
1995	579000		686000	694000	440000	534000
1996	294000		385000	410000	282000	288000
1997	303000		470000	473000	310000	314000

No.	Type of Data
1	USGS Record
2	Stage Record
3	Unregulated Data from NWO Model without Depletions
4	Unregulated Data from NWO Model with Depletions
5	Regulated Data from NWO Model without Depletions
6	Regulated Data from NWO Model with Depletions

NOTE: Regulated discharges could not be simulated prior to 1930 in the Osage River Basin using the ACCESS model described in this report.

Plate E-10



Kansas City MO Frequency Curve 1898-1997 Unregulated Conditions
FLOW in CFS
Percent Chance Exceedance
1000000.
100000.
10000.
99.99
99.9
99
90
50
10
1
.1
.01
Computed Probability Curve
Expected Probability Curve
16% Confidence Limits
84% Confidence Limits
Weibull Plotting Positions

Plate E-11

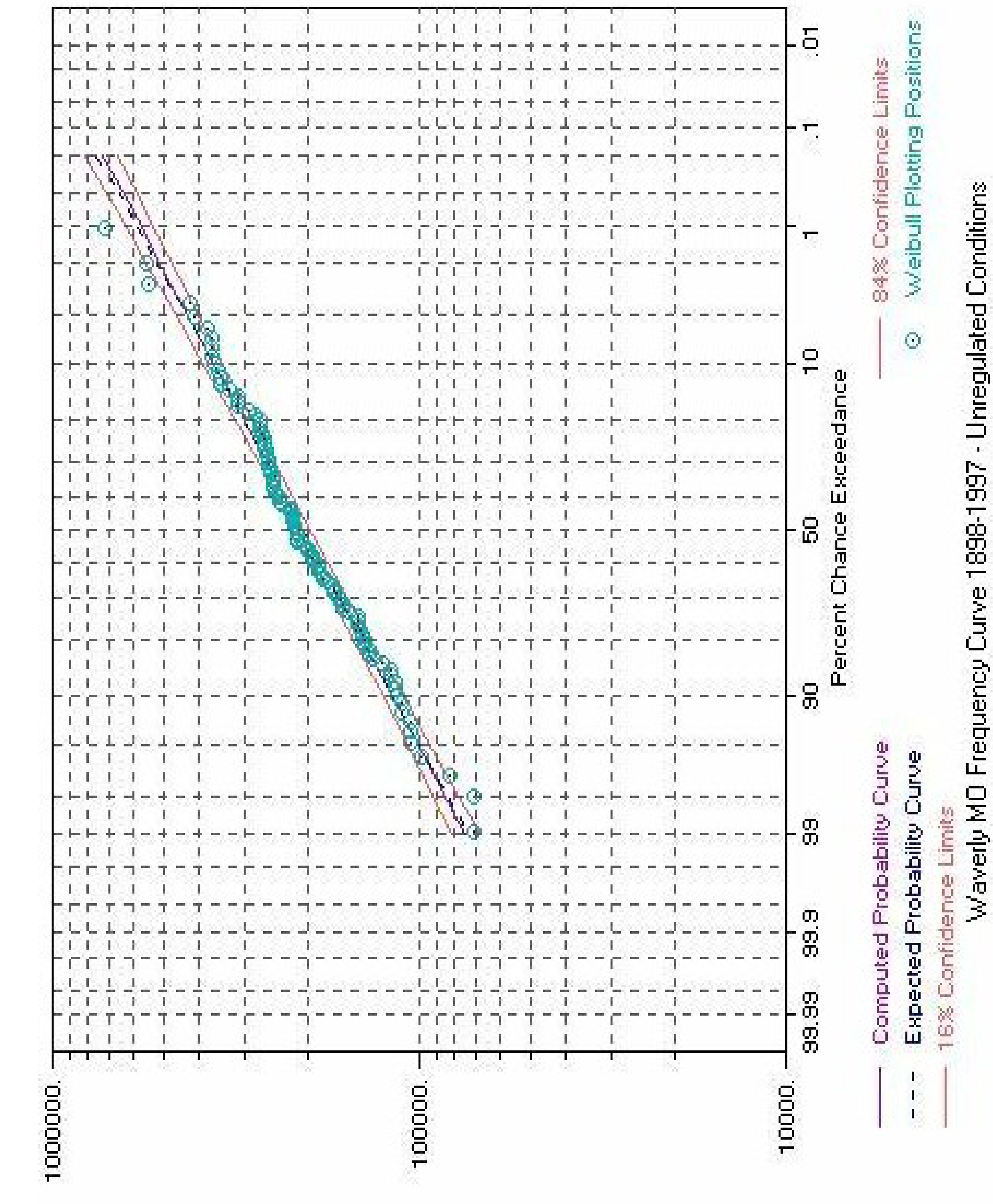
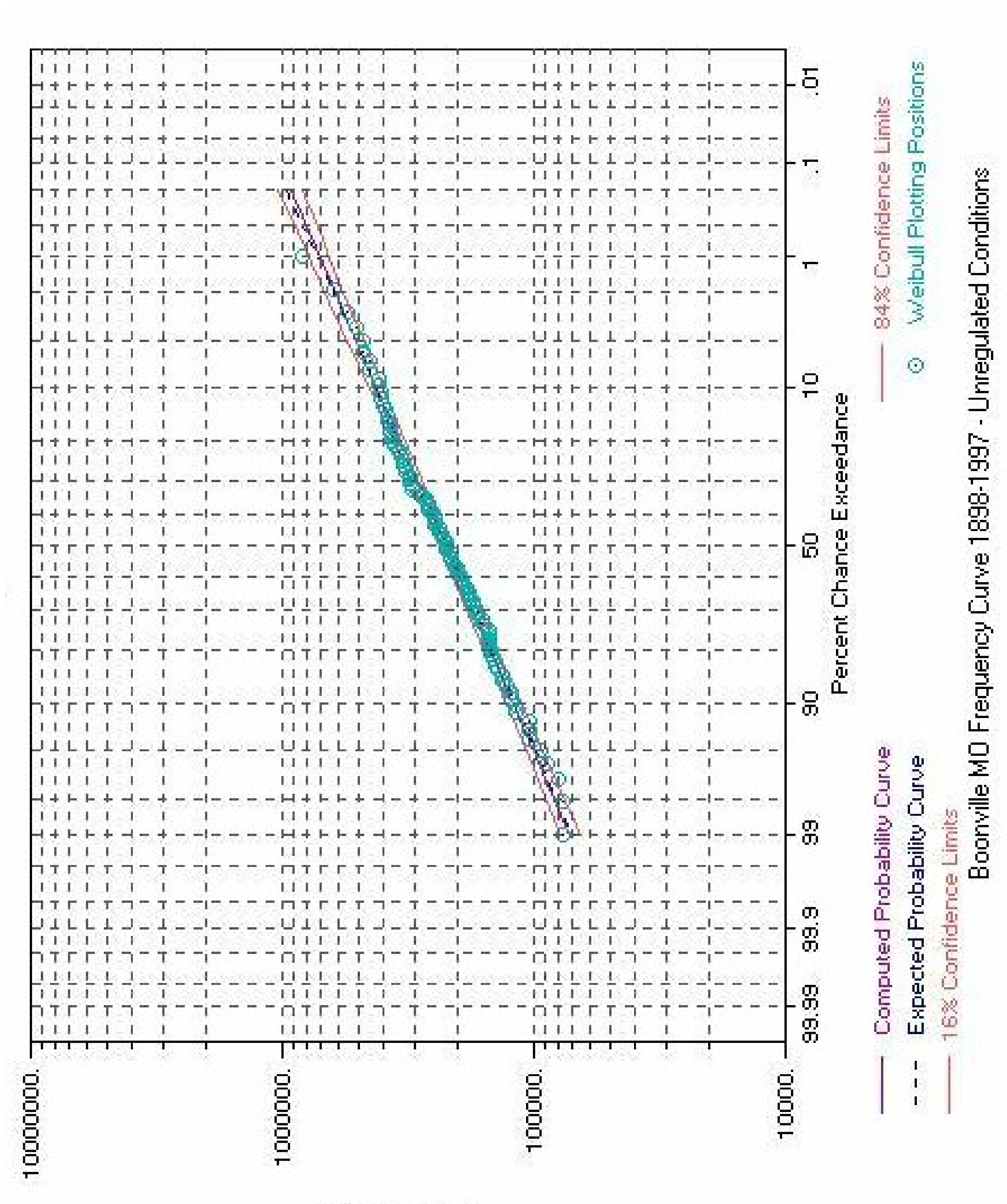
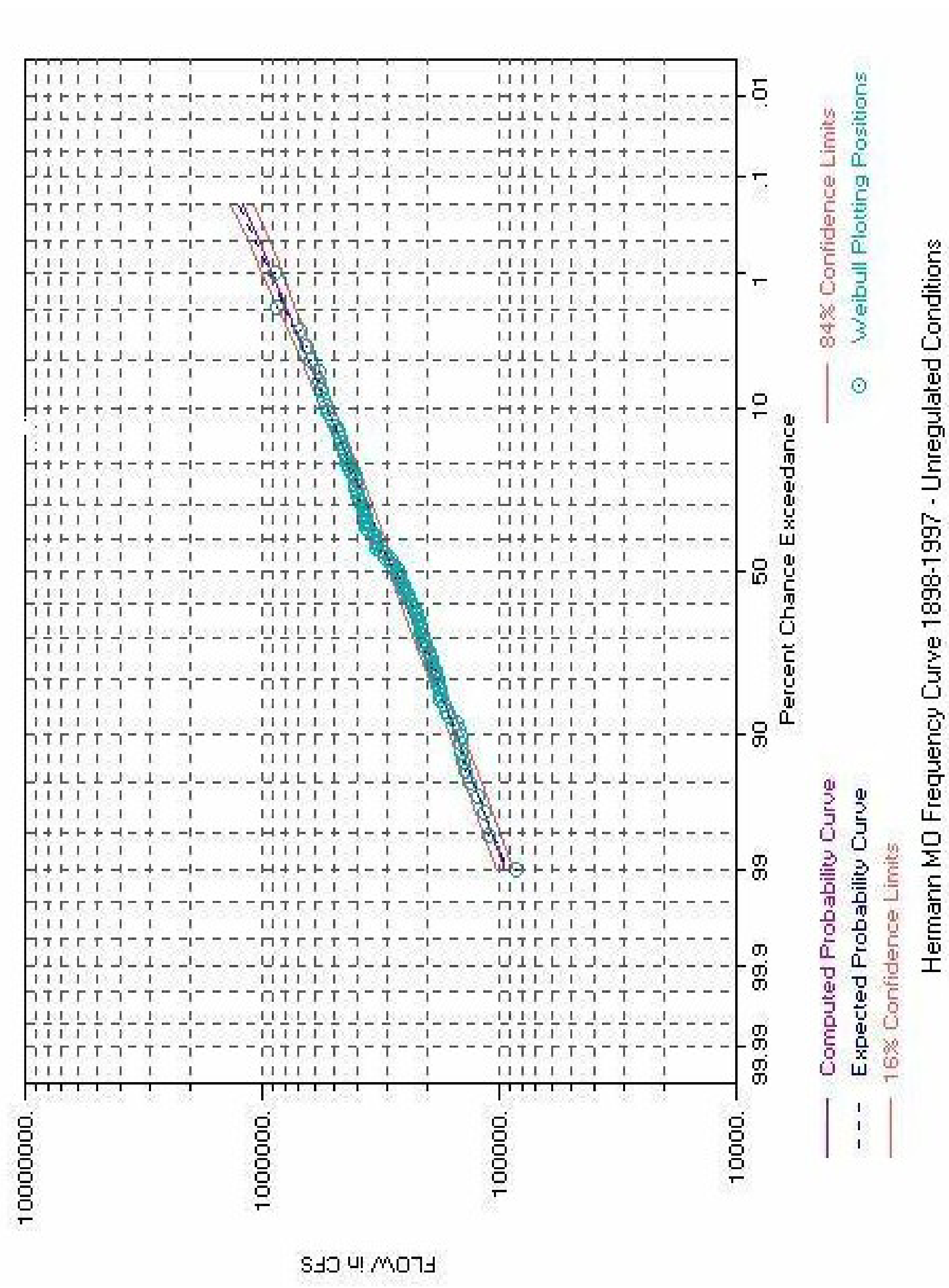

Waverly MO Frequency Curve 1898-1997 - Unregulated Conditions
Percent Chance Exceedance
FLOW in CFS
1000000.
100000.
10000.
99.99
99.9
99
90
50
10
1
.1
.01
Computed Probability Curve
Expected Probability Curve
16% Confidence Limits
84% Confidence Limits
Weibull Plotting Positions

Plate E-12



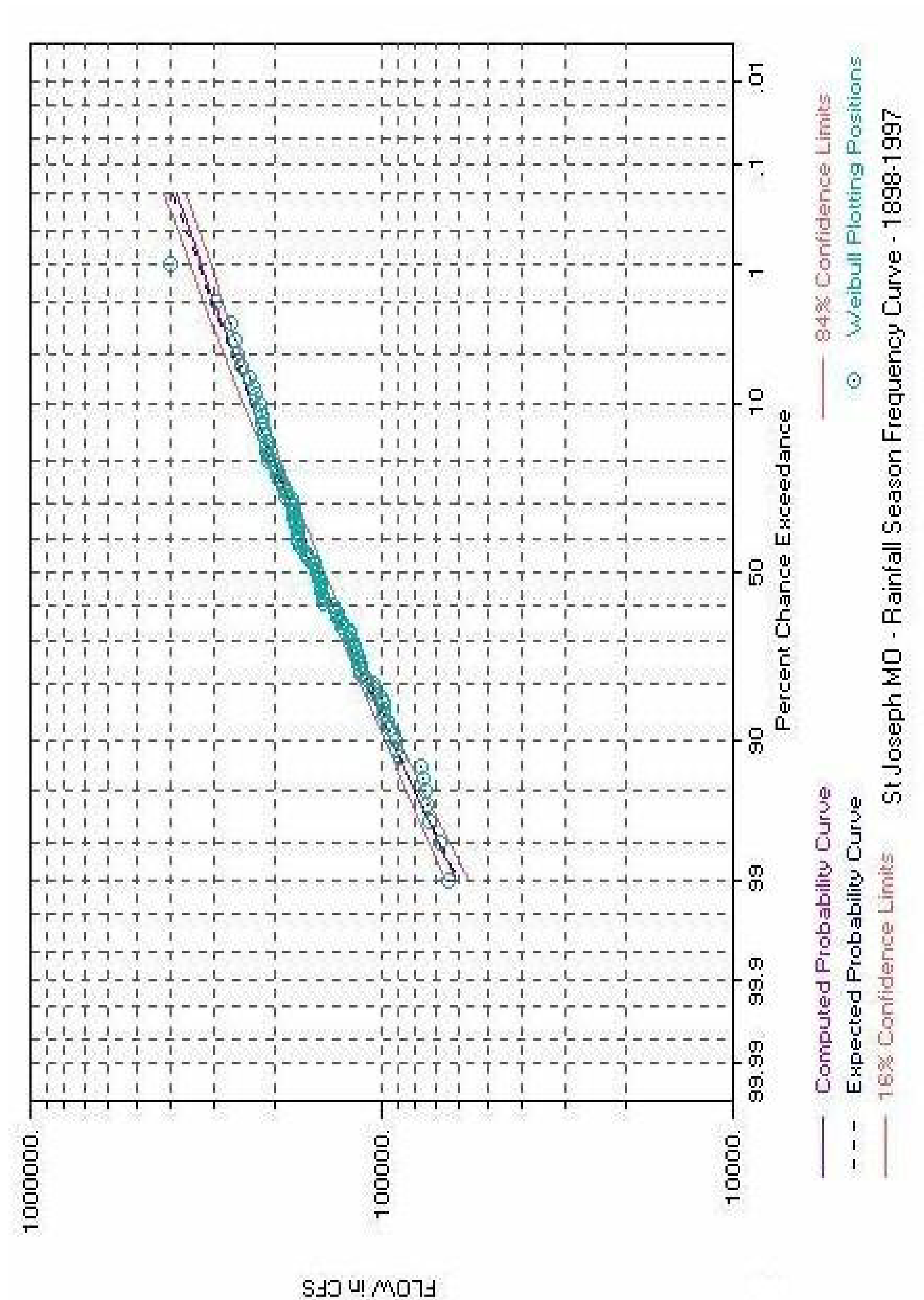
FLOW in CFS
10000000.
1000000.
100000.
10000.
99.99
99.9
99
90
50
10
1
.1
.01
Percent Chance Exceedance
Computed Probability Curve
Expected Probability Curve
16% Confidence Limits
84% Confidence Limits
Weibull Plotting Positions
Boonville MO Frequency Curve 1898-1997 - Unregulated Conditions

Plate E-13



Hermann MO Frequency Curve 1898-1997 - Unregulated Conditions
FLOW in CFS
Percent Chance Exceedance
10000000.
1000000.
100000.
10000.
99.99
99.9
99
90
50
10
1
.1
.01
Computed Probability Curve
Expected Probability Curve
16% Confidence Limits
84% Confidence Limits
Weibull Plotting Positions

Plate E-14



FLOW in CFS
1000000.
100000.
10000.
99.99
99.9
99
90
50
10
1
.1
.01
Percent Chance Exceedance
Computed Probability Curve
Expected Probability Curve
16% Confidence Limits
84% Confidence Limits
Weibull Plotting Positions
St Joseph MO - Rainfall Season Frequency Curve - 1898-1997

Plate E-15

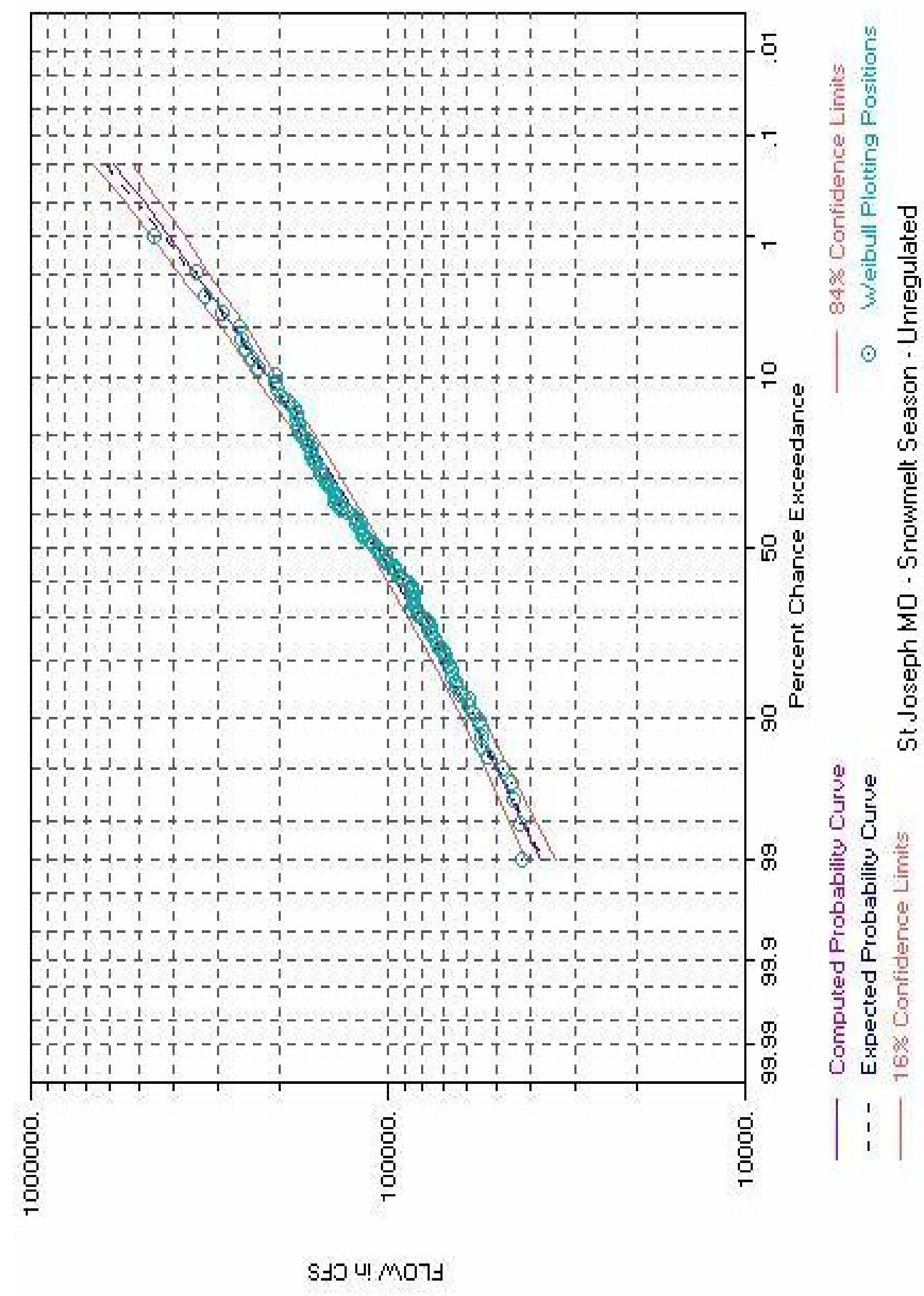

FLOW in CFS
1000000.
100000.
10000.
99.99
99.9
99
90
50
10
1
.1
.01
Percent Chance Exceedance
Computed Probability Curve
Expected Probability Curve
16% Confidence Limits
84% Confidence Limits
Weibull Plotting Positions
St.Joseph MO - Snowmelt Season - Unregulated
Frequency Curve - 1898-1997

Plate E-16

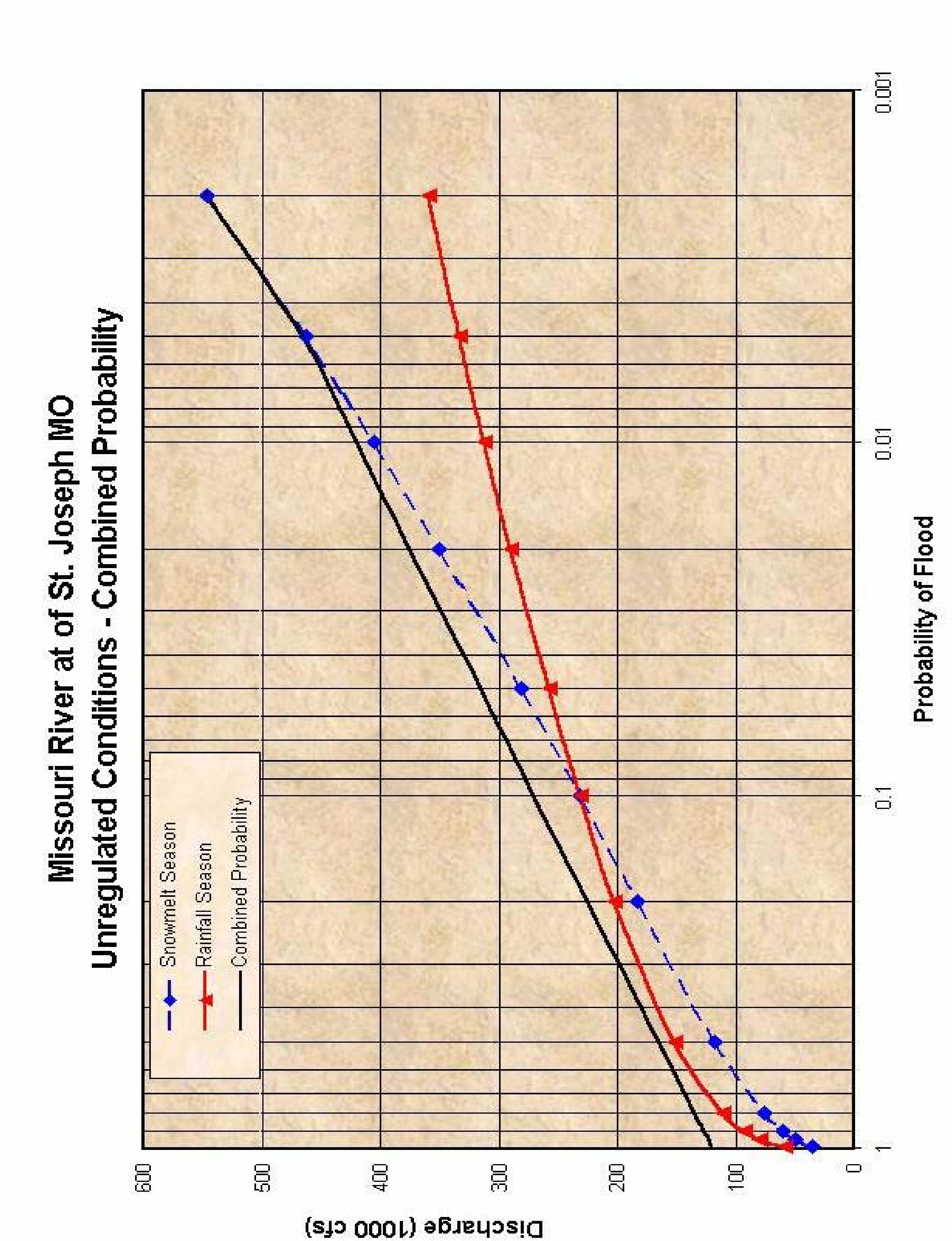
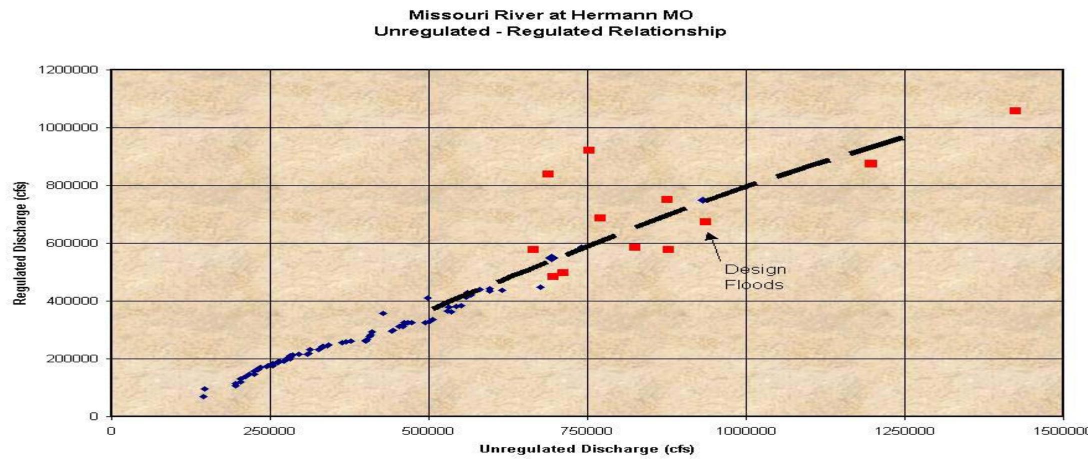
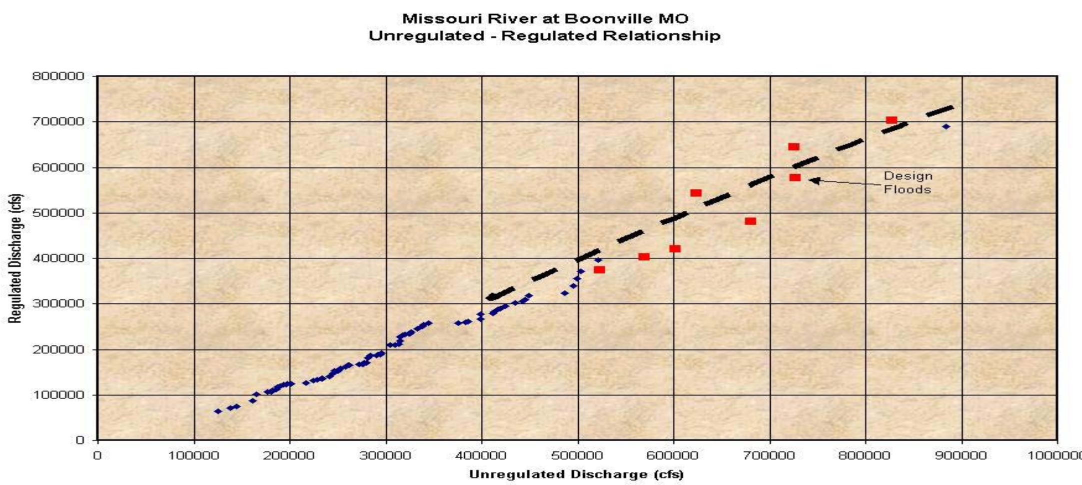

Missouri River at of St. Joseph MO
Unregulated Conditions - Combined Probability
Snowmelt Season
Rainfall Season
Combined Probability
Discharge (1000 cfs)
Probability of Flood
0
100
200
300
400
500
600
1
0.1
0.01
0.001

Plate E-17


Missouri River at Hermann MO
Unregulated - Regulated Relationship
1200000
1000000
800000
600000
400000
200000
0
Regulated Discharge (cfs)
0
250000
500000
750000
1000000
1250000
1500000
Unregulated Discharge (cfs)
Design Floods


Missouri River at Boonville MO
Unregulated - Regulated Relationship
800000
700000
600000
500000
400000
300000
200000
100000
0
Regulated Discharge (cfs)
0
100000
200000
300000
400000
500000
600000
700000
800000
900000
1000000
Unregulated Discharge (cfs)
Design Floods

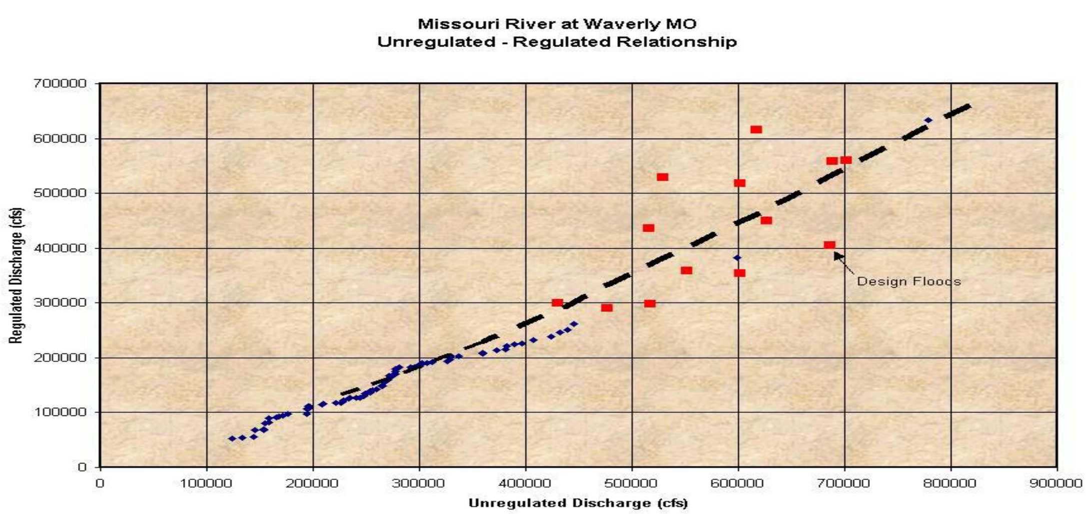
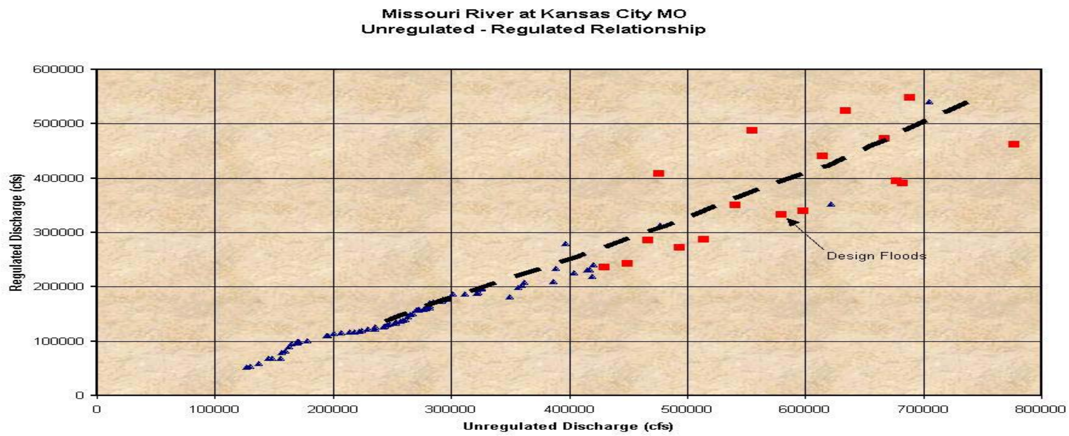
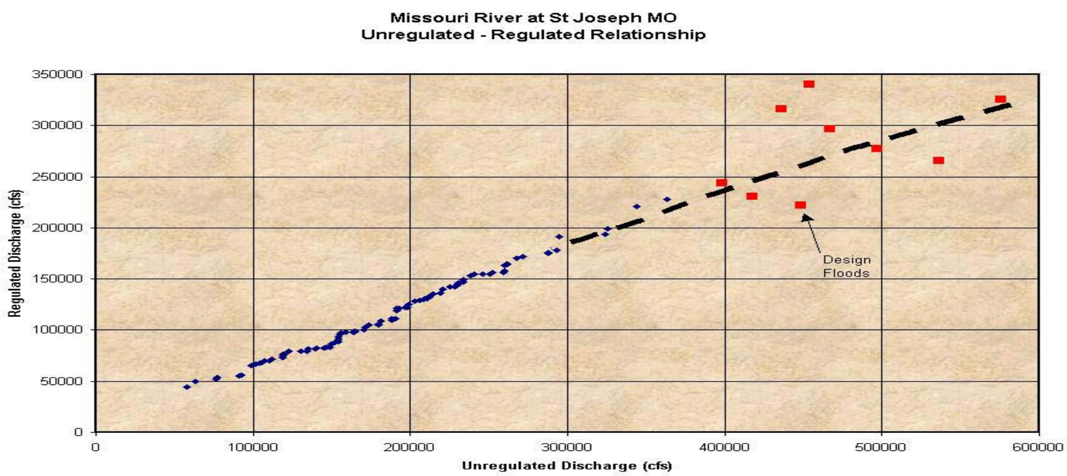

Missouri River at Waverly MO
Unregulated - Regulated Relationship
700000
600000
500000
400000
300000
200000
100000
0
Regulated Discharge (cfs)
0
100000
200000
300000
400000
500000
600000
700000
800000
900000
Unregulated Discharge (cfs)
Design Floods

Plate E-18


Missouri River at Kansas City MO
Unregulated - Regulated Relationship
Regulated Discharge (cfs)
Unregulated Discharge (cfs)
Design Floods
0
100000
200000
300000
400000
500000
600000
700000
800000


Missouri River at St Joseph MO
Unregulated - Regulated Relationship
Regulated Discharge (cfs)
Unregulated Discharge (cfs)
Design Floods
0
50000
100000
150000
200000
250000
300000
350000
400000
500000
600000

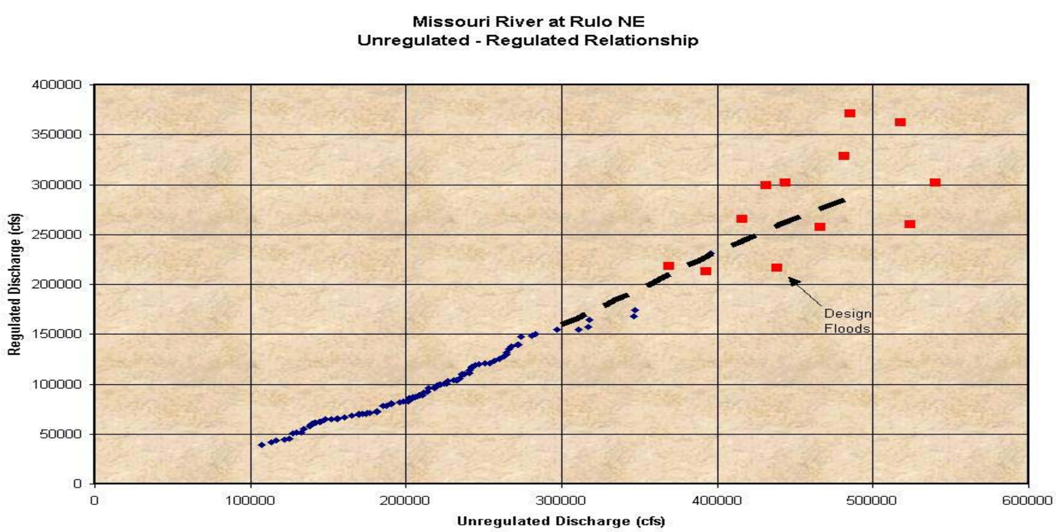

Missouri River at Rulo NE
Unregulated - Regulated Relationship
Regulated Discharge (cfs)
Unregulated Discharge (cfs)
Design Floods
0
50000
100000
150000
200000
250000
300000
350000
400000
500000
600000

Plate E-19

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Upper Mississippi River System Flow Frequency Study
Discharge Estimates
Kansas City District

Location	Missouri River River Mile	Missouri River Drainage Area	0.2	0.5	1	2	5	10	20	50	80	90	95	99
						Chance of Occurance in Percent								25-Feb-03 Rev 14 Mar 03
Mouth	0	524110	***	***	***	***	515000	443000	367000	250000	166000	133000	110000	86000
Coldwater Creek (ds)	6.9	524097	***	***	***	***	515000	443000	367000	250000	166000	133000	110000	86000
Coldwater Creek (us)	6.9	523969	***	***	***	***	515000	443000	366000	250000	166000	133000	110000	86100
St Charles	28.1	523969	829000	742000	674000	606000	515000	443000	366000	250000	166000	133000	110000	86100
Creve Coeur Creek (ds)	30.7	523969	829000	742000	674000	606000	515000	443000	366000	250000	166000	133000	110000	86100
Creve Coeur Creek (us)	30.7	523801	830000	742000	674000	606000	514000	442000	366000	249000	166000	133000	110000	86200
Femme Osage Creek (ds)	49.1	523801	830000	742000	674000	606000	514000	442000	366000	249000	166000	133000	110000	86200
Femme Osage Creek (us)	49.1	523423	831000	742000	674000	605000	513000	441000	365000	249000	166000	134000	110000	86500
Charrette Creek (ds)	67.6	523423	831000	742000	674000	605000	513000	441000	365000	249000	166000	134000	110000	86500
Charrette Creek (us)	67.6	523060	832000	742000	673000	605000	512000	440000	364000	249000	166000	134000	111000	86700
Lost Creek (ds)	90.8	523060	832000	742000	673000	605000	512000	440000	364000	249000	166000	134000	111000	86700
Lost Creek (us)	90.8	522488	833000	742000	673000	604000	511000	439000	363000	248000	166000	134000	111000	87000
Hermann Gage	97.9	522488	833000	742000	673000	604000	511000	439000	363000	248000	166000	134000	111000	87000
Gasconade River (ds)	104.4	522488	833000	742000	673000	604000	511000	439000	363000	248000	166000	134000	111000	87000
Gasconade River (us)	104.4	518906	837000	739000	666000	595000	501000	429000	354000	243000	165000	135000	113000	88600
Baileys Creek (ds)	107.9	518906	837000	739000	666000	595000	501000	429000	354000	243000	165000	135000	113000	88600
Baileys Creek (us)	107.9	518768	837000	739000	666000	595000	500000	429000	354000	243000	165000	135000	113000	88700
Auxvasse River (ds)	120.6	518769	837000	739000	666000	595000	500000	429000	354000	243000	165000	135000	113000	88700
Auxvasse River (us)	120.6	518168	836000	738000	665000	593000	498000	427000	352000	242000	165000	135000	113000	88900
Osage River (ds)	130.1	518168	836000	738000	665000	593000	498000	427000	352000	242000	165000	135000	113000	88900
Osage River (ds)	130.1	503080	774000	668000	591000	520000	430000	365000	300000	210000	149000	126000	109000	86300
Moreau River (ds)	138.2	503080	774000	668000	591000	520000	430000	365000	300000	210000	149000	126000	109000	86300
Moreau River (us)	138.2	502387	768000	662000	586000	515000	426000	361000	297000	208000	148000	125000	109000	85800
Jefferson City	143.9	502387	768000	662000	586000	515000	426000	361000	297000	208000	148000	125000	109000	85800
Cedar Creek (ds)	148.2	502387	768000	662000	586000	515000	426000	361000	297000	208000	148000	125000	109000	85800
Cedar Creek (us)	148.2	501819	763000	658000	582000	511000	422000	358000	294000	206000	147000	125000	108000	85400
Perchee Ck (ds)	170.6	501819	763000	658000	582000	511000	422000	358000	294000	206000	147000	125000	108000	85400
Perchee Ck (us)	170.6	501065	757000	651000	576000	506000	418000	354000	291000	204000	146000	124000	107000	84800
Moniteau Ck (ds)	186.5	501065	757000	651000	576000	506000	418000	354000	291000	204000	146000	124000	107000	84800
Moniteau Ck (us)	186.5	500652	753000	648000	573000	503000	415000	352000	289000	203000	145000	123000	107000	84500
Booneville Gage	196.6	500652	753000	648000	573000	503000	415000	352000	289000	203000	145000	123000	107000	84500
Lamine River (ds)	202.5	500652	753000	648000	573000	503000	415000	352000	289000	203000	145000	123000	107000	84500
Lamine River (us)	202.5	497869	725000	623000	550000	482000	397000	336000	276000	194000	139000	119000	104000	82100
Glasgow	226.3	497869	725000	623000	550000	482000	397000	336000	276000	194000	139000	119000	104000	82100
Little Chariton River (ds)	227.2	497869	725000	623000	550000	482000	397000	336000	276000	194000	139000	119000	104000	82100
Little Chariton River (us)	227.2	497108	717000	615000	543000	476000	392000	332000	272000	192000	138000	118000	103000	81300
Chariton River (ds)	238.8	497108	717000	615000	543000	476000	392000	332000	272000	192000	138000	118000	103000	81300
Chariton River (us)	238.8	494542	687000	589000	519000	454000	374000	317000	260000	183000	132000	113000	98900	78500
Grand River (ds)	250	494542	687000	589000	519000	454000	374000	317000	260000	183000	132000	113000	98900	78500
Grand River (us)	250	486659	573000	490000	432000	378000	311000	264000	216000	153000	111000	95100	84000	67300
Wakenda Creek (ds)	262.8	486659	573000	490000	432000	378000	311000	264000	216000	153000	111000	95100	84000	67300
Wakenda Creek (us)	262.8	486237	566000	484000	427000	374000	308000	261000	214000	151000	110000	94000	83100	66600

Plate E-20

Plate E-20 (cont)

Location	Missouri River River Mile	Missouri River Drainage Area	0.2	0.5	1	2	5	10	20	50	80	90	95	99
			Chance of Occurance in Percent											
Moss Creek (ds)	288.1	486237	566000	484000	427000	374000	308000	261000	214000	151000	110000	94000	83100	66600
Moss Creek (us)	288.1	485942	561000	480000	424000	371000	305000	258000	212000	150000	109000	93200	82400	66100
Waverly Gage	293.5	485942	561000	480000	424000	371000	305000	258000	212000	150000	109000	93200	82400	66100
Crooked River (ds)	313.6	485942	561000	480000	424000	371000	305000	258000	212000	150000	109000	93200	82400	66100
Crooked River (us)	313.6	485492	553000	474000	418000	366000	301000	255000	209000	148000	107000	92000	81400	65300
Sin-a-bar Creek (ds)	321.1	485492	553000	474000	418000	366000	301000	255000	209000	148000	107000	92000	81400	65300
Sin-a-bar Creek (us)	321.1	485121	547000	468000	413000	362000	298000	252000	207000	146000	106000	91000	80500	64700
Fishing River (ds)	334	485121	547000	468000	413000	362000	298000	252000	207000	146000	106000	91000	80500	64700
Fishing River (us)	334	484853	542000	465000	410000	359000	295000	250000	205000	145000	105000	90300	79900	64200
Little Blue River (ds)	339.5	484853	542000	465000	410000	359000	295000	250000	205000	145000	105000	90300	79900	64200
Little Blue River (us)	339.5	484444	535000	459000	405000	354000	292000	247000	203000	143000	104000	89200	78900	63500
Blue River (ds)	358	484444	535000	459000	405000	354000	292000	247000	203000	143000	104000	89200	78900	63500
Blue River (us)	358	484137	530000	454000	401000	351000	289000	245000	201000	142000	103000	88300	78100	62900
Kansas City Gage	366.1	484137	530000	454000	401000	351000	289000	245000	201000	142000	103000	88300	78100	62900
Kansas River (ds)	366.4	484137	530000	454000	401000	351000	289000	245000	201000	142000	103000	88300	78100	62900
Kansas River (us)	366.4	423553	358000	316000	289000	257000	220000	192000	162000	120000	86500	77200	68500	55100
Brush/Line Creeks (us)	372.1	423553	358000	316000	289000	257000	220000	192000	162000	120000	86500	77200	68500	55100
Brush/Line Creeks (us)	372.1	423409	356000	315000	287000	256000	219000	191000	161000	120000	86300	76900	68200	54900
Platte River (ds)	391	423409	356000	315000	287000	256000	219000	191000	161000	120000	86300	76900	68200	54900
Platte River (us)	391	420906	330000	292000	266000	238000	203000	178000	150000	111000	83000	72100	63900	51400
Bee Creek (ds)	401.3	420906	330000	292000	266000	238000	203000	178000	150000	111000	83000	72100	63900	51400
Bee Creek (us)	401.3	420675	328000	291000	264000	236000	202000	177000	149000	111000	82600	71600	63500	51100
Sugar Creek (ds)	418.3	420675	328000	291000	264000	236000	202000	177000	149000	111000	82600	71600	63500	51100
Sugar Creek (us)	418.3	420536	327000	290000	263000	235000	201000	176000	149000	110000	82400	71400	63300	50900
Independence Creek (ds)	424.1	420536	327000	290000	263000	235000	201000	176000	149000	110000	82400	71400	63300	50900
Independence Creek (us)	424.1	420091	324000	287000	261000	233000	199000	174000	147000	109000	81700	70600	62600	50400
St Joseph Gage	448.2	420091	324000	287000	261000	233000	199000	174000	147000	109000	81700	70600	62600	50400
Nodaway River (ds)	462.9	420091	324000	287000	259000	233000	199000	174000	147000	109000	81700	70600	62600	50400
Nodaway River (us)	462.9	418156	323000	285000	256000	225000	191000	167000	141000	104000	78300	67300	59800	48400
Wolf River (ds)	479.4	418156	323000	285000	256000	225000	191000	167000	141000	104000	78300	67300	59800	48400
Wolf River (us)	479.4	417828	322000	284000	255000	224000	190000	166000	140000	103000	77700	66700	59300	48100
Little Tarkio Ck (ds)	486.2	417828	322000	284000	255000	224000	190000	166000	140000	103000	77700	66700	59300	48100
Little Tarkio Ck (us)	486.2	417446	322000	284000	254000	223000	189000	164000	138000	102000	77000	66100	58800	47800
Tarkio River (ds)	492.3	417446	322000	284000	254000	223000	189000	164000	138000	102000	77000	66100	58800	47800
Tarkio River (us)	492.3	416826	321000	283000	253000	222000	187000	163000	137000	100000	75700	65100	58100	47300
Big Nemaha River (ds)	494.9	416826	321000	283000	253000	222000	187000	163000	137000	100000	75700	65100	58100	47300
Big Nemaha River (us)	494.9	414900	320000	281000	250000	220000	184000	158000	132000	96100	71600	62300	55800	46100
Rulo Gage	498	414900	320000	281000	250000	220000	184000	158000	132000	96100	71600	62300	55800	46100

Notes:

1. Flows in these reaches are indeterminate, due to the crossover flow into the Mississippi River
2. Drainage areas based on Jan 2003 study which assumes the 414900 sm USGS listing for the gage at Rulo NE is correct

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SUBJECT	SMITHVILLE LAKE	LONGVIEW LAKE	BLUE SPRINGS LAKE	RATHBUN LAKE	LONG BRANCH LAKE	REMARKS
GENERAL						
Location of Dam	Near Smithville, MO	Kansas City, MO	Kansas City, MO	Near Rathbun, IA	Near Macon, MO	(1) With pool at multipurpose level.
Stream / River	Little Platte River	Little Blue River	East Fork Little Blue River	Chariton River	East Fork Little Chariton River	(2) Damming height is from valley floor to top of flood control pool.
Miles above Mouth	13.6	42.9	28.8	142.3	78	(3) Based on latest available storage data. The dates of the current
Contributing Drainage Area, sq miles	213	50.3	32.8	549	109	area capacity tables are indicated below with the effective dates in
Approximate Length of Full Reservoir, miles	18	3.5	2.5	14	9	parenthesis:
Shoreline, miles (1)	175	24	12	155	24.2	Smithville Lake, February 1990 (effective 1 March 1990)
Maximum Discharge of Record Near Damsite	76,600 cfs (20 July 1965)	18,700 cfs (13 August 1982)	11,000 cfs (13 August 1982)	21,800 cfs (31 March 1960)	30,000 cfs (21 April 1973)	Longview Lake, May 1970 (initial)
Date of Closure	13 July 1976	16 June 1983	12 August 1986	29 September 1967	3 September 1976	Blue Springs Lake, September 1974 (initial)
Date Storage Began	19 October 1979	16 September 1985	27 September 1988	21 November 1969	2 August 1978	Rathbun Lake, January 1982 (effective 1 January 1982)
Multipurpose Level Reached	11 June 1982	21 September 1986	18 March 1990	10 October 1970	19 May 1981	Long Branch Lake, January 1989 (effective 1 July 1989)
Operating Agency	Corps of Engineers	Corps of Engineers	Corps of Engineers	Corps of Engineers	Corps of Engineers	(4) Spillway flood routing at Long Branch Lake revised for Emergency
DAM AND EMBANKMENT						Action Plan, dated 1981.
Top of Dam Elevation, feet msl	895	926.6	840	946	826	(5) The Rathbun outlet works cannot discharge more than 1,800 cfs
Length of Dam, feet (net)	4,000	1,900	2,500	10,600	3,550	without special approval from the Water Control office. Flows above
Damming Height, feet (2)	80.2	110	70	82	71	1,800 cfs result in overtopping of the outlet works stilling basin walls.
Type of Fill	Rolled Earth	Earth	Earth and Rock	Rolled Earth	Rolled Earth	
Fill Quantity, cubic yards	3,200,000	2,500,000	1,200,000	4,700,000	1,855,000	
SPILLWAY						
Location	Right Abutment	Left Abutment	Left Abutment	Right Abutment	Right Abutment	
Crest Elevation, feet msl	880.2	911.3	823.6	926	809	
Width, feet	50	200	300	500	50	
Number, Size, and Type of Gates	None	None	None	None	None	
Discharge Capacity, Top of Surcharge Pool	4,800 cfs	22,970 cfs	37,800 cfs	45,600 cfs	9,860 cfs (4)	
RESERVOIR (3)						**Chapter 2 TOTALS**
Surcharge Pool Elevation and Area	891.1 ft msl 14,611 ac	922.9 ft msl 3,207 ac	837.7 ft msl 1,200 ac	940.0 ft msl 29,475 ac	821.2 ft msl 6,608 ac (4)	55,101 ac
Flood Control Pool Elevation and Area	876.2 ft msl 9,990 ac	909.0 ft msl 1,964 ac	820.3 ft msl 982 ac	926.0 ft msl 20,974 ac	801.0 ft msl 3,663 ac	37,573 ac
Multipurpose Pool Elevation and Area	864.2 ft msl 7,115 ac	891.0 ft msl 927 ac	802.0 ft msl 722 ac	904.0 ft msl 10,989 ac	791.0 ft msl 2,429 ac	22,182 ac
Recreation Pool Elevation and Area		870.0 ft msl 432 ac				432 ac
Surcharge Storage	(891.1 - 876.2) 182,198 af	(922.9 - 909.0) 35,370 af	(837.7 - 820.3) 19,039 af	(940.0 - 926.0) 349,499 af	(821.2 - 801.0) 101,888 af (4)	687,994 af
Flood Control Storage	(876.2 - 864.2) 101,777 af	(909.0 - 891.0) 24,810 af	(820.3 - 802.0) 15,715 af	(926.0 - 904.0) 345,791 af	(801.0 - 791.0) 30,327 af	518,420 af
Multipurpose Storage	(864.2 - 799.0) 141,666 af	(891.0 - 870.0) 13,579 af	(802.0 - 760.0) 10,842 af	(904.0 - 855.0) 199,830 af	(791.0 - 751.1) 34,189 af	400,106 af
Recreation Storage		(870.0 - 810.4) 8,555 af				8,555 af
Gross Storage	(876.2 - 799.0) 243,443 af	(909.0 - 810.4) 46,944 af	(820.3 - 760.0) 26,557 af	(926.0 - 855.0) 545,621 af	(801.0 - 751.0) 64,516 af	927,081 af
Sediment Reserve Storage	52,300 af	2,000 af	300 af	24,000 af	4,000 af	82,600 af
Estimated Annual Sediment Inflow	523 af 100 years	20 af 100 years	3 af 100 years	240 af 100 years	40 af 100 years	
OUTLET WORKS						
Location	Right Abutment	Left Abutment	Right Abutment	Right Abutment	Right Abutment	
River Outlet Type	Rectangular Conduit	Concrete Arch	Arch Conduit	Horseshoe Conduit	Concrete Arch	ac = acres
Number and Size of Conduit	1 - 8’x9’	1 - 5.5’x5’	1 - 3.5’x4.75’	1 - 11’	1 - 6’x5.5’	af = acre-feet
Length of Conduit, feet	696	916	485	539	450	ft = feet
Entrance Invert Elevation	805 ft msl	816 ft msl	768.5 ft msl	855 ft msl	760 ft msl	msl = elevation above mean sea level
Drop Inlet Crest Elevation		891	802.0 ft msl			cfs = cubic feet per second
Low Flow Gate Intake Elevation		875 – 861	791.5			
Discharge Cap, Top Flood Control Pool	3,150 cfs	1,200 cfs	570 cfs	5,160 cfs (5)	910 cfs	
Discharge Cap, Top of Multipurpose Pool	2,940 cfs	0 (except low flow outlets)	0 (except low flow outlets)	4,220 cfs (5)	495 cfs	
Service Gates, Number and Size	2 - 4.25’x9.25’ Slide			2 - 6’x12’ Slide	2 - 24” Slide	
Emergency Gates, Number and Size	2 - 4.25’x9.25’ Slide	1 - 6’x7’	1-4.5’x5’	2 - 6’x12’ Slide	1 - 6’x6’	
Low Flow Gates, Number, Size, Type		2 - 24” Knife Valves	1-2’ Knife Valve			
Low Flow Gates, Number and Size	1 - 2’x2’	2 - 24” Knife Valves	1-2’ Knife Valve	2 - 2’ x2’ Slide	1 - 18” Slide	
Provision for Water Supply	1 - 5.75’ Pipe					
Provision for Power	None	None	None	None	None	

SUMMARY OF ENGINEERING DATA
LOWER MISSOURI RIVER BASIN PROJECTS

US Army Corps of Engineers
Kansas City Distict
December 1999

Plate E-21

SUBJECT	MILFORD LAKE	TUTTLE CREEK LAKE	PERRY LAKE	CLINTON LAKE	REMARKS
GENERAL					
Location of Dam	Near Junction City, KS	Near Manhatten, KS	Near Perry, KS	Near Lawrence, KS	
Stream / River	Republican River	Big Blue River	Delaware River	Wakanusa River	
Miles above Mouth	7.7	10	5.3	22.2	
Contributing Drainage Area, sq miles	17,388 (4)	9,628	1,117	367	
Approximate Length of Full Reservoir, miles	30	50	20	17	
Shoreline, miles (1)	163	112	160	82	
Maximum Discharge of Record near Damsite	171,000 cfs (3 June 1935)	98,000 cfs (June 1951)	94,600 cfs (June 1951)	24,200 cfs (July 1951)	
Date of Closure	24 August 1964	20 July 1959	2 August 1966	23 August 1975	
Date Storage Began	16 January 1967	7 March 1962	15 January 1969	30 November 1977	
Multipurpose Level Reached	14 July 1967	30 April 1963	3 June 1970	3 April 1980	
Operating Agency	Corps of Engineers	Corps of Engineers	Corps of Engineers	Corps of Engineers	
DAM AND EMBANKMENT					
Top of Dam Elevation, feet msl	1,213	1,159	946	928	
Length of Dam, feet (net)	6,300	7,487	7,750	9,250	
Damming Height, feet (2)	110.2	134	95	114	
Type of Fill	Earth	Earth, Rock	Earth	Earth	
Fill Quantity, cubic yards	15,000,000	21,000,000	8,000,000	10,423,000	
SPILLWAY					
Location	Right Abutment	Left Abutment	Left Abutment	Left Abutment	
Crest Elevation, feet msl	1,176.2	1,116	922	907.4	
Width, feet	1,250	1,059	300	500	
Number, Size, and Type of Gates	None	18 - 40'x20' Tainter	None	None	
Discharge Capacity, Top of Surcharge Pool	560,000 cfs	579,000 cfs	65,000 cfs	44,200 cfs	
RESERVOIR (3)					**Chapter 3 TOTALS**
Surcharge Pool Elevation and Area	1,208.2 ft msl 59,886 ac	1,151.4 fr msl 69,900 ac	941.2 ft msl 42,656 ac	921.4 ft msl 18,336 ac	190,778 ac
Flood Control Pool Elevation and Area	1,176.2 ft msl 32,979 ac	1,136.0 ft msl 53,679 ac	920.6 ft msl 25,363 ac	903.4 ft msl 12,890 ac	124,911 ac
Multipurpose Pool Elevation and Area	1,144.4 ft msl 15,709 ac	1,075.0 ft msl 12,367 ac	891.5 ft msl 11,146 ac	875.5 ft msl 7,120 ac	46,342 ac
Surcharge Storage	(1,208.2 - 1,176.2) 1,442,049 af	(1,151.4 - 1,136.0) 957,179 af	(941.2 - 920.6) 692,375 af	(921.4 - 903.4) 285,809 af	3,377,412 af
Flood Control Storage	(1,176.2 - 1,144.4) 756,669 af	(1,136.0 - 1,075.0) 1,895,828 af	(920.6 - 891.5) 515,795 af	(903.4 - 875.5) 268,783 af	3,437,075 af
Multipurpose Storage	(1,144.4 - 1,080.0) 388,816 af	(1,075.0 - 1,010.0) 298,883 af	(891.5 - 835.0) 209,513 af	(875.5 - 820.0) 125,334 af	1,022,546 af
Gross Storage	(1,176.2 - 1,080.0) 1,145,485 af	(1,136.0 - 1,010.0) 2,194,711 af	(920.6 - 835.0) 725,308 af	(903.4 - 820.0) 394,117 af	4,459,621 af
Sediment Reserve Storage	160,000 af	233,000 af	140,000 af	28,500 af	561,500 af
Estimated Annual Sediment Inflow	1,600 af 100 years	4,700 af 50 years	1,400 af 100 years	285 af 100 years	
OUTLET WORKS					
Location	Right Abutment	Right Abutment	Near Center of Dam	Left Abutment	
River Outlet Type	Gated Conduit	Gated Conduit	Gated Conduit	Gated Conduit	
Number and Size of Conduit	1 - 21'	2 - 20'	1 - 23.5'	1 - 12.5'x13' Arch	
Length of Conduit, feet	615.5	860	592	710	
Entrance Invert Elevation	1,080 ft msl	1,003 ft msl	833 ft msl	828 ft msl	
Gated Sluice, Number and Size	None	None	None	None	
Discharge Cap, Top of Flood Control Pool	23,100 cfs	45,900 cfs	27,500 cfs	7,570 cfs	
Discharge Cap, Top of Multipurpose Pool	18,600 cfs	31,300 cfs	21,200 cfs	5,900 cfs	
Service Gates, Number and Size	2 - 10.5'x21'	4 - 10'x20'	2 - 11.75'x23.5'	2 - 6.33'x12.67'	
Emergency Gates, Number and Size	2 - 10.5'x21'	1 - 10'x20'	2 - 11.75'x23.5'	1 - 6.33'x12.67'	
Low Flow Gates, Number and Size	2 - 2'x2'	2 - 24" Butterfly Valve	2 - 2'x2'	1 - 24" Knife Gate Value	
Water Supply Gate, Number and Size	None	None	None	1 - 54"x54" Slide Gate	
Provision for Irrigation	None	None	None	None	
Provision for Power	None	None	None	None	
Provision for Water Supply	None	None	None	36" Steel Pipe	

REMARKS

(1) With pool at multipurpose level.
(2) Damming height is from valley floor to top of flood control pool.
(3) Based on latest available storage data. The dates of the current area - capacity tables are indicated below with the effective dates in parentheses:
Milford Lake, March 1982 (effective 10 March 1982)
Tuttle Creek Lake, December 1996 (effective 1 February 1999)
Perry Lake, May 1990 (effective 1 June 1990)
Clinton Lake, December 1991 (effective 1 March 1994)
(4) Total drainage area above Milford is 38,621 square miles. The indicated total is the local drainage area below Harlan County Dam.

ac = acres
af = acre-feet
ft = feet
msl = elevation above mean sea level
cfs = cubic feet per second

SUMMARY OF ENGINEERING DATA
LOWER KANSAS RIVER BASIN PROJECTS

US. Army Corps of Engineers
Kansas City District
December 1999

Plate E-22

Chapter 4 SUBJECT	BONNY RESERVOIR	SWANSON LAKE	ENDERS RESERVOIR	HUGH BUTLER LAKE	HARRY STRUNK LAKE	KEITH SEBELIUS LAKE (Norton Dam)	HARLAN COUNTY LAKE	LOVEWELL RESERVOIR	REMARKS
GENERAL									
Location of Dam	Near Hale, CO	Near Trenten, NE	Near Enders, NE	Near McCook, NE	Near Cambridge, NE	Near Norton, KS	Nr Republican City, NE	Near Lovewell, KS	(1) With pool at MP level.
Stream / River	S. Fk Republican River	Republican River	Frenchman Creek	Red Willow Creek	Medicine Creek	Prairie Dog Creek	Republican River	White Rock Creek	(2) Damming height is
Miles above Mouth	60.4	359	81.7	18.7	11.9	74.9	232.3	19.3	from valley floor to top of
Contributing Drain Area, sq miles	1,435	3,941	786	310	642	688	13,536	358	flood control pool.
Approx Length of Full Resv, miles	5.5	9.0	6.0	7.5	8.5	9.5	17	11	(3) Based on latest storage
Shoreline, miles (1)	15.0	30	26	35	29	32	54	44	data. Date of current area
Max. Disch. of Record near Damsite	103,000 (31 May 1935)	200,000 (31 May 1935)	Insufficient Data	30,000 (22 June 1947)	120,000 (June 1947)	37,500 (28 May 1953)	260,000 (1 June 1935)	23,300 (10 July 1950)	capacity tables given below
Date of Closure	6 July 1950	4 May 1953	23 October 1950	5 September 1961	8 August 1949	28 January 1964	22 July 1951	29 May 1957	with effective date in ( ).
Date Storage Began	6 July 1950	4 May 1953	23 October 1950	5 September 1961	8 August 1949	5 October 1964	14 November 1952	2 October 1957	Bonny, Mar 51 (initial)
Multipurpose Level Reached	19 March 1954	15 May 1957	29 January 1952	21 May 1967	2 April 1951	21 June 1967	14 June 1957	20 May 1958	Swanson, Feb 84 (Feb 84)
Operating Agency	Bureau of Reclamation	Bureau of Reclamation	Bureau of Reclamation	Bureau of Reclamation	Bureau of Reclamation	Bureau of Reclamation	Corps of Engineers	Bureau of Reclamation	Enders, May 97 (1 Jan 99)
DAM AND EMBANKMENT									Butler, May 97 (1 Jan 99)
Top of Dam Elevation, feet msl	3,742.0	2,793.0	3,137.5	2,634.0	2,415.0	2,347.0	1,982.0	1,616.0	Strunk, May 81 (Oct 82)
Length of Dam, feet (Less Spillway)	9,141.5	8,600	2,242	3,159	5,665	6,344	11,830	8,392	Sebelius, Jan 65 (initial)
Damming Height, feet (2)	93.0	80.0	93.0	About 85	86	85.5	98.5	70.3	Harlan, Dec 89 (1 Jan 90)
Type of Fill	Earth	Earth	Earth	Earth	Earth	Earth	Earth	Earth	Lovewell, Jun 95 (1 Jan 97)
Fill Quantity, cubic yards	8,853,000	8,130,000	1,950,000	3,122,000	2,730,000	3,740,000	13,400,000	3,000,000	(4) Bartley Div Dam, Rep
SPILLWAY									R. below Red Willow Ck,
Location	Left Abutment	Left Abutment	Right Abutment	Right Abutment	Left Abutment	Right Abutment	Center of Dam	Right Abutment	conc ogee weir w/2-10x16
Crest Elevation, feet msl	3,710.0	2,743.0	3,097.0	2,604.9	2,386.2 (see also below)	2,296.0	1,943.5	1,575.3	gates to rivr, 2-10'x3' gates
Width, feet	121.5	142	361	31.5 (circ morning glory)	229	106	856	53	to canal, max cap 130 cfs.
Number, Size, and Type of Gates	None (see notes below)	3 - 42' x 30' Radial	6 - 50' x 30' Radial	None	None	3 - 30'x36.35' Radial	18 - 40'x30' Radial	2 - 25'x20' Radial	Franklin pumps on Rep R.
Disch. Cap. Top of Surcharge Pool	73,300 cfs (with sluice)	126,000 cfs	202,000 cfs (with notch)	4,910 cfs	99,000 cfs (with notch)	96,000 cfs	480,000 cfs	35,000 cfs	blw Harlan Cty, cap 40 cfs.
RESERVOIR (3)									**TOTALS**
Surcharge Pool Elev (ft msl), Area	3,736.2 8,579 ac	2,785.0 10,035 ac	3,129.5 ft msl 2,557 ac	2,628.0 ft msl 4,079 ac	2,408.9 ft msl 5,784 ac	2,341.0 ft msl 6,713 ac	1,975.5 ft msl 24,135 ac	1,610.3 ft msl 7,635 ac	69,517 ac
Flood Cntrl Pool Elev (ft msl), Area	3,710.0 5,036 ac	2,773.0 7,940 ac	3,127.0 ft msl 2,405 ac	2,604.9 ft msl 2,681 ac	2,386.2 ft msl 3,483 ac	2,331.4 ft msl 5,316 ac	1,973.5 ft msl 22,820 ac	1,595.3 ft msl 5,024 ac	54,705 ac
MP, or Top Cons Pool Elev, Area	3,672.0 2,042 ac	2,752.0 4,922 ac	3,112.3 ft msl 1,707 ac	2,581.8 ft msl 1,621 ac	2,366.1 ft msl 1,840 ac	2,304.3 ft msl 2,181 ac	1,946.0 ft msl 13,262 ac	1,582.6 ft msl 2,987 ac	30,562 ac
Inactive Pool Elev (ft msl), Area	3,638.0 331 ac	2,720.0 1,411 ac	3,082.4 ft msl 627 ac	2,558.0 ft msl 715 ac	2,343.0 ft msl 701 ac	2,280.4 ft msl 587 ac	1,927 ft msl 7,365 ac	1,571.7 ft msl 1,495 ac	13,232 ac
Dead Stor Pool Elev (ft msl), Area	3,635.5 242 ac	2,710.0 488 ac	3,080.0 ft msl 577 ac	2,552.0 ft msl 536 ac	2,335.0 ft msl 481 ac	2,275.0 ft msl 391 ac	1,885.0 ft msl 0 ac	1,562.07 ft msl 494 ac	3,209 ac
Surcharge Storage, af	(3,736.2-3,710) 178,230	(2,785 - 2,773) 107,610	(3,129.5 - 3,127) 6,203	(2,628.0-2,604.9) 76,829	(2,408.9-2,386.2)105660	(2,341 - 2,331.4) 58,285	(1,975.5-1,973.5) 46,947	(1,610.3-1,595.3) 94,140	673,904 af
Flood Control Storage, af	(3,710 - 3,672) 128,820	(2,773 - 2,752) 134,077	(3,127 - 3,112.3) 30,048	(2,604.9-2,581.8) 48,846	(2,386.2-2,366.1) 52,715	(2,331.4-2,304.3) 98,803	(1,973.5-1,946) 496,718	(1595.3 - 1582.6) 50,465	1,040,492 af
MP, or Active Conserv Storage, af	(3,672 - 3,638) 39,206	(2,752 - 2,720) 99,784	(3,112.3-3,082.4) 33,962	(2,581.8 - 2,558) 27,303	(2,366.1 - 2,343) 26,846	(2,304.3-2,280.4) 30,651	(1,946-1,932.4) 149,415	(1,582.6-1,571.7) 24,022	431,189 af
Inactive Storage, af	(3,638 - 3,635.5) 716	(2,720 - 2,710) 10,312	(3,082.4 - 3,080) 1,432	(2,558 - 2,552) 3,736	(2,343 - 2,335) 4,699	(2,880.4 - 2,275) 2,566	(1932.4 - 1,885) 165,675	(1,571.7-1,562.07) 9,985	199,121 af
Dead Storage, af	(3,635.5 - 3,617) 1,418	(2,710 - 2,693) 2,118	(3,080 - 3,042) 7,516	(2,552 - 2,511) 5,185	(2,335 - 2,318.5) 4,160	(2,275 - 2,247) 2,718	(Sluice crest at 1,885) 0	(1,562.07-1,535) 1,659	24,774 af
Gross Storage, af	(3,710 - 3,617) 170,160	(2,773 - 2,693) 246,291	(3,127 - 3,042) 72,958	(2,604.9 - 2,511) 85,070	(2,386.2-2,318.5) 88,420	(2,331.4-2,247) 134,738	(1,973.5-1,885) 811,808	(1,595.3 - 1,535) 86,131	1,695,576 af
Sediment Reserve Storage							200,000 af		
Estimated Annual Sediment Inflow	160 af 50 years	1,020 af 50 years	400 af 50 year	200 af 50 years	150 af 50 years	120 af 50 years	2,000 af 100 years	Actual 6024 af (1957-95)	
OUTLET WORKS									Courtland Div Dam, Rep R
Location	Left Abutment	Left Abutment	Right Abutment	Right Abutment	Right Abutment	Left Abutment	Center of Dam	Right Abutment	at Guide Rock, conc ogee
River Outlet Type	Gated Conduit	Gated Conduit	Gated Conduit	Gated Conduit	Gated Conduit	Gated Conduit	Gated Sluices	Spillway gates used for	w/2-20'x12' gates to river
Number and Size of Conduit	1 – 56" Cond to 26" Pipe	2 - 6' x 7.5'	1 - 84" Cond to 84"Pipe	1 - 82"	1 – 84" Cond to 44" Pipe	1 – 48" Cond to 38" Pipe	9 - 5'x8' thru Spillway	river releases. Gated	5-10'x6'gates to Courtland
Length of Conduit, feet	831.5	86.74	516	553.5	553	495 to Gate, 145 to Basin		wasteway with 1-10'x9'	canal (cap 751 cfs), 1-10x6
Entrance Crest Elevation	3,635.5 ft msl	2,710.0 ft msl	3,080.0 ft msl	2,552.0 ft msl	2,335.0 ft msl	2,275.0 ft msl	1,885.0 ft msl	radial gate from outlet	gate to Superior (cap 139).
Disch Cap, Top of Flood Cntrl Pool	140 cfs (approx)	4,300 cfs	1,430 cfs	1,170 cfs	398 cfs (max elev 2,379)	312 cfs	20,700 cfs	canal to stilling basin.	Other private diversion
Disch Cap, Top of MP (Consv) Pool	103 cfs	3,500 cfs	1,300 cfs	990 cfs	361 cfs	257 cfs	17,370 cfs	Wasteway is not used.	weirs exist on some creeks
Service Gates, Number, Size, Type	1 - 24" Hollow Jet Valve	2 - 6' x 7.5' Slide Gates	2-60" Hollow Jet Valves	2 - 42" Slide Gates	1 - 39" Slide Gate	1 - 33" Slide Gate	9 - 5' x 8' Slide Gates	None	like Riverside blw Enders
Provision for Irrigation	1 - 32" Pipe to 24" Valve	1 - 56" Pipe to 4' Gate	None	None	None	None	1-5.5'; 1-2.83' Conduits	1 - 8'x10' Gated Outlet	but div capacity minimal.
Provision for Power	Note: Storage owned by	None	None	None	None	None	12'x12' Plug for 9' Cond	None	ac = acres
Provision for Municipal Supply	CO for F&W, Recreation	None	None	None	None	1 - 16" Pipe to 16" Gate	None	None	af = acre-feet
Other Outlet	1 - 40" Capped Conduit	None	None	None	None	None	Notes: USBR can distrib water equitably to canals to elev 1,927, their base of active consv storage. 1-18" outlet for low flow regulation in mono 20. Franklin Canal conduit to 2-36" gates, cap 520 cfs. Naponee Canal conduit to 1-24" valve, cap 40 cfs. See also note (4)	Note: Inflow to lake also provided from gated Courtland Canal outlet.	ft = feet
									cfs = cubic feet per sec
	Notes: Spillway also has 16.5'x21.5' sluice, with 1 - 16.5' x 10.75'gate, crest elev 3,672.0. The 56" gated outlet conduit feeds all three gated sub outlets. Capacity of irrig pipe outlet limited to 34.5 cfs by canal cap.	Notes: Irrigation outlet in right abutment. River outlets must be closed at pool elevations above 2,773.0.	Notes: Spillway also has an uncontrolled notch w/ crest elevation at 3112.3. Concrete ogee weir diversion dam 52 miles d/s, w/ 2-14' x 9.5' gates plus 30" gated condut to river, and 2- 10'x6' gates to canal (cap 400 cfs).	Note: Concrete ogee weir diversion dam 13 miles downstream, w/ 1-6'x18' radial gate to river, and 2 - 5'x4' regulating gates to canal (max cap 90 cfs) Bartley Diversion Dam located below Rep. R. confluence. See note (4)	Notes: Spillway also has an uncontrolled notch w/ crest elevation at 2366.1. Concrete ogee weir diversion dam at mile 301.6 on Rep. R. blw Med Ck. 2-10'x14'gates to river and 4-10'x14' gates to canal (max cap 325 cfs).	Notes: Concrete ogee weir diversion dam 17.6 miles downstream, with 1 – 6'x18' radial gate to river, 2 – 6'x5' gates to Main Canal (cap 100 cfs) and 2 – 5'x4' gates to South Canal (capacity 36 cfs).			msl = elev abv mean sea lvl

SUMMARY OF ENGINEERING DATA
REPUBLICAN RIVER BASIN PROJECTS

US. Army Corps of Engineers
Kansas City District
December 1999

Plate E-23

SUBJECT	WACONDA LAKE	KIRWIN RESERVOIR	WEBSTER RESERVOIR	WILSON LAKE	KANOPOLIS LAKE	CEDAR BLUFF RESERVOIR
GENERAL						
Location of Dam	Near Glen Elder, KS	Near Kirwin, KS	Near Stockton, KS	Near Wilson, KS	Near Ellsworth, KS	Near Ellis, KS
Stream / River	Solomon River	North Fork Solomon River	South Fork Solomon River	Saline River	Smoky Hill River	Smoky Hill River
Miles above Mouth	172.4	67.8	92.4	153.9	183.7	333.4
Contributing Drain Area, sq miles	5,076 total (4)	1,367	1,150	1,917	7,860 total contributing (6)	5,365 total contributing
Approx Length of Full Reservoir, miles (1)	24	9	7	24	12	9
Shoreline, miles (1)	100	37	27	100	41	50
Maximum Discharge of Record near Damsite	125,000 cfs (July 1951)	24,000 cfs (Sep 1919)	55,200 cfs (July 1951)	25,700 cfs (Jul-Aug 1928)	61,000 cfs (June 1938)	98,000 cfs (May 1938)
Date of Closure	18 October 1967	7 March 1955	3 May 1956	3 September 1963	26 July 1946	13 November 1950
Date Storage Began	24 July 1968	5 October 1955	3 May 1956	29 December 1964	17 February 1948	13 November 1950
Multipurpose Level Reached	16 May 1973	2 July 1957	18 June 1957	12 March 1973	19 July 1948	21 June 1951
Operating Agency	Bureau of Reclamation	Bureau of Reclamation	Bureau of Reclamation	Corps of Engineers	Corps of Engineers	Bureau of Reclamation
DAM AND EMBANKMENT						
Top of Dam Elevation, feet msl	1,500.0	1,779.0	1,944.0	1,592.0	1,537.0	2,198.0
Length of Dam, feet (Less Spillway)	14,631	12,246	10,604	5,600	15,360	12,409.5
Damming Height, feet (2)	107.9	95	84.7	114	102	102
Type of Fill	Earth	Earth	Earth	Earth	Earth	Earth
Fill Quantity, cubic yards	8,050,000	9,537,000	8,145,000	8,500,000	15,200,000	8,490,000
SPILLWAY						
Location	Right Abutment	Right Abutment	Left Abutment	Right Abutment	Right Abutment	Right Abutment
Crest Elevation, feet msl	1,467.4	1,757.3	1,884.6	1,582.0	1,507.0	2,166.0
Width, feet	644	400 (uncontrolled)	116	450 (uncontrolled)	500 (uncontrolled)	150.5 (uncontrolled length)
Number, Size, and Type of Gates	12 - 50'x21.76' Radial	None, but see note below	3 – 33.33'x39.51' Radial	None	None	Gated orifice, see note blw
Discharge Capacity at Top of Surcharge Pool	278,000 cfs	96,000 cfs (sluices closed)	138,000 cfs	15,700 cfs	172,000 cfs	84,000 cfs (with orifice)
RESERVOIR (3)						
Surcharge Pool Elevation (ft msl), Area	1,492.9 ft msl 38,178 ac	1,773.0 ft msl 14,660 ac	1,938.0 ft msl 11,270 ac	1,587.5 ft msl 33,882 ac	1,531.8 ft msl 23,408 ac	2,192.0 ft msl 16,510 ac
Flood Control Pool Elevation (ft msl), Area	1,488.3 ft msl 33,682 ac	1,757.3 ft msl 10,639 ac	1,923.7 ft msl 8,478 ac	1,554.0 ft msl 20,027 ac	1,508.0 ft msl 13,958 ac	2,166.0 ft msl 10,790 ac
Multipurpose, or Top Cons Pool Elev, Area	1,455.6 ft msl 12,602 ac	1,729.25 ft msl 5,071 ac	1,892.45 ft msl 3,767 ac	1,516.0 ft msl 9,045 ac	1,463.0 ft msl 3,406 ac	2,144.0 ft msl 6,869 ac
Inactive Pool Elevation (ft msl), Area	1,428.0 ft msl 3,341 ac	1,697.0 ft msl 1,006 ac	1,860.0 ft msl 904 ac			2,107.8 ft msl 2,086 ac
Dead Storage Pool Elevation (ft msl), Area	1,407.8 ft msl 350 ac	1,693.0 ft msl 765 ac	1,855.5 ft msl 440 ac			2,090.0 ft msl 909 ac
Surcharge Storage, af	(1492.9-1488.3) 164,966 af	(1,773 - 1,757.3) 198,467 af	(1,938 - 1,923.7) 140,912 af	(1,587.5-1,554) 894,263 af	(1,531.8 - 1,508) 438,655 af	(2,192 - 2,166) 353,230 af
Flood Control Storage, af	(1488.3-1455.6) 722,315 af	(1757.3-1729.25) 215136 af	(1923.7-1892.45) 183353 af	(1,554 - 1,516) 530,204 af	(1,508 - 1,463) 369,278 af	(2,166 - 2,144) 191,860 af
MP, or Active Conservation Storage, af	(1,455.6 - 1,428) 204,789 af	(1,729.25-1,697) 89,639 af	(1,892.45-1,860) 71,926 af	(1,516 - 1,435) 242,528 af	(1,463 - 1,430) 49,474 af	(2,144 - 2,107.8) 149,770 af
Inactive Storage, af	(1,428 - 1,407.8) 35,435 af	(1,697 - 1,693) 3,546 af	(1,860 - 1,855.5) 2,975 af			(2,107.8 - 2,090) 27,059 af
Dead Storage, af	(1,407.8 - 1,386) 1,236 af	(1,693 - 1,662.3) 4,969 af	(1,855.5 - 1,839) 1,256 af			(2,090 - 2,064) 8,261 af
Gross Storage, af	(1,488.3-1,386) 963,775 af	(1757.3-1662.3) 313,290 af	(1,923.7 - 1,839) 259,510 af	(1,554 - 1,435) 772,732 af	(1,508 - 1,430) 418,752 af	(2,166 - 2,064) 376,950 af
Sediment Reserve Storage				40,000 af	51,500 af	
Estimated Annual Sediment Inflow	475 af 50 years	Actual 1,281 af (1955-96)	Actual 1,214 af (1956–96)	400 af 100 years	1,030 af 50 years	260 af 50 years
OUTLET WORKS						
Location	Left Abutment	Center of Dam	Right Abutment	Right Abutment	Right Abutment	Left Abutment
River Outlet Type	Gated Conduit	Gated Conduit	Gated Conduit	Gated Conduit	Gated Conduit (7)	Gated Conduit to River
Number and Size of Conduit	1 - 12.5'	7' Cond to 60" pipe (5)	4.5' Conduit to 48" pipe	1 - 12'	1 - 14'	1 - 5.5'
Length of Conduit, feet	575	(5)	538	1,097	2,443	863.5
Entrance Crest Elevation	1,407.8 ft msl	1,693 ft msl	1,855.5 ft msl	1,450 ft msl	1,415 ft msl	2,090 ft msl
Gated Sluice, Number and Size	None	See note below	None	None	None	8 - 5'x5', gated (8)
Discharge Cap, Top of Flood Control Pool	5,200 cfs	220 cfs (5)	480 cfs	6,500 cfs	6,400 cfs (7)	3,520 cfs (outlet, sluices) (8)
Disch Cap, Top of MP (Conservation) Pool	4,000 cfs	220 cfs (5)	385 cfs	5,300 cfs	4,500 cfs (7)	7,949 cfs (outlet, sluices) (8)
Service Gates, Number, Size, Type	2 - 6.5'x8' Slide Gates	1 - 4'x5' to stilling well (5)	1 - 3.5'x3.5' Slide Gate	2 - 6'x12' Service Gates	2 - 6'x12'	1 - 4'x5'
Emergency Gates, Number and Size	1 - 9'x12' Slide Gates	1 - 4'x5' (5)	1 - 3.5'x3.5' Slide Gate	2 - 6'x12' Slide Gates	1 - 6'x12'	1 - 4'x5'
Low Flow Gates, Number and Size	None	None	None	2 - 2'x2' Slide Gates	None	None
Provision for Irrigation	None	2 - 5.5'x8' openings (5)	None	None	None	1 - 4'x5' (8)
Provision for Power	None	None	None	None	See below	None
Provision for Municipal Supply	Supplied thru river releases.	None	None	None	See below	Thru river releases (9), but
	City of Beloit has contracted for up to 2,000 af of annual storage releases. Mitchell County Rural Water District No. 2 has contracted for up to 1,009 af of annual storage releases.	Note: 15 - 5' x 5' gated sluices located in concrete ogee section below spillway crest. Crest elevation at sluice entrance = 1,720.0. Discharge capacity at top of conserv pool = 4,800 cfs, top, flood pool = 15,350 cfs.	Note: When reservoir elevation is below 1,860, the outlet gate openings must be reduced to prevent air entrainment in conduit.	Note: Low flow gates are mounted in the service gates Low flow gates are used for river releases up to 200 cfs.	Provision for future steel penstock in outlet tunnel for power. Post Rock Irrigation District has supply contract to pump water to a supply pipe from an outlet in the lake near the intake tower.	no releases in recent years. Note: Spillway also has a gated orifice section at center with 1-14.5'x9.58' radial gate, crest elev 2,144. Spillway cap includes ogee and orifice. Sluices located in ogee section below crest.

REMARKS

(1) With pool at multipurpose or full conservation level.
(2) Damming height is height from valley floor to top of flood control pool.
(3) Based on latest available storage data. The dates of the current area - capacity tables are indicated below along with the effective dates in parenthesis:
Waconda, June 1971 (initial)
Kirwin, May 1996 (effective 1 January 1998)
Webster, May 1996 (effective 1 January 1998)
Wilson, December 1984 (effective 1 January 1985)
Kanopolis, February 1983 (effective 1 March 1983)
Cedar Bluff, 1951 (initial)
(4) DA below Kirwin, Webster Dams = 2,559 sq miles
(5) 7' conduit from intake tower to gate chamber. 4'x5' emergency gate to 60" pipe. Entrance to stilling well controlled by 4'x5' slide gate. From stilling well, 42" river outlet pipe controlled by 36" gate. River outlet capacity at top of MP pool and flood control pool about 220 cfs. Length of combined pipes from intake to stilling well about 500'. About 200' more to stilling basin. Canal releases from two openings at top of stilling well. Canal capacity is about 175 cfs, but combined capacity with river outlet about 395 cfs.
(6) DA below Cedar Bluff Dam = 2,330 sq miles

Chapter 5 TOTALS

Surcharge Pool Area	137,908 ac
Flood Control Pool Area	97,754 ac
Multipurpose Pool Area	40,760 ac
Surcharge Storage	2,190,493 af
Flood Control Storage	2,212,146 af
MP, or Active Conservation Storage	808,126 af
Inactive Storage	69,015 af
Dead Storage	15,722 af
Gross Storage	3,105,009 af

(7) In addition to the gated conduit, Kanopolis has an uncontrolled port opening 3.5'x13.75' in the 10' pier separating the two service gate openings. Crest elevation of the port is 1,463 ft msl. The max discharges given for the outlet is the combined total of the port and gates.
(8) River outlet crest elev is 2,090 ft msl. Crest elev of sluices under spillway is 2,134.82 ft msl. River outlet capacity at MP is 804 cfs, at top of flood pool is 909 cfs. Cedar Bluff also has an irrig canal outlet on Y junction from river outlet, 5.5' pipe to control house, canal flow controlled by 4'x5' gate (not used since 1978, irrigation district disbanded in 1994). Also a hatchery supply line from 18" valve on canal outlet, capacity 10 cfs. Lake storage owned by KS, for benefit of recreation and F&W. All releases coordinated with Kansas KDWP.
(9) 2,000 af annual storage supply contract for Russell.

Chapter 6 Abbreviations

ac = acres
af = acre-feet
ft = feet
msl = elevation above mean sea level
Cfs = cubic feet per second
MP = multipurpose pool elevation

SUMMARY OF ENGINEERING DATA
SMOKY HILL RIVER BASIN PROJECTS

U.S. Army Corps of Engineers
Kansas City District
December 1999

Plate E-24

SUBJECT	MELVERN LAKE	POMONA LAKE	HILLSDALE LAKE	STOCKTON LAKE	POMME DE TERRE LAKE	HARRY S. TRUMAN RESERVOIR	REMARKS
GENERAL							
Location of Dam	Near Melvern, KS	Near Pomona, KS	Near Paola, KS	Near Stockton, MO	Near Hermitage MO	Near Warsaw, MO	(1) With pool at multipurpose level.
Stream / River	Marais des Cygnes River	110 Mile Creek	Big Bull Creek	Sac River	Pomme de Terre River	Osage River	(2) Damming height is from valley floor to top of the
Miles above Mouth	175.4	8.3	18.2	51.4	45.6	175.1	flood pool.
Contributing Drainage Area, sq miles	349	322	144	1,160	611	8,914 (4)	(3) Based on latest available storage data. The dates of
Approximate Length of Full Reservoir, miles	22	12	15	24	28	122	the current area - capacity tables are indicated below
Shoreline, miles (1)	101	52	51	298	113	958	with the effective dates in parentheses:
Maximum Discharge of Record near Damsite	68,500 cfs (11 July 1951)	38,600 cfs (11 July 1951)	45,200 cfs (11 July 1951)	120,000 cfs (19 May 1943)	70,000 cfs (8 August 1927)	259,000 cfs (17 May 1943)	Melvern, February 1986 (effective 1 March 1986)
Date of Closure	2 October 1970	19 July 1962	15 June 1980	23 September 1968	28 June 1960	21 July 1977	Pomona, March 1990 (effective 1 April 1990)
Date Storage Began	1 August 1972	18 October 1963	19 September 1982	12 December 1969	29 October 1961	7 February 1979	Hillsdale, 1969 (initial)
Multipurpose Level Reached	4 April 1975	5 June 1965	23 February 1985	18 December 1971	15 June 1963	19 November1979	Stockton, February 1988 (effective 1 March 1988)
Operating Agency	Corps of Engineers	Corps of Engineers	Corps of Engineers	Corps of Engineers	Corps of Engineers	Corps of Engineers	Pomme de Terre, February 1985 (effect 1 Mar 85)
DAM AND EMBANKMENT							Harry S. Truman, April 1993 (effective 1 Mar 94)
Top of Dam Elevation, feet msl	1,078	1,031	952.2	911	906	756	(4) Total drainage area above Truman Reservoir is
Length of Dam, feet (net)	9,650	7,750	8,700 plus 3,300 dike	5,100 plus 5,600 dike	4,630 plus 2,790 dike	5,000 plus 7,500 dike	11,500 square miles. The indicated total is the local
Damming Height, feet (2)	105	83	79	132	124	105	drainage area below the upstream dams.
Type of Fill	Earth	Earth	Earth	Rock Shell	Earth	Earth	
Fill Quantity, cubic yards	9,100,000	5,200,000	6,964,000	7,100,000	5,800,000	8,500,000	
SPILLWAY							
Location	Left Abutment	Right Abutment	Right Abutment	Left Abutment	Right Abutment	Center of Dam	
Crest Elevation, feet msl	1,057	1,006	935	861.5	874	692.3	
Width, Feet	200	200	50	160	170	160	
Number, Size, and Type of Gates	None	None	None	4 - 40’x30.5’ Tainter	None	4 - 40’x47.3’ Tainter	
Discharge Capacity, Top of Surcharge Pool	36,000 cfs	50,300 cfs	4,750 cfs	182,500 cfs	73,000 cfs	284,000 cfs	
RESERVOIR (3)							**Chapter 7 TOTALS**
Surcharge Pool Elevation and Area	1,073 ft msl 22,673 ac	1,025.4 ft msl 14,584 ac	948 ft msl 10,983 ac	906.2 ft msl 48,053 ac	900.2 ft msl 25,456 ac	751.1 ft msl 295,870 ac	417,619 ac
Flood Control Pool Elevation and Area	1,057 ft msl 13,935 ac	1,003 ft msl 8,522 ac	931 ft msl 7,413 ac	892 ft msl 38,281 ac	874 ft msl 15,999 ac	739.6 ft msl 209,048 ac	293,198 ac
Multipurpose Pool Elevation and Area	1,036 ft msl 6,912 ac	974 ft msl 3,865 ac	917 ft msl 4,575 ac	867 ft msl 24,632 ac	839 ft msl 7,790 ac	706 ft msl 55,406 ac	103,180 ac
Surcharge Storage	(1,073 - 1,057) 289,410 af	(1,025.4 - 1,003) 255,327 af	(948 - 931) 155,799 af	(906.2 - 892) 608,708 af	(900.2 - 874) 535,724 af	(751.1 - 739.6) 2,910,768 af	4,755,736 af
Flood Control Storage	(1,057 - 1,036) 208,207 af	(1,003 - 974) 176,123 af	(931 - 917) 83,570 af	(892 - 867) 776,066 af	(874 - 839) 406,821 af	(739.6 - 706) 4,006,415 af	5,657,202 af
Multipurpose Storage	(1,036 - 960) 152,051 af	(974 - 912) 64,208 af	(917 - 852.5) 76,270 af	(867 - 760.4) 874,887 af	(839 - 750) 237,356 af	(706 - 630) 1,180,617 af	2,585,389 af
Gross Storage	(1,057 - 960) 360,258 af	(1,003 - 912) 240,331 af	(931 - 852.5) 159,840 af	(892 - 760.4) 1,650,953 af	(874 - 750.1) 644,177 af	(739.6 - 630) 5,187,032 af	8,242,591 af
Sediment Reserve Storage	26,000 af	28,000 af	11,000 af	25,000 af	13,000 af	244,000 af	347,000 af
Estimated Annual Sediment Inflow	260 af 100 years	280 af 100 years	110 af 100 years	250 af 100 years	260 af 50 years	2,440 af 100 years	
OUTLET WORKS							
Location	Right Abutment	Right Abutment	Left Abutment		Right Abutment		ac = acres
River Outlet Type	Gated Horseshoe Conduit	Gated Horseshoe Conduit	Gated Oblong Conduit	None	Gated Tunnel	None	af = acre-feet
Number and Size of Conduit	1 - 11.5’	1 - 13.5’	1 - 15.92’x11.67’		1 - 14’		ft = feet
Length of Conduit, feet	754	720.5	685		560		msl = elevation above mean sea level
Entrance Invert Elevation	962 ft msl	925 ft msl	868 ft msl		750 ft msl		cfs = cubic feet per second
Discharge Cap, Top of Surcharge Pool	6,700 cfs	9,200 cfs	8,200 cfs		12,750 cfs		kw = kilowatts
Discharge Cap, Top of Flood Control Pool	6,235 cfs	8,170 cfs	7,400 cfs		11,500 cfs		hp = horsepower
Discharge Cap, Top of Multipurpose Pool	5,520 cfs	6,400 cfs	6,150 cfs		9,650 cfs		
Service Gates, Number and Size	2 - 6’x12’	2 - 6.5’x14’	2 - 5.33’x15.92’		2 - 6.5’x14’		
Emergency Gates, Number and Size	2 - 6’x12’	2 - 6.5’x14’	1 - 5.33’x15.92’		1 - 6.5’x14’		
Low Flow Gates, Number and Size	2 - 2’x2’	2 - 2’x2’	2 - 2’x2’	2 - 24” dia	1 - 24” Butterfly		
Provision for Power	None	None	None	3 - 20’x40’		12 - 17’x26.5’	
POWER FACILITIES							
Generator Turbine Units, Number				1		6	
Generator Name Plate Capacity, kw				45,200		160,000	
Turbine Rating, hp				75,600 (56 ft head)		254,400	
Turbine Type				Kaplan (Vertical Shaft)		Kaplan (Inclined Shaft)	
Maximum (Full Pool) Head and Discharge				112 ft (6,300 cfs)		79.2 ft (31,800 cfs)	
Avg (Power & MP Pool) Head and Discharge				85 ft (7,900 cfs)		42.5 ft (65,000 cfs)	
Minimum Head and Discharge				62 ft (11,000 cfs)		41 ft (68,000 cfs)	
Reversible Pump Turbines				None		6	
Total Dynamic Head, feet						50	
Discharge. 5 Units at Max Head, cfs						27,500	
Maximum Power Required, hp						197,000	
Maximum Drawdown, feet msl				845		704	

SUMMARY OF ENGINEERING DATA
OSAGE RIVER BASIN PROJECTS

US Army Corps of Engineers
Kansas City District
December 1999

Plate E-25

SCHEMATIC OF MISSOURI RIVER UNET MODEL

FROM RIVER MILE 498.0 TO RIVER MILE 0.0

CURRENT CONDITIONS MODEL

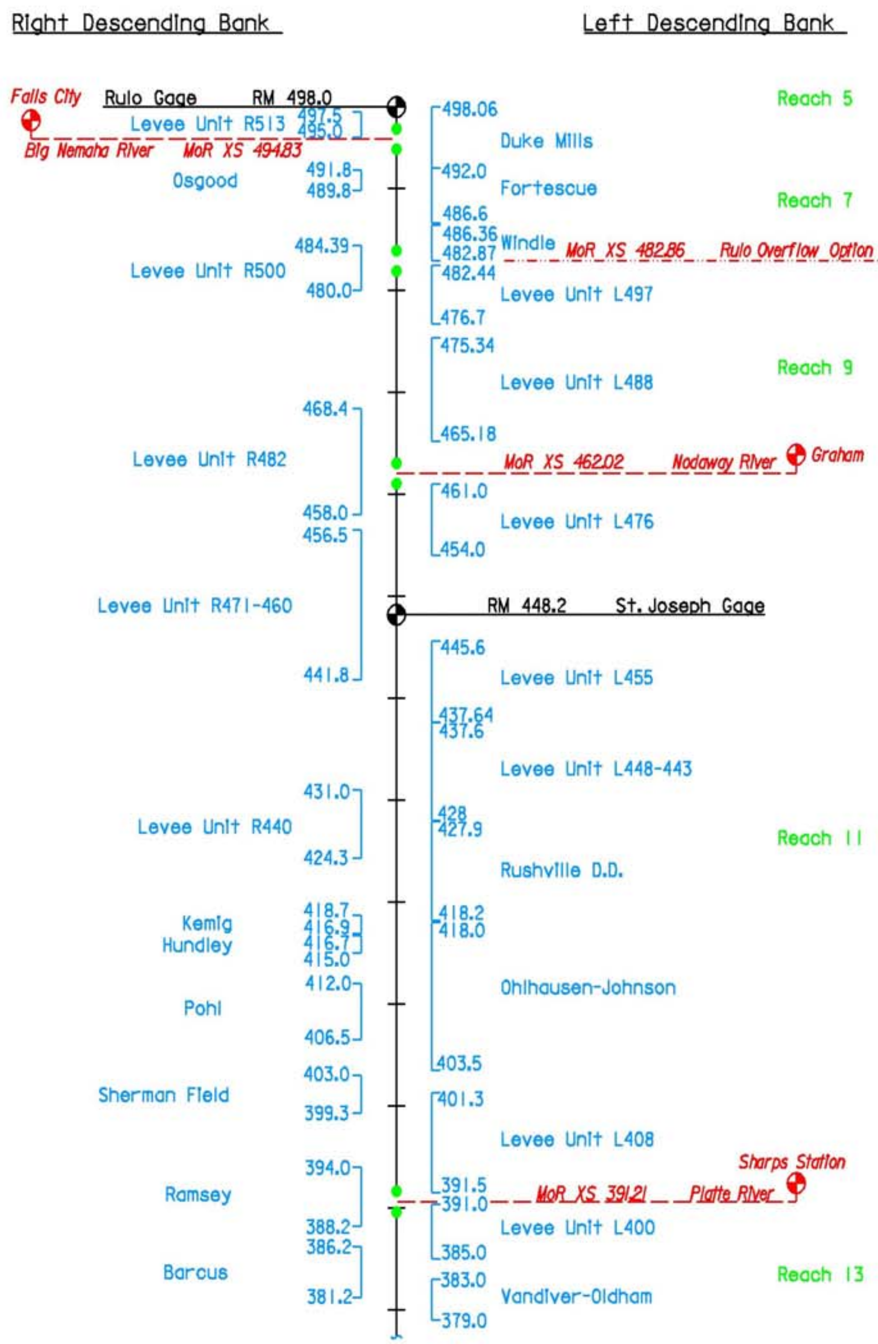
FEBRUARY 2003

LEGEND

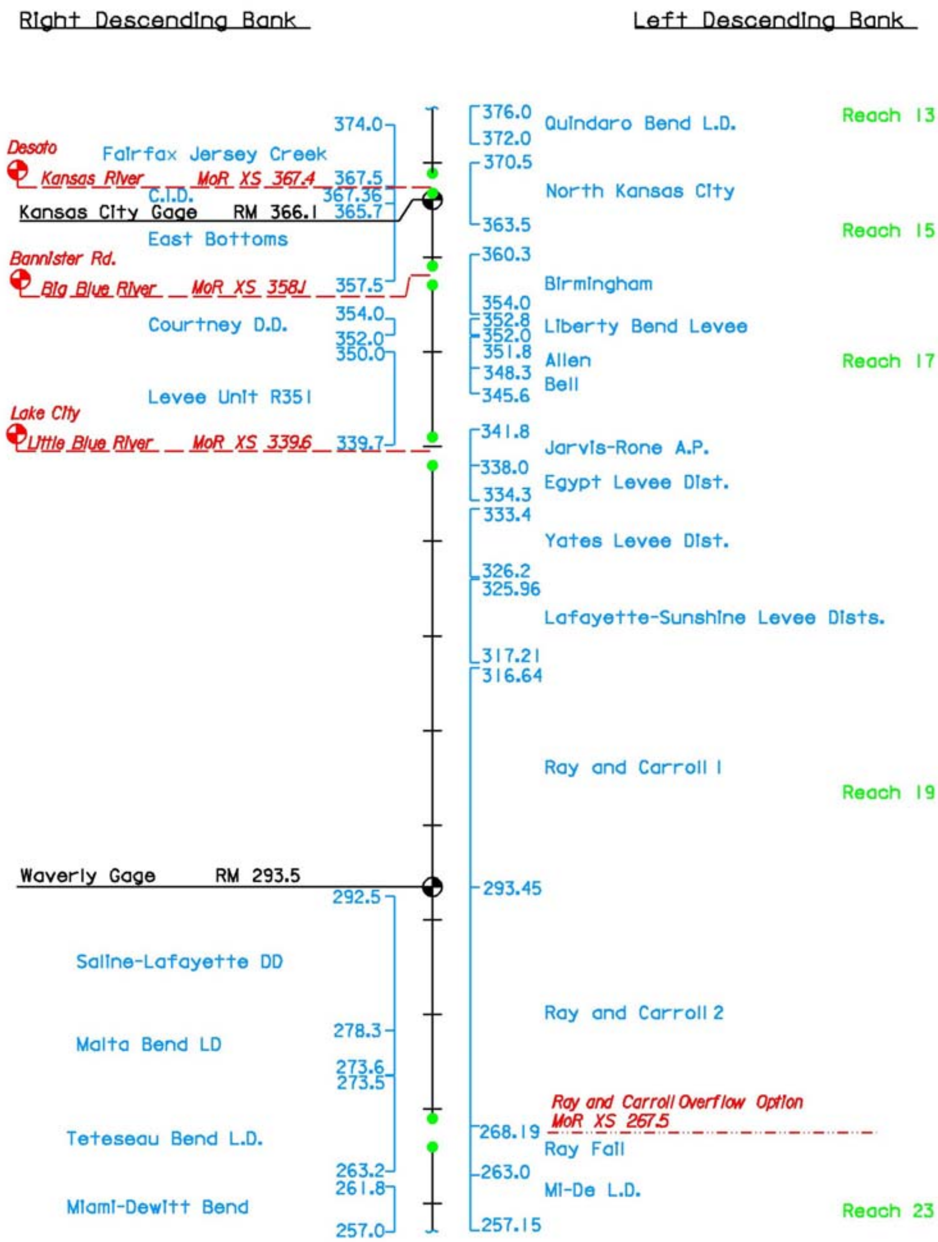
│	Missouri River Main Stem
—	10-Mile Intervals of River
Rulo Gage RM 498.0	Missouri River Stream Flow Gage with Location by River Mile (RM)
●	Reach Boundary
Reach 9	Reach Number
Duke Mills	Levee System Name
484.39 / 480.0	Levee System Boundaries in River Miles
Falls City / Big Nemaha River	Tributary Stream Flow Gage & Routing Reach
MoR XS 494.83	Tributary Inflow Location by Missouri River UNET Model Cross Section (MoR XS)
Rulo Overflow Option MoR XS 482.86	Missouri River UNET Model Option

Plate E-26

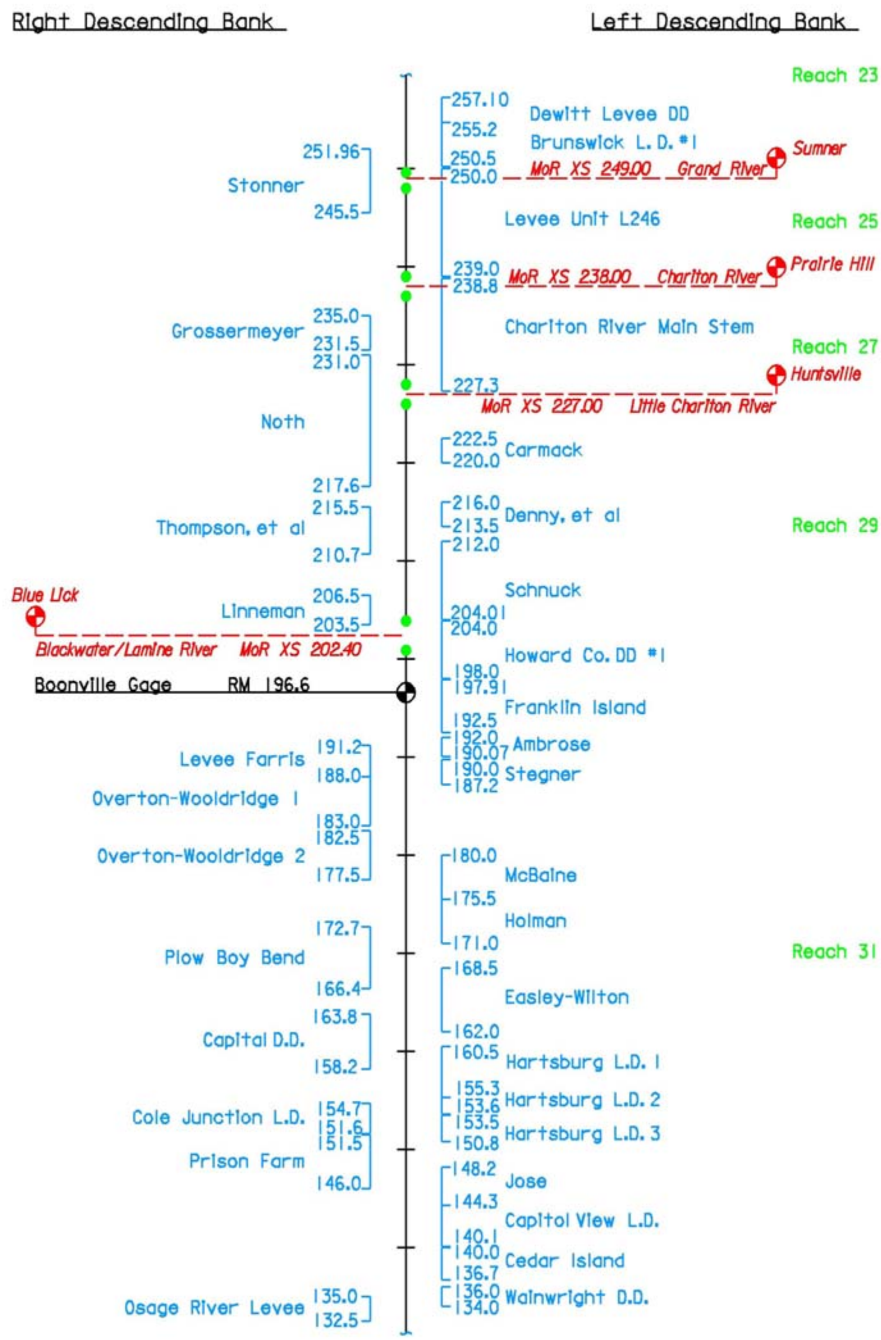
Missouri River Current Conditions UNET Model (Feb 2003)
From River Mile 498.0 to River Mile 377.0



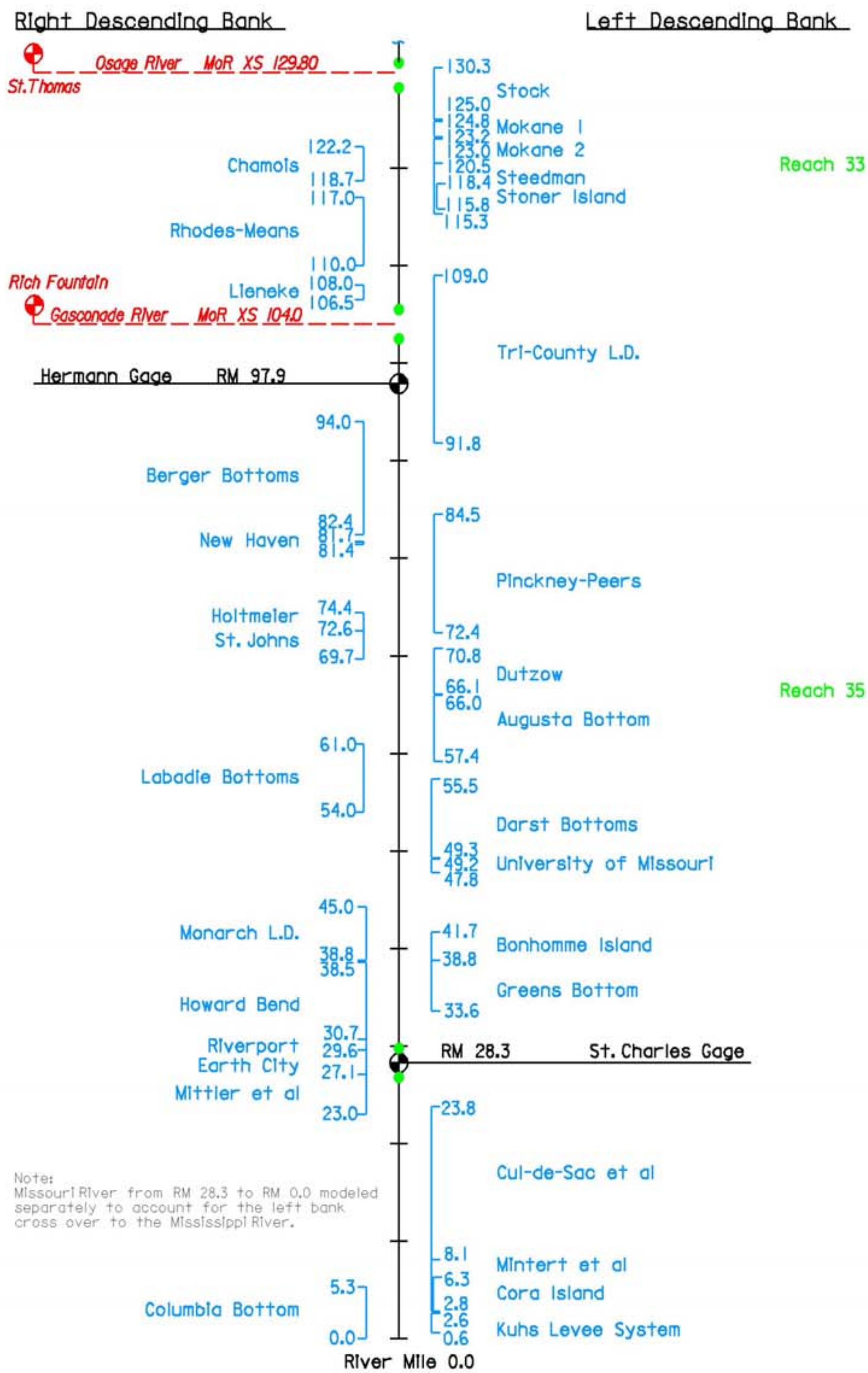
Missouri River Current Conditions UNET Model (Feb 2003)
From River Mile 377.0 to River Mile 257.0



Missouri River Current Conditions UNET Model (Feb 2003)
From River Mile 257.0 to River Mile 131.0



Missouri River Current Conditions UNET Model (Feb 2003)
From River Mile 131.0 to River Mile 0.0



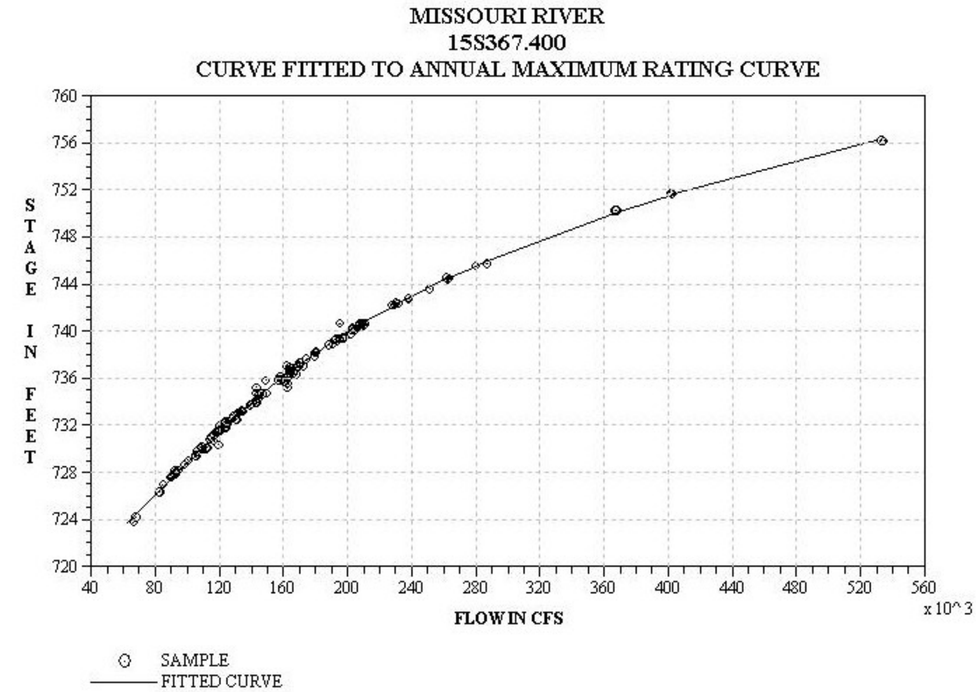


Plate E-27. Missouri River Rating Curve, Downstream of the Kansas River.

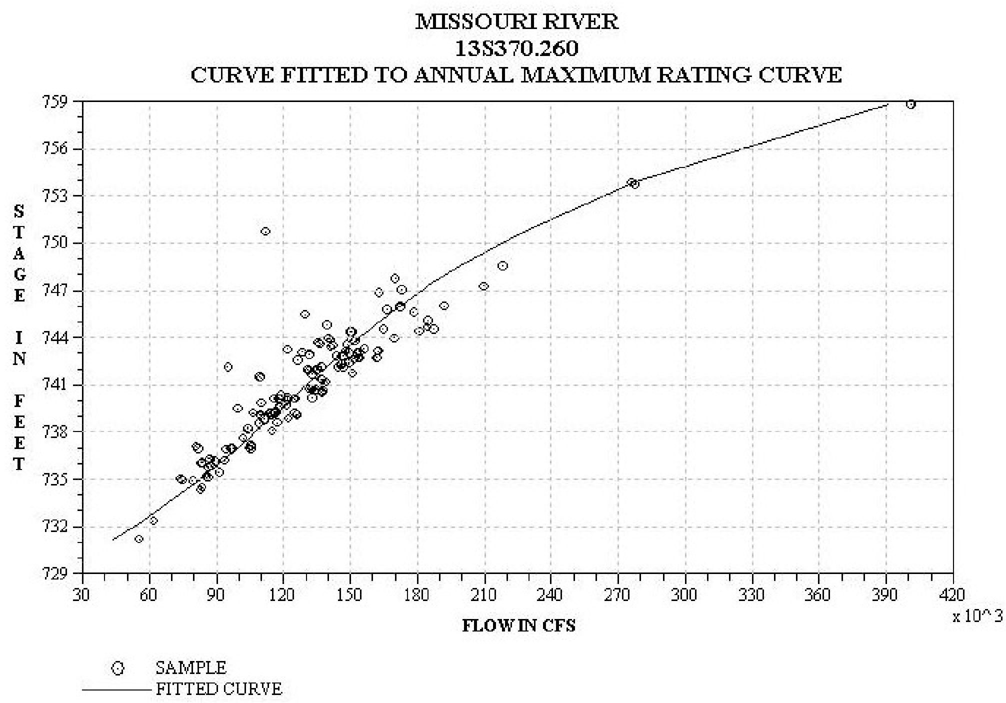


Plate E-28. Missouri River Rating Curve, Upstream of the Kansas River.

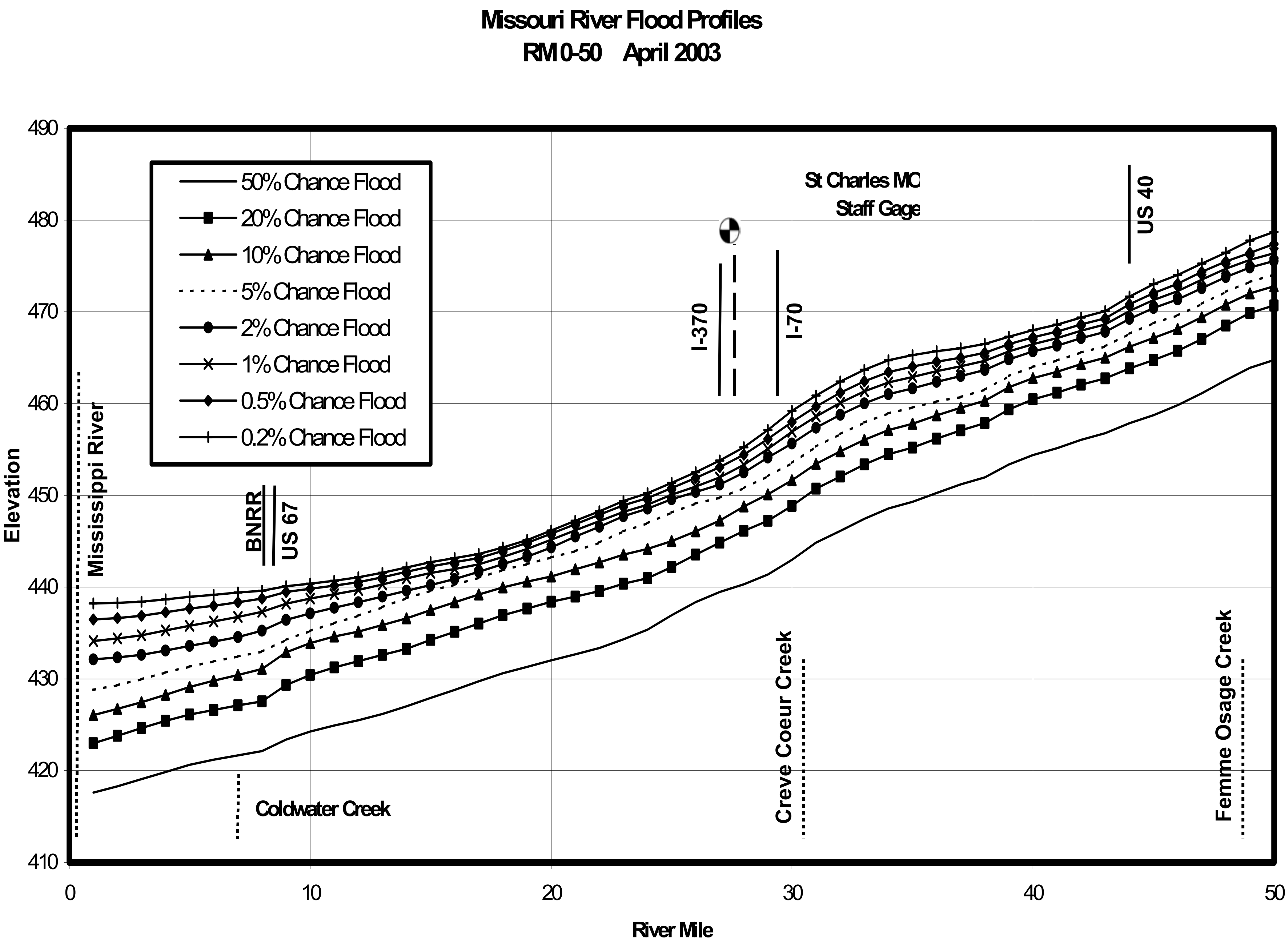
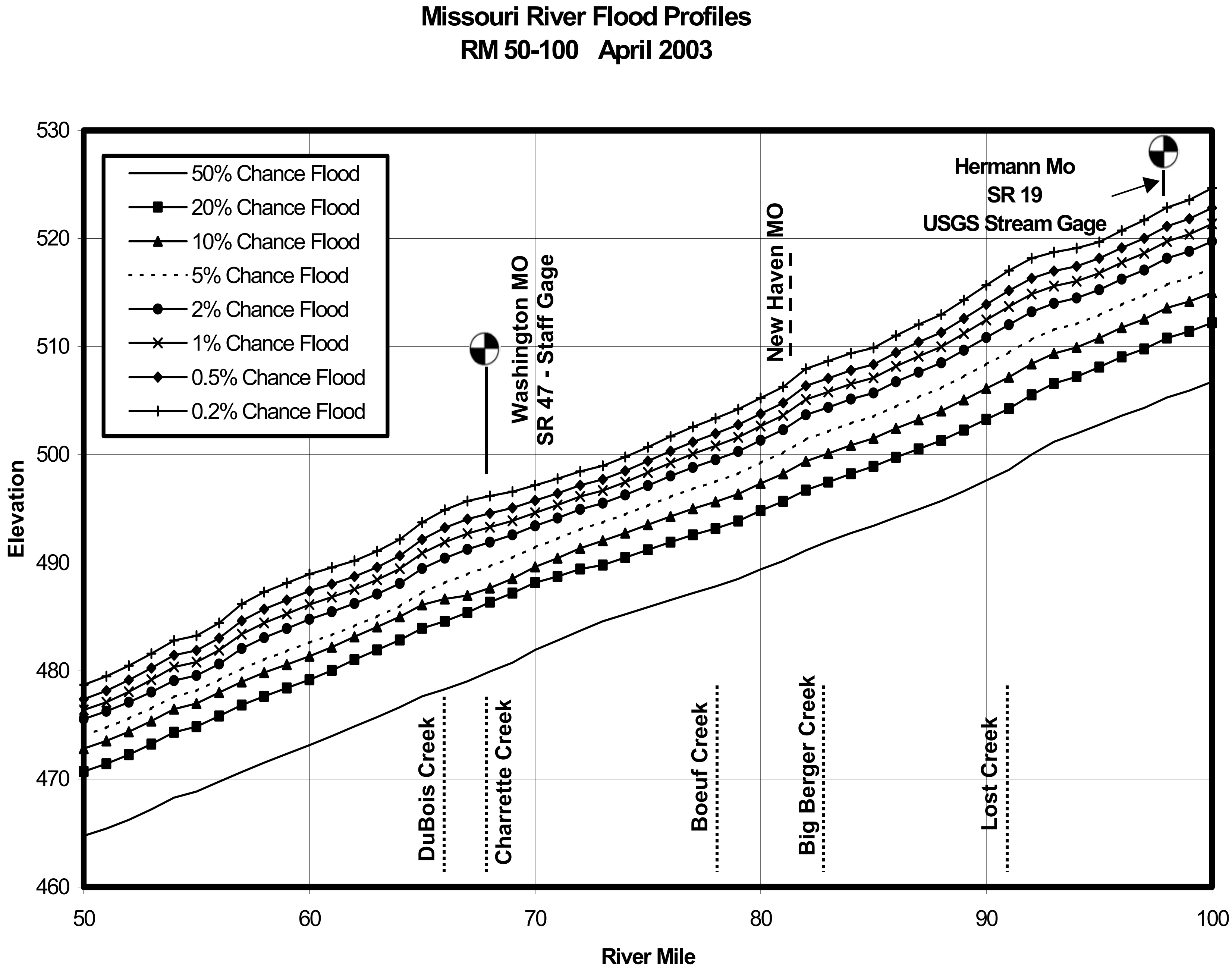
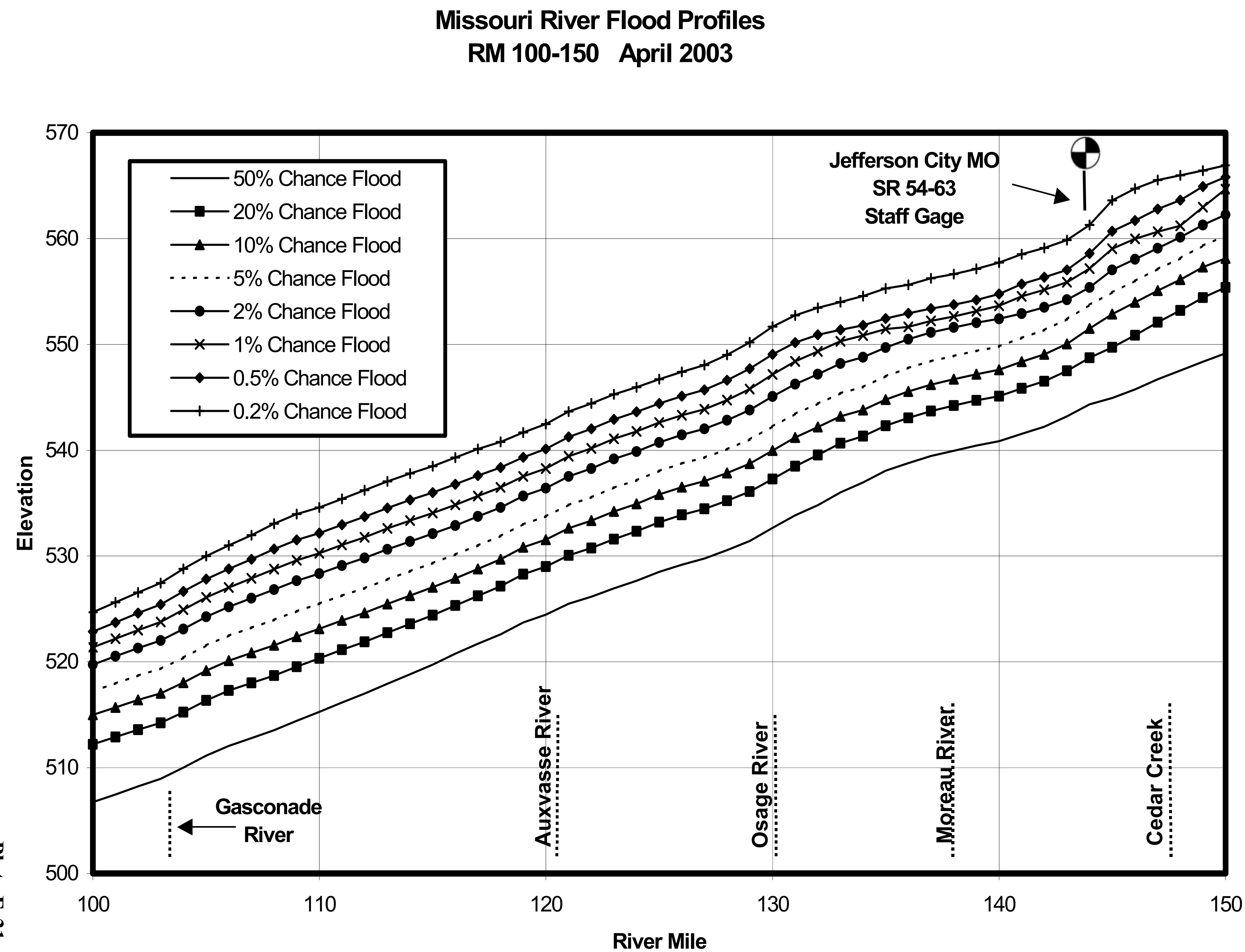

Missouri River Flood Profiles
RM 0-50 April 2003
Elevation
River Mile
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Mississippi River
BNRR
US 67
I-370
I-70
St Charles MO
Staff Gage
US 40
Coldwater Creek
Creve Coeur Creek
Femme Osage Creek
410
420
430
440
450
460
470
480
490
0
10
20
30
40
50

Plate E-29



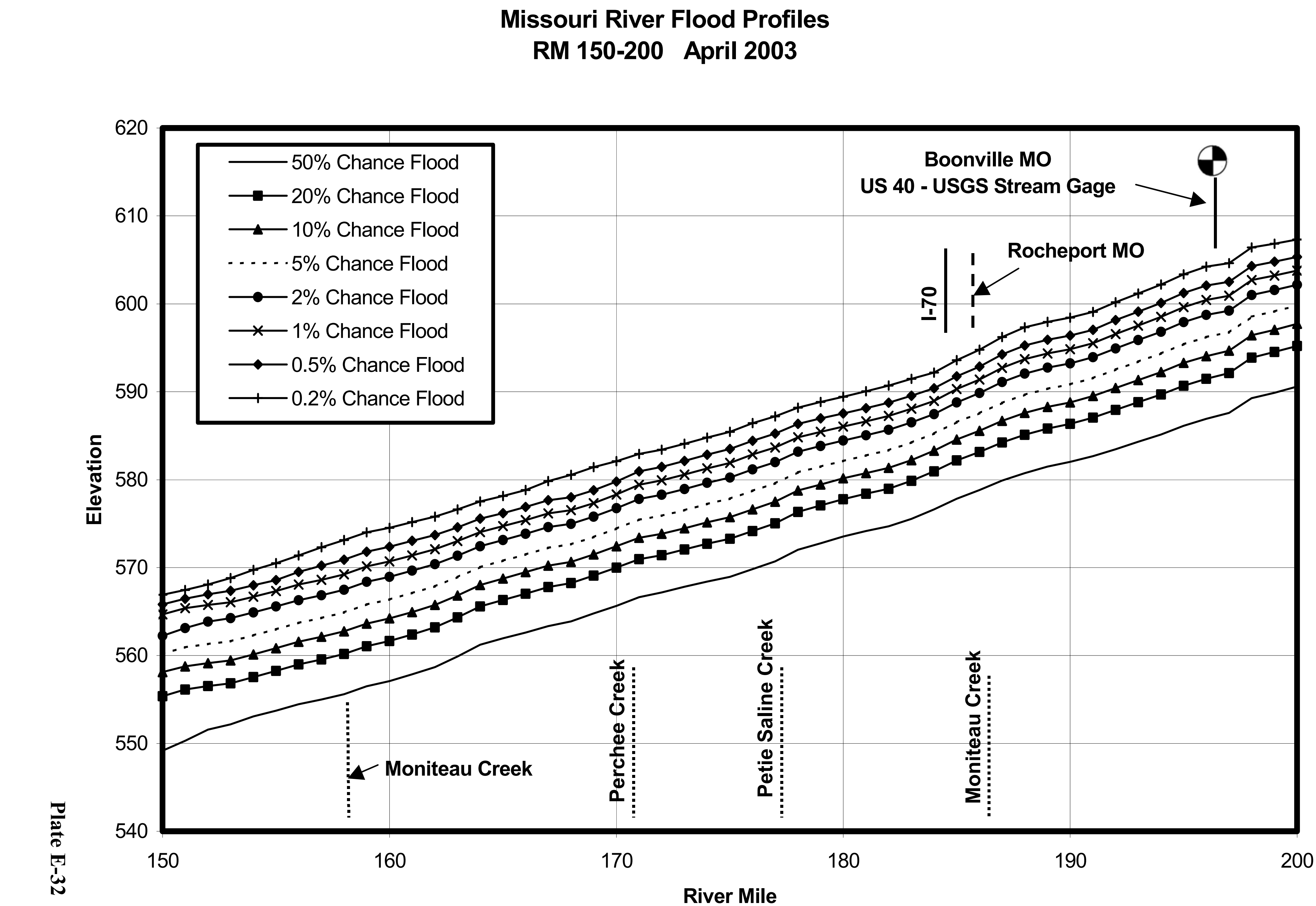
Missouri River Flood Profiles
RM 50-100 April 2003
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Washington MO
SR 47 - Staff Gage
New Haven MO
Hermann Mo
SR 19
USGS Stream Gage
DuBois Creek
Charrette Creek
Boeuf Creek
Big Berger Creek
Lost Creek
Elevation
River Mile
530
520
510
500
490
480
470
460
50
60
70
80
90
100

Plate E-30



Missouri River Flood Profiles
RM 100-150 April 2003
570
560
550
540
530
520
510
500
Elevation
100
110
120
130
140
150
River Mile
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Jefferson City MO
SR 54-63
Staff Gage
Gasconade
River
Auxvasse River
Osage River
Moreau River
Cedar Creek

Plate E-31



Missouri River Flood Profiles
RM 150-200 April 2003
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Boonville MO
US 40 - USGS Stream Gage
Rocheport MO
I-70
Moniteau Creek
Perchee Creek
Petie Saline Creek
Moniteau Creek
Elevation
River Mile
620
610
600
590
580
570
560
550
540
150
160
170
180
190
200

Plate E-32

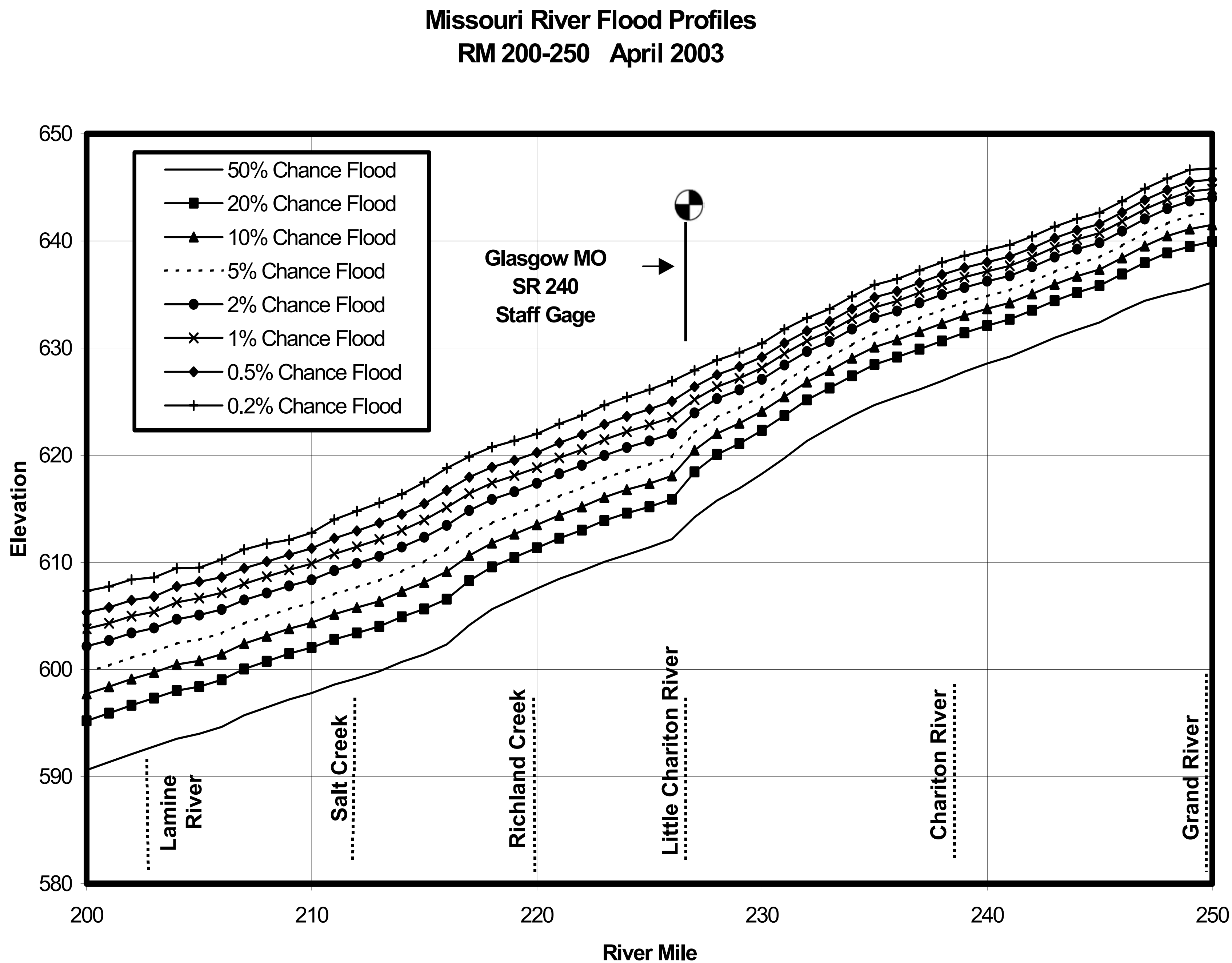

Missouri River Flood Profiles
RM 200-250 April 2003
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Glasgow MO
SR 240
Staff Gage
Elevation
River Mile
Lamine River
Salt Creek
Richland Creek
Little Chariton River
Chariton River
Grand River
650
640
630
620
610
600
590
580
200
210
220
230
240
250

Plate E-33

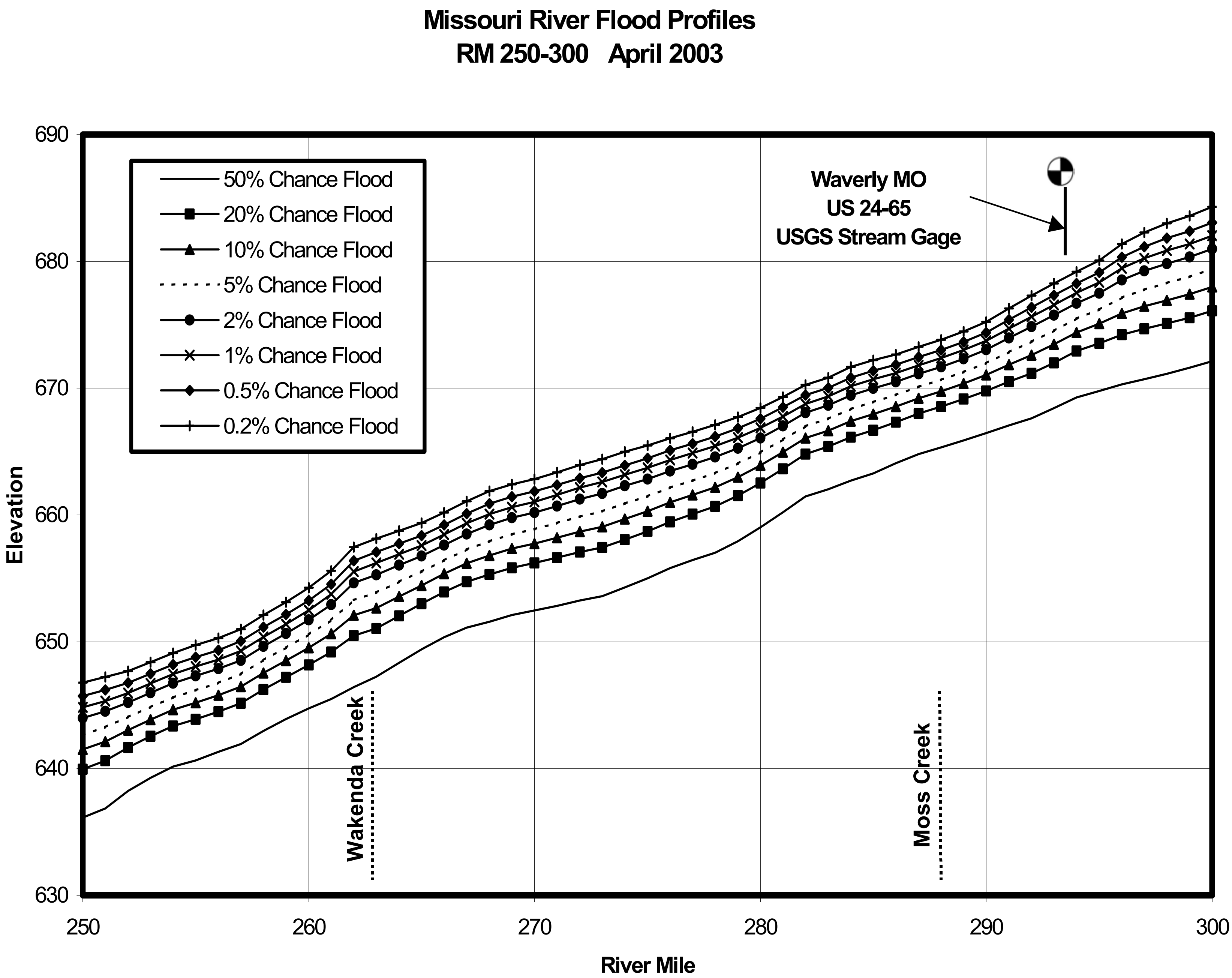

Missouri River Flood Profiles
RM 250-300 April 2003
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Waverly MO
US 24-65
USGS Stream Gage
Wakenda Creek
Moss Creek
Elevation
River Mile
690
680
670
660
650
640
630
250
260
270
280
290
300

Plate E-34

Missouri River Flood Profiles
RM 300-350 April 2003

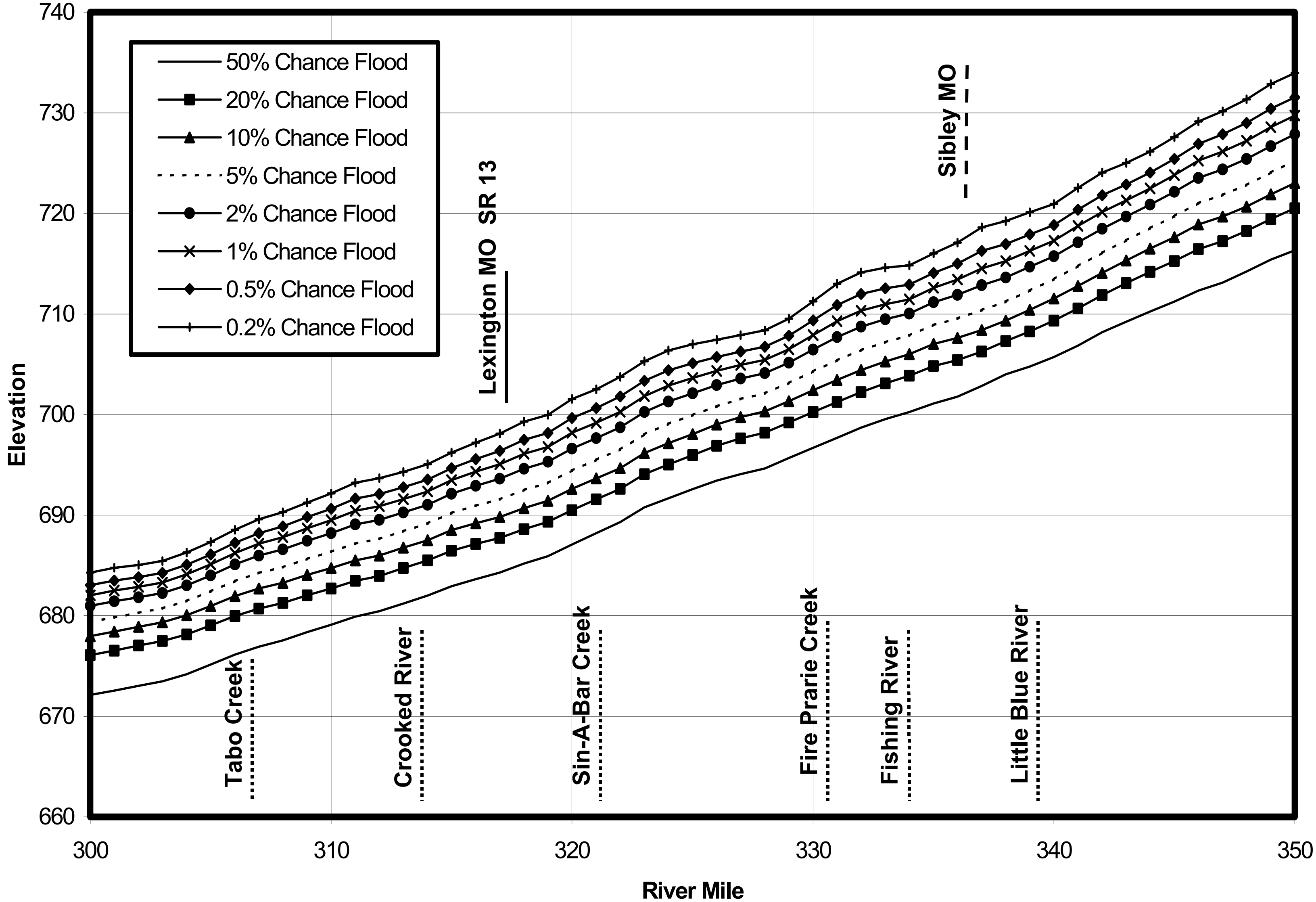
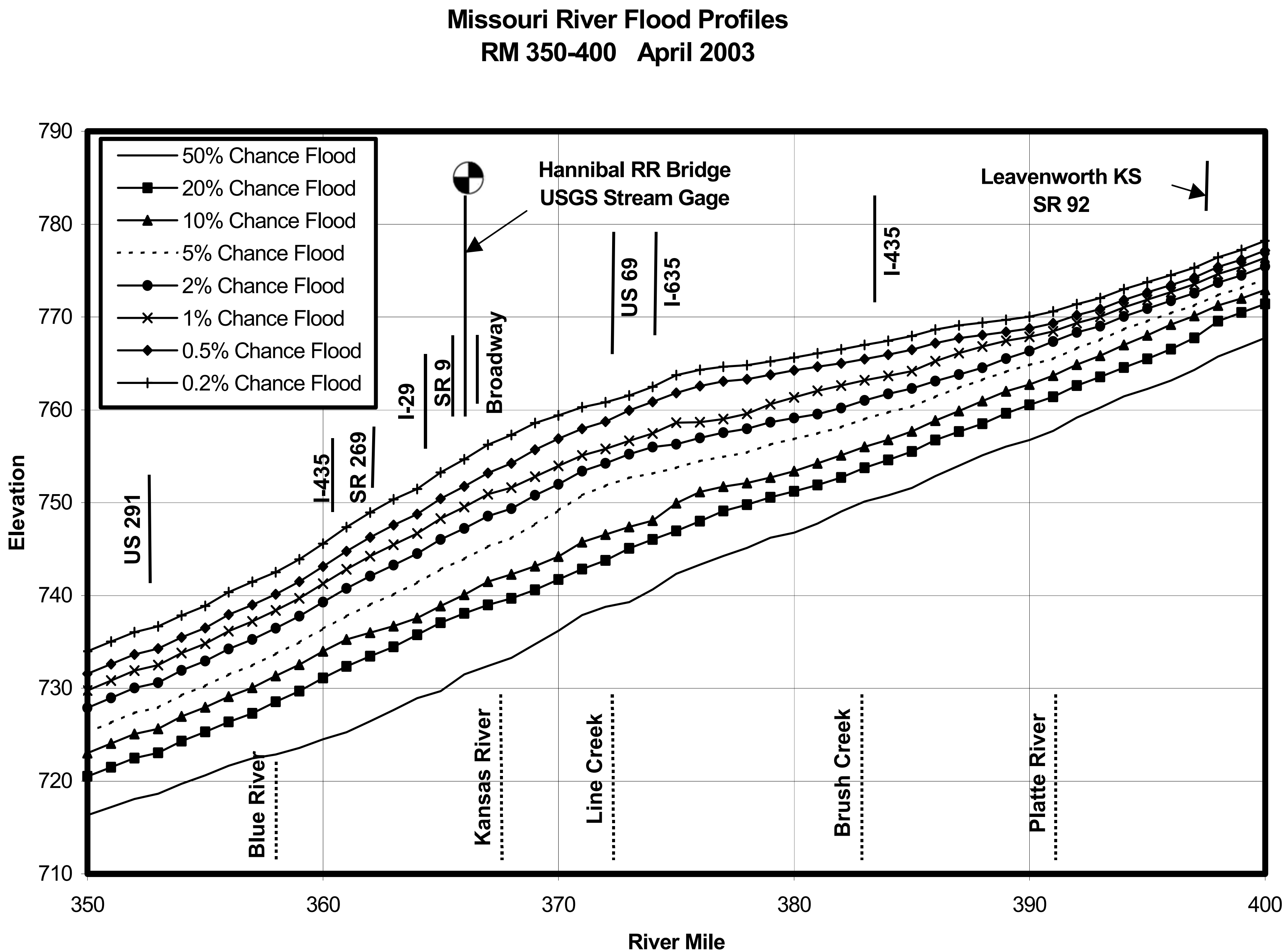
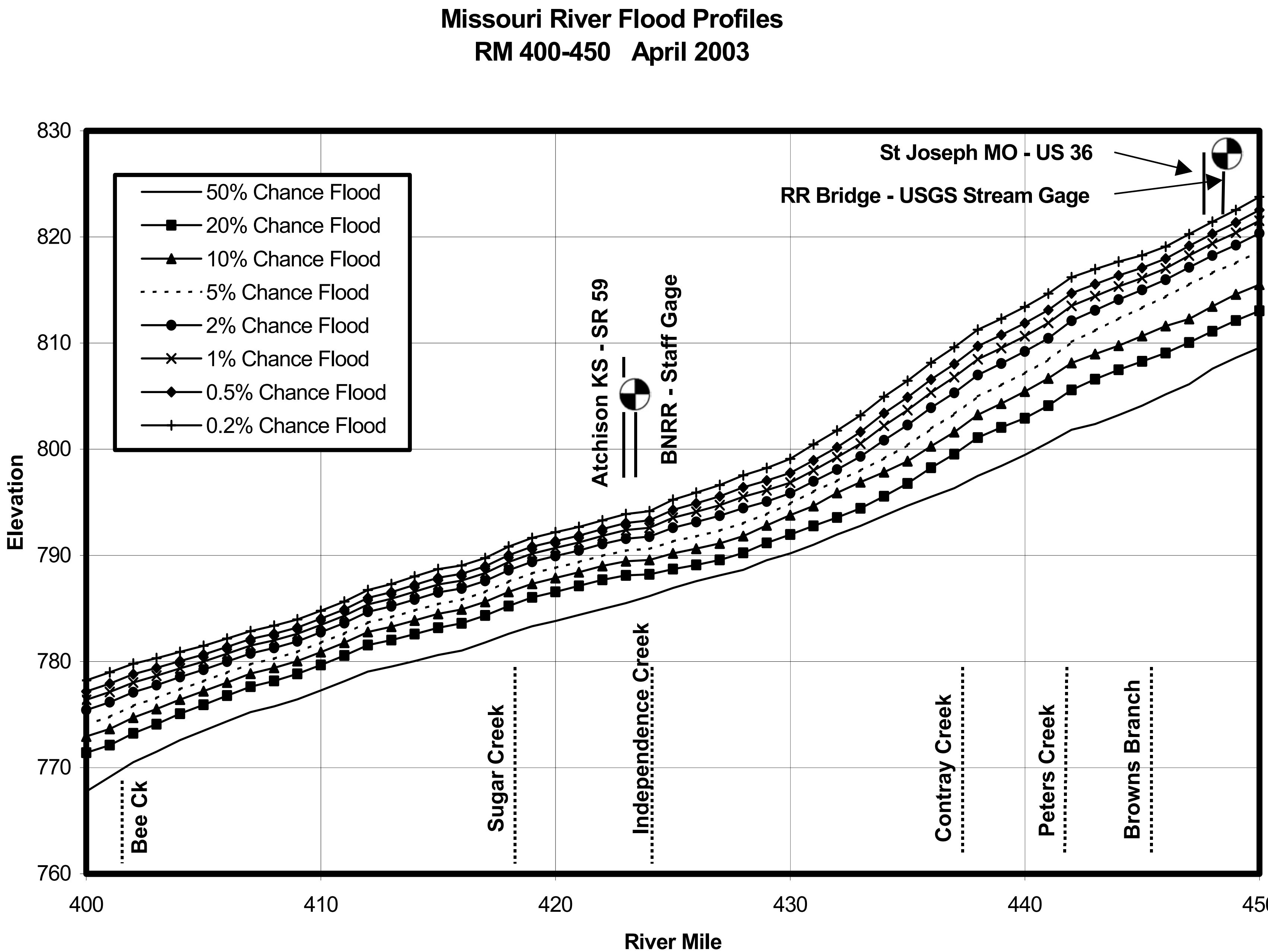


Plate E-35



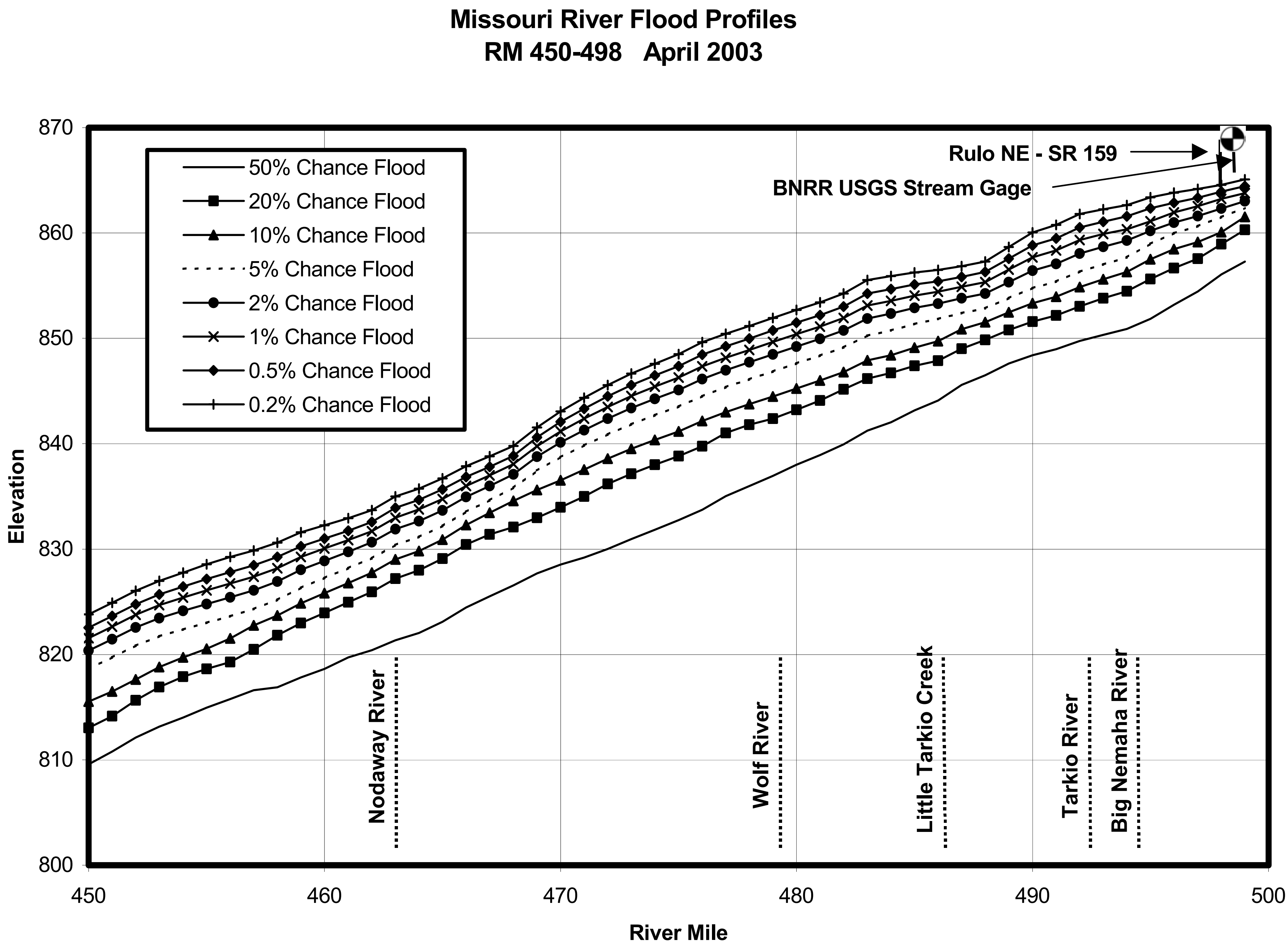
Missouri River Flood Profiles
RM 350-400 April 2003
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Hannibal RR Bridge
USGS Stream Gage
Leavenworth KS
SR 92
US 291
I-435
SR 269
I-29
SR 9
Broadway
US 69
I-635
I-435
Blue River
Kansas River
Line Creek
Brush Creek
Platte River
Elevation
River Mile
790
780
770
760
750
740
730
720
710
350
360
370
380
390
400

Plate E-36



Missouri River Flood Profiles
RM 400-450 April 2003
830
820
810
800
790
780
770
760
Elevation
400
410
420
430
440
450
River Mile
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
St Joseph MO - US 36
RR Bridge - USGS Stream Gage
Atchison KS - SR 59
BNRR - Staff Gage
Bee Ck
Sugar Creek
Independence Creek
Contray Creek
Peters Creek
Browns Branch

Plate E-37



Missouri River Flood Profiles
RM 450-498 April 2003
50% Chance Flood
20% Chance Flood
10% Chance Flood
5% Chance Flood
2% Chance Flood
1% Chance Flood
0.5% Chance Flood
0.2% Chance Flood
Rulo NE - SR 159
BNRR USGS Stream Gage
Nodaway River
Wolf River
Little Tarkio Creek
Tarkio River
Big Nemaha River
Elevation
River Mile
870
860
850
840
830
820
810
800
450
460
470
480
490
500

Plate E-38

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Table E-20

Missouri River Flood Profiles 02-Jun-03

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
0	416.9	422.2	425.5	428.5	432.0	434.0	436.4	438.2
1	417.6	423.0	426.1	428.9	432.1	434.2	436.5	438.2
2	418.3	423.8	426.8	429.4	432.4	434.5	436.7	438.3
3	419.1	424.6	427.5	430.0	432.7	434.8	436.9	438.4
4	419.9	425.4	428.3	430.7	433.1	435.3	437.3	438.7
5	420.6	426.1	429.1	431.3	433.6	435.8	437.6	438.9
6	421.1	426.6	429.8	431.9	434.1	436.3	438.0	439.2
7	421.6	427.1	430.4	432.4	434.6	436.8	438.3	439.4
8	422.1	427.5	431.1	432.9	435.2	437.3	438.7	439.6
9	423.4	429.3	432.8	434.3	436.4	438.2	439.4	440.1
10	424.2	430.3	433.8	435.2	437.1	438.7	439.8	440.4
11	424.9	431.2	434.6	436.0	437.7	439.2	440.2	440.7
12	425.5	431.9	435.2	436.9	438.4	439.7	440.6	441.1
13	426.2	432.6	435.9	437.8	439.0	440.3	441.1	441.6
14	427.0	433.3	436.6	438.7	439.6	440.9	441.6	442.1
15	428.0	434.3	437.5	439.6	440.3	441.5	442.3	442.7
16	428.8	435.1	438.4	440.3	440.9	442.0	442.7	443.2
17	429.7	436.0	439.2	441.0	441.6	442.5	443.2	443.7
18	430.6	436.9	440.0	441.8	442.5	443.3	444.0	444.4
19	431.3	437.7	440.6	442.5	443.4	444.2	444.9	445.2
20	432.0	438.3	441.2	443.2	444.4	445.2	445.8	446.2
21	432.7	439.0	441.9	444.0	445.5	446.2	446.8	447.2
22	433.4	439.6	442.7	444.9	446.6	447.2	447.9	448.3
23	434.3	440.4	443.5	446.0	447.7	448.2	448.9	449.3
24	435.4	441.0	444.1	446.9	448.5	449.0	449.7	450.2
25	437.0	442.2	445.1	448.1	449.6	450.1	450.8	451.4
26	438.3	443.5	446.1	449.0	450.4	451.0	451.9	452.5
27	439.4	444.8	447.2	449.7	451.2	452.0	453.1	453.8
28	440.3	446.1	448.8	450.8	452.5	453.3	454.4	455.2
29	441.4	447.3	450.2	452.1	454.1	455.1	456.2	457.1
30	443.1	449.0	451.7	453.6	455.7	457.0	458.1	459.2
31	444.8	450.7	453.4	455.3	457.4	458.6	459.7	460.9
32	446.1	452.0	454.7	456.6	458.7	460.0	461.1	462.3
33	447.4	453.3	456.0	457.9	460.0	461.3	462.4	463.6
34	448.5	454.4	457.1	458.9	461.0	462.2	463.4	464.6
35	449.3	455.2	457.8	459.5	461.6	462.9	464.0	465.2
36	450.3	456.2	458.7	460.2	462.4	463.5	464.5	465.7
37	451.2	457.1	459.6	460.8	463.0	464.1	465.0	466.1
38	452.0	457.9	460.4	461.5	463.7	464.7	465.6	466.5
39	453.3	459.3	461.7	463.0	464.8	465.7	466.5	467.3
40	454.3	460.4	462.7	463.9	465.6	466.5	467.2	468.0
41	455.1	461.1	463.4	464.7	466.3	467.1	467.8	468.6
42	456.1	462.1	464.4	465.6	467.2	468.0	468.7	469.4
43	456.8	462.8	465.0	466.3	467.9	468.7	469.4	470.2
44	457.9	463.9	466.2	467.6	469.2	470.1	470.8	471.6
45	458.8	464.8	467.2	468.7	470.4	471.3	472.1	473.0
46	459.9	465.8	468.2	469.7	471.4	472.3	473.1	474.0
47	461.1	467.0	469.4	470.8	472.6	473.5	474.3	475.2
48	462.6	468.5	470.8	472.1	473.8	474.7	475.5	476.5
49	463.8	469.8	471.9	473.2	474.8	475.6	476.4	477.7
50	464.8	470.7	472.8	474.1	475.6	476.4	477.4	478.8
51	465.5	471.4	473.6	474.8	476.3	477.2	478.2	479.6
52	466.3	472.3	474.4	475.6	477.1	478.1	479.2	480.5

Missouri River Flood Profiles
Upper Mississippi River System Flow Frequency Study

RM	Profiles - Percent Chance Flood 50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
53	467.2	473.2	475.3	476.5	478.0	479.1	480.2	481.6
54	468.2	474.3	476.4	477.6	479.1	480.3	481.4	482.7
55	468.8	474.8	477.0	478.2	479.6	480.8	481.9	483.3
56	469.8	475.9	478.0	479.2	480.7	482.0	483.1	484.5
57	470.7	476.8	479.0	480.2	482.0	483.4	484.6	486.1
58	471.5	477.7	479.9	481.1	483.1	484.4	485.7	487.3
59	472.3	478.4	480.5	481.8	483.9	485.2	486.5	488.1
60	473.1	479.2	481.3	482.6	484.7	486.1	487.3	488.9
61	473.9	480.0	482.2	483.3	485.5	486.8	488.0	489.5
62	474.9	481.1	483.2	484.2	486.3	487.6	488.8	490.3
63	475.7	481.9	484.1	485.1	487.1	488.5	489.6	491.1
64	476.6	482.9	485.0	486.0	488.1	489.5	490.7	492.2
65	477.6	483.9	486.0	487.2	489.4	490.8	492.0	493.6
66	478.3	484.6	486.6	488.1	490.4	491.8	493.1	494.8
67	479.0	485.4	487.0	488.9	491.2	492.7	494.0	495.7
68	480.0	486.4	487.7	489.8	492.0	493.4	494.6	496.2
69	480.8	487.2	488.5	490.5	492.6	493.9	495.1	496.6
70	481.9	488.1	489.6	491.5	493.4	494.7	495.8	497.2
71	482.8	488.7	490.4	492.2	494.1	495.4	496.4	497.8
72	483.7	489.3	491.3	493.0	494.8	496.0	497.1	498.4
73	484.6	489.8	492.1	493.8	495.6	496.7	497.8	499.0
74	485.2	490.5	492.8	494.5	496.3	497.5	498.5	499.8
75	485.9	491.3	493.6	495.4	497.2	498.4	499.5	500.8
76	486.6	491.9	494.3	496.1	498.0	499.3	500.3	501.7
77	487.2	492.6	495.0	496.8	498.8	500.1	501.2	502.6
78	487.8	493.2	495.7	497.5	499.6	500.8	502.0	503.4
79	488.5	493.9	496.4	498.3	500.4	501.7	502.8	504.3
80	489.4	494.8	497.3	499.2	501.3	502.6	503.8	505.3
81	490.1	495.6	498.2	500.2	502.3	503.6	504.8	506.3
82	491.1	496.7	499.4	501.4	503.7	505.1	506.3	507.9
83	492.0	497.5	500.2	502.2	504.5	505.9	507.2	508.8
84	492.7	498.2	500.9	502.9	505.1	506.5	507.8	509.3
85	493.5	499.0	501.6	503.6	505.8	507.2	508.5	510.0
86	494.2	499.8	502.4	504.5	506.8	508.2	509.5	511.1
87	495.0	500.5	503.3	505.4	507.6	509.1	510.4	512.0
88	495.7	501.3	504.1	506.2	508.5	510.0	511.4	513.0
89	496.6	502.3	505.1	507.3	509.7	511.2	512.6	514.3
90	497.6	503.3	506.2	508.4	510.9	512.5	513.9	515.7
91	498.6	504.3	507.1	509.4	512.0	513.6	515.1	516.9
92	500.0	505.5	508.4	510.7	513.2	514.8	516.3	518.1
93	501.1	506.5	509.3	511.5	513.9	515.5	516.9	518.7
94	502.0	507.3	510.0	512.2	514.6	516.1	517.5	519.2
95	502.8	508.1	510.8	513.0	515.3	516.9	518.2	519.8
96	503.6	509.0	511.7	513.9	516.2	517.8	519.1	520.7
97	504.3	509.8	512.5	514.7	517.1	518.6	520.0	521.6
98	505.3	510.8	513.6	515.8	518.2	519.7	521.2	522.9
99	506.0	511.5	514.3	516.5	518.9	520.5	521.9	523.7
100	506.8	512.2	515.0	517.2	519.7	521.4	522.9	524.7
101	507.5	512.9	515.7	518.0	520.5	522.2	523.7	525.6
102	508.2	513.6	516.4	518.7	521.3	523.0	524.6	526.5
103	508.9	514.2	517.0	519.3	522.0	523.8	525.4	527.4
104	510.0	515.2	518.0	520.4	523.1	524.9	526.6	528.8
105	511.1	516.4	519.2	521.5	524.2	526.1	527.8	530.0

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
106	512.1	517.3	520.1	522.5	525.2	527.0	528.8	531.0
107	512.8	518.0	520.8	523.2	526.0	527.9	529.7	532.0
108	513.5	518.7	521.6	524.0	526.8	528.8	530.7	533.1
109	514.4	519.5	522.4	524.8	527.7	529.6	531.5	534.0
110	515.3	520.3	523.1	525.5	528.3	530.3	532.2	534.6
111	516.2	521.1	523.9	526.3	529.1	531.0	533.0	535.4
112	517.0	521.9	524.6	527.0	529.8	531.8	533.7	536.2
113	517.9	522.8	525.5	527.8	530.6	532.6	534.5	537.0
114	518.8	523.6	526.3	528.6	531.4	533.4	535.3	537.8
115	519.7	524.4	527.1	529.3	532.1	534.1	536.0	538.5
116	520.8	525.3	527.9	530.1	532.9	534.8	536.8	539.3
117	521.7	526.2	528.8	531.0	533.7	535.7	537.6	540.1
118	522.6	527.1	529.7	531.9	534.6	536.5	538.4	540.8
119	523.7	528.3	530.8	533.0	535.7	537.5	539.3	541.7
120	524.5	529.0	531.6	533.7	536.4	538.3	540.1	542.5
121	525.5	530.1	532.6	534.8	537.5	539.4	541.3	543.6
122	526.1	530.8	533.3	535.6	538.3	540.2	542.0	544.4
123	526.9	531.6	534.2	536.4	539.2	541.1	542.9	545.3
124	527.7	532.3	534.9	537.2	539.9	541.8	543.6	545.9
125	528.5	533.2	535.8	538.0	540.7	542.6	544.4	546.7
126	529.2	533.9	536.5	538.7	541.4	543.3	545.1	547.4
127	529.8	534.5	537.1	539.3	542.0	543.9	545.7	548.0
128	530.5	535.2	537.8	540.1	542.8	544.7	546.6	549.0
129	531.4	536.1	538.7	541.0	543.8	545.8	547.7	550.2
130	532.6	537.3	540.0	542.2	545.1	547.1	549.1	551.7
131	533.8	538.5	541.2	543.4	546.2	548.4	550.2	552.7
132	534.8	539.5	542.2	544.4	547.2	549.3	550.9	553.5
133	536.0	540.7	543.2	545.4	548.2	550.3	551.4	554.0
134	536.9	541.3	543.8	546.0	548.8	550.8	551.8	554.6
135	538.1	542.3	544.8	547.0	549.7	551.5	552.4	555.3
136	538.8	543.0	545.6	547.8	550.5	551.7	552.9	555.6
137	539.4	543.7	546.2	548.4	551.1	552.2	553.4	556.2
138	539.9	544.2	546.7	548.9	551.6	552.6	553.7	556.6
139	540.4	544.7	547.2	549.4	552.0	553.1	554.2	557.1
140	540.8	545.1	547.6	549.8	552.4	553.7	554.8	557.7
141	541.6	545.8	548.4	550.6	552.9	554.5	555.7	558.5
142	542.2	546.5	549.1	551.3	553.5	555.2	556.3	559.1
143	543.2	547.5	550.0	552.4	554.2	555.9	557.0	559.9
144	544.3	548.7	551.5	553.7	555.4	557.2	558.6	561.3
145	544.9	549.7	552.9	554.9	557.0	559.0	560.7	563.6
146	545.8	550.9	554.0	556.0	558.1	560.0	561.7	564.7
147	546.7	552.1	555.1	557.1	559.1	560.6	562.8	565.5
148	547.5	553.2	556.1	558.1	560.1	561.2	563.6	566.0
149	548.4	554.4	557.3	559.3	561.3	563.0	564.9	566.4
150	549.2	555.4	558.1	560.2	562.2	564.7	565.8	566.9
151	550.3	556.1	558.7	560.9	563.1	565.4	566.5	567.5
152	551.6	556.5	559.1	561.3	563.9	565.8	567.0	568.1
153	552.2	556.8	559.4	561.6	564.2	566.1	567.4	568.8
154	553.1	557.5	560.1	562.3	564.9	566.7	568.0	569.7
155	553.7	558.3	560.8	563.0	565.6	567.3	568.6	570.5
156	554.5	559.0	561.6	563.7	566.3	568.1	569.5	571.4
157	555.0	559.5	562.1	564.3	566.9	568.6	570.2	572.3
158	555.6	560.2	562.7	564.9	567.5	569.2	570.9	573.1

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
159	556.5	561.1	563.6	565.8	568.4	570.1	571.8	574.0
160	557.1	561.6	564.2	566.4	568.9	570.7	572.4	574.5
161	557.9	562.4	564.9	567.1	569.6	571.4	573.0	575.2
162	558.7	563.2	565.7	567.9	570.4	572.1	573.7	575.8
163	559.9	564.3	566.8	568.9	571.4	573.0	574.6	576.6
164	561.2	565.6	568.0	570.1	572.4	574.0	575.6	577.5
165	562.0	566.3	568.8	570.8	573.1	574.7	576.2	578.1
166	562.6	567.0	569.5	571.5	573.8	575.4	576.9	578.8
167	563.3	567.8	570.2	572.3	574.6	576.2	577.7	579.8
168	563.9	568.2	570.7	572.6	575.0	576.5	578.0	580.5
169	564.8	569.1	571.5	573.5	575.8	577.3	578.8	581.4
170	565.6	570.0	572.4	574.4	576.8	578.3	579.8	582.1
171	566.6	571.0	573.4	575.5	577.8	579.4	580.9	582.9
172	567.2	571.4	573.8	575.9	578.3	579.9	581.5	583.4
173	567.8	572.1	574.5	576.5	578.9	580.6	582.1	584.1
174	568.4	572.7	575.2	577.2	579.6	581.3	582.8	584.8
175	568.9	573.3	575.7	577.8	580.2	581.9	583.5	585.5
176	569.8	574.2	576.6	578.7	581.2	582.9	584.4	586.4
177	570.7	575.0	577.5	579.6	582.0	583.7	585.2	587.2
178	572.0	576.3	578.8	580.8	583.2	584.8	586.3	588.2
179	572.8	577.1	579.5	581.5	583.8	585.5	587.0	588.8
180	573.5	577.8	580.1	582.1	584.5	586.0	587.5	589.4
181	574.1	578.4	580.8	582.8	585.1	586.6	588.1	590.1
182	574.7	579.0	581.3	583.3	585.7	587.3	588.8	590.7
183	575.6	579.9	582.2	584.2	586.5	588.1	589.6	591.5
184	576.6	581.0	583.3	585.3	587.5	589.0	590.4	592.2
185	577.8	582.2	584.6	586.5	588.8	590.3	591.7	593.6
186	578.8	583.2	585.6	587.6	589.8	591.4	592.9	594.8
187	579.9	584.2	586.7	588.7	591.1	592.7	594.2	596.2
188	580.7	585.1	587.6	589.7	592.1	593.7	595.3	597.3
189	581.5	585.8	588.3	590.3	592.7	594.4	595.9	598.0
190	582.0	586.3	588.8	590.8	593.2	594.8	596.4	598.4
191	582.7	587.1	589.5	591.6	593.9	595.5	597.1	599.1
192	583.5	587.9	590.4	592.5	594.9	596.6	598.1	600.2
193	584.3	588.8	591.3	593.4	595.9	597.5	599.1	601.2
194	585.1	589.7	592.2	594.4	596.8	598.5	600.1	602.2
195	586.1	590.7	593.3	595.4	597.9	599.6	601.2	603.4
196	586.9	591.5	594.1	596.2	598.7	600.5	602.1	604.2
197	587.6	592.1	594.7	596.8	599.2	600.9	602.5	604.6
198	589.3	593.9	596.4	598.5	601.0	602.7	604.3	606.4
199	589.9	594.5	597.1	599.2	601.6	603.2	604.8	606.8
200	590.6	595.2	597.7	599.8	602.2	603.8	605.3	607.3
201	591.3	595.9	598.4	600.4	602.8	604.3	605.9	607.8
202	592.1	596.6	599.1	601.1	603.4	604.9	606.4	608.3
203	592.8	597.4	599.8	601.7	604.0	605.5	606.9	608.7
204	593.5	598.0	600.5	602.4	604.7	606.2	607.7	609.4
205	594.1	598.5	600.9	602.9	605.1	606.7	608.2	609.7
206	594.7	599.1	601.4	603.4	605.6	607.2	608.6	610.2
207	595.7	600.1	602.4	604.3	606.5	608.0	609.5	611.2
208	596.5	600.7	603.1	605.0	607.1	608.6	610.1	611.7
209	597.2	601.4	603.8	605.6	607.8	609.3	610.7	612.2
210	597.8	602.0	604.4	606.2	608.4	609.9	611.3	612.9
211	598.6	602.8	605.2	607.1	609.2	610.8	612.2	614.0

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
212	599.2	603.4	605.7	607.7	609.9	611.4	612.9	614.8
213	599.9	604.1	606.5	608.4	610.7	612.3	613.8	615.6
214	600.8	605.0	607.4	609.3	611.6	613.1	614.7	616.6
215	601.4	605.6	608.1	610.1	612.3	613.9	615.5	617.5
216	602.4	606.7	609.2	611.3	613.5	615.1	616.7	618.8
217	604.1	608.2	610.6	612.6	614.8	616.4	617.9	619.8
218	605.6	609.6	611.8	613.7	615.9	617.4	618.9	620.8
219	606.6	610.5	612.6	614.5	616.6	618.1	619.6	621.4
220	607.5	611.3	613.5	615.2	617.3	618.8	620.2	622.0
221	608.5	612.3	614.4	616.2	618.3	619.8	621.2	623.0
222	609.2	613.0	615.1	616.9	619.0	620.5	621.9	623.7
223	610.1	613.9	616.1	617.9	620.0	621.5	622.9	624.7
224	610.7	614.6	616.7	618.5	620.7	622.2	623.6	625.4
225	611.4	615.2	617.4	619.2	621.3	622.8	624.3	626.1
226	612.1	615.8	618.0	619.8	622.0	623.5	625.0	626.9
227	614.1	618.2	620.3	621.9	623.8	625.1	626.4	627.9
228	615.8	620.0	622.0	623.5	625.2	626.4	627.5	628.9
229	617.0	621.2	623.0	624.5	626.2	627.2	628.3	629.6
230	618.3	622.3	624.1	625.5	627.1	628.2	629.2	630.5
231	619.7	623.6	625.4	626.8	628.3	629.4	630.4	631.7
232	621.4	625.2	626.9	628.2	629.7	630.7	631.7	632.9
233	622.5	626.3	627.9	629.2	630.7	631.6	632.6	633.7
234	623.6	627.4	629.0	630.3	631.7	632.7	633.6	634.8
235	624.7	628.5	630.1	631.4	632.8	633.8	634.7	635.8
236	625.4	629.2	630.8	632.0	633.5	634.4	635.3	636.5
237	626.2	629.9	631.5	632.8	634.2	635.2	636.1	637.2
238	626.9	630.6	632.3	633.5	634.9	635.9	636.8	637.9
239	627.8	631.5	633.1	634.3	635.7	636.6	637.5	638.6
240	628.6	632.1	633.7	634.9	636.3	637.2	638.1	639.2
241	629.2	632.7	634.3	635.5	636.8	637.8	638.6	639.7
242	630.1	633.6	635.1	636.3	637.6	638.5	639.4	640.5
243	630.9	634.4	635.9	637.1	638.4	639.4	640.2	641.3
244	631.7	635.1	636.7	637.8	639.2	640.1	641.0	642.0
245	632.4	635.8	637.4	638.5	639.9	640.8	641.6	642.7
246	633.5	636.9	638.5	639.6	641.0	641.9	642.7	643.8
247	634.3	637.9	639.5	640.7	642.0	642.9	643.8	644.8
248	635.0	638.8	640.4	641.6	642.9	643.8	644.7	645.8
249	635.5	639.5	641.1	642.3	643.7	644.5	645.5	646.5
250	636.1	639.9	641.5	642.7	644.0	644.8	645.7	646.8
251	636.9	640.7	642.2	643.3	644.5	645.3	646.2	647.2
252	638.2	641.7	643.0	644.1	645.2	646.0	646.8	647.7
253	639.3	642.5	643.9	644.9	646.0	646.7	647.5	648.4
254	640.1	643.3	644.6	645.6	646.7	647.4	648.2	649.1
255	640.6	643.8	645.1	646.1	647.2	648.0	648.7	649.7
256	641.3	644.5	645.8	646.8	647.9	648.6	649.4	650.3
257	641.9	645.2	646.5	647.5	648.5	649.3	650.0	651.0
258	643.0	646.3	647.6	648.6	649.7	650.4	651.2	652.2
259	643.9	647.2	648.5	649.5	650.7	651.4	652.2	653.2
260	644.7	648.2	649.6	650.6	651.8	652.6	653.3	654.3
261	645.5	649.2	650.6	651.7	653.0	653.8	654.6	655.6
262	646.4	650.4	652.0	653.2	654.5	655.4	656.2	657.3
263	647.3	651.1	652.7	653.9	655.3	656.2	657.1	658.1
264	648.4	652.1	653.6	654.8	656.1	656.9	657.8	658.8

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

RM	Profiles - Percent Chance Flood							
	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
265	649.4	653.0	654.4	655.5	656.8	657.6	658.4	659.4
266	650.3	653.9	655.4	656.4	657.7	658.5	659.2	660.2
267	651.0	654.7	656.1	657.2	658.5	659.3	660.1	661.0
268	651.6	655.3	656.8	657.9	659.2	660.0	660.8	661.8
269	652.1	655.8	657.3	658.5	659.8	660.6	661.4	662.4
270	652.5	656.2	657.8	658.9	660.2	661.1	661.9	662.9
271	652.9	656.6	658.2	659.4	660.7	661.6	662.4	663.4
272	653.2	657.1	658.7	659.9	661.2	662.1	662.9	663.9
273	653.6	657.4	659.1	660.3	661.7	662.6	663.3	664.4
274	654.3	658.1	659.7	660.9	662.3	663.2	664.0	665.0
275	655.0	658.7	660.3	661.5	662.9	663.7	664.5	665.5
276	655.8	659.4	661.0	662.1	663.5	664.3	665.1	666.1
277	656.4	660.1	661.6	662.7	664.0	664.9	665.6	666.6
278	657.0	660.7	662.2	663.3	664.5	665.4	666.2	667.1
279	658.0	661.6	663.0	664.1	665.3	666.2	666.9	667.8
280	659.0	662.6	663.9	665.0	666.1	666.9	667.6	668.5
281	660.2	663.6	665.0	665.9	667.0	667.8	668.5	669.3
282	661.4	664.7	666.0	667.0	668.0	668.7	669.4	670.2
283	662.0	665.4	666.7	667.6	668.7	669.4	670.1	670.9
284	662.7	666.1	667.4	668.3	669.4	670.1	670.8	671.6
285	663.3	666.7	668.0	668.9	670.0	670.7	671.4	672.2
286	664.1	667.3	668.6	669.5	670.5	671.2	671.9	672.7
287	664.8	668.0	669.2	670.1	671.1	671.8	672.5	673.3
288	665.3	668.6	669.8	670.7	671.7	672.4	673.0	673.8
289	665.9	669.1	670.4	671.3	672.3	673.0	673.7	674.5
290	666.5	669.8	671.1	672.0	673.1	673.8	674.5	675.3
291	667.1	670.5	671.8	672.8	674.0	674.7	675.4	676.3
292	667.6	671.1	672.6	673.6	674.8	675.6	676.3	677.2
293	668.4	672.0	673.5	674.5	675.7	676.5	677.3	678.2
294	669.3	672.9	674.4	675.5	676.8	677.6	678.3	679.3
295	669.8	673.5	675.1	676.2	677.5	678.4	679.2	680.2
296	670.3	674.2	675.8	677.1	678.5	679.4	680.2	681.3
297	670.7	674.7	676.5	677.8	679.2	680.2	681.2	682.3
298	671.2	675.1	676.9	678.3	679.8	680.8	681.8	683.0
299	671.6	675.5	677.4	678.8	680.3	681.4	682.4	683.6
300	672.1	676.1	678.0	679.4	681.0	682.0	683.0	684.2
301	672.6	676.5	678.4	679.8	681.4	682.5	683.5	684.7
302	673.1	677.0	678.9	680.3	681.9	682.9	683.9	685.1
303	673.6	677.5	679.4	680.8	682.3	683.4	684.4	685.6
304	674.3	678.2	680.1	681.5	683.1	684.2	685.1	686.4
305	675.1	679.0	681.0	682.4	684.0	685.1	686.1	687.3
306	676.1	679.9	681.9	683.4	685.1	686.2	687.2	688.5
307	676.9	680.7	682.7	684.2	685.9	687.1	688.2	689.5
308	677.6	681.3	683.3	684.9	686.7	687.9	688.9	690.4
309	678.4	682.0	684.1	685.6	687.5	688.7	689.8	691.3
310	679.1	682.7	684.7	686.4	688.2	689.5	690.6	692.2
311	679.9	683.4	685.4	687.1	689.0	690.3	691.5	693.1
312	680.5	684.0	686.0	687.7	689.6	690.9	692.1	693.7
313	681.2	684.7	686.8	688.4	690.3	691.6	692.8	694.4
314	682.0	685.5	687.6	689.2	691.1	692.4	693.6	695.2
315	682.9	686.4	688.5	690.2	692.1	693.4	694.6	696.2
316	683.6	687.1	689.2	690.9	692.9	694.3	695.5	697.2
317	684.3	687.7	689.8	691.6	693.6	695.1	696.4	698.1

Missouri River Flood Profiles
Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
318	685.2	688.6	690.7	692.5	694.6	696.1	697.5	699.3
319	686.0	689.4	691.5	693.3	695.4	696.9	698.3	700.1
320	687.1	690.5	692.6	694.4	696.6	698.1	699.6	701.5
321	688.2	691.6	693.7	695.5	697.7	699.2	700.7	702.6
322	689.3	692.7	694.7	696.6	698.8	700.3	701.8	703.8
323	690.7	694.0	696.1	697.9	700.2	701.7	703.2	705.2
324	691.7	695.0	697.1	699.0	701.2	702.8	704.3	706.3
325	692.6	696.0	698.1	699.9	702.1	703.6	705.1	707.0
326	693.4	696.8	698.9	700.8	702.9	704.3	705.7	707.4
327	694.1	697.6	699.7	701.5	703.6	704.9	706.3	707.9
328	694.7	698.3	700.4	702.2	704.2	705.6	706.9	708.5
329	695.7	699.3	701.4	703.2	705.3	706.6	708.0	709.7
330	696.7	700.3	702.4	704.3	706.5	707.9	709.4	711.3
331	697.7	701.3	703.4	705.4	707.6	709.2	710.8	712.8
332	698.6	702.2	704.4	706.3	708.6	710.2	711.8	713.9
333	699.5	703.0	705.2	707.1	709.4	710.9	712.4	714.5
334	700.2	703.8	705.9	707.8	710.0	711.5	713.0	714.9
335	701.1	704.8	707.0	708.9	711.1	712.5	714.0	716.0
336	701.9	705.5	707.6	709.6	711.9	713.5	715.0	717.1
337	702.8	706.3	708.4	710.4	712.8	714.4	716.1	718.4
338	704.0	707.3	709.4	711.3	713.7	715.3	717.0	719.3
339	704.7	708.2	710.3	712.2	714.6	716.2	717.8	720.0
340	705.8	709.4	711.6	713.5	715.8	717.4	719.0	721.1
341	706.8	710.5	712.7	714.7	717.0	718.7	720.3	722.4
342	708.2	711.9	714.1	716.1	718.5	720.2	721.8	724.1
343	709.2	713.0	715.3	717.3	719.7	721.3	722.9	725.1
344	710.2	714.2	716.5	718.5	720.9	722.6	724.1	726.3
345	711.2	715.2	717.6	719.7	722.1	723.8	725.4	727.5
346	712.4	716.5	718.9	721.1	723.6	725.3	727.0	729.2
347	713.2	717.3	719.7	721.9	724.4	726.2	727.9	730.2
348	714.2	718.2	720.6	722.8	725.4	727.2	729.0	731.3
349	715.4	719.4	721.9	724.1	726.7	728.5	730.4	732.8
350	716.3	720.5	723.0	725.3	727.9	729.8	731.6	734.0
351	717.2	721.5	724.0	726.3	728.9	730.8	732.6	735.0
352	718.1	722.4	725.0	727.3	730.0	731.8	733.6	736.0
353	718.6	723.1	725.7	727.9	730.6	732.5	734.2	736.6
354	719.7	724.3	726.9	729.2	731.9	733.8	735.5	737.8
355	720.6	725.3	728.0	730.3	733.0	734.8	736.6	738.9
356	721.6	726.3	729.1	731.4	734.2	736.1	737.9	740.3
357	722.4	727.3	730.1	732.5	735.2	737.2	739.0	741.4
358	722.9	728.5	731.3	733.7	736.5	738.4	740.1	742.5
359	723.5	729.7	732.5	734.9	737.7	739.7	741.5	743.9
360	724.5	731.1	734.0	736.4	739.2	741.2	743.1	745.5
361	725.3	732.3	735.2	737.8	740.8	742.8	744.8	747.4
362	726.4	733.4	735.9	739.0	742.1	744.2	746.2	748.9
363	727.7	734.5	736.7	740.1	743.2	745.4	747.6	750.3
364	728.9	735.7	737.6	741.4	744.5	746.7	748.8	751.5
365	729.7	737.0	738.9	742.8	746.0	748.3	750.4	753.3
366	731.4	738.1	740.1	743.9	747.2	749.5	751.8	754.7
367	732.4	739.0	741.5	745.2	748.5	750.9	753.2	756.2
368	733.3	739.7	742.3	746.2	749.4	751.6	754.3	757.3
369	734.7	740.6	743.2	747.7	750.8	752.8	755.7	758.5
370	736.2	741.7	744.2	749.1	752.0	753.9	756.9	759.4

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
371	737.9	742.8	745.7	750.8	753.4	755.1	757.9	760.2
372	738.7	743.8	746.5	751.8	754.2	755.8	758.7	760.8
373	739.3	745.1	747.4	752.7	755.2	756.7	759.9	761.5
374	740.6	746.0	748.1	753.1	756.0	757.5	760.9	762.5
375	742.3	747.0	749.9	753.8	756.3	758.6	761.8	763.7
376	743.3	748.0	751.1	754.5	756.9	758.7	762.5	764.3
377	744.3	749.1	751.7	755.0	757.5	759.1	763.0	764.6
378	745.1	749.7	752.1	755.4	758.0	759.6	763.3	764.8
379	746.2	750.6	752.7	756.3	758.7	760.6	763.8	765.2
380	746.8	751.2	753.4	756.9	759.1	761.3	764.2	765.6
381	747.8	751.9	754.2	757.5	759.6	762.0	764.6	766.1
382	749.0	752.8	755.1	758.2	760.2	762.6	765.0	766.5
383	750.1	753.7	756.0	759.0	761.0	763.2	765.5	767.0
384	750.8	754.6	756.8	759.7	761.7	763.7	766.0	767.4
385	751.6	755.5	757.7	760.4	762.3	764.2	766.5	768.0
386	752.9	756.7	758.8	761.4	763.1	765.2	767.2	768.6
387	754.0	757.6	759.9	762.4	763.8	766.1	767.7	769.1
388	755.1	758.5	760.9	763.2	764.5	766.8	768.0	769.4
389	756.1	759.6	762.0	764.1	765.5	767.4	768.4	769.7
390	756.8	760.5	762.7	764.8	766.3	767.9	768.8	770.1
391	757.7	761.4	763.6	765.5	767.3	768.5	769.3	770.6
392	759.2	762.6	764.9	766.7	768.4	769.4	770.2	771.4
393	760.2	763.5	765.8	767.6	769.1	770.1	770.9	772.1
394	761.4	764.6	767.0	768.7	770.1	771.1	771.8	773.0
395	762.3	765.5	768.1	769.5	770.9	771.9	772.6	773.7
396	763.2	766.6	769.1	770.4	771.7	772.7	773.4	774.5
397	764.3	767.7	770.1	771.2	772.6	773.5	774.2	775.3
398	765.7	769.5	771.2	772.4	773.7	774.6	775.4	776.4
399	766.7	770.5	772.0	773.1	774.5	775.4	776.2	777.2
400	767.9	771.4	772.9	774.1	775.4	776.4	777.2	778.2
401	769.1	772.1	773.6	774.8	776.2	777.1	777.9	779.0
402	770.5	773.2	774.7	775.8	777.1	778.0	778.8	779.8
403	771.5	774.1	775.5	776.5	777.8	778.6	779.4	780.3
404	772.6	775.1	776.5	777.4	778.6	779.4	780.1	780.9
405	773.5	775.9	777.2	778.2	779.2	780.0	780.7	781.5
406	774.3	776.7	778.0	778.9	780.0	780.7	781.3	782.1
407	775.2	777.6	778.9	779.7	780.8	781.5	782.1	782.9
408	775.8	778.2	779.4	780.3	781.3	782.0	782.6	783.4
409	776.5	778.9	780.1	781.0	782.0	782.7	783.3	784.0
410	777.3	779.7	780.9	781.8	782.8	783.5	784.1	784.8
411	778.1	780.5	781.7	782.6	783.6	784.3	784.9	785.6
412	779.0	781.5	782.8	783.6	784.6	785.4	786.0	786.7
413	779.5	782.0	783.3	784.2	785.2	785.9	786.5	787.3
414	780.0	782.6	783.9	784.8	785.8	786.6	787.2	788.0
415	780.6	783.2	784.5	785.4	786.5	787.2	787.9	788.7
416	781.0	783.6	784.9	785.8	786.9	787.6	788.3	789.1
417	781.8	784.4	785.7	786.6	787.7	788.4	789.0	789.8
418	782.6	785.2	786.5	787.5	788.6	789.3	790.0	790.8
419	783.3	786.0	787.3	788.3	789.4	790.2	790.8	791.6
420	783.8	786.6	787.9	788.8	789.9	790.7	791.3	792.2
421	784.4	787.1	788.4	789.4	790.5	791.2	791.9	792.7
422	784.9	787.7	789.0	789.9	791.0	791.8	792.5	793.3
423	785.5	788.1	789.4	790.4	791.6	792.4	793.0	793.9

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
424	786.2	788.2	789.6	790.7	791.8	792.7	793.4	794.2
425	787.0	788.7	790.2	791.3	792.6	793.5	794.3	795.2
426	787.5	789.1	790.6	791.8	793.2	794.1	794.9	795.9
427	788.1	789.6	791.1	792.3	793.7	794.7	795.6	796.6
428	788.7	790.3	791.9	793.1	794.5	795.5	796.4	797.6
429	789.5	791.2	792.8	793.9	795.1	796.2	797.1	798.3
430	790.2	791.9	793.7	794.9	795.9	796.9	797.8	799.2
431	791.0	792.8	794.7	796.0	797.0	798.0	799.0	800.4
432	792.0	793.6	795.9	797.1	798.2	799.3	800.3	801.9
433	792.8	794.5	796.9	798.1	799.4	800.6	801.7	803.3
434	793.8	795.6	797.9	799.2	800.9	802.2	803.4	804.9
435	794.6	796.8	798.9	800.4	802.3	803.7	804.9	806.4
436	795.5	798.2	800.3	801.9	803.8	805.3	806.5	808.1
437	796.3	799.5	801.6	803.2	805.3	806.7	808.0	809.5
438	797.5	801.1	803.3	805.0	807.0	808.5	809.7	811.3
439	798.5	802.1	804.4	806.1	808.1	809.6	810.8	812.4
440	799.5	803.0	805.5	807.2	809.3	810.7	811.9	813.5
441	800.6	804.1	806.6	808.4	810.4	811.9	813.1	814.6
442	801.8	805.6	808.1	810.1	812.1	813.5	814.7	816.2
443	802.4	806.6	809.0	811.2	813.1	814.4	815.5	817.0
444	803.2	807.5	809.8	812.3	814.1	815.3	816.4	817.7
445	804.1	808.3	810.7	813.3	815.0	816.1	817.1	818.3
446	805.2	809.1	811.6	814.4	816.0	817.1	818.0	819.1
447	806.1	810.0	812.3	815.5	817.1	818.2	819.1	820.3
448	807.6	811.1	813.5	816.6	818.3	819.4	820.3	821.5
449	808.7	812.2	814.6	817.6	819.3	820.4	821.4	822.6
450	809.6	813.1	815.5	818.6	820.3	821.5	822.5	823.8
451	810.8	814.2	816.5	819.7	821.4	822.6	823.6	824.9
452	812.1	815.6	817.7	820.8	822.5	823.7	824.8	826.0
453	813.1	816.9	818.8	821.7	823.4	824.7	825.7	827.0
454	814.0	817.8	819.7	822.4	824.1	825.4	826.4	827.8
455	815.0	818.6	820.6	823.0	824.8	826.1	827.2	828.5
456	815.8	819.3	821.5	823.6	825.4	826.7	827.8	829.2
457	816.5	820.5	822.7	824.3	826.1	827.4	828.5	829.9
458	817.0	821.8	823.7	825.2	826.9	828.2	829.3	830.6
459	817.8	823.0	824.9	826.3	828.0	829.2	830.2	831.6
460	818.7	823.9	825.8	827.2	828.9	830.0	831.0	832.3
461	819.7	824.9	826.8	828.2	829.7	830.8	831.8	832.9
462	820.4	825.9	827.7	829.1	830.6	831.7	832.6	833.7
463	821.4	827.2	829.1	830.4	831.9	833.0	833.9	835.0
464	822.1	828.0	829.8	831.2	832.7	833.8	834.7	835.7
465	823.1	829.1	830.9	832.2	833.7	834.8	835.7	836.7
466	824.5	830.4	832.3	833.6	835.0	836.0	836.9	837.9
467	825.5	831.3	833.4	834.6	836.0	837.0	837.8	838.8
468	826.5	832.1	834.5	835.8	837.1	838.1	838.9	839.8
469	827.7	833.0	835.6	837.4	838.8	839.8	840.6	841.6
470	828.5	834.0	836.6	838.7	840.1	841.1	842.1	843.0
471	829.2	835.0	837.6	839.8	841.3	842.3	843.3	844.3
472	830.0	836.1	838.5	840.8	842.4	843.5	844.5	845.5
473	830.9	837.1	839.5	841.8	843.4	844.5	845.5	846.6
474	831.8	838.0	840.3	842.7	844.2	845.4	846.4	847.6
475	832.7	838.8	841.1	843.5	845.1	846.3	847.3	848.5
476	833.8	839.8	842.1	844.5	846.1	847.3	848.4	849.6

Missouri River Flood Profiles

Upper Mississippi River System Flow Frequency Study

	Profiles - Percent Chance Flood							
RM	50.0	20.0	10.0	5.0	2.0	1.0	0.5	0.2
477	835.0	841.0	843.0	845.4	847.0	848.2	849.3	850.5
478	836.0	841.8	843.8	846.1	847.7	848.9	850.0	851.2
479	836.9	842.4	844.5	846.8	848.4	849.6	850.7	851.9
480	838.0	843.2	845.3	847.6	849.2	850.4	851.5	852.7
481	839.0	844.2	846.0	848.4	850.0	851.1	852.2	853.5
482	839.9	845.1	846.8	849.1	850.7	851.9	853.0	854.2
483	841.3	846.2	847.9	850.3	851.9	853.1	854.2	855.5
484	842.1	846.7	848.4	850.7	852.3	853.6	854.7	855.9
485	843.2	847.4	849.1	851.4	852.9	854.1	855.1	856.3
486	844.1	847.9	849.7	851.8	853.3	854.4	855.4	856.5
487	845.6	849.0	850.9	852.4	853.8	854.9	855.9	856.9
488	846.5	849.8	851.5	852.9	854.3	855.4	856.4	857.4
489	847.6	850.8	852.5	853.8	855.3	856.5	857.5	858.7
490	848.4	851.6	853.3	854.8	856.4	857.7	858.8	860.0
491	849.0	852.2	854.0	855.4	857.1	858.4	859.5	860.8
492	849.8	853.1	854.9	856.3	858.0	859.3	860.5	861.8
493	850.4	853.8	855.6	857.1	858.7	859.9	861.1	862.3
494	850.9	854.5	856.3	857.7	859.3	860.3	861.6	862.7
495	851.9	855.6	857.5	859.0	860.2	861.1	862.4	863.4
496	853.2	856.7	858.4	859.9	861.0	861.9	862.9	863.8
497	854.4	857.6	859.1	860.6	861.6	862.5	863.3	864.2
498	856.1	859.1	860.3	861.5	862.3	863.2	863.9	864.6