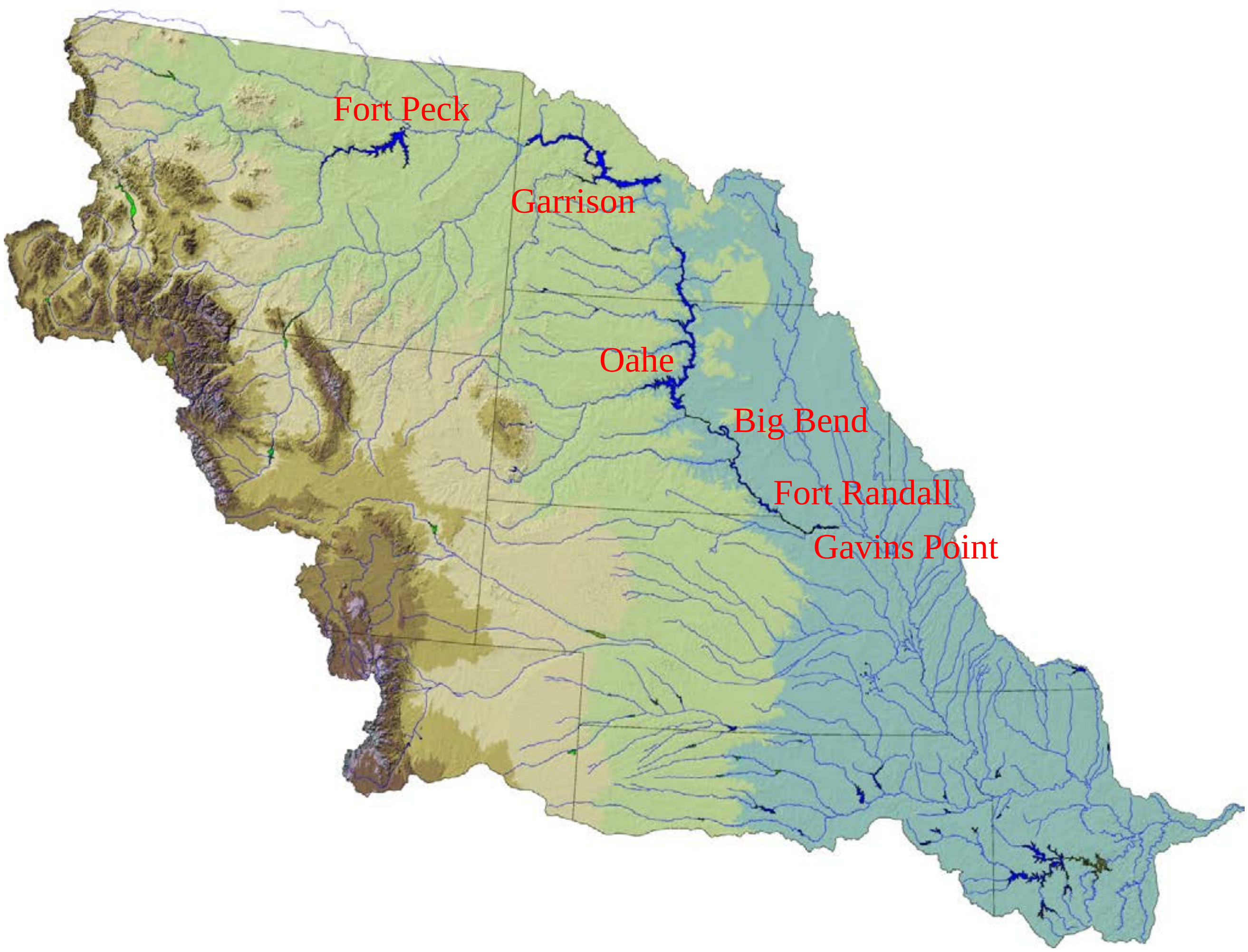
US Army Corps of Engineers
Northwestern Division

Missouri River Mainstem Reservoir System

Water Control Manual

Oahe Dam – Lake Oahe



Missouri River Basin Water Management Division
U.S. Army Corps of Engineers
Northwestern Division – Missouri River Basin
Omaha, Nebraska

December 2018

Missouri River Basin
Mainstem Reservoir System
Water Control Manual

In 7 Volumes Volume 4

OAHE PROJECT

Volume 1	Master Manual
Volume 2	Fort Peck (Fort Peck Lake)
Volume 3	Garrison (Lake Sakakawea)
Volume 4	Oahe (Lake Oahe)
Volume 5	Big Bend (Lake Sharpe)
Volume 6	Fort Randall (Lake Francis Case)
Volume 7	Gavins Point (Lewis and Clark Lake)

Prepared by
U.S. Army Engineer Division, Northwestern Division
Corps of Engineers
Omaha, Nebraska

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Mainstem Reservoir System
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OAHE PROJECT

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ABBREVIATIONS / ACRONYMS

AF	-	acre-feet
AOP	-	Annual Operating Plan
BIA	-	Bureau of Indian Affairs
cfs	-	cubic feet per second
Co-op	-	Cooperative Streamgaging Program
Corps	-	U.S. Army Corps of Engineers
CRREL	-	Cold Regions Research and Engineering Laboratory
CWA	-	Clean Water Act
DCP	-	Data Collection Platform
DPR	-	Definite Project Report
DRM	-	Daily Routing Model
EM	-	Corps' Engineering Manual
ER	-	Corps' Engineering Regulation
ESA	-	Endangered Species Act
°F	-	degrees Fahrenheit
kAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kV	-	kilovolt
kVA	-	kilovolt-amp
kW	-	kilowatt
least tern	-	interior least tern
M&I	-	Municipal and Industrial
MAF	-	million acre-feet
Master Manual	-	Master Water Control Manual
MBRFC	-	Missouri Basin River Forecast Center
MDRWS	-	Mid-Dakota Rural Water System
MRBIR	-	Missouri River Basin Interagency Roundtable
MRBWM	-	Missouri River Basin Water Management
MRD	-	Missouri River Division
MRNRC	-	Missouri River Natural Resources Committee
MRR	-	Missouri River Region
MRRIC	-	Missouri River Recovery Implementation Committee
MW	-	megawatt
MWh	-	megawatt hour
NAVD88	-	National American Vertical Datum of 1988
NGVD29	-	National Geodetic Vertical Datum of 1929
NWD	-	Northwestern Division
NWDR	-	Northwestern Division Regulation
NWS	-	National Weather Service
O&M	-	Operation and Maintenance
Oahe Unit	-	Oahe Diversion Unit
QPE	-	Quantitative Precipitation Estimate
PPCS	-	Powerplant Control System
RCC	-	Reservoir Control Center
RM	-	River Mile (1960 mileage)

SDF	-	Spillway Design Flood
Southwestern	-	Southwestern Power Administration
SPP	-	Southwest Power Pool
SWE	-	snow water equivalent
System	-	Missouri River Mainstem Reservoir System
T&E	-	threatened and endangered
tern	-	interior least tern
USBR	-	U.S. Bureau of Reclamation
USFWS	-	U.S. Fish and Wildlife Service
USGS	-	U.S. Geological Survey
WCM	-	water control manual
Western	-	Western Area Power Administration
WMS	-	Water Management System

Missouri River Basin
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I - Introduction

1-01. Authorization. This manual has been prepared as directed in the U.S. Army Corps of Engineers' (Corps) Engineering Regulation, ER 1110-2-240, which prescribes the policies and procedures to be followed by the Corps in carrying out water management activities, including establishment and the updating of water control plans for Corps and non-Corps projects, as required by federal laws and directives. This manual is prepared as the water control manual (WCM) for Oahe as discussed in that regulation. This WCM is also prepared in accordance with pertinent sections of the Corps' Engineering Manual, EM 1110-2-3600, and titled *Management of Water Control Systems*. This WCM is prepared under the general format and recommendations described in ER 1110-2-8156, dated August 31, 1995 and titled *Preparation of Water Control Manuals*. This Oahe WCM, like the Mainstem Master Water Control Manual (Master Manual) and its selected water control plan, establish guidelines intended to be used by the Corps in regulating Oahe. However, changed conditions or unforeseen conditions may necessitate changes or deviations from these guidelines. This is consistent with Corps' regulations that allow for both updates for changes in normal regulation as well as for deviations to the approved WCM. Revisions to this WCM are processed in accordance with ER 1110-2-240. Deviations from this WCM are processed in accordance with ER 1110-2-1400 and the Northwestern Division Regulation, NWDR 1110-2-6.

1-02. Purpose and Scope. This manual is one of the seven volumes prepared for the Missouri River Mainstem Reservoir System (System). Six of the volumes are for each of the six System projects (project name is the same as the name of the dam) and one is for total System regulation (Master Manual):

Volume	Project
1	Master Manual
2	Fort Peck – Fort Peck Dam / Fort Peck Lake
3	Garrison – Garrison Dam / Lake Sakakawea
4	Oahe – Oahe Dam / Lake Oahe
5	Big Bend – Big Bend Dam / Lake Sharpe
6	Fort Randall – Fort Randall Dam / Lake Francis Case
7	Gavins Point – Gavins Point Dam / Lewis and Clark Lake

1-02.1. This individual project WCM serves as a supplement to the Master Manual (Volume 1) and presents aspects of project regulation not common to the System as a whole. This includes detail on the incremental drainage areas regarding hydrology, hydrologic networks, forecasting, streamflow and runoff. This WCM also includes site-specific maps and regulation considerations. This individual project WCM, like the Master Manual, serves as a guide to the Missouri River Basin Water Management (MRBWM) Division in meeting the operational objectives of the System when regulating the six System reservoirs. Since Oahe is part of the System, any discussions regarding the regulation of Oahe that conflict with statements presented in the Master Manual will be secondary and conducted to the extent possible only after regulation of the System as a whole is accomplished.

1-03. Related Manuals and Reports. The System projects were constructed by the Corps for the purpose of flood control, navigation, recreation, water supply, water quality control, fish and wildlife, hydropower and irrigation. To achieve the multi-purpose benefits for which the System was authorized and constructed, it must be regulated as a hydraulically and electrically integrated system. Therefore, the Master Manual presents the basic System operational objectives and the plans for their optimum fulfillment, with supporting basic data. The Oahe WCM supplements the Master Manual by discussing the factors pertinent to the regulation of Oahe. The regulation of major tributary reservoirs located within the Missouri River basin affecting the regulation of Oahe is detailed in separate WCMs prepared for the individual tributary projects.

1-03.1. In an effort to reduce redundancy, frequent reference will be made in this WCM to information contained in the Master Manual. This is particularly true with respect to details concerning organization, coordination with other projects and agencies, and other factors that are pertinent to regulation of the System as a whole. This WCM presents further information and expands or emphasizes details that are of particular importance to Oahe and serves as a supplement to the Master Manual.

1-04. Project Owner. Oahe was constructed and is owned by the Corps of Engineers, Department of the Army.

1-05. Operating Agency. The Corps operates the System, which includes Oahe. The Corps' Northwestern Division's (NWD) MRBWM office, formerly known as the Reservoir Control Center (RCC), located in Omaha, NE, oversees the day-to-day implementation of the System Water Control Plan. The Omaha District of the NWD has staff located at Oahe, as well as the other System projects, to carry out the day-to-day operation (based on the reservoir regulation/power production orders received from the MRBWM office in Omaha) and maintenance of each project. All System dams have hydropower as an authorized purpose and are automated into a system called the Powerplant Control System (PPCS) for regulation of hydropower production and project releases. The Western Area Power Administration (Western) uses the System projects as an integral part of the Midwest power grid. Reservoir regulation/power production orders, reflecting the daily and hourly hydropower limits imposed on project regulation, are generated by the MRBWM office and sent to each mainstem project on a daily basis, or more frequently, as required. Also during critical periods, coordination between project personnel and MRBWM staff is conducted on an as-needed basis to ensure that expected release rates are achieved.

1-06. Regulating Agencies. As the Oahe owner, the Corps has the direct responsibility of regulating the project, as well as the other five System projects, to meet the authorized project purposes. This is accomplished in coordination with many others, including federal, state and Tribal agencies and a myriad of stakeholders. As these other entities provide input to the Corps regarding the System regulation through the Annual Operating Plan (AOP) process, the Corps must determine if the proposal is within the Corps' authority and has met all applicable laws and regulations regarding System regulation prior to incorporating any of this input into the AOP or day-to-day regulation. As part of its regulation of the System, the MRBWM office conducts day-to-day coordination with Western, which markets the power produced at each project and frequent coordination with the U.S. Fish and Wildlife Service (USFWS), which advises the Corps on the effects of System regulation related to fish and wildlife, including threatened and endangered (T&E) species. Coordination with the other previously mentioned specific interest groups is conducted on an as-needed basis, following initiation by either the Corps or the stakeholder.

1-07. Vertical Datum. The System projects were designed and constructed to a local project datum while recent hydrologic updates such as elevation-area and elevation-capacity curves and rating curve datums are in National Geodetic Vertical Datum of 1929 (NGVD29).

1-07.1. Corps regulation, ER 1110-2-8160, dated March 1, 2009 and titled *Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums*, specifies that a long-term effort should be programmed to transition from a legacy reference datum to the National Spatial Reference System (NSRS) which is currently the National American Vertical Datum of 1988 (NAVD88). However, conversion from local datum/NGVD29 to NAVD88 has not been conducted on the System projects at this time. See Table I-1 for adjustments for the three datums for Oahe. These are provided for reference only and should not be used for construction or other purposes.

Table I-1
Oahe Datums (in feet)

Local project datum	NGVD29	NAVD88
0.0	-0.10	+1.14
(ex.) 1607.5	1607.4	1608.64

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II - Legislative and Project Construction History

2-01. Project Authorization. The need for flood control projects along the Missouri River and its tributaries was long recognized. Comprehensive development was proposed by the Corps in House Document No. 238 (73rd Congress, 2nd Session 1934). While Oahe, as it exists today, was not included in the document, the report did propose construction of reservoirs on both the main stem of the Missouri River and on tributary streams in the Missouri River basin together with levees along the lower Missouri River as a flood control measure. The beneficial influence of the reservoirs on Missouri and Mississippi River navigation was also recognized.

2-01.1. House Document 475 (78th Congress, 2nd Session, 1944) presented the Corps' plan for the overall development of the main stem of the Missouri River. This document proposed a low dam near the present Oak Creek site, with such modifications as the Secretary of War and the Chief of Engineers might find advisable. The U.S. Bureau of Reclamation's (USBR) plans for Missouri River development, as contained in Senate Document 191, 78th Congress, provided for a high dam near the present Oahe site. The differences between the plans were adjusted in an inter-departmental conference and the coordinated plan, including the Oahe Project near its present site, was presented to Congress in Senate Document 247, otherwise known as the "Pick-Sloan Plan." Legislative history of the System and individual projects are described in greater detail in Chapter II of the Master Manual.

2-01.2. Oahe was authorized by the Flood Control Act, approved December 22, 1944 (Public Law 534, 78th Congress, 2nd Session), which states:

> "Sec. 9 (a) The general comprehensive plans set forth in House Document 475 and Senate Document 191, Seventy-eighth Congress, second session, as revised and coordinated by Senate Document 247, Seventy-eighth Congress, second session, are hereby approved and the initial stages recommended are hereby authorized and shall be prosecuted by the War Department and the Department of the Interior as speedily as may be consistent with budgetary requirements."

2-02. Project Development. Oahe was planned and constructed by the Corps' Omaha District under supervision of the Missouri River Division (MRD) and the Chief of Engineers. The Definite Project Report (DPR) prepared by the Omaha District was published in February 1946. Construction began in August 1948, with diversion of the Missouri River through the constructed outlet works accomplished in 1958 and completion of the embankment occurring in 1961. Installation of power units followed; most major construction was completed by 1966.

2-03. Construction History. The initial construction contract awarded for Oahe was for the west access highway. Work started in August 1948. The first of the eight earthwork contracts for the construction of the dam embankment was let in May 1950. The final contract on the dam embankment was completed in 1961. The contract for the first of five stages for construction of the outlet works was awarded in 1953. The river was diverted through the outlet works on

August 3, 1958. Earthwork on the spillway was completed in 1958 and the structure was completed in August 1963. Work on the powerhouse and associated structures was started in 1958 and progressed well ahead of schedule. The first of the seven power units became operational in early 1962 with additional units placed on line in the following months and the final unit placed in operation in June 1963. Formal dedication ceremonies were held on August 17, 1962. Contracts consisting of Stage V, construction of roads, parking areas and seeding around powerhouse areas, crest roadway lighting and relocation of 38 miles of Northern Pacific Railroad tract in North Dakota were completed in 1966. Plate II-1 presents a summary of the significant dates of the System dams' construction, diversion, closure, filling of the minimum operating pool, and initial generation of the first and last units.

2-04. Relocations. The relocations required for the development of the Oahe reservoir included portions of two federal highways, a North Dakota state highway and numerous county and Indian Agency roads that would be inundated by the reservoir. Railroad relocations included the main east-west line and branch lines of the Chicago, Milwaukee, St. Paul and Pacific Railroad as well as branch lines of the Minneapolis, St. Paul and Sault Ste. Marie and the Northern Pacific Railroads. Relocation of many miles of telephone, telegraph and power lines, as well as several cemeteries, was required. Several towns and villages including the Cheyenne Indian Agency, Mobridge, Forest City, Whitlock Crossing, Kenel and Pollock in South Dakota, as well as Fort Yates and Cannon Ball in North Dakota, required varying degrees of relocation or protection. Several small communities were entirely abandoned. New highway bridges were constructed where U.S. Highways 12 and 212 crossed the Missouri River valley. A bridge was also constructed for the Missouri River crossing of the Chicago, Milwaukee, St. Paul and Pacific Railroad. Low steel on the bridges crossing the Oahe reservoir is at about elevation 1656.0 feet, providing 36 feet of clearance above the maximum operating pool of elevation 1620.0 feet.

2-05. Real Estate Acquisitions. Over 400,000 acres of real estate in fee and 2,417 acres in easement were acquired by purchase and condemnation for Oahe (dam and reservoir) in North Dakota and South Dakota. In addition, 13,381 acres were transferred by Public Land Order from the Public Domain. The basis for real estate acquisition over most of the reservoir area was a quit-taking line of elevation 1620.0 feet, the maximum operating pool. An allowance from the taking line contour was made for possible bank erosion and the blocking out of perimeter ownerships to avoid excessive severances and expensive ground surveys. In the upstream end of the Oahe reservoir, aggradation and backwater effects were recognized with real estate acquired up to near an elevation 1630.0 feet guide-taking line. The guide-taking line in this reach was based on the profile associated with an inflow of 65,000 cubic feet per second (cfs), a reservoir level of 1617.0 feet, 25-year aggradation, and two feet of freeboard for wind effects.

2-06. Regulation History. Closure of Oahe and the first impoundment of water in the Oahe reservoir began in July 1958. During the early years the Oahe reservoir was regulated in conjunction with the Fort Peck, Garrison, Fort Randall and Gavins Point reservoirs to provide control of flood flows and to regulate available flows for production of additional power in the existing System hydroelectric plants, navigation and maintenance of sufficient flows for domestic and industrial uses and for water quality purposes. Oahe power generation began in 1962 with the completion of Unit No. 1 in April. Unit Nos. 2, 3 and 4 went on line in July, November and December 1962, respectively, followed by Unit Nos. 6 and 7 in 1963. The Permanent Zone (below elevation 1540.0 feet) was filled in 1962 and the Carryover Multiple

Use Zone was filled (to elevation 1607.5 feet) in 1968. As of the writing of this WCM, storage in the Exclusive Flood Control Zone (elevation 1617.0 to 1620.0 feet) has been utilized in ten years: 1975, 1984, 1986, 1995, 1996, 1997, 1999, 2010, 2011 and 2018. Further information concerning historical regulation is contained in Appendix A of this WCM. Detailed descriptions of each year's project regulation are detailed in that year's AOP and annual Summary of Actual Regulation reports published by the MRBWM office.

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Missouri River Basin
Oahe Dam – Lake Oahe
Water Control Manual

III - Basin Description and Characteristics

3-01. General Characteristics. The Missouri River basin drainage area upstream of Oahe includes all of Montana east of the Continental Divide, northern Wyoming, southwestern North Dakota, northwestern South Dakota, a very small portion of northwestern Nebraska, and portions of the tributary Milk River drainage lying in southwestern Canada. The total area controlled by Oahe Dam is 243,490 square miles. This includes 57,500 square miles of drainage above Fort Peck Dam and 123,900 square miles of drainage area between the Fort Peck and Garrison dams. Those portions of the Missouri River basin lying upstream from Garrison Dam are described in the Fort Peck and Garrison WCMs. The portion of the Missouri River basin described in this WCM consists of the 62,090 square miles of drainage area between Garrison and Oahe, as well as the drainage area contributing to the Missouri River in the reach immediately below Oahe into the headwaters of Big Bend. Further description of this downstream area is contained in the Big Bend WCM. Plate III-1 is a general map of the Missouri River basin. The incremental drainage area defined by Oahe, and described in this WCM, is shown on Plate III-2.

3-02. Topography. The Missouri River drainage area between Garrison and the headwaters of Big Bend forms a portion of the Great Plains province of the United States. The area to the north and east of the Missouri River is within the Glaciated Missouri Plateau. This plateau consists of gently rolling topography in which stream dissection and drainage are not well established except in areas immediately adjacent to the Missouri River. Drainage in upland areas is largely into pot holes, small intermittent lakes and a few larger permanent lakes. Most of the drainage in the Oahe incremental area lies within the Unglaciated Missouri Plateau, which is to the south and west of the Missouri River. Numerous small hilly areas, buttes and hogbacks having elevations higher than the general level of the plains characterize this region. While the region as a whole is rolling and rather thoroughly dissected by streams, there are small, nearly level areas on the stream divides. There are a few relatively larger areas of gently rolling relief scattered throughout the region.

3-02.1. The Black Hills Section is surrounded by the Unglaciated Missouri Plateau region. This is an elliptical-shaped mountainous area about 65 miles wide and 125 miles long centered along the border separating Wyoming and South Dakota. The slopes are steep to precipitous and covered in places by bare, craggy rocks.

3-02.2. The Unglaciated Missouri Plateau region has a general west to east slope of about 10 feet per mile. Elevations range from about 5,000 feet in the southwestern part of the incremental drainage area to near 1,500 feet on bottom lands adjacent to the Missouri River. Within the Black Hills, mountain peaks extend to over 7,000 feet.

3-03. Land Use. Agriculture represents the primary use of the land in this portion of the Missouri River basin with grasslands making up the vast majority (over 50 percent), followed by pasture/hay, row crops, small grains, and fallow areas. The basin also consists of shrub land, forested lands, and wetlands areas. Most of the forested lands are in the Black Hills region. The remainder is devoted to transportation, residential and bare areas. About 13 percent of the incremental area is in federal ownership, the remainder being owned by state, county, or private individuals. Irrigation is practiced on only a minor amount of land in the incremental drainage area, with irrigated lands less than 1 percent of total cropland. Water areas in this incremental drainage area make up about just over 1 percent of the total area with the Missouri River and the Oahe reservoir accounting for the majority of the area. Despite only being just over 1 percent of the area, the rivers, lakes, reservoirs, farm ponds and other bodies of water involved are extremely important to the region's economy. Refer to Plate III-3 for a graphical representation of land use in the Oahe incremental drainage area.

3-04. Drainage Pattern. The drainage pattern of the Missouri River basin is shown on Plate III-1. Noteworthy in the drainage basin above Oahe is the large area of the upper Missouri River controlled by the Fort Peck and Garrison reservoirs. These two upstream System projects control about 75 percent of the total drainage contributing to the runoff into Oahe, including all of the mountainous regions contributing flow to the Missouri River above Oahe.

3-04.1. The most prominent feature of the incremental Missouri River basin drainage from Garrison to immediately below Oahe is that every major tributary is a right bank tributary and flows in an easterly direction. This direction of flow is of particular importance from the standpoint of flow contribution from storms that typically move in an easterly direction. Additionally, it becomes important at the time of snow melt and ice break-up in the spring. This is because spring air temperatures in the tributary headwaters are significantly higher than at the tributary mouths, resulting in an aggravation to ice jamming near their mouths during the ice break-up period. The drainage pattern contributing from the area west of the Missouri in this reach is generally well defined. However, to the east of the river there are numerous potholes and depressions. It is estimated that more than 1,000 square miles in this area will not contribute directly to streamflow unless substantial amounts runoff were to occur that are sufficient to fill and overflow the low depressions that normally restrict runoff.

3-04.2. Major tributaries in the incremental reach, which drain from the west to the Missouri River, extending from Garrison to the headwaters of Big Bend are the Knife, Heart and Cannonball Rivers in North Dakota and the Grand, Moreau, Cheyenne and Bad Rivers, primarily in South Dakota. The drainage of the latter tributaries is primarily in western South Dakota although a significant area in northeastern Wyoming and a small region of northwest Nebraska does contribute to the Cheyenne River. The largest tributary in this reach is the Cheyenne River, draining an area almost five times as great as any other of the tributary streams. Left bank minor tributaries entering the Missouri River and Oahe include Turtle Creek, Painted Woods Creek, Apple Creek and Beaver Creek in North Dakota and Spring Creek in South Dakota. Table III-1 lists tributary streams and their drainage areas, as well as locations of tributary mouths and other significant features along the Missouri River in this reach.

3-05. Stream Slopes. The total fall of the Missouri River from Garrison to Oahe is about 250 feet, averaging about 0.8 foot per river mile. Tributary stream slopes are significantly steeper, generally averaging between 5 and 8 feet per mile. Slopes on the tributary streams tend to progressively flatten toward their mouths. Slopes of Cheyenne River tributaries are much steeper in the Black Hills region of South Dakota.

Table III-1
Missouri River Drainage Areas
Garrison to Below Oahe

Feature	Tributary Drainage Area (square miles)	Location, Missouri River Mile[1]
Garrison Dam	-	1389.86
Knife River	2,510	1375.72
Turtle Creek	813	1352.00
Painted Woods Creek	556	1348.88
Bismarck, ND streamgaging site	-	1314.50
Heart River	3,340	1311.00
Apple Creek	1,770	1300.68
Cannonball River	4,310	1269.62
Beaver Creek	717	1255.71
ND–SD State Line	-	1231.94
Spring Creek	1,530	1223.75
Grand River	5,700	1198.00
Mobridge, SD – U.S. Hwy 12 Bridge	-	1197.78
Moreau River	5,400	1175.88
Cheyenne River	25,500	1110.21
Oahe Dam	-	1072.30
Pierre, SD streamgaging site	-	1066.50
Bad River	3,120	1065.19
Big Bend Dam	-	987.44

[1]Tributary location is at the confluence with Missouri River. River miles listed are based on 1960 conditions.

3-06. Climate. The incremental portion of the Missouri River basin discussed in this WCM is located near the geographical center of the North American continent. The region lies near the center of the belt of westerly winds; however, the Rocky Mountains to the west form a barrier to a Pacific moisture source. Consequently, the climate of the region is generally classified as continental semi-arid. An exception is the Black Hills region of South Dakota where the high elevation, with associated orographic influences, creates a relatively small area where the climate is classified as humid. Throughout the region there is a marked seasonal variation in all weather phenomena.

3-06.1. Annual Precipitation. Annual precipitation over most of the Garrison to Oahe drainage area increases from west to east, ranging from about 12 inches in the headwaters of the tributary Cheyenne River to almost 18 inches east of the Missouri River. The Black Hills region receives considerably more precipitation than surrounding areas, with average annual amounts ranging up to, and in some isolated areas above, 24 inches. The pattern of average annual precipitation throughout the Missouri River basin is presented in Plate III-4. Monthly precipitation patterns are presented in the Master Manual (Plates III-4 through III-15). Wide variations from the average amounts may be experienced in any year, with severe, extended drought periods occasionally occurring.

3-06.2. Seasonal Precipitation. Precipitation over the drainage area between Garrison and Oahe usually occurs as snow during the months of November through March and as rain during the remainder of the year. About 75 percent of the total yearly precipitation occurs during the rainfall season, with May, June and July normally being the wettest months. Most rainfall occurs in showers or convective thunderstorms; however, steady rains lasting for several hours or a day or two may occasionally occur. Excessive rainfall over a relatively large area is unusual. More common are intense convective thunderstorms resulting in large precipitation amounts in a short period of time over a very restricted area.

3-06.3. Snow. Precipitation occurring as snow usually is at a very slow rate. During the entire winter season about 20 inches of total snowfall can usually be expected through most of the Garrison to Oahe drainage area. Snowfall is usually much heavier in the Black Hills region. Over the plains area, snow does not usually progressively accumulate through the winter season, but is melted by intermittent thaws. However, there have been notable exceptions when plains area snow accumulations containing as much as 6 inches or more of water equivalent have blanketed large areas prior to a significant melt period. Higher elevations in the Black Hills often progressively accumulate snow through the winter and early spring season up to a maximum accumulation in March or early April. Snowfall is usually accompanied by high winds resulting in drifting. Plates III-5 and III-6 present mean annual snowfall and maximum annual snowfall, respectively, across the Missouri River basin.

3-06.4. Temperature. Due to its mid-continent location, this region experiences temperatures noted for their wide fluctuations and extremes. Temperatures can range from a maximum of over 100 degrees Fahrenheit (°F) at some time during the summer months to a minimum of -30°F degrees or colder during the mid-winter period. Winters are long and cold. Cold temperatures may be interrupted during periods of downslope or "Chinook" winds when mild temperatures for the season prevail. Moderate temperatures usually prevail during the non-winter season, particularly in the higher elevations of the Black Hills. Periods of high temperature can be expected during every summer season, interrupted by outbreaks of cooler air from the north and west. Average annual minimum and maximum temperatures for the Missouri River basin are shown on Plates III-7 and III-8, respectively. Temperature extremes are shown in the Master Manual (Plates III-20 and III-21).

3-06.5. Evaporation. Annual evaporation from the surface of the Oahe reservoir is normally slightly less than 3 feet. This evaporation loss equates to approximately 900,000 acre-feet (AF) of volume (refer to Plates III-9 through III-12). Studies made by the MRBWM office concluded that the average net evaporation, which is evaporation adjusted for precipitation on the reservoir surface, runoff that would have occurred from land area now inundated by the reservoir and the original channel surface area existing prior to the development of Oahe, amounts to about 20 inches annually. Due to seasonal precipitation patterns and to the lag in normal lake surface temperatures from corresponding air temperatures, most of the annual net evaporation from the Oahe reservoir can be expected to occur during the 5-month period from August through December.

3-06.6. Storm Potentialities. The major source of moisture for most major storms in the plains region of the Missouri River basin is the Gulf of Mexico. Based on available moisture alone, major storms would be most probable in late July or early August, since it is at this time that normal and maximum recorded air mass moisture is at its highest. However, major storms result almost exclusively from conditions accompanying frontal systems. Since frontal passages are more numerous and more severe in May and June than later in the year, major storms occur more frequently in late spring and early summer than at the time of maximum moisture changes. Major storms alone do not provide a complete indication to the probability of large amounts of runoff within the region. A sequence of minor storms may saturate the soil and subsequently contribute much larger runoff volumes to streamflow than would be the case if dry conditions prevailed prior to the runoff producing events. During winter months continued minor storms are the rule, occasionally producing significant snow accumulations over the drainage area. Usually the highest annual flows experienced in the region result from melt of these plains snow accumulations. Severe flooding only occasionally will occur over portions of the basin due to an individual major storm event.

3-07. Streamflow Records. With the exception of a few stations, records of runoff from the incremental area considered in this WCM exist only from the early 1930s to date. As discussed in the Master Manual, planning of the System made it desirable to extend Missouri River streamflow records to the extent practicable. Daily records are available for the majority of streamgaging stations for the six System dams since their respective dates of closure, and daily flow data is available for the majority of streamgaging stations since 1930. Prior to 1930, there is a general lack of daily records in the basin. Representative daily data was constructed to cover the period from 1898 to 1929 because of the significance and statistical importance of the drought of the 1930s in System regulation. Inasmuch as water use for all purposes has expanded significantly since settlement of the region began, it is necessary to adjust System incremental inflow records to a common level of water resource development in order that flow data are directly comparable from year to year. The total flows originating in the Garrison to Oahe reach have been adjusted to the 1949 level of water resource development, with such adjustment being a continuing process as further data are accumulated. While any development level would have been satisfactory, the 1949 level, prior to recent accelerated resource development, was selected. As part of the 2004/2006 Master Manual revision, a continuous record of daily data was developed for the entire Missouri River basin for the time period of 1898-1997. A detailed explanation of the daily flow record and the modeling efforts is found in Section 6-04.1.6 of the 2004/2006 Master Manual. As part of ongoing studies, this continuous record of daily data is expanded as additional years become available. More information on this expanded dataset is found in Section 6-13 of the Master Manual.

3-08. Runoff Characteristics. The primary source of runoff from the Garrison to Oahe incremental drainage area is the melting of the plains snowpack, which usually occurs during March and April but can occur during January and February, which accumulated during the winter months. However, on occasion rainfall during May and June has resulted in substantial runoff amounts from the total incremental area. Runoff is extremely variable from year to year. The largest runoff producing region in this incremental drainage area is the Black Hills where average annual amounts over a restricted area can exceed four inches. Throughout most of the drainage area annual runoff averages less than one inch. Normal contributions to runoff from various drainage basins through this region are presented in Table III-2.

3-08.1. Seasonal Runoff Pattern. Runoff from the drainage area from Garrison Dam to below Oahe usually follows a characteristic seasonal pattern:

1. Winter is characterized by frozen streams, progressive accumulation of snow in the Black Hills of South Dakota and intermittent snowfall and thaws in the plains area. The season usually ends with a "spotty" snowpack of relatively low water content and a considerable amount of water in ice storage in the stream channels. Runoff during this period, which usually extends from late November into March, is very low.
2. Early spring is marked by a rapid melting of snow and ice on frozen ground, usually in March or April, as temperatures rise rapidly, accompanied usually by very little rainfall. This causes a characteristic early spring ice break-up and increases in tributary streamflow. Ice jams are frequently experienced on tributary streams during this period. The rapid release of water from melting snow and ice jams results in a flashy "March" rise in flow. Annual maximum peak stages and flows usually occur at this time along tributary streams.
3. Late spring consists of the months of May and June. During this time extensive general rains may occasionally occur, sometimes accompanied by severe local rainstorms. Runoff is usually quite low unless these rains occur.
4. Summer and autumn in this portion of the Missouri River basin are generally characterized by a lack of general rainfall and frequent, widely scattered thundershowers that contribute little to runoff. Total runoff in the Oahe incremental drainage area is usually very low from July through the remainder of the calendar year.

3-08.2. Total unregulated Missouri River runoff originating above Oahe usually follows a definite and characteristic annual pattern. Plate III-13 lists the Missouri River basin monthly runoff above Oahe from 1898 to 2014. Total monthly runoff above Oahe (maximum, minimum and average) for each month is shown on Plate III-14. Normal monthly runoff from the total contributing area shows a general increase from January through June and then decreases through December. As illustrated on Plate III-14, wide variations in total runoff have occurred during every month of the year. As would be expected, the variations are largest during the months comprising the March through July 5-month flood season, ranging from highs of 37.1 million acre-feet (MAF) in 2011, 27.0 MAF in 1997, 26.3 MAF in 1978, and 24.6 MAF in 1975, to a minimum of 5.1 MAF in 1961. As seen in Plate III-14, May, June and July 2011 were all record months contributing to the highest March through July runoff in 117 years of record (1898-2014). The effect of reservoir regulation on these runoff patterns and regulation of various flood events is discussed in Appendix A of this WCM.

Table III-2
Missouri River Basin - Average Annual Runoff
Between Garrison and Big Bend

Contributing Area	Period of Record	Drainage Area (sq mi)	Average Annual Runoff (1)	
			kAF	Inches
Knife River at Hazen, ND	1929-2014	2,240	124	1.04
Heart River nr Mandan, ND	1924-2014	3,310	197	1.12
Cannonball River at Breien, ND	1934-2014	4,100	182	0.83
Grand River at Little Eagle, SD	1958-2014	5,370	197	0.69
Moreau River nr Whitehorse, SD	1954-2014	4,880	203	0.78
Cheyenne River				
at Edgemont, SD	1903-2014	7,143	66	0.17
nr Wasta, SD	1914-2014	12,800	369	0.39
nr Plainview, SD	1950-2014	21,600	577	0.50
Spearfish Creek at Spearfish, SD (Cheyenne Trib)	1904-2014	168	43	4.77
Bad River at Fort Pierre, SD	1928-2014	3,107	123	0.74
Missouri River(2)	1898-2013			
Garrison Dam		181,400	17,936	1.85
Oahe Dam		243,490	20,401	1.57
Garrison-Oahe				
Incremental Drainage		62,090	3,358	0.74
Local Drainage (3)		20,590	1485	0.90

(1) Based on period of record at each location.
(2) Missouri River runoff at the 1949 level of water resources development
(3) Incremental drainage area between Garrison and Oahe Dams less Knife River at Hazen, Heart River nr Mandan, Cannonball River at Breien, Grand River at Little Eagle, Moreau River nr Whitehorse, and Cheyenne River nr Plainview.

3-08.3. Monthly maximum, minimum and average runoff originating from the incremental drainage area between Garrison and Oahe is illustrated on Plate III-15. Average runoff from this incremental area is at a maximum through the March-June period, with the average monthly maximum occurring in March as a result of runoff from the melting of accumulated plains winter snowpack. As shown by Plate III-15, the greatest March runoff (2.6 MAF) recorded from this reach since the closure of Oahe occurred in 1997. The greatest recorded monthly runoff of nearly 4 MAF occurred in April 1952, which primarily was a result of melting of the large plains snowpack. Refer to Appendix A for additional information regarding the 1952 and 1997 floods.

Very little runoff usually occurs, or has been recorded in any month, during the period extending from August through February. The exception was October 2013, when heavy rainfall in the incremental drainage resulted in a monthly runoff total of 1.2 MAF, nearly double the previous October high that occurred in 1923. Monthly runoff from this incremental drainage area has frequently been calculated to be negative throughout the available record period, indicating that evaporation from the Missouri River channel (or other losses, such as ice build-up) often exceeds the flow of tributaries entering the Missouri River in this reach.

3-08.4. The MRBWM Technical Report, *Hydrologic Statistics on Inflows*, dated July 2015, details the development of inflow volume probability relationships for various durations for both regulated and unregulated flows in the Garrison to Oahe reach. Some incremental runoff events of interest originating between Garrison and Oahe are illustrated on Plate III-16. See Section 6-14 and Plates VI-3 through VI-8 for regulated and incremental inflow volume probability relationships for various durations.

3-09. Effects on Basin-Wide Floods. Regulation provided by Oahe and the two upstream mainstem projects, augmented by upstream tributary reservoir storage, has greatly reduced, but not eliminated, flooding along the portion of the Missouri River extending below Oahe. Many instances of above-bankfull flows were experienced through this reach prior to the construction of the mainstem projects and would be continuing if the projects were not in operation. All floods recorded in this portion of the Missouri River prior to mainstem reservoir operation occurred in the March-July flood season.

3-09.1. Essentially all major Missouri River floods of past record at Oahe have resulted from runoff originating in the upper Missouri River basin, an area controlled by Fort Peck, Garrison and Oahe. Runoff originating only from the incremental drainage area between Garrison and Oahe will seldom be sufficient to tax the flood control capability of Oahe. Basin-wide floods are described in Appendix A of the Master Manual.

3-10. Effects of Oahe on Flood Inflows. Studies conducted by the MRBWM office indicate that regulation of Oahe, in conjunction with other upstream projects would greatly reduce, but not eliminate, significant flood damages in the reach extending from Oahe into Big Bend if any past floods of record were to recur. Further discussion of regulation effects on flood inflows is detailed in Appendix A of this WCM.

3-11. Water Travel Time to the Oahe Reservoir. Plate III-17 shows the graphical representation of travel times for the major tributaries in the Garrison to Oahe drainage area. See Plate IV-3 of the Master Manual for travel times for the entire Missouri River basin. Table III-3 presents the approximate time involved for changes in flow at select locations in the Garrison to Oahe drainage area to be reflected in Oahe inflows.

Table III-3
Water Travel Time to the Oahe Reservoir

Stream	Location	Approximate Travel Time in Days
Missouri River	Garrison Dam, ND	2
Knife River	Hazen, ND	2
Heart River	Heart Butte Dam, ND	2
	Mandan, ND	1
Cannonball River	Bentley, ND	3
	Breien, ND	1
Grand River	Shadehill Dam	3
	Little Eagle, SD	1
Moreau River	Faith, SD	3
	Whitehorse, SD	1
Cheyenne River	Plainview, SD	2
	Cherry Creek, SD	1
Bad River[1]	Midland, SD	1
	Fort Pierre, SD	0

[1]Travel time is to the Missouri River just below Oahe Dam

3-12. Water Quality. The Omaha District Water Control and Water Quality Section is responsible for the water quality monitoring of the mainstem projects and Missouri River, including the Oahe reservoir and the Missouri River downstream of Oahe. Omaha District conducts fixed-station ambient water quality monitoring at the System reservoirs and on the lower Missouri River. Water quality conditions of the water discharged through each of the mainstem dams is continuously monitored. Water quality stations and sampling is detailed further in Appendix C of this WCM and Section 5-11 and Appendix C of the Master Manual. Current and detailed water quality monitoring information is available in the Omaha District water quality reports on the Omaha District website.

3-13. Sediment. The upstream Garrison project acts as a sediment trap to all sediment originating above Garrison. Therefore, sediment transported into Oahe from the Missouri River originates from the bed and banks of the river or transported down from the major right bank tributaries. The largest accumulation of sediment in the Oahe reservoir occurs in the reservoir segment bounded by sediment ranges 1161.4 and 1165.5, which are located at river mile (RM) 1108.01 and 1111.66 respectively, immediately downstream of the Cheyenne River confluence. The second most highly active segment for deposition is between sediment ranges 1250.4 and 1257.0 (RM 1195.13 and 1201.17), downstream of the Cannonball River confluence. Thirty percent of sediment deposition along the mainstem Missouri River in Oahe has occurred between RM 1098.23 and 1124.66 in the vicinity of the Cheyenne River confluence. Storage capacity below the top of the Annual Flood Control and Multiple Use Zone, elevation 1617.0 feet, decreased from an original capacity of 22,693,038 AF in 1958 to 21,865,292 AF in 2010, the year of the most recent sediment range survey. This represents a decrease in storage of 827,746 AF, or 3.6 percent. From 1958 to 2010 the average annual depletion rate in the Oahe reservoir is estimated to be 14,800 AF/year. At this rate the estimated sediment life of the reservoir is 1,553 years. Since the reservoir traps the inflowing sediment, Oahe releases are clear and have little opportunity to pick up any significant sediment contribution above the headwaters of the downstream Big Bend. See Plates III-18 through III-20 for the location of sediment rangelines in the Oahe reservoir, major tributaries and the reach downstream of Oahe to the headwaters of Big Bend.

3-14. Missouri River Channel below Oahe. The downstream Big Bend reservoir extends upstream to the Oahe tailwater. Consequently, there is no portion of the original Missouri River channel below Oahe that is not influenced to some extent by the downstream reservoir. However, the backwater effects of Big Bend are generally not sufficient to result in extensive storage through the first 10 miles of river length below Oahe. The cities of Pierre, SD and Fort Pierre, SD are located on the left and right banks of the Missouri River, respectively, within this 10-mile reach. The Bad River, the only major tributary stream originating in the drainage area between Oahe and Big Bend, enters the Missouri River about 7 river miles downstream of Oahe. Plate III-21 is a composite aerial photograph of this reach of the Missouri River.

3-14.1. Channel Description. The Missouri River channel below Oahe is contained within a relatively narrow alluvial flood plain. From the Oahe Dam to Pierre, a distance of about 6 river miles, the left bank of the channel is immediately adjacent to high steep bluffs. There is no floodplain along the left bank until the Missouri River flows downstream of Pierre. Most developed areas within Pierre are located on relatively high benches. The existing floodplain through this short reach of the river below Oahe is along the right bank downstream, where the city of Fort Pierre is located and where the Bad River enters the Missouri River. Below the mouth of the Bad River, LaFramboise Island divides the Missouri River channel for a distance of about 3 miles, extending into the headwaters of the Big Bend reservoir.

3-14.2. Structures placed along the Missouri River between Oahe and Pierre confine the channel to the left bank bluffs. These structures consist of training dikes and channel blocks, which also serve the purpose of preventing erosion along the right bank of the stream. Additional bank protection in this reach to further reduce right bank erosion is under consideration. Extensive bank protection has been placed adjacent to both Pierre and Fort Pierre as an erosion control measure. Additionally, at the upstream end of LaFramboise Island, a channel block has been placed across the left channel of the Missouri River around this island. Culverts in this block allow minor amounts of flow through this channel for water quality control purposes.

3-14.3. Channel Capacity and Stage-Discharge Relationship. Flood stage at the Missouri River at Pierre, SD streamgaging station is 13.0 feet. Prior to construction of Big Bend and the downstream channel block at LaFramboise Island, Missouri River flows of almost 200,000 cfs could be accommodated without exceeding the established flood stage. Since construction of Oahe several factors have influenced stages through this reach, including channel degradation, channel constriction resulting from channel blocks, and backwater effects resulting from both the elevation of the Big Bend reservoir and from Bad River sediment deposition in the headwaters of the Big Bend reservoir.

3-14.4. Oahe releases are extremely variable due to control provided by the immediate downstream Big Bend and powerplant peaking operations. Average daily outflows typically range from as low as 1,000 cfs to near the powerplant capacity of about 54,000 cfs. Due to the large hourly variation in Oahe releases, definition of the stage-discharge relationship for lower releases at Pierre is rather indefinite; however, during 2011, Oahe releases in the 150,000 cfs range were maintained for an extended period. Measurements were taken during this period and an estimated stage-discharge relationship was developed and is shown on Plate III-22. This relationship indicates that the channel capacity at the established Pierre flood stage of 13.0 feet is about 65,000 cfs. It should be noted that the stage-discharge relationship was greatly affected at the higher flows by the building of emergency levees through the Pierre and Fort Pierre reach during the 2011 flood.

3-14.5. While significant damage probably will not occur with Missouri River at Pierre stages at 13.0 feet or below, overtopping of some areas of bank revetment or of channel blocks can be expected if Oahe releases should significantly exceed the powerplant capacity of about 54,000 cfs. This occurred in 2011 with peak releases of 160,300 cfs. Low-lying areas of Fort Pierre adjacent to the Missouri River may also be adversely affected. High Bad River flows coinciding with large Oahe powerplant releases can also adversely affect developed low-lying regions in Fort Pierre.

3-15. River Ice. Initially, when Oahe first began operation in 1958, the formation of ice on the Missouri River in the Pierre and Fort Pierre area had not restricted operation of the project. However, flooding in the Pierre-Fort Pierre area, especially at street intersections in the Stoeser Addition, became a recurring problem in 1979, 1981, 1983, 1995 and 1997. High Oahe releases, coupled with the formation of river ice cover in the LaFramboise Island area, have historically caused water to back up into a storm sewer outlet and flood street intersections. The city of Pierre installed a valve on the Stoeser Addition storm sewer in the fall of 1998 to prevent winter flooding; however, Oahe releases will continue to be constrained at times to prevent flooding at other locations. A study, referred to as the *Pierre/Ft. Pierre Flood Mitigation Project*, was initiated by the Omaha District in the late 1990s and finalized approximately seven years later. This project involved the purchase or flood-proofing of homes along the Missouri River that may be impacted by ice-affected Missouri River flows. Approximately 100 homes were purchased and removed and about 20 were flood-proofed. Some homeowners chose not to participate in the voluntary project.

3-15.1. In March 2000 the U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (CRREL) published a report titled, *Ice-Affected Flooding, Oahe Dam to Lake Sharpe, South Dakota*, for the Omaha District. This report investigated the wintertime operation of Oahe with two broad purposes. The first was to estimate the expected frequencies of the water surface stages for the Missouri River downstream of Oahe, under a variety of operating conditions, featuring current and future channel geometries. This information was used in the *Pierre/Ft. Pierre Flood Mitigation Project* that was discussed in Section 3-15. The second purpose of the study was to examine whether modifications in the operation of Oahe and Big Bend during wintertime might influence the potential for ice-affected flooding in the Pierre/Fort Pierre area. The analysis looked at the management of the heat content of the flow released from Oahe to prevent the formation of ice in the reach immediately downstream of the dam, the effect of drawing down the Big Bend pool based on expected ice conditions and the constraints on the Oahe release required to keep the water surface profile in the Missouri River below the restricted bankfull profile. The constraints were determined as a function of the position of the leading edge of the ice cover.

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IV - Project Description and History

4-01. Location. Oahe is located at RM 1072.3 (1960 mileage) on the Missouri River in Stanley and Hughes Counties, South Dakota, approximately 6 miles upstream from Pierre, the capital city of South Dakota. The Oahe reservoir extends 231 miles in a northerly direction through central South Dakota and central North Dakota, terminating near Bismarck, ND. A project photo is shown as Plate IV-1.

4-02. Embankment. The dam consists of rolled earthfill embankment with the outlet works tunnels in the right abutment and the power tunnels in the left abutment. State Highway 204 crosses the Missouri River on top of the dam. The embankment has a total length of 9,300 feet, a maximum height of 245 feet and a top elevation of 1660.0 feet. The total volume of fill in the embankment is approximately 92 million cubic yards. The maximum base width is 3,500 feet and the top width is 60 feet. Refer to Plate IV-1 for an aerial photo that shows the Oahe embankment, intakes, powerhouse and reservoir. Plan and cross sections of the embankment are shown on Plate IV-2. Refer to Plate II-1 for other pertinent System dam and reservoir information.

4-02.1. Embankment freeboard was based on an Oahe reservoir level of elevation 1644.4 feet, the maximum level attained during routing of the Spillway Design Flood (SDF). A set-up allowance of 1.8 feet and wave height plus ride-up allowance of 7.3 feet was developed in design studies. An additional safety factor of 6.5 feet resulted in a total freeboard allowance of 15.6 feet, establishing the embankment crest at elevation 1660.0 feet.

4-03. Spillway. The Oahe spillway is a remote spillway located on the right bank of the Missouri River about a mile west of the right abutment of the dam. An unlined approach channel has been excavated in shale to elevation 1590.0 feet for a distance of approximately 1,300 feet upstream of the weir. The width of the channel in the weir area is about 472 feet. Upstream of the shale excavation, the approach channel widens considerably due to the slope of the natural ground. Refer to Plates IV-3 and IV-4 for photos of the Oahe spillway gates and spillway discharge chute, respectively.

4-03.1. The spillway structure consists of a flat weir with a crest elevation of 1596.5 feet surmounted by tainter gates, a roadway, and service bridge and machinery platforms. A depressed concrete basin and paved apron with riprap side slopes is provided immediately downstream from the weir. The spillway is controlled by eight tainter gates, each 50 feet long by 23.5 feet high. The length of the spillway is 456 feet. The depressed concrete basin extends 101 feet downstream from the weir. It has a bottom elevation of 1590.0 feet and steps back up to elevation 1596.5 feet at the end sill. The paved apron extends 209 feet downstream from the end sill of the basin and varies in width from 456 feet at the end sill to 395 feet at the downstream end. The apron has a constant elevation of 1596.5 feet.

4-03.2. An unlined discharge channel extends approximately two miles downstream of the spillway structure. The channel slopes from elevation 1596.5 feet downstream from the apron cutoff wall on a 0.00067 slope. Immediately downstream of the cutoff wall the channel bottom width is 395 feet, converges to 334 feet wide at a point 341 feet downstream, and then remains constant to the end of the channel. The side slopes have a transition from a 1 vertical (V) on 2.5 horizontal (H) slope immediately downstream of the apron sidewalls to a 1V on 2H slope at a point 140 feet downstream. The side slopes in this transition are riprapped. The bottom of the channel has riprap protection for a distance of 240 feet downstream of the apron slab. Plan, profiles and sections of the spillway structure are shown on Plate IV-2. Spillway rating curves are shown on Plate IV-5.

4-03.3. The design of the Oahe spillway and the lack of a stilling basin requires a definite spillway gate operating schedule. The intent of the operating schedule is to reduce velocities and consequent erosion through the unpaved discharge channel. Additional guidance regarding best practices and/or special considerations and restrictions for use of the spillway at Oahe can be found in Exhibit A of this WCM. The spillway operating criteria are as follows:

1. Each gate will be opened in turn with the sequence consisting of gates 3, 5, 4, 6, 1, 2, 7 and 8.
2. Maximum changes of gate positions within each opening sequence are as follows:

Initial Position	Change in Position
All gates closed	Open in sequence to 2 feet
All gates 2’ open	Open in sequence to 5 feet
All gates 5’ open	Open in sequence to 6 feet
All gates 6’ open	Open in sequence to 7 feet
All gates 7’ open	Open in sequence to 8 feet
All gates 8’ open	Open in sequence to 9 feet
All gates 9’ open	Open in sequence to 10 feet
All gates 10’ open	Open in sequence to 11 feet
All gates 11’ open	Open in sequence to 12 feet
All gates 12’ open	Open in sequence to wide open

3. Closing of gates will be in the amount and sequence in reverse of the opening schedule given in 1) and 2).

4-04. Outlet Works. The outlet works are located on the right bank of the river and consist of an approach channel, six tunnels with intake structures and control shafts, a stilling basin and a discharge channel. Plan and profile of the outlet works are shown on Plate IV-2. The discharge rating curve for the six outlet tunnels is shown on Plate IV-6. Plate IV-7 shows a photo of the outlet tunnels and the outlet tunnel intake structure.

4-04.1. The approach channel from the river channel to the outlet works tunnel intake is excavated in the abutment of the dam and is approximately 2,000 feet long. The upstream portion of the channel is straight for a distance of about 1,300 feet and is on two levels, upper and lower. The lower level is at elevation 1425.0 feet with a bottom width of 100 feet and side slopes of 1V on 3H on the riverward side and 1V on 2H on the landward side. The upper level of the channel is formed by a berm 60 feet wide at elevation 1455.0 feet. The remaining length of the approach channel curves toward the intake structure with transition zones on the bottom and side slopes to meet the grade and the 1V on 6H side slopes at the intakes.

4-04.2. The intakes are individual submerged-type reinforced structures located at the end of the tunnels. The structures, with a top elevation of 1530.0 feet, are submerged to a depth of 10 feet at the minimum operating pool elevation of 1540.0 feet. Submergence increases to 90 feet when the reservoir surface rises to the maximum operating pool elevation of 1620.0 feet. The intake structures are staggered in plan and elevation. The No. 1 structure is set upstream with the invert elevation at 1425.0 feet. Each succeeding intake is located approximately 70 feet farther downstream with the invert elevation raised in increments of 6 feet. The channel apron extends for a distance of 100 feet immediately upstream of the intakes. The backfill slopes downstream and is covered with riprap between the intake structures.

4-04.3. Six tunnels have been provided in the outlet works for flood control and regulation purposes. The tunnels are parallel to each other and are spaced 85 feet on center. The tunnels are bored through the Pierre shale formation. The tunnels are concrete lined with finished inside diameters of 19.75 feet upstream of the control shafts and 18.25 feet downstream of the control shafts. The length of the tunnels from the upstream face of the intake to the downstream face of the tunnel outlet portal varies from 3,496 feet to 3,659 feet. The elevation of the intake invert varies from 1425.0 to 1455.0 feet. The elevation of the invert at the portal exit is 1420.0 feet.

4-04.4. The control shafts for the outlet works tunnels are located near the axis of the dam and house the control and emergency gates and other appurtenant equipment necessary for control of flows in these tunnels. The structures are 85 feet on center and are located fully underground, except for the gantry deck, which is at elevation 1661.0 feet, and the downstream walls of the operating rooms, which are exposed on the downstream slope of the embankment. The portion of the structures below elevation 1620.0 feet are isolated units, each consisting of a lined vertical shaft with an outside diameter of 38 feet and water passage transitions from the circular section of the tunnels to the rectangular section for the gates. The control shafts are transformed from circular to octagonal and from octagonal to square to accommodate the control gate hoists and other operating equipment on the floor at elevation 1648.0 feet. The six control gates include a 13-foot by 22-foot vertical lift cable suspended tractor-type gate installed in each of Tunnel Nos. 1 to 4 inclusive, and 13-foot by 22-foot hydraulic lift, wheeled-type gates installed in Tunnel Nos. 5 and 6 for fine regulation. Each of the six tunnels have 13-foot by 22-foot vertical lift tractor-type emergency gates. Plate IV-7 presents a photo of the tunnels.

4-04.5. The stilling basin is located downstream of the tunnel portals and consists of training piers, drop sections, retaining walls, weir baffles and the end sill. An ogee weir with a crest elevation of 1417.5 feet divides the stilling basin into a double-stage-type with a primary basin and a secondary basin. The basin floor slab is 8 feet thick. The top of the slab of the primary basin is at elevation 1395.5 feet. For the secondary basin, the slab slopes from elevation 1393.0 to 1391.0 feet. Two rows of 6-foot high concrete baffles are located in the secondary basin; the top of the baffles is at the same elevation as the end sill. The tops of the primary and secondary retaining walls are at elevation 1442.0 and 1430.0 feet, respectively.

4-04.6. The overall length of the discharge channel is 9,000 feet. The upper reach of the channel was excavated in shale to a bottom elevation of 1390.0 feet. The discharge channel tapers from a width of 500 feet at the stilling basin to 400 feet about 3,000 feet downstream. In the middle reach, a 2,500-foot long pilot channel was excavated to a bottom width of 150 feet. Side slopes of the pilot channel were excavated on a 1V on 3H slope down to a berm about 70 feet wide at the water table at elevation 1430.0 feet. Below the ground water level the pilot channel sides were excavated on a 1V on 1.5H slope. The remaining reach of the channel consisted largely of sandy material, which was eroded by flows through the outlet works after closure of the dam.

4-05. Powerplant and Switchyard. The seven power tunnels are located in the left abutment of the dam and extend from the downstream edge of the intake structure to the face of the surge tank base structures. The tunnels have a 24-foot inside diameter and are curved in plan. The upstream portions of the power tunnels are concrete lined and extend from the closure monolith at the intake structure to a point near the axis of the dam. The power tunnels vary in overall length: 3,280 feet for Tunnel No. 1, which is the riverward tunnel, to 4,005 feet for Tunnel No. 7, which is the landward tunnel. The downstream portions of the tunnels are lined and extend from the terminus of the concrete-lined sections near the axis of the dam to the edge of the tunnel entry structure, varying in length from 1,976.4 feet for Tunnel No. 1 to 2,389.8 feet for Tunnel No. 7. Downstream from the steel-lined section, each power tunnel consists of an 80-foot long tunnel entry structure, a 96-foot long cut-and-cover section and the 48-foot long tunnel terminal structure and are included as part of the overall length of the tunnels. The cut-and-cover segment and terminal structure consists of reinforced concrete and contain the freestanding penstocks.

4-05.1. Each of the seven penstocks have a 24-foot inside diameter and extend from the end of the embedded steel liners through the cut-and-cover sections, the terminal structures and the surge tanks to connect with the spiral case extensions at the upstream wall of the powerhouse. The total length of each penstock from the embedded liner to the spiral case extension is 294 feet. Two 70-foot diameter surge tanks, 145 feet in height, are provided for each penstock with the bottom of each tank at elevation 1515.0 feet. Penstocks for Unit Nos. 1 to 6, inclusive, each have a pair of 16-foot inside diameter risers connecting to its surge tanks. The two risers for Unit No. 7 were increased to 17 feet in diameter to permit tapping for the Oahe diversion project pumping plant. The surge tank base is 532 feet long and 167 feet wide and is supported by concrete sidewalls. A bubbler system is provided to prevent a solid ice cover forming on the water surface in the surge tanks in freezing weather. The surge tanks are insulated by 4-inch-thick cellular glass blocks covered with aluminum siding. The switchyard and surge tanks are shown on Plate IV-8.

4-06. Intake Structure. The intake for the power tunnels is located near the left abutment of the dam, a short distance upstream from the toe of embankment slope at elevation 1520.0 feet. The seven intake towers, spaced 90 feet on center, extend 145 feet above the level of the approach area at elevation 1520.0 feet. A cylinder gate, 10 feet high by 30 feet in diameter, is provided in each of the intake towers and controls the water passing through eight openings into the 30-foot diameter shafts, which connect with the 24-foot diameter tunnels at the bottom. The invert at the shaft and tunnel intersection is elevation 1390.0 feet. A bulkhead platform is provided on the outside of the tower at elevation 1620.0 feet for installing bulkheads. Three screw lift hoists and a hoist driving unit are supported on the floor at elevation 1645.0 feet, slightly above the maximum elevation from the SDF routing. The seven intake towers are connected at the top by simple bridge spans to form a continuous gantry crane deck 50 feet wide by 583.5 feet long. This deck is at elevation 1665.0 feet, 5 feet above the top of the dam. The access bridge to the intake is approximately 1,290 feet long and is divided into three 70-foot, three 110-foot and five 150-foot spans. The bridge has a 24-foot wide concrete deck with access to the intake structure at elevation 1664.9 feet. Refer to Plate IV-9 for a photo of the intake structure.

4-07. Powerhouse. The powerhouse structure encloses the seven generator bays, an assembly bay, a control bay and a service bay. Generator Bay No. 7 is located on the east end and the assembly bay, the control bay and the service bay are located on the west end. The powerhouse is located in the left abutment of the dam and is oriented so that the flow through the powerhouse is approximately north to south. The overall size of the substructure area for each unit is 97 feet wide by 123 feet long. The assembly bay adjacent to Generator Bay No. 1 has an assembly area approximately 94 feet wide by 73 feet long. The overall size of the service bay substructure is 40 feet wide by 97 feet long. The generator mezzanine floor is at elevation 1456.0 feet, the turbine room floor is at elevation 1438.0 feet, and the low point in the draft tubes is at elevation 1378.0 feet. The powerhouse superstructure is constructed of reinforced concrete and structural steel.

4-07.1. The seven hydraulic turbines are vertical-shaft, single runner-type, with welded steel scroll cases and elbow-type draft tubes. Each turbine is rated at 128,500 horsepower (hp) at a net head of 185 feet when operating at 100 revolutions per minute (rpm). Governors are of the isochronous, oil-hydraulic conventional-type capable of full opening or full closing time of five seconds. The original installation in the powerplant included seven 85,000 kilowatt (kW), 3-phase, 60 cycle, 13.8 kilovolt (kV), wye-connected, vertical shaft, water-wheel driven synchronous generators, with direct-connected main and field exciters and voltage regulators. The generators were rewound starting in 1983 with the work being finished in 1986 and were uprated to 112,300 kW at a 0.95 power factor. The generators have been designed for 115 percent of the nameplate rating. Main generator protection includes neutral grounding, surge protective equipment, differential relays, ground detectors, resistance temperature detectors and overspeed protection for each unit.

4-07.2. The main power transformers consist of a 3-phase transformer (No. 1) and three banks of three single-phase transformers (Nos. 2, 3 and 4) located in the transformer vaults on the draft tube deck at elevation 1456.0 feet. The 3-phase transformer has a voltage rating of 13.8-115 kV grounded wye and a capacity of 103,000 kilovolt-amps (kVA). Main transformer banks Nos. 2, 3 and 4 each contain three single-phase transformers and have a voltage rating of 13.8-250 kV grounded wye/115 kV. Each of the single-base transformers has a rated capacity of 68,677 kVA.

4-07.3. The tailrace is 508 feet wide and 114 feet long ascending from elevation 1387.0 feet at the draft tube exit on a 1V on 6H slope to elevation 1404.0 feet. The tailrace is paved with reinforced concrete, which is anchored to the foundation. The east tailrace retaining wall is a semi-gravity type and varies in height from 68 feet at the upstream end to 3 feet at the downstream end. The west tailrace retaining wall is built to elevation 1456.0 feet, retaining fill for the parking area and access to the powerhouse. The retaining wall consists of two sections. The deep section is adjacent to the powerhouse and is a semi-gravity type. The other section is a cantilever-type structure. The tailrace discharge channel has a width of 508 feet and extends for a distance of 1,200 feet downstream from the downstream end of the tailrace paving.

4-07.4. The Oahe switchyard is an outdoor-type and is located on the right side of the tailrace at elevation 1456.0 feet. The switchyard is divided into three sections: the autotransformer section, the 115 kV bay section and the 230 kV bay section. The autotransformer section is connected to the switchyard and the 230 kV bay section through a 100,000 kVA autotransformer. A 13.8 kV tertiary winding is provided in the autotransformer, which is a source of power for the station service switchgear, for the 13.8 kV power line to the spillway and outlet works and to the powerplant intake structure. The 115 kV bay section contains a generator bay, an autotransformer bay, two line bays and provisions for two future line bays. The 230 kV bay section contains three generator bays, an autotransformer bay, two sectionalizing bays, six line bays and provisions for two future line bays.

4-07.5. A more detailed description of power facilities, as well as other structures developed at the project, is contained in the Oahe Operation and Maintenance (O&M) Manual. Plan and sections of the powerhouse are shown on Plate IV-2. Powerplant tailwater rating curves and powerplant characteristic curves are shown on Plates IV-10 and IV-11, respectively.

4-08. Reservoir. The reservoir formed by Oahe Dam, Lake Oahe, bisects southern North Dakota and northern South Dakota. At elevation 1607.5 feet, the base of the Annual Flood Control and Multiple Use Zone, the reservoir has a length of 231 miles, a shoreline of 2,250 miles, a surface area of 311,000 acres and a maximum depth of 200 feet. The Oahe reservoir is long and narrow and largely confined to the Missouri River valley. However, exceptions occur where major tributaries enter the reservoir. These are sometime referred to as “arms” and take their names from the Cheyenne, Grand and Cannonball Rivers entering from the west. A map of the reservoir area is given on Plate IV-12.

Allocation of storage in Oahe was based on System authorized purposes as described in Section 7-03 of the Master Manual. Types of storage space, with associated elevations and storage quantities for each zone, are presented in Table IV-1. In addition to this allocated space, routing of the SDF results in a crest of elevation 1644.4 feet, representing a surcharge storage of 10.6 MAF above the top of the Exclusive Flood Control Zone, but well below the dam crest elevation of 1660.0 feet. Elevation-area and elevation-capacity tables for the Oahe reservoir are on Plate IV-13.

Table IV-1
Oahe Reservoir Storage Space Allocations

Storage Designation (Zone)	Elevation in feet		Storage Space in AF
	From	To	
Exclusive Flood Control	1617.0	1620.0	1,107,000
Annual Flood Control and Multiple Use	1607.5	1617.0	3,208,000
Carryover Multiple Use	1540.0	1607.5	13,353,000
Permanent	1415.0	1540.0	5,315,000
Total Storage			22,983,000

Note: Storage volumes are based on August 2013 elevation-area-capacity tables (2010-2012 surveys)

4-09. Recreation Facilities. Fluctuating reservoir levels can have a major effect on recreational use of the reservoir. Numerous public-use areas have been established around the shoreline of the project with a common development of most of these areas being a boat ramp that provides access to the reservoir. Recreation at System projects consists of both water-based and land-based activities. Water-based recreation includes boating, fishing, water skiing, jet skiing and swimming. Land-based recreation includes hunting, camping, picnicking, sightseeing, hiking and wildlife photography. Visitors participate in these activities at recreation areas that range from undeveloped reservoir access points to highly developed and extensively used campground areas. The six System projects have a total of 188 public recreation areas. Refer to Plates IV-14 and IV-15 for the 52 recreational facilities at the Oahe project. In 2002, most of the South Dakota federal recreation areas were transferred in fee title to the State of South Dakota or to the Bureau of Indian Affairs (BIA), which holds the areas in trust for the Lower Brule Sioux Tribe and the Cheyenne River Sioux Tribe, under Title VI of Public Law 105-53, Water Resources Development Act of 1999 (WRDA 1999) as amended by Public Law 106-541, Water Resources Development Act of 2000 (WRDA 2000). A total of 65 recreation areas on Oahe, Big Bend, Fort Randall and Gavins Point were transferred in fee title, along with the nine recreation areas leased in perpetuity, to be managed for the restoration of terrestrial wildlife habitat loss that occurred as a result of the flooding of lands related to the construction of the projects.

4-10. Leasing of Project Lands. Essentially all land surrounding the Oahe reservoir below elevation 1620.0 feet has been acquired or protected for project purposes. Unless unusual conditions should occur, inundation of lands lying in the Exclusive Flood Control Zone, between elevations 1617.0 and 1620.0 feet, would not be expected as part of normal operations. As a result of the Title VI portion of WRDA 1999 and subsequent technical amendments in WRDA 2000, all land lying above 1607.5 feet within recreation boundaries and above 1620.0 feet outside recreation boundaries was transferred to the State of South Dakota Game Fish and Parks (SD GF&P). Subsequently, the Corps has made land adjacent to those transferred lands available through a no-cost easement to the SD GF&P. The easement allows the State of South Dakota to use the land "for recreational and other purposes (including the construction, operation, maintenance and repair of water intake structures, publicly owned boat docks, publicly owned boat ramps and related publicly owned structures) ... and the administration of livestock grazing on said areas". This easement and all instruments issued under it provide for possible flooding of lands, if needed, for operational purposes and do not serve as an overriding constraint on regulation of the project for authorized purposes.

4-11. Reservoir Aggradation and Backwater. As mentioned in Section 3-13 of this WCM, the long-term sediment depletion of the Oahe reservoir is estimated at 14,800 AF/year. Major sediment deposition has occurred and will continue to occur in deltas at the head of the Oahe reservoir and in the tributary arms of the Cannonball, Grand, Moreau and Cheyenne Rivers. Smaller deltas can also be expected to develop where other streams enter the reservoir. The location and growth of individual delta formations will be dependent on the sediment inflow of each contributing stream and corresponding pool elevations. Redistribution and consolidation of the delta deposits will occur whenever the Oahe reservoir is drawn down for significant periods of time. Proportionately, the Cheyenne River drainage is expected to contribute about 35 percent of this total; the Moreau, Grand and Cannonball River drainages about 15 percent and the mainstem drainage above Oahe, the Heart and Knife Rivers, and all other tributary drainages account for the remaining 50 percent.

4-12. Tailwater Degradation. Due to construction of dikes and channel blocks in the Missouri River channel below Oahe, and to downstream Big Bend, there has been no significant lowering or degradation of the channel below the Oahe powerplant (see Plate IV-16).

4-13. History of Water Resources Development. Due to the lack of transportation facilities, development of water resources in the portion of the Missouri River basin extending from Garrison to the headwaters of the Big Bend reservoir began soon after westward settlement in the early 1800s. Initial development was concerned with navigation as a means of transportation in the region. The economy of the region is primarily agricultural. This, combined with the semi-arid climate, could have been expected to foster irrigation development. However, the lack of perennial streams in the region discouraged such development except in the Black Hills region of South Dakota and in restricted areas immediately adjacent to the Missouri River and other major tributaries. The most widespread development in relatively recent history has been construction of dams controlling small drainage areas to provide a water supply for the extensive livestock grazing practiced throughout this region. Control of floods became a major concern in the 1940s and more recently, municipal and industrial (M&I) water supply, recreation, water quality enhancement, as well as fish and wildlife enhancement and other matters related to the environment have been of increasing importance.

4-13.1. Federal legislation pertinent to water resource development throughout the Missouri River basin is summarized in Chapter II of the Master Manual. As indicated in the Master Manual, the Flood Control Act of 1944 is of primary importance through this portion of the basin. This act authorized the construction of Oahe, as well as four of the other System projects (Fort Peck was already constructed and was authorized by the Act to become part of the System) and many tributary reservoir projects, and emphasized the multiple-purpose aspects of water resource development for the region.

4-13.2. One important means of water resources development in this section of the Missouri River basin is the construction of dams controlling sizeable drainage areas and development of the associated reservoirs. In addition to Oahe, a number of tributary reservoir projects have been constructed in the incremental drainage area between Garrison and Oahe. While initially some of these tributary reservoirs may have been constructed for a single purpose, they all now serve several functions; service to some functions may be incidental to a primary purpose. Most of the reservoir projects in this incremental drainage area of the Missouri River basin were developed by the USBR for the primary purposes of irrigation and water supply. Flood control is also served by most of these projects. The Corps has also constructed several reservoirs in this area, primarily for flood control. Recreation and fish and wildlife enhancement are served by all of these projects. Reservoirs in the incremental drainage basin having a usable storage capacity of more than 5,000 AF are shown in Table IV-2.

4-13.3. The upstream tributary reservoirs can affect the regulation of Oahe by usually reducing the peak flows provided the significant runoff contributing to the peak flows originates upstream of these projects. In certain instances a reservoir may increase the size of the peak below the project over that which would be observed naturally either by the speed-up of travel time through the length of the reservoir or by delaying a portion of the runoff from a subarea to more nearly coincide with the peak on the main stream. However, with the storage space provided and the several reservoirs in this region that are tributary to the Missouri River main stem, the possibility of the aggregate effect increasing Missouri River peak flows is very remote.

Table IV-2
Reservoirs in the Incremental Drainage Basin Between Garrison and Oahe

Reservoir	Stream	River Basin	State	Total Storage (AF)	Flood Control Storage (AF)	Owner or Operator
Lake Edward Arthur Patterson (Dickinson Dam)	Heart River	Heart	ND	8,6100	None	USBR
Lake Tschida (Heart Butte Dam)	Heart River	Heart	ND	214,200	147,000	USBR
Bowman Haley	Grand River	Grand	ND	91,500	72,700	Corps
Shadehill	Grand River	Grand	SD	350,200	230,000	USBR
Angostura	Cheyenne River	Cheyenne	SD	80,800	none	USBR
Coldbrook	Cold Brook	Cheyenne	SD	7,200	6,680	Corps
Cottonwood Springs	Cottonwood Springs	Cheyenne	SD	8,400	7,730	Corps
Deerfield	Castle/Rapid Creek	Cheyenne	SD	15,700	none	USBR
Pactola	Rapid Creek	Cheyenne	SD	99,000	43,100	USBR
Keyhole	Belle Fourche River	Belle Fourche	WY	329,100	140,500	USBR
Belle Fourche	Owl Creek	Belle Fourche	SD	172,900	none	USBR

4-14. Flood Control. In addition to the flood control storage provided in Oahe, reservoir storage space allocated to this purpose has been provided in several of the tributary reservoirs located within this region as shown on Table IV-2. Tributary reservoir flood control storage space in the region totals over 600,000 AF and can be expected to store significant volumes of runoff during large plains snowmelt events such as occurred in 1950, 1952, 1997, 2009, 2010 and 2011, as well as in other years. However, tributary flood storage accumulated during such an event is usually evacuated quite soon after it is stored. Additionally, there is no assurance that most tributary space in this region will be effective for control of runoff that may tax the flood storage provided in a mainstem System project. Consequently, the availability of tributary flood control storage space in this region has had little significant effect on either storage requirements or on operation procedures of Oahe or the other five mainstem System projects. There are no local flood protection projects that affect, or are affected by, Oahe operation, except those downstream of the System, such as Omaha, NE and Kansas City, MO.

4-15. Irrigation. Irrigation is practiced at scattered locations through the incremental drainage area between Garrison and Oahe. Along the Missouri River bottoms below Garrison a number of individual irrigators draw water directly from the Missouri River. The major federally-funded irrigation projects existing in the incremental drainage area include the Fort Clark Unit along the Missouri River, the Dickinson and Heart Butte Units along the Heart River, the Belle Fourche project along the Belle Fourche River, which is a tributary to the Cheyenne River, the Rapid

Valley project along Rapid Creek, which is a Cheyenne River tributary, and the Angostura unit on the Cheyenne River in southwestern South Dakota. There are also scattered private irrigation developments in the headwaters of the Cheyenne River in northeastern Wyoming. In total, about 130,000 acres are irrigated from surface water supplies in this incremental drainage area. Of this total, 86,000 acres are irrigated at federally-developed irrigation projects. In recent years there has been an increasing development of sprinkler irrigation where groundwater supplies are available. Refer to Appendix E of this WCM or Appendix E of the Master Manual for additional information regarding irrigation.

4-15.1. The Oahe Diversion Unit (Oahe Unit) was authorized in the Flood Control Act of 1944 as part of the Pick-Sloan Missouri Basin Program. Plans by the USBR for the Oahe Unit called for irrigation of about 190,000 acres in the initial phase of development, provision of a M&I water supply in east-central South Dakota, development of fish and wildlife areas totaling about 40,000 acres, and the development of recreation facilities associated with the regulating reservoirs that form a portion of the diversion project. The Oahe Unit would have required the construction of 215 miles of major canals and 950 miles of smaller canals and laterals for the delivery of water to individual farmers. The three large reservoirs that would have been formed by the project, Blunt, Cresbard and Byron, would have had storage capacities of 185,000, 30,400 and 62,100 AF, respectively. All were to be located outside of the Garrison to Oahe incremental drainage area. Water would be pumped from the Oahe reservoir into the proposed 37-mile long Pierre Canal, which would flow into the proposed Blunt Reservoir, located on Medicine Knoll Creek, a minor left bank tributary entering the Missouri River a few miles downstream from Oahe Dam. From Blunt Reservoir, water would be transported by gravity across the divide between the Missouri and James River valleys by means of the proposed Highmore and Faulkton Canals to the proposed Cresbard Reservoir. Canals would lead from the Cresbard Reservoir to irrigated land west of the James River. Another pumping plant would divert water from the James River at the proposed James River Diversion Dam, located about 15 miles north of Huron, SD, into Lake Byron for further distribution to irrigated lands to the east of the James River Valley.

4-15.2. Construction started on the James River Diversion Dam in August 1963 and was completed the following year in November. The Oahe pumping plant, with a capacity of over 1,000 cfs, was constructed adjacent to the Oahe powerhouse with work beginning in May 1974 and was essentially complete by the fall of 1977. The piping was connected to the surge tank riser of the Oahe No. 7 generating unit, with power supplied to the pumps by the Oahe powerplant. The pumps were never connected to the riser. Canal construction was started in June 1976 and was moving forward when Congress cut funding for the Oahe Unit in the fall of 1977 because strong local opinion developed against the project. Land acquisition for the 185,000-AF Blunt Reservoir, which started in 1972, was also stopped by the Congressional defunding of the Oahe Unit. The Oahe Unit was never officially deauthorized. However, Congress passed H.R. 7347 in September 1982, which prohibited any further construction on the Oahe Unit without the approval of Congress. In 2006, additional legislation (Public Law 109-458) directed that parcels of land acquired for Blunt Reservoir and Pierre Canal features be conveyed to the Commission of School and Public Lands and the SD GF&P for the purpose of mitigating lost wildlife habitat, with the condition that preferential leaseholders had an option to purchase parcels.

4-15.3. Congress ultimately authorized and funded several other water projects including the Walsword, Edmunds and Brown Counties pipeline (WEB Pipeline) and the Mid-Dakota Rural Water System (MDRWS). While alternative water projects were developed and built to supply water to the Oahe project area, none of them used the constructed features of the Oahe Unit and all of them have focused on providing municipal, rural and industrial water, not water for irrigation purposes.

4-16. Navigation. Although navigation on the Missouri River through South Dakota opened up this region for initial westward settlement, there currently is no navigation through this reach of the river. No tributary reservoir storage space has been allocated for this purpose. Storage has been provided in Oahe for multiple purposes, including Missouri River navigation. However, storage and releases from the project serve navigation only indirectly, after re-regulation by downstream projects. A description of the Missouri River navigation project is contained in Chapter VII and Appendix G of the Master Manual.

4-17. Hydroelectric Power. The Oahe powerplant, with an installed capacity of 786,000 kW, is the only hydroelectric power generating located in the incremental Missouri River drainage area discussed in this WCM. At one time a hydroelectric powerplant was operated in connection with the tributary Angostura reservoir project; however, this facility is now inactive. All power generated by federal facilities in the Missouri River basin is marketed by the Western and power generation is integrated with the generation provided from other System projects, as well as that generated from other federal and private facilities throughout the power marketing area. Further details concerning hydropower generation and the Western power marketing and transmission facilities are provided in Section 7-12 and Appendix F of the Master Manual and Appendix F of this WCM.

4-18. Municipal and Industrial Water Supply. The Missouri River between Garrison and Oahe is the source of water supply for the municipalities of Riverdale, Washburn, Bismarck and Mandan in North Dakota along with the Standing Rock Reservation and the Cheyenne River Reservation. Industrial water intakes in this reach of the river include the Tesoro Mandan refinery near Mandan, the Basin Electric and Great River Energy coal-fired powerplant near Stanton, Ottertail Power Company plant at Washburn and the Montana-Dakota Utilities powerplant at Mandan. Adequate flows to sustain these facilities result from releases by the upstream Garrison, and in turn, are reflected in the inflows to the Oahe reservoir. The Oahe reservoir is utilized as water supply directly by four towns: Fort Yates, ND, Wakpala, SD, Mobridge, SD, and Huron, SD, and three rural water districts. The intake for the WEB water system is at RM 1184. The WEB water system serves 45 towns and over 7,000 rural households. The intake for the Cheyenne River Tribe Mni Waste´ Water Company is at RM 1110. The South Dakota communities served by this intake include Eagle Butte, LaPlante, Swiftbird, Whitehorse, Promise, Dupree, Iron Lightning, Thunder Butte, Faith, Howes, Isabel, Takina, Cherry Creek, Bridger, Lantry, Ridgeview, Red Elm, Red Scaffold, Blackfoot and Parade. The intake for the MDRWS is just upstream of the dam on the east side. Immediately downstream of Oahe Dam, the cities of Pierre and Fort Pierre obtain their water supply from wells. The Mni Wiconi Water Supply Project is a large municipal water intake located near Fort Pierre. This intake provides municipal, rural and industrial water supply to serve more than 51,000 people in 40 communities and 10 counties through about 4,400 miles of pipeline throughout central, and southern and western South Dakota involving four rural water systems: West River/Lyman-Jones, Oglala

Sioux, Rosebud Sioux Tribe and Lower Brule Sioux Tribe. At Fort Pierre, Missouri River water is accessed by a nearby water treatment plant before being delivered to points west and south through the pipeline.

4-19. Land Treatment. In response to the program administered by the U.S. Department of Agriculture, land treatment measures designed to reduce erosion and local floods and to increase the local surface water supply are in operation throughout the incremental drainage area discussed in this WCM. Associated with this program are many stock ponds or farm ponds that have been developed. While these ponds and other land treatment measures have a depleting effect on the overall local water supply to the Missouri River and provide a degree of local flood protection, their effect on major Missouri River flood flows is minimal. The reduction of erosion, however, could provide significant benefit to the System by reducing current and future sediment accumulation.

4-20. Fish, Wildlife and Recreation. The effects of water resource development on fish and wildlife are a major concern throughout the Missouri River basin in the planning and reservoir regulation processes. Recreation opportunities have generally been increased as a result of water resource development. To the degree practicable, fish and wildlife interests are considered prior to regulation of the projects. Recreational use of the Oahe reservoir continues to increase through the years. Since the South Dakota Title VI land transfer in 2002, recreation interests on the reservoir are primarily managed by the SD GF&P Department, the Tribes and various local entities. Appendix B of this WCM presents additional information regarding recreation.

4-21. Streambank Stabilization. Streambank erosion is a continuing process along the Missouri River and also along the tributaries in the region. Sediment inflow to the Oahe reservoir results almost entirely from this erosion process along streams contained within the incremental drainage area. The Missouri River, below Oahe Dam to the headwaters of Big Bend, has been fairly well stabilized by means of bank protection and the construction of channel blocks.

4-22. Streamflow Depletions. The major effect of the tributary water resource developments in the incremental drainage from Garrison to Oahe on the regulation of Oahe is a depletion in the available water supply. As resource development continues, a growth in depletions can be expected. While increasing depletions benefit the flood control function, it is evident that they may have adverse effects on other functions that are dependent on the availability of a continuing water supply.

4-22.1. Prior to 1865 streamflow throughout the Missouri River basin was largely unused, except for transportation. Settlers and homesteaders in the late 1800s and soon after the turn of the century started substantial irrigation and mining ventures in several regions of the upper Missouri River basin. However, in the western North Dakota and South Dakota drainage area contributing to the Missouri River reach discussed in this WCM, the available water supply was very small and unreliable. Consequently, irrigation development occurred in only scattered areas, principally in the Black Hills region where a more dependable water supply was available. The first major irrigation project to be developed was the Belle Fourche project that became operational after construction of the Belle Fourche Reservoir in 1908. Most other development occurred after 1949. Table IV-3 lists results of the 2005 USBR analysis of the historical and estimated future depletions in the Garrison to Oahe reach. Depletions are based on irrigation and as well as M&I uses. Future depletions are primarily based on projected population changes.

Table IV-3
Depletions in the Garrison to Oahe Reach

Time Period	Average Annual Depletions in kAF
1929 – 1940	434.7
1941 – 1950	342.1
1951 – 1960	376.9
1961 – 1970	406.8
1971 – 1980	407.2
1981 – 1990	389.8
1991 – 2002	414.5
Future (Estimated)	
2002 – 2010	342.0
2010 – 2015	342.2
2015 – 2020	342.5
2020 - 2025	342.8
2025 – 2030	343.1
2030 – 2050	344.0
2050 – 2070	344.3
2070 - 2090	343.6
2090 - 2110	343.0

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V - Data Collection and Communications Networks

5-01. General. Refer to Chapter V of the Master Manual for an outline of the basic hydrologic data required for regulation of the System. This chapter outlines agency responsibilities, communications methods and other details relevant to the data collection process.

5-02. Oahe Project Data. Hourly data are automatically transmitted from the Oahe PPCS via satellite telemetry from a data collection platform (DCP) to the MRBWM office and also to the Corps' Kansas City District for redundancy. The data include hourly releases, generation, pool elevations, tailwater elevations, air temperature and water temperature. The daily data files include daily maximum and minimum air temperatures, precipitation, manually-entered pan evaporation, and tailwater temperatures. Tailwater temperatures are obtained from a temperature probe on the downstream right wing wall. In the event the automatic data collection and transfer is not working, Oahe personnel fax or email hourly and daily project powerplant data to the MRBWM office and the MRBWM staff manually input the information into the Missouri River Region's (MRR) Corps Water Management System Oracle database. The Oahe monthly summary is faxed or emailed to the MRBWM office and is used to verify daily data.

5-02.1. During the winter season the data above may be supplemented by occasional reconnaissance reports of the reach of the Missouri River extending from Oahe Dam to the headwaters of the Big Bend reservoir by local Corps personnel. Pertinent observations during each reconnaissance include location of the head of ice cover, ice conditions, and available freeboard at critical locations not normally available on a routine basis. Reconnaissance observations are provided to the MRBWM office.

5-02.2. Throughout the year Oahe project personnel investigate requests and complaints that occur as a result of Oahe regulation and report their recommendations and findings to the MRBWM office. The MRBWM office keeps the Oahe project personnel advised concerning anticipated changes in releases and reservoir levels. Based on this information, project personnel assist in informing affected interests of any major changes in release rates or reservoir elevations that may be scheduled, and also informing affected interests of unusual reservoir elevations that may be anticipated. System coordination is discussed further in Chapter VIII of this WCM and also in the Master Manual.

5-03. Precipitation and Temperatures. Sections 5-03 and 5-04 of the Master Manual contains detailed descriptions of data collection procedures throughout the Missouri River basin. Precipitation data is available through automated precipitation gages at real-time DCP stations and observer precipitation stations, some described in greater detail later in this chapter. Spatially-distributed observed precipitation data is provided by the National Weather Service (NWS) through its quantitative precipitation estimates (QPE). Plate V-1 in the Master Manual presents NWS QPE site locations in the Missouri River basin. Forecasted precipitation grids 7 days in the future are also available for NWS quantitative precipitation forecasts (QPF) products. The hourly QPE and 6-hour QPF files are automatically retrieved from the NWS Missouri Basin

River Forecast Center (MBRFC) on a near real-time basis and stored in gridded format on the MRR Water Management System (WMS).

5-03.1. Air Temperature. Air temperature data is available via real-time DCP stations as well as through a comprehensive NWS-supported network of automated and observer stations. During periods of ice formation below Oahe Dam, the temperature data from Pierre, SD is particularly important for Oahe regulation. Spatially-distributed observed and forecasted temperature data derived by the NWS for the entire basin is provided to the MRBWM through a data exchange method developed and supported by the Corps' Cold Regions Research and Engineering Laboratory (CRREL) and HEC. The gridded temperature files are automatically created on a near real-time basis at the Corps' Central Processing Center in Vicksburg, MS and retrieved and stored in the MRR WMS. The observed air temperature data is converted into a gridded format at 1-hour time steps, both for observed data and for 16 days in the future. Additionally, forecasted temperature data at 6-hour time steps is available for 5-7 days in the future.

5-04. Snow. During the winter season, reports of snowfall and accumulated snow depths are received from numerous stations located throughout the Missouri River basin. Chapter V of the Master Manual presents detailed discussion regarding plains and mountain snow data.

5-05. Stages and Discharges. River stage information, which is reported to the MRBWM office as indicated by the basic network in Chapter V of the Master Manual, are supplemented by reports from many tributary locations, particularly during the March-July flood season or at other times of the year if unusual stages are occurring. See Plate V-1 and Table V-1 for key locations within the Oahe incremental drainage area and in the reach directly below Oahe, where streamgaging stations (DCPs) are located. Additional DCP information and DCP locations can be found at the U.S. Geological Survey (USGS) Water Resources website.

5-06. Communication during Normal Regulation. Oahe is regulated as a component of the System. As such, regulation must be fully coordinated with regulation of the other five projects; therefore, regulation of all System projects is directed by the MRBWM office. Full details relating to organizational responsibilities, coordination and communications pertinent to the System's regulation process are contained in Sections 5-21 through 5-23 of the Master Manual. Consequently, only a brief summarization is presented in this WCM and reference to the Master Manual is necessary for a complete understanding of these factors.

5-06.1. Reservoir regulation/power production orders to mainstem project personnel and Western are the basis of the regulation process. These are issued by the MRBWM office and are based on detailed analysis of current and expected hydrologic conditions throughout the Missouri River basin to meet the Congressionally authorized purposes of Oahe and the System. The MRBWM office is responsible for coordinating project regulation as described in the Master Manual and also in Chapter VIII of this WCM.

Table V-1
Garrison to Oahe Basin Data Collection Platforms

Corps ID	Location	USGS ID	NWS ID	DCP ID
HAND	Knife River at Hazen, ND	06340500	HZNN8	CE50CD5C
STND	Missouri River nr Stanton, ND (Stage Only)	06339010	STNN8	CE127628
WSND	Missouri River at Washburn, ND (Stage Only)	06341000	WSBN8	CE12E34A
PRND	Missouri River at Price, ND (Stage Only)	06342020	PRCN8	CE12D6D0
BIS	Missouri River at Bismarck, ND	06342500	BIWN8	CE50C38E
MAND	Heart River nr Mandan, ND	06349000	MDNN8	CE50D0F8
SHND	Missouri River nr Schmidt, ND (Stage Only)	06349700	MANN8	CE1200B8
BRND	Cannonball River at Breien, ND	06354000	BREN8	CE787548
LESD	Grand River at Little Eagle, SD	06357800	LIES2	CE787B9A
WHSD	Moreau River at Whitehorse, SD	06360500	WHIS2	CE788B1E
WSSD	Cheyenne River at Wasta, SD	06423500	WASS2	CE7896BA
	Belle Fourche River nr Elm Springs, SD	06438000	EMSS2	17AFB0A0
CCSD	Cheyenne River at Plainview, SD	06438500	PLNS2	CE789868
PIR	Missouri River at Pierre, SD (Stage Only)	06440000	PIRS2	CE12F03C
FPSD	Bad River at Ft. Pierre, SD	06441500	FTPS2	CE7885CC
LFSD	Missouri River at LaFramboise Island, SD (Stage Only)	06441590	LFIS2	CE6571B0
IWSD	Missouri River blw LaFramboise Island (Isaac Walton), SD (Stage Only)	06441592	LAFS2	CE3A6016
FISD	Missouri River at Farm Island, SD (Stage Only)	06441595	FRMS2	CE7474D4

5-06.2. Oahe personnel are expected to furnish the MRBWM office all information they may receive that is pertinent to the regulation process. This includes observations made by project personnel as well as complaints or suggestions from those affected by project regulation. In addition, project personnel assist in informing the public in the local area of current and probable near-future regulation activities. It is the responsibility of the MRBWM office to keep project personnel informed of such activities. Any requests for information that are complex and/or of a long-term nature, or that involve policy, are to be referred to the MRBWM office.

5-06.3. The Corps' Omaha District is responsible for project O&M, including maintenance of those facilities required to support the regulation process. District staff collect snow survey data pertinent to Oahe regulation on request by the MRBWM office. The District is also responsible for flood fighting activities in the incremental drainage area. Information that is considered pertinent to the regulation of Oahe, or other System projects, is to be furnished to the MRBWM office.

5-07. Emergency Regulation. If emergency conditions develop at Oahe, project personnel are expected to take appropriate action, which varies depending on the nature of the emergency. When there is an immediate threat of serious injury or loss of life at the project, or the probability that serious damage may occur or has occurred to project facilities, project personnel are expected to take the actions deemed necessary and notify the Omaha District and the MRBWM office of the circumstances and actions initiated as soon as conditions permit. Subsequent modification or continuance of regulation of project facilities will be based on an evaluation of current conditions and potential effects by all appropriate offices. The MRBWM office will direct this evaluation to ensure complete coordination in regulation of the project and the System.

5-07.1. During critical reservoir regulation periods, and to ensure timely response, significant coordination is often conducted by telephone between Oahe and the MRBWM office. This direct contact ensures that issues are completely coordinated and concerns by both offices are presented and considered before final release decisions are made by the MRBWM office. The MRBWM's Reservoir Regulation and Power Production team leaders, as well as the MRBWM chief, are generally available by cell phone as are the mainstem Operations Project Managers. The MRBWM weekend worker also carries a cell phone and has the responsibility of notifying the appropriate MRBWM staff so that proper coordination can occur before significant changes are made to project releases. More information on emergency regulation procedures can be found in Chapter VII of this WCM.

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VI - Hydrologic Forecasts

6-01. General. Regulation of Oahe as a component of the System requires continuing analysis of available hydrologic information and, to the degree practicable, forecasts of future events. These are considered in conjunction with the anticipated demands imposed in serving the various project purposes. These considerations may be of a long-term nature or may be based on anticipated inflows and demands for a relatively short period in the future. AOP studies are discussed in Section 6-12.3 of the Master Manual. Also discussed in Chapter VI of the Master Manual are analyses, forecasts and studies, while important for the regulation of Oahe, have essentially the same degree of importance for all of the other mainstem projects. Analyses considered to be unique or particularly important to Oahe regulation are presented in the following sections.

6-02. Precipitation and Temperature Forecasts. As discussed in Section 6-04 of the Master Manual, NWS precipitation and temperature forecasts are monitored by the MRBWM office. The NWS's short-term precipitation forecasts, often referred to as Quantitative Precipitation Forecasts (QPF), are not integrated into the short-range runoff forecasts for day-to-day actual regulation, but may add value for short-term planning purposes. Of particular importance in scheduling Oahe releases are forecasts of meteorological conditions that indicate substantial flows on the Bad River, a tributary entering the Missouri River immediately downstream of Oahe. Temperature forecasts are of particular importance during periods where an ice cover may form on the Missouri River below the project.

6-03. Runoff Forecasts. Short-range runoff forecasts are determined with water on the ground, per ER 1110-2-240, which consists of existing snowpack and recently observed rainfall. Particularly pertinent for the determination of inflows into Oahe are runoff forecasts prepared for southwestern North Dakota and western portions of South Dakota. The short-range runoff forecasts, which are discussed in greater detail in Section 6-08 of this WCM, are integral to the day-to-day regulation of Oahe.

6-04. Precipitation-Runoff Relationships. Infiltration of rainfall over the Missouri River basin between Garrison and Pierre, SD ranges from 0.50 to 1.00 inch for the initial loss. The constant infiltration losses range from 0.05 to 0.60 inch per hour on the western side of the Missouri River based on the clay and moderately fine textured soils. On the eastern side of the Missouri River, the constant infiltration losses range from 0.60 to 2.00 inches per hour for the medium textured soils. These values are based on generalized soil and infiltration maps of the basin since relatively few rainfall events have been centered and modeled in this area. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values aforementioned for rainfall. Runoff during any particular rainfall or snowmelt event would amount to the estimated depth of rainfall or snowmelt less the infiltration losses. In actual practice estimating the rainfall or snowmelt is very imprecise. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snowpack and snow water equivalent (SWE) available for melt, errors in estimating the snowmelt rate, and marked departures from the previously stated average infiltration or loss rates. Use of NWS-provided QPE data has improved knowledge of rainfall events.

6-05. Unit Hydrograph Analyses. A conventional means of forecasting flows from a particular drainage area is by the use of unit hydrographs. However, unit hydrograph development and subsequent use of the developed hydrographs as a forecasting tool has been found to be largely impractical for the drainage area under consideration in this WCM. Reasons for this include the large size of the drainage area, requiring the division of the area into many subareas, the lack of sufficient past rainfall and subsequent runoff events for unit hydrograph definition, the scarcity of, or lack thereof, rainfall, plains snowpack and soil moisture reporting stations needed for both analysis and forecasting purposes, and the fact that the majority of runoff that occurs from this drainage area does not result from particular rainfall events but results from progressive snowmelt, making runoff definition during a selected time period very challenging. Further, with the large amount of storage space available in the Oahe reservoir and the very nature of the regulation process, the effort necessary for a valid and complete analysis by means of unit hydrograph procedures is not believed to be warranted. However, runoff forecasting procedures will continue to receive consideration as a means of possibly improving the regulation process. As discussed in the Master Manual, future runoff modeling efforts include the use of QPE data within the Corps' Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), which should improve development of reliable real-time forecasting models.

6-06. Plains Snow. In many years a major portion of the annual runoff from the plains contributing area above Oahe is a result of melting the plains snowpack accumulated during the winter months. This melt usually occurs during late March or April, but can occur in February and even as early as January, and often results in the annual maximum peak flow from the Garrison to Oahe drainage area. Basic data pertinent to plains area volume analyses are: 1) precipitation during the late fall and winter months, 2) winter season temperatures, 3) water content of the accumulated snowpack prior to the melt period, and 4) soil conditions. However, even with these data, forecasts of the plains runoff volume have usually been quite imprecise. The MRBWM office continues to investigate new and improved techniques including soil condition instrumentation and continuous soil moisture accounting modeling to more accurately predict runoff from plains snow. Section 5-06 of the Master Manual contains additional information on snow.

6-06.1. Plains area snow surveys, requested by the MRBWM office and conducted by the Omaha District, are made during any year that a substantial snow accumulation exists over the drainage area. Results from the snow surveys are compared to the interactive snow map for modeled SWE from the NWS's National Operational Hydrologic Remote Sensing Center to help in the verification process. One method of obtaining quantitative estimates of runoff volume is to compare SWE of the current survey with surveys made in preceding years. This comparison will indicate which of the past years is most analogous to the current year for each portion of the total drainage basin between Garrison and Oahe. Forecasts are developed by assuming that the volume of snowmelt runoff from each portion of the basin should be similar to that observed in the most analogous year. These estimates are tempered by available ground condition data (e.g., frost depth, soil moisture), which could either increase or decrease the infiltration losses at the time of runoff. If analogous data are not available for a particular portion of the basin, it is necessary to estimate the runoff volume by noting runoff during previous years from other areas where snowpack conditions appear similar to this year's snowpack over the Garrison to Oahe incremental drainage area. For the entire Missouri River basin five years in particular, 1952, 1969, 1997, 2010 and 2011, experienced floods that were largely affected by melting of heavy snowpack on the northern plains. Table VI-1 contains information related to a plains snow comparison of the five years.

6-06.2. Improvement in the techniques of forecasting the runoff resulting from plains snowmelt is an ongoing priority of the MRBWM office. As technology continues to improve, more precise and objective forecasting methods are being developed. In addition, the NWS has initiated forecasts of plains snowmelt runoff volumes that are made just prior to the melt season. As experience is gained with new methods, it appears probable that better estimates of the runoff volume from plains snowmelt will be available than in the past. See Section 5-06.1.3 in the Master Manual for details regarding the Corps' Missouri Basin Snow Tool.

Table VI-1
Plains Snow in Major Floods

Late Winter Plains Snow in Major Flood Years (SWE in Inches)						
Stream	**Location**	**17-Mar-1952***	**31-Mar-1969***	**18-Mar-1997***	**4-Mar-2010****	**11-Feb-2011****
Milk River	Nashua, MT	3.0	2.0	<1	1.5	3.2
Knife River	Hazen, ND	2.8	2.3	1.8	4.7	5.0
Heart River	Mandan, ND	3.5	3.0	1.8	4.4	4.7
Apple Creek	Bismarck, ND	3.0	3.0	3.0	4.7	5.1
Beaver Creek	Linton, ND	3.5	2.5	4.3	5.2	4.8
Cannonball R	Breien, ND	3.5	3.0	3.4	4.4	3.8
Grand River	Little Eagle, SD	3.6	2.3	2.6	3.8	2.7
Moreau River	Whitehorse, SD	4.0	2.3	1.7	3.0	1.9
Cheyenne River	Eagle Butte, SD	5.0	1.0	<1	1.2	1.0
Bad River	Fort Pierre, SD	3.0	1.5	<1	3.4	1.3
Elm River	Westport, SD	5.0	5.0	3.2	5.0	4.2
James River	Scotland, SD	3.6	4.0	3.9	4.6	4.0
Vermillion R	Wakonda, SD	0.5	4.5	3.4	3.5	3.2
Big Sioux River	Watertown, SD	3.8	4.2	4.2	6.7	5.3
Floyd River	Sioux City, IA	0.5	3.3	0	4.3	3.2
Little Sioux R	Turin, IA	0	3.2	<1	5.1	2.4

*From the 1997 Midwest Floods Post Flood and After Action Report, Volume 1.
**From working files of Hydrology and Meteorology Section, Hydrologic Engineering Branch, Omaha District.

6-07. Monthly Reach Inflow (Runoff) Forecasts. Soon after the first of each month throughout the year a forecast of incremental monthly inflows to the System reservoirs, including those originating in the reaches between Garrison and Oahe and Oahe and Fort Randall is prepared by the MRBWM office. These forecasts are utilized to develop System regulation studies, as described in Section 6-12 of the Master Manual. An exception is the Oahe to Big Bend reach. Due to the relatively small drainage area between Oahe and Big Bend, the normal lack of substantial runoff from this area and the small amount of deliberate seasonal storage space in the Big Bend reservoir, this reach does not warrant a separate estimation of monthly runoff, and is included in the Oahe to Fort Randall reach.

6-07.1. Monthly reach inflow or runoff forecasts are based on, but are not limited to, monthly average reach runoff, antecedent reach runoff, antecedent soil moisture conditions, accumulated station and/or reach precipitation during March-April and May-July, observed reach temperature and accumulated snow over the incremental drainage area. In the Garrison to Oahe reach snow contributions to runoff are important only during the early spring (March-April) period of plains snowmelt runoff. There have been years when warmer-than-normal January and February temperatures have resulted in some or all of the plains snow melting during these months. Consequently, long-range reach inflow forecasts for periods other than this early spring period consist primarily of modifying the long-term normal runoff volume by observed antecedent basin conditions. These forecasts are utilized to develop System regulation studies, as described in Section 6-12 of the Master Manual. Details and techniques currently applicable for forecast development are contained in the MRBWM Technical Report, *Long-Term Runoff Forecasting*, dated February 2017.

6-08. Short-Range Forecasts of Daily Inflow. The MRBWM office develops forecasts of future daily inflows to the Oahe reservoir and the other associated System reservoirs at frequent intervals. Each week daily inflow forecasts extending three weeks or more into the future are developed. Experience has indicated that a satisfactory method of anticipating Oahe inflows for periods of up to a week beyond the current date consists of combining anticipated daily releases from the upstream Garrison with anticipated daily flows from each of the major tributaries contributing to the Oahe incremental drainage area. During significant flood events each tributary should be individually considered; however, most of the time the runoff originating between Garrison and Oahe can be considered in total, with forecasts largely an extrapolation of past total runoff in which current hydrologic conditions pertinent to short-term runoff are given due consideration. Typical inflow hydrographs from the total incremental area are discussed in Section 3-08 of this WCM. With the large amount of storage space available in Oahe, forecast emphasis is not toward exact definition of the incremental inflow hydrograph, but rather toward a definition of incremental inflow volumes over a relatively longer period of time (a week or more) so that release adjustments from upstream projects, and on occasion from Oahe, can be scheduled to meet regulation objectives. As discussed in the Master Manual, future runoff modeling efforts include the use of observed gridded precipitation in the Corps' HEC-HMS models.

6-09. Stage-Discharge Relationships. Stage-discharge relationships, sometimes referred to as rating curves, are maintained by the MRBWM office for key tributary streamflow stations in the Garrison to Oahe incremental drainage area. These are kept current on the basis of discharge measurements made by the USGS. Plate VI-1 shows the present stage-discharge relationships at key locations for developing short-range inflow forecasts pertinent to Oahe regulation. The stage-discharge relationship for the Bad River at Fort Pierre, which is located downstream of Oahe, is also shown on Plate VI-1.

6-10. Forecasts of Downstream Locations. The only time when forecasts of stages in the open water reach of the Missouri River below Oahe at Pierre, SD, will be required for regulation purposes is when releases in excess of the Oahe powerplant are required. Such prolonged releases have only occurred in 2011. Pierre stage forecasts should be made on the basis of anticipated Oahe releases and the Missouri River at Pierre rating curve, which is shown on Plate III-22.

6-11. Routing Procedures. A simple translation of observed or anticipated upstream flows by the approximate travel time from the upstream location is an adequate routing procedure for the purpose of forecasting inflow to Oahe. The large storage capacity of the Oahe reservoir and associated regulation procedures do not require precise definition of anticipated inflows. The lack of information from a considerable portion of the incremental Garrison to Oahe drainage area also precludes such precision.

6-11.1. Routing procedures are also utilized to translate the effects of upstream reservoirs to Oahe in order that the total reservoir effects at this location may be determined. These procedures are based on travel time to Oahe which would be appropriate prior to the development of either tributary or mainstem reservoirs. A simple lag-average routing method is used with coefficients as presented in Table VI-2.

Table VI-2
Lag Average Routing Coefficients
Upstream Dams to Oahe Dam

Reservoir	Average Days	Lag Days
Garrison	3	4
Heart Butte	3	5
Shadehill	3	4
Keyhole	3	5
Pactola	2	4
Angostura	2	4
Oahe Inflow	1	4

Note: 1. Data averaged is at the average daily rate.
2. Lag given is the number of days from the last day of average daily values averaged.

6-12. Evaporation. Due to its large surface area, evaporation is an important component of the overall water budget of the Oahe reservoir. An estimate of the daily evaporation volume is required for developing daily inflow estimates and for more precisely estimating the effects of reservoir development on the available water supply. Initially, observed pan measurements were taken daily at Oahe and then factored by an average monthly pan coefficient to come up with the reservoir evaporation. During those portions of the year when pan data were not available, normal evaporation depths for each month was considered the most practical means of developing evaporation estimates for day-to-day regulation activities. Pan coefficients and monthly evaporation rates were taken from the June 1973 MRD-RCC Technical Report JE-73 titled, *Missouri River Main Stem Reservoir System, Reservoir Evaporation Estimates*. Plates III-9 through III-12 show pertinent evaporation information for the System reservoirs. Observed pan measurements are currently taken by Oahe personnel and provided to MRBWM and the NWS in Aberdeen at the end of the month.

6-12.1. The MRBWM office and Omaha District partnered with the Corps' CRREL to develop a more accurate real-time model, known as the Omaha District Evaporation Technique, to determine reservoir evaporation. This real-time model uses local meteorological hourly parameters of air temperature, dew point, wind speed, relative humidity, air pressure and cloud cover to calculate solar radiation in addition to water temperature profiles. The MRBWM office plans to implement this new technique in 2019.

6-12.2. In addition to evaporation, development of the effects of the Oahe reservoir on streamflow must consider the offsetting effects of precipitation on the reservoir surface and must also make allowances for the channel area in existence prior to the impoundment of water in the reservoir. Also, allowance must be made for that portion of the rainfall now falling on the reservoir surface that prior to the formation of the reservoir would have contributed to direct runoff from the area now inundated. Precise calculations of these factors are impractical. As stated in MRD-RCC Technical Report JE-73, it is estimated that 75 percent of the precipitation that falls on the reservoir today historically would not have flowed into the Missouri River. This assumes that 10 percent of the precipitation would have fallen on original channel area and that 15 percent would have appeared as direct runoff from the former ground surface now inundated by the reservoir.

6-13. Wind Effects on Water Surface Elevations. The general orientation of the Oahe reservoir is to the north of the damsite where the pool level recorder is located. Winds from this direction result in pool level set-up at the dam while a wind from the opposite direction results in a pool level set-down. See Plate VI-2 for wind correction tables for the pool level recorder at the dam at various elevations. An anemometer is located near the dam; however, it should be recognized that only approximations of the wind effect on the reported pool level can be obtained with data from this instrument. The time required for set-up to be fully established, variations in wind velocity and direction over the entire reservoir surface, and the difficulty of having one location represent the entire length of the reservoir will result in deviations from calculated values. Synoptic surface weather maps may also be used for qualitative wind estimates or to determine the probable representativeness of the anemometer.

6-14. Daily Inflow Estimates. Estimates of inflow to the Oahe reservoir are made each day by the MRBWM office for regulation purposes. The steps involved consist of:

a. plotting hourly pool elevations as reported by the Corps' PPCS at Oahe;
b. utilizing reported wind reports to estimate the set-up or set-down effects on the reservoir to select an estimated midnight pool elevation;
c. calculating the reservoir storage change equivalent to the estimated 24-hour reservoir elevation change; and
d. using all this information, in conjunction with reported releases and estimated evaporation, to compute the daily reservoir inflow.

6-14.1. In addition, Garrison releases and gaged tributary flows are routed to the Oahe reservoir. These are combined with estimates of ungaged flow and precipitation on the reservoir surface to obtain an additional estimate of reservoir inflow. Differences in inflow estimates as determined by the previously defined process and the gaged tributary flows are reconciled by using experience and engineering judgment. At times it will be necessary to adjust data for previous days on the basis of continuing trends in the reservoir level that were not evident during those days. See Plates VI-3 through VI-8 for regulated and incremental inflow volume probability relationships for various durations. More information on the inflow volume probability for the mainstem projects can be found in the MRBWM Technical Report, *Hydrologic Statistics on Inflows*, July 2015.

6-15. Unregulated Flows. Construction of the Oahe project, together with the other mainstem and tributary projects in the basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows augmented by reservoir regulation. A quantitative estimate of the effects of regulation on flows at the damsite and important locations downstream is frequently required. This represents a continuing effort by the MRBWM office, and involves such factors as reservoir evaporation, precipitation on the Oahe reservoir, variations in travel time resulting from reservoir development, channel area inundated by the reservoir, runoff that could have been expected from previous overbank areas now inundated by the reservoir, inflows, releases and storage changes. Refer to the MRD-RCC Technical Study S-73, *Upper Missouri River, Unregulated Flow Development*, dated September 1973, for additional details of the analysis.

6-15.1. In addition to unregulated flows, development of flows at the 1949 level of basin development prior to construction of Oahe and other water resource development in the Missouri River basin represents a continuing effort of the MRBWM office. Oahe represents a location where such determinations are made. Reference is made to Section 6-15 of the Master Manual for further details of these analyses.

6-15.2. Refer to Plates VI-9 through VI-17 for flow probability relationship curves for tributary streams flowing into Oahe and the Bad River in the reach directly below Oahe. Table VI-3 lists the peak discharges for a given return period.

6-16. Evaluation of Regulation Effects. In evaluation of the effects of regulation on downstream flows, and consequent flood damage reduction estimates, Oahe is considered to be a component of the total System. Damage reductions attributable to regulation of this individual project are not differentiated from those resulting from the six-project System as a whole. Details of the evaluation process are presented in Sections 6-15 and 6-16 of the Master Manual.

Table VI-3
Tributary Flow Probability Relationships

Tributary	Drainage Area (sq mi)	Period of Record	Peak Discharge (in cfs) for Given Return Period (in years)			
			10	50	100	500
Knife River at Hazen, ND	2,240	1904-2014	13,700	28,800	37,300	62,800
Heart River nr Mandan, ND	3,310	1924-2014	17,600	34,000	41,500	90,100
Cannonball River at Breien, ND	4,100	1934-2014	16,900	38,000	50,500	14,600
Grand River at Little Eagle, SD	5,370	1958-2014	15,800	29,400	36,300	55,100
Moreau River nr Whitehorse, SD	4,880	1954-2014	20,800	40,800	50,900	77,800
Cheyenne River at Edgemont, SD	7,140	1903-2014	1,000	3,100	4,600	9,300
Cheyenne River nr Wasta, SD	12,800	1914-2014	26,700	47,500	58,000	97,200
Belle Fourche R nr Elm Springs, SD	7,210	1928-1932, 1934-2014	30,600	60,200	75,000	114,000
Cheyenne River nr Plainview, SD	21,600	1950-1981, 1994-2014	42,100	79,100	98,900	156,000
Bad River nr Fort Pierre, SD	3,107	1928-2014	21,000	46,200	61,200	99,500

6-17. Long-Term Studies. Simulated regulation of Oahe as a component of the System, through the entire period of available hydrologic record, is a technique utilized by the MRBWM office for the development and improvement of regulation criteria. Current regulation criteria are the result of many involved and detailed studies, augmented by actual regulation experience. Accomplishment of the long-term studies is described in Chapter VI and Appendix H of the Master Manual and in the detailed reports that have been published describing specific studies. From the long-term studies that incorporate current regulation criteria and water use, as well as studies that assume various potential future levels of water resource development in the Missouri River basin, long-term examples of Oahe regulation are available. From the examples incorporating the present level of water resource development, conclusions relative to regulation of Oahe can be established, as described in succeeding sections.

6-18. Oahe Elevations. Long-term analyses indicate the levels of the Oahe reservoir will fluctuate from the minimum pool of elevation 1540.0 feet upward to above the maximum normal operating pool elevation of 1617.0 feet, the base of the Exclusive Flood Control Zone. Utilization of some of the Exclusive Flood Control Zone, elevation 1617.0 to 1620.0 feet, was required in 1975, 1984, 1986, 1995, 1996, 1997, 1999, 2010, 2011 and 2018 for the purpose of downstream flood control during these nine high runoff years. Average levels of Oahe are influenced by long-duration periods of drought. For the period 1967 to 2015 the pool varied seasonally from a low at elevation 1598.4 feet in January to a high near elevation 1605.1 feet in June, which is below the base of the Annual Flood Control and Multiple Use Zone due to the two historic periods of extended drought, with an overall average near elevation 1601.7 feet. Extreme low elevations, below elevation 1580.0 feet, occurred in 2003, 2004, 2005, 2006 and 2007 during the drought of 2000-2007. A graph of approximate Oahe reservoir levels that would be experienced with a repetition of the available hydrologic record is presented in the Master Manual.

6-18.1. The Oahe reservoir elevation duration curve shown on Plate VI-18 indicates that a reservoir level at or above elevation 1607.5 feet, the base of the Annual Flood Control and Multiple Use Zone, can be expected almost 40 percent of the time. A pool-probability relationship of annual maximum Oahe elevations is shown on Plate VI-19. This relationship was developed from the long-range study analysis using the Daily Routing Model (DRM) simulation, as tempered by actual regulation experience of Oahe. In the case of Oahe, results of the DRM indicated low correlation between observed and simulated pools in some ranges. From this curve it is evident that a maximum annual reservoir level at or above the base of the flood control storage space, elevation 1607.5 feet, can be expected in six years out of every ten. An elevation of 1617.0 feet, the base of the Exclusive Flood Control Zone, can be expected in one out of five years. Further particulars regarding development of these pool-duration and pool-probability curves are given in MRBWM Technical Report, *Hydrologic Statistics,* dated September 2013.

6-18.2. Average Oahe reservoir levels and normal seasonal variations since 1967 are shown on Plate VI-20. These averages show the characteristic pool elevation rise during the first three months of the year, which is due to re-regulation of high winter power releases from upstream mainstem projects, combined with the usual period of highest seasonal runoff from the incremental drainage area between Garrison and Oahe. After navigation releases from the System begin in late March, the pool rise in the Oahe reservoir slows down, peaking near the end of June before levels start to decrease during the July to December period as navigation support releases continue.

6-19. Oahe Releases. Long-term regulation studies indicate that an Oahe release in excess of the powerplant capacity of about 54,000 cfs will be rare, as confirmed by actual regulation of the project to date. Duration curves of average daily releases shown on Plate VI-21 indicate that releases in excess of the full powerplant capacity will be necessary for just over one percent of the time. The median release for Oahe is 22,800 cfs. The frequency curve of annual maximum releases shown on Plate VI-22 was developed from long-term regulation study results augmented by data experienced during actual regulation. This curve reflects instantaneous releases at full powerplant capacity during all years to supply peak generation requirements. Further particulars regarding development of these frequency curves are given in the *Hydrologic Statistics* report referenced in Section 6-18.1.

6-19.1. Average monthly and daily elevations, inflows and releases based on System regulation since 1967 are shown on Plate VI-20. The seasonal release pattern illustrated by Plate VI-20 reflects the restricted System releases during the winter months and higher releases needed to support Missouri River navigation during much of the remainder of the year. Reduced releases during October and November allow for the evacuation of space in the downstream Fort Randall reservoir for recapturing power releases from the upstream reservoirs in the forthcoming winter period. The December releases permit Oahe to serve a higher than usual proportion of the System's winter power generation while freeze-up of the Missouri River channel is occurring below Garrison Dam and restricting releases.

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VII - Current Water Control Plan

7-01. Multiple Purpose Regulation. Aspects of multi-purpose regulation that are pertinent to the System as a whole are discussed in Chapter VII of the Master Manual. Since continuing development of System regulation plans requires coordination of plans for all mainstem projects, this subject has been explored thoroughly in the Master Manual and will not be repeated in this, the Oahe WCM. Rather, the following sections will be concerned with amplifying the regulation objectives and requirements given in the Master Manual that are pertinent to regulation of Oahe for the authorized purposes of flood control, navigation, hydropower, water supply, water quality control, irrigation, recreation and fish and wildlife, which includes T&E species. Regulation of Oahe for flood control is discussed later in this chapter.

7-02. Basis for Service. As an introduction to regulation of Oahe, the need to conform to certain storage provisions and basic regulation criteria should be recognized. The bottommost zone, the Permanent Zone, is the portion of the reservoir lying below elevation 1540.0 feet and is to remain permanently filled with water. This ensures maintenance of minimum power heads, a minimum level for the design of irrigation diversion and water supply facilities, and a minimum pool for recreation, and fish and wildlife purposes. The Carryover Multiple Use Zone extends from elevation 1540.0 to 1607.5 feet. This zone is to be used to provide service to authorized purposes during droughts. The Annual Flood Control and Multiple Use Zone extends from elevation 1607.5 to 1617.0 feet and is the preferred operating zone. Ideally, the runoff year begins with all 9.5 feet available to capture runoff during the wetter late winter, spring and early summer periods. The stored waters in the zone are then evacuated during the drier late summer, fall and early winter periods to meet all authorized purposes. The Exclusive Flood Control Zone extends from elevation 1617.0 to 1620.0 feet. This zone is reserved exclusively for flood control regulation of major floods. The next zone is the Surcharge Zone, which is from elevation 1620.0 feet, the elevation of the top of spillway gates when closed, to elevation 1644.4 feet, the maximum reservoir elevation from the routing of the SDF. This zone, which does provide some downstream flood risk reduction, is used during extreme flooding events. When the pool elevation is in this zone, release decisions are primarily made to ensure the safety of the project. Embankment freeboard is provided above the Surcharge Zone from elevation 1644.4 feet to the top of the dam embankment (1660.0 feet).

7-03. General Approach to Regulation. The following general approach is observed during regulation of Oahe:

a. Regulation of Oahe as an individual project must be subordinate to regulation of the entire System as a whole.
b. Flood control will be provided for by evacuating the storage space in the reservoir above elevation 1607.5 feet, to the degree practicable, prior to the start of the runoff season, approximately March of each year.

c. At all times when an adequate reserve of vacant flood control storage space is available, releases will be made in a manner to not contribute to significant flooding through the lower reaches of the Missouri River. If releases are reduced in the downstream reservoirs for flooding then Oahe releases will be adjusted as necessary to store water to allow the downstream reservoirs to return to or maintain their storage reserves at normal seasonal levels, if possible.
d. All irrigation and other upstream water requirements for beneficial consumptive purposes will be served to the extent reasonably possible.
e. By adjustment of the Oahe reservoir levels and releases, within the aforementioned designated criteria, the efficient generation of power to meet the area's needs as consistent with other uses and market conditions will be provided for.
f. Releases from the System to support Missouri River navigation will be backed up by releases from Oahe as appropriate to maintain storage reserves in the downstream reservoirs at normal seasonal levels.
g. Insofar as possible without serious interference with the aforementioned, Oahe will be regulated for maximum benefit to recreation and fish and wildlife, including T&E species.

7-04. Irrigation. There are no existing federal irrigation projects withdrawing water from this reservoir. The Oahe Diversion Unit was authorized in the Flood Control Act of 1944 as part of the Pick-Sloan Missouri Basin Program but was never completed. The project was never officially de-authorized, but Congress prohibited any further construction without its approval. Corps regulation responsibilities for irrigation are limited to estimating withdrawals and utilizing the estimates in the development of reservoir inflows and in deriving estimates of the actual available water supply. Table E-3 in Appendix E of the Master Manual lists the Missouri River water supply intakes throughout the System. Current estimates show that there are 179 irrigation intakes from the Missouri River in the Oahe reservoir. If other irrigation withdrawals directly from the Oahe reservoir should develop, similar regulation responsibilities are anticipated. Access to the available water supply from each System reservoir is the responsibility of the intake owner.

7-04.1. Currently there are no significant irrigation withdrawals from the Missouri River along the reach immediately below Oahe which require maintenance of minimum flows. Even if such withdrawals should develop, releases to supply them should not be required, provided the downstream Big Bend reservoir is at normal operating levels. When these normal levels occur, the upstream limits of Big Bend extend to the Oahe tailwater vicinity.

7-05. Water Supply and Water Quality Control. Extension of the upstream limits of the Big Bend reservoir into the Oahe tailwater area precludes the necessity of making Oahe releases for water supply purposes. If water supply intakes are contemplated, in order to obtain an assured water supply, withdrawal facilities must be designed to be operable with Oahe reservoir levels through the entire range of variations that may occur with elevation 1540.0 feet, the base of the Carryover Multiple Use Zone, a basis for design.

7-06. Navigation. All Oahe releases are re-regulated by downstream System reservoirs prior to serving the System's navigation function. Consequently, the regulation of Oahe for this function consists primarily of backing up the downstream System projects' navigation releases. This is not necessarily a day-to-day regulation consideration, due to storage normally available for this purpose in the downstream projects. Rather, it is usually a matter of scheduling Oahe releases to maintain downstream reservoirs in a range of desired seasonal levels, while recognizing that downstream System project releases are required to sustain the navigation function of the System.

7-07. Power Production. Hydroelectric power generated by Oahe is integrated with the power generated by the other System projects and many other public and private generation facilities in the Missouri River basin and surrounding areas. To the extent practical, all releases from Oahe are made through the powerplant. Releases in excess of the powerplant capacity, requiring outlet tunnel releases, have been required only in 1997 and 2011, the two highest runoff years on record. In 2011, the maximum sustained Oahe total release (powerplant plus outlet tunnels) was 160,300 cfs. Powerplant releases were about 50,000 cfs during the period of maximum releases. Additional information on the 2011 regulation can be found in Appendix A of this WCM. The maximum powerplant release of about 57,500 cfs was made in 1975 and 1997. Normal powerplant capacity is approximately 54,000 cfs. A supplementary release is occasionally required for test and maintenance purposes during normal operation; however, such releases represent only a very minute fraction of total releases. Any power unit failure or additional inflows to Oahe during the maximum release of the 2011 flood would have potentially required supplemental releases from the spillway, which has never been operated for flood control purposes. These additional inflows could have resulted either from modifications in upstream project regulation or from basin runoff in excess of that actually occurring.

7-07.1. The Western system power dispatcher in Watertown, SD schedules hourly loadings of the Oahe powerplant. These loadings must be within limits prescribed by the MRBWM office. These limits are developed on the basis of daily, as well as hourly, releases required to serve authorized purposes other than hydropower generation. Due to the changing power loads during the day, instantaneous releases will often fluctuate widely between 0 cfs and approaching the full powerplant capacity of approximately 54,000 cfs. Further discussion on power scheduling is presented in Section 7-12 of the Master Manual.

7-07.2. A seasonal variation in the general level of power releases from the reservoir usually occurs, reflecting service being provided other functions. During the open water season relatively large releases are required from Gavins Point to serve navigation needs in the lower Missouri River. The Gavins Point releases are normally backed up by corresponding releases from the Fort Randall, Big Bend and Oahe projects since relatively little inflow usually originates from the Oahe to Gavins Point portion of the drainage area during the navigation season. Additionally, during years of above normal water supply, the major portion of required System storage evacuation must be made during the open water season. These large releases generate substantial amounts of power.

7-07.3. During the winter months when Gavins Point releases are not being made to provide navigation flow support and in October and November when the navigation season may be shortened in extended droughts, releases from the System are usually restricted to less than half their navigation season level. In many years, the release is influenced in the winter months by the capacity of the ice-covered Missouri River channel below Gavins Point Dam. Corresponding reductions in releases and power production must also be made at Oahe. A means of partially compensating for the lesser amount of hydroelectric energy associated with lower winter release rates from Oahe and other mainstem reservoirs is the pre-winter drawdown of the Fort Randall reservoir. As part of this regulation, Oahe and Big Bend releases are reduced several weeks prior to the end of the navigation season. This leaves the Fort Randall reservoir in the position of supplying a majority of downstream release requirements from accumulated storage, resulting in a lowering reservoir level. This vacated storage space is refilled during the winter months by releases from Oahe and Big Bend in excess of those that would have been possible if drawdown of the Fort Randall reservoir had not been made. Similar regulation of Oahe, coordinated with upstream Garrison and Fort Peck releases, also increases the amount of winter energy generation. During the 4-month period, Garrison releases normally can be expected to be greater than Oahe releases. Recapture of these upstream releases typically results in a rise of the Oahe pool elevation during winter months.

7-08. Fish and Wildlife. Regulation of the Oahe reservoir for fishery purposes largely involves pool level manipulations, which provide a suitable environment for the spawning and initial growth of game and forage fish. Steady or rising reservoir elevations through the late March to early June period are desirable for this purpose. However, the ability to provide steady-to-rising pool levels in the upper three reservoirs in low runoff years is very dependent on the volume, timing and distribution of runoff. As part of the overall plan, an effort is made to rotate emphasis among the upper three reservoirs during the low runoff years when it may not be possible to keep all three reservoirs rising. Typically, Fort Peck and Oahe are scheduled to be favored in the same year while Garrison is favored in the following year if runoff conditions require it. Additionally, some species such as the northern pike require the inundation of terrestrial vegetation during the late March and April period for a suitable spawning habitat. The provision of such conditions at Oahe is not possible on a continuing annual basis; in some years, runoff events are such that fish spawning can be enhanced for some species with little adverse effect on other project functions. Since prolonged inundation destroys terrestrial vegetation, it can only be re-established by lowering and maintaining the level of the Oahe reservoir below the vegetative zone for an extended length of time during the growing season. The growing season coincides with and extends beyond the March through July flood season; therefore, maintenance of lowered Oahe reservoir levels to establish vegetation becomes practical when flood season runoff originating above Garrison Dam is also less than average.

7-08.1. Inundation of vegetation during the March-April spawning period is feasible on the shores of the Oahe reservoir. The normal recapture of Garrison power releases during the winter months will often raise the level of the Oahe reservoir to the vegetated shoreline while substantial amounts of runoff from the Garrison to Oahe incremental drainage area during the plains area snowmelt period can ensure inundation of an established vegetative cover. While the opportunities to enhance reproduction of the March-April spawning species can often occur, the chances of continuing an increase in the level of the Oahe reservoir into June and July, thereby enhancing reproduction of spawning species, are more remote. However, the possibility of this type of regulation during future years, when runoff conditions are appropriate, should be recognized. Refer to Appendix D of the Master Manual and Appendix D of this manual for further discussion of fish and wildlife.

7-09. Threatened and Endangered Species. Since 1986 releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered interior least tern (least tern) and threatened piping plover nesting. Releases from Fort Peck were also modified for several years, but no longer are due to the nesting patterns below that project. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Peaking may be restricted in both magnitude and duration at Garrison and Fort Randall. The regulation of Oahe is not adjusted for T&E nesting. Planned operations to address Endangered Species Act (ESA) requirements will normally be provided in the AOP. Refer to Appendix D of this WCM for further discussion of fish and wildlife.

7-10. Recreation. Water-based recreation at Oahe is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the project have top elevations extending from 1618.0 to 1624.0 feet and bottom elevations from 1570.0 to 1600.0 feet. Recreational facilities are also discussed in Section 4-09 of this WCM. Insofar as practicable, consistent with the water supply, other project purposes, and conditions in the other mainstem projects, the Oahe reservoir levels should be scheduled to provide continued access to the reservoir area for recreational use. Boating and fishing on the Missouri River below Oahe is also a popular recreational activity during the summer months. Hourly Oahe release variations appear to have little adverse effect on the use of tailwater areas since the higher power loads and consequent high releases desired by recreational interests usually occur during the daylight and evening hours when recreation use is at the highest. However, reduced daily power demands usually are experienced during weekends, particularly on Sundays, and as a consequence it may be necessary to schedule minimum Oahe releases during weekend daylight hours to satisfy the weekend recreation and fishing demand in the tailwater area. Since access to the tailwater area is not a problem in that the normal flat pool of the Big Bend reservoir extends into the area, the minimum releases are primarily a fish attraction measure.

7-11. Release Scheduling. As discussed in the Master Manual, scheduling of releases from Oahe, as well as all other System projects, is normally based on continuing studies by the MRBWM office in which all authorized purposes, including flood control, are considered. These studies are made at maximum intervals of one month and incorporate current conditions with the most recent estimates of future runoff, as expressed in terms of forecasted inflow, to the individual System projects. Service to all authorized purposes receives consideration including navigation requirements. The frequency of these studies is increased when previously unanticipated inflows occur that may have a substantial effect on System regulation. An example of these studies is included in the AOP, published each year as described in Section 6-12.3 the Master Manual.

7-11.1. On a short-term basis there are often modifications to the general long-term scheduling of Oahe releases, usually dictated by requirements of the downstream projects release requirements. In the winter season, long-term scheduling is usually followed much more closely than during the navigation season. As discussed in the Master Manual, a short-range forecast is prepared in addition to the long-term monthly forecasts. The Three-Week forecast is developed using a short-range System regulation model of the same name. The forecast presents forecasted inflows, releases, reservoir elevations and hydropower generation for a 3- to 5-week period for each of the System projects. The forecast serves as a guide for short-term System modifications and is used to make regulation adjustments within the range normally determined by the long-term monthly studies.

7-11.2. Reservoir regulation/power production orders, furnished by the MRBWM office to project personnel at Oahe and Western, are the basis for scheduling average daily releases from Oahe. Since exact daily power demands cannot be anticipated, reservoir regulation/power production orders usually allow a specified variation from scheduled average daily release rate. Allowable variations in Oahe release rates from those specified in the order are frequently quite high since Oahe and the downstream Big Bend powerplants are often designated as the "swing" plants, designated to meet the fluctuations in actual system load from the anticipated when release schedules are established. Due to the limited fluctuations allowed in the level of the downstream Big Bend reservoir, releases scheduled from Oahe and Big Bend projects, as well as "swings" or variations in actual releases from scheduled releases, are normally very similar. Hourly patterning of the Oahe average daily release rate, within limits prescribed by the MRBWM office, is accomplished by Western's scheduling of daily power production.

7-12. Objectives of Flood Control Regulation. The flood control regulation objectives of Oahe are to: 1) coordinate regulation of Oahe with the regulation of the other System projects to prevent runoff from the drainage basin above Oahe from contributing damaging flows through the lower reaches of the Missouri River; and 2) utilize available storage space in the best possible manner to prevent or reduce flooding in the Missouri River reach from Oahe to Big Bend. The first objective given is the primary flood control objective for the mainstem System as a whole. As a consequence, it is discussed in Section 7-04 of the Master Manual. The concerns of this WCM are to amplify System regulation procedures as they apply particularly to Oahe and to discuss regulation pertaining to the reduction in flooding along the Missouri River immediately below Oahe.

7-13. Method of Flood Control Regulation. In general, the developed method of regulation of Oahe may be classified as Method C, as defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available storage space in Oahe during each flood event, with regulation procedures based on the control of floods of approximate project design magnitude.

7-14. Storage Space Available for Flood Control Regulation. During any specific flood event all available space in Oahe will be utilized to the maximum extent practicable for flood control purposes. The control of floods will be combined with regulation for other beneficial water uses. Storage space allocated for flood control in the Oahe reservoir totals 4.3 MAF. Of this total, 1.1 MAF is in the Exclusive Flood Control Zone, to be utilized only during unusually large flood season inflow periods. The remainder of the storage space is in the Annual Flood Control and Multiple Use Zone that will be filled seasonally to the extent required by the available water supply, and subsequently evacuated in the interest of flood control and other beneficial uses. Surcharge storage space has also been provided in Oahe to ensure the safety of the project during extreme floods. However, utilization of this storage will usually provide some downstream flood reductions during these extreme flood events. Storage space in the Carryover Multiple Use Zone, when evacuated, will also serve the flood control function although deliberate evacuation of this space to serve flood control will not be scheduled.

7-14.1. As discussed in the Master Manual, replacement System flood control storage space has been provided in certain upstream tributary reservoirs. There is reasonably firm assurance that in years of large runoff from the floods total drainage area above Oahe, including the drainage area above Fort Peck and Garrison, that the replacement storage in these tributary reservoirs will be utilized for the control of mainstem floods. Due to the relative ease of transferring between the mainstem projects, including Fort Peck-to-Garrison-to-Oahe, or vice versa, the availability of existing tributary replacement storage space allows regulation of the Oahe reservoir and other upstream mainstem reservoirs at higher levels than would be possible with a strict adherence to specified flood control storage allocations given in this WCM. Essentially, tributary replacement storage space is utilized to replace a corresponding amount of space in the Annual Flood Control and Multiple Use Zone within the mainstem System, including such space in Oahe.

7-14.2. Operations of some tributary reservoir projects constructed in recent years in the drainage area above Oahe without specific allocations of replacement System flood control storage space can also have an effect on the amount of storage in the Annual Flood Control and Multiple Use Zone evacuated from Oahe prior to any specific flood season. At times, these tributary reservoirs are drawn well below their deliberate fill level prior to the flood season. Efficient basin water resources management requires that the status of storage in all upstream tributary reservoirs be considered to the extent practicable, and to the extent that filling of tributary storage during the flood season is reasonably assured, in regulation of Oahe.

7-15. Flow Regulation Devices. Releases from Oahe may be made through the powerplant, outlet works and the spillway. Normally, releases through the powerplant will be used to extent possible in order to achieve the maximum economic return from the project. The discharge capacity of the Oahe powerplant is about 54,000 cfs. When it is necessary to release at rates greater than the powerplant is capable of maintaining, the outlet tunnels, which are capable of passing over 100,000 cfs, will be used. If releases larger than combined capacity of the powerplant and outlet tunnels are required, releases must be made through the spillway. Due to the probable erosion in the unlined spillway discharge channel resulting from spillway discharges, releases from the Oahe spillway should be scheduled only when considered absolutely necessary for regulation purposes. In addition, operation of spillway gates, if required, must be in accordance with schedules designed to reduce channel erosion. The spillway gate operating schedule is presented in Section 4-03 of this WCM.

7-16. General Plan of Flood Control Regulation. Flood control regulation of Oahe to meet the stated objectives is based on consideration of the following factors:

a. coordination of flood control regulation of Oahe with the regulation of the other System reservoirs and upstream tributary reservoirs as described in Chapter VII of the Master Manual;
b. channel capacity through the reach of the Missouri River immediately downstream from Oahe;
c. observed and anticipated flows of the tributary Bad River entering the Missouri River immediately downstream from Oahe.
d. observed and anticipated inflows to Oahe;
e. space currently available within Oahe for storage of future inflows; and
f. release requirements from Oahe for purposes other than flood control.

7-16.1. The general plan of regulation applicable to most of System reservoirs, including Oahe, is to have the flood control storage space evacuated prior to the beginning of the March-July flood season. Flood season inflows that are in excess of the current multiple-use requirements are deliberately stored in the Annual Flood Control and Multiple Use Zone of the System until such time there is reasonable assurance that adequate reserves are stored to satisfy multiple-use requirements to the beginning of the next flood season without drawdown into the Carryover Multiple Use Zone. This deliberate storage for future multiple use also serves the flood control function. Following the time that an adequate supply of multiple-use storage is reasonably assured, releases in excess of multiple-use requirements are made as a storage evacuation measure when they are not anticipated to contribute to significant downstream flooding.

7-17. Local Flood Control Constraints. The short reach of the Missouri River between Oahe and Big Bend contains the cities of Pierre and Fort Pierre, SD. The Bad River is the only significant tributary entering in this reach. High water problems in Fort Pierre are usually adjacent to the Bad River channel and associated with large flows on this tributary. The Corps' analysis has indicated that Oahe releases within the Oahe powerplant capacity have little effect on Bad River stages in the lower reaches of the tributary. Open water Missouri River stages at Pierre with releases at full powerplant capacity are below the flood stage of 13.0 feet and any significant damage level. However, high Bad River flows coinciding with large Oahe powerplant releases can also adversely affect developed low-lying regions in Fort Pierre. In general, there are no flood constraints in the area immediately downstream from Oahe that would inhibit Oahe releases up to full powerplant capacity, provided the downstream Big Bend reservoir was at or below its normal operating level of elevation 1420.0 feet and flows on the Bad River are not extraordinarily high. Backwater effects from a high level of the Big Bend reservoir, combined with large flood flows from the Bad River, could require some restrictions in Oahe powerplant releases. The major purpose of Oahe powerplant release reductions during periods of large Bad River flows would be to reduce backwater effects near the mouth of the Bad River or to assist Big Bend and other downstream projects in achieving optimum flood control regulation.

7-17.1. Oahe releases in excess of powerplant capacity could be expected to result in damages along the Pierre and Fort Pierre waterfronts, dependent on the level of releases sustained. Such releases have only occurred in 2011 when releases were made in response to overall basin-wide reservoir regulation requirements.

7-18. Regulation during Missouri River Ice Formation. Ice formation through the Missouri River reach directly below Oahe affecting project regulation occurs only in years with severely cold temperatures. During these especially cold periods, the leading edge of the stationary ice cover can progress upstream until it reaches the cities of Pierre and Fort Pierre. This progression of river ice causes the river stage to rise. During these situations, stages at key locations downstream of Oahe are closely monitored. If stages approach or exceed specified alert levels the Oahe powerplant operator and Western are notified and releases from Oahe are adjusted to keep flows from exceeding bankfull. Table VII-1 lists the ice-affected stage alert levels for key locations downstream of Oahe. Prior to the onset of extreme weather conditions that are conducive to rapid ice formation, a minimum release of approximately one unit (approximately 90 to 100 megawatts (MW)) is often implemented to reduce ice formation directly below the dam. Problems resulting from ice formation in the short reach of the Missouri River extending from Oahe downstream of Pierre and Fort Pierre have been experienced in the past and is covered in detail in Section 3-15 of this WCM. More information on winter ice conditions can be found in the CRREL report *Ice-Affected Flooding, Oahe Dam to Lake Sharpe, South Dakota*, dated March 2000.

Table VII-1
Ice-Affected Stage Alert Levels at Key Locations Downstream of Oahe

Corps ID	Location	RM (1960 mileage)	Datum (feet)	Powerplant Notification (feet)	Target Elevation (feet)	Critical Elevation (feet)
	Oahe Tailrace	1071.9		1428.0		
PIR	Missouri River at Pierre, SD	1066.5	1414.3	1426.0	1426.5	1427.5
LFSD	Missouri River at LaFramboise Island, SD	1064.8	1400.0		1426.0	1426.5
IWSD	Missouri River blw LaFramboise Island (Isaac Walton), SD	1062.8	1400.0	1424.0	1425.3	1425.5
FISD	Missouri River at Farm Island, SD	1059.8	1400.0		1424.2	1424.5

7-19. Coordinated System Flood Control Regulation. The System, of which Oahe is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River. Release scheduling from Oahe to accomplish this objective is based on studies performed by the MRBWM office. The long-range studies of current operations extend from the current date through the succeeding months up the subsequent March 1, when the start of the water control year generally occurs. All factors listed in Section 7-16 are considered to the extent possible in these studies. Such studies are made at a maximum interval of one month as new estimates of future inflows are developed. If conditions change materially from those anticipated in previous monthly studies, additional within-month studies are made. Details of flood control regulation procedures applicable to the System are described in Section 7-04 of the Master Manual.

7-20. Exclusive Flood Control Regulation Techniques. Oahe will usually be operated at an elevation of 1617.0 feet or less. Occasionally flood inflows will be of such magnitude that encroachment into the Exclusive Flood Control Zone, which extends from elevation 1617.0 to 1620.0 feet, will occur. Consequential actions will be dependent on existing or anticipated conditions in the other System reservoirs. If a portion of the Annual Flood Control and Multiple Use Zone is vacant in upstream Garrison and is expected to remain vacant, an obvious action is to reduce Garrison releases to the minimum consistent with all functions being served. If the Exclusive Flood Control Zone is being utilized in all reservoirs, action will be on the basis of the studies described in preceding sections, with System releases and the balance of exclusive storage scheduled in each reservoir of the System in accordance with procedures discussed in the Master Manual. Generally these procedures recognize the desirability of maintaining somewhat more vacant storage space in the lower reservoirs than in Fort Peck and Garrison, since this storage distribution provides more and better opportunities for controlling downstream floods at the major damage centers.

7-20.1. At times, encroachment into the Oahe Exclusive Flood Control Zone will occur or will be anticipated when ample annual flood control storage space remains vacant in the downstream Fort Randall project. Normally when this occurs Oahe releases will be maintained at full powerplant capacity in an effort to transfer the excess water downstream, while at the same time obtaining the maximum practical power revenue. Flood control storage space within the System projects downstream from Oahe is relatively limited. Therefore, Oahe releases at the maximum powerplant rate for an extended time must also be accompanied by above-normal release rates from the System. Unless unprecedented inflows occur from the drainage area between the Garrison and Oahe dams, Oahe releases in excess of the powerplant capacity of about 54,000 cfs will not be scheduled, except during a deliberate coordinated process of storage evacuation from the System as a whole. Significant encroachment into the Exclusive Flood Control Zone will require releases in excess of the powerplant capacity in order that a storage space reserve can be maintained for future flood inflows. The regulation curves shown on Plate VII-1 serve as a guide for Oahe regulation, with discharges limited to the combined capacity of the outlet works and power units as long as the level of the reservoir is at elevation 1620.0 feet or below.

7-20.2. As discussed above, these curves serve only as a guide for possible regulation, since they are based on typical recession hydrographs for the particular types of floods Oahe experiences. Final release selection could be greater or less than indicated by the curves and would be based on anticipated inflows, the effects of release through downstream reaches, and the anticipated maximum pool level of the Oahe reservoir as reflected in additional system regulation studies performed at that time.

7-21. Surcharge Regulation Techniques. During exceptionally large flood inflows, all available flood control storage space may be utilized and Oahe may rise into the Surcharge Zone above elevation 1620.0 feet. Since the primary reason for providing surcharge space is to ensure the safety of Oahe and also since real estate surrounding the reservoir has in general not been acquired above elevation 1620.0 feet, significant Surcharge Zone encroachment should be allowed only when necessary to prevent extensive downstream damage or if unprecedented flood inflows were to occur. When unprecedented flood inflows occur, the regulation curves given with the emergency instructions on Plate VII-1 can be used as a guide for release scheduling. Portions of these regulation curves relate reservoir level and inflow to suggested release, with the suggested release based on typical recession curves, by the method outlined in EM 1110-2-3600. Use of these curves should prevent significant surcharge space encroachment except during the most extreme floods. When the Oahe reservoir level is expected to rise into the Surcharge Zone a maximum release of up to the combined capacity of the powerplant and outlet works of approximately 170,000 cfs should be scheduled with the spillway gates opened only to the extent necessary to prevent overtopping of the gates and with the remainder of the flow through the powerplant and outlet works. If it appears the reservoir level will rise above 1625.0 feet, release of inflows up to the full spillway capacity should be scheduled to prevent any further significant elevation increase. Releases from the outlet works may be adjusted or the gates closed as needed to minimize downstream damages. Additional guidance regarding any operational restrictions and best practices for use of the spillway at Oahe can be found in Exhibit A of this WCM. These curves serve only as a guide for possible regulation. Final release selection could be greater or less than indicated by the curves and would be based on anticipated inflows, the effects of release through downstream reaches, and the anticipated maximum pool level of the Oahe reservoir as reflected in additional system regulation studies performed at that time.

7-22. Responsibility for Application of Flood Control Regulation Techniques. As described in Section 7-04.23 of the Master Manual, the MRBWM office is responsible for and directs all regulation, including flood control regulation, of Oahe and the other System projects. Instructions to ensure continuation of Oahe regulation during periods of communication failure between the project and the MRBWM office are presented in succeeding sections and in Exhibit B of this WCM.

7-23. Emergency Regulation. Reliable and rapid communication is usually available between the MRBWM office and Oahe personnel. When communications are interrupted for any extended period of time, project personnel will be required to continue regulation, as discussed in Section 5-07 of this WCM. Exhibit B of this WCM outlines the emergency procedures to be followed. In general, these procedures are such that they will continue service to multiple-use functions through the period of communications failure at the approximate level prevailing prior to the communications outage, if Oahe inflows continue in the range of those previously anticipated. The emergency procedures also allow for increased inflows, up to those occurring during maximum possible floods, as developed for spillway design purposes.

7-23.1. Emergency regulation curves, shown on Plate VII-1, were developed by the method described in EM 1110-2-3600. The rainfall and plains snowmelt curves assume a recession constant (time of peak) of 5 days, with this time period selected on the basis of recession curves of experienced incremental inflow hydrographs as well as the Oahe inflow studies. The developed emergency procedures recognize the large discharge capacity of the Oahe powerplant, the large amount of discharge channel erosion that would probably result from spillway releases, the great amount of surcharge storage space that has been provided in the reservoir and the channel capacity along the Missouri River below Oahe and below the System.

Oahe releases under emergency conditions are related to inflows, subject to the following:

a. releases in excess of full powerplant capacity will not be scheduled until the level of Oahe exceeds the base of Exclusive Flood Control Zone, elevation 1617.0 feet;
b. with the level of the reservoir in the Exclusive Flood Control Zone, elevation 1617.0 to 1620.0 feet, releases will be restricted to the capacity of powerplant plus outlet works, with no releases over the spillway;
c. the discharge capacity of the outlet works plus powerplant is about 170,000 cfs. With Oahe releases of this magnitude, resultant flood damages can be expected downstream, particularly along the Missouri River below the mainstem System. Therefore, with an Oahe elevation between 1620.0 and 1625.0 feet, releases at the 170,000 cfs rate are planned but may be adjusted as needed as part of overall System flood control operation. Some balance between damages experienced in the reservoir area and those occurring downstream should result. In this range spillway gates should be opened only to the extent necessary to prevent overtopping, with the remainder of the flow through the powerplant and outlet works;
d. as the Oahe reservoir level exceeds elevation 1625.0 feet, it will be necessary to fully open the spillway gates and increase outflows to ensure safety of the structure and also to prevent, insofar as practicable, overtopping of protective works constructed in the reservoir area. Developed procedures specify the full opening of spillway gates

together with full powerplant releases. Releases from the outlet works may be adjusted or the gates closed as needed to minimize downstream damages.

7-24. Maximum Possible Early Spring Flood. As discussed in a previous section, regulation curves are shown on Plate VII-1 and were included with the emergency procedures in Exhibit B of this WCM. One example of using this set of curves as the only criteria for regulation of the Oahe reservoir is shown on Plate VII-2. The flood examined is the maximum possible early spring plains snowmelt flood, which was developed for spillway design purposes, with a peak inflow of nearly 1,000,000 cfs. An initial level of the Oahe reservoir at elevation 1610.0 feet was considered to be reasonable for this season of the year. Peak reservoir level and peak release are 1640.3 feet and 308,000 cfs, respectively. Of this peak release, about 260,000 cfs was through the spillway with the remainder through the powerplant, which was assumed to be operable through the flood period. These peak values are very close to those developed in the DPR at the time Oahe was designed in the mid-1940s. In the original design, the computed peak reservoir elevation was 1644.4 feet and the peak release was 304,000 cfs. The DPR studies did not assume the powerplant would be available for making releases during the SDF.

7-25. Maximum Possible Late Spring Flood. Use of the emergency regulation procedures given in Exhibit B during the maximum possible late spring flood, as developed for spillway design purposes, is illustrated on Plate VII-3. An initial Oahe reservoir level at elevation 1614.0 feet was considered reasonable. The peak inflow of about 1,250,000 cfs resulted in a peak release of 335,000 cfs of which about 285,000 cfs was through the spillway and the remainder through the powerplant, which was assumed to be operable through the flood period. A peak Oahe reservoir elevation of 1643.0 feet was coincident with the peak release.

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VIII - Water Management Organization

8-01. Responsibilities and Organization. This chapter describes the personnel and coordination necessary to regulate Oahe. Oahe is regulated as part of the System, which is comprised of six projects on the main stem of the Missouri River. The Corps has the long- and short-term direct responsibility for regulating Oahe as a hydraulically and electrically integrated project. This has been the case since August 1958, when Oahe was closed to begin storing water.

8-01.1. The NWD's MRBWM Division of the Programs Directorate, located in Omaha, NE, is comprised of a 12-person staff of engineers, biologists, information management specialists and support staff. The MRBWM office is comprised of two teams: Reservoir Regulation and Power Production. The Corps' Guidance Memorandum titled, *Reservoir Control Center*, dated March 1972, serves as the document that details the role and responsibilities of the MRBWM office in managing and regulating the System. The RCC, now known as MRBWM, was founded in 1954 and was the first RCC established in the Corps. The organization chart for the MRBWM office is provided on Plate VIII-1.

8-01.1.1. The Corps started construction of Oahe in 1948. Oahe is one of the six System projects that were constructed during the period from 1933 to 1966. The Corps is the sole owner and regulator of the six dams that comprise the System. The Chief of Engineers for the Corps has delegated the regulation of this System to the NWD Commander, who has in turn delegated the day-to-day regulation of the System to the MRBWM office. The MRBWM office has the direct responsibility of regulating the System and issuing reservoir regulation/power production orders to accomplish this mission. The O&M of the System dams and associated structures are the responsibility of the Omaha District of NWD. The Omaha District has staff physically located at the System projects to make the actual regulation changes stated on the reservoir regulation/power production orders developed and sent by the MRBWM office. The System is the largest reservoir system in the United States based on storage capacity. The MRBWM office prepares long- and short-term runoff and streamflow forecasts that are integrated into model simulations to effectively regulate the System, as described in Chapter VI of this WCM. Refer to Exhibit B of this WCM for instructions to the Oahe operations manager in case of loss of communication for an extended period of time during a significant or catastrophic event. The MRBWM staff maintains communication with Corps staff at the System projects via cell phones and computers that are available from work, their homes, and while they are on travel status. Maintaining these communication devices ensures that staff can be reached at any hour of any day of the year. Also, there is at least one staff person that physically reports to the MRBWM office, for at least part of each day. Detailed calling lists are provided to the System projects and Omaha District Emergency Operations staff in case there is a need to contact MRBWM staff during off-duty hours.

8-01.1.2. The two teams within the MRBWM office have the responsibility for regulating the System. The Reservoir Regulation Team in MRBWM has the responsibility of running the daily Missouri River streamflow forecast to determine releases (often called the System release) from the lowermost System dam (Gavins Point). This team forecasts runoff volumes for long-range monthly model simulations, and for some short-range simulations. The Reservoir Regulation Team reviews the deviation requests from the Omaha and Kansas City Districts for Corps tributary reservoirs and USBR tributary reservoirs that have Corps-regulated flood control zones. The Reservoir Regulation Team also coordinates tributary reservoir releases during significant basin-wide flood regulation to provide System flood control for the Missouri River basin. The Power Production Team has the responsibility of intrasystem regulation and forecasts runoff volumes for short-range model simulations. This team has the responsibility of T&E species coordination relating to System regulation. Intrasystem regulation oversight by this team is conducted to respond to widely varying Missouri River basin runoff to meet the operational objectives stated in the Master Manual. It also performs all hydropower-related activities.

8-01.1.3. A third team, the Missouri River Master Manual Team, was formed in 1989 to oversee the studies and documentation required for the review and update of the 2004/2006 Master Manual. This team also provided program management and oversight of the non-flow related actions for the Missouri River and tributaries necessary to comply with the ESA. This team also had the responsibility to ensure that the overall adaptive management process for both the flow and non-flow ESA-related actions was established and proceeded in an effective and efficient manner. A reorganization of the MRBWM dissolved this team in 2008 with functions transferred to the Power Production Team, the Omaha District and the Programs Directorate at NWD.

8-01.1.4. Adaptive Management. The Corps has implemented some System regulation changes via an adaptive management process for many years. The Corps, in implementing the current water control plan described in the Master Manual, will continue the use of the adaptive management process. The Corps recognizes that changes in the operation of the System may impact many river uses and is committed to ensuring that the public is actively involved and well informed of potential changes in System regulation and has the opportunity to comment on those proposed changes prior to any decision on implementation. The adaptive management process will be used to implement changes designed to improve the benefits provided by the System, including benefits to the T&E species. Decisions regarding actions proposed through the adaptive management process will meet the Corps' treaty and trust responsibilities to the Tribes and conform to all of the applicable requirements of federal laws including the National Environmental Policy Act (NEPA), ESA and the Flood Control Act of 1944. Additional details regarding adaptive management are presented in Section 7-10 of the Master Manual.

8-02. System Coordination. The MRBWM office strives to keep those interested in the short- and long-term regulation of the System informed as to the amount of water stored in the System, the outlook for future runoff, and the short- and long-term plans for System water management. As the largest storage reservoir system in the United States with the potential for a wide array of positive and negative impacts, the regulation of this System generates a high level of interest within and outside of the basin. The AOP process, developed by the MRBWM office, provides an important tool for the Corps to interact with, inform and coordinate with the public on a semi-annual basis. Other interests have a need to keep informed of changes and project status of the

System on an almost continual basis. Successful regulation of the System to meet the regulation objectives stated in the Master Manual is dependent on a group of well-informed stakeholders and partners providing dialog on the effects of actual and proposed System regulation. The following sections detail how this coordination is accomplished.

8-02.1. News Releases. The MRBWM office provides monthly and other special news releases concerning the regulation of the System. The NWD Public Affairs Office is responsible for issuing the official MRBWM news releases.

8-02.2. MRBWM Website. The MRBWM office maintains a public website at the following address: www.nwd-mr.usace.army.mil/rcc. This site contains information concerning System regulation. It includes forecasted reservoir levels and dam releases as well as historic data in both tabular and graphic formats. The website contains user-friendly, clickable maps to observe graphical streamflow and System project data. While the NWS has the responsibility for issuing streamflow forecasts, the MRBWM office performs streamflow forecasting at select locations needed to regulate the System. These results are provided for information only. The NWS forecasts are available as a link from the MRBWM website. The website contains both normal monthly new releases and special news releases concerning other significant items that occur on an unscheduled basis. In addition, the Corps produces numerous reports on a daily basis that provide updates of the System's status and regulation changes.

8-02.3. AOP Public Meetings. The Corps follows a public process as part of the AOP preparation and implementation process for regulating the System. This process involves the development and publishing of a draft AOP in the fall of each year. The draft AOP simulates the regulation of the System for five runoff scenarios for the remainder of the current year, plus the following calendar year. The draft AOP is generally provided to all interested stakeholders in late September via hardcopy or the MRBWM website. Public meetings are held at three to six sites within the basin, normally in October, to accept verbal comments from the public and provide a forum for discussion on the draft AOP. Written comments on the draft AOP are also accepted generally through mid-November. After considering the comments from the public meetings and any written comments provided during the comment period, appropriate changes are made to the draft AOP to produce a final AOP, which is normally made available in December. In the spring, the Corps again conducts public meetings to provide information on the current hydrologic conditions in the basin and the expected results of System regulation for the remainder of the year given the most-likely forecast and other possible runoff scenarios. Once again, comments are obtained for fine-tuning the System regulation for the spring and summer. Actual real-time regulation of the System is accomplished using the best information and tools available and is adjusted to respond to changing conditions on the ground. The process begins again in August for the next AOP. It should be stated that not all circumstances are covered in the AOP. Actual real-time regulation plans may indicate runoff volumes, reservoir levels and releases outside those described in the AOP. Flexibility in these situations allows the Corps to regulate the System for maximum benefit in an area of the continent where extreme climatic conditions can and frequently do occur.

8-02.4. National Weather Service Coordination. The NWS is the official federal agency responsible for issuing streamflow forecasts to the public. The Corps considers these forecasts in its regulation of the System. The NWS office interface for the MRBWM office is the NWS

MBRFC, located in Pleasant Hill, MO. The MBRFC has the forecasting responsibility for the entire Missouri River basin. The Corps and NWS share real-time data, USGS measurements and flood information, and forecasts for streamflow and runoff. The MRBWM office provides the MBRFC with System regulation data on a daily basis. The MBRFC integrates the Corps' forecasted System project releases with its short- and long-range streamflow forecasts for the Missouri River. The normal method of data and file exchange is through email and other file exchange methods or by direct telephone contact, when required. The Corps receives MBRFC forecasts and QPE rainfall radar imagery, as described in Section 5-03 of this WCM for integration into the MRBWM real-time forecasting models. During years of significant plains snowmelt, additional coordination between the Corps and MBRFC is necessary to ensure proper data exchange between the two agencies for the forecasting of plains snowmelt. In addition, whenever the Corps conducts special reconnaissance surveys of ice conditions on the Missouri River, the obtained information is readily shared with the MBRFC.

8-02.5. U.S. Geological Survey Coordination. The USGS is the primary source of data and hydrologic support to the Corps. The USGS obtains streamflow measurement data that it supplies to the MRBWM office in a real-time mode. This prompt delivery of data allows the MRBWM office to meet its mission of managing the basin's water resources. This effort is conducted through a cooperative stream-gaging program (Co-op), as described in Section 5-07.2 of the Master Manual. This Co-op program covers the 1) maintenance of DCP stations, 2) measurement of streamflow at select locations, and 3) sediment and water quality sampling at select locations. The MRBWM office has review responsibility for this program but has delegated the implementation of the program to the Corps' Omaha and Kansas City District Water Management staffs. The Districts negotiate separate programs with each state and manage these programs throughout the year.

8-02.6. Western Area Power Administration Coordination. Reservoir regulation/power production orders, reflecting the daily and hourly hydropower limits imposed on project regulation are generated by the MRBWM office and are sent to the mainstem projects on a daily basis. This information is also shared with Western via a daily phone call. Long-term (monthly) and short-term (weekly) regulation forecasts of energy generation and capability are coordinated with Western. These forecasts serve an important role in determining when surplus energy is available during high-water years, otherwise referred to as surplus sales, and when firm energy commitments cannot be met during low-water years, otherwise referred to as energy purchases. These "short-term" forecasts are also used to reflect unanticipated adjustments in project releases such as flood control regulation that can dramatically alter energy generation schedules. Scheduled and forced outages of the generating units are closely coordinated with Western. Coordination with Western is required during the planning and execution of major rehabilitation of the System powerplants.

8-02.7. U.S. Fish and Wildlife Service Coordination. The USFWS is the primary federal agency in charge of administering the ESA as it relates to protected species in the Missouri River basin. The MRBWM and the USFWS coordinate extensively on regulation of the System during the T&E nesting season and on other issues relating to the implementation of the USFWS's 2018 Final Biological Opinion on the *Operation of the Missouri River Mainstem Reservoir System, the Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, the Operation of the Kansas River Reservoir System, and the Implementation of the Missouri*

River Recovery Management Plan, dated April 13, 2018. Additional interagency coordination will continue and expand as the adaptive management process evolves.

8-03. Interagency Agreements. No permanent interagency agreements are in effect with regard to the regulation of the System. A considerable amount of coordination has been conducted between the MRBWM office and the federal agencies that have missions that are affected by the System. In 2003, the MRBWM office participated in a Memorandum of Understanding with the Southwestern Power Administration (Southwestern) with regard to hydropower generation on the Corps' tributary projects in the Kansas City District.

8-03.1. Replacement Storage. The MRBWM office has an existing agreement with the Great Plains Region of the USBR for the use of replacement System flood control storage. The agreement concerns the USBR Clark Canyon, Canyon Ferry, and Tiber projects. These three USBR tributary projects contain authorized Flood Control Storage Zones that are regulated by the Omaha District when water is stored in this zone. The flood control storage space provided in the System was developed on the basis that no upstream storage space existed although it was recognized that, as upstream space became operational, a re-evaluation of the mainstem System space requirements would be necessary. Continuing analysis of inflows into the mainstem System and into tributary reservoirs constructed upstream from the System has indicated that in certain instances, particularly when inflows are distinctly seasonal in nature, storage space provided in upstream reservoirs could effectively replace a portion of the Annual Flood Control and Multiple Use Zone initially provided in the mainstem System. Effective operations require a coordinated regulation of the upstream tributary storage space with the space in the mainstem System, which results in the most efficient overall utilization of the basin water resources. Such space provided in upstream reservoirs has been designated as "replacement System flood control storage space."

8-04. Commissions, River Authorities, Compacts and Committees. Refer to Section 8-04 of the Master Manual for a detailed history of the various commissions, river authorities, compacts and committees in the Missouri River basin. The Missouri River Recovery and Implementation Committee (MRRIC), the Missouri River Basin Interagency Roundtable (MRBIR), and the Missouri River Natural Resources Committee (MRNRC) are three such groups discussed in the following sections.

8-04.1. Missouri River Recovery Implementation Committee. This group is a 70-member committee made up of federal, state, Tribal, and stakeholder representatives from throughout the Missouri River basin. MRRIC serves as a collaborative forum developing a shared vision and comprehensive plan for the restoration of the Missouri River ecosystem. The committee provides guidance and recommendations to the Corps and USFWS on the current Missouri River Recovery Program for the river's T&E species and on the Missouri River Ecosystem Restoration Plan (currently not funded). MRRIC was established by Section 5018 of the Water Resources Development Act of 2007 under the authority of the Secretary of the Army.

8-04.2. Missouri River Basin Interagency Roundtable. This group was re-activated in 2001 to promote interagency cooperation among the federal agencies within the Missouri River basin. The mission is to foster effective communication and coordination among federal agencies, and, when possible and where appropriate, to communicate to other basin interests with a single federal voice. The cooperating agencies include, but are not limited to the Corps, National Park Service, USGS, USFWS, USBR, BIA, Environmental Protection Agency (EPA), Western, U.S. Forest Service and the U.S. Department of Agriculture's Natural Resources Conservation Service. Members are composed of executives of federal agencies with activities in the basin.

8-04.3. Missouri River Natural Resources Committee. The MRNRC is a non-profit corporation formed in 1988 by the Missouri River basin states to promote and facilitate the preservation, conservation and enhancement of the natural resources of the Missouri River. Its official members are the fish and wildlife conservation agencies of the states of Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas and Missouri. The MRNRC's ex-officio members are the Corps, the USFWS and Western.

8-05. Non-Federal Hydropower. All hydropower facilities located either at or in association with the System are federally owned and operated. This includes all hydropower facilities at Oahe. No non-federal hydropower facilities are currently located either at the System projects or on System project lands.

8-06. Reports. The MRBWM office prepares several reports to serve as summaries of activities and to communicate to others the current status and proposed regulation of the System. Most reports are available on the MRBWM website: www.nwd-mr.usace.army.mil/rcc. This website is used for public dissemination of water resource information related to regulation of the System. In addition to the reports shown in Table VIII-1, the MRBWM office prepares technical reports and flood reports on an as-required basis to provide information and additional guidance in regulation of the System.

Table VIII-1
Missouri River Basin Water Management Reports

Frequency	Type of Report	Reporting Requirement[1]
Hourly	15-day plots of hourly data of stream and reservoirs with DCP transmissions in basin.	
Daily	Daily Bulletin	
	Weekly Bulletin	
	Monthly Bulletin	
	Yearly Bulletin	
	Reservoir Summary Bulletins	
	Flood Report (as needed)	
	Power Production Orders	
	Missouri River Streamflow Forecast – 14 days	
	Ice Report (Seasonal Dec-Apr)	
	Mainstem Release and Energy Schedule	
Weekly	Reach Runoff Report	
	Three-Week Model Simulation	
	Weekly Mountain Snowpack Report	
Monthly	Basin Calendar – Year Runoff	
	Monthly Mountain Snow Report (Seasonal)	
	Runoff Outlook	ER Requirement
	Long-Range Monthly Model Simulation	
	Project Monthly Summary (MRD 0168)	ER Requirement
	Monthly Press Release	
	Monthly Project and System Energy Summary	
Yearly	Draft Annual Operating Plan (AOP)	
	Final Annual Operating Plan (AOP)	
	Annual Summary of Actual Operations	
	Division Annual Report	ER Requirement, includes District Reservoirs
	Flood Damages Prevented Report	ER Requirement – MRBWM office provides holdouts[2] and districts provide estimated damages prevented
	Stage Trends Report	
	Annual Sediment Report	
	Annual Water Quality Report	ER Requirement
	Cooperative Stream Gage Program (Co-op)	ER Requirement

[1] Report required per Corps Engineering Regulation (ER).
[2] Unregulated flows.

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Appendix A - Historic Droughts and Floods with Regulation Examples

A-01. Floods. Regulation provided by Oahe along with other upstream System projects and augmented by upstream tributary reservoir projects, has greatly reduced flooding along the portion of the Missouri River in the vicinity of Oahe. Many instances of above-bankfull flows were experienced through this reach prior to construction of the System. All floods recorded in this portion of the Missouri River prior to System regulation occurred in the March-July period. The Master Manual contains relatively detailed descriptions of several of the experienced Missouri River floods, including data that is pertinent to the incremental reach described in this WCM. Since there is little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed further in this WCM.

A-02. Flood of 1950. Monthly runoff originating in the Garrison to Oahe reach during April 1950 amounted to 3.8 MAF, which was the second largest monthly runoff from this incremental area during the 117 years (1898-2014) of available record. Snowfall had progressively accumulated over this incremental drainage area through the preceding winter season, which was characterized as being much colder than normal with well-above-normal precipitation. Runoff from tributary areas in South Dakota began during late March; however, maximum snowmelt occurred near mid-April. Peak inflow to the Missouri River from the total incremental area approximated 190,000 cfs. Table A-1 lists peak discharges for major tributary streams between Garrison and Oahe and were taken from USGS streamflow gages, unless noted otherwise. Peak discharges for ungaged tributaries were estimated near the mouth.

Table A-1
Tributary Peak Discharges – Flood of 1950

Tributary	Peak Discharge (cfs)	Date of Peak
Knife River at Hazen, ND	22,700	April 17
Heart River near Mandan, ND	30,500	April 19
Cannonball River at Breien, ND	94,800	April 19
Grand River near the mouth[1]	82,800	April 18
Moreau River near the mouth[1]	20,900	April 19
Cheyenne River near the mouth[1]	14,500	April 18
Bad River near Fort Pierre, SD	16,700	April 2

[1]Ungaged. Peak discharge estimated.

A-03. Flood of 1952. The maximum monthly runoff in the Garrison to Oahe reach of 3.95 MAF during the 1898-2014 period occurred in April 1952. This runoff resulted from a wet fall during 1951, well-above-normal precipitation, largely in the form of snow during the entire 1951-1952 winter season, formation of a significant ice layer over frozen ground during the early winter, and normal temperatures throughout most of the winter season, which resulted in a progressive accumulation of snow over a large portion of the incremental drainage area. Warm temperatures in late March and early April resulted in a rapid melting of the deep accumulated snowpack, contributing to extremely large tributary flows. Analysis indicates that total flows from the Garrison to Oahe incremental drainage area peaked at 285,000 cfs; however, peak flows along the Missouri River were augmented by severe Missouri River ice jams. As discussed in the

Master Manual, studies conducted by the MRBWM office indicate that the System would have controlled inflows to prevent downstream damages with a reserve of vacant space in the Exclusive Flood Control Zone throughout the flood. Table A-2 lists peak discharges for major tributary streams between Garrison and Oahe and were taken from USGS streamflow gages, unless noted otherwise. Peak discharges for ungaged tributaries were estimated near the mouth.

Table A-2
Tributary Peak Discharges – Flood of 1952

Tributary	Peak Discharge (cfs)	Date of Peak
Knife River at Hazen, ND	20,200	April 7
Heart River near Mandan, ND	30,000	April 4
Cannonball River at Breien, ND	21,300	April 7
Grand River near the mouth[1]	17,900	April 2
Moreau River near the mouth[1]	36,900	April 5
Cheyenne River near Plainview, SD	41,400	March 30
Bad River near Fort Pierre, SD	28,100	April 7

[1] Ungaged. Peak discharge estimated.

A-04. Flood of 1997. Flood season (March-July) runoff from the drainage controlled by the Missouri River System (above Gavins Point) during 1997 was 31.2 MAF. This 5-month runoff volume above Gavins Point is exceeded only by the 2011 record 5-month total of 40.9 MAF (1898-2014). The annual runoff in the upper basin (above Sioux City, IA) was 49.0 MAF, which was almost double the average annual runoff volume above Sioux City, and until 2011, was the highest annual runoff on record. The high runoff was the result of an unprecedented heavy plains snowpack concurrent with a near-record mountain snowpack. The melt sequence was more rapid than normal due to much-above-normal temperatures during the melt period, sometimes in the 80°F range, which significantly increased the total volume of runoff. Mountain snowpack for both January and February above Fort Peck (181 and 155 percent, respectively) and Garrison (169 and 159 percent, respectively) were significantly above average. In addition, plains snowpack depths ranged from 6 inches in eastern Montana to as much as 36 inches in eastern North Dakota and eastern South Dakota. The 1997 runoff volume above Sioux City during March and April of 7.2 MAF and 8.6 MAF, respectively, nearly mirrored the previous maximum of 15 MAF that occurred in 1952 before the System was constructed. Runoff in 1997 was primarily the result of mountain and plains snowmelt. Fortunately, heavy spring and summer rains did not materialize across the lower basin during the month of May. Dry conditions also continued to deepen in North Dakota and eastern Montana with less than half the normal May precipitation. During the summer, dryness continued to dominate in eastern Montana and western North Dakota and the lower basin experienced normal to slightly-below-normal June rainfall. During July, the lack of intense thunderstorms in the lower basin eased the adverse impacts of evacuating the flood waters stored in the System reservoirs.

A-05. Flood of 2010. Total runoff in the upper basin during 2010 was 38.7 MAF, the fourth highest on record (1898-2014). Plains snowfall began in the fall of 2009, and continued to accumulate in the plains as above-average snowfall and colder-than-normal temperatures persisted into March. By the beginning of the plains snowmelt, many areas in the basin had accumulated 4 to 6 inches of SWE from western North Dakota through much of South Dakota to northwest Iowa, and 3 to 4 inches in surrounding regions of Montana, Nebraska and southwest Iowa. In general, the precipitation during the 2010 calendar year was above average in the entire Missouri River basin. Areas of the basin received well-above-average precipitation in all periods; however, much greater-than-normal precipitation occurred in April through August.

A-06. Flood of 2011. The 2011 runoff year was the highest runoff year for the period of record (1898-2014), resulting in a total annual runoff of 61.0 MAF, almost 2.5 times average. It also marked the fourth consecutive year of above-average runoff in the upper basin, immediately following the 2000-2007 drought. May (9.2 MAF), June (14.8 MAF) and July (10.2 MAF) had the highest inflows for their respective months in the 117-year period of record (1898-2014). The 34.2 MAF of runoff received during that 3-month period exceeded the total annual runoff in 102 of the previous 113 years (1898-2010). The winter of 2010-2011 marked the third consecutive year of significant plains snowpack, and mountain snowpack was much above average. During May, heavy rains fell across eastern Montana, western South Dakota and northern Wyoming. In some isolated areas, 10-15 inches of rain fell over a 3-day period. Because this runoff came in the form of rainfall runoff rather than snowmelt runoff, the volume of runoff over this very large area quickly made its way to the Fort Peck and Garrison reservoirs and dictated a need to increase releases from all six reservoirs to record levels. System storage peaked at 72.8 MAF on July 1, occupying 98 percent of the allocated flood control storage space (16.0 MAF of 16.3 MAF).

A-07. Droughts. As outlined in Section 7-15 of the Master Manual, regulation of the System during drought was a significant consideration in the update of the 2004/2006 Master Manual. The System is the largest reservoir system in the United States serving all authorized purposes during an extended drought like the 1930s, which was part of the original objectives of the System. As outlined in Section 7-03.2.1.1 of the Master Manual, the System water-in-storage checks, which occur on March 15, July 1 and September 1 of each year, allow the System to function to meet authorized purposes during significant multi-year drought periods. Refer to Tables VII-2, VII-3 and VII-5 in the Master Manual for the relation of System storage to service level, navigation season length and winter releases, respectively. With the original design consideration of the System and with the implementation of the aforementioned water-in-storage checks, no separate drought contingency plan is needed or required for the System.

A-07.1. Two multi-year droughts have occurred in the upper Missouri River basin since the System was first filled in 1967. The first drought lasted from 1987 to 1992 with the Oahe pool level dropping to a low of 1580.7 feet in November 1989. The second drought occurred from 2000 to 2007 with the Oahe pool hitting a period of record low (1967-2016) of 1570.2 feet in August 2006; 37.3 feet below the top of the Carryover Multiple Use Zone. During this drought the System storage set a new record low of 33.9 MAF in February 2007, 6.9 MAF below the record of 40.8 MAF set in the previous drought in January 1991. See Section A-07 (Appendix A) of the Master Manual for additional information regarding Missouri River basin droughts and regulation of the mainstem projects during droughts.

A-08. Historical Regulation and Effects. Closure of Oahe Dam occurred in August 1958 beginning the accumulation of storage in the reservoir. The initial fill of Oahe was accomplished during 1967. The base of the Exclusive Flood Control Zone, elevation 1617.0 feet, has been exceeded several times since the System filled in 1967 including 1975, 1984, 1986, 1995, 1996, 1997, 1999, 2010, 2011 and 2018. Extreme low elevations, below elevation 1590.0 feet, occurred from 1988 to 1992 during the first major drought since the System first filled, and from 2002 to 2008 during the second major drought. The historical effects of regulation provided by Oahe, combined with effects of regulation of upstream and downstream reservoir projects, are illustrated on Plates A-1 through A-6 for the 1958-2014 period. Average daily unregulated flows shown on these plates are the computed estimates of flow at the Oahe damsite if none of the System projects, including Oahe, had been in operation. Regulation of the mainstem and tributary projects has resulted in substantial reductions to all annual peak flows that would have been experienced at the Oahe damsite. In addition, water stored in the conservation pools in Oahe, along with Fort Peck and Garrison, has made it possible to maintain adequate downstream Missouri River flows to support the authorized purposes of navigation, irrigation, recreation, water supply, hydropower generation, water quality control and fish and wildlife, including T&E species, during drought periods. Sections A-9 through A-25 discuss Oahe regulation during significant flooding and drought periods.

A-09. 1961 Regulation. During 1961, runoff above Sioux City totaled 12.4 MAF, the fifth lowest on record. Runoff originating from the Oahe reach totaled 374,000 AF and was the third lowest on record (1898-2014). Additionally, during 1961 the total storage within the System was at extremely low levels. The Oahe releases (regulated flows) shown on Plate A-7 are illustrative of the general release level from this project that would occur during periods of lower-than-average upper basin runoff. However, since the Oahe powerplant was not functioning in 1961, the daily fluctuations in release rate that would now occur are not apparent on Plate A-7. Comparison of regulated and unregulated flows indicates the supplementation of flows during low water periods resulting from operation of upstream reservoirs. Development of water resources in the basin above Oahe has continued since 1961 and, if 1961 hydrologic conditions should be repeated, the supplementation would be more marked. While similar regulated flows could be expected, the increased depletion occasioned by further water resource development would have the effect of resulting in an extended period of negative unregulated flows, indicating that the current resource development is served only by withdrawal from storage.

A-10. 1967 Regulation. The runoff between Garrison and Oahe during the June-July period was 1.2 MAF, 185 percent of average. Combined with this runoff into Oahe were severe flood flows originating below Oahe and in the Missouri River drainage areas below the System. Damages prevented by the regulation of Oahe and the other System projects during this flood period were about $2.1 billion (indexed to 2015). As illustrated on Plate A-8, average daily releases from Oahe during the flood period were generally less than 25,000 cfs. Unregulated flows would have been as high as 175,000 cfs during the two-week period. The Oahe reservoir level rose 20 feet in 1967 and reached the base of the Annual Flood Control and Multiple Use Zone for the first time since the start of the initial fill in 1958 (see Plate A-8).

A-11. 1972 Regulation. Missouri River basin runoff above Oahe during 1972 was 26.9 MAF, more than 6.5 MAF greater than the long-term average (1898-2014). March runoff into Oahe was exceptionally large with an unregulated peak flow of 232,000 cfs (see Plate A-9). At that time, it was the largest unregulated peak at this location since regulation of the reservoir began in 1958. Oahe releases through the year were well within the powerplant capacity. The level of the Oahe reservoir throughout the year remained within the normal operating range. A slightly larger-than-normal drawdown prior to and following 1972 was scheduled to investigate the relationship between the maximum level of the Oahe reservoir and the minor embankment movement that had been observed.

A-12. 1975 Regulation. Flood season (March-July) runoff originating in the Missouri River basin above Oahe during 1975 was 24.6 MAF, 168 percent of average, the highest 5-month runoff since 1952. While the unregulated flow peak of 172,000 cfs at Oahe was relatively small in relation to the flood season volume, the unusual aspect was the sustained large unregulated flows extending from late April through July, as illustrated on Plate A-10. Also unusual was that most of the well-above-normal precipitation contributing to the record-high runoff occurred after early April and extended through July. Oahe releases during the early portions of the year were continued at near-normal levels because downstream constraints prohibited significant release increases during May and June. It was not until July that downstream conditions allowed for Oahe releases to be increased to full powerplant capacity. With full powerplant releases, stages on the lower Missouri River below the System (below Gavins Point) were maintained very close to flood stage, leaving very little room to accommodate downstream incremental flood inflows, should they have occurred.

A-12.1. As illustrated on Plate A-10, a rising Oahe reservoir level occurred from mid-January through most of August, with a maximum elevation of 1617.9 feet. This was the first time that space in the Exclusive Flood Control Zone had been occupied in Oahe. Use of this space was necessary to re-regulate Garrison releases that were about 10,000 cfs greater than those from Oahe during the July-August period. Further information describing the 1975 flood and accompanying System regulation is given in the Master Manual and in the special MRD-RCC Summary Report, *Regulation of the Missouri River Main Stem Reservoir System to Control the 1975 Inflows*.

A-13. 1977 Regulation. As shown on Plate A-11, runoff above Oahe during 1977 was one of the lowest of record since 1898. The runoff originating from the total Missouri River drainage area above Oahe during 1977 totaled approximately 11.6 MAF, the lowest recorded at that time since the System had been regulated (1967-1977). Inflows were below normal throughout the summer and fall. Releases were maintained in the 30,000 cfs range to meet navigation and downstream purposes. The reservoir level dropped from an annual peak of 1608.2 feet at the end of March to 1594.5 feet by the end of November.

A-14. 1978 Regulation. Runoff above Oahe during 1978 totaled 33.3 MAF, the third highest on record during the 1898-2014 period. As shown on Plate A-12, the unregulated inflow into Oahe peaked at 254,000 cfs in early April, the highest on record since the System has been in operation. The Oahe reservoir level increased from elevation 1600.0 feet at the end of February to 1616.2 feet in July. Releases from Oahe fluctuated widely from hour-to-hour and day-to-day to meet varying power loads and to back up System releases. Oahe releases of at least 3,000 cfs were maintained during weekend daylight hours to enhance downstream fishing and recreational use during the recreation season. Oahe releases reached a maximum of 54,300 cfs in September. Further information describing the 1978 flood and accompanying System regulation is presented in the Master Manual and in the special MRD-RCC Summary Report, *Regulation of the Missouri River Main Stem Reservoir System to Control the 1978 Flood.*

A-15. 1984 Regulation. Runoff above Oahe during 1984 was 19.8 MAF, 97 percent of average (1989-2014). Due to low System releases in April through June, the Oahe reservoir level rose steadily throughout the spring and early summer and peaked at 1618.3 feet at the end of June, 1.3 feet into the 3-foot Exclusive Flood Control Zone (see Plate A-13). This elevation marked a record peak elevation, exceeding the previous record high set in 1975 by 0.4 foot.

A-16. 1986 Regulation. Runoff above Oahe during 1986 was 29.5 MAF, 127 percent of average. Heavy precipitation during April resulted in near-record runoff volumes in many Missouri River tributaries in western South Dakota. These large runoff volumes resulted in significant gains in storage in both Oahe and Fort Randall. Oahe set a new record high pool level of 1618.5 feet in May 1986. As shown on Plate A-14, storage gains tapered off during June, but heavy rains over portions of Montana and North Dakota resulted in continued high inflows. The pool level was maintained near the base of the Exclusive Flood Control Zone for the entire month of June and into early July. At the beginning of April, the Oahe pool was near elevation 1612.0 feet, 4.5 feet above the base of Annual Flood Control and Multiple Use Zone. It reached a record elevation of 1618.5 feet on May 16, 0.2 foot higher than the previous record set in 1984.

A-17. 1988 Regulation. 1988 was in the second year of the 6-year drought (1987-1992), the first extended drought since the System filled in 1967. The runoff upstream from Oahe for 1988 was 8.2 MAF, the lowest annual runoff since 1898. Runoff in 1988 was 40 percent of average due primarily to low mountain snowpack and below-normal rainfall runoff in the upper basin. System storage normally peaks in early July. In 1988, much-below-normal runoff along with high downstream water supply demands resulted in the System storage declining throughout the entire year. The peak annual System storage of 56.2 MAF was recorded on January 1 and set records for the earliest peak date as well as lowest System storage peak since the System reached normal operating levels in 1967. The year's lowest System storage of 45.7 MAF was recorded on December 31. The annual runoff for the Garrison to Oahe reach was 290,000 AF, only 12 percent of average. This was the second lowest runoff for this reach during the period 1898-2014. Reservoir elevation, and regulated and unregulated flows for 1988 are shown on Plate A-15.

A-18. 1993 Regulation. Runoff above Oahe was 24.4 MAF, 120 percent of average. Lower-than-average releases were made from the System due to high tributary inflows in the lower basin from the Great Flood of 1993. The low System releases had a significant impact on the accumulation of storage during July through September. The Great Flood of 1993, with its widespread and severe downstream flooding and above-normal upstream inflows, not only ended the 6-year drought but nearly refilled the System to normal levels. Under average runoff conditions, refilling the System after the 6-year drought would have taken more than six years. As shown on Plate A-16, the Oahe pool level was near elevation 1591.6 feet on January 1. The pool level climbed to a peak of 1611.6 feet in September, gaining nearly 20 feet and peaking 4.1 feet into the Annual Flood Control and Multiple Use Zone. Annual runoff in the Garrison to Oahe reach was 4.1 MAF, 164 percent of average (1898-2014). The total estimate of flood damages prevented by the System during 1993 was $8.2 billion (indexed to 2015). In comparison, total damages prevented from 1937 through 1992 totaled $13.5 billion (indexed to 2015). Most of the damages prevented during the 1993 flood were in the Kansas City District area of responsibility.

A-19. 1995 Regulation. Runoff above Oahe during 1995 totaled 24.7 MAF. The total estimate of flood damages prevented by the System during 1995 (indexed to 2015) was $3.3 billion. At Oahe and Big Bend, average daily releases were well-below normal during April through June to lessen flooding downstream. As shown in Plate A-17, the daily releases from Oahe averaged only 1,900 cfs during May, a record low. In June, releases averaged 11,100 cfs. These below-average releases, in conjunction with high inflows, resulted in a then-record-high pool level of 1618.7 feet on June 25. Releases were increased through the remainder of the summer and into the fall with a maximum daily release of 48,500 cfs in August. Continued evacuation of the stored flood waters through the fall gradually reduced the pool elevation to 1608.2 feet by the end of December, 0.7 foot above the base of the Annual Flood Control and Multiple Use Zone.

A-20. 1996 Regulation. Annual runoff above Oahe totaled 27.5 MAF. As shown on Plate A-18, Oahe was drawn down to within 0.4 foot of the base of the Annual Flood Control and Multiple Use Zone prior to February's record runoff of 896,000 AF. During February the pool level increased 3.5 feet, to 1611.1 feet, by March 1. The pool level continued to rise steadily through the early part of the summer as runoff from the mountain snowmelt poured into the upper reservoirs and System releases were restricted due to downstream flooding. The pool peaked at elevation 1618.67 feet on June 23, nearly identical to 1995's crest, which was the record at that time for Oahe, and 1.7 feet into the 3-foot Exclusive Flood Control Zone. Flood storage evacuation continued through the fall before releases were reduced just prior to the winter freeze-in.

A-21. 1997 Regulation. Runoff above Oahe during 1997 totaled 35.4 MAF. This was the second highest runoff of record (1898-2014) and almost two times average. The total runoff above Sioux City of 49.0 MAF was also the second highest on record and almost two times average. As shown on Plate A-19, the runoff during March through July of 27.0 MAF was nearly two times average during that 5-month period. A decision was made by the MRBWM office in late March to transfer plains snowmelt runoff from Oahe to Fort Randall because the runoff was forecasted to utilize most, if not all, of Oahe's Exclusive Flood Control Zone. However, snowmelt runoff from a late spring blizzard essentially refilled Oahe's storage space in its Exclusive Flood Control Zone that had been evacuated and left both Oahe and Fort Randall with very little available storage in their respective Exclusive Flood Control Zones. Fort Peck and Garrison releases were minimized early in the runoff period, to the extent possible, to stem the rise in Oahe and Fort Randall pool levels. Oahe and Fort Randall pool levels climbed rapidly during February and March. Oahe entered its Exclusive Flood Control Zone on March 28. The pool level at Fort Randall entered its Exclusive Flood Control Zone on April 5. Oahe climbed from a winter minimum level of 1607.5 to 1618.6 feet by early May, only 0.1 foot lower than the previous maximum pool experienced in 1995 and 1996. The peak unregulated inflow at Oahe of 236,000 cfs was recorded on March 1 and was the second highest peak on record (1898-2014), exceeded only in 1978. The total estimate of flood damages prevented by the System during 1997 (indexed to 2015) was $8.6 billion. Further information describing the 1997 flood and accompanying System regulation is presented in the Master Manual and in the special MRD-RCC Summary Report, *Regulation of the Missouri River Main Stem Reservoir System during the 1997 Flood.*

A-22. 1999 Regulation. The runoff in the spring and early summer of 1999 was about average. However, as seen on Plate A-20, runoff in June and July was significantly above average.

Annual runoff upstream of Oahe in 1999 was 21.9 MAF or about 1.5 MAF above the long-term average (1898-2014). During the late summer-early fall period the primary regulation objective of the System was to evacuate excess storage in the upper three reservoirs. Releases from the System were stepped up to 40,000 cfs for the months of September, October and November. The Oahe pool climbed to 1617.4 feet on July 9, 0.4 foot into the Exclusive Flood Control Zone.

A-23. 2006 Regulation. This marked the seventh year of what would turn out to be an 8-year drought. Annual runoff above Oahe totaled 13.5 MAF, 66 percent of average. As shown on Plate A-21, the Oahe annual minimum pool elevation of 1570.2 feet occurred on August 30. That pool level was about 32 feet below the 1967-2014 average of 1602.3 feet. This record low was almost 2 feet lower than the previous low set in 2004. The previous record low before the current drought was 1580.7 feet in November 1989.

A-24. 2010 Regulation. The 2010 runoff year marked the third consecutive year of above-average runoff conditions following the 2000-2007 drought. The 2010 runoff above Sioux City, IA was 38.7 MAF, 156 percent of average, and the fourth highest on record (1898-2014). Runoff above Oahe was 23.2 MAF. At the end of 2009, the Missouri River basin was almost entirely covered by plains snowpack as a result of October and early December snowfall in the plains coupled with colder-than-normal temperatures. Snowfall continued to accumulate in the plains as above-average snowfall and colder-than-normal temperatures persisted into March. By the beginning of the plains snowmelt, many areas in the basin had accumulated 4 to 6 inches of SWE from western North Dakota through much of South Dakota to northwest Iowa, and 3 to 4 inches in surrounding regions of Montana, Nebraska and southwest Iowa. The Oahe reservoir began the year at 1607.0 feet, 0.5 foot below the base of Annual Flood Control and Multiple Use Zone, as shown on Plate A-22. The melting of the above-normal plains snowpack brought high inflows to Oahe and similar high flows downstream, which limited Oahe release rates. As a result, the Oahe pool elevation continued to climb steadily as above-normal rainfall fell across South Dakota and the lower Basin, which prolonged the period of high inflows and low releases. This became especially important as high local inflow into Fort Randall and Gavins Point resulted in pool levels in both reservoirs rising into their respective Exclusive Flood Control Zones. The highest Oahe Reservoir level recorded during 2010 occurred on June 26 at 1617.9 feet. The reservoir had last been in its Exclusive Flood Control Zone in August 1999.

A-25. 2011 Regulation. The 2011 runoff year of 61.0 MAF, almost 2.5 times average, was the highest runoff year of record (1898-2014) in the upper Missouri River basin since record-keeping began. It also marked the fourth consecutive year of above-average runoff in the upper Missouri River basin, immediately following the 2000-2007 drought. May (9.2 MAF), June (14.8 MAF) and July (10.2 MAF) were the highest inflows for their respective months in the 117-year period of record. The 34.2 MAF of runoff received during that 3-month period exceeded the total annual runoff in 102 of the previous 113 years. The winter of 2010-2011 marked the third consecutive year of significant plains snowpack. While the mountain snowpack was very substantial, runoff from mountain snowpack normally extends over a 3-month period (May-July), and May 1 regulation studies indicated System evacuation releases of 57,500 cfs. During May, heavy rains fell across the regions of eastern Montana, western South Dakota and northern Wyoming, covering an area of 50 million acres, which is the approximate size of the State of South Dakota. In some isolated areas, 10-15 inches of rain fell over a 3-day period. Because this runoff came in the form of rainfall runoff rather than snowmelt runoff, the volume of runoff over this very large area quickly made its way to the Fort Peck and Garrison reservoirs and dictated a need to increase releases from all six System reservoirs to record levels. System storage peaked at 72.8 MAF on July 1, occupying 98 percent of the allocated flood control storage space. As shown on Figure A-23, the record maximum daily release from Oahe occurred on June 20 at 160,300 cfs. The previous record release was 59,300 cfs, which was established in July 1997. The old record release was exceeded for 122 days in 2011. The highest Oahe reservoir level during 2011 occurred on June 26 at 1619.7 feet, occupying 2.7 feet of the 3-foot Exclusive Flood Control Zone. The peak reservoir elevation set a record for the highest peak pool since the System first became fully operational in 1967. The prior record was 1618.7 feet, which was set in 1995 and 1996.

A-25.1. Outlet tunnel releases were made at Oahe from May 6 to October 7 and from November 9 to November 29. To accommodate variations in power demands during the 2011 record releases, powerplant releases at some of the projects, including Oahe, were varied in a day-to-night pattern, with higher powerplant releases occurring during the day. At Oahe, this required adjusting releases from the outlet tunnels twice per day to maintain the required total project release. In addition, power system load control required hourly variations in powerplant releases at either Oahe or Fort Randall, which required additional adjustments to supplemental releases. Fort Randall generally performed the hourly load control from about mid-June through early August. Oahe performed this function starting in early August. These release adjustments lessened late in the summer as power demands increased and total project releases were reduced. The outlet tunnels required repairs following the record releases in 2011. The Oahe spillway was not used during 2011.

A-26. Summary of Historical Regulation. Annual total upstream runoff during the historic period of record, 1898 to 2014, above Oahe has ranged from a minimum of 8.3 MAF (1988) to the maximum of 45.6 MAF (2011). Regulation during these years is believed to be quite representative of the range of conditions that are likely to prevail through the life of the project. Based on this experience and supplemented by analyses of the entire period of hydrologic record, it is believed that the regulation criteria developed for Oahe, and for the System as a whole (as presented in the Master Manual) as it affects Oahe regulation, are reasonable and represent a near-optimum utilization and control of the water supply that may be available. Of course, studies will continue through the life of the project in an effort to improve criteria as conditions change. Typically, Oahe releases will be maintained within the capacity of the Oahe powerplant except in years of extremely high basin runoff such as 1997 and 2011 when the outlet works were utilized. The spillway at Oahe has never been used and it would appear use of the spillway would only be necessary if an Oahe pool level higher than elevation 1620.0 feet appeared probable. With the large amount of storage space provided in Oahe and in other System reservoirs, chances of the spillway being used would be rare as evidenced by regulation of the maximum flood season runoff of record during 2011.

A-26.1. When the Oahe releases are less than full powerplant capacity, great variations in release have occurred, from hour to hour and day to day. Plates A-7 through A-23 illustrate the daily variations and the weekly cycle in release rates occasioned by lower power demands during weekends. During any one day releases have frequently ranged from 0 cfs to the full powerplant capacity in order to efficiently produce power. Daily variations from the general level of release rates can be expected to continue, both as a response to downstream needs and to enhance power production from the project and the reservoir System as a whole.

Appendix B - Recreation

B-01. General. The six reservoirs of the System and the Missouri River reaches between and downstream of these reservoirs provide recreation opportunities. Recreational activity is a source of income for businesses catering to boating, hunting, fishing, camping and other recreational pursuits. Service-related establishments located near the Missouri River also benefit from those recreating on the System reservoirs. A variety of recreational opportunities are available within the System and the lower Missouri River. Water-based recreation includes boating, fishing and swimming. Sport fishing is a primary component of recreation along the entire river. The wetlands along the river corridor provide waterfowl habitat, and waterfowl hunting is popular. Hunting for small and large game such as pheasant, grouse, rabbit and deer occurs on land along the System reservoirs and the river reaches. The aesthetically pleasing character of the reservoirs and river reaches attracts sightseers. Camping facilities vary from fully developed to primitive. Over 80,000 acres of recreational lands are located along nearly 6,000 miles of System reservoir shoreline. Of these 80,000 acres of recreational lands, 6,457 acres are designated as existing recreational areas located on Tribal Reservation lands along the main stem of the Missouri River with another 925 acres identified as future recreational areas. Recreation, an authorized System project purpose, has grown beyond original expectations. With time, recreational facilities became more developed and opportunities for recreation have increased. The introduction of additional fish species attracted greater numbers of fishermen to the reservoirs. Road improvements made the reservoirs and river reaches more accessible. Recently, the national trend towards outdoor recreation and the number of recreationists willing to travel longer distances have added to the recreational visitation all along the System. There is also a thriving recreation industry below the System on the lower Missouri River; approximately 30 percent of the total recreation benefits attributed to the Missouri River occur below the System.

B-02. System Recreation Visitation. Visitation data is maintained by the Corps in the Natural Resource Management's Visitation Estimation and Reporting System database. The methodology used for the Corps to determine visitation hours has been under revision since 2013. The new methodology will leverage metered data that is collected as vehicles enter and exit the recreation areas. Plate B-1 shows the annual visitation for the total System and the six individual System projects from 1954 to 2012. This plate shows that the trend is upward except during extended drought, when the trend levels off or is slightly reversed depending on the year. Other factors also affect the visitation numbers such as the overall United States economy. A survey completed in 1999 showed that, of the annual visits made to the six projects, approximately 37 percent are made by sightseers, 29 percent by fishermen, 24 percent by boaters, 10 percent by picnickers, 9 percent by swimmers, 2 percent by campers, 2 percent by water skiers, 2 percent by hunters, and 22 percent by visitors who participate in other activities. The visit percentages total more than 100 percent (137 percent) and indicate that some visits include multiple activities.

B-03. Oahe Recreation Visitation. Refer to Table B-1 for a history of Oahe recreation visitation. The reservoir levels of the lower three reservoirs (Big Bend, Fort Randall and Gavins Point) do not vary with annual runoff as much as the larger, upper three reservoirs. The lower reservoirs do not contain the flood storage volume or conservation storage that the upper three reservoirs (Fort Peck, Garrison and Oahe) do. Thus, recreation visitation in the lower three reservoirs is not affected as much during drought periods or flood periods because access issues do not normally occur.

Table B-1
Oahe Recreation Visitation of Corps' Recreation Areas

Year	Visitation in hours	Year	Visitation in hours
1954	189,070	1984	9,038,878
1955	321,530	1985	11,100,000
1956	370,740	1986	11,100,000
1957	350,020	1987	12,900,000
1958	475,080	1988	15,700,000
1959	592,370	1989	14,400,000
1960	711,510	1990	13,300,000
1961	815,850	1991	12,700,000
1962	710,770	1992	10,100,000
1963	860,620	1993	16,000,000
1964	1,285,010	1994	14,500,000
1965	1,535,500	1995	16,200,000
1966	2,400,560	1996	18,100,000
1967	6,788,020	1997	17,400,000
1968	6,747,690	1998	16,300,000
1969	8,441,180	1999	15,400,000
1970	6,884,960	2000	14,200,000
1971	7,144,700	2001	14,300,000
1972	7,408,510	2002*	10,200,000
1973	7,759,640	2003*	7,933,300
1974	7,252,000	2004*	7,140,000
1975	5,836,750	2005*	7,700,600
1976	7,417,227	2006*	7,386,000
1977	6,802,820	2007*	8,045,400
1978	7,004,370	2008*	9,641,300
1979	7,691,190	2009*	9,322,300
1980	7,937,980	2010*	9,503,100
1981	8,056,380	2011*	6,964,917
1982	8,426,380	2012**	10,863,700
1983	9,903,790		

* In 2002 many of the Corps' recreation areas were transferred to the State of South Dakota in the Title VI Land Transfer. The lower visitation numbers since 2002 reflect collection of visitation data at the remaining Corps recreation areas.
** 2012 visitation data is only January through September.

Appendix C - Water Quality

C-01. Missouri River Basin Water Quality. Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health and plant and animal life; temperature, which affects fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor and floating materials, which affect the water's potability and the aesthetic quality of the environment. In general, the mainstem reservoirs function as pollutant "sinks" in that sediment and adsorbed pollutants settle out and are deposited on the bottom of the reservoirs. Water discharged through Oahe for power production is withdrawn from the Oahe reservoir at elevation 1524.0 feet, approximately 114 feet above the reservoir bottom. Water discharged from Oahe through the six flood tunnels is withdrawn near the bottom of the Oahe reservoir. When water is released from the Oahe flood tunnels it may withdraw anoxic water of degraded quality from the bottom of the reservoir during prolonged thermal stratification and pass it downstream. However, it should be noted that water discharged from Oahe is mainly through the powerhouse and the flood tunnels are typically only used during large flood events such as 1997 or 2011. Although the Missouri River has historically contained high sediment loading and naturally occurring high concentrations of metals such as arsenic and selenium, the water quality characteristics of the Missouri River have changed within the past several decades. These water quality changes are a result of past and current changes in land use practices, increased urbanization, atmospheric deposition of pollutants, and dam construction and regulation within the Missouri River basin. Water quality impacts arising from the construction and regulation of the System can be broadly classified as direct impacts and indirect impacts.

C-02. Direct Water Quality Impacts of System Regulation. The System and its regulation have significantly improved water quality in the river reaches between the reservoirs and downstream of the System, compared to the water quality in the Missouri River before the System was constructed. The water quality has improved as seen through the Clean Water Act (CWA) because the river has become clearer and cooler and improved recreation and sport fishery. Conversely, the water quality has degraded as seen through the ESA because the natural turbid, warm river has become clearer and cooler which may affect native river fish. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality.

C-02.1. The majority of the water quality impacts that are a direct result of System regulation occurs in the upper portion of the Missouri River basin. These direct water quality impacts include temperature changes in the reaches downstream from several of the dams, low concentrations of suspended solids in the releases, and temperature and dissolved oxygen problems when the upper three reservoirs are drawn down during droughts. These impacts are more physical in nature, involving the management of streamflow and water storage in the System. Water temperature is recognized as an important water quality condition affecting the fishery population in the Missouri River reaches downstream of the dams. Because releases from the System dams contain low concentrations of suspended solids, some native riverine fish species may be adversely affected. The drawdown of the three larger reservoirs during extended droughts diminishes the coldwater habitat. The temperature increases are a direct impact of System regulation and less dissolved oxygen being available in the reservoirs is an indirect impact, as discussed in Section C-03. In turn, coldwater fish species in the reservoirs may be adversely affected.

C-03. Indirect Water Quality Impacts of System Regulation. Most water quality issues in the Missouri River basin are indirect impacts as they result from a combination of pollutant sources and hydrologic conditions throughout the watersheds. The Missouri River reservoirs and the tributaries receive pollutant loading from point and non-point sources within the watersheds. The Corps reservoirs are not the source of the pollutants that enter the Missouri River; however, they directly affect the hydrologic regimes that store or transport pollutants downstream. Water quality impairments and problems may, therefore, arise when the Corps is regulating the System to meet the Congressionally authorized System project purposes. Brief descriptions of these indirect water quality issues and impacts are discussed below.

C-03.1. During extended droughts, low reservoir levels in the summer result in reduced volumes of deeper, cooler hypolimnetic water in the three larger System reservoirs. The low reservoir levels may cause an increase in the overall temperature of the water in the reservoir and may reduce the total amount of oxygen available in hypolimnetic waters to meet demands of sediment and decomposing organic material, such as decaying algae.

C-03.2. Dissolved oxygen concentrations, especially in hypolimnetic waters, can be lowered through the decomposition of accumulated organic matter and the oxygen demand of sediments and reduced substances. The absence of dissolved oxygen (i.e., anoxic conditions) during summer conditions may result in an influx of metals, such as iron and manganese, from the sediments into the water column. Anoxic conditions, through the oxidation-reduction process, can also liberate nutrients such as phosphorus from the sediments. This can lead to nutrient enrichment and possible nuisance growth of algae.

C-03.3. Elevated metal concentrations have been detected in the water column and fish tissue and within the sediments of the System. The major metals of concern in the System are arsenic and mercury. The Fort Peck and Garrison reservoirs currently have fish consumption advisories issued for mercury. Natural background concentrations of arsenic, selenium and mercury in the System reservoirs are associated with the local geology, specifically the presence of Upper Cretaceous Age Pierre Shale. Elevated arsenic concentrations are a localized occurrence associated with large storm events that cause high sediment loading or wind action that results in re-suspension of the reservoir sediments. Arsenic is a naturally occurring metal within the watershed and readily adsorbs onto fine soil particles as they are transported downstream and deposited in the reservoirs. The majority of arsenic entering the System is adsorbed onto sediment particles. The sources of mercury are naturally occurring soils, point-source discharges and sediments generated from historical mining practices that have been transported downstream into the System reservoirs. Elemental mercury can be transformed to methyl mercury in rivers and reservoirs when organic matter and hypoxic conditions are present. Methyl mercury bioaccumulates in the aquatic food chain and accumulated levels in fish pose a threat to human health when the fish are consumed. Other metals that have been detected in the System reservoirs are copper, iron, manganese, nickel and zinc.

C-03.4. Agricultural practices, both past and present, include the application of pesticides throughout much of the Missouri River basin. The Omaha District Water Control and Water

Quality Section scans for the following pesticides: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, deethylatrazine, deisopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, profluralin, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate and trifluralin.

C-03.5. Throughout the Missouri River basin, tributary waters exhibit significant nutrient loadings because of effluent discharges, urban storm water and agricultural runoff, and other non-point sources of pollution. High nutrient levels in the Missouri River and its tributaries can deliver nutrients to the System reservoirs and lead to undesirable algal blooms.

C-04. Oahe Reservoir and Tailwater. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Oahe reservoir in the state's water quality standards: recreation (i.e., immersion and limited contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Missouri River on its Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river. The State of North Dakota has classified the Oahe reservoir as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery, swimming, boating, and other water recreation, irrigation, stock watering, wildlife and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the CWA, North Dakota has not placed the Oahe reservoir on the state's list of impaired waters. The State of North Dakota has issued a fish consumption advisory for the Oahe reservoir due to mercury concerns. The Cheyenne River Sioux Tribe has issued a fish consumption advisory for the Oahe reservoir and the Cheyenne and Moreau Rivers. Tribal lands of the Cheyenne River Sioux are located along the west side of the Oahe reservoir between the Moreau and Cheyenne Rivers.

C-04.1. South Dakota's water quality standards designate the following beneficial uses for the Missouri River downstream of Oahe: recreation (i.e., immersion and limited contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Missouri River on its Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

C-05. Water Quality Monitoring at the Project. The Corps has monitored water quality conditions at Oahe since the late 1970s. The near-dam location has been continuously monitored since 1980. Water quality monitoring locations have included sites on the reservoir and on the Missouri River upstream and downstream of Oahe. Data collection has varied through this period with the most recent reporting period (2010-2014) including the monitoring of ambient water quality conditions at the following locations: 1) five sites on the Oahe reservoir near the dam, mid-reach, and in the headwaters; 2) within the Oahe powerplant on water discharged through the turbines; 3) the Missouri River inflow to the Oahe reservoir at Bismarck, ND; and 4) Cheyenne River inflows near Cherry Creek, SD. The Omaha District Water Control and Water Quality Section is the primary office responsible for water quality data collection, analysis and documentation. The section publishes an annual water quality report regarding the district tributary projects as well as the System projects.

C-06. Water Quality Trends. Table C-1 summarizes the water quality conditions that were monitored in the Oahe reservoir near the damsite during 2010-2014. A review of these results indicate possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation (CPFLP). Dissolved oxygen levels continually degrade along the reservoir bottom as summer progresses and fall below 7.0 mg/L in late summer. During the 4 years from 2010-2014, dissolved oxygen levels generally remained above 6.0 mg/L in the area of the reservoir near Oahe. However, during 2011 dissolved oxygen levels fell below 5 mg/L near the dam during late summer. Table C-2 summarizes the water quality conditions that were measured in samples collected from water discharged through Oahe during the 5-year period 2010-2014. A review of these results indicated possible water quality concerns regarding temperature for the support of CPFLP in the Oahe tailwaters and arsenic for the protection of human health. Updated information and additional detail can be found in the annual water quality report.

C-06.1. Surface water quality trends were assessed by evaluating the Trophic State Index (TSI) values calculated from monitoring results obtained at the Oahe reservoir for the 2010-2014 period. The calculated TSI values indicate that the reservoir near the dam is in a mesotrophic (i.e., intermediate nutrient/intermediate productivity) state. At the next upstream monitoring site, the transition zone is mesotrophic, and the riverine zone is moderately eutrophic to eutrophic.

Table C-1
2010-2014 Water Quality Conditions – Oahe Reservoir

Parameter	Monitoring Results[A]						State WQS Criteria[D]	Water Quality Standards Attainment	
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1609.8	1611.9	1598.4	1619.2	-----	-----	-----
Water Temperature (°C)	0.1	1,315	12.5	10.3	4.8	25.6	18.3[1,6]	311	24%
Hypolimnion Water Temperature (°C)[E]	0.1	609	10.2	9.5	6.2	19.8	18.3[1,6]	5	1%
Dissolved Oxygen (mg/L)	0.1	1,315	9.5	9.5	4.2	12.5	6[1,7,9], 7[1,7,9]	20, 76	2%, 6%
Dissolved Oxygen (% Sat.)	0.1	1,315	91.6	94.9	41.3	126.8	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/L)[E]	0.1	706	9.8	9.7	5.2	12.5	5[3,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/L)[E]	0.1	609	9.2	9.4	4.2	11.7	6[1,7,9]	19	3%
Specific Conductance (uS/cm)	1	1,315	778	788	672	908	-----	-----	-----
pH (S.U.)	0.1	1,262	8.1	8.2	6.6	9.1	6.5[1,2,7], 9.0[1,2,6], 9.5[4,6]	0, 9, 0	0%, 1%, 0%
Turbidity (NTUs)	1	1,312	-----	n.d.	n.d.	87	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,258	338	355	126	477	-----	-----	-----
Secchi Depth (M)	1	24	4.11	3.82	0.99	7.01	-----	-----	-----
Alkalinity, Total (mg/L)	7	49	162	164	140	175	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	49	4.0	3.8	2.7	10.6	-----	-----	-----
Chemical Oxygen Demand (mg/L)	2	19	9	9	4	14	-----	-----	-----
Chloride (mg/L)	1	20	12	12	11	13	175[1,6], 100[1,8], 438[2,6], 250[2,8]	0	0%
Chlorophyll *a* (ug/L) – Field Probe	1	1,198	4	3	n.d.	81	-----	-----	-----
Chlorophyll *a* (ug/L) – Lab Determined	1	25	4	4	n.d.	11	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	4	40	24	23	13	34	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	48	568	563	372	820	1,750[2,6], 1,000[2,8], 3,500[4,6], 2,000[4,8]	0	0%
Nitrogen, Ammonia Total (mg/L)	0.02	49	-----	n.d.	n.d.	0.07	3.8 [1,6,10], 1.7 [1,8,10]	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	49	0.5	0.3	n.d.	3.7	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	49	-----	0.06	n.d.	0.30	88[5,6], 50[5,8], 10[2,6]	0	0%
Nitrogen, Total (mg/L)	0.1	49	0.6	0.4	0.1	3.7	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	50	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	49	-----	0.02	n.d.	0.05	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	49	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/L)	1	49	235	236	185	301	875[2,6], 500[2,8]	0	0%
Suspended Solids, Total (mg/L)	4	49	-----	n.d.	n.d.	34	53[1,6], 30[1,8]	0	0%
Microcystin, Total (ug/L)	0.1	25	-----	n.d.	n.d.	n.d.	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/L W. Temp. ≤ 18.3°C	1	4%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/L and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate state water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Criteria for the protection of fish and wildlife propagation, recreation, and stock watering.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) The 7.0 mg/L criterion applies to spawning areas during spawning season, and the 6.0 mg/L criterion applies otherwise.
- (10) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates a decrease of 1.0°C or more over a 1-meter depth increment, or a decrease of at least 0.5°C and a decrease of at least 1 mg/L dissolved oxygen over a 1-meter depth increment. The top of the hypolimnion is delineated as the depth where the above changes occur.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e. at least a 1-meter layer of water with a temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/L). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedances" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Table C-2
2010-2014 Water Quality Conditions – Oahe Reservoir

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedances	Percent WQS Exceedance
Powerplant Discharge (cfs)	1	40	30,599	30,225	5,300	57,233	-----	-----	-----
Water Temperature (°C)	0.1	40	12.7	13.6	0.9	24.0	18.3[(1,5)]	10	25%
Dissolved Oxygen (mg/L)	0.1	40	10.1	10.0	7.1	14.0	5[(3,6)], 6[(1,6,8)], 7[(1,6,8)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	40	97.0	97.2	80.0	111.0	-----	-----	-----
pH (S.U.)	0.1	39	8.2	8.2	7.3	8.9	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Specific Conductance (uS/cm)	1	39	784	789	665	1,011	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	39	359	361	210	691	-----	-----	-----
Turbidity (NTU)	1	40	13	14	1	24	-----	-----	-----
Alkalinity, Total (mg/L)	7	40	161	163	140	174	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	40	4.3	3.9	2.3	14.0	-----	-----	-----
Chloride, Dissolved (mg/L)	1	15	12	12	11	13	175[(1,5)], 438[(2,5)] 100[(1,7)], 250[(2,7)]	0	0%
Colorized Dissolved Organic Matter (ug/L)	4	31	24	23	17	3	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	40	560	544	360	890	1,750[(2,5)], 3,500[(4,5)] 1,000[(2,7)], 2,000[(4,7)]	0	0%
Nitrogen, Ammonia Total (mg/L)	0.02	40	-----	n.d.	n.d.	0.07	3.8 [(1,5,9)], 1.7 [(1,7,9)]	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	40	0.3	0.3	n.d.	1.3	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/L)	0.02	40	0.08	0.07	n.d.	0.20	10[(2,5)]	0	0%
Nitrogen, Total (mg/L)	0.1	40	0.4	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	40	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	40	-----	0.02	n.d.	0.10	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	40	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/L)	1	40	233	235	193	286	875[(2,5)], 500[(2,7)]	0	0%
Suspended Solids, Total (mg/L)	4	40	-----	5	n.d.	86	53[(1,5)], 30[(1,7)]	3, 4	8%, 10%

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/L and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate state water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/L criterion applies to spawning areas during spawning season, and the 6.0 mg/L criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

Appendix D - Fish and Wildlife

D-01. General. The USFWS has identified three protected species – the endangered least tern, the threatened piping plover and the endangered pallid sturgeon – that are affected by the regulation of the System. The least tern and piping plover utilize the shoreline of the Oahe reservoir for nesting purposes. Development of the System has transformed a major portion of the Missouri River valley extending from eastern Montana through the Dakotas from an area typical of alluvial streams into a chain of long, relatively deep reservoirs. This development, in an area where such a quantity of surface water did not exist naturally and that is characterized as having a relatively dry climate, has had a great effect on the environment of the area. The purchase and subsequent management of lands associated with the individual System projects has changed use patterns of lands adjacent to the System projects from the use experienced prior to projects. Regulation of the reservoirs also has affected the regime of the Missouri River through those reaches below the System and in those reaches between the System reservoirs where the river is still more or less in its natural state. The full impact of each of the reservoirs and its regulation on the environment is constantly changing as they adapt to new conditions. The environmental emphasis has changed since the System was authorized. Current efforts are focused on increased stewardship of the Missouri River and surrounding affected lands by maintaining them in as natural a condition as possible through enhancing and supporting native plants and species. The two basic goals of the Corps stewardship are to manage lands and waters to ensure their availability for future generations and to help maintain healthy ecosystems and biodiversity. Balancing the needs of the people with those of nature is the basic challenge. Through observations and discussion with interested individuals and agencies, many suggestions for environmental enhancement of the System have been received and are being implemented by the Corps. The adaptive management process discussed in Chapter VII of the Master Manual provides additional focus on this effort, and, through implementation of the actions developed and tested through this process, Missouri River ecosystem restoration will occur.

D-01.1. Another major point of emphasis in environmental considerations has been the effect of the various System regulation practices on fish and wildlife, including T&E species. Improvement of fish spawning activities by appropriate management for habitat development and subsequent spawning is an important consideration in System regulation. Suggestions have been made and adopted to the degree practicable for improving migratory waterfowl habitat and hunter access along the Missouri River below the projects. Other suggestions, such as reduction of flows during the migration period so that more sandbars could be available, cannot always be implemented without serious effects on other authorized project purposes. As further suggestions are received, they will be evaluated through the adaptive management process. Another area of environmental concern is the management of project lands. Currently, the major emphasis on the development of these lands is for water-oriented recreation; however, large areas of project lands are now being managed almost exclusively for wildlife purposes.

D-02. Fish and Wildlife. Fish and wildlife enhancement has been discussed in other portions of the Master Manual. Section 4-06.6 of the Master Manual presents information on the activities of two existing federal fish hatcheries and the Fort Peck State Fish Hatchery. At all times of the year, but particularly during the fish spawning period and the T&E nesting season, the MRBWM office recognizes and integrates fish and wildlife purpose considerations into System regulation decisions to the extent possible with consideration to other authorized purposes. The Corps coordinates closely with the USFWS and the state organizations to assure that the consideration of effects on fish and wildlife is provided. Appendix D of the Master Manual provides a detailed discussion of the existing Missouri River basin environment and historical System regulation related to this authorized purpose.

D-03. Regulation for Endangered and Threatened Species – Least Terns and Piping Plovers. Releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered least tern and threatened piping plover nesting since 1986. As a measure to minimize take while maintaining the flexibility to increase releases during the nesting season, hourly releases from Fort Randall and Garrison follow a repetitive daily pattern to limit peak stages below the project for nesting birds. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Average daily releases may be increased every third day to preserve the capability of increasing releases later in the summer with little or no incidental take if drier downstream conditions occur. If higher daily releases are required later in the nesting season, the daily peaking pattern may be adjusted, reduced or eliminated resulting in a steady release to avoid increased stages at downstream nesting sites. Additional System regulation criteria used for T&E species is discussed in Section 7-09 of this WCM and Section 7-10 and Appendix D of the Master Manual. The regulation of Oahe is not adjusted due to T&E species.

Appendix E - Water Supply and Irrigation

E-01. Introduction. System regulation has assured a relatively uniform supply of water for downstream municipalities and industrial uses. The Corps provides more than adequate flow in the river to meet the requirements of all who choose to utilize the Missouri River for their water supply. At times, releases from individual System projects have been adjusted to ensure continued satisfactory functioning of water intakes on a short-term basis. The Missouri River and its System reservoirs are a source of water for municipal water supply, irrigation, cooling water, and commercial, industrial and domestic uses. Approximately 1,600 water intakes of widely varying size are located within the System and the lower Missouri River. Access to water is a key concern because low water levels limit the ability of some intakes to access the water and increase the cost of getting water from both the reservoirs and Missouri River. Water supply is a purpose that has grown more than originally envisioned. The regulation of the System in such a predictable manner provides a dependable domestic and industrial water supply for many river communities for using the Missouri River as a source for domestic as well as industrial water supply. Releases have been of a uniformly good quality. There have been times when intake access becomes a problem, primarily during release reductions for flood control or because of reduced releases and low reservoir levels during an extended drought. It is the intake owner's responsibility to maintain adequate access to the water supply available in the Missouri River. Per the MRRMP-EIS, of the approximately 3.2 million persons served by water supply from the System, 89 percent are downstream of Gavins Point (see Table E-1 of the Master Manual). There are no thermal powerplants in the Oahe reservoir area or in the river reach below Oahe. More detailed discussion on water supply and irrigation can be found in Appendix E of the Master Manual.

E-02. Oahe Reservoir. As shown on Table E-3 of the Master Manual, there are 216 water supply intakes located on the Oahe reservoir. These include 8 municipal intakes, 179 irrigation intakes, 21 domestic intakes and 8 public intakes. The municipal water supply facilities serve a population of approximately 121,515 persons. Of the 216 water supply intakes, 14 serve the Standing Rock Reservation. These include 2 municipal intakes, 9 irrigation intakes, 1 domestic intake and 2 public intakes. The Reservation's municipal water supply facilities serve a population of approximately 1,550 persons. Likewise, 9 water supply intakes service the Cheyenne River Reservation. These include 1 municipal intake, 3 irrigation intakes, and 5 domestic intakes. The Reservation's municipal water supply facilities serve a population of approximately 10,000 persons.

E-03. Oahe Dam to Big Bend Reservoir. Downstream of Oahe, the municipalities of Pierre and Fort Pierre, located along this short reach, obtain their water supply from wells. There is a large municipal water intake located near Fort Pierre called the Mni Wiconi Water Supply Project. The Mni Wiconi Rural Water Supply provides municipal, rural and industrial water supply to serve more than 51,000 people in 40 communities and 10 counties.

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Appendix F - Hydropower

F-01. General. Hydropower generation by System powerplants represents one of the authorized project purposes. The hydropower production of the System continues to be of great importance and of direct interest because of the day-by-day direct benefits realized by a large segment of the Missouri River basin's population in the form of relatively low-cost power and the annual return of revenues to the U.S. Department of the Treasury. Hydropower plays an important role in meeting the electricity demands of our Nation. It is a renewable energy source that helps conserve the nonrenewable fossil and nuclear fuels. It helps meet the basin's needs at an affordable price in an environmentally safe way. Nearly $6 billion in cumulative hydropower benefits amortized to current dollars has occurred from the regulation of the System. At the six System dams, 36 hydropower units provide a combined capacity of 2,500 MW, as shown in Table F-1. These units have provided an average of 9.3 million (1967 – 2015) megawatt hours (MWh) per year. Western, of the U.S. Department of Energy, markets power generated at the System dams within the Southwest Power Pool (SPP). Western joined the SPP market in October 2015. Western had previously marketed energy in the Mid-continent Area Power Pool region.

F-02. Hydropower Capacity. The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20,000 MW, with an annual generation of over 90 million MWh. The investor-owned systems have about 60 percent of the basin's generating capacity. The publicly-owned systems consist of about 40 percent federal hydroelectric capacity and 60 percent thermal capacity owned by non-federal public bodies. Hydropower installations in the basin total about 3,000 MW, of which about 82 percent is federal, 14 percent is investor owned and 4 percent is publicly owned. The federal power system in the upper Missouri River basin includes the six Corps System powerplants as well as the Canyon Ferry and Yellowtail powerplants constructed by the USBR. Until October 1, 1977, power from all Missouri River basin federal powerplants was marketed by the USBR. At that time, the power marketing responsibility shifted to Western. The federal hydroelectric powerplants are connected with the extensive federal transmission system within Western's Eastern Division, Pick-Sloan Missouri Basin Program, power-marketing area, which includes Montana east of the Continental Divide, North and South Dakota, eastern Nebraska, western Minnesota and western Iowa. The transmission network is interconnected with numerous Rural Electric Association-financed cooperatives, municipal power systems, and investor-owned utilities. The Eastern Division transmission network is interconnected with Southwestern at Maryville, MO, and with the Western Division through a 100 MW direct current tie at Stegall, NE, owned by the Tri-States Cooperative. In addition, by a split-bus operation, a variable number of units can be operated on the Western system at the Fort Peck and Yellowtail (USBR reservoir project) powerplants.

F-03. Hydropower Facilities and Historic Regulation. The following sections describe the individual System project hydropower and generation. Chapter IV in the Master Manual contains a more detailed description of the hydropower and powerplant facilities. Table F-1 presents hydropower related information for the System projects. Refer to Appendix F of the Master Manual for additional hydropower information on System projects.

Table F-1
System Project Hydropower Data

Dam	Generator Capacity (MW)	Energy (million MWh)	Average Annual Energy Plant Factor (%)	Units	Average Gross Head (feet)	Average Flow (kcfs)	Normal Powerhouse** Capacity (kcfs)	Average Annual Flow Plant Factor (%)	Type
Fort Peck	185	1.0	63	5	194	9.2	16	58	Semi-Peaking
Garrison	583	2.2	43	5	161	21.6	41	53	Semi-Peaking
Oahe	786	2.6	38	7	174	23.2	54	43	Peaking
Big Bend	517	1.0	22	8	70	23.7	103	22	Peaking
Fort Randall	320	1.7	61	8	118	25.1	44.5	56	Semi-Peaking
Gavins Point	132	0.7	62	3	48	27.6	36	77	Baseload
Total	**2,523**	**9.3**		**36**					

** Normal powerhouse capacity is based on average reservoir elevation.

Note: **Flow plant factors are calculated based on average flows versus powerhouse flow capacities. These differ from energy-based plant factors to the extent that actual plant head is less than maximum gross head.**

Source: Corps, 1967-2015 actual data.

F-04. Oahe Dam. Seven units operate at Oahe, with a generating capacity of 786 MW. Normal powerhouse capacity (at rated head) is 54,000 cfs, and the average release is 23,200 cfs (1967-2015). Powerhouse releases up to approximately 57,500 cfs may be made under certain conditions. The average annual flow plant factor is 43 percent. The powerplant produces an average of 2.6 million MWh per year. Power generating units came on line between 1962 and 1963. The Oahe powerplant is a peaking plant.

F-05. Oahe Releases. Due to the control provided by the downstream Big Bend project, Oahe releases have been extremely variable since the project became fully operational. Minimum average daily releases of 1,000 cfs or less are not uncommon, while releases near the powerplant capacity of about 54,000 cfs are also frequently made. Since the powerplant became operational, nearly all releases have been made through the power turbines except during 1997 and 2011, when releases were very high to evacuate record runoff.

F-06. System Hydropower Generation Considerations. Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System. Adjustments, however, have been made to the extent possible to provide maximum power production during the summer and winter months when demand is high. Oahe and Big Bend power generation is relatively high during the winter. Since System release in the winter is low, the winter Oahe and Big Bend powerplant releases must be stored in the Fort Randall reservoir. To allow for this, the Fort Randall reservoir is drawn down during the fall of each year, as discussed in Section F-06.2 of this WCM.

F-06.1. Hourly patterning of the average daily releases is also of major importance in realizing the full power potential of the System powerplants. Based on past experience with both open water and a downstream ice cover, in most cases no limits need to be placed on daily peaking (with the exception of Gavins Point) up to the capacities of the individual powerplants, except during the T&E nesting seasons, provided the limiting average daily discharge is not exceeded. The minimum allowable hourly generation, and corresponding release, is dependent on the hydraulic characteristics of the river below each of the projects and the effect on water use in the downstream reaches. Downstream water supply intakes, fish spawning activities in the downstream channel, recreational usage, and other factors that may be seasonal in nature influence the selection of minimum limits. These constraints at particular projects are summarized in the Master Manual and additional detail for Oahe is found in this WCM.

F-06.2. Due to the flexibility inherent in such a large system of reservoirs, it is possible to pattern project releases (with the exception of Gavins Point) to cycles extending for periods longer than a day in duration for maximum power production while still providing full service to the authorized project purposes other than hydropower. During the navigation season when downstream flow requirements are high, large amounts of water are normally released from Gavins Point. This requires that large volumes of inflow to Gavins Point be supplied from Fort Randall. Fort Randall, in turn, requires similar support from Big Bend, and Big Bend from Oahe. Here the chain can be interrupted because Oahe is large enough to support high upstream releases for extended periods without correspondingly high inflows. High summer releases from Gavins Point, Fort Randall, Big Bend and Oahe result in high generation rates at these plants. To avoid generating more power than can be marketed advantageously under these circumstances and to provide more winter hydropower, the usual practice during this time of year is to hold releases and generation at Fort Peck and Garrison at lower levels unless the evacuation of flood control storage space or the desire to balance storages between projects becomes an overriding consideration. With the end of the navigation season, conditions are reversed. Releases from Gavins Point drop to about half of summer levels and the chain reaction proceeds upstream, curtailing releases from Fort Randall, Big Bend, and Oahe. A means of partially compensating for the lesser amount of hydroelectric energy associated with lower winter release rates from Fort Randall and other mainstem reservoirs is the pre-winter drawdown of the Fort Randall reservoir. As part of this regulation, Oahe and Big Bend releases are reduced several weeks prior to the end of the navigation season. This leaves the Fort Randall reservoir in the position of supplying a majority of downstream releases requirements from accumulated storage, resulting in a lowering reservoir level. This vacated storage space is refilled during the winter months by releases from Oahe and Big Bend in excess of those that would have been possible if drawdown of the Fort Randall reservoir had not been made. At this time, Fort Peck and Garrison winter releases are usually maintained relatively higher levels as permitted by the downstream ice cover to partially compensate for the reduction in generation downstream.

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Exhibit A

Missouri River Mainstem Dams

Operational Restrictions and Best

Practices for Spillway Gates and

Outlet Tunnels

CENWO-ED-DF 14 April 2017

MEMORANDUM FOR CENWD-PDR

SUBJECT: Missouri River Mainstem Dams, Operational Restrictions and Best Practices

1. In response to your 7 March 2017 request regarding current gate restrictions and/or operating guidelines, this memorandum contains all known operating restrictions that have been enacted by Engineering Division for the mainstem dams. Additional guidance regarding best practices and/or special considerations at the mainstem dams is also provided. The references listed in enclosure 1 provide the basis for these operational restrictions, best practices, and special considerations. More detailed information may be found within these documents.

a) General Operational Restrictions and Best Practices:

(1) Operation of Adjacent Tainter Gates - Operation of the tainter gates shall be sequenced such that differences in openings between adjacent gates shall not exceed 6 feet at any time in order to avoid excessive eccentricity of load on the trunnion beam and anchors. (ref. 1)

(2) Operation Adjacent to a Dewatered Tainter Gate - Do not operate a tainter gate that is subject to hydrostatic load if it is adjacent to a dewatered gate in order to avoid excessive eccentricity of load on the trunnion beam and anchors. (ref. 1)

(3) Ice on or Adjacent to Spillway Gates - Spillway tainter gates and spillway vertical lift gates shall not be operated if ice is present on the gate or if there is lake ice adjacent to the gate. Operation of a gate with ice either on or adjacent to the gate would risk overstressing of steel members, overload of the hoist mechanism, and damage to the seals. (ref. 1)

(4) Overtopping of Spillway Gates – Releases shall be managed to prevent the reservoir from rising above the top of the tainter gates and vertical lift gates. Overtopping would increase stresses in the steel framing beyond the design forces. (ref. 1 & 2)

(5) Operation of Gates with Wave Splash Over - There is no restriction against operating gates while waves are splashing over the top of the gate if the average pool elevation is not above the top of the gate. (ref. 1)

(6) Operation of Spillway Gates with Exceptionally Large Waves - If possible, operation of the spillway gates should be postponed until exceptionally large waves have subsided. (ref.1)

b) Project Specific Operational Restrictions and Best Practices:

(1) Oahe Dam Tainter Gate Deflector Plates - Releases shall be managed to prevent the Oahe Reservoir from rising above the top of the tainter gates and onto the wave splash deflector plates. The deflector plates were added in 1994 to the top of the tainter gates to prevent wave splash-over from impacting the top girder on the downstream side of the gate. The deflector plates were not intended to allow pool elevations higher than the original top of gate. (ref. 3)

(2) Fort Peck Spillway Vertical Lift Gates - Operation of spillway gates 11, 12, 13 and 16 shall be restricted as much as possible until the counterweight plates connected to the lifting

chain on those gates have been replaced. Ultrasound inspection of those connectors observed internal delamination. (ref. 4)

(3) Fort Peck Outlet Tunnels - Previous studies have reported damage to the ring gates, shaft, and tunnels during releases through the outlet works. The studies also questioned the ability to place the emergency gates during flow conditions. It is recommended that ring gates should not be used except in a case of a dam safety emergency. Engineering Division shall be notified in advance of any planned releases through the outlet works. (ref. 5)

(4) Garrison Dam Outlet Regulating Gates - The regulating gates shall not be operated at or below the 6 inch open position. The regulating gates in tunnels no. 7 and 8 shall not be operated at an opening greater than 19.0 feet, except in an emergency and then the gate must be fully opened. The regulating gate in tunnel no. 6 shall not be operated at an opening greater than 23.5 feet. Hydraulic model testing revealed unstable flow conditions at certain openings. The O&M manual states that the controls for these gates have been set to prevent operation of these gates at the openings identified above. (ref. 7)

c) Project Specific Special Considerations:

(1) Gavins Point Lake Yankton Embankment - The Lake Yankton Embankment includes the original training dike which starts at the left spillway wall and extends approximately 3,400 feet downstream to the hydraulic fill section. The Lake Yankton Embankment impounds water for recreational use, but Lake Yankton also provides a stabilizing effect on the under seepage performance of the Gavins Point Dam Embankment. The loss of Lake Yankton could initiate rapid development of high exit gradients immediately downstream of the relief wells and potentially threaten the integrity of Gavins Point Dam. While a formal operational restriction is not recommended, releases from the Gavins Point spillway should be coordinated with Omaha District Dam Safety staff so that release does not compromise the integrity of the Lake Yankton Embankment. Integrity concerns for Lake Yankton Embankment could include scour due to high spillway releases, overtopping of the embankment or sudden drawdown stability concerns caused by significant reduction in spillway releases in a short time period. (ref. 8)

2. Point of contact for this memo is Wayne Boeck, Chief, Structural Section, (402) 995-2151, email Wayne.R.Boeck@usace.army.mil.

JOHN J. BERTINO, JR., P.E.
Chief, Engineering Division

Encl:
1. References

CF:
CEWNO-OD-GP (Becker)
CENWO-OD-FR (Curran)
CENWO-OD-BB
CENWO-OD-OA (Stasch)
CENWO-OD-GA (Lindquist)
CENWO-OD-FP (McMurry)

REFERENCES

1. *Missouri River Mainstem Dams, Spillway Gate Plan of Action*, Memorandum from CENWO-ED for CENWO-OD (10 March 2015)

2. *Overtopping of the Fort Peck Spillway Gates*, Memorandum from CENWO-ED-DA for CENWO-ED-G (22 December 1997)

3. *Design Report on Overtopping Tainter Gates/Oahe Tainter Gate Renovation* Memorandum from CEMRO-ED-DI for Commander, Missouri River Division)18 March 1994)

4. *Fort Peck Dam, Spillway Gate Operational Restrictions*, Memorandum from CENWO-ED for CENWO-OD (21 June 2016)

5. *Outlet Works Modifications, Fort Peck Dam, Major Rehabilitation Evaluation Report* (March 1994)

6. *Oahe Outlet Works Bridge Scour Monitoring Plan* ,CEBIS Bridge File (03 March 2012)

7. *Operation and Maintenance Manual, Garrison Dam,* Paragraph 5-04L *Regulating Gates and Associated Equipment* (1982)

8. *2011 Flood Surveillance and Assessment, Gavins Point Dam Missouri River* (March 2012)

Exhibit B

Emergency Regulation Procedures

for

Oahe Project

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, NORTHWESTERN DIVISION
1616 CAPITOL AVENUE
OMAHA NE 68102

REPLY TO
ATTENTION OF

CENWD-PDR (11-2-240a) 1 September 2017

MEMORANDUM FOR Oahe Operations Project Manager

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Oahe

1. Procedures applicable to the regulation of Oahe during any period that communication with the Missouri River Basin Water Management (MRBWM) Division or the Omaha District Water Control and Water Quality Section is not possible are outlined in the following paragraphs. These instructions supersede all previously furnished emergency regulation criteria.

2. Normally, reservoir regulation orders specifying future project releases and power production are furnished by the MRBWM office to Oahe. Oahe shall provide to the MRBWM project data such as observed reservoir elevations, releases, power generation and related hydrologic data.

3. The MRBWM office normally transmits the reservoir regulation orders via e-mail to Oahe on a daily basis. Regulation instructions for the weekend and holidays are contained in the previous normal working day's orders. Oahe utilizes the Power Plant Control System (PPCS) to transmit observed hourly and daily project data, via the Data Collection Platforms (DCPs) to the MRBWM office. If e-mail or network communication between the MRBWM office and Oahe is not available, an alternate means of communication and/or data transfer shall be used. Alternate means of communication includes facsimile (fax), land-line telephone, cellular telephone, relay of data by other Missouri River Mainstem project offices and utilization of Western Area Power Administration (Western) facilities.

4. When communication, as outlined in paragraph 3 above, cannot be established, the following will apply:

a. Every reasonable effort will be made to re-establish communication between Oahe and the MRBWM office.

b. During this initial period of communication failure, project personnel should note the reservoir elevations and releases on the latest regulation forecasts (three-week and monthly) if available. As long as reservoir elevations do not vary significantly from these regulation forecasts, the provision of the latest regulation order will be extended. Hourly powerplant loading will follow the Western loading schedule, if available. If the hourly schedule has not been received from Western, powerplant releases will be made to provide the daily energy schedule specified in the latest regulation order and will be patterned similar to recent experience. If significant variations occur from the current forecasts, follow procedures as outlined in 4.c. and 4.d.

c. Following a communications failure, the provision of the latest regulation order will be extended. Hourly powerplant loading will be as described in 4.b. If requested by Western, and if power emergency conditions have been declared, energy generation may be increased to the maximum allowable limit shown on the latest regulation order. These procedures will continue to be utilized until communications are re-established as long as the Oahe reservoir level remains below elevation 1608.0 feet.

d. If the Oahe reservoir level is above elevation 1608.0 feet, procedures outlined in paragraph 4.b. will be applicable during the first day of communication failure, after which conditions will be reviewed to determine if the release level should be changed. Procedures are as follows:

(1) Minimum release will be the release specified in the most recent available regulation order.

(2) The mean inflow for the preceding 24 hours will be estimated by computing the storage change during the 24-hour period on the basis of pool elevations observed at the damsite. Normally, the pool elevation will follow a relatively smooth curve. Therefore, any sudden fluctuations in the pool level recorder trace from a smooth curve (probably due to wind effects on the reservoir gage) should be disregarded and the storage change based on an extrapolation of the smoothed pool level curve through the 24-hour period. The approximate mean inflow in cfs is equivalent to the mean outflow in cfs plus one-half the storage change in acre-feet during the 24-hour period. Twenty-four hour inflow may also be approximated by the equation:

$$\text{Inflow} = \text{Outflow} + (182{,}000 \times \text{elevation change in feet})$$

(3) Utilizing the inflow as developed above and the current pool elevation as indicated by the smoothed pool level curve, determine the rule curve release by use of the emergency curves shown on Plate VII-1 in the Oahe Water Control Manual (WCM) and as Enclosure 1 to this document.

(4) If the rule curve release developed by (3) is greater than the release given by (1), make release specified by the appropriate rule curve. However, increases in release rates will be limited to twice the average rate for the preceding 24 hours.

(5) With an Oahe reservoir level at or below elevation 1617.0 feet, releases will be limited to the capacity of the available powerplant units.

(6) With an Oahe pool between elevations 1617.0 and 1620.0 feet, releases will be limited to the combined capacity of all available power units and the total discharge capacity of the outlet works tunnels.

(7) With an Oahe pool between elevations 1620.0 and 1625.0 feet, a total release of 170,000 cfs will be maintained. Spillway gate openings will be required, but only as necessary to prevent spilling over the top of the gates. Reductions in outlet releases will be made to compensate for spillway gate openings to maintain total releases specified.

(8) With Oahe at or above elevation 1625.0 feet, spillway gates will be fully opened and outlet gates closed. Total release will consist of the combined capacity of all available powerplant units and the spillway.

(9) The following criteria will govern operation of the Oahe spillway gates:

(a) All gates will be operated at a uniform gate setting.

(b) Gates will be opened in the following sequence: 3, 5, 4, 6, 1, 2, 7 and 8.

(c) With a five foot opening or less, the maximum increment of opening is two feet. From a five foot to a 12 foot gate opening, the opening increment is limited to one foot. Beyond an opening of 12 feet, the spillway gates will be operated in one increment to the full opening of 45.5 feet.

(d) Closing of gates will be in a reverse sequence to that given in paragraph (b) with incremental closings similar to the openings specified in (c).

(10) With an Oahe pool below elevation 1617.0 feet, any release adjustments made necessary by these instructions should be made once daily. With an Oahe pool above elevation 1617.0 feet, the analysis and necessary adjustments should be at intervals of 12 hours or less.

(11) If release is less than full powerplant capability, powerplant loading will be patterned similar to recent experience or as prescribed by Western if communication with their System Operations Office is possible.

5. In the event of downstream flooding, as reported to or anticipated by the Oahe Operations Project Manager, releases will be reduced as deemed necessary to alleviate these conditions. However, with the Oahe reservoir above elevation 1617.0 feet, releases will not be reduced below those levels defined by the preceding emergency instructions.

6. The foregoing procedures are not intended to relieve the Oahe Operations Project Manager of taking such additional measures believed necessary to assure the safety of the project.

// signed copy on file

JODY S. FARHAT, P.E.
Chief, Missouri River Basin Water
Management Division

Encl

Oahe Dam – Lake Oahe

Water Control Manual

Plates

Summary of Engineering Data -- Missouri River Mainstem System

Item No.	Subject	Fort Peck Dam - Fort Peck Lake	Garrison Dam - Lake Sakakawea	Oahe Dam - Lake Oahe
1	Location of Dam	Near Glasgow, Montana	Near Garrison, ND	Near Pierre, SD
2	River Mile - 1960 Mileage	Mile 1771.5	Mile 1389.9	Mile 1072.3
3	Total & incremental drainage areas in square miles	57,500	181,400 (2) 123,900	243,490 (1) 62,090
4	Approximate length of full reservoir (in valley miles)	134, ending near Zortman, MT	178, ending near Trenton, ND	231, ending near Bismarck, ND
5	Shoreline in miles (3)	1520 (elevation 2234)	1340 (elevation 1837.5)	2250 (elevation 1607.5)
6	Average total & incremental inflow in cfs	10,200	25,600 15,400	28,900 3,300
7	Max. discharge of record near damsite in cfs	137,000 (June 1953)	348,000 (April 1952)	440,000 (April 1952)
8	Construction started - calendar yr.	1933	1946	1948
9	In operation (4) calendar yr.	1940	1955	1962
	Dam and Embankment			
10	Top of dam, elevation in feet msl	2280.5	1875	1660
11	Length of dam in feet	21,026 (excluding spillway)	11,300 (including spillway)	9,300 (excluding spillway)
12	Damming height in feet (5)	220	180	200
13	Maximum height in feet (5)	250.5	210	245
14	Max. base width, total & w/o berms in feet	3500, 2700	3400, 2050	3500, 1500
15	Abutment formations (under dam & embankment)	Bearpaw shale and glacial fill	Fort Union clay shale	Pierre shale
16	Type of fill	Hydraulic & rolled earth fill	Rolled earth filled	Rolled earth fill & shale berms
17	Fill quantity, cubic yards	125,628,000	66,500,000	55,000,000 & 37,000,000
18	Volume of concrete, cubic yards	1,200,000	1,500,000	1,045,000
19	Date of closure	24 June 1937	15 April 1953	3 August 1958
	Spillway Data			
20	Location	Right bank - remote	Left bank - adjacent	Right bank - remote
21	Crest elevation in feet msl	2225	1825	1596.5
22	Width (including piers) in feet	820 gated	1336 gated	456 gated
23	No., size and type of gates	16 - 40' x 25' vertical lift gates	28 - 40' x 29' Tainter	8 - 50' x 23.5' Tainter
24	Design discharge capacity, cfs	275,000 at elev 2253.3	827,000 at elev 1858.5	304,000 at elev 1644.4
25	Discharge capacity at maximum operating pool in cfs	230,000	660,000	80,000
	Reservoir Data (6)			
26	Max. operating pool elev. & area	2250 msl 245,000 acres	1854 msl 383,000 acres	1620 msl 386,000 acres
27	Max. normal op. pool elev. & area	2246 msl 240,000 acres	1850 msl 365,000 acres	1617 msl 362,000 acres
28	Base flood control elev & area	2234 msl 211,000 acres	1837.5 msl 308,000 acres	1607.5 msl 311,000 acres
29	Min. operating pool elev. & area	2160 msl 89,000 acres	1775 msl 125,000 acres	1540 msl 115,000 acres
	Storage allocation & capacity			
30	Exclusive flood control	2250-2246 971,000 a.f.	1854-1850 1,495,000 a.f.	1620-1617 1,107,000 a.f.
31	Flood control & multiple use	2246-2234 2,704,000 a.f.	1850-1837.5 4,211,000 a.f.	1617-1607.5 3,208,000 a.f.
32	Carryover multiple use	2234-2160 10,700,000 a.f.	1837.5-1775 12,951,000 a.f.	1607.5-1540 13,353,000 a.f.
33	Permanent	2160-2030 4,088,000 a.f.	1775-1673 4,794,000 a.f.	1540-1415 5,315,000 a.f.
34	Gross	2250-2030 18,463,000 a.f.	1854-1673 23,451,000 a.f.	1620-1415 22,983,000 a.f.
35	Reservoir filling initiated	November 1937	December 1953	August 1958
36	Initially reached min. operating pool	27 May 1942	7 August 1955	3 April 1962
37	Estimated annual sediment inflow	17,200 a.f./year 1073 yrs.	21,600 a.f./year 1,086 yrs.	14,800 a.f./year 1553 yrs.
	Outlet Works Data			
38	Location	Right bank	Right Bank	Right Bank
39	Number and size of conduits	2 - 24' 8" diameter (nos. 3 & 4)	1 - 26' dia. and 2 - 22' dia.	6 - 19.75' dia. upstream, 18.25' dia. downstream
40	Length of conduits in feet (8)	No. 3 - 6,615, No. 4 - 7,240	1529	3496 to 3659
41	No., size, and type of service gates	1 - 28' dia. cylindrical gate 6 ports, 7.6' x 8.5' high (net opening) in each control shaft	1 - 18' x 24.5' Tainter gate per conduit for fine regulation	1 - 13' x 22' per conduit, vertical lift, 4 cable suspension and 2 hydraulic suspension (fine regulation)
42	Entrance invert elevation (msl)	2095	1672	1425
43	Avg. discharge capacity per conduit & total	Elev. 2250 22,500 cfs - 45,000 cfs	Elev. 1854 30,400 cfs - 98,000 cfs	Elev. 1620 18,500 cfs - 111,000 cfs
44	Present tailwater elevation (ft msl)	2032-2036 5,000 - 35,000 cfs	1669-1677 15,000- 60,000 cfs	1422-1427 20,000-55,000 cfs
	Power Facilities and Data			
45	Avg. gross head available in feet (14)	194	161	174
46	Number and size of conduits	No. 1-24'8" dia., No. 2-22'4" dia.	5 - 29' dia., 24' penstocks	7 - 24' dia., imbedded penstocks
47	Length of conduits in feet (8)	No. 1 - 5,653, No. 2 - 6,355	1829	From 3,280 to 4,005
48	Surge tanks	PH#1: 3-40' dia., PH#2: 2-65' dia.	65' dia. - 2 per penstock	70' dia., 2 per penstock
49	No., type and speed of turbines	5 Francis, PH#1-2: 128.5 rpm, 1-164 rpm , PH#2-2: 128.6 rpm	5 Francis, 90 rpm	7 Francis, 100 rpm
50	Discharge cap. at rated head in cfs	PH#1, units 1&3 170', 2-140' 8,800 cfs, PH#2-4&5 170'-7,200 cfs	150' 41,000 cfs	185' 54,000 cfs
51	Generator nameplate rating in kW	1&3: 43,500; 2: 18,250; 4&5: 40,000	3 - 121,600, 2 - 109,250	112,290
52	Plant capacity in kW	185,250	583,300	786,030
53	Dependable capacity in kW (9)	181,000	388,000	534,000
54	Avg. annual energy, million kWh (12)	1,035	2,254	2,622
55	Initial generation, first and last unit	July 1943 - June 1961	January 1956 - October 1960	April 1962 - June 1963
56	Estimated cost September 1999 completed project (13)	$158,428,000	$305,274,000	$346,521,000

Summary of Engineering Data -- Missouri River Mainstem System

	Big Bend Dam - Lake Sharpe	Fort Randall Dam - Lake Francis Case	Gavins Point Dam - Lewis & Clark Lake	Total	Item No.	Remarks
	21 miles upstream Chamberlain, SD	Near Lake Andes, SD	Near Yankton, SD		1	(1) Includes 4,280 square miles of non-contributing areas.
	Mile 987.4	Mile 880.0	Mile 811.1		2	
	249,330 (1) 5,840	263,480 (1) 14,150	279,480 (1) 16,000		3	
	80, ending near Pierre, SD	107, ending at Big Bend Dam	25, ending near Niobrara, NE	755 miles	4	(2) Includes 1,350 square miles of non-contributing areas.
	200 (elevation 1420)	540 (elevation 1350)	90 (elevation 1204.5)	5,940 miles	5	(3) With pool at base of flood control.
	28,900	30,000 1,100	32,000 2,000		6	
	440,000 (April 1952)	447,000 (April 1952)	480,000 (April 1952)		7	(4) Storage first available for regulation of flows.
	1959	1946	1952		8	(5) Damming height is height from low water to maximum operating pool. Maximum height is from average streambed to top of dam.
	1964	1953	1955		9	
	1440	1395	1234		10	
	10,570 (including spillway)	10,700 (including spillway)	8,700 (including spillway)	71,596	11	(6) Based on latest available storage data.
	78	140	45	863 feet	12	
	95	165	74		13	(7) River regulation is attained by flows over low-crested spillway and through turbines.
	1200, 700	4300, 1250	850, 450		14	
	Pierre shale & Niobrara chalk	Niobrara chalk	Niobrara chalk & Carlile shale		15	
	Rolled earth, shale, chalk fill	Rolled earth fill & chalk berms	Rolled earth & chalk fill		16	(8) Length from upstream face of outlet or to spiral case.
	17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds	17	(9) Based on 8th year (1961) of drought drawdown (From study 8-83-1985).
	540,000	961,000	308,000	5,554,000 cu. yds.	18	
	24 July 1963	20 July 1952	31 July 1955		19	
	Left bank - adjacent	Left bank - adjacent	Right bank - adjacent		20	(10) Affected by level of Lake Francis case. Applicable to pool at elevation 1350.
	1385	1346	1180		21	
	376 gated	1000 gated	664 gated		22	(11) Spillway crest.
	8 - 40' x 38' Tainter	21 - 40' x 29' Tainter	14 - 40' x 30' Tainter		23	(12) 1967-2015 Average
	390,000 at elev 1433.6	620,000 at elev 1379.3	584,000 at elev 1221.4		24	(13) Source: Annual Report on Civil Works Activities of the Corps of Engineers. Extract Report Fiscal Year 1999.
	270,000	508,000	345,000		25	
	1423 msl 62,000 acres	1375 msl 102,000 acres	1210 msl 29,000 acres	1,206,000 acres	26	(14) Based on Study 8-83-1985
	1422 msl 60,000 acres	1365 msl 94,000 acres	1208 msl 25,000 acres	1,146,000 acres	27	
	1420 msl 58,000 acres	1350 msl 76,000 acres	1204.5 msl 21,000 acres	984,000 acres	28	
	1415 msl 51,000 acres	1320 msl 36,000 acres	1204.5 msl 21,000 acres	437,000 acres	29	
	1423-1422 61,000 a.f.	1375-1365 986,000 a.f.	1210-1208 54,000 a.f.	4,674,000 a.f.	30	
	1422-1420 118,000 a.f.	1365-1350 1,306,000 a.f.	1208-1204.5 79,000 a.f.	11,626,000 a.f.	31	
		1350-1320 1,532,000 a.f.		38,536,000 a.f.	32	
	1420-1345 1,631,000 a.f.	1320-1240 1,469,000 a.f.	1204.5-1160 295,000 a.f.	17,592,000 a.f.	33	
	1423-1345 1,810,000 a.f.	1375-1240 5,293,000 a.f.	1210-1160 428,000 a.f.	72,428,000 a.f.	34	
	November 1963	January 1953	August 1955		35	
	25 March 1964	24 November 1953	22 December 1955		36	
	3,445 a.f./year 525 yrs.	15,800 a.f./year 334 yrs.	2,700 a.f./year 159 yrs.	77,400	37	
		Left Bank			38	
	None (7)	4 - 22' diameter	None (7)		39	
		1013			40	
		2 - 11' x 23' per conduit, vertical lift, cable suspension			41	
	1385 (11)	1229	1180 (11)		42	
		Elev 1375			43	
	1351-1355(10) 25,000-100,000 cfs	32,000 cfs - 128,000 cfs 1228-1237 10,000-60,000 cfs	1153-1161 15,000-60,000 cfs		44	
	70	117	48	764 feet	45	
	None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46	
		1,074		55,083	47	
	None	59' dia, 2 per alternate penstock	None		48	
	8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49	
	67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50	
	67,275	40,000	44,100		51	
	517,470	320,000	132,300	2,501,200 kw	52	
	497,000	293,000	74,000	1,967,000 kw	53	Corps of Engineers, U.S. Army
	980	1,726	725	9,342 million kWh	54	Compiled by
	October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1943 - July 1966	55	Northwestern Division
	$107,498,000	$199,066,000	$49,617,000	$1,166,404,000	56	Missouri River Region December 2016

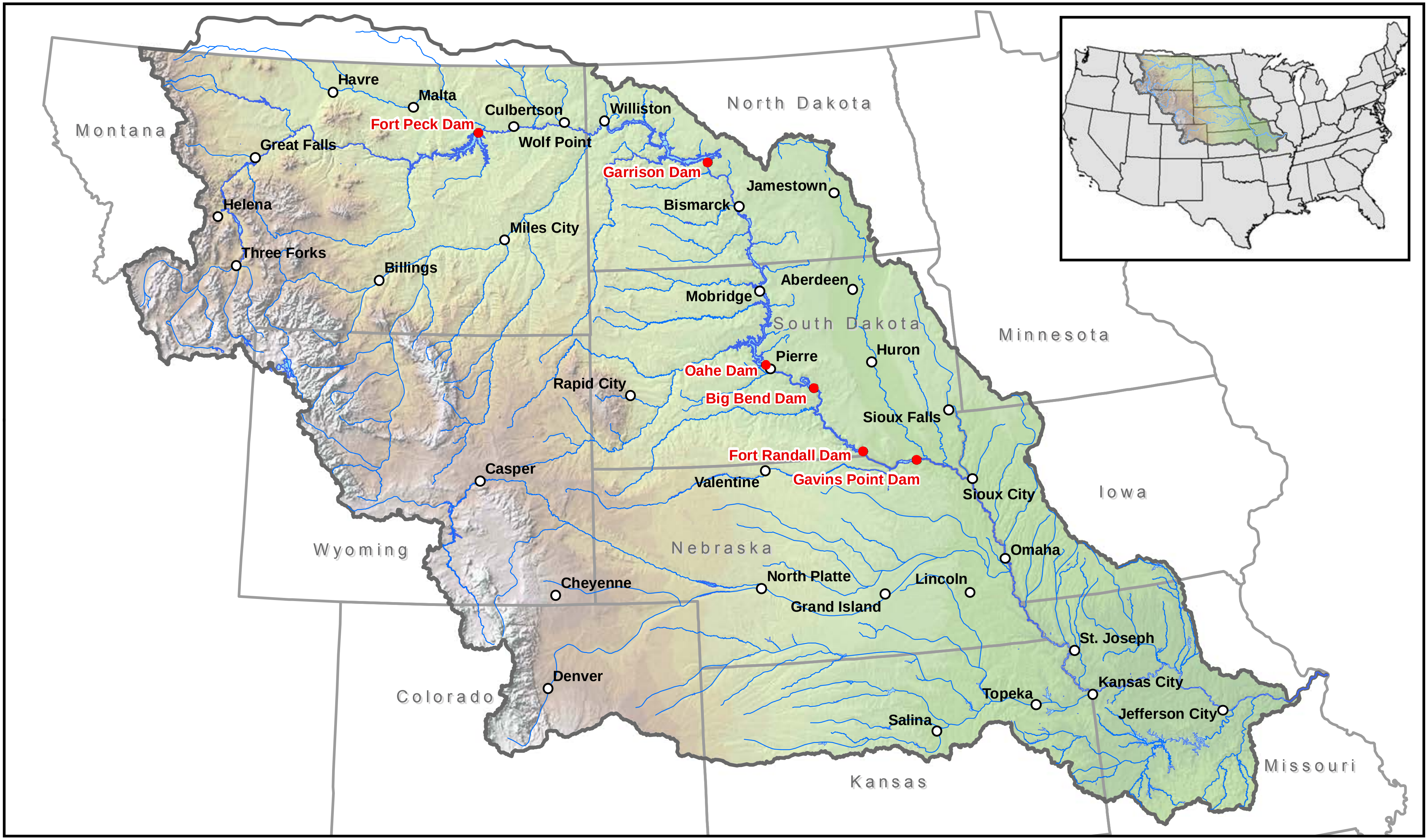

Plate III-1

US Army Corps of Engineers®
Northwestern Division

Missouri River Basin
GENERAL LOCATION
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

River	Drainage Area (sq.mi.)
Grand River	5200
Moreau River	5400
Cheyenne River	25500
Cannonball River	4310
Knife River	2510
Heart River	3340
Oak Creek	380
Other	15450
Total	62090

Plate III-2

US Army Corps of Engineers®
Northwestern Division

Missouri River Basin
OAHE DRAINAGE AREA
INCREMENTAL DRAINAGE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-3

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Oahe Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 25 50 100 150 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
OAHE DRAINAGE AREA
LAND USE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-4

US Army Corps of Engineers®
Northwestern Division

- Mainstem Dam
- Cities
- Rivers
- Reservoirs/Lakes
- Omaha/Kansas City District Boundaries
- State Boundaries

Average Precipitation - Annual

- < 8.0"
- 8.0" - 20.0"
- 20.0" - 40.0"
- 40.0" - 60.0"
- > 60.0"

0 50 100 200 300 Miles

N E S W

Data Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
AVERAGE PRECIPITATION
ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

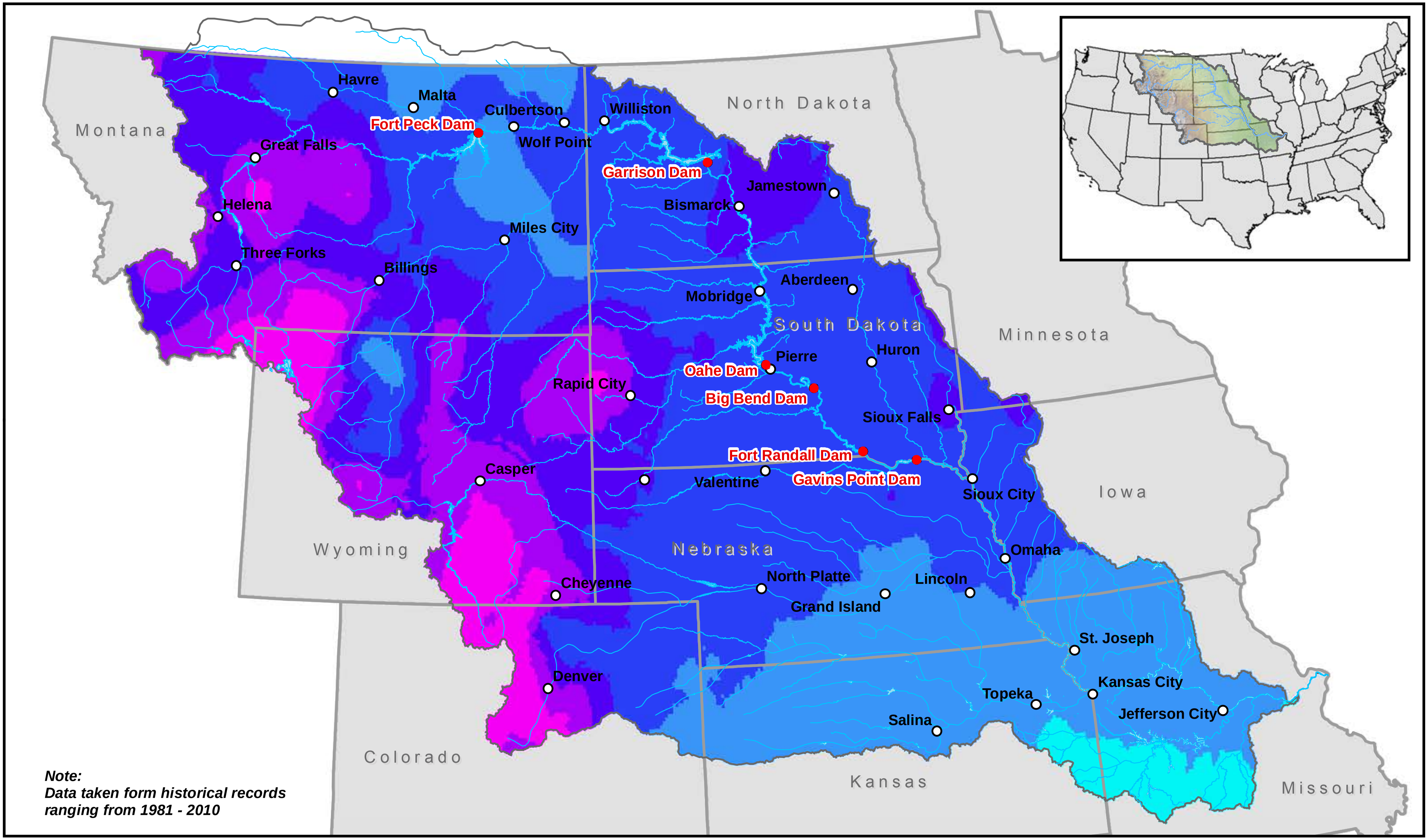

Plate III-5

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Annual Mean Snowfall
< 12 Inches
12 - 24 Inches
24 - 36 Inches
36 - 48 Inches
48 - 72 Inches
> 72 Inches

0 50 100 200 300 Miles

N W E S

Data Source:
http://scacis.rcc-acis.org

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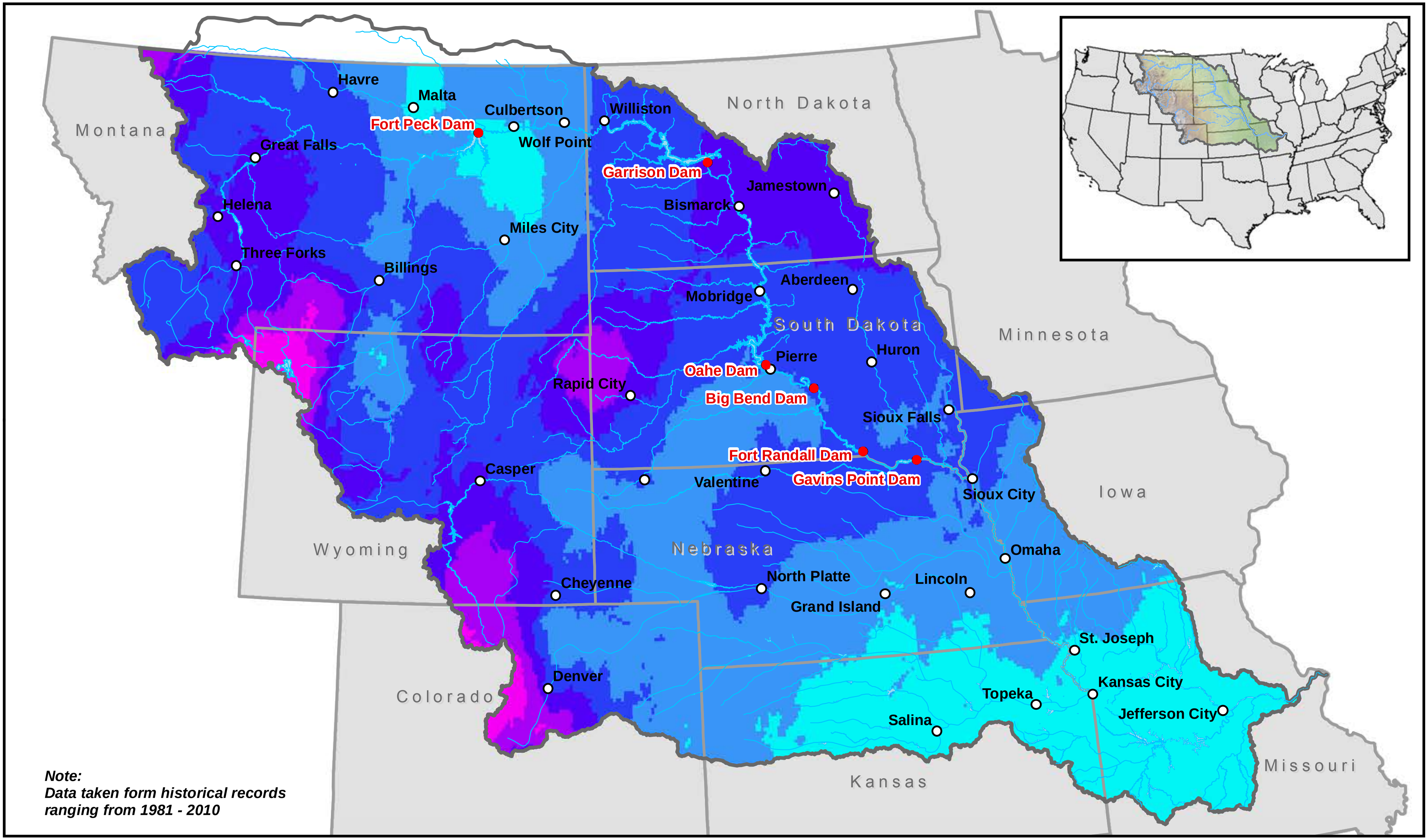
Missouri River Basin
ANNUAL MEAN SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Note:
Data taken form historical records ranging from 1981 - 2010

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Annual Maximum Snowfall
- < 40 Inches
- 40 - 60 Inches
- 60 - 80 Inches
- 80 - 110 Inches
- 110 - 150 Inches
- > 150 Inches

0 50 100 200 300 Miles

N W E S

Data Source:
http://scacis.rcc-acis.org

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Missouri River Basin
ANNUAL MAXIMUM SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

US Army Corps of Engineers®
Northwestern Division

Plate III-6

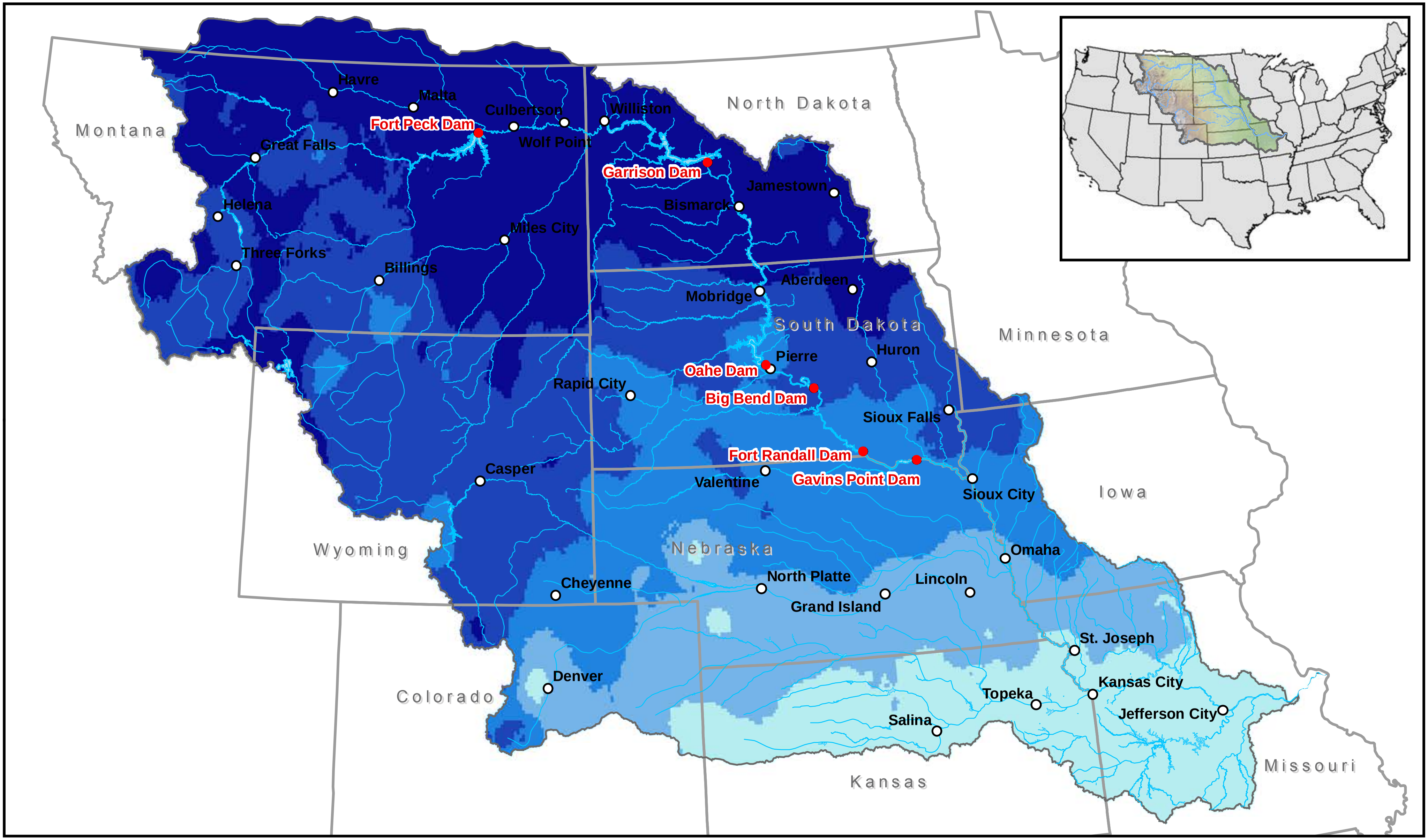
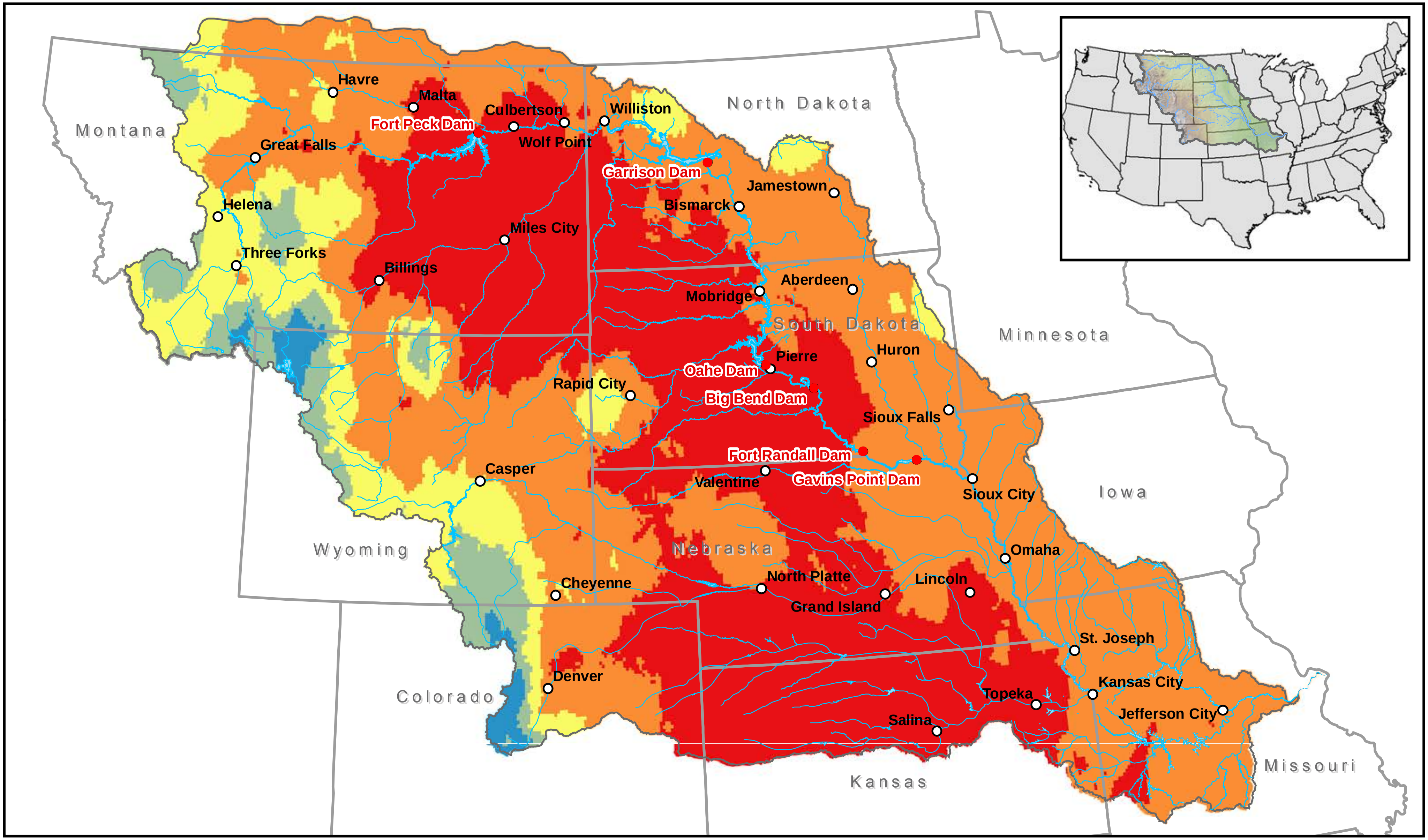


Plate III-7

US Army Corps of Engineers®
Northwestern Division

Missouri River Basin
AVERAGE MINIMUM TEMPERATURE
ANNUAL
U.S. Army Engineer Division,
Northwestern Corps of Engineers, Omaha,
Nebraska September 2017



Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Average Maximum Temperature

- 78°F - 85°F
- 85°F - 90°F
- 90°F - 95°F
- 95°F - 100°F
- 100°F - 105.5°F

0 50 100 200 300 Miles

N W E S

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
AVERAGE MAXIMUM TEMPERATURE
ANNUAL

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

US Army Corps of Engineers®
Northwestern Division

Plate III-8

Missouri River Mainstem Reservoir System

Normal Monthly Pan Evaporation
Inches of Depth

Month	Missouri River Mainstem Project					
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
January	0.62	0.51	1.02	0.80	1.02	0.74
February	0.74	0.58	1.14	0.98	1.16	0.91
March	1.68	1.42	2.24	1.97	2.31	1.91
April	3.50	2.79	4.70	4.48	4.27	4.19
May	6.96	6.35	7.80	7.83	6.74	7.30
June	8.05	7.07	8.51	8.47	7.54	8.30
July	10.45	8.97	10.74	10.85	9.00	9.64
August	10.22	8.56	10.44	10.31	8.13	8.41
September	5.97	6.63	7.25	7.26	5.07	5.57
October	4.03	4.07	4.92	4.06	4.42	4.46
November	1.96	1.38	2.25	1.83	2.34	1.79
December	0.83	0.70	1.19	1.04	1.24	0.87
Annual	55.01	49.03	62.20	59.88	53.24	54.09

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 9.

Normal values in the above table were defined by all available pan data through the years 1963-1972. During months pan data were not available, pan depths were computed by a mass-transfer equation assuming pan water temperature to be equivalent to air temperature. Values given are for current pan installations and include depths for Oahe and Big Bend, which are believed to be unrepresentative. Adjustments for Oahe and Big Bend are accounted for in the lake evaporation coefficients table (Plate III-10).

Missouri River Basin

Oahe Water Control Manual
Normal Monthly Pan Evaporation
in Inches

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Missouri River Mainstem Reservoir System

Normal Pan to Lake Evaporation Coefficients

Month	Missouri River Mainstem Project					
	Fort Peck	**Garrison**	**Oahe**	**Big Bend**	**Fort Randall**	**Gavins Point**
January	1.28	0.70	0.73	0.63	0.70	0.70
February	0.70	0.70	0.56	0.63	0.70	0.70
March	0.60	0.70	0.49	0.54	0.63	0.62
April	0.11	0.14	0.13	0.47	0.19	0.53
May	0.22	0.20	0.16	0.35	0.32	0.53
June	0.32	0.21	0.18	0.39	0.37	0.53
July	0.39	0.26	0.22	0.53	0.42	0.56
August	0.64	0.64	0.50	0.70	0.78	0.70
September	1.21	1.13	0.89	0.82	1.31	0.93
October	1.32	1.44	1.19	1.05	1.42	0.97
November	2.57	3.74	2.22	1.52	1.62	1.59
December	4.22	5.04	3.42	1.36	1.39	1.57

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 11.

These coefficients are applicable to the pan installations currently in operation in conjunction with the projects. They make allowances for the fact that the Oahe and Big Bend installations are not considered to be representative installations. If pan evaporation is available, lake evaporation depths are estimated by application of the above coefficients.

For example: Oahe, May = 7.80 in (Plate III-9) x 0.16 (Plate III-10) = 1.25 in (Plate III-11).

Missouri River Basin
Oahe Water Control Manual
Pan to Lake Evaporation Coefficients

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Missouri River Mainstem Reservoir System

Normal Monthly Lake Evaporation
Inches of Depth

Month	Missouri River Mainstem Project					
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
January	0.79	0.36	0.74	0.50	0.71	0.52
February	0.52	0.41	0.64	0.62	0.81	0.64
March	1.01	0.99	1.10	1.06	1.46	1.18
April	0.38	0.39	0.61	2.11	0.81	2.22
May	1.53	1.27	1.25	2.74	2.16	3.87
June	2.58	1.48	1.53	3.30	2.79	4.40
July	4.08	2.33	2.36	5.75	3.78	5.41
August	6.54	5.48	5.22	7.22	6.34	5.89
September	7.22	7.49	6.45	5.95	6.64	5.18
October	5.32	5.86	5.85	4.26	6.28	4.33
November	5.04	5.16	5.00	2.78	3.79	2.85
December	3.50	3.53	4.07	1.41	1.72	1.37
Annual	38.51	34.75	34.82	37.70	37.29	37.85

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 12.

Normal depths for each project as shown above were developed by application of the normal pan to lake coefficients in Plate III-10 to the normal monthly pan evaporation as shown on Plate III-9.

Missouri River Basin
Oahe Water Control Manual
Normal Monthly Lake Evaporation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Missouri River Mainstem Reservoir System

Normal Monthly Lake Evaporation
in 1000 Acre-Feet

Month	Missouri River Mainstem Project						System
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	
January	14	9	19	2	5	1	50
February	9	11	17	3	5	1	46
March	18	26	29	5	10	3	91
April	7	10	16	10	5	5	53
May	27	33	33	13	14	8	128
June	46	39	40	16	19	10	170
July	73	61	62	27	25	12	260
August	117	144	136	34	42	13	486
September	129	167	168	28	44	11	547
October	95	154	153	20	42	9	473
November	90	135	130	13	25	6	399
December	63	93	106	7	11	3	283
Annual	688	882	909	178	247	82	2,986

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 13.

Volumes computed by assuming that each reservoir was at the base of its flood control pool.

Missouri River Basin
Oahe Water Control Manual
Normal Monthly Lake Evaporation
in 1000 AF

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Monthly Runoff - Missouri River Basin Upstream of Oahe Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

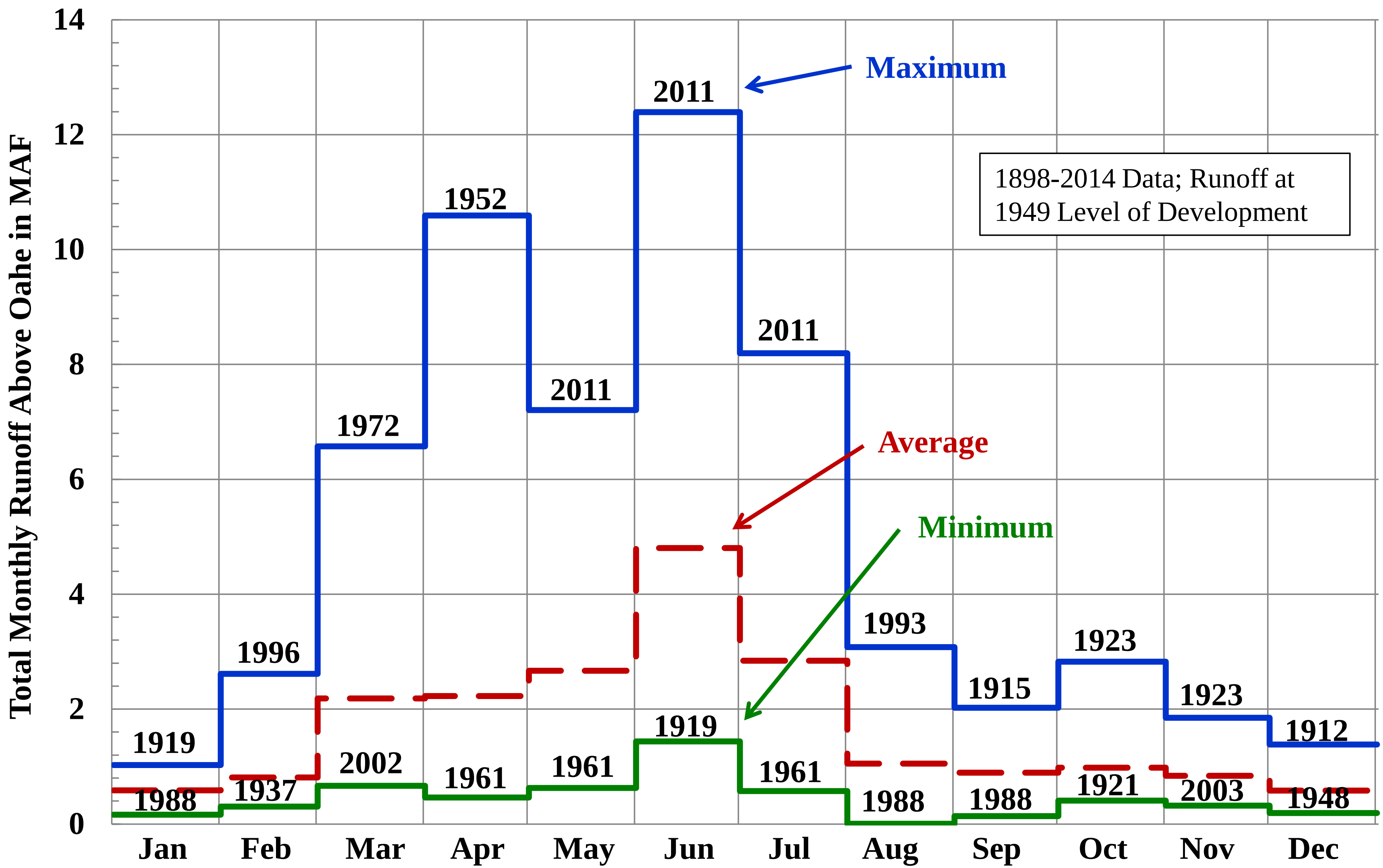
	Runoff in 1,000 acre-feet												Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1898	466	680	2,002	2,482	3,814	7,512	3,568	950	878	857	828	505	24,542	19,378
1899	516	548	1,992	4,477	3,148	7,272	6,113	1,341	974	777	898	505	28,561	23,002
1900	551	742	2,676	1,991	3,544	4,644	1,394	495	755	886	702	507	18,887	14,249
1901	492	536	1,936	1,313	4,649	4,675	2,168	631	1,287	901	673	494	19,755	14,741
1902	506	655	2,430	1,091	2,491	4,296	2,156	745	1,054	872	769	468	17,533	12,464
1903	520	756	1,799	1,827	1,936	4,717	2,942	1,170	1,527	1,151	829	623	19,797	13,221
1904	630	807	1,892	2,293	3,368	6,083	3,159	1,120	999	742	656	454	22,203	16,795
1905	457	643	1,879	1,001	1,438	4,505	2,810	859	635	500	595	536	15,858	11,633
1906	506	542	1,790	1,808	3,031	5,960	2,691	1,243	1,881	1,220	1,005	705	22,382	15,280
1907	729	669	2,060	1,622	3,025	6,927	6,826	2,189	1,278	1,494	1,315	740	28,874	20,460
1908	677	815	2,130	1,954	2,817	8,573	4,801	1,621	1,059	1,128	1,132	1,055	27,762	20,275
1909	756	851	1,993	1,610	3,163	9,238	5,089	1,664	1,529	1,095	892	573	28,453	21,093
1910	624	792	2,786	2,570	3,789	3,810	1,755	886	716	758	690	434	19,610	14,710
1911	417	552	1,601	1,309	1,837	5,768	2,731	1,371	1,825	1,319	811	642	20,183	13,246
1912	657	643	2,261	3,645	3,314	5,867	4,164	1,938	1,986	1,737	1,533	1,385	29,130	19,251
1913	921	605	1,381	2,549	3,156	6,795	3,148	1,715	1,507	1,304	1,278	1,077	25,436	17,029
1914	785	738	2,119	1,950	3,688	6,282	2,237	885	1,226	1,315	1,613	871	23,709	16,276
1915	875	839	2,029	2,112	2,679	5,746	3,979	1,797	2,022	1,829	1,291	822	26,020	16,545
1916	690	970	3,991	2,164	2,808	6,343	5,493	1,642	1,041	1,168	1,167	688	28,165	20,799
1917	710	801	2,246	3,857	4,028	7,320	5,026	1,270	1,262	1,178	1,190	707	29,595	22,477
1918	766	831	2,757	2,491	2,603	6,444	3,027	1,323	1,097	689	713	442	23,183	17,322
1919	1,028	761	1,765	1,815	1,783	1,436	649	325	304	434	405	438	11,143	7,448
1920	448	774	2,749	2,130	3,743	6,230	3,580	1,116	766	636	679	758	23,609	18,432
1921	524	737	2,106	1,769	2,685	6,521	2,227	676	655	406	515	460	19,281	15,308
1922	467	794	2,297	1,991	3,382	6,355	2,332	972	776	609	781	434	21,190	16,357
1923	447	700	1,870	2,400	2,684	4,666	4,575	1,349	1,243	2,824	1,850	1,181	25,789	16,195
1924	923	1,353	2,269	3,654	3,563	4,380	2,359	845	791	1,125	1,193	710	23,165	16,225
1925	828	1,351	2,392	2,523	3,247	6,170	3,273	1,162	839	1,089	998	693	24,565	17,605
1926	698	1,061	1,878	2,035	3,441	3,134	2,205	1,053	1,465	1,264	938	581	19,753	12,693
1927	585	983	2,821	3,130	4,725	8,944	4,342	2,010	1,838	1,418	1,027	778	32,601	23,962
1928	719	963	2,815	2,061	4,844	5,665	4,782	1,422	1,085	899	906	556	26,717	20,167
1929	528	535	3,071	2,136	2,789	4,576	2,447	739	669	902	696	446	19,534	15,019
1930	485	1,025	2,394	2,515	2,138	2,501	1,177	1,153	847	967	644	434	16,280	10,725
1931	444	678	900	897	1,077	2,064	685	611	414	561	403	359	9,093	5,623
1932	362	390	1,184	2,169	2,567	5,054	1,966	988	704	698	501	305	16,888	12,940
1933	498	392	2,090	1,200	3,187	4,340	1,271	695	922	639	760	338	16,332	12,088
1934	581	737	1,349	1,285	1,503	1,602	613	399	318	514	534	269	9,704	6,352
1935	289	536	827	1,237	1,282	3,830	2,218	651	476	496	352	407	12,601	9,394
1936	348	355	1,825	1,634	1,961	2,275	911	635	458	631	617	446	12,096	8,606
1937	306	302	1,012	1,302	1,163	3,560	2,053	574	420	659	385	321	12,057	9,090

Monthly Runoff - Missouri River Basin Upstream of Oahe Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

	Runoff in 1,000 acre-feet												Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1938	454	399	2,116	964	1,863	5,186	3,703	760	779	707	516	247	17,694	13,832
1939	623	379	3,878	922	2,220	3,306	1,231	551	512	678	603	502	15,405	11,557
1940	361	460	748	1,438	1,696	2,397	877	440	454	891	379	641	10,782	7,156
1941	488	506	863	1,402	1,330	3,804	1,123	904	1,301	1,455	948	726	14,850	8,522
1942	558	663	1,708	2,047	3,715	5,546	2,388	881	601	795	767	573	20,242	15,404
1943	675	1,635	3,495	5,304	2,444	7,343	4,136	1,355	877	956	960	442	29,622	22,722
1944	635	677	1,616	4,163	2,021	7,385	3,423	1,087	765	829	908	415	23,924	18,608
1945	629	1,073	3,411	1,274	1,472	4,051	2,842	1,135	808	926	710	596	18,927	13,050
1946	790	770	1,856	1,219	1,898	3,619	2,321	667	958	1,206	787	772	16,863	10,913
1947	703	1,039	3,545	3,218	3,435	5,368	2,949	1,186	847	1,144	683	607	24,724	18,515
1948	661	657	2,387	3,317	3,128	6,899	3,185	1,122	627	904	788	192	23,867	18,916
1949	593	570	3,223	3,955	2,440	3,228	1,515	586	517	863	956	372	18,818	14,361
1950	485	633	1,707	6,991	2,604	4,279	3,096	1,429	1,097	1,278	614	831	25,044	18,677
1951	860	706	1,567	3,936	2,706	3,943	2,709	1,659	1,487	1,416	896	366	22,251	14,861
1952	697	1,061	1,252	10,591	4,018	3,638	2,097	998	745	748	687	466	26,998	21,596
1953	648	758	1,496	1,161	2,046	8,105	2,339	1,060	680	763	845	520	20,421	15,147
1954	466	1,126	1,163	2,055	2,007	2,680	2,329	1,118	877	867	918	486	16,092	10,234
1955	351	528	1,013	2,419	2,190	3,064	2,215	827	525	693	429	680	14,934	10,901
1956	793	601	1,995	1,982	2,213	4,746	1,900	977	771	670	885	496	18,029	12,836
1957	421	536	1,455	1,367	2,619	5,102	2,876	758	859	936	1,030	765	18,724	13,419
1958	480	522	1,314	1,637	1,856	3,479	1,990	759	636	769	687	612	14,741	10,276
1959	575	550	3,500	1,603	1,536	3,466	2,305	632	643	1,099	689	1,211	17,809	12,410
1960	537	845	2,892	2,529	1,591	2,175	732	483	468	547	590	254	13,643	9,919
1961	567	614	1,047	462	627	2,389	572	378	709	843	914	204	9,326	5,097
1962	532	1,060	1,269	1,919	3,034	5,735	3,540	1,287	834	1,023	796	456	21,485	15,497
1963	404	1,221	1,691	1,121	1,880	5,176	2,316	767	880	822	636	224	17,138	12,184
1964	507	634	810	1,164	2,695	6,719	4,107	749	916	821	628	421	20,171	15,495
1965	869	897	1,164	3,604	4,052	5,813	5,278	1,651	1,247	1,470	1,085	815	27,945	19,911
1966	409	693	3,235	1,798	1,657	2,065	1,610	578	701	668	808	556	14,778	10,365
1967	463	962	2,360	2,261	2,993	8,397	4,936	1,030	987	982	1,098	352	26,821	20,947
1968	753	857	2,199	1,255	1,514	5,113	3,009	1,451	1,517	1,193	1,192	650	20,703	13,090
1969	661	797	2,825	4,469	3,140	3,189	4,452	974	697	808	967	654	23,633	18,075
1970	286	842	1,284	2,032	4,708	5,974	3,537	1,005	971	1,106	947	643	23,335	17,535
1971	648	2,021	3,371	3,172	3,178	6,007	3,675	1,166	1,215	1,591	1,108	555	27,707	19,403
1972	621	990	6,575	1,748	3,109	5,783	2,435	1,610	1,084	1,130	1,265	589	26,939	19,650
1973	918	851	1,959	1,353	2,605	3,289	1,709	799	1,256	1,114	935	789	17,577	10,915
1974	751	1,023	1,414	1,886	2,505	5,520	3,612	1,224	997	825	986	809	21,552	14,937
1975	294	509	1,498	3,570	6,556	6,431	6,569	1,786	1,024	1,149	1,035	994	31,415	24,624
1976	871	1,492	2,333	1,962	3,812	5,286	3,242	1,508	1,093	1,036	935	716	24,286	16,635
1977	395	849	1,284	1,166	1,554	1,974	828	461	945	1,016	438	655	11,565	6,806

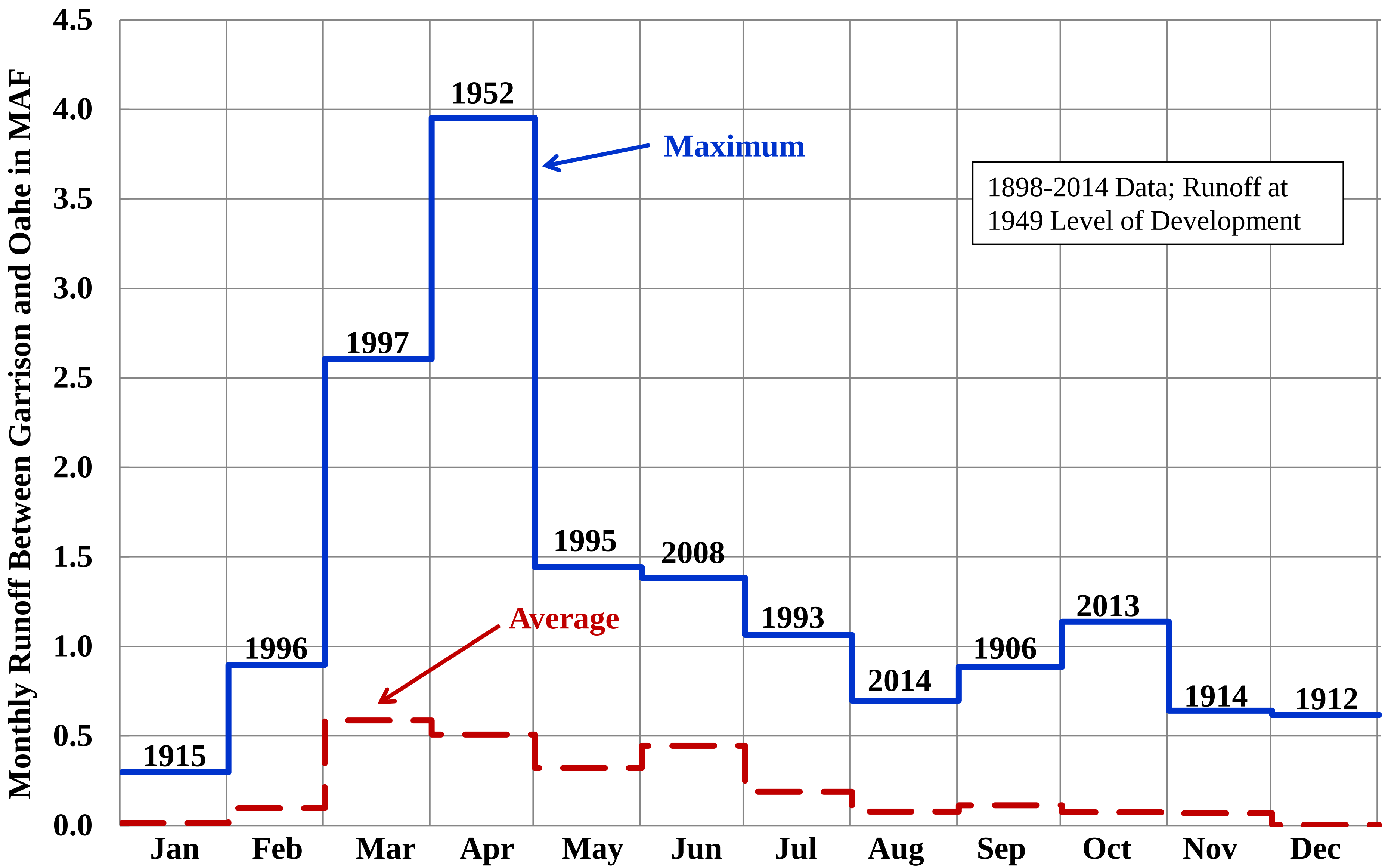
Monthly Runoff - Missouri River Basin Upstream of Oahe Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

	Runoff in 1,000 acre-feet												Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1978	481	694	5,220	5,662	5,251	5,450	4,671	1,528	1,773	1,139	677	738	33,284	26,254
1979	571	742	3,526	5,437	3,079	3,527	2,087	921	974	567	797	496	22,724	17,656
1980	307	523	1,314	1,388	1,911	3,662	1,702	517	838	1,218	965	552	14,897	9,977
1981	885	752	1,228	679	2,449	5,311	1,907	820	405	895	1,040	616	16,987	11,574
1982	309	1,200	2,677	3,806	3,367	5,568	4,773	1,652	1,060	1,829	1,275	1,007	28,523	20,191
1983	789	1,205	2,160	1,195	1,944	3,577	3,214	1,021	702	1,237	1,157	300	18,501	12,090
1984	887	1,262	1,541	1,425	2,797	4,599	2,850	1,138	649	1,164	1,075	398	19,785	13,212
1985	775	598	2,083	1,483	1,414	1,772	703	862	724	1,361	804	709	13,288	7,455
1986	895	704	5,154	2,148	3,757	4,737	2,326	698	1,637	1,998	990	903	25,947	18,122
1987	425	964	3,305	2,231	1,651	1,981	1,029	961	799	650	730	429	15,155	10,197
1988	161	608	1,200	776	1,568	1,658	661	3	138	532	530	399	8,234	5,863
1989	231	414	1,894	2,046	2,539	2,611	1,540	614	795	794	1,005	340	14,823	10,630
1990	935	571	1,523	1,128	1,665	2,867	2,092	791	585	606	881	270	13,914	9,275
1991	514	716	1,129	924	2,760	6,036	2,896	589	686	788	921	612	18,571	13,745
1992	513	776	1,165	794	1,138	1,957	2,444	839	590	785	891	194	12,086	7,498
1993	350	727	2,368	1,588	2,584	4,196	5,053	3,078	1,263	1,167	1,094	958	24,426	15,789
1994	661	699	4,172	1,596	2,882	2,400	1,029	329	416	1,000	641	568	16,393	12,079
1995	489	1,181	2,494	1,543	4,040	5,780	4,466	1,088	765	1,044	1,107	730	24,727	18,323
1996	787	2,612	3,474	3,209	3,084	6,829	3,159	873	730	882	948	878	27,465	19,755
1997	947	1,744	5,211	5,433	3,950	8,011	4,411	1,861	1,072	843	1,003	899	35,385	27,016
1998	178	1,160	1,358	1,643	1,721	3,294	4,098	1,371	724	1,423	1,127	565	18,662	12,114
1999	791	1,131	2,860	1,587	3,006	5,233	3,174	1,087	855	763	766	659	21,912	15,860
2000	416	760	1,483	1,190	1,508	2,968	1,834	491	439	969	670	404	13,132	8,983
2001	807	614	2,534	1,551	1,109	2,154	1,802	738	300	532	557	424	13,122	9,150
2002	409	535	664	1,179	1,029	3,365	2,036	770	562	702	592	400	12,243	8,273
2003	290	671	2,379	1,348	1,790	3,642	1,636	568	336	561	319	528	14,068	10,795
2004	348	499	1,996	1,096	814	2,318	1,811	786	614	752	746	305	12,085	8,035
2005	422	798	992	754	2,033	3,993	2,850	798	431	775	665	226	14,737	10,622
2006	946	508	1,050	1,629	1,969	3,213	1,434	580	371	808	687	310	13,505	9,295
2007	431	592	1,747	1,323	2,338	3,883	1,394	701	359	644	545	324	14,281	10,685
2008	386	464	969	914	2,014	6,784	4,440	1,226	821	911	752	493	20,174	15,121
2009	788	1,190	3,675	5,078	2,886	4,932	3,610	1,392	965	974	825	547	26,862	20,181
2010	687	673	2,714	2,103	2,464	6,001	4,087	1,250	1,061	836	590	701	23,167	17,369
2011	819	1,319	4,173	5,157	7,207	12,390	8,193	2,383	1,000	1,180	822	920	45,563	37,120
2012	509	1,178	1,628	1,267	2,134	3,504	2,096	792	234	587	770	554	15,253	10,629
2013	491	790	1,193	1,686	2,091	5,688	2,310	1,108	806	2,287	820	546	19,816	12,968
2014	976	863	3,566	2,328	3,484	6,433	4,114	2,764	1,800	1,194	643	1,183	29,348	19,925



Missouri River Basin
Oahe Water Control Manual
Unregulated Monthly Runoff Distribution above Oahe

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



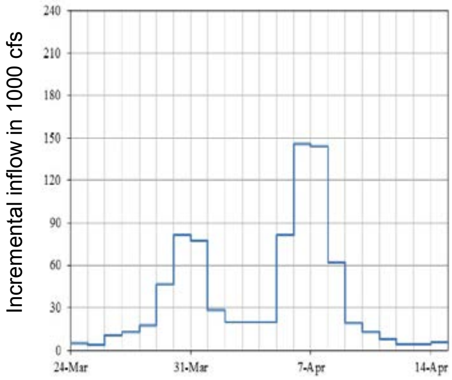
Missouri River Basin

Oahe Water Control Manual

Monthly Runoff Between Garrison and Oahe

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Incremental Inflow Hydrographs Garrison to Oahe



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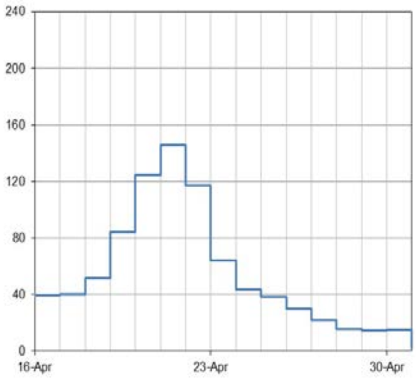

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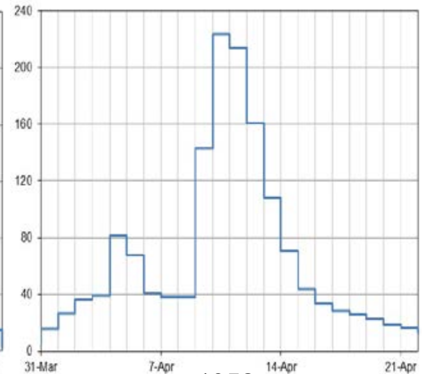

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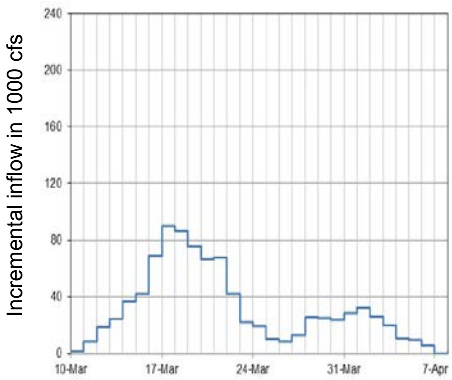

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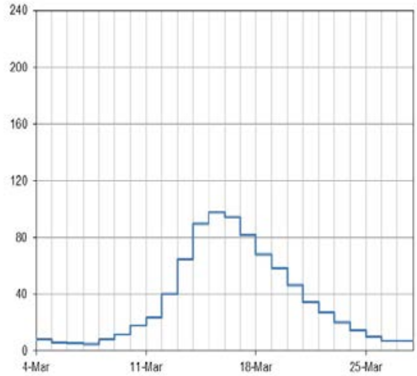

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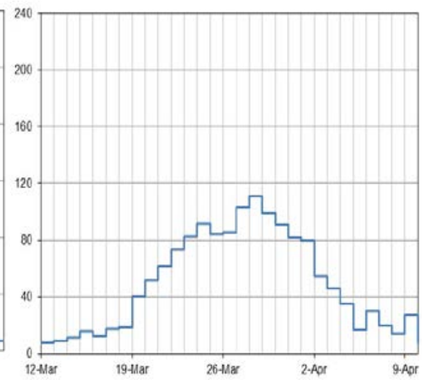

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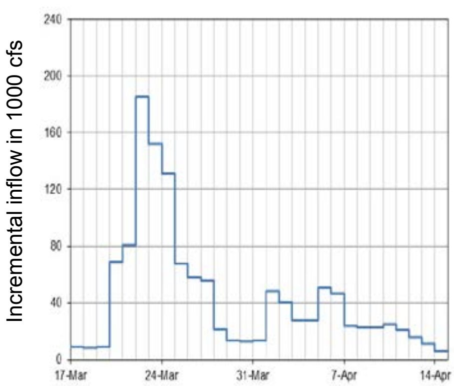

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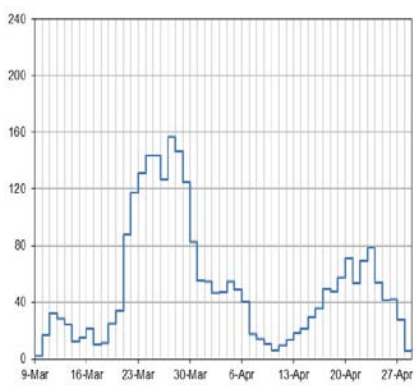

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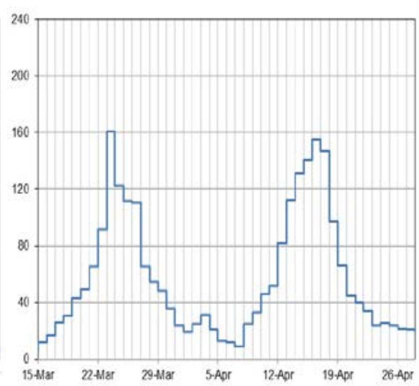

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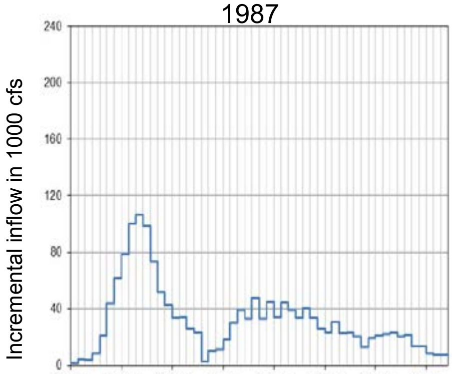
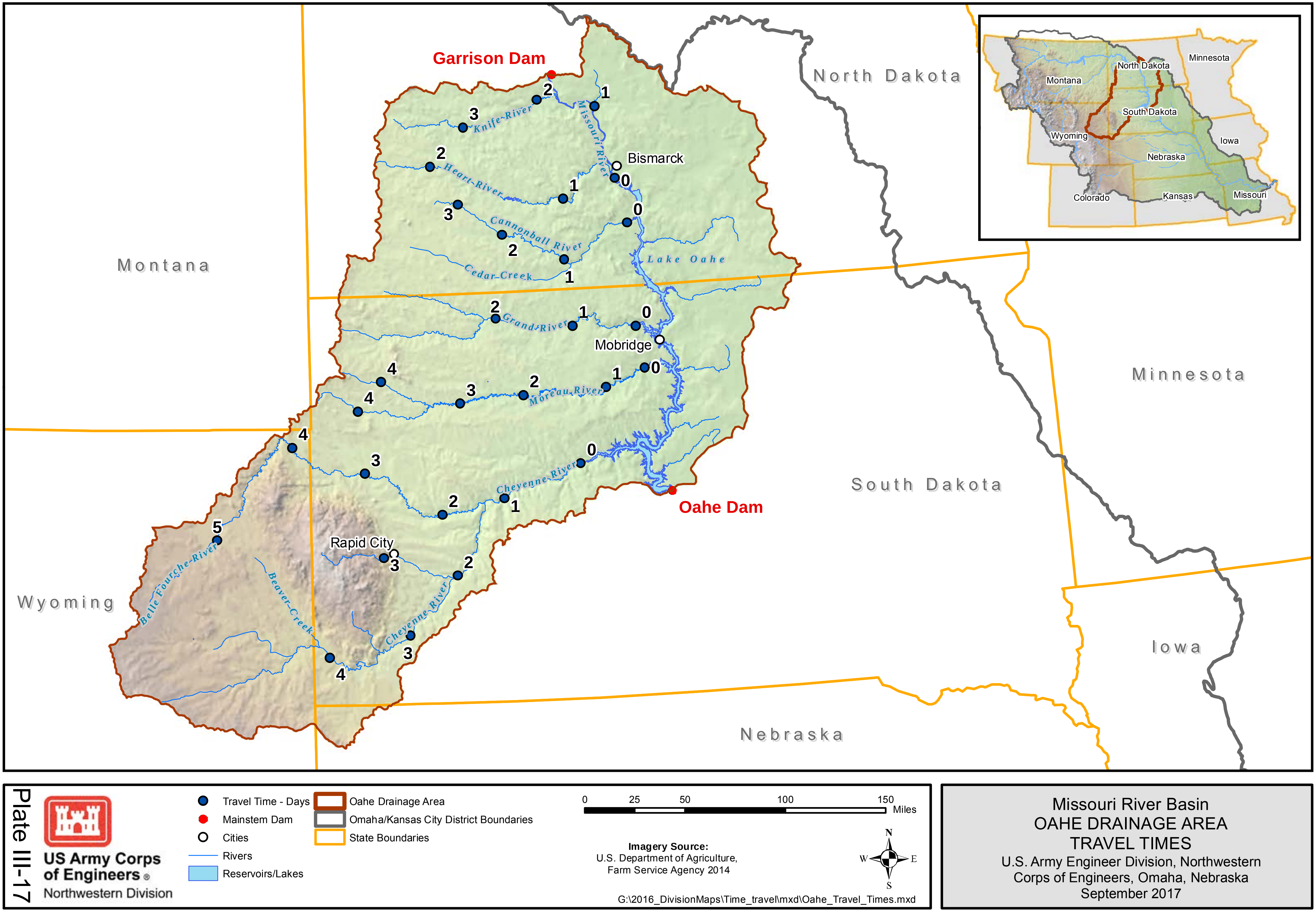


2011

Incremental flow data set used in the Hydrologic Statistics on Inflows Technical Report – June 2015.

Missouri River Basin
Oahe Water Control Manual
Incremental Inflow Hydrographs
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
OAHE DRAINAGE AREA
TRAVEL TIMES
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-17

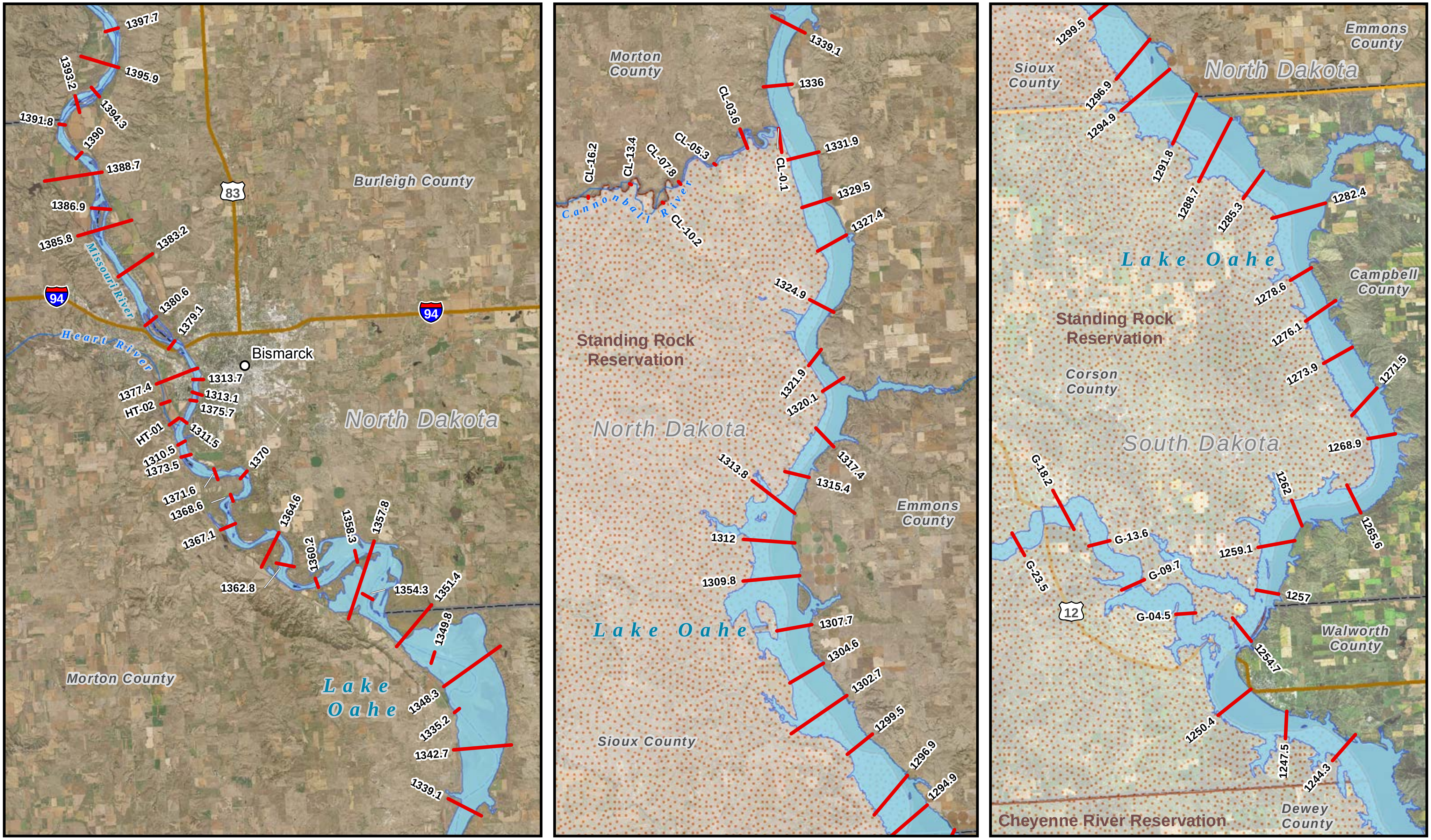


Plate III-18

US Army Corps of Engineers®
Northwestern Division

Cities	Reservations
Aggregation Rangeline	Reservoirs/Lakes
Rivers	State Boundaries
Roads	County Boundaries

0 2.5 5 10 15 Miles

N W E S

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2015

G:\2016_DivisionMaps\Sediment_Rangeline\mxd\Oahe_Sediment_Range_Up_Map.mxd

Missouri River Basin
OAHE PROJECT
SEDIMENT RANGE UPPER RESERVOIR MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

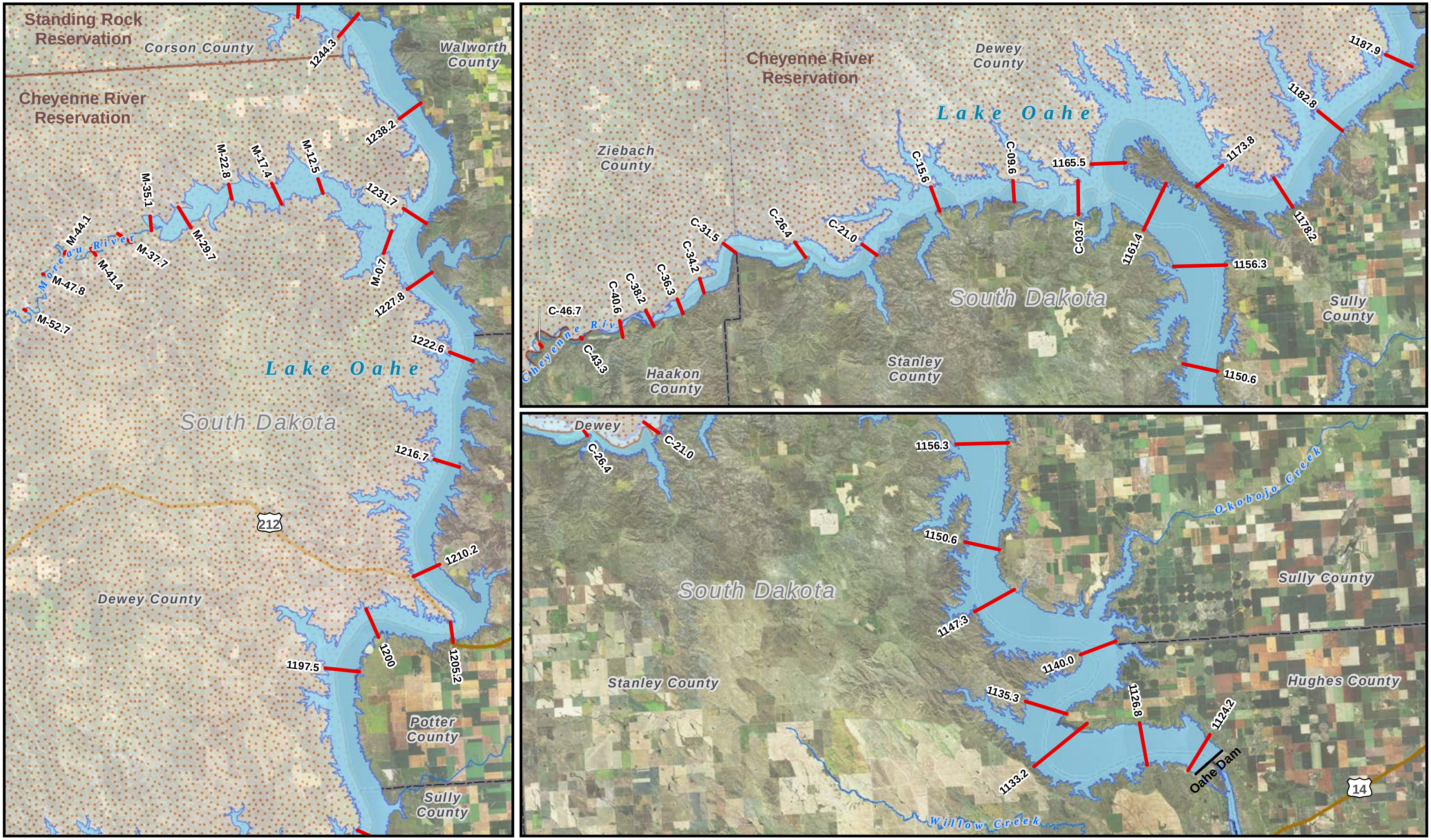


Plate III-19

US Army Corps of Engineers®
Northwestern Division

○ Cities
Aggregation Rangeline
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 5 10 20 Miles

N E S W

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2015

G:\2016_DivisionMaps\Sediment_Rangeline\mxd\Oahe_Sediment_Range_Down_Map.mxd

Missouri River Basin
OAHE PROJECT
SEDIMENT RANGE LOWER RESERVOIR MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

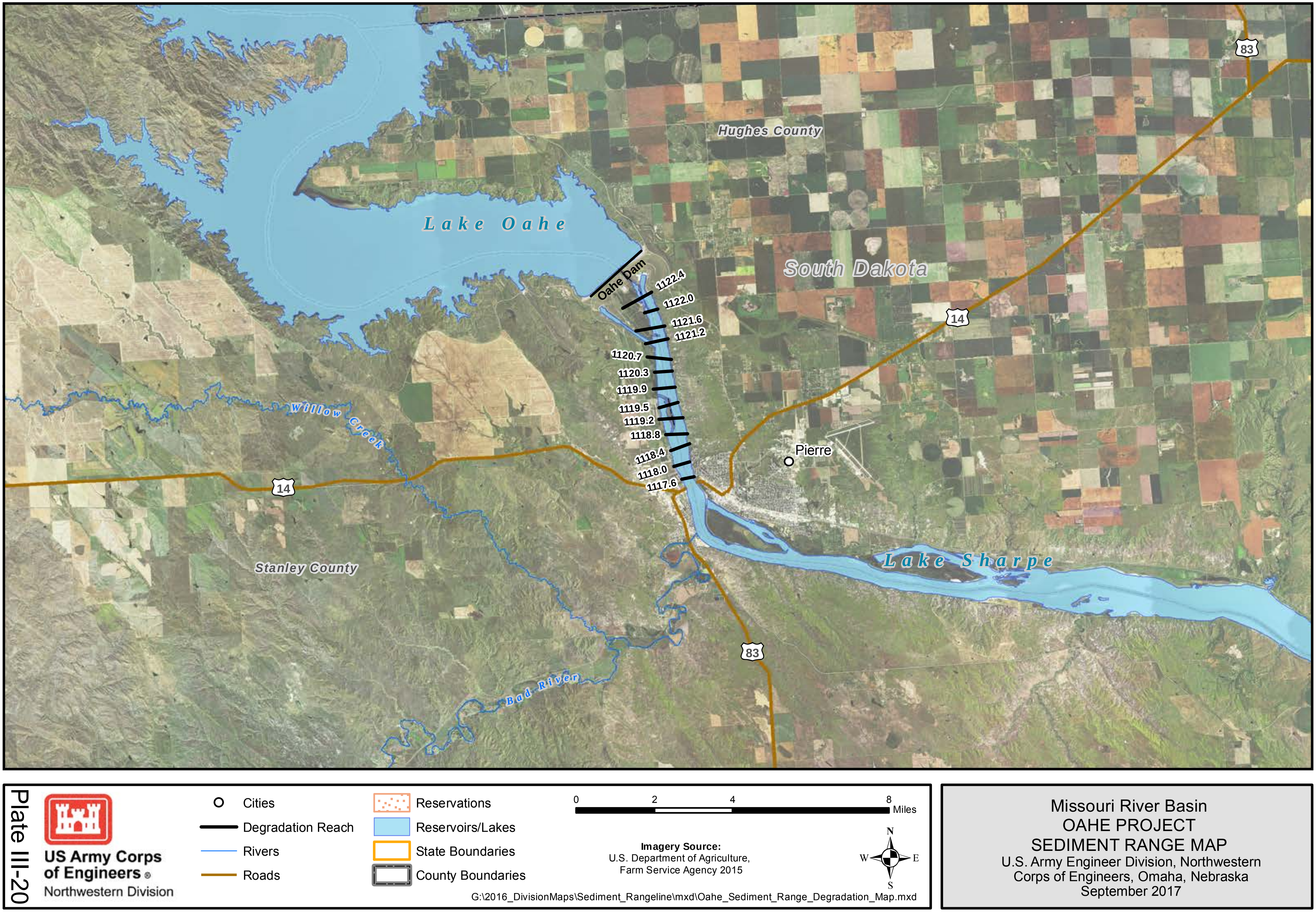
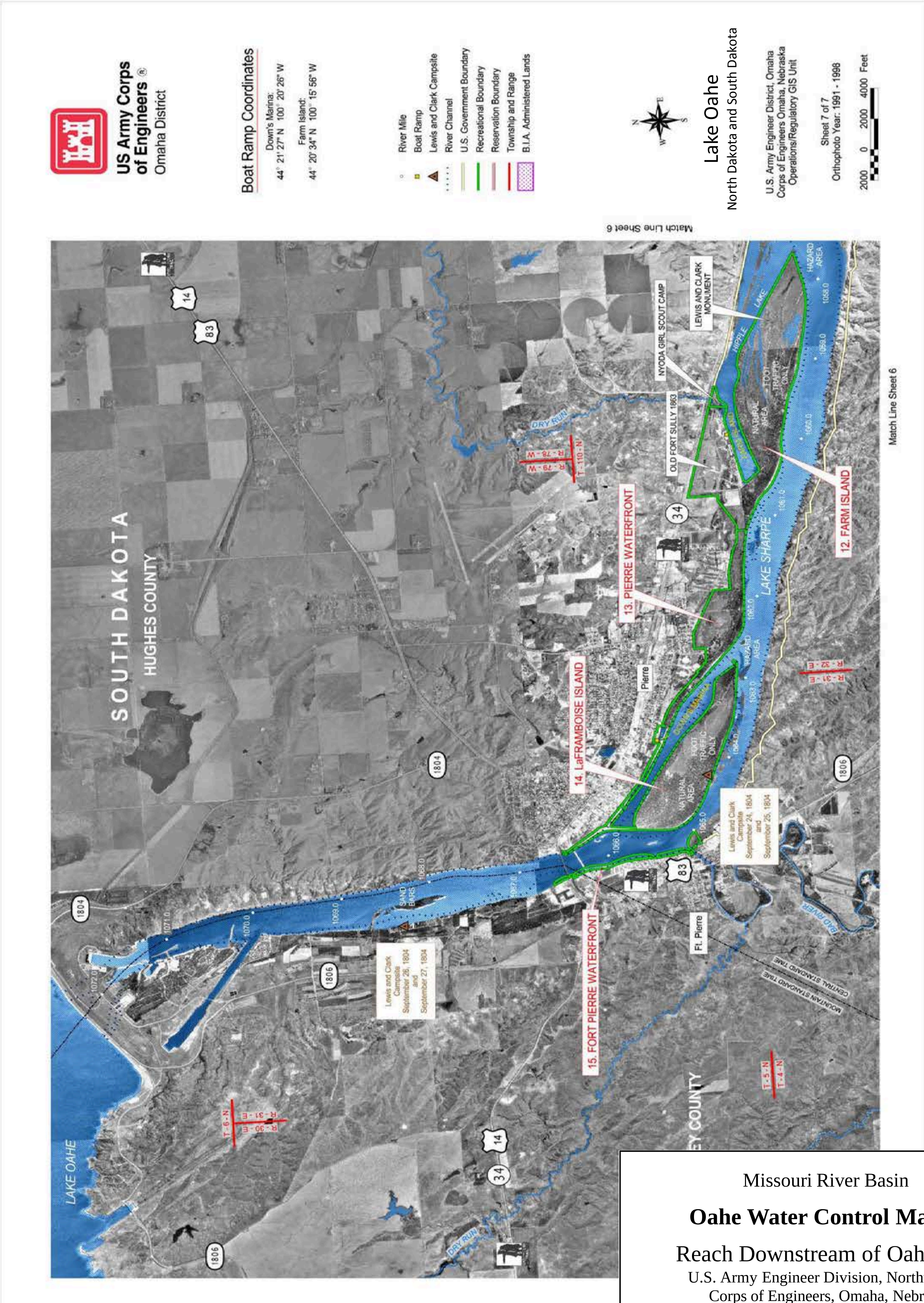

Lake Oahe
Hughes County
South Dakota
Oahe Dam
1122.4
1122.0
1121.6
1121.2
1120.7
1120.3
1119.9
1119.5
1119.2
1118.8
1118.4
1118.0
1117.6
Pierre
83
14
Willow Creek
Stanley County
Lake Sharpe
Bad River
Cities
Degradation Reach
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries
0 2 4 8 Miles
Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2015
N
W
E
S
G:\2016_DivisionMaps\Sediment_Rangeline\mxd\Oahe_Sediment_Range_Degradation_Map.mxd
US Army Corps of Engineers®
Northwestern Division
Missouri River Basin
OAHE PROJECT
SEDIMENT RANGE MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-20



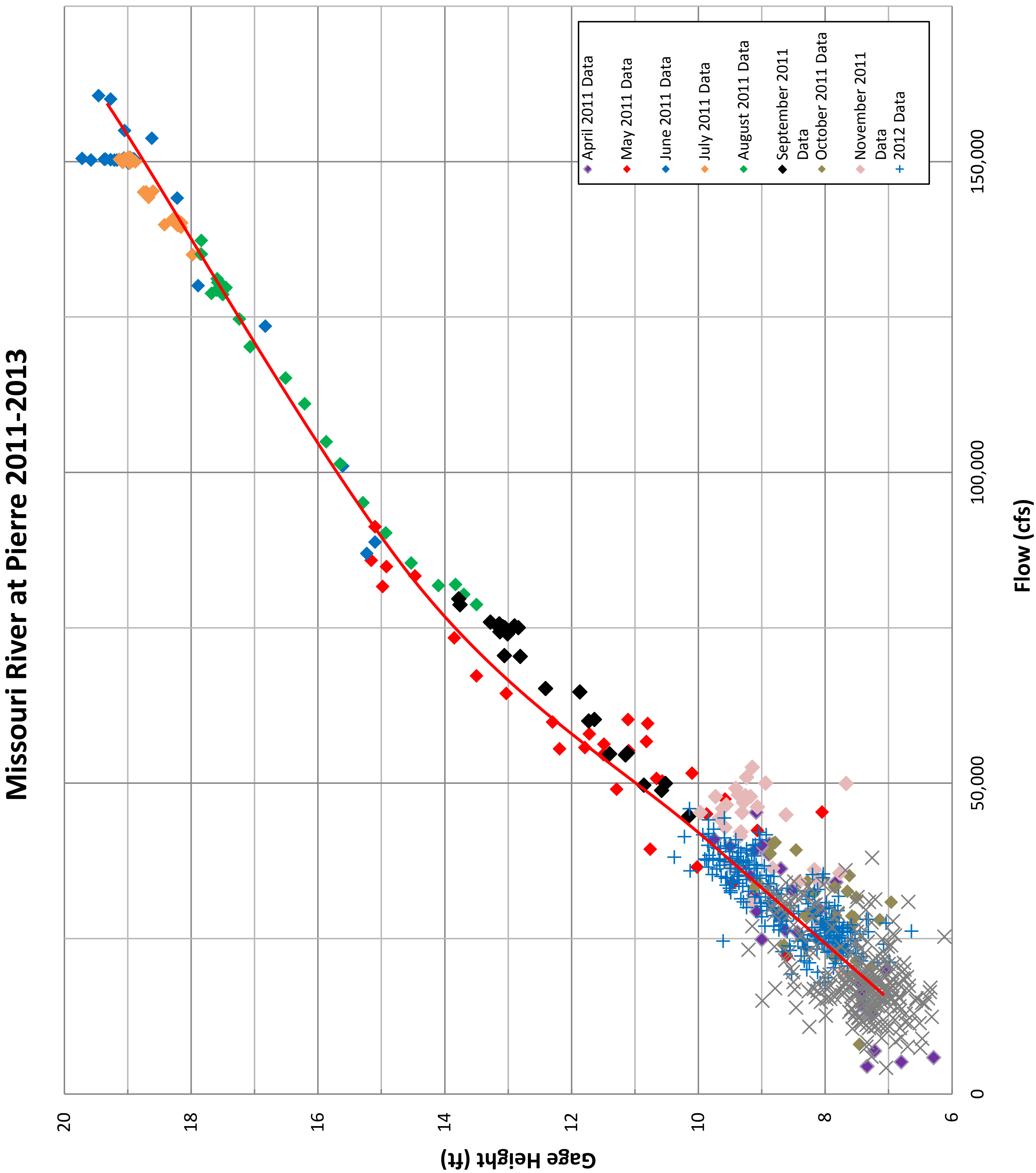
Missouri River Basin

Oahe Water Control Manual

Reach Downstream of Oahe Dam

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-21



Missouri River Basin

Oahe Water Control Manual

Missouri River at Pierre, SD Estimated Rating Curve

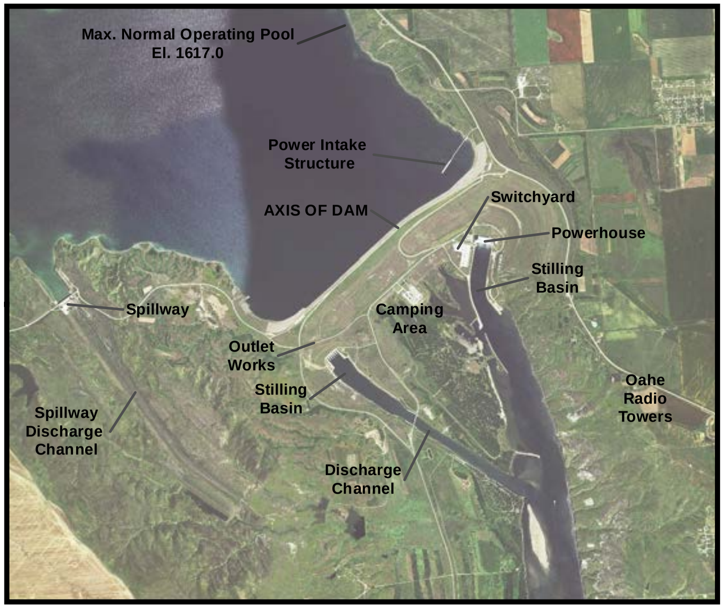
U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

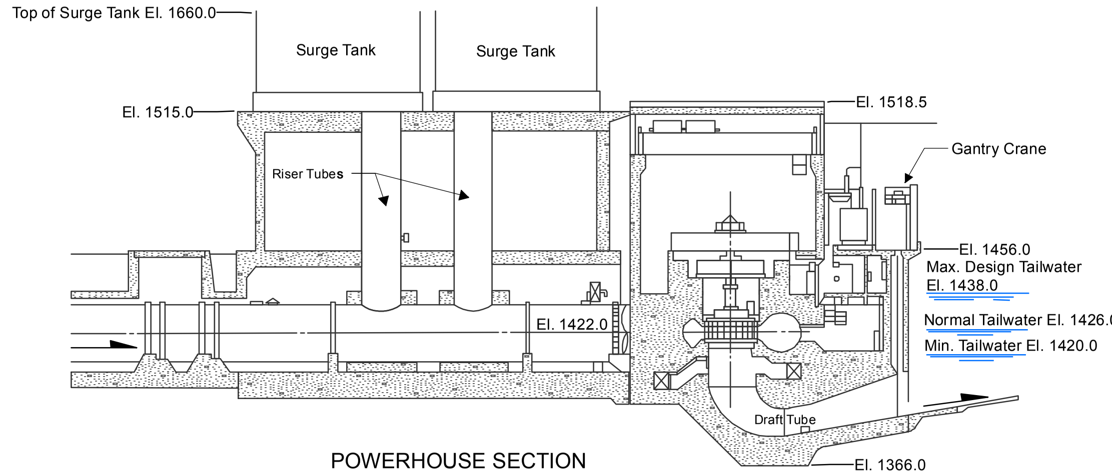
September 2017

Plate III-22

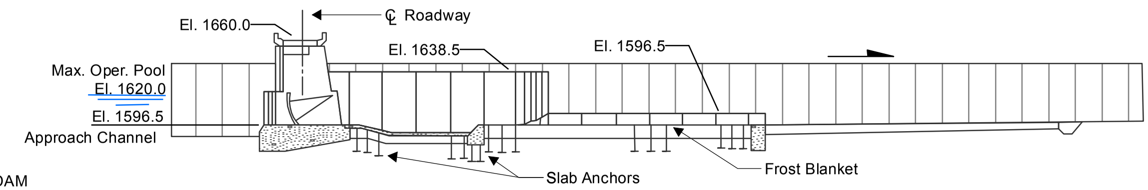
Missouri River Basin
Oahe Water Control Manual
Reservoir, Embankment, Intakes, Powerhouse and Outlet Tunnels
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



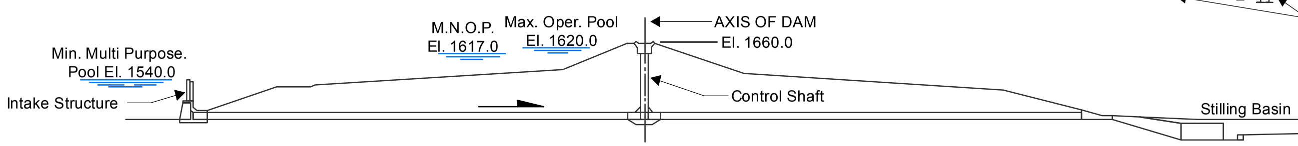
PLAN VIEW



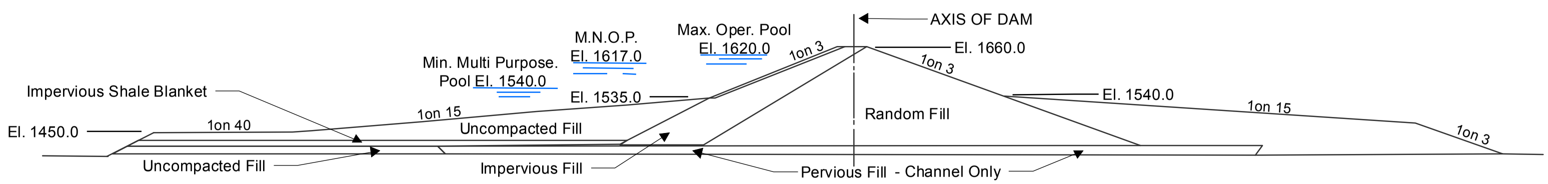
POWERHOUSE SECTION



SPILLWAY PROFILE



OUTLET WORKS PROFILE
FLOOD CONTROL TUNNELS



EMBANKMENT SECTION

Plate IV-2

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

N
W E
S

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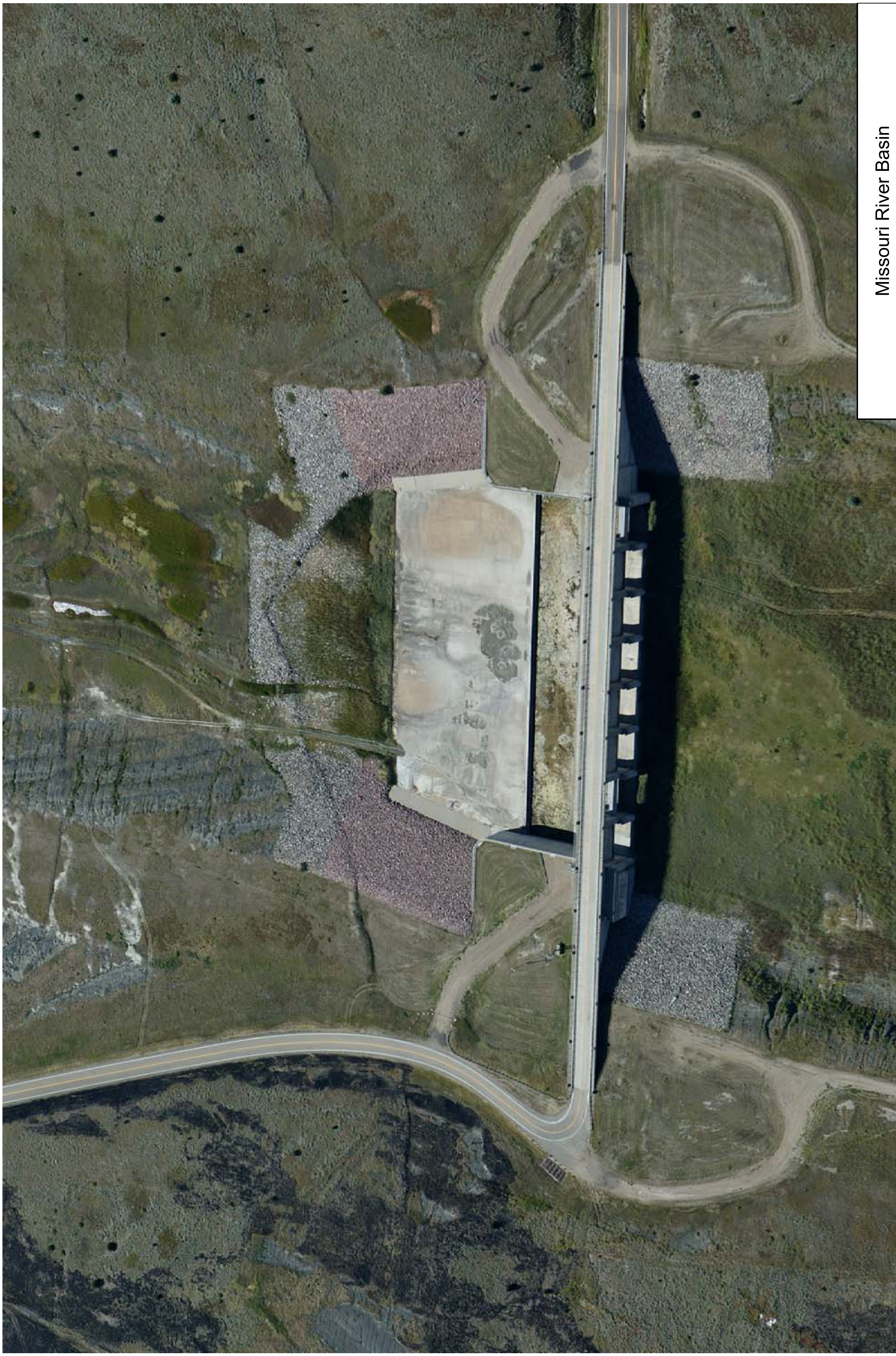
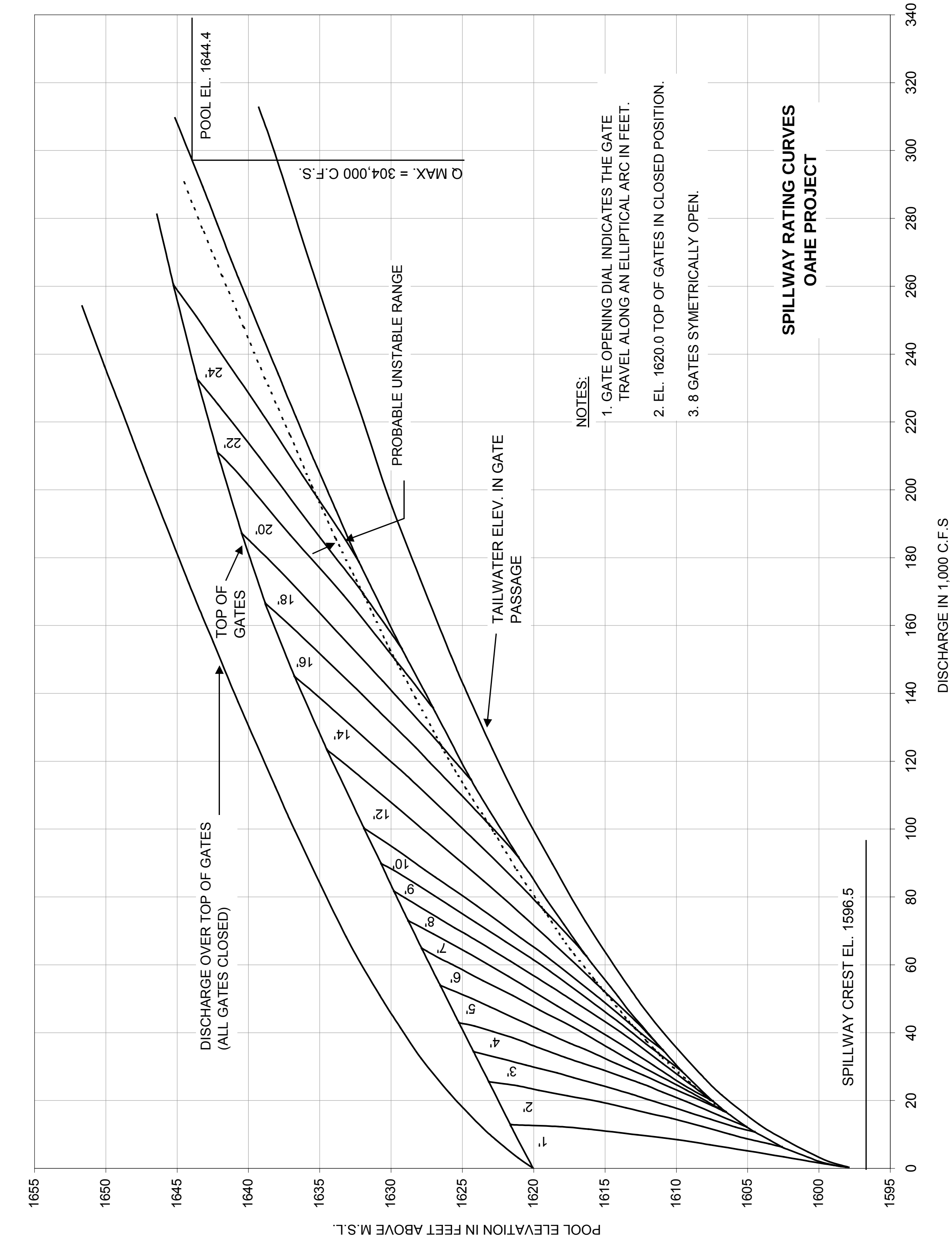
Missouri River Basin
OAHE DAM
WATER CONTROL PROJECT
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Missouri River Basin
Oahe Water Control Manual
Spillway Gates
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Oahe Water Control Manual
Spillway Gates and Discharge Chute
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

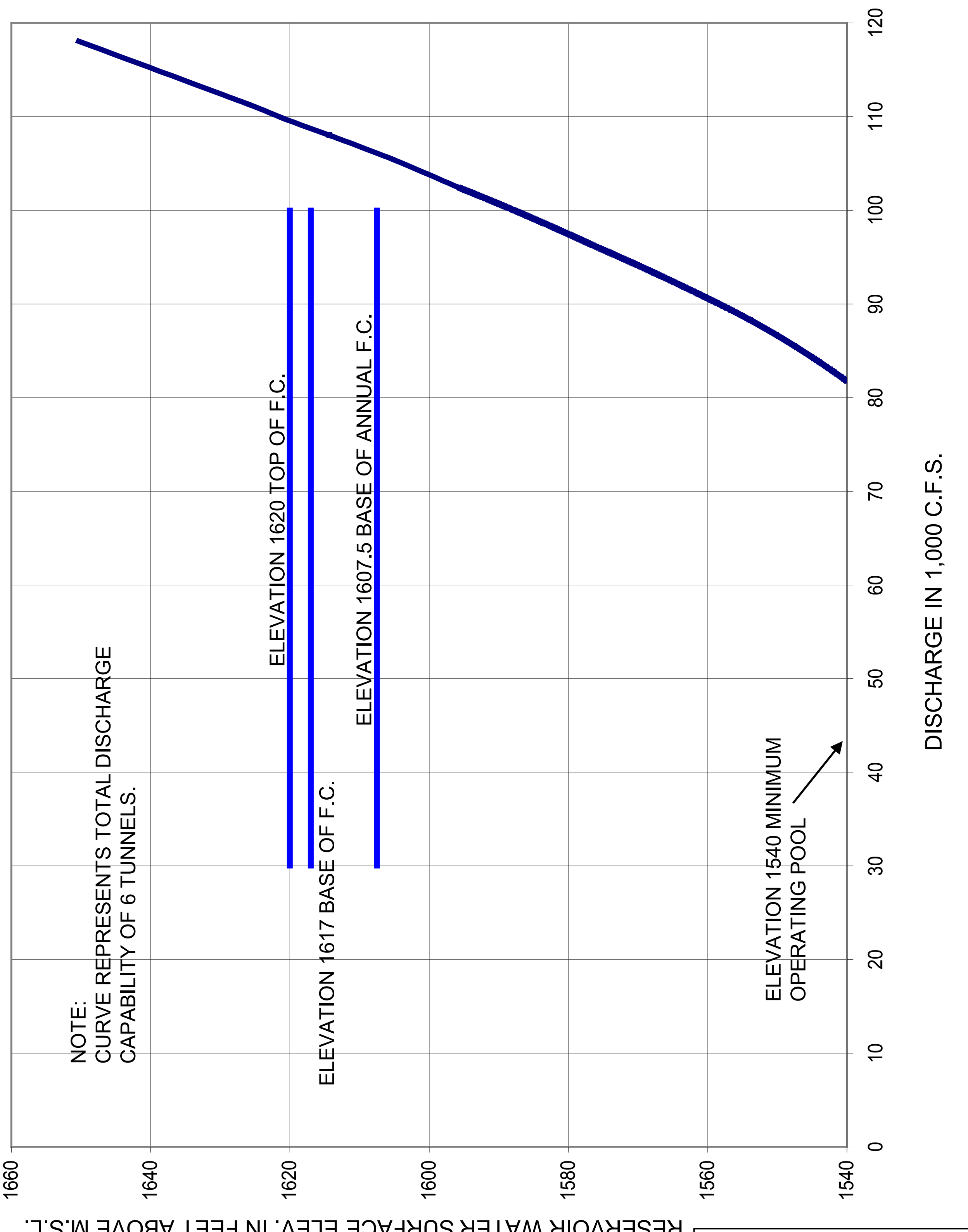


Missouri River Basin

Oahe Water Control Manual

Spillway Rating Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin

Oahe Water Control Manual

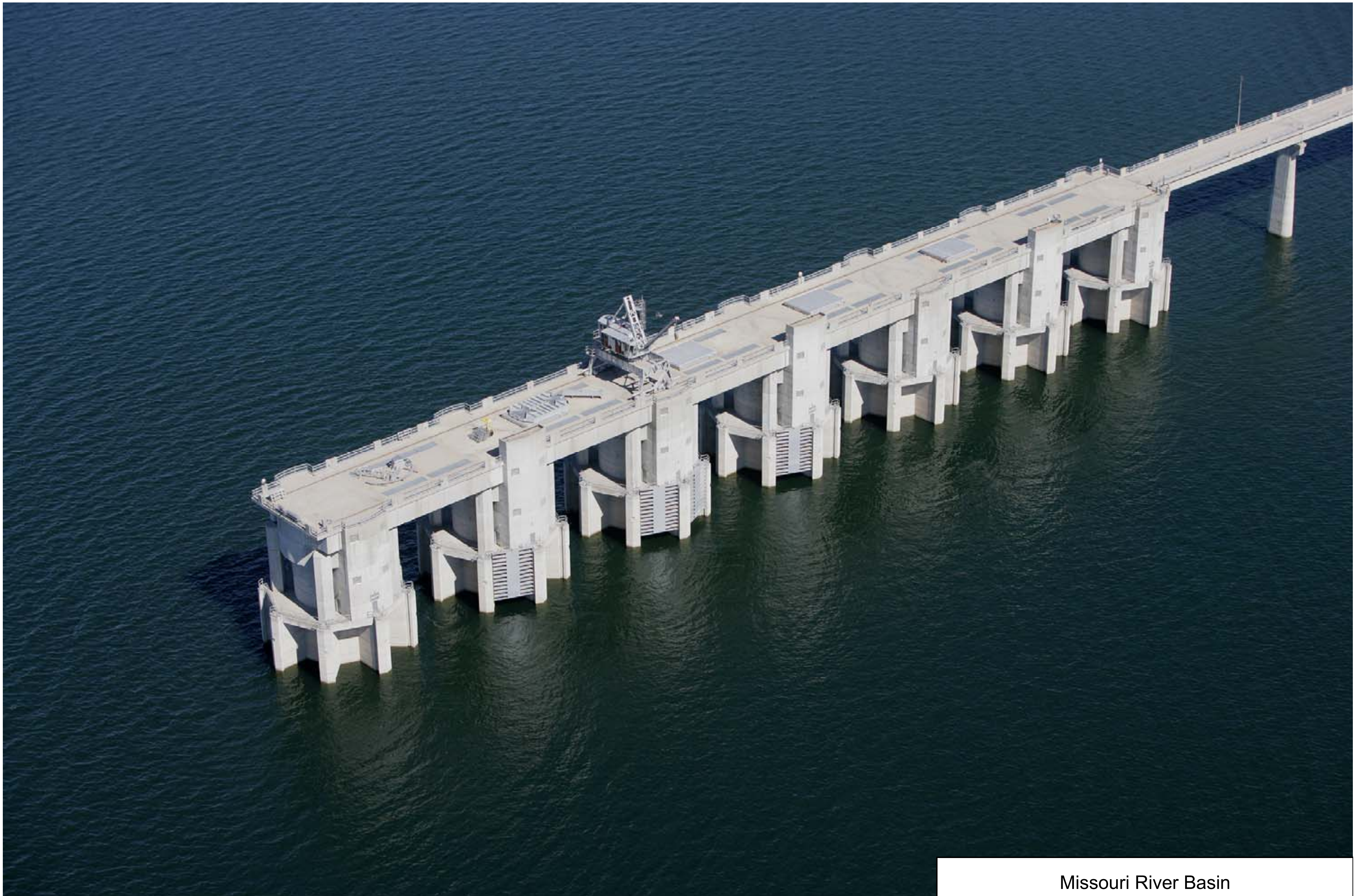
Outlet Works Rating Curve

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

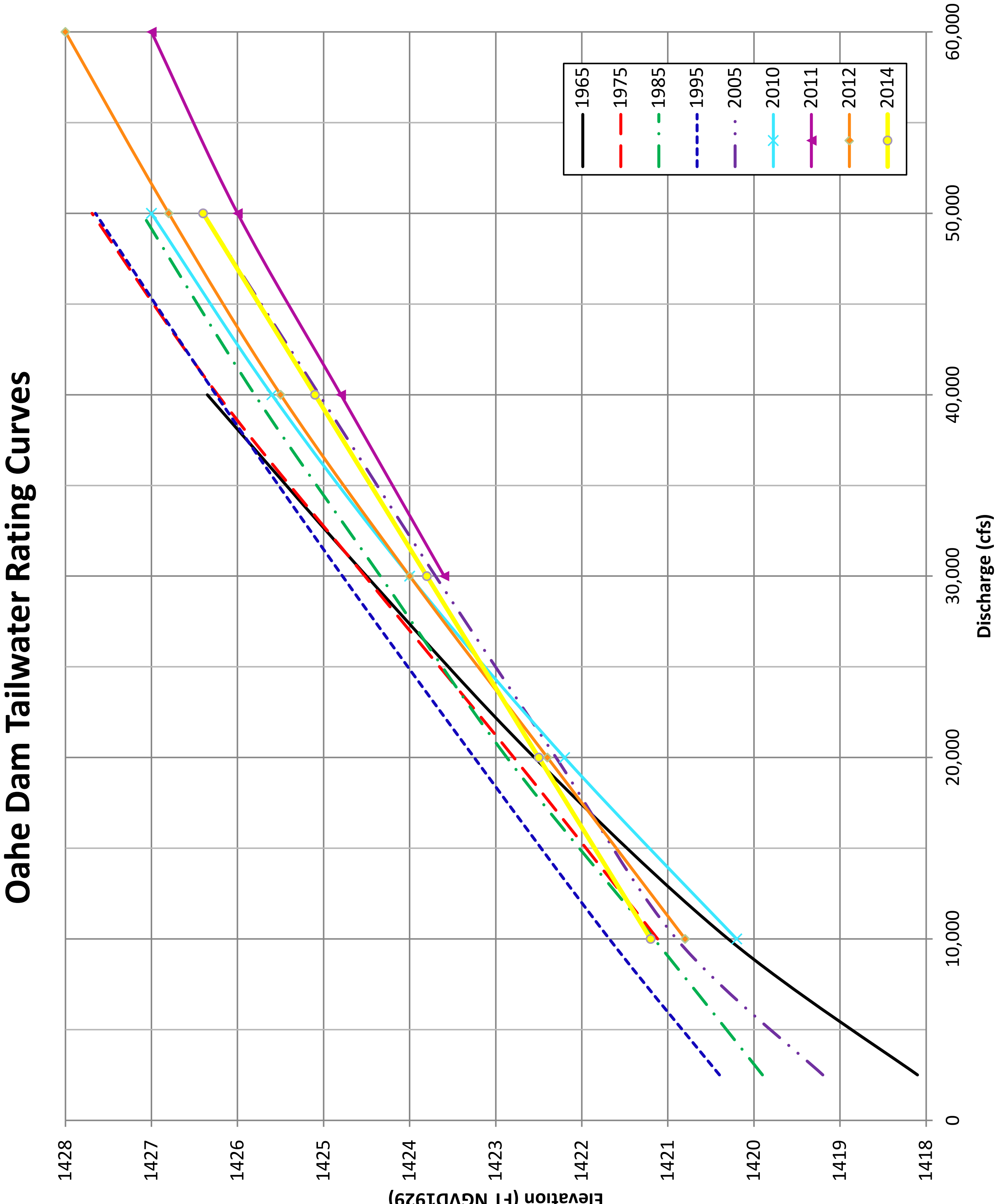
Plate IV-6

Missouri River Basin
Oahe Water Control Manual
Outlet Tunnels and Intake Structure
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Missouri River Basin
Oahe Water Control Manual
Switchyard and Surge Tanks
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Oahe Water Control Manual
Powerplant Intake Structure
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



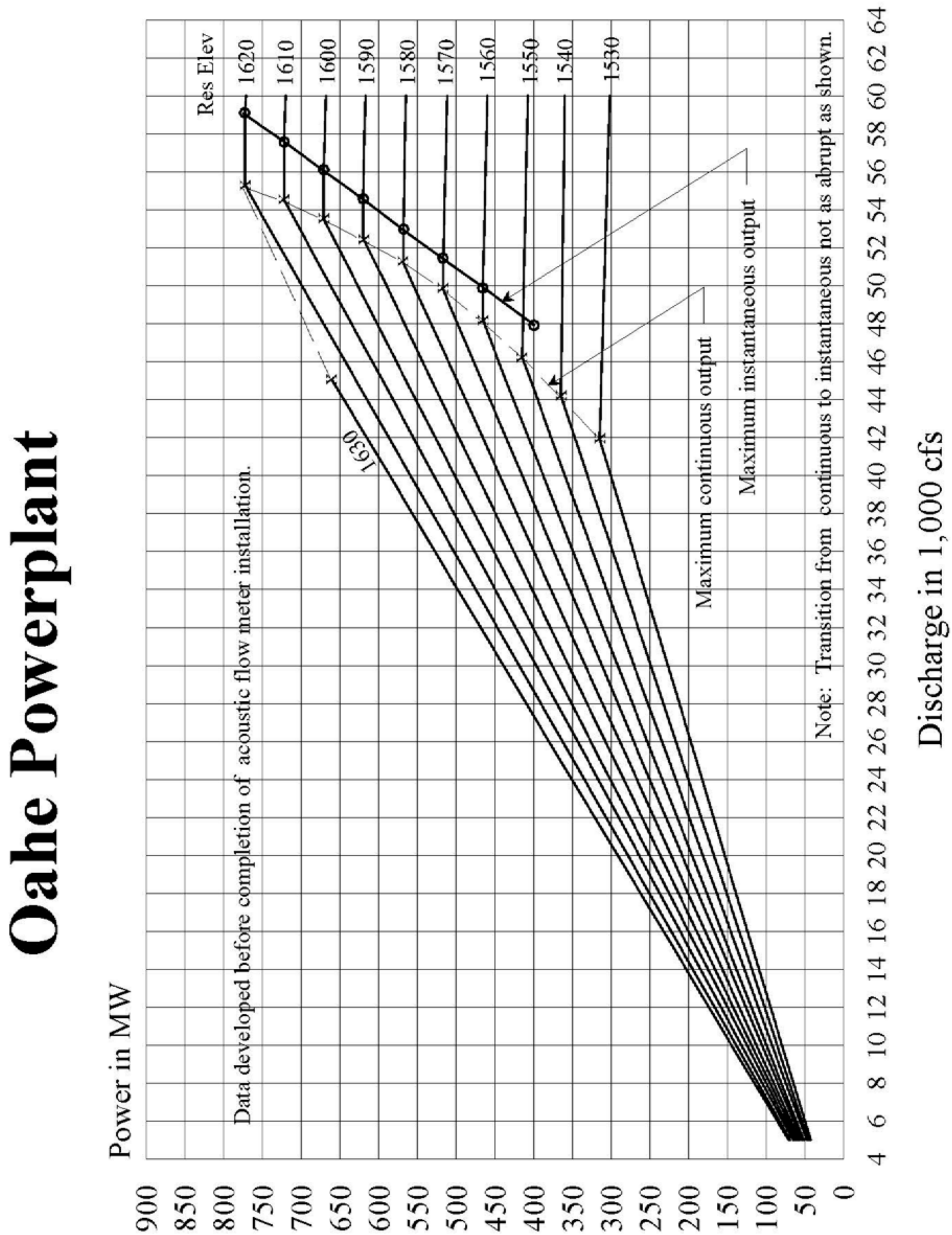
Missouri River Basin

Oahe Water Control Manual

Oahe-Tailwater Rating Curves

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate IV-10



Missouri River Basin

Oahe Water Control Manual

Oahe Powerplant Characteristics

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate IV-11

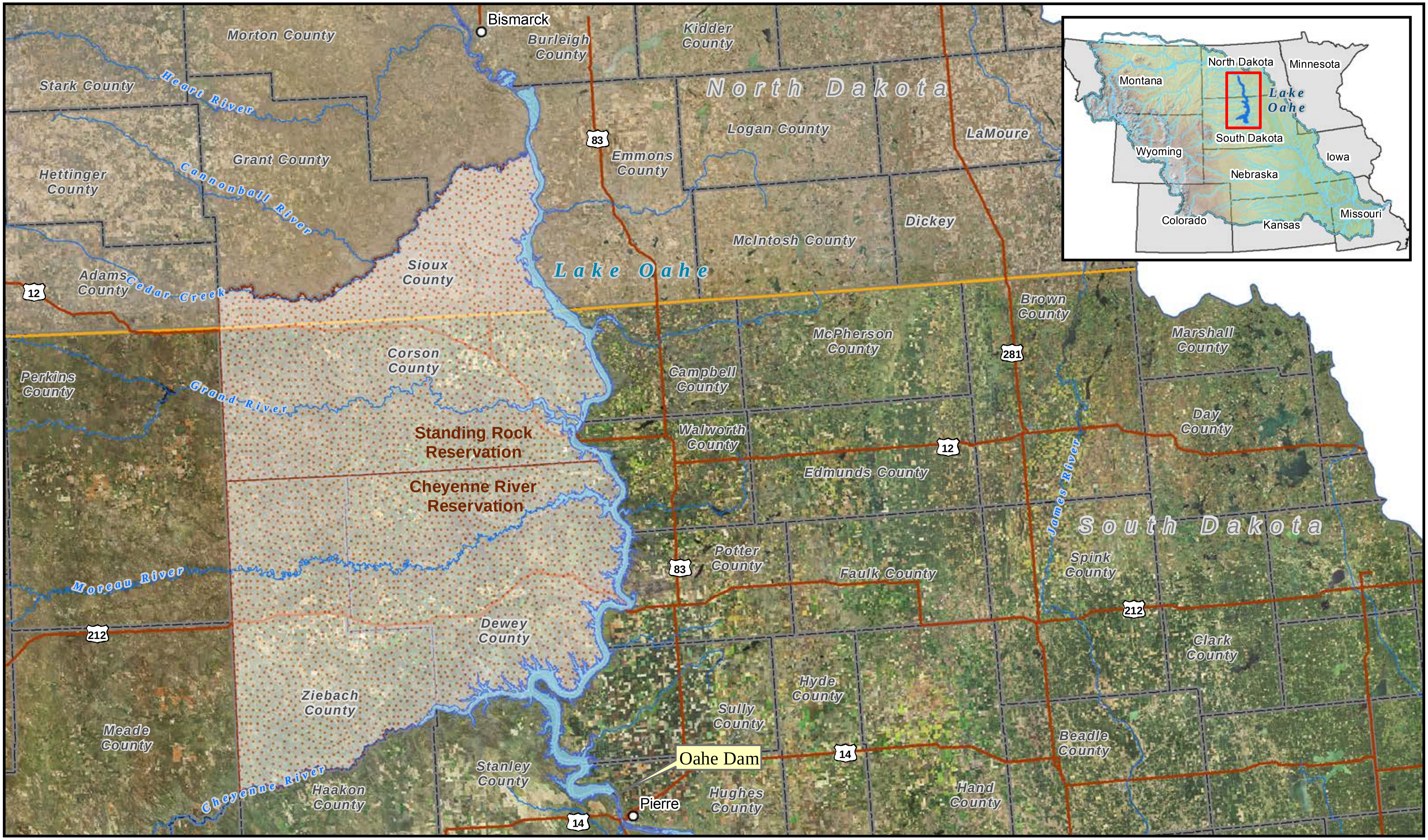


Plate IV-12

US Army Corps of Engineers®
Northwestern Division

Cities	Reservoirs/Lakes
Rivers	State Boundaries
Roads	County Boundaries
Reservations	

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2015

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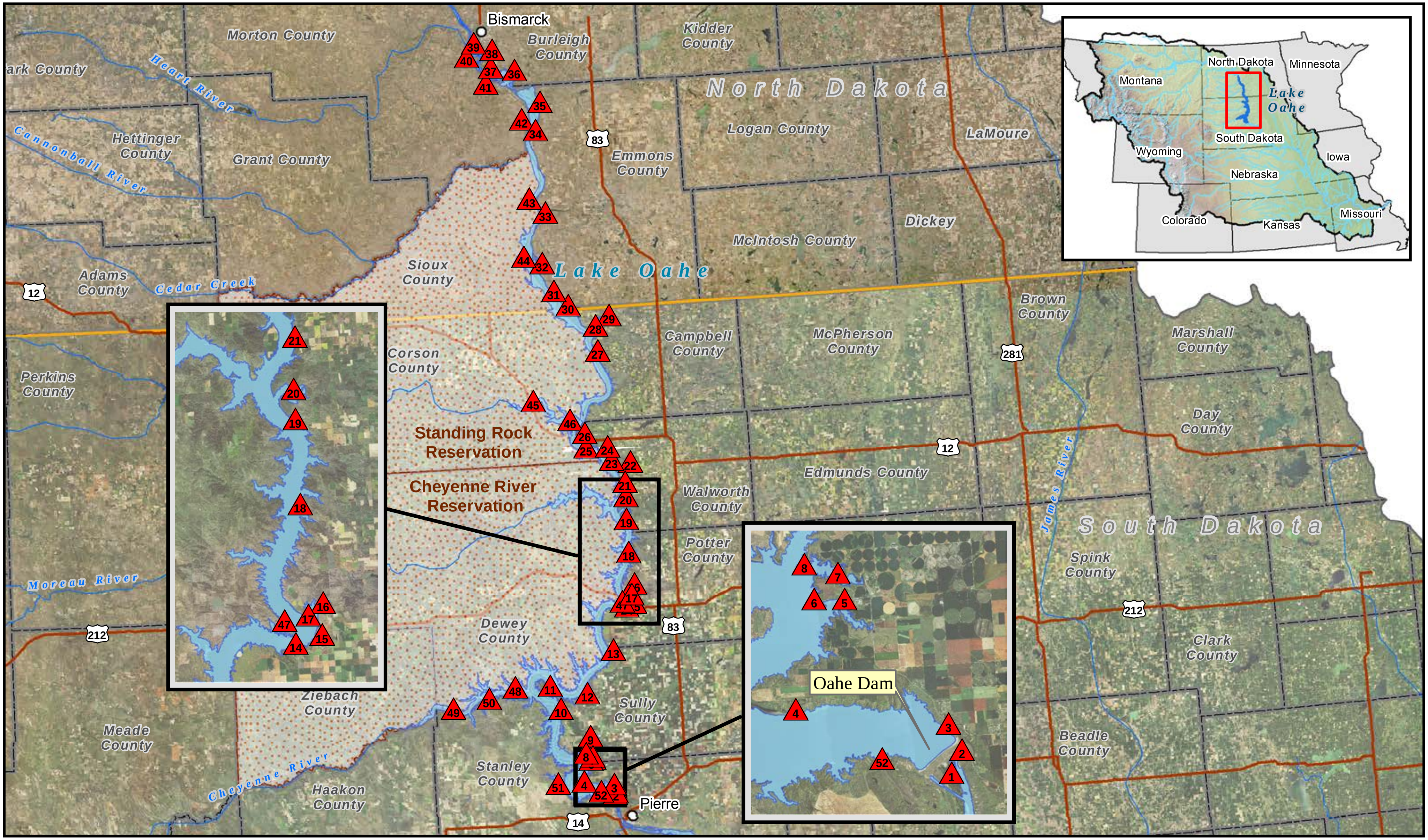
Missouri River Basin
OAHE PROJECT
PROJECT MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

LAKE OAHE - 2010 AREA & CAPACITY TABLES - Effective date 23-JAN-2013 RESERVOIR SURFACE AREA IN ACRES (From 2010 Hydrographic Survey Data - NGVD1929)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1410	0	0	0	0	0	0	0	0	0	4
1420	44	90	137	241	400	614	885	1212	1595	2033
1430	2445	2744	3004	3306	3649	4033	4459	4925	5433	5983
1440	6485	6860	7209	7627	8112	8664	9285	9974	10731	11555
1450	12359	13042	13677	14347	15053	15795	16572	17384	18233	19116
1460	19962	20704	21424	22197	23025	23906	24842	25832	26876	27975
1470	29079	30121	31123	32124	33122	34119	35115	36109	37101	38092
1480	39042	39932	40827	41776	42779	43835	44945	46108	47325	48596
1490	49895	51168	52399	53597	54764	55900	57003	58075	59115	60124
1500	61082	62005	62957	63971	65048	66188	67390	68655	69982	71372
1510	72775	74117	75410	76694	77967	79231	80484	81727	82961	84184
1520	85356	86461	87580	88766	90018	91339	92726	94179	95701	97289
1530	98802	100110	101377	102752	104235	105827	107526	109334	111251	113276
1540	115352	117368	119299	121172	122989	124749	126452	128098	129688	131221
1550	132594	133791	135048	136513	138184	140063	142148	144441	146941	149648
1560	152181	154174	156033	158147	160517	163143	166023	169159	172551	176198
1570	179831	183109	186201	189340	192525	195760	199040	202375	205755	209175
1580	212675	216215	219715	223130	226450	229685	232835	235895	238865	241755
1590	244405	246810	249310	252105	255205	258595	262285	266285	270575	275160
1600	279520	283135	286555	290315	294415	298850	303630	308750	314205	320000
1610	325930	331635	337065	342350	347505	352515	357385	362120	366715	371165
1620	385585									

LAKE OAHE - 2010 AREA & CAPACITY TABLES - Effective date 23-JAN-2013 RESERVOIR CAPACITY IN ACRE-FEET (From 2010 Hydrographic Survey Data - NGVD1929)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1410	0	0	0	0	0	0	0	0	0	0
1420	8	89	189	364	671	1164	1900	2935	4325	6125
1430	8392	11016	13880	17025	20493	24323	28559	33241	38410	44108
1440	50377	57079	64097	71498	79351	87722	96680	106293	116629	127755
1450	139740	152473	165824	179827	194518	209933	226108	243077	260877	279543
1460	299110	319468	340519	362316	384914	408366	432727	458051	484392	511804
1470	540342	569962	600585	632209	664833	698454	733072	768684	805290	842887
1480	881474	920972	961338	1002627	1044891	1088185	1132562	1178075	1224779	1272726
1490	1321971	1372516	1424308	1477314	1531503	1586843	1643303	1700850	1759453	1819081
1500	1879701	1941246	2003712	2067161	2131655	2197258	2264032	2332039	2401342	2472004
1510	2544087	2617555	2692321	2768375	2845709	2924310	3004171	3085279	3167626	3251201
1520	3335994	3421913	3508917	3597074	3686449	3777111	3869127	3962563	4057486	4153965
1530	4252065	4351569	4452285	4554323	4657789	4762793	4869443	4977846	5088112	5200349
1540	5314664	5431053	5549401	5669651	5791745	5915629	6041243	6168533	6297440	6427909
1550	6559882	6693097	6827465	6963194	7100491	7239563	7380617	7523860	7669499	7817743
1560	7968796	8122105	8277145	8434171	8593439	8755206	8919725	9087253	9258044	9432355
1570	9610441	9792017	9976660	10164420	10355340	10549470	10746860	10947550	11151610	11359060
1580	11569960	11784410	12002390	12223840	12448650	12676740	12908020	13142410	13379810	13620140
1590	13863320	14108950	14356940	14607570	14861150	15117980	15378340	15642550	15910910	16183700
1600	16461230	16742740	17027500	17315850	17608130	17904680	18205830	18511940	18823330	19140350
1610	19463330	19792210	20126600	20466340	20811300	21161350	21516330	21876120	22240570	22609550
1620	22982900	23380720	23814310	24270350	24735540	25196560	25640110	26052870	26421530	26732790
1630	26973320									



Recreation Area
Cities
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 10 20 40 60 Miles

N W E S

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2015

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US Army Corps of Engineers®
Northwestern Division

Missouri River Basin
OAHE PROJECT
RECREATION AREAS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate IV-14

Plate IV-15

US Army Corps of Engineers®
Northwestern Division

0 10 20 40 60 Miles

N W E S

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2015

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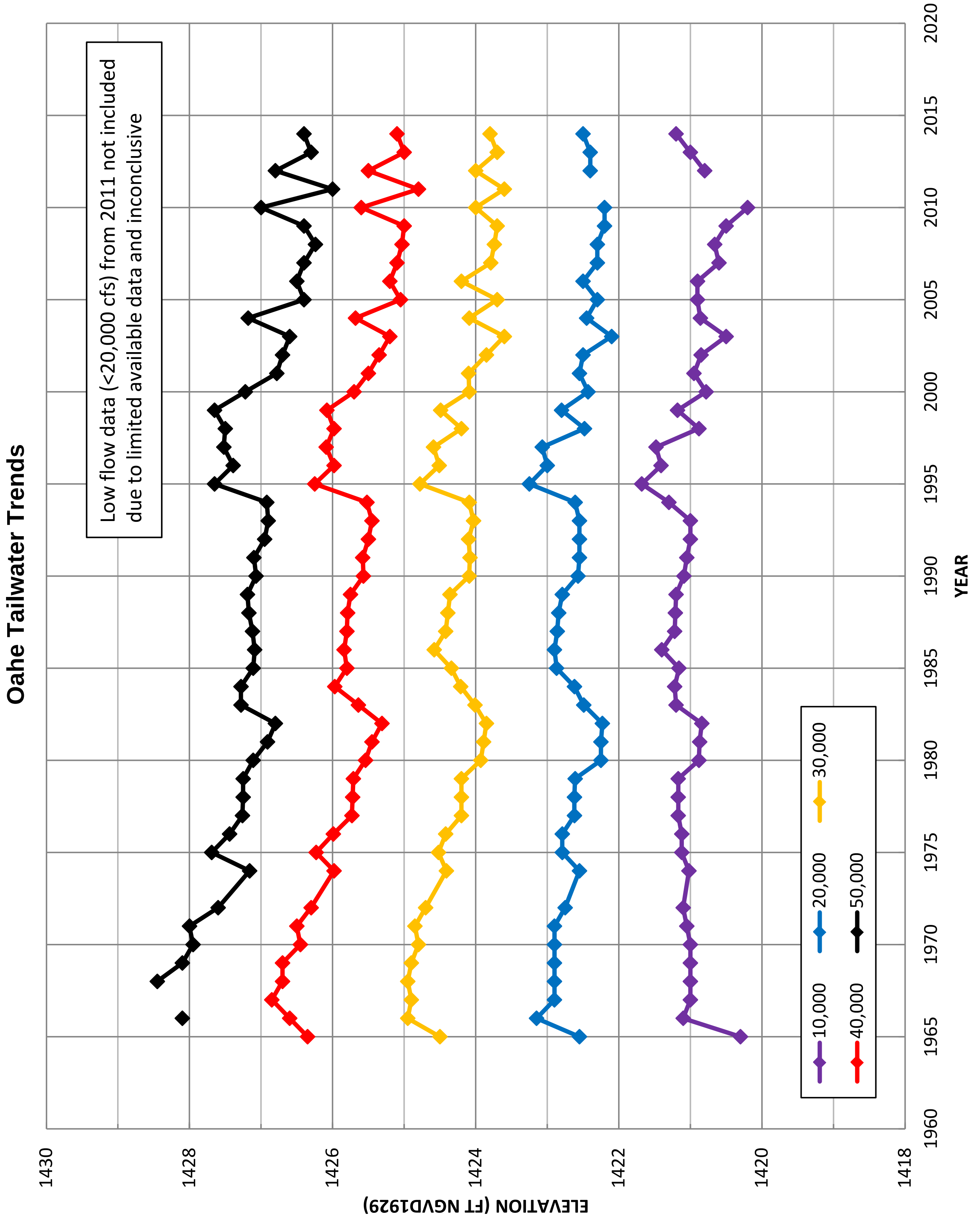
Missouri River Basin
OAHE PROJECT
RECREATION AREA INDEX
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin

Oahe Water Control Manual

Oahe -Tailwater Trends

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate IV-16

Plate V-1

Missouri River Basin
OAHE DRAINAGE AREA
KEY STREAMGAGING STATIONS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Stage	Flow in cfs									
	Knife River at Hazen, ND	Missouri River at Bismarck, ND	Heart River nr Mandan, ND	Cannonball River at Breien, SD	Grand River at Little Eagle, SD	Moreau River nr White Horse, SD	Cheyenne River nr Wasta, SD	Belle Fourche River nr Elm Springs, SD	Cheyenne River nr Plainview, SD	Bad River nr Fort Pierre, SD
	Rating #22.0	Rating #17.1	Rating #18.2	Rating #17.0	Rating #35.0	Rating #30.0	Rating #27.0	Rating #26.0	Rating #7.0	Rating #29.0
Stage	Fld Stg = 21 ft	Fld Stg = 14.5ft	Fld Stg = 17 ft	Fld Stg = 10 ft	Fld Stg = 15 ft	Fld Stg = 21 ft	Fld Stg = 14 ft	Fld Stg = 19 ft	Fld Stg = 16 ft	Fld Stg = 21 ft
0.0			63				18			
1.0	20		194				216			
2.0	97		491		9		711			
3.0	210	12,300	870		136	55	1600			34
4.0	346	15,800	1,390		422	267	2700	9		144
5.0	508	20,000	1,980	1,040	823	630	3950	229		337
6.0	693	24,500	2,610	1,720	1,370	1140	5410	970		618
7.0	897	29,300	3,350	2,510	2,070	1740	7080	1,980		988
8.0	1,130	34,300	4,150	3,470	2,910	2420	8970	3,130		1,490
9.0	1,380	39,600	5,040	4,600	3,910	3150	11100	4,520	122	2,130
10.0	1,650	45,100	5,950	5,900	5,070	3940	13400	6,150	688	2,840
11.0	1,980	50,500	6,900	7,340	6,380	4790	15900	8,010	1,870	3,560
12.0	2,370	56,700	7,800	8,900	7,870	5720	18700	10,100	3,790	4,340
13.0	2,790	63,000	8,820	8,900	9,510	6750	21700	12,400	6,500	5,210
14.0	3,240	71,000	9,870	8,900	11,300	7900	24800	14,900	9,340	6,100
15.0	3,710	80,000	11,200	8,900	13,400	9140		17,700	12,800	6,980
16.0	4,200	92,700	12,800	8,900	15,600	10400		20,600	17,000	7,970
17.0	4,720	110,000	14,500	8,900	18,000	11800		23,800	22,000	8,920
18.0	5,260	130,000	16,300	8,900	20,600	13300		27,200	27,900	9,880
19.0	5,820	153,000	18,300	8,900	23,500	14800		30,800	34,800	11,000
20.0	6,400	179,000	20,400	8,900	27,000	16400		34,500	43,000	12,000
21.0	6,940	207,000	22,600	8,900	32,400	18000		38,500	54,900	13,100
22.0	7,590	239,000	25,000	8,900	41,300	19600		42,700	68,900	14,200
23.0	8,430	274,000	27,500	8,900	53,900	21400		47,100		15,400
24.0	9,910	312,000	30,300	8,900	69,400	23500		51,700		16,700
25.0	13,700	354,000	33,200	8,900	88,300	26100		56,500		18,300
26.0	19,100	400,000	36,300			29900				20,500
27.0	26,300	450,000	39,500							23,300
28.0	35,700									26,800
29.0										33,700
30.0										
31.0										
32.0										
33.0										
34.0										
35.0										

Missouri River Basin
Oahe Water Control Manual
Key Gaging Station Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Oahe
to Allow for Wind Effects
Reservoir Elevation at 1620 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Direction	Wind Speed in Miles Per Hour														
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
360	-0.0	-0.0	-0.1	-0.1	-0.3	-0.4	-0.6	-0.9	-1.4	-2.0	-2.8	-3.5	-4.4	-5.3	-6.2
10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.5	-0.9	-1.4	-2.0	-2.7	-3.5	-4.3	-5.2	-6.0
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.3	-1.8	-2.5	-3.3	-4.1	-5.0	-5.8
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.9	-3.7	-4.5	-5.3
40	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.9	-2.5	-3.2	-3.8	-4.7
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.1	-3.7
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.9	-1.3	-1.7	-2.1	-2.7
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.6	-0.9	-1.2	-1.5
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.8	+0.9	+1.1	+1.3
110	+0.0	+0.0	+0.0	+0.1	+0.1	+.03	+0.4	+0.6	+0.8	+1.0	+1.3	+1.5	+1.8	+2.2	+2.5
120	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.3	+2.8	+3.2	+3.7
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.2	+1.5	+2.0	+2.5	+3.0	+3.5	+4.0	+4.6
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+3.0	+3.5	+4.1	+4.7	+5.4
150	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.2	+1.6	+2.1	+2.6	+3.3	+3.9	+4.5	+5.3	+6.0
160	+0.0	+0.0	+0.1	+0.3	+0.5	+0.9	+1.3	+1.7	+2.3	+2.9	+3.5	+4.2	+4.9	+5.7	+6.6
170	+0.0	+0.0	+0.1	+0.3	+0.6	+0.9	+1.3	+1.8	+2.4	+3.0	+3.7	+4.3	+5.1	+5.9	+6.8
180	+0.0	+0.0	+0.1	+0.3	+0.6	+0.9	+1.4	+1.8	+2.5	+3.1	+3.7	+4.4	+5.2	+6.0	+6.9
190	+0.0	+0.0	+0.1	+0.3	+0.6	+0.9	+1.3	+1.8	+2.4	+3.0	+3.7	+4.3	+5.1	+5.9	+6.8
200	+0.0	+0.0	+0.1	+0.3	+0.5	+0.9	+1.3	+1.7	+2.3	+2.9	+3.5	+4.2	+4.9	+5.7	+6.6
210	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.2	+1.6	+2.1	+2.6	+3.3	+3.9	+4.5	+5.3	+6.0
220	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+3.0	+3.5	+4.1	+4.7	+5.4
230	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.2	+1.5	+2.0	+2.5	+3.0	+3.5	+4.0	+4.6
240	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.3	+2.8	+3.2	+3.7
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.5	+1.8	+2.2	+2.5
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.8	+0.9	+1.1	+1.3
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.6	-0.9	-1.2	-1.5
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.9	-1.3	-1.7	-2.1	-2.7
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.1	-3.7
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.9	-2.5	-3.2	-3.8	-4.7
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.9	-3.7	-4.5	-5.3
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.3	-1.8	-2.5	-3.3	-4.1	-5.0	-5.8
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.5	-0.9	-1.4	-2.0	-2.7	-3.5	-4.3	-5.2	-6.0

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Oahe
to Allow for Wind Effects
Reservoir Elevation at 1610 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.5	-0.8	-1.4	-1.9	-2.6	-3.4	-4.2	-5.1	-5.9
10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.3	-1.9	-2.6	-3.3	-4.1	-5.0	-5.8
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.7	-2.4	-3.1	-3.9	-4.7	-5.5
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.9	-3.7	-4.5	-5.3
40	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.3	-1.7	-2.3	-3.0	-3.7	-4.4
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.8	-2.3	-2.9	-3.5
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.4	-0.4	-0.6	-0.9	-1.2	-1.6	-2.1	-2.6
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.6	-0.9	-1.1	-1.4
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.5
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.5	+0.6	+0.7	+0.9	+1.1	+1.2
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.6	+0.7	+1.0	+1.2	+1.5	+1.8	+2.1	+2.4
120	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.8	+2.2	+2.7	+3.1	+3.5
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.1	+1.5	+1.9	+2.4	+2.9	+3.4	+3.9	+4.4
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.7	+2.2	+2.8	+3.4	+3.9	+4.5	+5.2
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.1	+1.5	+2.0	+2.6	+3.2	+3.7	+4.4	+5.1	+5.8
160	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.7	+2.2	+2.8	+3.4	+4.0	+4.7	+5.5	+6.3
170	+0.0	+0.0	+0.1	+0.2	+0.6	+0.9	+1.3	+1.7	+2.3	+2.9	+3.5	+4.2	+4.9	+5.7	+6.5
180	+0.0	+0.0	+0.1	+0.2	+0.6	+0.9	+1.3	+1.7	+2.4	+3.0	+3.5	+4.2	+5.0	+5.8	+6.7
190	+0.0	+0.0	+0.1	+0.2	+0.6	+0.9	+1.3	+1.7	+2.3	+2.9	+3.5	+4.2	+4.9	+5.7	+6.5
200	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.7	+2.2	+2.8	+3.4	+4.0	+4.7	+5.5	+6.3
210	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.1	+1.5	+2.0	+2.6	+3.2	+3.7	+4.4	+5.1	+5.8
220	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.7	+2.2	+2.8	+3.4	+3.9	+4.5	+5.2
230	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.1	+1.5	+1.9	+2.4	+2.9	+3.4	+3.9	+4.4
240	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.8	+2.2	+2.7	+3.1	+3.5
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.6	+0.7	+1.0	+1.2	+1.5	+1.8	+2.1	+2.4
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.5	+0.6	+0.7	+0.9	+1.1	+1.2
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.5
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.6	-0.9	-1.1	-1.4
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.4	-0.4	-0.6	-0.9	-1.2	-1.6	-2.1	-2.6
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.8	-2.3	-2.9	-3.5
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.3	-1.7	-2.3	-3.0	-3.7	-4.4
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.1	-1.6	-2.1	-2.7	-3.5	-4.3	-5.1
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.7	-2.4	-3.1	-3.9	-4.7	-5.5
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.3	-1.9	-2.6	-3.3	-4.1	-5.0	-5.8

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Oahe
to Allow for Wind Effects
Reservoir Elevation at 1600 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Direction	Wind Speed in Miles Per Hour														
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
360	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.5	-0.8	-1.3	-1.8	-2.5	-3.2	-4.0	-4.9	-5.6
10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.3	-1.7	-2.4	-3.1	-3.9	-4.8	-5.5
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.7	-2.3	-2.9	-3.7	-4.5	-5.3
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-2.0	-2.6	-3.4	-4.1	-4.9
40	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.8	-1.3	-1.7	-2.2	-2.8	-3.5	-4.2
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.7	-2.2	-2.8	-3.4
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.6	-1.9	-2.4
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.5	-0.8	-1.1	-1.4
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.4	-0.4	-0.5
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.4	+0.5	+0.7	+0.8	+1.0	+1.2
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.5	+0.7	+1.0	+1.2	+1.4	+1.7	+2.0	+2.3
120	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+2.9	+3.4
130	+0.0	+0.0	+0.1	+0.1	+0.3	+0.5	+0.8	+1.1	+1.4	+1.8	+2.2	+2.7	+3.2	+3.7	+4.3
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.2	+2.7	+3.2	+3.8	+4.3	+5.0
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.1	+1.4	+1.9	+2.5	+3.0	+3.6	+4.2	+4.9	+5.6
160	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.1	+1.6	+2.1	+2.6	+3.2	+3.8	+4.5	+5.2	+6.0
170	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.7	+2.2	+2.8	+3.4	+4.0	+4.7	+5.5	+6.3
180	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.3	+1.7	+2.2	+2.8	+3.4	+4.1	+4.8	+5.5	+6.4
190	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.7	+2.2	+2.8	+3.4	+4.0	+4.7	+5.5	+6.3
200	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.1	+1.6	+2.1	+2.6	+3.2	+3.8	+4.5	+5.2	+6.0
210	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.1	+1.4	+1.9	+2.5	+3.0	+3.6	+4.2	+4.9	+5.6
220	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.2	+2.7	+3.2	+3.8	+4.3	+5.0
230	+0.0	+0.0	+0.1	+0.1	+0.3	+0.5	+0.8	+1.1	+1.4	+1.8	+2.2	+2.7	+3.2	+3.7	+4.3
240	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+2.9	+3.4
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.5	+0.7	+1.0	+1.2	+1.4	+1.7	+2.0	+2.3
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.4	+0.5	+0.7	+0.8	+1.0	+1.2
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.5
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.5	-0.8	-1.1	-1.4
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.6	-1.9	-2.4
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.7	-2.2	-2.8	-3.4
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.8	-1.3	-1.7	-2.3	-2.8	-3.5	-4.2
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-2.0	-2.6	-3.4	-4.1	-4.9
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.7	-2.3	-2.9	-3.7	-4.5	-5.3
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.3	-1.7	-2.4	-3.1	-3.9	-4.8	-5.5

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Oahe
to Allow for Wind Effects
Reservoir Elevation at 1590 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.7	-2.4	-3.1	-3.9	-4.7	-5.4
10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.7	-2.4	-3.0	-3.8	-4.6	-5.3
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.6	-2.2	-2.8	-3.6	-4.3	-5.1
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.2	-3.9	-4.7
40	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.6	-2.1	-2.8	-3.4	-4.1
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.2	-1.7	-2.1	-2.6	-3.2
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.4	-1.8	-2.3
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.5	-0.6	-0.7	-1.0	-1.3
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.5
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.5	+0.6	+0.7	+0.8	+1.0	+1.2
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.6	+1.9	+2.2
120	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.7	+2.0	+2.4	+2.8	+3.2
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.4	+1.7	+2.1	+2.6	+3.0	+3.6	+4.1
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.3	+1.6	+2.1	+2.6	+3.1	+3.6	+4.2	+4.8
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.4	+2.9	+3.5	+4.0	+4.7	+5.3
160	+0.0	+0.0	+0.1	+0.2	+0.5	+0.7	+1.1	+1.5	+2.0	+2.6	+3.1	+3.7	+4.3	+5.0	+5.8
170	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.6	+2.1	+2.7	+3.3	+3.9	+4.5	+5.2	+6.0
180	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.6	+2.1	+2.7	+3.3	+3.9	+4.6	+5.3	+6.1
190	+0.0	+0.0	+0.1	+0.2	+0.5	+0.8	+1.2	+1.6	+2.1	+2.7	+3.3	+3.9	+4.5	+5.2	+6.0
200	+0.0	+0.0	+0.1	+0.2	+0.5	+0.7	+1.1	+1.5	+2.0	+2.6	+3.1	+3.7	+4.3	+5.0	+5.8
210	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.4	+2.9	+3.5	+4.0	+4.7	+5.3
220	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.3	+1.6	+2.1	+2.6	+3.1	+3.6	+4.2	+4.8
230	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.4	+1.7	+2.1	+2.6	+3.0	+3.6	+4.1
240	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.7	+2.0	+2.4	+2.8	+3.2
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.6	+1.9	+2.2
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.5	+0.6	+0.7	+0.8	+1.0	+1.2
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.5
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.5	-0.6	-0.7	-1.0	-1.3
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.4	-1.8	-2.3
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.2	-1.7	-2.1	-2.6	-3.2
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.6	-2.1	-2.8	-3.4	-4.1
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.2	-3.9	-4.7
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.6	-2.2	-2.8	-3.6	-4.3	-5.1
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-1.2	-1.7	-2.4	-3.0	-3.8	-4.6	-5.3

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Oahe to Allow for Wind Effects

Reservoir Elevation at 1580 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.8	-1.2	-1.7	-2.3	-3.1	-3.8	-4.6	-5.3
10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.8	-1.2	-1.7	-2.3	-3.0	-3.7	-4.5	-5.2
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.8	-3.5	-4.3	-5.0
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-1.0	-1.4	-1.9	-2.5	-3.2	-3.9	-4.6
40	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.5	-0.8	-1.1	-1.6	-2.1	-2.7	-3.3	-4.0
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.6	-2.1	-2.6	-3.2
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.5	-1.9	-2.3
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.5	-0.8	-1.0	-1.3
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+0.9	+1.1
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.5	+0.7	+0.9	+1.1	+1.3	+1.6	+1.9	+2.2
120	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.5	+0.8	+1.0	+1.3	+1.6	+2.0	+2.3	+2.8	+3.1
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.0	+3.4	+4.0
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.5	+3.0	+3.5	+4.1	+4.6
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.3	+3.9	+4.5	+5.2
160	+0.0	+0.0	+0.1	+0.2	+0.4	+0.8	+1.1	+1.5	+2.0	+2.5	+3.1	+3.6	+4.2	+4.9	+5.6
170	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.1	+1.6	+2.1	+2.6	+3.2	+3.8	+4.4	+5.1	+5.9
180	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.1	+1.6	+2.1	+2.7	+3.2	+3.8	+4.5	+5.2	+6.0
190	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.1	+1.6	+2.1	+2.6	+3.2	+3.8	+4.4	+5.1	+5.9
200	+0.0	+0.0	+0.1	+0.2	+0.4	+0.8	+1.1	+1.5	+2.0	+2.5	+3.1	+3.6	+4.2	+4.9	+5.6
210	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.3	+3.9	+4.5	+5.2
220	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.5	+3.0	+3.5	+4.1	+4.6
230	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.0	+3.4	+4.0
240	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.5	+0.8	+1.0	+1.3	+1.6	+2.0	+2.3	+2.8	+3.1
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.5	+0.7	+0.9	+1.1	+1.3	+1.6	+1.9	+2.2
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+0.9	+1.0
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.5	-0.8	-1.0	-1.3
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.5	-1.9	-2.3
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.6	-2.1	-2.6	-3.2
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.5	-0.8	-1.1	-1.6	-2.1	-2.7	-3.3	-4.0
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-1.0	-1.4	-1.9	-2.5	-3.2	-3.9	-4.6
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.8	-3.5	-4.3	-5.0
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.8	-1.2	-1.7	-2.3	-3.0	-3.7	-4.5	-5.2

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

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U.S. Army Engineer Division, Northwestern
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to Allow for Wind Effects
Reservoir Elevation at 1570 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

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10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.8	-3.5	-4.2	-4.9
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.1	-1.5	-2.0	-2.7	-3.3	-4.0	-4.7
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.8	-2.3	-3.0	-3.6	-4.3
40	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.5	-2.0	-2.5	-3.1	-3.8
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.5	-2.0	-2.4	-3.0
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.7	-1.1	-1.4	-1.7	-2.1
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.7	-1.0	-1.2
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.9	+1.1
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.1	+1.3	+1.5	+1.8	+2.1
120	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.5	+0.7	+1.0	+1.3	+1.5	+1.9	+2.2	+2.6	+3.0
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.3	+1.6	+2.0	+2.4	+2.9	+3.3	+3.8
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.3	+3.9	+4.4
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+1.0	+1.3	+1.7	+2.2	+2.7	+3.2	+3.7	+4.3	+5.0
160	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.1	+1.4	+1.9	+2.4	+2.9	+3.4	+4.0	+4.7	+5.4
170	+0.0	+0.0	+0.1	+0.2	+0.5	+0.7	+1.1	+1.5	+2.0	+2.5	+3.0	+3.6	+4.2	+4.9	+5.6
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200	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.1	+1.4	+1.9	+2.4	+2.9	+3.4	+4.0	+4.7	+5.4
210	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+1.0	+1.3	+1.7	+2.2	+2.7	+3.2	+3.7	+4.3	+5.0
220	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.3	+3.9	+4.4
230	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.3	+1.6	+2.0	+2.4	+2.9	+3.3	+3.8
240	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.5	+0.7	+1.0	+1.3	+1.5	+1.9	+2.2	+2.6	+3.0
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.1	+1.3	+1.5	+1.8	+2.1
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.9	+1.1
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	+0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.7	-1.0	-1.2
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.7	-1.1	-1.4	-1.7	-2.1
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.5	-2.0	-2.4	-3.0
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.5	-2.0	-2.5	-3.1	-3.8
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.8	-2.3	-3.0	-3.6	-4.3
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.1	-1.5	-2.0	-2.7	-3.3	-4.0	-4.7
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.6	-2.2	-2.8	-3.5	-4.2	-4.9

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Oahe
to Allow for Wind Effects
Reservoir Elevation at 1560 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

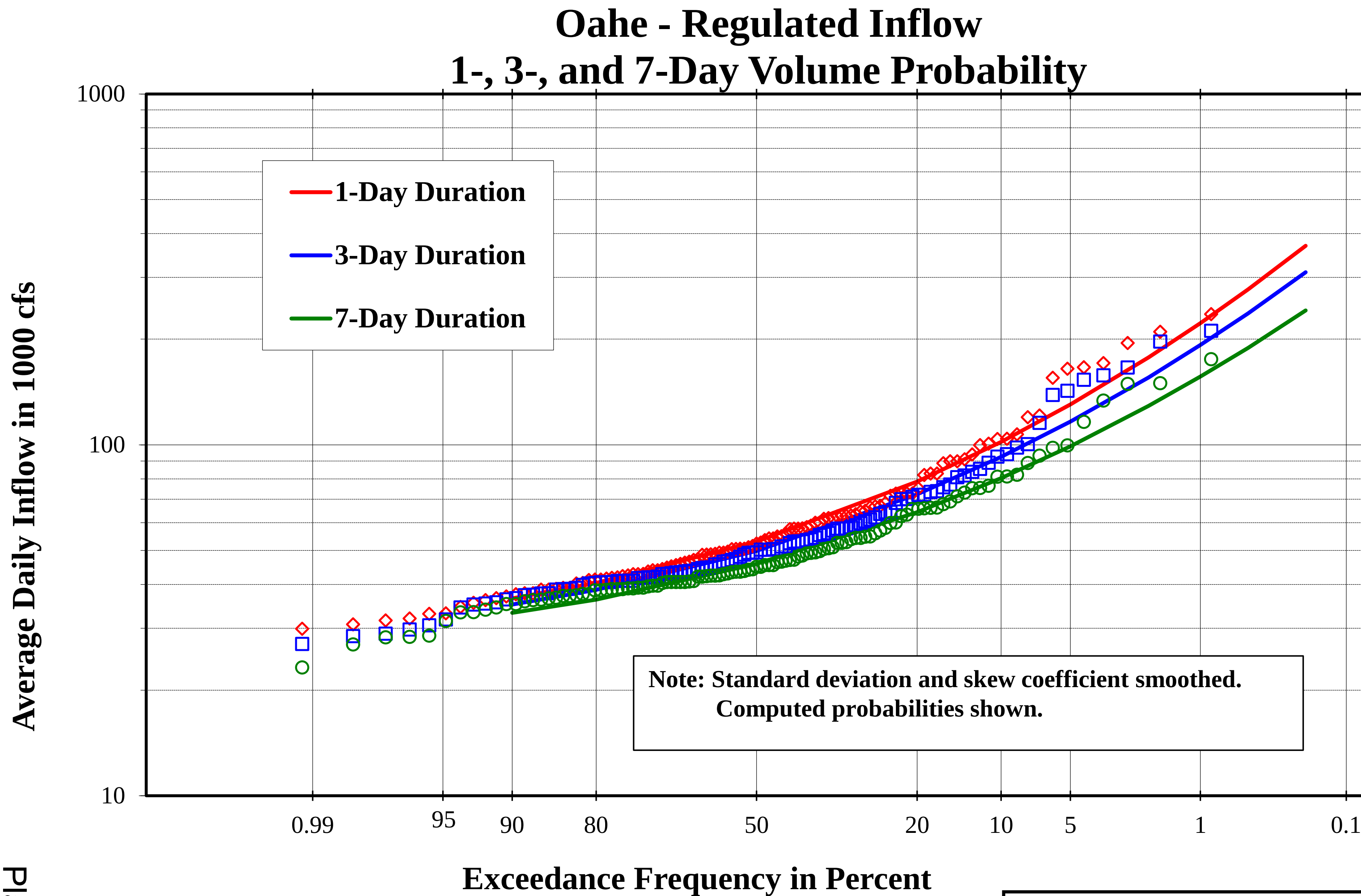
Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.2	-3.9	-4.6
10	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.9	-2.5	-3.1	-3.8	-4.5
20	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.7	-2.3	-2.9	-3.6	-4.3
30	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.5	-0.7	-1.1	-1.6	-2.0	-2.6	-3.2	-3.9
40	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.7	-2.2	-2.8	-3.4
50	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-1.0	-1.3	-1.7	-2.2	-2.7
60	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.9	-1.2	-1.5	-1.9
70	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.6	-0.8	-1.1
80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
90	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
100	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.2	+1.4	+1.6	+1.9
120	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.7	+2.0	+2.4	+2.7
130	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.6	+0.9	+1.2	+1.4	+1.8	+2.2	+2.6	+3.0	+3.5
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.1	+1.4	+1.7	+2.2	+2.6	+3.0	+3.5	+4.0
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.2	+1.5	+1.9	+2.5	+2.9	+3.4	+3.9	+4.5
160	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.3	+1.7	+2.2	+2.6	+3.2	+3.7	+4.3	+4.9
170	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.8	+2.3	+2.7	+3.3	+3.8	+4.5	+5.1
180	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.3	+3.9	+4.5	+5.2
190	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.8	+2.3	+2.7	+3.3	+3.8	+4.5	+5.1
200	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.3	+1.7	+2.2	+2.6	+3.2	+3.7	+4.3	+4.9
210	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.2	+1.5	+1.9	+2.5	+2.9	+3.4	+3.9	+4.5
220	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.1	+1.4	+1.7	+2.2	+2.6	+3.0	+3.5	+4.0
230	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.6	+0.9	+1.2	+1.4	+1.8	+2.2	+2.6	+3.0	+3.5
240	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.7	+2.0	+2.4	+2.7
250	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.2	+1.4	+1.6	+1.9
260	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
270	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
280	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	+0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.6	-0.8	-1.1
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.9	-1.2	-1.5	-1.9
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-1.0	-1.3	-1.7	-2.2	-2.7
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.7	-2.2	-2.8	-3.4
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.5	-0.7	-1.1	-1.6	-2.0	-2.6	-3.2	-3.9
340	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.7	-2.3	-2.9	-3.6	-4.3
350	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.9	-2.5	-3.1	-3.8	-4.5

Reservoir Elevation Wind Corrections in Feet

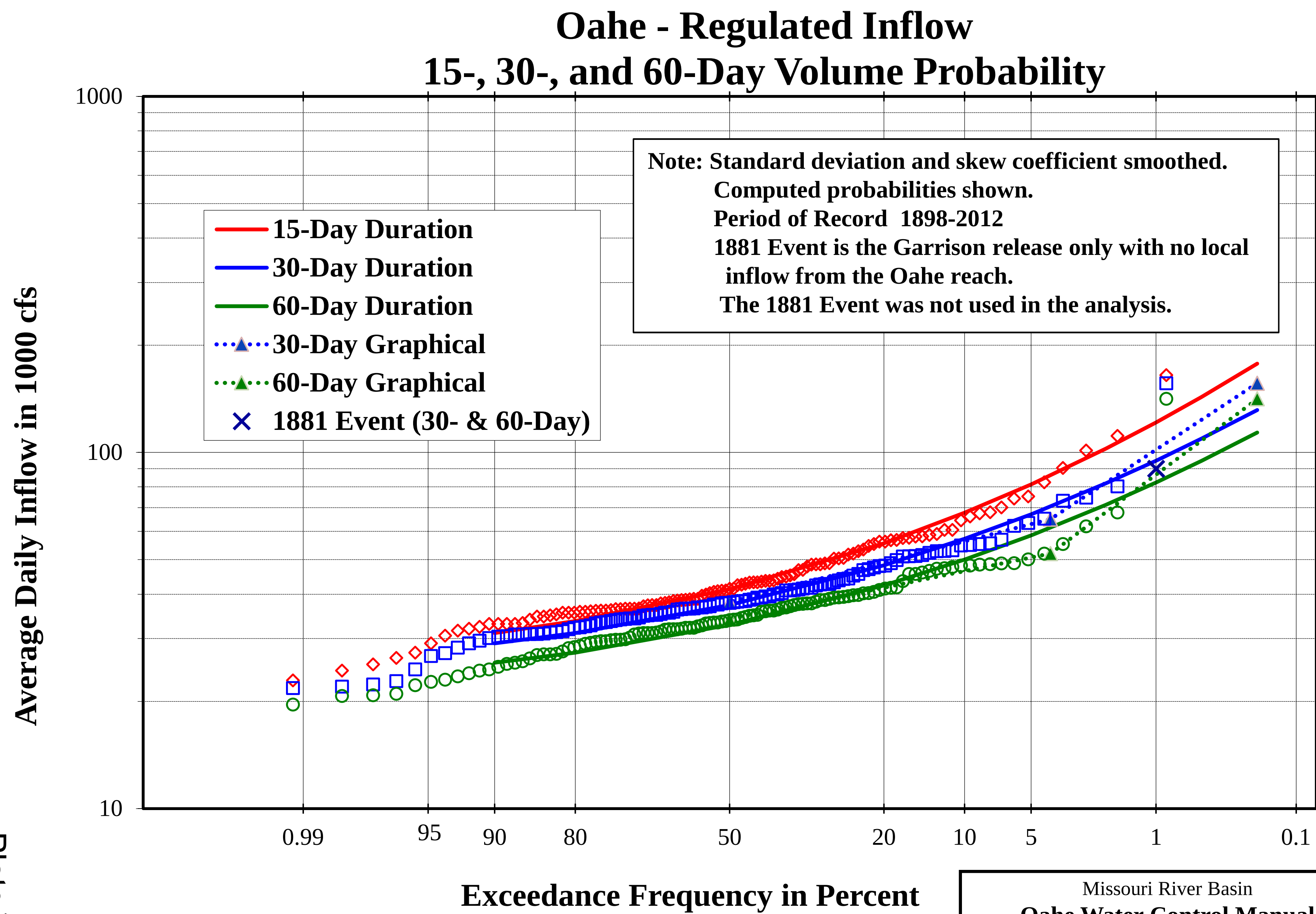
*** Pool elevation as measured at the dam.**

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Oahe Water Control Manual
Oahe Regulated Inflow Probability
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

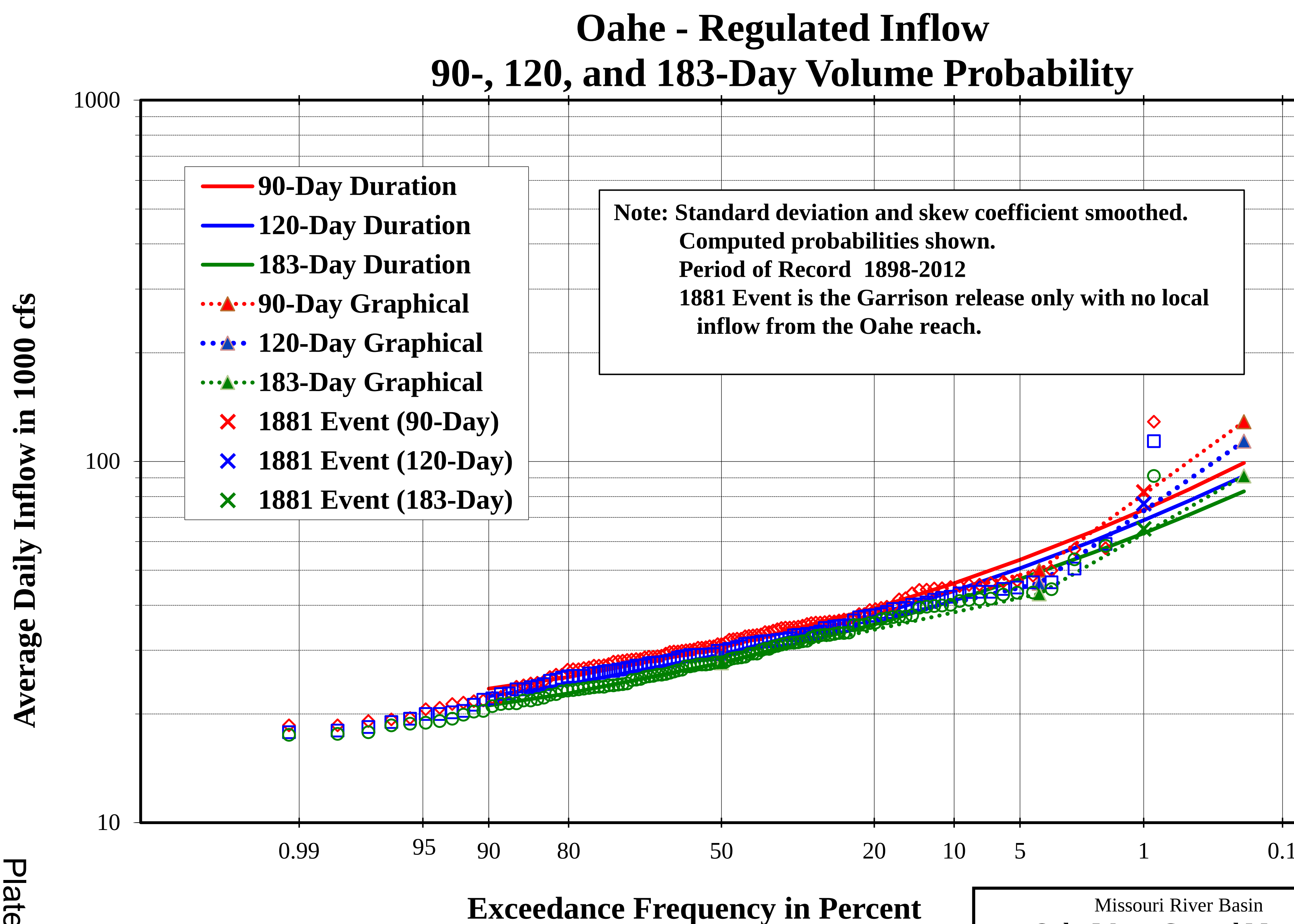


Missouri River Basin

Oahe Water Control Manual

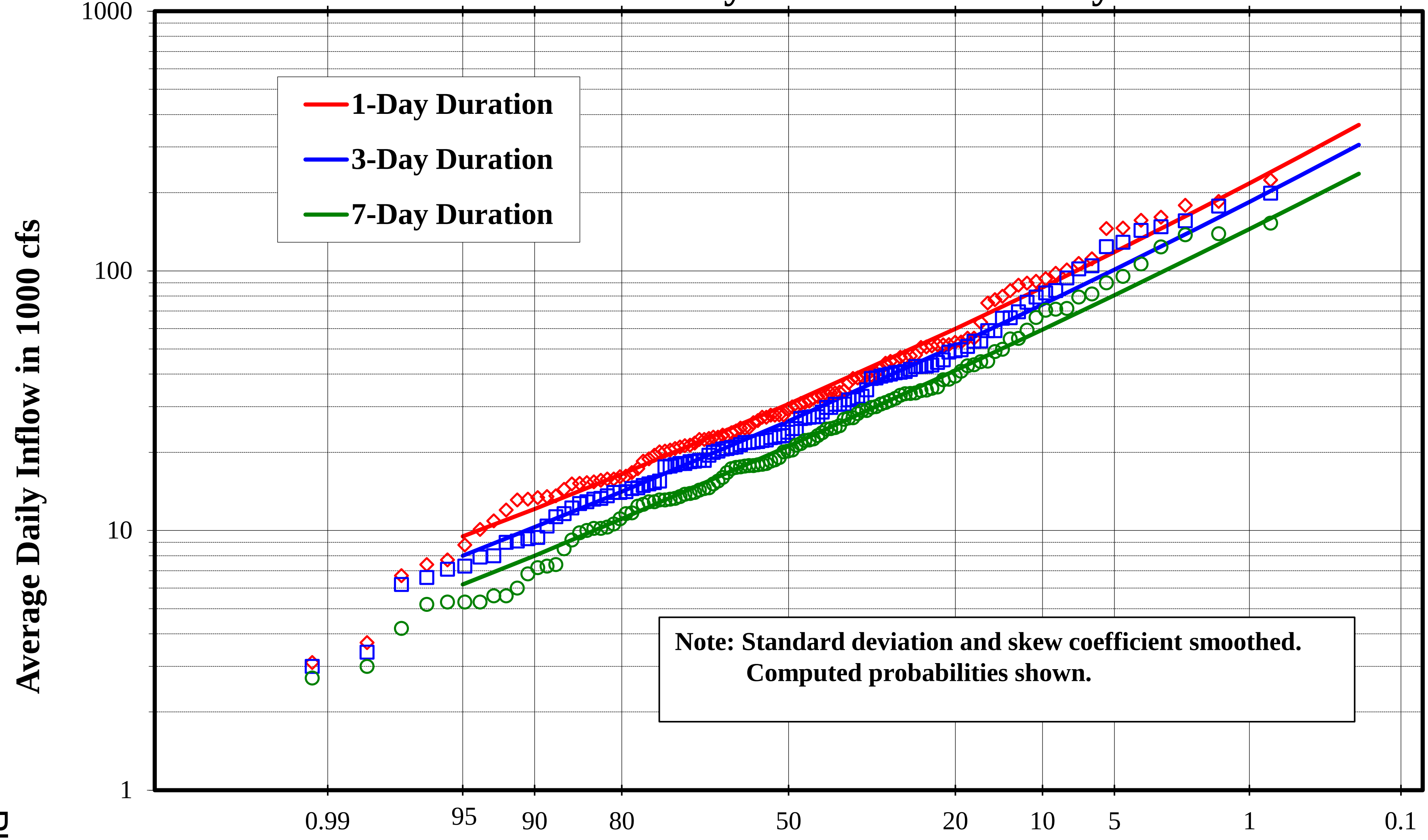
Oahe Regulated Inflow Probability

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



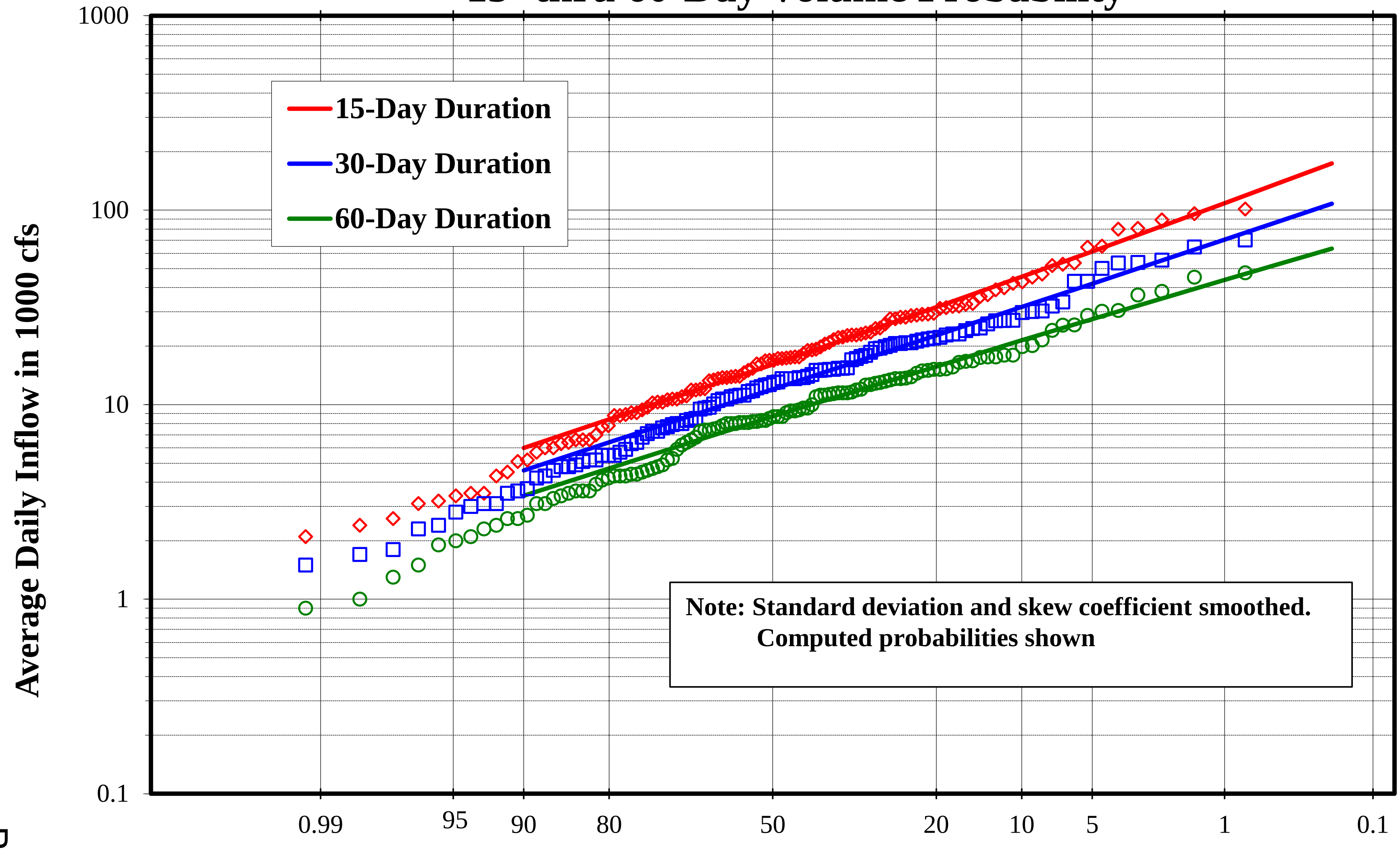
Missouri River Basin
Oahe Water Control Manual
Oahe Regulated Inflow Probability
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Oahe - Incremental Inflow
1- thru 7-Day Volume Probability

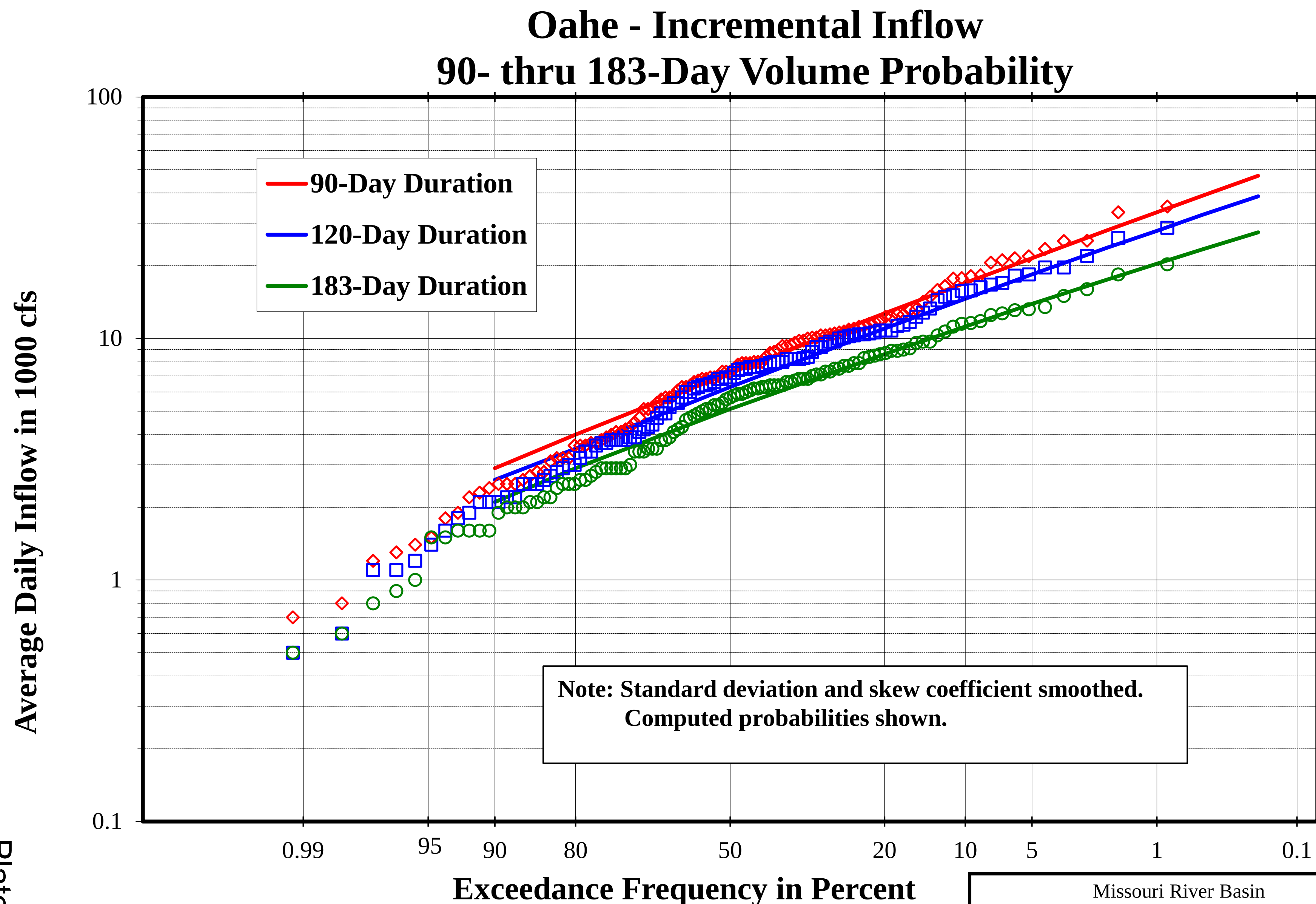


Missouri River Basin
Oahe Water Control Manual
Oahe Incremental Inflow Probability
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

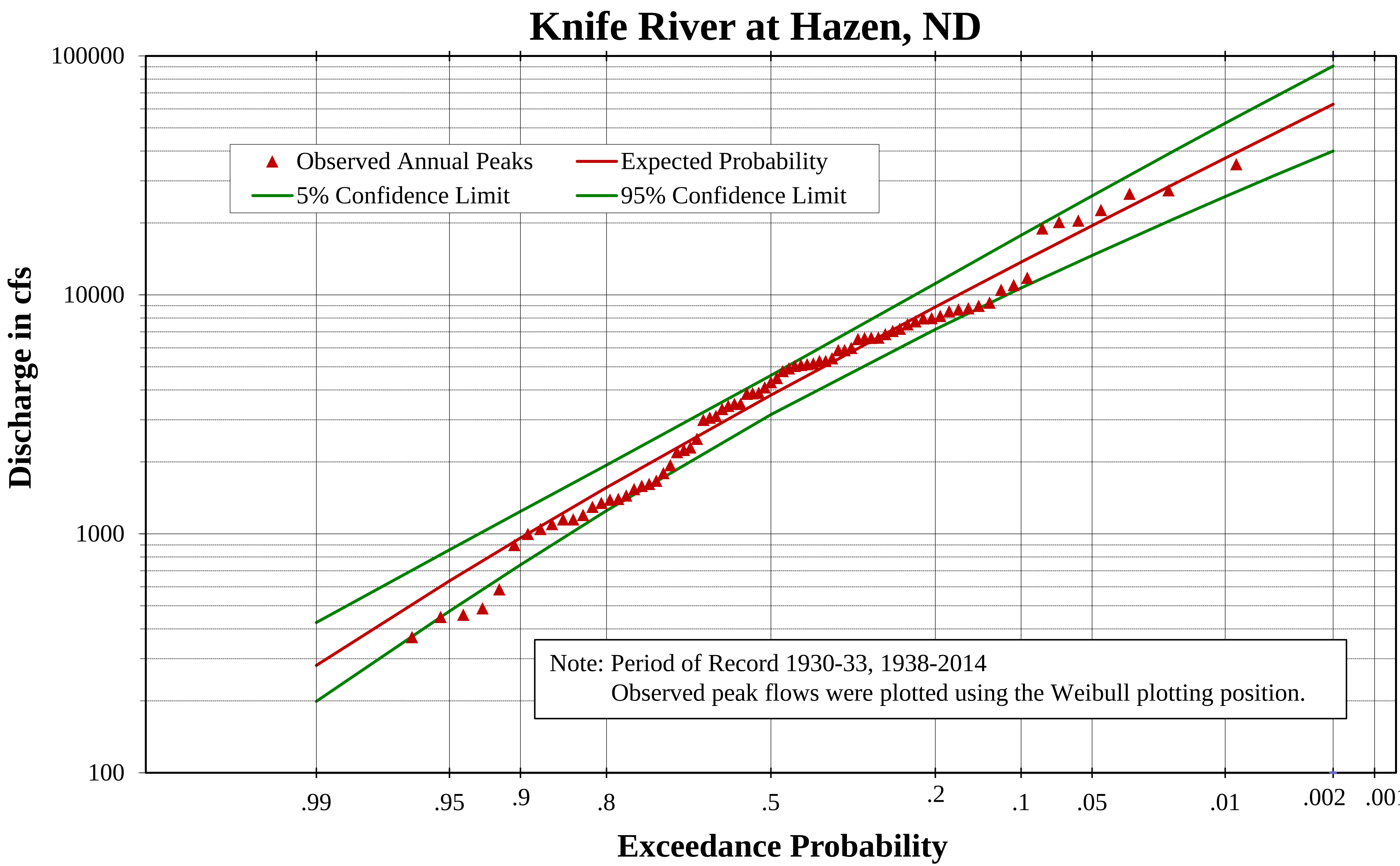
Oahe - Incremental Inflow
15- thru 60-Day Volume Probability



Missouri River Basin
Oahe Water Control Manual
Oahe Incremental Inflow Probability
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Oahe Water Control Manual
Oahe Incremental Inflow Probability
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



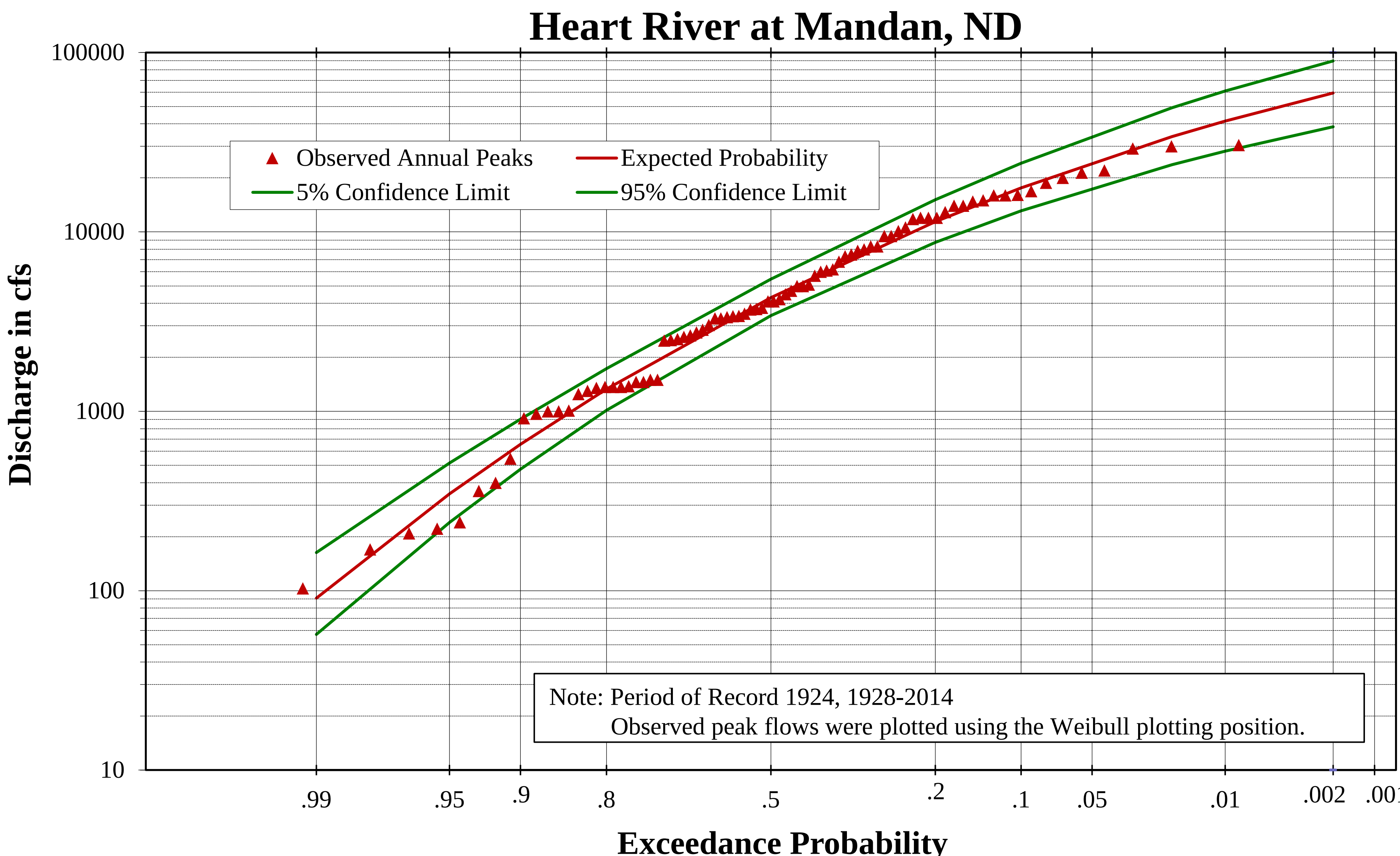
Missouri River Basin

Oahe Water Control Manual

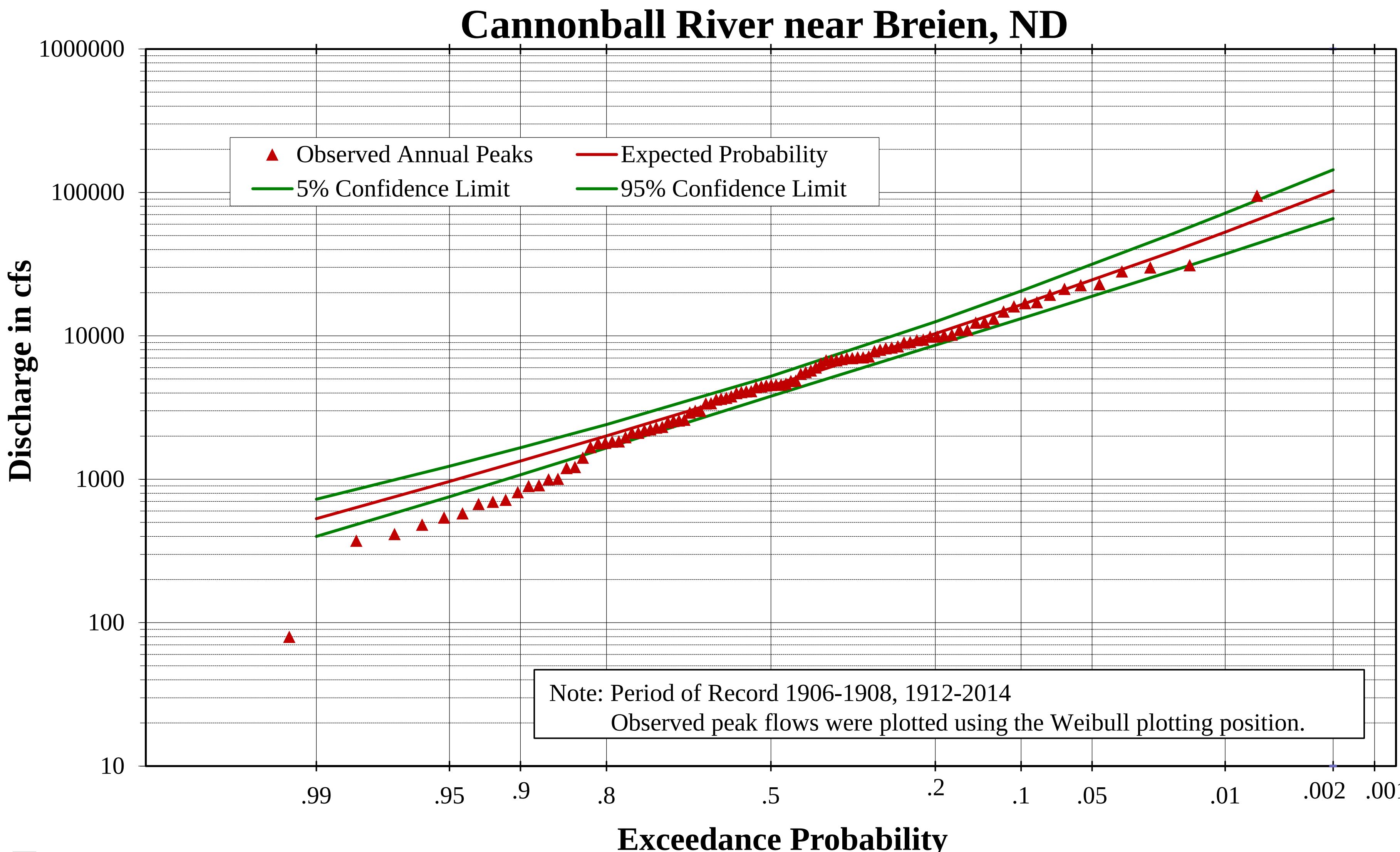
Probability Curve – Knife River at Hazen, ND

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate VI-9



Missouri River Basin
Oahe Water Control Manual
Probability Curve – Heart River at Mandan, ND
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

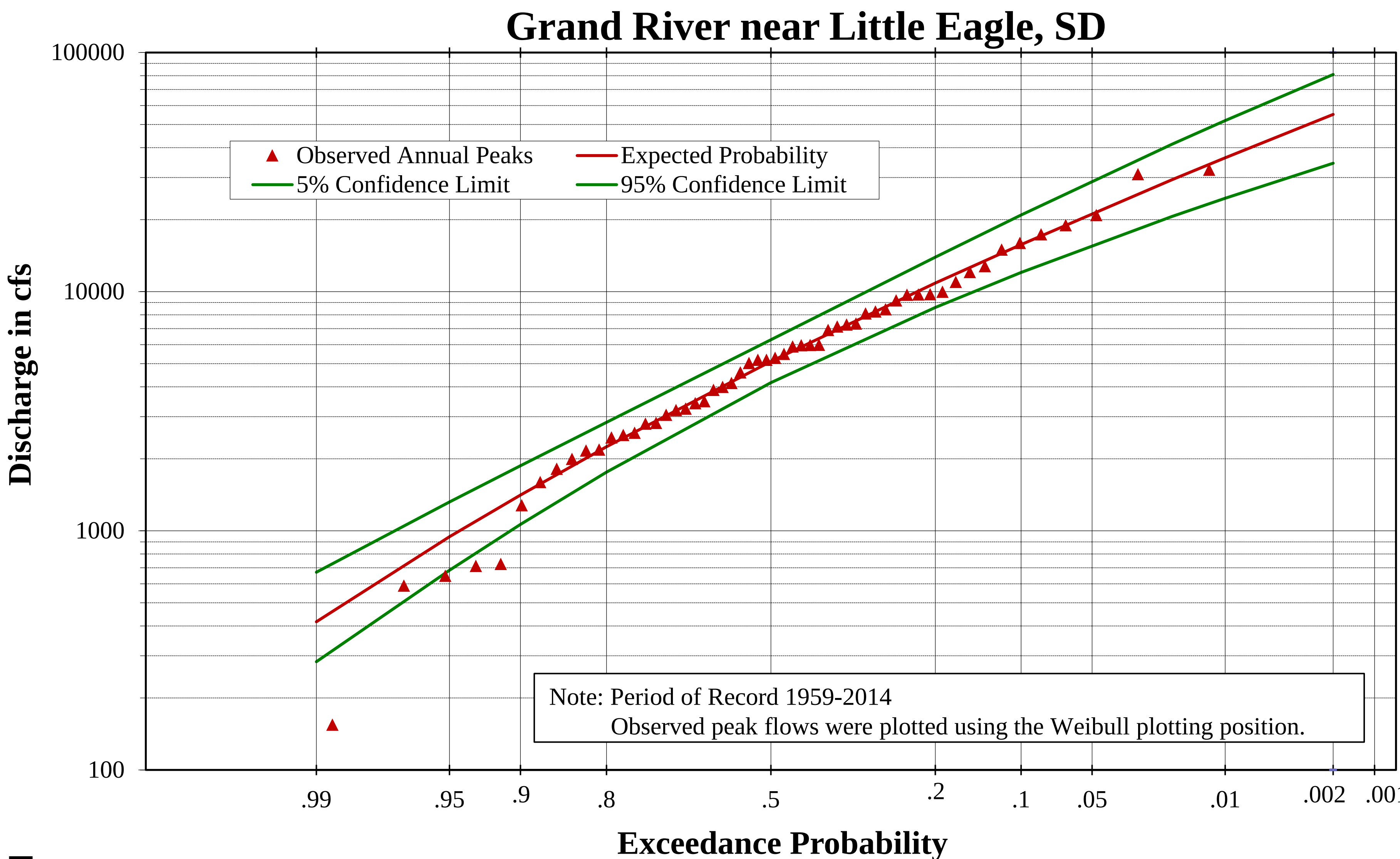


Missouri River Basin

Oahe Water Control Manual

Probability Curve – Cannonball River at Breien, ND

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin

Oahe Water Control Manual

Probability Curve – Grand River near Little Eagle, SD

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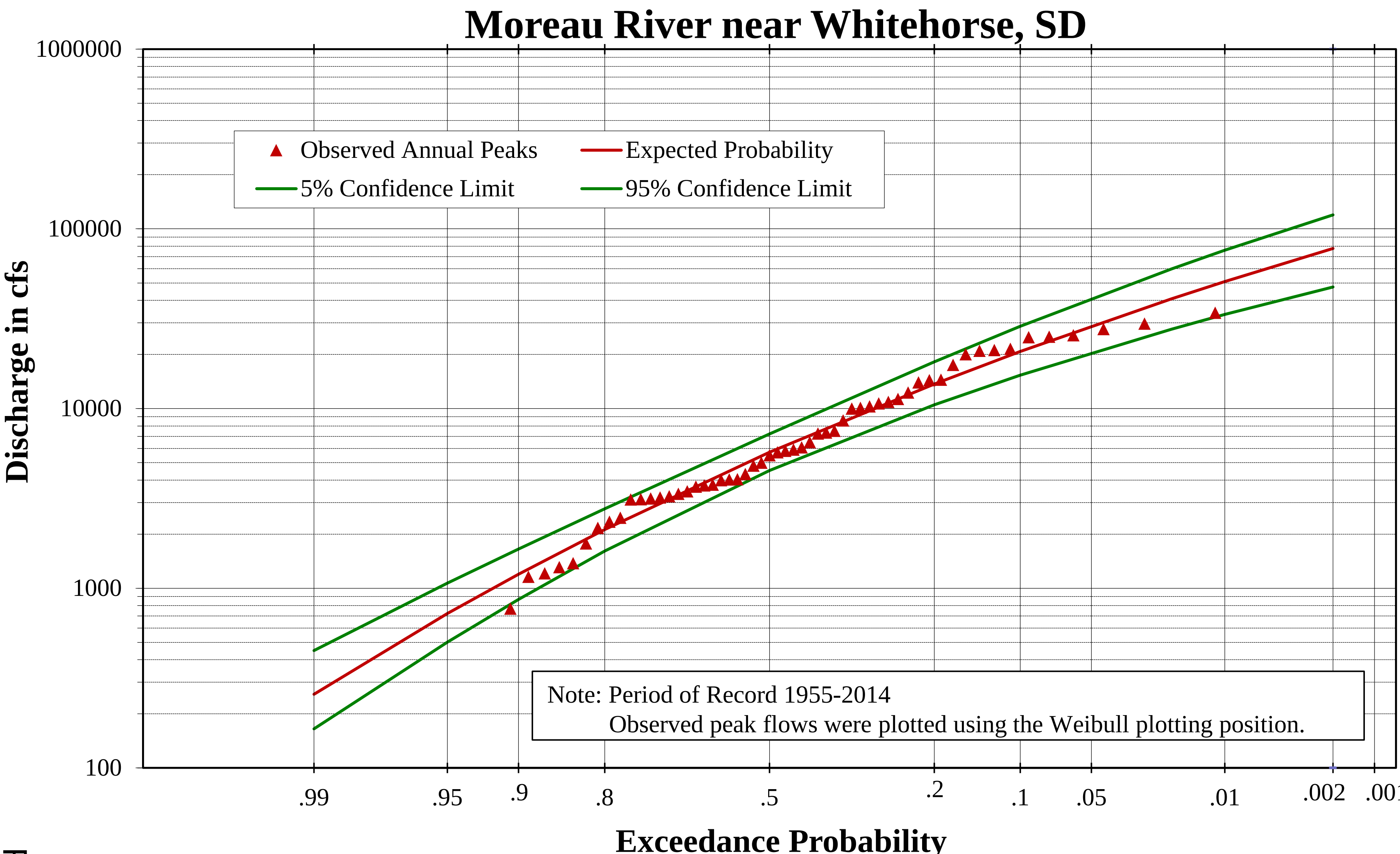
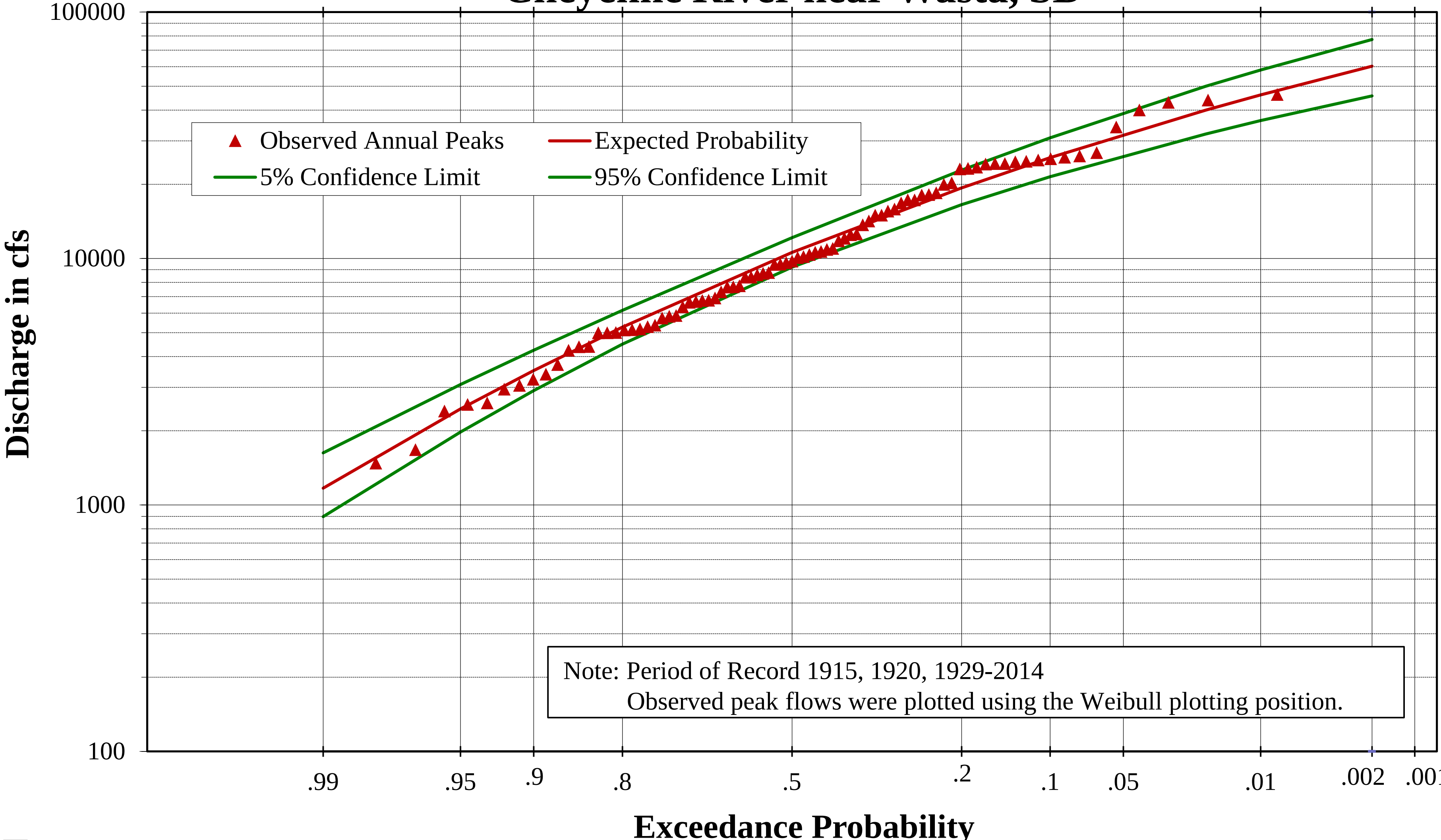
Corps of Engineers, Omaha, Nebraska
September 2017

Plate VI-12



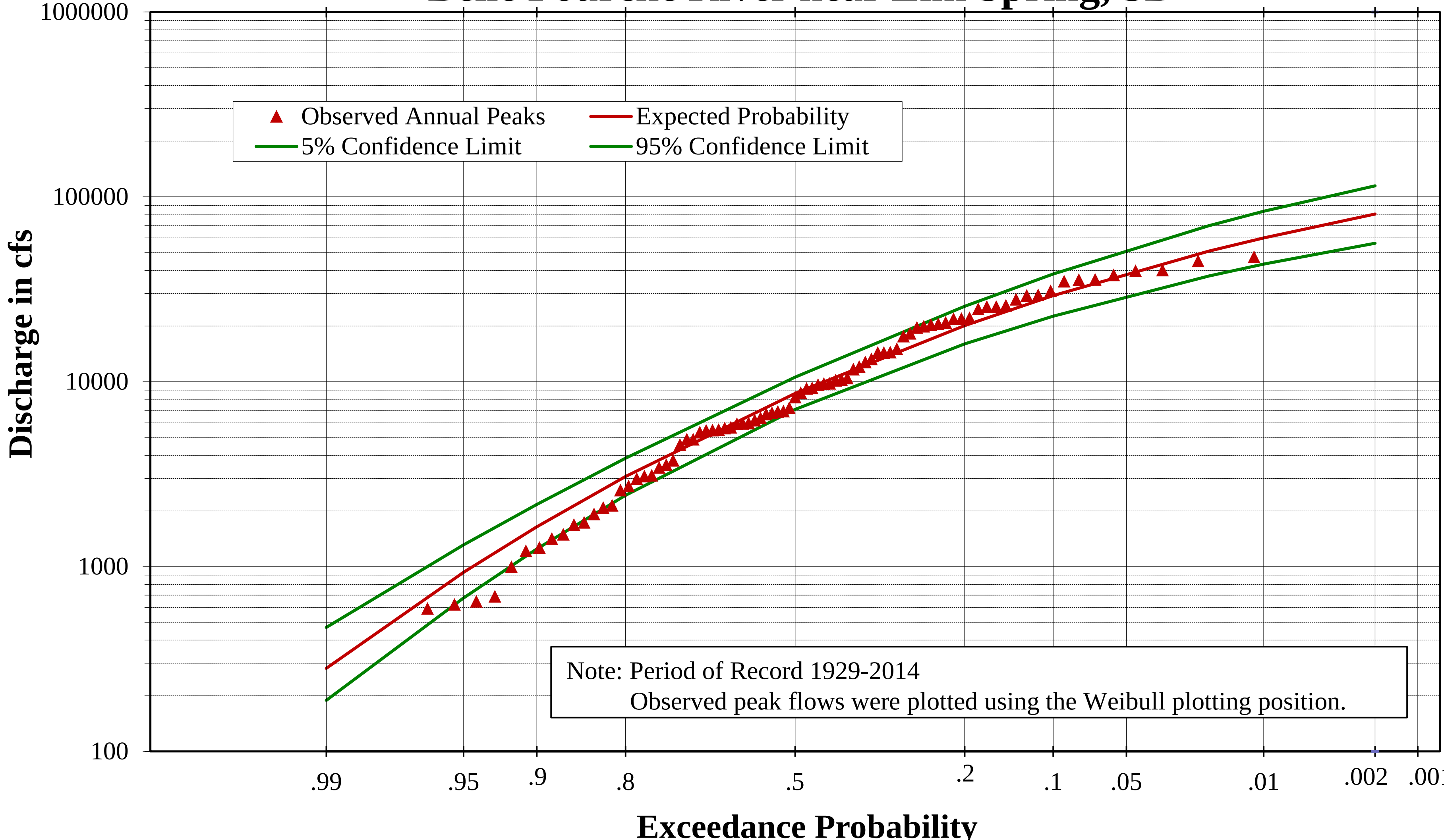
Missouri River Basin
Oahe Water Control Manual
Probability Curve – Moreau River near Whitehorse, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Cheyenne River near Wasta, SD



Missouri River Basin
Oahe Water Control Manual
Probability Curve – Cheyenne River near Wasta, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Belle Fourche River near Elm Spring, SD

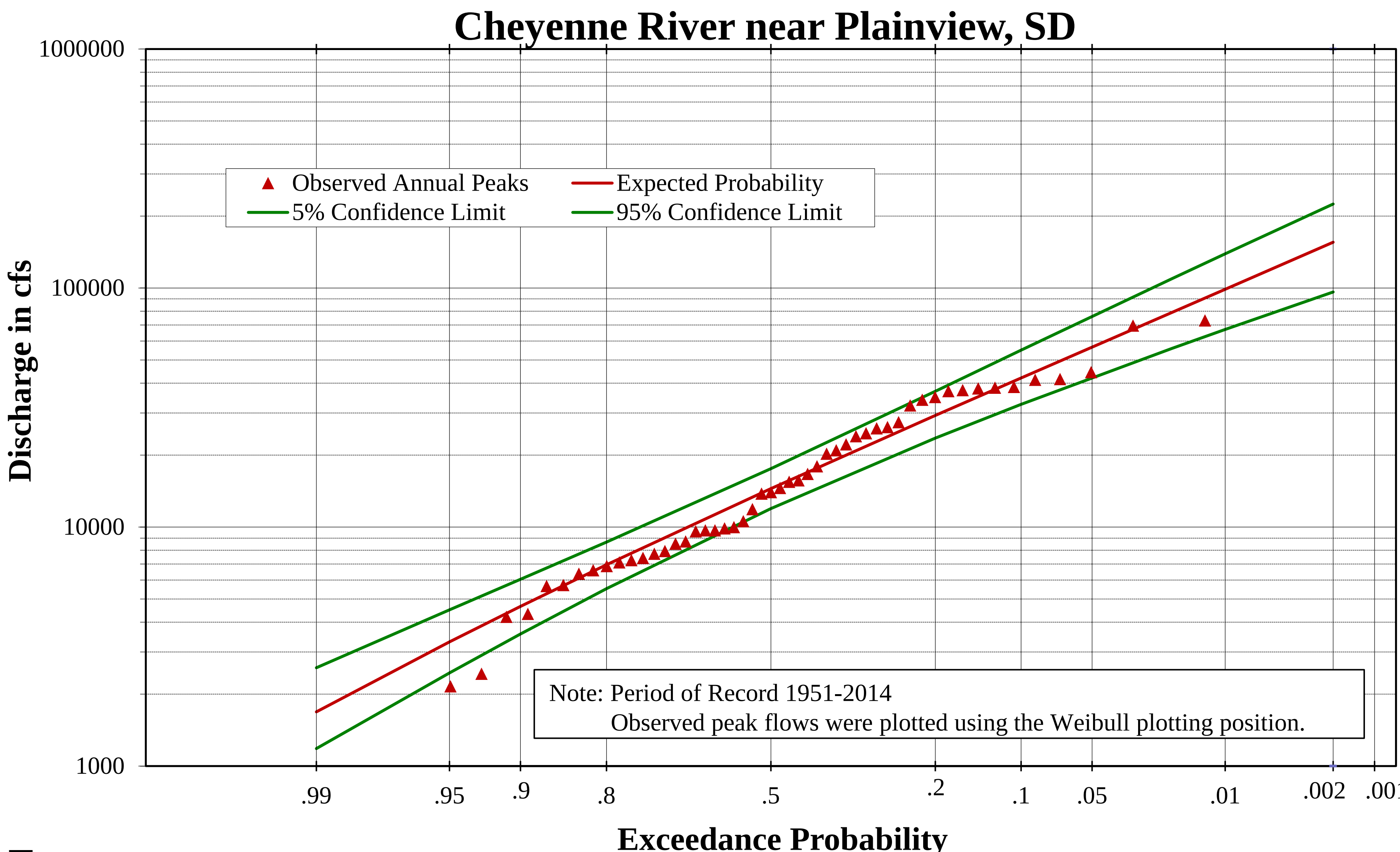


Missouri River Basin

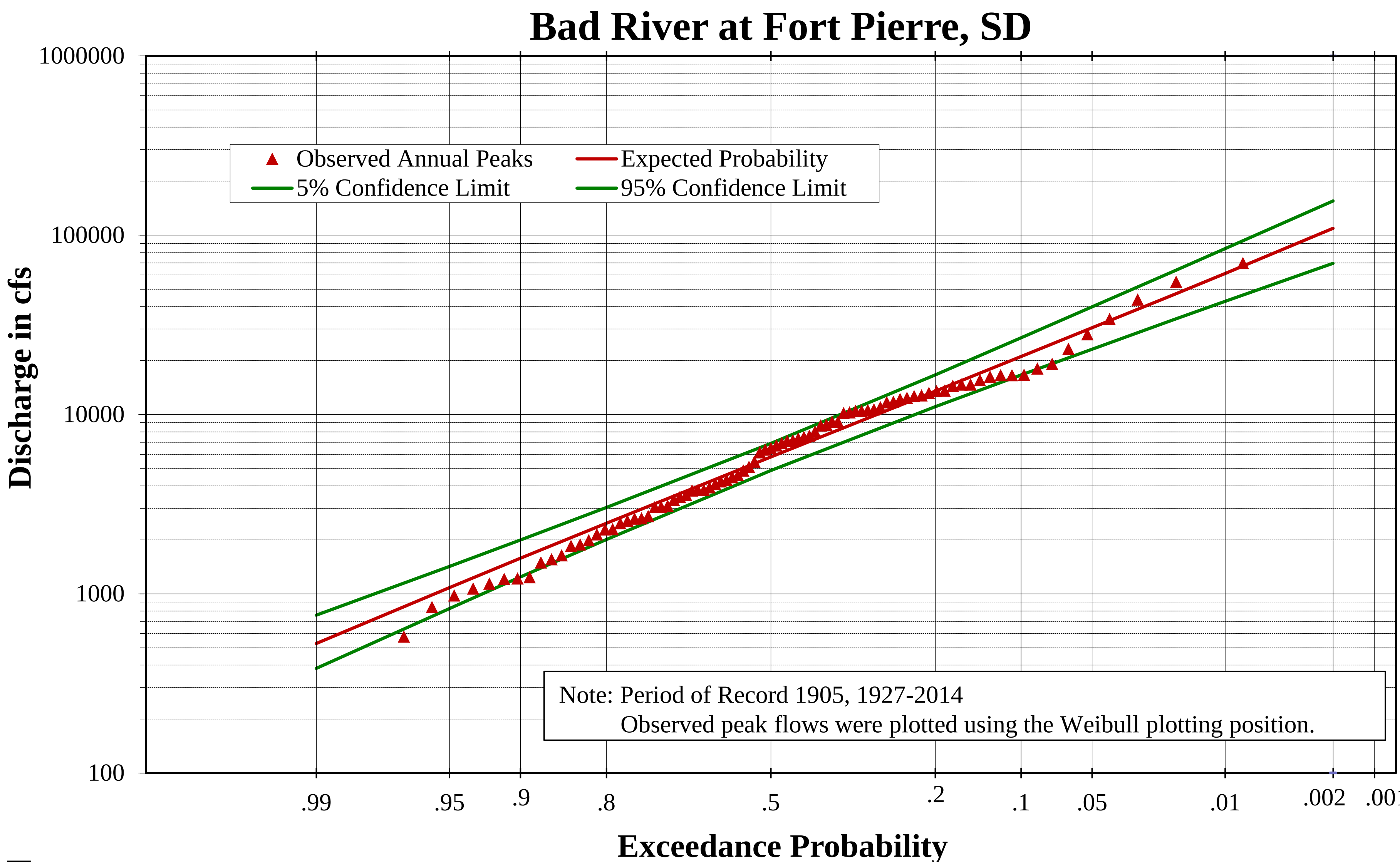
Oahe Water Control Manual

Probability Curve – Belle Fourche River near Elm Spring, SD

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Oahe Water Control Manual
Probability Curve – Cheyenne River near Plainview, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

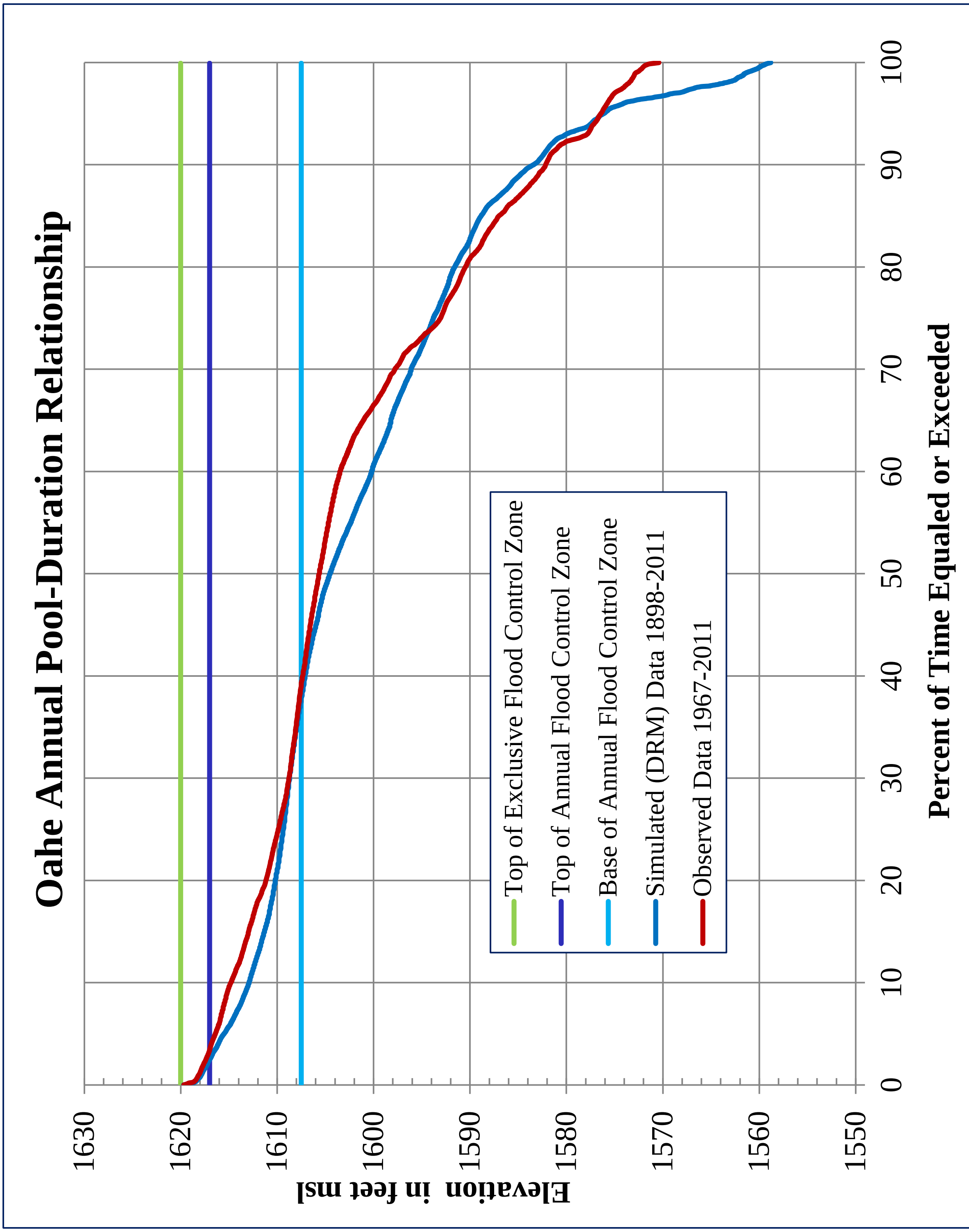


Missouri River Basin

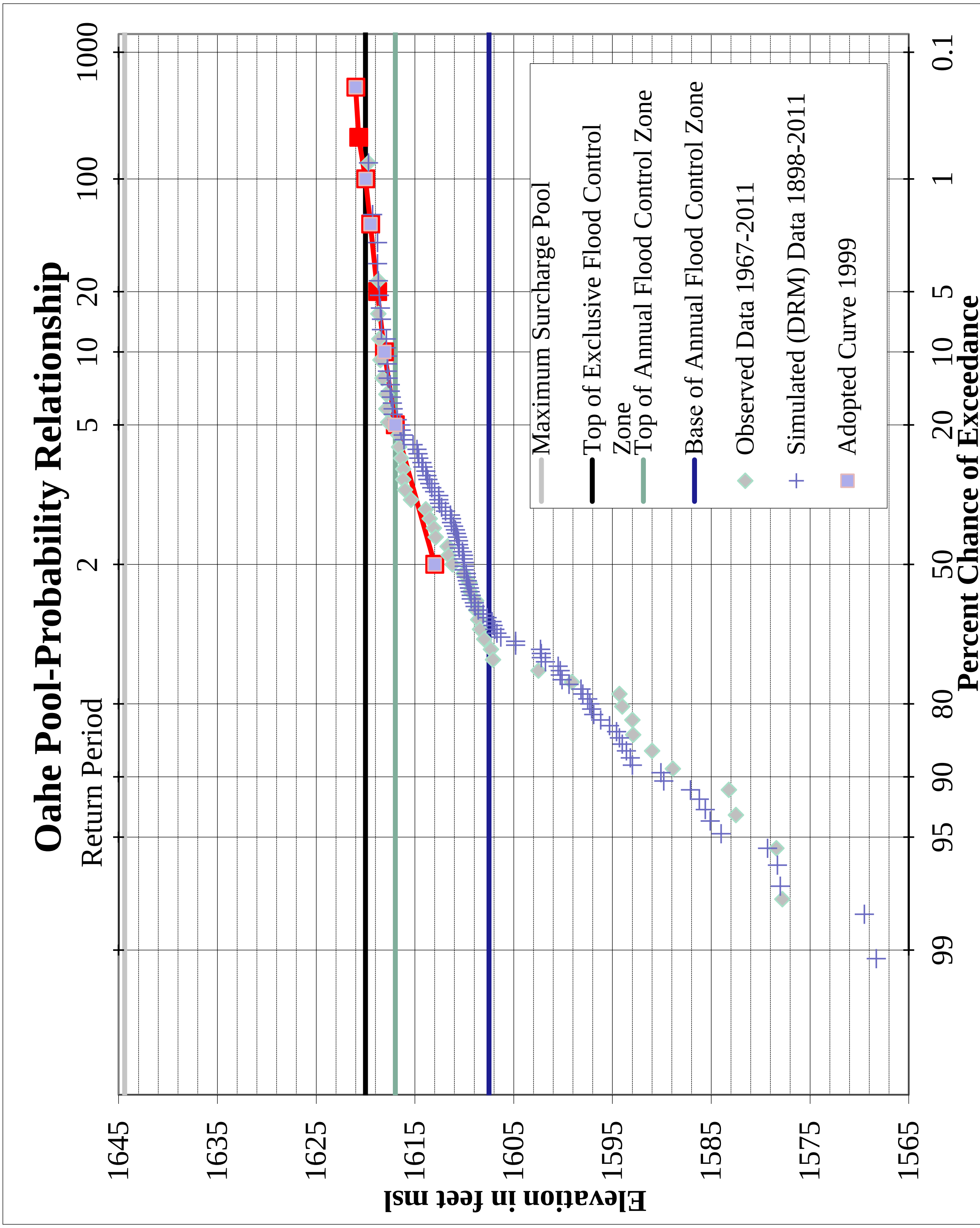
Oahe Water Control Manual

Probability Curve – Bad River at Fort Pierre, SD

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Oahe Water Control Manual
Oahe-Duration Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

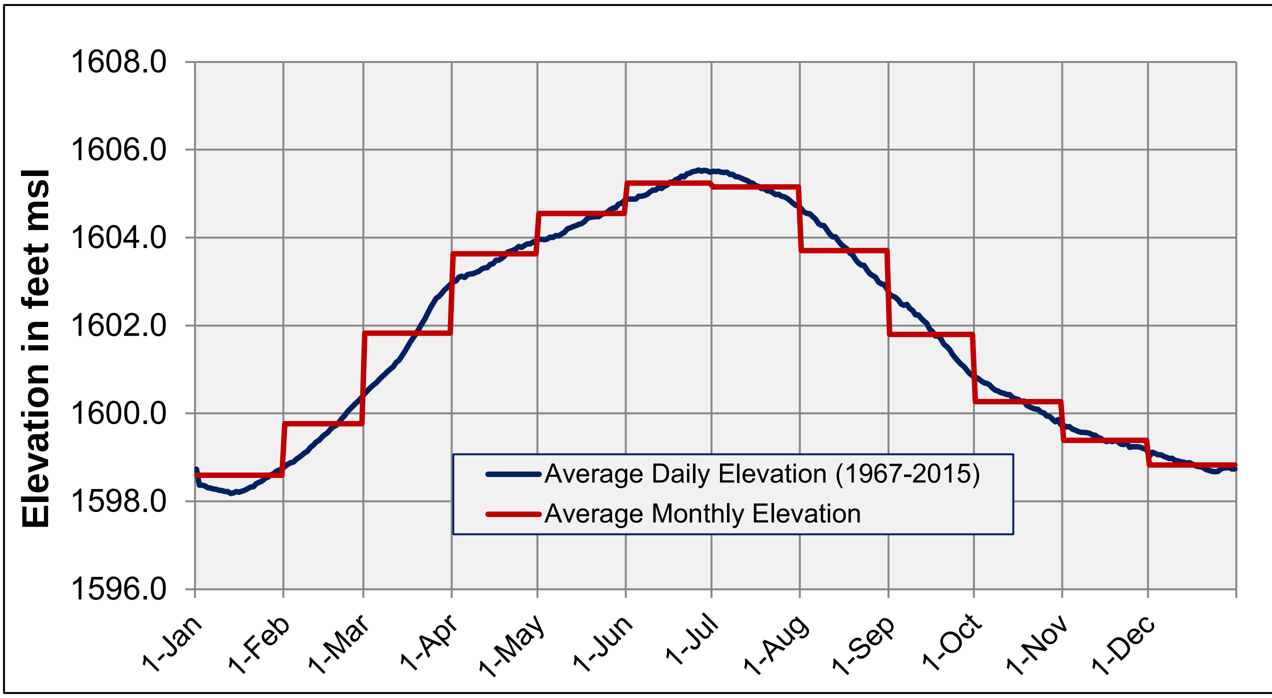


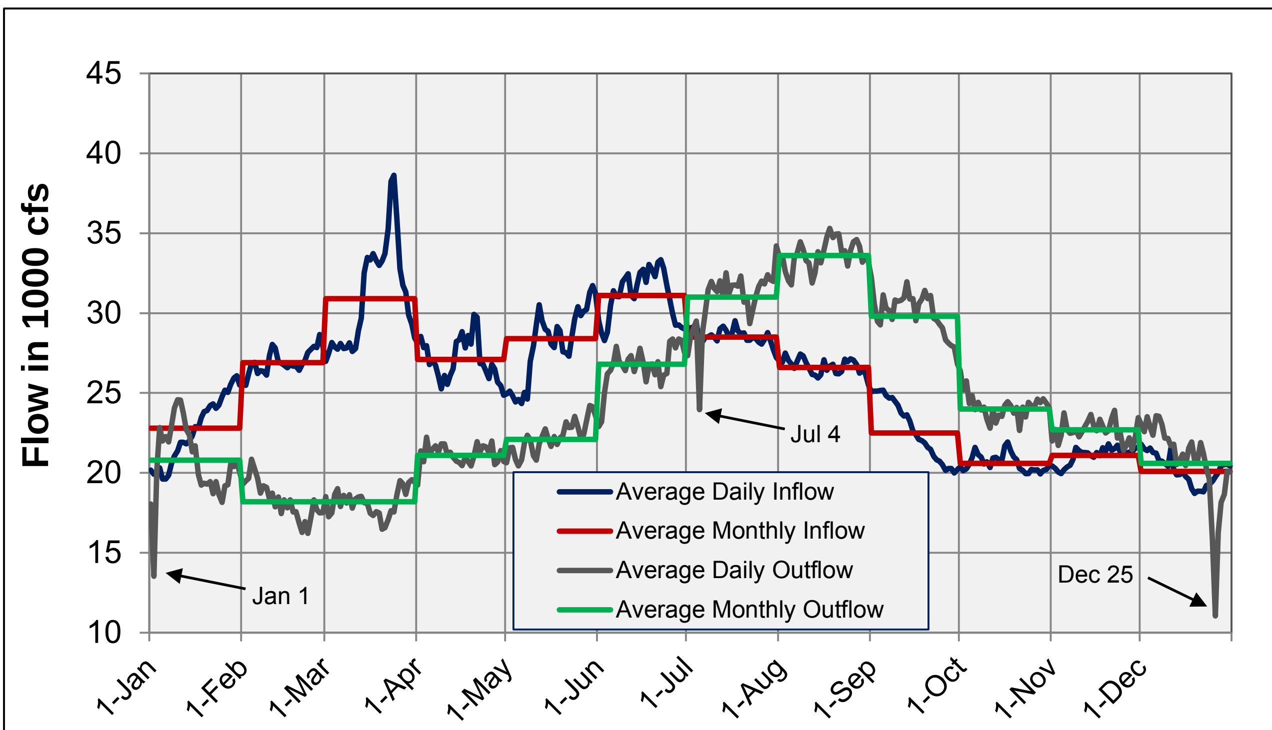
Missouri River Basin

Oahe Water Control Manual

Oahe Pool-Probability Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017





Period of Record: 1967 - 2015

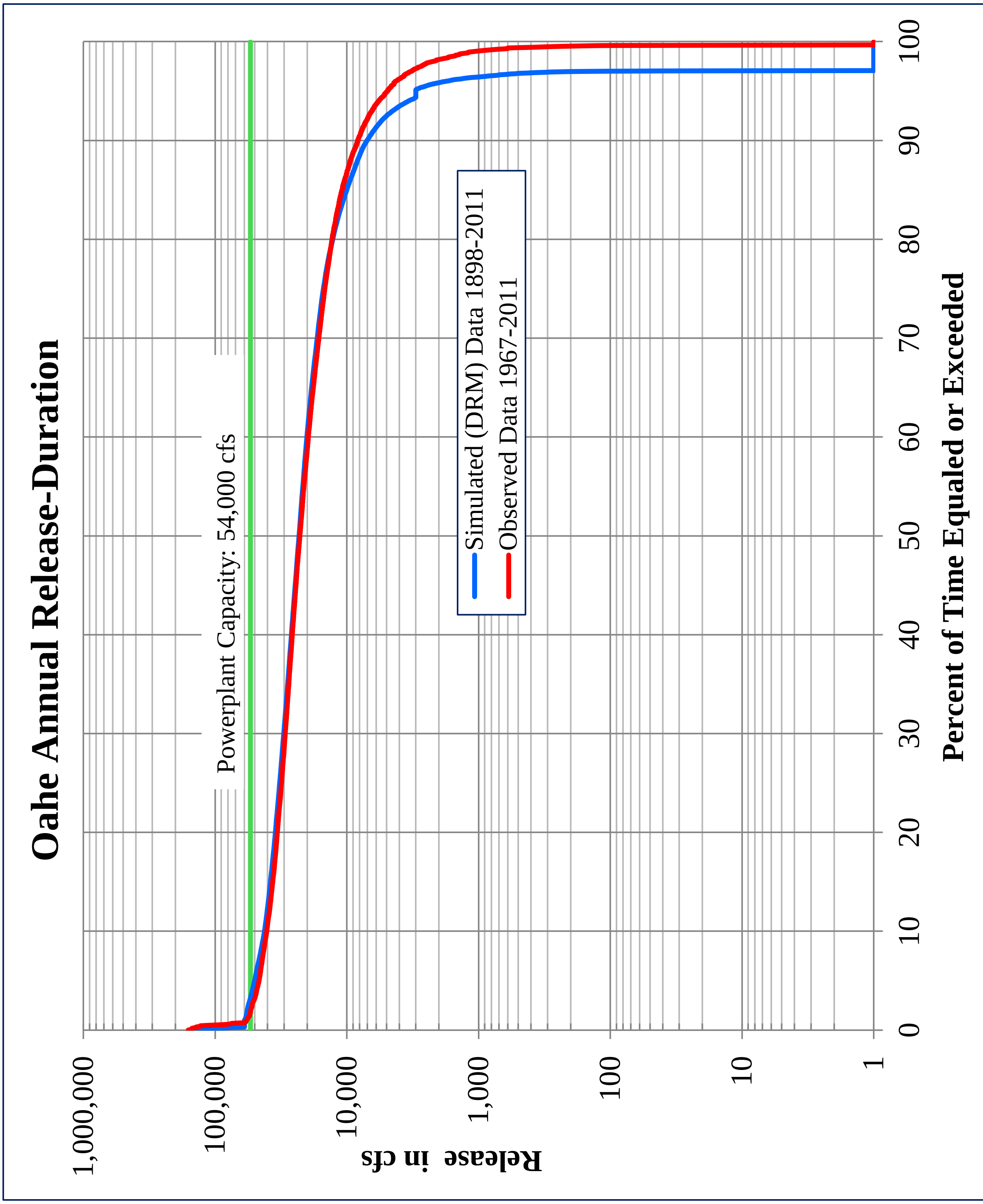
Missouri River Basin

Oahe Water Control Manual

Average Daily and Monthly Elevations, Inflow and Outflow

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Plate VI-20

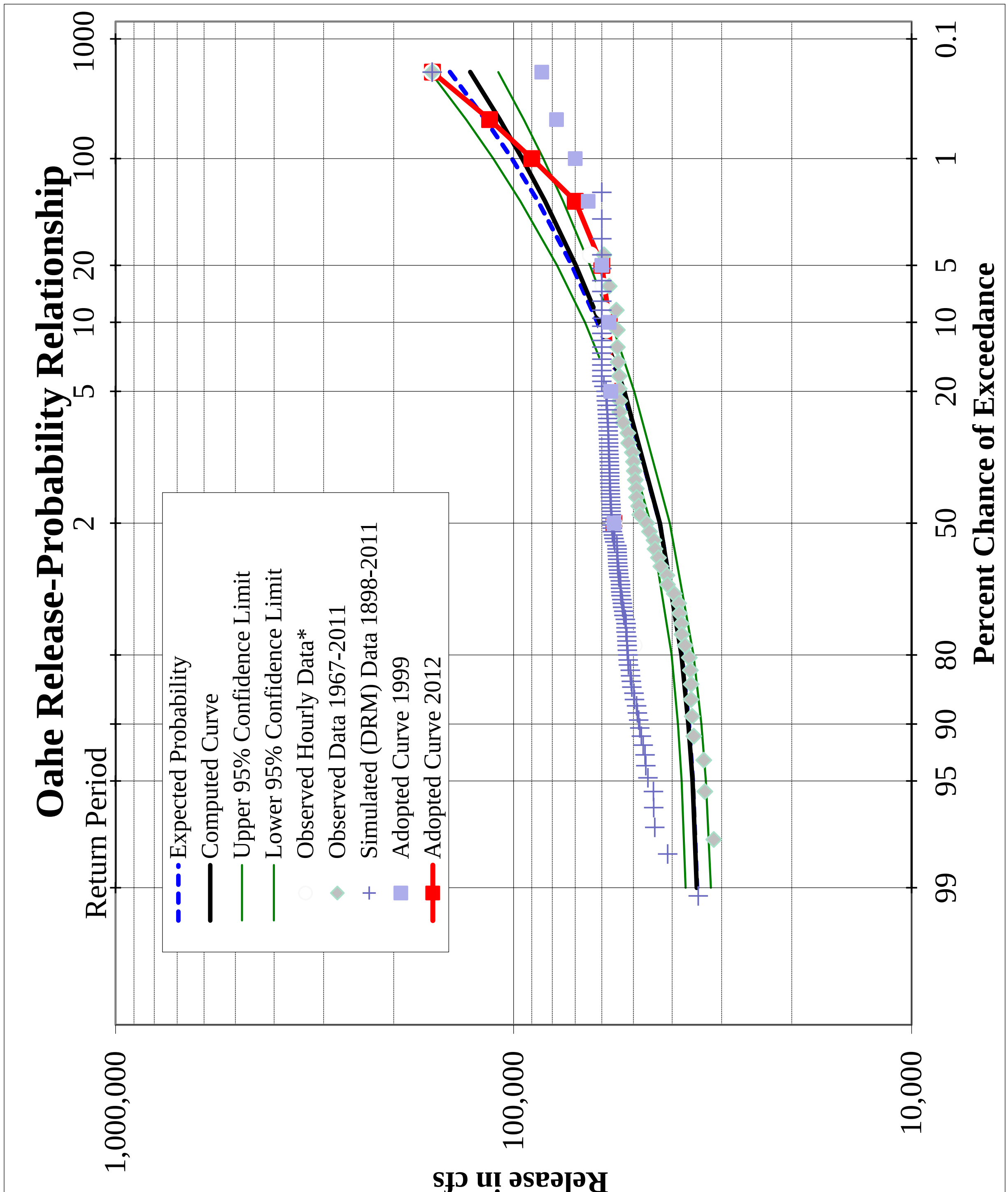


Missouri River Basin

Oahe Water Control Manual

Oahe Release-Duration Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

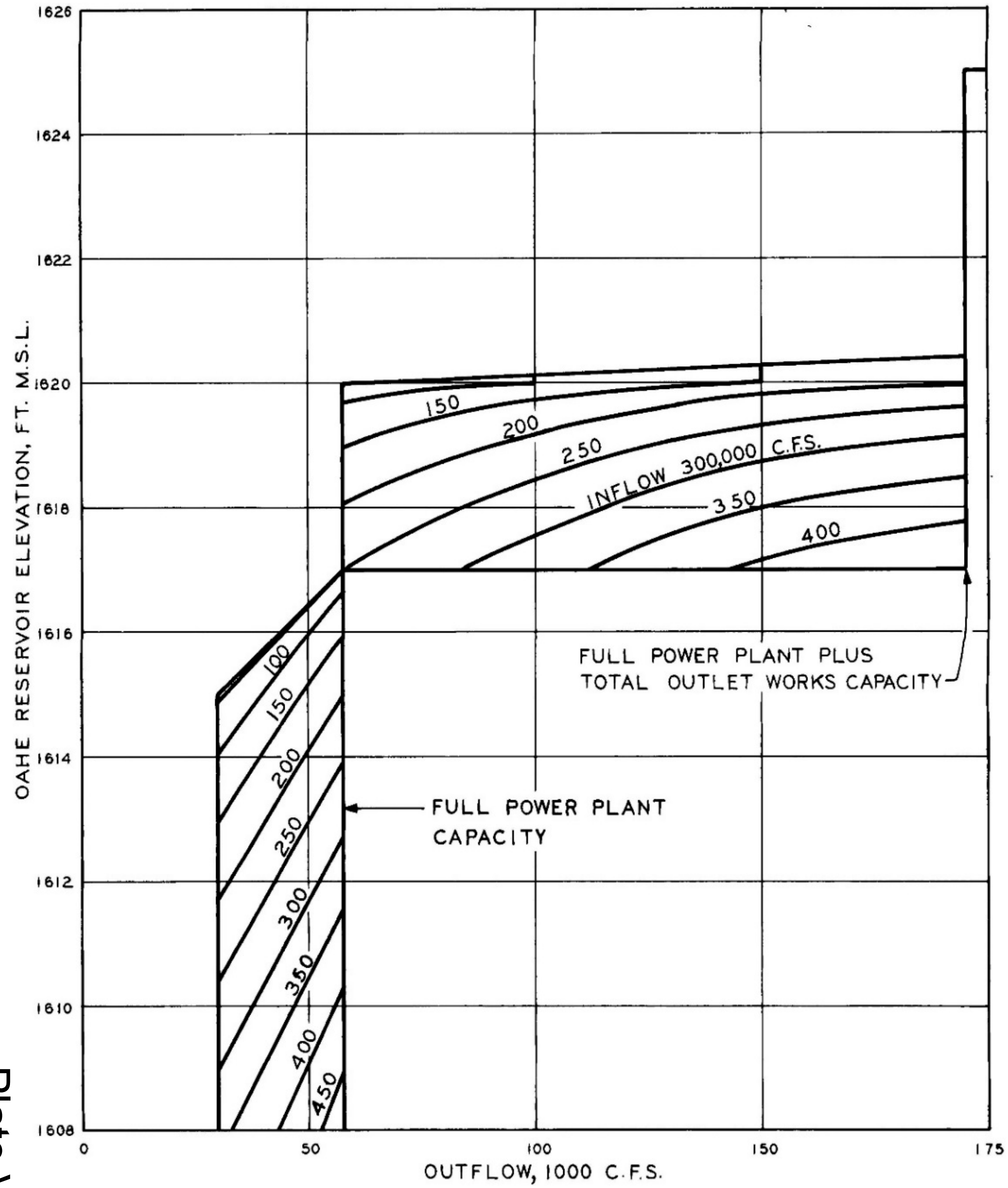


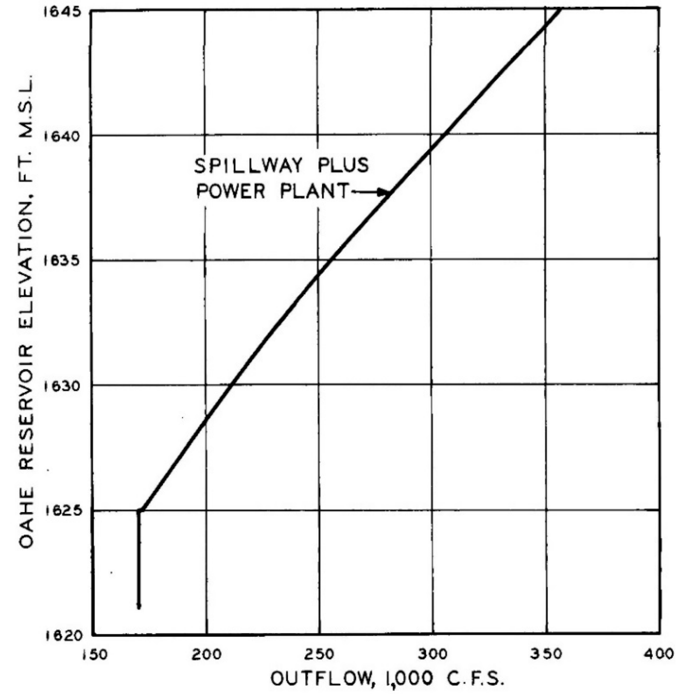
Missouri River Basin

Oahe Water Control Manual

Oahe Release-Probability Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

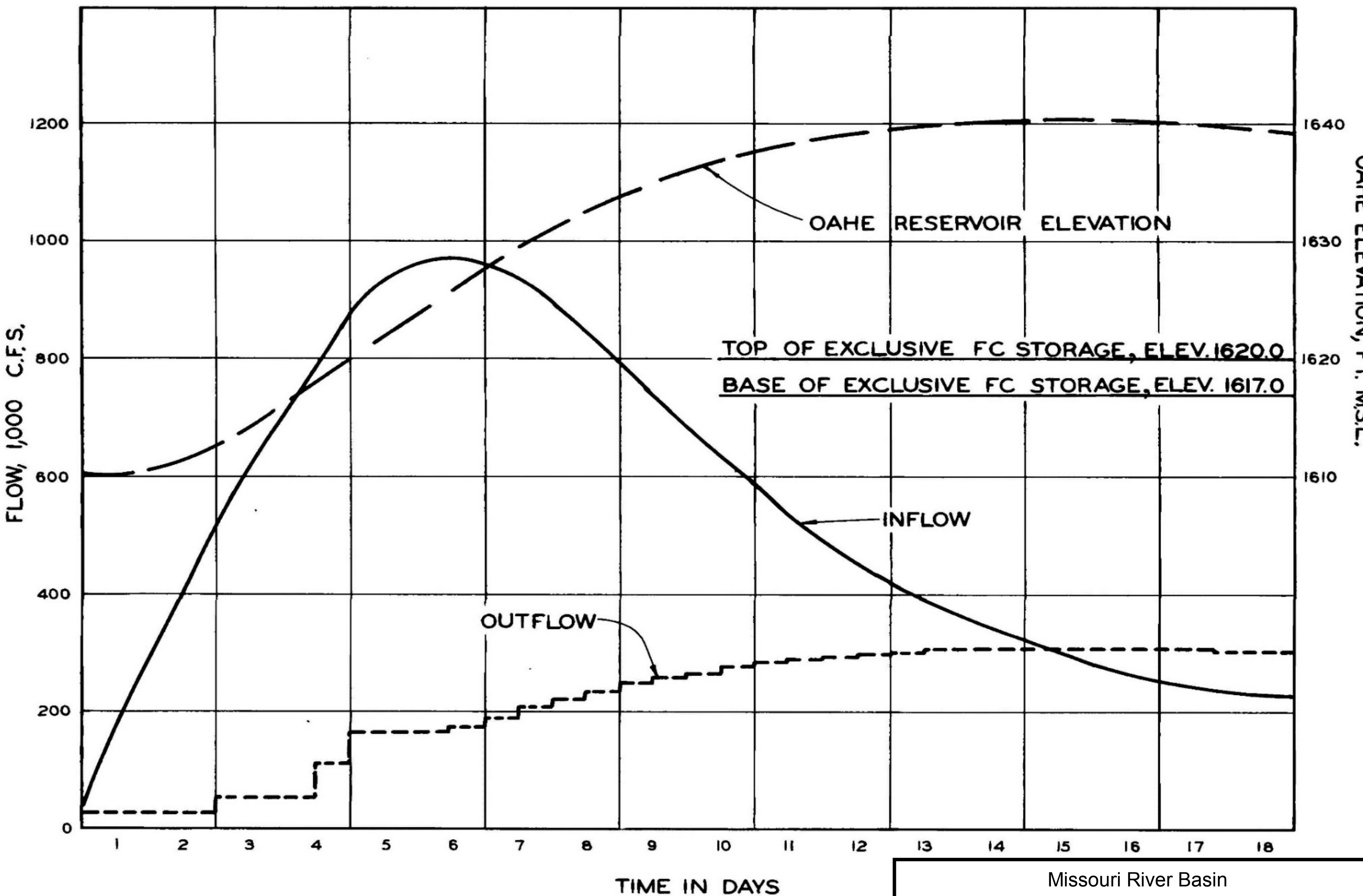




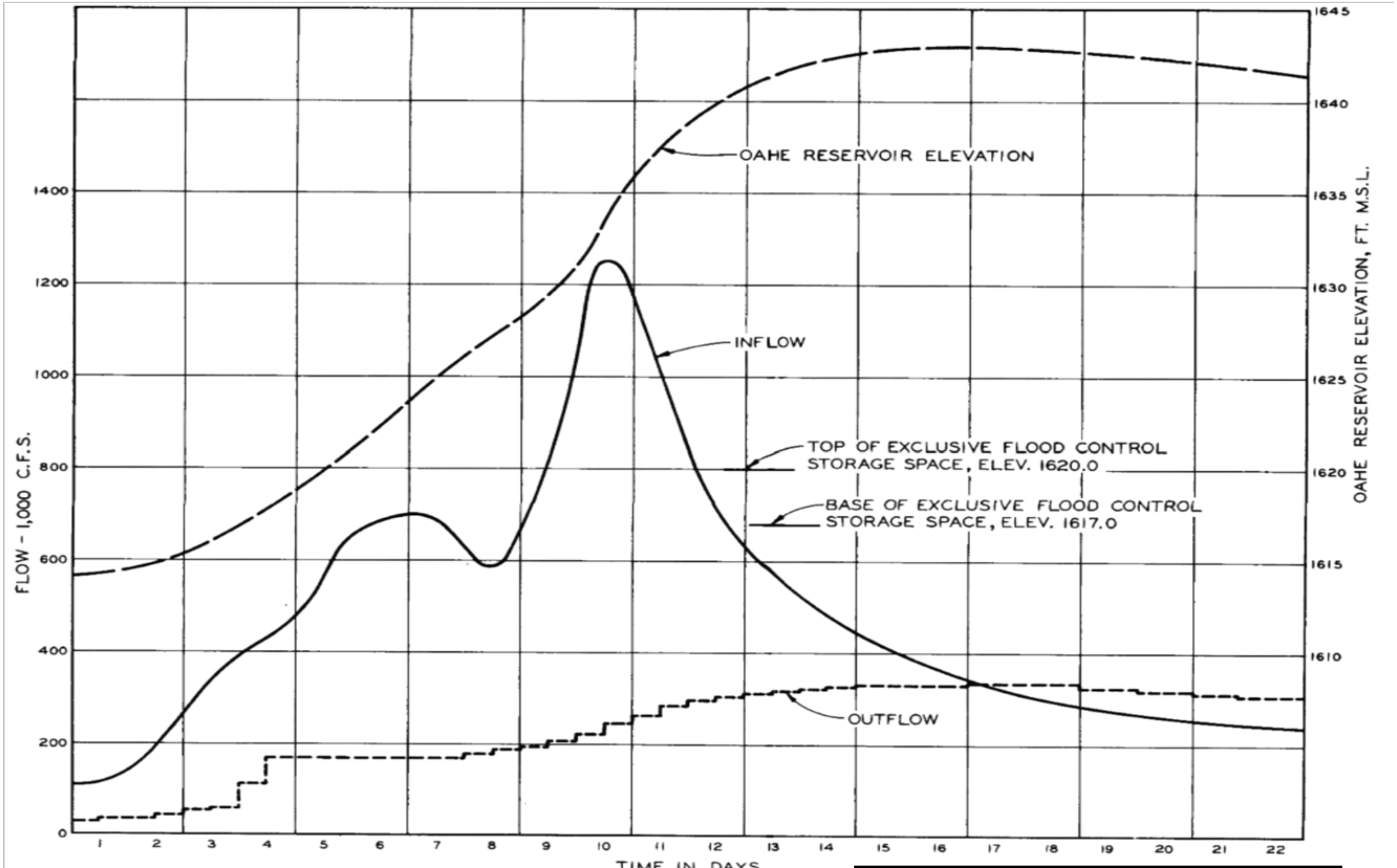
NOTES:

1. NUMBERED CURVES REPRESENT INFLOW IN THOUSAND C.F.S.
2. EMERGENCY PROCEDURE WILL CONSIST OF:
   A. ENTER CURVES WITH CURRENT POOL ELEVATION.
   B. PROCEED TO CURVE WHICH EQUALS INFLOW AS DETERMINED FOR PRECEDING 24-HOURS.
   C. MAINTAIN RELEASE AS INDICATED BY POINT OF INTERSECTION.
   D. NO RELEASE SHALL EXCEED A RATE GREATER THAN TWICE THE AVERAGE RELEASE RATE FOR THE PRECEDING 24-HOURS.

Missouri River Basin
Oahe Water Control Manual
Emergency Regulation Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Oahe Water Control Manual
Emergency Regulation of Maximum Possible Early Spring Flood
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin

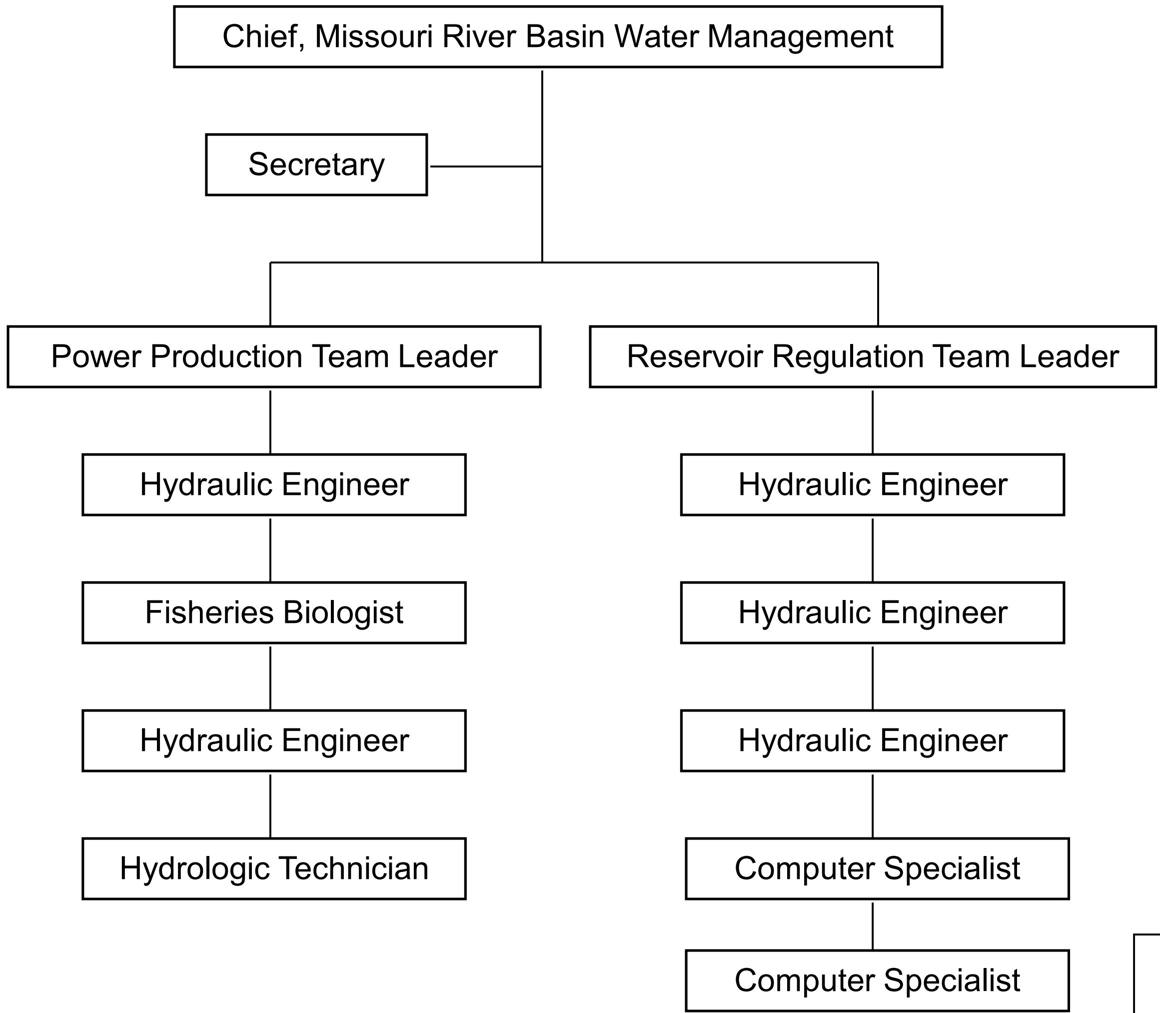
Oahe Water Control Manual

Emergency Regulation of Maximum Possible Late Spring Flood

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

NWD-Omaha

Missouri River Basin Water Management Division



Budget Analyst is shared with Columbia River Basin Water Management

Missouri River Basin
Oahe Water Control Manual
MRBWMD Organization Chart

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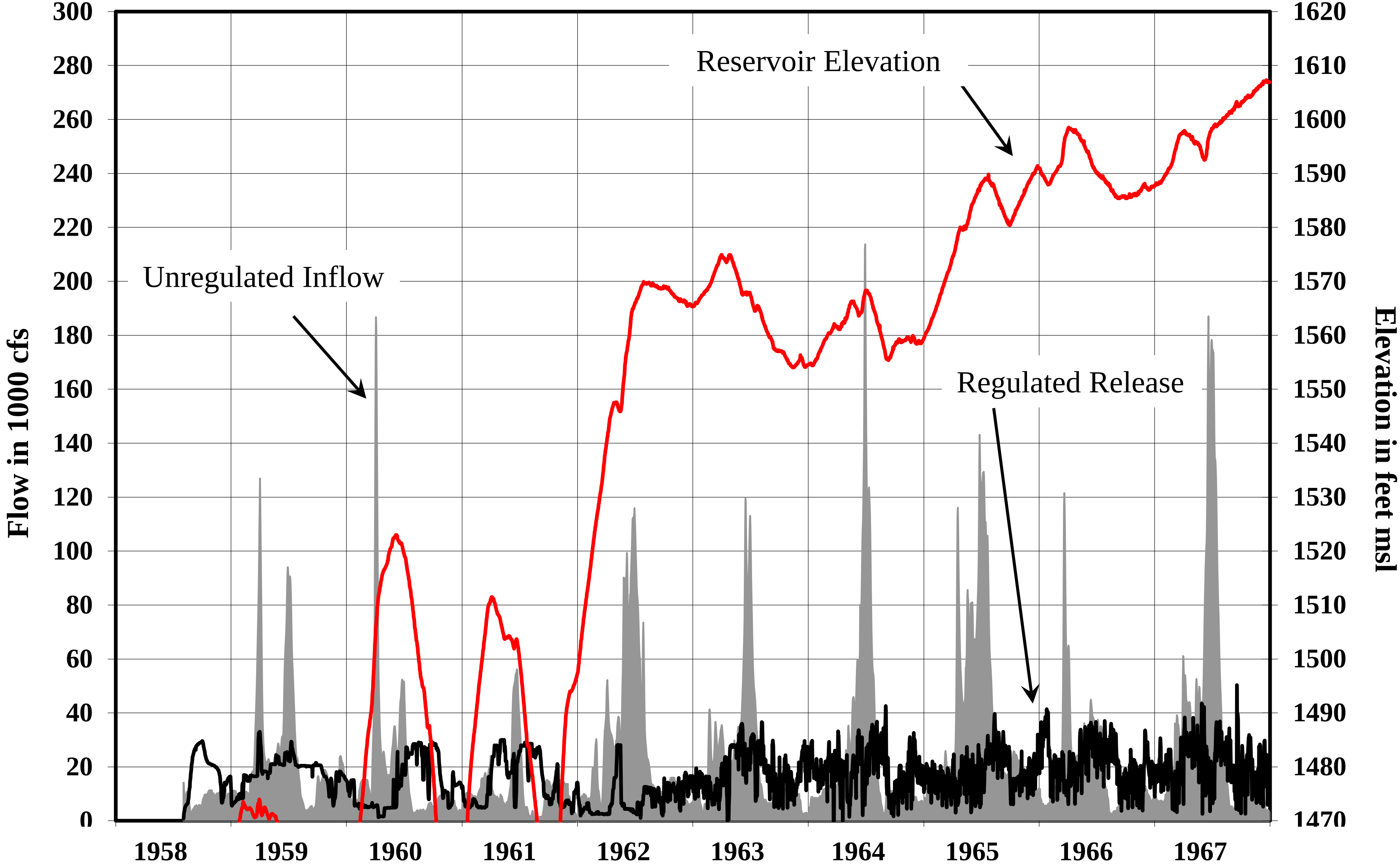

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Reservoir Elevation, Regulated and Unregulated Flows, 1958 -1967

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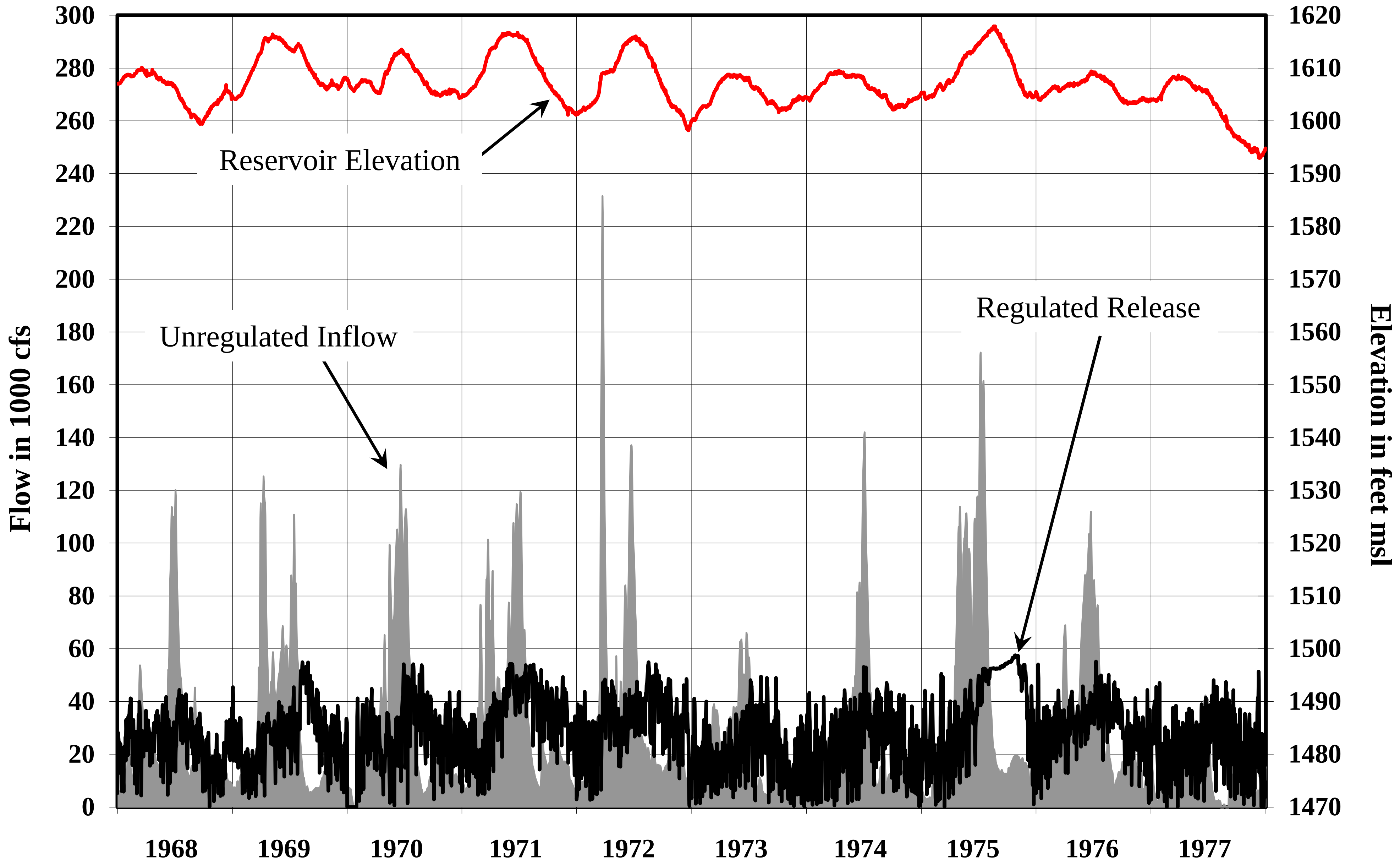

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Reservoir Elevation, Regulated and Unregulated Flows, 1968 -1977

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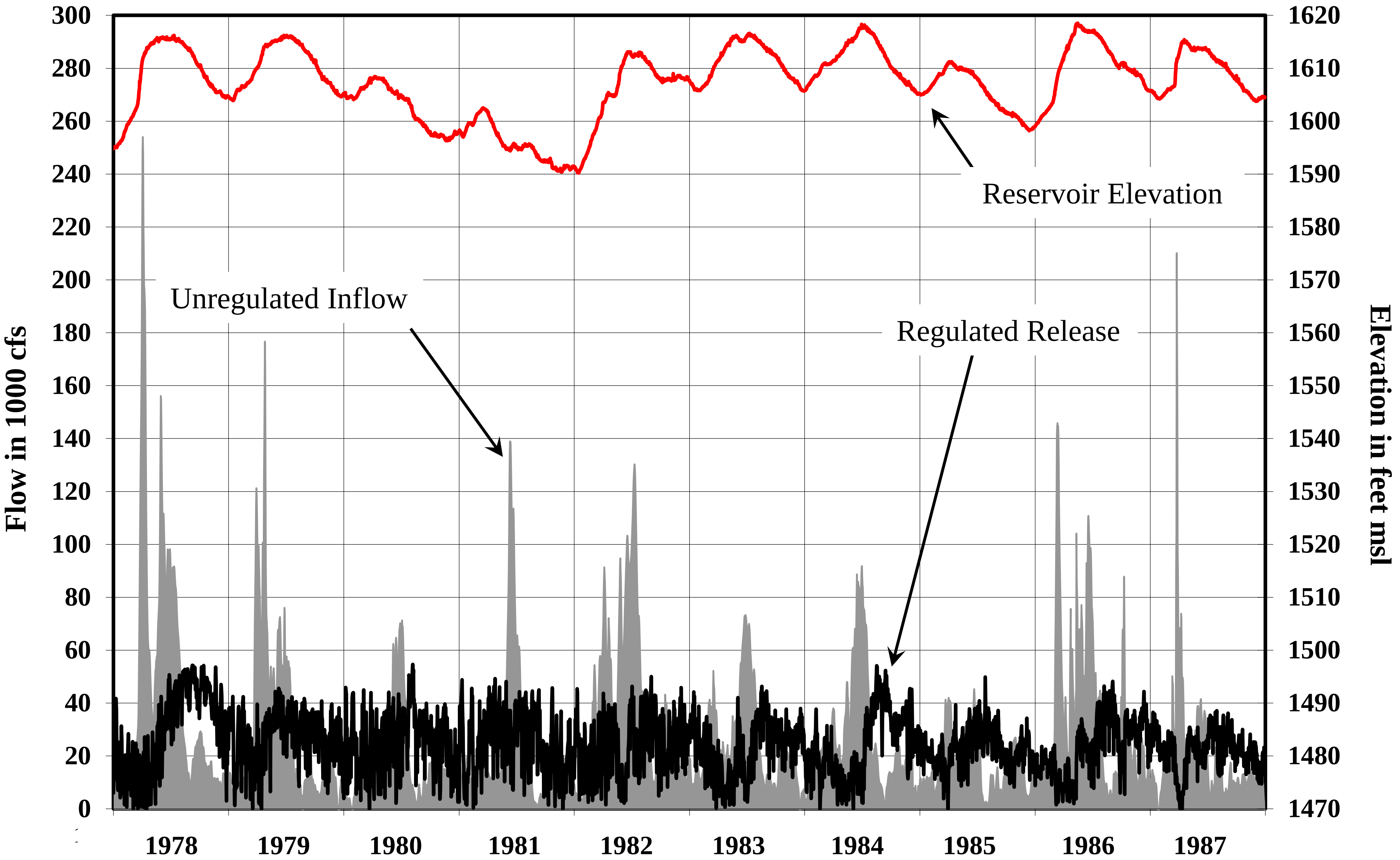

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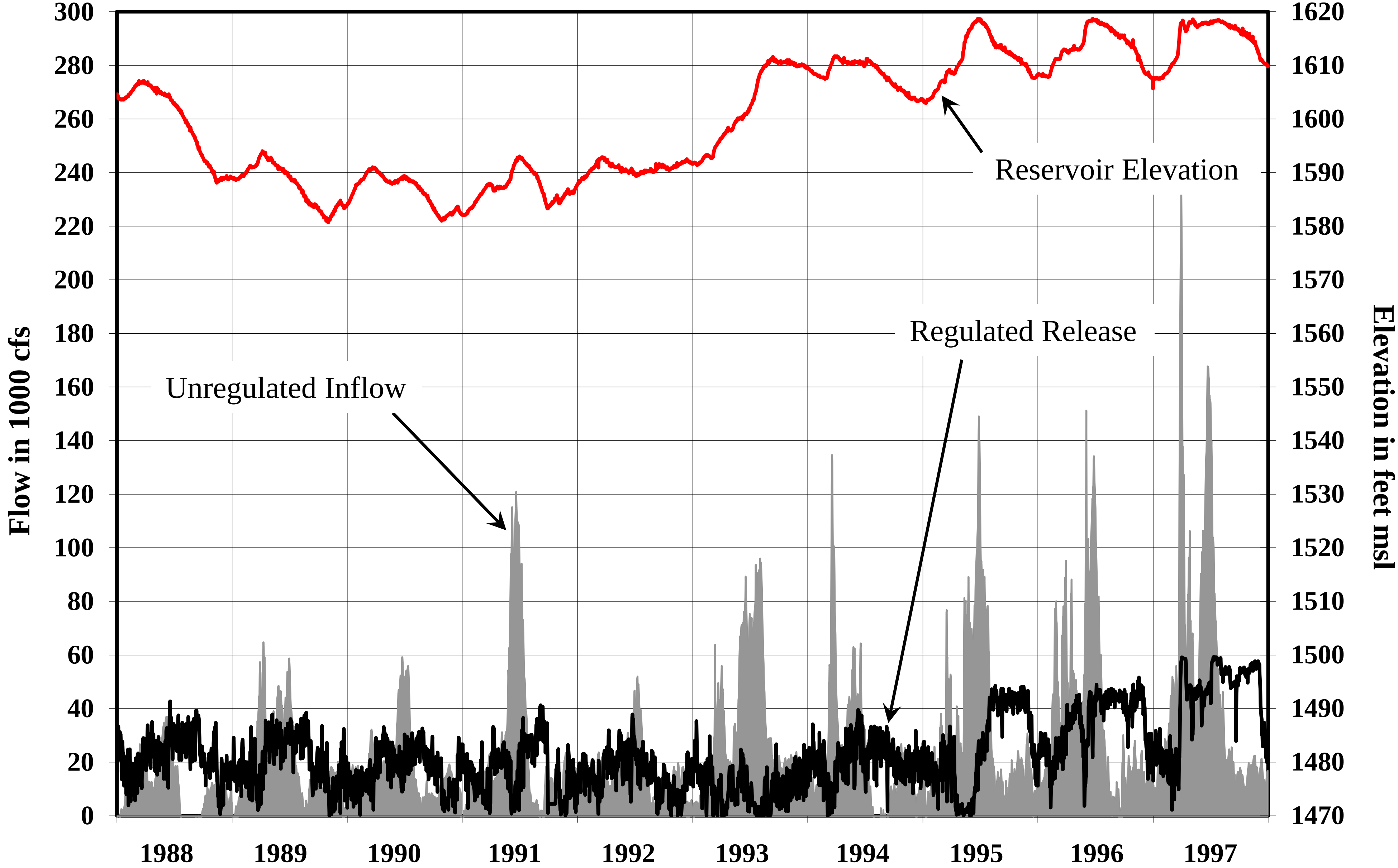

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Reservoir Elevation, Regulated and Unregulated Flows, 1988 -1997

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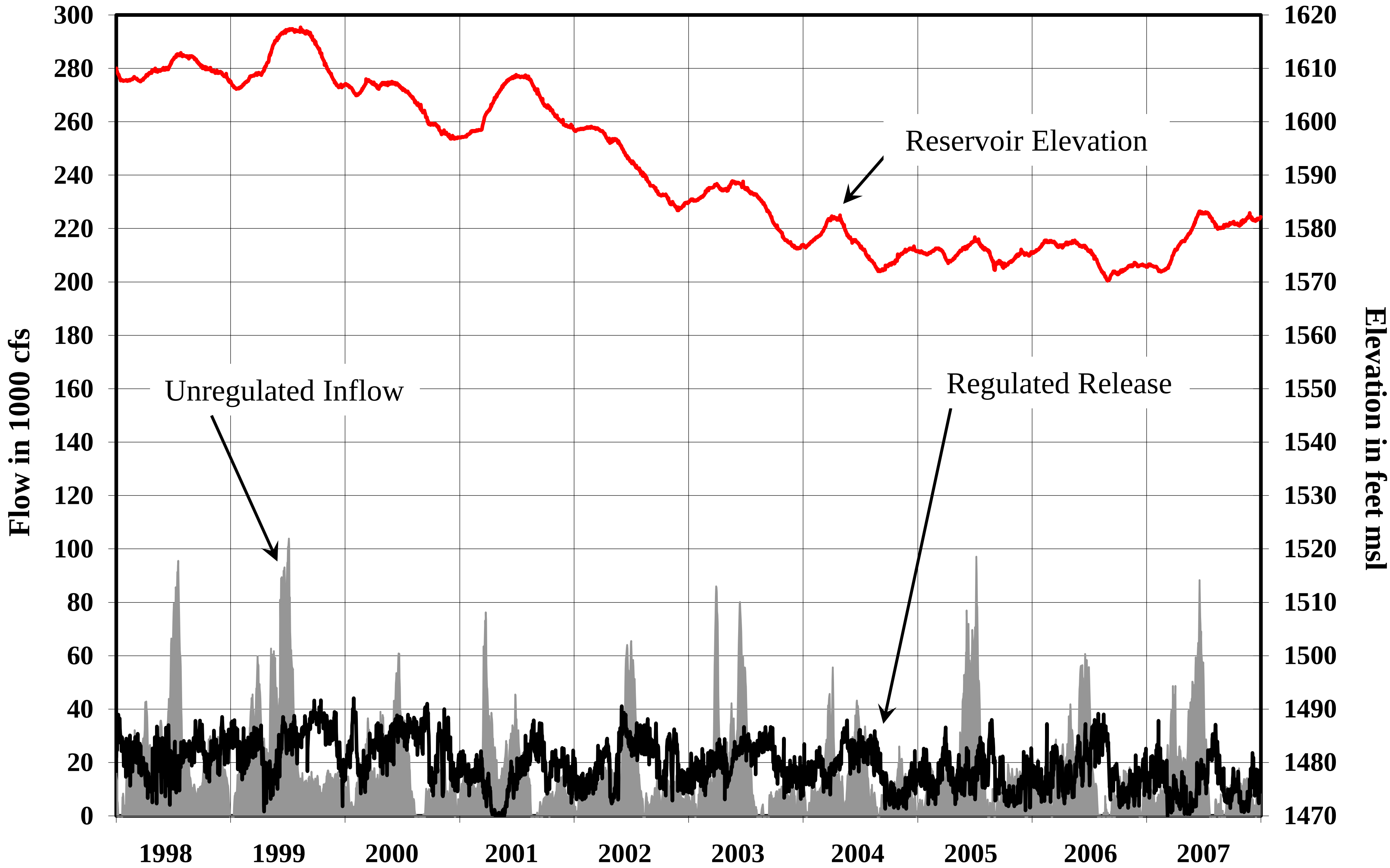

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Reservoir Elevation, Regulated and Unregulated Flows, 1998 -2007

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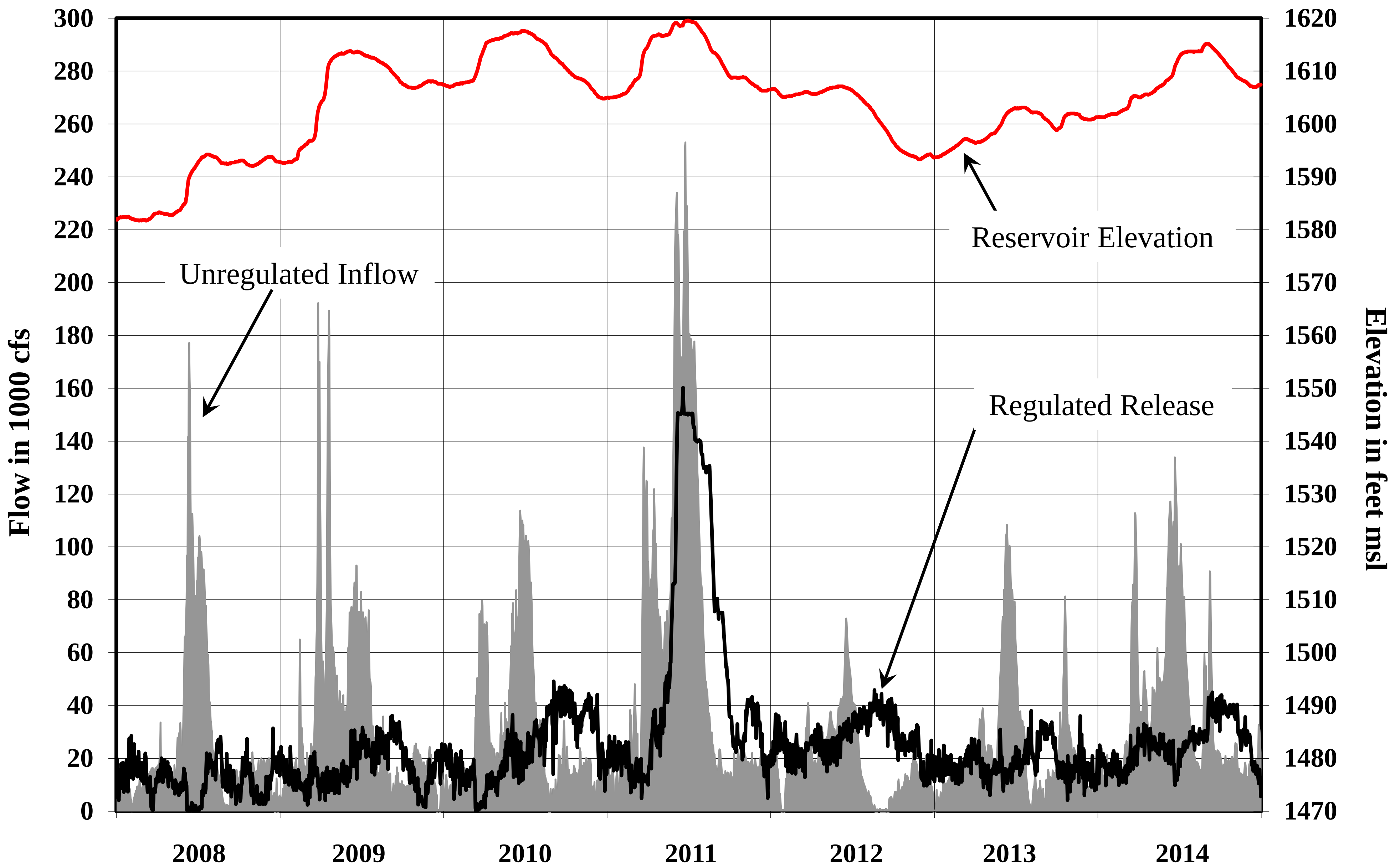
Plate A-5



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Reservoir Elevation, Regulated and Unregulated Flows, 2008 -2014

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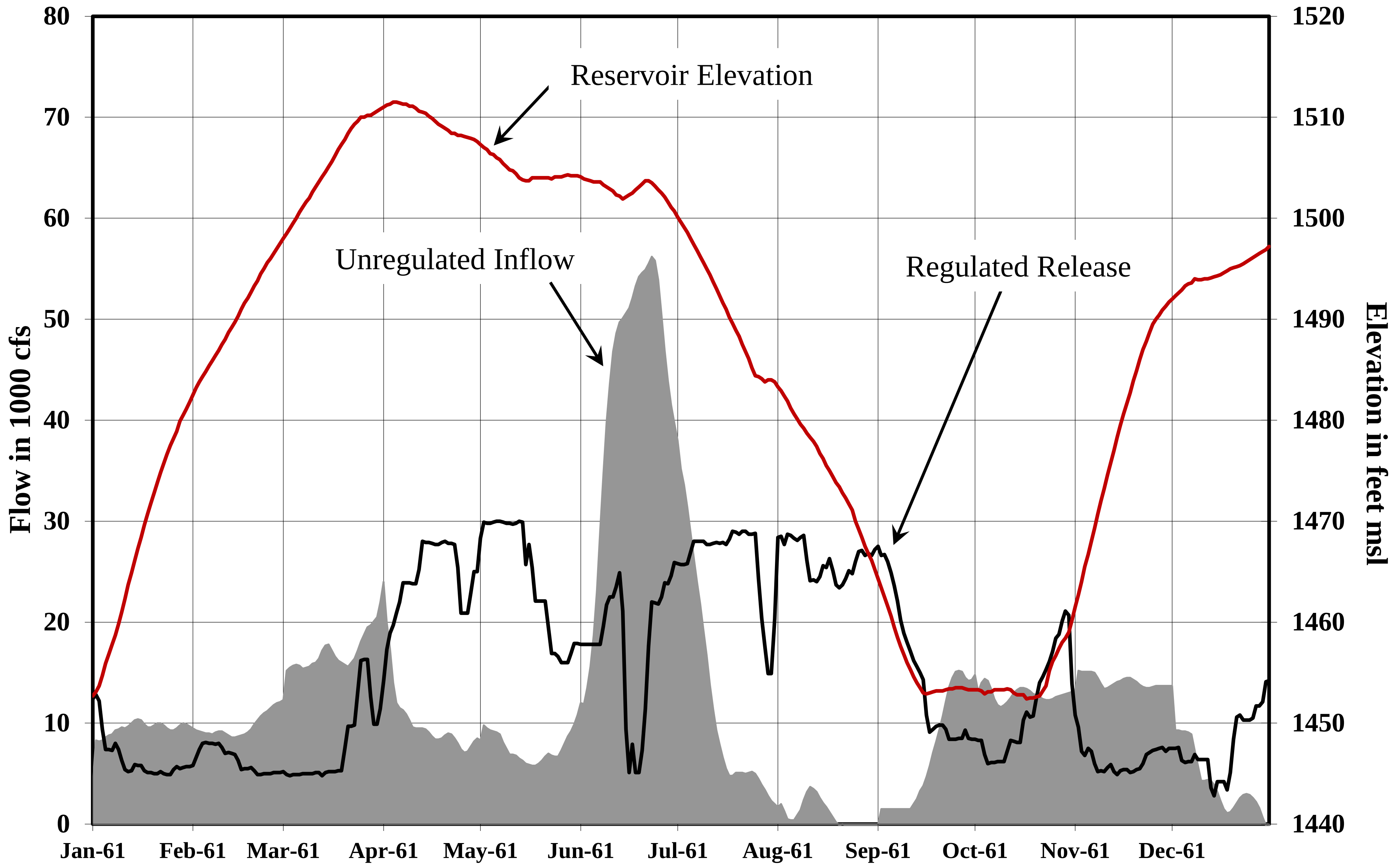
Plate A-6



Missouri River Basin

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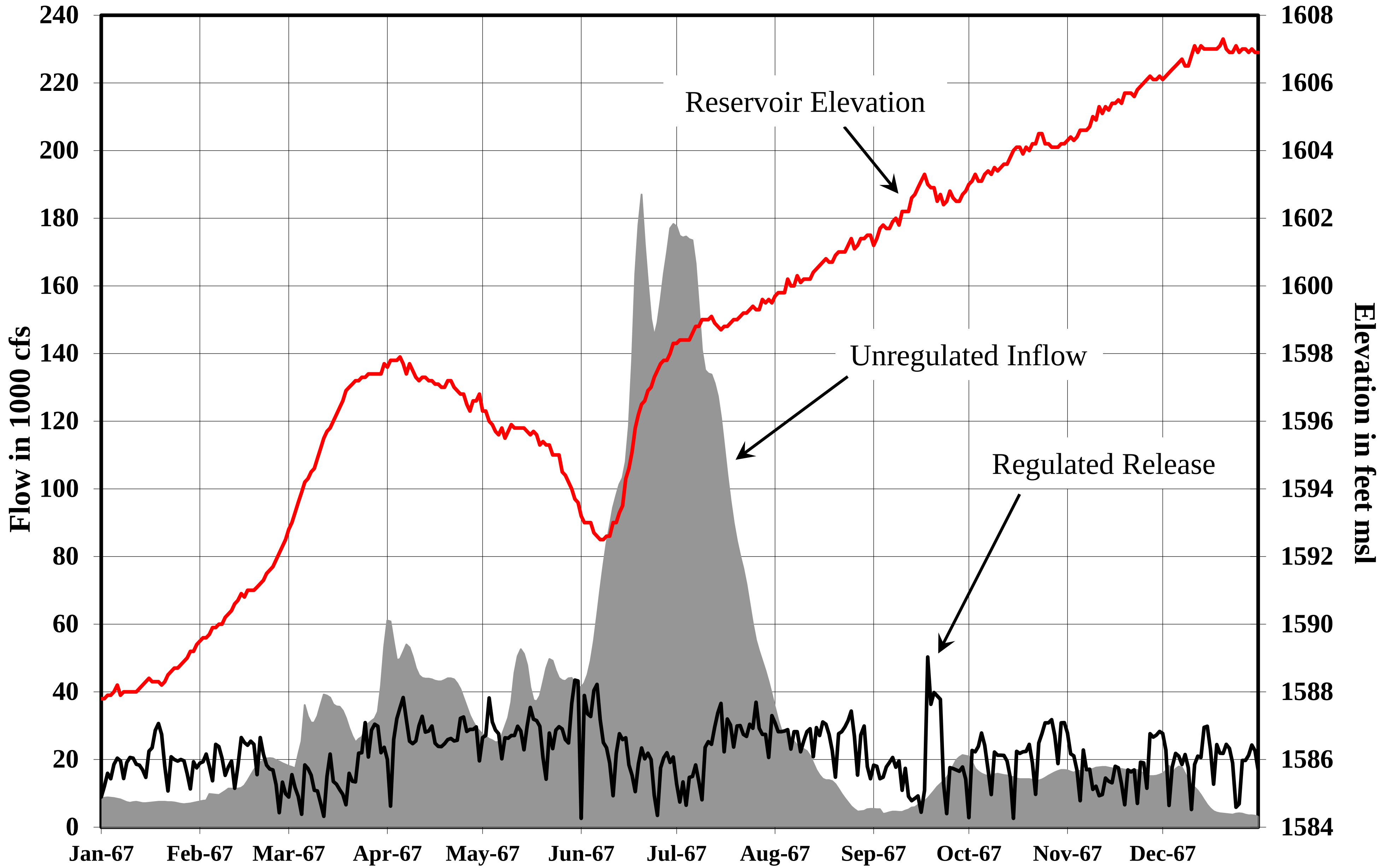

Missouri River Basin
Oahe Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1967

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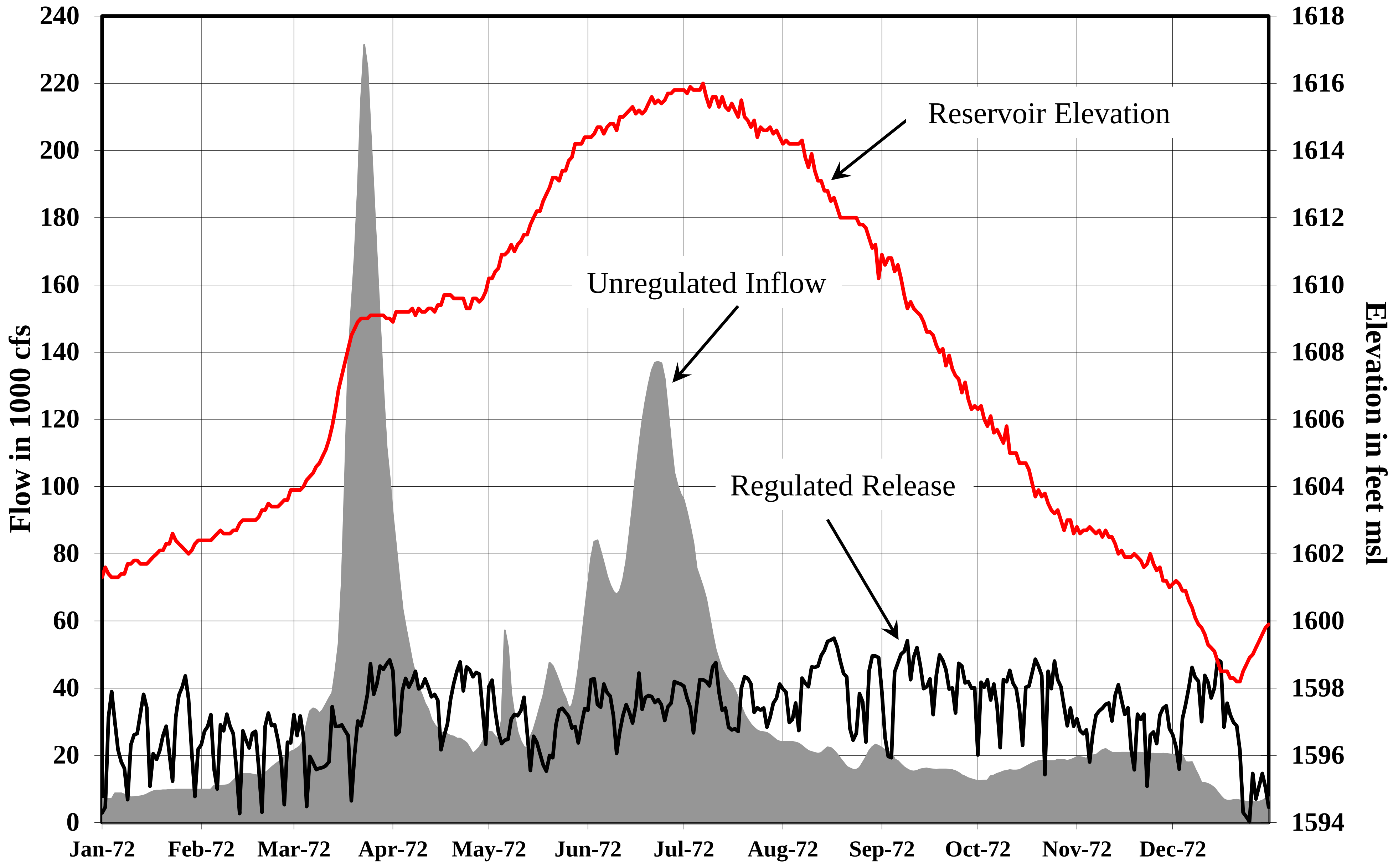

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Oahe Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1972

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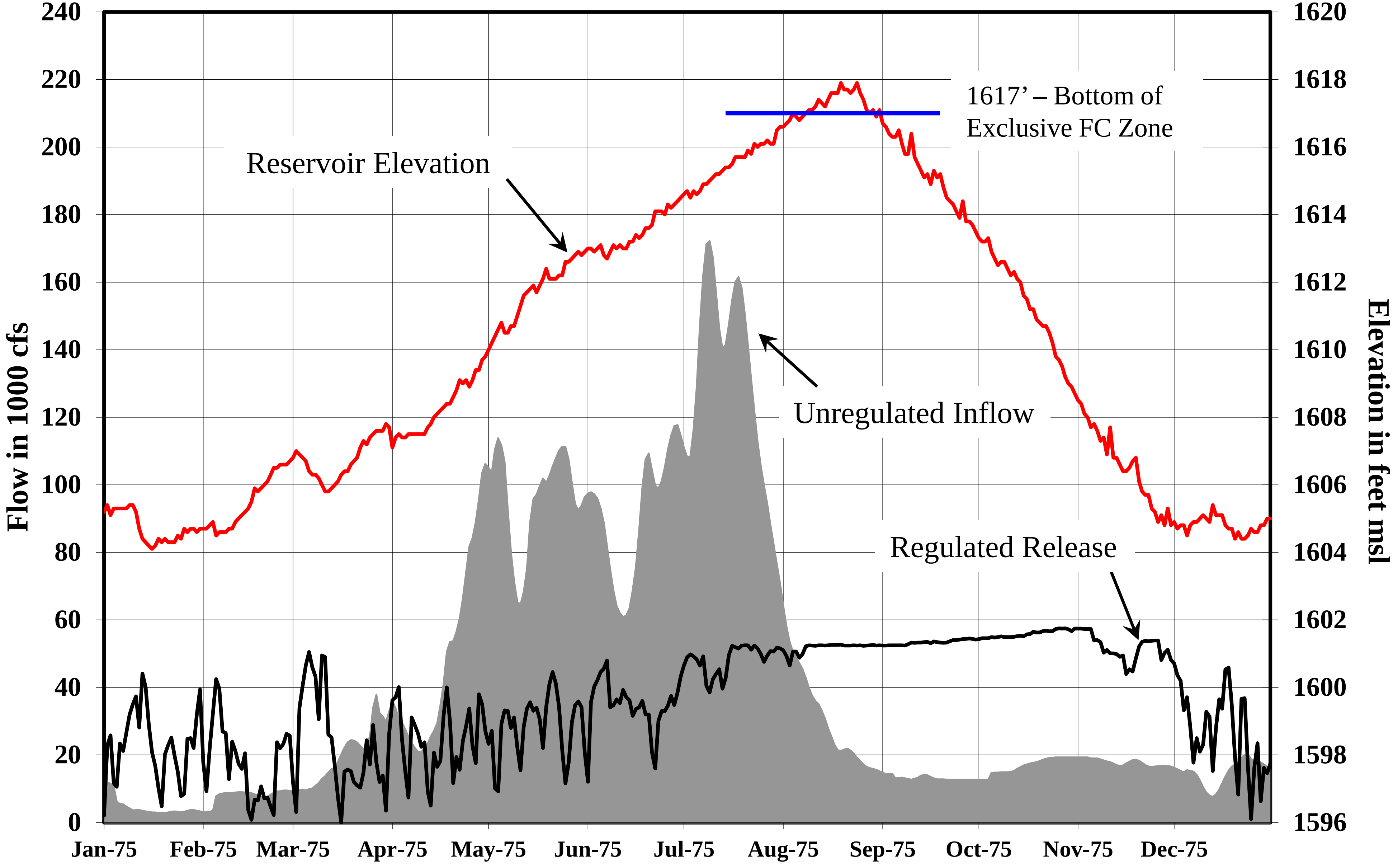

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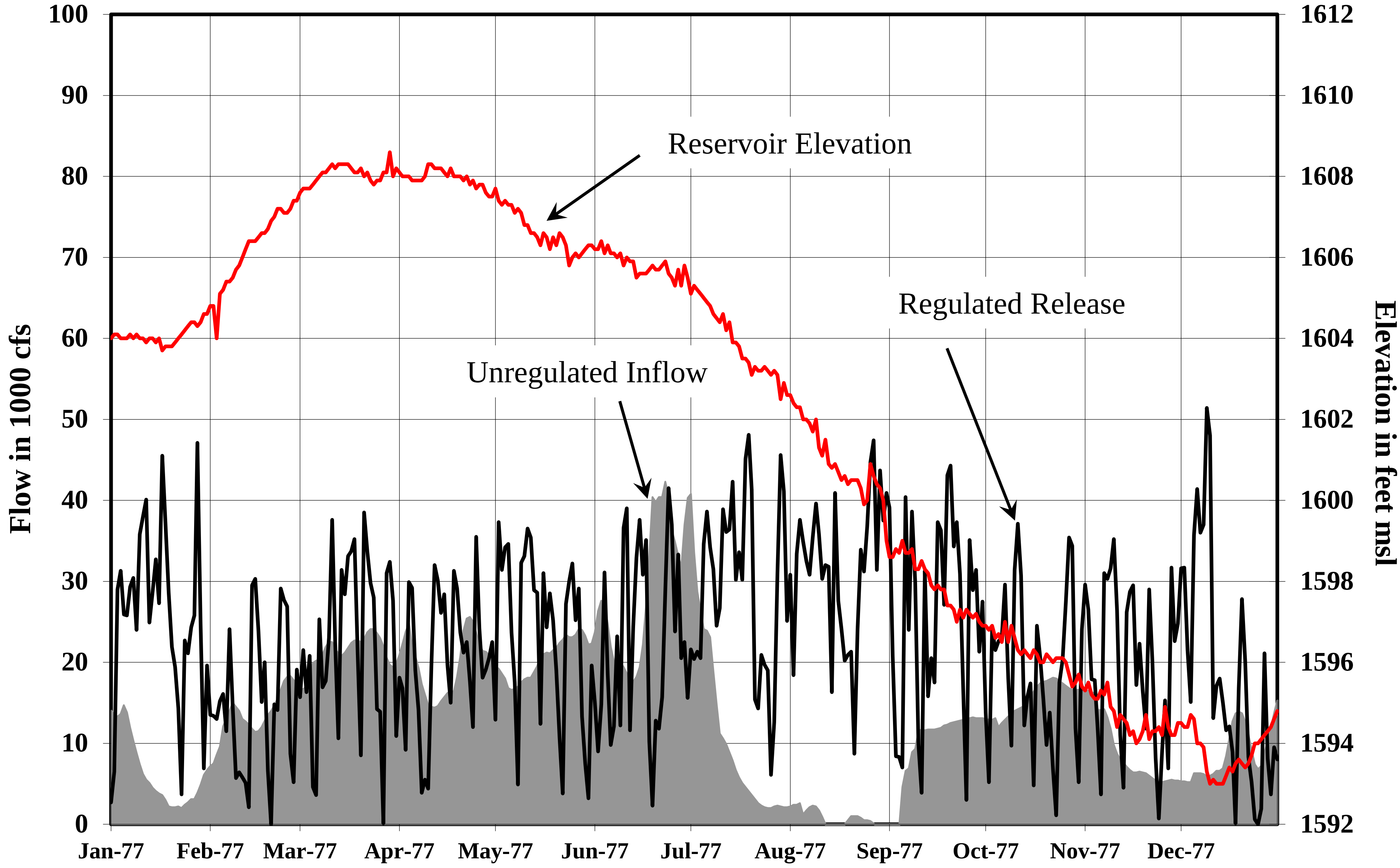

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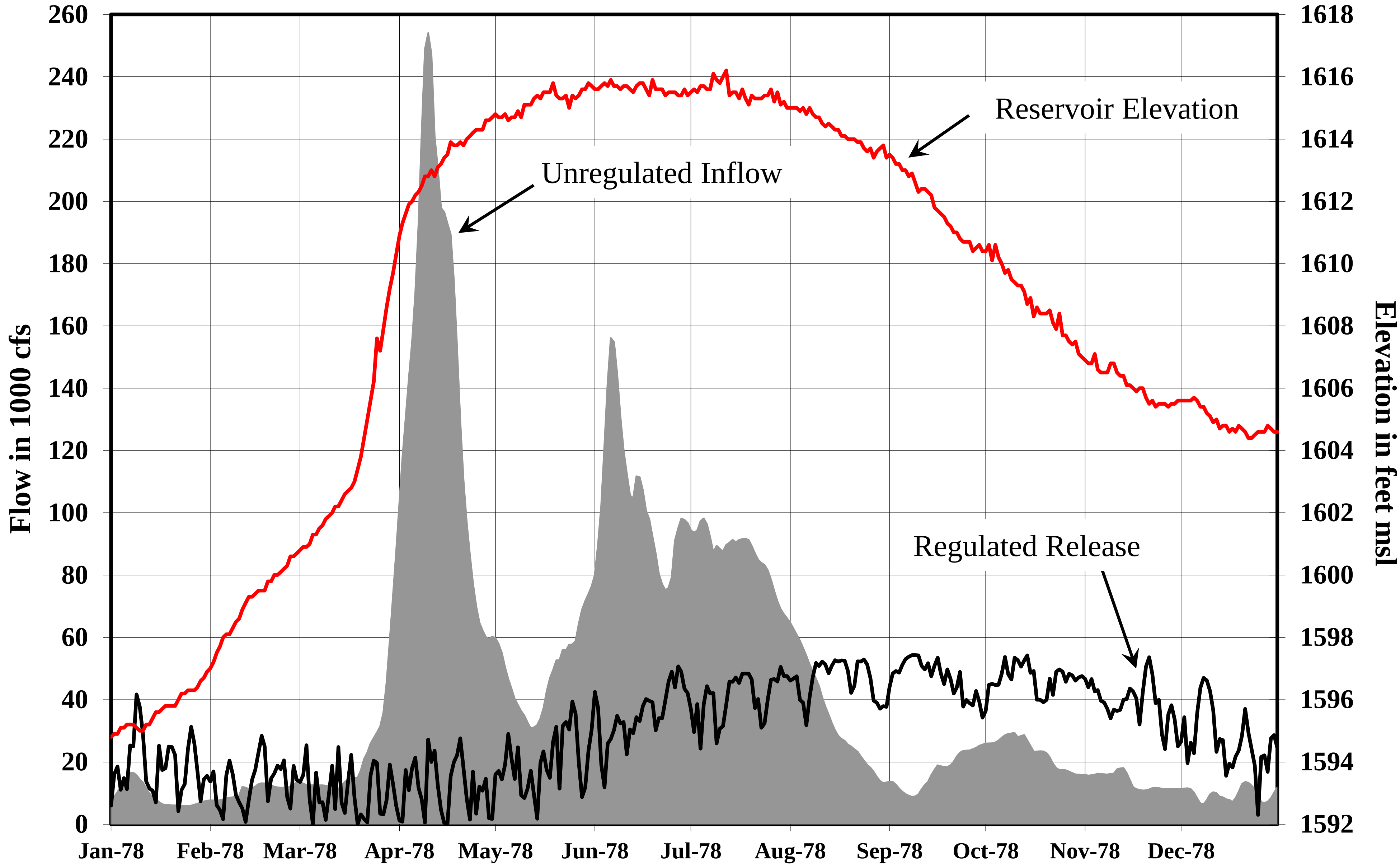

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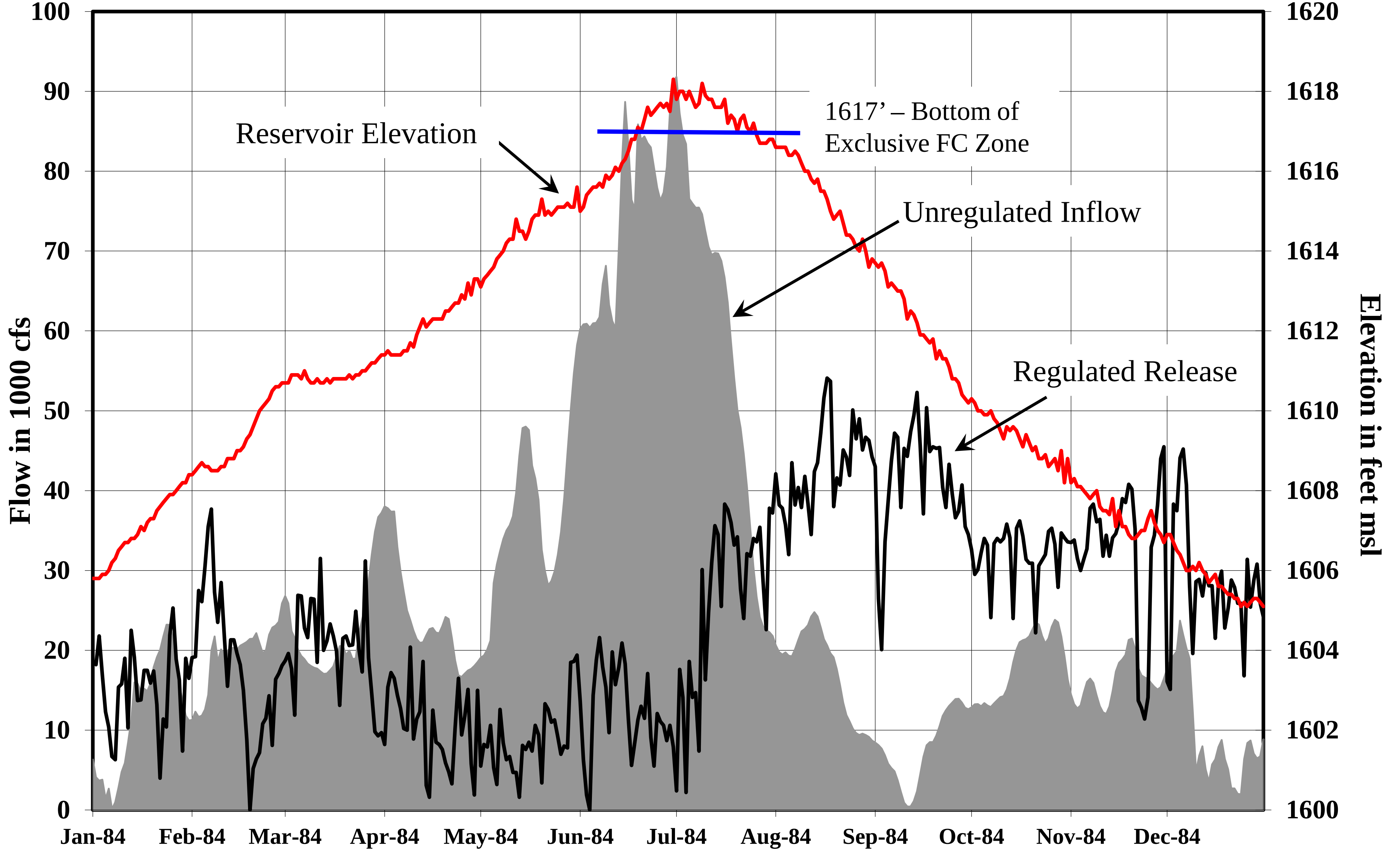

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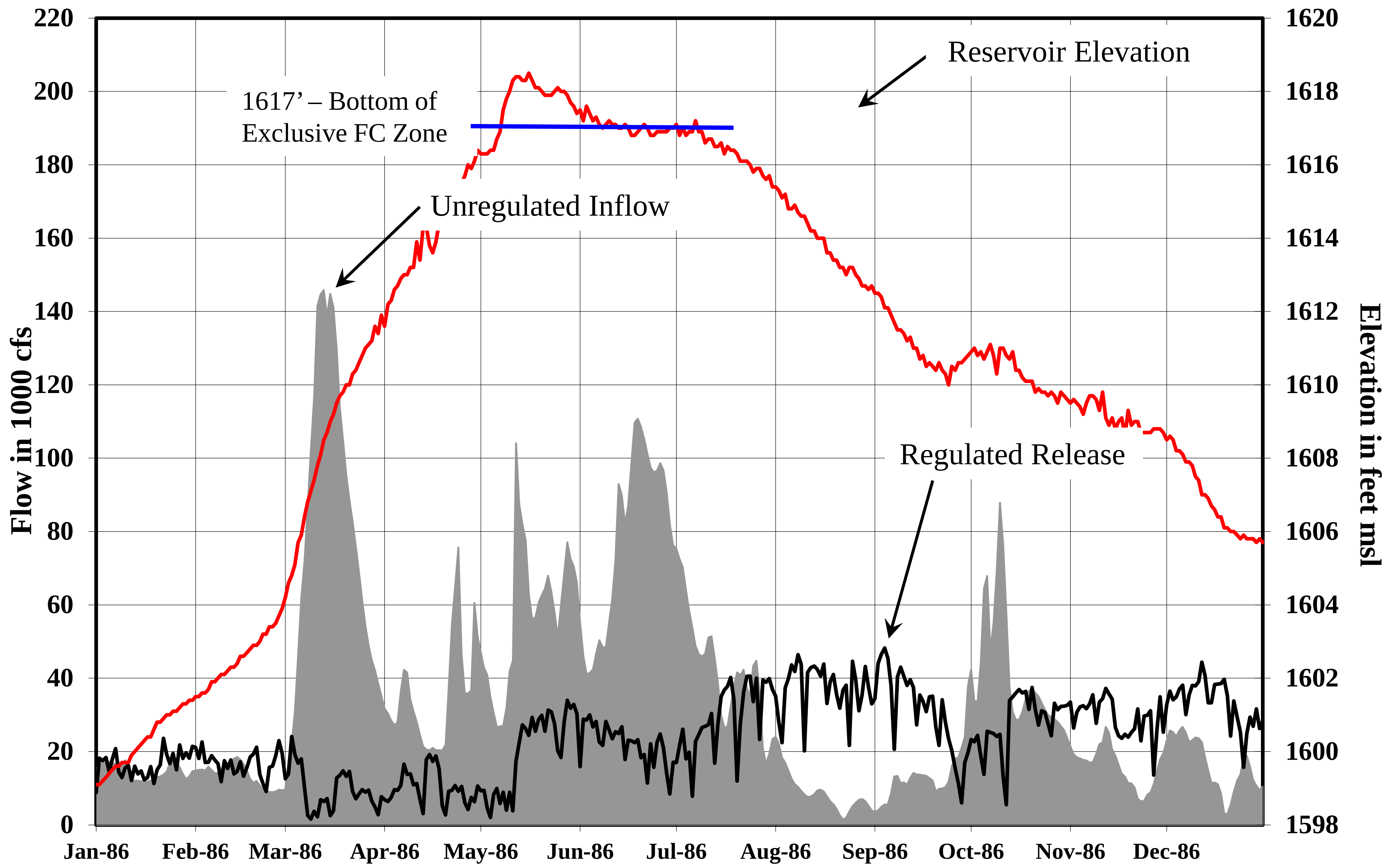

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Reservoir Elevation, Regulated and
Unregulated Flows, 1986

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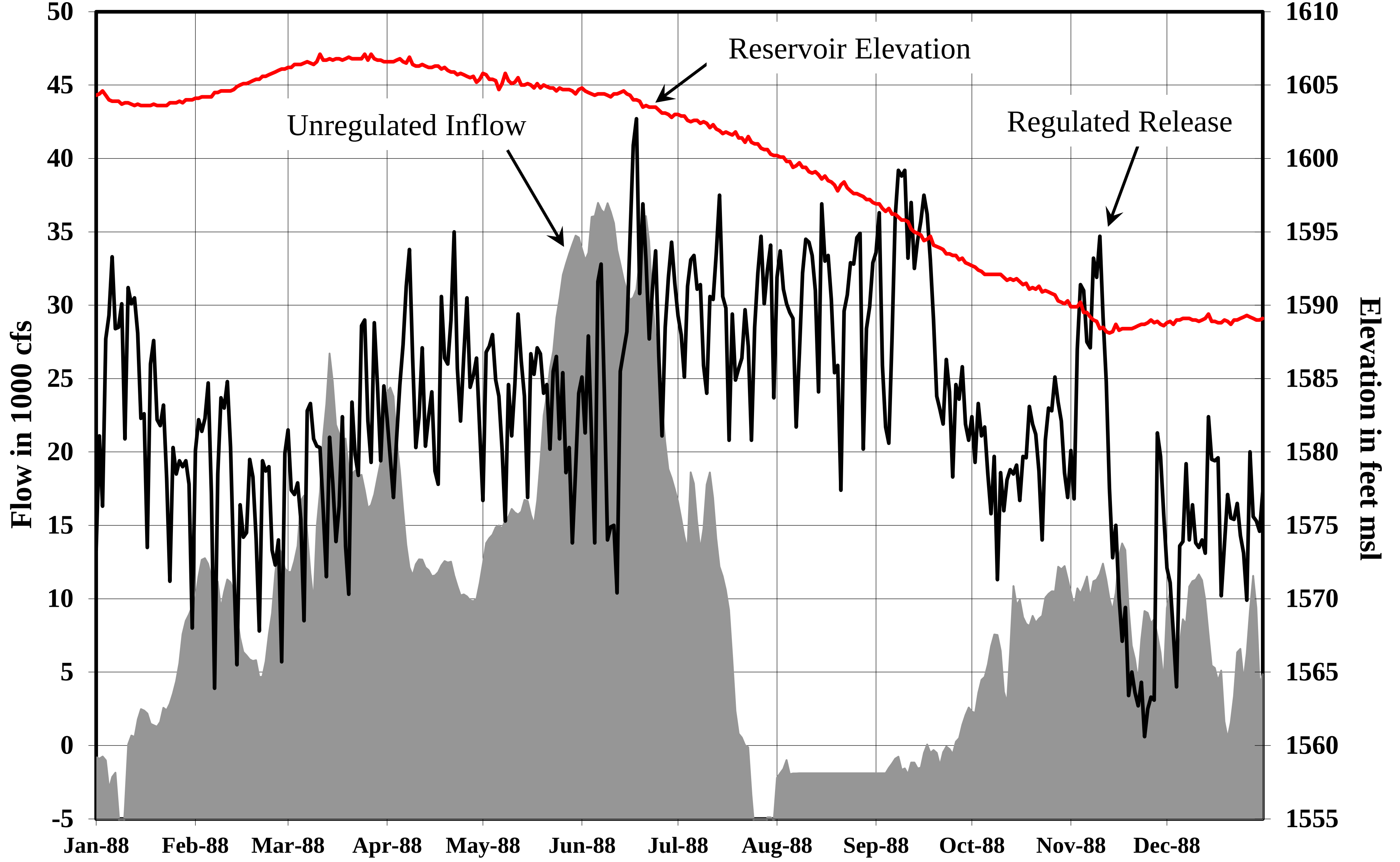

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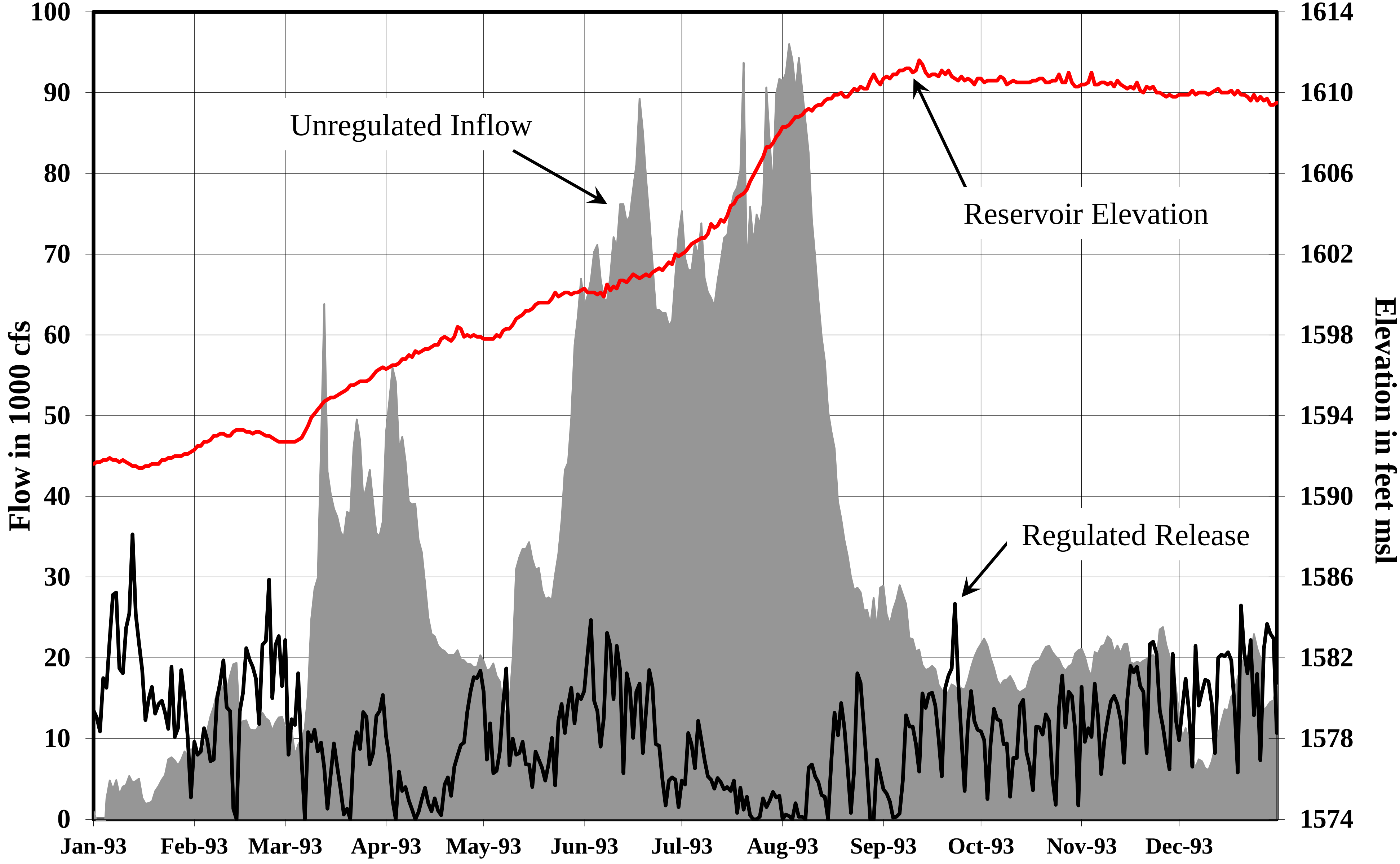

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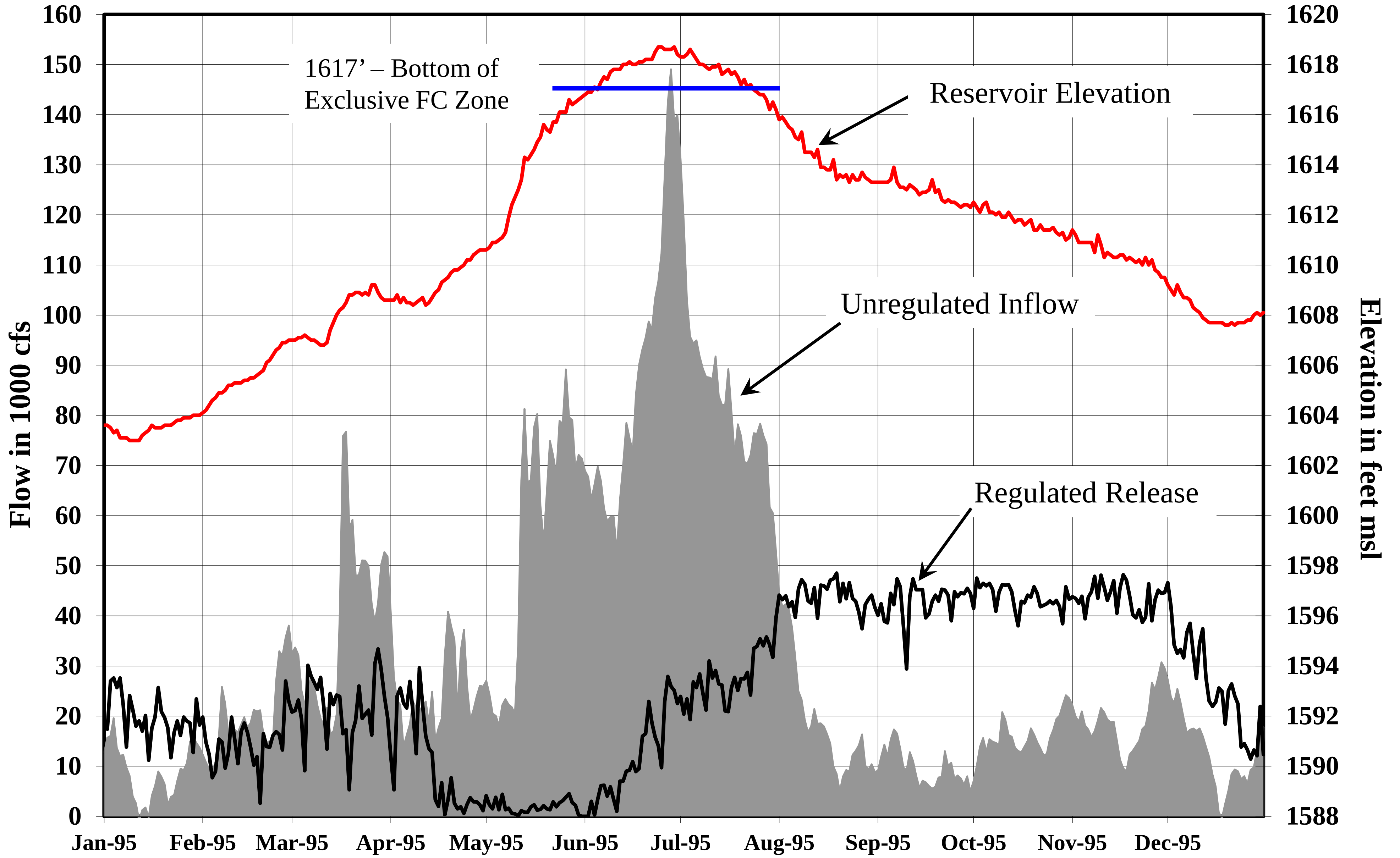

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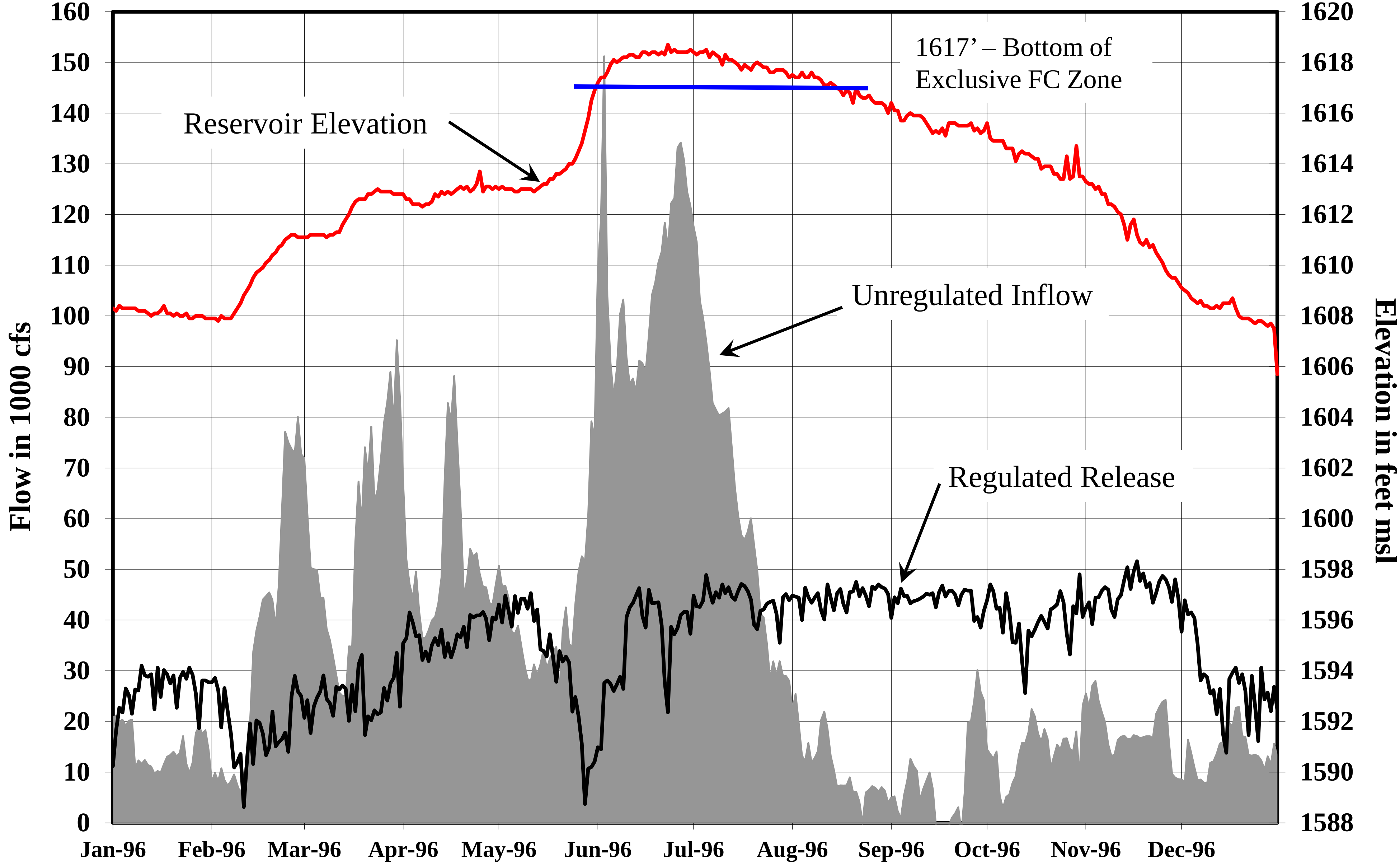

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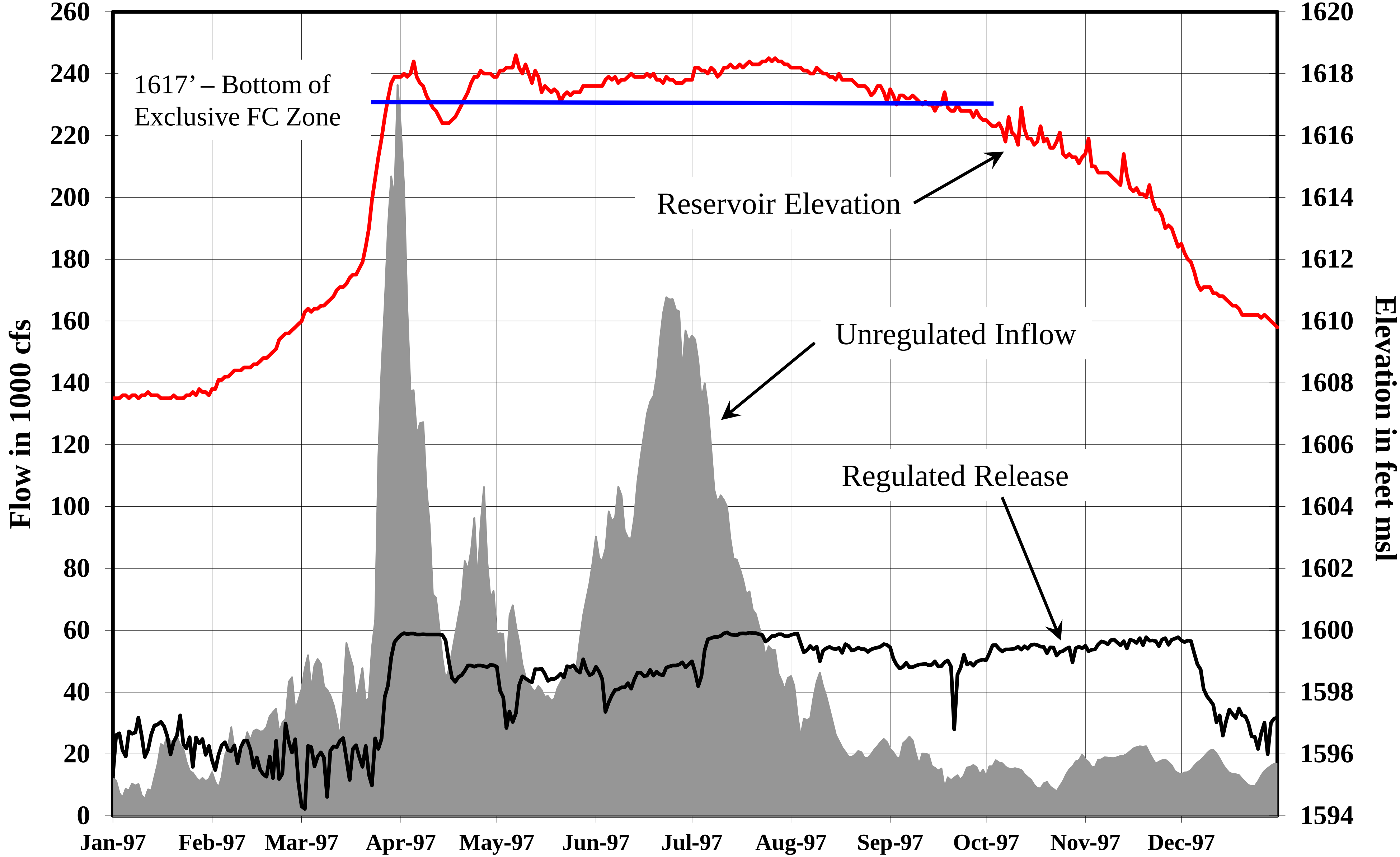

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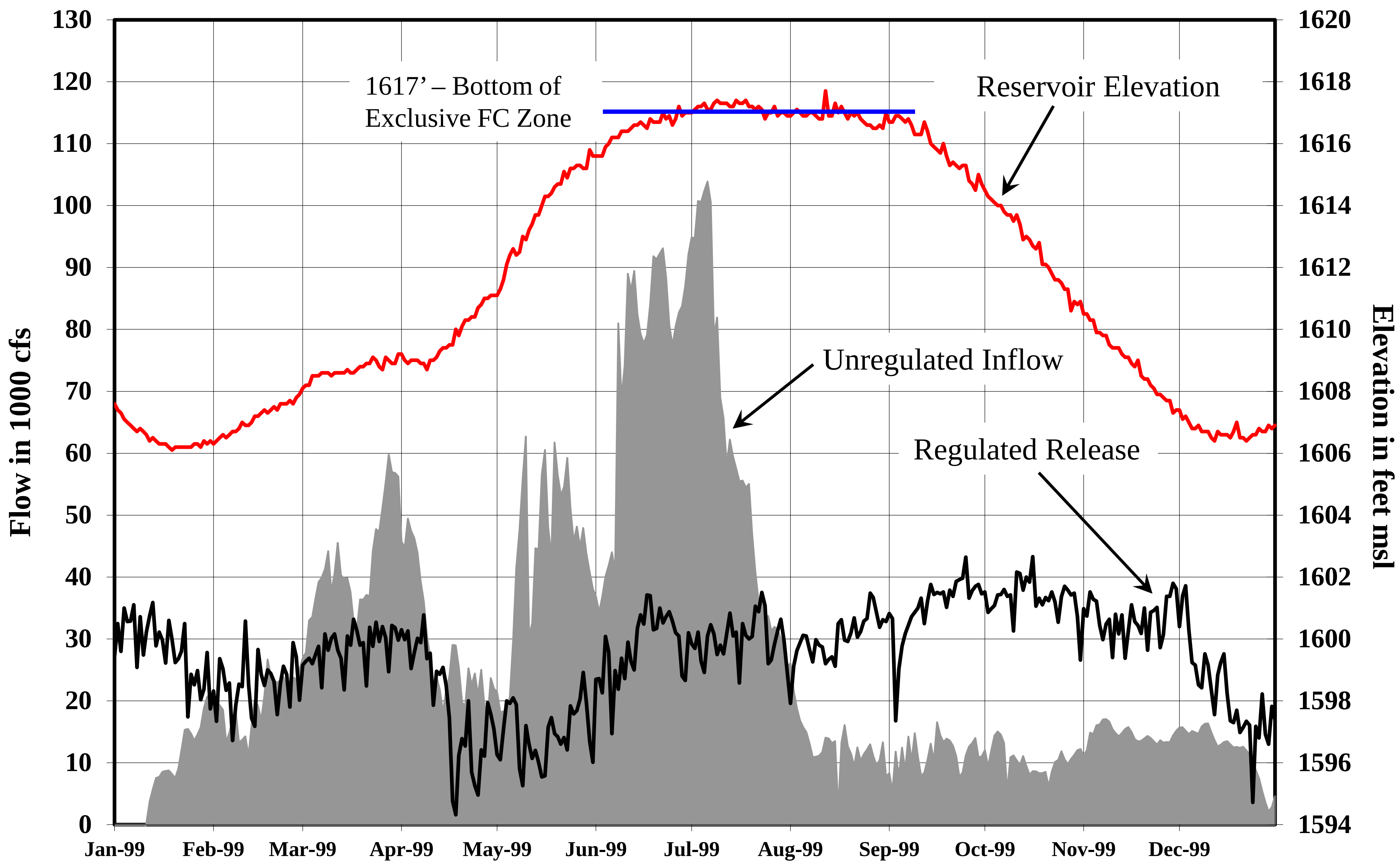

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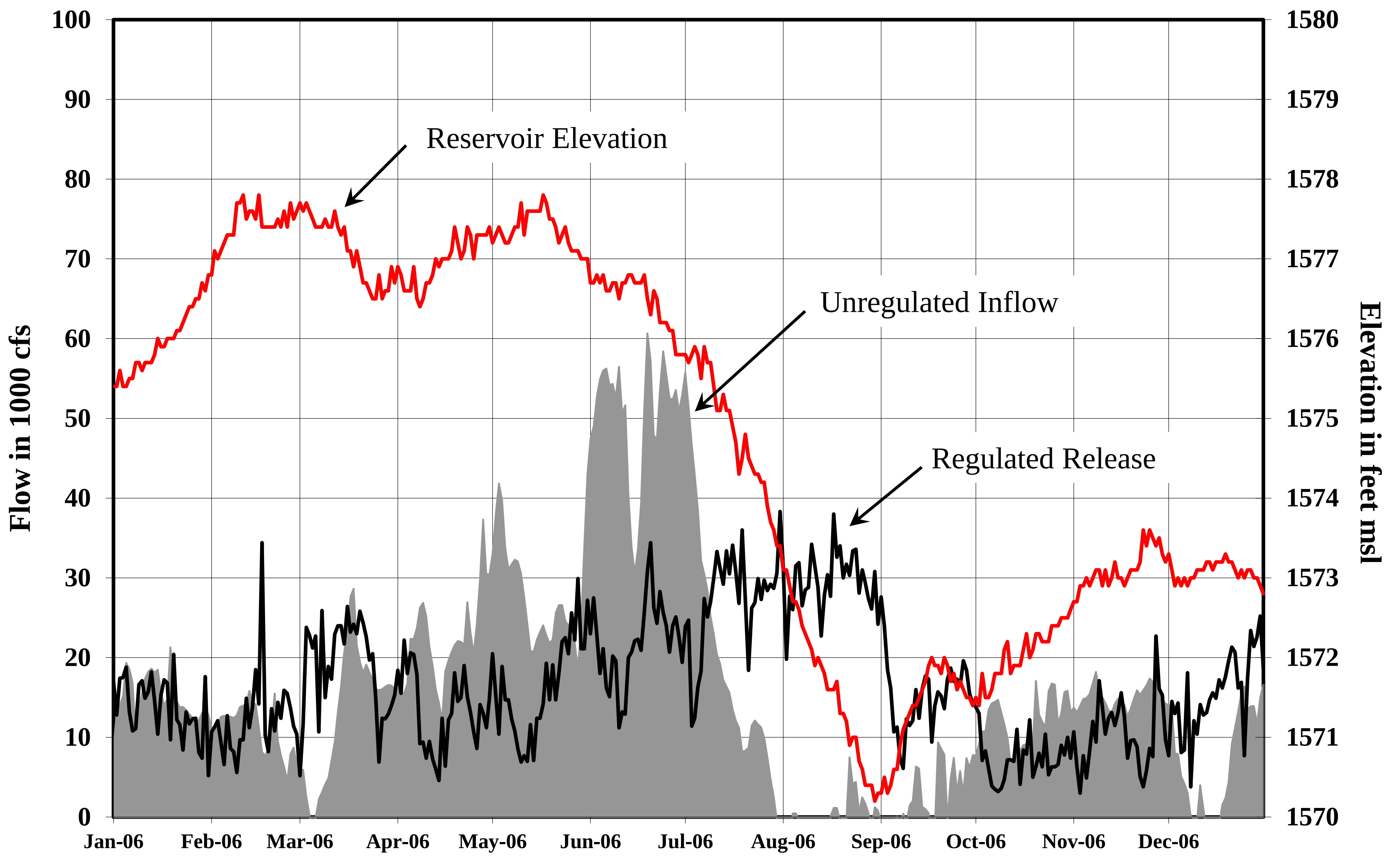

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Oahe Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 2006

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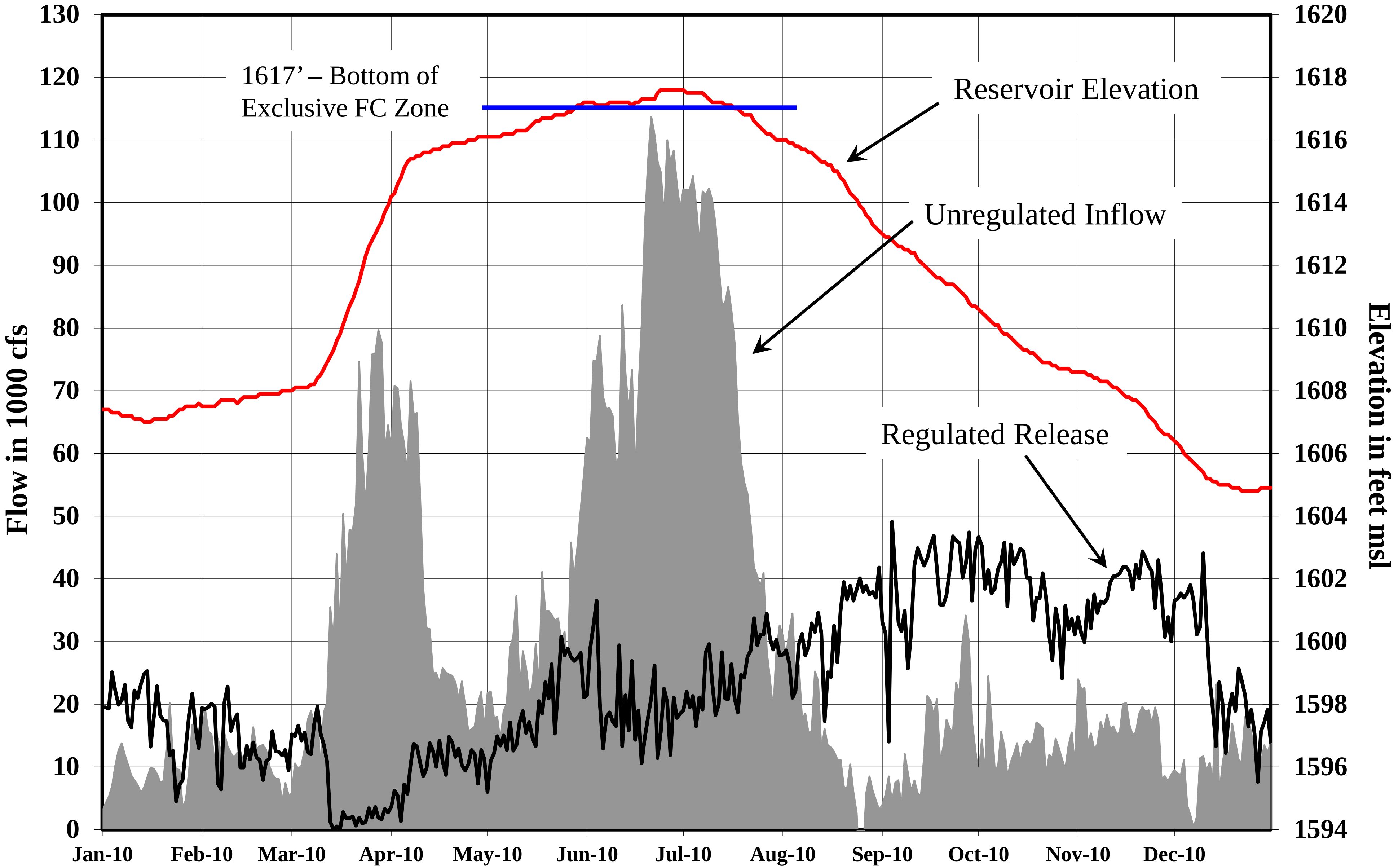

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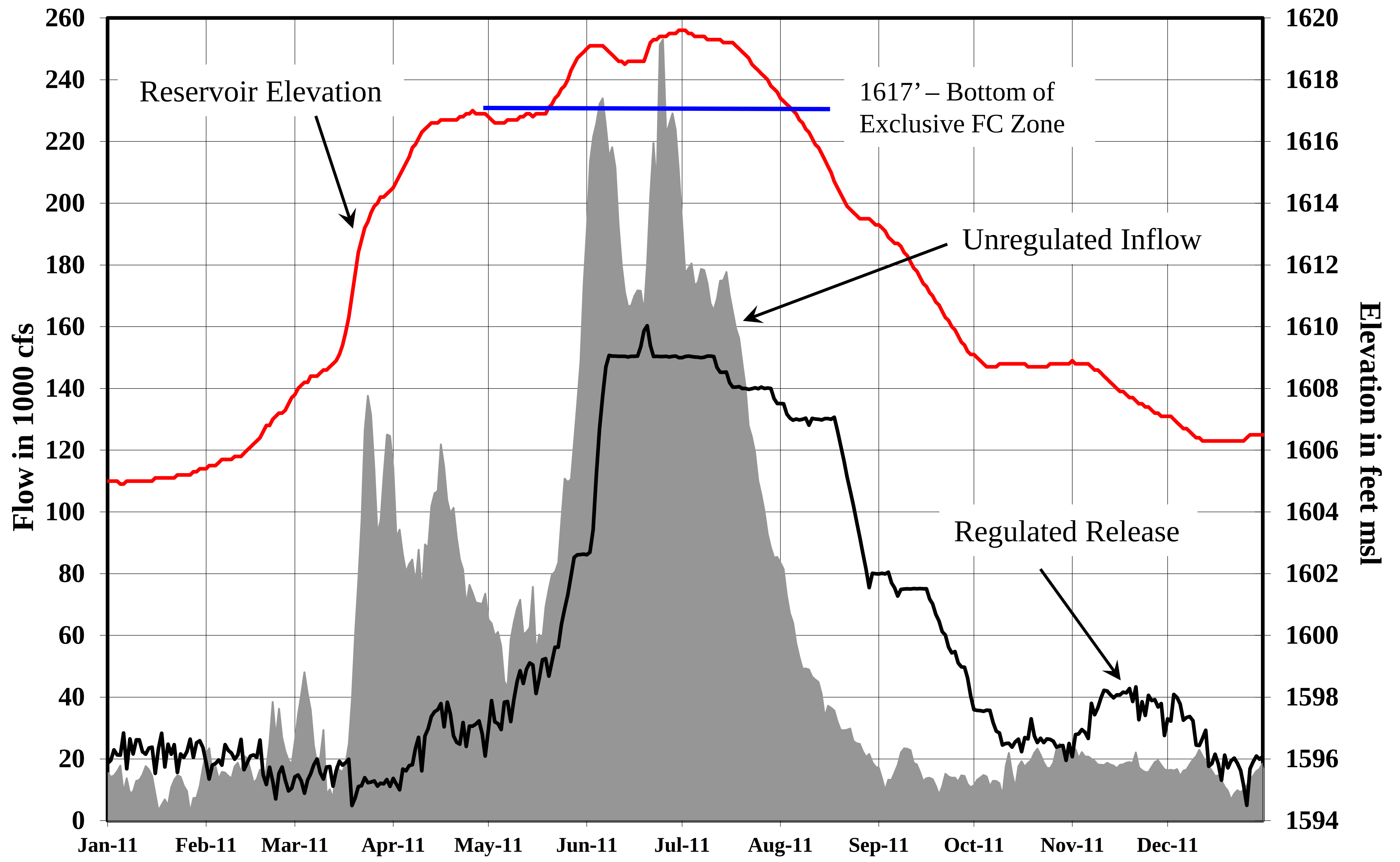

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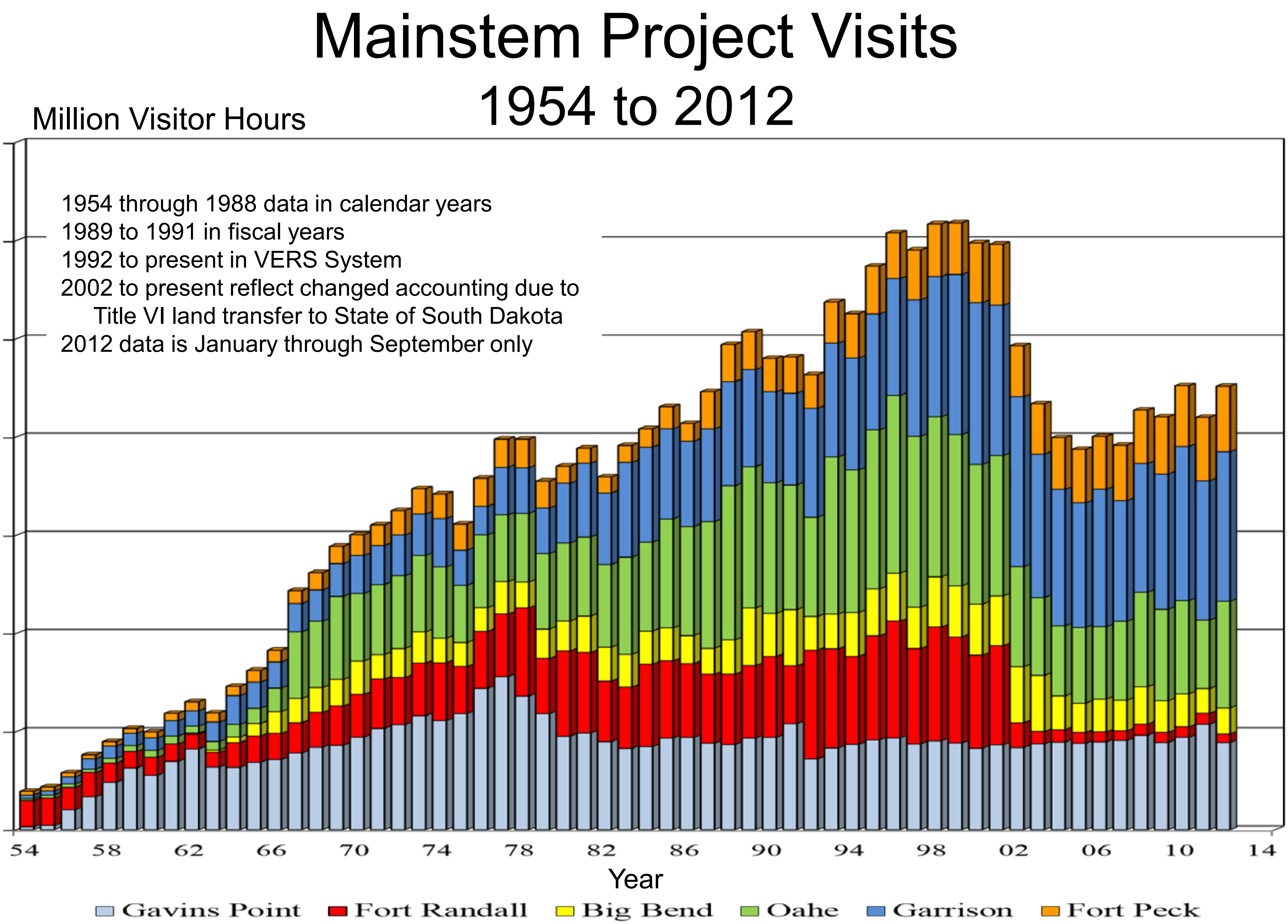

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