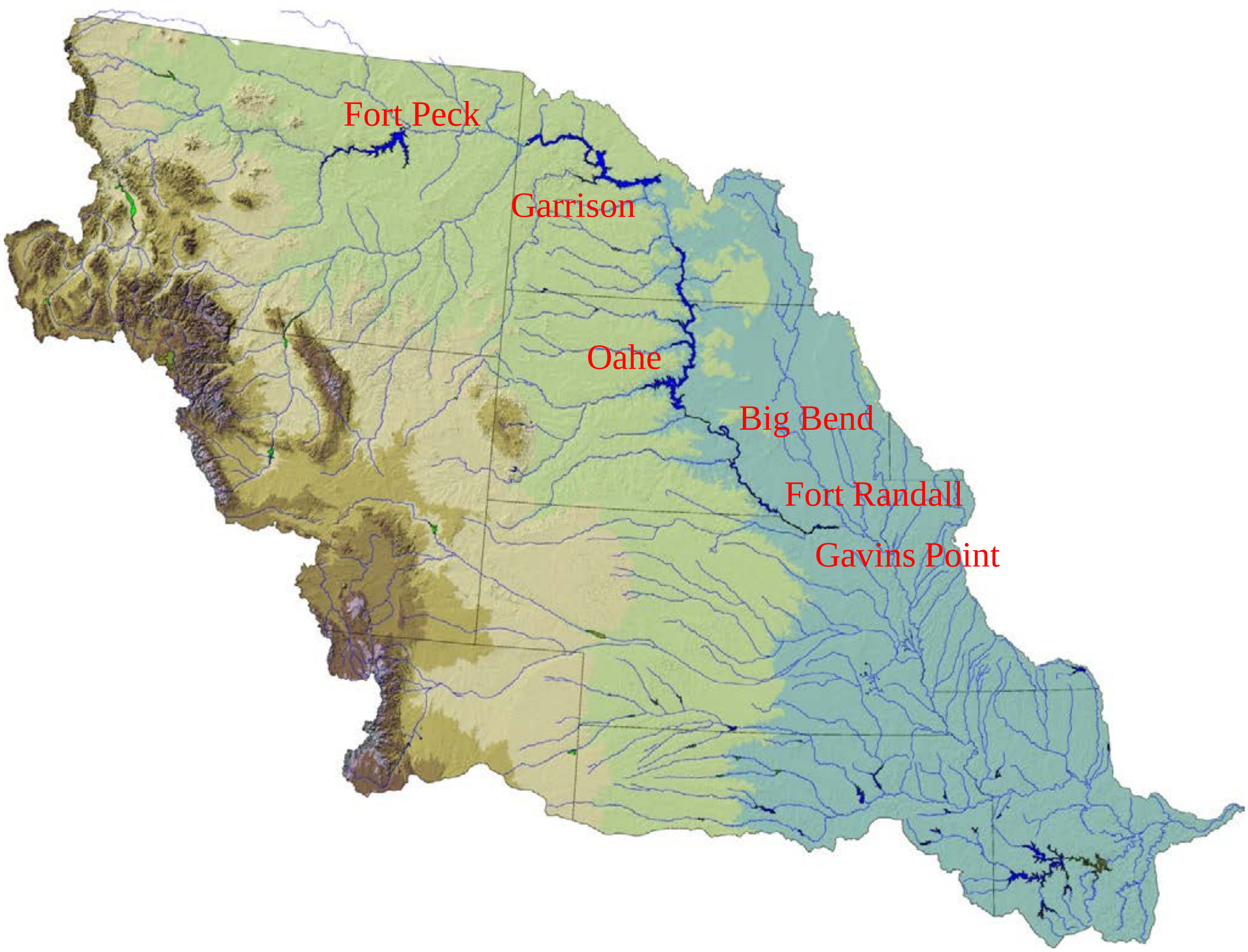
US Army Corps of Engineers ®
Northwestern Division

Missouri River Mainstem Reservoir System

Water Control Manual

Big Bend Dam – Lake Sharpe



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 5

BIG BEND 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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BIG BEND 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
DCP	-	Data Collection Platform
DRM	-	Daily Routing Model
EM	-	Corps' Engineering Manual
ESA	-	Endangered Species Act
ER	-	Corps' Engineering Regulation
°F	-	Degrees Fahrenheit
GF&P	-	Game Fish and Parks
kAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
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
MRBIR	-	Missouri River Basin Interagency Roundtable
MRBWM	-	Missouri River Basin Water Management Division
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
PPCS	-	Powerplant Control System
QPE	-	Quantitative Precipitation Estimate
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

TMDL	-	total maximum daily load
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

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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 Big Bend 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 Big Bend 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 Big Bend. 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 WCM 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 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 Big Bend is part of the System, any discussions regarding the regulation of Big Bend 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 Big Bend WCM supplements the Master Manual by discussing the factors pertinent to the regulation of Big Bend. The regulation of major tributary reservoirs located within the Missouri River basin affecting the regulation of Big Bend 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 Big Bend and serves as a supplement to the Master Manual.

1-03.2. In a further effort to reduce redundancy among the individual project manuals, frequent reference will be made to the Oahe WCM in connection to Big Bend inflows and releases. With the relatively small incremental drainage area contributing directly to the Big Bend reservoir (Lake Sharpe), the small runoff depths usually originating from this area, and regulation procedures applicable to Big Bend, release definition at Oahe defines both inflows and releases at Big Bend most of the time.

1-04. Project Owner. Big Bend 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 Big Bend. 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 Big Bend, 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 releases rates are achieved.

1-06. Regulating Agencies. As the Big Bend 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) processes, 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 Big Bend. These are provided for reference only and should not be used for construction or other purposes.

Table I-1
Big Bend Datums (in feet)

Local project datum	NGVD29	NAVD88
0.0	-1.130	-0.049
(ex.) 1420.0	1418.87	1419.951

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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 Big Bend, 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. The first studies by a federal agency for a dam in this reach of the Missouri River were made by the U.S. Bureau of Reclamation (USBR) and were included in Senate Document 191, 78th Congress. The damsite proposed in this report was several miles upstream from the present location. The Corps' plans for Missouri River basin development as contained in House Document 475 (78th Congress, 2nd Session 1944) proposed several damsites along the Missouri River, which included modifications as the Secretary of War and the Chief of Engineers might find advisable. A dam at the current Big Bend location was not included in this document. The differences between the USBR's and Corps' plans was adjusted in an inter-departmental conference and the coordinated plan, including Big Bend, was presented to Congress in Senate Document No. 247, 78th Congress, 2nd Session, otherwise known as the "Pick-Sloan Plan." Legislative history of the System projects is described in greater detail in Chapter II of the Master Manual.

2-01.2. Big Bend 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. Big Bend was planned and constructed by the Corps of Engineers' Omaha District under supervision of the Missouri River Division (MRD) and the Chief of Engineers. The initial design study of the project was completed in March 1954 (Omaha District Design Memorandum No. MO-27). Construction of the project began in 1959, with diversion of the Missouri River through the powerhouse during July 1963. Delivery of power began in October 1964 and most major construction was completed by December 1966. Formal dedication ceremonies were held on September 15, 1966. Full operation of the project has continued since that time.

2-03. Construction History. The initial construction contracts awarded for Big Bend were for the access road, a construction bridge across the Missouri River and administrative facilities. Work was started in 1959. The first of the two earthwork contracts, which included the construction of the dam embankment, was started in May 1960. The second stage earthwork contract was essentially complete by October 1963. The powerhouse substructure and intake were started on January 3, 1961 and were essentially complete by October 1963. The river was diverted through the powerhouse on July 24, 1963. Work on the spillway structure was essentially complete in December 1962. Work on the powerhouse superstructure and installation of equipment was started in October 1962. The first of the eight 58,500 kilowatt (kW) generating units (Unit No. 1) began power delivery in October 1964. The last generating unit (Unit No. 8) started production of power in July 1966. Contracts for the powerhouse superstructure, installation of generating equipment and appurtenances, roads and parking areas, crest road lighting and relocations were essentially complete in December 1966. Plate II-1 presents a summary of the significant date 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. Extensive relocations resulting from construction of Big Bend were not required due to the sparsely settled condition of the surrounding area. It was necessary to modify about six miles of Chicago and Northwestern Railway tracks adjacent to the reservoir areas while about 27 miles of Native American reservation and county roads were affected. Fifteen miles of road were abandoned and the remainder relocated or improved to accommodate maximum operating pool levels. It was necessary to relocate several cemeteries and the Big Bend Dam embankment axis, as constructed, was chosen in a manner to provide minimum disturbance to a large cemetery located in the left abutment area. Recreational facilities, including a golf course on Farm Island immediately downstream from Pierre, were relocated to higher elevations outside the reservoir area to permit operation of the reservoir at planned levels.

2-05. Real Estate Acquisition. Approximately 45,412 fee acres and 169 acres in easements were acquired by purchase and condemnation for Big Bend. In addition, Public Land Order transferred 13 acres from the public domain. In addition to the land acquired for the Big Bend project, approximately 15,000 acres of land in the Big Bend reservoir area had previously been acquired in connection with the Fort Randall project. Land acquisition was based on a guide-taking line at elevation 1423.0 feet, plus allowances for wave heights, set-up, wave run-up, erosion and bank caving, or 300 feet set back from the 1423.0 feet contour, whichever was the greater. Of the total easement acreage, flowage easements were acquired on four tracts of land having a total area of less than 10 acres.

2-06. Regulation History. Big Bend was the last of the Missouri River mainstem reservoir projects to be constructed. Closure of Big Bend Dam and the first impoundment of water in the Big Bend reservoir began in July 1963. Run-of-the-river conditions, with no deliberate storage, were maintained until November 1963. After that time, the reservoir level was slowly raised to the interim fill limit of 1417.0 feet by April 1964. Filling to the normal operating level of 1420.0 feet was delayed until December 1965. Big Bend has been and will be regulated in conjunction with the other System reservoirs to provide control of flood flows, to produce hydroelectric power (primarily peaking power), and to maintain sufficient flows for navigation, domestic and industrial uses, and for water quality purposes. Big Bend power production began in October 1964 with the completion of Unit Nos. 1 and 2 in October and November, respectively. Unit

Nos. 3, 4 and 5 went on line in February, May and October 1965, respectively, followed by Unit Nos. 6, 7 and 8 in January, May and July 1966, respectively. The reservoir level normally fluctuates +/- 1 foot from elevation 1420.0 feet on a weekly basis. Since the project began operation, exclusive flood control storage space (above elevation 1422.0 feet) has been utilized only once (June 1991) for a short period. Further information concerning historical operation is contained in Appendix A of this WCM. Detailed descriptions of each year's project operations are detailed in the AOPs and yearly Summary of Actual Regulation Reports published by the MRBWM office.

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III - Basin Description and Characteristics

3-01. General Characteristics. The Missouri River basin drainage area upstream from Big Bend Dam 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 southern Canada. The total area controlled by Big Bend Dam is 249,330 square miles. This includes 57,500 square miles of drainage above Fort Peck Dam, 123,900 square miles between Fort Peck and Garrison dams and 62,090 square miles of drainage area between the Garrison and Oahe dams. Those portions of the Missouri River basin lying upstream from the Oahe Dam are described in the Fort Peck, Garrison and Oahe WCMs. The portion of the Missouri River basin described in this WCM consists of the 5,840 square miles of drainage area between Oahe and Big Bend. Plate III-1 is a general map of the Missouri River basin. The incremental drainage area defined by Oahe and Big Bend, and described in this WCM, is shown on Plate III-2.

3-02. Topography. The Missouri River drainage area between Oahe and Big Bend forms a portion of the Great Plains province of the United States. The small portion of the incremental drainage area to the north and east of the Missouri River is within the Glaciated Missouri Plateau consisting 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 potholes, small intermittent lakes and a few larger permanent lakes. Most of the drainage in the Oahe to Big Bend 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 Unglaciated Plateau region, comprising most of the incremental drainage area, has a general west to east slope of about 10 feet to the mile. Elevations range from about 3,000 feet in the western part of the incremental drainage area to near 1,350 feet on bottomlands adjacent to the Missouri River.

3-03. Land Use. Agriculture represents the primary use of the land in this portion of the Missouri River basin, estimated to extend over 95 percent of the total area. The remainder is devoted to recreation, fish and wildlife, transportation and built-up areas. Pasture and range (grasslands/herbaceous and pasture/hay) is the primary agricultural pursuit, utilizing about 70 percent of the total area. Cropland (row crops, small grains and fallow) comprises about 27 percent of the total area. Woodlands or forests are restricted to bottomlands adjacent to streams and woodlots or groves planted for protective or aesthetic purposes. Consequently, only a minor portion of the incremental drainage area is forestland. Due to the general lack of an assured water supply 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 2 percent of the total area, but 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 to Big Bend incremental drainage area.

3-04. Drainage Pattern. The drainage pattern of the Missouri River basin is presented on Plate III-1. Noteworthy in the drainage basin above Big Bend is the large area of the upper Missouri River basin controlled by the Fort Peck, Garrison and Oahe projects. These upstream mainstem projects control almost 98 percent of the total drainage area contributing to the Missouri River above the Big Bend project, including all of the mountainous area contributing to the Missouri River above Big Bend.

3-04.1. The prominent feature of the incremental portion of the Missouri River basin between Oahe and Big Bend, as shown on Plate III-2, is the Bad River, the single major tributary within this reach. The Bad River is a right bank tributary flowing in an easterly direction. The drainage pattern contributing from the area west of the Missouri River in this reach is generally well defined. Numerous potholes and depressions exist east of the Missouri River. Portions of this region do not contribute directly to streamflow unless substantial amounts of runoff were to occur sufficient to fill and overflow the low depressions that normally restrict runoff.

3-04.2. The Bad River tributary drainage area is about 100 miles long, has a maximum width of 46 miles and enters the Missouri River near the headwaters of the Big Bend reservoir 78 river miles upstream from Big Bend Dam and 7 river miles below Oahe Dam. The Bad River drainage area of 3,000 square miles is all located in western South Dakota. Numerous small creeks discharging directly into the Missouri River drain the remainder of the Oahe to Big Bend incremental drainage area, which amounts to 2,840 square miles. The largest of these is Medicine Knoll Creek, a left bank tributary having a drainage area of about 800 square miles and entering the Missouri River about 60 miles upstream from Big Bend Dam. Medicine Creek enters the Missouri River from the right bank about 33 miles upstream from Big Bend Dam and has a drainage area of about 600 square miles.

3-05. Stream Slopes. The total fall of the Missouri River from Oahe Dam to Big Bend Dam is about 75 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 of the tributary streams progressively tend to flatten toward their mouths.

3-06. Climate. The Oahe to Big Bend incremental drainage area of the Missouri River basin is located near the geographical center of the North American continent. While the area lies near the center of the belt of westerly winds, the Rocky Mountains form a barrier to a Pacific moisture source. Consequently, the climate of the region is generally classified as continental semi-arid. The region is affected by a marked seasonal variation in all weather phenomena.

3-06.1. Annual Precipitation. Although there is a slight increase in the amount of average annual precipitation from west to east within the Oahe to Big Bend incremental drainage area, at no point does it vary significantly from a range of 16 to 17 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 as well as successive years of well-above-normal amounts of precipitation occasionally occurring.

3-06.2. Seasonal Precipitation. Precipitation over the drainage area between the Oahe and Big Bend dams usually occurs as snow during the months 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 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 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 Oahe to Big Bend drainage 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. Snowfall is usually accompanied by high winds resulting in much drifting. Refer to Plates III-5 and III-6 for a representation of 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 each year can usually range from a maximum of over 100 degrees Fahrenheit (°F) at some time during the summer months to a minimum of -30°F 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, although 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 air temperatures for the Missouri River basin are shown on Plates III-7 and III-8, respectively. Air 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 Big Bend reservoir is about 3 feet. This evaporation loss equates to approximately 178,000 acre-feet (AF) of volume (refer to Plates III-9 through III-12). Evaporation studies made by the MRBWM office conclude that the average annual net evaporation is about 22 inches. The net evaporation, which is adjusted for precipitation on the reservoir surface, is the amount of evaporation that would have occurred from land area now inundated by the reservoir and the channel surface area existing prior to development of the Big Bend project. Due to seasonal precipitation patterns, seasonal patterns of gross evaporation depths, and the lag in normal lake surface temperatures from corresponding air temperatures, most of the annual net evaporation from the Big Bend reservoir can be expected to occur during the 6-month period from July through December.

3-06.6. Storm Potentialities. The major source of moisture for all 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 charge. 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 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 will only occasionally occur over portions of the basin due to an individual major storm event.

3-07. Streamflow Records. Records of tributary streamflow within the incremental drainage area discussed in this WCM have been accumulated on the Bad River, Medicine Knoll Creek and Medicine Creek. Records near the mouth of the Bad River at the Fort Pierre streamgaging location are available since 1928. Missouri River streamflow records throughout the Missouri River basin are available since the early 1930s. As discussed in the Master Manual, planning of the System made it desirable to extend Missouri River streamflow records to the extent practicable. From the studies carried on at the time, based on mainstem stages and the discharge records available, records of monthly flows were developed for several locations along the main stem of the Missouri River. However, the Big Bend damsite was not one of these locations. Selected development locations in the vicinity were Pierre, SD (Oahe damsite) and the Fort Randall damsite. Practice has been to consider the total incremental flow as developed from these two locations as being incremental inflow to the downstream Fort Randall reservoir. Consequently, the only records of total incremental inflow between the Oahe and Big Bend dams are those derived from simultaneous outflow records obtained since the Big Bend project became operational. 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 Oahe to Big Bend incremental drainage area is the melting of the snow accumulated during the winter months. However, on occasion rainfall during May and June has resulted in substantial runoff amounts from the incremental area. Runoff is extremely variable from year to year. U.S. Geological Survey (USGS) flow records (1929-2014) indicate that runoff from the Bad River at Fort Pierre streamgaging site averages about 123,000 AF per year, equivalent to a runoff depth of 0.74 inch each year from the 3,107 square miles contributing to this location. Available streamflow records for Medicine Knoll Creek near Blunt, SD (record of 1950-1989) and Medicine Creek near Kennebec, SD (record of 1955-1989) indicate average annual runoff depths of 0.21 and 0.55 inch, respectively. Analysis of incremental runoff originating from the Oahe to Big Bend incremental area on the basis of simultaneous operation of these two mainstem projects indicates an average annual incremental inflow of about 50,000 AF. As noted earlier, the average annual Bad River flow at the Fort Pierre streamgaging site is 123,000 AF. The reasons for this inconsistency are not certain, but are believed to be largely due to minor inconsistencies in release determinations at the two projects. In any case, the runoff originating in the reach defined by the Oahe and Big Bend projects is fairly small when compared to the total runoff of the Missouri River basin originating from above these projects. The runoff into the Big Bend reservoir is on the order of one-half percent of the total Missouri River flow. Average annual runoff from the Missouri River basin above the Oahe and Big Bend dams is about 21 million acre-feet (MAF) at the 1949 level of water resource development.

3-08.1. Seasonal Runoff Pattern. Runoff from the Missouri River drainage basin between Oahe Dam and Big Bend usually follows a characteristic seasonal pattern as follows:

1. Winter is characterized by frozen streams, intermittent snowfall and thaws in the drainage area where the season usually ends with a “spotty” snow cover 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 rise. Ice jams are frequently experienced on tributary streams during this period. The rapid release of water from melting snow and ice jams results in flashy rises in tributary flows. Annual maximum peak stages and flows often occur at this time along tributary streams.
3. Late spring consists of the months of May and June. At this time extensive general rains may occasionally occur, sometimes accompanied by severe local rainstorms. Runoff is usually quite low unless these rains occur. However, intense rains sometimes will cause large and sharp crest flows on tributary streams. The maximum flow of record on the Bad River at Fort Pierre of 43,800 cubic feet per second (cfs), resulted from such a rainstorm in June 1967. Previous to the record period, historical evidence indicates a flow of about 55,000 cfs in April 1927. In July 1905 a peak stage occurred which was estimated to be 2 feet higher than the peak stage observed in 1927.
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 to the Oahe to Big Bend incremental drainage area is usually very low from July through the remainder of the calendar year.

3-08.2. The larger amounts of total incremental runoff originating between the Oahe and Big Bend dams is illustrated on Plate III-13. Before the two projects began operating in 1963, runoff in the incremental area was very significant in 1942 and 1952. During the 15-day period in 1952, the average daily incremental flow was over 14,000 cfs. In 2011, an 8-day runoff period in late June resulted in average daily incremental flow over 15,000 cfs.

3-08.3. Total unregulated Missouri River runoff originating above Big Bend usually follows a definite and characteristic annual pattern, with an increase in flows from January through June followed by decreasing flows during the remainder of the year. However, wide variations in monthly runoff amounts occur from year to year. Reference is made to the Oahe Project WCM for a further description of total Missouri River runoff patterns at the approximate Big Bend Dam location.

3-08.4. The MRBWM Technical Report, *Hydrologic Statistics on Inflows*, June 2015, details the development of inflow volume probability relationships for various durations for both regulated and unregulated flow in the Oahe to Big Bend reach. See Section 6-13 in this WCM for discussion regarding regulated and incremental inflow volume probability relationships for various durations.

3-09. Effects on Basin-Wide Floods. The relatively minor amount of flood control storage capacity contained within the Big Bend reservoir can be utilized for control of flood events originating in the Oahe to Big Bend incremental area. It is not sufficient for any significant degree of control over large basin-wide floods originating upstream. Flood control is considered a major function of the upper three System projects that control all but a very small portion of the total area. Only in very exceptional circumstances, if ever, would storage in the Big Bend reservoir be a factor in the control of floods originating from areas other than its immediate incremental drainage area.

3-10. Effects of Big Bend on Flood Inflows. System regulation studies conducted by the MRBWM office indicate that operation of Big Bend, in conjunction with other upstream reservoir projects, would significantly reduce flood damages in the Big Bend tailwater/Fort Randall headwater reach 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. At normal operating levels the Big Bend reservoir extends upstream into the Oahe tailwater. Thus, Oahe outflows are fully reflected as Big Bend inflows in only a few hours. For most mainstem routing purposes, for which a minimum time interval of 12 hours is utilized, the effect is considered to occur in the same day. The same is true for Bad River flows, as defined by the Bad River at Fort Pierre streamgaging station. The travel time from the Bad River streamgaging station at Midland, SD to the Big Bend reservoir is about one day (see Plate III-14). See Plate IV-1 of the Master Manual for estimates of water travel time throughout the Missouri River basin.

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 the Missouri River, including the Big Bend reservoir and the Missouri River downstream of Big Bend. The Omaha District conducts fixed-station ambient water quality monitoring at the mainstem reservoirs and on the 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 Corps estimated a Big Bend sediment depletion rate of about 3,445 AF/year based on sediment range survey analyses conducted in 1963 and 2012. At this rate the estimated sediment life of the reservoir is 525 years. Gross storage capacity below elevation 1423.0 feet has decreased by 168,819 AF in the period from 1963 to 2012. The reservoir storage loss equates to a rate of 0.17 percent per year for a total loss of slightly less than 10 percent. Due to the high rate of reservoir bank erosion, storage in the maximum normal operating pool range, elevation 1420.0 to 1423.0 feet, has shown a slight increase between 1962 and 2012. Additional information can be found in Corps' M.R.B. Sediment Memoranda No. 31, *Lake Sharpe Aggradation Study, 1963-2012*. See Plate III-15 for the location of sediment range lines in the Big Bend reservoir, the Bad River and in the Oahe tailrace.

3-14. Missouri River Channel below Big Bend Dam. With the downstream Fort Randall reservoir at its normal operating level of elevation 1350.0 feet, the entire Missouri River channel immediately below Big Bend is occupied by this downstream reservoir. Since the normal operating levels of the Fort Randall reservoir extend upward from elevation 1350.0 feet to as high an elevation as 1375.0 feet, there is no natural channel remaining that serves as a constraint on the regulation of Big Bend. At such times that the Fort Randall reservoir is drawn below elevation 1350.0 feet toward its minimum operating level of elevation 1337.5 feet, portions of the normally flooded original floodplain reappear. However, this is only temporary and does not result in any constraint on Big Bend regulation.

3-15. River Ice. Since Big Bend first began operation in 1963 the formation of ice on the Missouri River has not restricted regulation of the project. The only effect of such ice formation on reservoir regulation would be the increase in tailwater levels above what they would otherwise have been. To date, these increased tailwater levels have not resulted in any regulation constraints.

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Missouri River Basin
Big Bend Dam – Lake Sharpe
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IV - Project Description and History

4-01. Location. Big Bend is located at Missouri River Mile (RM) 987.4 in Buffalo and Lyman Counties, South Dakota, approximately 21 miles upstream from the city of Chamberlain, SD. The project is fourth in downstream order of the six Missouri River mainstem projects constructed by the Corps. The Big Bend reservoir (Lake Sharpe) created by the dam extends 80 river miles upstream with the headwaters near Pierre, SD. A project photo is shown on Plate IV-1.

4-02. Embankment. The dam is a rolled earthfill embankment with the powerhouse at the right abutment and the spillway at the left abutment. The total embankment length, including the spillway, is 10,570 feet. Maximum dam height is 95 feet, top elevation is 1440.0 feet, maximum embankment base width including berms is 1,200 feet and the top-of-dam width is 50 feet. The embankment makes a gentle S-curve across the valley and is composed of approximately 17 million cubic yards of fill material. The embankment is built on dredged pervious fill, which has a top elevation near 1357.0 feet. A central impervious core along the entire length of the embankment extends from the pervious fill to 5 feet below the top of the dam to control seepage through the embankment. An impervious blanket ties into the central impervious core and extends 425 to 540 feet through the major portion of the embankment. A pervious drain section is located on the downstream side of the impervious core. Plan and 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 a Big Bend reservoir level of 1433.6 feet, the maximum level attained during routing of the Spillway Design Flood (SDF). A set-up allowance of 0.7 foot and wave height plus ride-up allowance of 3.3 feet was developed in design studies. An additional safety factor of 2.4 feet resulted in a total freeboard allowance of 6.4 feet, establishing the embankment crest at elevation 1440.0 feet.

4-03. Spillway. The Big Bend spillway is located on the left bank of the river at the end of the embankment section of the dam. The approach channel is about 2,700 feet long and curves through an angle of 90 degrees on the riverward side and 70 degrees on the landward side. The bottom of the approach channel is excavated to elevation 1375.0 feet. Side slopes are 1 vertical (V) on 3 horizontal (H). The minimum width of the approach channel is 376 feet at the gated weir. The maximum approach width, located at the junction with the reservoir, is approximately 1,400 feet. A concrete approach slab with semi-gravity sidewalls extends 100 feet upstream from the concrete weir. Riprap is provided on the curved side slopes of the approach channel sidewall on the riverward side and at the upstream end of the approach slab sidewall on the landward side.

4-03.1. The spillway structure consists of an ogee weir with a crest elevation of 1385.0 feet. The spillway crest elevation is 10 feet above the bottom of the approach channel, surmounted by tainter gates, a highway bridge, equipment platforms and service walkways. Eight tainter gates control the spillway. Each tainter gate is 40 feet long and 38 feet high and are all separated by piers 8 feet wide. The net length of the spillway crest is 320 feet. The gates operate individually and may be opened or closed in 1-foot increments. Additional guidance regarding best practices and/or special considerations for use of the spillway can be found in Exhibit A of this WCM. Plan and profile of the spillway is shown on Plate IV-2. See Plates IV-3 through IV-5 for photos of the spillway approach, spillway chute and spillway channel, respectively. See Plate IV-6 for the spillway rating curves.

4-03.2. A 376-foot wide concrete paved chute extends from the spillway weir to the stilling basin. From the downstream end of the weir the chute slopes downstream on a 3 percent grade a distance of 120 feet. Beyond this initial 120-foot distance, the slope steepens to a 25 percent grade for a distance of 175 feet to a transition with the stilling basin slab. The sidewalls of the chute are semi-gravity concrete walls and vary in height from 18 to 46 feet. The stilling basin, including the end sill, is 194 feet long. The floor of the stilling basin is at elevation 1320.0 feet. The stilling basin walls are sloped 4V on 1H from elevation 1320.0 feet to 1362.0 feet and vertical from elevation 1362.0 feet to 1365.0 feet. The bottom width of the stilling basin at elevation 1320.0 feet is 345 feet and the top width of the stilling basin is 376 feet. The end sill is stepped in 5-foot increments from elevation 1320.0 feet to 1330.0 feet. Two rows of concrete baffles with a top elevation of 1332.0 feet are located in the stilling basin.

4-03.3. The spillway discharge channel is 4,125 feet long. The channel immediately downstream from the stilling basin has been excavated to elevation 1330.0 feet and has a bottom width of 376 feet for a distance of 3,000 feet. This is followed by a transition section that is 750 feet long. This 750-foot transition section was excavated to elevation 1330.0 feet and converges to a bottom width of 200 feet at the downstream end. A second transition section 375 feet long is excavated to a bottom elevation of 1350.0 feet with a bottom width of 50 feet at the downstream end for the pilot channel. The discharge channel has been excavated an additional 300 feet downstream. Side slopes of the discharge channel are 1V on 2.5H for slopes protected by riprap and 1V on 3H for unprotected excavated slopes. Riprap is provided for the side slopes of the discharge channel from elevation 1330.0 feet to berms at elevation 1368.0 feet for 3,000 feet downstream of the stilling basin on the riverward side and for 500 feet downstream from the stilling basin on the landward side. A dike with a top elevation of 1380.0 feet extends along the right bank of the discharge channel to protect the embankment of the dam from high flows in the spillway channel.

4-04. Outlet Works. Conventional outlet works structures were not provided at Big Bend. Releases must be made either through the spillway or the powerplant.

4-05. Powerplant and Switchyard. Power facilities for Big Bend are located in the right abutment of the dam. The flow of water from the reservoir is guided by an approach channel curving in plan along a circular arc, which has a bottom elevation of 1345.0 feet with 1V on 2.5H side slopes to berms on both sides to elevation 1355.0 feet. The side slopes above the berms are 1V on 3H. The width of the channel at elevation 1345.0 feet is about 400 feet. At elevation 1355.0 feet the channel width converges from a maximum of 800 feet approximately 600 feet upstream from the intake to 675 feet at the intake. About 120 feet upstream of the powerhouse intake, the bottom of the channel slopes downward on a 1V on 8H slope to elevation 1330.0 feet to provide sufficient entrance area at the intake. Concrete approach walls line the approach channel at the intake. The left approach wall extends 285 feet upstream from the intake while the right wall extends 243 feet.

4-06. Intake Structure. The intake structure contains separate intakes for each of the eight turbines. Each unit intake is divided into three water passages by intermediate piers. Each of the water passages contains two sets of gate slots, one for the service gate and one for the bulkhead gate. Three tractor-type, vertical lift service gates are provided for each of the unit intakes. A total of three emergency bulkhead-type gates are provided for use in any of the upstream bulkhead gate slots. See Plate IV-7 for a photo of the powerhouse intake structure.

4-07. Powerhouse. The powerhouse consists of two elements, the main structure and the service bay. The powerhouse is constructed integrally with the intake structure. The main structure provides housing for the power units, service and storage rooms and personnel facilities. The service bay is located along the downstream side and contains the control room, various service rooms, offices and public facilities. The generator bay substructure is divided into eight separate monoliths, each 86 feet wide. The erection bay is located on the north end of the powerhouse and has a substructure of heavy reinforced concrete. The superstructure of the generator room and erection bay is constructed of massive reinforced concrete up to the elevation of the crane rails, and light reinforced concrete walls above that elevation. Access roads to the powerhouse and tailrace are provided from the highway that crosses the dam. See Plates IV-8 and IV-9 for photos of the powerhouse draft tube deck and the powerhouse.

4-07.1. Eight hydraulic turbines of the vertical shaft, fixed blade, propeller-type, with concrete semi-spiral cases and concrete, elbow-type draft tubes are installed in the powerhouse as shown on Plate IV-10. Each turbine is rated 90,300 horsepower (hp) at 67 feet net head, operating at normal speed of 81.8 revolutions per minute (rpm). Governors are cabinet actuator, oil-hydraulic conventional-type and are capable of a full opening or full closing time of 5 seconds. The original installation in the powerplant included eight 58,500 kW, 3-phase, 60-cycle, 13.8 kV wye-connected vertical shaft, hydraulic turbine-driven synchronous generators, with bus-connected static exciter voltage regulators. The generators were rewound starting in 1990 with work finishing up in 2009 and have an upgraded nameplate rating of 67,300 kW. Main generator protection includes neutral grounding, surge protection equipment, differential relays, ground detectors, resistance temperature detectors and overspeed protection for each unit. Each pair of the main generators is connected to one of the four 3-phase, 13.8 kV/230 kV main power transformers located on the draft tube deck.

4-07.2. The main power transformers and high voltage switching facilities consist of four 3-phase transformers, circuit switcher disconnects, busses, take-off structures and appurtenances located on the draft tube deck of the powerhouse. Each pair of the main generators is connected to one of the four 3-phase main power transformers. Each of the main power transformers is rated 142 MVA, 13.8 kV to 230 kV and is paralleled through fault interrupting SF6 circuit switcher disconnects to a sectionalized 230 kV paralleling bus. The line take-offs are from the opposite ends of the paralleling bus at Unit Bay No. 1 and Unit Bay No. 8.

4-07.3. A more detailed description of power facilities, as well as other structures at the damsite, is contained in the Big Bend Operation and Maintenance (O&M) Manual. Plan and section of the powerhouse are shown on Plate IV-2. Powerplant tailwater rating curves and powerplant characteristic curves are shown on Plates IV-12 and IV-13, respectively.

4-07.4. Tailrace. The tailrace is 675 feet wide and 140 feet long rising from elevation 1290.0 feet at the draft tube exit on a 1V on 3.5H slope to elevation 1330.0 feet (see Plate IV-11). The tailrace is paved with reinforced concrete anchored to the foundation. The right tailrace wall is an anchored-slab type wall, which slopes upward at 4V on 1H, a receding upward slope of the outer face of a structure, from the base at elevation 1290.0 feet. A retaining wall on the right side of the tailrace is constructed to elevation 1383.0 feet, retaining fill for parking and access to the powerhouse. The tailrace discharge channel is excavated to elevation 1330.0 feet to the chalk outcrop 1,350 feet downstream from the downstream end of the tailrace paving. The bottom width of the tailrace channel widens to 800 feet at the chalk outcrop. Side slopes are 1V on 2.5H. The tailrace channel extends for an additional 3,000 feet with a bottom width of 400 feet across an island formed near the chalk outcrop. A training dike 1,200 feet long with a top elevation of 1360.0 feet extends along the left side of the tailrace channel between the embankment of the dam and the downstream island.

4-08. Reservoir. The reservoir formed by Big Bend Dam, Lake Sharpe, extends through central South Dakota. At normal operating levels the reservoir has a length of 80 miles, a shoreline of 200 miles, a surface area of 57,000 acres and a maximum depth of 78 feet. The Big Bend reservoir is long and narrow and confined almost entirely to the Missouri River valley. Since no major tributaries enter the main body of the reservoir there are no large tributary arms characteristic of the larger and longer mainstem reservoir projects. The Big Bend reservoir area is shown on Plate IV-14. Elevation-area and elevation-capacity tables for the Big Bend reservoir are on Plate IV-15.

4-08.1. While allocation of storage in the larger System reservoirs was based on mainstem multiple-use requirements as described in Section 7-03 of the Master Manual, storage space in the Big Bend reservoir has been allocated to provide major contribution to hydroelectric power generation. The relatively small amount of exclusive flood control storage space provides only short-term storage for large and “flashy” type runoff events that can occasionally occur in the Oahe to Big Bend drainage area. The small amount of multiple-use storage space between elevations 1420.0 and 1422.0 feet is primarily a zone within which power generation benefits can be maximized by storage fluctuations that best enable the System as a whole to follow daily and weekly variations in power demand. Types of storage space, with associated elevations and storage quantities for each type, are listed in Table IV-1. In addition to this allocated space, the reservoir level during the SDF peaked at elevation 1433.6 feet, representing surcharge storage of about 0.7 MAF above the top of the Exclusive Flood Control Zone.

4-09. Recreation Facilities. Fluctuating water levels can have a major effect on recreational use of reservoirs. However, the fluctuation in water level of the Big Bend reservoir is normally less than on any of the other System reservoirs other than the Gavins Point reservoir. Unless very unusual conditions occur, a Big Bend reservoir level within one foot of the normal operating level of elevation 1420.0 feet is maintained. Numerous public use areas have been established around the Big Bend reservoir shoreline. 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 lake access points to highly developed and extensively used campground areas. The six System projects have a total of 188 public recreation areas. Plates IV-16 and IV-17 present the 24 recreational facilities at the Big Bend project. In 2002, most of the federal recreation areas in South Dakota 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). The 65 recreation areas transferred in fee title, along with the nine recreation areas leased in perpetuity, will 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 Oahe, Big Bend, Fort Randall and Gavins Point projects.

Table IV-1
Big Bend Reservoir Storage Space Allocations

Storage Designation (Zone)	Elevation in feet		Storage Space in AF
	From	To	
Exclusive Flood Control	1422.0	1423.0	61,000
Annual Flood Control and Multiple Use	1420.0	1422.0	118,000
Permanent	1345.0	1420.0	1,631,000
Total Storage			1,810,000

Note: Storage volumes are based on January 2014 elevation-area-capacity tables (2012 surveys).

4-10. Leasing of Project Lands. Approximately 45,412 acres in fee, 13 acres in public domain and 169 acres in easements were acquired for the Big Bend project. Land acquisition was based on a guide-taking line at elevation 1423.0 feet, which is the top of the Exclusive Flood Control Zone. Land acquisition included allowances for wave heights, set-up, wave run-up, erosion and bank caving, or a 300-foot setback from the 1423.0 foot contour, whichever was the greater. Flowage easements were acquired on four tracts of land having a total area of less than 10 acres. As a result of the Title VI portion of WRDA 1999 and subsequent technical amendments in WRDA 2000, all land lying above 1420.0 feet within recreation boundaries and above 1423.0 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. The Corps estimated a Big Bend sediment depletion rate of about 3,445 AF/year based on sediment range survey analysis taken in 1963 and 2012. The upstream Oahe Dam acts as a sediment trap and Oahe releases are essentially sediment free. The primary sediment sources contributing to Lake Sharpe, according to the 1999 Omaha District study *Missouri River - Oahe Dam to Big Bend Dam Aggradation Assessment*, *M.R.B. Sediment Memoranda #22,* were estimated as 52 percent from the Bad River, 27 percent from reservoir bank erosion and 21 percent from all other tributaries combined. Subsequent studies made by the Corps in 2009 and 2015 have determined annual sediment rates from these sources, which would change the estimated sediment source percentages in the Corps' 1999 study, but still support that the Bad River and reservoir bank erosion are the two primary contributors of sediment to the Big Bend reservoir. Reservoir shoreline erosion is dependent on bank material, vegetative cover and bank orientation to prevailing wind and waves. The constant pool levels on the Big Bend reservoir result in year-round attack by the forces of wind, wave and ice on the same bank elevations. Tributary-borne sediment levels are higher during heavy precipitation when eroded soils are washed into streams and carried downstream into the reservoir. Stream velocity decreases after entering the reservoir, which diminishes sediment transport capacity, and the sediment deposits into the reservoir forming a delta. This delta formation has encroached into the middle reaches of the Big Bend reservoir, near RM 1041, primarily in the old Missouri River channel. The Missouri River delta is progressing primarily in the downstream direction. The main channel has a wide range of deposited sediment depths. Deposition near Farm Island (RM 1058 to 1061) varies from negligible to a few feet. Sediment deposition depths increase in the downstream direction, reaching over 20 feet in some cross sections. Deposition near Big Bend varies from 1 to 3 feet in the former channel and 0 to 6 inches in the former floodplain. See Plate III-15 for the location of the Big Bend reservoir aggradation and the Oahe degradation range lines.

4-12. Tailwater Degradation. Since the Fort Randall reservoir extends into the Big Bend tailwater area most of the time, Big Bend tailwater trends, as shown on Plate IV-12, show little change since the last update in 1972. In contrast to several other System dams, tailwater trends will have only a minor, if any, influence on Big Bend power generating activities. Tailwater monitoring is performed annually by the Omaha District.

4-13. History of Water Resources Development. Due to the lack of land transportation facilities, development of water resources in the portion of the Missouri River basin in the vicinity of Big Bend began soon after American expansion 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. 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 in recent years municipal and industrial (M&I) water supply, recreation, water quality enhancement, fish and wildlife and 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 that manual, the Flood Control Act of 1944 is of primary importance. This act authorized the construction of Big Bend, 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. Reservoirs. One important means of water resource development in the Missouri River basin is the construction of dams controlling sizeable drainage areas and development of the associated reservoirs. However, in the Oahe to Big Bend drainage area no sizeable reservoirs other than the Big Bend reservoir have been developed. The lack of an assured irrigation water supply and infrequent substantial runoff amounts, as well as the sparsely settled area, resulting in only minimal flood damages, have precluded tributary reservoir development.

4-14. Flood Control. Big Bend is the only major flood control project constructed in this area of the Missouri River basin. There are no local flood protection projects that affect, or are affected by, the regulation of Big Bend, except those significantly downstream from the System, such as the protective works at Omaha and Kansas City.

4-15. Irrigation. There are no large irrigation projects in the Oahe to Big Bend reach of the Missouri River. Scattered private irrigation development does exist, utilizing tributary surface water when available. Utilization of the water supply in the Big Bend reservoir is limited. About 30 private irrigators acquire water directly from the reservoir. 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.

4-16. Navigation. Although navigation on the Missouri River through South Dakota opened up this region for initial American settlement, there is now no commercial navigation through this reach of the river. Storage space has not been provided in the Big Bend reservoir to support Missouri River navigation. Releases from upstream mainstem reservoirs intended to serve downstream navigation are passed through Big Bend.

4-17. Hydroelectric Power. The Big Bend powerplant, with an installed capacity of 517,000 kW, is the only hydroelectric power generating facility located in the incremental Missouri River drainage area discussed in this WCM. All power generated by federal facilities in the Missouri River basin is marketed by Western. Big Bend power generation is integrated with the generation provided from other mainstem 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 South Dakota municipalities of Pierre and Fort Pierre, located along this reach, obtain their water supply by pumping 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 through about 4,400 miles of pipeline throughout central, southern and western South Dakota involving four rural water systems; West River/Lyman-Jones, the Oglala Sioux Rural Water Supply System, the Rosebud Sioux Tribe Rural Water System and the Lower Brule Sioux Tribe Rural Water System. Surface water is taken out of the Missouri River at Fort Pierre to 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 water supply to the Missouri River and provide a degree of local flood protection, their effect on Missouri River flows is minimal. The reduction of erosion, however, could provide significant benefits 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 consideration 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 projects. Recreational use of the Big Bend 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, 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 into the Big Bend reservoir results almost entirely from this erosion process along tributary streams contained within the incremental drainage area. The Missouri River channel from Oahe Dam to the headwaters of the Big Bend reservoir has been fairly well stabilized by means of bank protection and the construction of channel blocks. Current proposals include further bank protective measures, encompassing nearly all of the readily erodible banks within this relatively short reach of the Missouri River.

4-22. Streamflow Depletions. The major effect of water resource development in the incremental drainage between Oahe and Big Bend on the regulation of Big Bend is a depletion of the available water supply. As resource development continues, a growth in depletions can be expected. While increasing depletions probably 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. Depletion Growth. 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 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 widely scattered areas. No large irrigation projects were developed. Table IV-2 lists results of the 2005 USBR analysis of the historical and estimated future depletions in the Oahe to Big Bend reach. Depletions are based on irrigation and as well as M&I uses. Future depletions are primarily based on projected population changes.

Table IV-2
Depletions in the Oahe to Big Bend Reach

Time Period	Average Annual Depletions in kAF
1929 – 1940	22.1
1941 – 1950	15.2
1951 – 1960	18.3
1961 – 1970	17.1
1971 – 1980	18.8
1981 – 1990	18.1
1991 – 2002	16.1
Future (Estimated)	
2002 – 2010	16.9
2010 – 2015	17.4
2015 – 2020	18.5
2020 – 2025	19.6
2025 – 2030	20.6
2030 – 2050	23.3
2050 – 2070	26.1
2070 – 2090	27.4
2090 – 2110	28.6

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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. Big Bend Project Data. Hourly data are automatically transmitted from the Big Bend 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 wind conditions. 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 thermometer located in a turbine unit. Precipitation, air temperature and wind data are obtained from a weather station located on the intake structure. In the event the automatic data collection and transfer is not working, Big Bend personnel fax or email hourly and daily project powerplant data to MRBWM and the MRBWM staff manually inputs the information into the Missouri River Region's (MRR) Corps Water Management System Oracle database. The Big Bend monthly summary is faxed or emailed to the MRBWM office and is used to verify daily data.

5-02.1. Throughout the year Big Bend project personnel investigate requests and complaints that occur as a result of Big Bend regulation and report their recommendations and findings to the MRBWM office. The MRBWM office keeps the Big Bend 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 Temperature. 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. 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. Refer to Chapter V of the Master Manual for detailed discussion regarding plains and mountain snow data.

5-05. Stages and Discharges. River stage information 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. Plate V-1 and Table V-1 indicate key locations within the incremental drainage area where streamgaging stations (DCPs) are located. Additional DCP information and DCP locations can be found at the USGS Water Resources website.

Table V-1
Data Collection Platforms – Oahe Dam to Big Bend Dam

Corps ID	Location	USGS ID	DCP ID	NWS ID
	Missouri River			
OAHE	at Oahe Dam, SD	n/a	CE0A6666	PIES2
PIR	at Pierre, SD	06440000	CE12F03C	PIRS2
	Bad River			
n/a	S Fork Bad R near Cottonwood, SD	06440200	DE0107AC	CTTS2
n/a	Bad River near Midland, SD	06441000	16DF442A	MIDS2
FPSD	Bad River near Fort Pierre	06441500	CE7885CC	FTPS2
	Missouri River			
LFSD	at LaFramboise Island at Pierre, SD	06441590	CE6571B0	LFIS2
IWSD	bl LaFramboise Island at Pierre, SD	06441592	CE346016	LAFS2
FISD	at Farm Island near Pierre, SD	06441595	CE747AD4	n/a
n/a	Cedar Creek near Presho, SD	06442130	16DF21CC	FRMS2
n/a	Medicine Creek near Lower Brule, SD	06442600	16DF32BA	n/a
BEND	at Big Bend Dam, SD	n/a	CE0A7510	BBDS2

5-06. Communication during Normal Regulation. Big Bend 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 as 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 must 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 and releases needed to meet the Congressionally authorized purposes of Big Bend 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.

5-06.2. Big Bend personnel are expected to furnish the MRBWM office 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 Big Bend 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 Big Bend, or other System projects, is to be furnished to the MRBWM office.

5-07. Emergency Regulation. If emergency conditions develop at Big Bend, 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 Big Bend 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 Big Bend 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 Big Bend, have essentially the same degree of importance for all of the other mainstem projects. Analyses considered to be unique or particularly important to Big Bend 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.

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 to regulation of the Big Bend are forecasts prepared for the west central portions of South Dakota of those elements that would contribute to runoff from the Oahe to Big Bend incremental drainage area. 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 Big Bend.

6-04. Precipitation-Runoff Relationships. Infiltration of rainfall over the Missouri River basin between Oahe and Big Bend ranges from 0.50 to 1.00 inch for the initial loss and from 0.10 to 0.25 inch per hour infiltration loss. These values are based on only a few observed rainfall events due to the rarity of heavy rainfall centers in the area. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values previously mentioned 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 runoff is very imprecise. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snow cover and snow water equivalent (SWE) available for melt, errors in estimating the snowmelt rate, as well as marked departures from 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 impractical for the drainage area under consideration in this WCM. Reasons for this include the lack of rainfall and subsequent runoff events for unit hydrograph definition, the scarcity of rainfall reporting stations needed for both analysis and forecasting purposes, and the fact that by far the greatest amount 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 imprecise. In addition, the Big Bend reservoir has a relatively substantial amount of storage space above the normal operating level in relation to the amounts of runoff that has been experienced from the Oahe to Big Bend incremental drainage area. The maximum amount of incremental runoff experienced in any one day since 1963 when Big Bend became operational was 42,000 AF, coincident with the maximum discharge of record from the Bad River in June 1967. Storage space available above the normal operating pool elevation 1420.0 feet is 177,000 AF. The maximum experienced incremental inflow observed during a particular flood event since the project became operational was in March 1966 when a two-week inflow volume of about 170,000 AF was recorded. Consequently, the effort necessary for a valid, complete and continuing analysis by means of unit hydrograph procedures is not believed to be warranted, particularly in view of the ease by which Big Bend storage space can be evacuated through a combination of reducing Oahe releases and increasing Big Bend releases. However, runoff forecasting procedures will continue to receive consideration as a means of possibly improving the regulation process, and as discussed in the Master Manual, future runoff modeling efforts include the use of QPE 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 Big Bend is a result of melting the plains snowpack accumulated during the winter months. This melt usually occurs during late March or April and often results in the annual maximum peak flow from the Oahe to Big Bend drainage area. Basic data pertinent to plains area snowmelt 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 snowmelt runoff volume are usually 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. Refer to Section 5-06 of the Master Manual for 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. Snow surveys are one method of obtaining quantitative estimates of runoff volume by comparing water content 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 Oahe and Big Bend. 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 depths during previous years from other areas where snowpack conditions appear similar to the current year's snowpack over the Oahe to Big Bend 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 Snow Moisture 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 inflows originating between the System dams is made 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 incremental 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. Therefore, a reach forecast is made for the Oahe to Fort Randall drainage area and is further described in Section 6-07 of the Fort Randall WCM.

6-08. Short-Range Forecasts of Daily Inflow. Daily inflows to the Big Bend reservoir consist almost entirely of releases from the immediate upstream Oahe project, except on those few occasions each year when the Bad River is contributing significant flows. Travel time from Oahe Dam to the headwaters of the Big Bend reservoir is only a matter of a few hours. Therefore, for practical purposes, Big Bend inflows on any day are equivalent to Oahe releases for the same day. Daily inflow forecasts are usually identical with the anticipated Oahe release schedule. Modifications will be necessary when significant flows are originating in the Oahe to Big Bend reach. Incremental inflows originating between the Oahe and Big Bend are readily apparent on a daily basis. Forecasts of continuation of this inflow will be largely an extrapolation of past inflows 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. These extrapolations will be modified on the basis of flows observed at the upstream Bad River gaging station at Midland, SD. 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 in the MRBWM for the two streamgaging stations on the Bad River, the only major tributary in the Oahe to Big Bend drainage area. These rating curves are kept current on the basis of discharge measurements made by the USGS. Plate VI-1 shows the current stage-discharge relationship for the Bad River at Fort Pierre, SD. The flows at the Fort Pierre streamgaging site are only a few hours of travel time from the reservoir. The flows observed at this location are considered to be a current component of the total Big Bend reservoir inflow.

6-10. Forecasts of Downstream Locations. Big Bend releases flow directly into the downstream Fort Randall reservoir. Consequently, there are no damage centers affected directly by Big Bend releases. Forecasts of the effects of Big Bend releases are not required other than those relating to Fort Randall inflows, as discussed in Sections 6-06 and 6-07 of the Fort Randall WCM.

6-11. Evaporation. Evaporation is an important component of the overall water budget of the Big Bend reservoir due to the large reservoir surface area. An estimate of the daily evaporation volume is required for developing daily inflow estimates as well as for more precisely estimating the effects of reservoir development on the available water supply. Application of the commonly used 0.7 pan-to-reservoir factor is not considered reliable for the Big Bend reservoir due to the difference between the lake surface temperature and pan temperature. MRD-RCC Technical Report JE-73, *Missouri River Main Stem Reservoir System Reservoir Evaporation Estimates,* June 1973, addresses this problem in detail and recommends the use of a variable pan-to-reservoir factor. This factor for the Big Bend reservoir varies from as little as 0.35 (May) during periods when reservoir surface temperatures are less than air temperatures to as high as 1.52 (November) when reservoir surface temperatures materially exceed air temperatures. Plates III-9 through III-12 indicate pertinent evaporation information for the System reservoirs. During those portions of the year when evaporation pan data are not available, normal evaporation depths for the season of the year appear to offer the most practical means of developing evaporation estimates for day-to-day regulation activities. Reference is made to the cited technical report for further details pertinent to the development of evaporation estimates for this project.

6-11.1. The MRBWM office and Omaha District partnered with the Corps' Cold Regions Research and Engineering Laboratory 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 measured or estimated water temperature profiles. The MRBWM office plans to implement this new technique in 2019.

6-11.2. In addition to evaporation, development of the effects of the Big Bend 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, which 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.

6-12. Wind Effects on Water Surface Elevations. The general orientation of the Big Bend reservoir is to the northwest from Big Bend Dam. However, the large bend in the Missouri River, from which the project derives its name, materially reduces the fetch through which the wind action can influence the water surface at the dam. Nevertheless, winds with a northwesterly component result in set-up at the dam while a wind component from the opposite direction results in set-down. See Plate VI-2 for a wind correction table for the pool level recorder at the dam. An anemometer is located adjacent to 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 reservoir surface and the difficulty of having one location represent the entire length of the reservoir will all 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.

6-13. Daily Inflow Estimates. Estimates of inflow to the Big Bend reservoir are made each day by the MRBWM office for operational purposes. The steps involved consist of

a) plotting hourly pool elevations as reported by the Corps' PPCS at Big Bend;
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.

6-13.1. An additional estimate of reservoir inflows consists of comparing the Oahe releases during the preceding 24-hour period, adjusted by about 4 hours to correspond to the short travel time to the Big Bend reservoir. When significant runoff is originating in the Oahe to Big Bend incremental area, this additional inflow is estimated by noting probable Bad River flows combined with estimates of ungaged flow and precipitation on the reservoir surface. Differences in inflow estimates as determined by the previously defined processes 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*, dated June 2015.

6-14. Unregulated Flows. Construction of the Big Bend project, together with the other mainstem and tributary projects in the Missouri River basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows augmented by reservoir regulation. However, since Big Bend is essentially a run-of-river project, little modification results from Big Bend regulation alone. While the unregulated flows at the Big Bend damsite are determined (as described in MRD-RCC Technical Study S-73, *Upper Missouri River, Unregulated Flow Development*, dated September 1973), the development is primarily required as a part of the analysis of the reservoir system as a whole. Records of flows at the 1949 level of basin development, which is prior to construction of the Big Bend project and most other water resource development in the Missouri River basin, are not maintained for Big Bend. This is because of the minor difference in flows at Big Bend as compared to Oahe. Refer to Plates VI-9 and VI-10 for tributary flow probability relationship curves at the Bad River at Fort Pierre, SD and Medicine Knoll Creek near Blunt, SD, respectively. Flow probability relationships were developed for tributary streams flowing into the Big Bend reservoir between Oahe Dam and Big Bend and are shown in Table VI-2.

6-15. Evaluation of Regulation Effects. In the evaluation of the effects of regulation on downstream flows and consequent flood damage reduction estimates, Big Bend 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-2
Tributary Flow Probability Relationships

Tributary	Drainage Area (sq mi)	Peak Discharge (in cfs) for Given Return Period (in years)			
		10	50	100	500
Bad River at Fort Pierre, SD	3,107	21,400	44,300	57,000	94,300
Antelope Creek	106	1,900	4,500	5,400	9,100
Cedar Creek	155	2,300	5,500	6,600	11,000
Medicine Creek	668	5,400	12,800	15,000	24,700
Medicine Knoll Creek nr Blunt, SD	317	1,400	7,600	13,500	40,900
Medicine Knoll Creek at mouth	847	2,800	10,000	15,200	33,100
Chapelle Creek	260	3,100	7,400	8,800	14,600

6-16. Long-Term Studies. Simulated regulation of Big Bend 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 Big Bend regulation are available. From the examples incorporating the present level of water resource development, conclusions relative to regulation of Big Bend can be established, as described in succeeding sections.

6-17. Frequency Estimates. Frequency of occurrence estimates of reservoir elevations and releases at each of the System reservoirs were developed as described in MRBWM Technical Report, *Hydrologic Statistics*, dated September 2013. Per Table 16 of that report, the 1 percent chance of exceedance pool elevation is estimated to be 1422.4 feet. The maximum pool of record (1898-2014) was elevation 1422.1 feet in June 1991. Per Table 17 of that report, the 1 percent chance of exceedance for hourly peak and average daily maximum releases from Big Bend are estimated at 190,000 cfs and 160,000 cfs, respectively. During the 2011 flood, the maximum Big Bend release was 166,300 cfs. See Plates VI-11 through VI-14 for pool duration, pool probability, release duration and release probability curves, respectively.

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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 operating 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 Big Bend 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 Big Bend 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 Big Bend for flood control is discussed later in this chapter.

7-02. Basis for Service. As an introduction to regulation of Big Bend, 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 1420.0 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 Annual Flood Control and Multiple Use Zone extends from elevation 1420.0 to 1422.0 feet and is the preferred operating zone. The waters in this zone are used to meet all authorized purposes. The Exclusive Flood Control Zone extends from elevation 1422.0 to 1423.0 feet. This zone is reserved exclusively for flood control regulation of floods. The next zone is the Surcharge Zone, which is the zone above elevation 1423.0 feet, the elevation of the top of spillway gates when closed. The top of this zone is the maximum pool elevation from the routing of the SDF event (1433.6 feet). 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 1433.6 feet to the top of the dam embankment (1440.0 feet.)

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

a. Regulation of Big Bend as an individual project must be subordinate to regulation of the entire System as a whole.
b. To the extent practicable, flood control will be provided for by maintaining the reservoir level near elevation 1420.0 feet, particularly during the March-July flood season when substantial runoff amounts may occur from the Oahe to Big Bend incremental drainage area.
c. All irrigation and other upstream water requirements for beneficial consumptive purposes will be served to the extent reasonably possible.
d. Releases will be through the Big Bend powerplant to the maximum degree practicable, subject to storage limitations imposed by project design.

e. Releases from upstream reservoirs to support Missouri River navigation will be passed downstream through the Big Bend powerplant.
f. Insofar as possible without serious interference with the foregoing, Big Bend will be regulated for maximum benefit to recreation and fish and wildlife, including T&E species.

7-03.1. As noted in Section 7-03.1.5.2.4 of the Master Manual, a settlement agreement was approved in an order of dismissal by the United States District Court, District of South Dakota on August 8, 2003, in the case of Lower Brule Sioux Tribe et al. v. Rumsfeld, et al. (Civil No. 02-3014 (D.S.D.)). The agreement provides that the Corps will consult with the Lower Brule Tribe and the Crow Creek Sioux Tribe during any review and revision of the Master Manual. This agreement also provides that the Corps will coordinate the regulation of Big Bend and the water level of the Big Bend reservoir with the two Tribes to include the following: the Corps will normally strive to maintain a Big Bend reservoir level between elevation 1419.0 and 1421.5 feet and, when the level of the Big Bend reservoir, adjusted for wind effects, drops below elevation 1419.0 feet or exceeds elevation 1421.5 feet, the Chief of MRBWM will provide notice to such persons as the Tribes shall designate in writing. When it is anticipated that the water level will drop below 1418.0 feet or rise above 1422.0 feet or, in the event the water level, adjusted for wind effects, falls below 1418.0 feet or rises above 1422.0 feet, the Commander, NWD, or his designee, shall immediately contact the Chairpersons of the Tribes or their designees to notify them of the situation and discuss proposed actions to remedy the situation.

7-04. Irrigation. No federally financed irrigation projects are either in existence or are currently being proposed that are directly associated with Big Bend. However, upstream irrigation has a depleting effect on inflows and power revenues derived from the project will help finance federal irrigation projects in the Missouri River basin. Minor private irrigation withdrawals from the Big Bend reservoir are occurring and these can be expected to increase in the future. Maintaining the Big Bend reservoir elevation near 1420.0 feet provides almost ideal reservoir level conditions for setting and operation of the irrigation intakes. The Big Bend release level should not normally affect irrigation withdrawals from below Big Bend, since the Fort Randall reservoir extends upstream to the Big Bend tailwater area during the irrigation season. Access to the available water supply from each System reservoir and the Missouri River is the responsibility of the intake owner.

7-05. Water Supply and Water Quality Control. Extension of the upstream limits of the Fort Randall reservoir into the Big Bend tailwater area precludes the necessity of making Big Bend releases for any water supply demands that may develop. Maintaining the Big Bend reservoir level near elevation 1420.0 feet will also provide near ideal conditions for any water supply intakes utilizing the reservoir as a source. The only pollutant contribution of consequence in the area is at the upstream end of the Big Bend reservoir where the South Dakota cities of Pierre and Fort Pierre are located. Minor fluctuations in the Big Bend reservoir levels have a tendency to move the pollutants from their source. However, no special operations are made for this purpose. Table E-3 in Appendix E of the Master Manual lists the Missouri River water supply intakes throughout the System.

7-06. Navigation. Storage space to sustain navigation on the lower Missouri River is not provided in the Big Bend reservoir. Upstream reservoir storage released for this purpose is passed downstream through the Big Bend powerplant.

7-07. Power Production. Hydroelectric power generated by Big Bend 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. The release capability of the full Big Bend powerplant is in excess of 100,000 cfs. The maximum release from Big Bend of 166,300 cfs was made during the 2011 flood. This was the only time that spillway releases were made at Big Bend.

7-07.1. The Western system power marketer or dispatcher in Watertown, SD schedules hourly loading of the Big Bend powerplant. These hourly 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 functions other than hydropower generation. Due to the changing power loads during the day, instantaneous releases will often fluctuate widely. The loadings will range from zero at times when demand is light up to the full powerplant capacity during the heavy load hours. A weekly cycle in Big Bend power releases and reservoir levels is normally advantageous. Big Bend releases are typically reduced on Saturday and Sunday, when power loads are lower, and the reservoir level is allowed to rise to near elevation 1421.0 feet by Sunday night. This provides for additional power generation during the ensuing week, when power loads exceed Sunday loads, by increasing Big Bend power releases and drawing the reservoir down to near 1420.0 feet. A typical hourly and weekly release pattern is shown on Plate VII-1. 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 Big Bend usually occurs, reflecting service being provided other functions by the remaining System projects. During the open water season relatively large releases are required from Gavins Point, the lowermost reservoir of the System, to support navigation. These Gavins Point releases are normally backed up by correspondingly large releases from the Fort Randall, Big Bend and Oahe projects since relatively little inflow usually originates from the Oahe to Gavins Point drainage area during the navigation season. Although Big Bend storage space does not serve navigation, the lack of such space makes it necessary to essentially release the inflows, which consists primarily of the Oahe releases, as they occur. Additionally, during years of above normal water supply, the major portion of required storage evacuation of upstream reservoirs through the Big Bend reservoir must be made during the open water season. These large releases generate substantial amounts of power.

7-07.3. During the winter months when navigation flow support is not provided, releases from the System are usually restricted to less than half their navigation season level, due to the reduced capacity of the ice-covered Missouri River channel below Gavins Point. With the limited System storage capacity downstream from the Oahe project, reductions in System releases also will usually require a reduction in the releases from Oahe, and in turn, Big Bend.

7-08. Fish and Wildlife. Regulation of Big Bend for fishery purposes largely involves pool level manipulations that will provide a suitable environment for the spawning and initial growth of game and forage fish. Steady or rising reservoir elevations from late March to early July are desirable for this purpose. Additionally, some species such as the northern pike require the inundation of terrestrial vegetation from late March through April for a suitable spawning habitat. Since Big Bend is regulated to maintain reservoir levels very close to elevation 1420.0 feet at all times, propagation of most fish species is enhanced. Shortly after the System closed it was considered desirable to raise the reservoir level about one foot during the northern pike spawning period to inundate established shoreline terrestrial vegetation. This operational adjustment has not been done in recent years. However, terrestrial vegetation in the zone is likely to be sparse due to the preceding year's wave action. The opportunity for a substantial increase of reservoir levels into the vegetation zone of the Big Bend reservoir is not available as on other System reservoirs, nor is it possible to provide any continuing significant increase in levels throughout the spawning season.

7-09. Threatened and Endangered Species. There are no T&E species that are affected by Big Bend operations. Planned operations to address Endangered Species Act (ESA) requirements will normally be provided in the AOP. Refer to Appendix D of this WCM and Appendix D of the Master Manual for further explanation of fish and wildlife.

7-10. Recreation. Water-based recreation at Big Bend is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the reservoir have top elevations extending from 1423.0 to 1430.0 feet and bottom elevations ranging from 1412.0 to 1415.0 feet, as described in Section 4-09 of this WCM. Maintaining the Big Bend reservoir level close to elevation 1420.0 feet, as is practiced, provides ideal access to the reservoir at all times. Access to the tailwater area is largely dependent on the downstream Fort Randall reservoir elevation. Under normal conditions the Fort Randall reservoir elevation is at a level where no access problems exist in the Big Bend tailwater area. Additional information is available in Section 7-11 of the Fort Randall WCM.

7-11. Release Scheduling. As discussed in the Master Manual, scheduling of releases from Big Bend and the other System projects is normally based on continuing studies by MRBWM 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 functions receives consideration. 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 of the Master Manual.

7-11.1. On a short-term basis there are often modifications to the general long-term scheduling of Oahe and Big Bend 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 daily 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 MRBWM to operating personnel at the Big Bend and Oahe projects and Western, are the basis for scheduling average daily releases from Big Bend. Since exact daily power demands cannot be anticipated, reservoir regulation/power production orders usually allow a specified variation from this scheduled average daily release rate. Allowable variations in Big Bend release rates from those specified in the order are frequently quite high since Big Bend and the upstream Oahe powerplant are often designated as the "swing" plants, designated to meet the fluctuations in actual system load from that anticipated when release schedules were established. Due to the limited fluctuations allowed in the level of the downstream Big Bend reservoir, releases scheduled from Oahe and Big Bend, "swings" or variations in actual releases from scheduled releases are normally very similar. Hourly patterning of the Big Bend 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 primary objective during flood regulation of the Big Bend reservoir is to control flood runoff originating between the Oahe and Big Bend dams. There are no damage centers immediately below Big Bend Dam and Big Bend releases flow directly into the Fort Randall reservoir. Therefore, meeting the flood control objective at Big Bend is the result of controlling Big Bend inflows in such a manner that Big Bend releases made during the flood period can be limited insofar as possible to the Big Bend powerplant capacity, and the maximum beneficial use is attained from required releases. System flood control objectives are discussed in Section 7-04 of the Master Manual.

7-13. Method of Flood Control Regulation. In general, the developed method of regulation of Big Bend 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 the reservoir 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. Storage space allocated for flood control in the Big Bend reservoir totals 179,000 AF. Of this, 61,000 AF are allocated to the Exclusive Flood Control Zone, to be utilized only during unusually large flood season inflows. The remaining 118,000 AF of flood control storage is allocated to the Annual Flood Control and Multiple Use Zone. The zone is deliberately used temporarily during periods of low flood potential in the Oahe to Big Bend incremental area to improve power production from the System as a whole, or for other multiple-purpose uses. During periods of high flood potential in the Oahe to Big Bend drainage area, this zone will be kept available to temporarily store increased runoff amounts as it occurs. The Surcharge Zone is used to ensure the safety of the Big Bend project during extreme flood events. However, utilization of the Surcharge Zone as well as the two flood control zones will have only a minor effect on regulation of the downstream System projects.

7-15. Flow Regulation Devices. Releases from Big Bend may be made through the powerplant and the spillway. Normally, discharge through the powerplant will be used to the fullest extent possible in order to achieve the maximum economic return from the project. As detailed in Section 7-07 of this WCM, the discharge capacity of the Big Bend powerplant is approximately 100,000 cfs. This discharge rate, which was exceeded in 2011, greatly exceeds the discharge rate that will be maintained from downstream reservoirs or that can be expected to occur for any significant period of time from the Oahe to Big Bend incremental drainage area except under extreme conditions. Consequently, the possibility of spillway discharges is very remote. The spillway has a discharge capacity of 270,000 cfs at elevation 1423.0 feet, the top of the Exclusive Flood Control Zone.

7-16. General Plan of Flood Control Regulation. The plan for regulating flood storage in the Big Bend reservoir is quite simple, namely the maintenance of pool levels near elevation 1420.0 feet. This will be accomplished either by appropriate manipulation of Big Bend releases or through manipulation of inflows by adjusting releases from the upstream Oahe project or a combination of the two processes. Selection of the more appropriate method will be dependent on the advisability of transferring storage from the Oahe reservoir into the Fort Randall reservoir.

7-17. Coordinated System Flood Control Regulation. The System, of which Big Bend is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the System. In most projections of System flood control operations and subsequent release scheduling, Big Bend inflows and releases are assumed to be identical with the Oahe releases. Scheduling of releases from Oahe and Big Bend to accomplish System flood control objectives is based on studies performed by MRBWM. The long-range studies of current operations extend from the current date through the succeeding months up to the subsequent March 1, when the start of the following flood season generally occurs. Such studies are made at a maximum interval of one month as new estimates of future runoff 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.

7-18. Exclusive Flood Control Regulation Techniques. Only under the most extreme conditions will storage in the Exclusive Flood Control Zone of the Big Bend reservoir for any extended period of time be necessary. Ordinarily any encroachment into this zone will be evacuated as soon as practicable. Long-term utilization of the exclusive space will likely represent a surcharge operation of other System projects. Unless floods approaching the spillway design capacity were to occur, the Big Bend reservoir level should be maintained near to or below elevation 1423.0 feet, the top of Exclusive Flood Control Zone. If releases in excess of the powerplant capacity appear necessary, releases will be made through the spillway. Additional guidance regarding best practices and/or special considerations for use of the spillway at Big Bend can be found in Exhibit A of this WCM.

7-19. Surcharge Regulation Techniques. During exceptionally large flood inflows, all available flood control storage space may be utilized and the Big Bend reservoir may rise into the Surcharge Zone, above elevation 1423.0 feet. The primary reason for providing surcharge space is to ensure the structural integrity of the Big Bend project. Since real estate surrounding the reservoir has, in general, not been acquired above elevation 1423.0 feet, significant surcharge encroachment will be allowed only if unprecedented flood inflows occur. When unprecedented flood inflows occur and reservoir levels exceed elevation 1423.0 feet, the regulation procedures given with the emergency instructions, presented as Exhibit B in this WCM, may be used as a guide for release scheduling. These procedures require releases up to the full capacity of the Big Bend spillway to prevent reservoir levels from materially exceeding elevation 1423.0 feet.

7-20. 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 Big Bend and the other System projects. Instructions to ensure continuation of Big Bend regulation during periods of communication failure between the project and the MRBWM office are detailed in succeeding sections and in Exhibit B of this WCM.

7-21. Emergency Regulation. Reliable and rapid communication is usually available between the MRBWM office and Big Bend 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 Big Bend 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.

7-21.1. Emergency regulation procedures presented in Exhibit B recognize the relatively small amount of storage space contained in the Big Bend Surcharge Zone as well as the lack of any damage centers immediately below the project. Consequently, there is no effort to induce surcharge storage during extremely large flood inflows. Rather, all effort at such times should be to limit the encroachment into storage space above elevation 1423.0 feet.

7-22. Emergency Regulation – Spillway Design Flood. As discussed in Section 7-20, regulation procedures have been developed for emergency conditions and are presented in Exhibit B of this WCM. One example of using these procedures as the only criteria for regulation of Big Bend is shown on Plate VII-2. The SDF is the computed summer flood which combines the runoff from the maximum probable summer rainstorm with a 50,000 cfs release from Oahe. The SDF has a peak inflow of 725,000 cfs and a maximum 6-day volume of 2,825,000 AF. An initial level of the Big Bend reservoir at elevation 1420.0 feet was considered to be reasonable. Respective peak reservoir level and release are elevation 1433.5 feet and 388,000 cfs. This routing assumed that the Big Bend powerplant would be inoperative when releases exceeded 100,000 cfs. Continuation of powerplant releases in addition to spillway releases during the SDF routing would have resulted in a lower maximum pool level and greater maximum releases, but with a lower maximum release through the spillway. The peak values noted on Plate VII-2 are essentially the same as those developed in Big Bend spillway design studies, which indicate the peak elevation and release at 1433.6 feet and 390,000 cfs, respectively. The minor variation results from capacity curve changes since the design studies and minor modifications in the release schedule.

7-23. Emergency Regulation – One-Quarter Maximum Possible Flood. In order to more completely illustrate application of the emergency procedures, an inflow hydrograph approximating one-fourth of the SDF hydrograph was routed through the Big Bend reservoir utilizing these emergency procedures. Results are illustrated on Plate VII-3. The peak inflow of about 185,000 cfs was reduced to a maximum outflow of 140,000 cfs while the reservoir was maintained at elevation 1423.8 feet or below throughout the flood period.

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VIII - Water Management Organization

8-01. Responsibilities and Organization. This chapter describes the personnel and coordination necessary to regulate Big Bend. Big Bend is regulated as part of the System, which is comprised of six projects on the Missouri River main stem. The Corps has the long- and short-term direct responsibility for regulating Big Bend as a hydraulically and electrically integrated project. This has been the case since July 1963, when Big Bend was closed to begin storing water.

8-01.1. 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 Big Bend in 1959. Big Bend 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 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 Big Bend 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 office 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 snowpack, 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 streamgaging program (Co-op), as described in Section 5-07.2 of the Master Manual. The 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 space 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." Replacement storage does not impact the regulation of Big Bend.

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 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 Big Bend. 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 News Release	
	Monthly Project and System Energy Summary	
Yearly	Draft Annual Operating Plan (AOP)	
	Final Annual Operating Plan (AOP)	
	Annual Summary of Actual Regulation	
	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 Big Bend along with the other upstream System projects, augmented by upstream tributary reservoir storage, has greatly reduced flooding along the portion of the Missouri River near Big Bend. Many instances of above-bankfull flows were experienced on the Missouri River 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 are pertinent to the incremental reach described in this WCM. Since there are little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed in this WCM.

A-02. 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 and was designed to serve all authorized purposes during an extended drought like the 1930s. 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. 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-03. Runoff. Within the incremental Oahe to Big Bend drainage area, streamflow records are available on the Bad River. As indicated previously, the average annual runoff from this tributary is only slightly greater than 100,000 AF; however, on occasion this volume may be greatly exceeded during a single runoff event.

A-04. Incremental Runoff. Of interest is the incremental flow originating between Oahe and Big Bend exclusive of, but coincident with, Bad River floods. Simultaneous discharge and storage change records of both Oahe and Big Bend since 1963 enable calculations of total incremental inflow. The runoff from the ungaged incremental area may be determined by subtracting the total incremental inflow from the gaged Bad River flow.

A-05. Historical Regulation – Big Bend Reservoir Elevations. Closure of Big Bend Dam was made in July 1963, beginning the accumulation of storage in the reservoir. The first power unit did not become operable until October 1964 and until that time significant storage was not accumulated. From October 1964 through 1965 relocation work in the reservoir area required that fill be limited and it was not until December 1965 that regulation near the normal operating level of elevation 1420.0 feet began. Since that time the Big Bend reservoir has been regulated very close to elevation 1420.0 feet. With a few exceptions, average monthly reservoir levels have been within 0.6 foot of this elevation. One exception occurred in 1971 when an average monthly level of elevation 1421.4 feet was recorded as a result of deliberate storage in the reservoir to enhance fish spawning activities. Plates A-1 through A-5 show the reservoir levels, unregulated inflows and releases of Big Bend since initial fill of the minimum pool occurred in 1963.

A-05.1. Maximum and minimum storages during each month and year of the record period, as evidenced by reservoir levels, have also been very close to elevation 1420.0 feet. The average annual variation between maximum and minimum levels has been about 2 feet. The only years that a significant variation in reservoir levels have occurred since 1965 were in 1967 and 1996, when the Big Bend reservoir was temporarily lowered to elevation 1414.7 feet (September 1967) and 1414.9 feet (October 1996). In both cases the lowering was to investigate the effects that this might have in the redistribution of Bad River sediment in the Big Bend headwaters area. Monthly maximum, minimum and average elevations, as well as daily reservoir levels, are on record with the MRBWM office and, due to their near constant nature, a graphical illustration in this manual is not warranted.

A-06. Big Bend Releases. Since there has been very little variation experienced in the Big Bend reservoir levels, it follows that at all times average daily releases from the project are a close approximation of inflows over a period of a day or two. The large power peaking capability available at Big Bend has occasionally resulted in some variations between inflow and release, particularly during and following weekends. This may also result in extreme fluctuations in hourly releases, with hourly releases ranging from 0 cfs during the low-power-demand periods in the early morning up to near the powerplant release capability during the maximum-load hours. An illustration of experienced variations in releases is shown on Plate VII-1. As future power loads within the region increase, the daily variations may become more extreme, although scheduling during recent years has indicated a preference to keeping more capability in reserve for emergencies. Releases in excess of the Big Bend powerplant capacity have only been needed during the 2011 flood.

A-06.1. The small incremental drainage area between Oahe and Big Bend, together with the generally small runoff depths contributed from this area, results in Big Bend inflows almost identical to Oahe releases. Since Big Bend storage effects are minimal, there is very little difference between Oahe and Big Bend releases. The Oahe average daily and average monthly releases presented in the Oahe manual reflect closely the releases from Big Bend. Therefore, a similar plate is not included in this WCM. Reference should be made to the Oahe WCM for this information.

A-07. Regulation Effects. The historical effects of regulation provided by Oahe, combined with regulation of upstream reservoir projects, are illustrated in the Oahe WCM. The average monthly unregulated flows shown are the computed estimates of flows at the Oahe damsite if none of the upstream projects, including Oahe, had been in operation. Average daily maximum and minimum flows for each year of the period for regulated (observed) and unregulated conditions are also presented. From these data it is evident that upstream reservoir regulation has resulted in substantial reductions to all annual peak flows that would have been experienced at the Oahe damsite. The Oahe WCM also presents detailed daily hydrographs of regulation effects during particular years of the experienced record period. The lack of any significant re-regulation of Oahe releases by Big Bend, as well as the general lack of substantial incremental inflows, makes development of similar data for the Big Bend project superfluous. Reference is made to the Oahe WCM for such data that are essentially applicable to the Big Bend.

A-08. Summary of Historical Regulation. Historical regulation of Big Bend covers only a relatively short period of time. However, annual upstream runoff during this period has ranged from near minimum to the maximum recorded since 1898. Therefore, regulation during these years is believed to be quite representative of conditions that are likely to prevail through the life of the project. Based on this experience, supplemented by analyses of the entire period of hydrologic record, it is believed that the regulation criteria developed for Big Bend, and for the System as a whole, as presented in the Master Manual, as it affects Big Bend 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. In general, it may be stated that unless the most extreme conditions occur, Big Bend releases will be maintained within the capacity of the Big Bend powerplant. Greater releases are very apt to contribute to downstream floods and it would appear that such would be necessary only if a Big Bend level higher than elevation 1423.0 feet appeared probable or in the case of a large system runoff event similar to 2011. Chances for high reservoir levels due to a local runoff event are remote. Reservoir levels significantly below elevation 1420.0 feet have not been experienced (with the exception of sediment movement studies), nor would they be anticipated in the future, except of an occasional temporary nature in connection with some special operation not covered by routine regulation procedures.

A-08.1. Great variations in Big Bend releases have occurred, from hour to hour and day to day. Big Bend daily releases nearly always parallel those made from Oahe and appropriate plates in the Oahe WCM illustrate the daily variations and the weekly cycle in release rates occasioned by low power demands during weekends. During any one day Big Bend releases have frequently ranged from 0 cfs to near the full powerplant.

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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 1954-2012. This plate shows that, for the six projects, the trend is upward except during extended drought, when the trend leveled off or slightly reversed depending on the year. However, since the Big Bend reservoir level is held fairly steady during droughts, that trend does not apply to Big Bend. 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. Big Bend Recreation Visitation. Refer to Table B-1 for a history of Big Bend 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
Big Bend Recreation Visitation of Corps' Recreation Areas

Year	Visitation in hours	Year	Visitation in hours
1962	115,440	1988	3,489,800
1963	240,130	1989	5,853,500
1964	570,910	1990	4,379,700
1965	1,279,460	1991	5,709,600
1966	2,229,250	1992	3,423,500
1967	2,472,340	1993	3,537,100
1968	2,537,090	1994	4,474,500
1969	2,713,950	1995	4,779,200
1970	3,400,300	1996	4,886,700
1971	2,477,520	1997	4,196,400
1972	2,944,830	1998	5,107,500
1973	3,184,220	1999	5,215,300
1974	2,508,600	2000	5,203,990
1975	2,442,740	2001	5,057,400
1976	2,405,496	2002*	5,706,800
1977	3,294,850	2003*	5,701,600
1978	2,634,382	2004*	3,433,500
1979	2,973,690	2005*	2,980,900
1980	3,035,110	2006*	3,325,000
1981	3,686,310	2007*	3,096,900
1982	3,452,470	2008*	3,794,000
1983	3,330,740	2009*	3,210,200
1984	3,370,108	2010*	3,346,500
1985	3,354,446	2011*	2,528,118
1986	2,850,351	2012**	2,651,700
1987	2,634,700		

* 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. Bottom-release deep reservoirs, such as Fort Peck, Garrison and Fort Randall may withdraw stagnant water of degraded quality from the bottom of the reservoir during prolonged thermal stratification and pass it downstream. This is not an issue at Big Bend; the reservoir is shallow and Big Bend is a run-of-the-river project with a fairly short detention storage time. 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 changed 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 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 (Fort Peck, Garrison and Oahe). 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’s Water Control and Water Quality Section currently scans for the following pesticides: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, deethylatrazine, deisopropylatrazine, dimethenamid, diuron, S-ethyl dipropylthiocarbamate, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, 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 accelerated eutrophication and undesirable algal blooms.

C-04. Big Bend Reservoir. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Big Bend reservoir (Lake Sharpe) in the state's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering) and fish and wildlife propagation. The State of South Dakota listed Lake Sharpe on the state's 2014 Section 303(d) list of impaired waters and targeted the reservoir for development of a total maximum daily load (TMDL) in 2016. The reservoir use identified as impaired is coldwater permanent fish life propagation waters and the cause of impairment is identified as warm water temperatures. Lake Sharpe does not regularly form a coldwater hypolimnion and summer water temperatures discharged from Oahe, especially during times when the Oahe reservoir has lower pool levels, do not meet the temperature criteria for a coldwater fishery use. South Dakota had recently delisted Lake Sharpe for Section 303(d) impairment due to sedimentation. The reservoir was previously listed as water-quality impaired due to accumulated sediment from the Bad River watershed. A sediment TMDL was recently developed and is being implemented to address this concern, resulting in the delisting of Lake Sharpe for sedimentation. South Dakota has not issued a fish consumption advisory for the reservoir.

C-05. Missouri River Downstream of Big Bend Dam. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Missouri River downstream of Big Bend Dam: domestic water supply waters, warmwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering) and fish and wildlife propagation. Big Bend is the current demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of Warmwater Permanent Fish Life Propagation applies to Big Bend tailwaters rather than the Coldwater Permanent Fish Life Propagation (CPFLP) use that applies to Lake Sharpe. South Dakota has not issued a fish consumption advisory for the Missouri River downstream of Big Bend.

C-06. Water Quality Monitoring. The Corps has collected water quality data at Big Bend since the late 1970s. Water quality monitoring locations includes sites on the reservoir and on the inflow to and outflow from the reservoir. The water quality conditions of the Oahe dam discharge represent the inflow water quality conditions to the Big Bend reservoir. Water quality data collection has varied through this period and has included the monitoring of ambient water quality conditions at three in-reservoir locations as well as from discharges from the Big Bend powerplant. 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-07. Summary of Water Quality Conditions. Table C-1 summarizes the water quality conditions that were monitored in the Big Bend reservoir (Lake Sharpe) near the damsite during 2010-2014. Due to its shallowness and high flows released from the Oahe dam, a hypolimnion rarely forms in the Big Bend reservoir and water temperatures throughout the reservoir regularly exceed 18.3°C in the summer. Dissolved oxygen levels near the bottom of the reservoir occasionally fall below the 6.0 mg/L CPFLP criterion during the summer. The lowest dissolved oxygen concentration measured during the 5-year period at the three sites was 3.6 mg/L and occurred near the dam in August 2010. The suspended solids criteria for the protection of CPFLP are regularly exceeded in the upper end of the Big Bend reservoir. This is attributed to finer sediment that has been deposited in the Big Bend reservoir below the confluence of the Bad River and its continual resuspension with wave action. Table C-2 summarizes the water quality conditions that were monitored in the Missouri River in the tailwaters of Big Bend during 2010-2014.

C-08. Water Quality Trends. Water quality trends over the 35-year period from 1980-2014 were determined for the Big Bend reservoir for Secchi depth, total phosphorus, chlorophyll *a* and Trophic state index (TSI) values. The assessment was based on near-surface sampling of water quality conditions in the reservoir during the May-October period at the near-dam, ambient monitoring site. For the assessment period, the Big Bend reservoir exhibited significant trends for Secchi depth (decreasing) and TSI (increasing). No significant trend was detected for total phosphorus and chlorophyll *a*. Over the 35-year period, the reservoir has generally remained mesotrophic to moderately eutrophic.

Table C-1
2010-2014 Water Quality Conditions – Big Bend Reservoir

Parameter	Monitoring Results[A]						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	1420.3	1420.4	1419.3	1420.8	-----	-----	-----
Water Temperature (°C)	0.1	522	19.0	20.2	9.9	27.6	18.3[1,5]	328	63%
Hypolimnion Water Temperature (°C)[E]	0.1	21	22.4	22.7	20.7	24.3	18.3[1,5]	21	100%
Dissolved Oxygen (mg/L)	0.1	522	8.5	8.4	3.6	11.5	6[1,6,8], 7[1,6,8]	35, 57	7%, 11%
Dissolved Oxygen (% Sat.)	0.1	522	94.7	96.2	43.6	133.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/L)[E]	0.1	500	8.7	8.5	4.7	11.5	5[3,6]	1	<1%
Hypolimnion Dissolved Oxygen (mg/L)[E]	0.1	21	4.9	5.1	3.6	6.2	6[1,6,8]	20	95%
Specific Conductance (uS/cm)	1	522	797	809	660	939	-----	-----	-----
pH (S.U.)	0.1	522	8.3	8.4	7.5	8.9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	521	3.8	2.7	n.d.	116	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	501	326	323	182	482	-----	-----	-----
Secchi Depth (M)	0.02	22	1.83	1.63	0.56	4.06	-----	-----	-----
Alkalinity, Total (mg/L)	7	49	159	165	114	172	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	49	3.9	3.9	2.4	5.2	-----	-----	-----
Chloride (mg/L)	1	19	12.2	12.0	11.0	14.0	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/L) – Field Probe	1	479	6	5	n.d.	21	-----	-----	-----
Chlorophyll *a* (ug/L) – Lab Determined	1	25	6	5	n.d.	14	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	4	39	24	22	16	34	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	48	571	552	370	842	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Nitrogen, Ammonia Total (mg/L)	0.02	49	-----	n.d.	n.d.	0.25	2.6 [1,5,9], 0.85 [1,7,9]	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.08	48	0.32	0.29	n.d.	0.62	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	49	-----	0.05	n.d.	1.00	10[2,5]	0	0%
Nitrogen, Total (mg/L)	0.08	48	0.42	0.38	n.d.	1.56	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	49	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	49	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	49	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/L)	1	49	241	242	191	301	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/L)	4	49	-----	5	n.d.	15	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/L)	0.1	25	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	24	-----	-----	-----	-----	D.O ≥ 6 mg/L W. Temp. ≤ 18.3°C	14	58%

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) 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.

(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. A defined hypolimnion was monitored on 4 of the 25 occasions (i.e. 16%) that monthly depth profiles were measured from May through September. Measured water depths in this area of Lake Sharpe were < 23 meters.

(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. During the 5-year period 2010 through 2014, water temperatures greater than 18.3°C throughout the water column precluded the occurrence of Coldwater Permanent Fish Life Propagation habitat from late-June through early-September.

Table C-2
2010-2014 Water Quality Conditions – Big Bend Powerplant Releases

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
Dam Discharge, Powerplant (Mean Daily, cfs)	1	40	32,204	28,750	2,600	78,100	-----	-----	-----
Dam Discharge, Powerplant + Spillway (Mean Daily, cfs)	1	40	36,974	28,750	2,600	145,900	-----	-----	-----
Water Temperature (°C)	0.1	40	14.3	14.4	1.2	24.9	27(1,2)	0	0%
Dissolved Oxygen (mg/L)	0.1	40	9.7	9.6	5.5	14.4	5(1,3)	0	0%
Dissolved Oxygen (% Sat.)	0.1	40	94.9	95.3	66.0	114.0	-----	-----	-----
pH (S.U.)	0.1	38	8.2	8.3	7.2	9.1	6.5(1,3), 9.0(1,2)	0, 1	0%, 3%
Specific Conductance (uS/cm)	1	40	792	806	642	966	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	38	348	333	162	714	-----	-----	-----
Turbidity (NTU)	1	40	35	4	n.d.	708	-----	-----	-----
Alkalinity, Total (mg/L)	7	40	162	164	116	225	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	40	4.5	4.1	2.7	13.8	-----	-----	-----
Chloride, Dissolved (mg/L)	1	15	12	12	11	14	438(2,4), 250(2,6)	0	0%
Colorized Dissolved Organic Matter (ug/L)	4	31	24	22	15	42	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	40	584	588	378	786	1,750(2,4), 1,000(2,6), 3,500(3,4), 2,000(3,6)	0	0%
Nitrogen, Ammonia Total (mg/L)	0.02	40	-----	n.d.	n.d.	0.15	4.7 (1,4,7), 1.4 (1,6,7)	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	39	0.50	0.39	n.d.	3.38	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/L)	0.02	40	-----	0.08	n.d.	1.00	10(2,4)	0	0%
Nitrogen, Total (mg/L)	0.1	39	0.60	0.47	n.d.	3.38	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	40	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	39	0.08	0.03	n.d.	0.06	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	40	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/L)	1	40	237	241	187	299	875(2,4), 500(2,6)	0	0%
Suspended Solids, Total (mg/L)	4	38	-----	7	n.d.	73	158(1,4), 90(1,6)	0	0%

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 warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) 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. Currently, the least tern and piping plover do not utilize the Big Bend reservoir or the Missouri River reach downstream of Big Bend 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-02.1. The Big Bend reservoir is maintained in the normal 1420.0 to 1421.0 foot range year round, regardless of basin conditions.

D-03. Regulation for Endangered and Threatened Species – Least Terns and Piping Plovers. Currently, there no regulation restrictions at Big Bend for least terns and piping plovers. Releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate T&E nesting since 1986 as noted in their respective WCMs. Additional System regulation criteria used for T&E species is discussed in Sections 7-09 of this WCM and Section 7-10 and Appendix D of the Master Manual.

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 Big Bend reservoir area. More detailed discussion on water supply and irrigation can be found in Appendix E of the Master Manual.

E-02. Big Bend Reservoir. As shown on Table E-3 of the Master Manual, there are 115 water supply intakes located on the Big Bend reservoir. These include 3 municipal intake facilities, 91 irrigation intakes, 19 domestic intakes and 2 public intakes. The municipal water supply facilities serve a population of approximately 900 persons. Of the 115 water supply intakes, 77 serve the Lower Brule and Crow Creek reservations.

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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 megawatts (MW), as shown in Table F-1. These units have provided an average of 9.4 million (1967-2013) 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 3,300 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 Dakota, 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. Big Bend Dam. Eight units operate at Big Bend, with a generating capacity of 517 MW. At this rating, the powerhouse capacity is 103,000 cfs. The average annual release is 23,700 cfs (1967-2015) and the average annual flow plant factor is 22 percent, the lowest of the six System powerplants. The powerplant produces, on average, 1.0 million MWh per year. Power generating units came on line from 1964 through 1966. Big Bend Dam is primarily a peaking powerplant that normally only fluctuates through a very narrow 1-foot range in reservoir elevation.

F-05. Big Bend Dam Releases. Releases experienced from this project have been very similar to that described for Oahe Dam, with a maximum average daily release of 166,300 cfs occurring during 2011, a combination of powerplant and spillway releases. Prior to 2011, releases had been entirely through the powerplant since the facilities became fully operational. An average daily release of zero is frequently made from the project, usually on a Sunday to facilitate refilling the project for the next week’s releases.

F-05.1. On October 8, 1997, releases were made through the powerhouse without any associated generation. Generation was suspended for part of the day for replacement of equipment that was damaged during a spring ice storm. Water was released through the units at “speed no load” during the outage, with hourly discharges ranging from approximately 20,000 to 29,000 cfs.

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 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 Big Bend 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 at 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.

[redacted]

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

Big Bend 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) 01 September 2017

MEMORANDUM FOR Oahe and Big Bend Operations Project Manager

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Big Bend

1. Procedures applicable to the regulation of Big Bend 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 to Big Bend. Big Bend 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 Big Bend on a daily basis. Regulation instructions for the weekend and holidays are contained in the previous normal working day's orders. Big Bend utilizes the Power Plant Control System (PPCS) to transmit observed hourly and daily project data, via Data Collection Platforms (DCPs) to the MRBWM office. If e-mail or network communication between the MRBWM and Big Bend 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 Big Bend 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 Big Bend reservoir level remains below elevation 1422.0 feet, the top of the flood control pool.

d. If the Big Bend reservoir level is between elevation 1422.0 and 1423.0 feet, or above 1423.0 feet and falling, procedures outlined in paragraph 4.c. 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. If the reservoir level is above 1423.0 feet and rising, release changes, if required, will begin as soon as the communications failure becomes apparent. Procedures are as follows:

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

(2) A continuing surveillance of reservoir elevations will be maintained. Normally those elevations will follow a relatively smooth curve. Therefore, any sudden fluctuations in the reservoir level recorder trace from a smooth curve (probably due to wind effects on the reservoir gage) should be disregarded and the estimated true reservoir level should be based on extrapolation of the smoothed reservoir level curve.

(3) With an estimated true reservoir level between elevation 1422.0 and 1423.0 feet, after the first day of communications failure, release the greater of:

a. The full discharge capability of all available power units.

b. 100,000 cfs.

(4) With an estimated true reservoir elevation between elevation 1423.0 and 1423.5 feet, release as necessary to maintain the reservoir within this range, subject to a minimum release as outlined in (3) above.

(5) With an estimated true reservoir level above elevation 1423.5 feet, release at the full capacity of the Big Bend spillway with gates fully open.

(6) With a Big Bend reservoir level between 1422.0 and 1423.0 feet, any release adjustments made necessary by these instructions should be made at intervals of 6 hours or less. With a pool level above elevation 1423.0 feet the release adjustments should be made at 2-hour intervals.

5. The foregoing procedures are not intended to relieve the Big Bend 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

Big Bend Dam – Lake Sharpe

Water Control Manual

Plates

Item No.	Subject	Fort Peck Dam - Fort Peck Lake	Garrison Dam - Lake Sakakawea	Oahe Dam - Lake Oahe
	Summary of Engineering Data -- Missouri River Mainstem System			
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.
21 miles upstream Chamberlain, SD	Near Lake Andes, SD	Near Yankton, SD		1
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
200 (elevation 1420)	540 (elevation 1350)	90 (elevation 1204.5)	5,940 miles	5
28,900	30,000 1,100	32,000 2,000		6
440,000 (April 1952)	447,000 (April 1952)	480,000 (April 1952)		7
1959	1946	1952		8
1964	1953	1955		9
1440	1395	1234		10
10,570 (including spillway)	10,700 (including spillway)	8,700 (including spillway)	71,596	11
78	140	45	863 feet	12
95	165	74		13
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
17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds	17
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
1385	1346	1180		21
376 gated	1000 gated	664 gated		22
8 - 40' x 38' Tainter	21 - 40' x 29' Tainter	14 - 40' x 30' Tainter		23
390,000 at elev 1433.6	620,000 at elev 1379.3	584,000 at elev 1221.4		24
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
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 32,000 cfs - 128,000 cfs			43
1351-1355(10) 25,000-100,000 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
980	1,726	725	9,342 million kWh	54
October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1943 - July 1966	55
$107,498,000	$199,066,000	$49,617,000	$1,166,404,000	56

Remarks

(1) Includes 4,280 square miles of non-contributing areas.
(2) Includes 1,350 square miles of non-contributing areas.
(3) With pool at base of flood control.
(4) Storage first available for regulation of flows.
(5) Damming height is height from low water to maximum operating pool. Maximum height is from average streambed to top of dam.
(6) Based on latest available storage data.
(7) River regulation is attained by flows over low-crested spillway and through turbines.
(8) Length from upstream face of outlet or to spiral case.
(9) Based on 8th year (1961) of drought drawdown (From study 8-83-1985).
(10) Affected by level of Lake Francis case. Applicable to pool at elevation 1350.
(11) Spillway crest.
(12) 1967-2015 Average
(13) Source: Annual Report on Civil Works Activities of the Corps of Engineers. Extract Report Fiscal Year 1999.
(14) Based on Study 8-83-1985

Corps of Engineers, U.S. Army
Compiled by
Northwestern Division
Missouri River Region
December 2016

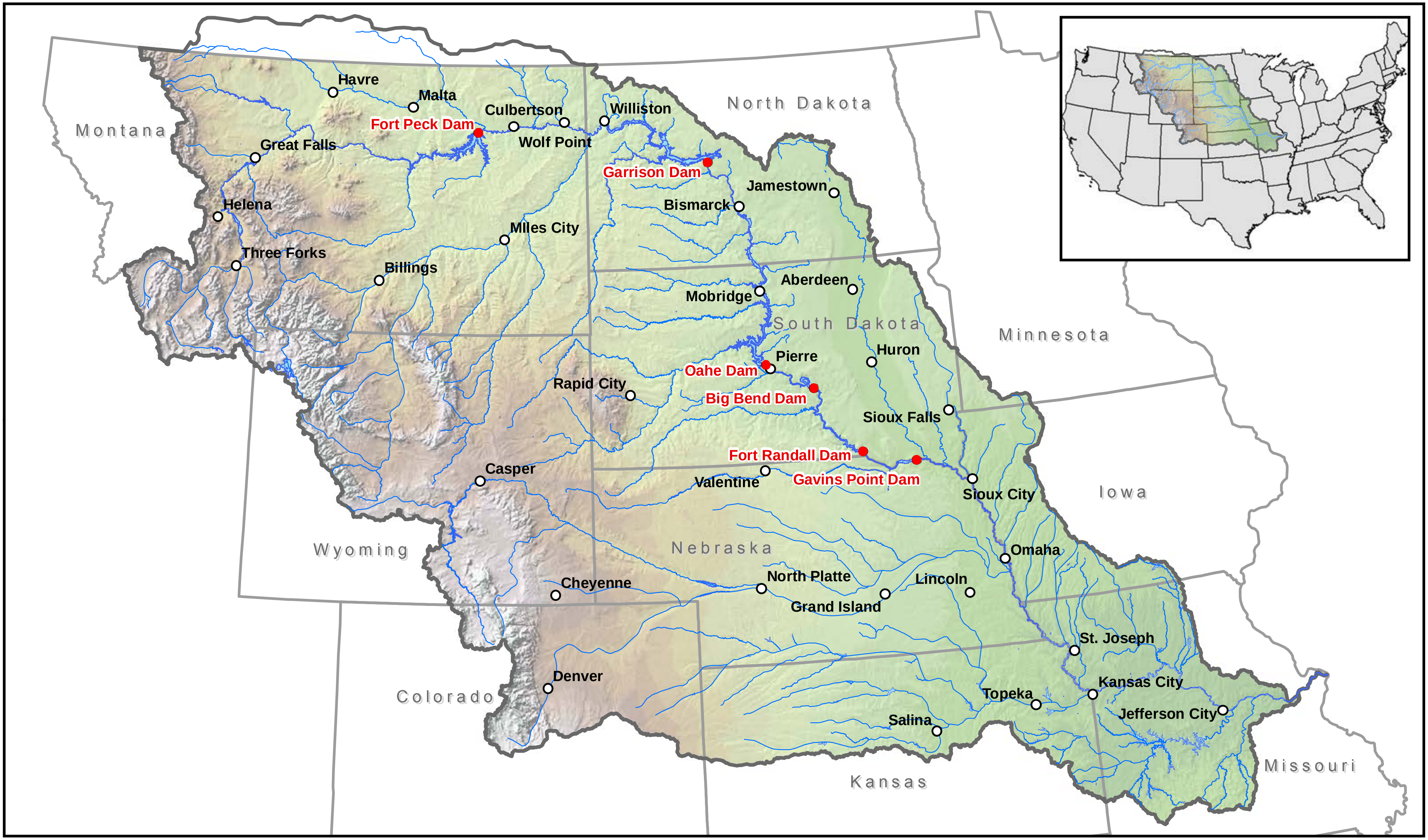
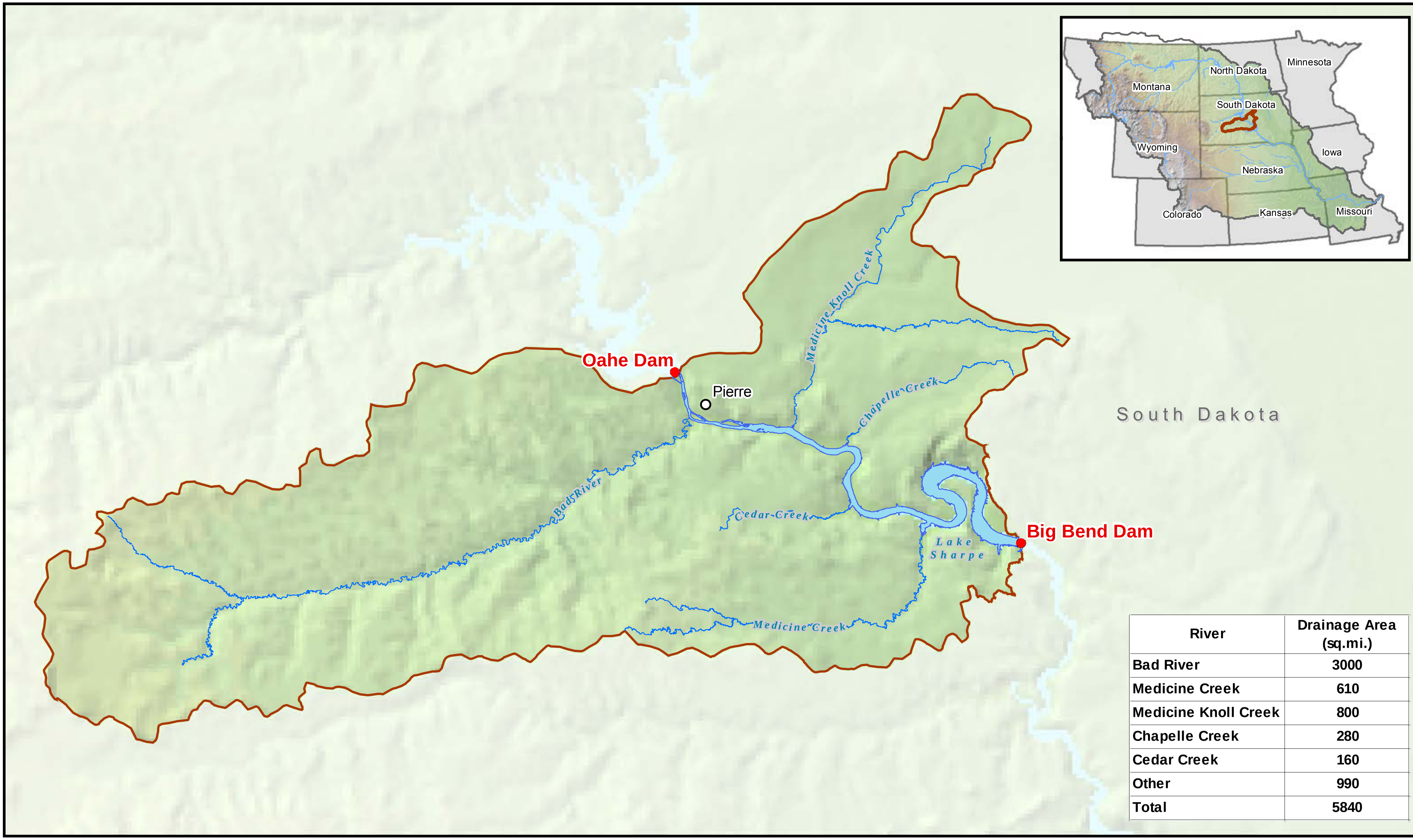


Plate III-1

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

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



River	Drainage Area (sq.mi.)
Bad River	3000
Medicine Creek	610
Medicine Knoll Creek	800
Chapelle Creek	280
Cedar Creek	160
Other	990
Total	5840

Mainstem Dam
Cities
River
Reservoirs/Lakes
Big Bend Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 10 20 40 Miles

N S E W

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

US Army Corps of Engineers®
Northwestern Division

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Plate III-2

Plate III-3

US Army Corps of Engineers®
Northwestern Division

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

G:\2016_DivisionMaps\Land_Cover\mxd\Big_Bend_Land_Use_Map.mxd

Missouri River Basin
BIG BEND 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 W E S

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

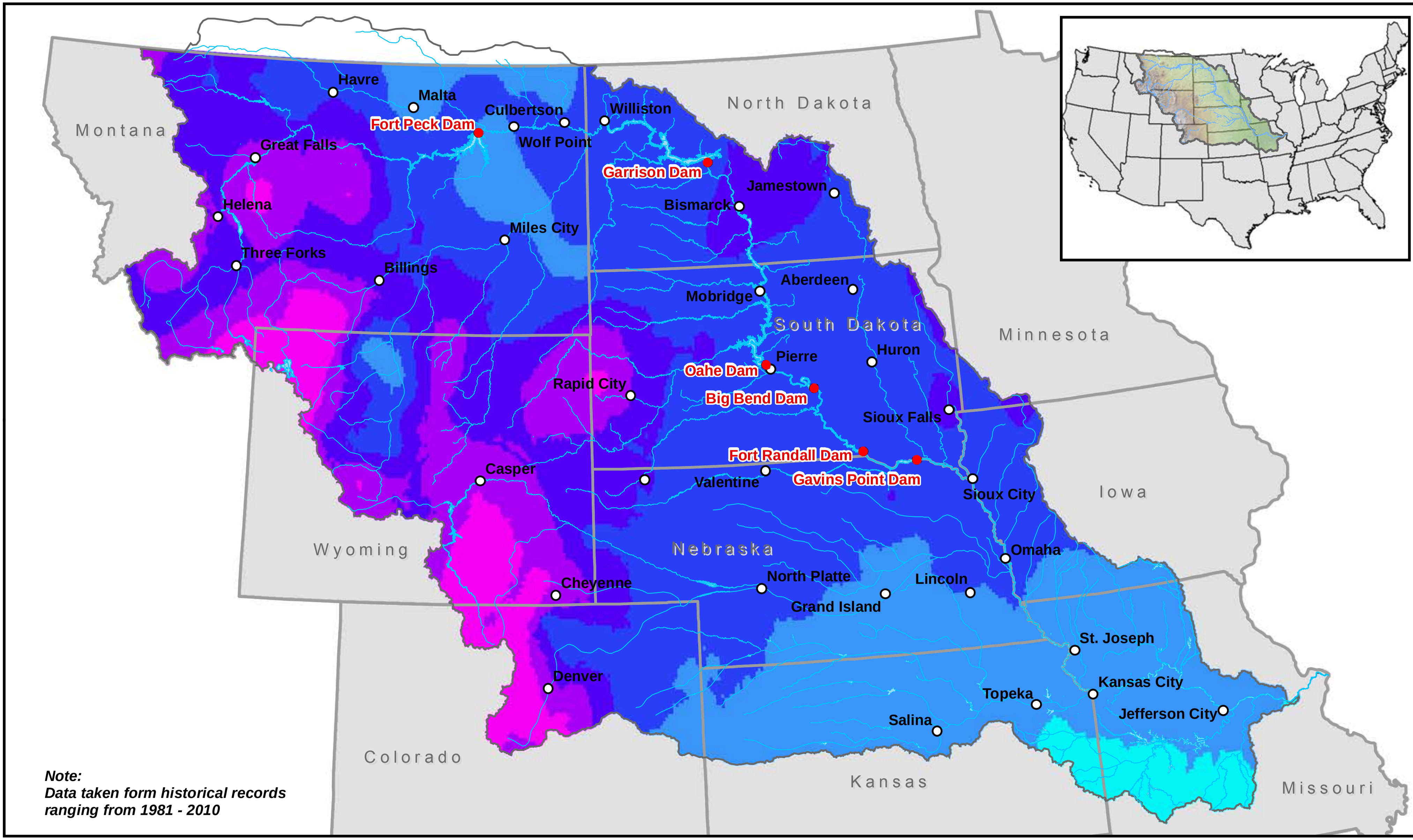
G:\2016_DivisionMaps\MO_Precip\mxd\Precipitation_Annual_Map.mxd

Missouri River Basin
AVERAGE PRECIPITATION
ANNUAL

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

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 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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US Army Corps of Engineers®
Northwestern Division

Plate III-5

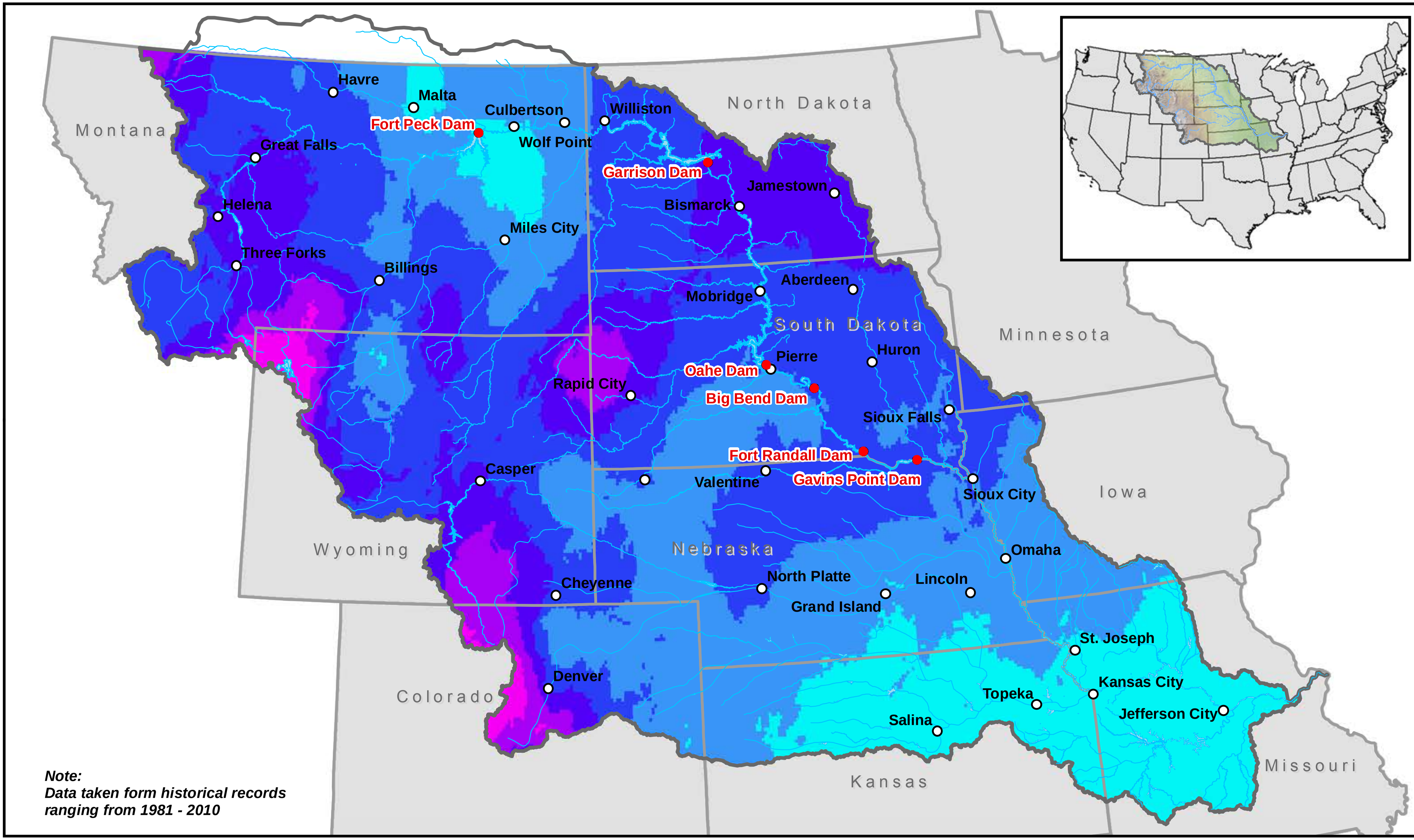

Plate III-6

US Army Corps of Engineers®
Northwestern Division

- 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

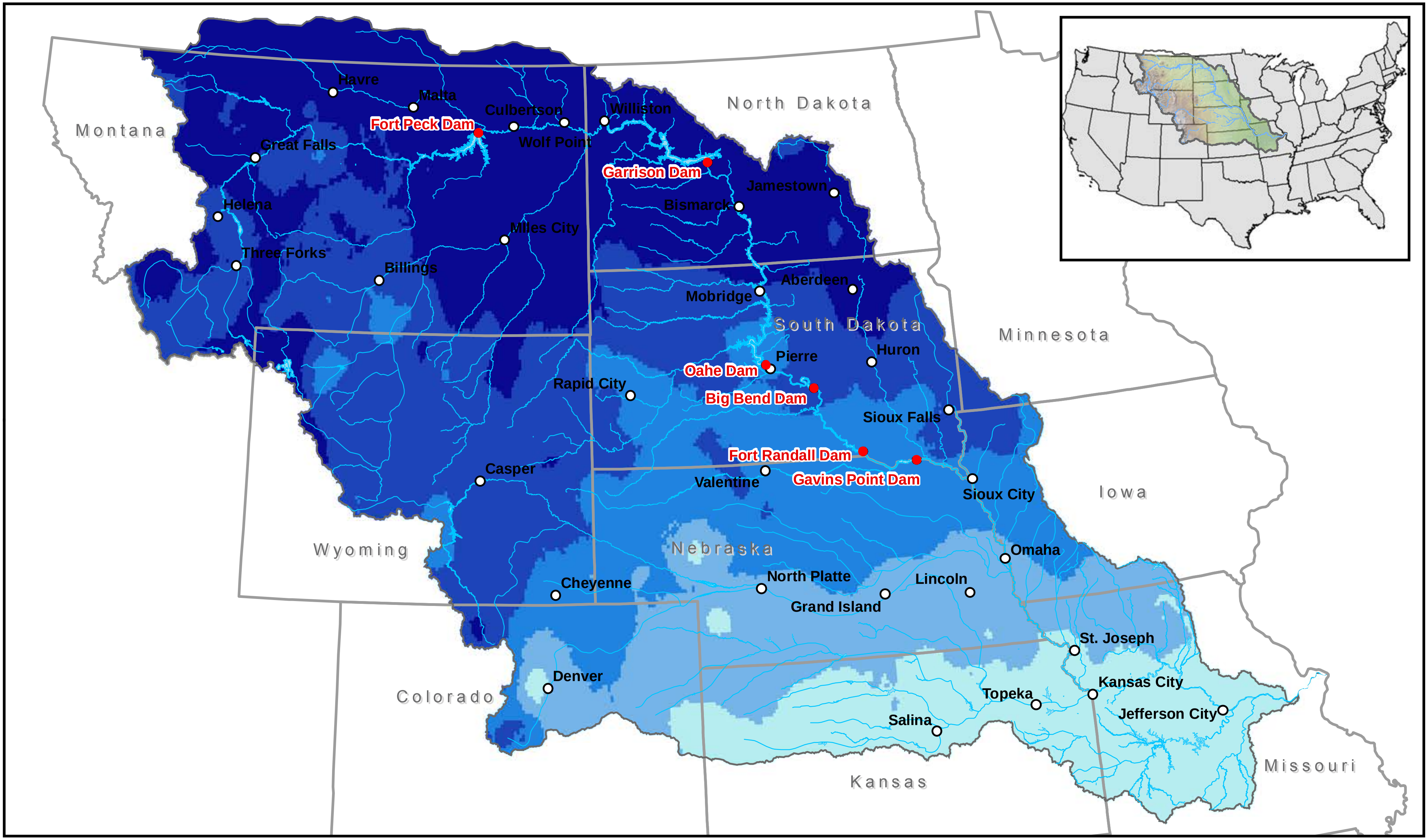

Plate III-7

US Army Corps of Engineers®
Northwestern Division

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

Average Minimum Temperature
-36°F to -25°F
-25°F to -20°F
-20°F to -15°F
-15°F to -10°F
-10°F to 2.6°F

0 50 100 200 300 Miles

N E S W

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

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

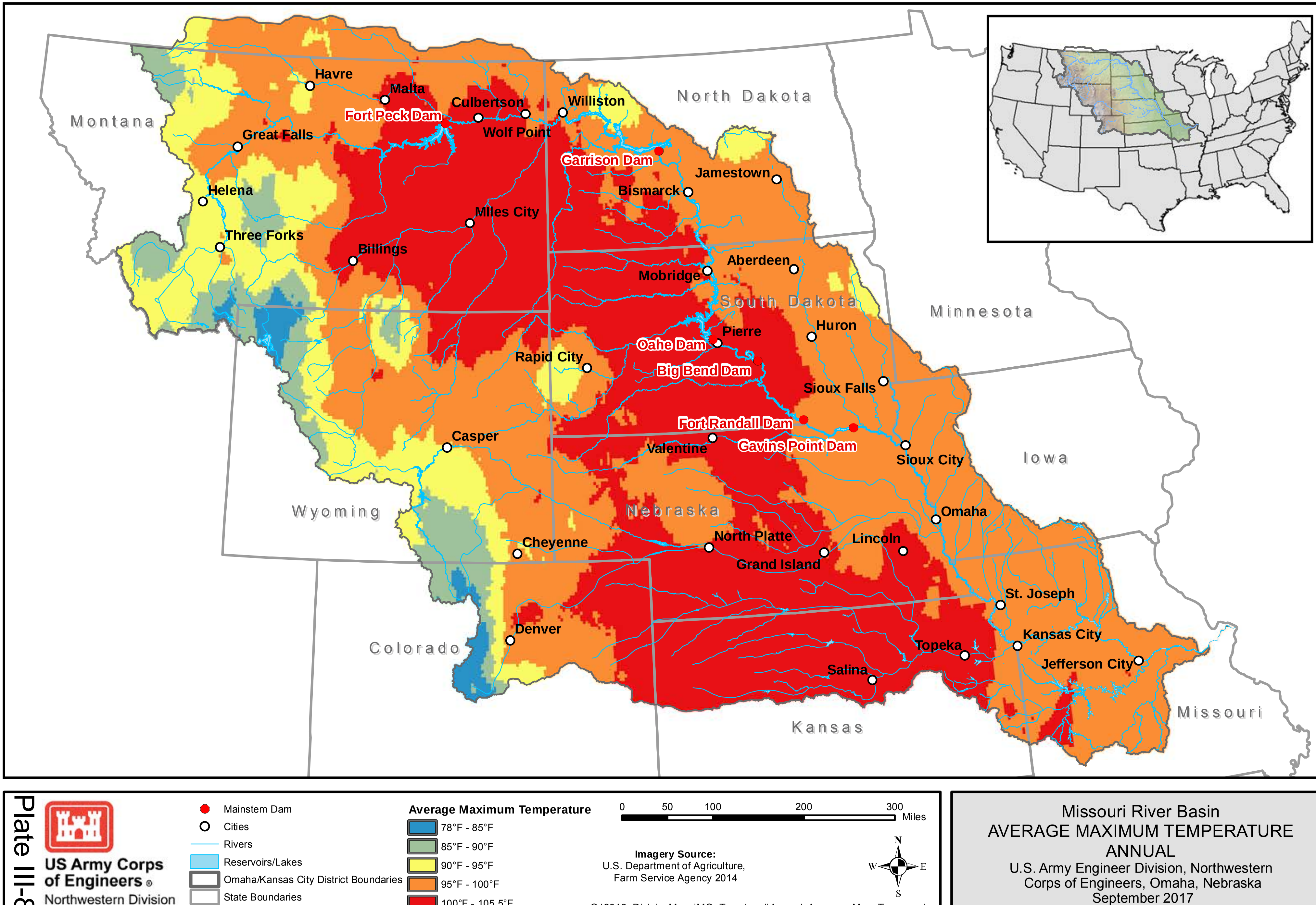


Plate III-8

US Army Corps of Engineers®
Northwestern Division

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

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
Big Bend 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: Garrison, May = 6.35 in (Plate III-9) x 0.20 (Plate III-10) = 1.27 in (Plate III-11).

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 Figure 11 (Plate III-10) to the normal monthly pan evaporation as shown on Figure 9 (Plate III-9).

Missouri River Basin

Big Bend Water Control Manual
Normal Monthly Lake Evaporation in Inches

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

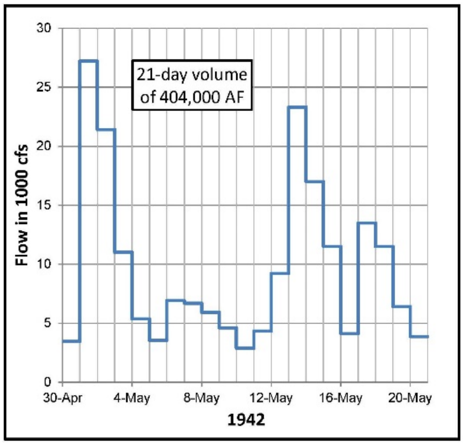
Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 13.

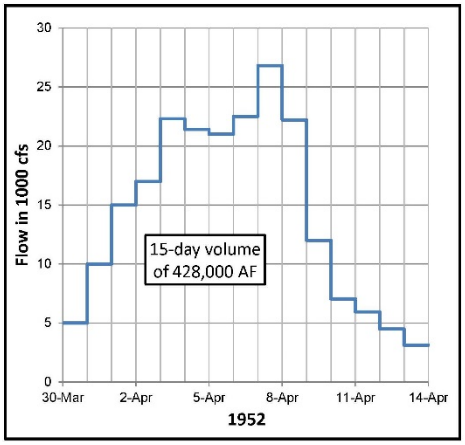
Volumes computed by assuming that each reservoir was at the base of its flood control pool.

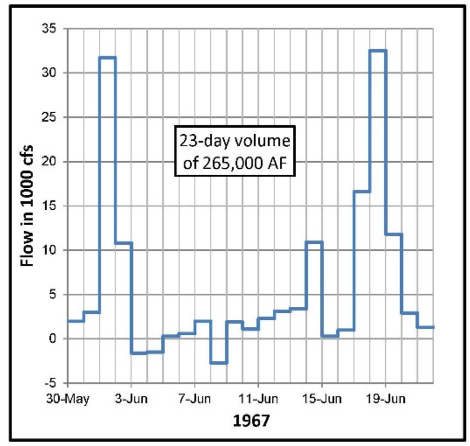
Missouri River Basin
Big Bend Water Control Manual
Normal Monthly Lake Evaporation
in 1000 AF

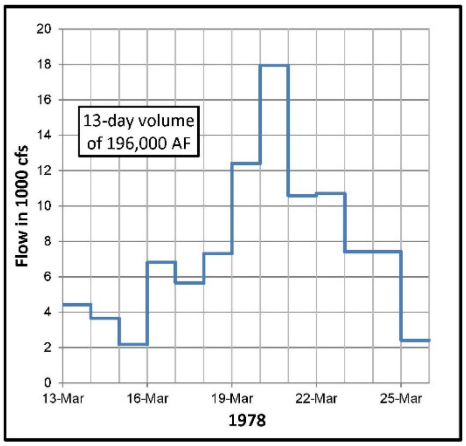
U.S. ARMY ENGINEER DIVISION,
NORTHWESTERN CORPS OF ENGINEERS,
OMAHA, NEBRASKA
September 2017

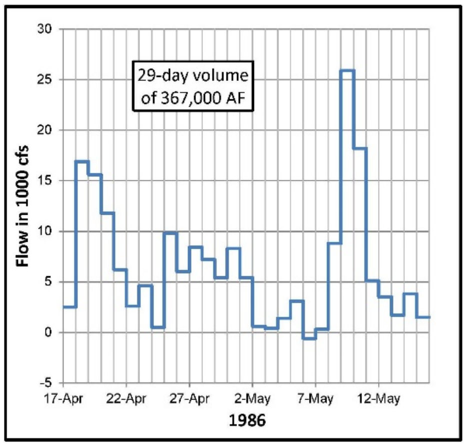
Incremental Inflow Hydrographs – Oahe to Big Bend

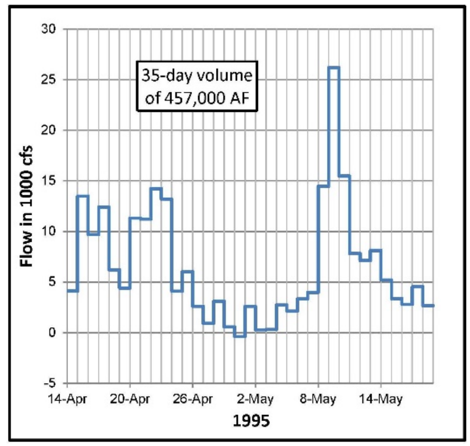


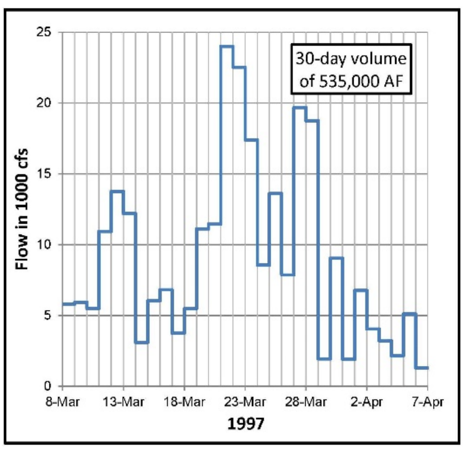


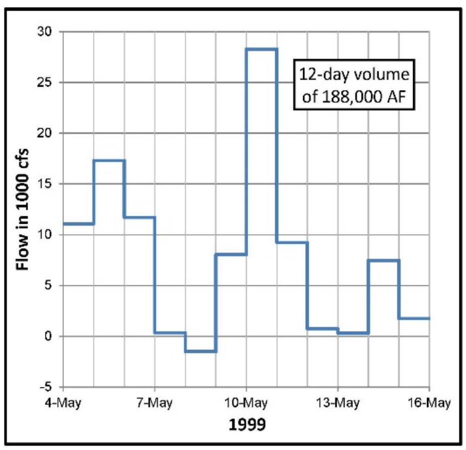


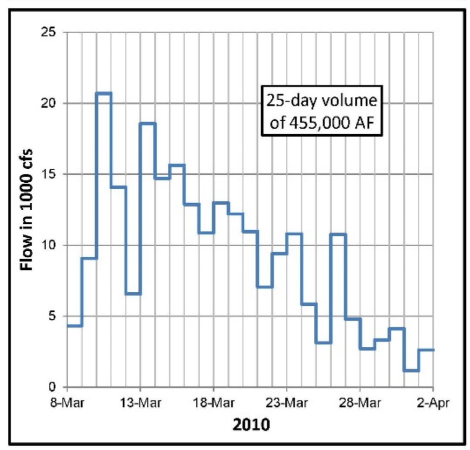


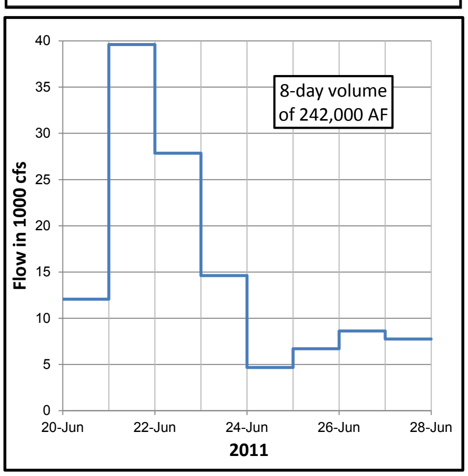












Year	Timeframe	No. Days	Total Volume (kAF)	Average flow (kcfs)
1942	30 Apr - 20 May	21	404	9.7
1952	30 Mar - 13 Apr	15	428	14.4
1967	30 May - 21 Jun	23	265	5.8
1978	13 Mar - 25 Mar	13	196	7.6
1986	17 Apr - 15 May	29	367	6.4
1995	14 Apr - 18 May	35	457	6.6
1997	8 Mar - 6 Apr	30	535	9.0
1999	4 May - 15 May	12	188	7.9
2010	8 Mar - 1 Apr	25	455	9.2
2011	20 Jun - 27 Jun	8	242	15.2

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

Missouri River Basin
Big Bend Water Control Manual
Incremental Inflow Hydrographs
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
July 2016

Plate III-14

US Army Corps of Engineers®
Northwestern Division

Travel Time - Days
Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Big Bend Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 10 20 40 Miles

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

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

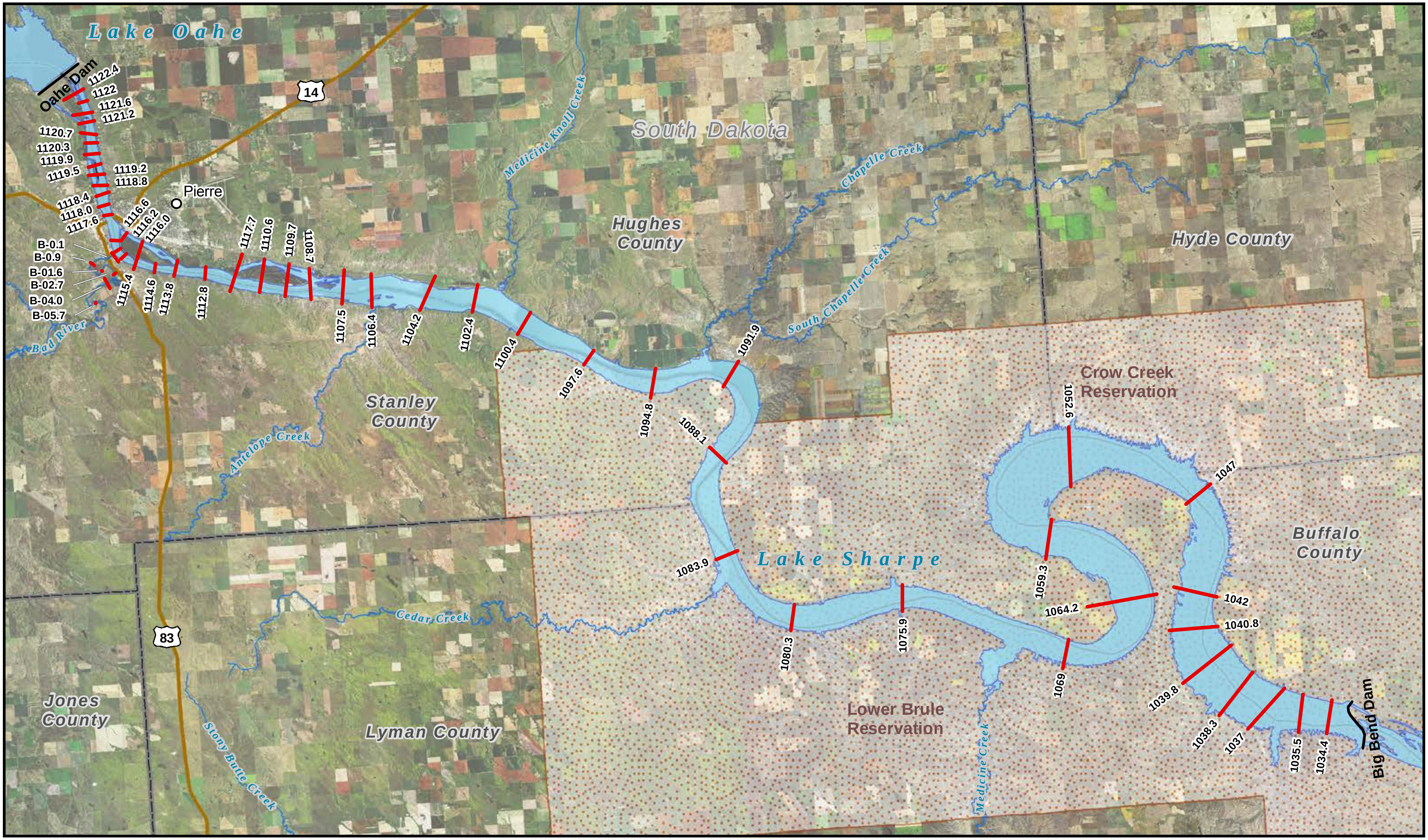

Plate III-15

US Army Corps of Engineers®
Northwestern Division

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

0 2 4 8 12 Miles

N W E S

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

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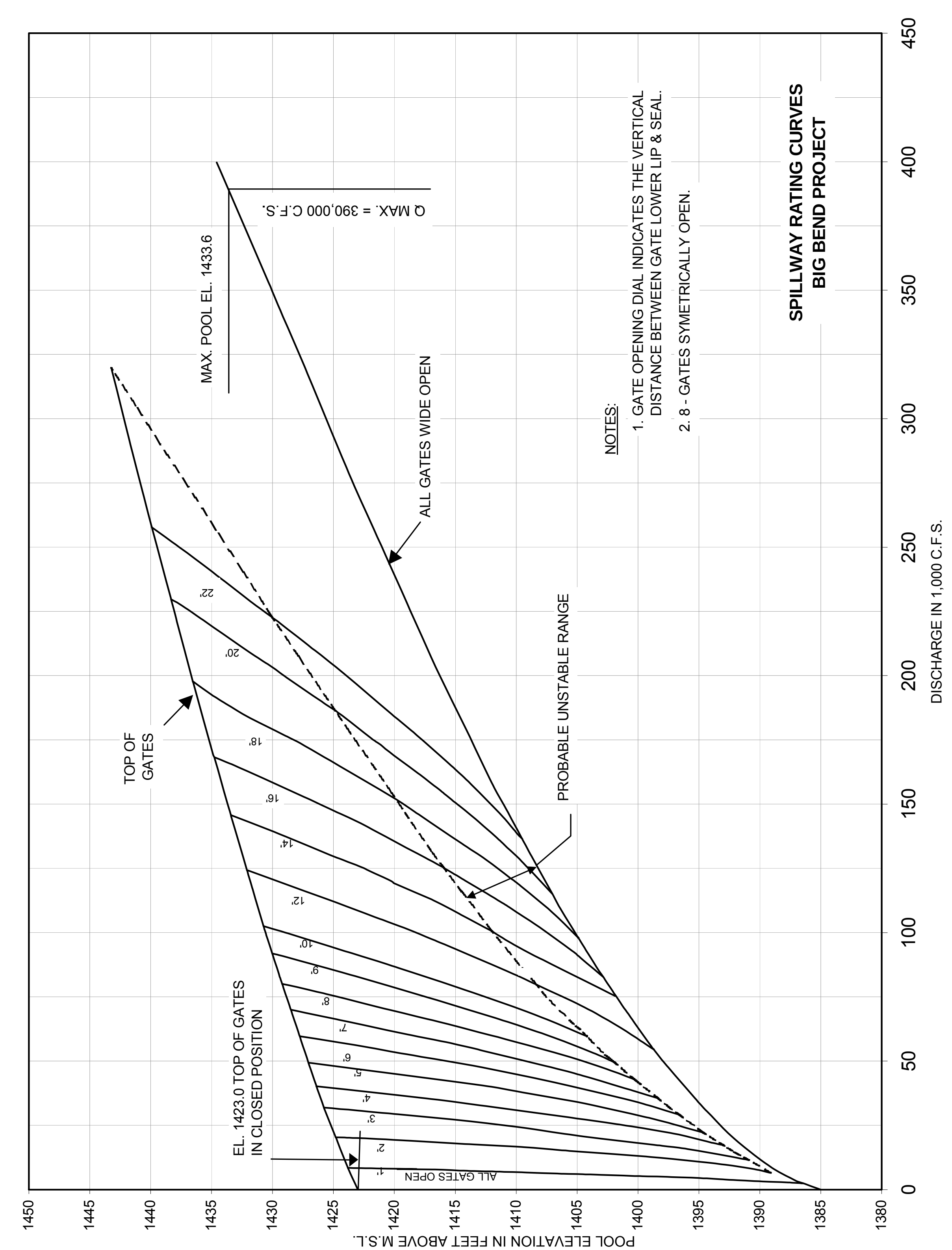
Missouri River Basin
BIG BEND PROJECT
SEDIMENT RANGE MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Missouri River Basin
Big Bend Water Control Manual
Powerhouse, Spillway, Reservoir
and Embankment
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

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

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

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



Missouri River Basin

Big Bend Water Control Manual

Spillway Rating Curves

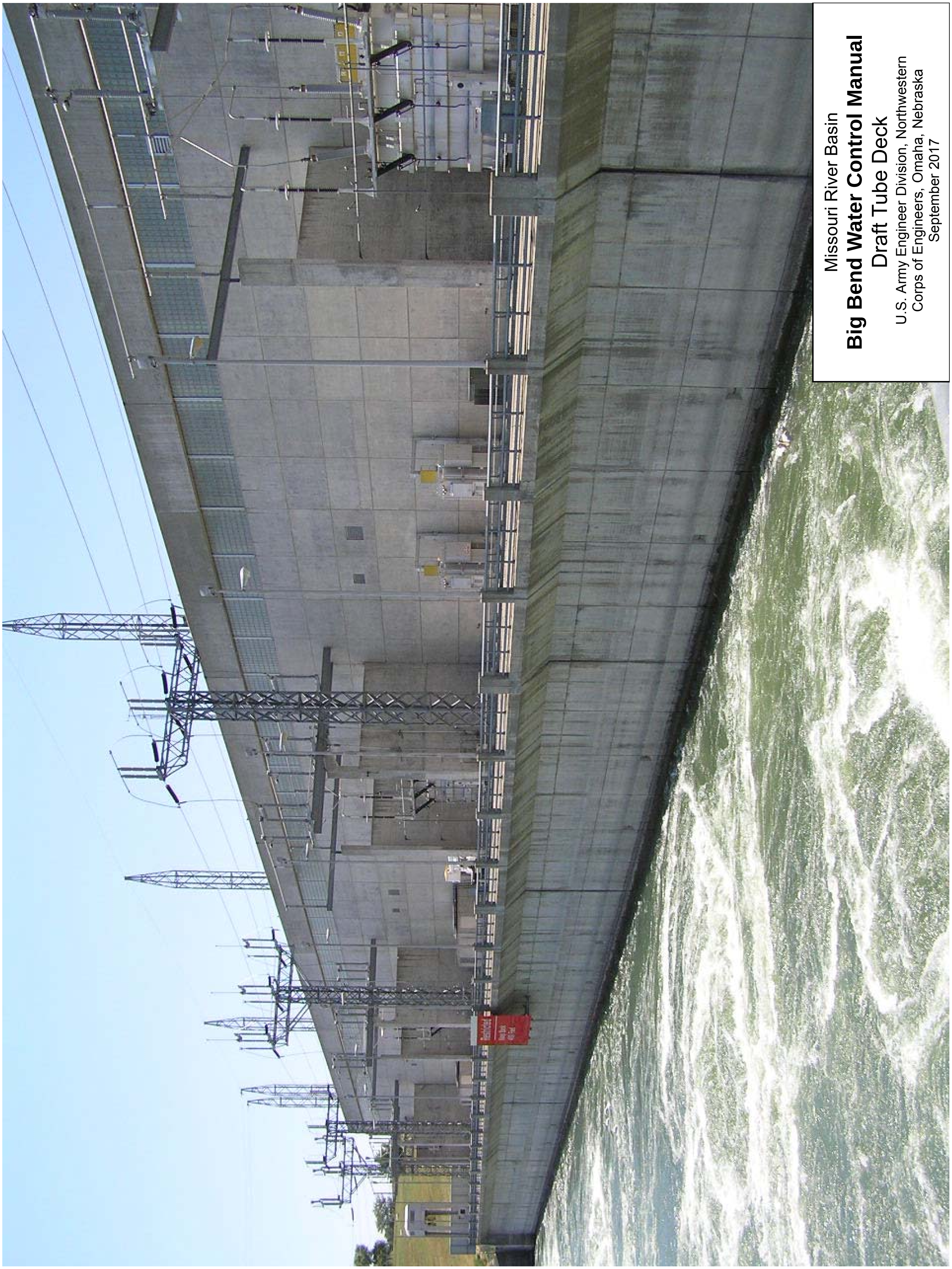
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Missouri River Basin

Big Bend Water Control Manual

Powerhouse Intake Structure

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



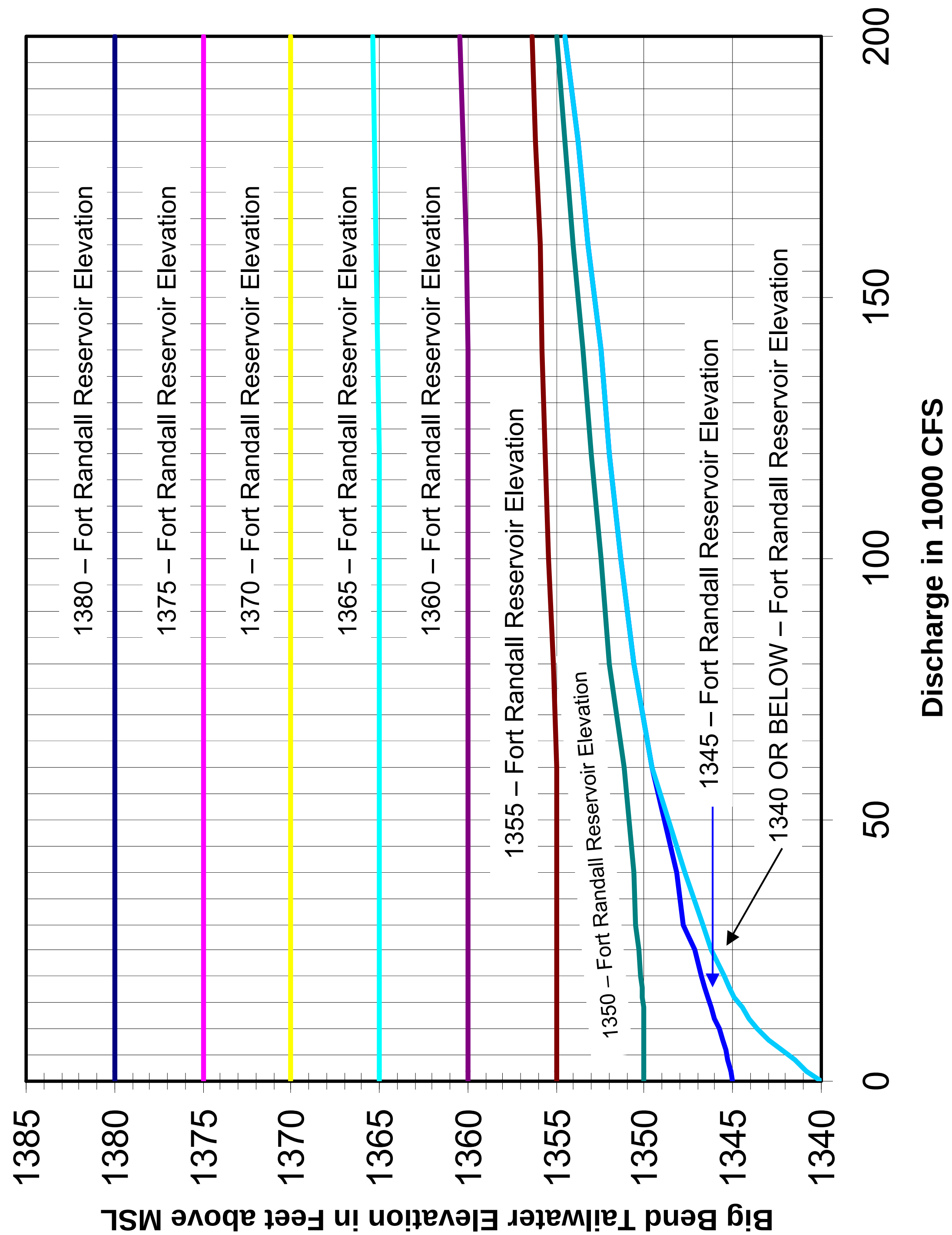
Missouri River Basin
Big Bend Water Control Manual
Draft Tube Deck
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Missouri River Basin
Big Bend Water Control Manual
Powerhouse
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

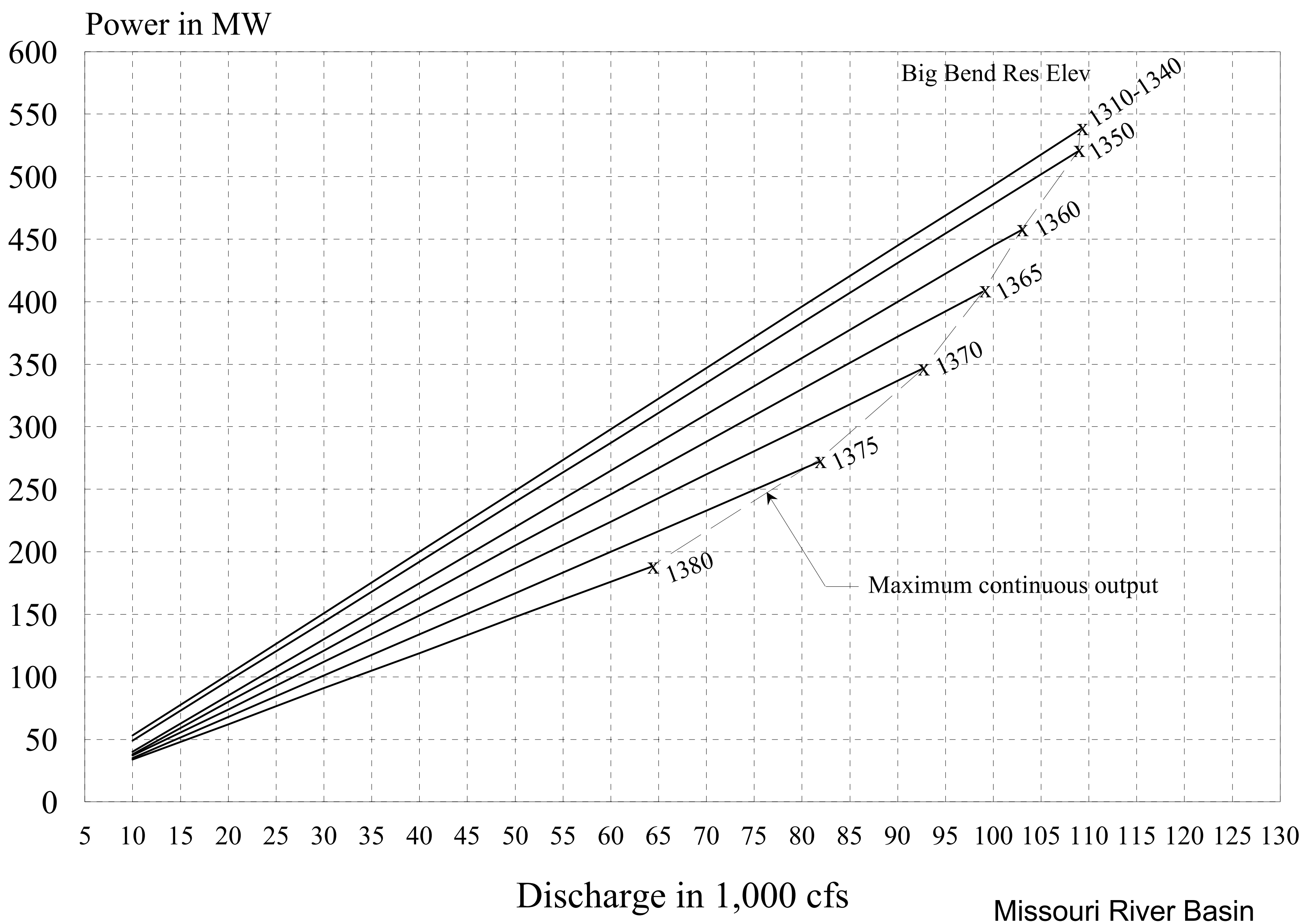
Missouri River Basin
Big Bend Water Control Manual
Powerhouse Generators

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

Missouri River Basin
Big Bend Water Control Manual
Tailrace Channel
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Big Bend Water Control Manual
Tailwater Rating Curves
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin

Big Bend Water Control Manual
Powerplant Characteristics

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

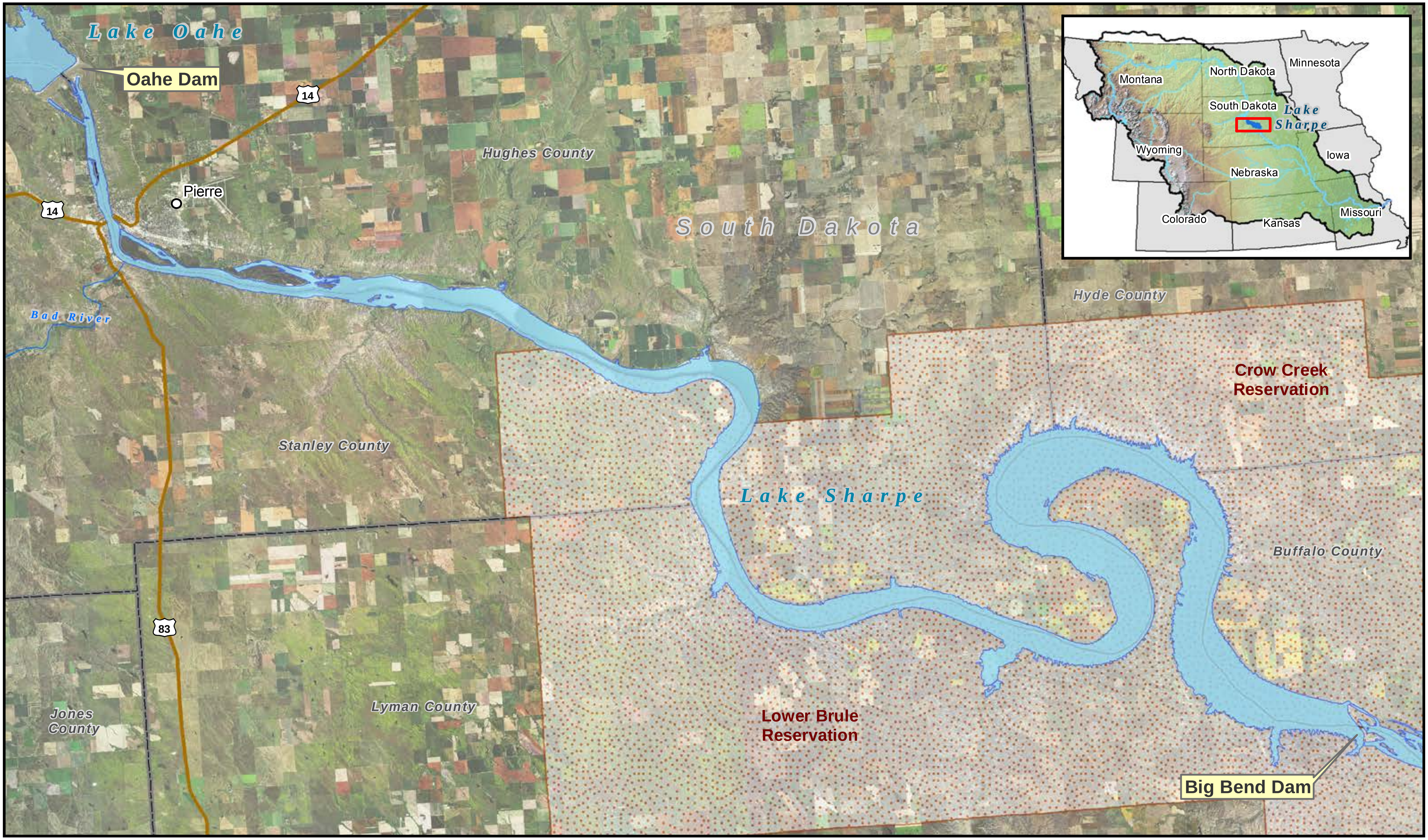


Plate IV-14

US Army Corps of Engineers®
Northwestern Division

Cities		Reservoirs/Lakes	
Rivers		State Boundaries	
Roads		County Boundaries	
Reservations			

0 2 4 8 12 Miles

N W E S

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

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

Big Bend (Lake Sharpe) - 2013 AREA AND CAPACITY TABLES - 1 Foot
Effective date: 08 January 2014
(2012 Hydrographic Surveys - NGVD29)

Elevation - feet	Volume - ac-ft	Surface Area - ac
1342.5	0	0
1343.0	80	180
1344.0	271	211
1345.0	501	251
1346.0	772	291
1347.0	1,083	331
1348.0	1,434	371
1349.0	1,825	411
1350.0	2,256	816
1351.0	3,457	1,193
1352.0	4,642	1,235
1353.0	5,927	1,392
1354.0	7,425	1,663
1355.0	9,253	2,049
1356.0	11,524	2,550
1357.0	14,353	3,166
1358.0	17,856	3,897
1359.0	22,147	4,742
1360.0	27,341	5,597
1361.0	33,341	6,318
1362.0	39,976	6,952
1363.0	47,246	7,587
1364.0	55,150	8,222
1365.0	63,690	8,857
1366.0	72,865	9,493
1367.0	82,675	10,129
1368.0	93,122	10,765
1369.0	104,205	11,401
1370.0	115,925	12,035
1371.0	128,276	12,665
1372.0	141,256	13,295
1373.0	154,867	13,929
1374.0	169,113	14,565
1375.0	183,998	15,205
1376.0	199,523	15,848
1377.0	215,693	16,494
1378.0	232,511	17,143
1379.0	249,980	17,796
1380.0	268,103	18,464
1381.0	286,907	19,151
1382.0	306,405	19,835
1383.0	326,576	20,498
1384.0	347,401	21,141
1385.0	368,859	21,765
1386.0	390,930	22,368

Elevation - feet	Volume - ac-ft	Surface Area - ac
1387.0	413,595	22,951
1388.0	436,833	23,515
1389.0	460,624	24,058
1390.0	484,949	24,532
1391.0	509,689	24,924
1392.0	534,798	25,339
1393.0	560,367	25,844
1394.0	586,486	26,439
1395.0	613,245	27,124
1396.0	640,735	27,900
1397.0	669,045	28,766
1398.0	698,266	29,722
1399.0	728,489	30,768
1400.0	759,803	31,692
1401.0	791,874	32,309
1402.0	824,421	32,873
1403.0	857,619	33,609
1404.0	891,640	34,519
1405.0	926,657	35,602
1406.0	962,843	36,858
1407.0	1,000,372	38,287
1408.0	1,039,417	39,889
1409.0	1,080,150	41,664
1410.0	1,122,745	43,478
1411.0	1,167,106	45,128
1412.0	1,213,001	46,645
1413.0	1,260,397	48,130
1414.0	1,309,261	49,583
1415.0	1,359,562	51,003
1416.0	1,411,266	52,390
1417.0	1,464,342	53,745
1418.0	1,518,757	55,068
1419.0	1,574,478	56,359
1420.0	1,631,474	57,646
1421.0	1,689,771	58,972
1422.0	1,749,418	60,322
1423.0	1,810,414	61,671
1424.0	1,872,760	63,021
1425.0	1,936,456	64,371
1426.0	2,001,502	65,721
1427.0	2,067,898	67,071
1428.0	2,135,643	68,420
1429.0	2,204,739	69,770
1430.0	2,275,184	71,120

Missouri River Basin
Big Bend Water Control Manual
Area and Capacity Tables
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

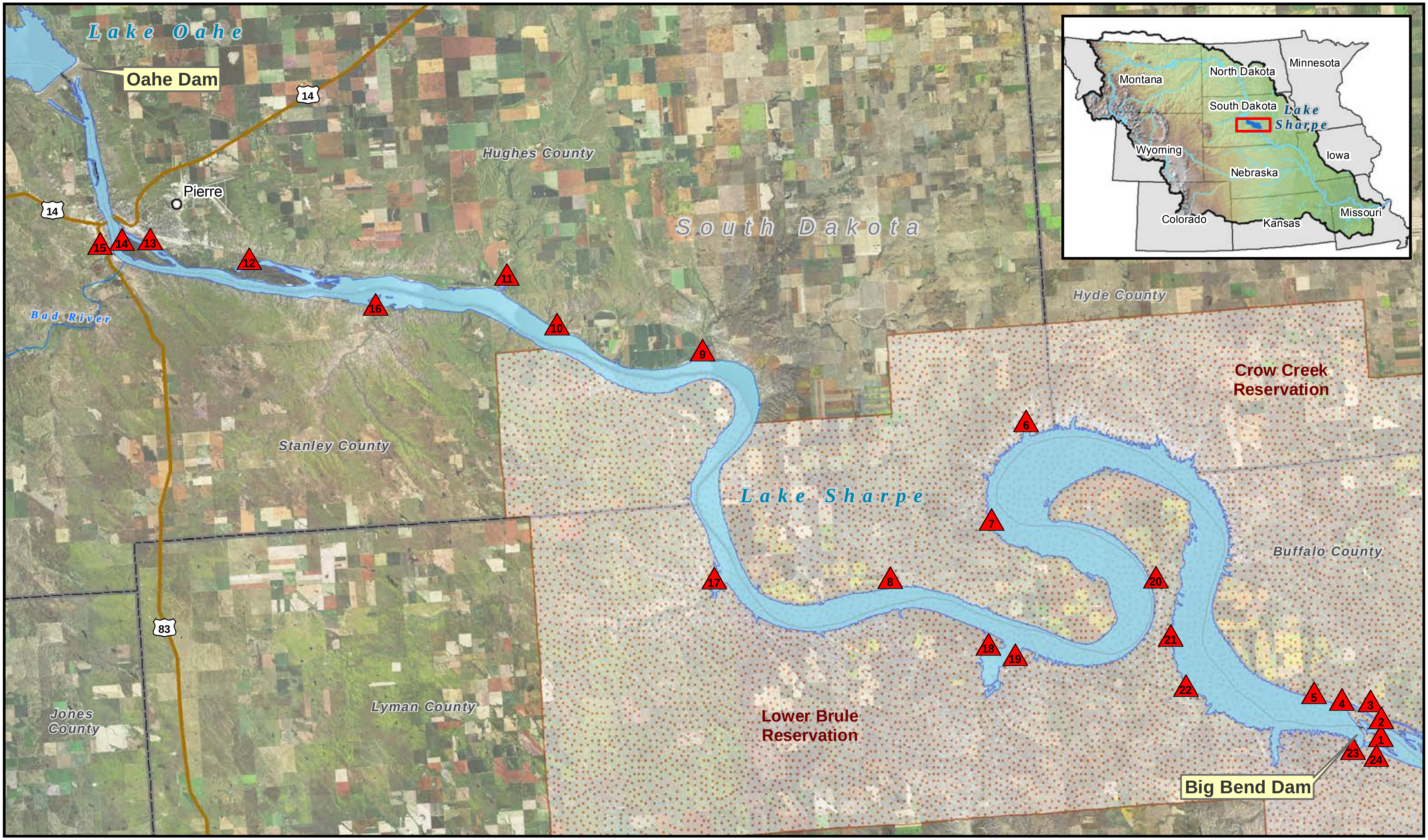

Plate IV-16

US Army Corps of Engineers®
Northwestern Division

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

Miles: 0 2 4 8 12

N E S W

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

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

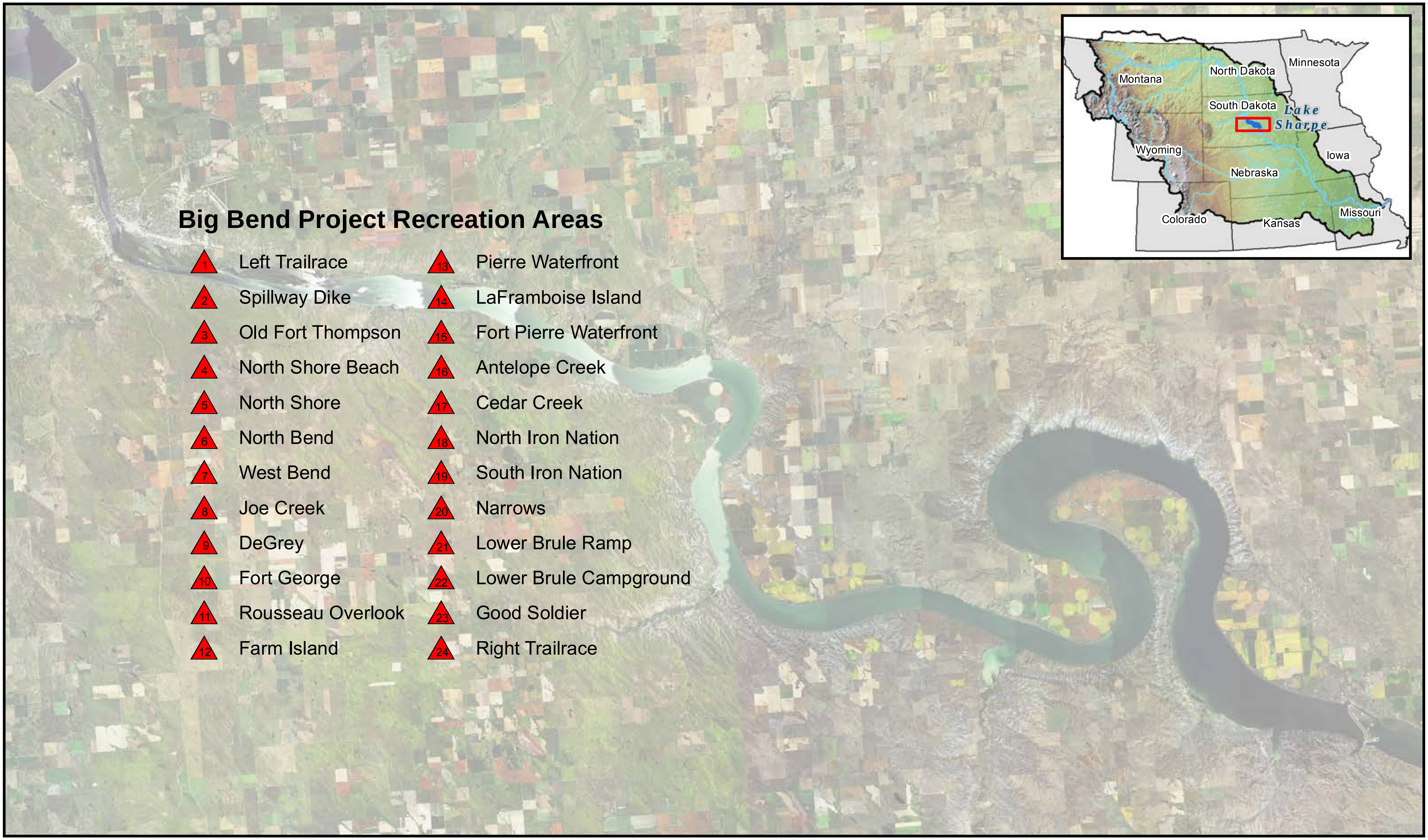

Plate IV-17

US Army Corps of Engineers®
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Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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

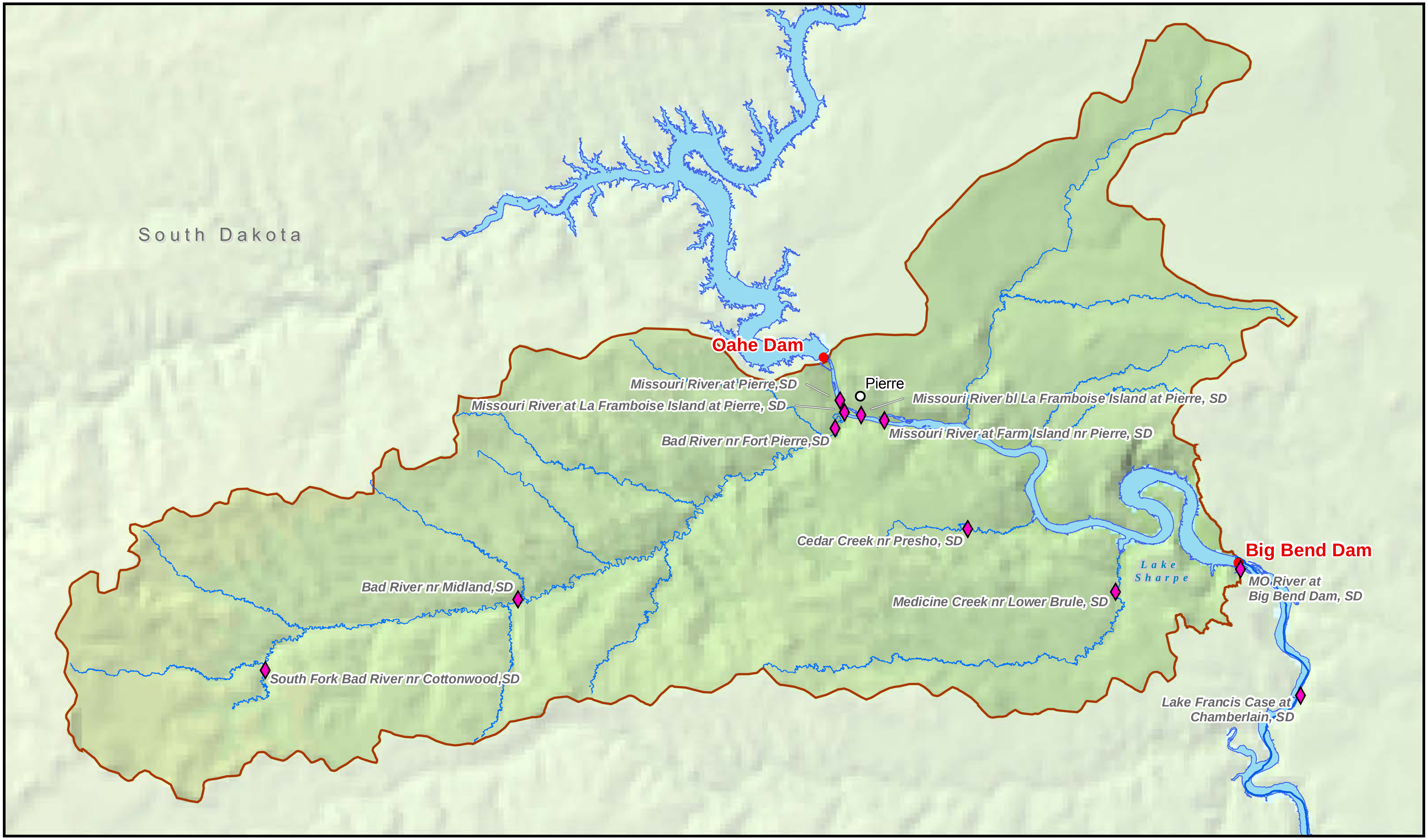

Plate V-1

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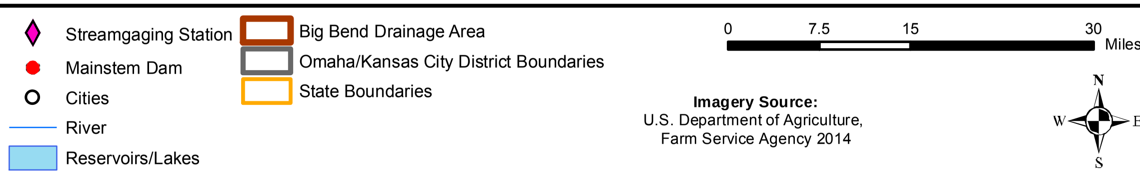
Northwestern Division



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

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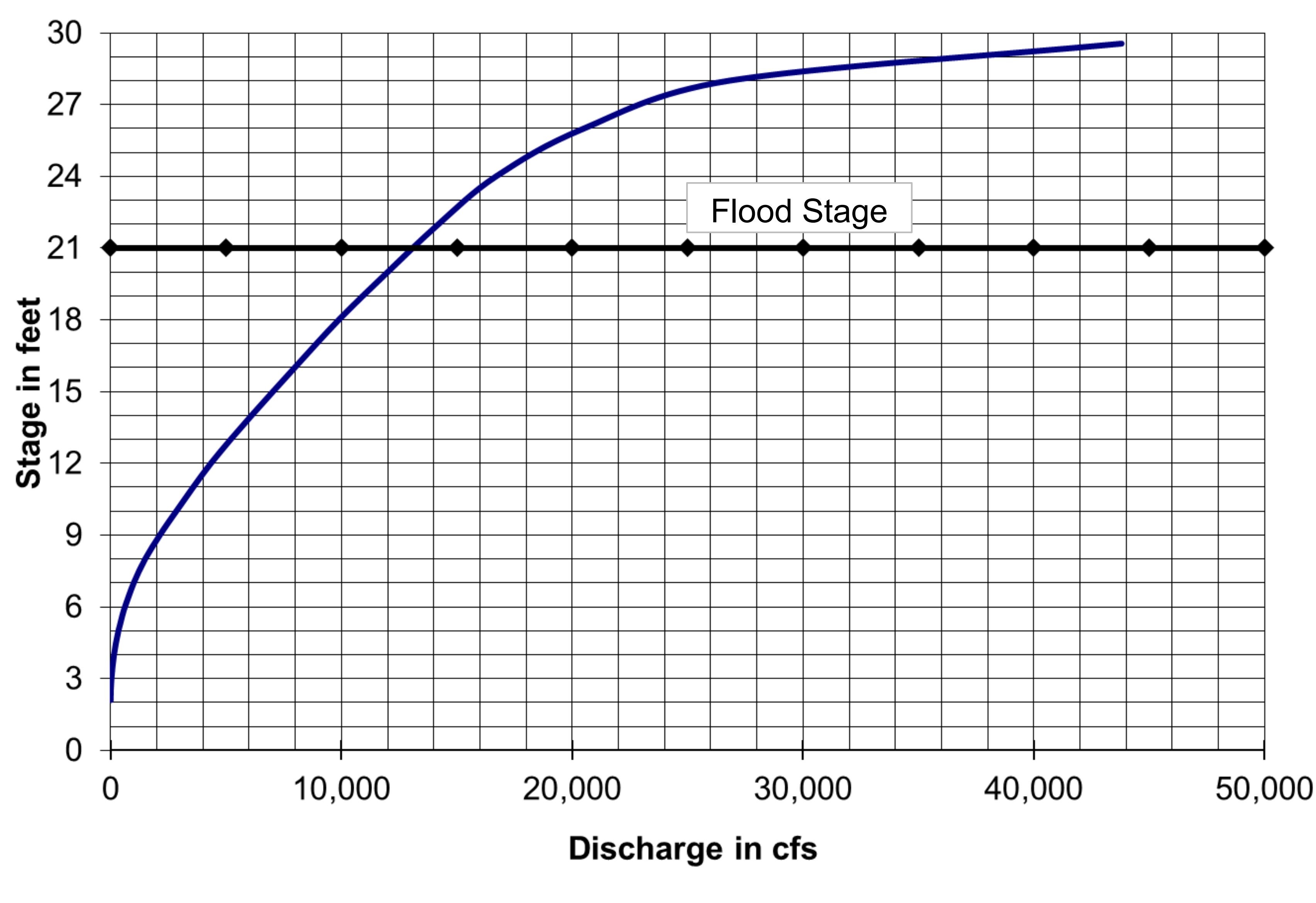
Missouri River Basin
BIG BEND DRAINAGE AREA
KEY STREAMGAGING STATIONS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Datum of gage is 1,427.83 feet above sea level NGVD29.

Missouri River Basin
Fort Randall Water Control Manual
Rating Curve – Bad River at Fort Pierre, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Big Bend to Allow for Wind Effects

(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

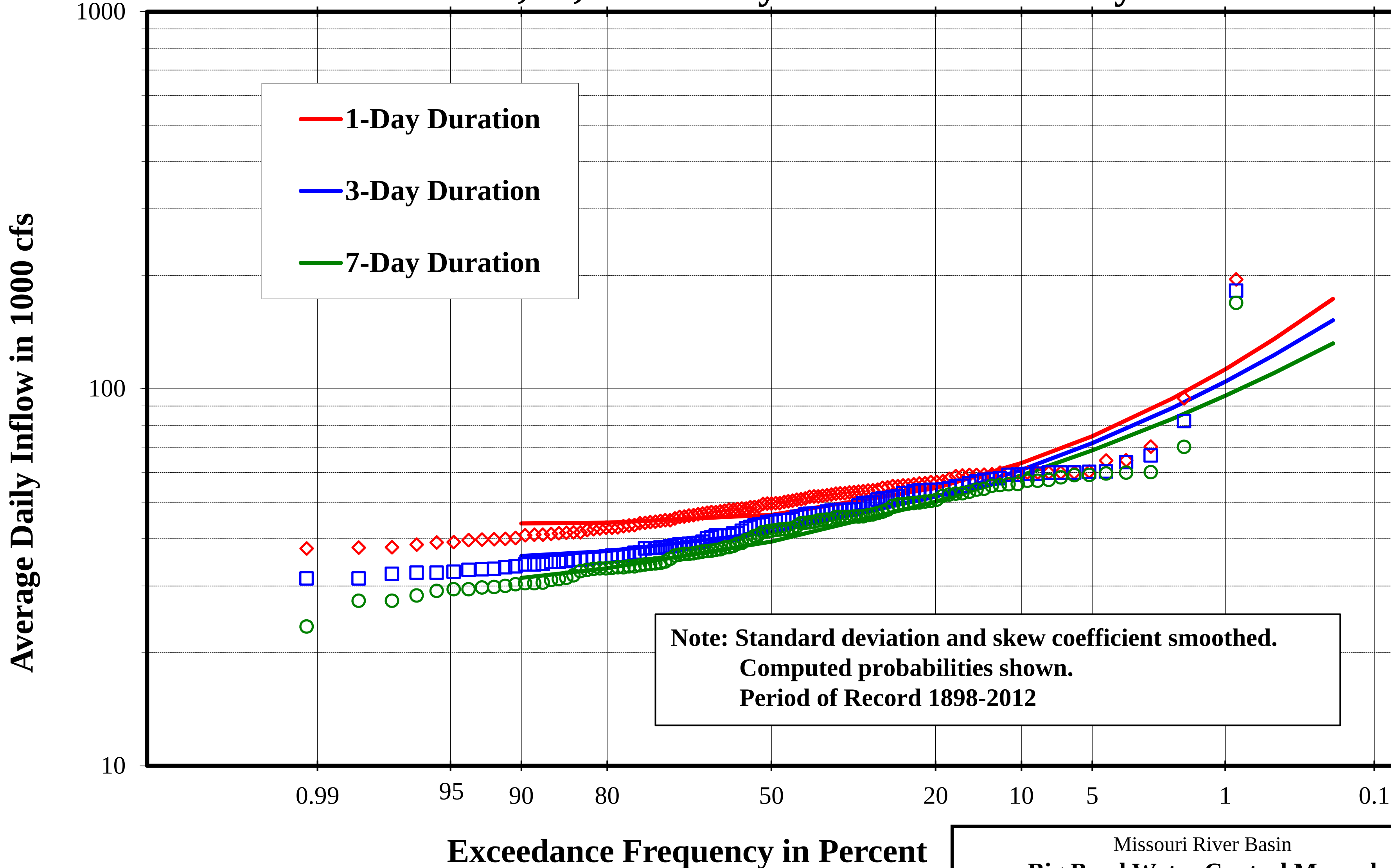
Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.7	-1.0	-1.3	-1.6	-1.9
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-0.9	-1.1
20	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.4
30	-0.0	-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
40	+0.0	+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	+0.8
50	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+1.0	+1.2	+1.5	+1.7
60	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.5	+1.8	+2.0	+2.3
70	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6	+3.0
80	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.9	+2.2	+2.6	+3.1	+3.5
90	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+2.9	+3.4	+3.9
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.5	+1.9	+2.3	+2.7	+3.2	+3.7	+4.3
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+1.9	+2.3	+2.8	+3.3	+3.9	+4.4
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.4	+2.8	+3.4	+3.9	+4.5
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+1.9	+2.3	+2.8	+3.3	+3.9	+4.4
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.5	+1.9	+2.3	+2.7	+3.2	+3.7	+4.3
150	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+2.9	+3.4	+3.9
160	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.9	+2.2	+2.6	+3.1	+3.5
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6	+3.0
180	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.5	+1.8	+2.0	+2.3
190	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+1.0	+1.2	+1.5	+1.7
200	+0.0	+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	+0.8
210	-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
220	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.4
230	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-0.9	-1.1
240	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.7	-1.0	-1.3	-1.6	-1.9
250	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.4	-1.8	-2.2	-2.6
260	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.4	-1.8	-2.3	-2.7	-3.1
270	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.6	-0.9	-1.2	-1.6	-2.1	-2.6	-3.0	-3.5
280	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.6	-1.0	-1.4	-1.8	-2.3	-2.8	-3.3	-3.8
290	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.7	-1.1	-1.5	-1.9	-2.5	-2.9	-3.5	-4.0
300	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.7	-1.1	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.7	-1.1	-1.5	-1.9	-2.5	-2.9	-3.5	-4.0
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.6	-1.0	-1.4	-1.8	-2.3	-2.8	-3.3	-3.8
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.6	-0.9	-1.2	-1.6	-2.1	-2.6	-3.0	-3.5
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.4	-1.8	-2.3	-2.7	-3.1
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.4	-1.8	-2.2	-2.6

Reservoir Elevation Wind Corrections in Feet

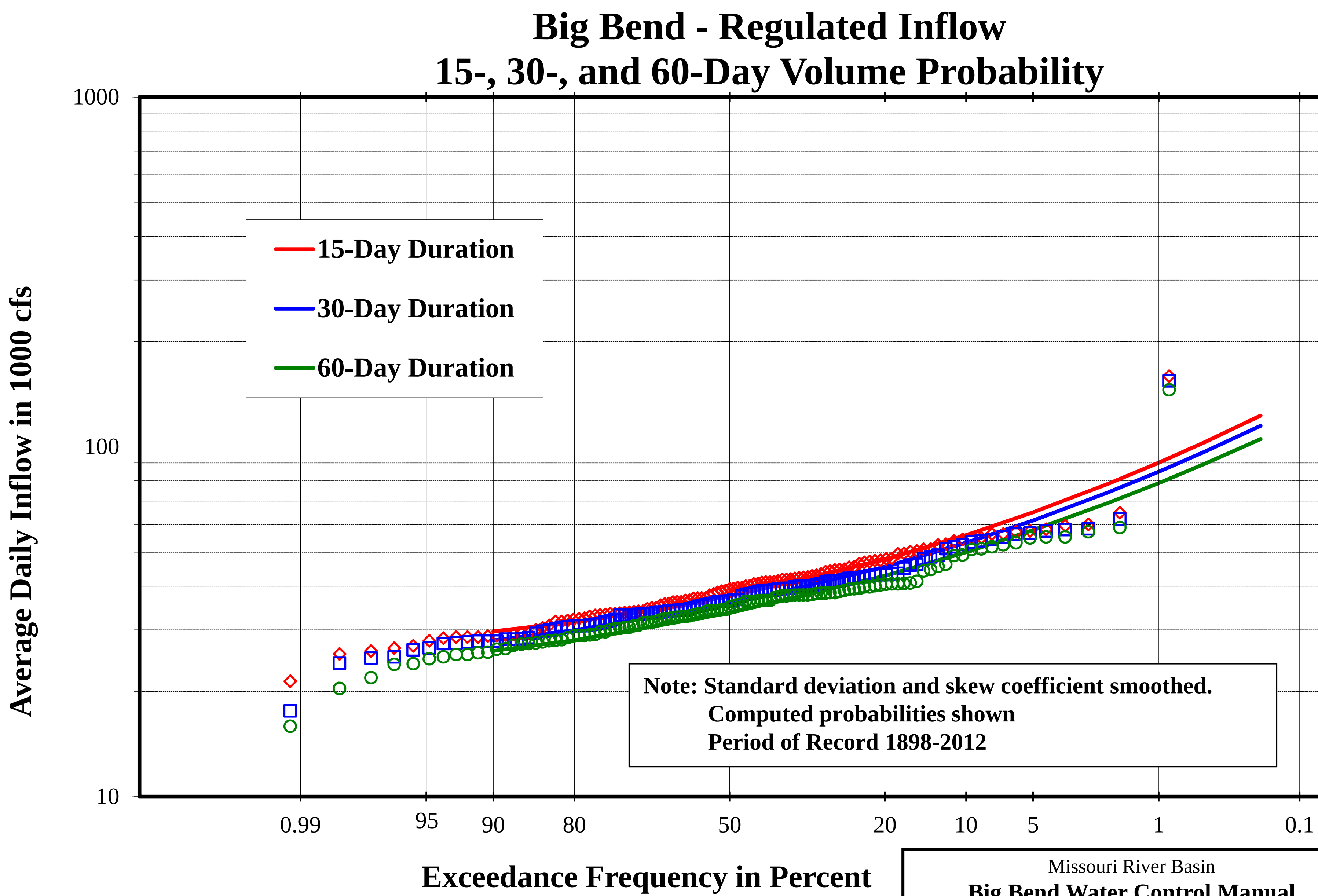
*** Pool elevation as measured at the dam.**

Missouri River Basin
Big Bend Water Control Manual
Reservoir Elevation Wind Correction Table
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

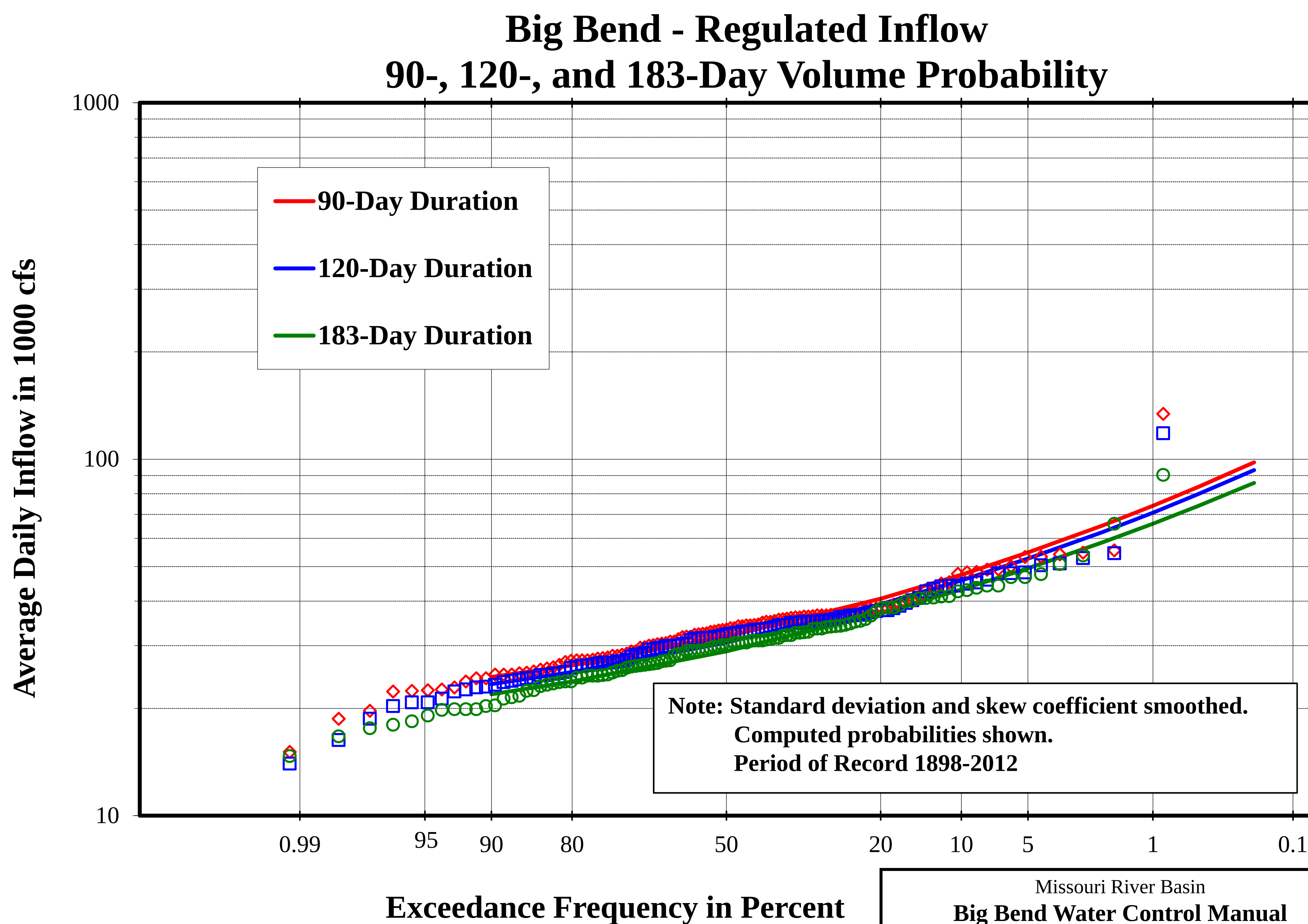
Big Bend - Regulated Inflow
1-, 3-, and 7-Day Volume Probability



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



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

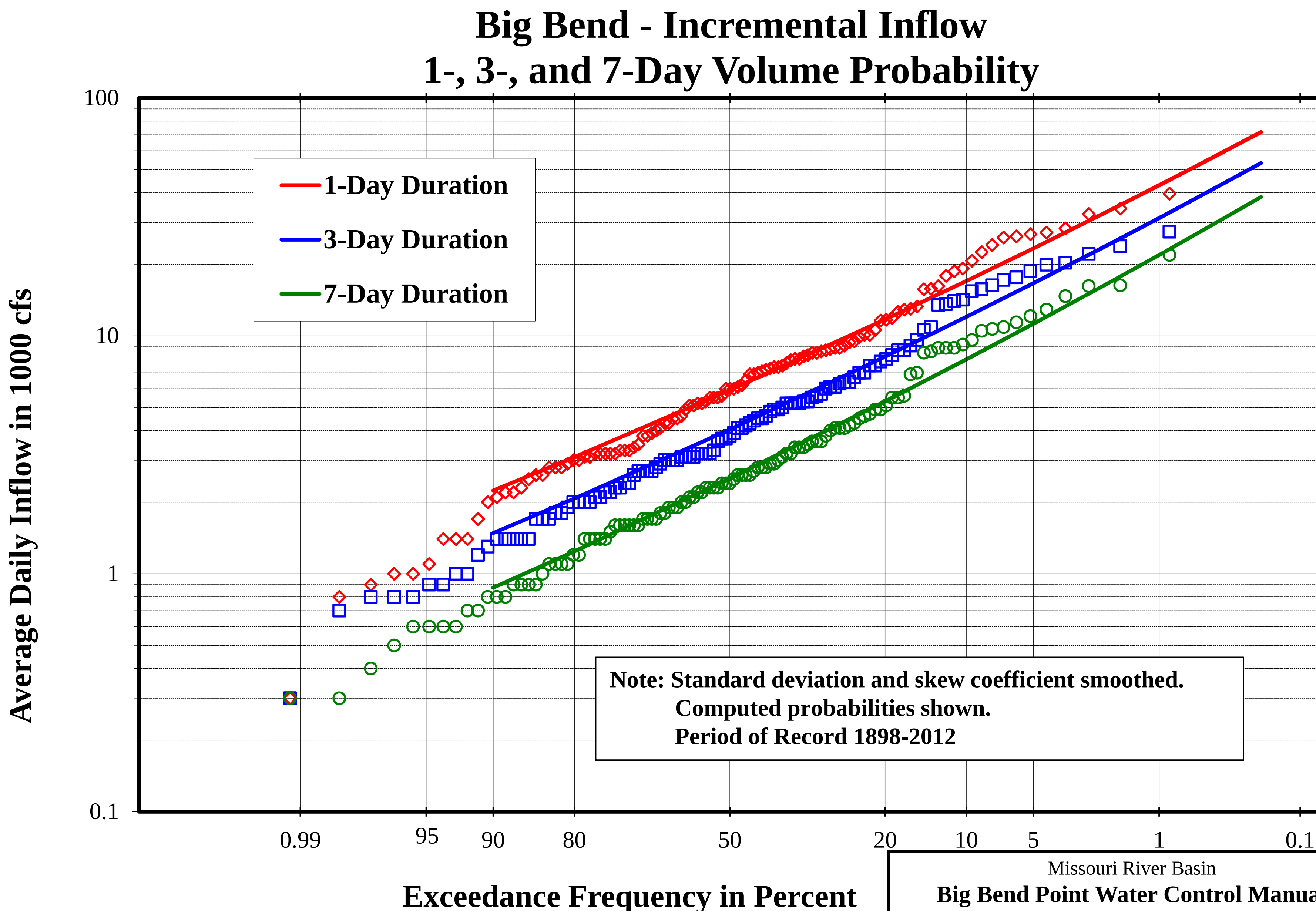


Missouri River Basin

Big Bend Water Control Manual

Big Bend Regulated Inflow Probability

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

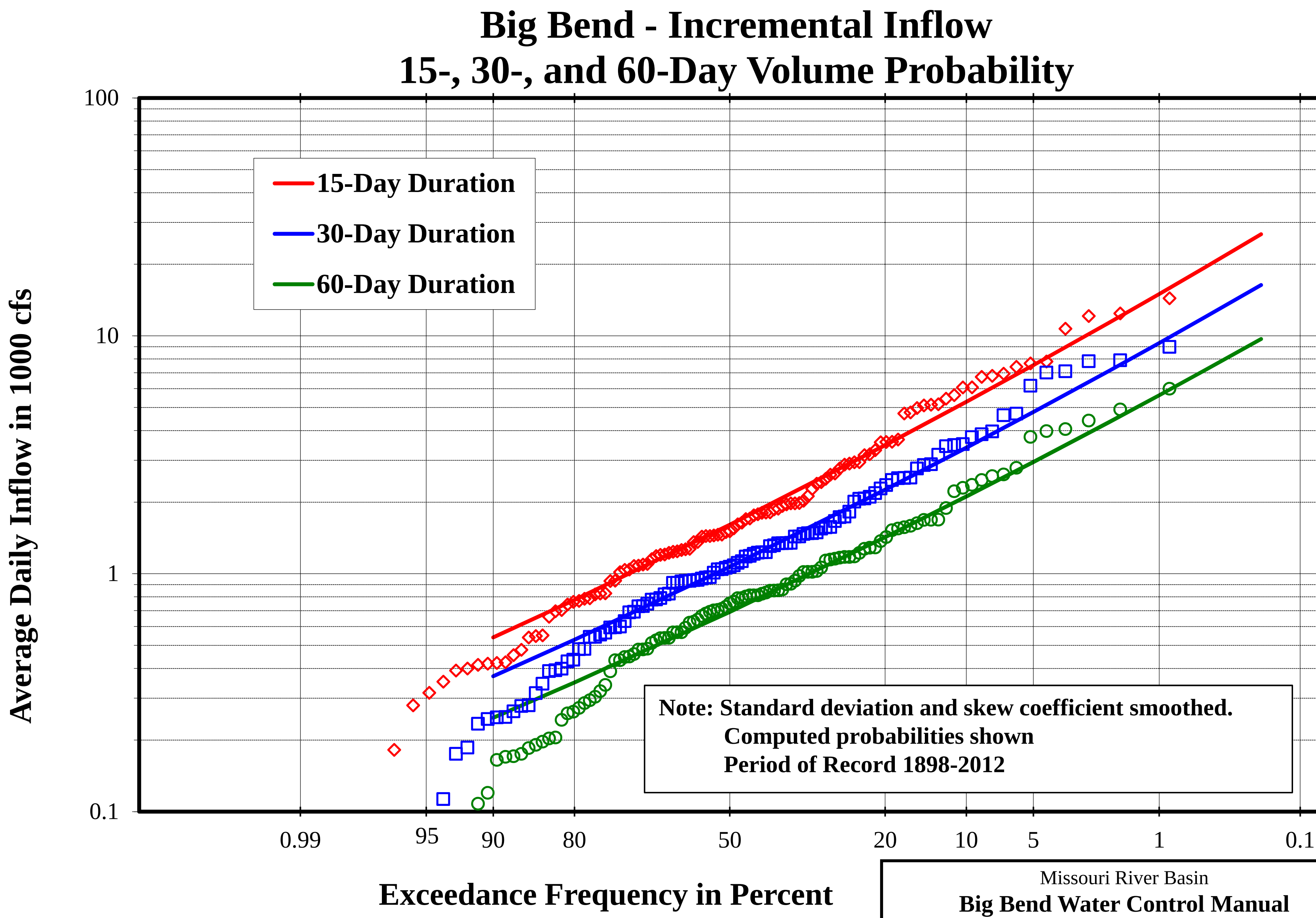


Missouri River Basin

Big Bend Point Water Control Manual

Big Bend Incremental Inflow Probability

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



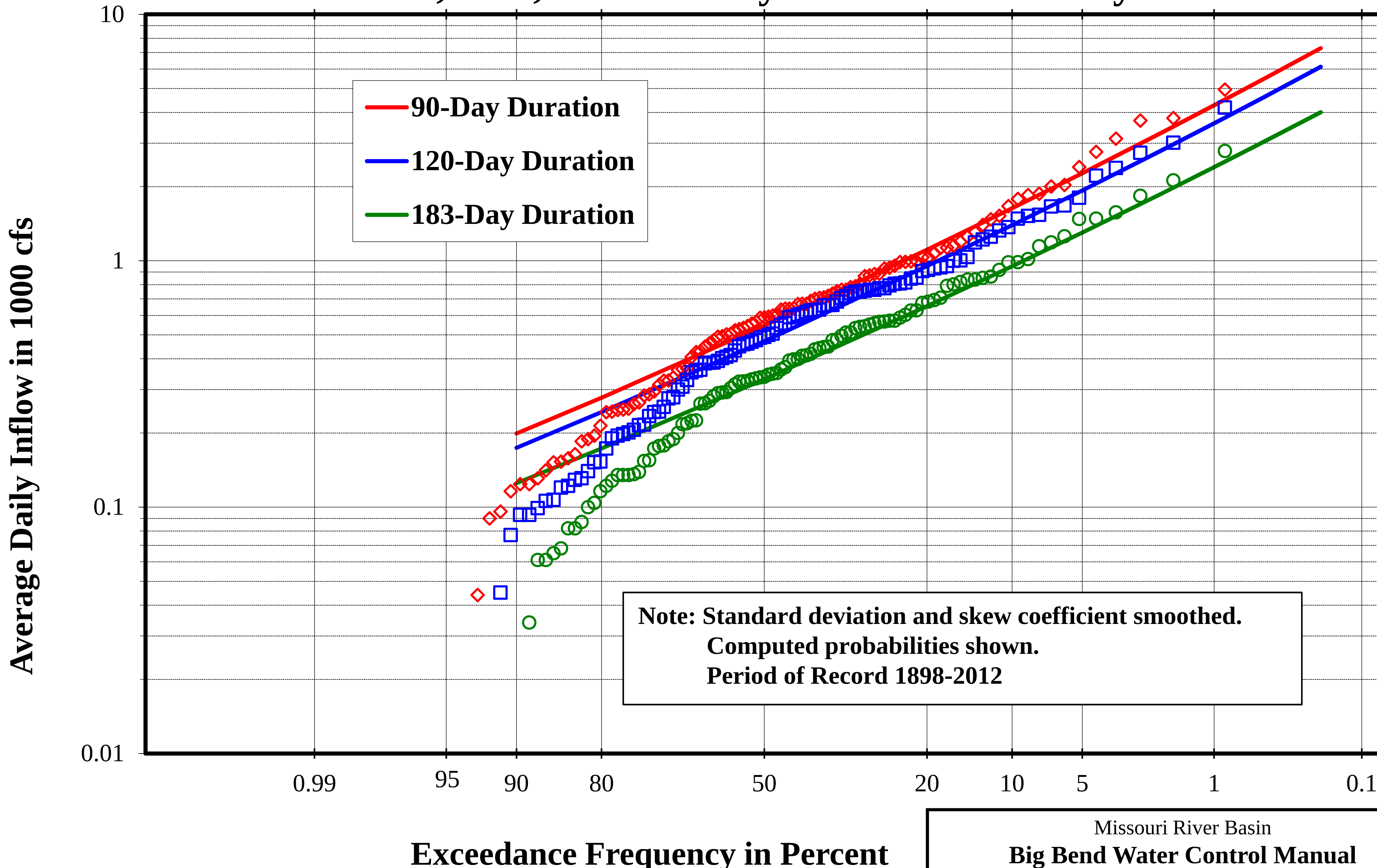
Missouri River Basin

Big Bend Water Control Manual

Big Bend Incremental Inflow Probability

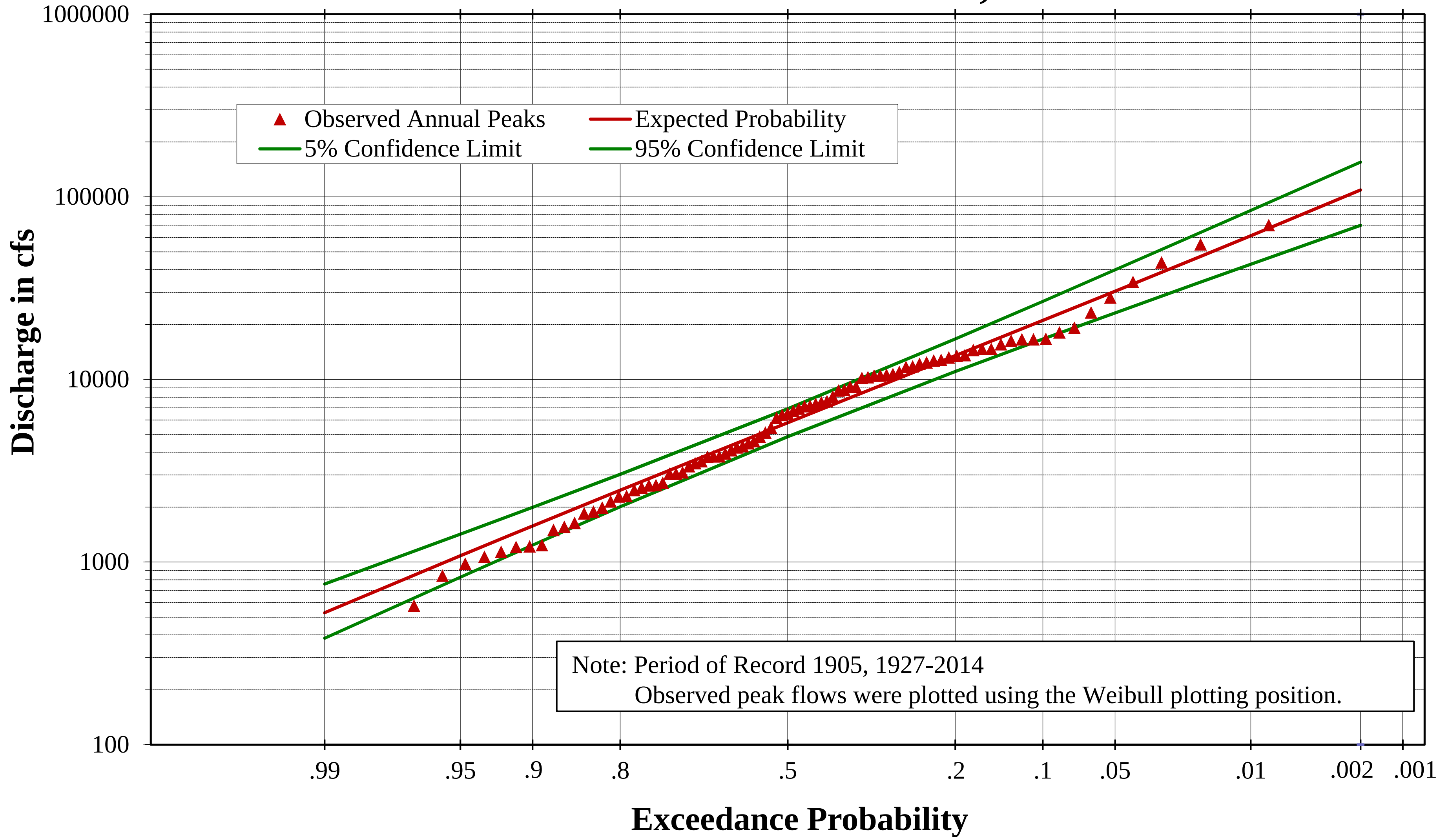
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Big Bend - Incremental Inflow
90-, 120-, and 183-Day Volume Probability



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

Bad River at Fort Pierre, SD

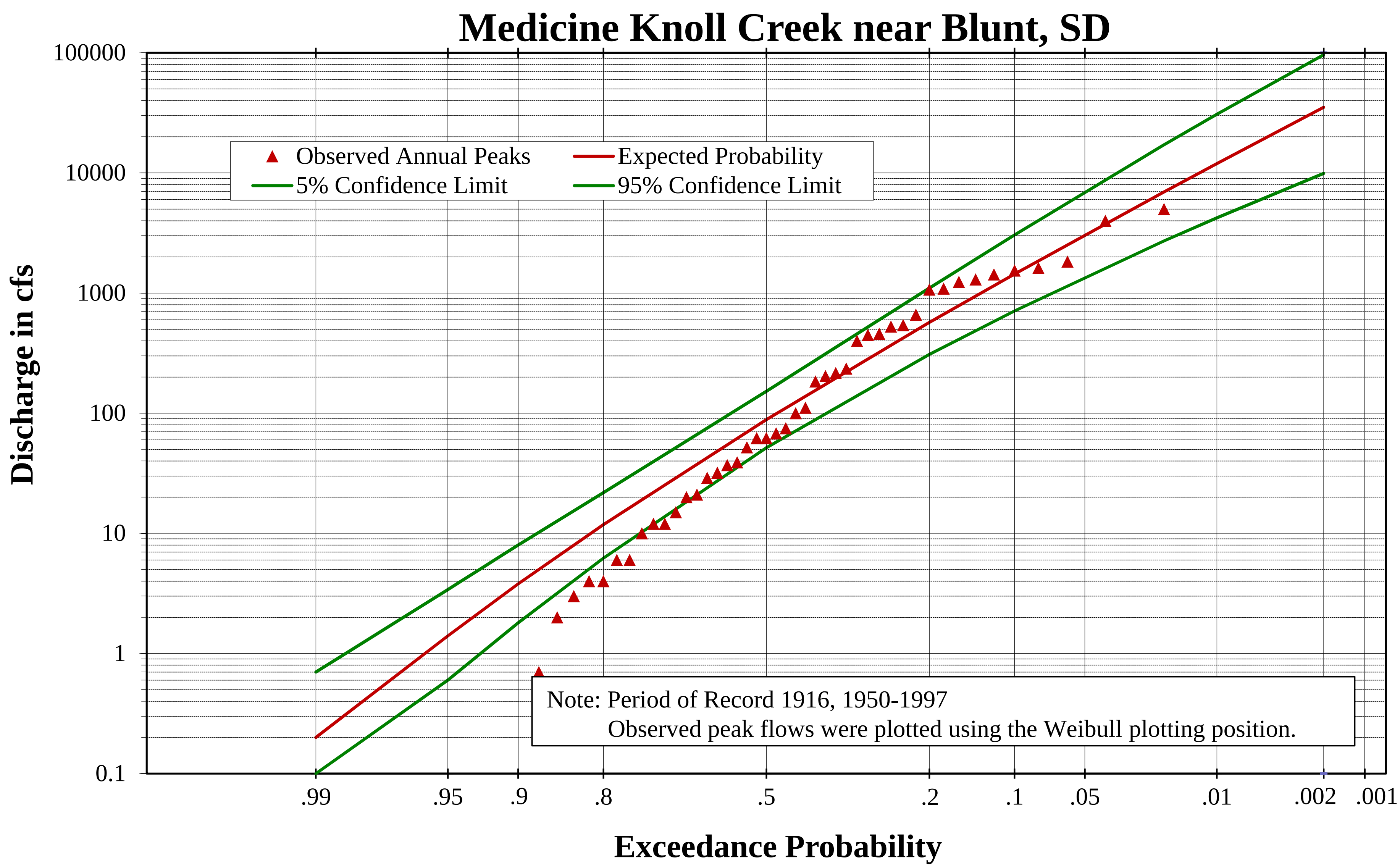


Missouri River Basin

Big Bend Water Control Manual

Probability Curve – Bad River at Fort Pierre, SD

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

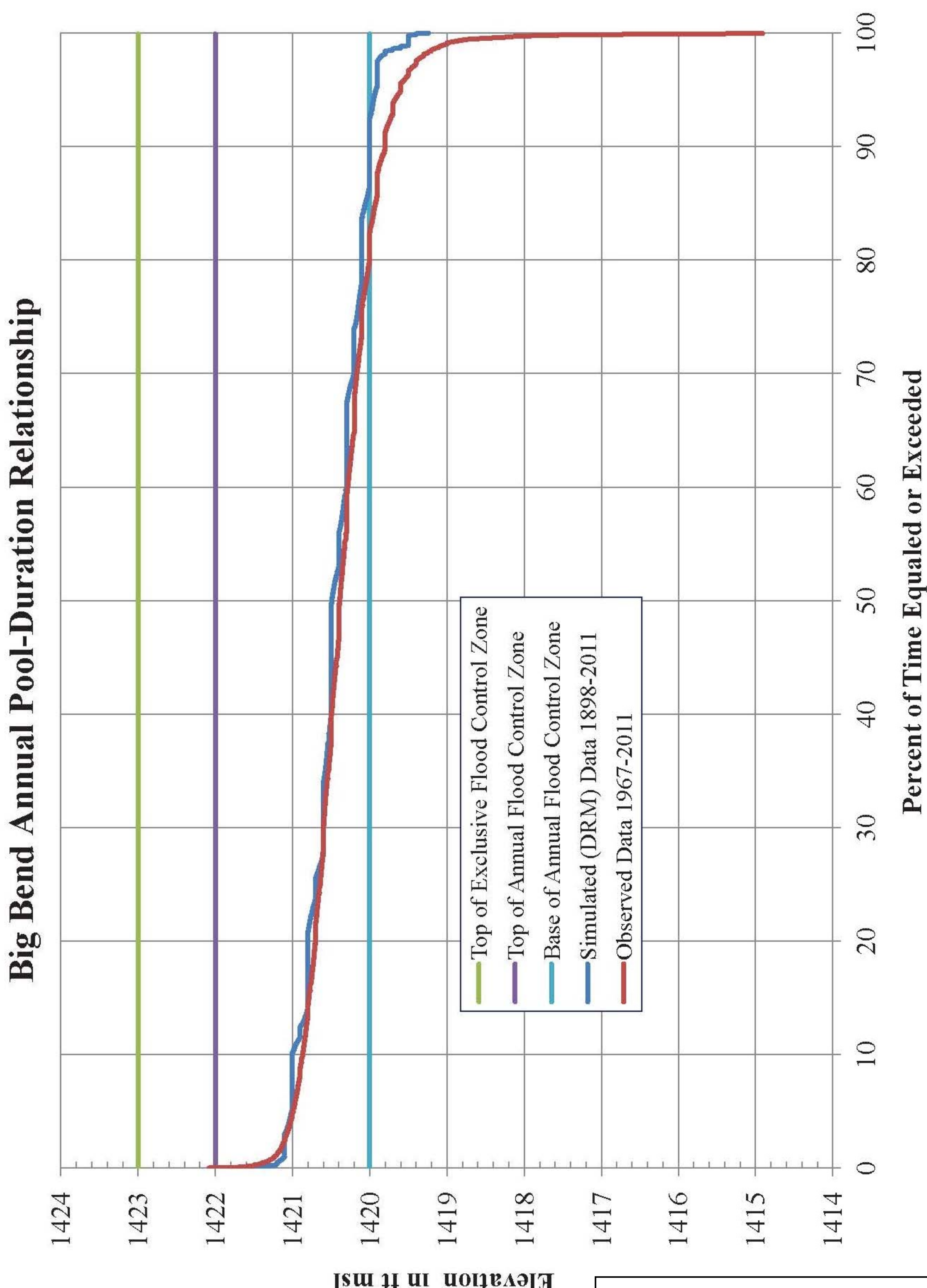


Missouri River Basin

Big Bend Water Control Manual

Probability Curve – Medicine Knoll Creek nr Blunt, SD

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

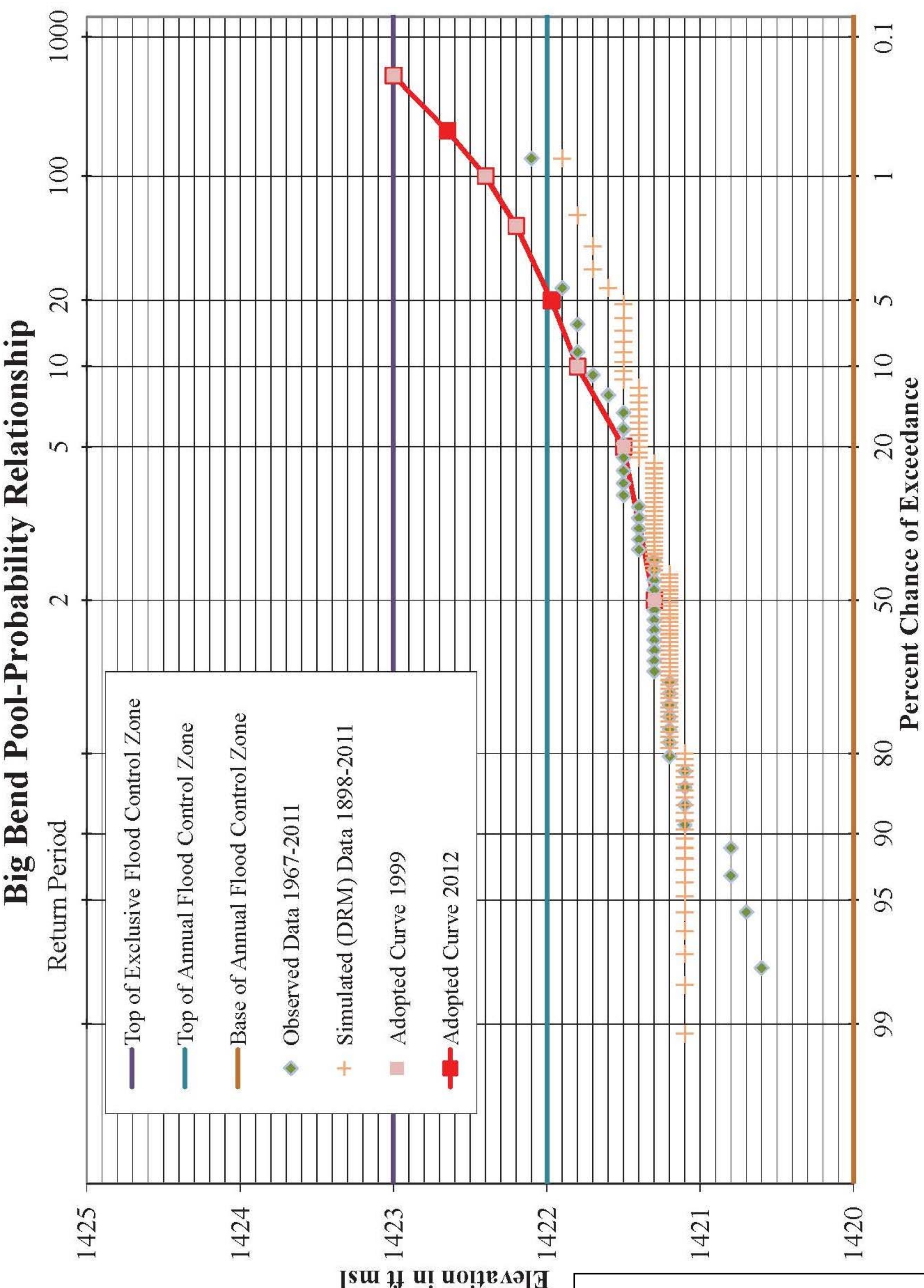


Missouri River Basin

Big Bend Water Control Manual

Big Bend Pool-Duration Relationship

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

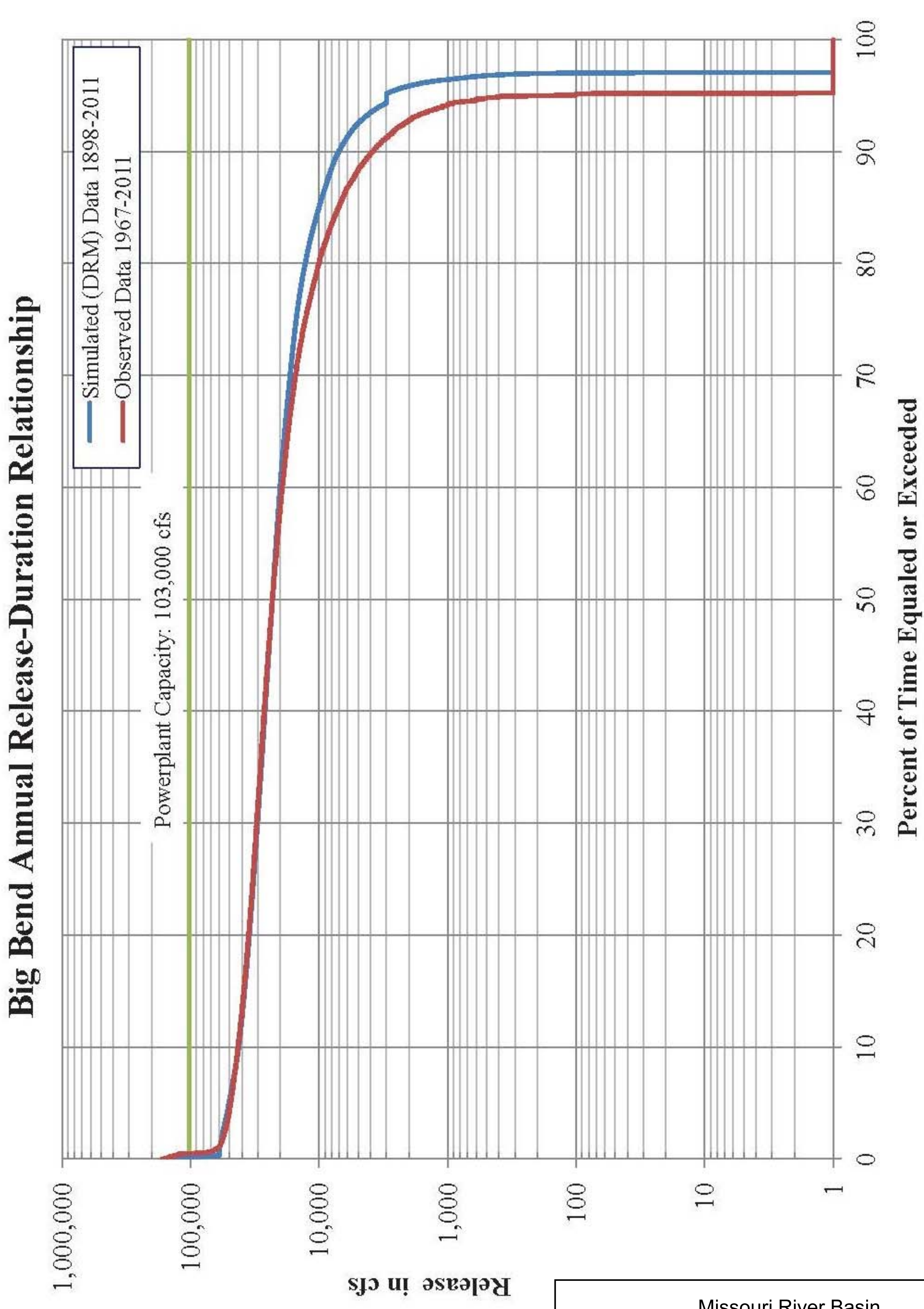


Missouri River Basin

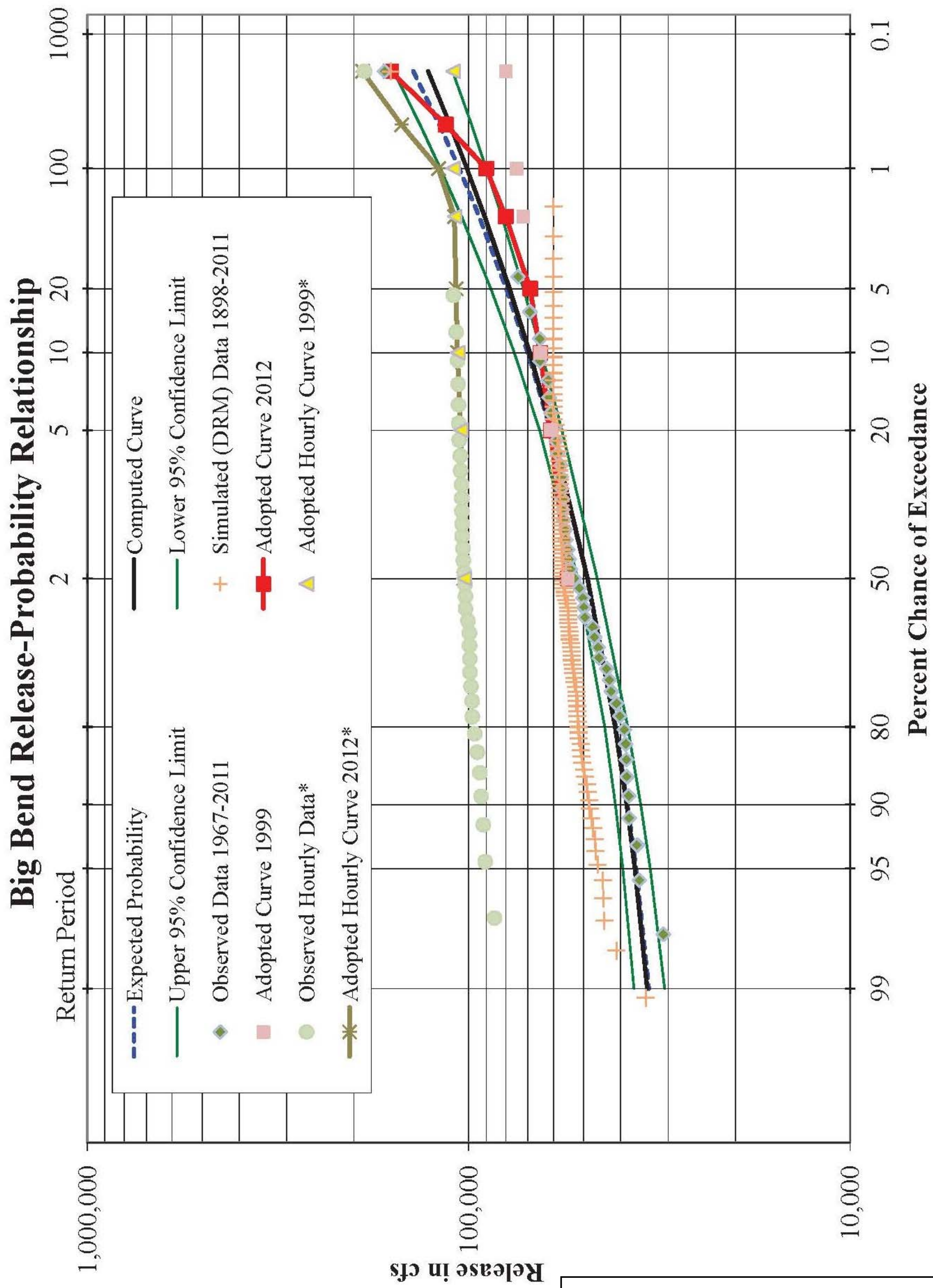
Big Bend Water Control Manual

Big Bend Pool-Probability Relationship

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



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

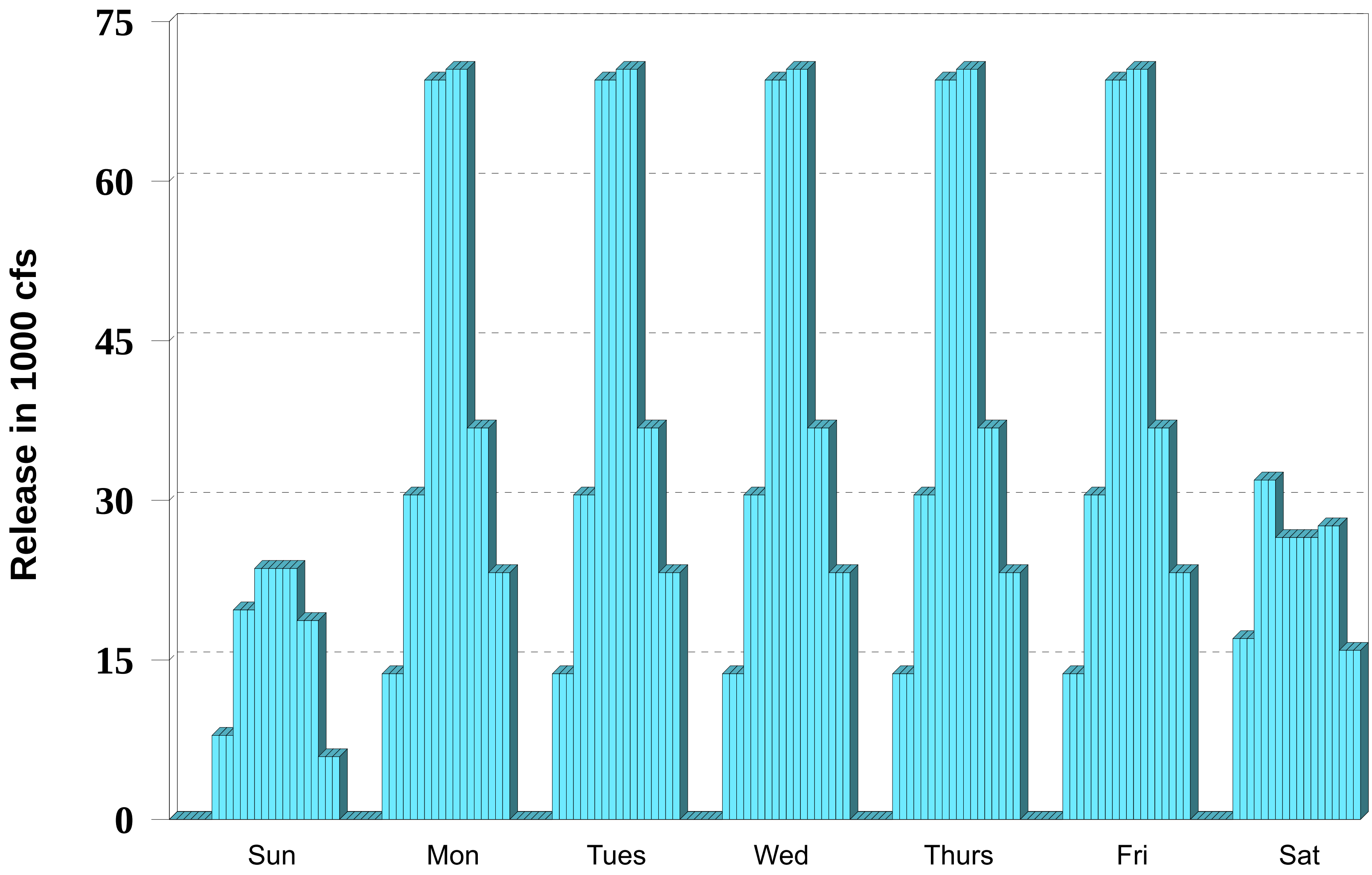


Missouri River Basin

Big Bend Water Control Manual

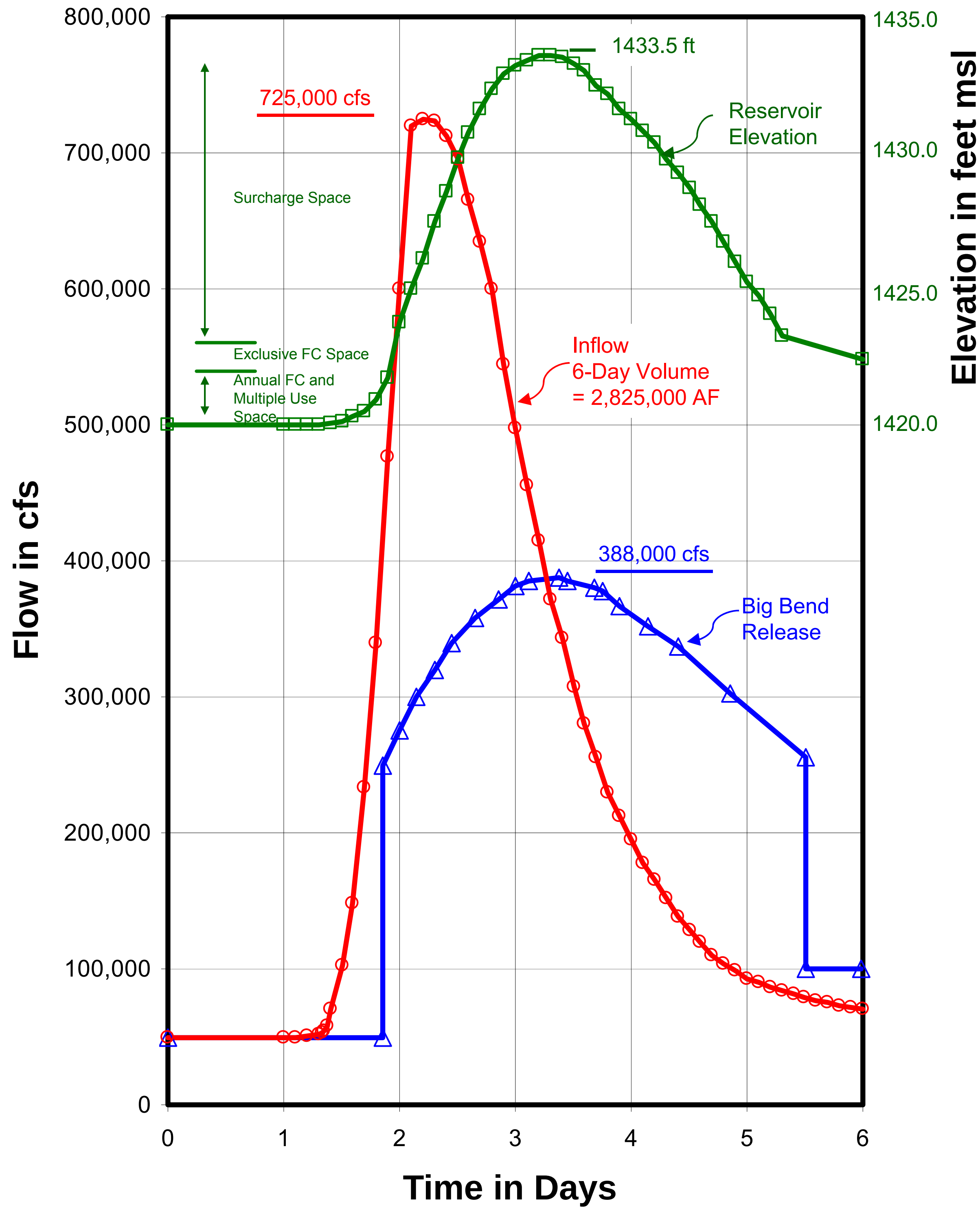
Big Bend Release-Probability Relationship

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



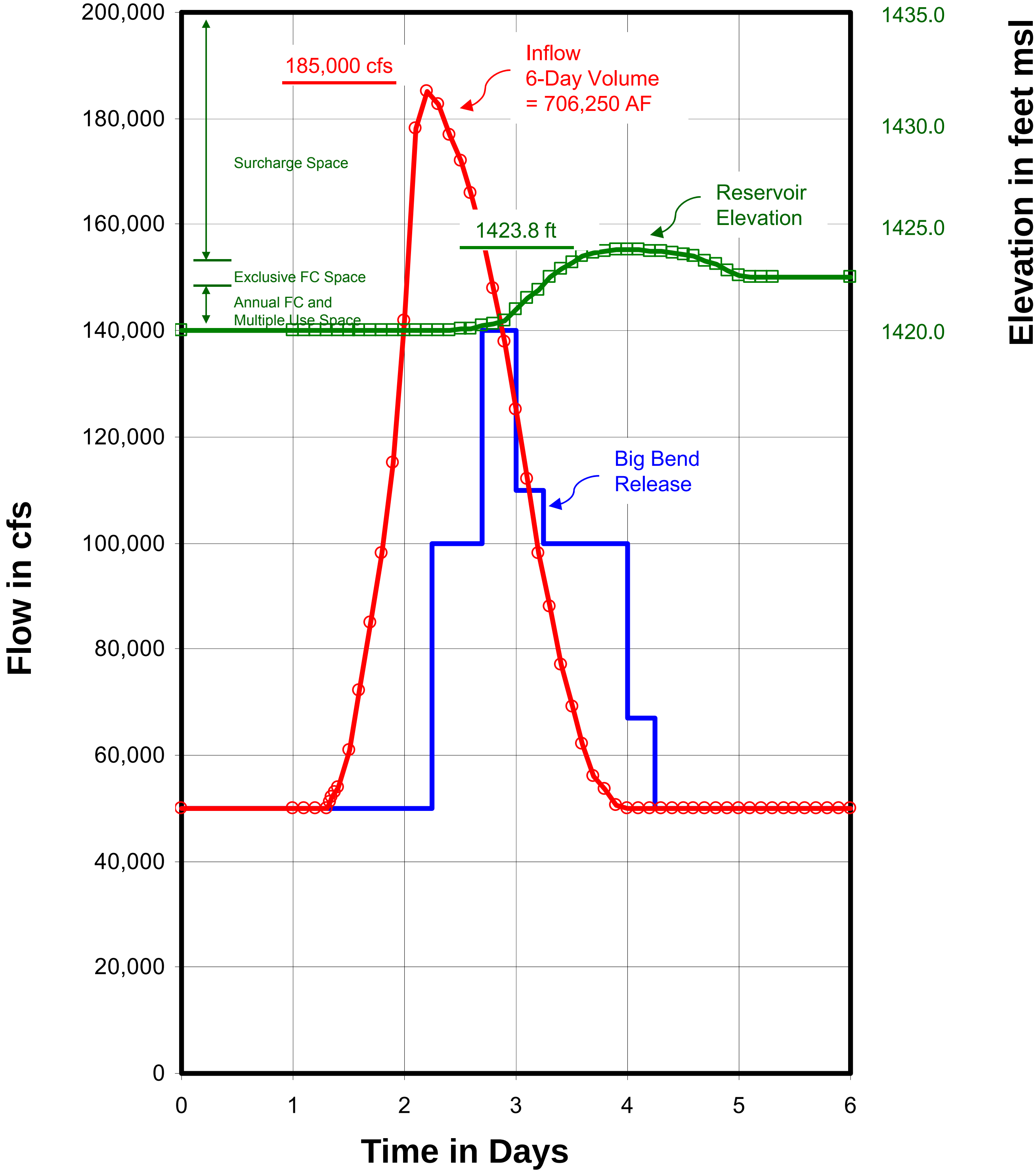
Missouri River Basin
Big Bend Water Control Manual
Typical Weekly Release Pattern

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



Note: Routing assumes 50,000 cfs release from Oahe Dam over the 6-day period.

Missouri River Basin
Big Bend Water Control Manual
Spillway Design Flood Routing
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

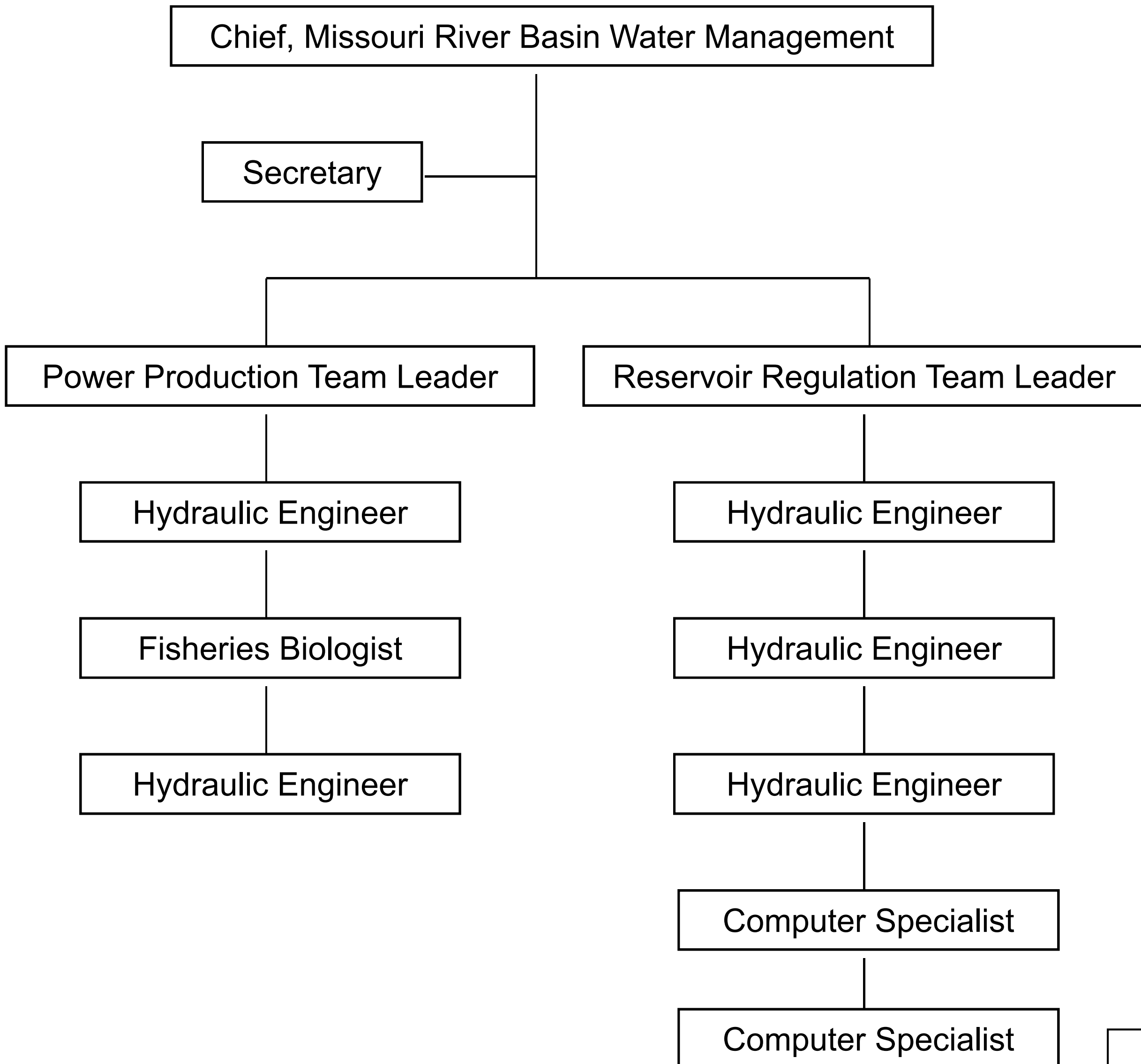


Note: Routing assumes 50,000 cfs release from Oahe Dam over the 6-day period.

Missouri River Basin
Big Bend Water Control Manual
One-Quarter Spillway Design Flood Routing
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

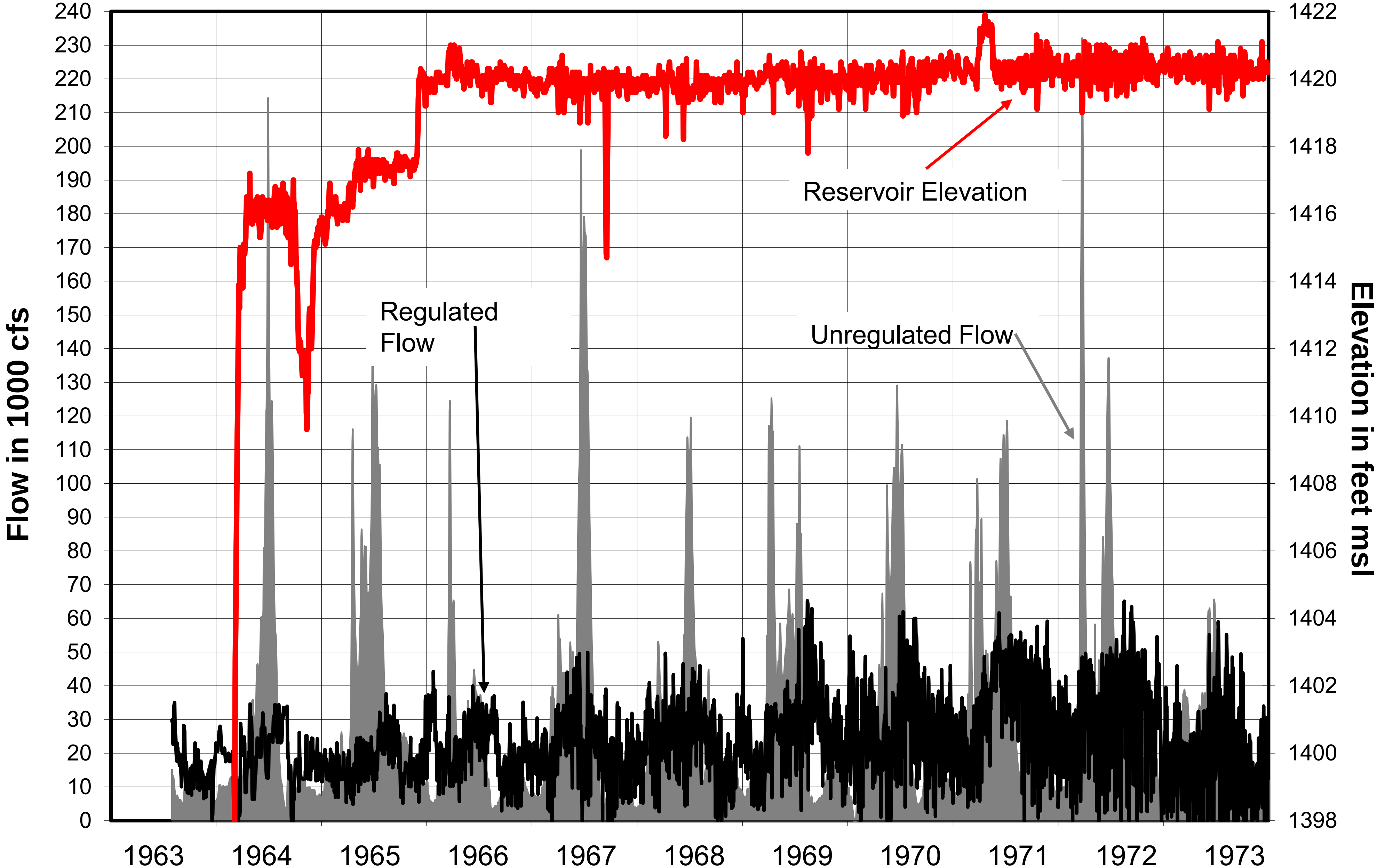
NWD-Omaha

Missouri River Basin Water Management Division



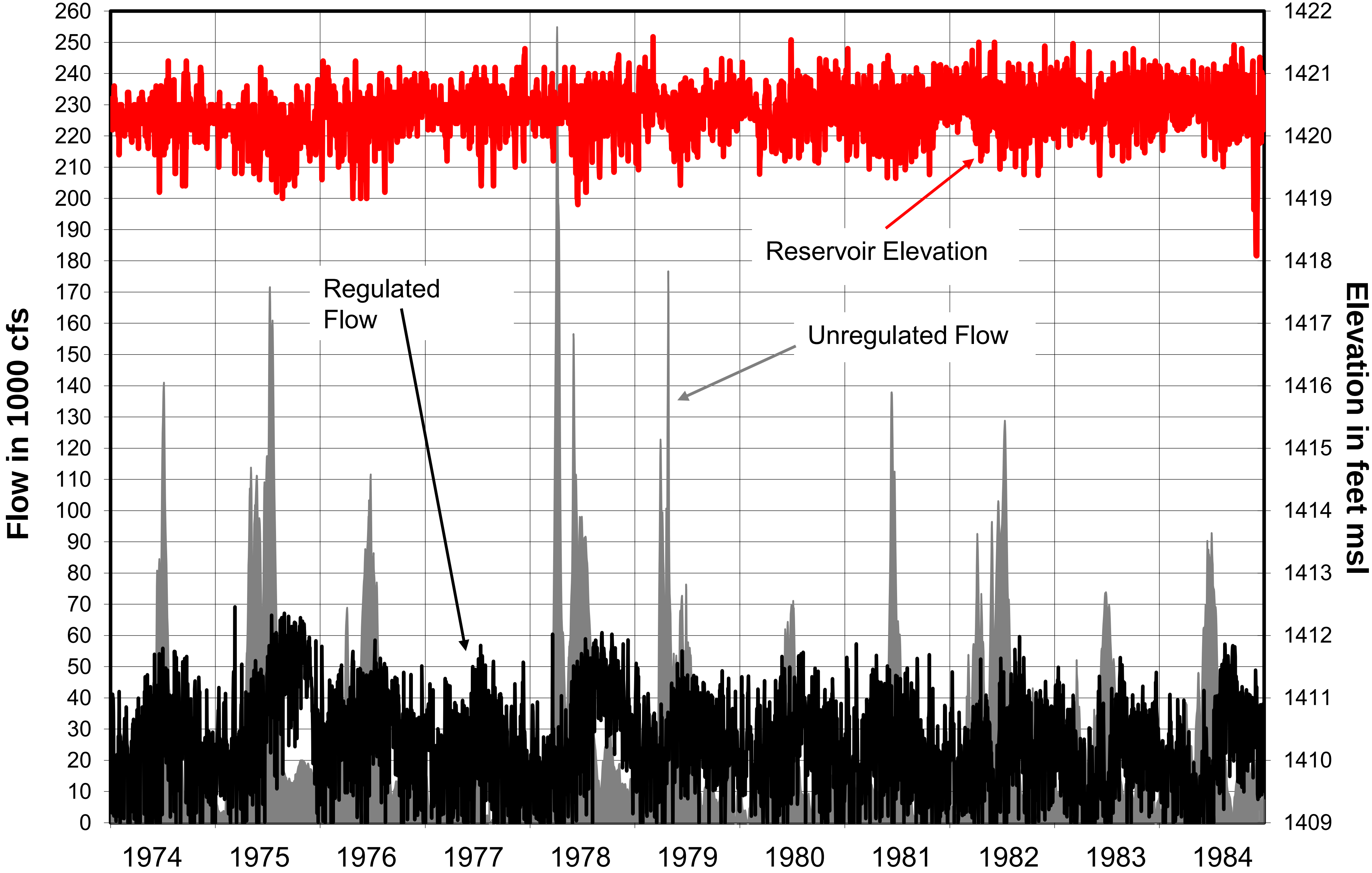
Budget Analyst is shared with Columbia River Basin Water Management

Missouri River Basin
Big Bend Water Control Manual
MRBWMD Organization Chart
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Big Bend Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1963-1973
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate A-1



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Big Bend Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1974-1984
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Corps of Engineers, Omaha, Nebraska
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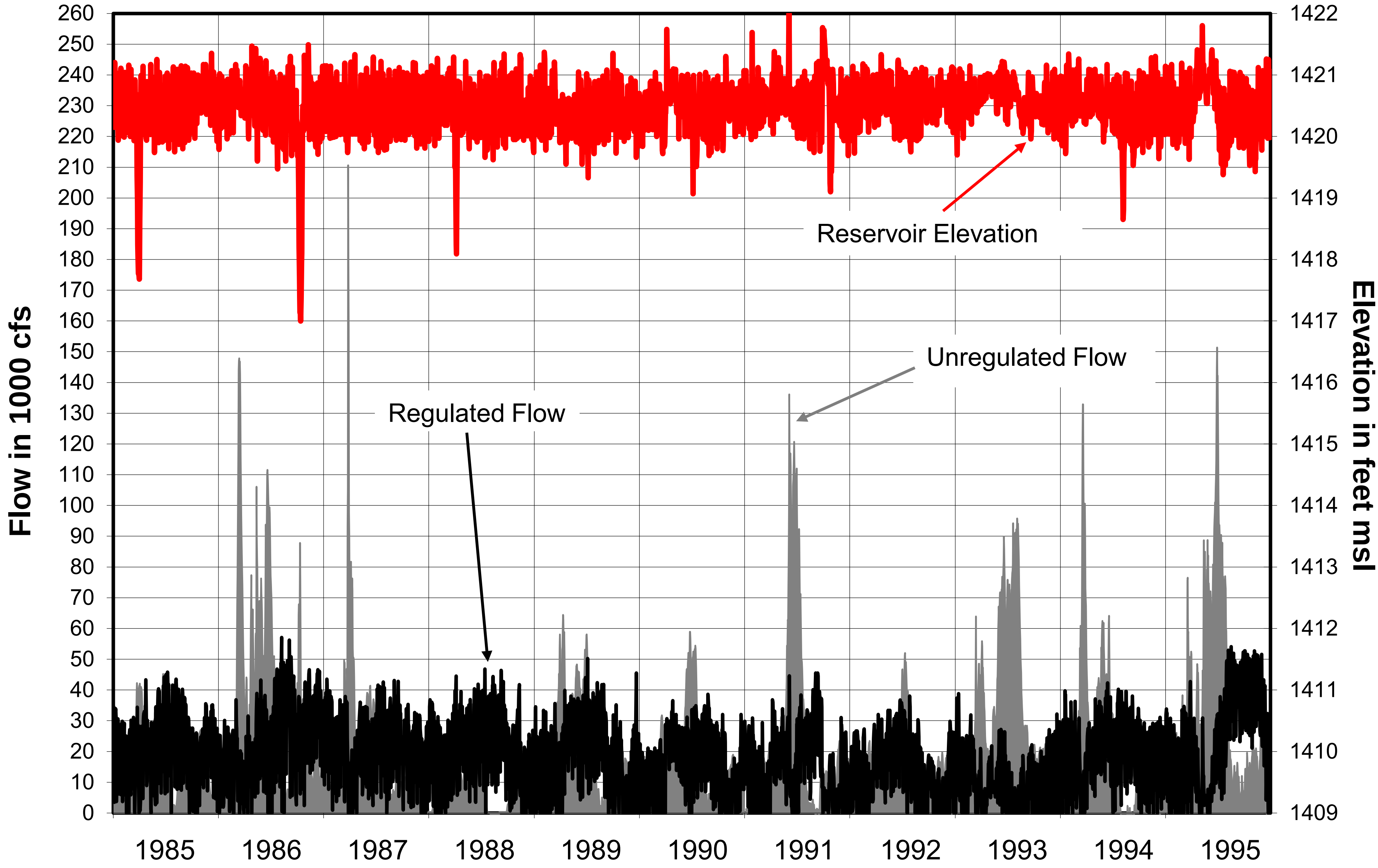

Missouri River Basin

Big Bend Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1985-1995

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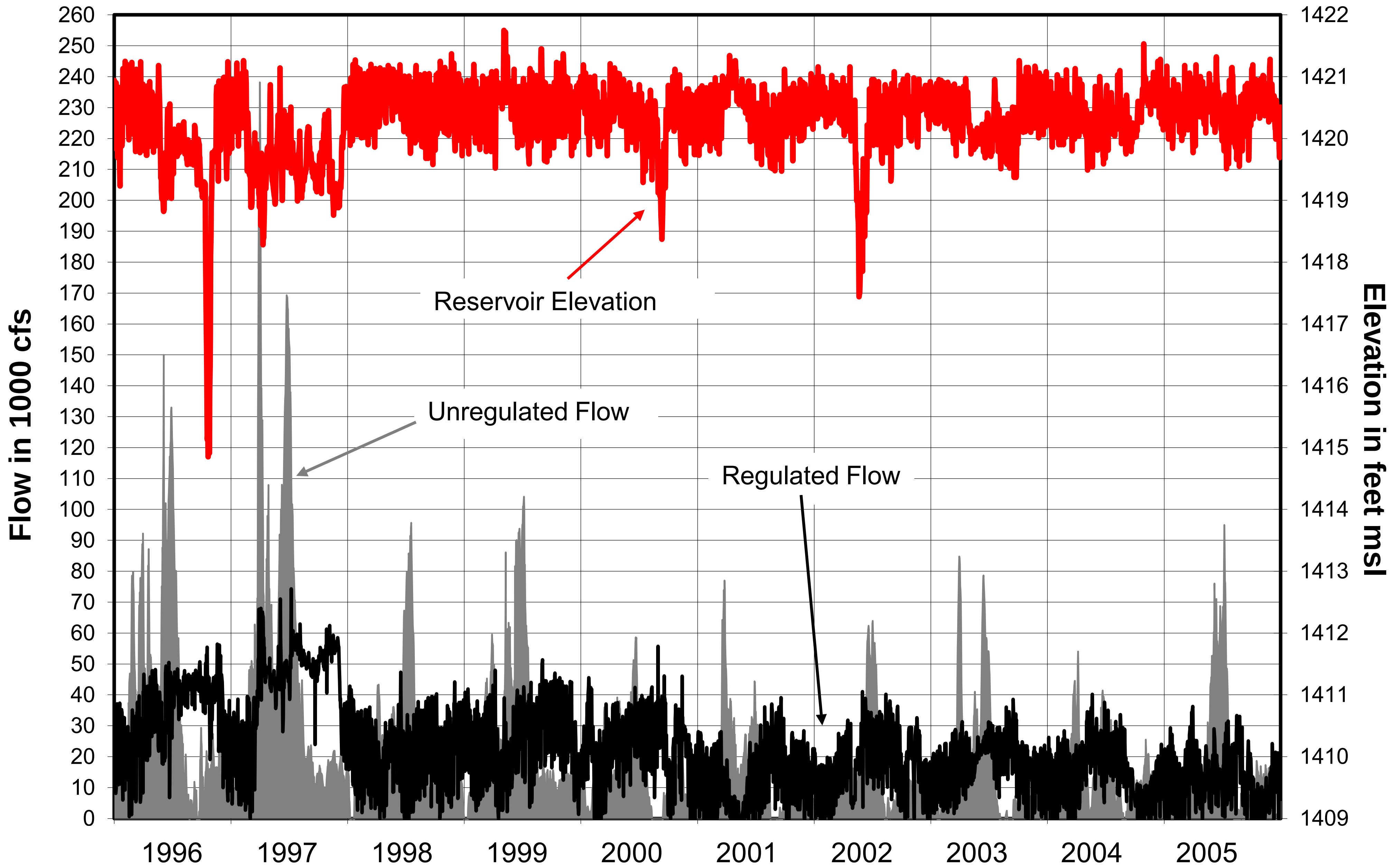

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Big Bend Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1996-2005
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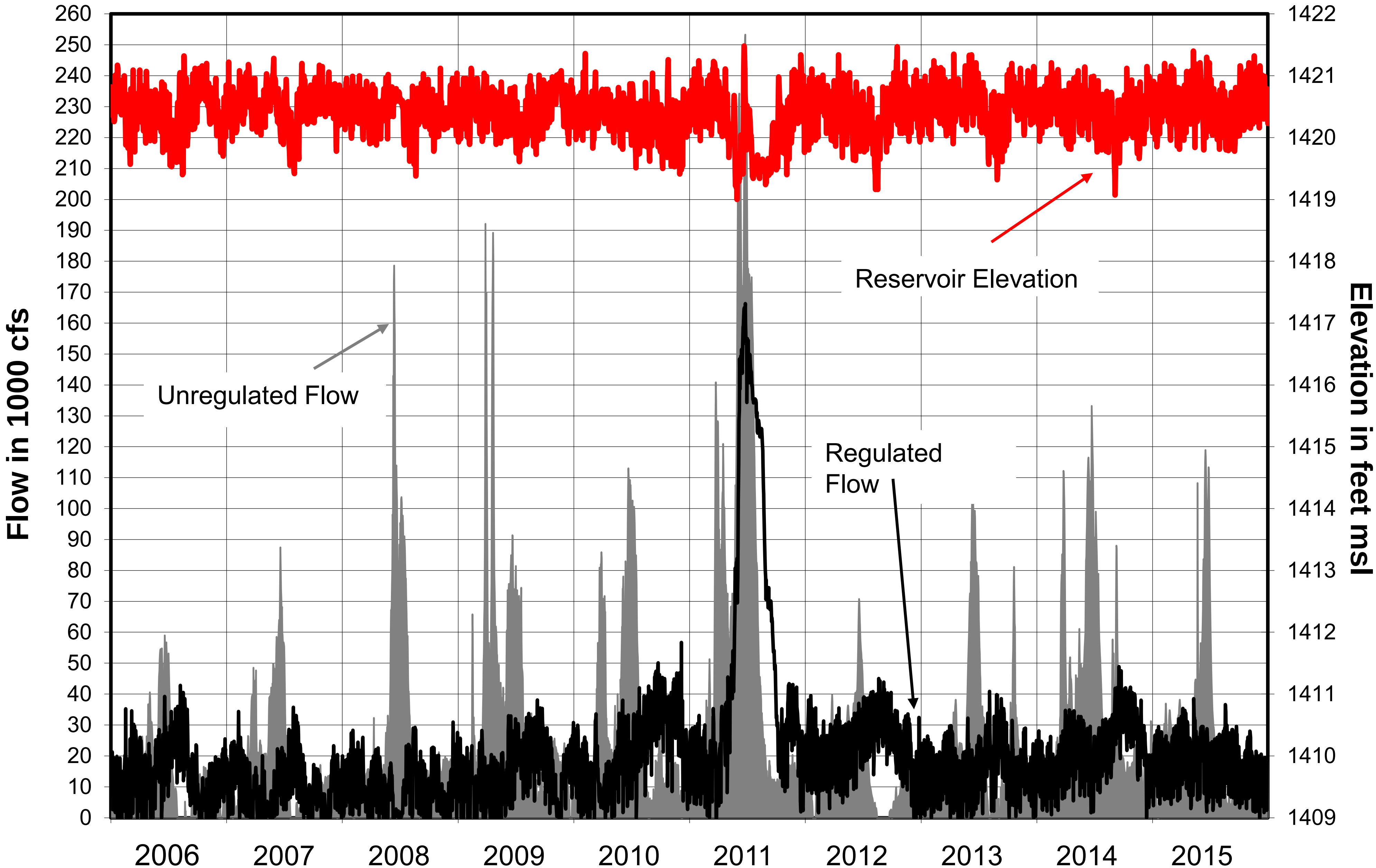
September 2017



Missouri River Basin
Big Bend Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 2006-2015
U.S. Army Engineer Division, Northwestern
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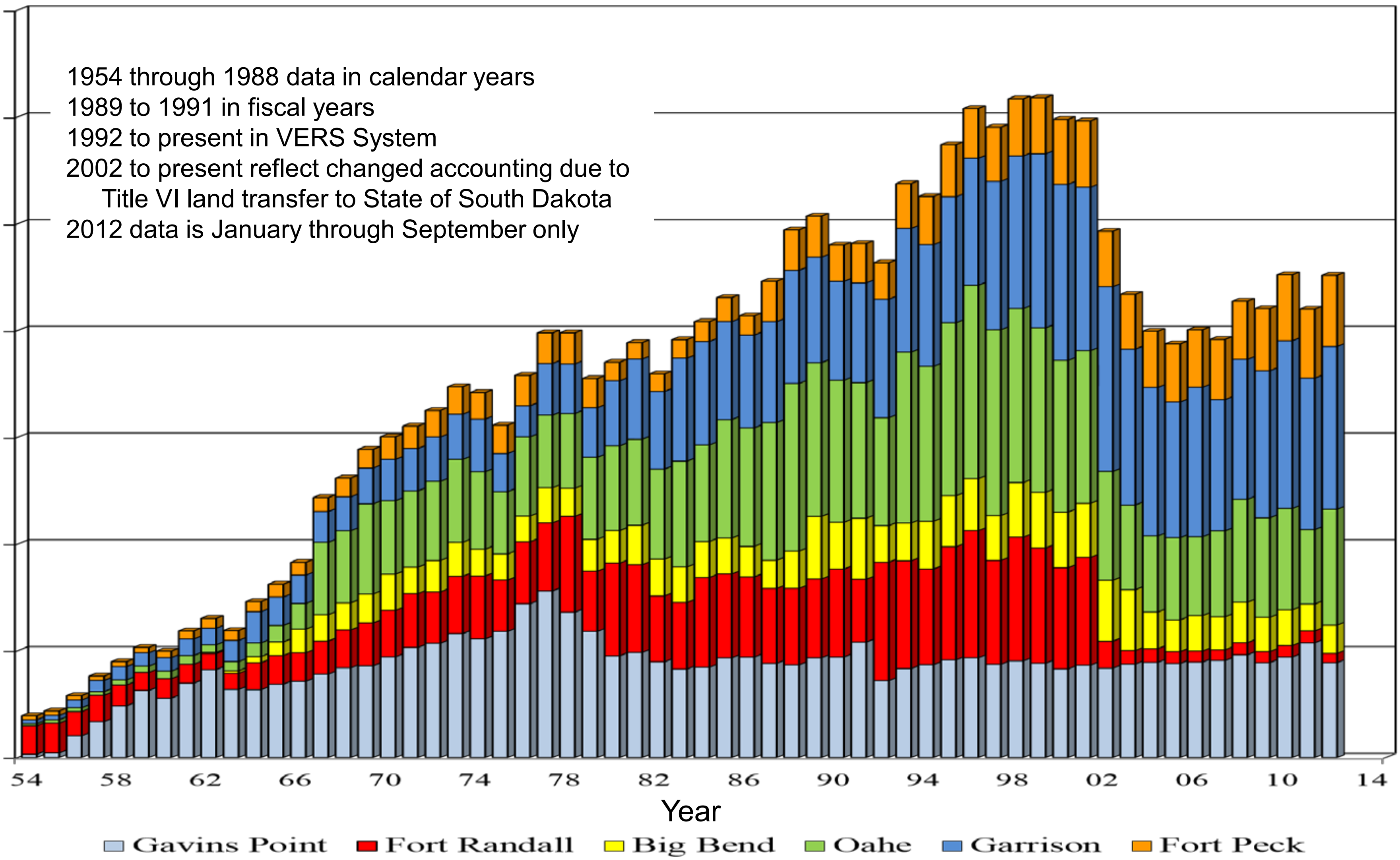
September 2017

Plate A-5

Mainstem Project Visits

1954 to 2012



Missouri River Basin
Big Bend Water Control Manual
Mainstem Project Visitor Hours

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