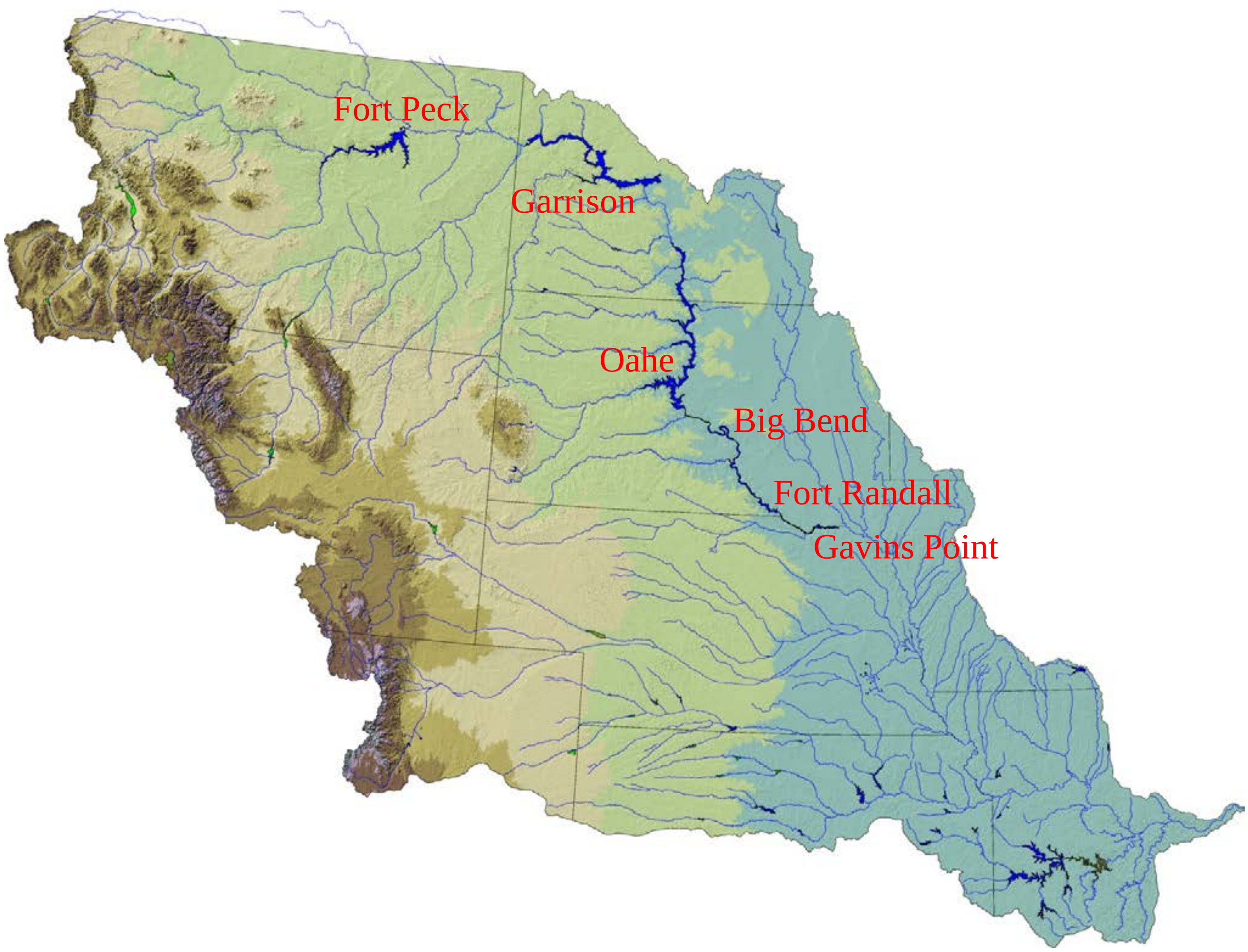
US Army Corps of Engineers ®
Northwestern Division

Missouri River Mainstem Reservoir System

Water Control Manual

Fort Randall Dam – Lake Francis Case



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

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Missouri River Basin
Mainstem Reservoir System
Water Control Manual

In 7 Volumes — Volume 6

FORT RANDALL 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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Missouri River Basin
Mainstem Reservoir System
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In 7 Volumes Volume 6

FORT RANDALL PROJECT

IV – Project Description and History

V – Data Collection and Communication Networks

VI – Hydrologic Forecasts

VII – Current Water Control Plan

VIII – Water Management Organization

APPENDICES

EXHIBITS

TABLES

PLATES

ABBREVIATIONS / ACRONYMS

AF	-	acre-feet
AOP	-	Annual Operating Plan
BIA	-	U.S. 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
DPR	-	Definite Project Report
DRM	-	Daily Routing Model
EM	-	Corps' Engineering Manual
EPA	-	Environmental Protection Agency
ER	-	Corps' Engineering Regulation
ESA	-	Endangered Species Act
°F	-	Degrees Fahrenheit
GF&P	-	Game Fish and Parks
kAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kV	-	kilovolt
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
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
NPS	-	U.S. National Park Service
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)
rpm	-	revolutions per minute
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
TSI	-	trophic state index
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
WRDA	-	Water Resources Development Act
WMS	-	Water Management System

Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

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 Fort Randall, 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 Fort Randall 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 Fort Randall. 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 the same as the name of the dam) and one is for total System regulation (Master Manual):

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

1-02.1. This individual project WCM serves as a supplement to the Master Manual (Volume 1) and presents aspects of project regulation not common to the System as a whole. This includes detail on the incremental drainage areas regarding hydrology, hydrologic networks, forecasting, streamflow and runoff. This WCM also includes site-specific maps and regulation considerations. This individual project WCM, like the Master Manual, serves as a guide to the Missouri River Basin Water Management (MRBWM) Division in meeting the operational objectives of the System when regulating the six System reservoirs. Since Fort Randall is part of the System, any discussions regarding the regulation of Fort Randall 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 Fort Randall WCM supplements the Master Manual by discussing the factors pertinent to the regulation of Fort Randall. The regulation of major tributary reservoirs located within the Missouri River basin affecting the regulation of Fort Randall 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 Fort Randall and serves as a supplement to the Master Manual.

1-03.2. In a further effort to reduce redundancy among the individual project WCMs, frequent reference will be made to the Big Bend and Gavins Point WCMs in connection to Fort Randall inflows and releases. With the relatively small incremental drainage area contributing directly to the Fort Randall reservoir, the small amount of runoff usually originating from this area, and regulation procedures applicable to Fort Randall, releases from Big Bend defines both inflows and releases from Fort Randall most of the time.

1-04. Project Owner. Fort Randall 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 Fort Randall. 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 Fort Randall, as well as the other System projects, to carry out the day-to-day operation (based on the reservoir regulation/power production orders received from the MRBWM office in Omaha) and maintenance of each project. All System dams have hydropower as an authorized purpose and are automated into a system called the Powerplant Control System (PPCS) for regulation of hydropower production and project releases. The Western Area Power Administration (Western) uses the System projects as an integral part of the Midwest power grid. Reservoir regulation/power production orders, reflecting the daily and hourly hydropower limits imposed on project regulation, are generated by the MRBWM office and sent to each mainstem project on a daily basis, or more frequently, as required. Also during critical periods, coordination between project personnel and MRBWM staff is conducted on an as-needed basis to ensure that expected release rates are achieved.

1-06. Regulating Agencies. As the Fort Randall 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 Fort Randall. These are provided for reference only and should not be used for construction or other purposes. Fort Randall has two local datums as shown in the table.

Table I-1
Fort Randall Datums (in feet)

Local project datum	NGVD29	NAVD88
0.0	-0.0126/-0.035	+0.937/+0.915
(ex.) 1355.0	1354.987/1354.965	1355.937/1355.915

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Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

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 Fort Randall, as it exists today, was not included in the document, the report did propose construction of reservoirs on both the main stem of the Missouri River and on tributary streams in the Missouri River basin together with levees along the lower Missouri River as a flood control measure. The beneficial influence of the reservoirs on Missouri and Mississippi River navigation was also recognized.

2-01.1. House Document 475 (78th Congress, 2nd Session, 1944) presented the Corps' plan for the overall development of the main stem of the Missouri River. This document proposed a dam at the Fort Randall site, together with other projects along the main stem of the Missouri River with such modifications as the Secretary of War and the Chief of Engineers might find advisable. U.S. Bureau of Reclamation (USBR) plans for Missouri River development, as contained in Senate Document 191, 78th Congress, also proposed a series of dams along the main stem of the Missouri River, differing in some extent from those envisioned by the Corps. The difference between the plans were adjusted in an inter-departmental conference and the coordinated plan, including Fort Randall near its present site, was presented to Congress in Senate Document 247, 78th Congress, 2nd Session, otherwise known as the "Pick-Sloan Plan". Legislative history of the System and individual projects are described in greater detail in Chapter II of the Master Manual.

2-01.2. Fort Randall 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. Fort Randall was planned and constructed by the Corps' Omaha District under supervision of the Missouri River Division (MRD) and the Chief of Engineers. The Definite Project Report (DPR) was prepared by the Omaha District and was published in June 1946. Construction began in August 1946 with diversion of the Missouri River through the constructed outlet works accomplished in 1952. The first power unit started generating commercial energy in March 1954. Most major construction activities were completed by 1956.

2-03. Construction History. The initial construction contract for Fort Randall was awarded in August 1946 for relocation of U.S. Highways 18 and 281 to provide access to the damsite. Construction of government housing and administration facilities soon followed. Initial earthwork began in September 1947 with diversion of the Missouri River through the completed outlet works and closure of the dam accomplished in July 1952. Storage space for deliberate regulation of inflow was available in 1953. The first power unit became operational in early 1954 with additional units placed on line in the following months and the final unit placed in operation in January 1956. Plate II-1 presents a summary of the significant dates of the System dams' construction, diversion, closure, filling of the minimum operating pool, and initial generation of the first and last units.

2-04. Relocations. Construction of Fort Randall involved the relocation of 31 miles of federal highway, 33 miles of state highway and 9 miles of other roads. U.S. Highway 18 crossing the Missouri River was moved from a bridge 17 miles upstream from Fort Randall Dam to the dam. U.S. Highway 281 was relocated in a similar manner. The crossing of U.S. Highway 16 at the city of Chamberlain, SD required raising the existing Missouri River bridge and modification of the approach. Since Fort Randall began operation, a crossing of Interstate Highway 90 near Chamberlain has been constructed as well as the Platte-Winner bridge over the reservoir some 41 miles above Fort Randall Dam. A new bridge to carry the Chicago, Milwaukee, St. Paul and Pacific Railroad across the Missouri River in the vicinity of Chamberlain was required as well as relocation of approaches to the bridge, and new depot and yard facilities in Chamberlain. It was necessary to relocate about 20 pole-miles of power, telephone and telegraph lines. Relocation or protection was required for portions of the developed area of Chamberlain and Oacoma, SD and the Native American Agency headquarters located adjacent to the reservoir area. It was also necessary to relocate six cemeteries containing approximately 400 Native American burial sites.

2-05. Real Estate Acquisitions. Approximately 114,163 acres in fee and 649 acres in easements were acquired for the Fort Randall project, including a total of 514 acres of flowage easements at 15 locations. In addition, Public Land Order transferred 173 acres from the Public Domain. Of the total initially acquired, approximately 15,000 acres were later included as necessary real estate for the upstream Big Bend project. The basis for real estate acquisition over most of the reservoir area was a guide-taking line at an elevation of 1375.0 feet.

2-06. Regulation History. Closure of Fort Randall Dam, together with the first impoundment of water in the reservoir, occurred in July 1952. This was the second of the System projects to be placed in operation. Initially Fort Randall was regulated in conjunction with the existing Fort Peck project for Missouri River navigation and the maintenance of sufficient downstream flows for domestic and industrial uses and for water quality purposes. Fort Randall power generation began in 1954 with the completion of power Unit No. 1 in March. Additional units were placed in operation during succeeding months with the eighth and final unit coming on line in January 1956. Inactive storage space (below elevation 1320.0 feet) was filled in June 1954 and the Carryover Multiple Use Zone was first filled (to elevation 1350.0 feet) in May 1957. Exclusive flood control storage space (above elevation 1365.0 feet) has been utilized only a few times: June 1967, May-June 1995, April-September 1997, June-July 2010 and June-August 2011. Further information concerning historical regulation is contained in Appendix A of this WCM. Detailed descriptions of each year's project regulation are detailed in the AOPs and yearly Summary of Actual Regulation Reports published by the MRBWM office.

2-06.1. As discussed in Chapter VII of this WCM, an annual fall drawdown of the Fort Randall reservoir is an important part of the regulation process designed to increase winter energy generation from the System. During drought years, it is also important in order to permit utilization of the power generation capability of the upstream Big Bend and Oahe powerplants when System releases must be reduced to conserve storage. During years before 1971 this drawdown was to approximately elevation 1320.0 feet prior to the start of the winter season. This annual drawdown resulted in considerable criticism from local interests. Cited were unsightly mudflats in the reservoir headwaters, blowing dust from exposed sandbars near Chamberlain, difficulty of access to the reservoir for stock watering, boat ramps out of the water, problems associated with fall irrigation, adverse effects on ice fishing, the discouraging effect on potential developments around the reservoir, and the general unfavorable impression created by the lowered reservoir level. In response to Section 226 of the Flood Control Act of 1970, a study of Fort Randall's water control plan was made. As a result of this study, criteria for Fort Randall regulation were changed to limit the late fall drawdown to no lower than elevation 1337.5 feet, except during drought and System refill periods when drawdown to as low as 1320.0 feet would be allowed as necessary to maintain winter release values of 15,000 cubic feet per second (cfs) from the upstream Oahe and Big Bend projects. Since 1971, the 1337.5 feet drawdown limit has been effective. Further details concerning these operational changes are outlined in the Omaha District report, *Modification of Operation of Lake Francis Case, South Dakota*, dated October 1972.

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Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

III - Basin Description and Characteristics

3-01. General Characteristics. The Missouri River basin drainage area upstream from Fort Randall includes all of Montana east of the continental divide, northern Wyoming, southwestern North Dakota, western 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 Fort Randall Dam is 263,480 square miles. This includes 57,500 square miles of drainage above Fort Peck Dam, 123,900 square miles between Fort Peck and Garrison dams, 62,090 square miles between Garrison and Oahe dams, and 5,840 square miles of drainage area between Oahe and Big Bend dams. Those portions of the Missouri River drainage area lying upstream from Big Bend are described in the Fort Peck, Garrison, Oahe and Big Bend WCMs. The portion of the Missouri River basin described in this WCM consists of the 14,150 square miles of drainage area between Big Bend and Fort Randall, as well as the drainage area contributing to the Missouri River in the reach immediately below Fort Randall. Further description of this downstream area is contained in the Gavins Point WCM. Plate III-1 is a general map of the Missouri River basin. The incremental drainage area defined by Big Bend and Fort Randall, and described in this WCM, is shown on Plate III-2.

3-02. Topography. The Missouri River drainage area between Big Bend and Fort Randall forms a portion of the Great Plains province of the United States. The area to the north and east of the Missouri River is within the Glaciated Missouri Plateau 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 Big Bend to Fort Randall 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 5,000 feet in the western part of the incremental drainage area to near 1,250 feet on the bottomlands adjacent to the Missouri River. The Badlands area of South Dakota, characterized by extremely rough topography, is contained within the drainage area.

3-03. Land Use. Agriculture represents the primary use of the land in this portion of the Missouri River basin. Forested and wetland areas comprise about 5 percent of the drainage area. The Missouri River and the Fort Randall reservoir account for about 1.5 percent of the total drainage area. The remaining land use consists of bare and residential areas. Woodlands, or forests, are generally restricted to bottomlands adjacent to streams or to woodlots and groves planted for protective or aesthetic purposes. Additionally, minor amounts of relatively sparse forests occur in extreme western portions of the incremental drainage area. 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 comprising less than 1 percent of total cropland. Water areas in this incremental drainage make up about 1 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 Big Bend to Fort Randall 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 located above Fort Randall is the large area of the upper Missouri River basin controlled by the Fort Peck, Garrison, Oahe and Big Bend projects. These upstream System projects control about 95 percent of the total drainage area contributing to runoff into Fort Randall, including all of the mountainous regions contributing flow to the Missouri River above Fort Randall.

3-04.1. The prominent feature of the Missouri River basin between Big Bend and Fort Randall, as shown in Plate III-2, is the White River, the only major tributary in this reach. The White River is a right bank tributary flowing in an easterly direction. This direction of flow is of particular importance from the standpoint of flow contribution from storms that typically move in an easterly direction. Additionally, it becomes important at the time of snowmelt and ice break-up in the spring since normal temperatures at that time in the tributary headwaters are significantly higher than at the tributary mouth, resulting in an aggravation to ice jamming near the mouth during the ice break-up period. 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 the region to the east will not contribute directly to streamflow unless substantial amounts of runoff were to occur that are sufficient to fill and overflow the low depressions that normally restrict runoff.

3-04.2. The headwaters of the White River begins in northwestern Nebraska, flows north-eastward through southwestern South Dakota and joins the Missouri River at River Mile (RM) 955 (1960 mileage) some 75 river miles above Fort Randall Dam and 32 river miles below Big Bend. The White River drains 10,200 square miles of the 14,150-square mile drainage area between Big Bend and Fort Randall. Left bank minor tributaries entering the Fort Randall reservoir include Crow Creek, Pease Creek and Platte Creek. Right bank minor tributaries include Bull Creek and Whetstone Creek. The drainage area of each of these minor tributaries is less than 1,000 square miles.

3-05. Stream Slopes. The total fall of the Missouri River from Big Bend to Fort Randall is about 115 feet, averaging about 1 foot per river mile. Tributary stream slopes are significantly steeper, generally averaging between 5 and 8 feet per mile. Slopes at the tributary streams progressively tend to flatten toward their mouths.

3-06. Climate. The Big Bend to Fort Randall incremental drainage area of the Missouri River basin is located near the geographical center of the North American continent. While the region 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. Annual precipitation over the Big Bend to Fort Randall drainage area generally increases from west to east, ranging from about 16 inches over portions of the White River to about 23 inches at Fort Randall. 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 incremental drainage area between the Big Bend and Fort Randall dams usually occurs as snow during the months of November through March and as rain during the remainder of the year. About 75 percent of the total yearly precipitation occurs during the rainfall season, with May, June and July normally being the wettest months. Most rainfall occurs in showers or convective thunderstorms; however, steady rains lasting for several hours or a day or two may occasionally occur. Excessive rainfall over a relatively large area is unusual. More common are intense, convective thunderstorms resulting in large precipitation amounts in a short period of time over a very restricted area.

3-06.3. Snow. Precipitation occurring as snow usually is at a very slow rate. During the entire winter season about 24 to 36 inches of total snowfall can usually be expected through most of the incremental region. 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 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 degrees or colder during the mid-winter period. Winters are long and cold. Cold temperatures may be interrupted during periods of downslope, or “Chinook”, winds when mild temperatures, for the season, prevail. Moderate temperatures usually prevail during the non-winter season, 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 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 Fort Randall reservoir is about 3 feet. This evaporation loss equates to approximately 247,000 acre-feet (AF) of volume as presented on Plates III-9 through III-12. Evaporation studies made by the MRBWM office conclude that the average annual net evaporation is about 19 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 Fort Randall. Due to seasonal precipitation patterns, seasonal patterns of gross evaporation depths and to the lag in normal reservoir surface temperatures from corresponding air temperatures, essentially all of the annual net evaporation from the Fort Randall 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 most major storms in the plains region of the Missouri River basin is the Gulf of Mexico. Based on available moisture alone, major storms would be most probable in late July or early August since it is at this time that normal and maximum recorded air mass moisture is at its highest. However, major storms result almost exclusively from conditions accompanying frontal systems. Since frontal passages are more numerous and more severe in May and June than later in the year, major storms occur more frequently in late spring and early summer than at the time of maximum moisture changes. Major storms alone do not provide a complete indication to the probability of large amounts of runoff within the region. A sequence of minor storms may saturate the soil and subsequently contribute much larger 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. With the exception of a few stations, records of runoff from the incremental area considered in this WCM exist only from the early 1930s to date. As discussed in the Master Manual, planning of the System made it desirable to extend Missouri River streamflow records to the extent practicable. In view of the relatively small incremental area between Oahe and Big Bend (5,840 square miles; the incremental area between Garrison and Oahe is over 60,000 square miles) and the unavailability of stage data, the decision was made to eliminate the Big Bend site as a location for which Missouri River flows would be developed for the purpose of planning studies. Daily records are available for the majority of streamgaging stations for the six System dams since their respective dates of closure, and daily flow data is available for the majority of gaging stations since 1930. Prior to 1930, there is a general lack of daily records in the basin. Representative daily data was constructed to cover the period from 1898 to 1929 because of the significance and statistical importance of the drought of the 1930s in System regulation. Inasmuch as water use for all purposes has expanded significantly since settlement of the region began, it is necessary to adjust System incremental inflow records to a common level of water resource development in order that flow data are directly comparable from year to year. The total flows originating in the Oahe to Fort Randall reach have been adjusted to the 1949 level of water resource development, with such adjustment being a continuing process as further data are accumulated. While any development level would have been satisfactory, the 1949 level was selected because that year was prior to significant resource development in the basin. 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 Fort Randall incremental drainage area is the melting of the plains snow accumulated during the winter months. However, on occasion rainfall has resulted in substantial runoff amounts from the total incremental area. Runoff is extremely variable from year to year. Throughout most of the drainage area annual runoff averages less than one inch. Normal contributions to annual runoff from drainage areas within or near to the incremental drainage area discussed in this WCM are presented in Table III-1.

Table III-1
Missouri River Basin - Normal Annual Runoff
Between Oahe Dam and Fort Randall

Contributing Area	Drainage Area (sq mi)	Average Daily Runoff (1)	
		kAF	Inches
Bad River at Fort Pierre	3,107	123	0.74
White River at Oacoma	10,200	585	0.78
Missouri River (2)			
Oahe Dam	243,490	20,401	1.57
Fort Randall Dam	263,480	21,306	1.52
Oahe to Fort Randall			
Incremental Drainage	19,990	905	0.85
Local Drainage (3)	6,683	359	1.01

(1) Based on available record at each location, 1928-2014
(2) Missouri River runoff at the 1949 level of water resources development.
(3) Incremental drainage area between Oahe and Fort Randall less Bad River at Fort Pierre and White River at Oacoma.

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

1. Winter is characterized by frozen streams and intermittent snowfall and thaws in the 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 plains 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 frequently 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 intense local rainstorms. Runoff is usually quite low unless these rains occur.

4. Summer and autumn in this portion of the Missouri River basin are generally characterized by a lack of general rainfall and frequent, widely scattered thundershowers that contribute little to runoff. Total runoff in the Big Bend to Fort Randall incremental drainage area is usually very low from July through the remainder of the calendar year.

3-08.2. Total unregulated Missouri River runoff originating above Fort Randall usually follows a definite and characteristic annual pattern. Plate III-13 lists the Missouri River basin monthly runoff above Fort Randall for the period 1898 to 2014. Total monthly runoff above Fort Randall (maximum, minimum and average) for each month is shown in Plate III-14. Normal monthly runoff from the total contributing area shows a general increase from January through June and then decreases through December. As illustrated on Plate III-14, wide variations in total runoff have occurred during every month of the year. As would be expected, the variations are largest during the months comprising the March-July flood season, with total flood season volumes ranging from highs of 39.5 million acre-feet (MAF) in March-July 2011 (maximum), 29.4 MAF in March-July 1997, 27.8 MAF in March-July 1978, and 25.5 MAF in March-July 1927 to a minimum of 5.5 MAF in 1961. As seen in Plate III-14, May, June and July 2011 were all record months contributing to the highest March-July runoff in 117 years of record (1898-2014). The effects of project regulation on these runoff patterns and regulation of various flood events is discussed in Appendix A of this WCM.

3-08.3. The average and maximum monthly runoff originating from the incremental drainage area between Oahe Dam and Fort Randall Dam are illustrated on Plate III-15. Average runoff from this incremental area is at a maximum through the March-June period, with the average monthly maximum occurring in March as a result of runoff from the melting of accumulated winter snow cover. As shown by Plate III-15, the greatest March runoff recorded from this reach since the closure of Fort Randall Dam occurred in 2010. The greatest monthly runoff recorded occurred in May 1942 as a result of rainfall over the incremental drainage area. The May 1942 event was estimated to be a volume of 1.66 MAF in the Oahe to Fort Randall reach. The second highest monthly runoff from this reach of 1.3 MAF occurred in May 1952. This runoff was due mostly due to the melting of the large plains snow cover. Refer to Appendix A for additional information regarding the 1942 and 1952 floods. Very little runoff usually occurs, or has been recorded, in any month during the period extending from August through February. Monthly runoff from the Oahe to Fort Randall incremental drainage area has frequently been calculated to be negative throughout the available record period, indicating that evaporation from the Missouri River channel (or other losses, such as ice build-up) often exceeds the flow of tributaries entering the Missouri River in this reach.

3-08.4. The MRBWM Technical Report, *Hydrologic Statistics on Inflows*, dated July 2015, details the development of inflow volume probability relationships for various durations for both regulated and unregulated flows in the Oahe to Big Bend and Big Bend to Fort Randall reaches. Some incremental runoff events of interest originating between Big Bend and Fort Randall are illustrated on Plate III-16. See Plates VI-4 through VI-9 for regulated and incremental inflow volume probability relationships for various durations.

3-09. Effects on Basin-Wide Floods. Essentially all major Missouri River floods of past record at Fort Randall have resulted from runoff originating in the upper Missouri River basin, an area controlled by Fort Peck, Garrison and Oahe. At times these floods have been augmented by flows originating from the Oahe to Fort Randall incremental drainage area. Floods of this type are described in Appendix A of this WCM as well as Appendix A of the Master Manual.

3-10. Effects of Fort Randall on Flood Inflows. System regulation studies conducted by the MRBWM office indicate that regulation of Fort Randall, in conjunction with other upstream reservoir projects, would significantly reduce flood damages in the reach extending downstream from Fort Randall to below Gavins Point Dam if any past floods of record were to recur. Further discussion of regulation effects on flood inflows is detailed in Appendix A of this WCM.

3-11. Water Travel Time to the Fort Randall Reservoir. At normal operating levels, the Fort Randall reservoir extends into the Big Bend tailwater. Thus, releases from Big Bend appear as Fort Randall inflows in a few hours. At lower Fort Randall reservoir levels, the travel time is extended due to the delta formation near the White River, which is discussed in Section 4-11. The White River streamgaging station at Oacoma, SD is located very close to the reservoir and there is only a few hours of travel time between the streamgaging station and the reservoir. Runoff originating in the upper portion of the White River basin would take about five days to travel to the reservoir. However, most of the incremental drainage area runoff originating between Big Bend and Fort Randall will appear as inflow to the Fort Randall reservoir within two days. A two-day travel time to the Fort Randall reservoir is also expected for White River flows observed at the Kadoka, SD streamgaging station. See Plate III-17 for a graphical representation of White River travel times to the Fort Randall reservoir.

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 on the Missouri River, including the Fort Randall reservoir and the Missouri River downstream of Fort Randall. 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 main sediment inflow into the Fort Randall reservoir is from the White River. Other sources of sediment depletion are the smaller ungaged tributaries and reservoir bank erosion. Prior to closure of the Big Bend dam in 1963, sediment inflow from the Missouri River into the Fort Randall reservoir was very high. Since then, there has been no appreciable sediment inflow from the Missouri River. The Corps estimates that the annual suspended sediment load from the White River is about 9,700,000 tons/year based on readings from 1945 through 2011. Much of this sediment originates in the Badlands area of South Dakota and is the result of erosion during high flow periods. Surveys of sediment range lines reveal that the average annual depletion rate is approximately 15,800 AF to elevation 1375.0 feet, the Fort Randall reservoir maximum operating pool level. At this rate the estimated sediment life of the reservoir is 334 years. See Plate III-18 for the location of sediment aggradation range lines in the Fort Randall reservoir and the White River.

3-14. Missouri River Channel below Fort Randall Dam. The Missouri River below Fort Randall Dam flows a distance of about 40 river miles through a sparsely populated area downstream to the headwaters of the Gavins Point reservoir. This section of the Missouri River was designated by the National Park Service (NPS) as the Missouri National Recreational River. Two major tributaries enter this reach of the Missouri River: Ponca Creek, which drains an area of 827 square miles, and the Niobrara River, which drains an area of about 12,000 square miles. Ponca Creek enters the Missouri River about 6 miles north of the town of Niobrara, NE. The Niobrara River enters the Missouri River immediately upstream from the Gavins Point reservoir in the vicinity of Niobrara, NE. See Plate III-19 for the location of degradation range lines downstream of Fort Randall.

3-14.1. Channel Description. The Missouri River channel in the Fort Randall to Gavins Point reach meanders through an alluvial floodplain. With normal Fort Randall releases required to sustain multiple-use requirements, the water surface of the channel is usually 5 to 10 feet below the adjacent floodplain. However, in the reach extending about 10 miles upstream from the mouth of the Niobrara River, located 36 miles below Fort Randall Dam, this freeboard has been markedly reduced due to sediment deposited in the Missouri River by the Niobrara River. The relatively swift flows of the Niobrara River have always transported sediment into the Missouri River. Prior to construction of the System, periodic Missouri River flood flows would scour this sediment and transport it downstream on the Missouri River and a channel capacity in the 150,000 cfs range would be maintained through this reach. Since construction of the System, the periodic large Missouri River flood flows have been eliminated and sediment continues to accumulate in this location. As seen in years with higher releases such as 1975, 1997 and 2010, the effects of the accumulated sediment had progressed to the extent that Fort Randall releases near the powerplant capacity of 44,500 cfs resulted in some flooding and water-logging of the adjacent low-lying floodplain. Use of portions of the floodplain for agricultural purposes has been restricted and remedial measures consisting of obtaining flowage easements have begun.

3-14.2. Throughout most of its length, the Missouri River in this reach is a braided stream containing many small islands, sand bars and adjacent chutes. Channel widths at normal flows generally range upwards from near 1,000 feet in relatively restricted areas to a half mile or more in some areas immediately above the mouth of the Niobrara River. Very little bank stabilization has been done in this reach of the Missouri River and the channel is characterized by eroding banks, although there are plans to construct stabilization structures at locations where erosion has been particularly severe. There are no communities developed on the adjacent floodplain upstream from the town of Niobrara, NE, located in the headwaters region of the Gavins Point reservoir. Due to the effects of the Niobrara River delta, the stage-discharge relationship varies through the reach. Plate III-20 displays the relationship developed on the basis of recent Fort Randall releases at a location near Verdel, NE, above the mouth of the Niobrara River. The stage-discharge relation in the Fort Randall tailwater area is discussed in Chapter IV of this WCM. Plates III-21 through III-23 are orthophotos of the Missouri and Niobrara Rivers and Verdigre Creek, a tributary of the Niobrara River.

3-15. River Ice. During most winters the Missouri River can be expected to have a complete ice-cover extending from a point about 10 miles below Fort Randall Dam into the Gavins Point reservoir. The upstream limits of this ice-cover will vary, depending on the temperatures being experienced. In exceptionally cold periods, the head of the ice-cover can be expected to move upstream to such an extent that Fort Randall tailwater levels will be affected. The formation of an ice-cover significantly reduces the channel capacity. Unless it is necessary to continue evacuation of accumulated flood storage during the winter period, releases are generally restricted to no more than 23,000 cfs. This release generally does not result in problems associated with high river levels. The river reach between Fort Randall and the Gavins Point reservoir is relatively short and the ice-cover is usually eroded by progressive melting during the spring season rather than the break-up and associated ice jams characteristic of the Missouri River prior to construction of the System.

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Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

IV - Project Description and History

4-01. Location. Fort Randall is located at RM 880.0 in Charles Mix and Gregory Counties, South Dakota, approximately 6 river miles south of the town of Lake Andes. The Fort Randall reservoir extends 107 miles in a generally northwesterly direction to Big Bend located 21 river miles upstream from Chamberlain, SD. Pickstown, SD, a community developed for construction and operation of the Fort Randall project, is located on the bluffs adjacent to the dam. A project photo is shown as Plate IV-1.

4-02. Embankment. The dam consists of a concrete spillway section near the left bank abutment flanked by rolled earthfill embankments and outlet sections, consisting of a powerplant and outlet works. U.S. Highways 18 and 281 cross the Missouri River on top of the dam. The dam has a total length of 10,700 feet at elevation 1395.0 feet, which is the top of the dam. The embankment is of the rolled fill type, primarily using materials obtained from the spillway and outlet works excavations. The total volume of fill in the embankment is approximately 50 million cubic yards. The maximum base width is 4,500 feet and the top width is 60 feet. Rock fill riprap protection is provided for the upstream earthfill slopes above elevation 1310.0 feet. The downstream slopes, including a chalk berm, originally were top-soiled where necessary and seeded to vegetative cover. Prior to 1997 the embankment was rip-rapped to elevation 1371.0 feet. Extensive damage was experienced in 1997 due to an extended period of high reservoir elevations in conjunction with wind-wave action. After the runoff season, additional rock was placed to elevation 1381.0 feet. Refer to Plate IV-1 for an aerial photo that shows the Fort Randall embankment, intake structure, powerhouse, outlet works, spillway and reservoir. Plan and cross sections of the embankment are shown on Plate IV-2. Refer to Plate II-1 for other pertinent System dam and reservoir information.

4-02.1. Embankment freeboard was based on a Fort Randall reservoir level of elevation 1379.3 feet, the maximum level attained during routing of the Spillway Design Flood (SDF). A set-up allowance of 2.5 feet and wave height plus ride-up allowance of 6.9 feet was developed in design studies. An additional safety factor of 6.3 feet resulted in a total freeboard allowance of 15.7 feet, which established the embankment peak at elevation 1395.0 feet.

4-03. Spillway. The Fort Randall spillway is a structure of the conventional chute-type located near the left abutment of the dam. A large ravine upstream from the dam, supplemented by a relatively small amount of unlined excavation to elevation 1325.0 feet, provided an excellent approach channel for the spillway. The approach channel is of such nature that water flowing from the reservoir will sweep through an arc of about 90 degrees before discharging over the spillway. Refer to Plates IV-3 through IV-5 for photos of the Fort Randall spillway gates, spillway outlet apron and spillway discharge channel, respectively.

4-03.1. The spillway structure consists of a concrete ogee crest weir with a peak elevation of 1346.0 feet, surmounted by tainter gates, a roadway and service bridge and machinery platforms. The spillway has a gross length of 1,000 feet and is controlled by 21 tainter gates. Each spillway gate is 40 feet long and 29 feet high and are separated by 8-foot long piers. The net length of the spillway peak is 840 feet. The gates operate individually and may be opened or closed in l-foot increments. A 1,000-foot wide paved chute connects the spillway weir with the stilling basin. From the downstream end of the weir, the chute slopes downstream on a 4 percent grade a distance of 1,025 feet after which the slope steepens to a 10 percent grade for a distance of 355 feet to a transition with the stilling basin floor. The chute is paved with concrete and has retaining walls that transition from 17 to 30 feet high.

4-03.1. A 230-foot long stilling basin extends below the concrete spillway chute. The floor of the stilling basin is at elevation 1198.0 feet and has a bottom width of 971.5 feet. Sloping walls provide a top width of 1,000 feet at elevation 1255.0 feet. The end sill is stepped at 5-foot increments from elevations 1198.0 to 1218.0 feet. The spillway discharge channel, with bottom elevation at 1218.0 feet, is paved for a distance of 75 feet downstream from the back of the end sill of the stilling basin. The stilling basin walls continue 155 feet downstream from the back of the end sill. The discharge channel gradually contracts to a minimum width of about 830 feet at the exit. The contracted channel represents a compromise between excessive excavation on the left bank and undesirable flow characteristics including excessive velocities with further contraction. It is expected that exit velocities will be high along the left bank during high discharges. Model tests indicate probable bottom velocities ranging from 14 to 23 feet per second. Plan, profiles and sections of the spillway structure are shown on Plate IV-2. Spillway rating curves are shown on Plate IV-6. Additional guidance regarding best practices and/or special considerations and restrictions for use of the spillway at Fort Randall can be found in Exhibit A of this WCM.

4-04. Outlet Works. The outlet works through Fort Randall Dam are located near the left bank of the river, approximately 800 feet riverward of the spillway structure. Tunnels providing for both powerplant releases and supplementary outflows are included. Plan and profile of the outlet works are shown on Plate IV-2. The discharge rating curve of the supplementary release tunnels is shown on Plate IV-7.

4-04.1. The approach channel from the river channel to the outlet works tunnel intake also serves the adjacent spillway and is approximately 6,400 feet long with a bottom width of 575 feet. The channel floor was constructed to elevation 1227.0 feet. The prime function of the channel was to serve as an approach to the intake structure and conduits during the construction diversion period and until the reservoir pool reached the normal operating levels.

4-04.2. Eight tunnels are used for power discharges and four other tunnels are used to make supplementary releases. The No. 10 flood control tunnel is equipped with a special regulating gate to permit fine control of discharges from the reservoir. The lower portion of this regulating gate broke off during the extended period of high releases in 1975 and was not replaced. The twelve tunnels are in straight-and-parallel alignment with a uniform spacing of 70 feet on center. Each tunnel is 870 feet long. The eight power tunnels (Nos. 1 to 8) and regulating tunnel (No. 10) were constructed 22 feet in diameter for the first 215 feet downstream of the transition section connecting the intake structure with the tunnels. For the remainder of their length, each of these tunnels is 28 feet in diameter. The remaining flood control tunnels (Nos. 9, 11 and 12) are 22 feet in diameter throughout their entire length. Steel pipe penstocks, 22 feet in diameter, are installed in the downstream portion of the eight power tunnels and the No. 10 regulating tunnel. The invert elevation at the upper portal is 1229.0 feet in all tunnels. The slope of all tunnels is slightly greater than 1 percent, but is not quite the same in all tunnels due to the details of construction. Plates IV-8 and IV-9 present photos of the surge tanks and draft tube, respectively.

4-04.3. Service gates on Tunnel No. 11 were modified in 1999 with the installation of a high-density polyethylene strip on the back surface of the gate to reduce vibration between the roller chain and the gate. Internal memorandums were sent from the Omaha District to the MRBWM office on October 9, 1999 and November 5, 1999. The following describes use of the gates:

a. Operation of the gates to regulate flows can be done without concern for the integrity of the gate leaf.
b. Operation of the gates to regulate flows can be done without any change in the operator system. The existing gate hoists can be used as they are without loading them outside the design capacity, and without uplift problems.
c. Service gates on Tunnel No. 11 can be operated remotely from the Control Room and can be used for fine regulation of flows, to provide the best tunnel and downstream flow conditions. Remote operation became functional in 2017. Trash racks should be in place while regulating flow. If additional releases are required beyond the capacity of one tunnel, other tunnels should be used fully opened in this order of preference: 9, 12 and 10. Service gates on tunnels 9, 10 and 12 currently cannot be used for fine regulation and do not have remote control capability.
d. Whenever possible, gates should be operated at openings greater than 4 feet, to avoid possible cavitation and vibration caused by smaller openings.
e. Tunnel No. 11 gates may be operated using two gates at equal openings greater than 2 feet, unless smaller releases are required. A single gate can be used at openings between 2 and 4 feet. If the releases require a single-gate opening greater than 4 feet, the operation should be changed back to a double-gate opening, with a 2-foot minimum opening. Gates should not be operated at openings less than 2 feet. If a daily average outlet tunnel release of less than a single gate opened 2 feet is needed (ex: single gate opened 2 feet at elevation 1355 feet equals a release of 1863 cfs), gates may be alternately opened for part of the day and closed for part of the day to achieve the desired average daily release.
f. Inspection. The gate, rollers, slots, cathodic protection, seals and tunnel surfaces downstream of the gates should be carefully inspected soon after the operating period is completed. This inspection should document any wear and damage due to the operation, and determine if problems are developing which require changes in operation or maintenance procedures, and decide on suitability of the gate for continued use as a regulating gate.

4-04.4. The stilling basin extends downstream from the tunnel portal wall approximately 731 feet, and consists of a retaining wall on the landward side, a training wall separating the stilling basin and tailrace, and a series of baffle piers between these two walls to dissipate the energy resulting from the high velocity discharge from the flood control tunnels as shown on Plate IV-1. The stilling basin is divided into an upstream primary basin and a downstream secondary basin by a concrete ogee weir section located with the centerline of its peak 505 feet downstream of the portal wall of the tunnels. The ogee weir crest is at elevation 1244.0 feet or approximately 25 feet above the floor of the primary basin. The weir extends the full width of the stilling basin, a distance of 400 feet. In the primary basin, three training piers extend approximately 198 feet downstream from the portal wall of the tunnels to separate the flow from the four tunnels. The floor of the secondary basin is at elevation 1200.0 feet. Two rows of baffle piers for energy dissipation are placed across the width of the secondary basin, with the piers in each row staggered with respect to those in the other row. An end sill and cutoff wall are located at the downstream end of the basin's concrete floor slab. Appropriate drains and anchors are provided for in the basin retaining walls and floor slabs to ensure stability of the structure. Plate IV-10 presents a photo of the tailrace.

4-05. Powerplant and Switchyard. The intake for the power tunnel, as well as tunnel and penstock structures, are as described in preceding sections. Eight surge tanks are located upstream of the powerhouse and are connected in pairs to the penstocks serving each of Unit Nos. 1, 3, 5 and 7. The penstocks without surge tanks are connected to turbines with slow-acting governors, while the penstocks with surge tanks are connected to turbines with fast-acting governors. The surge tanks are constructed of rolled steel plates welded to form a tank 59 feet in diameter and 100 feet high. The switchyard is discussed in more detail in Section 4-07.4. Plate IV-11 presents a photo of the switchyard.

4-06. Intake Structure. The reinforced concrete intake structure consists of twelve towers spaced 70 feet on center and rising approximately 180 feet above their chalk foundation. Each tower is divided into a series of wells to accommodate two 11-foot by 23-foot service gates and two emergency gates that control the flow into the tunnels. A 490-foot transition connects the two 11-foot by 23-foot conduits in each tower with the 22-foot diameter tunnels. In order to increase the rigidity and stability of the structure, each pair of towers has a common base slab and is tied together at the top and the bottom by a series of deep girders. The girders are aligned to furnish a continuous track for the gantry crane from tower to tower and provide support for the gantry deck bridge. The continuous 53.5-foot by 827-foot gantry deck is pierced by hatches located directly over the gate wells and in the downstream half of the deck slabs over the equipment and storage rooms of the tower unit. Access to the intake structure is by a service bridge, which connects the gantry deck to the highway on the main embankment. Plate IV-12 presents a photo of the intake structure.

4-06.1. The flow through each conduit is controlled by gate installations in the intake structure located at the upstream end of the conduits. Each intake consists of two 11-foot by 23-foot rectangular gate passages that converge in a 490-foot length of transition section to a 22-foot diameter circular section. Each passageway is provided with twin gate slots, in tandem, for installation of the 11-foot by 23-foot emergency and service gates. The design of the water passages and air vents are nearly identical in both power and flood conduits, which provided uniformity in construction.

4-07. Powerhouse. The powerhouse structure is 561 feet long by 78 feet wide and consists of 8 generator bays, an erection bay and a service bay. The longitudinal centerline of the units runs east and west, with Unit No. 1 being the west unit and Unit No. 8 the east. Each of the generator bays is 70 feet wide, except Unit No. 8 bay, which is 73 feet wide. The erection and service bays, 70 and 76 feet wide, respectively, extend westward from Unit No. 1. The generator room floor is at elevation 1273.0 feet and the turbine room floor at elevation 1244.0 feet. The powerhouse superstructure is made of reinforced concrete and structural steel. The powerhouse also contains office space, a control room, a public reception lobby, an observation balcony, a machine shop and all necessary water treatment, sewage treatment, heating and air conditioning facilities.

4-07.1. Eight hydraulic turbines of the vertical-shaft, single runner Francis-type, with plate-steel spiral casings are installed in the powerhouse. The turbines are rated 57,500 horsepower (hp) at 112 feet net head and operate at 85.7 revolutions per minute (rpm). Governors are cabinet-actuator, oil-hydraulic conventional-type capable of full opening or full closing time of 5 seconds and are installed on Unit Nos. 1, 3, 5 and 7. Governors with a full opening or full closing time of 13 seconds are used on Unit Nos. 2, 4, 6 and 8. Each governor on a main unit is arranged for load and frequency control.

4-07.2. The main generators are 40 megawatts (MW), 3-phase, 60-cycle, 13.8 kilovolt (kV), wye-connected, 85.7 rpm units, with Class B insulation for normal temperature rise of 60 degrees Celsius (°C). The units are enclosed, forced-air cooled, with waste heat used to warm the generator room and the surge tank enclosures. Each generator has a direct-connected exciter permanently connected to the generator field, a pilot exciter, and a high-speed voltage regulator. Main generator protective equipment includes a neutral reactor and circuit breaker, differential relays, ground detector, resistance temperature detectors and over-speed protection for each unit. Refer to Plate IV-13 for a photo of the generators.

4-07.3. The tailrace is approximately 560 feet wide and extends 500 feet downstream from the powerhouse. The sidewall on the right bank is the switchyard retaining wall. The sidewall on the left is the boundary wall between the tailrace and the stilling basin. The floor of the tailrace is paved for 146 feet downstream of the powerhouse. The top of the slab slopes upward from elevation 1192.75 feet at the end of the draft tubes to elevation 1209.0 feet at the downstream terminal, thus practically maintaining the slope of the draft tube floor. The chalk floor of the tailrace continues to slope uniformly upward to the approximate elevation of the riverbed.

4-07.4. An outdoor switchyard containing the main transformers and switch gear is located immediately to the right and downstream from the powerhouse, as shown on Plate IV-11. The main high voltage busses, circuit breakers, transformers, disconnects, lightning arresters and instrument transformers are located outdoors. Main power transformers are single-phase outdoor-type units, connected delta on the low side and wye connected on the high side. The switchyard is arranged for switching at 115 kV or 230 kV and further arranged so that any operating unit can serve any outgoing transmission line through either of the main high-voltage busses or through the 115/230 kV interconnecting transformers, which will prevent shutdown of a generator due to bus failure.

4-07.5. A more detailed description of power facilities, as well as other structures developed at the damsite, is contained in the Fort Randall Operation and Maintenance (O&M) Manual. Plan and sections of the powerhouse are shown on Plate IV-2. Powerplant tailwater rating curves and powerplant characteristic curves are shown on Plates IV-14 and IV-15, respectively.

4-08. Reservoir. The reservoir formed by Fort Randall Dam, Lake Francis Case, lies in south central South Dakota and extends northward from the dam about 107 miles, past Chamberlain, SD to the tailwater area of the Big Bend Dam. In accordance with Public Law 88-97, approved August 15, 1963, the reservoir is also known as Lake Francis Case, named for the late senator from South Dakota. At normal operating levels the reservoir has a shoreline of 540 miles, a surface area of 77,000 acres and a maximum depth of 140 feet. The Fort Randall reservoir is long and narrow, largely confined to the Missouri River valley except where tributaries enter the reservoir. The largest of these tributaries, entering below Chamberlain, is the White River and forms the White River arm of the reservoir. A map of the reservoir area is given on Plate IV-16.

4-08.1. Allocation of storage space in the Fort Randall reservoir was based on System authorized purposes as described in Section 7-03 of the Master Manual. Types of storage space, with associated elevations and storage quantities for each type, are presented in Table IV-1. In addition to this allocated space, routing of the SDF results in a peak of elevation 1379.3 feet, representing a surcharge storage of about 0.45 MAF above the top of the Exclusive Flood Control Zone, but well below the dam peak at elevation 1395.0 feet. The elevation-area and elevation-capacity tables for the Fort Randall reservoir are on Plate IV-17.

Table IV-1
Fort Randall Reservoir Storage Space Allocations

Storage Designation (Zone)	Elevation in feet		Storage Space in AF
	From	To	
Exclusive Flood Control	1365.0	1375.0	986,000
Annual Flood Control and Multiple Use	1350.0	1365.0	1,306,000
Carryover Multiple Use	1320.0	1350.0	1,532,000
Permanent	1240.0	1320.0	1,469,000
Total Storage			5,293,000

Note: Storage volumes are based on August 2013 elevation-area-capacity tables (2011 surveys).

4-09. Recreation Facilities. Fluctuating levels have a significant effect on recreational use of the reservoir, particularly since the Fort Randall reservoir level typically fluctuates from above elevation 1355.0 feet to elevation 1337.5 feet or below throughout each year. During the main recreation season (spring and summer months) reservoir levels are expected to range from elevations 1350.0 to 1355.0 feet. Numerous public use areas have been established around the shoreline of the project with a common development of most of these areas being a boat ramp providing access to the reservoir. Recreation at System projects consists of both water-based and land-based activities. Water-based recreation includes boating, fishing, water skiing, jet skiing and swimming. Land-based recreation includes hunting, camping, picnicking, sightseeing, hiking and wildlife photography. Visitors participate in these activities at recreation areas that range from undeveloped reservoir access points to highly developed and extensively used campground areas. The six System projects have a total of 188 public recreation areas. Plates IV-18 and IV-19 present the 25 recreational facilities at the Fort Randall project. In 2002, most of the South Dakota federal recreation areas were transferred in fee title to the State of South Dakota or to the Bureau of Indian Affairs (BIA), which holds the areas in trust for the Lower Brule Sioux Tribe and the Cheyenne River Sioux Tribe, under Title VI of Public Law 105-53, Water Resources Development Act of 1999 (WRDA 1999) as amended by Public Law 106-541, Water Resources Development Act of 2000 (WRDA 2000). A total of 65 recreation areas on Oahe, Big Bend, Fort Randall and Gavins Point were transferred in fee title, along with the nine recreation areas leased in perpetuity, to be managed for the restoration of terrestrial wildlife habitat loss that occurred as a result of the flooding of lands related to the construction of the projects.

4-10. Leasing of Project Lands. As indicated previously, essentially all land surrounding the Fort Randall reservoir below elevation 1375.0 feet has been acquired for project purposes. Unless unusual conditions should occur, inundation of lands lying in the Exclusive Flood Control Zone, between elevations 1365.0 and 1375.0 feet, would not be expected as part of normal operations. As a result of the Title VI portion of WRDA 1999 and subsequent technical amendments in WRDA 2000, all land lying above 1350.0 feet within recreation boundaries and above 1375.0 feet outside recreation boundaries was transferred to the State of South Dakota Game Fish and Parks (SD GF&P). Subsequently, the Corps has made land adjacent to those transferred lands available through a no-cost easement to the SD GF&P. The easement allows the State of South Dakota to use the land "for recreational and other purposes (including the construction, operation, maintenance and repair of water intake structures, publicly owned boat docks, publicly owned boat ramps and related publicly owned structures) ... and the administration of livestock grazing on said areas". This easement and all instruments issued under it provide for possible flooding of lands, if needed, for operational purposes and do not serve as an overriding constraint on regulation of the project for authorized purposes.

4-11. Reservoir Aggradation and Backwater. As mentioned in Section 3-13 of this WCM, the long-term sediment depletion of the Fort Randall reservoir is estimated at 15,800 AF per year. Since closure of Big Bend Dam in 1963, most of this deposition is contributed by the White River and is deposited in a delta that extends both upstream and downstream of the White River confluence. These deposits are composed of mostly silts and clay with a relatively high concentration of montmorillonite and only 5 to 10 percent sand. A substantial redistribution of each year's accumulation of these semi-fluid deposits occurs during the annual late season reservoir drawdown. These reservoir drawdowns move large quantities of material farther into the reservoir before sediments have an opportunity to consolidate. This feature of project regulation lengthens the time it will take backwater effects from the delta to affect power releases at Big Bend. The delta has extended almost all the way across the reservoir and restricts flowrates at lower pool elevations. In the fall, when the reservoir is drawn down, there is a difference in pool elevations above and below the delta in the range of 8 to 11 feet. The Big Bend tailwater is affected with a Fort Randall reservoir above elevation 1342.0 feet. These effects become increasingly large when the reservoir rises into the upper portions of the Annual Flood Control and Multiple Use Zone or higher.

4-12. Tailwater Degradation. Since the Fort Randall project traps essentially all inflowing sediments, the water released from the dam is mostly sediment free. Thus, the suspended sediment load gradually increases downstream from the dam as a result of bank erosion, scour from the riverbed and sediment inflow from tributaries. As the finer sand particles in the streambed are gradually leached from between the larger sand or gravel particles and transported downstream, a gradual lowering or degradation of the channel below the dam occurs. As seen by the tailwater trends on Plate IV-20, about 7 feet of degradation has occurred below Fort Randall between 1952 and 2013. The stage trends at the Missouri River at Greenwood, SD streamgaging site, located approximately 17 river miles downstream of Fort Randall Dam, are shown on Plate IV-21. The channel below Fort Randall is discussed in Section 3-14 of this WCM.

4-13. History of Water Resources Development. Due to the lack of transportation facilities, development of water resources in the portion of the Missouri River basin extending through the vicinity of the Fort Randall reservoir began soon after westward 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. However, the lack of perennial streams in the region discouraged such development except in scattered areas in the White River's headwaters region and in areas immediately adjacent to the Missouri River. 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, as well as fish and wildlife enhancement and other matters related to the environment have been of increasing importance.

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

4-13.2. One important means of water resource development in this section of the Missouri River basin is the construction of dams controlling sizeable drainage areas and development of the associated reservoirs. However, in the Big Bend to Fort Randall drainage area no sizeable reservoirs other than Fort Randall have been developed. The lack of an assured irrigation water supply, and infrequent substantial runoff amounts, as well as the sparsely settled area, results in only minimal flood damages prevented. Due to sparse development in this drainage area, tributary reservoir development has not occurred.

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

4-15. Irrigation. Irrigation is practiced throughout the entire length of the Fort Randall reservoir. New irrigation permit applications are received each year. There has been no federally-funded irrigation development in the Big Bend to Fort Randall drainage area of the Missouri River basin. In recent years there has been an increase in the development of sprinkler irrigation on lands within pumping distance of the reservoir. 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 westward expansion, there is currently no commercial navigation on this reach of the river. Storage has been provided in the Fort Randall reservoir for multiple purposes, including Missouri River navigation. However, storage and releases from the project serve navigation indirectly, after re-regulation by the downstream Gavins Point project. A description of the Missouri River navigation project is contained in Chapter VII and Appendix G of the Master Manual.

4-17. Hydroelectric Power. The Fort Randall powerplant, with an installed capacity of 320,000 kilowatts (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. Power generation at Fort Randall 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. There are five municipal surface water intakes located in the Fort Randall reservoir. Of these, three are located upstream of the White River confluence near the South Dakota towns of Oacoma and Chamberlain. The other two intakes, which are operated by Randall Community Water District, are located downstream of the White River confluence. One intake is located near Platte, SD and the other is located near Pickstown, SD. There are no municipal intakes in the river reach below Fort Randall. The city of Pickstown abandoned their water intake and treatment facility in 2001, which were located below Fort Randall. The city now utilizes the Randall Community Rural Water District as its source of water supply.

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

4-20. Fish, Wildlife and Recreation. The effects of water resource development on fish and wildlife are a 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 the projects. Recreational use of the Fort Randall 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 its tributaries. Sediment inflow to the Fort Randall reservoir results almost entirely from erosion along tributary streams contained within the incremental drainage area. Since the Fort Randall reservoir extends upstream to the tailwater reach of the Big Bend project, bank stabilization measures along the reservoir are not required. Additionally, there is no appreciable sediment inflow to the project from the Fort Randall reservoir bankline.

4-22. Streamflow Depletions. The major effect of the water resource development in the incremental drainage between the Big Bend and Fort Randall dams on the regulation of Fort Randall is 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. Prior to 1865 streamflow throughout the Missouri River basin was largely unused, except for transportation. Settlers and homesteaders in the late 1800s and soon after the turn of the century started substantial irrigation and mining ventures in several regions of the upper Missouri River basin. However, in the western South Dakota drainage area contributing to the Missouri River reach discussed in this WCM, the available water supply was very small and unreliable. Consequently, irrigation development occurred in only scattered areas, in the tributary headwater's region where a more dependable water supply was available. 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 Big Bend to Fort Randall 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 Big Bend to Fort Randall Reach

Time Period	Average Annual Depletions in kAF
1929 – 1940	82.3
1941 – 1950	65.4
1951 – 1960	74.4
1961 – 1970	70.0
1971 – 1980	76.4
1981 – 1990	71.1
1991 – 2002	63.6
Future (Estimated)	
2002 – 2010	78.6
2010 – 2015	79.0
2015 – 2020	79.7
2020 – 2025	80.5
2025 – 2030	81.2
2030 – 2050	83.2
2050 – 2070	85.3
2070 – 2090	86.6
2090 – 2110	87.8

Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

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. Fort Randall Project Data. Hourly data are automatically transmitted from the Fort Randall PPCS via 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 DCP is not working, Fort Randall 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 Fort Randall monthly summary is faxed or emailed to the MRBWM office and is used to verify daily data.

5-02.1. Throughout the year Fort Randall project personnel investigate requests and complaints that occur as a result of Fort Randall regulation and report their recommendations and findings to the MRBWM office. The MRBWM office keeps the Fort Randall project personnel advised concerning anticipated changes in releases and reservoir levels. Based on this information, project personnel assist in informing affected interests of any major changes in release rates or reservoir elevations that may be scheduled, and also informing affected interests of unusual reservoir elevations that may be anticipated. System coordination is discussed further in Chapter VIII of this WCM and also in the Master Manual.

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

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

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

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

Table V-1
Data Collection Platforms – Big Bend Dam to near the Gavins Point Headwaters

Corps ID	Location	USGS ID	DCP ID	NWS ID
	White River near NE-SD State Line	06445685	17385140	NEBS2
	White River near Oglala, SD	06446000	DD09640A	WOGS2
	White River near Interior, SD	06446500	DD589236	IRRS2
	Bear in the Lodge Creek near Wanblee, SD	06446700	17954706	BERS2
	White River near Kadoka, SD	06447000	DD0E96BA	KDKS2
	Black Pipe Creek near Belvidere, SD	06447230	1735112C	PIPS2
	White River near White River, SD	06447450	DD0FC43C	WHRS2
	Little White River near Martin, SD	06447500	173864DA	LITS2
	Little White River near Vetal, SD	06449100	DD79B7CE	VTLS2
	Little White River near Rosebud, SD	06449500	DDCC4142	RSBS2
	Little White River below White River, SD	06450500	DD79C15E	LWRS2
OCSD	White River near Oacoma, SD	06452000	CE241570	OACS2
	Lake Francis Case at Chamberlain, SD	06442996	CE306144	CBLS2
	Platte Creek near Platte, SD	06452320	17BA75E0	PCPS2
GWSD	Missouri River below Greenwood, SD	06453020	CE1213CE	GRWS2
VENE	Missouri River near Verdel, SD	06453620	CE12C5A6	MRVN1
NMNE	Missouri River at Niobrara, NE	06466010	CE377006	MRNN1
SPSD	Missouri River at Springfield, SD	06466700	CE12B336	SPGS2
VRNE	Niobrara River near Verdel, NE	06465500	CE1DE5D8	VRDN1
VDNE	Ponca Creek at Verdel, NE	06453600	CE35531E	VERN1

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

5-06.1. Reservoir regulation/power production orders to mainstem project personnel and Western are the basis of the regulation process. These are issued by the MRBWM office and are based on detailed analysis of current and expected hydrologic conditions throughout the Missouri River basin and releases needed to meet the Congressionally authorized purposes of Fort Randall 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. Fort Randall 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 Fort Randall 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 Fort Randall, or other System projects, is to be furnished to the MRBWM office.

5-07. Emergency Regulation. If emergency conditions develop at Fort Randall, 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 Fort Randall 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.

Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

VI - Hydrologic Forecasts

6-01. General. Regulation of Fort Randall as a component of the System requires continuing analyses 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 Fort Randall, have essentially the same degree of importance for all of the other mainstem projects. Analyses considered to be unique or particularly important to Fort Randall 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. Precipitation forecasts of particular importance are those that could lead to substantial flow changes on the Niobrara River, a significant tributary entering the Missouri River below Fort Randall.

6-03. Runoff Forecasts. Short-range runoff forecasts are determined with water on the ground, per ER 1110-2-240, which consists of existing snowpack and recently observed rainfall. Particularly pertinent for the determination of inflows into Fort Randall are forecasts prepared for southwestern and south-central South Dakota. Since Fort Randall is the most downstream of the mainstem projects containing a significant amount of flood storage space, runoff forecasts that are applicable to System release determination, as described in Chapter VII of the Master Manual, are also very pertinent to determination of releases from Fort Randall. Factors relevant to runoff from the Fort Randall to Gavins Point incremental area downstream are also important. 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 Fort Randall.

6-04. Precipitation-Runoff Relationships. Infiltration of rainfall over the Missouri River basin between the Big Bend and Fort Randall Dams ranges from 0.50 to 1.00 inch for the initial loss. The constant infiltration losses range from 0.05 to 0.20 inch per hour for the textured clay soils on the western side of the Missouri River. The constant infiltration losses range from 0.20 to 0.60 inch per hour for the moderately fine textured soils on the eastern side of the Missouri River. These values are based on a generalized soils and infiltration map of the basin since relatively few rainfall events have been centered and modeled in this area. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values 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 runoff or snowmelt rates is very imprecise in this area. 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 the previously stated average infiltration or loss rates. Use of NWS-provided QPE data has improved knowledge of rainfall events.

6-05. Unit Hydrograph Analyses. A conventional means of forecasting flows from a particular drainage area is by the use of unit hydrographs. However, unit hydrograph development and subsequent use of the developed hydrographs as a forecasting tool has been found to be impractical for the drainage area under consideration in this WCM. Reasons for this include the large size of the drainage area, which requires the division of the drainage area into many sub-areas, 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. Further, with the large amount of storage space available in the Fort Randall reservoir and the very nature of the regulation process, the effort necessary for a valid and complete analysis by means of unit hydrograph procedures is not believed to be warranted. However, runoff forecasting procedures will continue to receive consideration as a means of possibly improving the regulation process 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 Fort Randall 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 Big Bend to Fort Randall 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, past forecasts of the plains snowmelt runoff volume have usually been quite imprecise. The MRBWM office continues to investigate new and improved techniques including soil condition instrumentation and continuous soil moisture accounting modeling to more accurately predict runoff from plains snow. Section 5-06 of the Master Manual contains additional information on snow.

6-06.1. Plains area snow surveys, requested by the MRBWM office and conducted by the Omaha District, are made during any year that a substantial snow accumulation exists over the drainage area. Results from the snow surveys are compared to the interactive snow map for modeled SWE from the NWS's National Operational Hydrologic Remote Sensing Center to help in the verification process. 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 Big Bend and Fort Randall. 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, 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 Big Bend to Fort Randall 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 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. The reach most pertinent to Fort Randall, which does contain runoff estimates, extends from Oahe to Fort Randall and includes the Oahe to Big Bend incremental area.

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

6-08. Short-Range Forecasts of Daily Inflow. The MRBWM office develops forecasts of future daily inflows to the Fort Randall reservoir and the other associated System reservoirs at frequent intervals. Each week daily inflow forecasts extending three weeks into the future are developed. Experience has indicated that a satisfactory method of anticipating Fort Randall inflows for periods of up to a week beyond the current date consists of combining anticipated daily releases from upstream Big Bend with anticipated inflows from the Big Bend to Fort Randall incremental drainage area. Most of the time the flows originating between these two projects can be considered in total and will be of the order of 1,000 cfs or less. However, at times, substantial runoff originates from this incremental area. Forecasts of total incremental area inflows are an extrapolation of past total runoff in which current hydrologic conditions pertinent to short-term runoff are given due consideration. Typical inflow hydrographs from the total incremental area are discussed in Section 3-08 of this WCM. When substantial flows are occurring on the White River, real-time flows on this stream are used to provide a further indication of subsequent incremental inflow to the project. With the relatively large amount of storage space available in Fort Randall, forecast emphasis is not toward exact definition of the incremental inflow hydrograph, but rather toward a definition of incremental inflow volumes over a relatively longer period of time (a week or more) in order that release adjustments from upstream projects, and on occasion from Fort Randall, can be scheduled to meet regulation objectives. As discussed in the Master Manual, future runoff modeling efforts include the use of observed gridded precipitation in the Corps' HEC-HMS models.

6-09. Stage-Discharge Relationships. Stage-discharge relationships, sometimes referred to as rating curves, are maintained by the MRBWM office for key tributary streamflow stations in the Oahe to Fort Randall incremental drainage area. These are kept current on the basis of discharge measurements made by the USGS. Plate VI-1 shows the present stage-discharge relationship at

White River at Oacoma, SD, a key location for developing short-range inflow forecasts pertinent to Fort Randall regulation. Plate VI-2 lists rating curves for locations in the White River basin.

6-10. Flow Forecasts at Downstream Locations. Flows through the reach extending from Fort Randall Dam to the headwaters region of the Gavins Point reservoir generally consist of Fort Randall releases. Near the headwaters of the Gavins Point reservoir, Fort Randall releases are supplemented by flows from Ponca Creek and the Niobrara River. Estimation of flows below the confluence of these two tributaries with the Missouri River consider this tributary flow supplementation. Forecasts of the flow supplementation generally consist of noting Ponca Creek and Niobrara River actual flows at Verdel, NE and developing the daily runoff from the remainder of the incremental drainage area. Extrapolation of future flows are based on hydrologic conditions occurring or anticipated in the incremental drainage area. Typical incremental drainage area hydrographs are presented in the Gavins Point WCM. Future HEC-HMS model development will likely include this downstream area, or at the very least, the Niobrara River basin.

6-11. Downstream Stage Forecasts. There are no urban damage centers in the reach extending from Fort Randall Dam to the headwaters region of the Gavins Point reservoir. Stages adjacent to the town of Niobrara, NE, in the Gavins Point headwater's region are influenced by the Niobrara River delta. However, the town has been relocated to higher ground and the relocated town is generally not affected by flows in the Missouri River. The agricultural region upstream from the Niobrara River delta formation in the Missouri River channel experiences some inundation and high groundwater problems with Fort Randall releases exceeding the powerplant capacity of about 45,000 cfs. The changing effects of the Niobrara River delta on Missouri River stages in this vicinity are illustrated by the stage trend curves shown on Plate III-20 for a location near Verdel, NE, just upstream of the mouth of the Niobrara River. These stage trend curves for flows of 20,000, 30,000 and 40,000 cfs show a general upward shift of stage in this area since the closure of Fort Randall.

6-12. Routing Procedures. A simple translation of observed or anticipated upstream flows by the approximate travel time from the upstream location is an adequate routing procedure for the purpose of anticipating inflow to Fort Randall. The large storage capacity and associated regulation procedures do not require precise definition of anticipated inflows. Big Bend is the only reservoir project of significant size contributing directly to Fort Randall. Since Big Bend releases normally enter directly into the Fort Randall reservoir, routing of these releases is not required for Fort Randall inflow estimates. A simple procedure for estimating Fort Randall inflows is to lag Big Bend average daily releases by one day.

6-13. Evaporation. Evaporation is an important component of the overall water budget of the Fort Randall reservoir due to the large reservoir surface area. An estimate of the daily evaporation volume is required for developing daily inflow estimates and for more precisely estimating the effects of reservoir development on the available water supply. Initially, observed pan measurements were taken daily at Fort Randall and then factored by an average monthly pan coefficient to determine the reservoir evaporation. During those portions of the year when pan data were not available, normal evaporation depths for each month was considered the most practical means of developing evaporation estimates for day-to-day regulation activities. Pan coefficients and monthly evaporation rates were taken from the June 1973 MRD-RCC Technical

Report JE-73 titled, *Missouri River Main Stem Reservoir System, Reservoir Evaporation Estimates*. Plates III-9 through III-12 show pertinent evaporation information for the System reservoirs. Fort Randall personnel have since stopped taking observed pan measurements and the MRBWM office has started using estimated values year round.

6-13.1. 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.

6-13.2. In addition to evaporation, development of the effects of the Fort Randall reservoir on streamflow must consider the offsetting effects of precipitation on the reservoir surface and must also make allowances for the channel area in existence prior to the impoundment of water in the reservoir. Also, allowance must be made for that portion of the rainfall now falling on the reservoir surface that prior to the formation of the reservoir would have contributed to direct runoff from the area now inundated. Precise calculations of these factors are impractical. As stated in MRD-RCC Technical Report JE-73, it is estimated that 75 percent of the precipitation that falls on the reservoir today historically would not have flowed into the Missouri River. This assumes that 10 percent of the precipitation would have fallen on original channel area and that 15 percent would have appeared as direct runoff from the former ground surface now inundated by the reservoir.

6-14. Wind Effects on Water Surface Elevations. The general orientation of the Fort Randall reservoir is to the northwest of the damsite where the pool level recorder is located. Winds with a component from this direction result in set-up at the dam while a wind component from the opposite direction results in set-down. See Plate VI-3 for wind correction tables for the pool level recorder at the dam at various elevations. An anemometer is located near the dam; however, it should be recognized that only approximations of the wind effect on the reported pool level can be obtained with data from this instrument. The time required for set-up to be fully established, variations in wind velocity and direction over the entire reservoir surface, and the difficulty of having one location represent the entire length of the reservoir will result in deviations from calculated values. Synoptic surface weather maps may also be used for qualitative wind estimates or to determine the probable representativeness of the anemometer.

6-15. Daily Inflow Estimates. Estimates of inflow to the Fort Randall reservoir are made each day by the MRBWM office for regulation purposes. The steps involved consist of:

a. plotting hourly pool elevations as reported by the Corps' PPCS at Fort Randall;
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.

6-15.1. In addition, Big Bend releases and gaged White River flows are routed to the Fort Randall reservoir. These are combined with estimates of ungaged flow and precipitation on the reservoir surface to obtain an additional estimate of reservoir inflow. Differences in inflow estimates as determined by the previously defined process and the gaged White River flows are reconciled by using experience and engineering judgment. At times it will be necessary to adjust data for previous days on the basis of continuing trends in the reservoir level that were not previously evident. See Plates VI-4 through VI-9 for regulated and incremental inflow volume probability relationships for various durations. More information on the inflow volume probability for the mainstem projects can be found in the MRBWM Technical Report, *Hydrologic Statistics on Inflows*, July 2015.

6-16. Unregulated Flows. Construction of Fort Randall 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. A quantitative estimate of the effects of regulation on flows at the damsite and important locations downstream is frequently required. This represents a continuing effort by the MRBWM office and involves such factors as reservoir evaporation, precipitation on the Fort Randall reservoir, variations in travel time resulting from reservoir development, channel area inundated by the reservoir, runoff that could have been expected from previous overbank areas now inundated by the reservoir, inflows, outflows and storage changes. Refer to the MRD-RCC Technical Study S-73, *Unregulated Flow Development*, dated September 1973, for additional details of the analysis.

6-16.1. In addition to unregulated flows, determination of flows at the 1949 level of basin development prior to construction of Fort Randall and other water resource development in the Missouri River basin represents a continuing effort of the MRBWM office. Fort Randall represents a location where such determinations are made. Reference is made to Section 6-15 of the Master Manual for further details of these analyses.

6-16.2. Refer to Plates VI-10 and VI-11 for tributary flow probability relationship curves at White River near Oacoma, SD and Platte Creek near Platte, SD, respectively. Flow probability relationships were developed for tributary streams flowing into the Fort Randall reservoir between Big Bend and Fort Randall and are shown in Table VI-2.

Table VI-2
Tributary Flow Probability Relationships

Tributary	Drainage Area (square miles)	Peak Discharge (in cfs) for Given Return Period (in years)			
		10	50	100	500
White River at Oacoma, SD	10,200	27,900	49,700	61,400	95,500
Bull Creek	330	1,700	5,600	8,700	21,700
Whetstone Creek	260	1,500	5,000	7,800	19,300
Crow Creek	1,182	3,200	10,600	16,600	41,100
Platte Creek	740	2,500	8,400	13,100	32,500
Pease Creek	100	900	3,100	4,800	11,900

6-17. Evaluation of Regulation Effects. In evaluation of the effects of regulation on downstream flows and consequent flood damage reduction estimates, Fort Randall 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.

6-18. Long-Term Studies. Simulated regulation of Fort Randall 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 Fort Randall regulation are available. From the examples incorporating the present level of water resource development, conclusions relative to regulation of Fort Randall can be established, as described in succeeding sections.

6-19. Fort Randall Elevations. Long-term analyses indicate that the level of the Fort Randall reservoir will vary from the base of the Carryover Multiple Use Zone, elevation 1320.0 feet, to above the base of the Exclusive Flood Control Zone, elevation 1365.0 feet. This variation could occur in a single year, such as during a recurrence of 1942 flood conditions, or during or immediately following an extended drought period. However, with a normal water supply, variations between elevation 1337.5 and 1365.0 feet are the rule. Utilization of some of the space in the Exclusive Flood Control Zone, from elevation 1365.0 to 1375.0 feet, was required in 1995, 1997, 2010 and 2011 for the purpose of downstream flood control during these four high runoff years. See Chapter VII of the Master Manual for additional information regarding intrasystem regulation during high runoff years.

6-19.1. The Fort Randall reservoir elevation duration curve shown on Plate VI-12 indicates that a reservoir level at or above elevation 1350.0 feet, the base of the Annual Flood Control and Multiple Use Zone, can be expected about 65 percent of the time. A probability curve of annual maximum Fort Randall reservoir elevation is shown on Plate VI-13. This curve was developed from the long-range study analysis using the Daily Routing Model (DRM), as tempered by actual regulation experience of Fort Randall. In the case of Fort Randall, results of the DRM indicated low correlation between observed and simulated pools in some ranges. Some of this lack of correlation can be attributed to model constraints and parameters. The DRM does not fully utilize the Fort Randall storage to the extent that is done in actual practice. The adopted curve indicates that a maximum annual reservoir level of 5 feet or more above the base of the Annual Flood Control and Multiple Use Zone, elevation 1350.0 feet, can be expected in every year. An elevation of 1365.0 feet, the base of the Exclusive Flood Control Zone, is equaled or exceeded in about one year out of seven. Further particulars regarding development of these pool-duration and pool-probability curves are given in MRBWM Technical Report, *Hydrologic Statistics*, dated September 2013.

6-19.2. Average Fort Randall reservoir levels and normal seasonal variations since 1967 are shown on Plate VI-14. These averages show the characteristic increase in reservoir levels from the minimum at the end of the navigation season to a mid-March level of about elevation 1355.0 feet. This increase can largely be attributed to recapture of upstream power releases. From mid-March through mid-July average levels remain relatively constant. Deliberate retention of storage at or near this level provides a "cushion" to satisfy unexpected release demands for downstream navigation while continuing efficient power production from upstream projects. A gradual drawdown of storage through the later summer and early fall to elevation 1350.0 feet, the base of the Annual Flood Control and Multiple Use Zone, in early October is the normal occurrence. Accelerated drawdown in October and November to evacuate storage space for upstream winter power release recapture purposes then occurs. Reservoir levels during individual years will usually not vary significantly from the average levels. An exception would be in years of extremely deficient water supply when the fall drawdown would be to elevation 1320.0 feet. Also, when it is necessary to reduce the length of the Missouri River navigation season because of low System storage, a drawdown would occur earlier in the year than indicated by the averages.

6-20. Fort Randall Releases. Long-term regulation studies indicate that a Fort Randall release in excess of the powerplant capacity of about 44,500 cfs will be necessary at times during years experiencing an excess water supply, as confirmed by actual regulation of the project to date. Since 1978, releases through the powerplant have been limited to 44,500 cfs. Releases in excess of approximately 44,500 cfs, such as in 1995, 1996, 1997, 2010 and 2011, have been released via the outlet tunnels and the spillway. Duration curves of average monthly releases given on Plate VI-15 indicate that outflows in excess of the full powerplant capacity will be necessary less than 10 percent of the time. A median mean daily outflow of 27,000 cfs is indicated. The frequency curve of annual maximum releases shown on Plate VI-16 was developed from long-term regulation study results (DRM) augmented by data experienced during actual regulation. This curve reflects instantaneous releases at full powerplant capacity during all years to supply peak generation requirements. Further particulars regarding development of these frequency curves are given in the *Hydrologic Statistics* report referenced in Section 6-19.1.

6-20.1. Average monthly and daily elevations, inflows and releases based on System regulation since 1967 are shown on Plate VI-14. The seasonal release pattern illustrated in Plate VI-14 reflects the restricted System releases during the winter months and higher releases needed to support Missouri River navigation or for flood storage evacuation purposes during the remainder of the year. Evacuation of Fort Randall storage space during the fall months for winter recapture of upstream power releases is not accomplished by increasing Fort Randall releases, but rather by reducing releases from upstream reservoirs while maintaining Fort Randall releases at rates required for navigation or System storage evacuation purposes.

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Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

VII - Current Water Control Plan

7-01. Multiple Purpose Regulation. Aspects of multi-purpose regulation that are pertinent to the System as a whole are discussed in Chapter VII of the Master Manual. Since continuing development of System regulation plans requires coordination of plans for all mainstem projects, this subject has been explored thoroughly in the Master Manual and will not be repeated in this, the Fort Randall 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 Fort Randall 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 Fort Randall for flood control is discussed later in this chapter.

7-02. Basis for Service. As an introduction to regulation of Fort Randall, 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 1320.0 feet and is to remain permanently filled with water. This ensures maintenance of minimum power heads, a minimum level for the design of irrigation diversion and water supply facilities and a minimum pool for recreation and fish and wildlife purposes. The Carryover Multiple Use Zone extends from elevation 1320.0 to 1350.0 feet. The Annual Flood Control and Multiple Use Zone extends from elevation 1350.0 to 1365.0 feet. These two zones provide for the multiple-purpose regulation mentioned in the previous section. The Exclusive Flood Control Zone extends from elevation 1365.0 to 1375.0 feet. This zone is reserved exclusively for flood control regulation of major floods. The next zone is the Surcharge Zone, which is the zone above elevation 1375.0 feet which corresponds to 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 (1379.3 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 1379.3 feet to the top of the dam embankment (1395.0 feet).

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

a. Regulation of Fort Randall as an individual project must be subordinate to regulation of the entire System as a whole.
b. Flood control will be provided for by evacuating the storage space in the reservoir above elevation 1355.0 feet during the summer and limiting refill of the project during the winter months to 1353.0 feet prior to March of each year. During those years that a significant snow cover accumulates during the winter months, the limit of fill prior to early March is at elevation 1350.0 feet.

c. At all times releases will be such as to maintain the downstream Gavins Point reservoir at the level appropriate for the season of the year as described in the Gavins Point WCM.
d. To the extent practicable, in view of the water supply originating upstream of Fort Randall, the Fort Randall reservoir will be maintained between elevations 1350.0 feet and 1365.0 feet from the month of March until 6 to 8 weeks prior to the close of the navigation season by appropriate scheduling of releases from the upstream Oahe and Big Bend projects. During the late fall months of each year, prior to the end of the Missouri River navigation season, upstream reservoir releases will be adjusted to lower the level of the Fort Randall reservoir to elevation 1337.5 feet in each year, and to as low as elevation 1320.0 feet during severe and extended drought periods.
e. All irrigation and other upstream water requirements for beneficial consumptive purposes will be served to the extent reasonably possible.
f. By adjustment of the Fort Randall reservoir levels and releases, within the aforementioned designated criteria, the efficient generation of hydroelectric power to meet the area's needs as consistent with other uses and market conditions will be provided for.
g. Releases from the downstream Gavins Point reservoir to support Missouri River navigation will be backed up by releases from Fort Randall.
h. Insofar as possible without serious interference with the aforementioned, the Fort Randall reservoir will be regulated for maximum benefit to recreation and fish and wildlife, including T&E species.

7-04. Irrigation. There are no authorized or existing federal irrigation projects withdrawing water from this reservoir. Corps regulation responsibilities for irrigation are limited to estimating withdrawals and utilizing the estimates in the development of reservoir inflows and in deriving estimates of the actual available water supply. Refer to Section 4-15 of this WCM for additional information regarding irrigation.

7-04.1. Table E-3 in Appendix E of the Master Manual lists the Missouri River water supply intakes throughout the System. Current estimates show that there are 100 irrigation intakes on the Missouri River along the reach immediately below Fort Randall that require maintenance of minimum flows. Similar to other reaches of the Missouri River below System projects, there may be some problems associated with access to the supply due to fluctuating release or reservoir levels. 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. Presently, there are no withdrawals from the Missouri River in the reach extending from below Fort Randall to the headwaters of the Gavins Point reservoir for M&I purposes. The city of Springfield, SD withdraws water from the Gavins Point reservoir headwaters region. However, the intake is affected primarily by Gavins Point reservoir levels rather than the magnitude of releases from Fort Randall. Municipal supplies from the Fort Randall reservoir are provided for the city of Lake Andes, SD. The intake is operable through the entire range of reservoir elevations likely to occur extending upward from elevation 1320.0 feet. If other intakes to serve water supply purposes from the reservoir are contemplated, their design should recognize planned variations in the reservoir level. The availability of good quality water in the reservoir and lack of significant pollution sources in the immediate downstream reach makes it unnecessary to schedule releases to serve only the water quality function. Refer to Section 4-18 of this WCM for additional information regarding water supply.

7-06. Navigation. Although all Fort Randall releases are re-regulated by the downstream Gavins Point project, the primary burden of sustaining navigation flows on a continuing basis rests on Fort Randall and the three uppermost System projects. This is because Big Bend reservoir has very little flood control storage and is considered mainly a hydropower peaking project and the Gavins Point reservoir contains only a small amount of storage space and the pool level in this downstream project is held relatively constant from day to day. Thus, the daily release requirements for navigation must be translated upstream to Fort Randall. Ultimately the Fort Randall daily release for this purpose must be backed up by the three upstream projects with the initial effects felt at Oahe. This backup can be scheduled on a fairly long-term basis, allowing variations in the Fort Randall storage level to meet daily and weekly variations in the navigation requirements.

7-07. Power Production. Hydroelectric power generated by Fort Randall is integrated with the power generated by the other System projects and many other public and private generation facilities in the Missouri River basin and surrounding areas. To the extent practical, all releases are made through the powerplant. Since the Fort Randall powerplant units were completed in 1955, releases in excess of powerplant capacity have been required only in years of an over-abundant water supply, primarily to evacuate upstream storage space to provide control for the following year's runoff. The maximum sustained Fort Randall total release of 160,000 cfs (powerplant plus spillway and/or outlet tunnels) since powerplant operation began occurred in 2011. In 2011, powerplant releases were not generally maximized due to overall power regulation, and daily powerplant releases mostly ranged from about 20,000 cfs to 25,000 cfs during the period of maximum releases. More information on the 2011 regulation can be found in Appendix A. The next highest total release was in 1997. From November 20, 1997 to November 29, 1997 an average daily release of 67,500 cfs was made. Of the 67,500 cfs release, 37,000 cfs was through the powerplant and 30,500 cfs from the outlet tunnels. The annual maximum powerplant release in 1997 was 43,000 cfs. The maximum powerplant release of 47,500 cfs was made in 1971, 1972 and 1975. In 1978, powerplant releases of 46,000 cfs were made. Currently, maximum powerplant releases are generally considered to be about 44,500 cfs. System regulation criteria, as described in Chapter VII of the Master Manual, are designed to pass releases whenever possible through the individual project powerplants, and thus reduce spillway flows by the projects to a practicable minimum.

7-07.1. The Western system power dispatcher in Watertown, SD, schedules hourly loadings of the Fort Randall powerplant. These loadings must be within limits prescribed by the MRBWM office. These limits are developed on the basis of daily as well as hourly releases required to serve authorized purposes other than hydropower generation. Due to the changing power loads during the day, instantaneous releases may fluctuate widely between zero and the full powerplant capacity (44,500 cfs). Further discussion on power scheduling is presented in Section 7-12 of the Master Manual.

7-07.2. A seasonal variation in the general level of power releases from the Fort Randall reservoir usually occurs, largely reflecting service being provided to other functions. During the open-water season, relatively large releases are required for navigation from Gavins Point, the lowermost reservoir of the System. These releases are normally backed up by correspondingly large releases from Fort Randall, since relatively little inflow usually originates from the Fort Randall to Gavins Point drainage area during the navigation season. Additionally, during years of above-normal water supply, the major portion of required System storage evacuation must be made during the open-water season. These large releases generate substantial amounts of hydroelectric power.

7-07.3. During the winter months when navigation flow support is not provided and in October and November when the navigation season may be shortened in extended droughts, releases from the System are usually restricted to less than half of the navigation flow support level. In many years, the release is influenced in the winter months by the capacity of the ice-covered Missouri River channel below Gavins Point. Corresponding reductions in releases and power production must also be made at Fort Randall. 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. The drawdown of the Fort Randall reservoir will normally be limited to elevation 1337.5 feet. During severe extended droughts, a drawdown as low as elevation 1320.0 feet may be scheduled to allow an average winter release rate of 15,000 cfs from the upstream Oahe and Big Bend projects.

7-08. Fish and Wildlife. Minimum releases from Fort Randall are imposed for fish spawning downstream of the project in years when daily average releases are sufficiently high. The most recent Missouri River Natural Resources Committee (MRNRC) recommendation is a minimum release of 9,000 cfs from April through June. Regulation of the Fort Randall reservoir 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. Stationary or rising reservoir elevations through the late March to early July period are desirable for this purpose. Additionally, some species such as the northern pike require the inundation of terrestrial vegetation during the late March and April period for a suitable spawning habitat. Due to the relatively small amount of storage space involved in providing significant elevation changes in the Fort Randall reservoir, as compared to the large upstream mainstem reservoirs, as well as the normal seasonal regulation of the project for other purposes, regulation of the project for northern pike spawning can often be accomplished with little disruption of the other functions the project was designed to serve. Maintaining a stationary or rising reservoir level through June is considerably more difficult, particularly if less than normal runoff originates above Fort Randall or if downstream navigation requirements are above the normal level. However, it can often be accommodated with relative ease during years of above normal water supply.

7-09. Threatened and Endangered Species. Since 1986 releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered interior least tern (least tern) and threatened piping plover nesting. Releases from Fort Peck were also modified for several years, but no longer are due to the nesting patterns below that project. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Peaking may be restricted in both magnitude and duration at Garrison and Fort Randall. Planned operations to address Endangered Species Act (ESA) requirements will normally be provided in the AOP. Refer to Appendix D of this WCM for further discussion of fish and wildlife and T&E species.

7-10. Downstream Channel Spawning Conditions. Degradation of the Missouri River channel below Fort Randall has resulted in the formation of a coarse gravel bottom in some reaches downstream of the dam. This forms an ideal spawning bed for the sauger and walleye pike species of fish. Additionally, paddlefish spawn in this reach of open water between Fort Randall Dam and the headwaters of the Gavins Point reservoir. Fluctuating stage levels resulting from power peaking can result in the exposing of eggs deposited during high water periods. Regulation for the least terns and piping plovers as discussed in Section D-03 of Appendix D reduces impacts during a portion of the spawning period by limiting peaking and minimizing periods of zero release.

7-11. Recreation. Water-based recreation at Fort Randall is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the reservoir have top elevations extending up to elevation 1365.0 feet and bottom elevations from 1326.0 feet to about 1340.0 feet as described in Section 4-09 of this WCM. Insofar as practicable, consistent with the water supply, other project purposes, and conditions in the other mainstem projects, the Fort Randall reservoir levels should be scheduled to provide continued access to the reservoir area for recreational use. The modification in Fort Randall regulation procedures that was made in 1971, discussed in Chapter IV of this manual, was partly in response to demands for continuing access to the reservoir during the pre-winter drawdown of the reservoir. Even with this changed procedure, lowering of the pool level from the normal operating level of 1355.0 feet to the drawdown level, which is normally elevation 1337.5 feet, should be delayed to the extent practicable. Boating and fishing on the Missouri River below Fort Randall Dam are also popular recreational activities during the summer months. Hourly Fort Randall release variations appear to have little adverse effect on the use of tailwater areas since the higher power loads and consequent high releases desired by recreational interests usually occur during the daylight and evening hours when recreation use is highest. In addition, navigation release demands during the summer recreation season are usually quite high, limiting the power peaking that can be accomplished from Fort Randall. During periods of rapid release reductions or extremely low daily average flows, boating and fishing activities may be affected due to low stages further downstream in the reach.

7-12. Release Scheduling. As discussed in the Master Manual, scheduling of releases from Fort Randall and the other System projects is normally based on continuing studies by the MRBWM office in which all authorized purposes, including flood control, are considered. These studies are made at maximum intervals of one month and incorporate current conditions with the most recent estimates of future runoff, as expressed in terms of forecasted inflow, to the individual System projects. Service to all authorized purposes receives consideration including navigation requirements. The frequency of these studies is increased when previously unanticipated inflows occur that may have a substantial effect on System regulation. An example of these studies is included in the AOP, published each year as described in Section 6-12.3 of the Master Manual.

7-12.1. On a short-term basis there are often modifications to the general long-term scheduling of Fort Randall releases, usually dictated by requirements of the downstream Gavins Point release requirements. In the winter season, long-term scheduling is usually followed much more closely than during the navigation season. Day-by-day variations in navigation release requirements must be reflected almost immediately by variations in the Fort Randall release rate due to the lack of any substantial storage in the downstream Gavins Point reservoir. As discussed in the Master Manual, a short-range forecast is prepared in addition to the long-term monthly forecasts. The Three-Week forecast is developed using a short-range System regulation model of the same name. The forecast presents forecasted inflows, releases, reservoir elevations and hydropower generation for a 3- to 5-week period for each of the System projects. The forecast serves as a guide for short-term System modifications and is used to make regulation adjustments within the range normally determined by the long-term monthly studies.

7-12.2. Reservoir regulation/power production orders, furnished by the MRBWM office to operating personnel at Fort Randall and Western, are the basis for scheduling daily average releases from this project. Since exact daily power demands cannot be anticipated, reservoir regulation/power production orders usually allow a specified variation from this scheduled daily average release rate. Allowable variations in Fort Randall release rates from those specified in the order are usually very low since this project effectively sustains System releases that are maintained within close tolerances. Hourly patterning of the Fort Randall daily average release rate, within limits prescribed by the MRBWM office, is accomplished by Western's scheduling of daily power production except during the T&E nesting season, where the peaking pattern is prescribed by the MRBWM office.

7-13. Objectives of Flood Control Regulation. The flood control regulation objectives of the Fort Randall reservoir are to: 1) coordinate regulation of Fort Randall with the regulation of the other System projects to prevent runoff from the drainage basin above Fort Randall from contributing to damaging flows through the lower reaches of the Missouri River and 2) utilize available storage space in the best possible manner to prevent or reduce flooding in the reach from Fort Randall to the headwaters of the Gavins Point reservoir. The first objective is the primary flood control objective for the mainstem System as a whole. As a consequence, it is discussed in Section 7-04 of the Master Manual. The concerns of this WCM relate to the second objective: to amplify System regulation procedures as they apply particularly to Fort Randall and to discuss regulation pertaining to the reduction in flooding along the Missouri River between Fort Randall and Gavins Point.

7-14. Method of Flood Control Regulation. In general, the developed method of regulation of Fort Randall 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.

7-15. Storage Space Available for Flood Control Regulation. During any specific flood event all available space in the Fort Randall reservoir will be utilized to the maximum extent practicable for flood control purposes. The control of floods will be combined with regulation for other beneficial water uses. Storage space allocated for flood control in the Fort Randall reservoir totals 2.3 MAF. Of this total, 1.0 MAF is in the Exclusive Flood Control Zone, to be utilized only during unusually large flood season inflows. The remainder is in the Annual Flood Control and Multiple Use Zone and will be filled seasonally to the extent required by the available water supply and subsequently evacuated in the interest of flood control and other beneficial uses. Surcharge storage space has also been provided in the Fort Randall reservoir to ensure the safety of the project during extreme floods. Additionally, utilization of this storage will usually provide some downstream flood reductions during the extreme flood events. Carryover multiple use storage space in the Fort Randall reservoir, when evacuated, may also serve the flood control purpose although deliberate evacuation of this space to serve flood control will not be scheduled. The annual evacuation of a portion of the carryover storage space in the Fort Randall reservoir is for the sole purpose of increasing winter power production from the upstream projects. Refill of the space will usually be made prior to the flood season. However, in years when the flood potential between Oahe and Fort Randall is particularly high, it may become desirable to delay complete refill until the flood runoff begins.

7-16. Flow Regulation Devices. Releases from Fort Randall may be made through the powerplant, the outlet works 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. The discharge capacity of the Fort Randall powerplant ranges up to about 44,500 cfs. When it is necessary to release at rates greater than the powerplant is capable of maintaining, the outlet tunnels are used or spillway releases are made. The outlet tunnels are capable of passing over 100,000 cfs. The spillway is capable of discharging 500,000 cfs when the pool is at the top of the Exclusive Flood Control Zone. If supplemental releases are required in the fall, after the fall drawdown is in progress, the outlet tunnels must be used once the reservoir elevation approaches the spillway crest elevation of 1346.0 feet.

7-17. General Plan of Flood Control Regulation. Flood control regulation of Fort Randall to meet the stated flood control objectives is based on consideration of the following factors:

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

7-17.1. The general plan of regulation applicable to most of the System reservoirs, including the Fort Randall reservoir, is to have the flood control storage space evacuated prior to the beginning of the March-July flood season. Flood season inflows that are in excess of the current multiple-use requirements are deliberately stored in the System's Annual Flood Control and Multiple Use Zone until such time there is reasonable assurance that adequate reserves are stored to satisfy multiple-use requirements to the beginning of the next flood season without drawdown into the Carryover Multiple Use Zone. Deliberate fill of the Fort Randall reservoir is usually limited to be no higher than 1355.0 feet. Additional fill above this level has an adverse effect on overall System power peaking capability due to increasing tailwater levels at upstream Big Bend. However, if additional fill of the Annual Flood Control and Multiple Use Zone appears desirable for multiple-use purposes, it will be made. This deliberate storage for present and future multiple-purpose use also serves the flood control purpose. Following the time that an adequate supply of multiple-use storage in the System is reasonably assured, releases in excess of current multiple-use requirements are made as a flood storage evacuation measure when these releases are not anticipated to contribute to significant downstream flooding.

7-18. Local Flood Control Constraints. The relatively short reach of the Missouri River extending from Fort Randall Dam to the headwaters of the Gavins Point reservoir has no urban areas along the banks other than the relocated town of Niobrara, NE, which is located in the headwaters area of the Gavins Point reservoir at the confluence of the Niobrara and the Missouri Rivers. The town was relocated to higher ground because of high groundwater problems and potential future adverse effects due to aggradation and backwater from the downstream Gavins Point reservoir. With this relocation, urban flooding in the town of Niobrara has been limited. The existing groundwater problem is due to the higher Missouri River stages caused by the Niobrara River delta.

7-18.1. The delta formed in the Missouri River by accumulation of sediment from the Niobrara River basin at the mouth of this tributary has severely restricted the channel capacity through the 10-mile reach extending above the mouth of the Niobrara River. Continuing flows at the maximum Fort Randall powerplant capacity now result in some overbank flooding and water-logging in this reach. Flows in excess of the maximum powerplant capacity result in inundation of increasing amounts of agricultural areas. Summer homes built in this reach along the banks of the Missouri River experienced very little freeboard during 1975 when Fort Randall releases of 60,000 cfs were required for an extended period of time. Owners of the agricultural land affected have, through court action, been awarded damages, with the award contingent on the plaintiffs delivering deeds conveying a perpetual easement to the flood lands required for operational purposes. In 1994 the Omaha District conducted a study on sedimentation impacts in this area. Some overbank flows occurred and rerouting of tributaries in this reach were noted during the test period. High releases coupled with degraded channel capacity caused lowland flooding in this reach during the period 1995 to 1997. In addition, the high releases of 67,000 cfs in 1997 caused a notable, but temporary, increase in the channel capacity. Record high releases in 2011 also caused an increase in channel capacity, which was still noticeable in the fall of 2014, but will again likely diminish over time.

7-18.2. Within the Fort Randall reservoir area, pool elevations approaching or exceeding the base of the Exclusive Flood Control Zone have an adverse effect on access to boat ramps in several of the recreation areas surrounding the reservoir. Camping facilities in some areas are also adversely affected. County roads located in the reservoir area become inundated when reservoir levels are above elevation 1365.0 feet. While these are not serious constraints, they should be given consideration, to the extent feasible, in regulating the System.

7-18.3. The major constraint affecting flood control regulation of Fort Randall is the status of the downstream Gavins Point, including current and expected elevations, inflows and releases. With the lack of appreciable storage space in the Gavins Point reservoir, which allows only a minimum amount of re-regulation of Fort Randall releases, it becomes necessary to consider all constraints to System flood control releases when scheduling releases from Fort Randall. The criteria applicable to System releases are given in detail in the Master Manual.

7-19. Coordinated System Flood Control Regulation. The System, of which Fort Randall is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the System. Release scheduling from Fort Randall to accomplish this objective is based on studies performed by the MRBWM office. The long-range studies of current operations extend from the current date through the succeeding months up to the subsequent March 1, when the start of the runoff season generally occurs. All factors listed in Section 7-17 of this WCM are considered to the extent possible in these studies. Such studies are made at a maximum interval of one month as new estimates of future inflows are developed. If conditions change materially from those anticipated in previous monthly studies, additional within-month studies are made. Details of flood control regulation procedures applicable to the System are described in Section 7-04 of the Master Manual.

7-20. Exclusive Flood Control Regulation Techniques. Fort Randall will usually be regulated at an elevation of 1365.0 feet or less. Occasionally flood inflows will be of such magnitude that encroachment into the Exclusive Flood Control Zone, above elevation 1365.0 feet, will occur. Consequential actions will be dependent on existing or anticipated conditions in the other System reservoirs. If space in the Annual Flood Control and Multiple Use Zone remains vacant in the upstream Oahe reservoir and is expected to remain available, an obvious action is to reduce Oahe releases to the minimum consistent with all authorized purposes being served. If exclusive flood control space is being utilized in all reservoirs, action will be on the basis of the studies described in the preceding sections, with System releases and the balance of exclusive storage scheduled in each reservoir of the System in accordance with procedures discussed in Chapter VII of the Master Manual. These procedures give evacuation of exclusive flood control storage in Fort Randall a higher priority than the evacuation of similar space in the major upstream reservoirs.

7-20.1. Fill of the Exclusive Flood Control Zone and encroachment into the Surcharge Zone, should be avoided by reducing Oahe releases and increasing Fort Randall releases to the extent possible without contributing to substantial downstream flood damages. If releases in excess of the powerplant capacity appear necessary, they may be made through the outlet works tunnels or the spillway. Additional guidance regarding any operational restrictions and best practices for use of the spillway at Fort Randall can be found in Exhibit A of this WCM.

7-21. Surcharge Regulation Techniques. During exceptionally large flood inflows, all available flood control storage space may be utilized and the Fort Randall reservoir may rise into the Surcharge Zone above elevation 1375.0 feet. The primary reason for providing surcharge space is to ensure the safety of Fort Randall Dam. Since real estate surrounding the reservoir has, in general, not been acquired above elevation 1375.0 feet, surcharge encroachment should be allowed only when necessary to prevent extensive downstream damage or if unprecedented flood inflows were to occur. When unprecedented flood inflows occur, the regulation curves included with the emergency instructions in Exhibit B can be used as a guide for release scheduling. Portions of these regulation curves relate reservoir level and inflow to a suggested release, with the suggested release based on typical recession curves, by the method outlined in EM 1110-2-3600. Use of these curves should prevent significant surcharge space encroachment except during the most extreme floods. If the reservoir should rise into the Surcharge Zone, release of inflows up to the full spillway capacity should be scheduled to prevent any further significant elevation increase. These curves serve only as a guide for possible regulation. Final release selection could be greater or less than indicated by the curves and would be based on anticipated inflows, the effects of release through downstream reaches, and the anticipated maximum pool level of the Fort Randall reservoir as reflected in additional system regulation studies performed at that time.

7-22. Responsibility for Application of Flood Control Regulation Techniques. As described in Section 7-04.23 of the Master Manual, the MRBWM office is responsible for and directs all regulation, including flood control regulation, of Fort Randall and the other System projects. Instructions to ensure continuation of Fort Randall 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.

7-23. Emergency Regulation. Reliable and rapid communication is usually available between the MRBWM office and Fort Randall 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 Fort Randall inflows continue in the range of those previously anticipated. The emergency procedures also allow for increased inflows, up to those occurring during maximum possible floods, as developed for spillway design purposes.

7-23.1. Emergency regulation curves, shown on Plate VII-1, were developed by the method described in EM 1110-2-3600. A recession constant, or time of peak (T_s value), of 3.5 days was selected in curve development with this value based on experienced incremental inflow hydrographs as well as the Fort Randall reservoir inflow hydrographs of maximum possible floods developed during spillway design studies. The developed emergency procedures recognize the relatively small amount of surcharge storage space provided in the Fort Randall reservoir, as well as the appropriate Missouri River channel capacity existing below the reservoir extending downstream to Gavins Point.

7-23.2. Fort Randall releases under emergency conditions are related to inflows, subject to the following:

a. releases in excess of 100,000 cfs, the approximate Missouri River channel capacity below the System, will not be scheduled until the level of the Fort Randall reservoir exceeds, or is forecast to exceed, the base of the Exclusive Flood Control Zone, elevation 1365.0 feet;
b. with a Fort Randall reservoir level in the Exclusive Flood Control Zone (elevation 1365.0 feet to 1375.0 feet) and inflows greater than 50,000 cfs, minimum releases will be in the 50,000 to 100,000 cfs range, dependent on the degree of encroachment, in order that this zone can be evacuated for control of subsequent runoff in a reasonable period of time;

c. with a Fort Randall reservoir level in the Surcharge Zone (above elevation 1375.0 feet) releases should equal inflow, up to full spillway discharge capability;
d. in order to remain compatible with the spillway design of the downstream Gavins Point project, total (turbine + outlet tunnel + spillway) Fort Randall releases should not exceed the full Fort Randall spillway capacity at the prevailing Fort Randall reservoir elevation.

7-24. Emergency Regulation – Spillway Design Flood. The design flood for the Fort Randall spillway was a late spring or summer type of flood in which large Oahe and Big Bend releases resulting from large amounts of runoff in the drainage area above the Oahe project were augmented by runoff from a maximum possible rainstorm over the Oahe to Fort Randall drainage area. The 1948 DPR routed this event with peak outflows of 615,000 cfs and a peak reservoir elevation of 1379.6 feet. Peak inflows to Fort Randall were 849,000 cfs. The final spillway design as discussed in the October 1951 report *Spillway – Stage II* used peak outflows of 620,000 cfs with a maximum reservoir elevation of 1379.3 feet.

7-24.1. In a September 1999 Omaha District report titled, *Dam Safety Evaluation for Pool Levels Exceeding Elevation 1375*, the SDF was re-routed with similar assumptions to the DPR and updated area-capacity tables. This updated routing resulted in a peak outflow of 633,000 cfs and a peak elevation of 1379.8 feet. See Plate VII-2 for this flood routing.

7-25. Emergency Regulation – One-Half Spillway Design Flood. To illustrate application of the emergency procedures given in Exhibit B and the emergency regulation curves that are shown on Plate VII-1, Fort Randall inflows approximating one-half of those used for spillway design purposes were assumed, together with an initial reservoir level of elevation 1355.0 feet. Regulation by the emergency procedures alone resulted in reducing a peak inflow of about 400,000 cfs to a maximum release of 140,000 cfs. The Fort Randall reservoir peaked at elevation 1375.0 feet, the base of the Surcharge Zone. Hydrographs for this flood routing are shown on Plate VII-3.

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Missouri River Basin
Fort Randall Dam – Lake Francis Case
Water Control Manual

VIII - Water Management Organization

8-01. Responsibilities and Organization. This chapter describes the personnel and coordination necessary to regulate Fort Randall. Fort Randall is regulated as part of the System, which is comprised of six projects on the main stem Missouri River. The Corps has the long- and short-term direct responsibility for regulating Fort Randall as a hydraulically and electrically integrated project. This has been the case since July 1952, when Fort Randall 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 Fort Randall in 1946. Fort Randall 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 Fort Randall 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 news 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 effects 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 operation requires 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 reservoir has been designated as "replacement System flood control storage space." Replacement storage does not impact the regulation of Fort Randall.

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 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, NPS, USGS, USFWS, USBR, BIA, Environmental Protection Agency (EPA), Western, U.S. Forest Service and the USDA'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 Fort Randall. 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 Fort Randall along with the other upstream System projects and augmented by upstream tributary reservoir projects, has greatly reduced flooding along the portion of the Missouri River in the vicinity of Fort Randall. 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 is pertinent to the incremental reach described in this WCM. Since there is little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed further in this WCM.

A-02. Flood of 1942. As illustrated on Plate III-15, monthly runoff during May 1942 from the Oahe to Fort Randall drainage area substantially exceeded that recorded in any other month during the 1898-2014 period of available record. Runoff during the month of June 1942 from this reach was also well above average and the 2-month May-June incremental volume of over 2 MAF in 1942 (2.1 MAF to 1949 level of development) exceeded the next largest 2-month volume, which occurred in March-April 1952, by over 0.35 MAF. The May-June 1997 incremental volume was 1.0 MAF, less than half of the 1942 volume. The 5-month March-July 1942 runoff (2.2 MAF to 1949 level of development) indicates that less than 0.1 MAF of runoff occurred in March, April and July 1942. The total 1942 runoff to the 1949 level of development was just over 2.3 MAF. This is the fourth highest yearly total of record (1898-2014), exceeded only in 1953 (2.34 MAF), 2011 (3.2 MAF) and 1997 (3.4 MAF). Extensive rainfall in several separate rainstorms occurred over the southern portions of South Dakota, beginning in late April 1942 and extending through most of June, with the heaviest amount occurring in May. Although the peak flow of 35,300 cfs near the mouth of the White River has been exceeded on other occasions, there were five distinct peaks on this stream during the May-June period, each exceeding 10,000 cfs. The Bad River, which drains into the upstream Big Bend reservoir, also experienced large flows during this period. These 1942 flows were the first substantial runoff to occur from this portion of the Missouri River drainage since extreme drought conditions began in 1930. However, following the severe drought period of the 1930s, emphasis was placed on filling vacant System storage space. Studies indicate that runoff originating below Oahe during May was considerably greater than necessary to sustain System release requirements and the combined May-June runoff from this drainage area would serve the requirement. Consequently, careful scheduling of power releases from the upstream Oahe and Big Bend projects would have been necessary during this period in order to conserve water in the System while maintaining the Fort Randall exclusive flood control space vacant for the control of further inflows, should they have occurred.

A-03. Flood of 1952. The second largest monthly runoff of record (1898-2014) from the Oahe to Fort Randall incremental drainage area of 1.3 MAF occurred in April 1952 as a result of melting of an extremely large plains snowpack. This was a portion of the large basin-wide flood discussed in Appendix A of the Master Manual. The peak flow of 51,900 cfs near the mouth of the White River is the largest peak that has been experienced at that location since records began (1928-2014). A peak flow of 28,100 cfs occurred on the upstream Bad River during this time. The System was not in operation during 1952. However, as discussed in the Master Manual, studies conducted by the MRBWM office indicate that the System would have controlled inflows to prevent downstream damages with a reserve of vacant exclusive flood control space remaining throughout the flood. The total runoff in the Oahe to Fort Randall draining area during 1952 was 2.0 MAF (1949 level of development), more than twice the long-term average (1898-2014).

A-04. Flood of 1960. The maximum average daily incremental drainage area inflow into the Fort Randall reservoir since regulation of the project began in 1953 occurred in March 1960 when a peak daily flow of 60,000 cfs was computed. The runoff resulted from the melt of a substantial snowpack accumulated during the previous winter season. The peak flow near the mouth of the White River was 23,400 cfs while the upstream Bad River peaked at 16,600 cfs at the same time. Considerable flow was added to the incremental drainage area peaks from minor tributaries entering this reach of the Missouri River. This is confirmed by a recorded peak of 8,970 cfs from the 465-square mile drainage area of Medicine Creek at Kennebec, SD.

A-05. Flood of 1962. Frequent rainfall throughout May-July 1962 over the incremental drainage area resulted in 3-month runoff at a level over four times the long-term average (1898-2014). Runoff amounts from this incremental reach during July were the maximum of record, as indicated on Plate III-15. However, peak flows on tributary streams were not particularly high. Average daily flows near the mouth of the White River peaked at 20,000 cfs while the upstream Bad River peaked at 10,500 cfs. Computed incremental flows from the total Big Bend to Fort Randall incremental drainage area peaked at 28,600 cfs. Similar to the 1942 flood flows discussed earlier, the primary concern of regulation should there be a repeat of the 1962 rainfall flood, would be conserving the available water supply in the System in an efficient manner rather than minimizing downstream flood damages.

A-06. Flood of 1997. Flood season runoff from the drainage area controlled by the Missouri River mainstem system during 1997 is currently the second highest on record. Total runoff for 1997 totaled 49.0 MAF, nearly twice the average runoff (1898-2014). The high runoff was the result of an unprecedented heavy plains snowpack concurrent with a near-record mountain snowpack. The melt sequence was more rapid than normal due to much-above-normal temperatures during the melt period, sometimes in the 80°F range, which significantly increased the total volume of runoff. Mountain snowpack for both January and February above Fort Peck (181 percent and 155 percent) and Garrison (169 percent and 159 percent), respectively, were significantly above average. In addition, plains snowpack ranged from 6 inches in eastern Montana to as much as 36 inches in eastern portions of North Dakota and South Dakota. In the Oahe to Fort Randall reach, annual runoff was a record high 3.4 MAF (1898-2014).

A-07. Flood of 2010. Total runoff during 2010 was 38.7 MAF, the fourth highest on record (1898-2014). Plains snowfall began in the fall of 2009, and continued to accumulate in the plains as above-average snowfall and colder-than-normal temperatures persisted into March. By the beginning of the plains snowmelt, many areas in the basin had accumulated 4 to 6 inches of SWE from western North Dakota through much of South Dakota to northwest Iowa, and 3 to 4 inches in surrounding regions of Montana, Nebraska and southwest Iowa. In general, the precipitation during the 2010 calendar year was above average in the Missouri River basin. Areas of the basin received well-above-normal precipitation in all periods; however, much greater-than-normal precipitation occurred in April through August. As shown on Plate III-15, March runoff in the reach from Oahe to Fort Randall was a record high (1898-2014).

A-08. Flood of 2011. The 2011 runoff year was the highest runoff year of record (1898-2014) in the upper Missouri River basin since record-keeping began, resulting in a total annual runoff of 61.0 MAF, almost 2.5 times average. It also marked the fourth consecutive year of above-average runoff in the upper Missouri River basin, immediately following the 2000-2007 drought. May (9.2 MAF), June (14.8 MAF) and July (10.2 MAF) had the highest runoff for their respective months in the 117-year period of record (1898-2014). The 34.3 MAF of runoff received during that 3-month period exceeded the total annual runoff in 102 of the previous 113 years (1898-2010). The winter of 2010-2011 marked the third consecutive year of significant plains snowpack and mountain snowpack was much above average. While the mountain snowpack was very substantial, runoff from mountain snowpack normally extends over a 3-month period (May-July). During May, heavy rains fell across eastern Montana, western South Dakota and northern Wyoming. In some isolated areas, 10 to 15 inches of rain fell over a 3-day period. Because this runoff came in the form of rainfall runoff rather than snowmelt runoff, the volume of runoff over this very large area quickly made its way to the Fort Peck and Garrison reservoirs and dictated a need to increase releases from all six reservoirs to record levels. As shown on Plate III-15, June and August runoff in the reach from Oahe to Fort Randall were record highs.

A-09. 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 System projects during droughts.

A-10. Historical Regulation and Effects. Closure of Fort Randall Dam was made in July 1952 beginning the accumulation of storage in the reservoir. Initially the project was regulated for flood control and navigation and, in combination with the operational Fort Peck project, initiated the regulation of the System. The minimum pool, elevation 1320.0 feet, was filled in mid-1954 in anticipation of the first power units coming on line. Prior to 1957 an interim base of flood control at elevation 1340.0 feet governed regulation of the project, recognizing continuing construction of the project and the incomplete nature of the System as a whole. Since 1957 Fort Randall has been regulated within the normal range of reservoir elevations. The base of the Exclusive Flood Control Zone, elevation 1365.0 feet, has been exceeded several times since the System closed in 1967: 1967, 1995, 1997, 2010 and 2011. Plates A-1 through A-6 show the levels of the Fort Randall reservoir since initial fill of the minimum pool occurred in 1954.

A-10.1. Plates A-1 through A-6 illustrate the past annual variations in reservoir levels. Average daily unregulated flows shown on these plates are the computed estimates of flow at the damsite if none of the System projects, including Fort Randall, had been in operation. Typically, the minimum level occurs in the early winter season at the end of the Missouri River navigation season. Recapture of winter power releases from upstream reservoirs raises the reservoir level during the winter months to about elevation 1350.0 feet by early March. In years with light plains snowpack, the reservoir is refilled to elevation 1353.0 feet by early March. Additional runoff during March generally raises the reservoir level to the desired operating level of 1355.0 feet. Rainfall events through the summer and fall occasionally raise the reservoir above the 1355.0-foot level. If that occurs, releases from upstream projects are adjusted as needed to evacuate the accumulated storage in an orderly manner while still serving authorized purposes. In early fall accelerated evacuation occurs to provide carryover space during the winter months for recapture of upstream power releases.

A-10.2. The fall drawdown of Fort Randall began in 1962, after the upstream Oahe power units became available. During the years 1962 through 1970 the drawdown was to elevation 1320.0 feet, except in 1964 when the reservoir was drawn down to 1313.5 feet. As discussed in Section 2-06.1 of this manual, this annual drawdown generated many complaints, mostly of a recreational and environmental nature. Consequently, beginning in 1971, regulation criteria were changed and since that time, drawdown has been limited to approximately elevation 1337.5 feet.

A-10.3. Regulation of the mainstem and tributary projects has resulted in substantial reductions to all annual peak flows that would have been experienced at the Fort Randall damsite. Conversely, water stored in the Carryover Multiple Use Zones in the three upper mainstem reservoirs has made it possible to maintain adequate downstream Missouri River flows to support the authorized purposes of navigation, irrigation, recreation, water supply, hydropower generation, water quality control and fish and wildlife during drought periods. Sections A-11 through A-26 discuss Fort Randall regulation during significant flooding and drought periods.

A-11. 1961 Regulation. Runoff originating from the total Missouri River drainage area above Fort Randall during 1961 totaled about 9.8 MAF (1949 level of development), less than one-half of the long-term average (1898-2014). Since runoff records first became available in 1898 there has been only two years with less runoff from this drainage area, 1931 (9.4 MAF) and 1988 (8.8 MAF). Additionally, during 1961 the initial fill of the System had not been completed and the total storage within the System was at extremely low levels. The 1961 Fort Randall releases (regulated flows) shown on Plate A-7 are illustrative of the release level from this project that is typical during periods of extremely deficient water supply. Comparison of regulated and unregulated flows on Plate A-7 indicates the supplementation of flows during the April-September growing season resulting from regulation of reservoirs primarily to provide downstream flow support on the Missouri River. Development of water resources in the basin above Fort Randall has continued since 1961 and, if 1961 hydrologic conditions should be repeated, the flow supplementation would be more marked. While similar regulated flows could be expected, the increased depletion occasioned by further water resource development would have the effect of resulting in an extended period of negative unregulated flows, indicating that during some years the current resource development is served only by withdrawal from storage. Weekly cycling of power releases from Fort Randall is very evident on Plate A-7, reflecting low weekend power loads and the availability of re-regulating storage space in the downstream Gavins Point reservoir. Since 1961 the upstream Oahe and Big Bend powerplants have come into operation and have assumed more of the power cycling requirements, allowing Fort Randall power releases to be at a more uniform level.

A-12. 1964 Regulation. Unregulated daily flows at Fort Randall during 1964 peaked at 214,000 cfs, among the largest unregulated peaks that have occurred at this location since regulation by the Fort Randall reservoir began in 1953. Only 1972, 1978 and 1997 experienced higher unregulated flows. As illustrated on Plate A-8, daily Fort Randall releases during the flood period averaged about 25,000 cfs, although there was considerable variation from this rate, largely representing power peaking. Of interest is the period of a few days in mid-June when releases were extremely low. This represented regulation designed to reduce inflows into the downstream Gavins Point reservoir because of substantial runoff originating between Fort Randall and Gavins Point. Similar regulation has occurred several times since the projects became operational, with 0 cfs or near 0 cfs daily releases from Fort Randall. From Plate A-8, it is evident that System storage gains resulting from 1964 runoff did not occur in the Fort Randall reservoir but in the upstream System projects. Initial fill of upstream System reservoirs was in progress during 1964, however if the 1964 runoff should be repeated with the System at normal operating levels, very little difference in Fort Randall regulation would be expected. A somewhat higher level of releases, particularly during the winter season, would probably occur.

A-13. 1967 Regulation. Total Missouri River basin runoff above Fort Randall Dam during the June-July period of 1967 was among the largest of record for this period of the year, almost 75 percent greater than the long-term average. Combined with this runoff above Fort Randall were severe flood flows originating between the Fort Randall and Gavins Point dams and in the Missouri River drainage areas below the System. Damages prevented by the regulation of Fort Randall and the other System reservoirs during this flood approached $250 million. As illustrated on Plate A-9, average daily releases from the Fort Randall reservoir during the flood period were generally less than 35,000 cfs. Unregulated flow in the 175,000 cfs range would have occurred for a two-week period without upstream regulation. During June it was necessary to maintain releases at a very low level due to flooding along the lower Missouri River. Prior to 1967, initial fill of the System had not been completed, and as a consequence, effort was being made to retain storage within the System while providing the downstream flood control. Fort Randall reservoir peaked at elevation 1366.5 feet, 1.5 feet into the Exclusive Flood Control Zone, as illustrated on Plate A-9.

A-14. 1972 Regulation. Missouri River basin runoff above Fort Randall Dam during 1972 was more than 7 MAF greater than the long-term average. March runoff was exceptionally large, as indicated by Plate A-10, with an unregulated peak flow of 231,000 cfs, the largest unregulated peak at this location since regulation of the reservoir began in 1953. The System was at normal storage levels prior to 1972, water was captured during the runoff season, and then evacuated prior to the following year's runoff season. As a result, Fort Randall releases were maintained at well-above-average rates through the year. The relative uniformity of releases during the April-November open-water season is illustrated on Plate A-10 with releases being near the maximum powerplant release capability through much of the season. Downward adjustments in the release rate represent reductions occasioned by downstream flood control considerations. From Plate A-10 it is evident that, in spite of the large amount of upstream runoff, the Fort Randall reservoir elevations were maintained within the normal operating range.

A-15. 1975 Regulation. The April through July runoff of 23.8 MAF originating in the Missouri River basin above Fort Randall during 1975 was the second highest since runoff records began in 1898. The 1997 April through July runoff was 23.4 MAF, and the 2011 April through July runoff was 34.7 MAF. While the peak unregulated flow of 173,000 cfs at the Fort Randall damsite was relatively small in relation to the flood season volume, the unusual aspect was the sustained large unregulated flows extending from late April through July, as illustrated on Plate A-11. Also unusual was that most of the above-normal precipitation contributing to the record high runoff occurred after early April and extended through July. As a consequence, Fort Randall releases during the early portions of the year were at near-average levels. During May and June release increases were made; however, they were limited due to high tributary inflows into the Missouri River below Gavins Point and consequent flood control regulations. Release restrictions continued through the first half of July, preventing probable inundation of cropland yet to be harvested in the Missouri River reach above the mouth of the Niobrara River. A release of 60,000 cfs began in mid-July, after harvest of low-lying crops and construction of low-elevation levees by private interests, and continued at this rate through the remainder of the 1975 open-water season. Although record high amounts of runoff originated above Fort Randall, and releases were the largest necessary since regulation of the project began, the Fort Randall reservoir levels were maintained in the normal range, as indicated by Plate A-11. Further information relating to this flood and regulation afforded by all reservoirs in the System is presented in the Master Manual and in the special MRD-RCC Summary Report, *Regulation of the Missouri River Main Stem Reservoir System to Control the 1975 Inflows*.

A-16. 1977 Regulation. As shown on Plate A-12, runoff above Fort Randall during 1977 was one of the lowest on record. The runoff originating from the total Missouri River drainage area above Fort Randall during 1977 totaled approximately 12.6 MAF, the lowest recorded at that time since the System had been regulated. Inflows dropped dramatically from mid-July to early September. Releases were maintained near 30,000 cfs to meet navigation and downstream purposes.

A-17. 1978 Regulation. Runoff above Fort Randall during 1978 was decidedly different than the previous year, as shown on Plate A-13. Due to the large runoff that began about mid-March, Fort Randall releases were reduced to near 1,000 cfs for one week to limit the pool rise in the downstream Gavins Point reservoir, which in turn permitted Gavins Point releases to be held to a minimum. The large inflows, coupled with the low releases, resulted in the Fort Randall reservoir levels increasing nearly 12 feet in a 10-day period. In early April the unregulated inflow into Fort Randall peaked at 254,000 cfs, the highest on record. The March through July System inflow volume of 27.8 MAF was almost twice the average March-July runoff volume of 15.3 MAF, at that time was the largest of record. Instantaneous releases were maintained above 15,000 cfs beginning on May 2 and extending through June in order to improve walleye, sauger and paddlefish spawning below the project. Releases exceeded 50,000 cfs from August to late November as part of flood storage evacuation. A 10-day extension to the normal 8-month navigation season was provided, which is consistent with above-average water supply criteria. From August 1 to the end of the navigation season, Fort Randall releases generally paralleled System releases. Releases in excess of powerplant capacity were required to evacuate stored floodwaters and these supplemental releases totaled nearly 1.5 MAF. The Fort Randall pool level declined gradually and uniformly throughout much of the period, beginning at elevation 1358.0 feet and lowering at a rate of 2 feet per month during August and September. Additional information describing the 1978 flood and accompanying System regulation is presented in the Master Manual and in the special MRD-RCC Summary Report, *Regulation of the Missouri River Main Stem Reservoir System to Control the 1978 Flood.*

A-18. 1988 Regulation. The runoff above Fort Randall during 1988 of 8.8 MAF is the lowest on record (1898-2014). Similar to 1977, inflows dropped dramatically from mid-July to early October. Releases were maintained near 30,000 cfs to meet navigation and other downstream purposes. This was the second year of what later would be referred to as the 6-year drought of 1987–1992, the first extended drought to occur since the System filled in 1967. See Plate A-14 for the regulated and unregulated flows.

A-19. 1993 Regulation. While 1993 is remembered as the "The Great Flood of 1993", runoff from the Missouri River basin upstream of Fort Randall totaled 25.3 MAF, 120 percent of average. The runoff above Sioux City totaled 36.2 MAF, 145 percent of average. The large runoff that affected the Missouri River occurred mainly downstream of the System. To alleviate downstream flooding, System releases and Fort Randall releases were dramatically reduced from mid-July through August, as shown of Plate A-15. As a result of above-average runoff above the System and reduced releases, the System recovered from the 6-year drought in a single summer. The total estimate of flood damages prevented by the System during 1993 (indexed to 2016) was $8.4 billion. In comparison, total damages prevented from 1937 through 1992 totaled $13.8 billion (indexed to 2016). Most of the damages prevented during the 1993 flood were in the Kansas City District area of responsibility.

A-20. 1995 Regulation. As shown on Plate A-16 the runoff above Fort Randall during 1995 totaled 26.7 MAF. During the first part of the year until mid-April, Fort Randall releases generally paralleled those from Gavins Point. In early April System releases were decreased to 12,000 cfs to reduce the threat of downstream flooding due to high tributary inflows between Gavins Point and Sioux City. From mid-April through the first of June, average daily Fort Randall releases were less than 10,000 cfs for all but nine days and, on May 30, releases were reduced to 0 cfs. By June 1, the Fort Randall reservoir rose to an elevation of 1367.9 feet, its highest elevation since closure of the dam in 1952. As downstream conditions allowed, the System releases and Fort Randall releases were slowly increased during June and July to evacuate flood storage. The total estimate of flood damages prevented by the System during 1995 (indexed to 2014) was $3.2 billion.

A-21. 1996 Regulation. The runoff above Fort Randall during 1996 totaled 28.2 MAF. Runoff during February of 2.9 MAF was more than three times average. Monthly runoff totals during the next five months were all above average, ranging from 110 percent to 180 percent of average. Releases from Fort Randall paralleled the System releases from Gavins Point. Releases averaged 35,500 cfs in April (average April release is 22,500 cfs), 32,400 cfs in May (average May release is 26,200 cfs), 35,400 cfs in June (average June release is 28,200 cfs) and 45,100 cfs in July (average July release is 31,700 cfs). As shown on Plate A-17, the Fort Randall releases were decreased for short periods on four occasions during the summer. The decrease in System releases were in response to downstream flood control regulation.

A-22. 1997 Regulation. Runoff above Fort Randall during 1997 totaled 38.8 MAF. This was the second highest runoff of record (1898-2014). The total runoff above Sioux City of 49.0

MAF was also the second highest on record and almost twice average. As shown on Plate A-18, the runoff during March through July of 29.4 MAF was nearly twice average during that 5-month period (15.3 MAF). A decision was made by the MRBWM office in late March to transfer plains snowmelt runoff from Oahe to Fort Randall because the runoff was forecasted to utilize most if not all of the exclusive flood control space at Oahe. The Fort Randall pool elevation rose above the base of its Exclusive Flood Control Zone, elevation 1365.0 feet, during the first week in April where it stayed through early September. A late spring blizzard essentially refilled the exclusive flood control storage space that had been evacuated at Oahe and left both projects with very little space in their respective Exclusive Flood Control Zones. Therefore, release reductions for downstream flood control were not possible during the spring and summer of 1997, but Fort Randall continued to provide flood control by capturing localized rainfalls and metering out the water at reduced rates. The peak unregulated inflow of 245,000 cfs on April 3 was the second highest peak on record (1898-2014), exceeded only in 1978. Due to single-unit spring outages for unit maintenance and inspection, Fort Randall spillway releases were initiated on March 31 as releases were increased beyond the remaining seven units' discharge capacity. The spring outage schedule was shortened and modified to accommodate planned fall outages. Combined powerhouse and spillway releases reached 53,000 cfs in April as the Fort Randall reservoir continue to rise to record levels. Fort Randall releases of 67,500 cfs, a record high at that time, were made in 1997 (previous high of 60,600 cfs in 1975). As had occurred in the previous two years, the high releases from Fort Randall caused flooding in two low-lying areas west of Lazy River Acres. House trailers were flooded to within one foot of their floor elevation. Water rose into yards at several low-lying areas away from the river. Farmland on both sides of the river was flooded. On May 7, the Fort Randall reservoir peaked at elevation 1372.2 feet, 4.3 feet higher than the previous maximum pool of 1367.9 feet experienced in 1995, which had been the highest pool elevation since the dam closed in 1952. The total estimate of flood damages prevented by the System during 1997 (indexed to 2014) was $8.4 billion. Further information describing the 1997 flood and accompanying System regulation is given in the Master Manual and in the special MRD-RCC summary report, *Regulation of the Missouri River Main Stem Reservoir System during the 1997 Flood.*

A-23. 1999 Regulation. The runoff in the spring and early summer of 1999 was about average. However, as seen on Plate A-19, runoff in June and July was significant. During the late summer/early fall period the primary regulation objective of the System was to evacuate stored floodwaters from the upper three reservoirs. Releases from the System were stepped up to 40,000 cfs for the months of September, October and November. Since the System closed in 1967, average System releases during these three months are approximately 35,000 cfs, 34,000 cfs and 30,000 cfs, respectively.

A-24. 2010 Regulation. Total runoff during 2010 was 38.7 MAF, the fourth highest on record (1898-2014). Runoff above Fort Randall was 25.4 MAF. In general, the precipitation during the 2010 calendar year was above normal in the Missouri River basin. Areas of the basin received well-above-normal precipitation in all periods; however, greater-than-normal precipitation occurred in April through August. Plains snowpack was significant and by the beginning of the plains snowmelt, many areas in the basin had accumulated 4 to 6 inches of SWE from western North Dakota through much of South Dakota to northwest Iowa, and 3 to 4 inches in surrounding regions of Montana, Nebraska and southwest Iowa. During March, the Fort Randall reservoir elevation climbed from 1349.0 to 1361.1 feet due to a combination of low releases and above-average runoff. Releases from Fort Randall averaged less than 7,000 cfs in March due to high tributary flows downstream of the System. As shown on Plate III-15, March runoff in the reach from Oahe to Fort Randall was a record high. Runoff from above-normal rainfall upstream and low releases, due to rainfall downstream of Fort Randall, resulted in the pool elevation reaching a maximum of 1368.1 feet in June, 3.1 feet into the 10-foot Exclusive Flood Control Zone. As shown in Plate A-20, the reservoir was in the Exclusive Flood Control Zone from June 14 through July 9. Fort Randall releases reached an annual maximum of 48,300 cfs in late October.

A-25. 2011 Regulation. The 2011 runoff year was the highest runoff year of record (1898-2014) in the upper Missouri River basin since record-keeping began, resulting in a total annual runoff of 61.0 MAF, almost 2.5 times average. It also marked the fourth consecutive year of above-average runoff in the upper Missouri River basin, immediately following the 2000-2007 drought. May (9.2 MAF), June (14.8 MAF) and July (10.2 MAF) had the highest inflows for their respective months in the 117-year period of record (1898-2014). The 34.3 MAF of runoff received during that 3-month period exceeded the total annual runoff in 102 of the previous 113 (1898-2010) years. The winter of 2010-2011 marked the third consecutive year of significant plains snowpack, and mountain snowpack was much above average. While the mountain snowpack was very substantial, runoff from mountain snowpack normally extends over a 3-month period (May-July), and May 1 regulation studies indicated System evacuation releases of 57,500 cfs. During May, heavy rains fell across eastern Montana, western South Dakota and northern Wyoming. In some isolated areas, 10-15 inches of rain fell over the 3-day period. Because this runoff came in the form of rainfall runoff rather than snowmelt runoff, the volume of runoff over this very large area quickly made its way to the Fort Peck and Garrison reservoirs and dictated a need to increase releases from all six System projects to record levels. System storage peaked at 72.8 MAF on July 1, occupying 98 percent of the allocated flood control storage space (16.0 MAF of 16.3 MAF).

A-25.1. As shown in Plate A-21, the Fort Randall reservoir was near the base of the Annual Flood Control and Multiple Use Zone on March 1. Inflows from plains snowmelt and rainfall runoff resulted in the pool rising to almost 1360.0 feet by May 1. The reservoir continued to rise through June due to a combination of increased Oahe releases and additional rainfall runoff in mid-June. The reservoir peaked at elevation 1374.0 feet on July 7, 1.0 foot below the top of the Exclusive Flood Control Zone. This record elevation exceeded the previous record high of 1372.2 feet, set in May 1997. The reservoir entered the Exclusive Flood Control Zone on June 19 and exited the zone on August 17. Releases from Fort Randall reached a maximum of 160,000 cfs on July 27. The previous record of 67,500 cfs was set in November 1997 and was exceeded for 119 days in 2011. Supplemental releases were made from the outlet tunnels and the spillway. Spillway releases were made from late April to early October, with maximum hourly spillway releases of about 142,000 cfs on July 7 and 13. Outlet tunnel releases were made from late May to late June and for a few days in July. Outlet tunnel releases resumed in mid-September and continued until December 8. Maximum hourly outlet tunnel releases were approximately 117,000 cfs on July 7. Daily average powerplant, spillway and outlet tunnel releases are shown on Plate A-22. Record daily inflows of 218,000 cfs, which included the Big Bend release, occurred on June 21. Both the spillway and the outlet tunnels required repairs following the record releases made in 2011.

A-25.2. To accommodate variations in power demands during the 2011 record releases, powerplant releases at some of the projects, including Fort Randall, were varied in a day-to-night pattern, with higher powerplant releases occurring during the day. This required adjusting releases from the outlet tunnels or spillway twice per day to maintain the required total project release. In addition, power system load control required hourly variations in powerplant releases at either Oahe or Fort Randall, which required additional adjustment to supplemental releases. Fort Randall generally performed the hourly load control from mid-June through early August. These release adjustments lessened later in the summer as power demands increased and total project releases were reduced.

A-26. Summary of Historical Regulation. Annual total upstream runoff during the historical regulation period (1898-2014) of Fort Randall has ranged from the minimum of 8.8 MAF (1988) to the maximum of 48.7 MAF (2011). 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 Fort Randall, and for the System as a whole (as presented in the Master Manual) as it affects Fort Randall regulation, are reasonable and represent a near-optimum utilization and control of the water supply that may be available. Of course, studies will continue through the life of the project in an effort to improve criteria as conditions change. In general, it may be stated that unless runoff originating upstream from the project is well above normal, Fort Randall releases will be maintained within the capacity of the Fort Randall powerplant. Only in 1975, 1978, 1995, 1996, 1997, 2010, 2011 and 2018, the years that a high amount of upstream runoff occurred, were significant supplemental releases made in excess of powerplant capacity. It is also evident that the amount of runoff originating in the incremental area between Oahe and Fort Randall dams has little effect on Fort Randall pool elevations. Only with extremely large amounts of total runoff or when the total water supply is much below average, such as during the drought of the 1930s, will the variations in seasonal reservoir levels depart significantly from the pattern shown on Plate VI-14. Daily variations from the general level of release rates illustrated on Plates A-7 through A-21 can be expected to continue, both as a response to downstream needs and to enhance power production from the project and the System as a whole.

Appendix B - Recreation

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

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

B-03. Fort Randall Recreation Visitation. Refer to Table B-1 for a history of Fort Randall 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
Fort Randall Recreation Visitation of Corps' Recreation Areas

Year	Visitation in hours	Year	Visitation in hours
1954	2,673,250	1984	8,414,207
1955	2,787,580	1985	7,855,851
1956	2,254,780	1986	7,518,393
1957	2,459,760	1987	7,022,400
1958	1,959,890	1988	7,166,400
1959	1,686,090	1989	7,383,400
1960	1,827,430	1990	8,241,200
1961	1,774,520	1991	5,894,200
1962	1,491,470	1992	11,092,100
1963	1,507,380	1993	10,060,700
1964	2,527,100	1994	8,963,700
1965	2,676,210	1995	10,571,400
1966	2,662,520	1996	11,919,500
1967	3,099,120	1997	9,734,600
1968	3,550,150	1998	11,593,600
1969	4,016,350	1999	10,811,200
1970	4,349,720	2000	9,489,311
1971	5,049,020	2001	10,128,400
1972	4,805,930	2002*	2,529,800
1973	5,374,250	2003*	1,265,500
1974	5,903,831	2004*	1,275,400
1975	4,815,180	2005*	1,103,600
1976	5,803,513	2006*	1,033,400
1977	6,368,958	2007*	1,000,100
1978	8,976,378	2008*	1,139,800
1979	5,657,300	2009*	1,030,900
1980	8,695,000	2010*	1,067,000
1981	8,229,910	2011*	1,108,489
1982	6,175,670	2012**	860,300
1983	6,238,200		

* 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 reservoirs, such as Fort Randall, may withdraw stagnant water of degraded quality from the bottom of the reservoir during prolonged thermal stratification and pass it downstream. Although the Missouri River has historically contained high sediment loading and naturally occurring high concentrations of metals such as arsenic and selenium, the water quality characteristics of the Missouri River have changed within the past several decades. These water quality changes are a result of past and current changes in land use practices, increased urbanization, atmospheric deposition of pollutants, and dam construction and regulation within the Missouri River basin. Water quality impacts arising from the construction and regulation of the System can be broadly classified as direct impacts and indirect impacts.

C-02. Direct Water Quality Impacts of System Regulation. The System and its regulation have significantly improved water quality in the river reaches between the reservoirs and downstream of the System, compared to the water quality in the Missouri River before the System was constructed. The water quality has improved as seen through the Clean Water Act 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 and hydrologic conditions, 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 results in reduced volumes of deeper, cooler hypolimnetic water in the three larger System reservoirs. The low reservoir level 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. Fort Randall Reservoir. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Fort Randall reservoir in the state's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Fort Randall reservoir on the state's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir. Suspended solids levels in the area just downstream of the White River inflow occasionally exceed the state's water quality criteria for aquatic life protection. Dissolved oxygen levels below the state criterion of 5 mg/l occasionally occur in the hypolimnion near the reservoir bottom during summer thermal stratification of the Fort Randall reservoir. Although the EPA's recommended drinking water criteria for arsenic and mercury historically have not been exceeded, the Corps has recommended that local municipalities monitor raw water intakes.

C-05. Missouri River Downstream of Fort Randall Dam. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Missouri River downstream of Fort Randall Dam: recreation (i.e. immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Missouri River downstream of Fort Randall Dam on the state's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir.

C-06. Water Quality Monitoring. The Corps has collected water quality data at Fort Randall since the late 1970s. Water quality monitoring locations includes sites on the reservoir and on the Missouri River upstream and downstream of Fort Randall. Water quality data collection has varied through this period and has included the monitoring of ambient water quality conditions at the following locations: 1) deepwater sites in the Fort Randall reservoir near the dam and near Chamberlain, SD; 2) the Missouri River downstream of the dam in the tailwater region; 3) within the Fort Randall powerplant on water discharged through the turbines; and 4) tributary inflows to the Fort Randall reservoir. 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 Fort Randall reservoir (Lake Francis Case) near the damsite during 2010-2014. A review of these results indicated a possible water quality concern regarding dissolved oxygen for the support of warmwater permanent fish life propagation. Dissolved oxygen levels degrade along the reservoir bottom as summer progresses and fall below 5.0 mg/L in July and August. The lowest dissolved oxygen concentration measured at the four reservoir sites was 0.4 mg/L and occurred at the reservoir bottom at the near-dam site in August 2010. Table C-2 summarizes the water quality conditions that were monitored in the Missouri River in the tailwaters of Fort Randall during 2010-2014. A review of these results indicated no significant water quality concerns. Monitoring of metals and pesticide levels indicate the human health criterion for total arsenic was exceeded on several occasions. Updated information and additional detail can be found in the annual water quality report.

C-08. Surface Water Quality Trends. Surface water quality trends were assessed by evaluating the Trophic State Index (TSI) values calculated from monitoring results obtained at the Fort Randall reservoir for the period 2010-2014. The calculated TSI values indicate that the reservoir near the dam is in a mesotrophic (i.e. intermediate nutrient/intermediate productivity) state. At the next upstream monitoring site the reservoir is moderately eutrophic (i.e., high nutrient/high productivity), and in the upstream transition and riverine zones of the reservoir, it is in a eutrophic state.

Table C-1
2010-2014 Water Quality Conditions – Fort Randall Reservoir

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	**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	1357.8	1355.7	1352.5	1373.8	-----	-----	-----
Water Temperature (°C)	0.1	878	19.2	21.5	7.7	28.8	27[1,5]	2	<1%
Dissolved Oxygen (mg/L)	0.1	878	8.1	8.1	0.4	11.8	5[1,6]	44	5%
Dissolved Oxygen (% Sat.)	0.1	878	90.2	92.9	4.4	113.1	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/L)[E]	0.1	791	8.3	8.2	2.9	11.8	5[3,6]	15	2%
Hypolimnion Dissolved Oxygen (mg/L)[E]	0.1	86	6.3	7.2	0.4	9.2	5[1,6]	29	34%
Specific Conductance (uS/cm)	1	878	803	814	702	933	-----	-----	-----
pH (S.U.)	0.1	877	8.3	8.3	7.2	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	876	2	2	n.d.	35	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	839	318	337	121	431	-----	-----	-----
Secchi Depth (M)	0.02	23	2.41	2.13	1.22	4.27	-----	-----	-----
Alkalinity, Total (mg/L)	7	49	157	164	127	170	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	49	4	4	3	6	-----	-----	-----
Chemical Oxygen Demand (mg/L)	2	20	11	11	4	19	-----	-----	-----
Chloride (mg/L)	1	19	12	12	11	13	438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/L) – Field Probe	1	804	-----	2	n.d.	23	-----	-----	-----
Chlorophyll *a* (ug/L) – Lab Determined	1	25	-----	3	n.d.	17	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	4	39	24	24	15	36	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	48	577	562	402	848	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	-----	0.02	n.d.	0.18	4.7 [1,5,8], 0.93[1,7,8]	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	49	0.4	0.4	n.d.	2.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	49	-----	0.08	n.d.	0.60	10[2,5]	0	0%
Nitrogen, Total (mg/L)	0.1	49	0.6	0.04	n.d.	2.8	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	49	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	49	0.02	0.02	n.d.	0.09	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	49	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/L)	1	49	243	247	201	295	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/L)	4	49	-----	4	n.d.	39	158[1,5], 90[1,7]	0	0%
Microcystin, Total (ug/L)	0.1	25	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, Oxidation-Reduction Potential, 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 warmwater 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] 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.

Table C-2
2010-2014 Water Quality Conditions – Fort Randall Tailwater

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
Streamflow (cfs)	1	59	31,821	24,585	0	154,161	-----	-----	-----
Water Temperature (°C)	0.1	58	11.4	9.8	0.1	26.6	27(1,4)	0	0%
Dissolved Oxygen (mg/L)	0.1	58	11.0	11.3	5.2	14.3	≥ 5(1,5)	0	0%
Dissolved Oxygen (% Sat.)	0.1	58	101.0	101.0	66.4	125.6	-----	-----	-----
pH (S.U.)	0.1	57	8.2	8.2	6.9	9.3	6.5(1,2,5), 9.0(1,2,4), 9.5(3,4)	0, 1, 0	0%, 2%, 0%
Specific Conductance (uS/cm)	1	57	801	803	706	959	-----	-----	-----
Oxidation-Reduction Potential	1	57	358	359	201	530	-----	-----	-----
Alkalinity, Total (mg/L)	7	59	162	164	128	182	-----	-----	-----
Carbon, Total Organic (mg/L)	0.3	59	4.0	4.1	n.d.	7.2	-----	-----	-----
Chemical Oxygen Demand (mg/L)	2	53	11	11	2	18	-----	-----	-----
Chloride (mg/L)	1	59	13	12	5	29	438(2,4), 250(2,6)	0	0%
Colorized Dissolved Organic Matter (ug/L)	4	44	23	22	14	43	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	59	564	544	406	750	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0	0%
Nitrogen, Ammonia Total (mg/L)	0.02	59	-----	0.03	n.d.	0.24	5.7 (1,4,7), 1.7 (1,6,7)	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	59	0.42	0.39	n.d.	2.24	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	59	-----	0.08	n.d.	0.40	10(2,4)	0	0%
Nitrogen, Total (mg/L)	0.1	59	0.51	0.46	n.d.	2.36	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	56	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	59	-----	0.02	n.d.	0.09	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	59	-----	n.d.	n.d.	0.05	-----	-----	-----
Suspended Solids, Total (mg/L)	4	58	-----	6	n.d.	91	158(1,4), 90(1,6)	0, 1	0%, 2%
Turbidity (NTU)	1	58	-----	3	n.d.	21	-----	-----	-----
Acetochlor, Total (ug/L)(D)	0.1	58	-----	n.d.	n.d.	0.2	-----	-----	-----
Atrazine, Total (ug/L)(D)	0.1	58	-----	n.d.	n.d.	0.6	-----	-----	-----
Metolachlor, Total (ug/L)(D)	0.1	58	-----	n.d.	n.d.	0.8	-----	-----	-----

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 n.d., 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.
- (8) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (9) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (10) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e. cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

Appendix D - Fish and Wildlife

D-01. General. The USFWS has identified three protected species – the endangered least tern, the threatened piping plover and the endangered pallid sturgeon – that are affected by the regulation of the System. The least tern and piping plover utilize the Missouri River reach downstream of Fort Randall 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. As discussed in the Master Manual, 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 Fort Randall reservoir is kept on a fairly normal annual reservoir level cycle, regardless of basin conditions. Thus, access to the reservoir is also fairly consistent, except during the lowest levels of the cycle, which occur in the fall. Fort Randall offers a very good walleye/sauger fishery. Smallmouth, white bass and catfish fisheries are underutilized. Paddlefish populations are declining and pallid sturgeon are T&E species. The annual fall drawdown exposes aquatic vegetation and organisms, and restricts boat access.

D-03. Regulation for Endangered and Threatened Species – Least Terns and Piping Plovers. Releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered least tern and threatened piping plover nesting since 1986. As a measure to minimize take while maintaining the flexibility to increase releases during the nesting season, hourly releases from Fort Randall follow a repetitive daily pattern to limit peak stages below the project for nesting T&E birds. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Average daily releases may be increased every third day to preserve the capability of increasing releases later in the summer with little or no incidental take if drier downstream conditions occur. If higher daily releases are required later in the nesting season, the daily peaking pattern may be adjusted, reduced or eliminated resulting in a steady release to avoid increased stages at downstream nesting sites. Periods of zero release are minimized to the extent reasonably possible during the nesting season given daily average releases, real-time hydrologic conditions, and System generating constraints as defined in coordination with Western. Additional System regulation criteria used for T&E species is discussed in Section 7-09 of this WCM and Section 7-10 and Appendix D of the Master Manual.

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 Fort Randall reservoir area or in the river reach below Fort Randall. More detailed discussion on water supply and irrigation can be found in Appendix E of the Master Manual.

E-02. Fort Randall Reservoir from Fort Randall Dam to Gavins Point Reservoir. As shown in Table E-3 of the Master Manual, there are approximately 84 water supply intakes are located on the Fort Randall reservoir (Lake Francis Case). These include 5 municipal water supply facilities, 72 irrigation intakes, 4 domestic intakes and 3 public intakes. The municipal water supply facilities serve a population of approximately 12,100 persons. Of the 100 irrigation intakes located on the river reach downstream of Fort Randall, four are located on the Yankton Reservation.

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Appendix F - Hydropower

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

F-02. Hydropower Capacity. The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20,000 MW, with an annual generation of over 90 million MWh. The investor-owned systems have about 60 percent of the basin's generating capacity. The publicly-owned systems consist of about 40 percent federal hydroelectric capacity and 60 percent thermal capacity owned by non-federal public bodies. Hydropower installations in the basin total about 3.300 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	67	5	194	9.2	16	58	Semi-Peaking
Garrison	583	2.2	45	5	161	21.6	41	53	Semi-Peaking
Oahe	786	2.6	39	7	174	23.2	54	43	Peaking
Big Bend	517	1.0	23	8	70	23.7	103	22	Peaking
Fort Randall	320	1.7	63	8	118	25.1	44.5	56	Semi-Peaking
Gavins Point	132	0.7	64	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. Fort Randall Dam. Eight units operate at the Fort Randall project, with a generating capacity of 320 MW. Normal powerhouse capacity is 44,500 cfs, and the average release is 25,100 cfs (1967-2015). The average annual flow plant factor is 56 percent. The powerplant produces an average of 1.7 million MWh per year. Power generating units came on line between 1954 and 1956. The Fort Randall powerplant is a semi-peaking plant.

F-05. Fort Randall Dam Releases. The reservoir regulation of this project has been essentially a repetitive annual cycle. A reservoir level at or above elevation 1350.0 feet is normally maintained through the spring and summer months. A maximum release of 160,000 cfs occurred in 2011. A maximum pool elevation of 1374.0 feet occurred in 2011. During the fall period, prior to the close of the Missouri River navigation season, the reservoir is lowered to well below the base of the Annual Flood Control and Multiple Use Zone to near elevation 1337.5 feet. Refill of this evacuated space during the winter months results in increased hydropower generation at the upstream dams during the winter period and compensates for the reduced winter releases from Fort Randall and Gavins Point that are scheduled to reduce the downstream flood risk. The winter period experiences increased downstream flood risk because of a reduction in channel capacity due to river ice formation.

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-05 and Chapter VII of this WCM.

F-06.1. Hourly patterning of the average daily releases is also of major importance in realizing the full power potential of the System powerplants. Based on past experience with both open water and a downstream ice cover, in most cases no limits need to be placed on daily peaking (with the exception of Gavins Point) up to the capacities of the individual powerplants, except during the T&E nesting seasons, provided the limiting average daily discharge is not exceeded. The minimum allowable hourly generation, and corresponding release, is dependent on the hydraulic characteristics of the river below each of the projects and the effect on water use in the downstream reaches. Downstream water supply intakes, fish spawning activities in the downstream channel, recreational usage, and other factors that may be seasonal in nature influence the selection of minimum limits. These constraints at particular projects are summarized in the Master Manual and additional detail for Fort Randall 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. As discussed in Section F-05 and Chapter VII of this WCM, 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 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

Fort Randall 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 Fort Randall Operations Project Manager

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Fort Randall

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

2. Normally, reservoir regulation orders specifying future project releases and power production are furnished by the MRBWM office to Fort Randall. Fort Randall 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 Fort Randall on a daily basis. Regulation instructions for the weekend and holidays are contained in the previous normal working day’s orders. Fort Randall utilizes the Power Plant Control System (PPCS) to transmit observed hourly and daily project data, via the Data Collection Platforms (DCPs) to the MRBWM office. If e-mail or network communication between the MRBWM office and Fort Randall 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 Fort Randall 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 Fort Randall reservoir level remains below elevation 1355.0 feet.

d. If the Fort Randall reservoir level is above elevation 1355.0 feet, 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. Procedures are as follows:

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

(2) The mean inflow for the preceding 12 hours will be estimated by computing the storage change during the 12-hour period on the basis of pool elevations observed at the damsite. Normally, the pool elevation will follow a relatively smooth curve. Therefore, any sudden fluctuations in the pool level recorder trace from a smooth curve (likely due to wind effects on the reservoir gage) should be disregarded and the storage change based on an extrapolation of the smoothed pool level curve through the 12-hour period. The approximate mean inflow in cfs is equivalent to the mean outflow in cfs plus the storage change in acre-feet during the 12-hour period. Twelve-hour inflow may also be approximated by the equation:

Inflow = Outflow + (95,000 x 12-hour elevation change in feet)

(3) Utilizing the inflow as developed above and the current pool elevation as indicated by the smoothed pool level curve developed in (2), determine the rule curve release by use of the emergency curves shown on Plate VII-1 in the Fort Randall Water Control Manual and as Enclosure 1 to this document.

(4) If the rule curve release developed by (3) is greater than the release given by (1), and the reservoir level is between 1355.0 and 1375.0 feet, make release specified by the rule curve. With Fort Randall pool at or below elevation 1365.0 feet, releases will be limited to a maximum of 100,000 cfs.

(5) While releases may be made by any combination of powerplant, outlet tunnels or spillway releases, total releases should not exceed those that would be possible through the spillway alone, subject to considerations in (4) above.

(6) With a Fort Randall pool above elevation 1375.0 feet, release inflows up to the full spillway release capacity in order to prevent further increases in the reservoir elevation. After inflows peak, maintain releases at the maximum release rate reached until the reservoir level drops below elevation 1375.0 feet.

(7) With Fort Randall pool below elevation 1356.0 feet, any release adjustments made necessary by these instructions should be made once daily. With Fort Randall pool above elevation 1356.0, the analysis and necessary adjustments should be at intervals of 12 hours or less.

(8) If release is less than full powerplant capacity, powerplant loading will be patterned similar to recent experience or as prescribed by Western if communication with their office is possible.

5. In the event of downstream flooding, as reported to or anticipated by the Fort Randall Operations Project Manager, during such time the Fort Randall elevation is below elevation 1356.0 feet, releases will be reduced as deemed necessary to alleviate these conditions. However, with the Fort Randall reservoir above elevation 1356.0 feet, releases will not be reduced below those levels defined by the preceding emergency instructions.

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

// signed copy on file

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

Encl

Fort Randall Dam – Lake Francis Case

Water Control Manual

Plates

Summary of Engineering Data -- Missouri River Mainstem System

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

Summary of Engineering Data -- Missouri River Mainstem System

Big Bend Dam - Lake Sharpe	Fort Randall Dam - Lake Francis Case	Gavins Point Dam - Lewis & Clark Lake	Total	Item No.
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			43
1351-1355(10) 25,000-100,000 cfs	32,000 cfs - 128,000 cfs 1228-1237 10,000-60,000 cfs	1153-1161 15,000-60,000 cfs		44
70	117	48	764 feet	45
None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46
	1,074		55,083	47
None	59' dia, 2 per alternate penstock	None		48
8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49
67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50
67,275	40,000	44,100		51
517,470	320,000	132,300	2,501,200 kw	52
497,000	293,000	74,000	1,967,000 kw	53
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

Missouri River Basin
GENERAL LOCATION

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

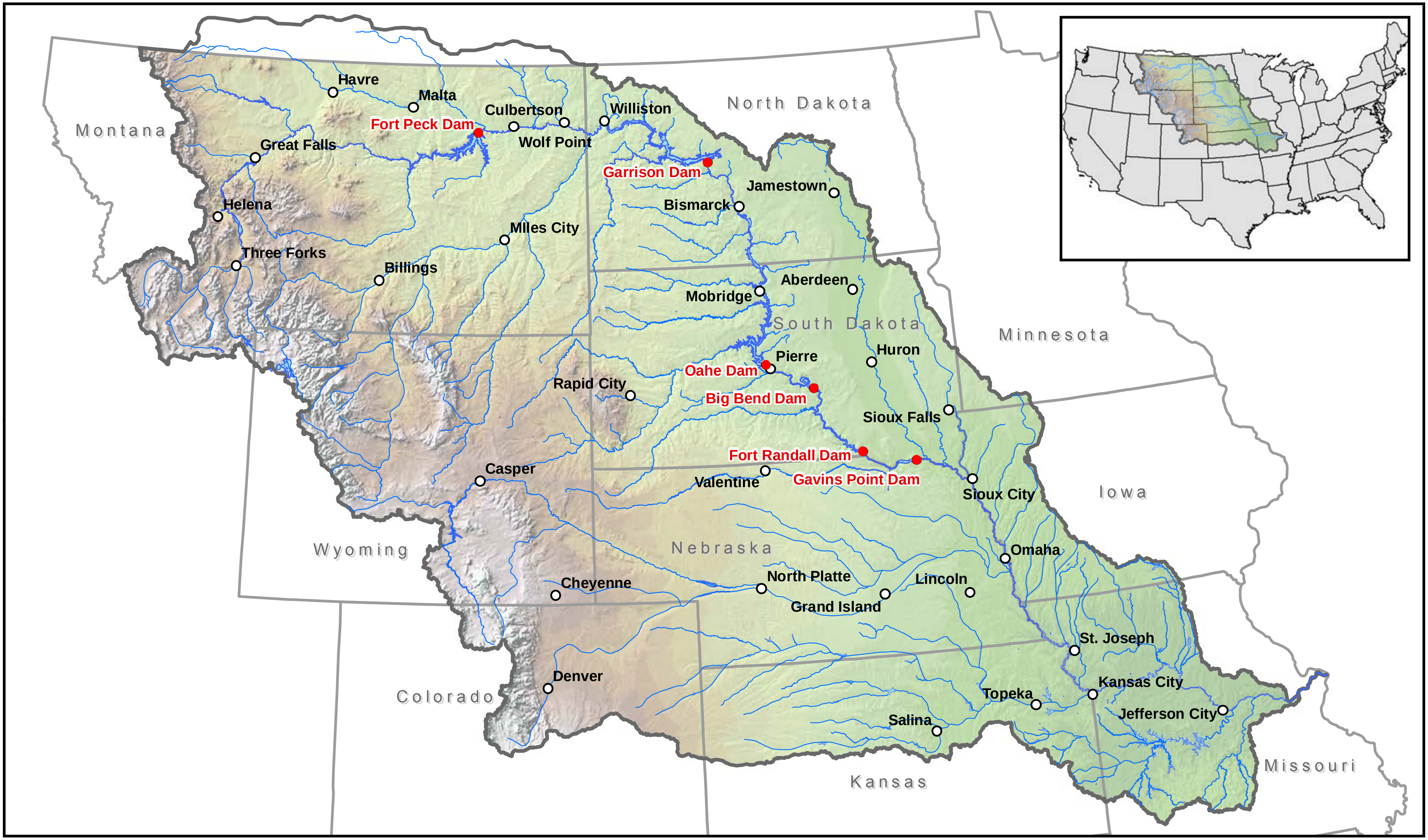

Plate III-1

US Army Corps of Engineers®
Northwestern Division

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

0 50 100 200 300 Miles

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

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The table needs to fixed

River	Drainage Area (sq.mi.)
White River	569.5
Crow Creek	75.8
Platte Creek	58.9
Pease Creek	30.3
Other	2759.2
Total	3493.7

Plate III-2

US Army Corps of Engineers®
Northwestern Division

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

0 10 20 40 60 Miles

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

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

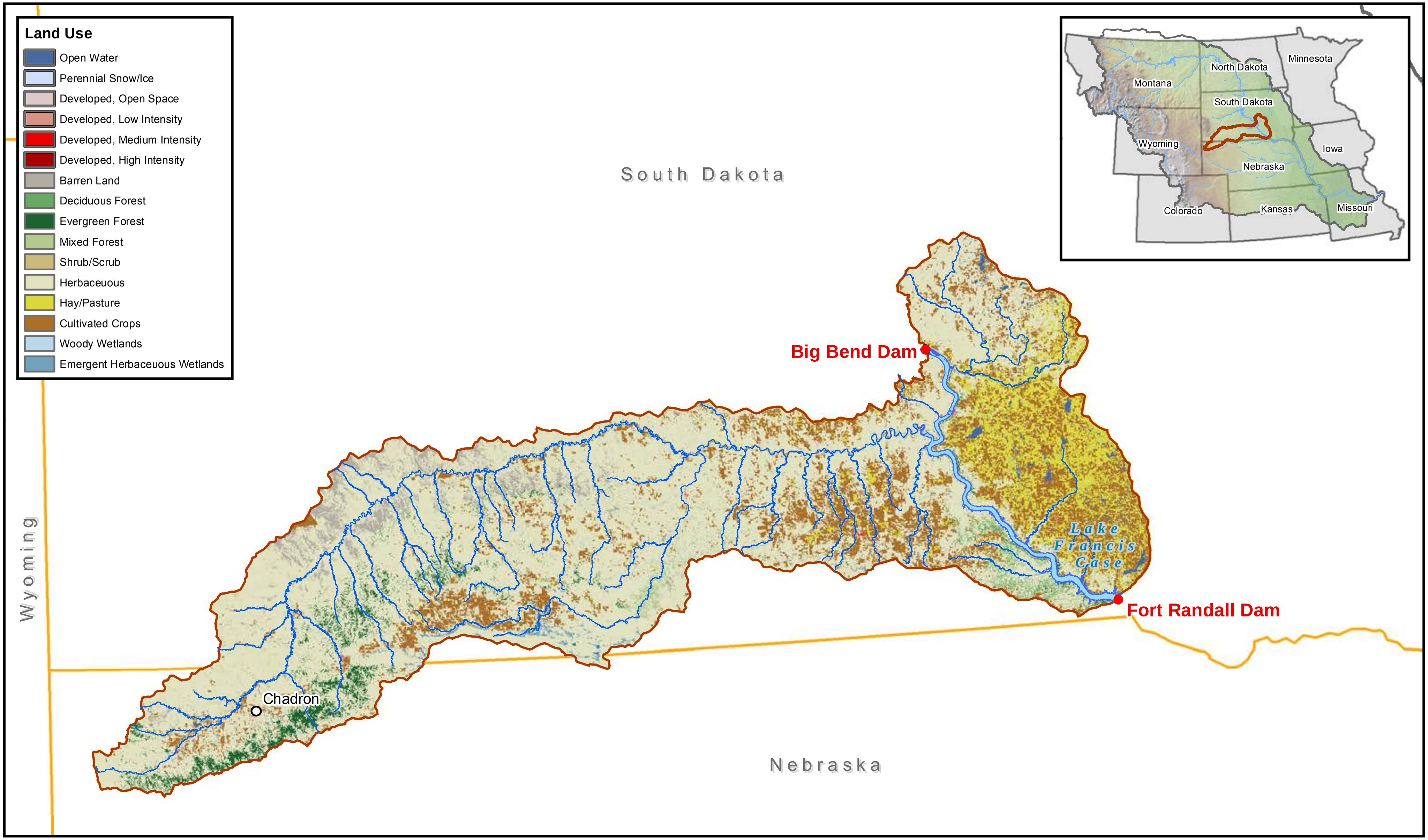

Plate III-3

US Army Corps of Engineers®
Northwestern Division

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

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Missouri River Basin
FORT RANDALL 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 S E W

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

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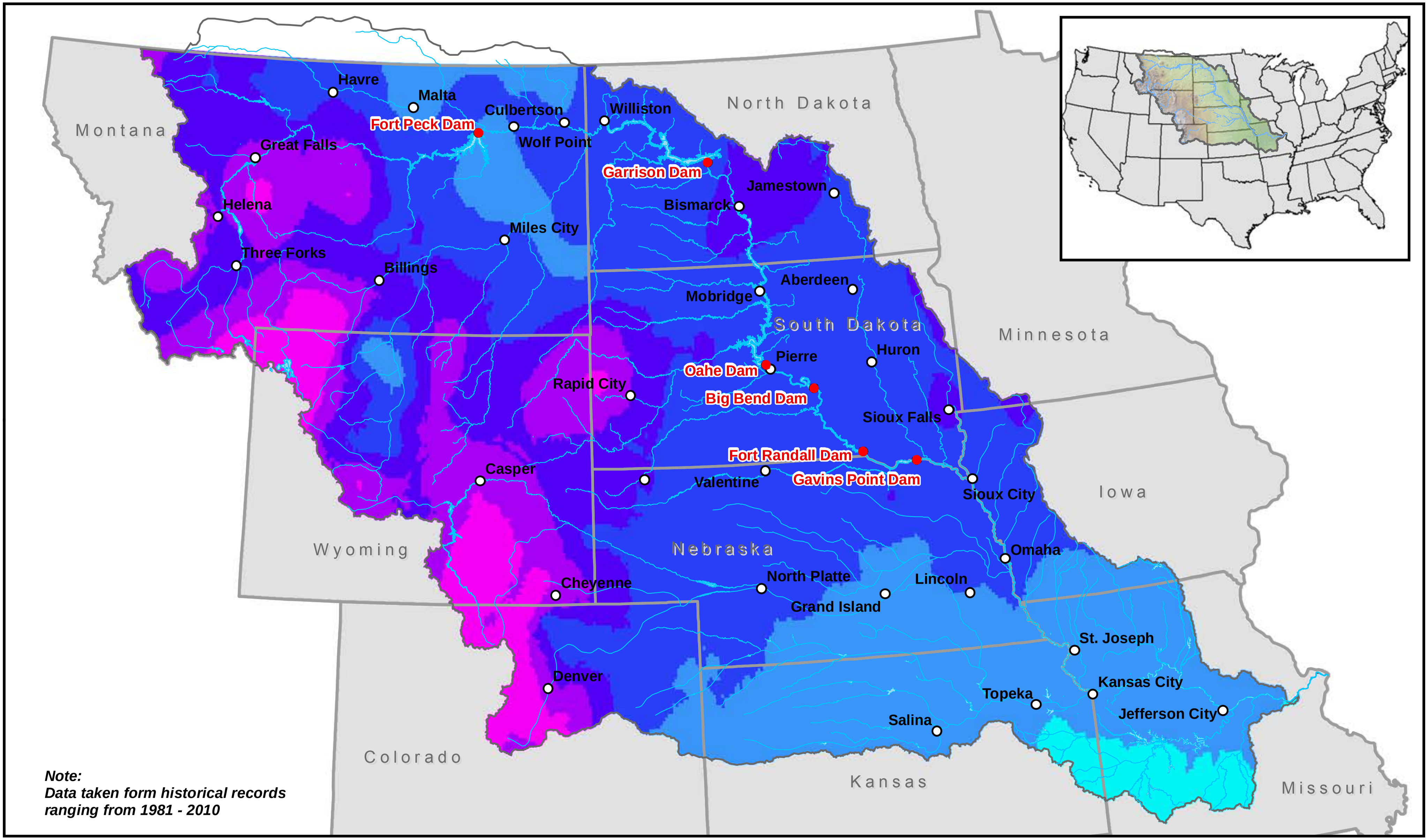
Missouri River Basin
AVERAGE PRECIPITATION
ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



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

Plate III-5

US Army Corps of Engineers®
Northwestern Division

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

Annual Mean Snowfall

- < 12 Inches
- 12 - 24 Inches
- 24 - 36 Inches
- 36 - 48 Inches
- 48 - 72 Inches
- > 72 Inches

0 50 100 200 300 Miles

N W E S

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

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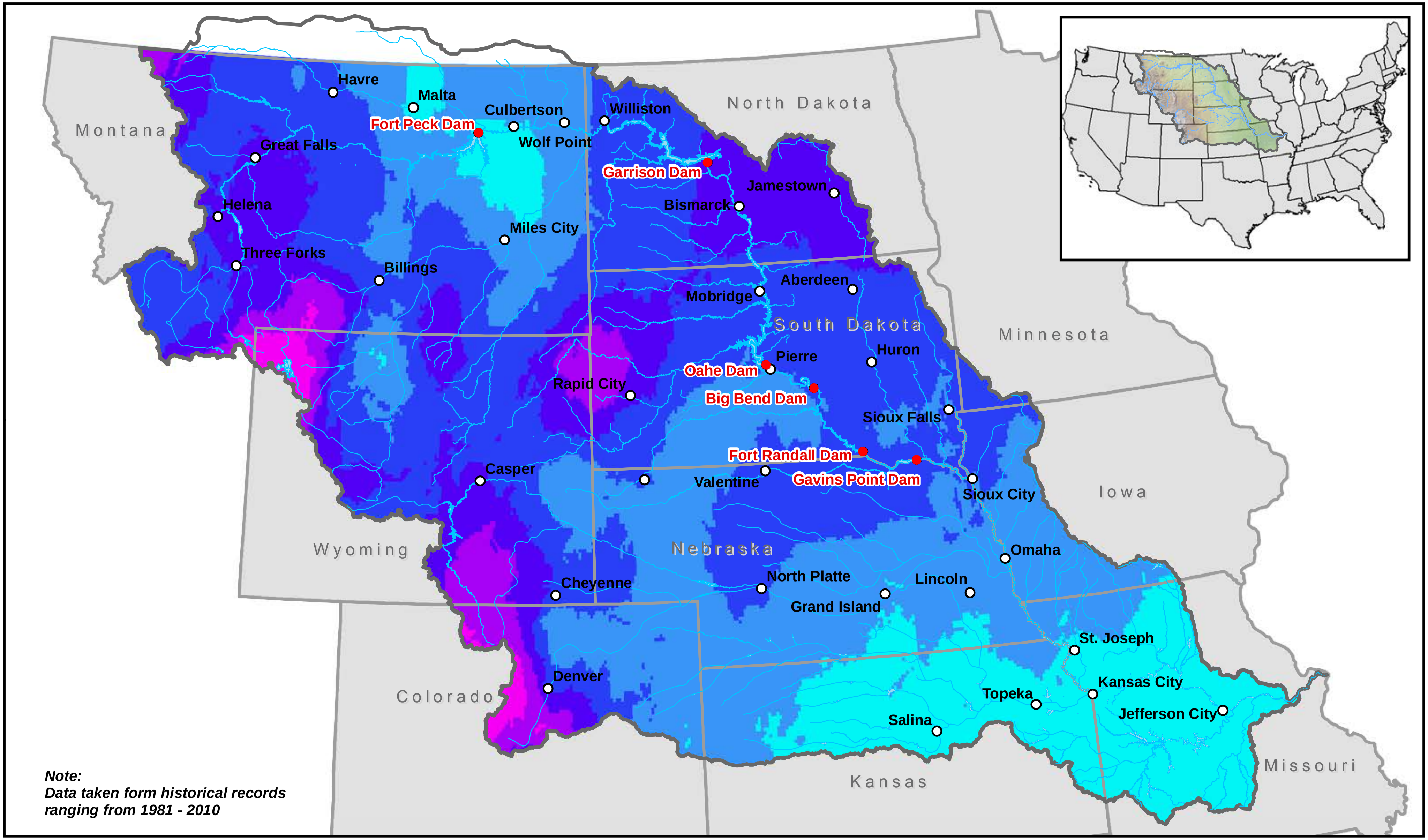
Missouri River Basin
ANNUAL MEAN SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



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

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

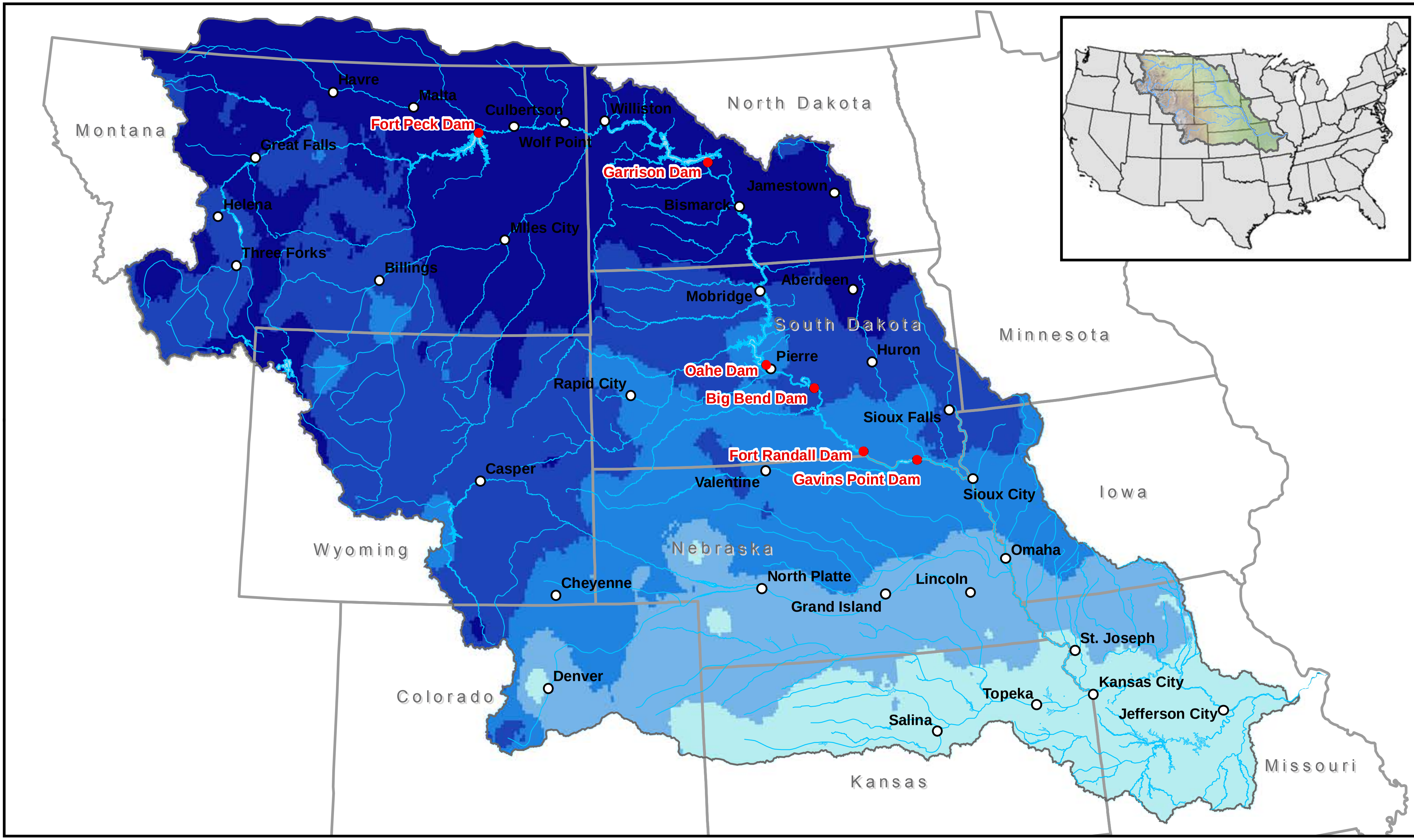

Plate III-7

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 S E 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

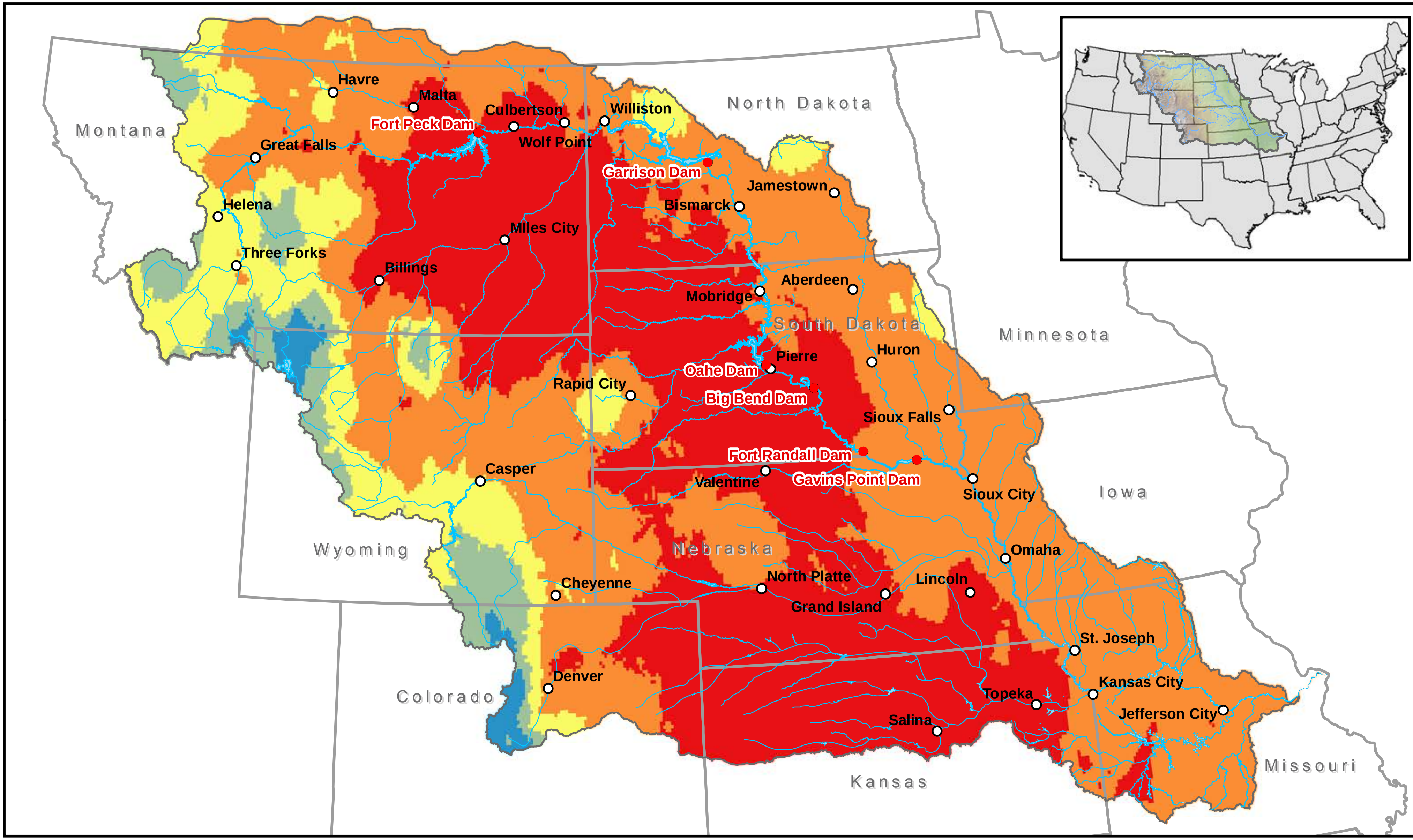

Plate III-8

US Army Corps of Engineers®
Northwestern Division

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

Average Maximum Temperature

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

0 50 100 200 300 Miles

N S E W

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

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Missouri River Basin
AVERAGE MAXIMUM TEMPERATURE
ANNUAL

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

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
Fort Randall 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
Fort Randall 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
Fort Randall Water Control Manual
Normal Monthly Lake Evaporation
in 1000 AF

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

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

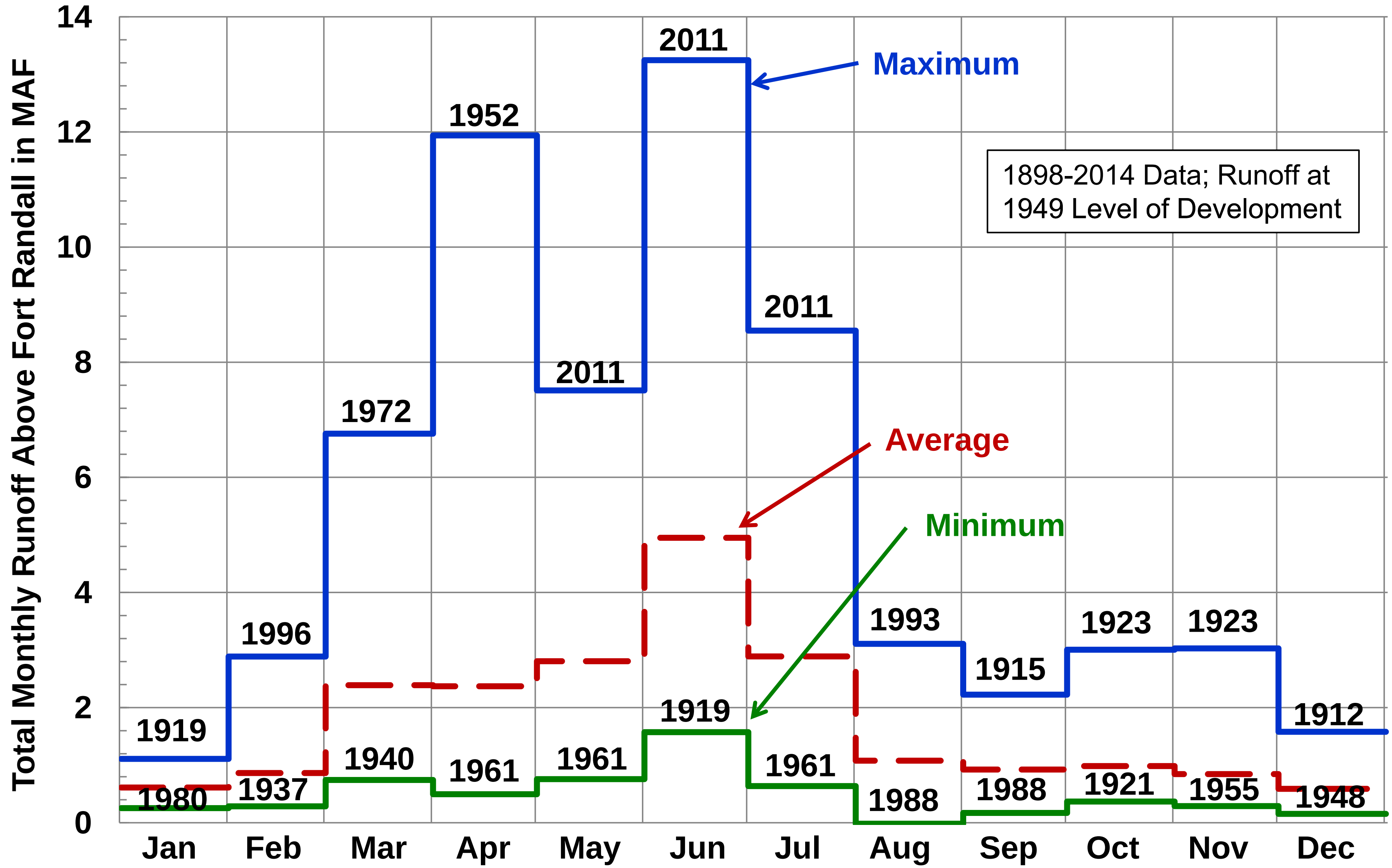
						Runoff in 1,000 acre-feet						Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1898	412	684	2,153	2,593	4,054	7,575	3,758	974	910	871	886	507	25,377	20,133
1899	520	562	2,502	4,620	3,273	7,451	6,180	1,375	1,049	797	922	467	29,718	24,026
1900	493	754	2,862	2,191	3,570	4,779	1,608	533	822	908	728	471	19,719	15,010
1901	488	552	2,164	1,460	4,695	4,959	2,206	655	1,462	953	663	492	20,749	15,484
1902	508	661	2,670	1,178	2,521	4,387	2,184	771	1,163	890	811	456	18,200	12,940
1903	488	776	2,019	2,006	2,015	4,822	3,083	1,194	1,755	1,238	863	593	20,852	13,945
1904	604	823	1,944	2,418	3,435	6,260	3,298	1,138	1,068	752	672	396	22,808	17,355
1905	399	653	2,127	1,110	1,630	4,731	2,905	883	683	460	593	546	16,720	12,503
1906	470	554	2,066	2,088	3,160	6,079	2,701	1,299	2,163	1,375	1,106	763	23,824	16,094
1907	787	705	2,185	1,727	3,180	7,072	7,046	2,209	1,332	1,619	1,444	776	30,082	21,210
1908	697	835	2,318	2,071	2,974	8,795	4,886	1,647	1,079	1,063	1,190	1,144	28,699	21,044
1909	770	916	2,185	1,830	3,433	9,422	5,216	1,727	1,589	1,093	916	561	29,658	22,086
1910	594	802	3,048	2,681	3,843	3,971	1,832	904	684	774	686	408	20,227	15,375
1911	421	568	1,651	1,420	1,885	5,816	2,775	1,399	1,982	1,422	839	678	20,856	13,547
1912	697	655	2,420	3,871	3,381	5,932	4,303	1,978	2,180	1,820	1,640	1,581	30,458	19,907
1913	1,000	609	1,433	2,587	3,176	6,813	3,168	1,721	1,686	1,356	1,373	1,196	26,118	17,177
1914	807	762	2,246	2,236	3,763	6,429	2,291	903	1,355	1,392	1,817	964	24,965	16,965
1915	968	970	2,531	2,364	2,798	6,020	4,205	1,813	2,226	1,986	1,414	854	28,149	17,918
1916	686	980	4,181	2,265	2,959	6,581	5,551	1,682	1,079	1,235	1,258	684	29,141	21,537
1917	712	821	2,663	4,083	4,177	7,433	5,086	1,288	1,351	1,273	1,287	709	30,883	23,442
1918	714	845	3,007	2,719	2,714	6,605	3,142	1,351	1,172	566	679	303	23,817	18,187
1919	1,109	787	1,868	1,930	1,831	1,575	710	335	268	408	328	375	11,524	7,914
1920	388	814	3,158	2,507	3,943	6,627	3,669	1,134	784	612	631	774	25,041	19,904
1921	494	741	2,322	1,832	2,802	6,604	2,372	714	695	370	483	404	19,833	15,932
1922	415	844	2,563	2,090	3,527	6,619	2,501	1,002	796	611	801	371	22,140	17,300
1923	387	706	2,072	2,565	2,787	5,088	4,734	1,442	1,354	3,006	2,038	1,276	27,455	17,246
1924	893	1,379	2,428	3,694	3,577	4,560	2,381	871	815	1,181	1,292	712	23,783	16,640
1925	723	1,367	2,444	2,632	3,279	6,493	3,334	1,186	815	1,085	996	614	24,968	18,182
1926	621	1,069	1,886	2,039	3,536	3,318	2,354	1,077	1,606	1,355	972	498	20,331	13,133
1927	502	1,005	3,531	3,428	4,995	9,115	4,423	2,060	1,949	1,472	997	730	34,207	25,492
1928	689	1,009	3,255	2,148	4,967	5,959	4,869	1,462	1,158	897	932	495	27,840	21,198
1929	516	569	3,400	2,338	2,843	4,701	2,542	751	657	858	646	386	20,207	15,824
1930	463	973	2,803	2,463	2,120	2,447	1,124	1,214	859	977	612	343	16,398	10,957
1931	438	847	920	970	1,144	1,969	746	603	460	565	403	335	9,400	5,749
1932	322	426	1,372	2,225	2,757	5,234	1,803	1,153	704	692	428	228	17,344	13,391
1933	498	406	2,225	1,329	3,352	4,265	1,265	844	906	665	738	290	16,783	12,436
1934	617	551	1,547	1,285	1,523	1,685	706	415	338	498	512	209	9,886	6,746
1935	261	554	847	1,342	1,468	3,979	2,285	595	498	478	310	316	12,933	9,921
1936	354	349	2,422	1,666	1,898	2,210	871	629	494	617	613	385	12,508	9,067
1937	304	286	1,161	1,320	1,213	3,808	1,966	602	357	625	385	289	12,316	9,468

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

					Runoff in 1,000 acre-feet								Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1938	436	395	2,124	1,091	2,018	5,257	3,610	736	831	709	480	217	17,904	14,100
1939	651	375	4,368	575	2,287	3,338	1,185	585	484	636	587	488	15,559	11,753
1940	315	436	744	1,549	1,716	2,282	879	400	488	853	367	601	10,630	7,170
1941	478	484	903	1,398	1,265	3,836	1,107	856	1,347	1,528	1,002	702	14,906	8,509
1942	526	611	1,706	2,196	5,375	5,972	2,338	1,006	668	805	775	569	22,547	17,587
1943	679	1,591	3,588	5,284	2,498	7,573	4,108	1,351	881	924	1,031	343	29,851	23,051
1944	641	651	1,733	4,387	2,235	7,875	3,602	1,267	819	821	958	241	25,230	19,832
1945	560	1,128	3,832	1,334	1,468	4,041	2,850	1,198	748	928	726	560	19,373	13,525
1946	798	810	1,987	1,358	1,987	3,687	2,400	746	1,026	1,293	884	629	17,605	11,419
1947	705	1,051	3,759	3,359	3,352	5,763	2,770	1,184	787	1,136	701	508	25,075	19,003
1948	726	768	2,625	3,307	3,172	6,974	3,044	1,132	631	759	840	154	24,132	19,122
1949	555	580	3,778	3,941	2,626	3,244	1,424	560	511	915	991	374	19,499	15,013
1950	409	672	2,118	7,225	2,809	4,266	3,139	1,463	1,105	1,306	614	801	25,927	19,557
1951	888	710	1,712	4,040	2,783	4,177	2,778	1,684	1,546	1,514	990	369	23,191	15,490
1952	749	1,183	1,631	11,938	4,132	3,755	2,155	1,006	689	712	663	401	29,014	23,611
1953	619	806	2,106	1,387	2,623	8,283	2,597	1,278	780	942	874	470	22,765	16,996
1954	511	1,218	1,256	2,024	2,001	2,839	2,352	1,176	885	839	913	440	16,454	10,472
1955	308	540	1,414	2,510	2,245	3,231	2,245	957	636	830	290	721	15,927	11,645
1956	802	616	2,047	2,051	2,308	4,842	1,916	1,072	767	615	924	456	18,416	13,164
1957	398	549	1,531	1,478	2,842	5,328	2,974	766	884	944	1,093	745	19,532	14,153
1958	437	544	1,440	1,840	1,911	3,508	2,044	725	614	798	687	599	15,147	10,743
1959	588	554	3,559	1,612	1,607	3,498	2,327	645	692	1,105	673	1,246	18,106	12,603
1960	533	877	3,514	3,031	1,703	2,278	767	553	476	601	583	248	15,164	11,293
1961	604	659	1,094	495	759	2,510	637	395	718	834	955	172	9,832	5,495
1962	557	1,087	1,413	2,142	3,446	6,435	3,987	1,373	795	971	788	510	23,504	17,423
1963	433	1,381	1,830	1,153	2,001	5,402	2,444	792	846	842	573	432	18,129	12,830
1964	680	717	822	1,351	2,900	6,937	4,197	821	891	780	651	594	21,341	16,207
1965	1,009	1,017	1,255	3,682	4,300	5,959	5,402	1,744	1,349	1,452	1,055	905	29,129	20,598
1966	619	797	3,826	1,963	1,766	2,223	1,756	767	791	738	839	684	16,769	11,534
1967	518	1,049	2,495	2,352	3,162	9,073	5,052	1,111	1,077	1,034	1,139	403	28,465	22,134
1968	840	985	2,275	1,499	1,619	5,479	3,135	1,554	1,582	1,185	1,195	618	21,966	14,007
1969	871	864	3,154	4,813	3,218	3,282	4,623	1,065	725	844	1,010	664	25,133	19,090
1970	437	926	1,414	2,355	4,827	6,065	3,561	1,020	1,031	1,120	953	699	24,408	18,222
1971	712	2,169	3,586	3,385	3,342	6,189	3,745	1,298	1,337	1,707	1,163	671	29,304	20,247
1972	721	1,125	6,758	1,875	3,530	5,976	2,657	1,806	1,223	1,244	1,334	726	28,975	20,796
1973	1,045	1,005	2,144	1,440	2,722	3,370	1,812	914	1,341	1,161	909	868	18,731	11,488
1974	871	1,125	1,523	2,000	2,613	5,602	3,703	1,351	1,069	860	1,004	859	22,580	15,441
1975	342	567	1,596	3,816	6,708	6,579	6,680	1,871	1,072	1,230	1,081	1,095	32,637	25,379
1976	908	1,542	2,371	2,001	3,839	5,306	3,313	1,556	1,075	982	890	761	24,544	16,830
1977	481	876	1,551	1,421	1,663	2,065	858	501	1,006	998	448	730	12,598	7,558

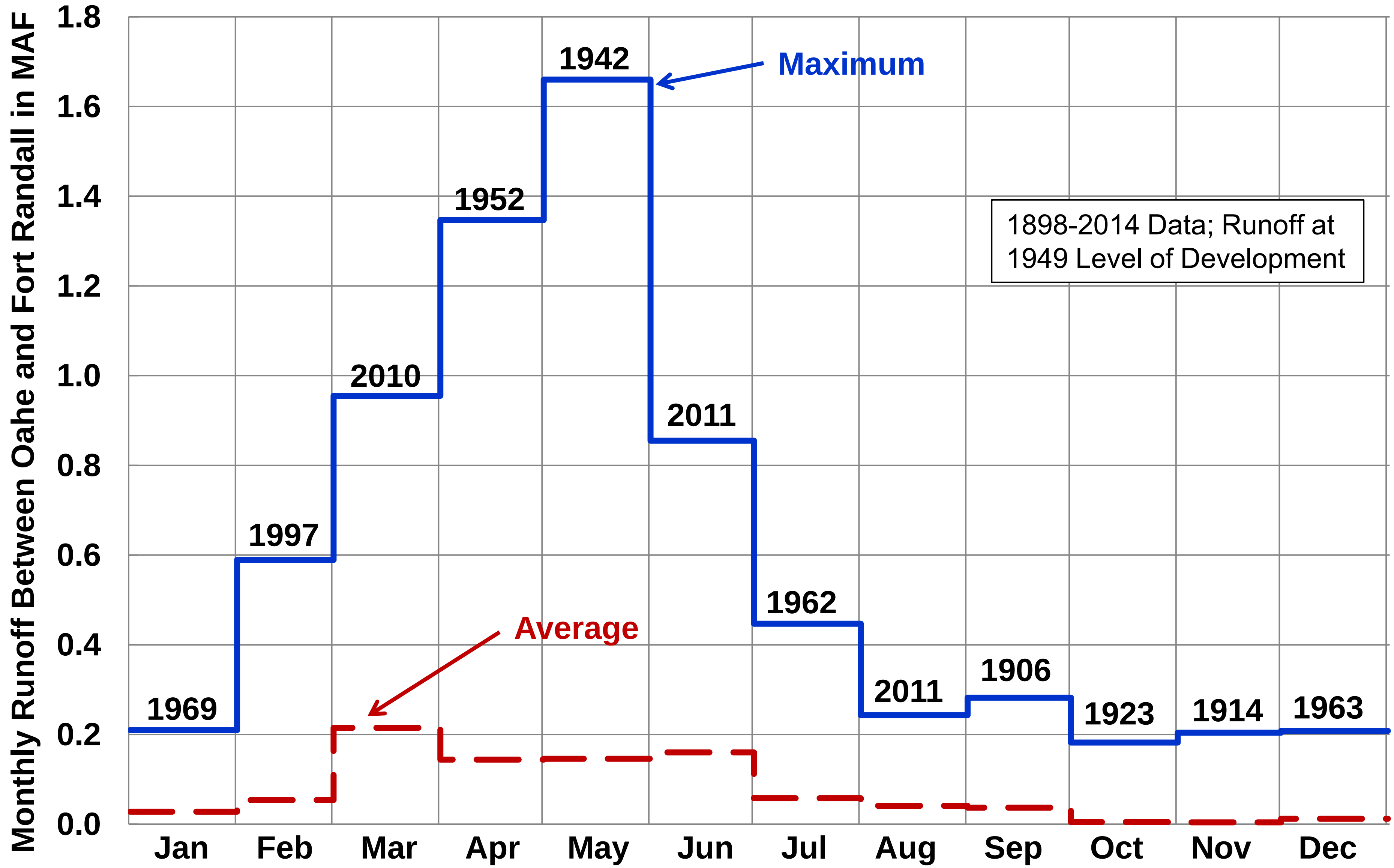
Monthly Runoff - Missouri River Basin Upstream of Fort Randall Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

													Annual	Mar-Jul
						Runoff in 1,000 acre-feet								
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1978	550	732	6,144	5,853	5,425	5,579	4,764	1,620	1,930	1,205	725	804	35,331	27,765
1979	652	760	3,742	5,465	3,166	3,652	2,195	1,030	1,005	589	763	549	23,568	18,220
1980	255	600	1,368	1,428	1,957	3,697	1,690	607	855	1,269	965	532	15,223	10,140
1981	911	750	1,234	661	2,422	5,290	1,886	863	363	846	1,002	588	16,816	11,493
1982	338	1,276	2,720	3,908	3,796	5,693	4,757	1,586	1,011	1,872	1,009	1,026	28,992	20,874
1983	870	1,281	2,225	1,299	2,300	3,753	3,261	1,065	680	1,233	1,140	376	19,483	12,838
1984	985	1,419	1,709	1,659	2,892	4,867	2,824	1,209	689	1,125	989	481	20,848	13,951
1985	861	682	2,293	1,523	1,396	1,764	707	898	633	1,212	670	817	13,456	7,683
1986	927	806	5,614	2,625	4,177	4,938	2,318	745	1,707	1,919	907	926	27,609	19,672
1987	539	1,025	3,749	2,600	1,773	2,001	1,040	944	812	615	648	449	16,195	11,163
1988	316	675	1,325	825	1,776	1,685	708	-16	172	379	522	467	8,834	6,319
1989	279	447	2,052	2,059	2,563	2,576	1,513	590	795	733	990	393	14,990	10,763
1990	920	625	1,530	1,125	1,723	2,962	2,031	760	528	495	875	203	13,777	9,371
1991	540	704	1,150	955	2,966	6,481	2,872	599	744	619	969	681	19,280	14,424
1992	546	864	1,232	798	1,141	1,969	2,552	917	513	755	899	187	12,373	7,692
1993	522	738	2,589	1,692	2,692	4,382	5,274	3,109	1,207	1,086	1,017	998	25,306	16,629
1994	711	836	4,573	1,618	2,906	2,462	1,056	313	418	943	541	658	17,035	12,615
1995	530	1,232	2,551	2,177	4,852	6,250	4,418	1,043	666	1,000	1,095	897	26,711	20,248
1996	763	2,887	3,641	3,219	3,343	7,007	3,076	739	723	844	965	953	28,160	20,286
1997	1,061	2,333	6,056	5,884	4,365	8,594	4,516	2,015	1,089	859	955	1,090	38,817	29,415
1998	337	1,294	1,514	1,748	1,815	3,553	4,218	1,495	748	1,488	1,095	606	19,911	12,848
1999	949	1,209	2,904	1,822	3,742	5,422	3,294	1,101	1,013	823	648	696	23,623	17,184
2000	409	844	1,525	1,310	1,535	2,853	1,730	363	281	649	690	454	12,643	8,953
2001	874	660	2,909	2,093	1,331	2,267	1,820	736	345	463	504	474	14,476	10,420
2002	473	560	756	1,260	1,065	3,421	2,064	818	614	606	636	439	12,712	8,566
2003	287	752	2,454	1,412	1,888	3,695	1,676	580	338	538	309	543	14,472	11,125
2004	344	579	2,009	1,091	843	2,360	1,823	791	674	726	720	331	12,291	8,126
2005	463	844	998	807	2,187	4,200	2,831	771	405	760	632	273	15,171	11,023
2006	1,033	522	1,117	1,740	1,974	3,208	1,382	588	356	745	663	404	13,732	9,421
2007	414	686	1,893	1,326	2,444	3,967	1,331	793	298	692	457	399	14,700	10,961
2008	344	565	1,024	936	2,123	7,202	4,504	1,197	809	911	828	407	20,850	15,789
2009	905	1,407	3,840	5,307	2,918	4,985	3,689	1,456	1,006	979	831	559	27,882	20,739
2010	863	792	3,669	2,375	2,604	6,441	4,211	1,289	1,068	828	598	704	25,442	19,300
2011	897	1,532	4,820	5,405	7,510	13,245	8,548	2,626	1,123	1,180	834	1,004	48,724	39,528
2012	640	1,305	1,734	1,340	2,225	3,503	2,033	787	299	536	707	546	15,655	10,835
2013	524	884	1,230	1,799	2,232	5,816	2,345	1,202	803	2,422	766	500	20,523	13,422
2014	1,095	974	3,709	2,441	3,707	6,615	4,141	2,882	1,853	1,175	642	1,257	30,491	20,613



Missouri River Basin
Fort Randall Water Control Manual
Unregulated Monthly Runoff
Distribution above Fort Randall

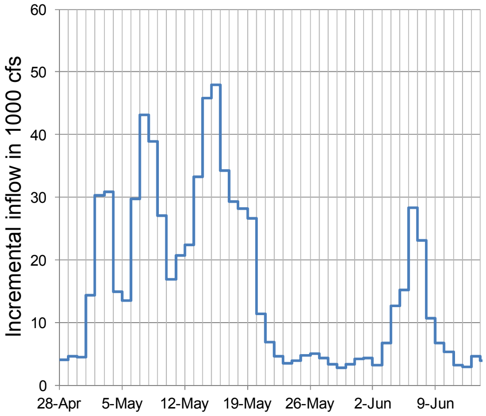
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Monthly Runoff Between Oahe and Fort Randall

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

Incremental Inflow Hydrographs Big Bend to Fort Randall



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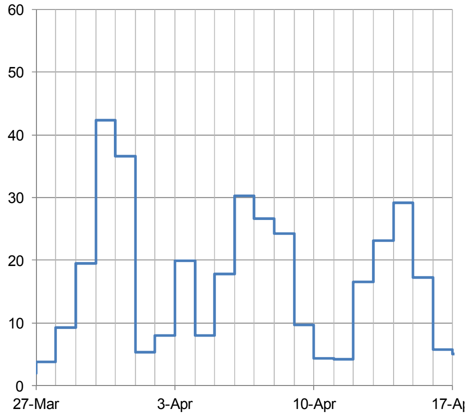

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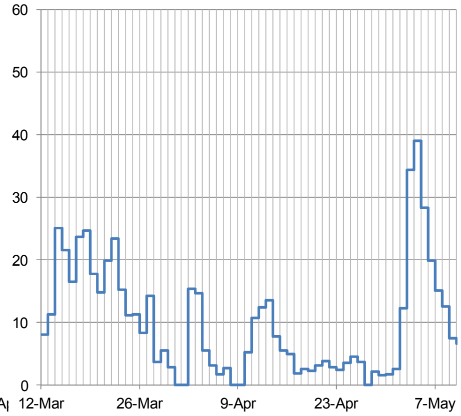

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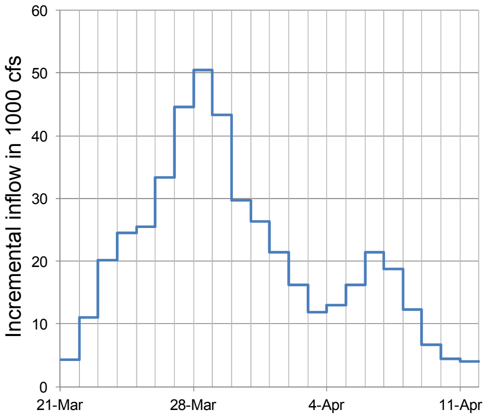

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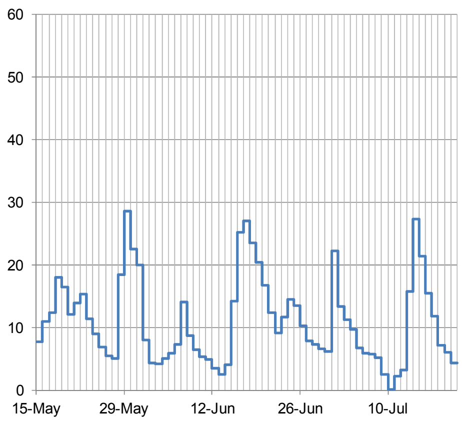

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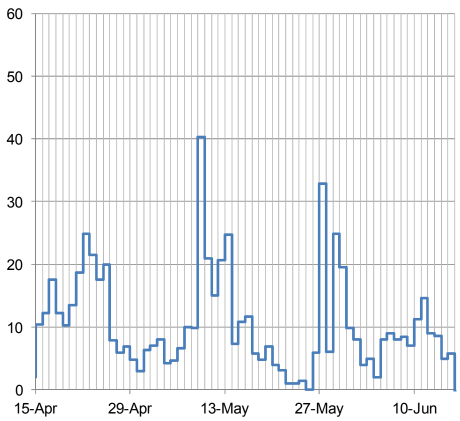

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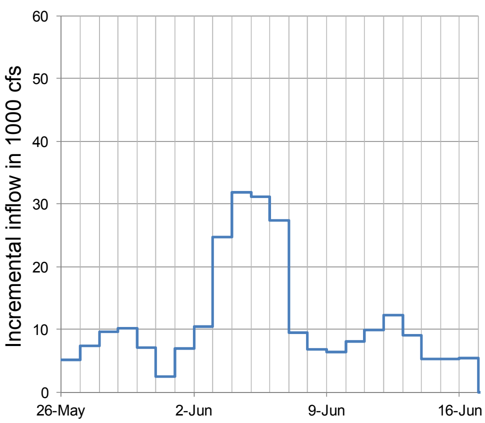

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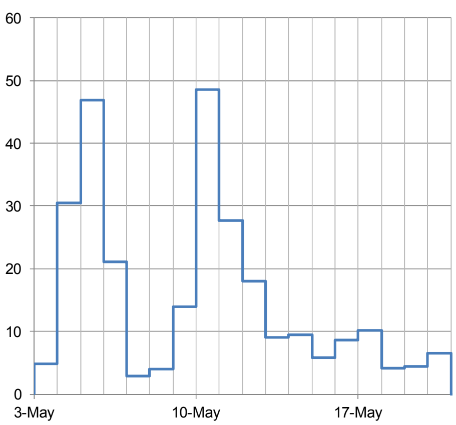

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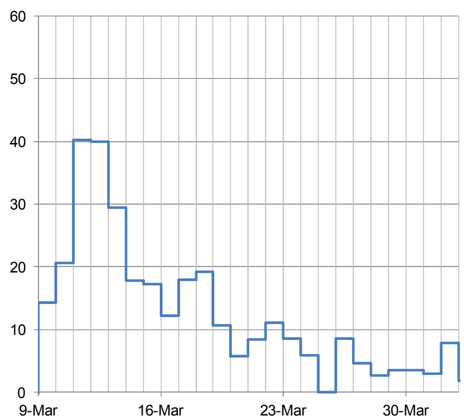

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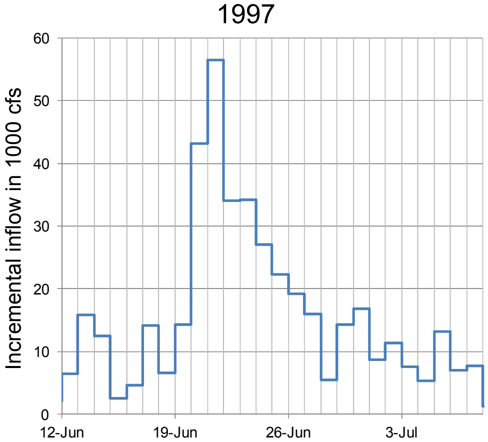

2011

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

Missouri River Basin

Fort Randall Water Control Manual

Incremental Inflow Hydrographs

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

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

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Missouri River Basin
FORT RANDALL DRAINAGE AREA
TRAVEL TIMES

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

US Army Corps of Engineers®
Northwestern Division

Plate III-17

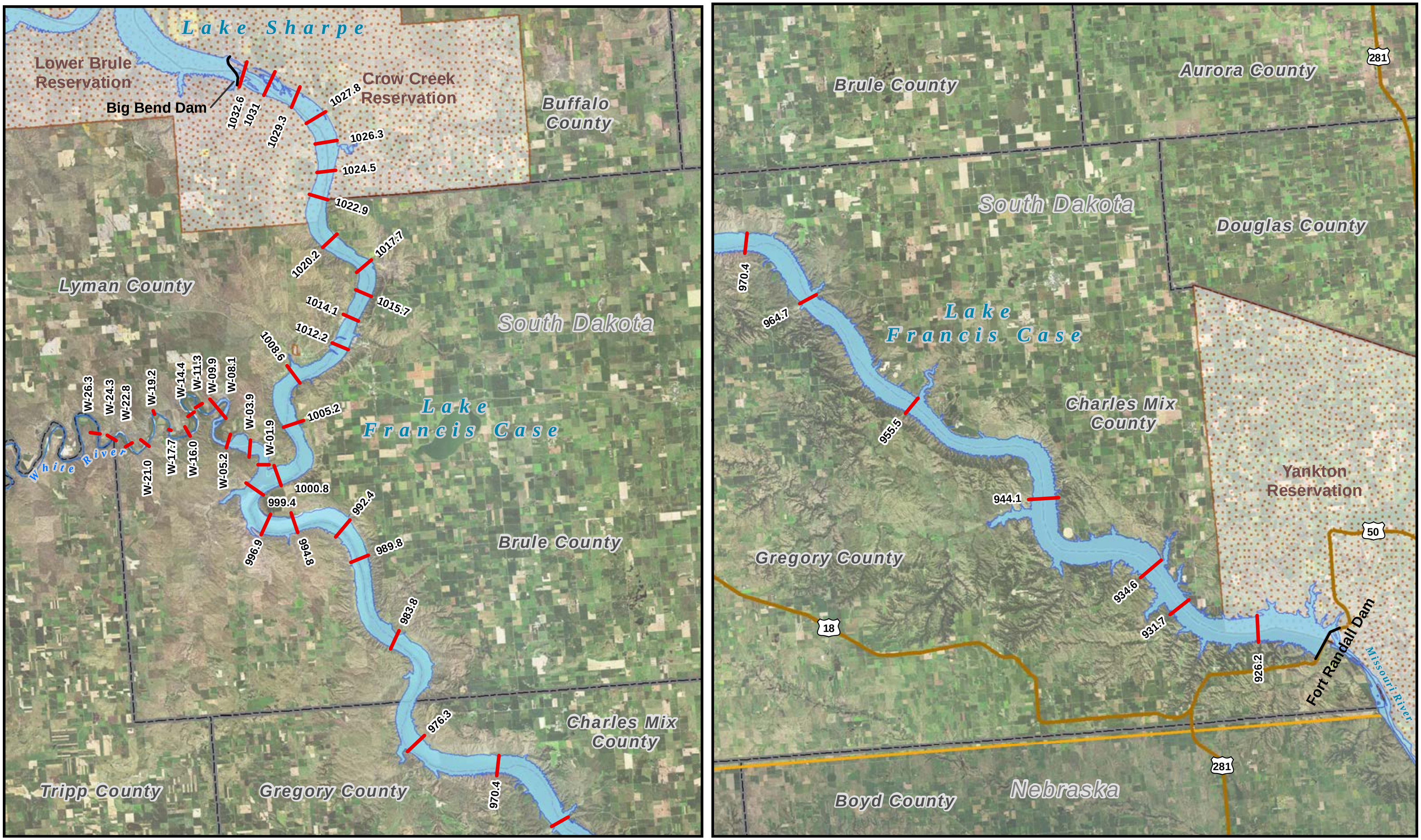

Plate III-18

US Army Corps of Engineers®
Northwestern Division

Cities	Reservations
Aggradation Range Line	Reservoirs/Lakes
Rivers	State Boundaries
Roads	County Boundaries

0 2.5 5 10 15 Miles

N W E S

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

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

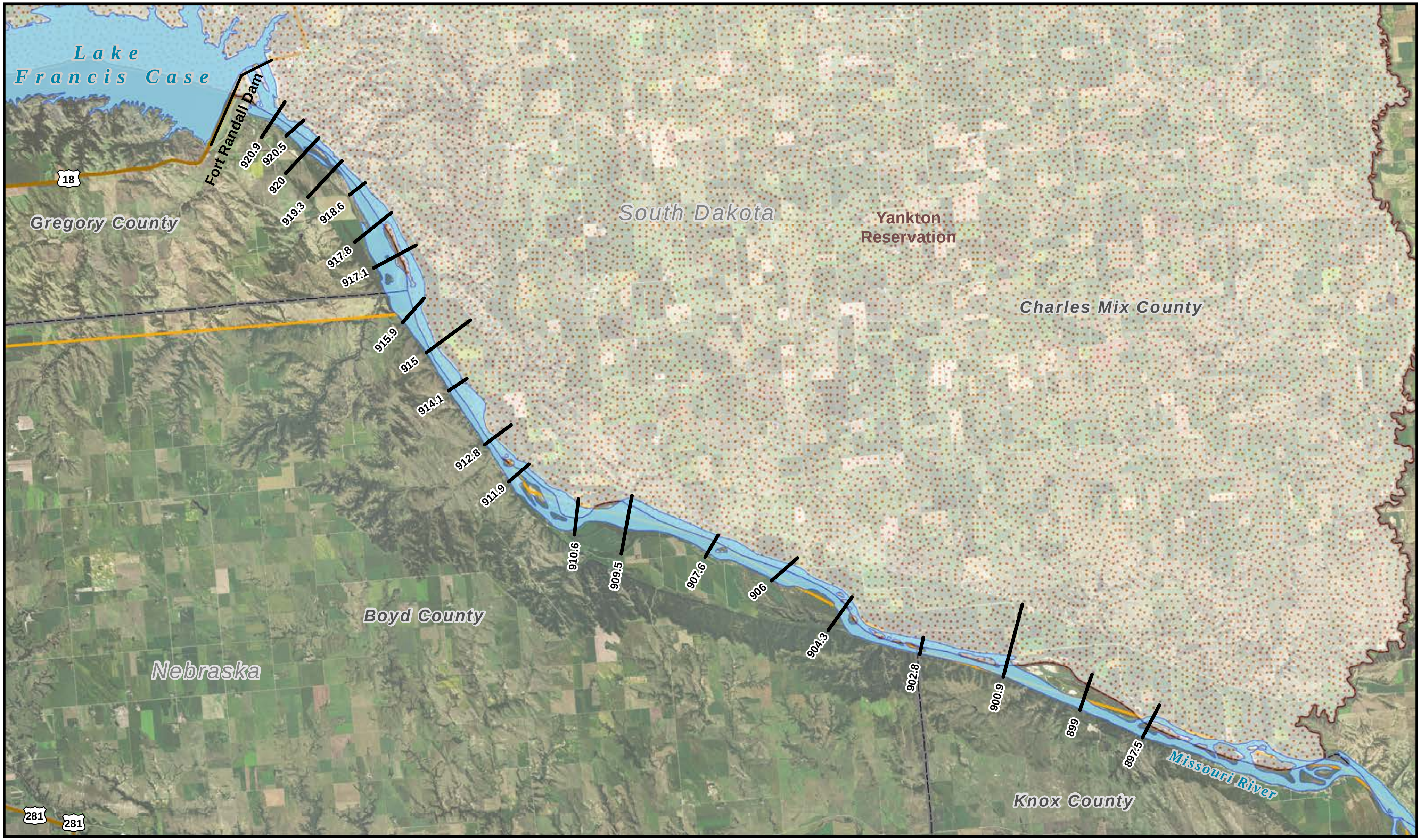


Plate III-19

US Army Corps of Engineers®
Northwestern Division

Cities	Reservations
Degradation Range Line	Reservoirs/Lakes
Rivers	State Boundaries
Roads	County Boundaries

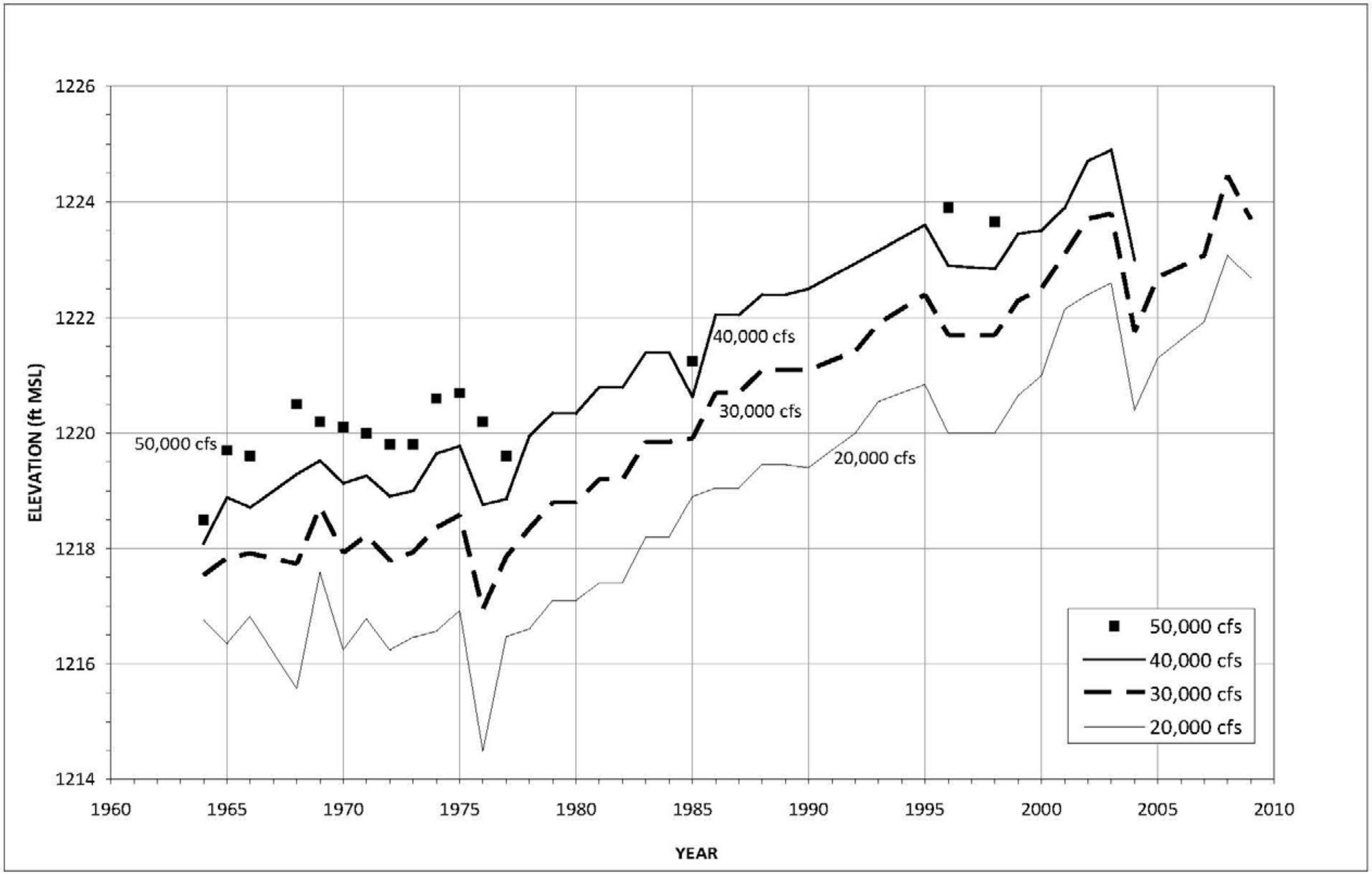
0 1 2 4 6 Miles

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

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

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

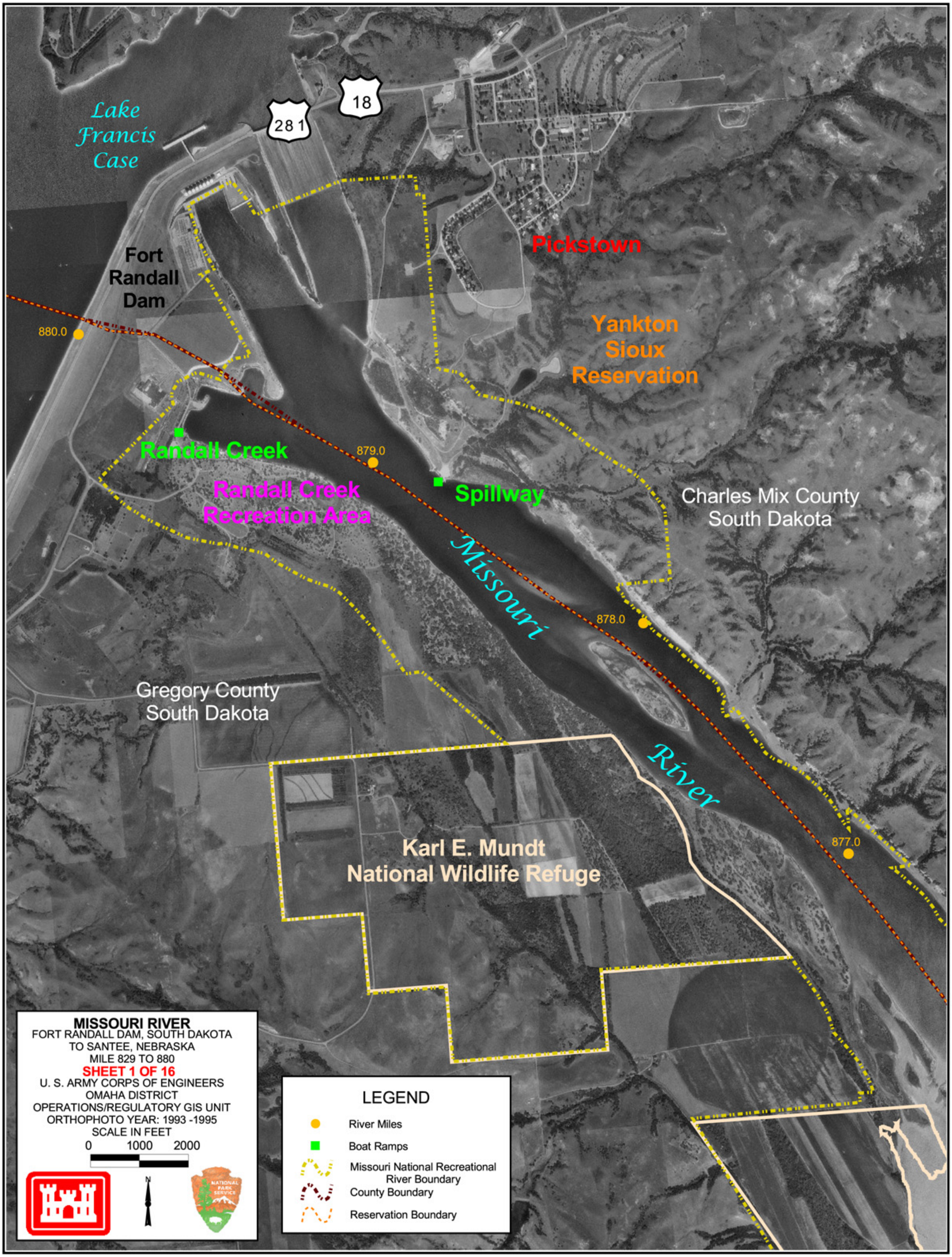
Stage Trends – Missouri River at Verdel



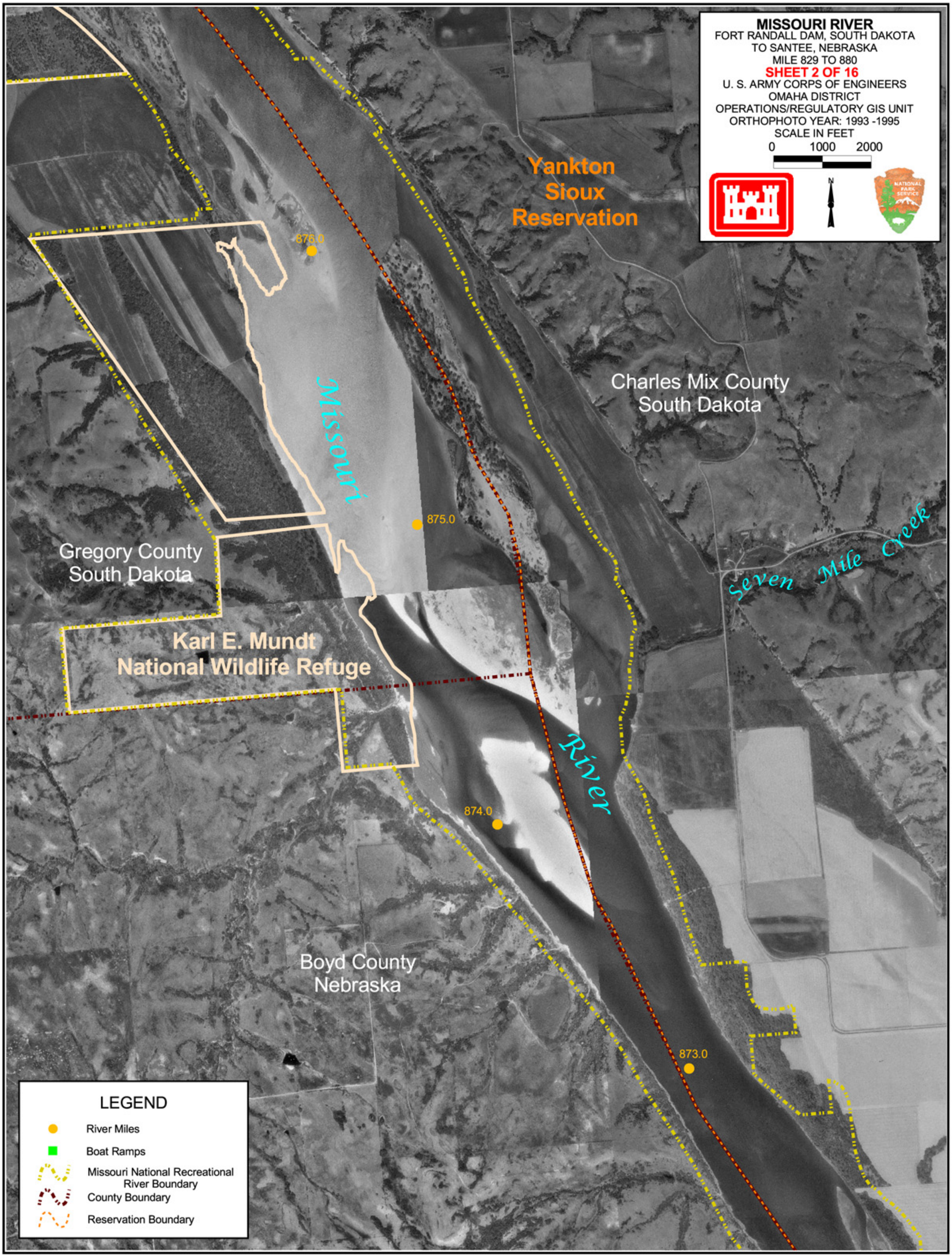
Stage Trends – Verdel Gage (1960 RM 845.91)

Source: Missouri River Fort Randall Project
Downstream Channel and Sediment Trends Study
Updated June 2012

Missouri River Basin
Fort Randall Water Control Manual
Stage Trends – Missouri River at Verdel, NE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Lake Francis Case
281
18
Fort Randall Dam
Pickstown
Yankton Sioux Reservation
880.0
879.0
878.0
877.0
Randall Creek
Randall Creek Recreation Area
Spillway
Charles Mix County South Dakota
Missouri River
Gregory County South Dakota
Karl E. Mundt National Wildlife Refuge
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 1 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 2 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
Yankton Sioux Reservation
876.0
Missouri
Charles Mix County South Dakota
875.0
Gregory County South Dakota
Seven Mile Creek
Karl E. Mundt National Wildlife Refuge
River
874.0
Boyd County Nebraska
873.0
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary

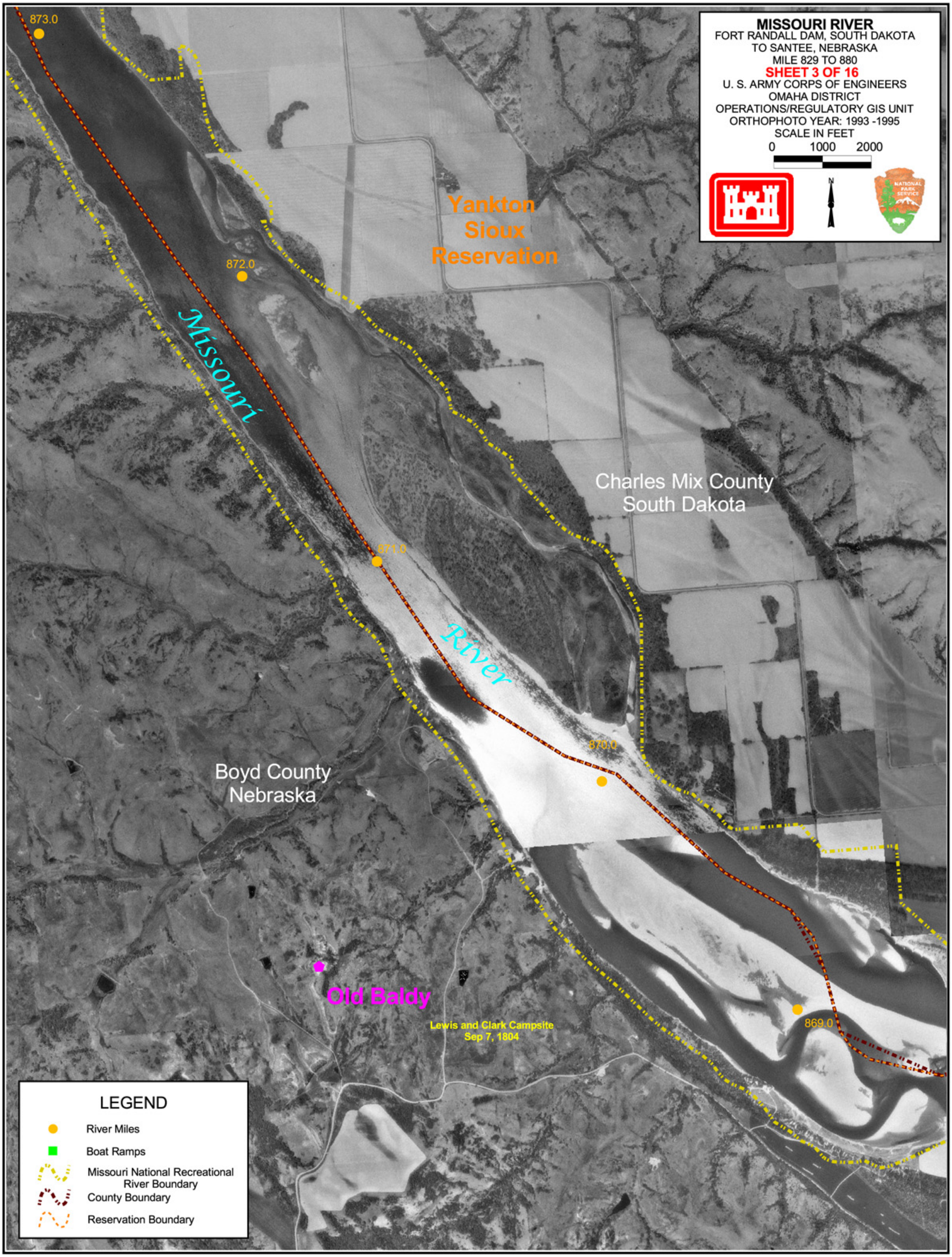
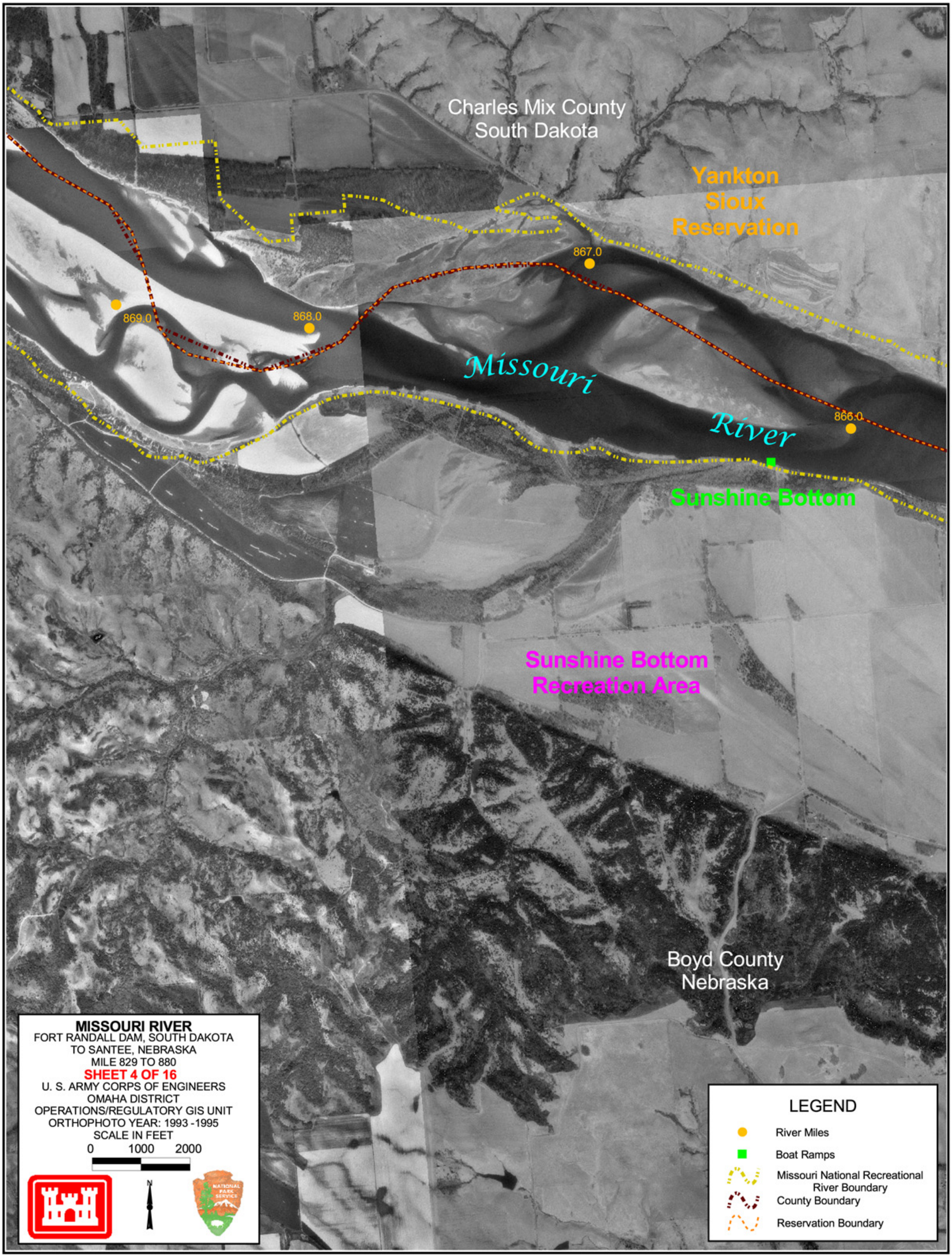
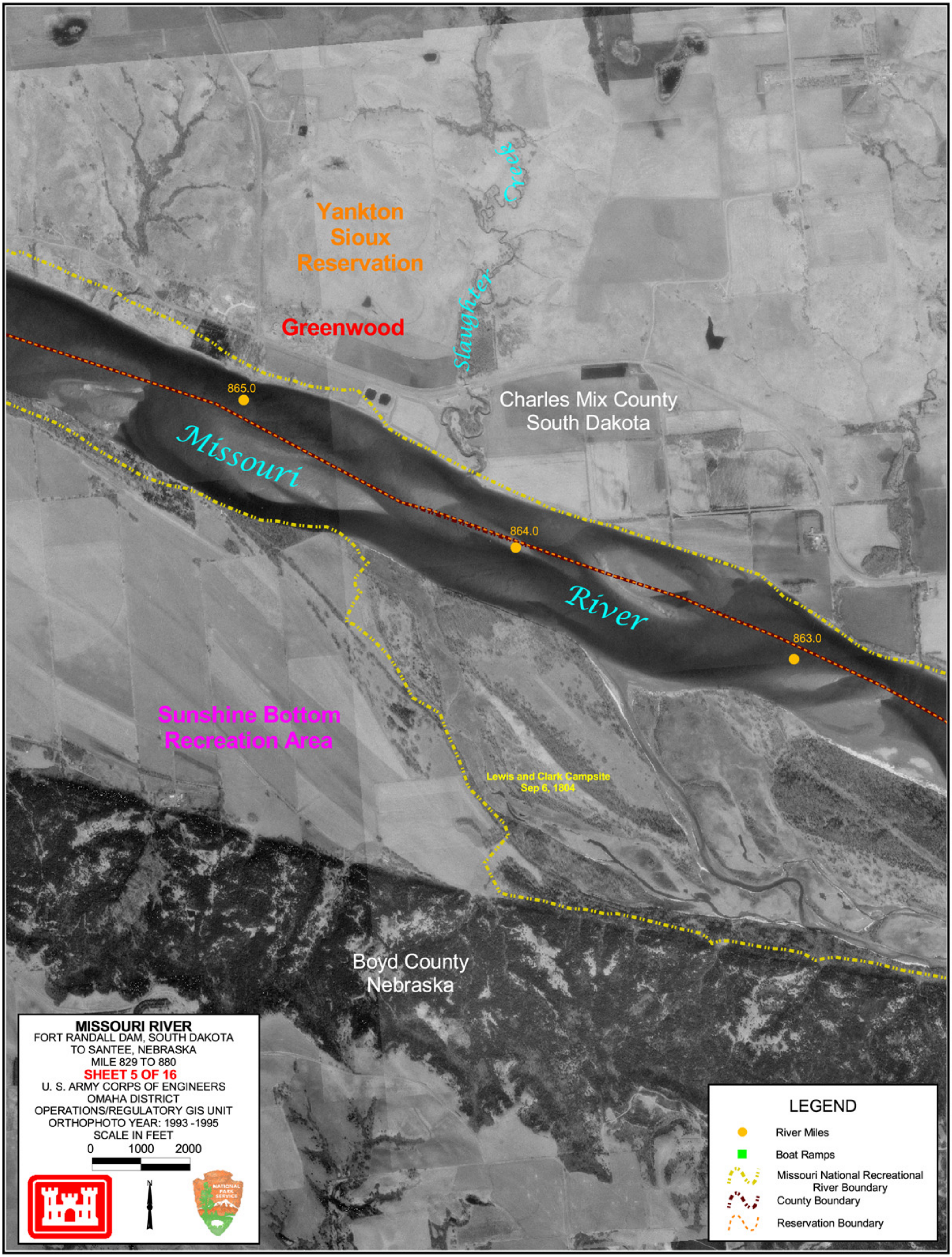
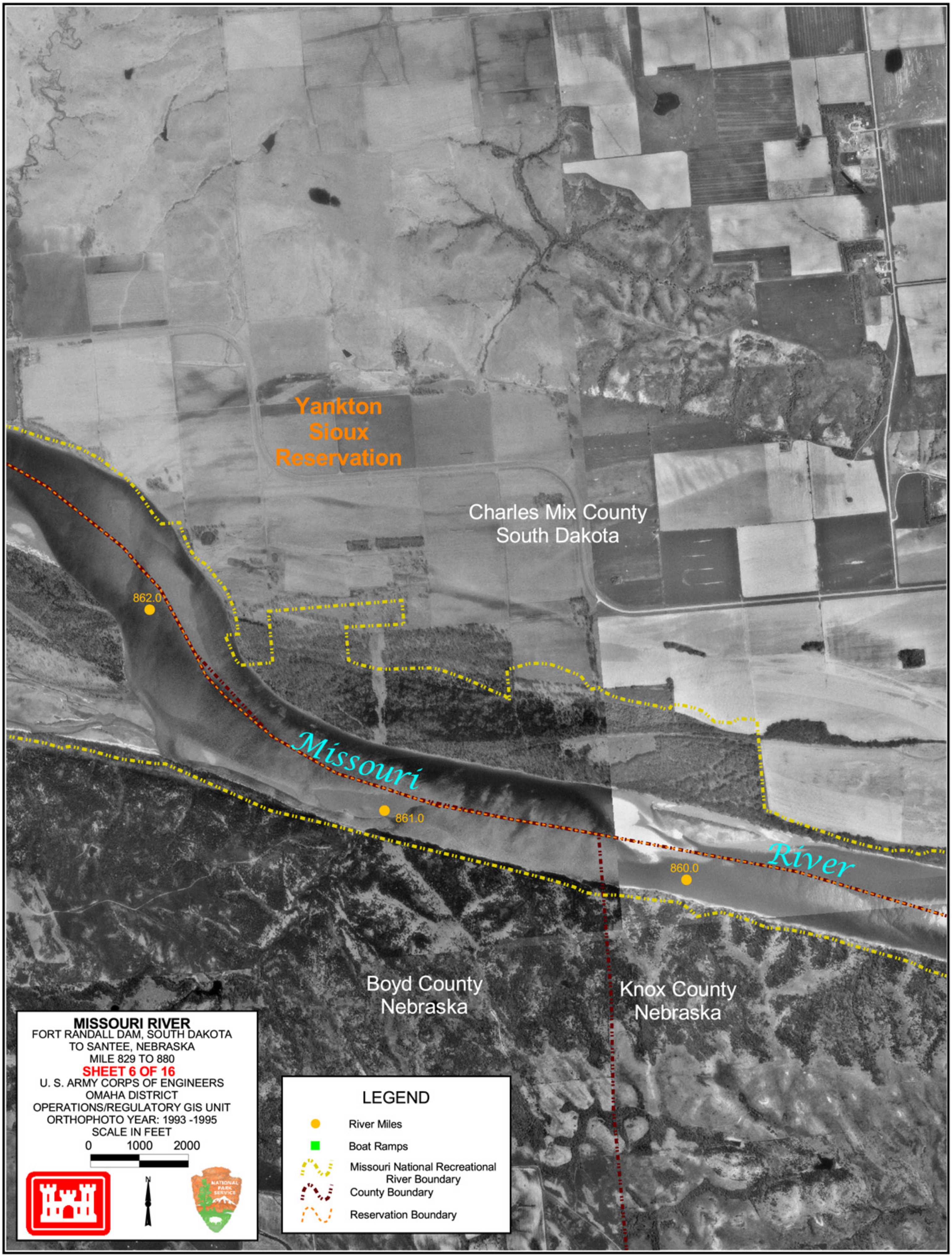
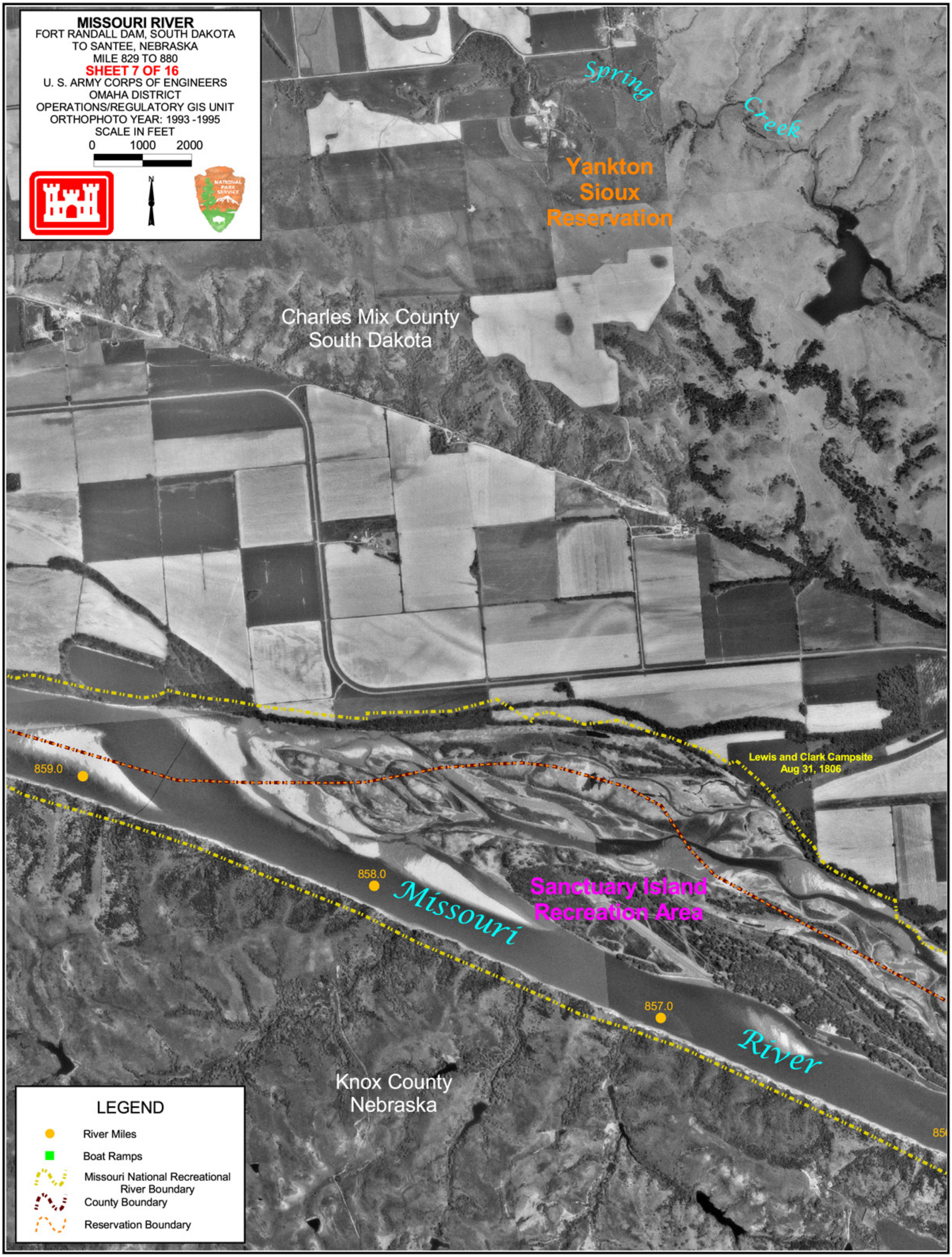

MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 3 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
873.0
872.0
871.0
870.0
869.0
Yankton Sioux Reservation
Missouri River
Charles Mix County South Dakota
Boyd County Nebraska
Old Baldy
Lewis and Clark Campsite Sep 7, 1804
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary

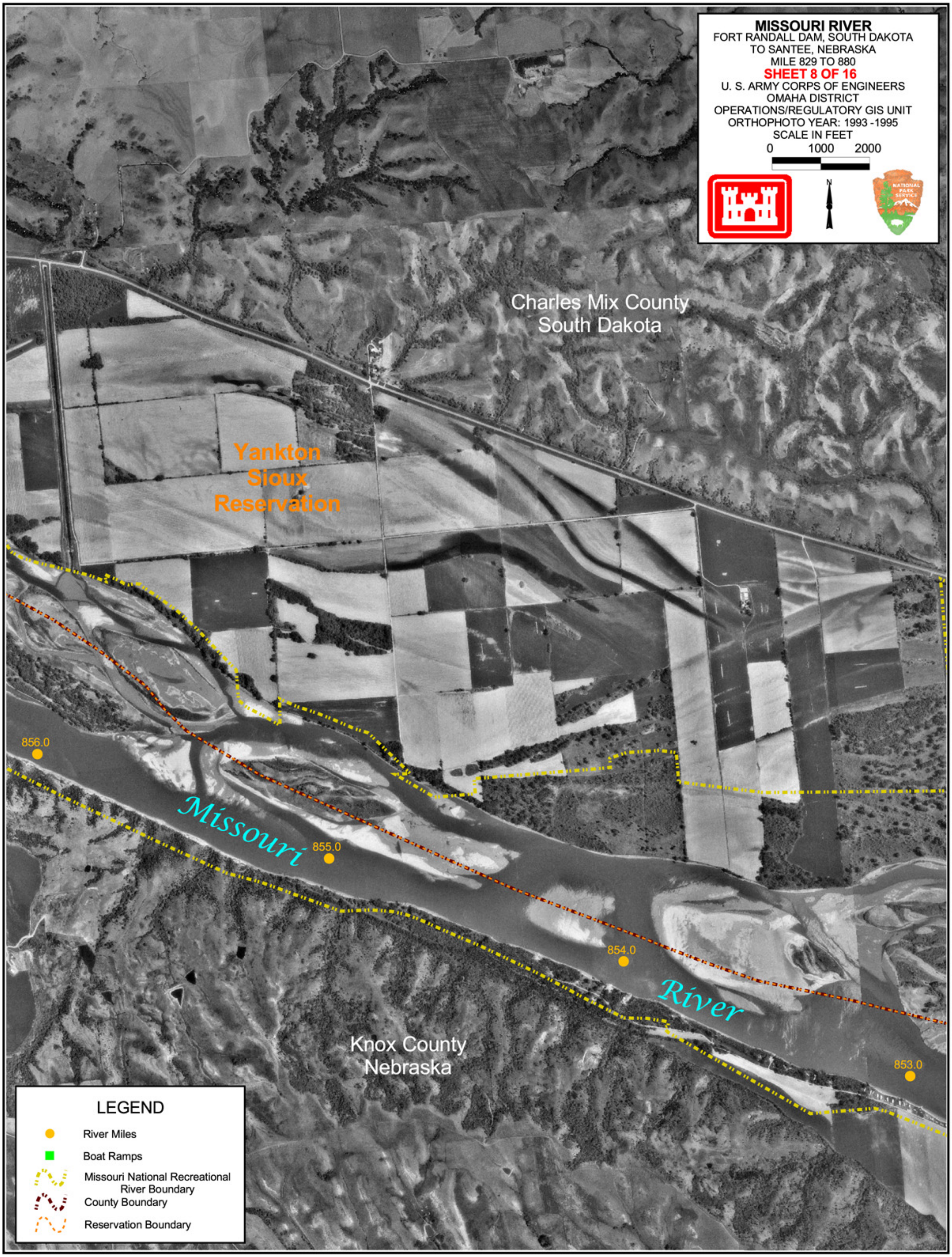
Plate III-21

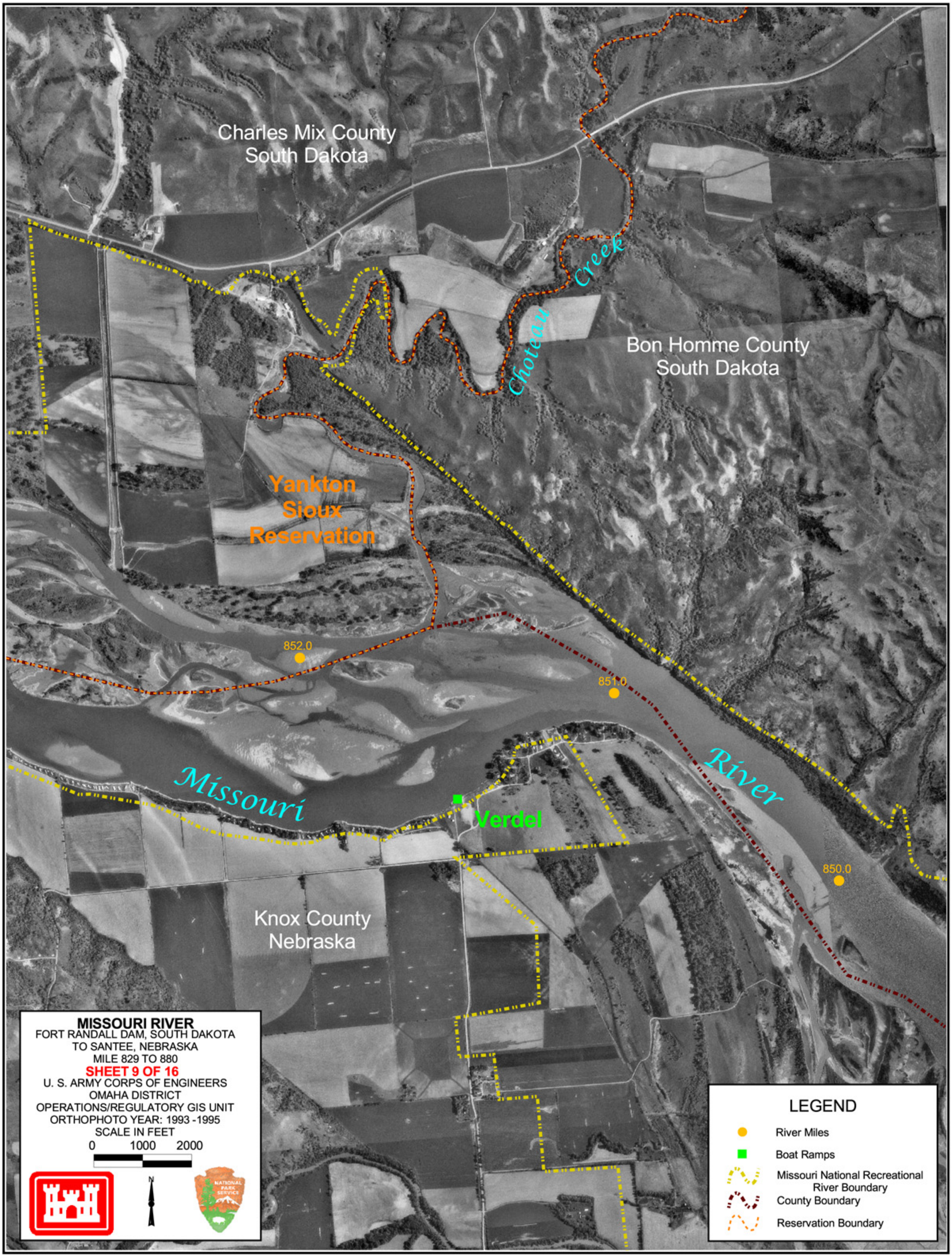

Charles Mix County
South Dakota
Yankton
Sioux
Reservation
867.0
869.0
868.0
Missouri
River
866.0
Sunshine Bottom
Sunshine Bottom
Recreation Area
Boyd County
Nebraska
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 4 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational
River Boundary
County Boundary
Reservation Boundary

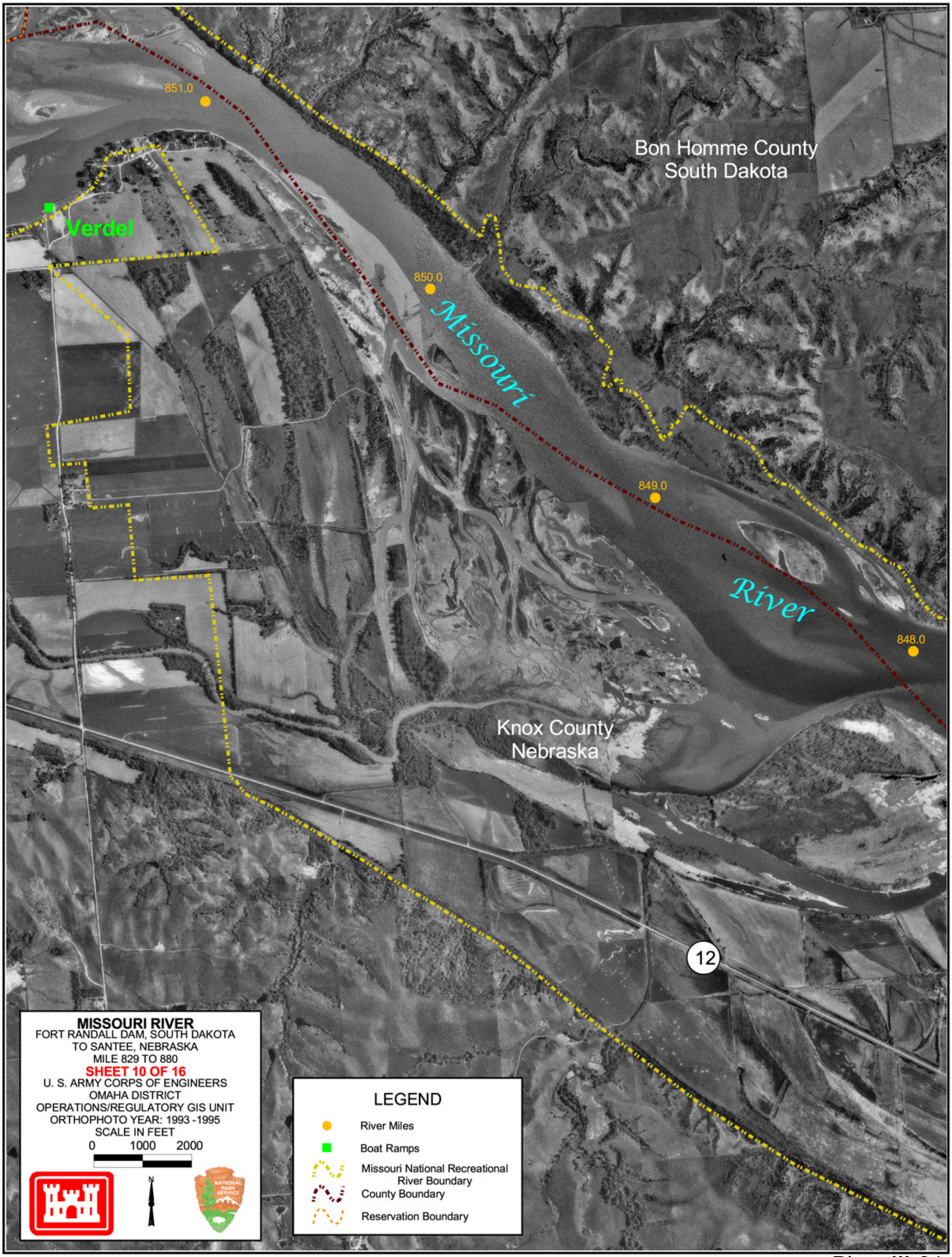

Yankton
Sioux
Reservation
Greenwood
Slaughter Creek
865.0
Charles Mix County
South Dakota
Missouri
864.0
River
863.0
Sunshine Bottom
Recreation Area
Lewis and Clark Campsite
Sep 6, 1804
Boyd County
Nebraska
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 5 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


Yankton
Sioux
Reservation
Charles Mix County
South Dakota
862.0
Missouri
861.0
860.0
River
Boyd County
Nebraska
Knox County
Nebraska
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 6 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
NATIONAL PARK SERVICE
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 7 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Spring Creek
Yankton Sioux Reservation
Charles Mix County
South Dakota
Lewis and Clark Campsite
Aug 31, 1806
859.0
858.0
857.0
Missouri River
Sanctuary Island
Recreation Area
Knox County
Nebraska
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 8 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Charles Mix County
South Dakota
Yankton
Sioux
Reservation
856.0
Missouri
855.0
854.0
River
Knox County
Nebraska
853.0
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


Charles Mix County
South Dakota
Choteau Creek
Bon Homme County
South Dakota
Yankton
Sioux
Reservation
852.0
851.0
850.0
Missouri
River
Verdel
Knox County
Nebraska
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 9 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


851.0
850.0
849.0
848.0
Bon Homme County
South Dakota
Verdel
Missouri
River
Knox County
Nebraska
12
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 10 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
NATIONAL PARK SERVICE
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary

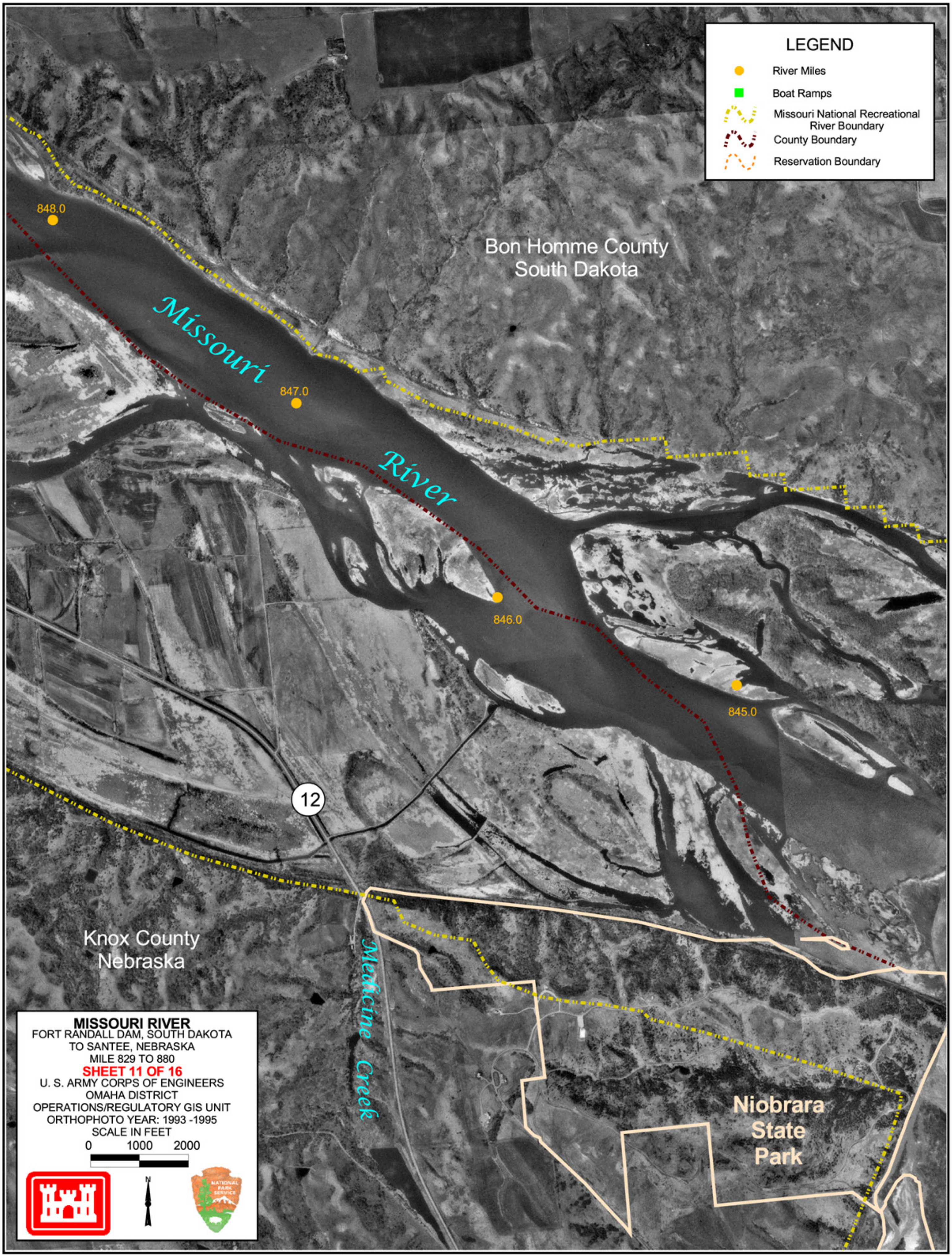
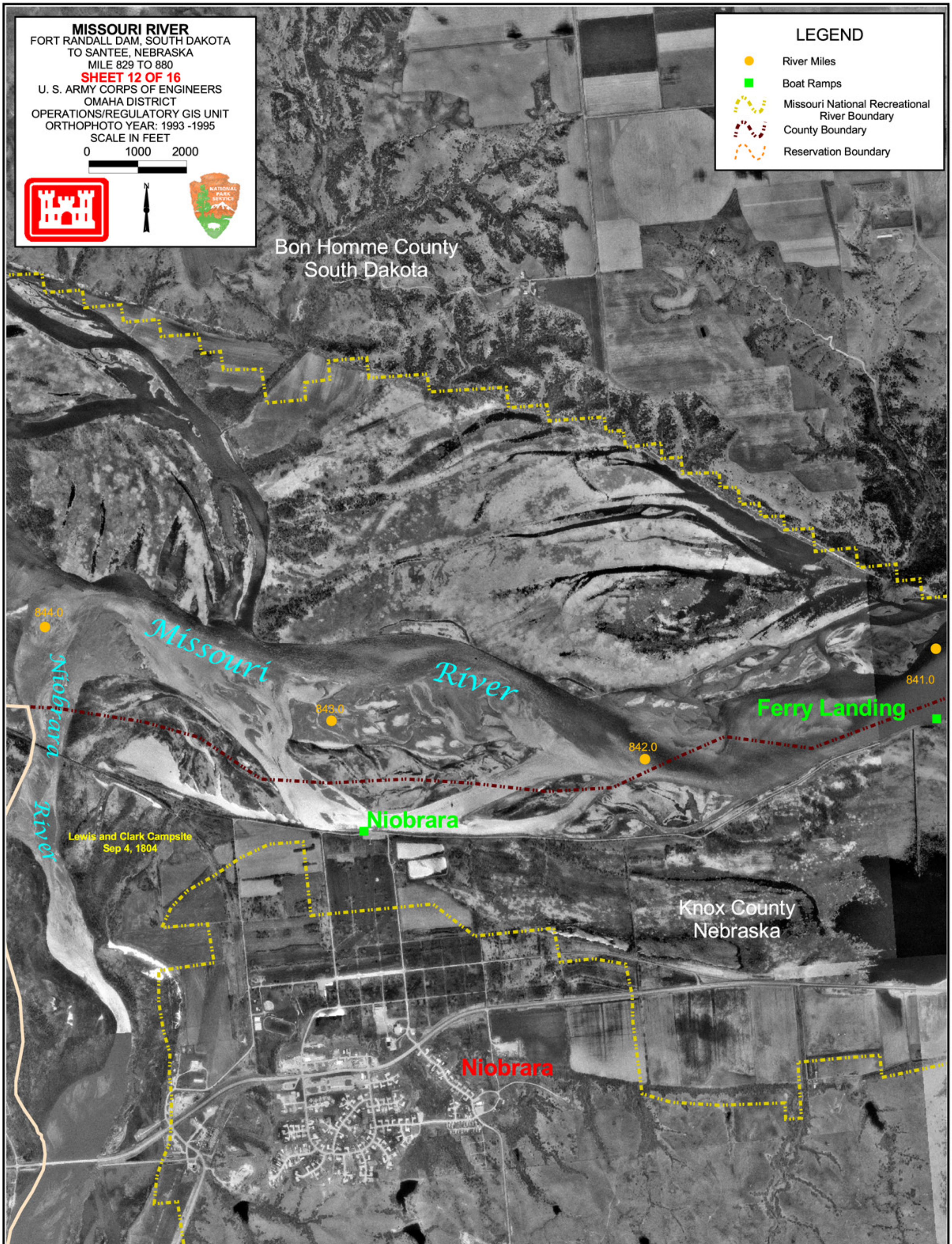

LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
848.0
847.0
846.0
845.0
Missouri River
Bon Homme County
South Dakota
12
Knox County
Nebraska
Medicine Creek
Niobrara State Park
MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 11 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000

Plate III-21



MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 12 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
Bon Homme County
South Dakota
844.0
843.0
842.0
841.0
Missouri
River
Niobrara River
Ferry Landing
Niobrara
Lewis and Clark Campsite
Sep 4, 1804
Knox County
Nebraska
Niobrara

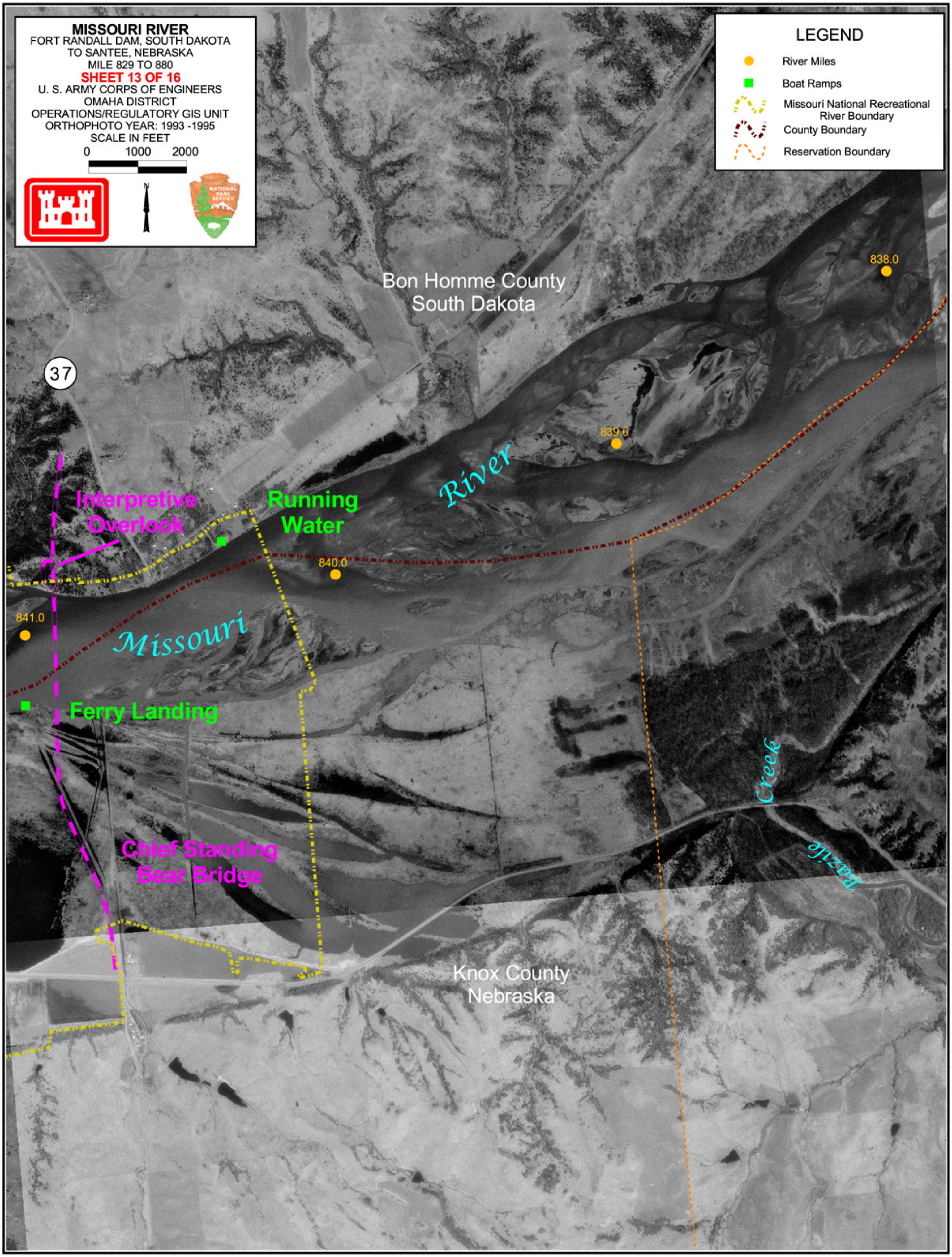
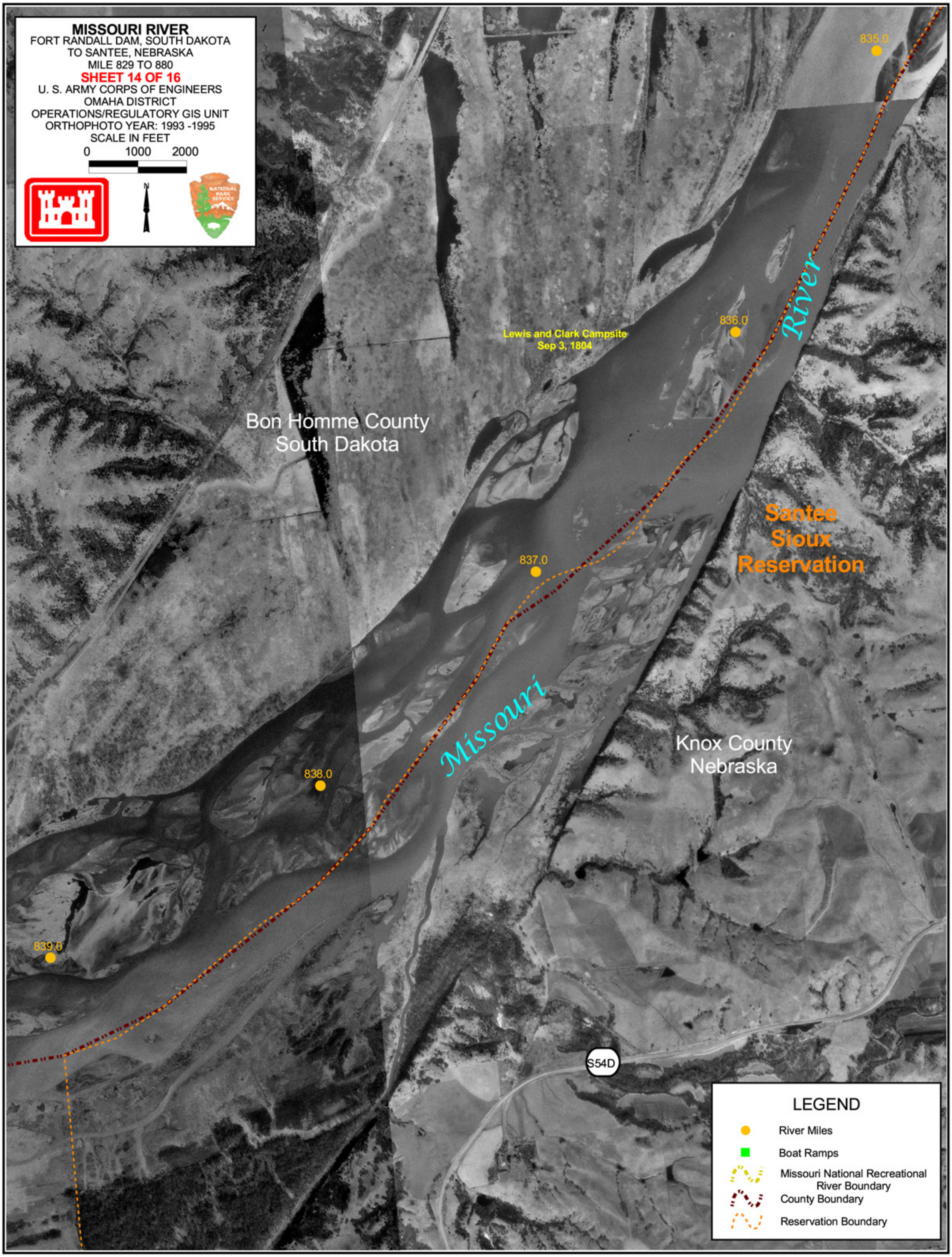
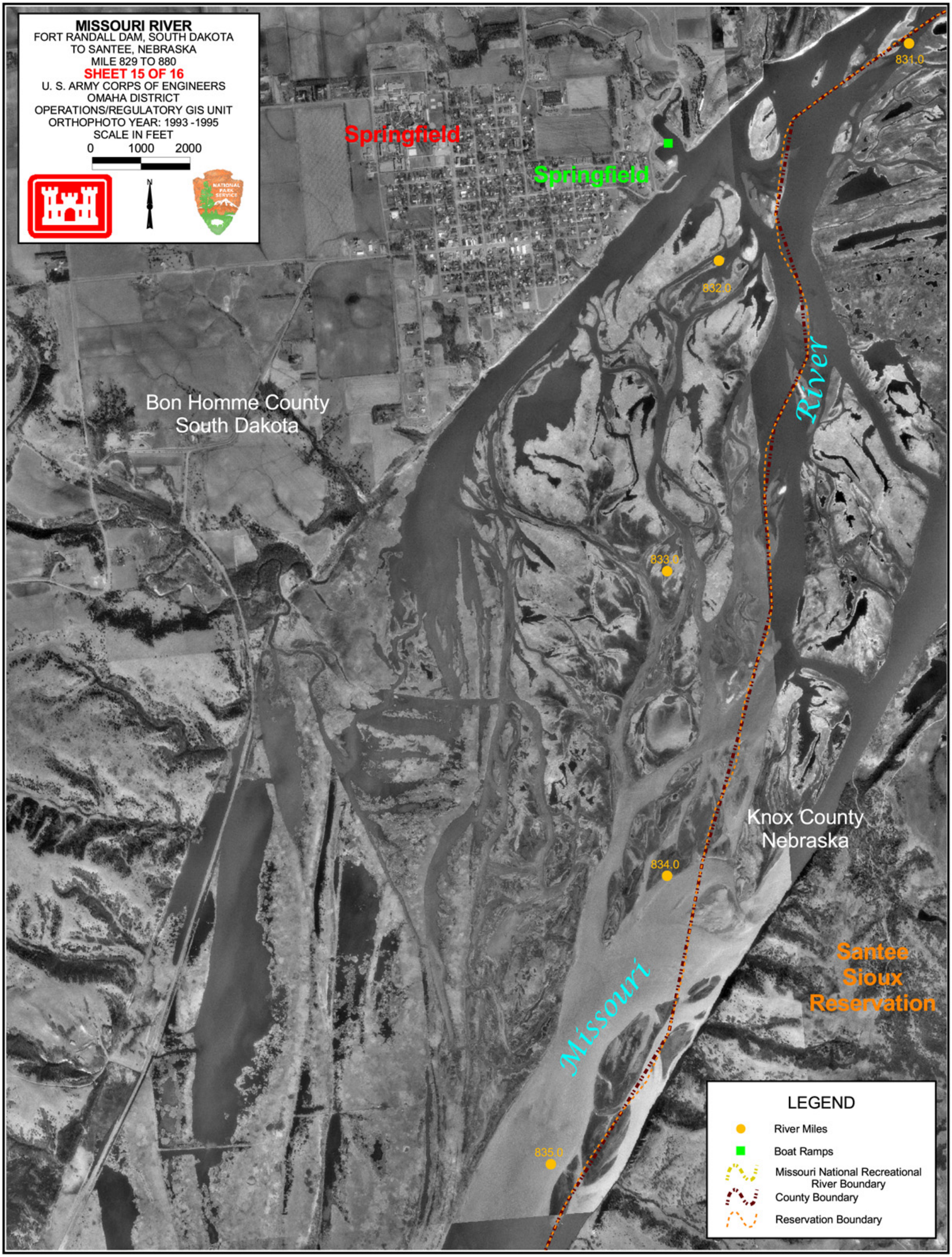
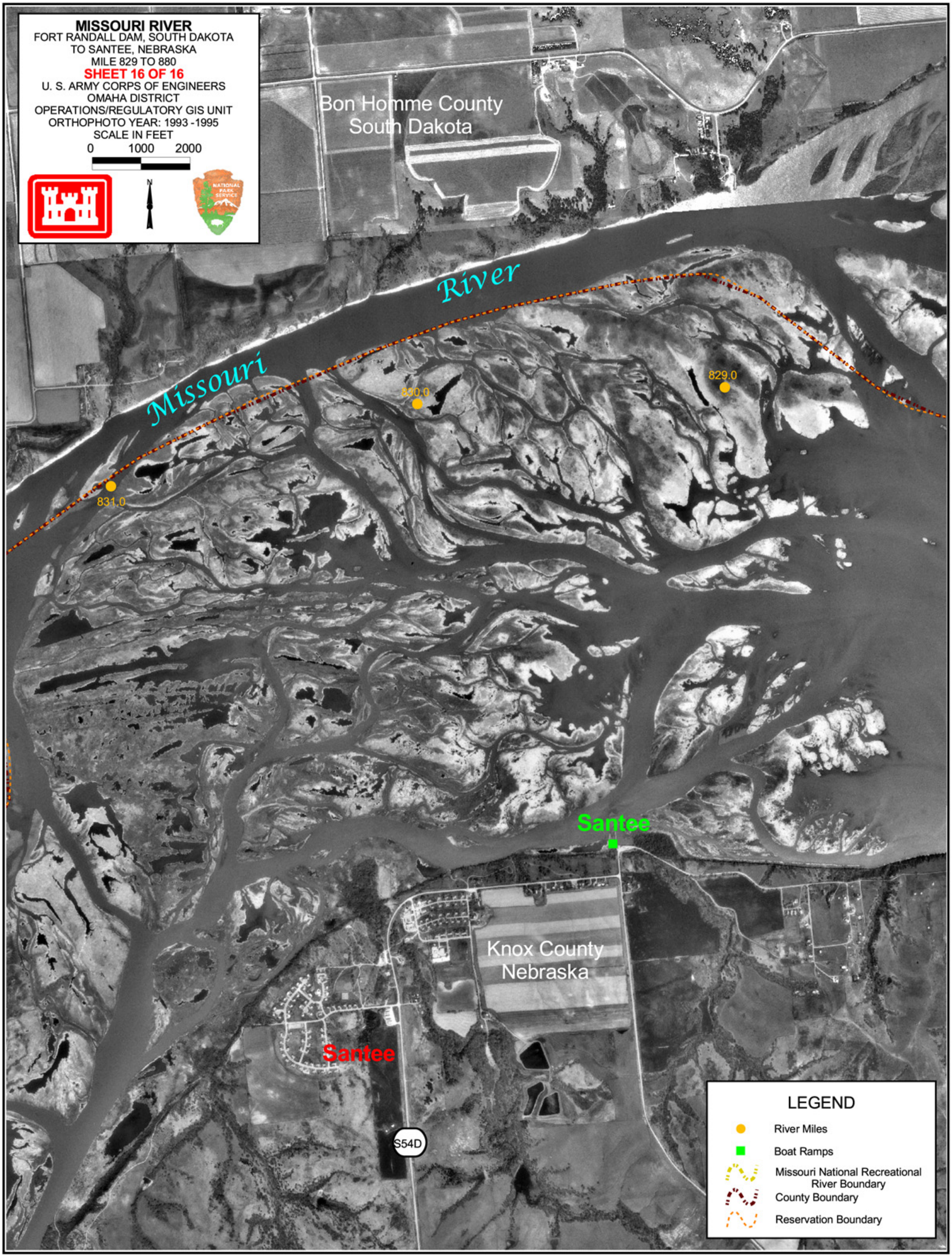
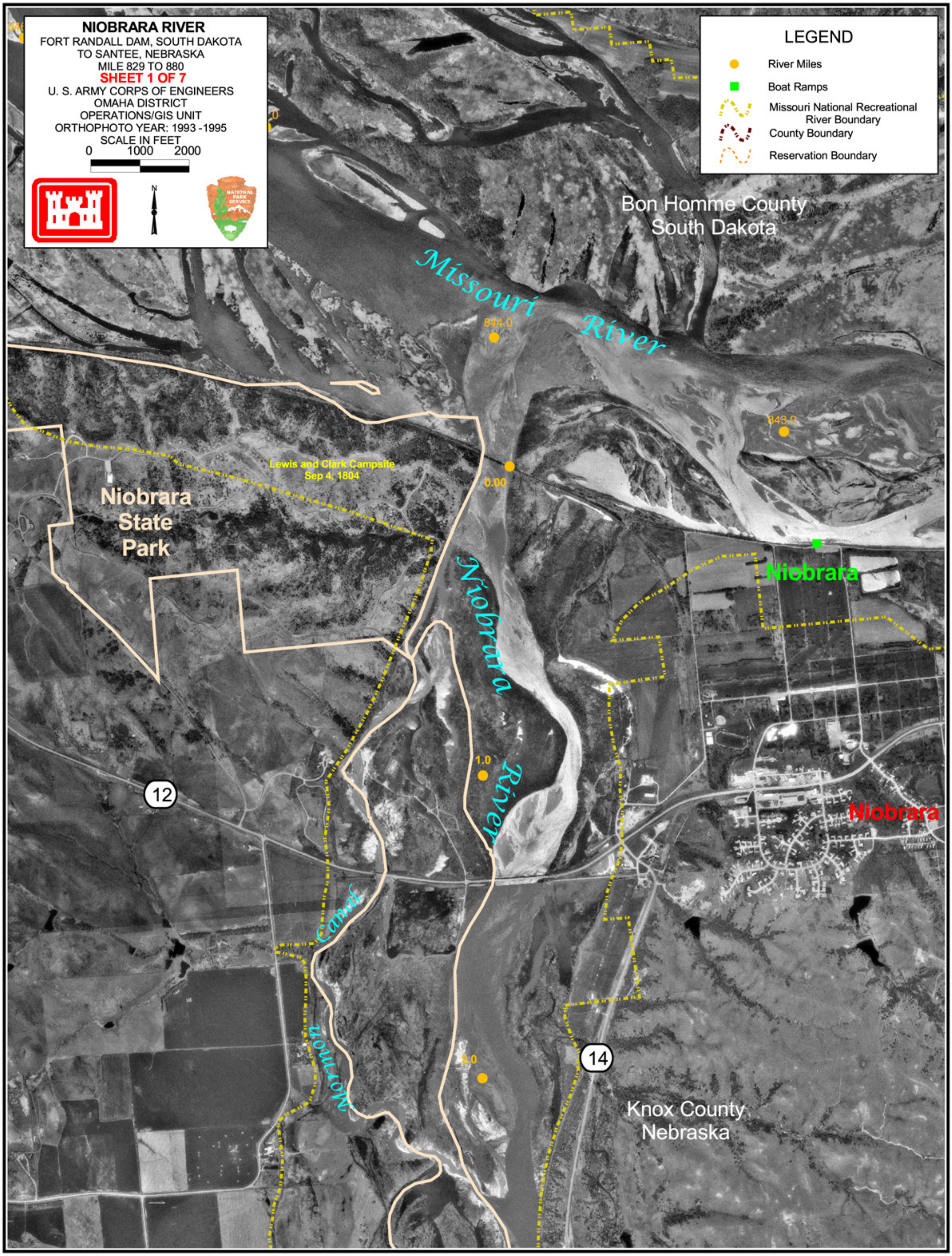

MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 13 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
Bon Homme County
South Dakota
37
838.0
839.0
840.0
841.0
River
Missouri
Interpretive Overlook
Running Water
Ferry Landing
Chief Standing Bear Bridge
Creek
Bazile
Knox County
Nebraska

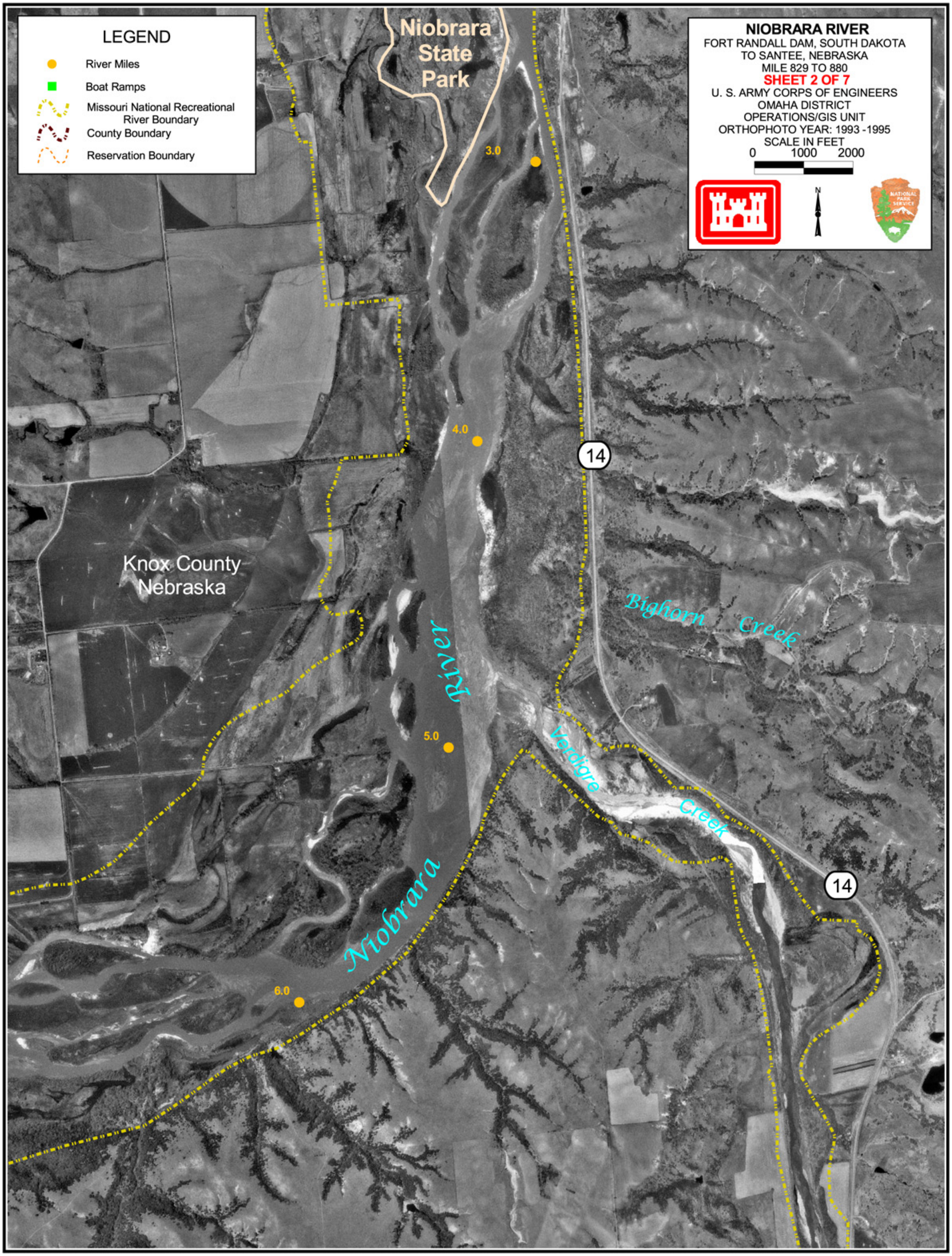
Plate III-21

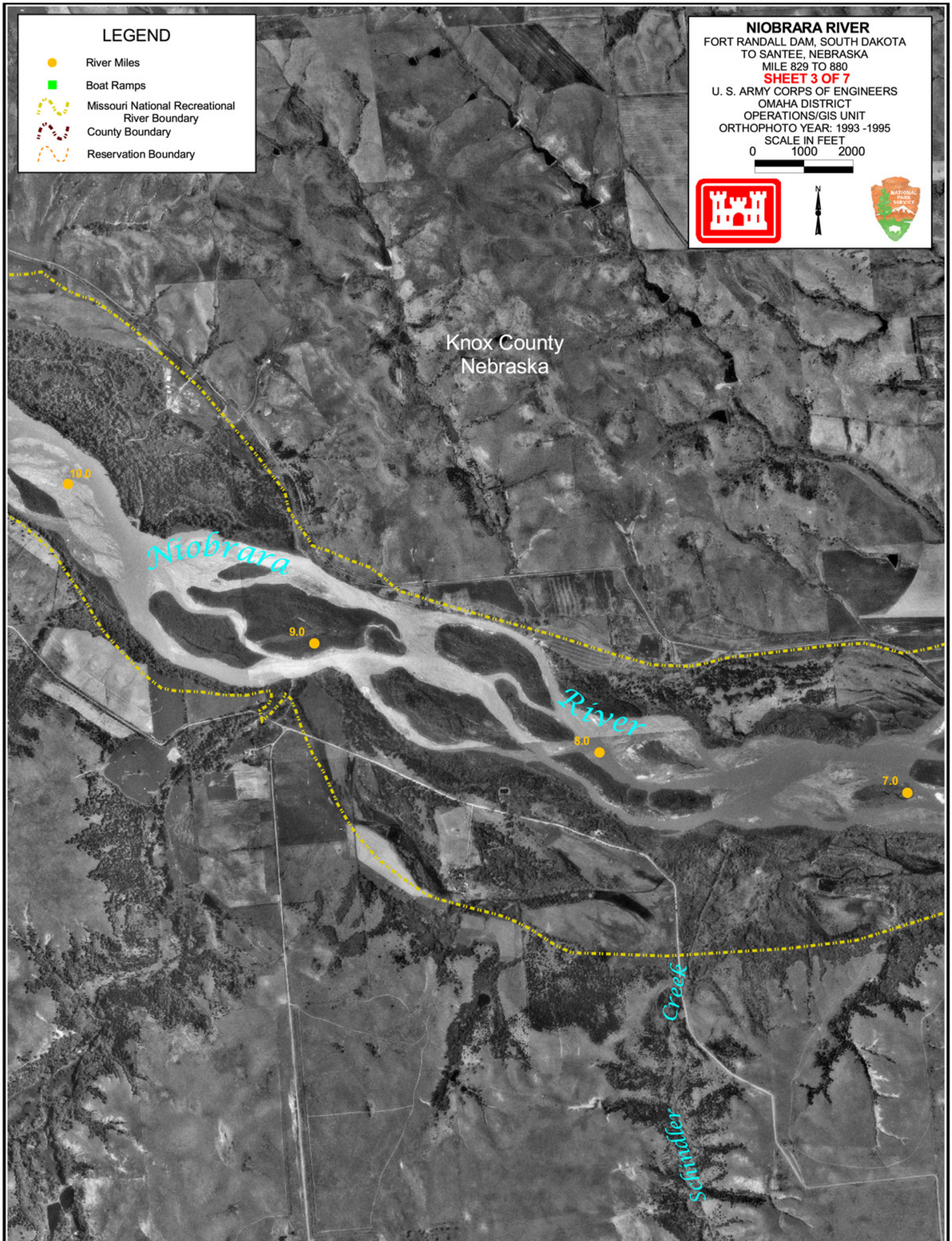

MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 14 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
835.0
836.0
Lewis and Clark Campsite
Sep 3, 1804
Bon Homme County
South Dakota
River
Santee
Sioux
Reservation
837.0
Missouri
Knox County
Nebraska
838.0
839.0
S54D
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary

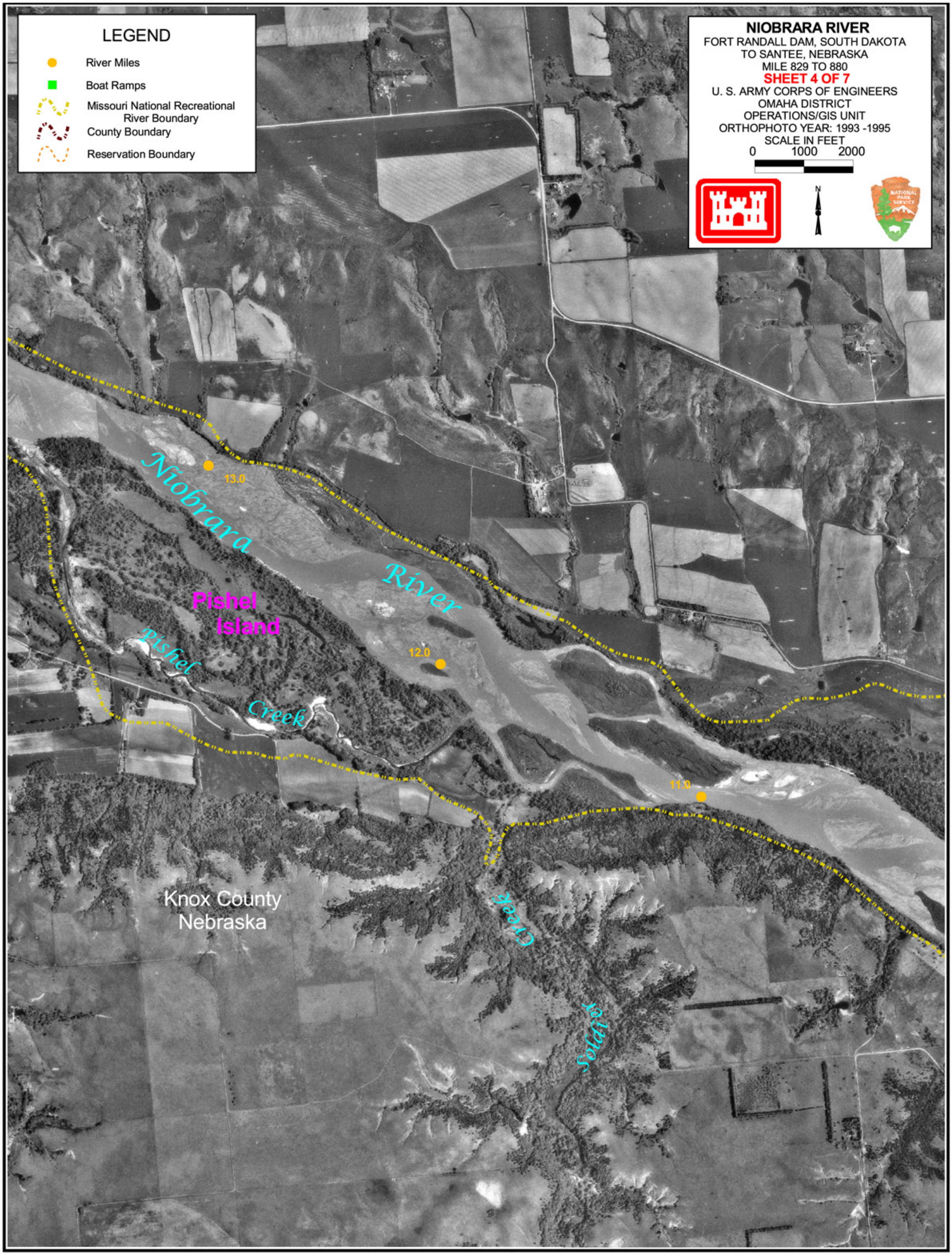

MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 15 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Springfield
Springfield
831.0
832.0
833.0
834.0
835.0
Bon Homme County
South Dakota
River
Missouri
Knox County
Nebraska
Santee
Sioux
Reservation
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


MISSOURI RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 16 OF 16
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
Bon Homme County
South Dakota
Missouri River
829.0
830.0
831.0
Santee
Knox County
Nebraska
Santee
S54D
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary


NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 1 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
Bon Homme County
South Dakota
Missouri River
844.0
843.0
0.00
Lewis and Clark Campsite
Sep 4, 1804
Niobrara State Park
Niobrara
Niobrara River
1.0
12
Niobrara
Canal
Mormon
2.0
14
Knox County
Nebraska


LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 2 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Niobrara State Park
3.0
4.0
5.0
6.0
14
14
Knox County Nebraska
Niobrara River
Bighorn Creek
Verdigre Creek


LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 3 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0
1000
2000
N
Knox County
Nebraska
10.0
Niobrara
9.0
River
8.0
7.0
Creek
Schindler


LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 4 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
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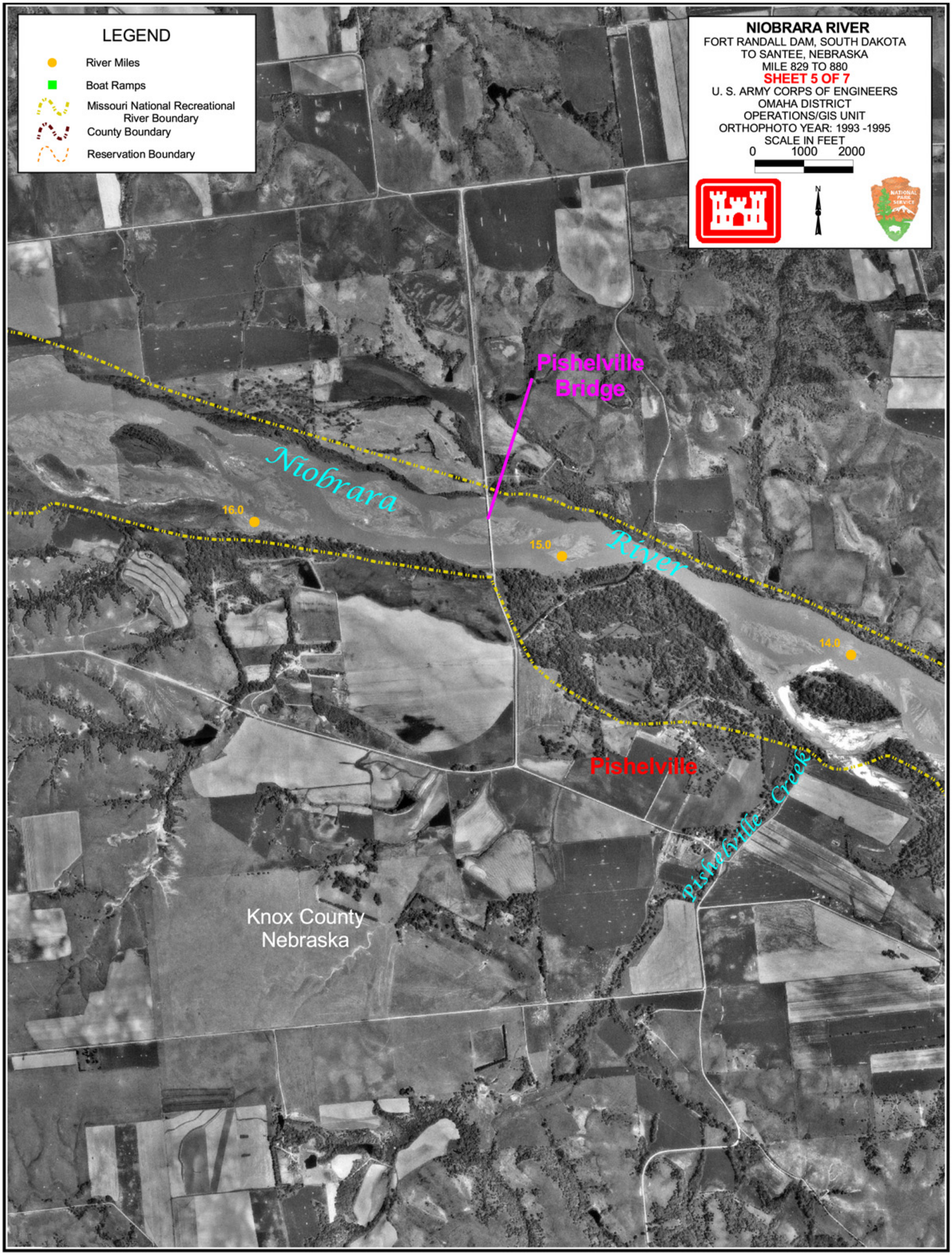
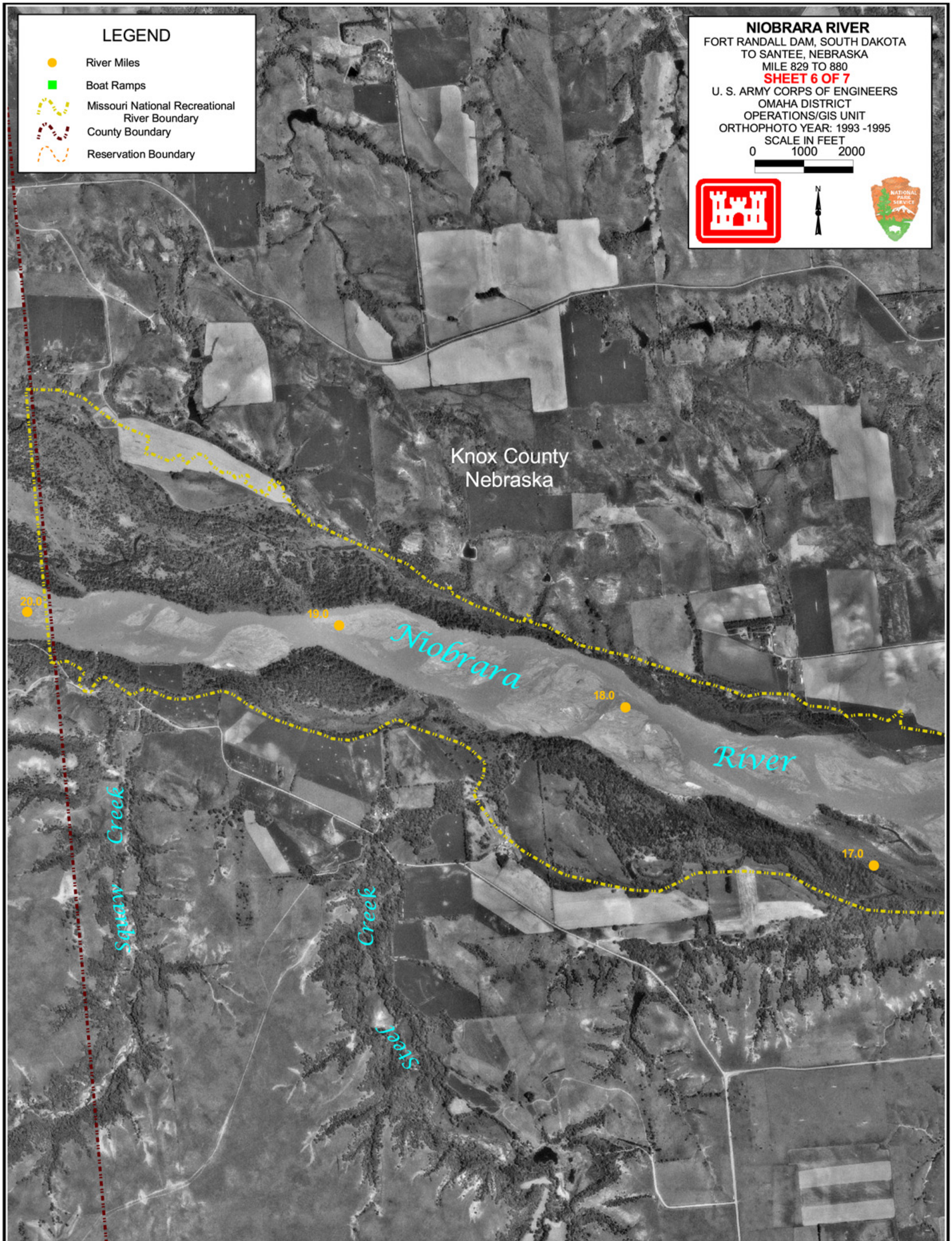
Niobrara River
13.0
12.0
11.0
Pishel Island
Pishel Creek
Knox County
Nebraska
Soldier Creek


LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 5 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Pishelville Bridge
Niobrara River
16.0
15.0
14.0
Pishelville
Pishelville Creek
Knox County Nebraska


LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 6 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Knox County
Nebraska
20.0
19.0
18.0
17.0
Niobrara
River
Squaw Creek
Steel Creek

LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary
NIOBRARA RIVER
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 7 OF 7
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
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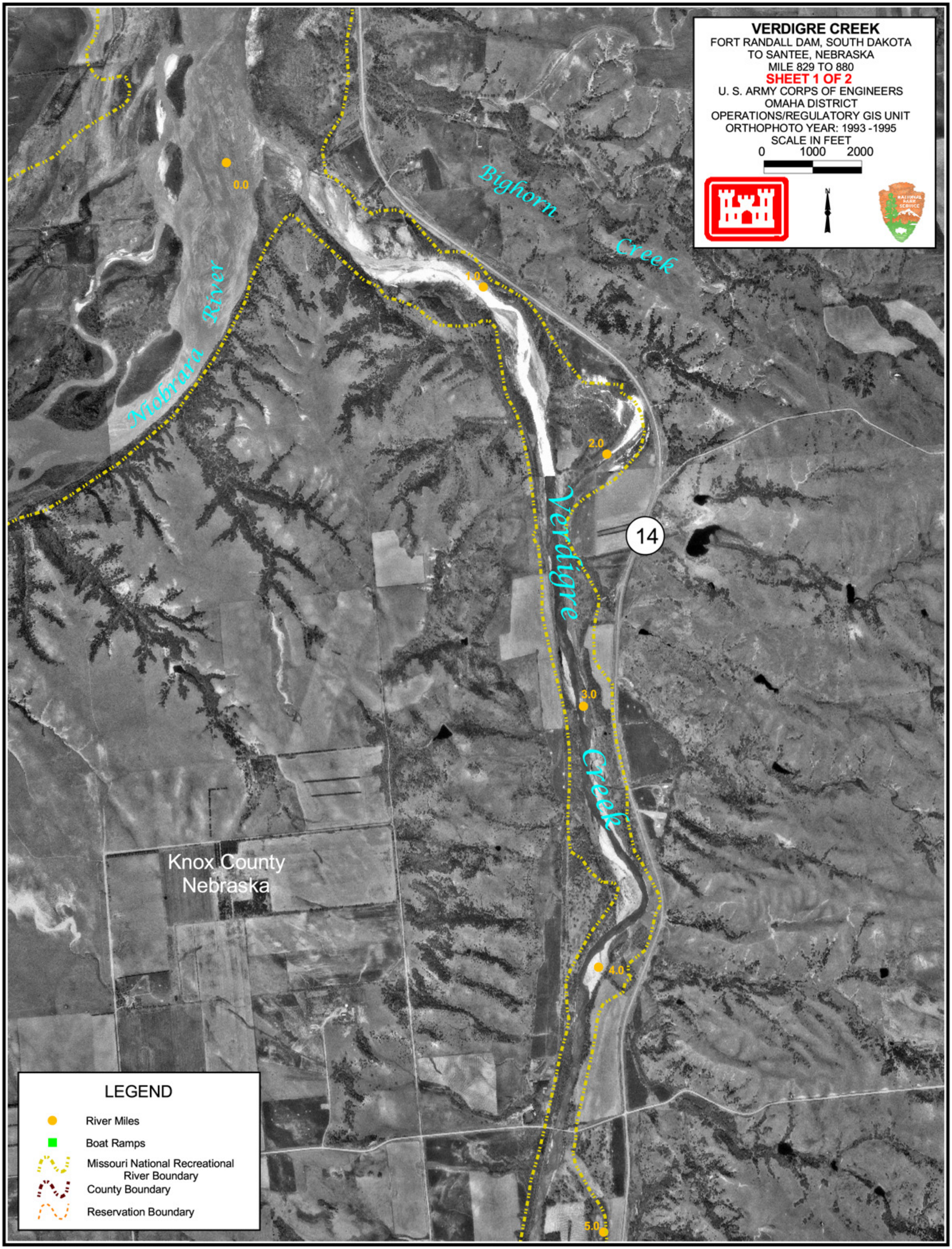
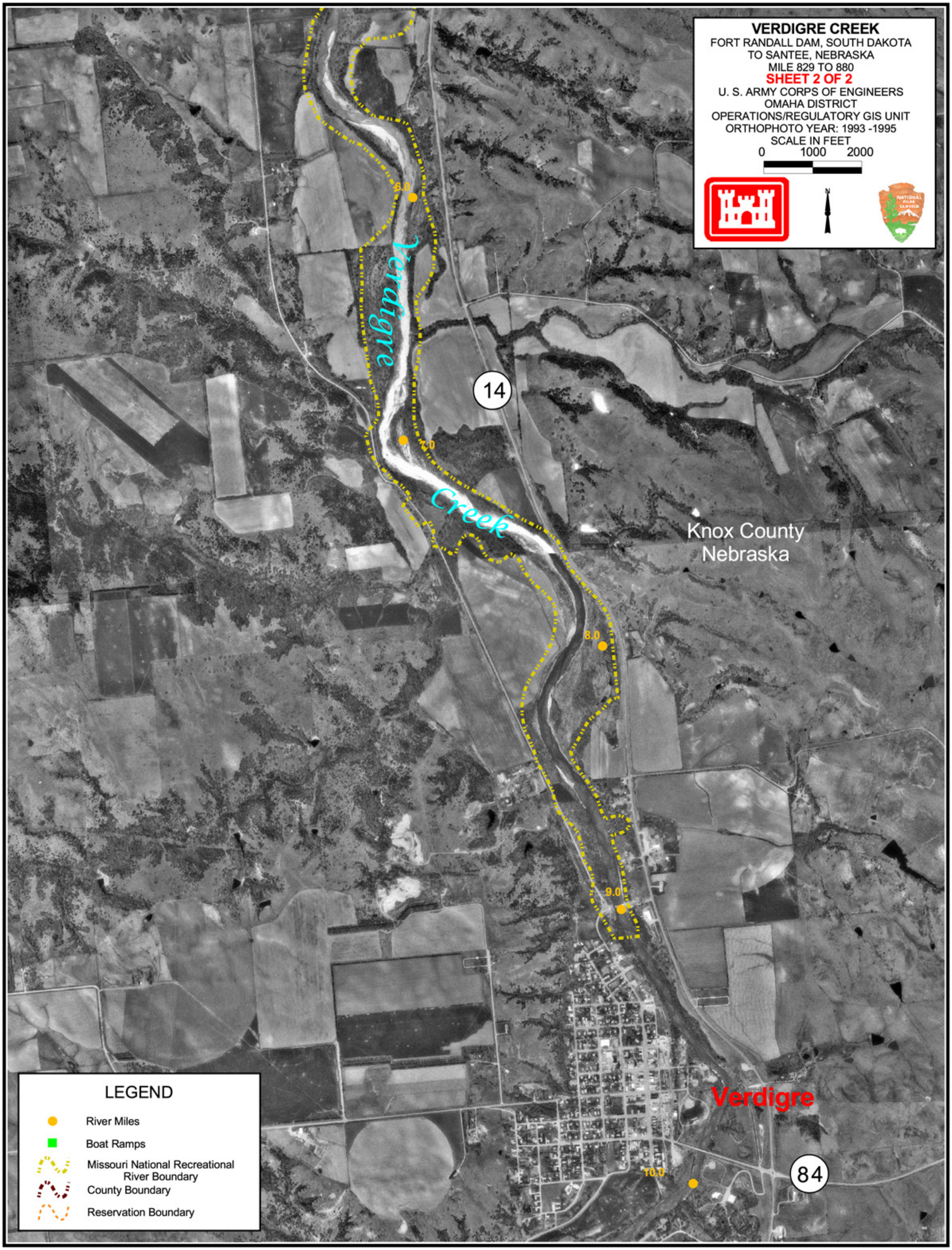
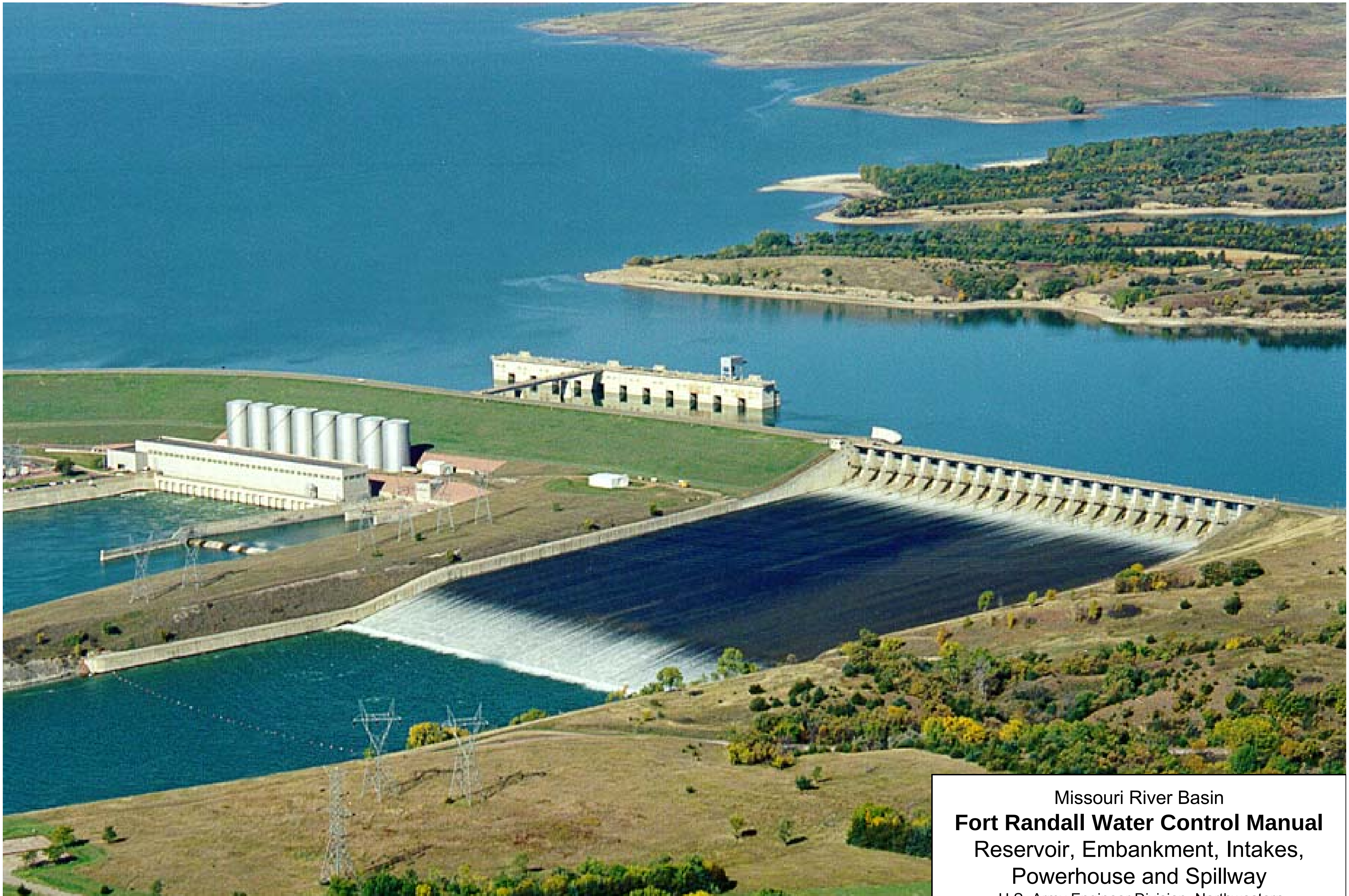
Boyd County
Nebraska
Niobrara
River
22.0
21.0
20.0
Holt County
Nebraska


VERDIGRE CREEK
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 1 OF 2
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
Bighorn Creek
Niobrara River
Verdigre Creek
14
Knox County
Nebraska
0.0
1.0
2.0
3.0
4.0
5.0
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary



VERDIGRE CREEK
FORT RANDALL DAM, SOUTH DAKOTA
TO SANTEE, NEBRASKA
MILE 829 TO 880
SHEET 2 OF 2
U. S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT
OPERATIONS/REGULATORY GIS UNIT
ORTHOPHOTO YEAR: 1993 -1995
SCALE IN FEET
0 1000 2000
N
6.0
Verdigre
14
7.0
Creek
Knox County
Nebraska
8.0
9.0
Verdigre
84
10.0
LEGEND
River Miles
Boat Ramps
Missouri National Recreational River Boundary
County Boundary
Reservation Boundary

Plate III-23



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

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

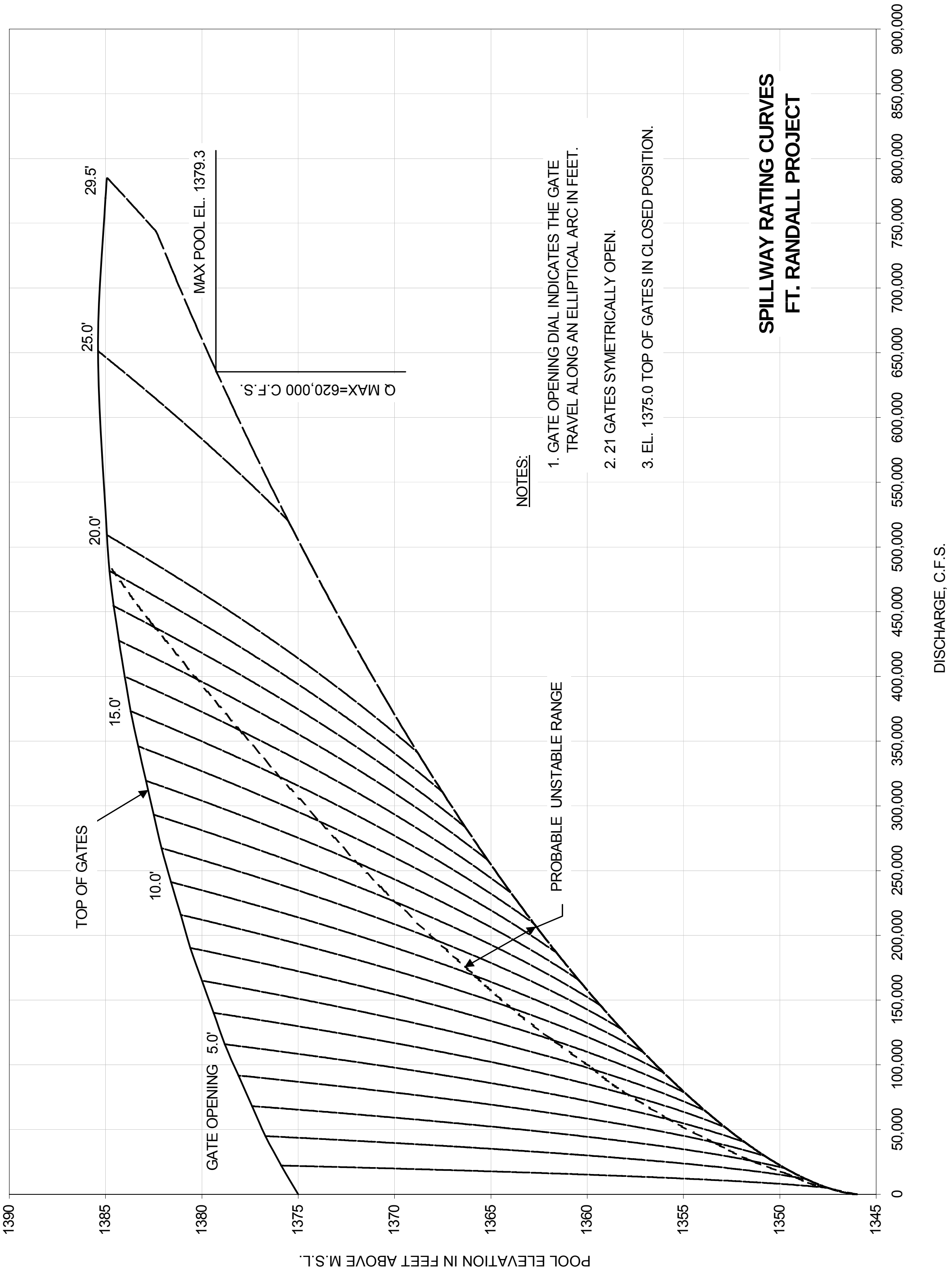
Missouri River Basin

Fort Randall Water Control Manual

Spillway Outlet Apron

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

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

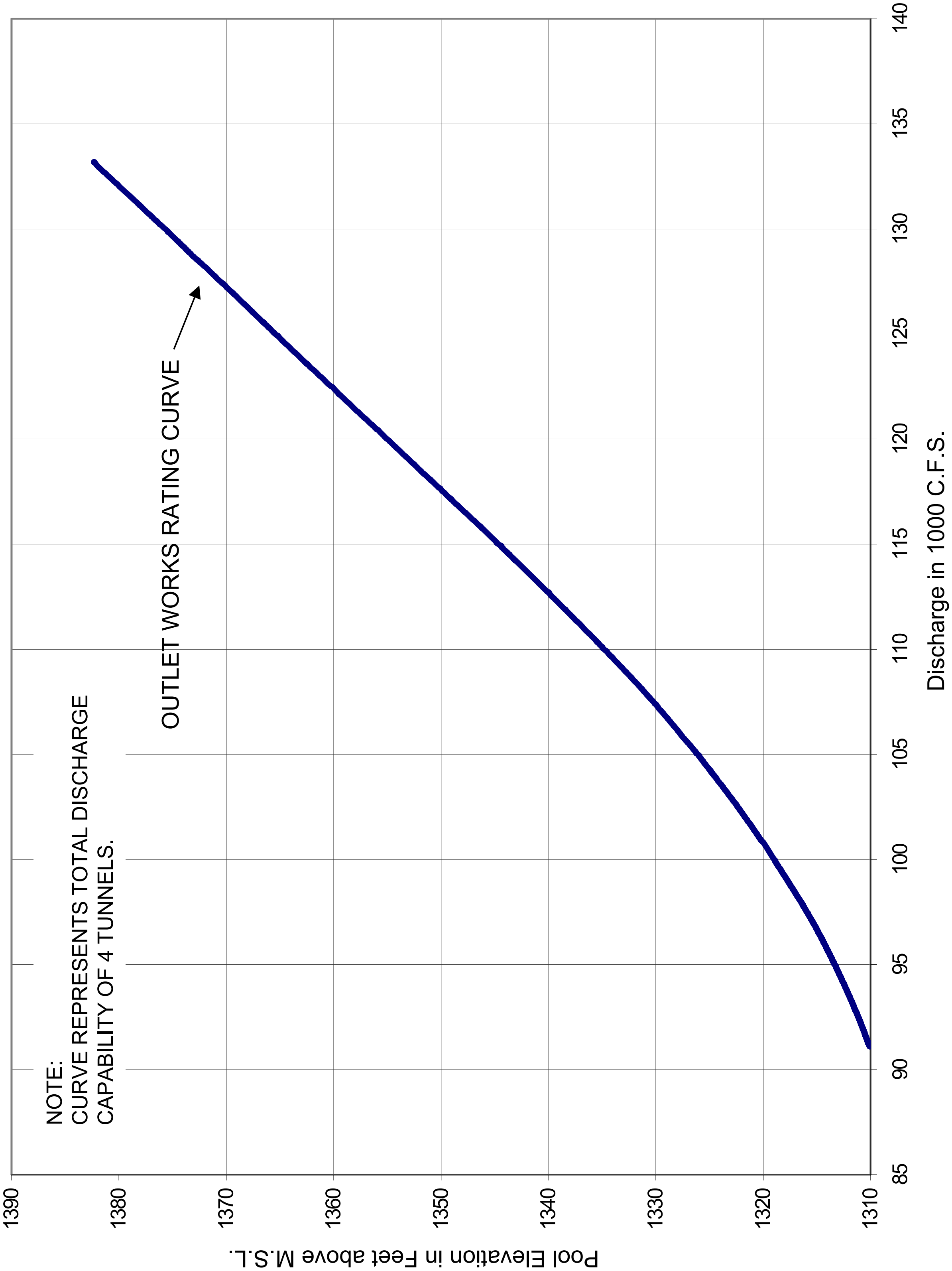


Missouri River Basin

Fort Randall Water Control Manual

Spillway Rating Curves

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



Missouri River Basin

Fort Randall Water Control Manual

Outlet Works Rating Curve

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

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

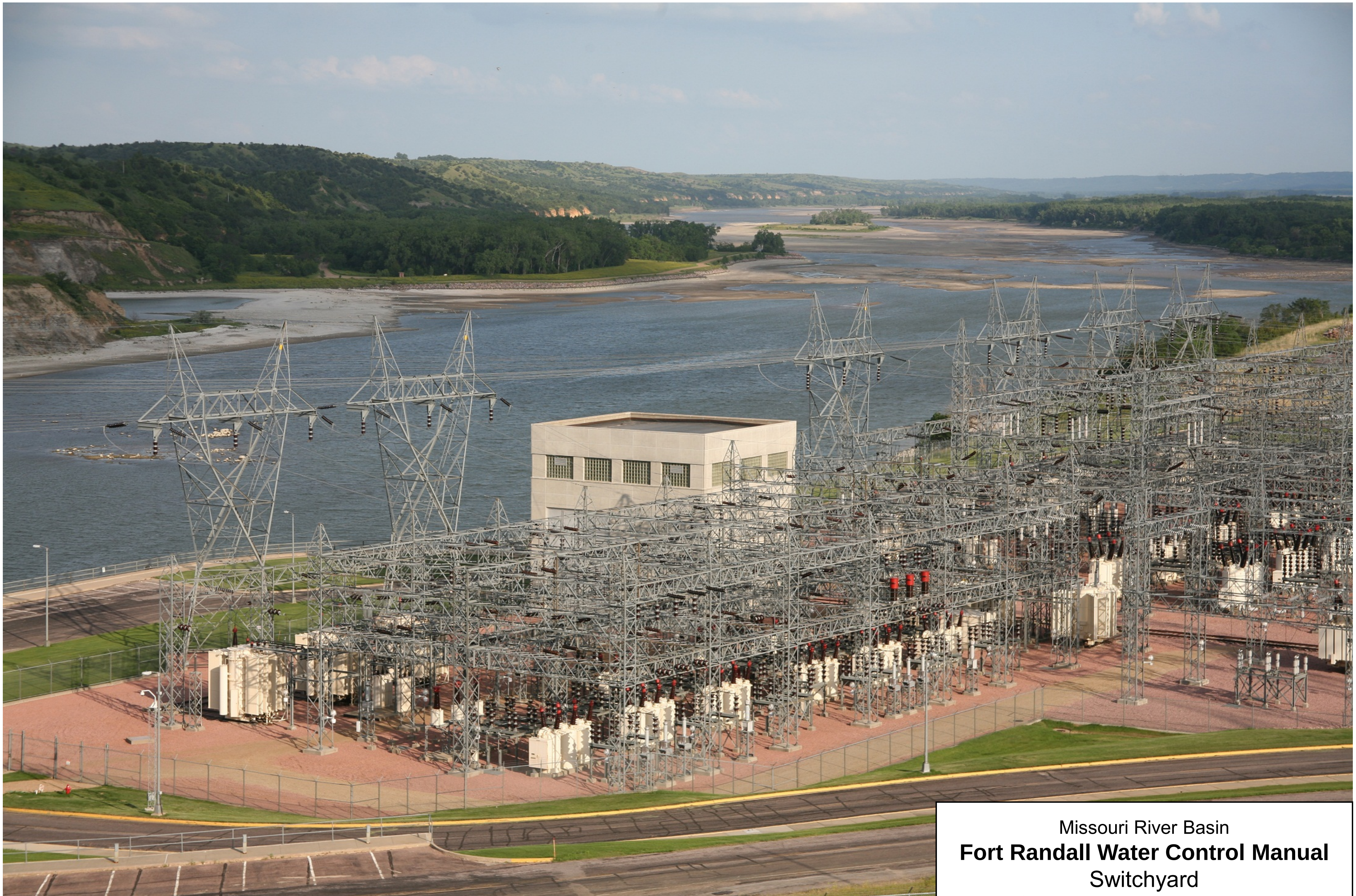
Missouri River Basin

Fort Randall Water Control Manual

Draft Tube

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

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

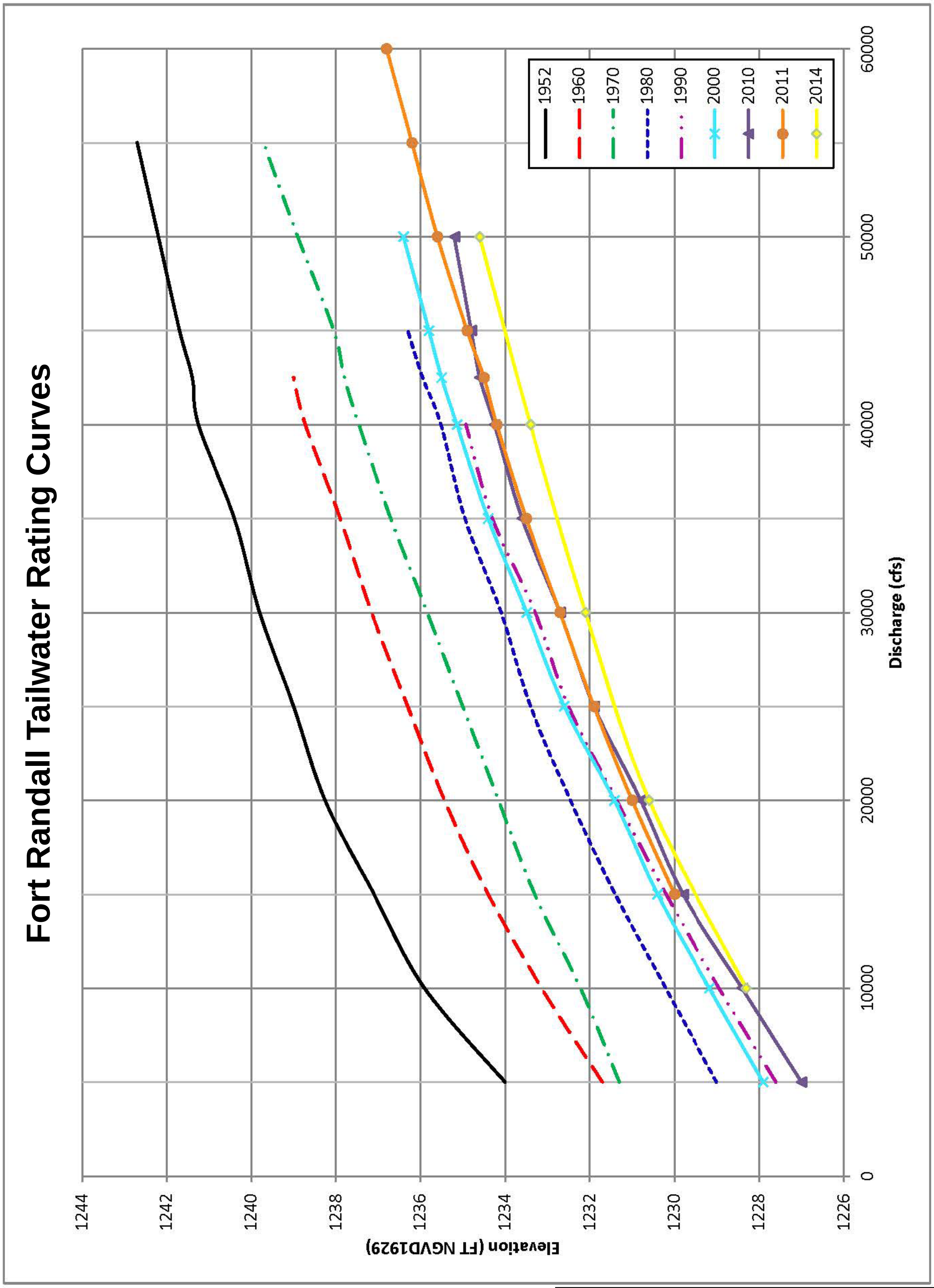


Missouri River Basin
Fort Randall Water Control Manual
Switchyard
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

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

Missouri River Basin
Fort Randall Water Control Manual
Generators
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

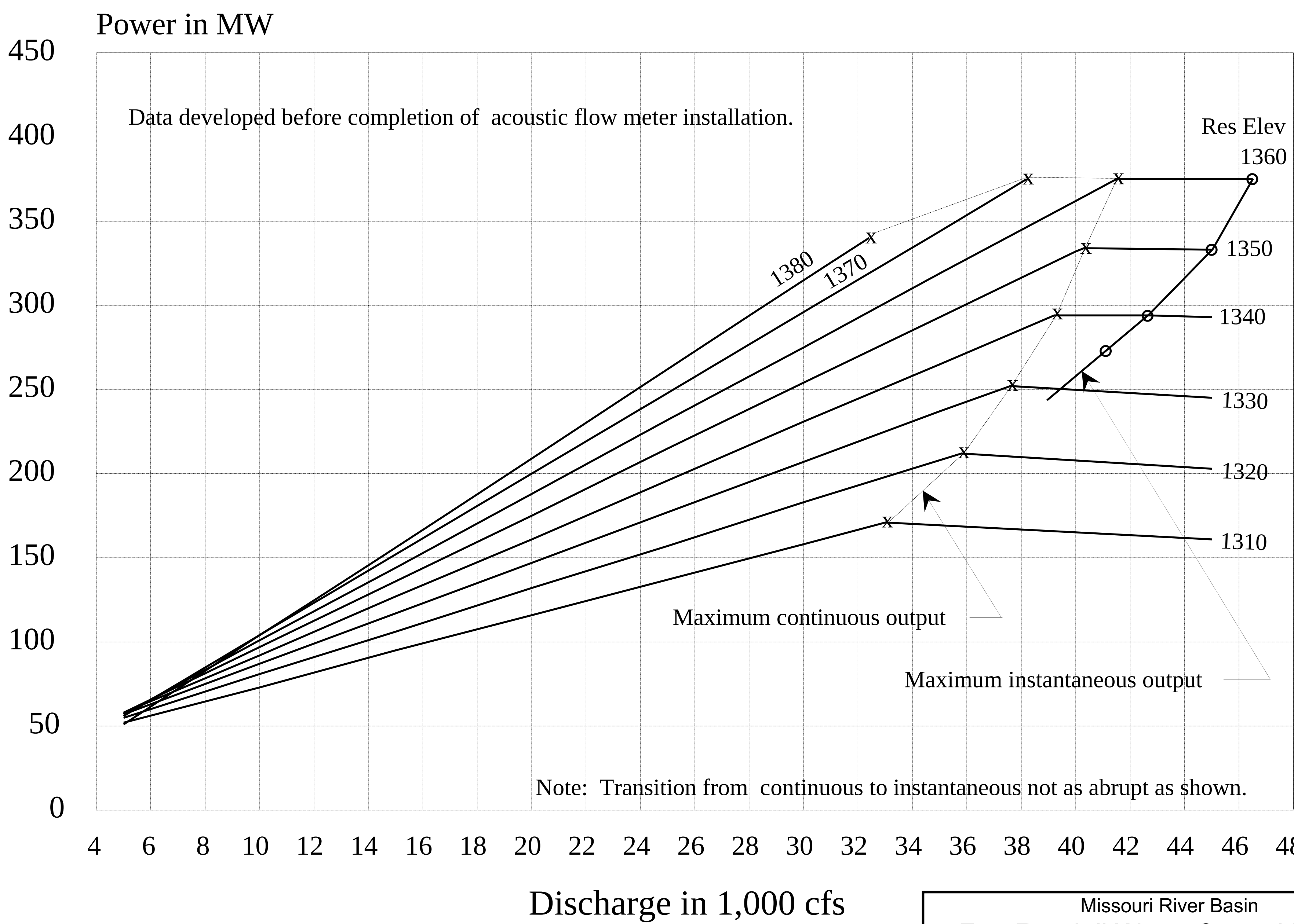
Plate IV-13



January 2015

Missouri River Basin
Fort Randall Water Control Manual
Fort Randall Tailwater Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate IV-14



Missouri River Basin

Fort Randall Water Control Manual

Powerplant Characteristics

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

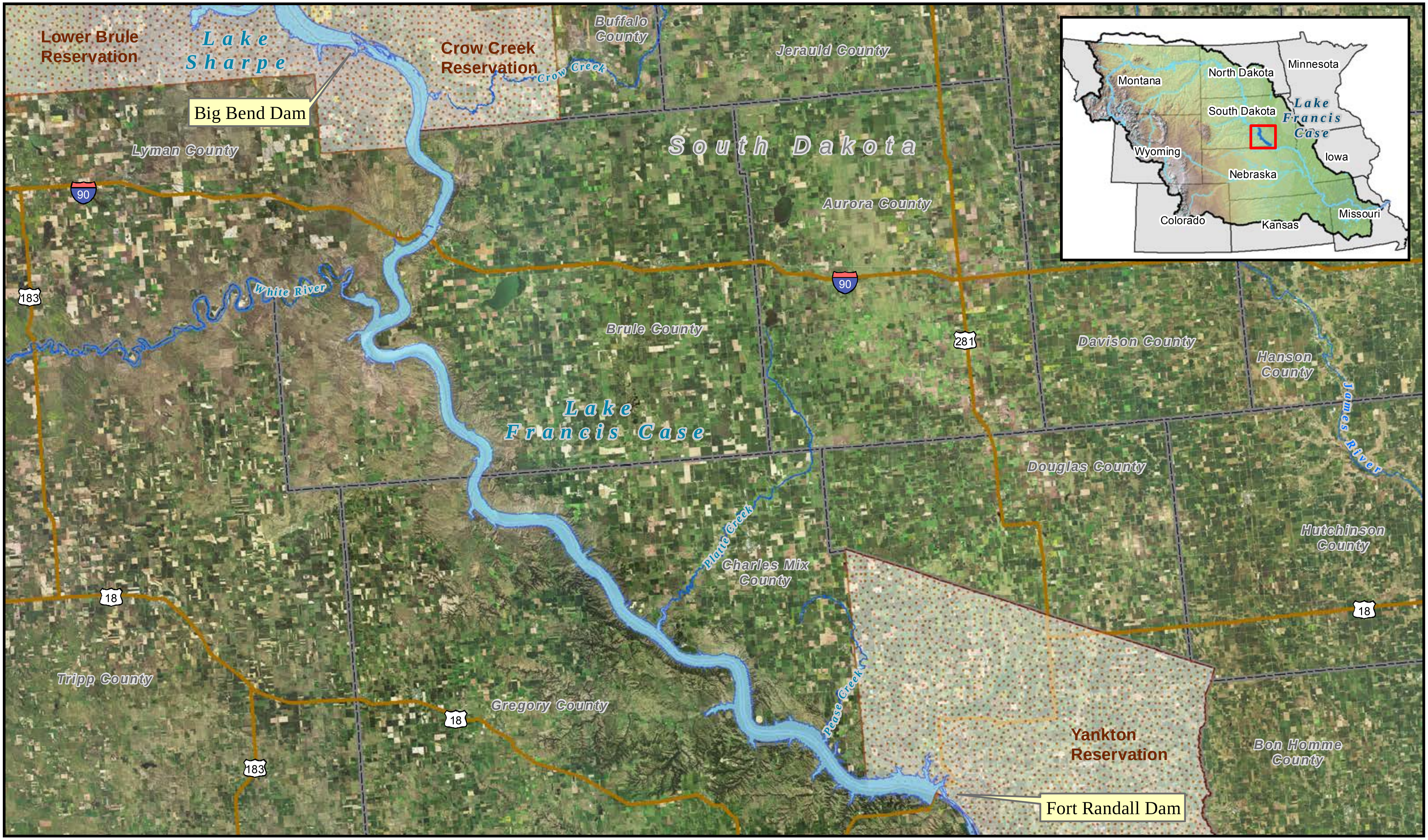


Plate IV-16

US Army Corps of Engineers®
Northwestern Division

Cities	Reservoirs/Lakes
Rivers	State Boundaries
Roads	County Boundaries
Reservations	

0 5 10 20 30 Miles

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

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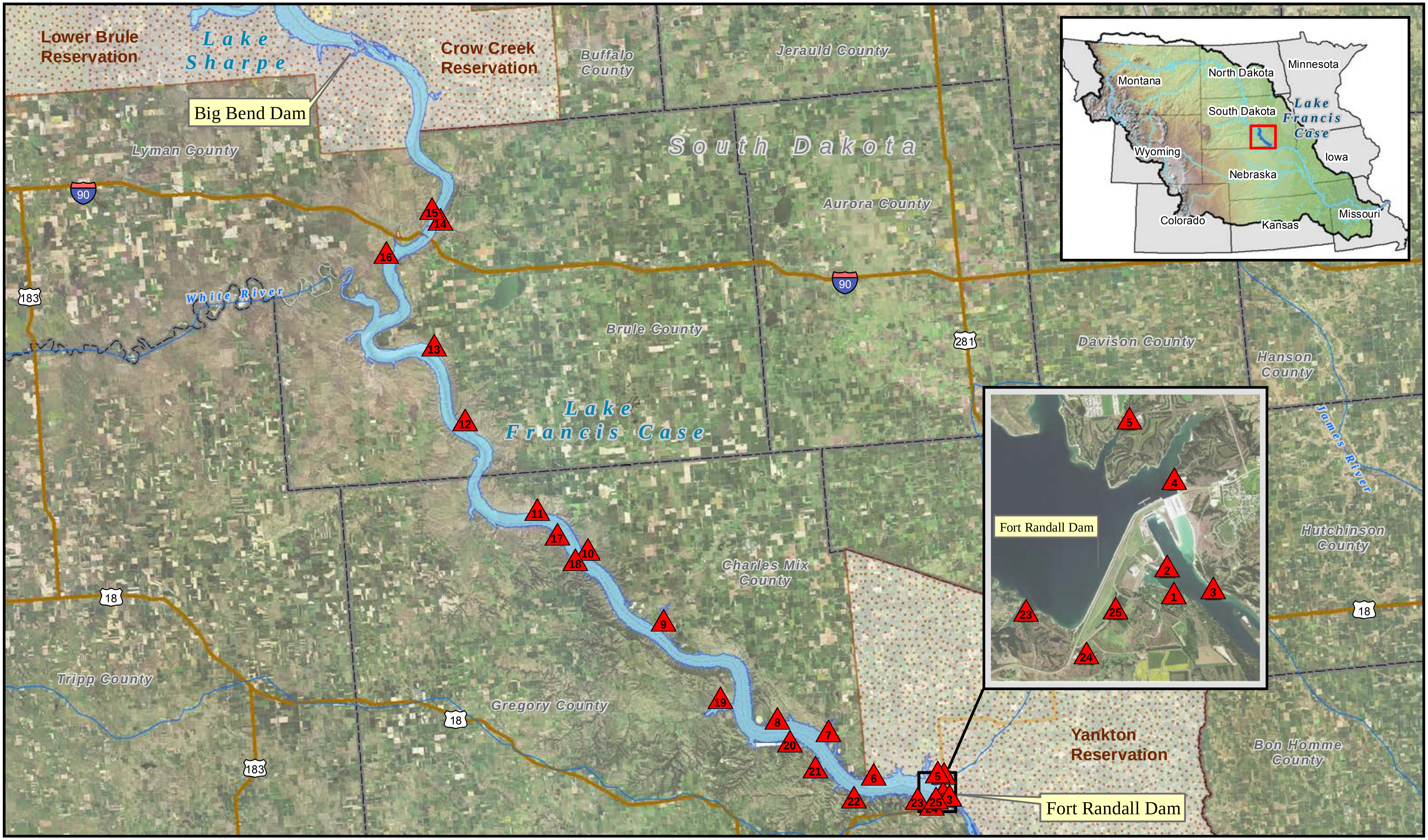
Missouri River Basin
FORT RANDALL PROJECT
PROJECT MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Fort Randall Area and Capacity Tables Surface Area in Acres Effective date 19 January 2012 (2011 Surveys)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1240	0	190	222	254	286	317	349	381	413	445
1250	1438	2533	2804	3145	3558	4042	4597	5223	5920	6688
1260	7486	8238	8934	9598	10231	10832	11401	11938	12444	12917
1270	13362	13803	14270	14773	15311	15884	16492	17135	17813	18527
1280	19276	20033	20761	21446	22088	22687	23243	23757	24228	24656
1290	25134	25744	26381	26947	27442	27866	28218	28500	28711	28851
1300	28936	29026	29175	29391	29672	30019	30432	30911	31455	32066
1310	32744	33443	34085	34644	35120	35513	35823	36049	36193	36254
1320	36100	35720	35426	35409	35668	36203	37015	38104	39469	41111
1330	42615	43545	44286	45242	46413	47798	49399	51214	53244	55489
1340	57772	59833	61730	63603	65450	67271	69068	70838	72584	74304
1350	76206	78426	80644	82616	84342	85821	87053	88039	88779	89273
1360	89779	90623	91648	92630	93568	94462	95313	96121	96884	97604
1370	98323	99096	99902	100705	101504	102300	103094	103883	104669	105453
1380	106236	107023	107812	108601	109390	110180	110969	111758	112547	113336
1390	114126	0	0	0	0	0	0	0	0	0

Fort Randall Area and Capacity Tables Capacity in Acre-Feet Implemented by MRBWM August 2013 (2011 Surveys)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1240	0	175	381	620	890	1192	1525	1891	2288	2717
1250	3178	5594	8245	11202	14536	18319	22620	27513	33066	39353
1260	46443	54325	62920	72194	82117	92657	103781	115459	127658	140347
1270	153493	167071	181099	195612	210645	226234	242413	259218	276683	294845
1280	313738	333397	353805	374919	396697	419095	442071	465582	489585	514038
1290	538898	564307	590387	617069	644281	671953	700013	728390	757013	785812
1300	814716	843685	872769	902036	931551	961381	991590	1022245	1053412	1085156
1310	1117544	1150645	1184430	1218816	1253719	1289057	1324746	1360703	1396845	1433090
1320	1469353	1505290	1540794	1576143	1611612	1647479	1684019	1721510	1760228	1800449
1330	1842451	1885680	1929542	1974253	2020027	2067079	2115624	2165877	2218053	2272366
1340	2329032	2387910	2448698	2511371	2575904	2642271	2710447	2780407	2852124	2925575
1350	3000732	3077988	3157585	3239276	3322817	3407960	3494459	3582067	3670538	3759626
1360	3849085	3939185	4030332	4122482	4215592	4309618	4404517	4500245	4596759	4694014
1370	4791967	4890660	4990160	5090465	5191570	5293473	5396171	5499661	5603938	5709000
1380	5814844	5921473	6028890	6137097	6246093	6355878	6466453	6577816	6689969	6802911
1390	6916642	0	0	0	0	0	0	0	0	0

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



Recreation Area

Cities

Rivers

Roads

Reservations

Reservoirs/Lakes

State Boundaries

County Boundaries

0 5 10 20 30 Miles

N E S W

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

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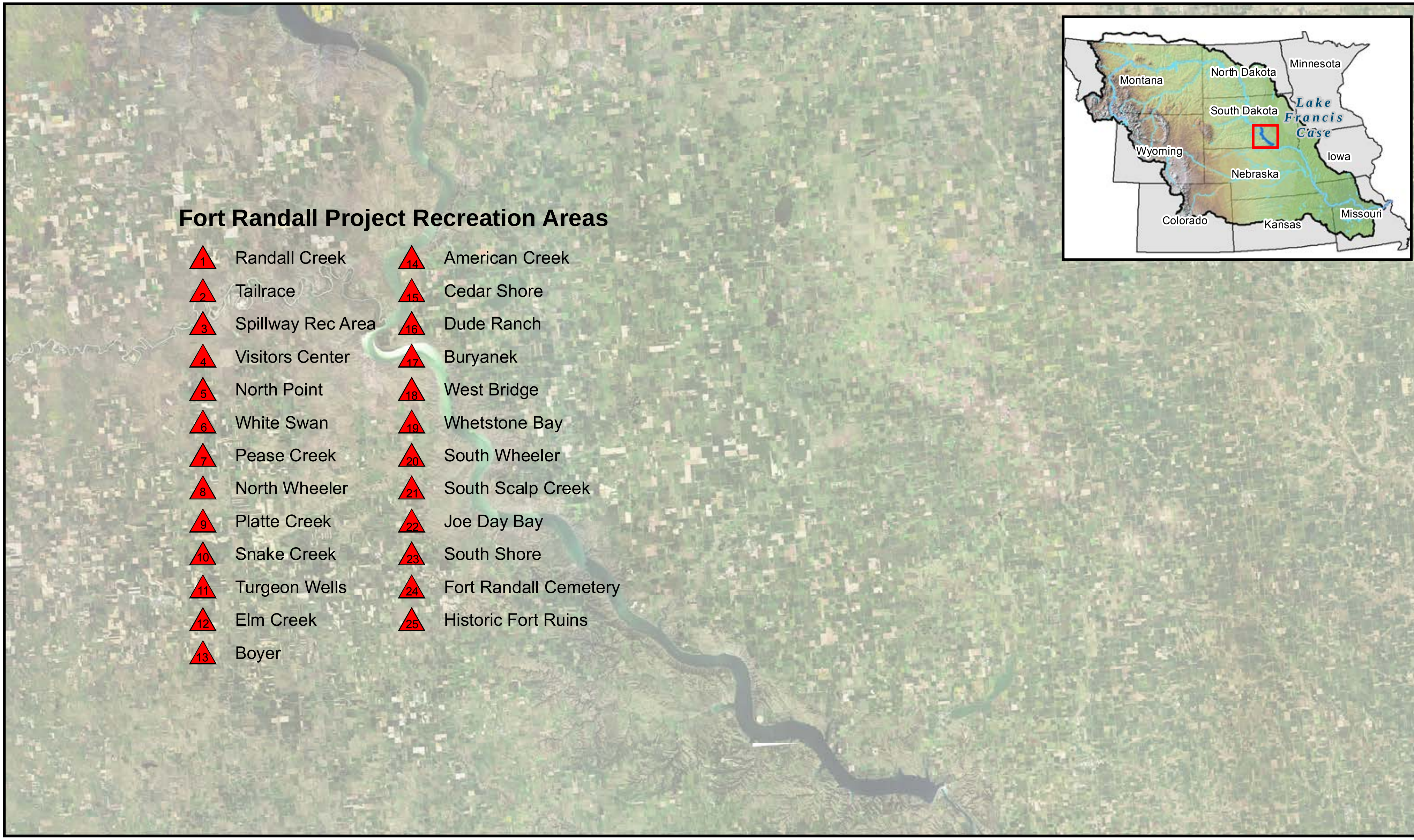
US Army Corps of Engineers®
Northwestern Division

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

Plate IV-18



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

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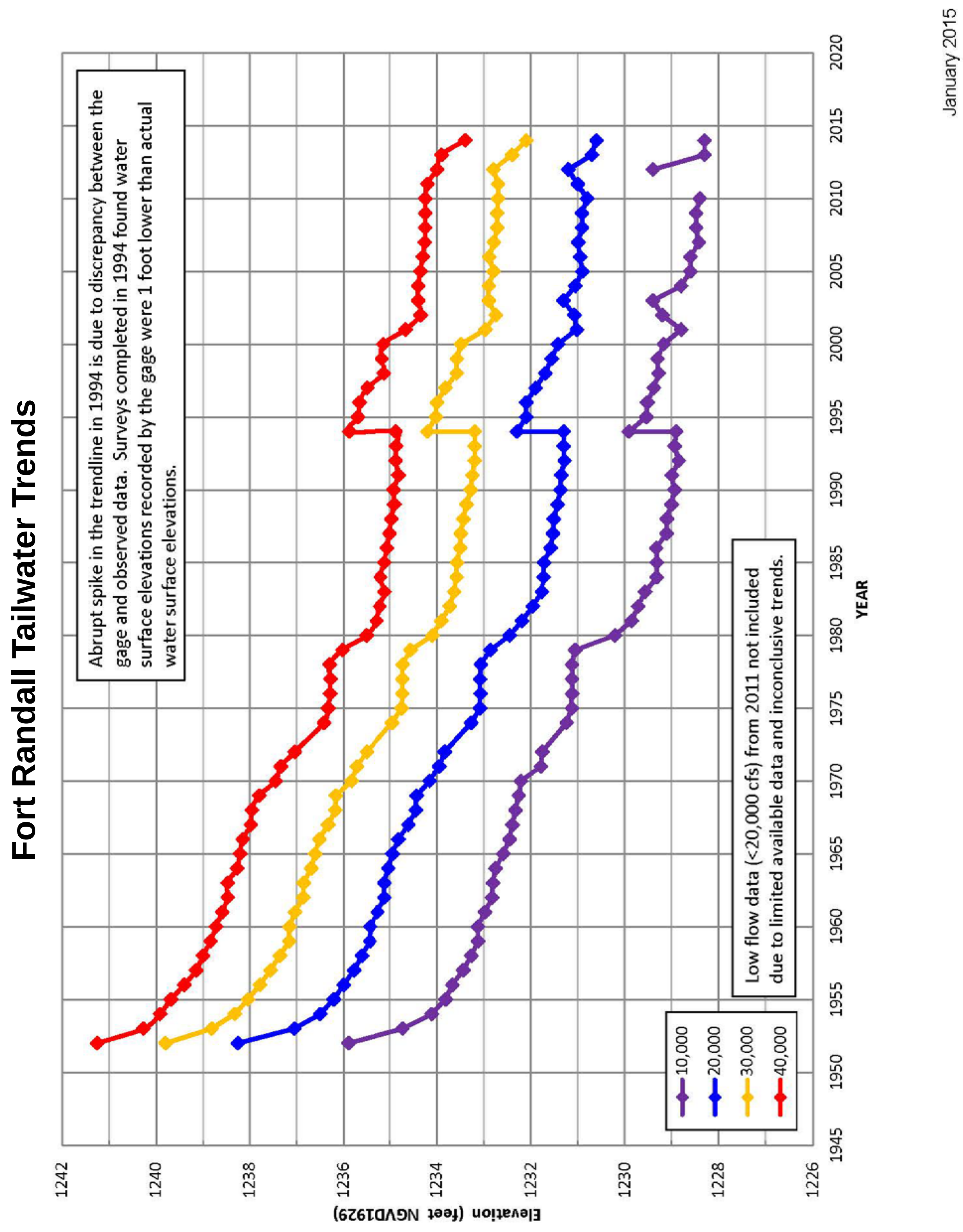
US Army Corps of Engineers®
Northwestern Division

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

Plate IV-19



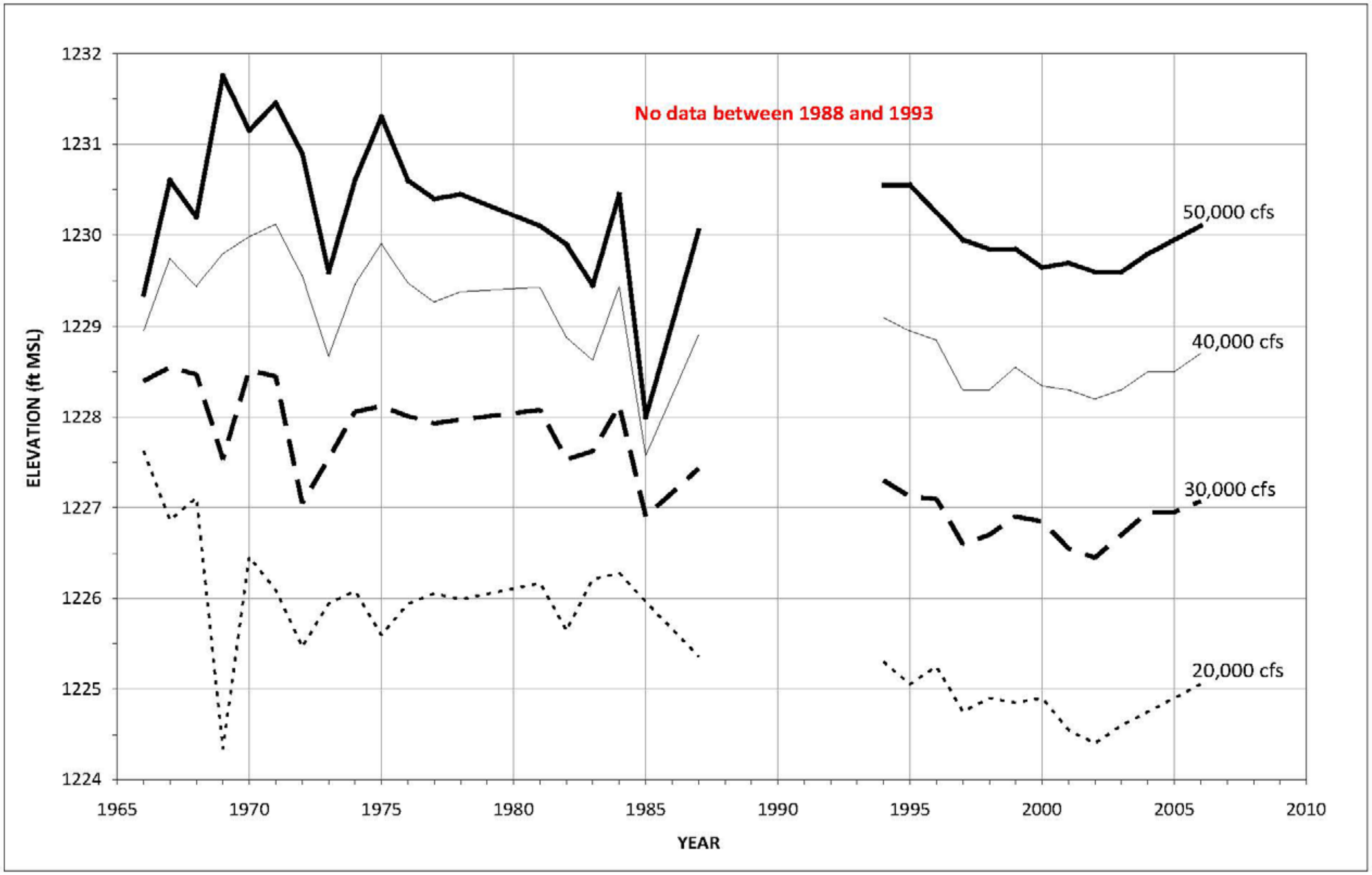
Missouri River Basin

Fort Randall Water Control Manual

Fort Randall Tailwater Trends

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

Stage Trends – Missouri River at Greenwood



Stage Trends – Greenwood Gage (1960 RM 862.9)

Source: Missouri River Fort Randall Project
Downstream Channel and Sediment Trends Study
Updated June 2012

Missouri River Basin
Fort Randall Water Control Manual
Stage Trends – Missouri River at Greenwood, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate V-1

US Army Corps of Engineers®
Northwestern Division

Streamgaging Station
Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Fort Randall Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 10 20 40 60 Miles

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

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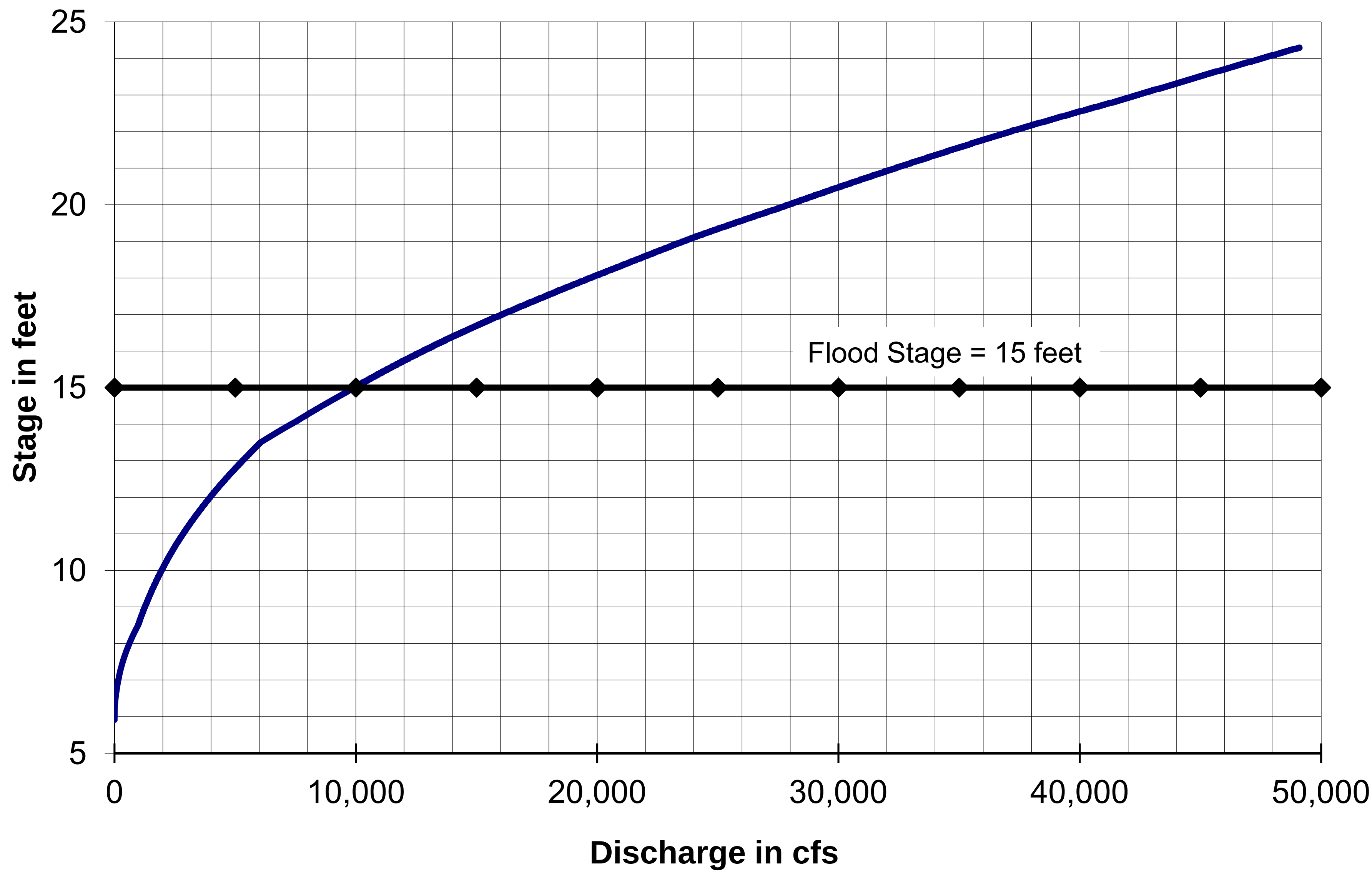
Missouri River Basin
FORT RANDALL DRAINAGE AREA
KEY STREAMGAGING STATIONS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Datum of gage is 1,377.29 feet above sea level NGVD29.

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

Stage	Flow in cfs							
	White River at NE-SD State Line	White River at near Ogalala, SD	White River near Interior, SD	White River near Kadoka, SD	White River near White River, SD	White River near Oacoma, SD	Black Pipe Cr near Belvidere, SD	Bear-in-the-Lodge Cr nr Wanblee, SD
	Rating #4 Fld Stg = 18'	Rating #12 Fld Stg = 19'	Rating #5 No flood stage	Rating #16 Fld Stg = 13'	Rating #6 No flood stage	Rating #26 Fld Stg = 15'	Rating #6 Fld Stg = 14'	Rating #7 Fld Stg = 10'
1.0								7
1.5								22
2.0				18				44
2.5				80			1	67
3.0				193	0		27	93
3.5	1		15	347	9		87	122
4.0	18		108	537	79		184	154
4.5	59	4	258	773	209		321	189
5.0	102	18	462	1,040	385		476	236
5.5	148	35	725	1,360	610		619	294
6.0	191	53	1,040	1,720	869	2	780	365
6.5	236	75	1,400	2,100	1,170	42	993	452
7.0	284	101	1,720	2,510	1,520	158	1,230	550
7.5	334	129	2,040	2,970	1,910	342	1,490	660
8.0	386	161	2,380	3,470	2,340	618	1,780	782
8.5	440	195	2,720	4,020	2,810	978	2,080	917
9.0	495	232	3,080	4,600	3,330	1,260	2,410	1,070
9.5	552	271	3,480	5,230	3,890	1,590	2,760	
10.0	610	313	3,900	5,900	4,490	1,960	3,130	
10.5	669	357	4,500	6,600	5,140	2,370	3,520	
11.0	730	403	5,150	7,340	5,870	2,850	3,910	
11.5	792	452	5,900	8,100	6,650	3,370	4,310	
12.0	860	502	6,700	8,900	7,490	3,960	4,720	
12.5	929	555	7,570		8,530	4,600	5,150	
13.0	1,000	610	8,500		9,670	5,310	5,600	
13.5	1,070	668	9,500		10,900	6,050	6,060	
14.0	1,160	727	10,600		12,700	7,320	6,540	
14.5	1,260	788	11,800		14,800	8,600	7,030	
15.0	1,350	851				9,940	7,540	
15.5	1,450	916				11,300	8,060	
16.0	1,600	983				12,800	8,600	
16.5	1,750	1,070				14,400	9,040	
17.0	1,970	1,170				16,100		
17.5	2,200	1,280				17,900		
18.0	2,500	1,410				19,700		
19.0	3,280	1,730				23,600		
20.0		2,200				27,900		
21.0		2,370				32,400		
22.0						37,100		

Missouri River Basin

Fort Randall Water Control Manual

White River Basin Rating Curves

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

Reservoir Elevation Corrections at Fort Randall to Allow for Wind Effects

Reservoir Elevation at 1370 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

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

Reservoir Elevation Wind Corrections in Feet

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

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

Reservoir Elevation Corrections at Fort Randall to Allow for Wind Effects

Reservoir Elevation at 1360 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

Wind Direction	Wind Speed in Miles Per Hour														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-1.1	-1.4	-1.8	-1.8	-2.3
10	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.4	-1.4	-1.8
20	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.7	-0.9	-1.0	-1.2
30	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.5	-0.5	-0.6
40	-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	-0.2	-0.3
50	-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
60	+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	+0.6	+0.7
70	+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	+1.3	+1.4
80	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+1.0	+1.2	+1.4	+1.7	+1.8	+2.1
90	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.5	+0.7	+1.0	+1.2	+1.5	+1.9	+2.2	+2.3	+2.7
100	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.7	+2.8	+3.2
110	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.0	+3.1	+3.6
120	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.1	+1.4	+1.8	+2.3	+2.7	+3.2	+3.4	+3.9
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.3	+3.5	+4.0
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.5	+2.9	+3.4	+3.6	+4.0
150	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.3	+3.5	+4.0
160	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.1	+1.4	+1.8	+2.3	+2.7	+3.2	+3.4	+3.9
170	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.0	+3.1	+3.6
180	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.7	+2.8	+3.2
190	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.5	+0.7	+1.0	+1.2	+1.5	+1.9	+2.2	+2.3	+2.7
200	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+1.0	+1.2	+1.4	+1.7	+1.8	+2.1
210	+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	+1.3	+1.4
220	+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	+0.6	+0.7
230	-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
240	-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	-0.2	-0.3
250	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.5	-0.5	-0.6
260	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.7	-0.9	-1.0	-1.2
270	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.1	-1.4	-1.4	-1.8
280	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-1.1	-1.4	-1.8	-1.8	-2.3
290	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.7	-2.1	-2.2	-2.7
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.4	-1.9	-2.4	-2.5	-3.0
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.5	-0.8	-1.1	-1.5	-2.0	-2.6	-2.6	-3.2
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.5	-0.8	-1.1	-1.6	-2.0	-2.6	-2.7	-3.2
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.5	-0.8	-1.1	-1.5	-2.0	-2.6	-2.6	-3.2
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.4	-1.9	-2.4	-2.5	-3.0
350	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.7	-2.1	-2.2	-2.7

Reservoir Elevation Wind Corrections in Feet

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

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

Reservoir Elevation Corrections at Fort Randall
to Allow for Wind Effects
Reservoir Elevation at 1350 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

Wind Direction	Wind Speed in Miles Per Hour														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.2	-1.6	-2.1	-2.5	-3.0
10	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.2	-1.6	-2.0	-2.4
20	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7
30	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.7	-1.0
40	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3
50	-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
60	+0.0	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8
70	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+1.1	+1.3	+1.5	+1.7
80	+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	+2.2	+2.5
90	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+2.0	+2.4	+2.7	+3.1
100	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+0.9	+1.2	+1.6	+2.0	+2.4	+2.8	+3.2	+3.7
110	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.1	+1.4	+1.8	+2.2	+2.7	+3.1	+3.6	+4.1
120	+0.0	+0.0	+0.0	+0.2	+0.4	+0.6	+0.8	+1.2	+1.5	+2.0	+2.4	+2.9	+3.3	+3.9	+4.4
130	+0.0	+0.0	+0.0	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.1	+2.5	+2.9	+3.5	+4.0	+4.6
140	+0.0	+0.0	+0.0	+0.2	+0.4	+0.7	+0.9	+1.3	+1.7	+2.2	+2.6	+3.1	+3.6	+4.2	+4.8
150	+0.0	+0.0	+0.0	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.1	+2.5	+2.9	+3.5	+4.0	+4.6
160	+0.0	+0.0	+0.0	+0.2	+0.4	+0.6	+0.8	+1.2	+1.5	+2.0	+2.4	+2.9	+3.3	+3.9	+4.4
170	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.8	+1.1	+1.4	+1.8	+2.2	+2.7	+3.1	+3.6	+4.1
180	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+0.9	+1.2	+1.6	+2.0	+2.4	+2.8	+3.2	+3.7
190	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+2.0	+2.4	+2.7	+3.1
200	+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	+2.2	+2.5
210	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+1.1	+1.3	+1.5	+1.7
220	+0.0	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8
230	-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
240	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3
250	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.7	-1.0
260	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7
270	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.2	-1.6	-2.0	-2.4
280	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.2	-1.6	-2.1	-2.5	-3.0
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.5	-1.9	-2.4	-2.9	-3.6
300	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.6	-2.1	-2.7	-3.3	-3.9
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.9	-1.3	-1.7	-2.2	-2.9	-3.5	-4.1
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-1.0	-1.4	-1.9	-2.4	-3.0	-3.7	-4.3
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.9	-1.3	-1.7	-2.2	-2.9	-3.5	-4.1
340	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.6	-2.1	-2.7	-3.3	-3.9
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.5	-1.9	-2.4	-2.9	-3.6

Reservoir Elevation Wind Corrections in Feet

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

Missouri River Basin
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U.S. Army Engineer Division, Northwestern
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September 2017

Reservoir Elevation Corrections at Fort Randall to Allow for Wind Effects

Reservoir Elevation at 1340 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.3	-1.7	-2.2	-2.7	-3.3
10	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.4	-0.7	-1.0	-1.3	-1.7	-2.2	-2.6
20	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.7	-0.9	-1.2	-1.5	-1.9
30	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.5	-0.7	-0.9	-1.1
40	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3
50	-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
60	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.3	+0.4	+0.5	+0.7	+0.8	+0.9
70	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.1	+1.3	+1.6	+1.8
80	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.1	+1.3	+1.6	+2.0	+2.3	+2.6
90	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.4	+2.8	+3.2
100	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.3	+1.6	+2.1	+2.4	+2.9	+3.3	+3.8
110	+0.0	+0.0	+0.0	+0.2	+0.3	+0.6	+0.8	+1.1	+1.5	+1.9	+2.3	+2.7	+3.2	+3.7	+4.3
120	+0.0	+0.0	+0.0	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.5	+3.0	+3.5	+4.0	+4.6
130	+0.0	+0.0	+0.0	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.1	+3.6	+4.2	+4.8
140	+0.0	+0.0	+0.0	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.2	+2.6	+3.1	+3.6	+4.3	+4.9
150	+0.0	+0.0	+0.0	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.1	+3.6	+4.2	+4.8
160	+0.0	+0.0	+0.0	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.5	+3.0	+3.5	+4.0	+4.6
170	+0.0	+0.0	+0.0	+0.2	+0.3	+0.6	+0.8	+1.1	+1.5	+1.9	+2.3	+2.7	+3.2	+3.7	+4.3
180	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.3	+1.6	+2.1	+2.4	+2.9	+3.3	+3.8
190	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.4	+2.8	+3.2
200	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.1	+1.3	+1.6	+2.0	+2.3	+2.6
210	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.1	+1.3	+1.6	+1.8
220	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.3	+0.4	+0.5	+0.7	+0.8	+0.9
230	-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
240	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3
250	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.5	-0.7	-0.9	-1.1
260	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.7	-0.9	-1.2	-1.5	-1.9
270	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.4	-0.7	-1.0	-1.3	-1.7	-2.2	-2.6
280	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.3	-1.7	-2.2	-2.7	-3.3
290	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.6	-2.1	-2.6	-3.2	-3.8
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.3	-0.6	-0.9	-1.3	-1.8	-2.3	-2.9	-3.5	-4.1
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.1	-3.7	-4.3
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.4	-2.0	-2.5	-3.1	-3.7	-4.3
330	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.5	-3.1	-3.7	-4.3
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.3	-0.6	-0.9	-1.3	-1.8	-2.3	-2.9	-3.5	-4.1
350	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.6	-2.1	-2.6	-3.2	-3.8

Reservoir Elevation Wind Corrections in Feet

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

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

Reservoir Elevation Corrections at Fort Randall to Allow for Wind Effects

Reservoir Elevation at 1330 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

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

Reservoir Elevation Wind Corrections in Feet

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

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

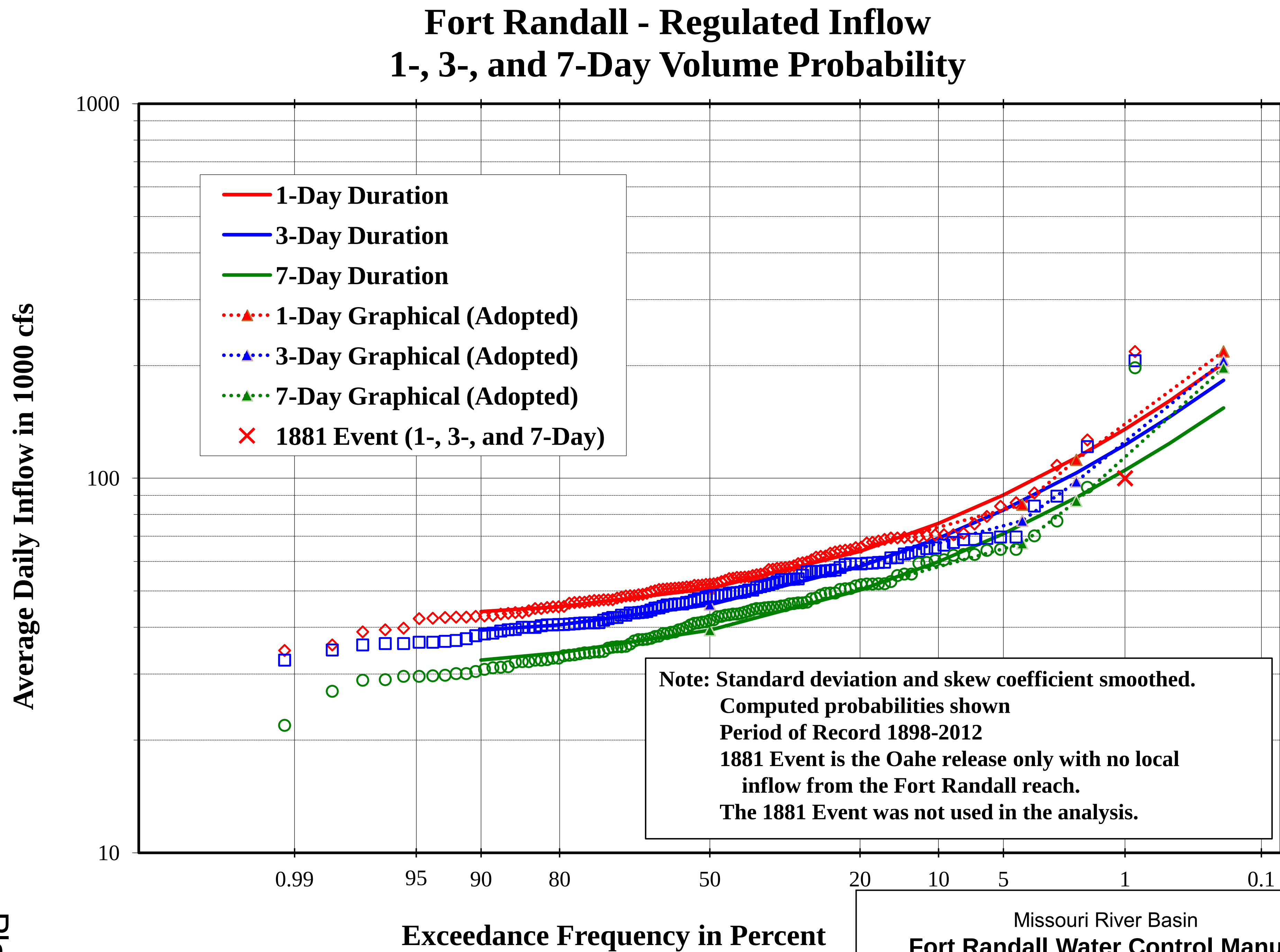
Reservoir Elevation Corrections at Fort Randall
to Allow for Wind Effects
Reservoir Elevation at 1320 feet msl
(True Elevation = Reported Pool Elevation* + Correction)

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

Reservoir Elevation Wind Corrections in Feet

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

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



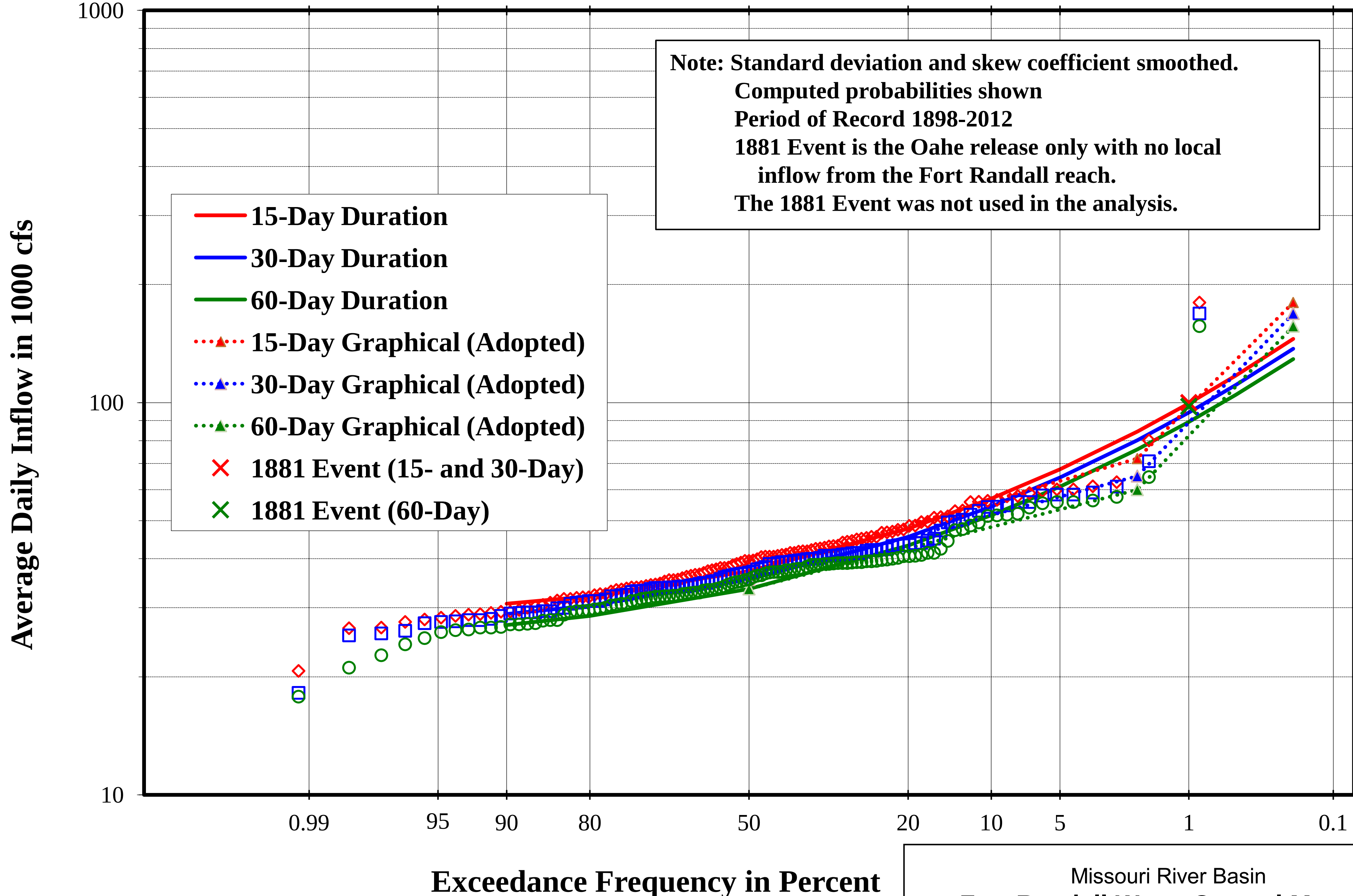
Missouri River Basin

Fort Randall Water Control Manual

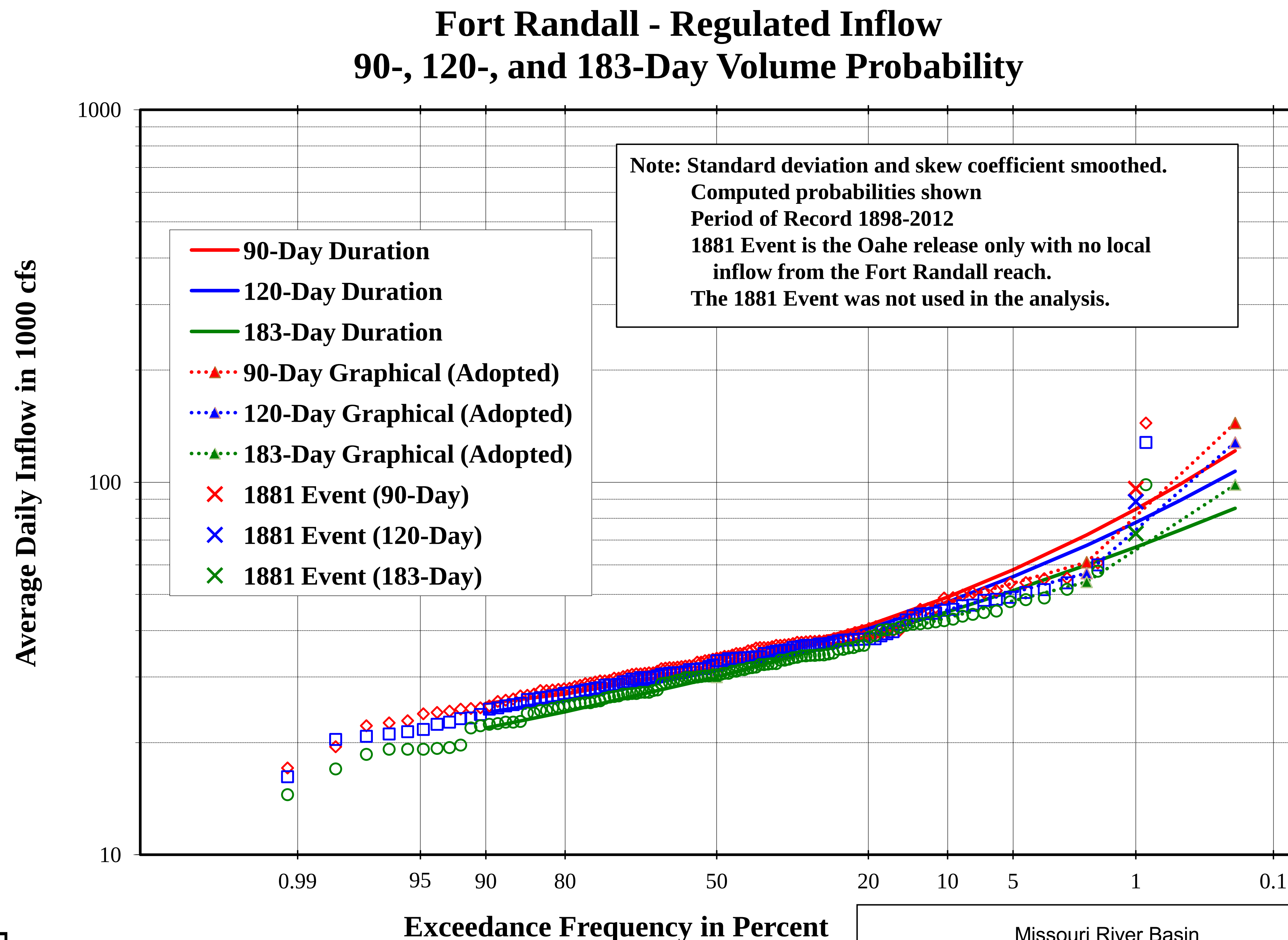
Fort Randall Regulated Inflow Probability

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

Fort Randall - Regulated Inflow
15-, 30-, and 60-Day Volume Probability

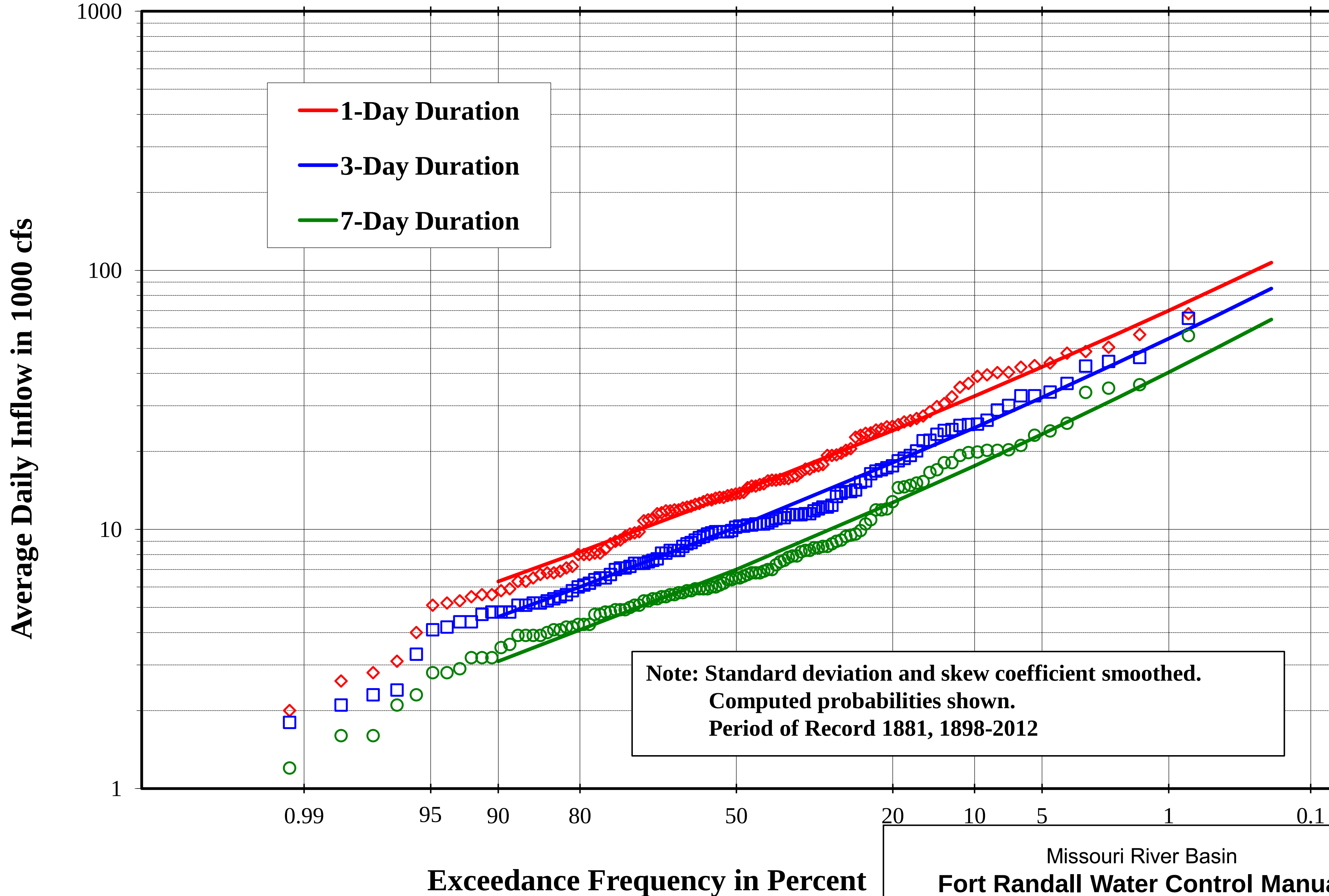


Missouri River Basin
Fort Randall Water Control Manual
Fort Randall Regulated Inflow Probability
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Fort Randall Regulated Inflow Probability
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Fort Randall - Incremental Inflow
1-, 3-, and 7-Day Volume Probability



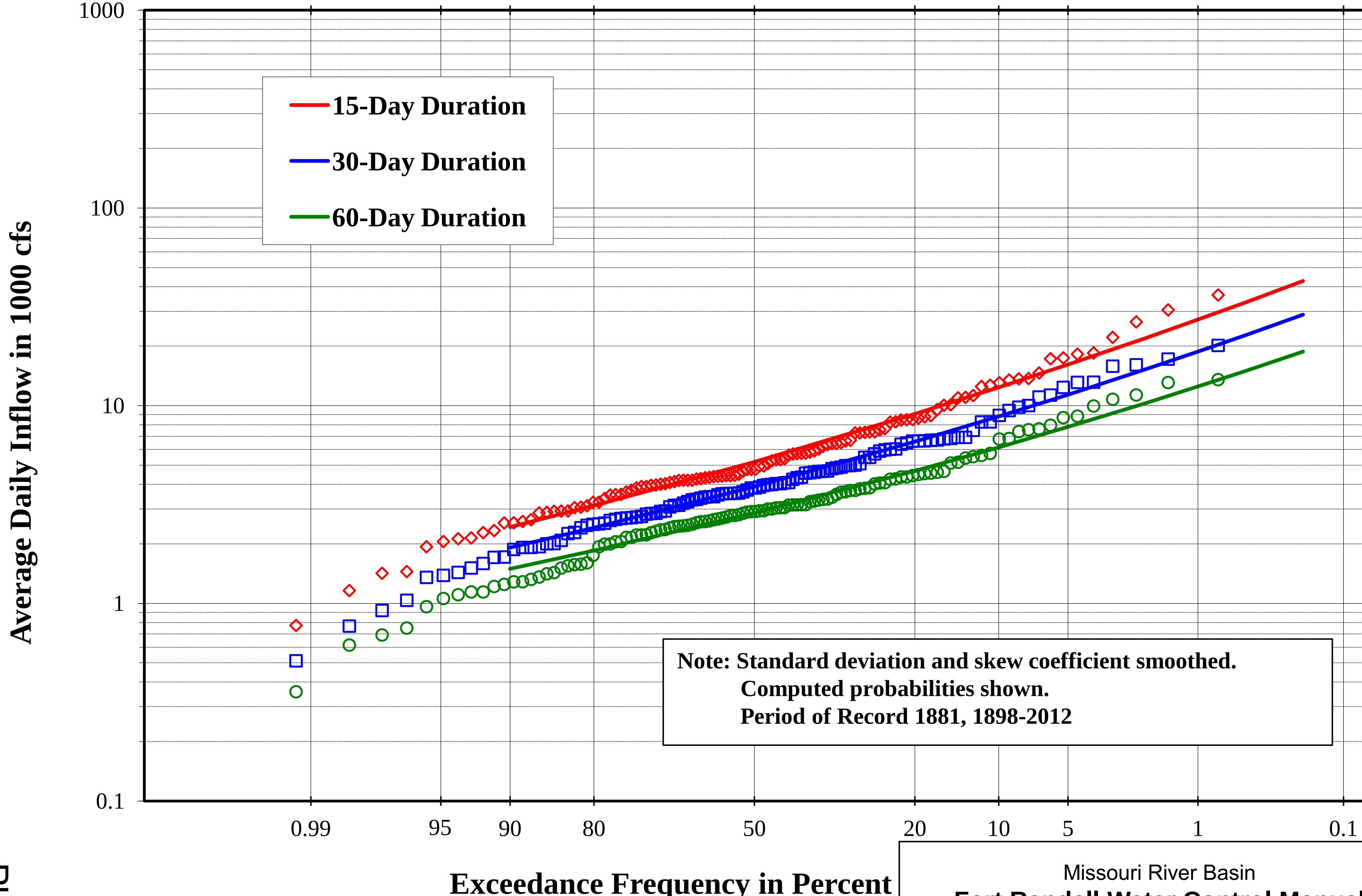
Missouri River Basin

Fort Randall Water Control Manual

Fort Randall Incremental Inflow Probability

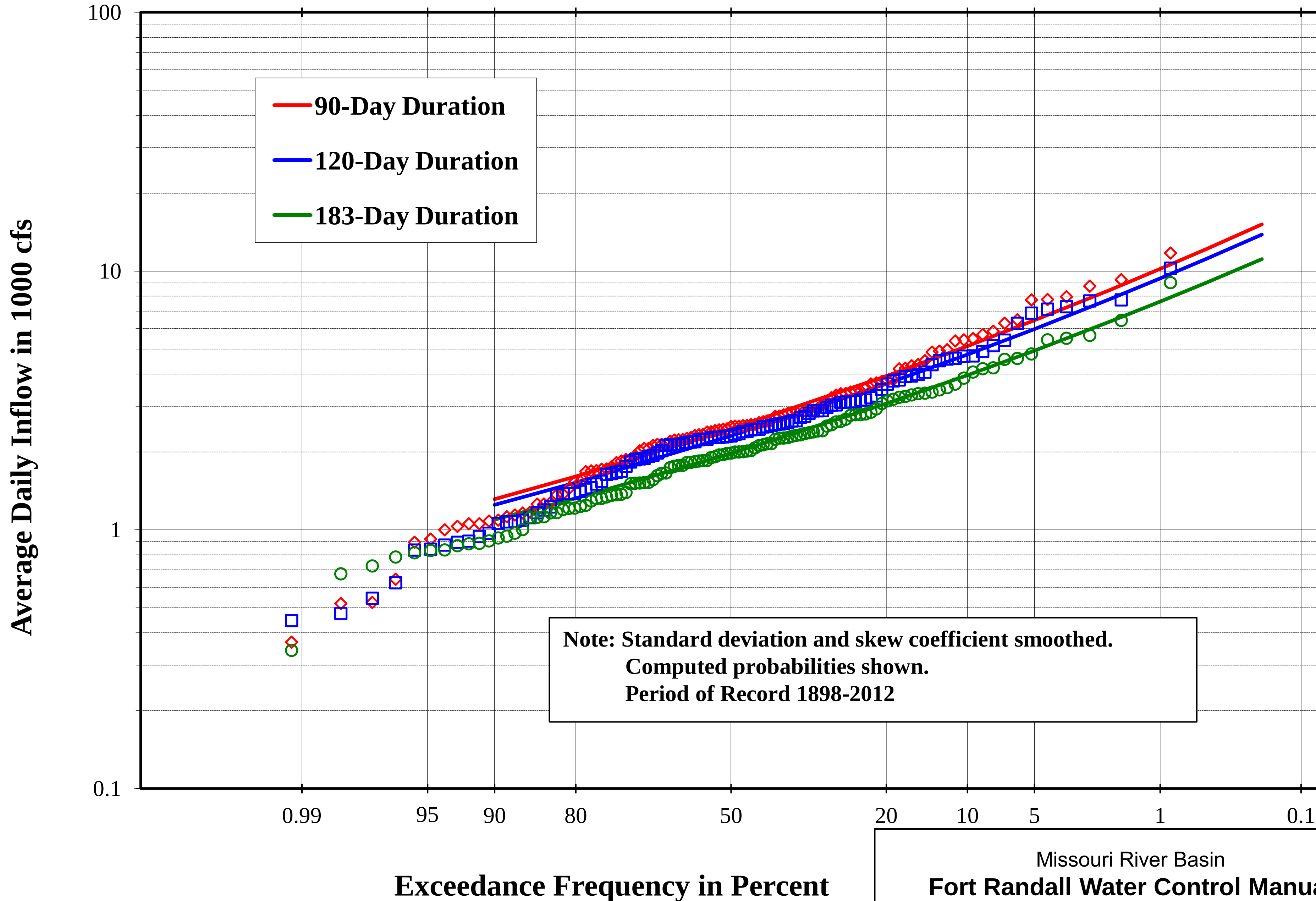
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Fort Randall - Incremental Inflow
15-, 30-, and 60-Day Volume Probability



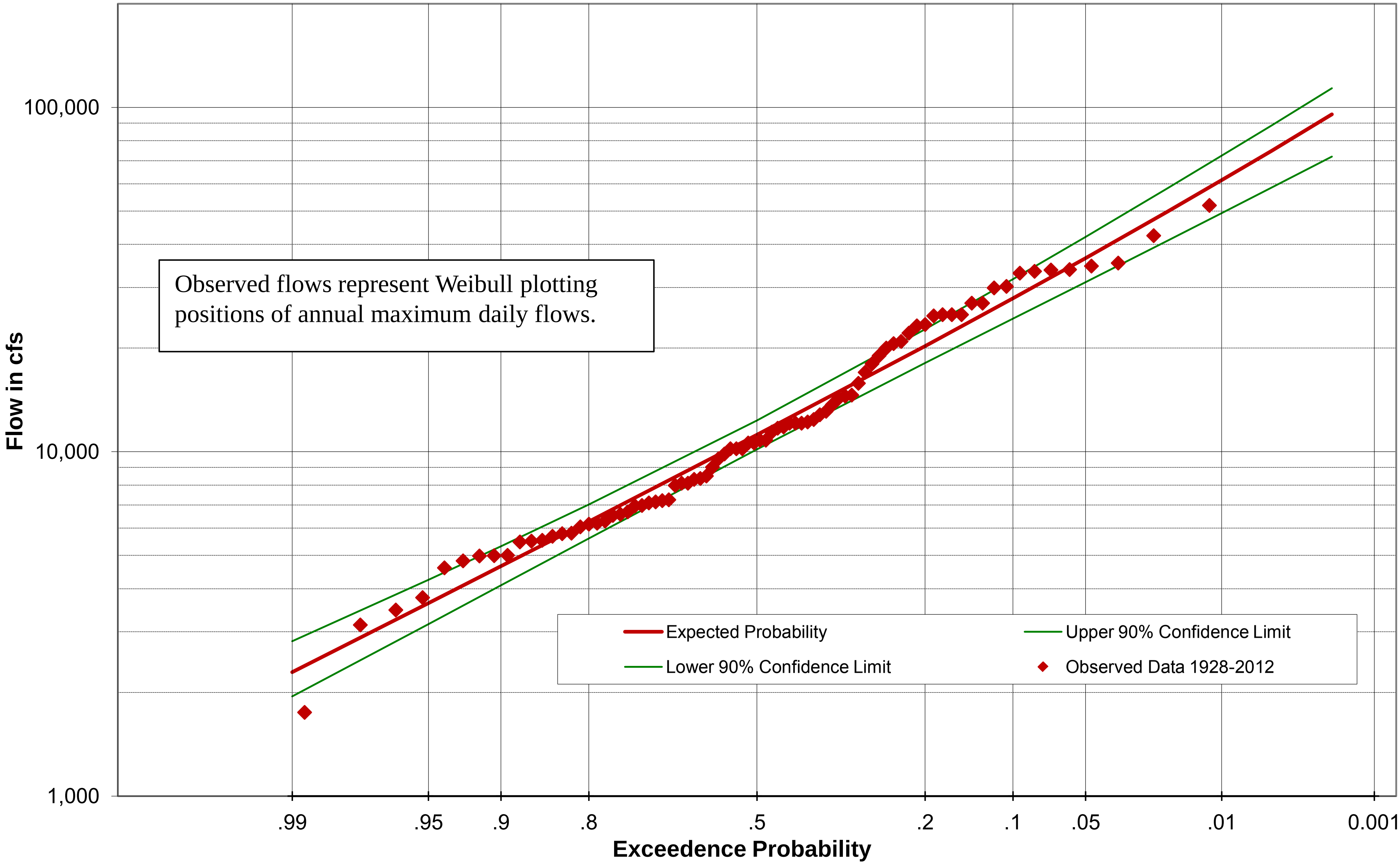
Missouri River Basin
Fort Randall Water Control Manual
Fort Randall Incremental Inflow Probability
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Fort Randall - Incremental Inflow
90-, 120-, and 183-Day Volume Probability

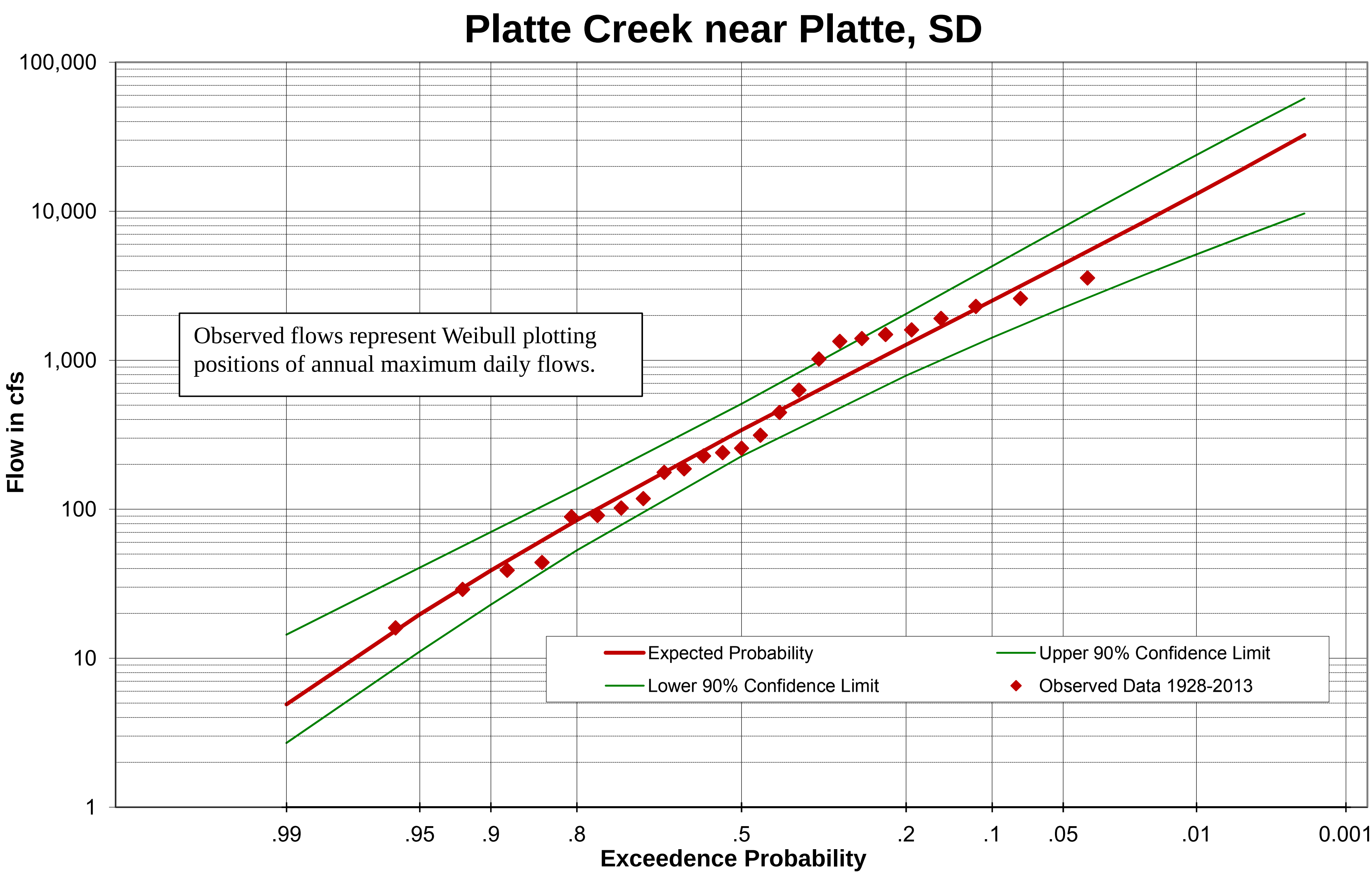


Missouri River Basin
Fort Randall Water Control Manual
Fort Randall Incremental Inflow Probability
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

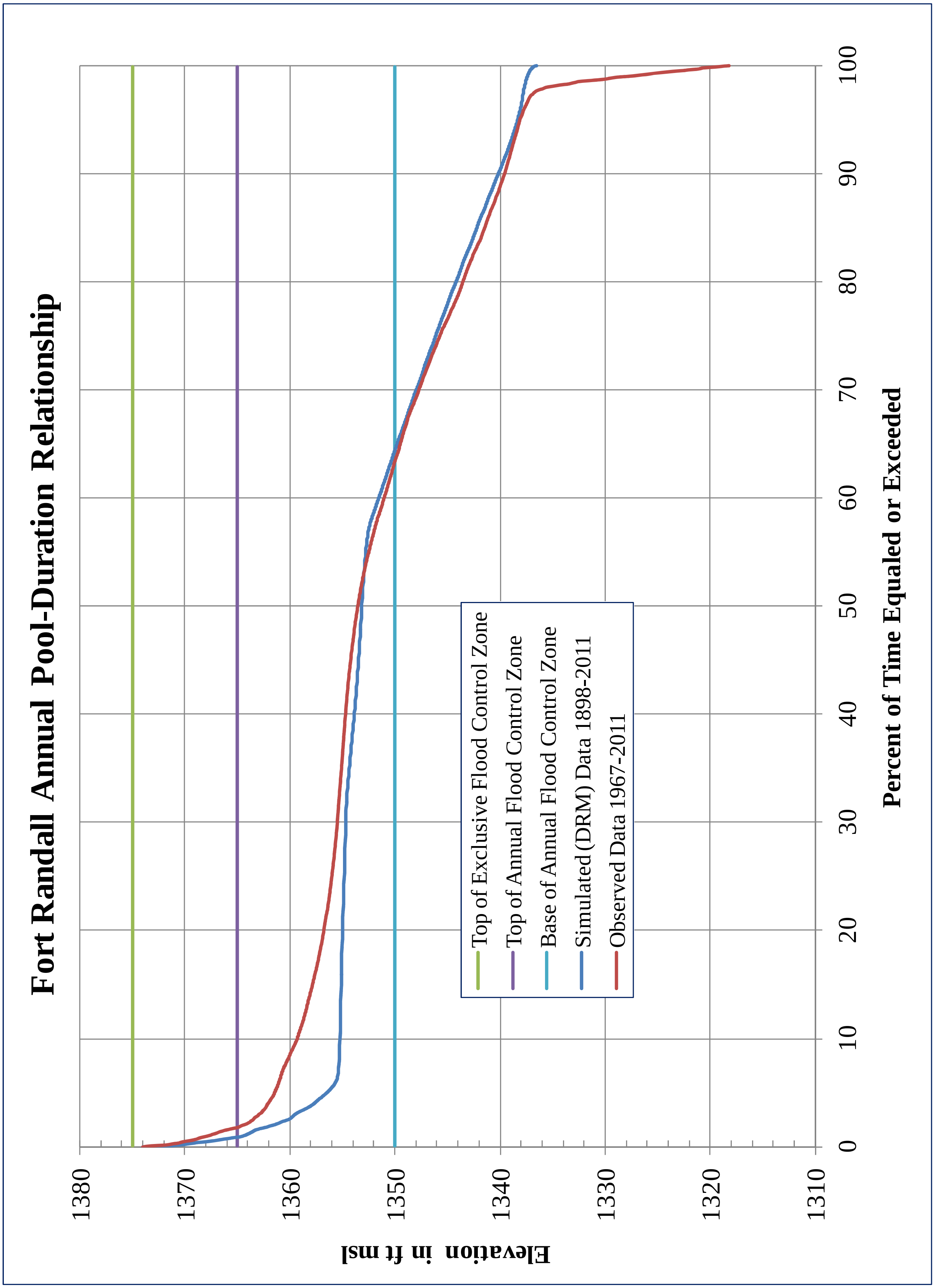
White River near Oacoma, SD



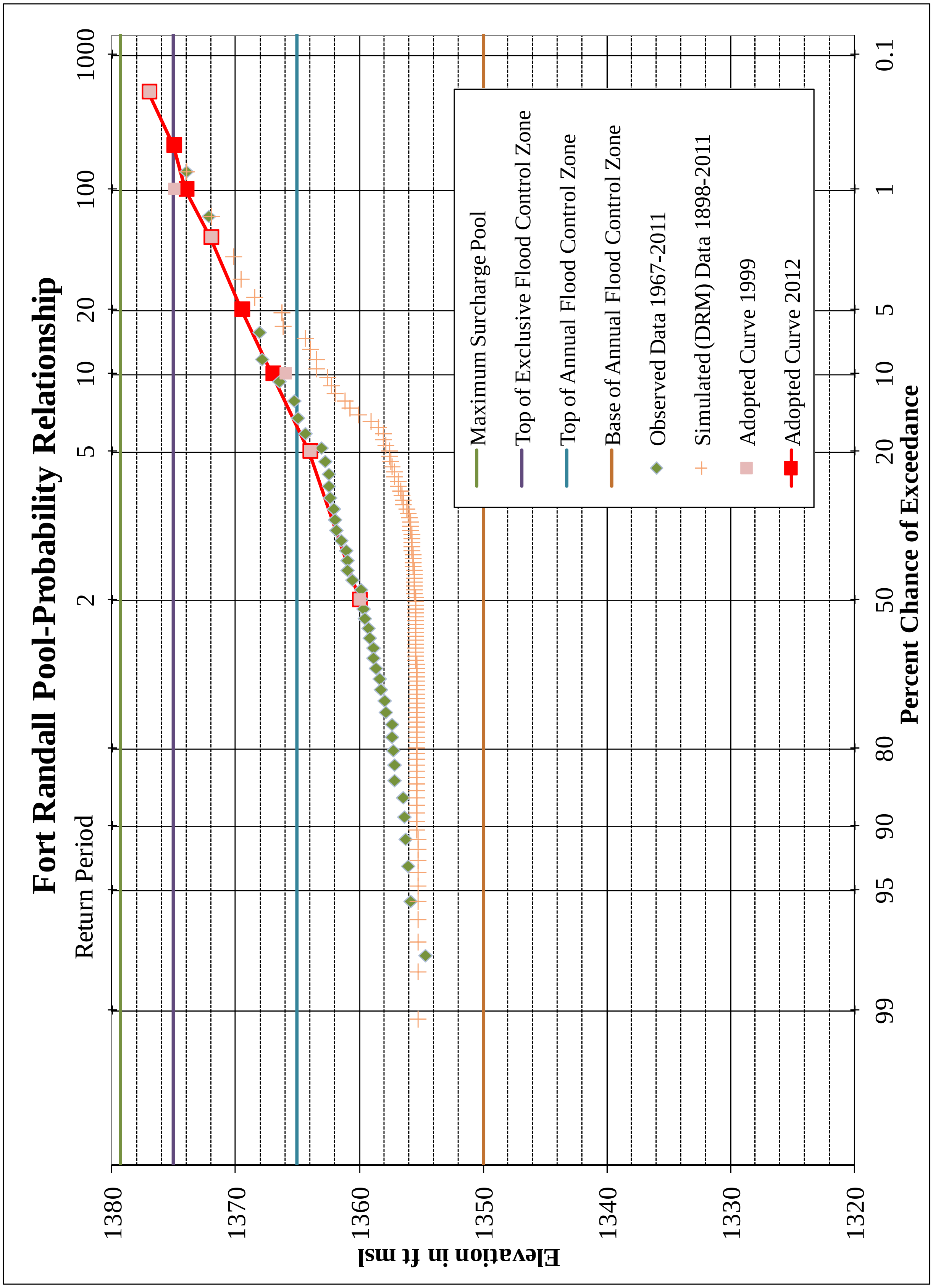
Missouri River Basin
Fort Randall Water Control Manual
Probability Curve – White River at Oacoma
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Probability Curve – Platte Creek at Platte
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



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

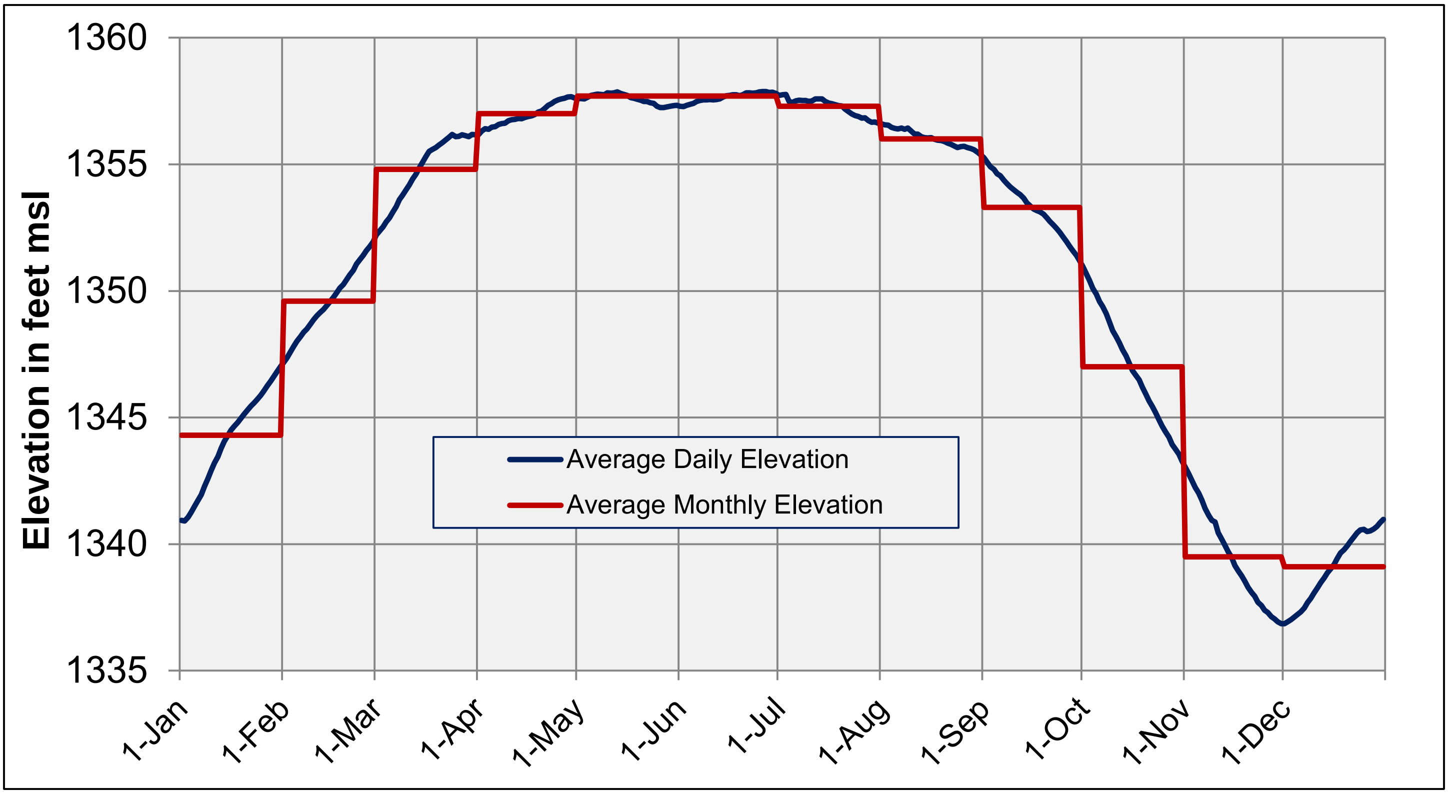


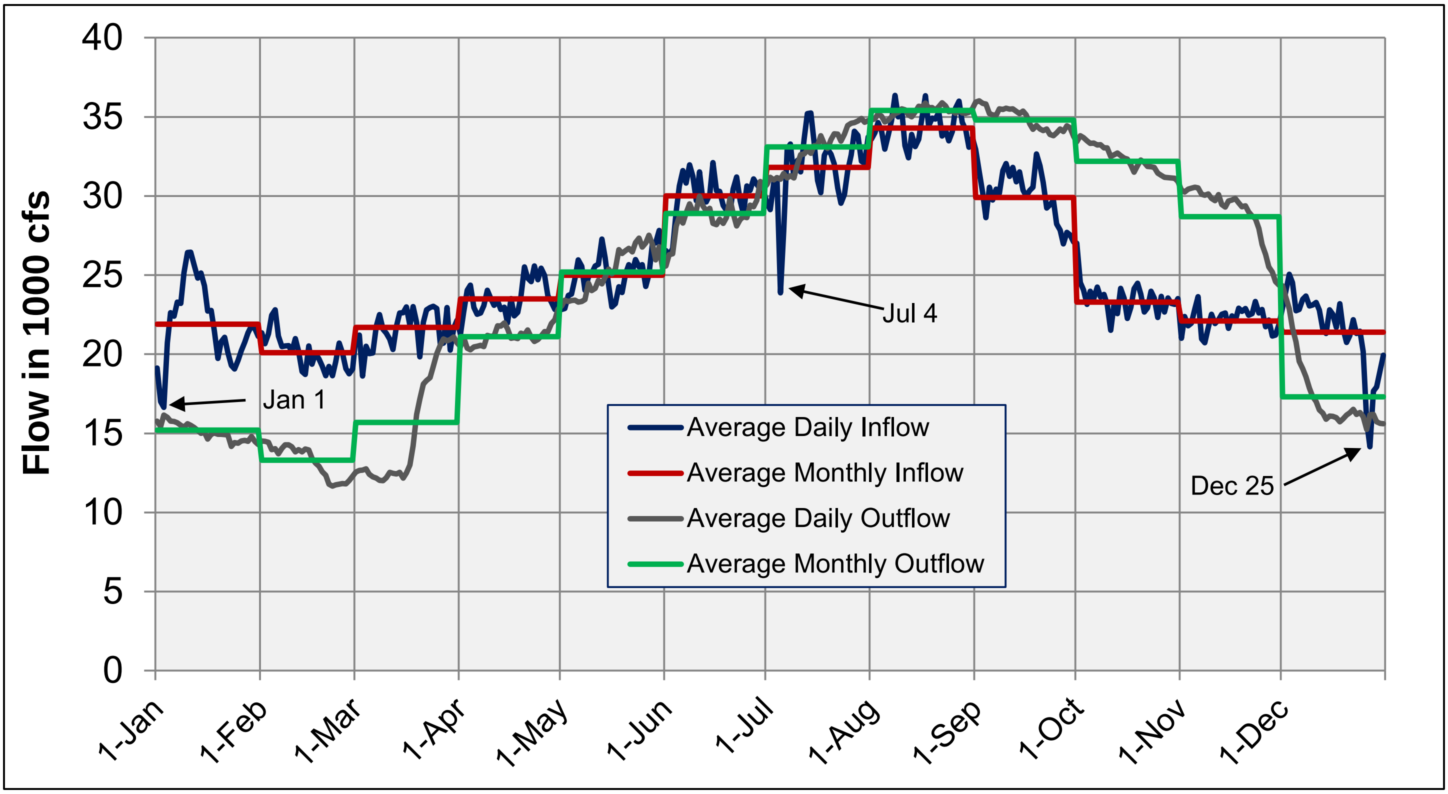
Missouri River Basin

Fort Randall Water Control Manual

Fort Randall Pool-Probability Relationship

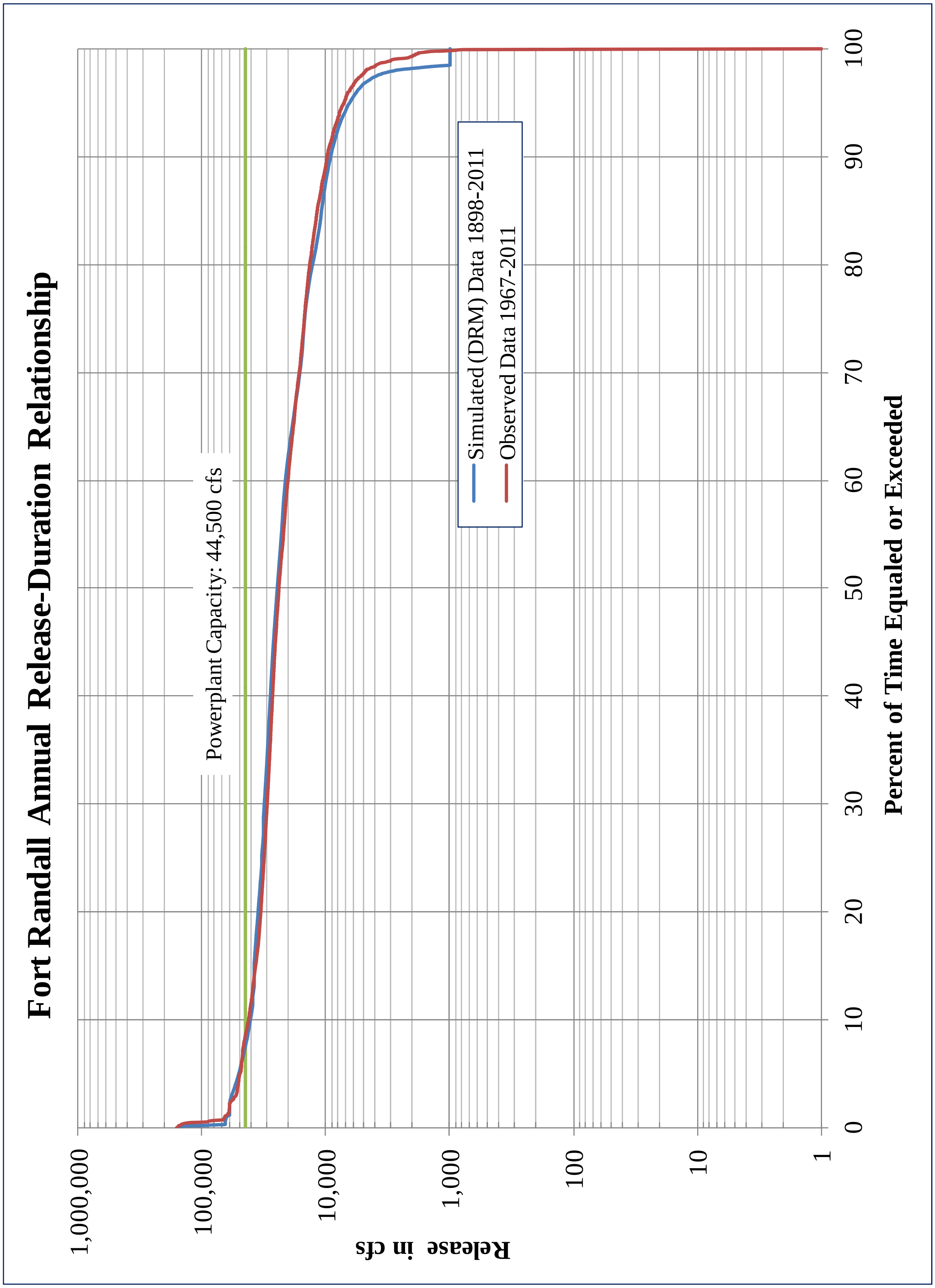
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017





Period of Record: 1967 - 2013

Missouri River Basin
Fort Randall Water Control Manual
Average Daily and Monthly Elevations, Inflow and Outflow
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

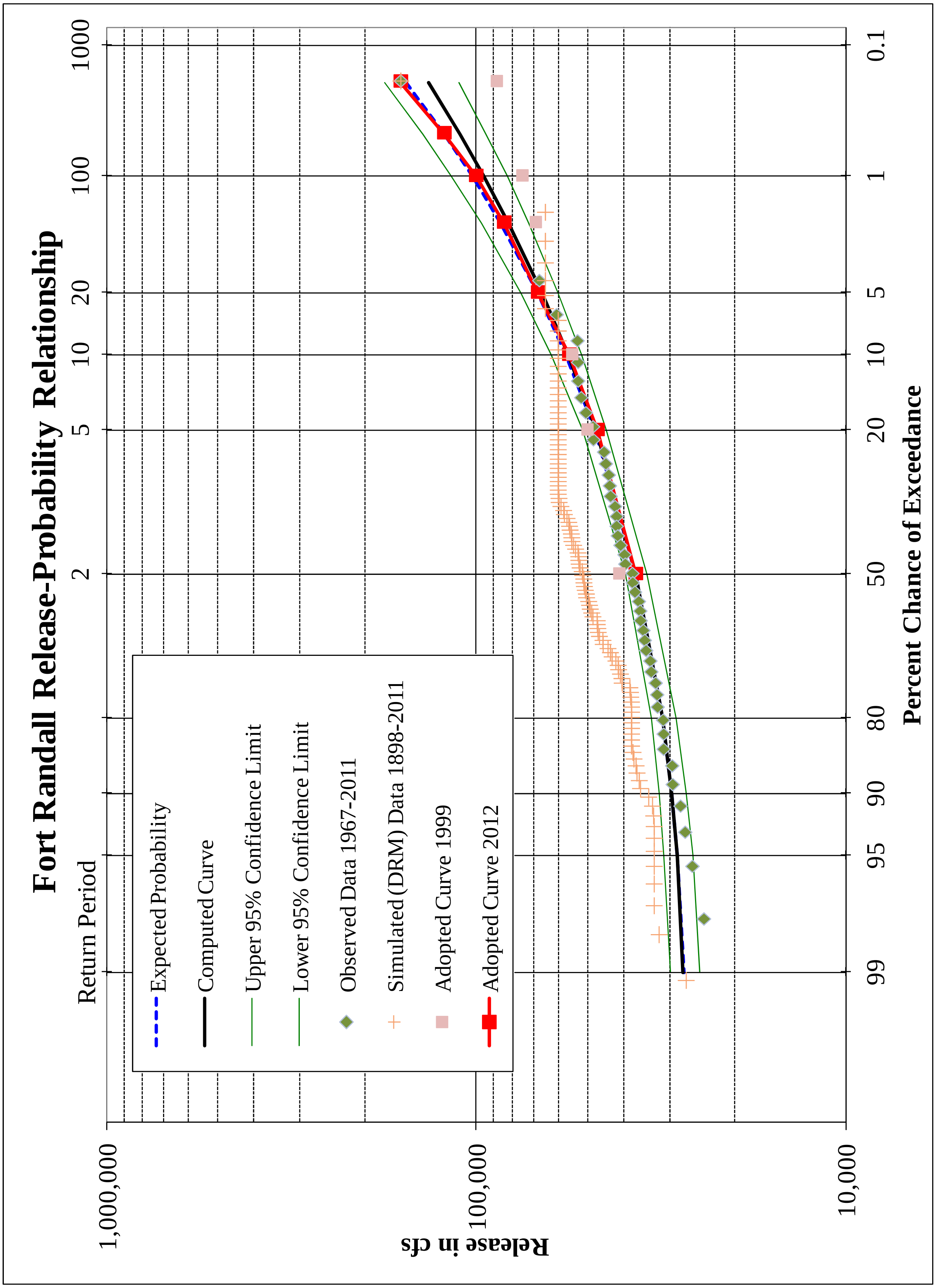


Missouri River Basin

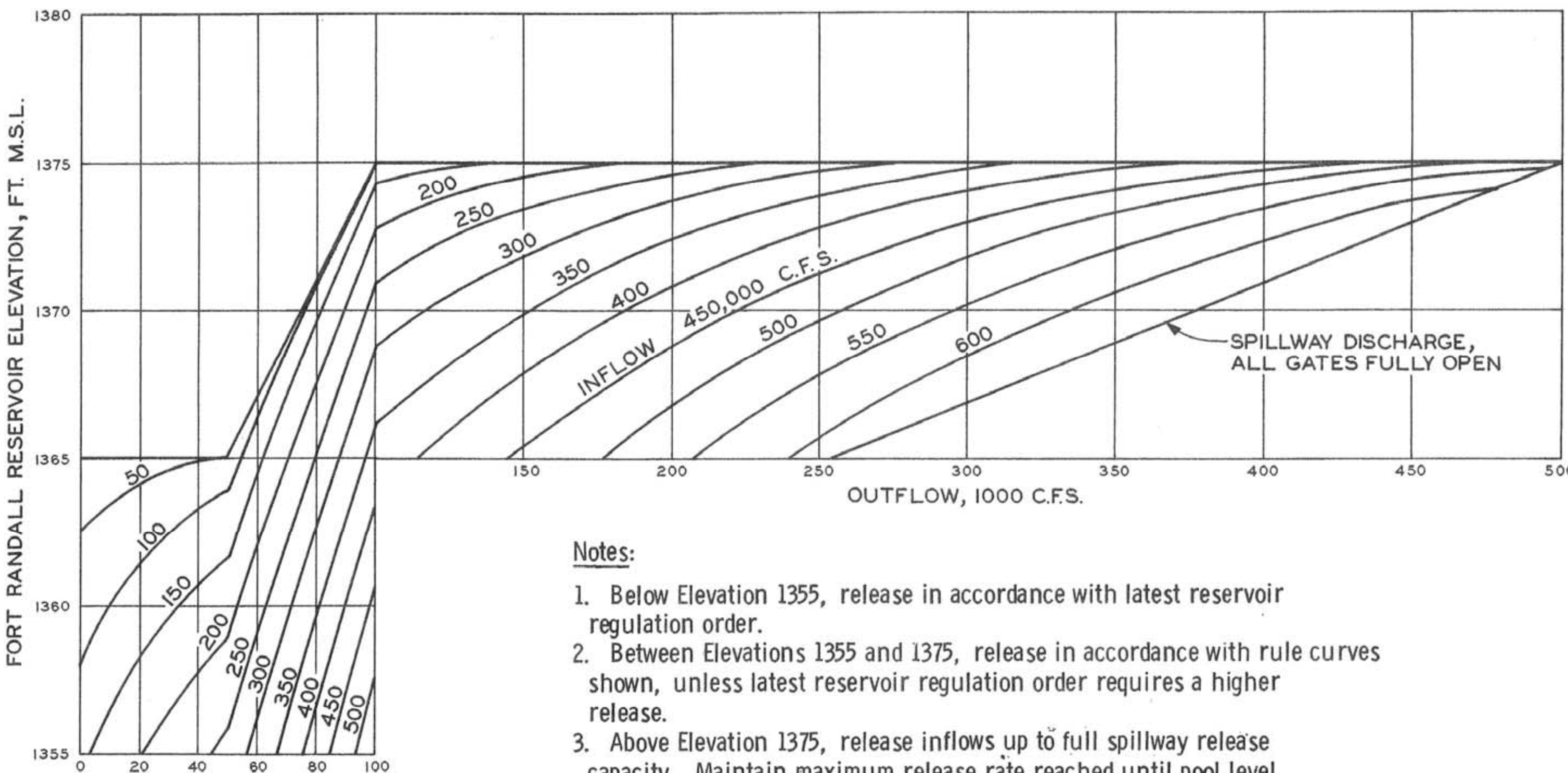
Fort Randall Water Control Manual

Fort Randall Release-Duration Relationship

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



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



Notes:

1. Below Elevation 1355, release in accordance with latest reservoir regulation order.
2. Between Elevations 1355 and 1375, release in accordance with rule curves shown, unless latest reservoir regulation order requires a higher release.
3. Above Elevation 1375, release inflows up to full spillway release capacity. Maintain maximum release rate reached until pool level drops below 1375.

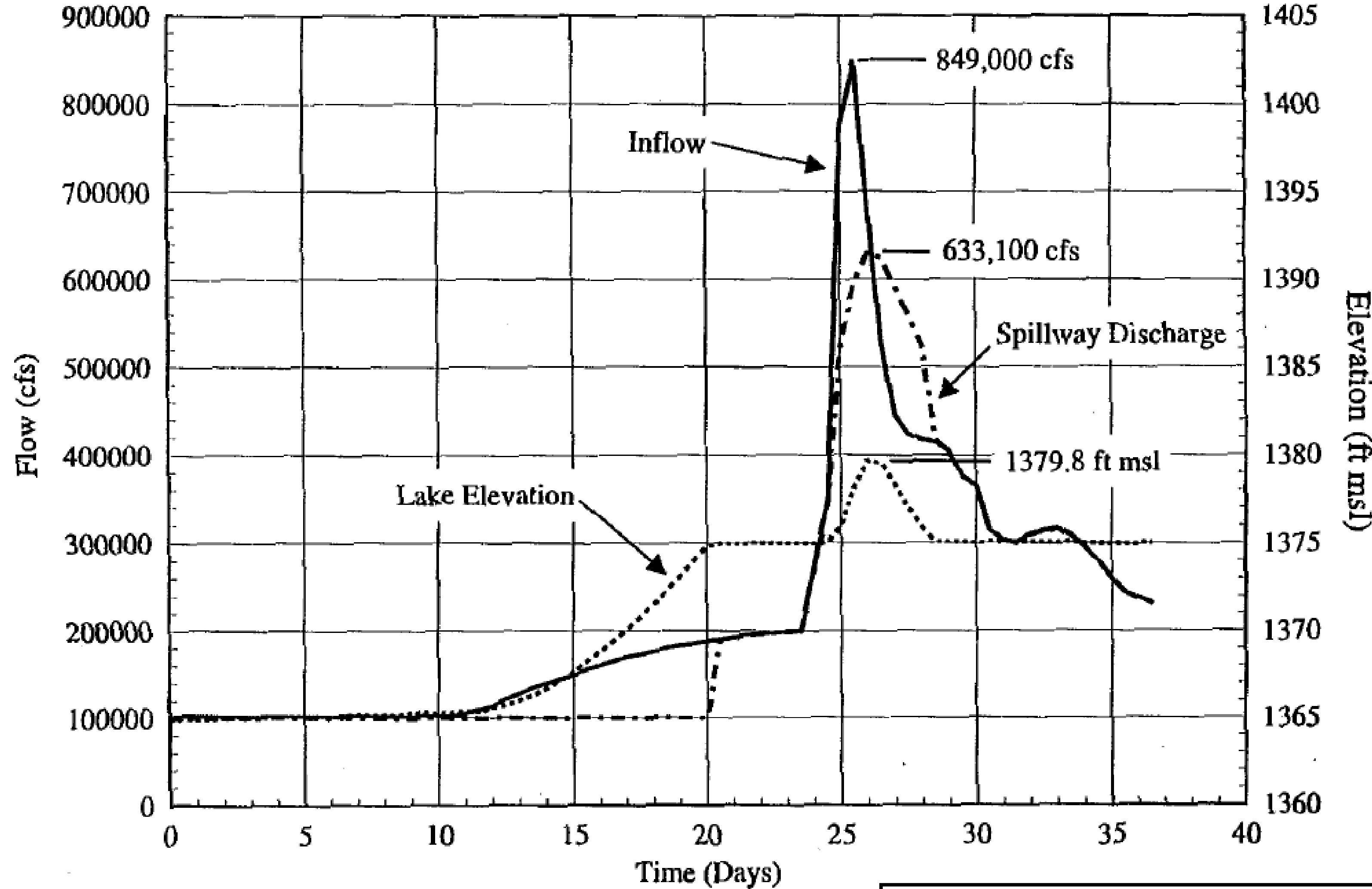
Missouri River Basin

Fort Randall Water Control Manual

Emergency Regulation Curves

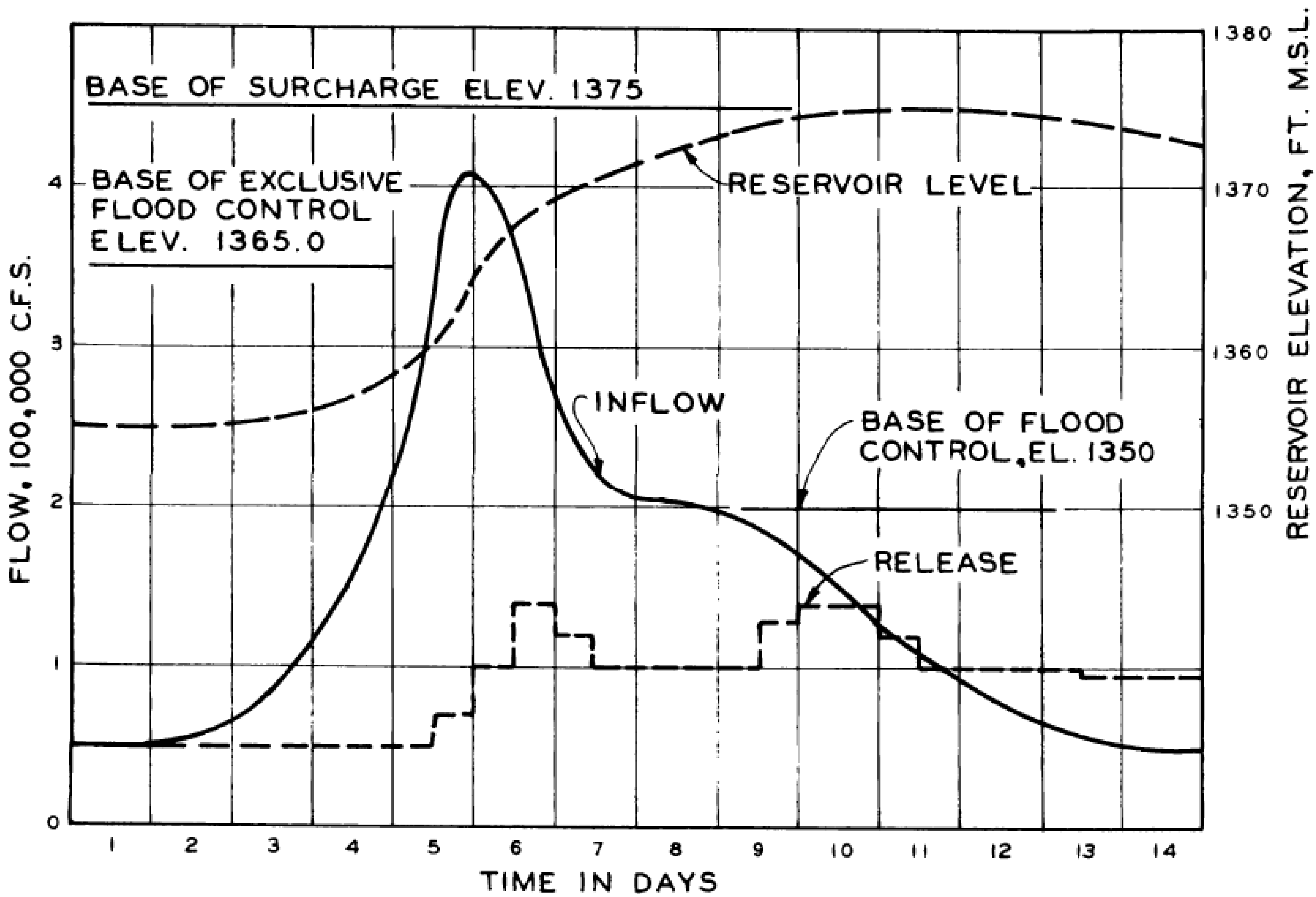
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Fort Randall Reservoir
Spillway Design Flood (SDF) Inflow Hydrograph, Outflow, and Lake Elevation



Note: Elevation-Capacity Relationship Based on 1996 Lake Survey

Missouri River Basin
Fort Randall Water Control Manual
Example of Emergency Regulation - Routing of Spillway Design Flood
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



NOTE: ASSUMES RESERVOIR REGULATION IN EFFECT CALLS FOR RELEASE OF 50,000 C.F.S.

Missouri River Basin

Fort Randall Water Control Manual

Example of Emergency Regulation - One-Half Spillway Design Flood

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
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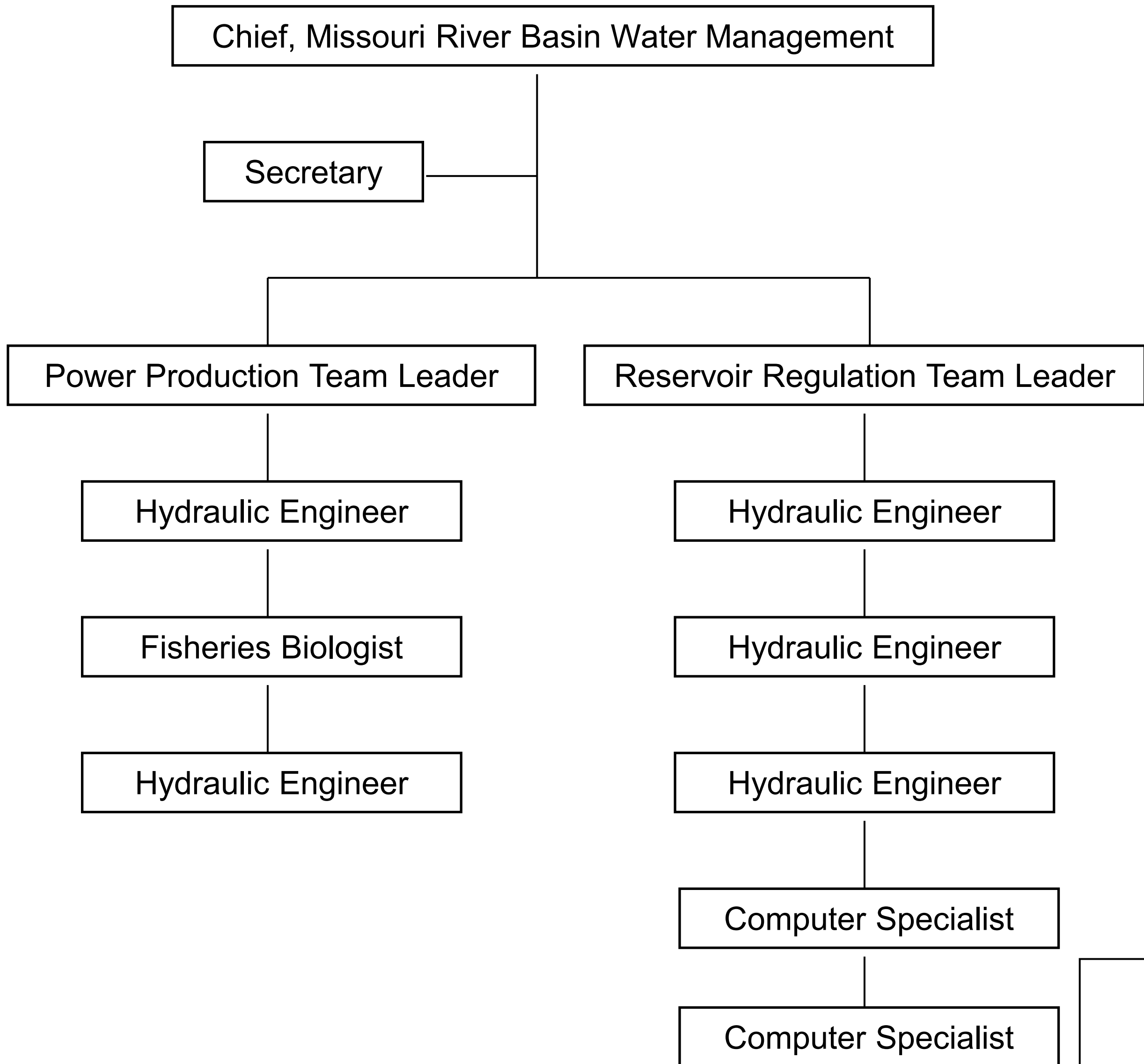
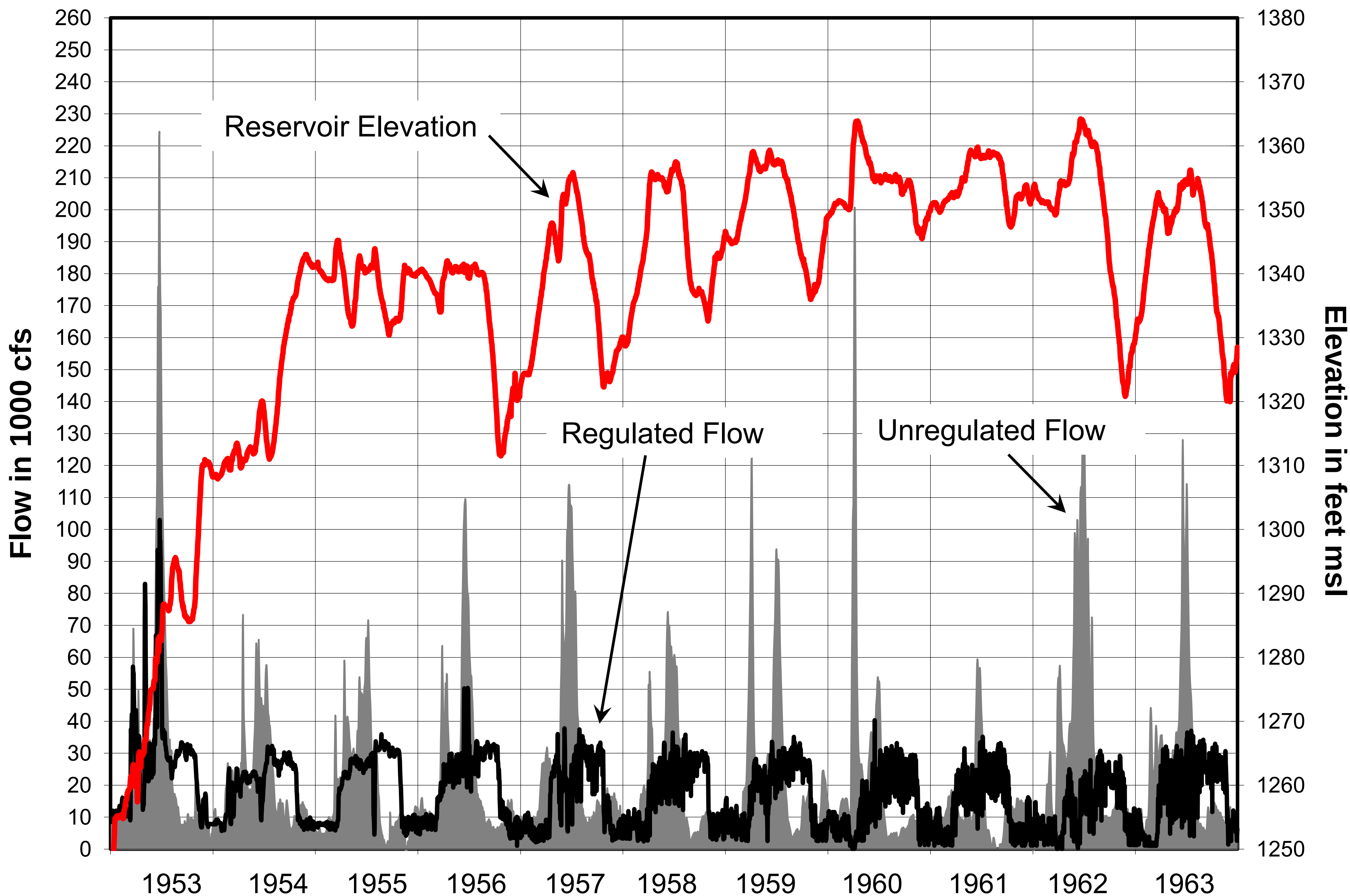
NWD-Omaha

Missouri River Basin Water Management Division



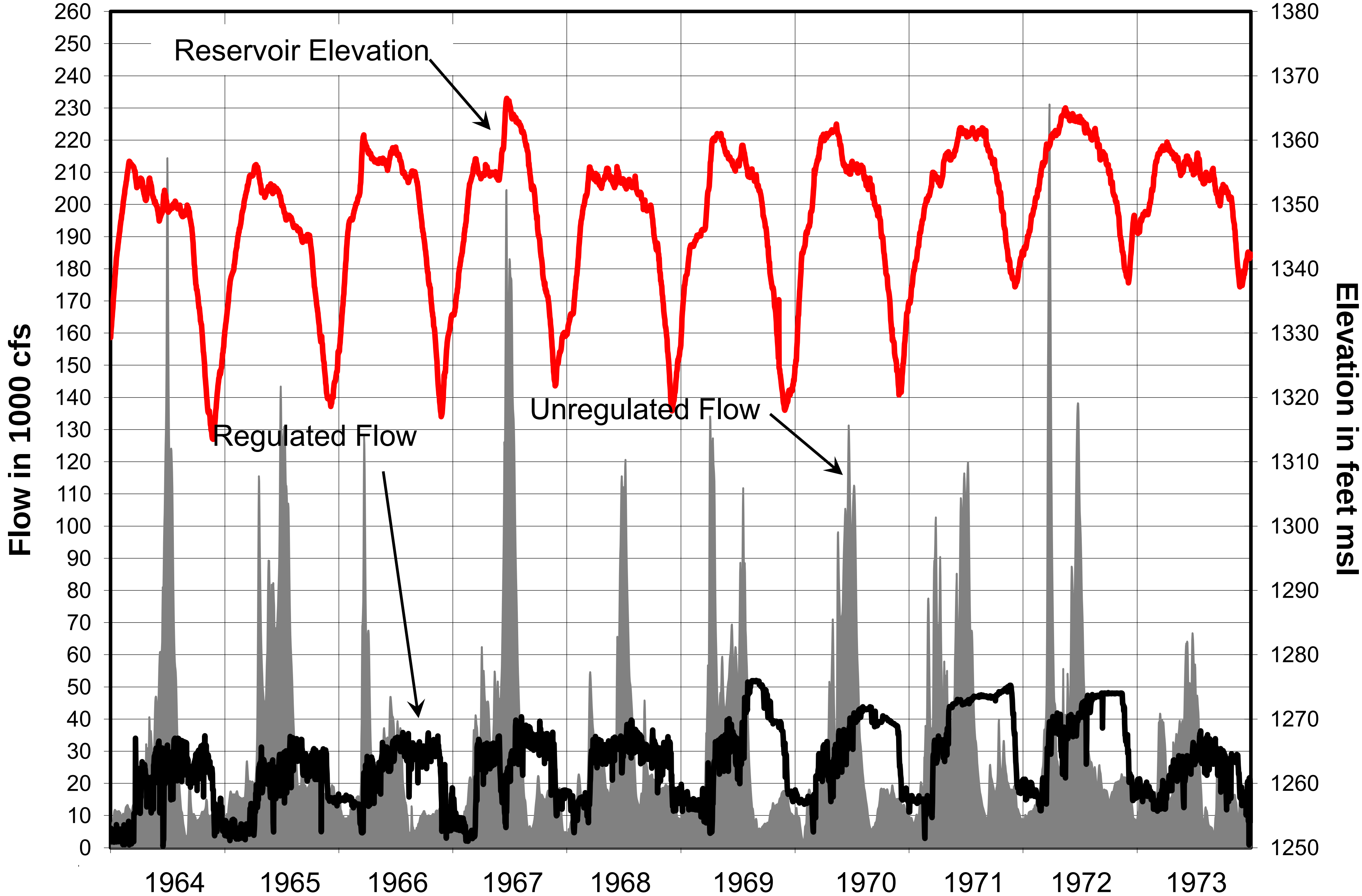
Budget Analyst is shared with Columbia River Basin Water Management

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



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1953 -1963
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Plate A-1



Missouri River Basin

Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1964 -1973

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
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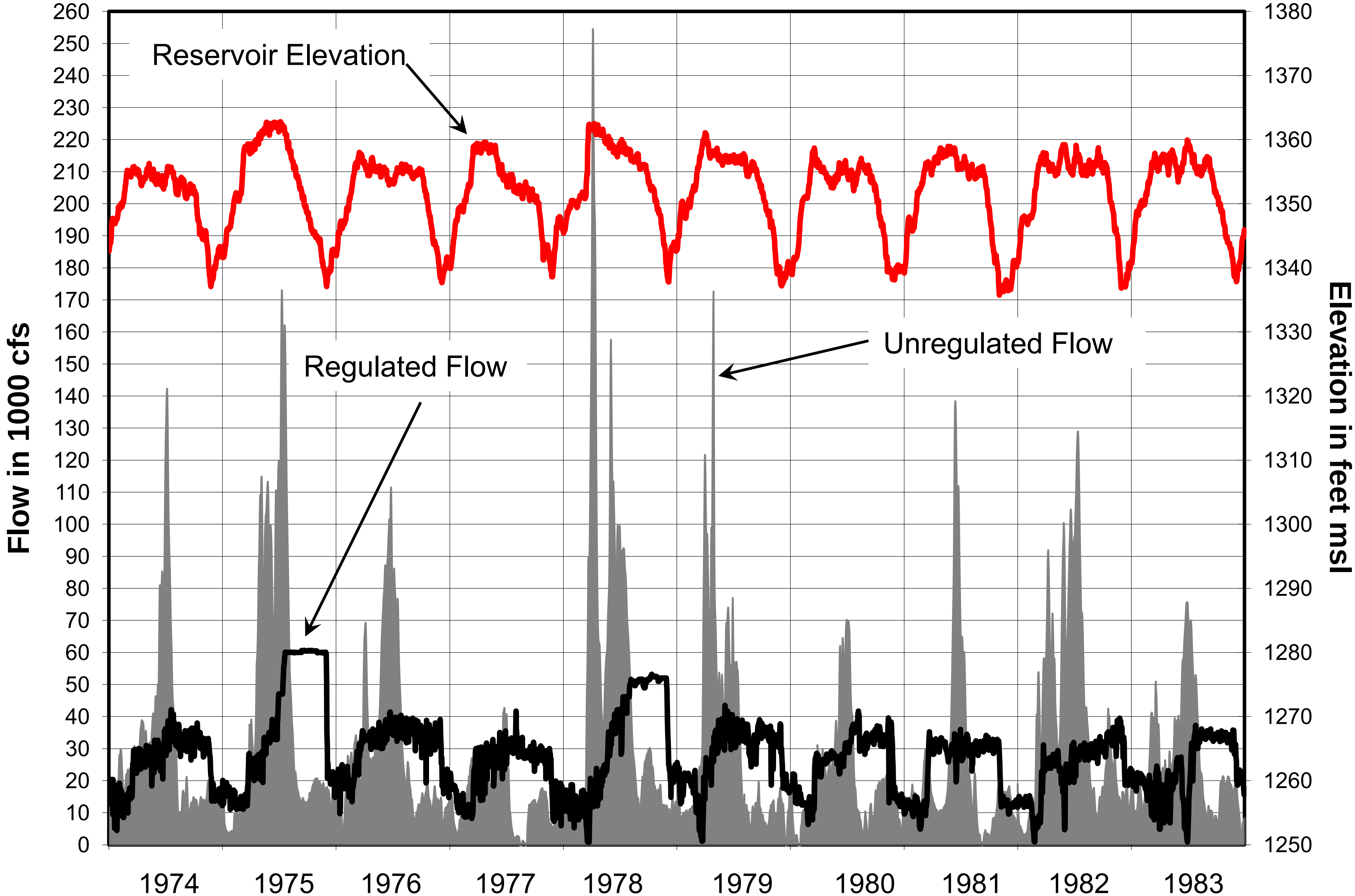
Plate A-2

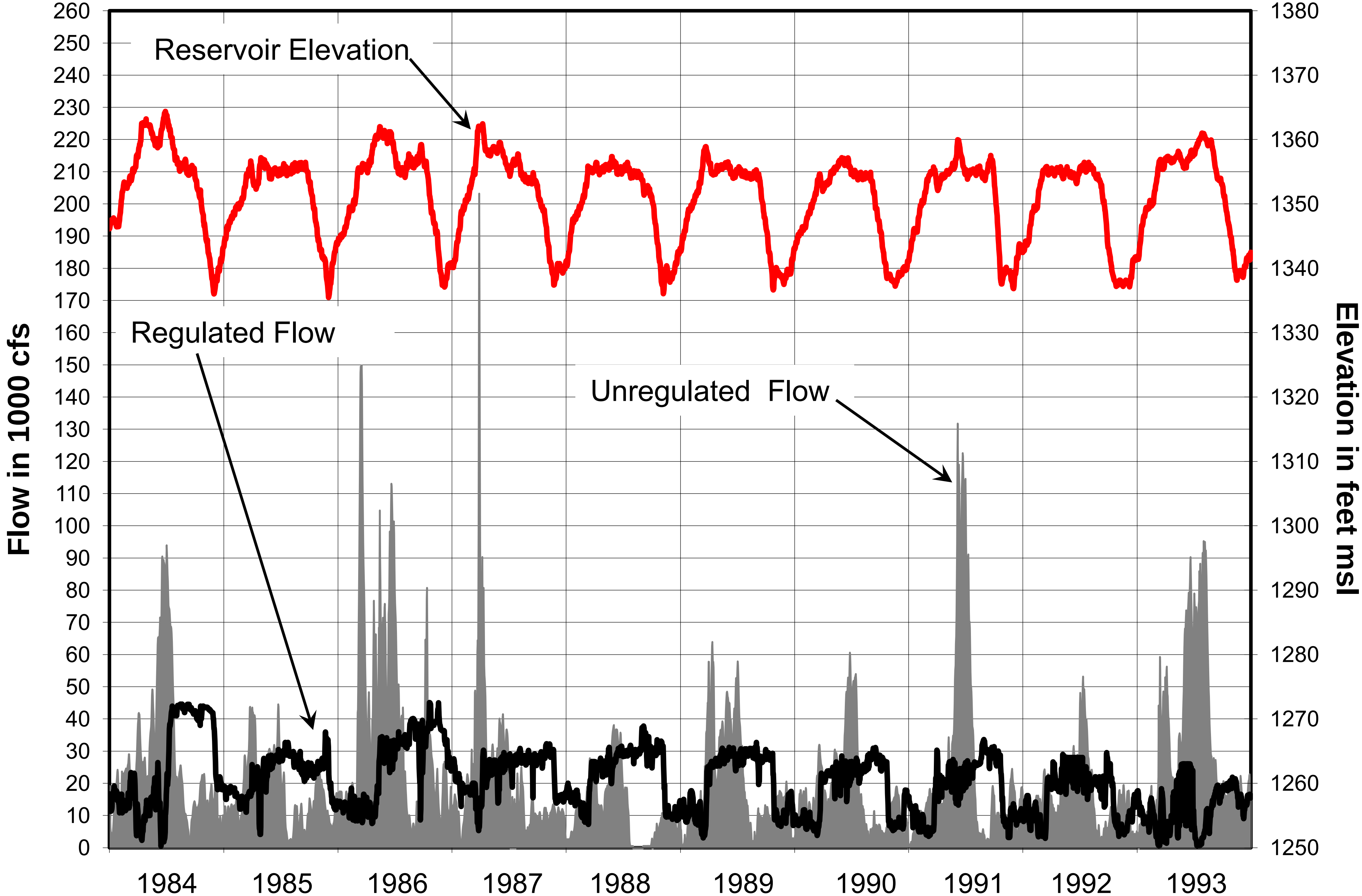


Missouri River Basin

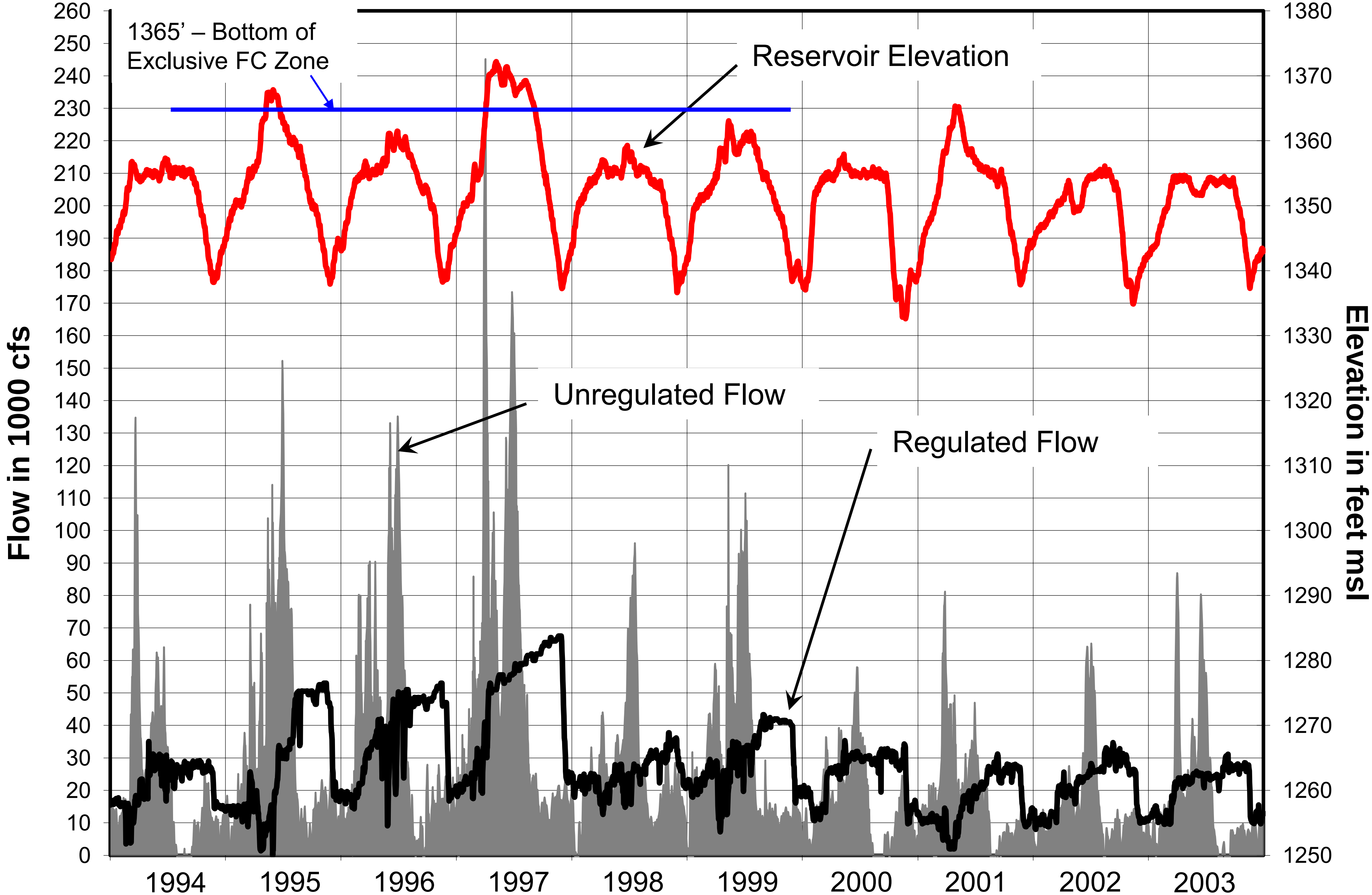
Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1974 -1983

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



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1984 -1993
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



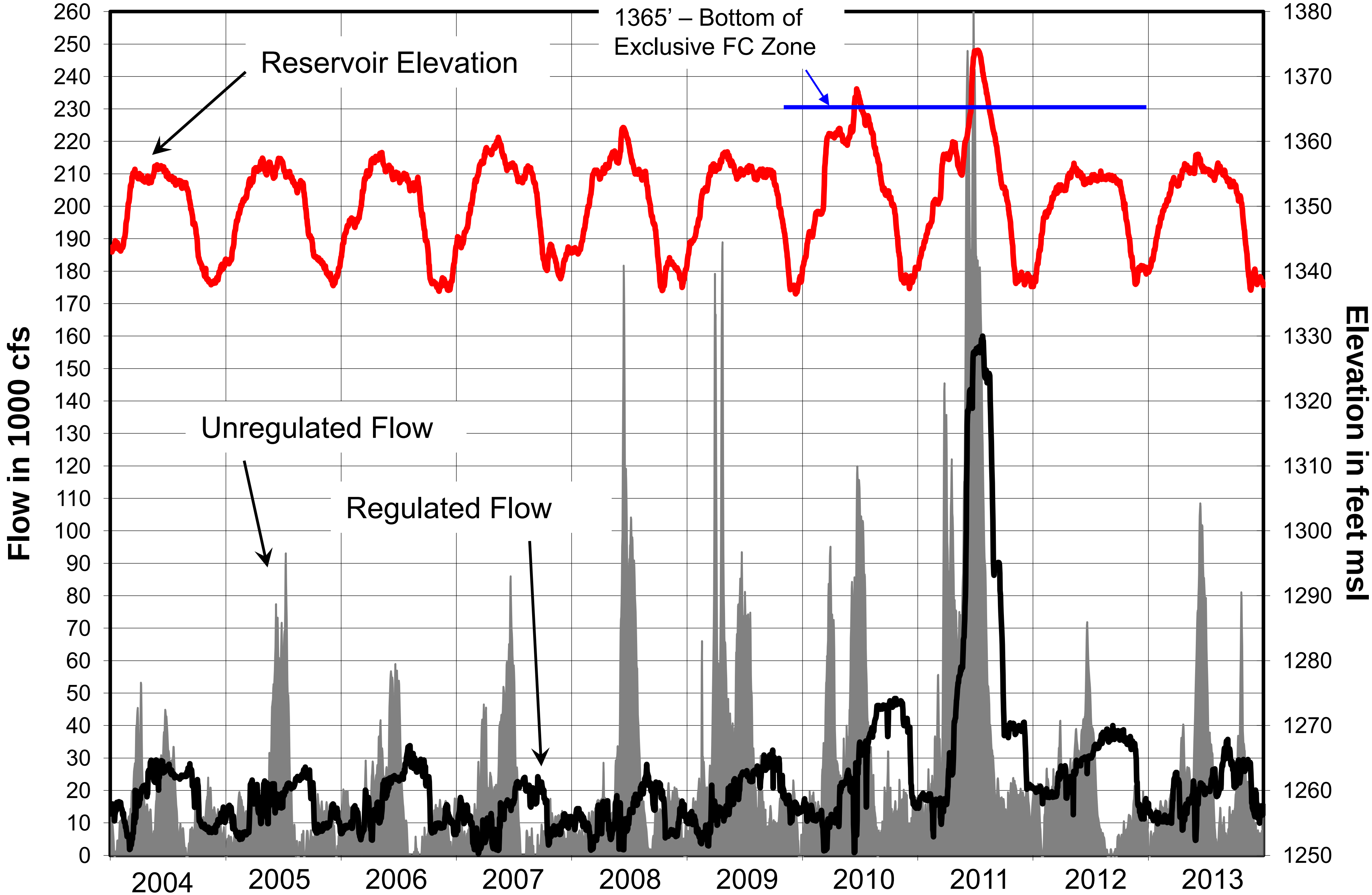
Missouri River Basin

Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1994 -2003

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

Plate A-5



Missouri River Basin

Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 2004-2013

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
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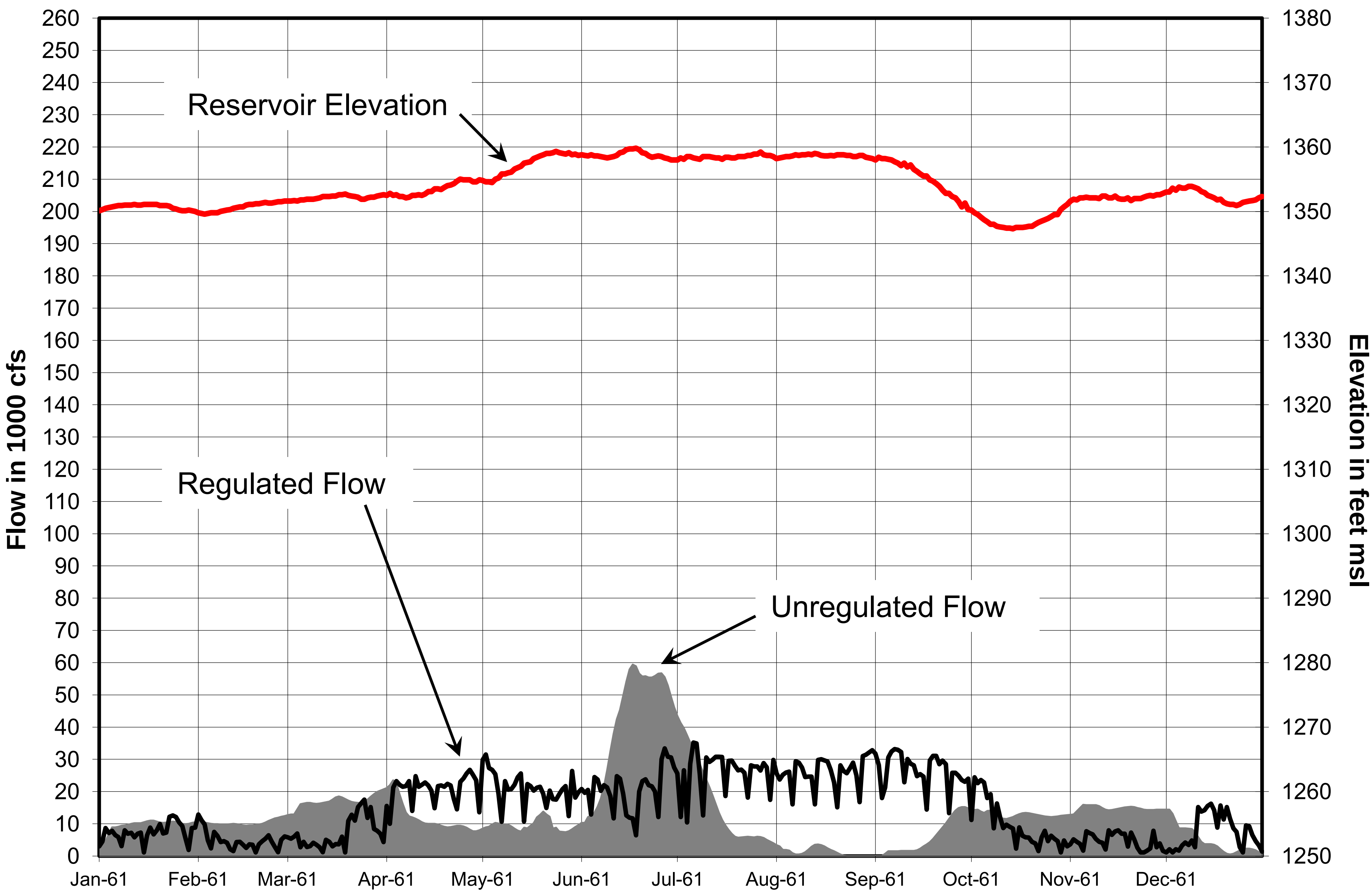
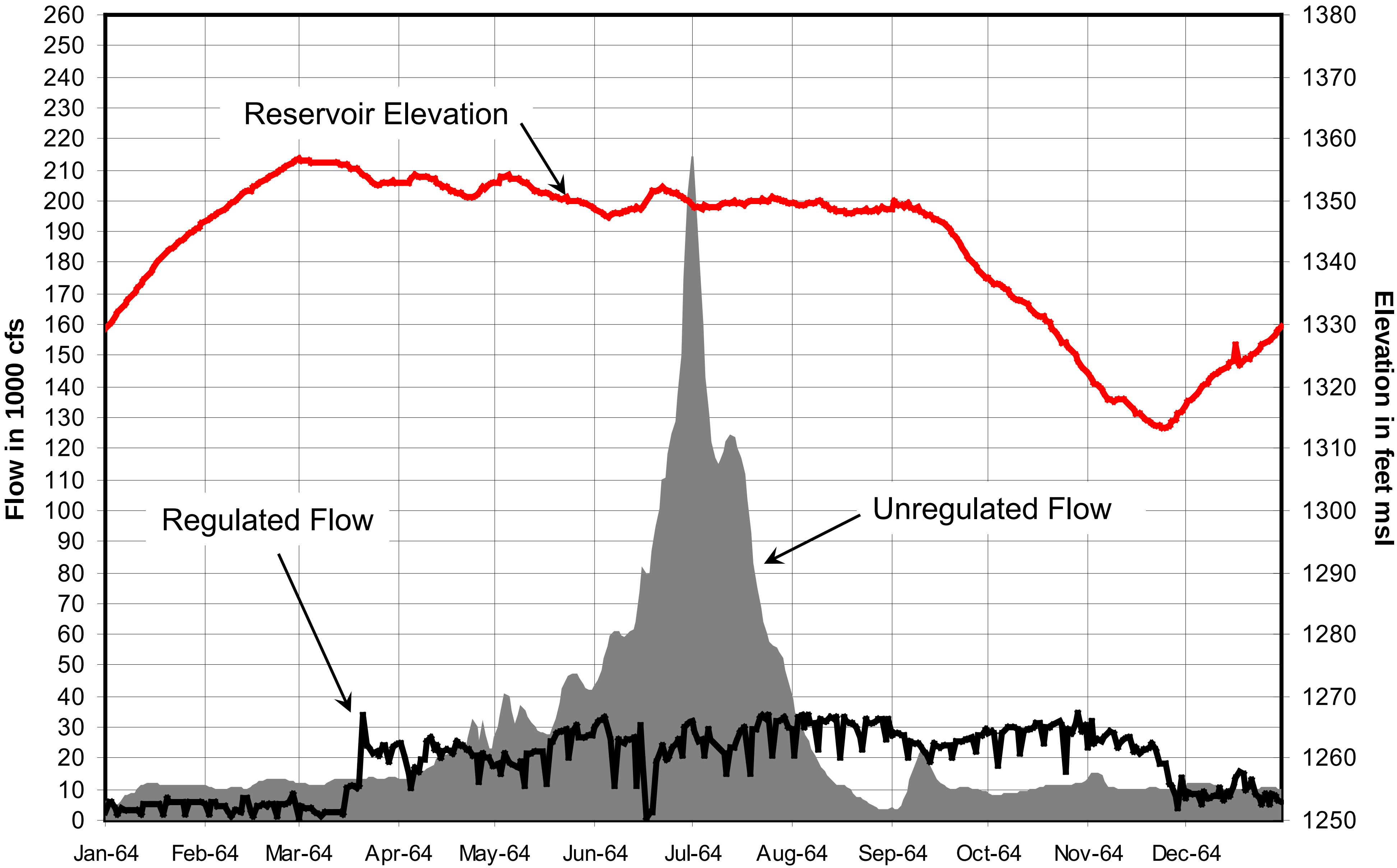
Plate A-6



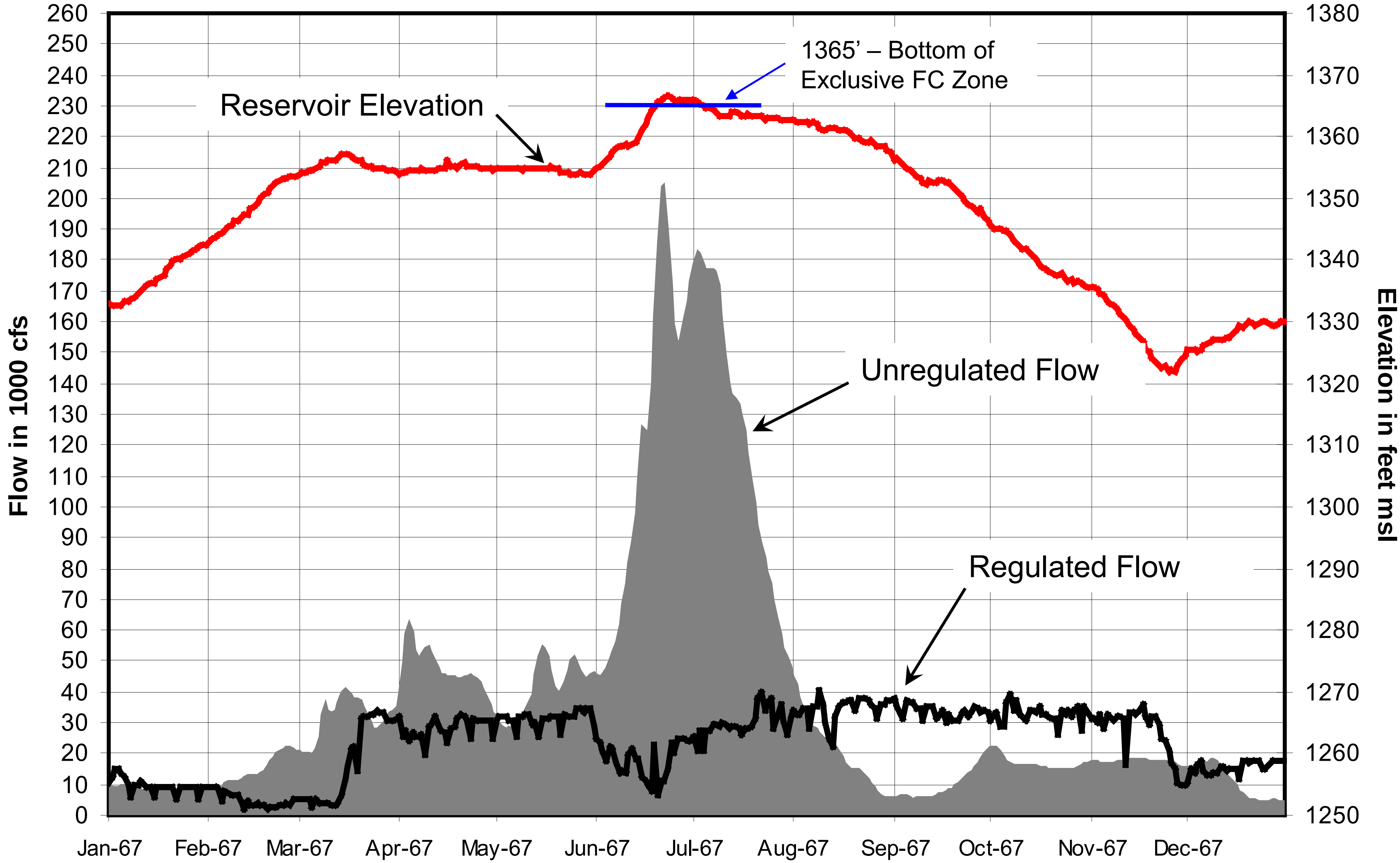
Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1961

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



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1964

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

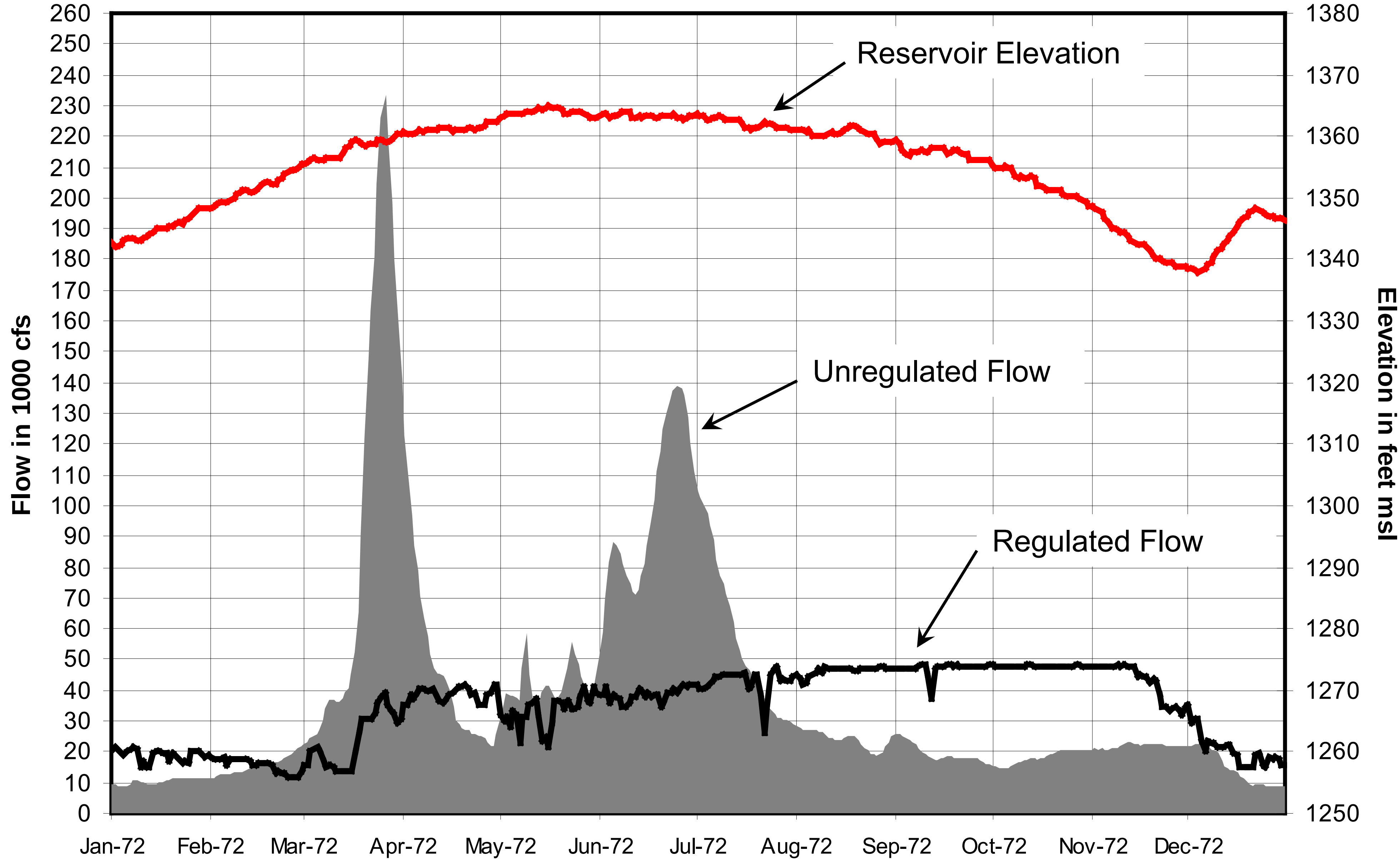


Missouri River Basin

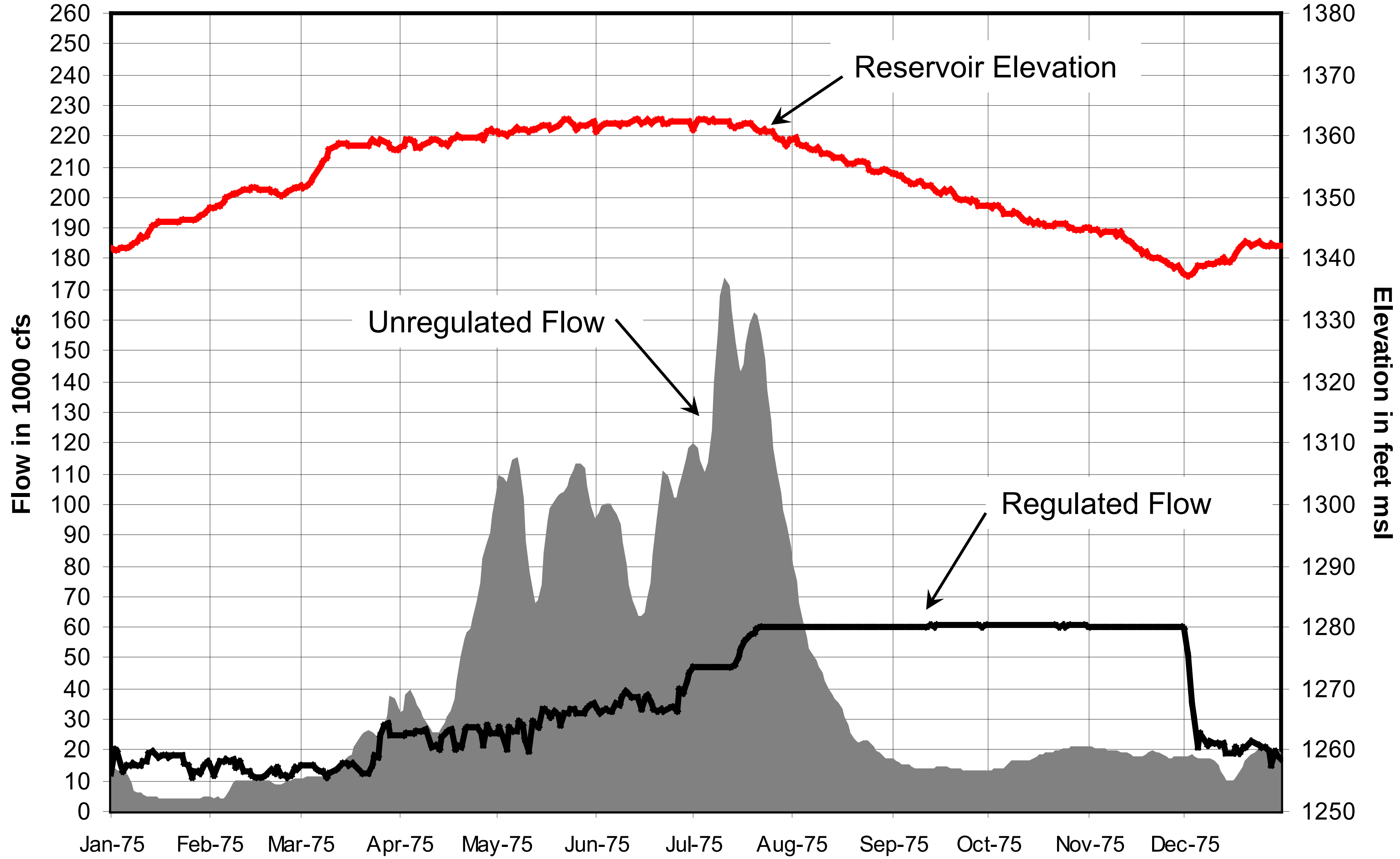
Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1967

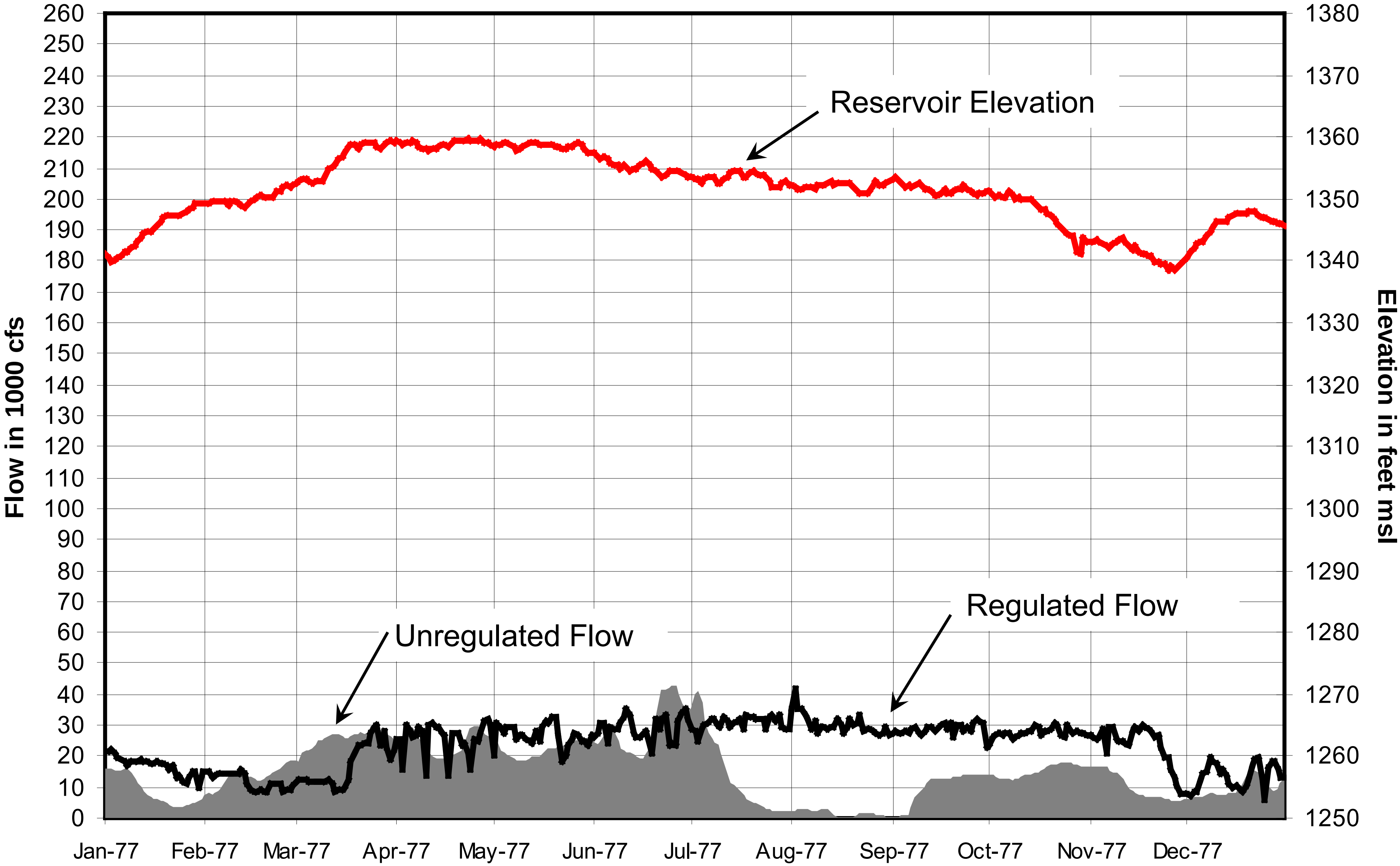
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1972
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

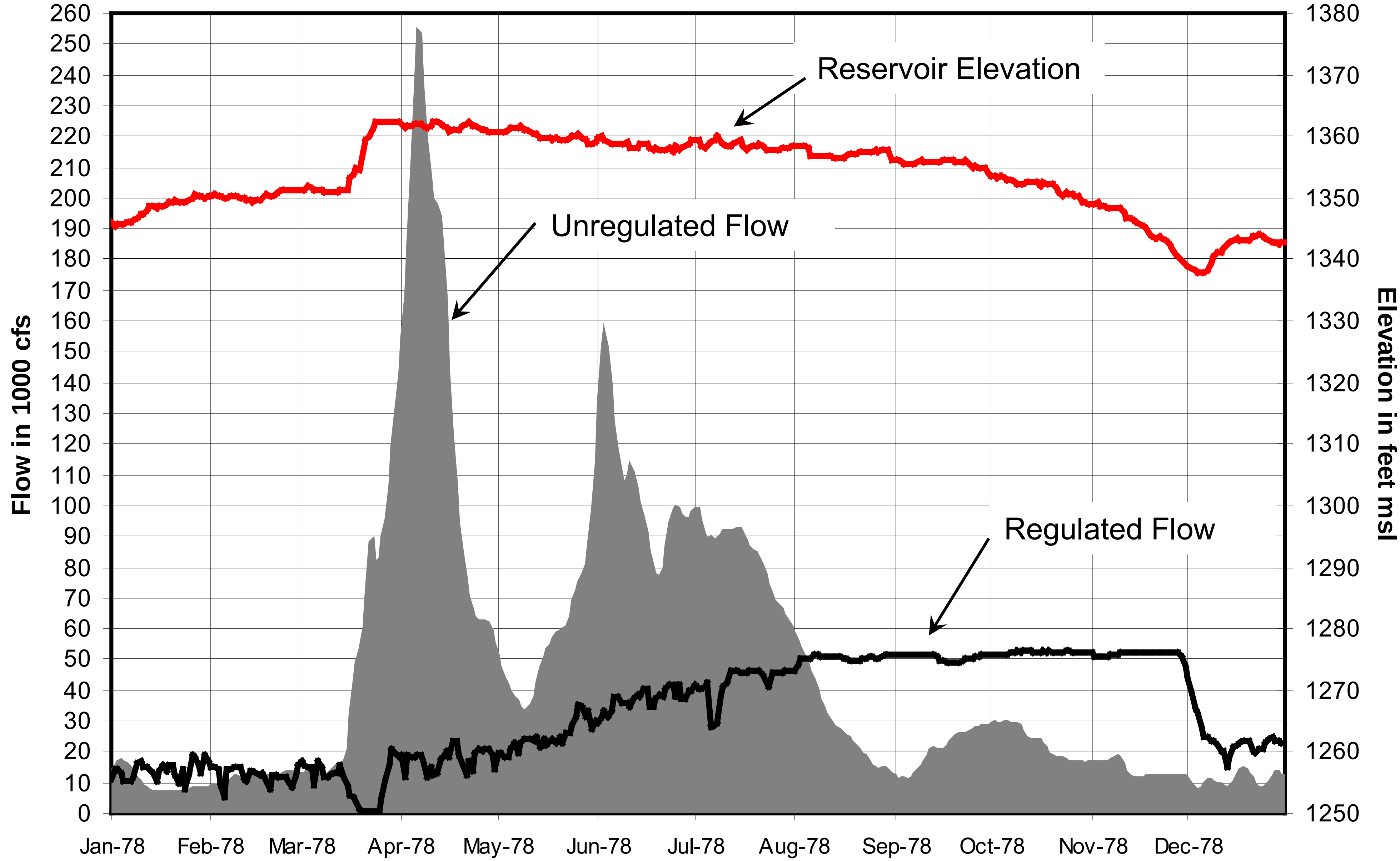


Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1975
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1977

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

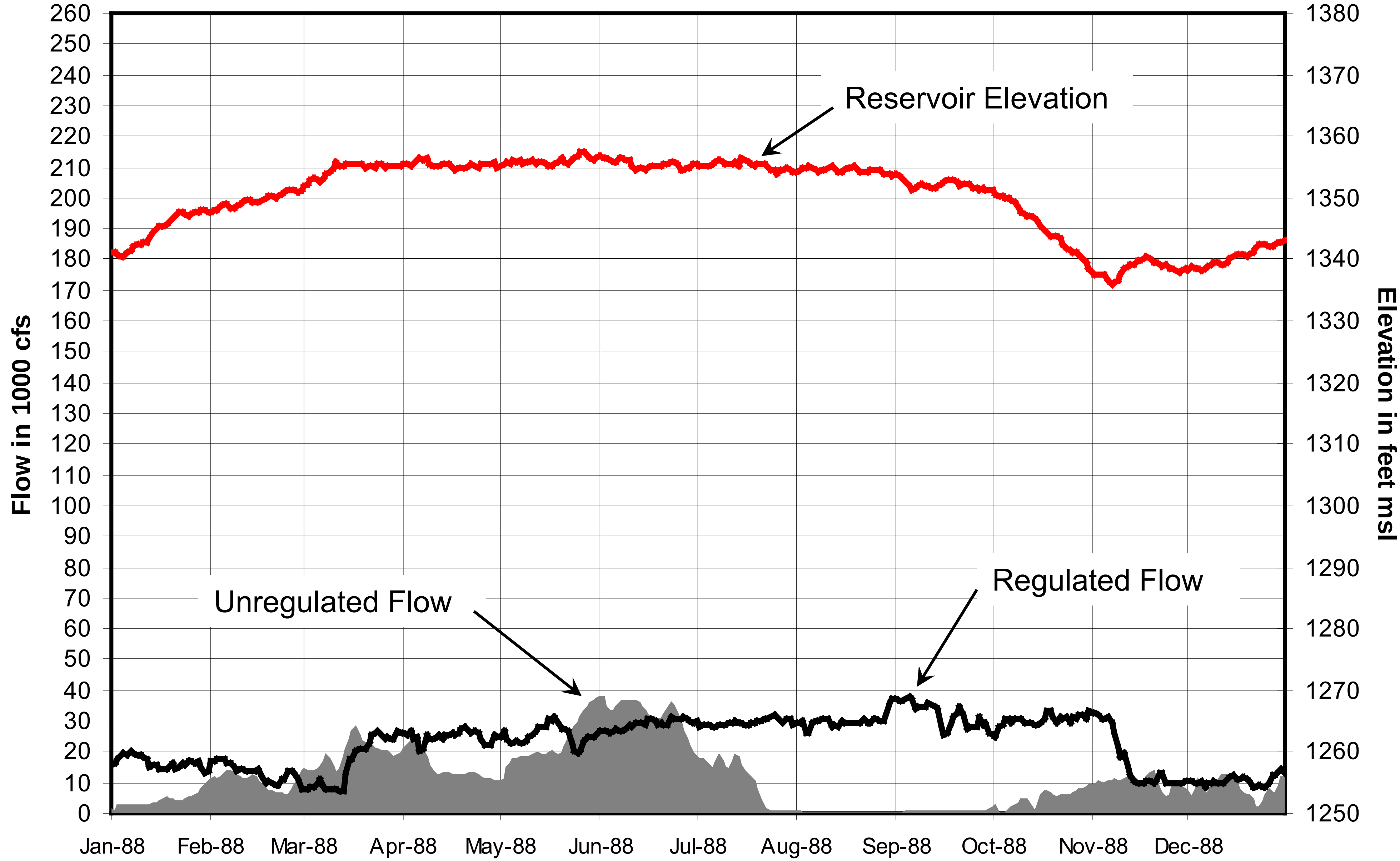


Missouri River Basin

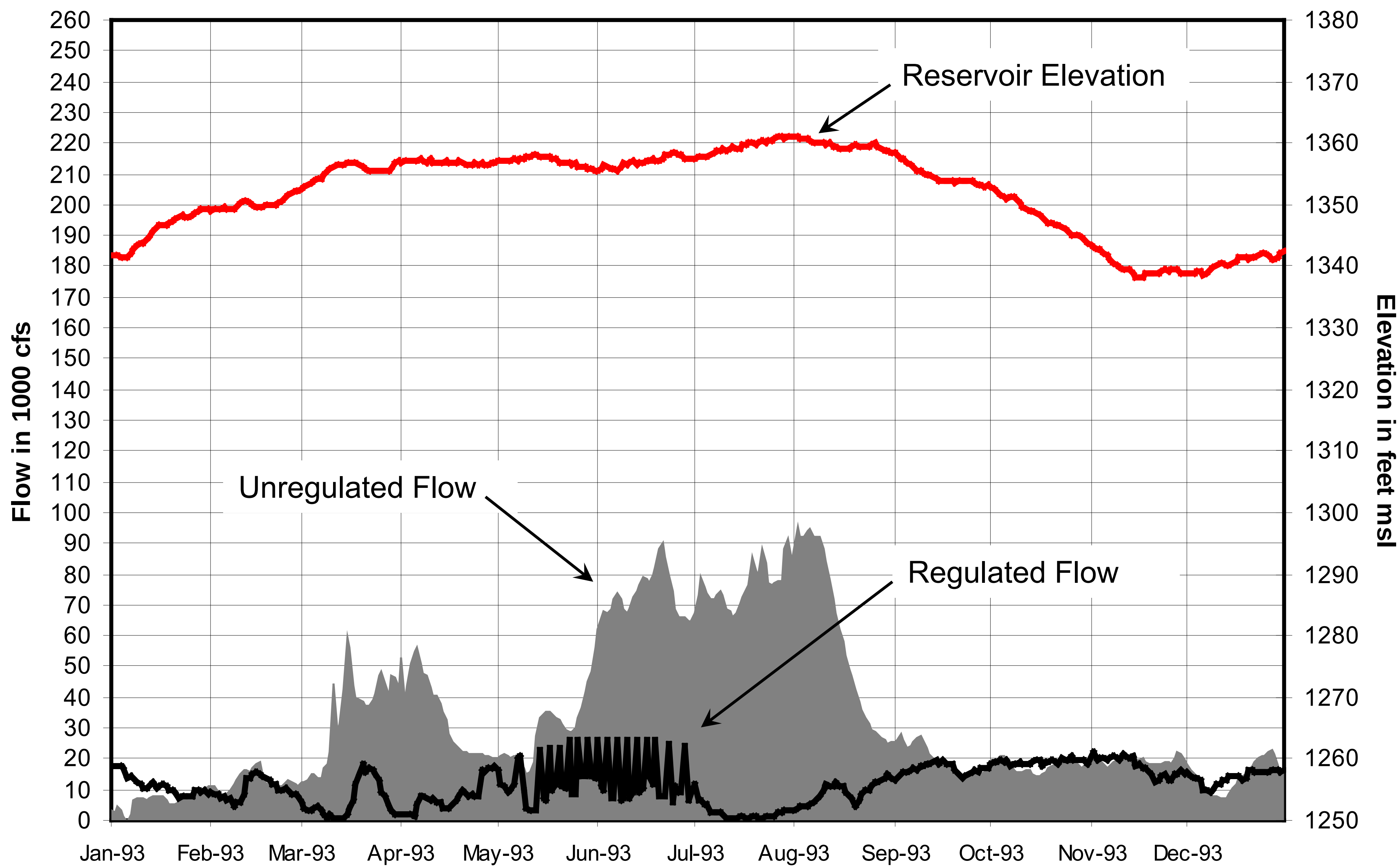
Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1978

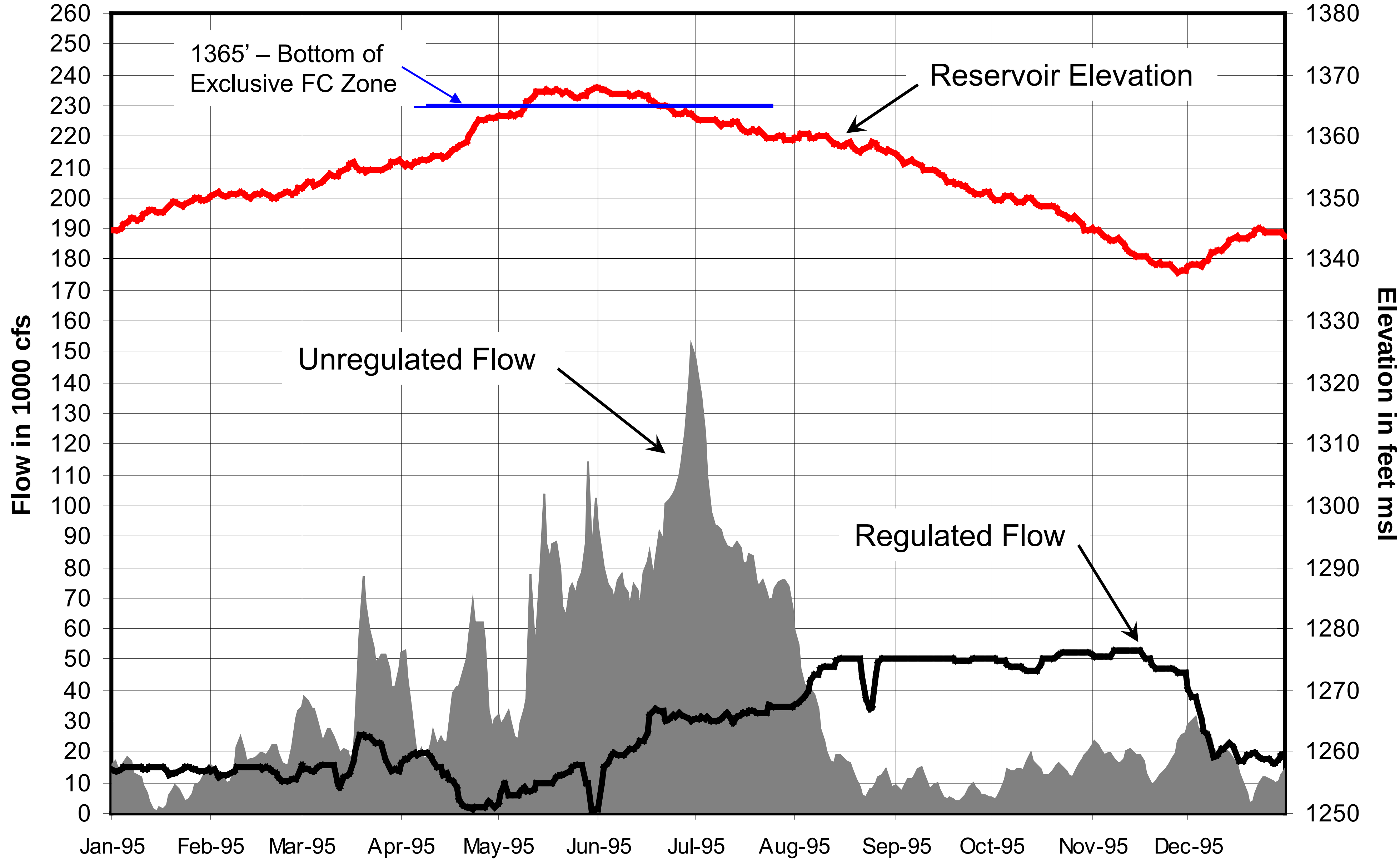
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



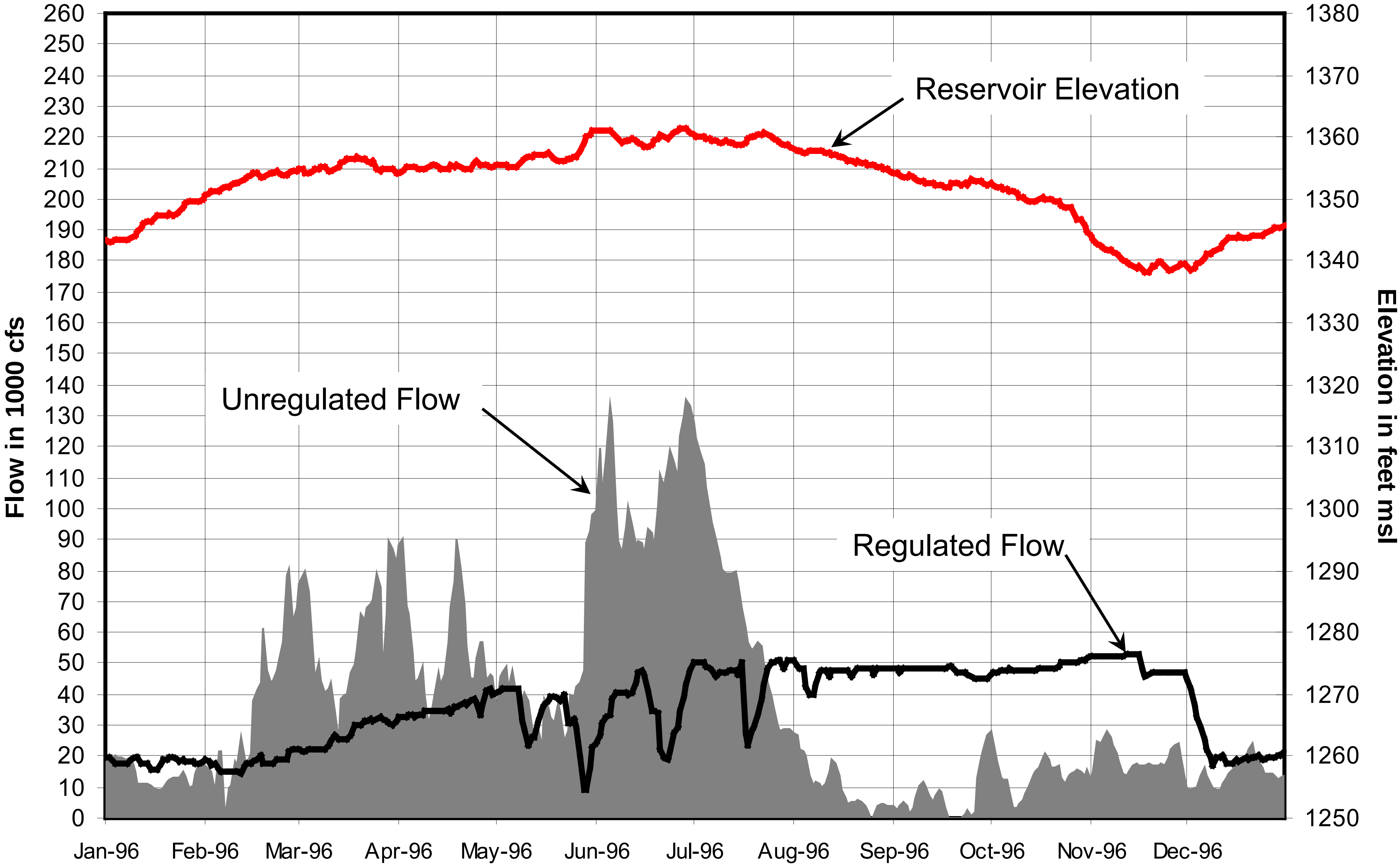
Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1988
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1993
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

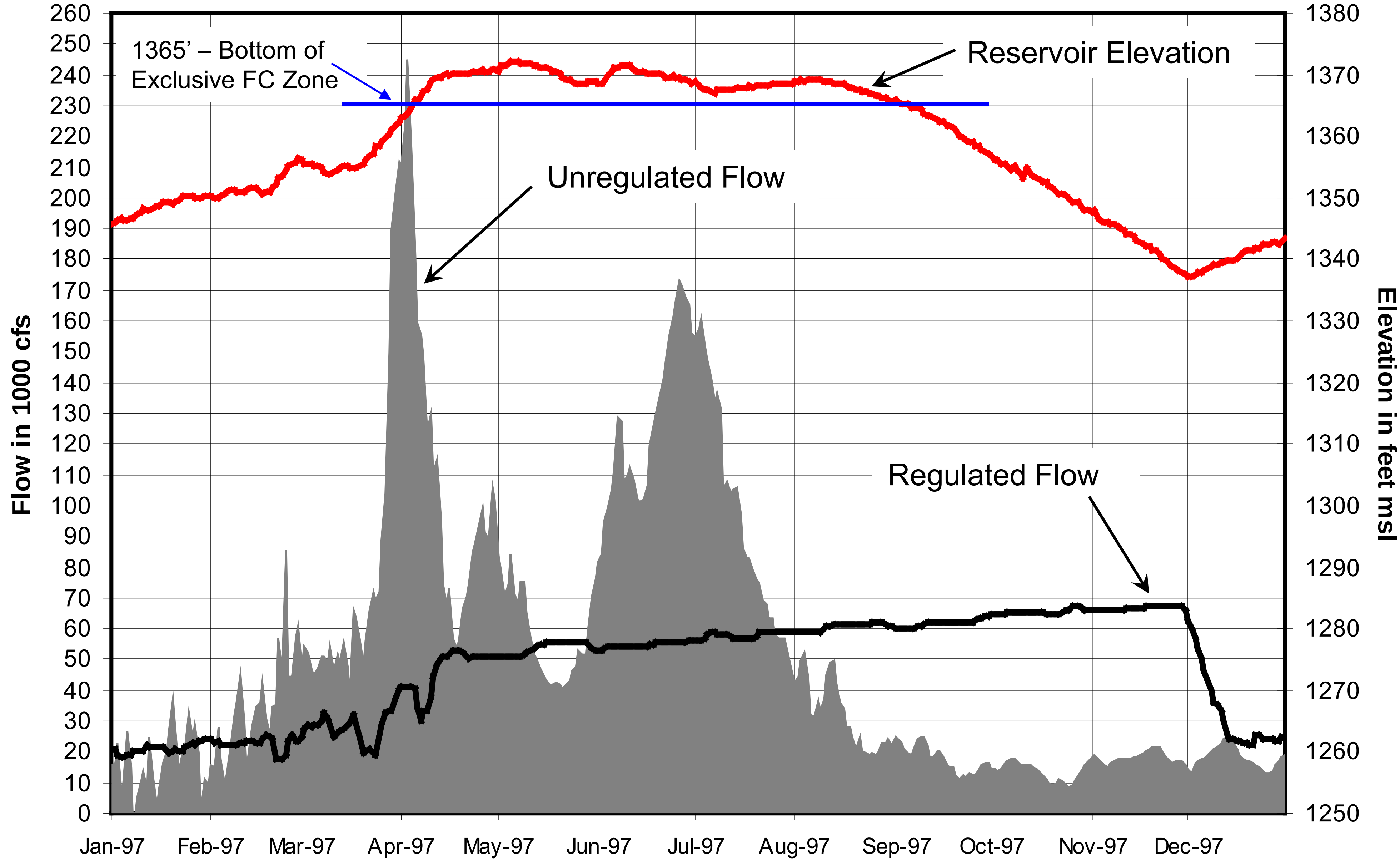


Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1995
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

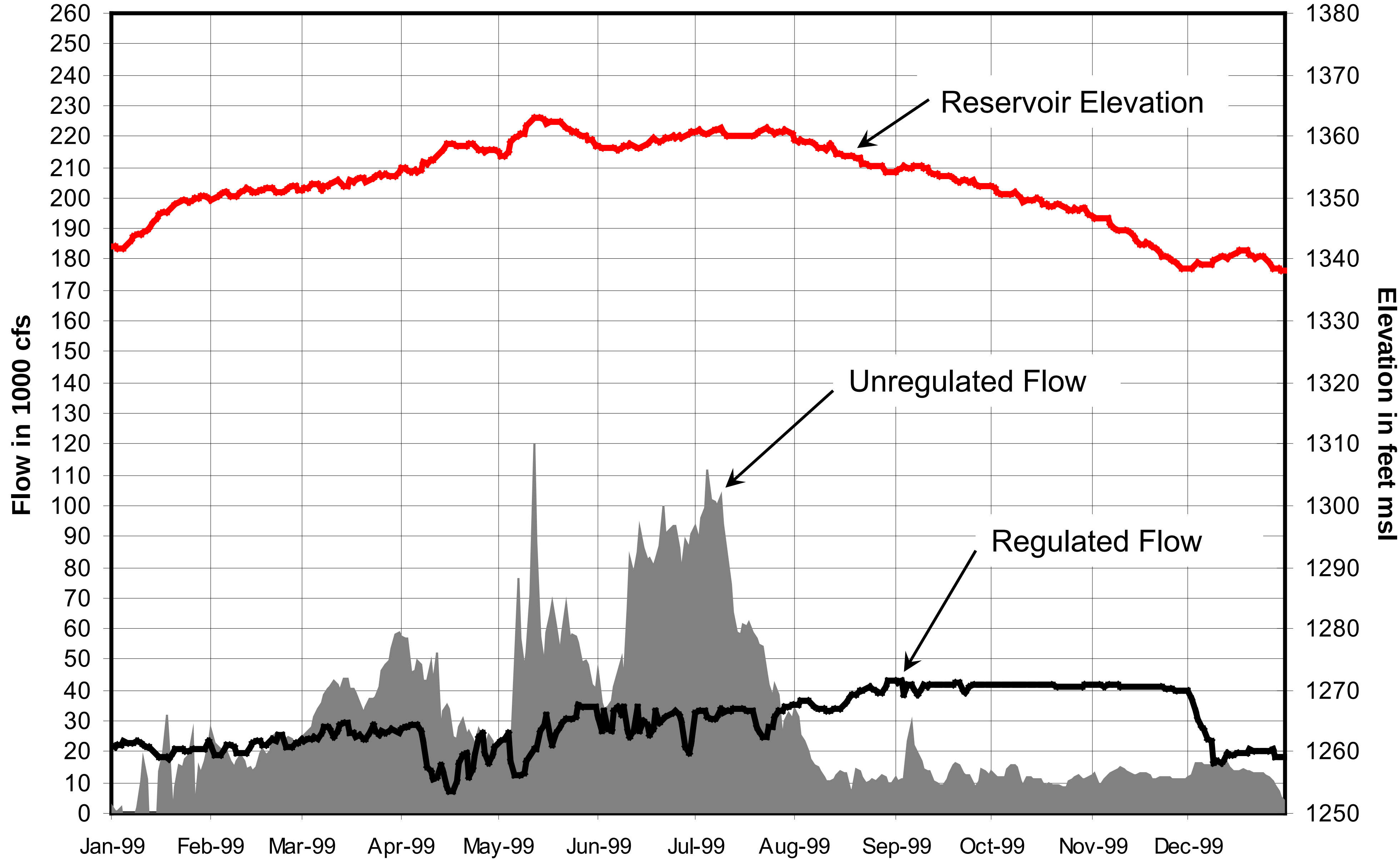


Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1996

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



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 1997
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

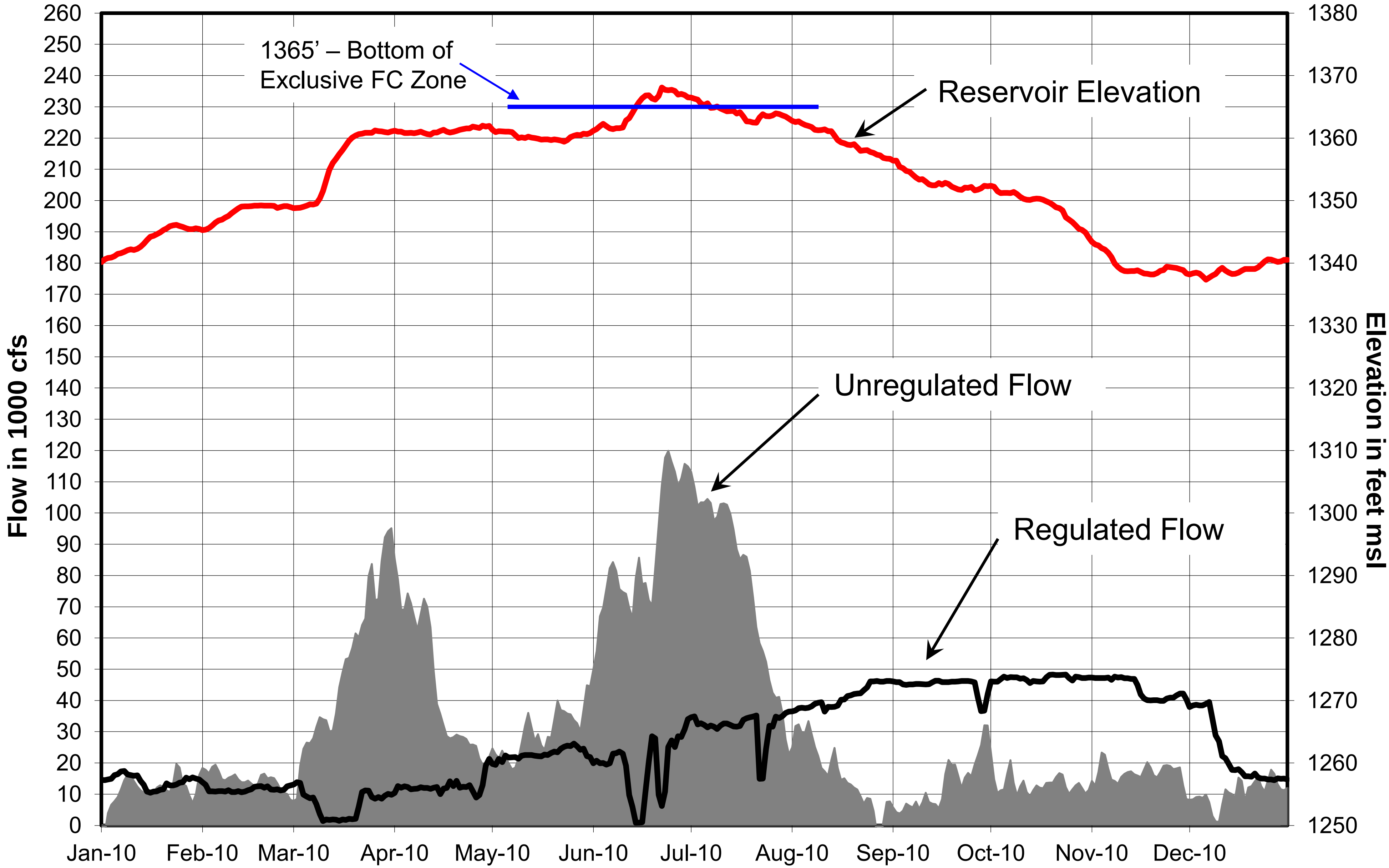


Missouri River Basin

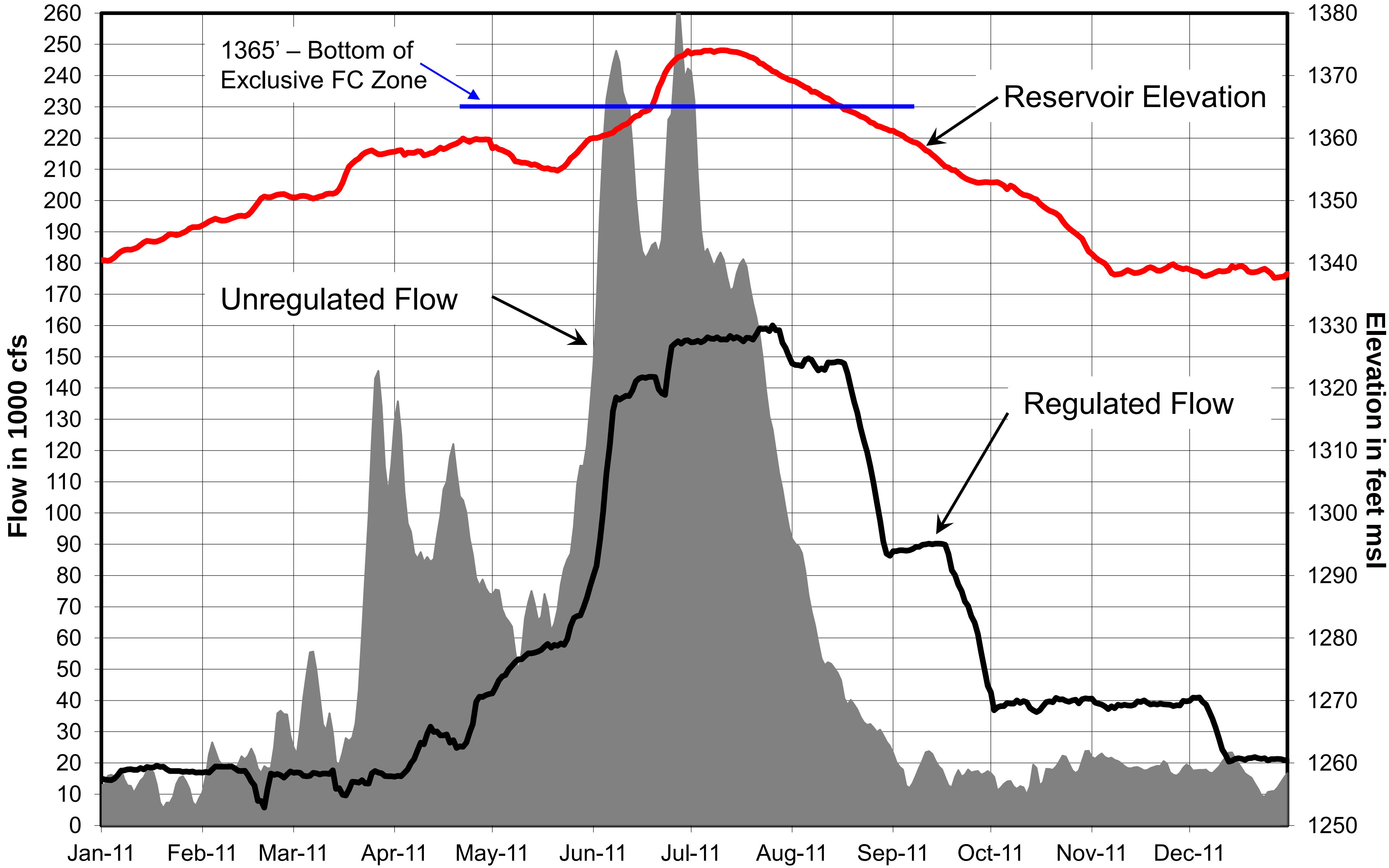
Fort Randall Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1999

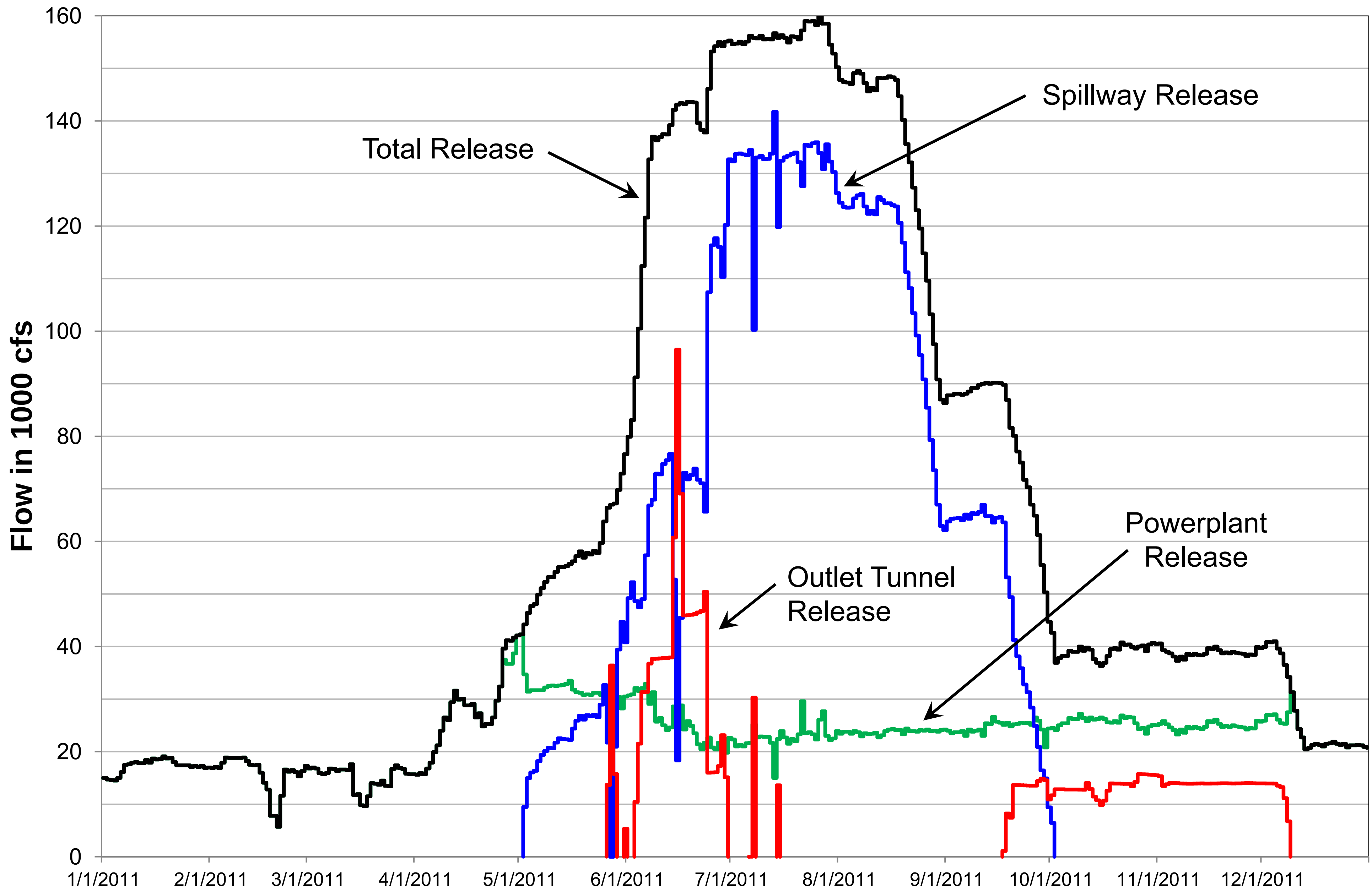
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and
Unregulated Flows, 2010
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



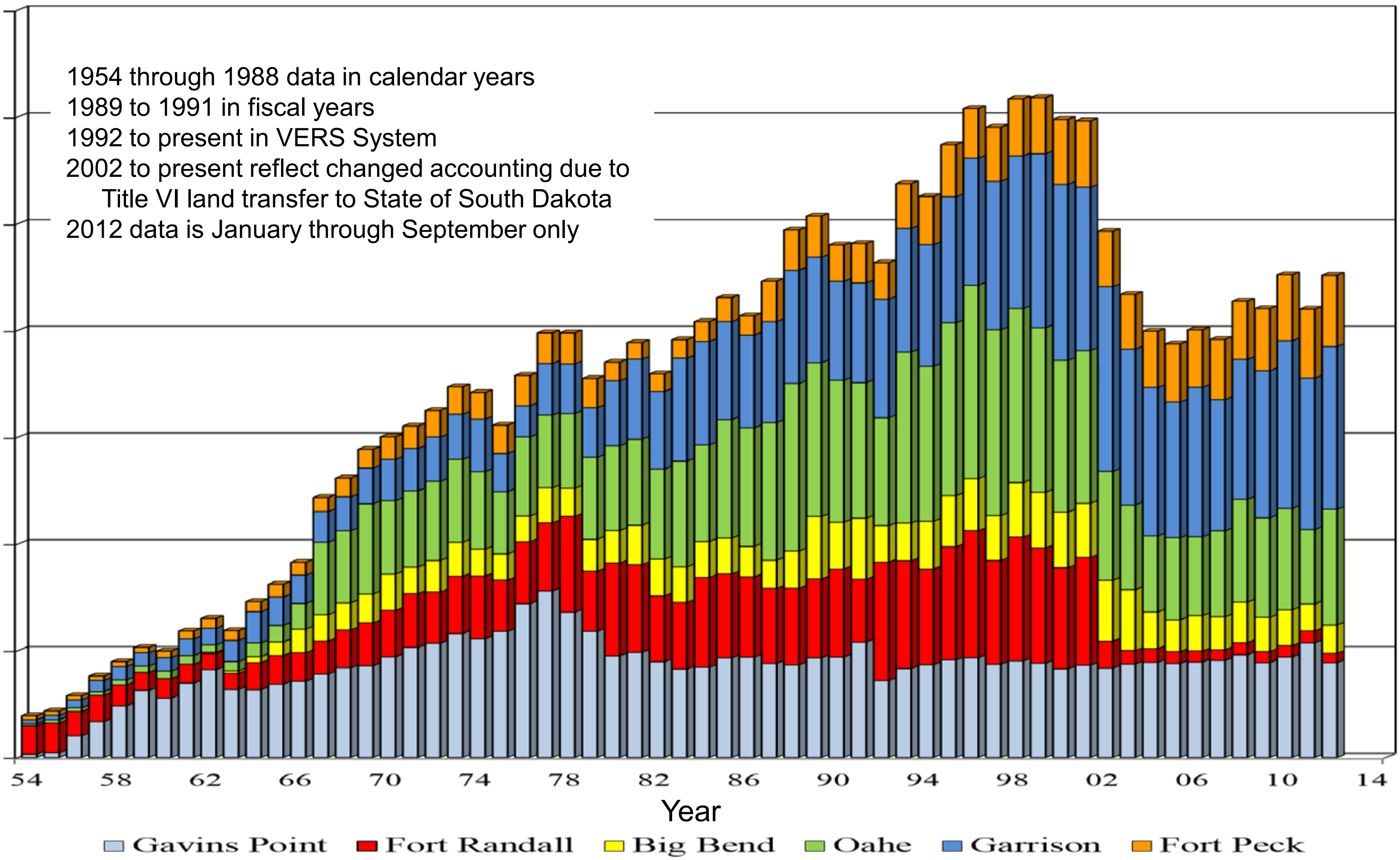
Missouri River Basin
Fort Randall Water Control Manual
Reservoir Elevation, Regulated and Unregulated Flows, 2011
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin
Fort Randall Water Control Manual
2011 Powerplant, Spillway, Outlet Tunnel and Total Releases

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

Mainstem Project Visits
1954 to 2012



Missouri River Basin
Fort Randall Water Control Manual
Mainstem Project Visitor Hours

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