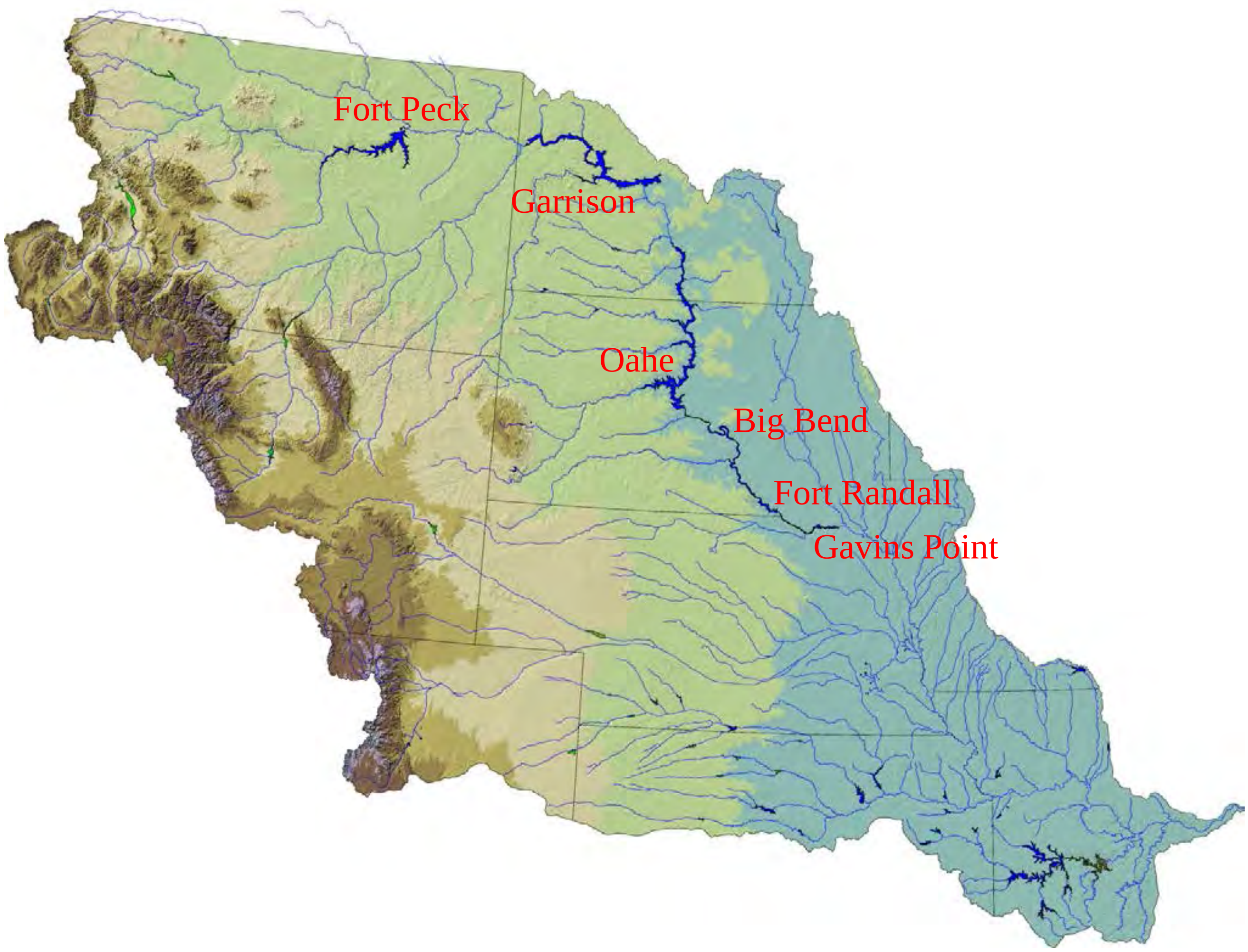
US Army Corps of Engineers®
Northwestern Division

Missouri River Mainstem Reservoir System

Master Water Control Manual

Missouri River Basin



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

November 2018

Missouri River Basin
Mainstem Reservoir System
Water Control Manual

In 7 Volumes | Volume 1

MASTER MANUAL

Volume 1	Master Manual
Volume 2	Fort Peck (Fort Peck Reservoir)
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)

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Omaha, Nebraska

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Missouri River Basin
Mainstem Reservoir System
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In 7 Volumes — Volume 1

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Abbreviations and Acronyms

AIS	-	automated information system
AOP	-	Annual Operating Plan
BSNP	-	Bank Stabilization and Navigation Project
cfs	-	cubic feet per second
Co-op	-	Cooperative Streamgaging Program
COOP	-	Continuity of Operations
Corps	-	U.S. Army Corps of Engineers
CRREL	-	Corps' Cold Regions Research and Engineering Laboratory
CWA	-	Clean Water Act
CWCP	-	current water control plan
CWMS	-	Corps Water Management System
DCP	-	data collection platform
DRM	-	Daily Routing Model
EAP	-	Emergency Action Plan
EC	-	Engineering Circular
EIS	-	Environmental Impact Statement
EM	-	Corps' Engineering Manual
EOC	-	Emergency Operations Center
EPA	-	Environmental Protection Agency
ER	-	Corps' Engineering Regulation
ESA	-	Endangered Species Act
°F	-	degrees Fahrenheit
FEMA	-	Federal Emergency Management Agency
FUI	-	Forecasted Ungaged Inflow
GRFT	-	Gavins Release Forecasting Tool
GSA	-	General Services Administration
HEC-HMS	-	Corps' Hydrologic Engineering Center Hydrologic Modeling System
HEC-ResSim	-	Corps' Hydrologic Engineering Center Reservoir System Simulation
HUC	-	hydrologic unit code
IRP	-	Independent Review Panel
kAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kW	-	kilowatt
LDM	-	local data manager
MAF	-	million acre-feet
Master Manual	-	Missouri River Mainstem Reservoir System Master Water Control Manual
MBIAC	-	Missouri Basin Inter-Agency Committee
MBRFC	-	Missouri Basin River Forecast Center
MBSA	-	Missouri Basin States Association
MBSC	-	Missouri Basin Survey Commission
MBST	-	Missouri Basin Snow Tool
MoRAST	-	Missouri River Association of States and Tribes

MRBA	-	Missouri River Basin Association
MRBC	-	Missouri River Basin Commission
MRBWM	-	Missouri River Basin Water Management
MRCC	-	Missouri River Coordinating Committee
MRBIR	-	Missouri River Basin Interagency Roundtable
MRD	-	Missouri River Division
MRNRC	-	Missouri River Natural Resources Committee
MRRIC	-	Missouri River Recovery Implementation Committee
MRRMP	-	Missouri River Recovery Management Plan
MRR	-	Missouri River Region
MRSC	-	Missouri River States Commission
MW	-	megawatt
MWh	-	megawatt hour
NAVD88	-	National American Vertical Datum of 1988
NEPA	-	National Environmental Policy Act
NGVD29	-	National Geodetic Vertical Datum of 1929
NOAA	-	National Oceanic and Atmospheric Administration
NOHRSC	-	National Operational Hydrologic Remote Sensing Center
NOSC	-	Network Operations Security Center
NRCS	-	Natural Resource Conservation Service
NRMS	-	Natural Resource Management System
NWCC	-	USDA-NRCS National Water and Climate Center
NWD	-	Northwestern Division
NWDR	-	Northwestern Division Regulation
NWS	-	National Weather Service
O&M	-	Operation and Maintenance
OPM	-	Operations Project Manager
P.L.	-	Public Law
Plover	-	piping plover
PPCS	-	powerplant control system
QPF	-	quantitative precipitation forecast
RCC	-	Reservoir Control Center
RM	-	River Mile (1960 mileage)
ROD	-	Record of Decision
SDF	-	Spillway Design Flood
SNOTEL	-	snow telemetry
SPP	-	Southwest Power Pool
SR-FTT	-	Steady Release – Flow to Target
SSM/I	-	Special Sensor Microwave/Imager
SWE	-	snow water equivalent
System	-	Missouri River Mainstem Reservoir System
tern	-	interior least tern
T&E	-	threatened and endangered
USBR	-	U.S. Bureau of Reclamation
USCG	-	U.S. Coast Guard
USDA	-	U.S. Department of Agriculture
USFWS	-	U.S. Fish and Wildlife Service
USGS	-	U.S. Geological Survey

WAP	-	waterways action plan
WCM	-	water control manual
Western	-	Western Area Power Administration
WFO	-	NWS Weather Forecast Office
WMS	-	water management system
WRDA	-	Water Resources Development Act
WRRDA	-	Water Resources Reform and Development Act

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I - Introduction

1-01. Authorization. This manual has been prepared as directed in the U.S. Army Corps of Engineers' (Corps) Engineering Regulation (ER), ER 1110-2-240, titled *Water Control Management,* dated May 30, 2016, 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 a Master Water Control Manual (Master Manual) as discussed in that regulation. This manual is also prepared in accordance with pertinent sections of the Corps' Engineering Manual (EM), EM 1110-2-3600, titled *Management of Water Control Systems,* dated October 10, 2017. This Master Manual is prepared under the general format and recommendations described in ER 1110-2-8156, titled *Preparation of Water Control Manuals,* dated August 31, 1995. Revisions to this manual are processed in accordance with ER 1110-2-240. Deviations from this manual are processed in accordance with ER 1110-2-1400, titled *Reservoir/Water Control Management,* dated May 30, 2016 and the Corps' Northwestern Division (NWD) Regulation, NWDR 1110-2-6, titled *Deviation Requests for Approved Water Control Manuals*, dated November 9, 2005.

1-02. Purpose and Scope. Master Manuals for river basins that include more than one Corps District are prepared by, or under direct supervision of, Division Commanders. The system of six dams on the Missouri River affects not only the states within the Missouri River basin in which the six dams and their reservoirs are located, but also the downstream reaches of the Missouri River to its mouth near St. Louis, MO. The states are located within the Corps' Omaha and Kansas City Districts; therefore, the Missouri River Basin Water Management (MRBWM) Division, Programs Directorate, of the Corps' NWD located in Omaha, NE has prepared this Master Manual. The MRBWM office is responsible for the day-to-day regulation of the Missouri River Mainstem Reservoir System (System). Section 9 of the 1944 Flood Control Act authorized the System to be operated for the purposes of flood control, navigation, irrigation, power, water supply, water quality control, recreation, and fish and wildlife. In addition, operation of the System must also comply with other applicable federal statutory and regulatory requirements. Furthermore, to achieve the multi-purpose benefits for which they were authorized and constructed, the six System reservoirs must be operated as a hydraulically and electrically integrated system. A Master Manual is required because the System consists of the integrated operation of multiple projects, each having its own water control manual (WCM). The Master Manual serves as a guide to the MRBWM office in meeting the operational objectives of the System when regulating the six System reservoirs. This Master Manual also includes the integrated operation of both System and tributary reservoir water control plans so that an effective plan for flood control and conservation operations exists within the basin. The sheer size of the System dwarfs all other tributary reservoir projects within the Missouri River basin; therefore, this plan must serve to integrate all those operations to remain effective in meeting the overall operational objectives of the System.

1-02.1. Set of Water Control Manuals. The total set of WCMs for the System numbers seven, one for each of the individual projects and this Master Manual. The WCM for the entire System is in seven volumes as follows:

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

1-02.2. Individual Water Control Manuals. The individual project WCMs serve as supplements to this Master Manual and present aspects of project usage not common to the System as a whole, including added detail on the incremental drainage areas regarding hydrology, hydrologic networks, forecasting, streamflow and runoff. Also, site-specific maps and regulation considerations for each individual project are discussed in greater detail in the individual WCMs than in this manual.

1-02.3. System Water Control Plan. This Master Manual describes the water control plan for the System. The plan consists of the water control criteria for the management of the System for the full spectrum of anticipated runoff conditions that could be expected to occur. According to ER 1110-2-240, "Development, revision, and evaluation of WCMs shall comply with Corps policies, objectives, and principles of water control management and ecological sustainability (to the extent allowed) including those described in Chapter 2 of this regulation. Administrative updates to WCMs which are not updates to the water control plan should be performed not less than every ten years." Annual water management plans (Annual Operating Plans or AOPs) are prepared each year, based on the water control criteria contained in the Master Manual, in order to detail reservoir regulation of the System for the current operating year. Because the System is so large, it can respond to extreme conditions of longer than 1-year duration. The AOP also provides an outlook for planning purposes in future years.

1-02.4. Corps Policy - Update of Water Control Plans. Revision of this manual may be necessary in the future because of the possible changing emphasis on the level of service to various authorized or new project purposes or with new knowledge that is gained from additional actual operating experience. According to ER 1110-2-240, "Water control plans will be revised as necessary to conform with changing requirements resulting from developments in the project area and downstream, improvements in technology, improved understanding of ecological response and ecological sustainability, new legislation, reallocation of storage, new regional priorities, changing environmental conditions and other relevant factors." The emphasis will remain, however, on maintaining the inherent flexibility that exists and is required for effective operation of the System. New information on the needs of the project purposes and compliance with applicable law, including adjustments to meet requirements for threatened and endangered (T&E) species, may also require revision of the water control plan and, subsequently, the Master Manual. Furthermore, other factors within the basin, such as a significant reduction in the availability of water (changes in depletions of water within and downstream from the System), may also require a revision of the water control plan included in this manual.

1-02.5. Corps Policy - Development of Water Control Plans. Chapter 3 of EM 1110-2-3600 outlines the various steps and technical considerations necessary to develop water control plans. This chapter states, "Development of water control plans involves input from external agencies, entities, or stakeholders that may be affected by water management activities. These interests may include non-governmental entities as well as federal, state, local, and tribal organizations." ER 1110-2-240 also addresses public input when it states, "… water control plans for projects owned and operated by USACE shall be developed in concert with all basin interests which may be impacted by or influence project regulation, and public involvement in the development or significant revision of water control plans shall be provided for as required under this regulation." Basin interests can anticipate continued public involvement in the water control management process and any significant water control plan or Master Manual revisions in the future will be processed in accordance with ER 1110-2-240. Minor revisions to this or any of the previously mentioned individual project manuals will be the responsibility of the MRBWM office and do not require coordination throughout the basin. In addition, changed circumstances or unforeseen conditions may necessitate short-term deviations from the current water control plan (CWCP). Such deviations are reviewed and approved by the NWD Commander in accordance with ER 1110-2-1400 and NWDR 1110-2-6.

1-03. Current Water Control Plan. As described in the Record of Decision (ROD) dated 20 November 2018, for the 2018 Final Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS), after thorough analysis and input by the public, the 2004/2006 water control plan was modified by removing criteria for 1) the bimodal spring pulse and 2) reservoir unbalancing, both of which were added in 2004/2006.

1-04. Related Manuals and Reports. The Master Manual was first published in December 1960. Selected pages were revised in November 1973, and a revised Master Manual was published in 1975. Regulation criteria for flood control were revised, and the Master Manual was republished in 1979. Public concern over the drought conservation plan presented in the 1979 Master Manual surfaced early in the 1987-1992 drought. This was the first major drought to occur in the basin since the System was originally filled and became fully operational in 1967. The NWD initiated an update of the water control plan in 1989 because of this concern. The update to the 1979 water control plan was considered a major revision that required extensive coordination with basin interests. As part of the subsequent review and update process for the Master Manual, an EIS under the auspices of the National Environmental Policy Act (NEPA) was prepared. Numerous supporting technical reports and five versions of the EIS (preliminary draft (May 1993), draft (July 1994), preliminary revised draft (August 1998), revised draft (August 2000), and final (March 2004)) were prepared. The basis for the selection of the water control plan included in the 2004 Master Manual is outlined in the 2004 Final EIS and the subsequent ROD. There was extensive coordination activities conducted by the NWD during the 14-year process of updating the 2004 Master Manual. The 2004 Master Manual was updated in 2006 to include bimodal spring pulse criteria and adaptive management measures for T&E species, the endangered interior least tern, the endangered pallid sturgeon, and the threatened piping plover.

1-04.1. Master Manual Versions. This Master Manual and all previous versions were developed in consultation with state governments and Tribal Nations within the Missouri River basin and federal agencies having related authorities and responsibilities.

1-05. Project Owner. The System was constructed and is owned, operated, and maintained by the Corps of Engineers, Department of the Army.

1-06. Operating Agency. The Corps operates the System. The Corps' MRBWM office, part of the NWD and located in Omaha, NE, oversees the day-to-day implementation of this water control plan. The Omaha District of the NWD has staff located at each of the System's projects to carry out the day-to-day operation, based on the water management regulation orders received from the MRBWM office, and maintenance. All of the System dams serve hydropower as an authorized function and, therefore, 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 Mainstem 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 assure that expected releases rates are achieved.

1-07. Regulating Agencies. As the project owner, the Corps has the direct responsibility of regulating the System to meet the authorized project purposes. This is accomplished in coordination with many others, including federal and state agencies, Tribal Nations and a myriad of stakeholders. As these other entities provide input to the Corps on the Master Manual and through the AOP process, the Corps must determine if the proposal is within the Corps' authority and has met all applicable laws and regulations regarding System operation 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 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.

1-08. 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). 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, 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 in the individual WCMs for adjustments for the three datums at each System project. These datum adjustments are provided for reference only and should not be used for construction or other purposes.

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II - Legislative and System Construction History

2-01. Water Resources Authorization History. This section describes the authorization history of water resources projects in the Missouri River basin.

2-01.1. Early Development. The United States acquired the land that forms the Missouri River basin by a treaty signed on April 30, 1803. At more than 800,000 square miles in size, the Louisiana Territory was purchased for $15 million from France, commonly referred to as the Louisiana Purchase. The first federal exploration/survey of the Missouri River basin was made in 1804-1806 by two Army officers, Captains Meriwether Lewis and William Clark. Development of the basin's water resources began in the 1800s with the earliest efforts being single-purpose developments in response to specific needs, such as use of the rivers for water supply, irrigation, navigation or mining. The first steamboat entered the Missouri River in 1819 and traffic developed rapidly to meet the needs of the expanding West. The first federal development was initiated when Congress appropriated funds to the Corps in 1824 for a program of snag removal to aid navigation. Navigation of the Missouri River by steamboat reached a peak in about 1880 and dwindled to nothing by about 1890 because of the expansion and use of the railroads. In 1884, at about the peak of steamboat traffic, Congress created the Missouri River Commission within the Corps for the purpose of improving the river channel and decreasing the transportation hazards. When the Missouri River Commission ceased to exist in 1902, the Corps resumed its normal activities in the basin.

2-01.2. Missouri River Streamflow Prior to 1865. Prior to 1865, streamflow in the Missouri River basin was largely unused except for transportation by water and as a source of water supply. At about that time, the early settlers and homesteaders, their numbers swollen by uprooted Civil War survivors, began irrigation and mining ventures in substantial numbers. By 1900, streamflow depletions in the Missouri River basin due to these private developments had increased to about 3 million acre-feet (MAF) per year. Prior to 1900, Congressional legislation dealing with water resource development other than navigation was primarily concerned with support and encouragement of private development of water resources. This emphasis changed shortly after the turn of the century; within the overall scope of the history of basin water resources development, several aspects of federal legislation merit specific mention.

2-01.3. The Reclamation Act of 1902. This Act authorized development of irrigation projects with federal financing subject to partial repayment by irrigators and partial reimbursement from hydroelectric power revenues. The Act is limited in application to the 17 states west of the 98th Meridian. The fundamental purpose of the Act was to reclaim and foster settlement on undeveloped lands in the western states. Accordingly, a limitation of 160 acres was placed on the amount of individually owned land that would be furnished irrigation water. The Act has since been amended and expanded to permit water resources development for other beneficial purposes besides irrigation.

2-01.4. The Rivers and Harbors Act of 1912. This Act authorized a 6-foot navigation channel for the Missouri River from the mouth to Kansas City, Missouri. Several subsequent Congressional acts modified this navigation project, the latest being the Rivers and Harbors Act of 1945, which provided for works to secure a 9-foot deep by 300-foot wide channel from the mouth to Sioux City, IA.

2-01.5. The Rivers and Harbors Act of 1927. Pursuant to this Act, the Corps undertook the first comprehensive investigation and study ever made of the water resources and associated problems of the Missouri River basin. The entire river system was examined to determine the water resources and the prospects of its development for flood control, navigation, irrigation and power. The reports of these investigations, commonly referred to as the “308 Reports,” are historic reference documents for water resource development in the Missouri River basin. This comprehensive investigation and its reports identified many projects that did not appear to be feasible at that time or within the scope of national policy for federal development but were subsequently adopted by the Corps and the U.S. Bureau of Reclamation (USBR) as integral parts of the Missouri Basin Plan. Experience was gained and a large amount of data was collected in diversified fields that have subsequently made important contributions to the solution of basin problems.

2-01.6. The Rivers and Harbors Act of 1935. The construction of Fort Peck Dam was commenced under Executive Order in October 1933 with funds provided by Congress for the relief of unemployment. Subsequently, the project was specifically authorized by Congress in the Rivers and Harbors Act, approved August 30, 1935, in accordance with the Chief of Engineers’ recommendations included in House Document No. 238, 73rd Congress, 2nd Session. The Fort Peck Power Act of 1938 authorized construction of the power facilities. Originally, the project was authorized primarily for improving navigation on the Missouri River and the incidental purposes of flood control and hydroelectric power production. The Fort Peck Power Act of 1938 also designated the USBR as marketing agent for generated power and made power rate schedules subject to the confirmation and approval of the Federal Power Commission.

2-01.7. The Flood Control Act of 1936. This Act established the policy that (a) flood control on navigable waters or their tributaries is a proper activity of the federal government in cooperation with the states, and (b) the Corps’ Chief of Engineers would have jurisdiction over, and supervision of, federal investigations and improvements of rivers and other waterways for flood control and allied purposes. Subsequent flood control acts amended this Act to authorize federal participation in more comprehensive water resources developments.

2-01.8. The Flood Control Act of 1938. This Act resulted from studies of floods on the Mississippi River and did not authorize a large number of projects to be built in the Missouri River basin. The Act recognized the Missouri River basin as having a general flood problem in the lower portion of the basin and a significant contributor to the disastrous floods on the Mississippi River. Accordingly, the Act authorized the Corps to construct nine reservoirs in the lower part of the Missouri River basin for flood control. The Act adopted comprehensive plans for many basins, including the Missouri River basin. This was the initial step toward the overall Missouri Basin Development Plan. The first expansion of this plan resulted from additional Corps studies and appeared in the Flood Control Act of 1941, wherein levee protection along the

Missouri River from Sioux City, IA to Kansas City, MO and the Harlan County Reservoir on the Republican River in Nebraska were authorized.

2-01.9. The Flood Control Act of 1944. This Act approved a plan of development for the Missouri River basin based on a Corps proposal, as presented in House Document No. 475, 78th Congress, 2nd Session, and a proposal by the USBR, as presented in Senate Document No. 191, 78th Congress, 2nd Session. The coordinated result of these two plans was presented in Senate Document No. 247, 78th Congress, 2nd Session. Under this Act, the Corps was given the responsibility for development of projects on the main stem of the Missouri River. Tributary projects were made the responsibility of the Corps if the dominant purpose was flood control. The Department of the Interior was designated as the marketing agent for all power, beyond project requirements, generated at Corps projects. The Department of the Interior subsequently designated the USBR as the marketing agent for power generated by the mainstem projects and the Southwestern Power Administration as the marketing agent for power generated at basin projects within the state of Missouri. Rate schedules for the sale of generated power are subject to confirmation and approval by the Federal Power Commission. Section l(b) of the Act, sometimes referred to as the O'Mahoney-Millikin Amendment, provides that, for water rising in states wholly or partly west of the 98th Meridian, use for navigation shall be subordinate to present or future beneficial consumptive use in those states. Under the 1944 Flood Control Act, approximately 100 tributary reservoirs were authorized in addition to the Garrison, Oahe, Big Bend, Fort Randall and Gavins Point projects on the main stem of the Missouri River. The Act incorporated the Fort Peck project into the multi-purpose System.

2-01.10. The Watershed Protection and Flood Prevention Act of 1954. This Act extended federal interest and financial participation to land stabilization and flood prevention measures on smaller watersheds. Thus, this Act served to supplement the policy for flood control measures on major streams established earlier. Subsequent amendments to this Act increased the limitations on size of watershed eligible for improvement and on storage capacity of individual reservoirs. These amendments also authorized provision of storage for purposes other than flood prevention, within the overall storage limitation.

2-01.11. The 1958 Water Supply Act. In this Act, Congress recognized that the states and local interests have primary responsibility for developing water supplies for domestic, municipal, industrial, and other purposes; however, it provided that the federal government should participate and cooperate by making provision for water supply in the construction, maintenance and operation of federal navigation, flood control, irrigation or multiple-purpose projects. Accordingly, storage for water supply may be included in any federally-constructed reservoir project, subject to consummation of certain assurances or agreements for non-federal repayment of costs allocated to water supply.

2-01.12. The Federal Water Project Recreation Act of 1965. This Act established the development of the recreation potential at federal water resource projects as a full project purpose.

2-01.13. The 1986 Water Resources Development Act. Section 906 of this Act establishes a comprehensive mitigation policy for water resource projects, including Section 906e, which authorizes the Secretary of Army to provide for fish and wildlife mitigation resulting in projects under his or her jurisdiction.

2-01.14. Other Federal Legislation. There is a significant amount of other federal legislation of particular importance to land and water resources development in the Missouri River basin. This legislation has had a significant impact on water resources development and the implementation of the authorized purposes of the System and is, therefore, included here to provide additional understanding to the complexity of the System and the implementation of these laws into System regulation.

2-01.14.1. The Fish and Wildlife Coordination Act of 1946. This Act promotes the preservation and enhancement of fish and wildlife through equal consideration of their habitat needs in conjunction with federal participation in water resource development and is commonly referred to as the "Coordination Act."

2-01.14.2. The Federal Water Pollution Control Act of 1956 and subsequent amendments. This Act provides for the preservation of water quality through low-flow augmentation.

2-01.14.3. The Fish and Wildlife Coordination Act of 1958. This Act provides that equal consideration should be given to fish and wildlife resources through consideration of their habitat needs in conjunction with federal participation in water resource development. This Act also provides authority to modify projects for the benefit of fish and wildlife enhancement.

2-01.14.4. The National Environmental Policy Act of 1969. This Act outlines the actions to be taken relative to protecting and enhancing the quality of the human environment. In general, it requires that the impacts to the human environment be evaluated as a project is planned, with the impacts presented in an environmental impact statement. Further, this documentation needs to be coordinated with the public so that its comments are considered as the final project is selected.

2-01.14.5. The Federal Water Pollution Control Act of 1972. Referred to as the "Clean Water Act," this Act established goals to restore and maintain the quality of the Nation's waters. The effects of the regulation of the System on water quality are continuously monitored to ensure that the System regulation enhances water quality to the extent reasonably possible.

2-01.14.6. The 1973 Endangered Species Act as amended. The 1973 Endangered Species Act (ESA) (Public Law 93-205 and as amended in Public Laws 95-632, 96-159 and 97-304) states the policy of Congress is that all federal departments and agencies shall seek to conserve T&E species and shall utilize their authorities in furtherance of the purposes of this Act. The purposes of this Act are to provide a means whereby the ecosystems upon which T&E species depend may be conserved and to provide a program for the conservation of such T&E species. Section 7 states that all federal departments and agencies shall, in consultation with and with the assistance of the Secretary of the Interior/Commerce, ensure that any actions authorized, funded, or carried out by them are not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of habitat determined by the Secretary of Interior to be critical unless an exception has been granted by the Endangered Species

Committee. The USFWS of the Department of Interior is the federal agency responsible for implementing ESA consultation provisions within the Missouri River basin. There are T&E listed species within the Missouri River basin project area.

2-01.15. Legislation of Significance to Tribes with Regard to System Regulation. A number of federal laws and regulations deal with impacts to Tribal resources and federal agency coordination and consultation requirements with Native American Tribes. Responsibilities toward Tribes in the Missouri River basin are governed by a number of treaties, statutes, and executive orders. The treaties are not a grant of rights to the Tribes, but as the U.S. Supreme Court has said, it is a "grant of rights from them" *U.S. v. Winans*, 198 U.S. 371 (1905). The Tribes therefore retain any right that was not expressly extinguished in the treaty or later nullified by Congress. These rights, often called reserved rights, include water rights and traditional hunting and fishing rights. Some of the more significant laws that directly structure the Corps' relationship with Tribes include: the National Historic Preservation Act (16 U.S.C. § 470 *et seq*.), the Archaeological Resources Protection Act (16 U.S.C. §§ 470aa-mm), the Native American Graves Protection and Repatriation Act (25 U.S.C. § 3001 *et seq.*), and Executive Order 13007. These laws seek to protect Native American cultural resources, human remains, and sacred sites. They provide requirements and processes for the Corps to protect and preserve cultural resources. The statutes also provide a framework for consultation with Tribes on issues of mutual importance.

2-01.16. Summary - Specific Project Authorizations. The 1944 Flood Control Act authorized construction of all of the System projects with the exception of Fort Peck, which was originally authorized by the Rivers and Harbors Act of 1935. The inclusion of the Fort Peck project as part of the multi-purpose System was authorized in the 1944 Flood Control Act. The Fort Peck Power Act of 1938 authorized construction of power facilities at the project while the 1944 Flood Control Act authorized multiple-purpose regulation of the Fort Peck project similar to the other System projects. As can be determined by reading the aforementioned federal water resource legislative history, several acts influenced or guided the development of and/or regulation of the System and determined the operational objectives stated in this manual in the form of a water control plan for the System.

2-02. Project Planning and Design History. The following sections provide a brief history of the planning and design of the System by reviewing the early days of water resource development in the Missouri River basin.

2-02.1. The 1944 Flood Control Act. The House Committee on Flood Control passed a resolution in 1943 asking the Corps to produce a plan for flood control and other purposes in the Missouri River basin. This request followed significant basin flooding in 1943, which is discussed in detail in Appendix A of this manual. Both the Corps and the USBR prepared plans for the multiple-purpose water resource management throughout the Missouri River basin. The Corps' then Missouri River Division (MRD) Engineer, Colonel Lewis A. Pick, developed the Pick Plan, emphasizing navigation and flood control purposes. The Corps prepared a plan that relied heavily on a "308 Report" prepared in 1934. Three types of projects were proposed in the Pick Plan: 1) 1,500 miles of levees along both sides of the Missouri River from Sioux City to the mouth, 2) many small reservoirs located on the tributaries, and 3) five additional mainstem dams. William G. Sloan, Assistant Regional Director of the USBR's Upper Missouri Region, developed the Sloan Plan, emphasizing irrigation for economic stability and hydroelectric power for economic growth. Rivalry existed between the Corps and USBR over which of the two plans should be followed. The Corps' Pick Plan (House Document No. 475, 78th Congress, 2nd Session) was submitted to the Congress on March 2, 1944. The USBR's Sloan Plan (Senate Document No. 191, 78th Congress, 2nd Session) was presented to the Congress on May 5, 1944. A coordinated plan, developed by the Corps and USBR and commonly referred to as the Pick-Sloan Plan, was submitted to the Senate on November 21, 1944 (Senate Document No. 247). President Franklin D. Roosevelt signed the Flood Control Act of 1944 on December 22, 1944 (Public Law 534, 78th Congress, 2nd Session), which approved the coordinated Pick-Sloan Plan and authorized appropriations to each of the two agencies for initial construction.

2-02.2. Missouri River Basin Project/Pick-Sloan Plan Missouri Basin Program. The Missouri River Basin Project, authorized by the Flood Control Act of 1944, envisioned a comprehensive system of flood control, navigation improvement, irrigation, municipal and industrial water supply, and hydroelectric generation facilities for the 10 states in the Missouri River basin. As originally planned, the project was to include 213 single and multiple-use projects, providing hydroelectric capacity and irrigation for 5.3 million acres of farmland. Construction began when basin interests encouraged people to return to the Missouri River basin. This effort followed an exodus that began during the Great Drought of the 1930s and extended through World War II, when people left for jobs in industrial centers on the east and west coasts. The plan was only partially completed; however, it completely changed water resource development in the basin. Congress passed legislation in 1970 to recognize the two visionary individuals who spearheaded the basin water resource planning by changing the project's name to the Pick-Sloan Missouri Basin Program.

2-03. Mainstem Dam Construction History. The Summary of Engineering Data - Missouri River Mainstem System, Plates II-1 and II-2, present 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. Plates II-3 through II-81 contain the pertinent details for each of the Corps' System projects, including maps of each reservoir area, details of embankments, spillways, and outlet facilities, area-capacity tables, tailwater rating curves, spillway-outlet works discharge capabilities and powerplant characteristic curves. A brief description of the significant construction dates of each of the six System projects is presented in the following sections. Additional project-specific construction details are provided in the individual project WCMs. The dates that are noted in these sections and reflected in the Summary of Engineering Data are when the service availability was essentially complete. Service to navigation and flood control was initiated, to a limited extent, at the time closure of the dam was made. This service increased progressively to the in-service dates indicated when the project was essentially complete or full service to these authorized purposes was rendered by having a full System.

2-03.1. Construction of Fort Peck Dam – Fort Peck Lake. Fort Peck Dam is located on the Missouri River at river mile (RM) 1772 in northeastern Montana, 17 miles southeast of Glasgow, MT and 9 miles south of Nashua, MT. Construction of the Fort Peck project was initiated in 1933 and embankment closure was made in 1937 (see Plate II-1). The project was regulated for the authorized purposes of navigation and flood control in 1938. The Fort Peck Dam embankment is nearly 4 miles long (excluding the spillway) and rises over 250 feet above the original streambed. Fort Peck Dam remains the largest dam embankment in the United States (126 million cubic yards of fill) and the largest "hydraulic fill" dam in the world. The Fort Peck reservoir (Fort Peck Lake) is the third largest Corps reservoir in the United States and the fifth largest reservoir in the U.S. When full (at the base of the Annual Flood Control and Multiple Use Zone), the reservoir is 134 miles long. The concrete spillway is 4,800 feet long, almost a full mile. In 1943, the first hydropower unit went on line, and the third unit became operational in 1951, completing construction of the first powerplant. Construction of a second powerplant began in the late 1950s and the two units in this powerplant became operational in 1961. The Permanent Pool Zone (inactive storage) of the reservoir was initially filled (elevation 2150 feet) in April 1942 and the Carryover Multiple Use Zone (elevation 2234 feet) first filled in 1947, five years later. Drought conditions during the late 1950s, combined with withdrawals to provide water for the initial fill of other System projects, resulted in a drawdown of the reservoir level to elevation 2167.4 feet in early 1956, followed by a generally slow increase in pool elevation. The Carryover Multiple Use Zone was finally refilled in July 1964. Generally, it has remained filled from that time with storage primarily in the Annual Flood Control and Multiple Use Zone, with the exception of the 1987-1992 and 2000-2007 droughts. Storage in the Exclusive Flood Control Zone first occurred in 1969, and then again in 1970, 1975, 1976, 1978, 1979, 1996, 1997, 2011 and 2018. In 1975 and 2011 all the flood control storage (Annual Flood Control and Multiple Use Zone and Exclusive Flood Control Zone) was occupied and the reservoir level entered the Surcharge Zone. In 2011, the record elevation of 2252.3 feet was reached, 2.3 feet above the top of the Exclusive Flood Control Zone and 2.3 feet into the Surcharge Zone.

2-03.2. Construction of Garrison Dam – Lake Sakakawea. Garrison Dam is located in central North Dakota on the Missouri River at RM 1390, about 75 river miles northwest of Bismarck, ND and 11 miles south of the town of Garrison, ND. Construction of the project was initiated in 1946, closure was made in April 1953, and the navigation and flood control functions of the project were placed in operation in 1955. The first hydropower unit of the project went on line in January 1956, followed by the second and third units in March and August of the same year. Power Units No. 4 and 5 were placed in operation in October 1960. The Garrison reservoir (Lake Sakakawea) first reached its minimum operating level (elevation 1775 feet, top of Permanent Pool Zone) in late 1955. Due to the drought conditions it was not until 10 years later, in 1965, that the Carryover Multiple Use Zone (elevation 1837.5 feet) was first filled. Generally, it remained filled from that time except for the two drought periods to date. Exclusive flood control storage space was used in 1969, 1975, 1995, 1997, 2010 and 2011. During 1975, 1997, 2011 and 2018, all flood control space was filled and the maximum reservoir level entered the Surcharge Zone. In 1975, the record reservoir level was 0.8 foot above the top of the Exclusive Flood Control Zone, elevation 1854.8 feet (0.8 feet into the Surcharge Zone). The Garrison reservoir is the largest Corps reservoir and the third largest reservoir in the U.S. When full (at the base of the Annual Flood Control and Multiple Use Zone), the reservoir is 178 miles long and up to 6 miles wide. At elevation 1854 feet, the top of the Exclusive Flood Control Zone, the reservoir storage capacity is 23.5 MAF. This volume is almost a third of the total storage capacity of the System.

2-03.3. Construction of Oahe Dam – Lake Oahe. The Oahe Dam is located on the Missouri River at RM 1072, 6 miles northwest of Pierre, SD. Construction of Oahe Dam was initiated in September 1948. Closure of the dam was completed in 1958 and deliberate accumulation of storage was begun in late 1961, just before the first hydropower unit came on line in April 1962.

The last of the seven hydropower units became operational in July 1966. Permanent Pool storage space in the Oahe reservoir (Lake Oahe) was first filled in 1962 and the Carryover Multiple Use Zone was filled in 1967. Generally, the Carryover Multiple Use Zone remained filled from that time, except for seasonal drawdowns in the interest of increased winter power generation and the two drought periods to date (1987-1992 and 2000-2007). The Exclusive Flood Control Zone in the Oahe reservoir was used in 1975, 1984, 1986, 1995, 1996, 1997, 1999, 2010, 2011 and 2018. The record elevation of 1619.7 feet was experienced in 2011, when the Oahe pool occupied 2.7 feet of the 3-foot Exclusive Flood Control Zone. The Oahe reservoir is the second largest Corps reservoir and the fourth largest reservoir in the U.S. with just under 23 MAF of storage capacity at elevation 1620 feet, the top of its Exclusive Flood Control Zone. When full (at the base of the Annual Flood Control and Multiple Use Zone), the reservoir is 231 miles long and has 2,250 miles of shoreline.

2-03.4. Construction of Big Bend Dam – Lake Sharpe. Big Bend Dam is located on the Missouri River at RM 987, near Fort Thompson, SD and about 20 miles upstream from Chamberlain, SD. The Big Bend reservoir (Lake Sharpe) extends 80 miles upstream to the vicinity of the Oahe dam. Big Bend is a run-of-the-river project. Regulation of releases are limited almost entirely to daily and weekly hydropower-peaking operations within a narrow band of elevations. Construction began in 1959 with closure in July 1963. The first hydropower unit was placed on line in October 1964 and the last of the eight units began operation during July 1966. Since full operation began, the reservoir has been held very near the normal operating elevation of 1420 feet. A maximum reservoir elevation of 1422.1 feet, 0.1 foot into the Exclusive Flood Control Zone, occurred in June 1991.

2-03.5. Construction of Fort Randall Dam – Lake Francis Case. Fort Randall Dam is located on the Missouri River at RM 880, about 6 miles south of Lake Andes, SD. The Fort Randall reservoir (Lake Francis Case) extends to the Big Bend dam. Construction of the project was initiated in August 1946, closure was made in July 1952, initial power generation began in March 1954, and the project reached an essentially complete status in January 1956 when the eighth and final unit of the 320,000-kilowatt installation came into service. The reservoir filling was initiated in January 1953 and reached the minimum operating pool elevation of 1320 feet on November 24, 1953. The maximum reservoir elevation of 1374.0 feet, 1.0 foot below the top of the Exclusive Flood Control Zone, was experienced in July 2011.

2-03.6. Construction of Gavins Point Dam – Lewis and Clark Lake. Gavins Point Dam is located on the Missouri River at RM 811 on the Nebraska-South Dakota state border, 4 miles west of Yankton, SD. The Gavins Point reservoir (Lewis and Clark Lake) extends 37 miles to the vicinity of Niobrara, NE. Construction was initiated in 1952 and closure was made in July 1955, with initial power generation beginning in September 1956. The third and final unit of the 100,000-kilowatt installation came into service in January 1957. Like Big Bend, Gavins Point is considered a run-of-the-river project. The Gavins Point reservoir has a small amount of flood control storage, but that storage is generally used for short-term storage of local tributary runoff, primarily the Niobrara River. Gavins Point is the lowermost of the six Missouri River mainstem projects or System. Thus, Gavins Point releases are sometimes referred to as “System” releases.

Missouri River Basin
Mainstem Reservoir System
Master Water Control Manual

III - Basin Description and Characteristics

3-01. General Characteristics. The Missouri River extends 2,619 miles from its source at Hell Roaring Creek and 2,321 miles from Three Forks, MT where the Jefferson, Madison and Gallatin Rivers converge in southwestern Montana, near the town of Three Forks. The Missouri River is the longest river in the United States. The Missouri River flows generally east and south about 2,321 miles to join the Mississippi River just upstream from St. Louis, MO. The Missouri River basin has a total drainage area of 529,350 square miles, including about 9,700 square miles in Canada. The portion of the basin within the United States extends over one-sixth of the Nation's area, exclusive of Alaska and Hawaii. It includes all of Nebraska; most of Montana, Wyoming, North Dakota, and South Dakota; about half of Kansas and Missouri; and smaller parts of Iowa, Colorado, and Minnesota. Plate III-1 shows a map depicting the shape of the Missouri River basin and identifying the location of the six System projects: Fort Peck, Garrison, Oahe, Big Bend, Fort Randall and Gavins Point, including the major streams and tributaries.

3-01.1. Channel Slope. The slope of the entire 2,321-mile long Missouri River averages 1.5 feet per mile. The slope ranges from 4.3 feet per mile from Three Forks, MT (head of the Missouri River) to above the falls at Great Falls, MT, 3.7 feet per mile from below the falls to Zortman, MT (near the headwaters of the Fort Peck reservoir), 1.1 feet per mile from Zortman to the confluence of the Missouri and Yellowstone Rivers, and 0.9 foot per mile from the Yellowstone-Missouri confluence to the mouth at St. Louis, MO**.**

3-01.2. Elevation Range. Grays Peak in Colorado, which is the highest point on the Continental Divide, is located near the headwaters of the Platte River. At an elevation of 14,270 feet, Grays Peak is the highest point in the Missouri River basin. The lowest elevation in the basin is 405 feet and is near the confluence of the Missouri River with the Mississippi River at St Louis, MO. The elevation of the Missouri River streambed near Toston, MT, which is about 20 river miles downstream of Three Forks, is approximately 3,905 feet.

3-02. Topography. The Rocky Mountains form the Missouri River basin's western boundary. The Rocky Mountains have an exceptionally rugged topography, with many peaks surpassing 14,000 feet in elevation. The Rocky Mountains in the Missouri River basin extend over an area of about 51,000 square miles. The 51,000-square mile area contains many narrow valleys, but the peaks and mountain spurs dominate the area. Plates III-1 and III-2 show the topographic features that are discussed in the following sections.

3-02.1. Plains. Sloping eastward from the Rocky Mountains, the Great Plains form the heartland of the Missouri River basin. This broad belt of highlands covers approximately 370,000 square miles. The eastern boundary lies along the 1,500-foot contour. The western boundary at the foot of the Rocky Mountains averages about 5,000 feet in elevation. West-to-east slopes average about 10 feet per mile. South and west of the Missouri River, the surface mantle and topography have been developed largely by erosion of a fluvial plain extending eastward from the mountains. North and east of the Missouri River, and even extending south of the Missouri River in some places, the Great Plains has been affected by continental glaciation. The topography in this area of the basin was shaped primarily by erosion of the glacial drift and till. Within the Great Plains, isolated mountainous areas were developed by erosion of dome-like uplifts. Principal among these uplifts are the Black Hills of western South Dakota and northeastern Wyoming, which extend over an elliptical area 60 miles wide and 125 miles long.

3-02.2. Central Lowlands. The Central Lowlands border the Great Plains to the east, and often there is no perceptible line of demarcation between them. The Central Lowlands extend roughly from a line between Jamestown, ND, and Salina, KS, eastward to the drainage divide between the Missouri and Mississippi Rivers. This entire area of 90,000 square miles was developed by erosion of a mantle of glacial drift and till. Coarser drift material covers the northern portion, while the finer till and loess is dominant in the southern portion.

3-02.3. Ozark Plateau. In the southeastern part of the Missouri River basin in southern Missouri, an area of about 11,000 square miles of the basin lies in the Ozark Plateau. The topography in this area was developed by erosion of the Ozark uplift and is hilly to mountainous. Sedimentary formations with great depth underlie the moderate uplift and only sedimentary rocks are left exposed. The basic surface material is limestone, and cavernous channels with spring flows abound in the area.

3-03. Geology and Soils. The Missouri River basin has a very diverse range of geology and soils. The geological history of the basin begins with the Precambrian Era, the oldest, and extends to the Cenozoic Era, the most recent. Many unique and rare geology formations are located in the Missouri River basin. The tectonic processes that formed the Rocky Mountains, the western border of the basin, are still active and continue to be present (e.g., volcanic activity) in Yellowstone Park. Plate III-2 shows the different types of surficial geology deposits within the Missouri River basin. This map also identifies the basin's seven physiographic provinces.

3-04. Sediment. In its pre-dam (mainstem or tributary) or natural state, the Missouri River transported a sediment load averaging 25 million tons per year in the vicinity of Fort Peck, MT; 150 million tons per year at Yankton, SD; 175 million tons per year at Omaha, NE; and approximately 250 million tons per year at Hermann, MO, near its confluence with the Mississippi River. With the construction of the six System and multiple federal and non-federal tributary dams, the reservoirs behind each dam has acted as a catchment for the tremendous load of sediment carried by the Missouri River and its tributaries. The latest survey data for the System reservoirs include 2007 for Fort Peck; 2012 for Garrison; 2010 for Oahe; 2012 for Big Bend; 2011 for Fort Randall; and 2011 for Gavins Point. Analysis of the data by the Omaha District River and Reservoir Engineering Section indicate that sediment deposition averages 76,000 acre-feet annually and this is distributed within the mainstem System:

Fort Peck	17,180 acre-feet/year
Garrison	21,640 acre-feet/year
Oahe	14,800 acre-feet/year
Big Bend	3,445 acre-feet/year
Fort Randall	15,780 acre-feet/year
Gavins Point	2,660 acre-feet/year

The loss of System reservoir storage capacity is currently approaching 6 percent of the original total System storage. Refer to Section H-08 of Appendix H of this manual for additional information regarding sediment deposition in the System reservoirs. The sediment deposition location varies within each reservoir. Sediment that deposits in the upper portion of a reservoir, or the headwaters, forms a delta over time. Large tributaries that enter the reservoir with their own sediment load will form secondary deltas with the tributary input reservoir arm. As sediment continues to deposit, the delta grows and transports material further into the reservoir. Coarse sediments deposit first and fine sediments are transported further into the reservoir. Sediment deposition results in a corresponding loss of reservoir storage capacity. Multiple storage zones in the reservoir are impacted by different sediment deposition rates. Factors such as reservoir pool level, the entering sediment load, and the sediment material size all affect the variability in the sediment deposition rate and location within the reservoir.

3-04.1. Shoreline Erosion. In addition to sediment transported to the reservoirs by the Missouri River and its tributaries, some sediment enters the System reservoirs due to shoreline erosion. Reservoir shorelines are highly erodible because the river valley slopes are terraced and the soils consist of erodible sands, silts, clays, gravels and shales. The thousands of miles of reservoir shoreline in the System reservoirs remain largely unprotected, primarily because the cost of shoreline protection is very high. Shorelines consisting of highly erodible soils, and subjected to wave and ice action, have experienced accelerated shoreline erosion in the form of slumping cut-banks. Erosion of the shorelines of the System reservoirs is expected to continue throughout the life of the projects. The slumping cut-bank material forms shelves of shallow water along the shorelines. The majority of eroded material usually remains immediately offshore, forming a very flat beach slope. As a result, the perimeters of the reservoirs are slowly becoming shallower and wider. In some cases, sediment moves along the shoreline in the direction of the prevailing wind or current and collects in deeper channels of tributary arms. Some tributary arms are filling with sediment at their mouths and being cut off by these reservoir sediments and collapsing cut-banks.

3-05. Basin Climate. The broad range in latitude, longitude, and elevation of the Missouri River basin and its location near the geographical center of the North American continent results in wide variations in climatic conditions. The climate in the basin is produced largely by interactions of three great air masses that have their origins over the Gulf of Mexico, the northern Pacific Ocean, and the northern Polar Regions. These great air masses regularly influence the weather over the basin throughout the year. The Gulf air mass tends to dominate the weather in summer and the Pacific and Polar air masses dominate during the winter. This seasonal domination by the air masses and the frontal activity caused by their collisions produce the general weather regimes in the basin. As is typical of a continental-interior plains area, the variations from normal climatic conditions, from season to season and from year to year, are very great. Several extreme events have occurred in the period of record from the severe plains area drought of the 1930s when above-average summer temperatures and below-average precipitation prevailed for more than a decade to a high mountains snowpack with periods of heavy spring rainfall resulting in record flooding for numerous rivers across the basin in 2011.

3-05.1. Precipitation. Average annual precipitation ranges from as low as 8 to 10 inches just east of the Rocky Mountains to more than 40 inches in the southeastern part of the Missouri River basin and in parts of the Rocky Mountains. The pattern of average annual precipitation for the basin is shown on Plate III-3. The monthly average precipitation is shown on Plates III-4 through III-15. Prolonged droughts of several years' duration and frequent shorter periods of deficient moisture, interspersed with periods of abundant to excessive precipitation, are characteristic of the Great Plains.

3-05.1.1. Cyclonic Activity. Deep cyclones (low-pressure systems) and accompanying frontal systems moving from the southern Great Plains states toward the northeast can cause widespread precipitation over the basin during all seasons of the year. This is due to the resulting influx of moist tropical air from the Gulf of Mexico. Cyclonic activity over the basin is at a maximum during the late winter and spring months. The cyclonic activity decreases to a minimum during the late summer and early fall months when the majority of precipitation results from air mass thunderstorms and orographic activity. The moisture-carrying ability of an air mass is dependent on the temperature of the air mass and is normally at a maximum at mid-summer and at a minimum in mid-winter. The combination of moderate cyclonic activity and increased air mass moisture content that occurs during the spring and early summer months results in the normal seasonal precipitation maximum being observed throughout the basin during that time. Plates III-7 through III-10 illustrate the distribution of precipitation in the Missouri River basin for the months of April, May, June and July, respectively. April is a transition month with mountainous areas, and occasionally the northern plains, still in the grip of winter at the start of the month. The lower basin is typically well into spring by late April. For most of the basin, May is the wettest month, with southeast Nebraska, southern Iowa, eastern Kansas, and Missouri receiving more than 6 inches of precipitation during an average year. July marks the start of dry weather for the inner-mountain deserts of Wyoming and southern Montana.

3-05.1.2. Summer Precipitation. Precipitation during the summer and early fall months is usually of the short-duration thunderstorm type with small centers of high intensity. However, widespread general rains will occasionally occur, especially in the lower basin. In the areas around Denver, CO, a weak monsoonal moisture flow begins along the Front Range of the Rockies in Colorado by mid-July, which adds to precipitation amounts during July and August. The monsoonal season, however, can begin as early as June and extend well into September. Precipitation amounts during the months of August through October are generally less than those observed during the late spring and early summer for most of the basin, as noted on Plates III-11 through III-13.

3-05.1.3. Winter Precipitation. Winter precipitation usually results from the passage of well-developed low-pressure systems and active fronts. This precipitation occurs in the form of snow in the northern and central portions of the basin; however, it may occur in the lower basin as either rain or snow or a mixture of both. Winter precipitation depths are, in general, considerably less than during other seasons of the year. This is due to the decreased moisture-carrying ability of the colder air masses and the barrier imposed by the Rocky Mountains to the westerly circulation that generally prevails through this season. The dry conditions are noted on Plates III-14 and III-15 for November and December, respectively, and Plates III-4 through III-6 for January, February and March, respectively. Normally, the basin has fairly frequent and light winter snows, interspersed with a few heavy storms. The average annual snowfall over the Great Plains increases from south to north. It ranges from about 12 inches in parts of the lower basin to more than 36 inches in North Dakota and to more than 48 inches in the high plains areas in the west (see Plate III-16). High elevation stations in the Black Hills and in the Rockies along the western edge of the basin receive in excess of 72 inches of snowfall in many years. By late May, snow depths up to 6 feet, with a water equivalent of approximately 2 feet, are not uncommon at mountain locations. Snow does not usually progressively accumulate over the central plains, but is melted by intervening thaws. The northern plains, however, has accumulated snow into the spring, especially when snow that accumulated on the ground by the end of winter had water equivalent of 3 inches or more in the season. A map of maximum seasonal snowfalls encountered during the period 1981 to 2010 is shown on Plate III-17. Maps of maximum and minimum annual snowfall totals observed in the basin since 1890 is shown on Plate III-18 and Plate III-19, respectively. The data for Plates III-18 and III-19 are not a continuous record.

3-05.2. Temperature. Because of its mid-continent location, the basin experiences large temperature fluctuations and extremes. Winters are relatively cloudy and cold over much of the basin, while summers are fairly warm to hot. Spring is normally cool, humid and windy, while autumn is normally cool and dry. Temperature extremes range from winter lows of near -50° Fahrenheit (F) in Montana and North Dakota to summer highs of near 115°F in South Dakota, Nebraska and Kansas. Parts of the basin regularly experience maximum temperatures above 100°F in the summer and minimums below -25°F in the Rocky Mountains and on the plains of Montana and North Dakota. The temperature variability of the Missouri River basin is shown on Plates III-20 through III-23.

3-05.3. Evaporation. Average annual reservoir evaporation in the Missouri River basin varies from less than 2 feet in the western Rocky Mountains to over 6 feet in the plains area of western Kansas. Evaporation from the System reservoirs averages about 3 feet annually. For smaller reservoirs whose surface temperatures approximate air temperatures, most evaporation occurs during the April through October period. Due to the large size of the System reservoirs, there is a considerable time lag between air temperatures and surface water temperatures. Also, because precipitation over the System reservoirs is normally at a maximum during the April-June period, net evaporation (evaporation less precipitation) is concentrated almost entirely in the July-December period. Normal annual net evaporation averages about 20 inches for the System as a whole, ranging from about 25.5 inches at Fort Peck to nearly 17 inches at Gavins Point. Plate III-24 shows the net reservoir evaporation for the System projects.

3-05.4. Wind. Due to its mid-continent location, most extreme winds are caused by frontal passages and severe thunderstorm activity. While tornadoes produce the greatest wind speeds, they are short-lived and localized and thus have little effect on reservoir elevation. Hurricanes do not reach the Missouri River basin, although cyclonic remnants of tropical storms occasionally reach the southern portions of Kansas and Missouri. On most reservoirs, winds capable of damaging riprap and eroding shorelines are those in excess of 45 miles per hour that are sustained for periods of an hour or more. In addition to generating significant waves with heights of 6 feet or more, sustained winds of that magnitude cause noticeable reservoir set-up or set-down, particularly when the winds blow along the long fetch of a shallow reservoir. Wind conditions at five of the System reservoirs (no wind data is collected at Oahe) are monitored using anemometers on automated weather stations operated by the Corps. Real-time regional weather data can be accessed from the National Weather Service (NWS) via the Internet. See Chapter VI of the individual WCMs for additional detail regarding wind effects on reservoir water surface elevations.

3-06. Basin Storm Potentialities and Major Basin Floods. Due to the extensive size of the Missouri River basin, there is a significant seasonal variability to the location of heavy rainfall events. Flood-producing storms in the plains area of the upper basin and in the northern Rockies are generally constricted to the period from May through August, whereas the central Rockies, Nebraska, and Iowa can expect occasional rainfall-induced flooding from April through October. Due to a closer proximity to moisture availability, the lower basin from Rulo, NE downstream across Kansas and Missouri has the potential to experience regional flooding year-round. Most major flooding basin-wide, however, is a combination of mountain snowmelt, plains snowmelt, and rainfall and typically occurs between April and June. By month, June has had the greatest number of occurrences. In some areas of the country, surface dew-point temperatures are used as an index for the amount of moisture in a warm air mass from which precipitation falls. The source of moisture for all major storms in the basin is the Gulf of Mexico. Based on moisture potentialities alone, major storms would be most probable in late July or early August because normal and maximum recorded air mass moisture is the greatest during these months. Major storms throughout the Missouri River basin, however, result almost exclusively from conditions accompanying frontal systems. Since frontal passages are more numerous and more severe in May and June than in the middle of summer, major storms occur more frequently in late spring and early summer than at the time of maximum moisture charges in late July or early August.

3-06.1. Major Storms. Major storms do not provide a complete index to the probability of flood flows within the basin. Minor storms also may satisfy the infiltration capacities that exist in the basin, resulting in any additional rainfall contributing much larger volumes to streamflow than would have been the case if the ground had been relatively dry prior to the larger storm. Because of this, a continuing sequence of smaller storms, which may occur at any time of the year over portions of the basin, can also result in severe flooding. During the winter months, successive minor storms in the upper basin often result in a sufficient snow accumulation to cause the greatest flows of the year when the snow accumulation melts and appears as streamflow.

3-06.2. Missouri River Floods. Many instances of above-bankfull flows were experienced through the reach from Fort Peck to the Platte-Missouri River confluence below Omaha, NE prior to System regulation. Since regulation of System commenced, there would have been many more flood occurrences were it not for the upstream regulation. Regulation provided by the System, augmented by upstream tributary reservoir storage, has greatly reduced significant flood flows on the Missouri River in this reach. Still, the System has not created a flood-free zone along the Missouri River for all conditions. Downstream of the Platte-Missouri River confluence, the incremental drainage area is of sufficient size that above-bankfull Missouri River stages can continue to be expected. This is primarily a result of runoff from major storms over the unregulated tributary watershed areas downstream of the System.

3-06.2.1. All major runoff events experienced in the upper basin except one have occurred in the March-July season, with snowmelt as an important flood component. The one exception occurred in 1923 when a large September rainstorm in southern Montana and northern Wyoming resulted in an early October Missouri River flood. During the 1923 flood, estimated Missouri River peak flows exceeded 100,000 cfs at Pierre, SD and at all Missouri River locations between Pierre and the Yellowstone-Missouri River confluence. In the lower basin, floods have followed the same seasonal pattern observed in the upper basin; however, damaging floods have occasionally occurred prior to or following the normal March-July flood season, due mainly to heavy rainfall downstream of the System. Peak stage and flow data for past major Missouri River floods are summarized in Appendix A of this manual. Significant flood occurrences, with specific causative factors, are also discussed in Appendix A.

3-07. Runoff Characteristics. Runoff into, and downstream from, the System varies in terms of the geographic distribution and seasonal fluctuation of the inflows. The distribution of streamflow in combination with extreme seasonal variation results in significant change. This variability requires a System water control plan that is very flexible to allow the Corps to meet the water resources mission and regulate the System to meet the operational objectives stated in this manual. Because the Missouri River basin is so large, individual project basin descriptions and modeling parameters are provided in the six individual project WCMs, Volumes 2 through 7, as described in Section 1-02 of this manual. Some general information is provided in the following sections.

3-07.1. Drainage Pattern. The drainage pattern of the Missouri River basin and the locations of all of the federal tributary projects in the basin are shown on Plate III-25. The three significant Missouri River tributaries are: the Yellowstone River, which drains an area of over 70,000 square miles and enters the Missouri River near the Montana-North Dakota state boundary; the Platte River, which has an 85,000-square mile drainage area that enters the Missouri River in eastern Nebraska; and the Kansas River, which empties into the Missouri River near Kansas City, MO and drains an area of approximately 60,000 square miles. The most prominent feature of the drainage pattern of the upper (above Fort Peck Dam) and middle (Fort Peck Dam to Gavins Point Dam) portions of the Missouri River basin is that every major tributary, with the exception of the Milk River, is a right bank tributary flowing to the east or to the northeast. Only in the lower basin, below Gavins Point Dam, is a fair balance reached between left and right bank tributaries. The direction of flow of the major tributaries is of particular importance from the standpoint of potential concentration of flows from storms that typically move in an easterly direction. The direction of flow is also important for another reason on the Yellowstone River because early spring temperatures in the western Yellowstone River basin in Montana range normally from 8 to 12°F higher than along the northernmost reach of the Missouri River near Williston, ND. This often results in ice break-up on the Yellowstone River prior to the time the ice breaks up on the main stem of the Missouri River, thereby contributing to ice-jam flooding on the downstream reaches of the Yellowstone River and the Missouri River upstream from the Garrison reservoir.

3-07.2. Streamflow Records. The collection of systematic and continuous stage and discharge records by the U.S. Geological Survey (USGS) in cooperation with the states, the Corps, and other agencies over most of the Missouri River basin has developed over the past three decades. Discharge records for stations on the Missouri River at Craig, Cascade and Fort Benton, MT are available since 1890, 1902 and 1910, respectively, and for the Yellowstone River at Glendive, MT since 1898. Some records were obtained on the Missouri River at Williston, ND during 1905 through 1907; at Bismarck, ND during 1904-05; and at Kansas City, MO during 1905 and 1906. Aside from these, streamflow measurements at the present stations on the main stem of the Missouri River were not initiated until 1928. However, daily stage records for many of the Missouri River stations began in the 1870s. Systematic and continuous stage-discharge measurements at scattered tributary locations began much earlier than on the main stem, with some tributary records beginning in the early 1900s. Only a few locations have records prior to 1900.

3-07.2.1. During planning studies of the System in the 1940s, extension of the Missouri River discharge data prior to 1928 was considered to be essential. Accordingly, comprehensive studies were made and monthly streamflow data developed for selected stations through the period extending from 1898 to the initiation of the expanded streamflow measurement program that began in 1928. Because water use for all purposes has expanded significantly since settlement of the basin first began, adjustment of the records to represent a common level of water resource development was also considered necessary so that the flow data would be directly comparable from year to year. While any development level would have been satisfactory, the 1949 level was selected because it was just before the accelerated resource development that occurred in the Missouri River basin during the 1950s. Records accumulated since then have also been adjusted to the 1949 level for comparability purposes.

3-07.3. Tributary Streamflow Characteristics. Tributary streamflow characteristics vary widely across the basin depending on the location and source/type of associated runoff. Mean annual runoff in terms of depth not only varies drastically throughout the Missouri River basin, but can vary drastically on the same tributary. For example, in the mountainous areas of the upper Yellowstone River in western Montana, mean annual direct runoff depths of 20 inches will occur. Conversely, areas of Yellowstone River basin that are in the plains area of eastern Montana may experience mean annual direct runoff depths of less than an inch.

3-07.3.1. Rocky Mountain Area. Streams emanating from the Rocky Mountains are fed by snowmelt, are clear flowing, have steep gradients, and have cobble-lined channels. Stream valleys often are narrow in the mountains and widen out as they emerge from the mountains onto the out-wash plains. Mean annual runoff in terms of depth from the mountainous areas is high, exceeding 20 inches in some areas along the Continental Divide. Flood flows in this area are generally associated with the mountain snowmelt period occurring in May and June. Occasionally, summer rainfall floods with high, sharp peaks occur in the foothills areas.

3-07.3.2. Plains Area. Streams flowing across the plains areas of Montana, Wyoming and Colorado have variable characteristics. The larger streams with tributaries originating in the mountain areas carry sustained spring and summer flows from mountain snowmelt and have moderately broad alluvial valleys. Streams originating locally often are wide and sandy-bottomed, experience intermittent flows, and are subject to high-peak rainfall floods. Mean annual runoff depths from this upper plains area is low and variable, normally ranging from 0.25 to 0.50 inch event totals; however, convective storms in the spring and summer can produce larger runoff depths in localized areas. Streams in the plains region of the Dakotas, Nebraska, and Kansas, with the exception of the Nebraska Sandhills area, generally have flat gradients and broad valleys. Except for the Platte River, most of the streams originate in the area and are fed by plains snowmelt in the early spring and occasional rainfall runoff throughout the warm season. Streamflow is erratic. Stream channels are small for the size of the drainage areas involved and the flood potentials are high. When major rainstorms occur in the tributary area, streams are forced out of their banks onto the broad floodplains. Mean annual runoff is low, with runoff depths ranging from as little as 0.25 to 2 inches. In many of these streams there may be no flow during drought periods. During periods of high flow the streams generally are turbid and carry large suspended sediment loads.

3-07.3.3. Sandhills Area. Streams originating in the Nebraska Sandhills, such as the Loup and Niobrara Rivers, are steady flowing, with much of the flow attributable to groundwater accretions. Floods are rare because initial and constant infiltration rates are much higher than other areas of the Missouri River Basin. Only a very small part of the Sandhills area contributes direct-flow runoff. The streams carry heavy loads of sand sediments, although they are relatively low in silt and colloidal sediments. Runoff, as measured streamflow, is higher than generally found in the adjoining plains areas, with depths ranging up to 4 inches.

3-07.3.4. Eastbank Streams. Streams in the region east of the Missouri River have variable characteristics. Those in the Dakotas, such as the Big Sioux and James Rivers, are meandering streams with extremely flat gradients and very small channel capacities in relation to the areas drained. Drainage areas generally are covered with glacial drift, are extremely flat, and contain many pothole lakes and marshes. Rainfall in the spring often combines with the annual plains snowmelt to produce floods that exceed channel capacities and spread onto the broad floodplains. In late summer and fall, flows often drop to zero for extended periods. Streams in the eastern border region of Nebraska, Iowa, Missouri and Kansas drain hard-soiled, hilly lands with relatively steep gradients and narrow valleys. Channels are deep and U-shaped. Flooding caused by high rainfall storms is frequent. Average annual runoff is high, with runoff depths ranging from 2 to 8 inches. Streamflow is generally turbid because of high concentrations of suspended sediments. Streamflow is somewhat more stable than in the plains area to the west, but the flow in many streams often approaches zero in late summer and fall.

3-07.3.5. Ozark Highland Area. Streams in the Ozark Highlands of Missouri resemble mountain streams with their clear, dependable base flows. Much of the area is underlain by limestone and contains cavernous underground springs. The hilly terrain produces high-peak runoff, which contributes to frequent high-peak floods of large volume. Average annual runoff is high, with runoff depths ranging from 10 to 14 inches. High flows generally are experienced every year during the months of March, April, May and June. Flows then normally recede, often to less than 15 percent of their average, during August, September and October. Drainage areas are generally well timbered and sediment yields are normally small.

3-07.4. Missouri River Flow Characteristics. Unregulated Missouri River flows usually follow a definite and characteristic annual pattern, as illustrated by the monthly distribution of streamflow presented on Plate III-26 for Sioux City and St. Joseph. Average flows, in general, increase from January to June and then gradually decrease through December. Historic maximum and minimum monthly mean Missouri River flows at Sioux City are 187,000 cfs in April 1952 and 3,700 cfs in January 1940, respectively. At Kansas City, corresponding Missouri River flows are 301,000 cfs in June 1908 and 5,000 cfs in January 1940. The “regulated” graph on Plate III-26 and the data provided in Tables III-1 through III-5 illustrate the major changes in the monthly streamflow distribution that have occurred as a result of reservoir regulation. Table III-1 illustrates the extreme daily values since the System became operational, while the seasonal tables, Tables III-2 through III-5, show the distribution of flow according to the maximum and minimum monthly average flows. Although the general pattern of summer flows being higher than winter flows still prevails, System regulation serves to reduce high spring and summer flows in most years and to release the stored water to increase flows during the low-water fall and winter periods.

3-07.4.1. Winter Period. In the upper portions of the Missouri River basin, winter is characterized by frozen streams, a progressive accumulation of snow in the mountain areas, and intermittent snows and thaws in the plains areas. The winter 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 in the winter, which usually extends from late November into March, is low. In the lower basin, milder temperatures prevail during the winter months and considerable precipitation may occur in the form of rain or snow, which melts rapidly and contributes immediately to streamflow. This may occasionally result in substantial flows in this region, although winter runoff is usually quite low due to the relatively light amounts of precipitation that usually occurs in this season. Intermittent freeze-up and break-up of river ice on both the Missouri River main stem and the tributaries are common in the lower basin.

3-07.4.2. Early Spring Period. Early spring is marked by the rapid melting of snow and ice accumulations in the northern plains area, usually in March or April but sometimes as early as February, ordinarily accompanied by very little rainfall. This results in the characteristic early spring ice break-up and an increase in streamflow, which is known as the early spring rise, or "March rise." Flood crests in the upstream reaches are flashy, particularly when associated with relatively sudden releases of ice jams. Ice jams are particularly severe in the Dakotas and on the lower Yellowstone River in Montana. The highest peak stages of record on the Missouri River above the mouth of the Kansas River through the Dakotas have resulted from the spring break-up creating ice jam floods. Snowmelt in the mountains usually begins during this period, but contributes little to runoff until later in the year. Flows originating in the middle Missouri River basin are generally from plains snowmelt, but can be augmented by rainfall in the lower basin, sometimes resulting in flood flows in the lower Missouri River reaches.

3-07.4.3. Late Spring and Early Summer. Late spring and early summer are characterized by extensive rains over large areas of the basin, accompanied by occasional and severe local rainstorms and rapid melting of the mountain snowpack. Peak runoff from these sources usually occurs in late May, June, or the first part of July. This results in the characteristic late spring rise, or "June rise," with peak discharges above Sioux City (except in the headwaters) usually less and volumes of runoff usually greater than during the early spring rise. A short interlude of Missouri River and tributary streamflow is normally experienced between the early spring and late spring rises. Occasionally, runoff from severe rainstorms in the upper plains area synchronizes with the high runoff from mountain snowmelt and general rainfall in the plains during this period. Runoff from rainstorms in the lower Missouri River basin during the months of May, June and July can result in very severe Missouri River and tributary flooding below Sioux City, IA.

3-07.4.4. Late Summer and Fall. Late summer and fall are generally characterized by diminishing general rainfall, fairly frequent, intense, and widely scattered local rainstorms, and occasionally, severe storms. Missouri River flow in the upper basin normally decreases rapidly in late July once the mountain snowpack has melted. Tributary flows decrease gradually, with an occasional rise, to the levels experienced during the winter period. Very severe floods have occurred on tributaries during this period. See Section 3-06.2.1 of this manual for a description of the 1923 flooding event that occurred during this period. However, there are no records of severe storms in this period having produced floods on the upper Missouri River anywhere near the magnitude of the fairly frequent early spring or late spring floods. Runoff originating in the lower basin usually decreases, although several large floods have occurred on the lower Missouri River due to severe floods emanating from the tributaries.

3-07.4.5. Mississippi River. The Mississippi River could be adversely affected by reservoir regulation in the upper Missouri River basin. High flows and stages on the Mississippi River, particularly below the confluence with the Ohio River, may be expected any time from January through July. Since the late 1800s, the greatest Mississippi River floods have occurred in February and during the April to August period. High Missouri River flows in the lower basin have occurred in winter, but the primary Missouri River flood season extends from April through July. The 1993 Missouri River flood occurred in July and exacerbated flooding on the Mississippi River. Runoff from the Missouri River basin during the early spring and late spring flood periods could, therefore, contribute substantially to lower Missouri and Mississippi River floods. From August to December, both the lower Missouri and Mississippi Rivers are usually characterized by low flows, much the same as the upper Missouri River; however, large storms or a sequence of lesser storms over the lower Missouri and Mississippi Rivers during this period have occasionally resulted in severe flooding.

3-07.5. Missouri River Sediment Characteristics. See Section 3-04 of this manual for details on reservoir capacity depletion and the corresponding Missouri River basin sediment loads to each System project. With the construction of each of the System dams, beginning with the closure of Fort Peck Dam in 1936, the sediment entering each of the respective reservoirs was trapped. The flow released from the reservoirs was clear and essentially free from sediment. Clear water releases from the reservoirs have excess energy available to transport sediment, which resulted in the creation of a channel degradation reach downstream of each System dam. Reservoir sediment trapping has affected the sediment transport rate and sediment size downstream of each System dam. Analysis of the sediment transport in the Missouri River at Omaha, NE shows that the sediment load presently is composed of about 70 percent sand-size material; whereas, the sand-size material was only about 30 percent of the total sediment load prior to closure of the upstream dams and armoring of the channel bank below Sioux City during construction of the Missouri River Bank Stabilization and Navigation Project (BSNP). Subsequent to the closure of Fort Randall Dam in 1952, the total Missouri River suspended sediment load at Omaha has been relatively consistent at approximately 20 to 25 million tons per year, versus the prior to dam construction previous long-term average of 175 million tons per year. At the mouth of the Missouri River near St. Louis, the total suspended sediment load now is about half the load experienced prior to closure of the System and tributary dams.

Table III-1
Annual Runoff Characteristics at Key Control Points Since System Closed

Key Control Point	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	160,000	1,000	10,000	1968 - 2017
Fort Peck Release - Fort Peck, MT	65,900	0	9,100	1968 - 2017
Missouri River at Wolf Point, MT	90,600	2,800	9,760	1968 - 2017
Missouri River at Culbertson, MT	97,200	2,800	10,100	1968 - 2017
Garrison Calculated Inflow	190,000	1,000	22,900	1968 - 2017
Garrison Release - Riverdale, ND	150,600	0	21,600	1968 - 2017
Missouri River at Bismarck, ND	154,000	8,660	23,200	1968 - 2017
Oahe Calculated Inflow	210,000	500	25,300	1968 - 2017
Oahe Release - Pierre, SD	160,300	0	24,000	1968 - 2017
Big Bend Calculated Inflow	195,000	0	23,900	1968 - 2017
Big Bend Release - Ft. Thompson, SD	166,300	0	23,500	1968 - 2017
Fort Randall Calculated Inflow	218,000	0	25,300	1968 - 2017
Fort Randall Release - Pickstown, SD	160,000	0	24,900	1968 - 2017
Missouri River at Verdel, NE	stage only station			
Gavins Point Calculated Inflow	168,000	2,000	27,600	1968 - 2017
Gavins Point Release – Yankton, SD	160,700	6,000	27,500	1968 - 2017
Missouri River at Sioux City, IA	189,000	5,060	31,600	1968 - 2017
Missouri River at Omaha, NE	212,000	5,460	36,100	1968 - 2017
Missouri River at Nebraska City, NE	221,000	5,200	42,900	1968 - 2017
Missouri River at Rulo, NE	302,000	7,450	46,200	1968 - 2017
Missouri River at Kansas City, MO	529,000	6,690	58,900	1968 - 2017
Missouri River at Waverly, MO	611,000	9,000	61,000	1968 - 2017
Missouri River at Jefferson City, MO	stage only station			
Missouri River at Boonville, MO	721,000	11,000	72,100	1968 - 2017
Missouri River at Hermann, MO	739,000	13,900	92,200	1968 - 2017

Table III-2
Plains Snowmelt (March, April and May) Flows Since System Closed

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	46,100	4,600	12,400	1968 - 2017
Fort Peck Release - Fort Peck, MT	18,700	3,200	8,000	1968 - 2017
Missouri River at Wolf Point, MT	26,100	4,400	9,410	1968 - 2017
Missouri River at Culbertson, MT	32,800	4,760	10,200	1968 - 2017
Garrison Calculated Inflow	88,200	10,200	26,300	1968 - 2017
Garrison Release - Riverdale, ND	50,700	9,000	19,900	1968 - 2017
Missouri River at Bismarck, ND	51,100	10,400	22,100	1968 - 2017
Oahe Calculated Inflow	68,700	11,900	28,600	1968 - 2017
Oahe Release - Pierre, SD	53,000	1,200	20,400	1968 - 2017
Big Bend Calculated Inflow	54,900	1,600	20,700	1968 - 2017
Big Bend Release - Ft. Thompson, SD	53,800	2,100	20,500	1968 - 2017
Fort Randall Calculated Inflow	60,200	5,200	23,400	1968 - 2017
Fort Randall Release - Pickstown, SD	57,000	3,500	20,700	1968 - 2017
Missouri River at Verdel, NE	stage only station			
Gavins Point Calculated Inflow	59,600	9,700	24,400	1968 - 2017
Gavins Point Release - Yankton, SD	59,500	10,100	24,300	1968 - 2017
Missouri River at Sioux City, IA	88,000	11,500	31,300	1968 - 2017
Missouri River at Omaha, NE	93,800	14,100	37,100	1968 - 2017
Missouri River at Nebraska City, NE	100,000	18,800	46,700	1968 - 2017
Missouri River at Rulo, NE	106,000	21,200	51,100	1968 - 2017
Missouri River at Kansas City, MO	149,000	24,700	67,900	1968 - 2017
Missouri River at Waverly, MO	168,000	24,300	70,600	1968 - 2017
Missouri River at Jefferson City, MO	stage only station			
Missouri River at Boonville, MO	235,000	28,200	87,700	1968 - 2017
Missouri River at Hermann, MO	333,000	30,900	117,000	1968 - 2017

Table III-3
High Mountain Snowmelt (June, July and August) Flows Since System Closed

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	61,200	4,100	13,000	1968 - 2017
Fort Peck Release - Fort Peck, MT	52,600	4,700	10,300	1968 - 2017
Missouri River at Wolf Point, MT	70,500	5,800	10,900	1968 - 2017
Missouri River at Culbertson, MT	73,900	5,950	11,100	1968 - 2017
Garrison Calculated Inflow	144,600	7,600	33,100	1968 - 2017
Garrison Release - Riverdale, ND	136,600	11,100	25,200	1968 - 2017
Missouri River at Bismarck, ND	138,000	11,700	27,000	1968 - 2017
Oahe Calculated Inflow	147,500	14,200	28,700	1968 - 2017
Oahe Release - Pierre, SD	144,200	3,300	30,300	1968 - 2017
Big Bend Calculated Inflow	143,000	4,800	29,800	1968 - 2017
Big Bend Release - Ft. Thompson, SD	142,100	4,200	29,400	1968 - 2017
Fort Randall Calculated Inflow	157,000	6,000	31,600	1968 - 2017
Fort Randall Release - Pickstown, SD	156,000	2,600	31,900	1968 - 2017
Missouri River at Verdel, NE	stage only station			
Gavins Point Calculated Inflow	159,800	8,500	34,300	1968 - 2017
Gavins Point Release - Yankton, SD	159,700	8,000	33,900	1968 - 2017
Missouri River at Sioux City, IA	181,000	20,200	39,000	1968 - 2017
Missouri River at Omaha, NE	193,000	26,800	44,600	1968 - 2017
Missouri River at Nebraska City, NE	208,000	28,000	51,800	1968 - 2017
Missouri River at Rulo, NE	221,000	29,300	56,300	1968 - 2017
Missouri River at Kansas City, MO	288,000	33,000	72,900	1968 - 2017
Missouri River at Waverly, MO	306,000	33,000	76,000	1968 - 2017
Missouri River at Jefferson City, MO	stage only station			
Missouri River at Boonville, MO	375,000	33,600	87,700	1968 - 2017
Missouri River at Hermann, MO	376,000	37,900	107,000	1968 - 2017

Table III-4
Fall Runoff (September, October and November) Flows Since System Closed

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	17,300	4,400	7,400	1968 - 2017
Fort Peck Release - Fort Peck, MT	23,000	3,000	8,200	1968 - 2017
Missouri River at Wolf Point, MT	24,200	3,130	8,480	1968 - 2017
Missouri River at Culbertson, MT	24,300	3,400	8,640	1968 - 2017
Garrison Calculated Inflow	37,300	7,500	16,700	1968 - 2017
Garrison Release - Riverdale, ND	49,400	9,900	19,700	1968 - 2017
Missouri River at Bismarck, ND	48,200	10,200	21,000	1968 - 2017
Oahe Calculated Inflow	48,600	10,700	21,300	1968 - 2017
Oahe Release - Pierre, SD	67,300	5,300	25,200	1968 - 2017
Big Bend Calculated Inflow	77,600	5,000	25,200	1968 - 2017
Big Bend Release - Ft. Thompson, SD	62,800	4,400	24,400	1968 - 2017
Fort Randall Calculated Inflow	68,900	3,800	24,900	1968 - 2017
Fort Randall Release - Pickstown, SD	80,000	5,400	31,700	1968 - 2017
Missouri River at Verdel, NE	stage only station			
Gavins Point Calculated Inflow	82,500	7,800	33,900	1968 - 2017
Gavins Point Release - Yankton, SD	81,900	7,500	33,700	1968 - 2017
Missouri River at Sioux City, IA	89,000	9,880	36,300	1968 - 2017
Missouri River at Omaha, NE	98,100	12,700	39,700	1968 - 2017
Missouri River at Nebraska City, NE	106,000	16,300	44,400	1968 - 2017
Missouri River at Rulo, NE	113,000	17,800	46,900	1968 - 2017
Missouri River at Kansas City, MO	135,000	20,400	56,600	1968 - 2017
Missouri River at Waverly, MO	142,000	21,300	57,600	1968 - 2017
Missouri River at Jefferson City, MO	stage only station			
Missouri River at Boonville, MO	188,000	22,600	65,900	1968 - 2017
Missouri River at Hermann, MO	287,000	24,800	79,200	1968 - 2017

Table III-5
Winter Runoff (December, January and February) Flows Since System Closed

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	16,200	3,800	7,400	1968 - 2017
Fort Peck Release - Fort Peck, MT	15,200	4,300	10,000	1968 - 2017
Missouri River at Wolf Point, MT	15,800	4,660	10,200	1968 - 2017
Missouri River at Culbertson, MT	17,400	4,700	10,500	1968 - 2017
Garrison Calculated Inflow	31,800	8,400	15,700	1968 - 2017
Garrison Release - Riverdale, ND	33,700	12,900	21,600	1968 - 2017
Missouri River at Bismarck, ND	34,800	13,300	22,900	1968 - 2017
Oahe Calculated Inflow	37,000	12,900	23,100	1968 - 2017
Oahe Release - Pierre, SD	36,100	10,600	19,900	1968 - 2017
Big Bend Calculated Inflow	36,600	10,400	19,600	1968 - 2017
Big Bend Release - Fort Thompson, SD	35,400	10,900	19,500	1968 - 2017
Fort Randall Calculated Inflow	38,400	12,400	21,100	1968 - 2017
Fort Randall Release - Pickstown, SD	32,400	5,900	15,300	1968 - 2017
Missouri River at Verdel, NE	stage only station			
Gavins Point Calculated Inflow	37,500	9,100	17,700	1968 - 2017
Gavins Point Release - Yankton, SD	37,100	9,900	18,000	1968 - 2017
Missouri River at Sioux City, IA	39,900	11,200	19,800	1968 - 2017
Missouri River at Omaha, NE	44,300	13,400	22,700	1968 - 2017
Missouri River at Nebraska City, NE	52,400	14,000	28,400	1968 - 2017
Missouri River at Rulo, NE	63,500	14,700	30,400	1968 - 2017
Missouri River at Kansas City, MO	87,800	16,100	38,000	1968 - 2017
Missouri River at Waverly, MO	90,200	16,600	39,700	1968 - 2017
Missouri River at Jefferson City, MO	stage only station			
Missouri River at Boonville, MO	128,000	20,200	47,100	1968 - 2017
Missouri River at Hermann, MO	203,000	21,600	65,700	1968 - 2017

3-08. Missouri River Basin Land Use. The Missouri River basin's land area totals 529,350 square miles, which is about 338 million acres. As shown on Plate III-27 and Table III-6, land use is distributed among a wide variety of categories.

Table III-6
Missouri River Basin Land Use

Land Type	Area (million acres)	Portion of Missouri River Basin (percent)
Rangeland	126	37.1
Cropland	92	27.1
Forests and woodlands	50	14.7
Shrub land	38	11.3
Developed land	12	3.8
Wetlands	12	3.7
Water	6	1.8
Barren	2	0.5
Total	338	100

3-08.1. Land Treatment Considerations. Throughout the Missouri River basin, farmers have implemented soil conservation practices for many years, and since 1933, the U.S. Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service, has encouraged these practices by providing incentive payments. Various soil conservation projects have been instituted that enhance soil and water conservation by increasing the infiltration and water holding capacity of the soil, provide for surface water storage, and stabilize water disposal systems through such measures as terracing, contouring, strip-cropping, grassed waterways, stabilization structures, crop rotation, pastures and woodlands. Other soil conservation measures instituted in the Missouri River basin include land treatment measures for gully-erosion control, grade stabilization and flood damage reduction.

3-08.1.1. The forestry program of the USDA also affects the water resources of the Missouri River basin. A large portion of the runoff appearing as streamflow in the upper Missouri River basin originates in the forested mountain areas. The forestry program includes the cutting of merchantable timber in a manner that will break up extensive, dense stands but maintain partial cover and provide for reproduction, thinning of even-aged stands of young timber, tree planting in denuded areas for timber production and erosion prevention, forest management for increased snow catch and water, intensification of fire and disease prevention and construction of improvements incidental to the foregoing.

3-09. Missouri River Basin Population. Approximately 15.5 million people live in the Missouri River basin according to the 2012 census information. Plate III-28 shows the population distribution by county in the basin. The basin is primarily rural but does contain several large population urban centers and medium-sized cities. Many of the larger cities are located adjacent to the Missouri River.

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Missouri River Basin
Mainstem Reservoir System
Master Water Control Manual

IV - Missouri River Basin Federal Projects and River Reach Descriptions

4-01. Missouri River Basin - Mainstem System Reservoirs. The System is comprised of six reservoirs that were constructed by the Corps. These six Corps reservoirs contain about 72.4 MAF of storage capacity, which constitutes over 50 percent of the total storage in the Missouri River basin's 17,200-plus reservoirs. The System is the largest reservoir system in the United States. It contains 84 percent of the installed capacity in the basin's federal hydroelectric power system, provides almost all of the reservoir support for downstream flow support on the Missouri River, and contributes greatly to flood protection for over 2 million acres of land in the floodplain of the Missouri River. When the reservoir levels are at the base of their respective Annual Flood Control and Multiple Use Zones, the reservoirs provide an aggregate water surface area of 984,000 acres for recreation and fish and wildlife enhancement.

4-02. Authorized Purposes of the Mainstem Reservoir System. The six System dams are regulated as a hydraulically and electrically integrated system for the Congressionally authorized purposes of flood control, navigation, hydropower, water supply, water quality control, irrigation, recreation, and fish and wildlife. The 1944 Flood Control Act authorized construction of the System projects, with the exception of Fort Peck, which was authorized by the Rivers and Harbors Act of 1935. The Fort Peck Power Act of 1938 authorized the construction of hydropower facilities at Fort Peck. The 1944 Flood Control Act also recognized that all of the authorized purposes for the other System projects should apply to Fort Peck as well as making Fort Peck part of the System. The 1973 ESA requires federal agencies who carry out activities that may affect listed species to consult with the appropriate Service over potential impacts of those activities on T&E species or their habitat. It also dictates that all federal agencies seek to conserve T&E species and utilize their authorities in furtherance of the purposes of the ESA. The ESA is discussed in greater detail in Section 2-01.14.6 of this manual. The Missouri River basin has T&E species that are impacted by Corps operations and, therefore, the System has been and continues to be operated for the continued existence of these species in coordination with the USFWS. This Master Manual presents the guidelines and operational objectives for regulating the System for the Congressionally authorized purposes, in compliance with all laws, with recognition that other incidental benefits are also achieved.

4-03. System Project Locations. The System extends from the upper reaches of the Fort Peck reservoir in northeastern Montana to Gavins Point Dam in southeastern South Dakota and northeastern Nebraska. The System controls runoff from 279,480 square miles of the upper Missouri River basin. A map of the Missouri River basin with the mainstem and federal tributary projects is shown on Plate III-25. A Summary of Engineering Data containing pertinent System information is shown on Plates II-1 and II-2.

4-03.1. Fort Peck Dam Location. Fort Peck Dam is located at RM 1771.5 in McCone and Valley Counties, Montana, 17 miles southeast of Glasgow, MT and 9 miles south of Nashua, MT. The western boundary of the 57,500-square mile drainage area is the Continental Divide.

4-03.2. Garrison Dam Location. Garrison Dam is located at RM 1389.9 in Mercer and McLean Counties, North Dakota. Garrison Dam is 75 river miles northwest of Bismarck, ND, the state capital, and 11 miles south of the town of Garrison, ND. The Yellowstone River, the primary tributary between the Fort Peck and Garrison dams, enters the Missouri River at RM 1582, about 14 miles above the headwaters of the Garrison reservoir (Lake Sakakawea).

4-03.3. Oahe Dam Location. Oahe Dam is located at RM 1072.3 in Stanley and Hughes Counties, South Dakota, 6 miles northwest of Pierre, SD, the state capital. The Cheyenne River, draining southwestern South Dakota and northeastern Wyoming, is the largest tributary between the Garrison and Oahe dams. Other major tributaries in the reach between Garrison and Oahe include the Knife River, the Cannonball River, the Heart River, and the Grand River.

4-03.4. Big Bend Dam Location. Big Bend Dam is located at RM 987.4 in Buffalo and Lyman Counties, South Dakota, near Fort Thompson, SD and about 20 miles upstream from Chamberlain, SD. The primary tributary between the Oahe and Big Bend dams is the Bad River, which enters the Missouri River at Fort Pierre, SD in the upper end of the Big Bend reservoir (Lake Sharpe) and immediately downstream of Oahe Dam.

4-03.5. Fort Randall Dam Location. Fort Randall Dam is located at RM 880.0 in Charles Mix and Gregory Counties, South Dakota, about 6 miles south of Lake Andes, SD. The primary tributary between the Big Bend and Fort Randall dams is the White River, which enters the Fort Randall reservoir (Lake Francis Case) at RM 955.

4-03.6. Gavins Point Dam Location. Gavins Point Dam is the lowermost System dam and is located at RM 811.1 on the South Dakota-Nebraska state line 4 miles west of Yankton, SD. The right abutment and powerhouse are located in Cedar County, Nebraska. The left abutment is located in Yankton County, South Dakota. The primary tributary between the Fort Randall and Gavins Point dams is the Niobrara River, a right bank tributary that enters the Missouri River about 8 miles above the headwaters of the Gavins Point reservoir (Lewis and Clark Lake).

4-04. System Project Physical Components. The following sections describe the embankments, spillways, outlet works, hydroelectric powerplants, and water supply facilities for each of the System projects. Plates II-3 through II-81 contain maps of each project, including details of embankments, spillway, outlet works and powerplant facilities, area-capacity tables, tailwater rating curves, spillway and outlet works discharge rating curves, and powerplant characteristics.

4-04.1. Fort Peck Dam. The following sections describe the physical features of the System project, Fort Peck Dam.

4-04.1.1. Fort Peck Embankment. The dam consists of an earthfill embankment with an impervious core approximately four miles in length including the two mile dike section. The embankment has a maximum height of 250.5 feet and a maximum width of 4,900 feet. The crest elevation of the dam is at elevation 2280.5 feet with crest widths of 50 feet on the main dam section and on the dike section. The dam is a hydraulic fill type except for the final topping out and a section at the end of the dike, which are rolled fill. The upstream face of the dam is protected from wave action by riprap placed above elevation 2162.0 feet. Gravel was placed in the downstream toe of the dam to stabilize the slopes and facilitate drainage at the downstream toe. Seepage control is provided by a continuous sheet steel piling cutoff well, which is located 37.5 feet upstream from the axis of the dam. A system of relief wells were installed along the downstream toe to facilitate drainage of seepage water and reduce hydrostatic pressures in the foundation material downstream from the cutoff wall. See Section 4-02 of the Fort Peck WCM for more details on the Fort Peck embankment.

4-04.1.2. Fort Peck Spillway. The spillway, located in a natural saddle of the reservoir rim, about three miles east of the dam, consists of a partially lined approach channel, the gate control structure including the training wall section, the lined discharge channel and the unlined earth discharge channel which enters the Missouri River approximately 9 miles downstream of the dam. The concrete gate structure is surmounted by a highway bridge, a service bridge, equipment platform, and service walkways. The spillway crest elevation is 2225 feet. The 16 vertical lift spillway gates are each 25 feet high by 40 feet wide. The gates are electrically operated and can be individually controlled from the service bridge. The concrete-lined spillway channel is about 4,800 feet long varying in width from about 700 feet at the end of the training wall section to 120 feet at the downstream end of the cutoff structure. Discharge capacity at elevation of 2250 feet, which is the elevation of the top of the spillway gates when closed and also the top of the Exclusive Flood Control Zone, is 230,000 cfs.

4-04.1.3. Post-2011 Spillway Construction. Since completion of the emergency spillway, the spillway has been operated approximately a dozen times, never passing discharges greater than 25,000 cfs until 2011. During the 2011 flood, spillway releases were made from May 6-22 and June 2-September 30. Peak spillway releases were 52,200 cfs for several days in June. Scour in the downstream channel reached a maximum depth of more than 40 feet, leaving less than 30 feet of embedment of the spillway cutoff wall structure. As a result, the downstream face of the cutoff structure was determined to be potentially unstable with concerns that the erosion would flank the cutoff structure and ultimately lead to progressive failure of the spillway chute. AECOM Technical Services, Inc. was contracted in 2012 to perform various analyses and develop repair alternatives to return the emergency spillway back to a pre-flood level of service. Construction of the plunge pool repair was substantially completed in November 2016. See Section 4-03 of the Fort Peck WCM for more details on the Fort Peck spillway.

4-04.1.4. Fort Peck Outlet Works and Power Tunnels. The Fort Peck outlet release system consists of four tunnels, the intake structure, the emergency control shafts, the main control shafts and the outlet structure. The tunnels are spaced 125 feet center to center at the intake and control shafts and fan out to 195 feet center to center at the outlet. The tunnels vary in length; the length of Tunnel Nos. 1, 2, 3 and 4 are 5,653 feet, 6,355 feet, 6,615 feet and 7,240 feet, respectively, and bypass the dam through the right abutment. Tunnel Nos. 1 and 2 are used to supply water to the power units and Tunnel Nos. 3 and 4 are used for flood control purposes and to supplement downstream flows. The four tunnels are reinforced concrete lined, with steel liners installed downstream from the control shafts in Tunnel Nos. 1 and 2. The finished inside diameter of Tunnel Nos. 1, 3 and 4 is 24 feet 8 inches. Tunnel No. 2 has an inside finished diameter of 24 feet 8 inches upstream from the control shafts and 22 feet 4 inches inside diameter downstream from the main control shaft. Approximate discharge capacities of Tunnels No. 1, 2, 3 and 4 are 8,800 cfs, 7,200 cfs, 22,500 cfs and 22,500 cfs, respectively. The tunnels discharge into a stilling pool located downstream from the dam embankment and adjacent to the downstream riverbed. The stilling pool is protected by reinforced concrete retaining walls, training walls, outlet portals, a base slab and baffle piers. Since 1975, supplemental releases above powerplant capacity have been made over the spillway. Additional guidance regarding best practices and/or special considerations and restrictions for use of the outlet works can be found in Exhibit A of the Fort Peck WCM. Per Section 1.6.3 of Exhibit A, it is recommended that the ring gates (Tunnel Nos. 3 and 4) should not be used except in case of a dam safety emergency in coordination with Omaha District Engineering Division. See Section 4-04 of the Fort Peck WCM for more details on the Fort Peck outlet works and tunnels.

4-04.1.5. Fort Peck Powerplants. Powerplant No. 1 is on the left bank of the discharge channel with the center line of units approximately 263 feet downstream from the portal of Tunnel No. 1. Principal features of the powerplant include three penstocks extending from a wye branch at the outlet end of Tunnel No. 1 to the surge tanks; an enclosed surge tank section that houses three interconnected surge tanks; a generator section that houses the generators, turbines, a control room and related equipment; the three draft tubes that carry turbine outflows to the tailrace; and the outdoor substation and switchyard. The generating facilities include one 18,250 kW (Unit No. 2) and two 43,500 kW turbine-driven generators (Unit Nos. 1 and 3) and associated control and switching equipment. The powerhouse consists of three generator bays and an erection bay. 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 ventilating facilities. The control room, cubicles, offices, machine shop and station service facilities are located in the surge tank base immediately adjacent to the upstream side of the powerhouse.

4-04.1.5.1. Powerplant No. 2 is located to the right of the tailrace from Powerplant No. 1, with the center line of units approximately 350 feet downstream from the portal of Tunnel No. 2. Principal features of the Powerplant No. 2 include two penstocks extending from a wye branch at the outlet end of Tunnel No. 2 to the surge tanks; an enclosed surge tank structure that houses two interconnected surge tanks; a generator section that houses the generators; turbines; an erection bay; switchgear, oil storage and purification facilities and other equipment; two draft tubes that carry turbine discharge to the tailrace; and the outdoor substation and switchyard. The generating facilities include two 40,000 kW turbine-driven generators and associated control and switching equipment. Unit Nos. 4 and 5 became operational in 1961, and no rewinds have been required. The discharge capacity of Powerplant No. 2 is 7,200 cfs.

4-04.1.5.2. Each powerplant has a separate switchyard with a tie line for power interchange between the powerplants. Generation from Powerplant No. 1 is transmitted to either the east or west grid. Unit Nos. 1 and 3 are important to Western for load control on the west grid. Powerplant No. 2 supplies energy to the east grid only. See Sections 4-05 and 4-06 of the Fort Peck WCM for more details on the Fort Peck powerplants and switchyards.

4-04.1.6. Fort Peck Water Supply Facilities. The town of Fort Peck maintains the only municipal intake at Fort Peck. The intake is fed from the penstocks and the tap is located downstream of the dam. There is a cross connection so the intake can be fed from either powerplant. The Corps owns the taps, valves and line from the penstock to the point exterior to Powerplant No. 1, located just south of the Switchyard No. 1 boundary fence.

4-04.2. Garrison Dam. The following sections describe the physical features of the System project, Garrison Dam.

4-04.2.1. Garrison Embankment. Garrison Dam consists of a rolled earthfill embankment that is 11,300 feet in length at the crest, with a crest at elevation 1875.0 feet, which is over 200 feet above the old riverbed. The upstream portion of the embankment is composed of dense impervious material and the downstream portion is semi-pervious with a pervious drainage blanket over the old streambed. The maximum width of the base is about 2,600 feet with an impervious blanket extending an additional 1,250 feet upstream from the upstream toe of the dam. The crest is 60 feet wide. Seepage control is addressed with a combination of the upstream impervious blanket, steel sheet piling cutoff walls, impervious filled cutoff trenches, grout curtains at the abutments and a toe drain in the downstream section of the embankment. A system of relief wells located about 175 feet downstream from the toe of the dam also facilitates drainage of seepage water and reduces hydrostatic pressures in the foundation material downstream from the cutoff walls. The upstream face of the dam is protected from wave action by riprap placed above elevation 1800.0 feet. A gravel blanket extends from the bottom of the riprap to elevation 1770.0 feet. See Section 4-02 of the Garrison WCM for more details on the Garrison embankment.

4-04.2.2. Garrison Spillway. The spillway is located in the left abutment and separated from the main embankment by about 800 feet of natural ground. The spillway is of the conventional concrete chute type with crest gates at the upper end and consists of the approach channel, control gate structure, lined chute, stilling basin and unlined discharge channel. The spillway crest consists of an ogee-type weir, divided into 28 bays, with a crest elevation of 1825.0 feet. Each bay contains a tainter gate 40 feet wide by 29 feet high. The gates are electrically operated and can be individually controlled from the service bridge. A concrete-lined spillway discharge chute extends from the crest structure 2,605 feet downstream to the stilling basin. The stilling basin is 800 feet wide and over 200 feet long with a floor at elevation 1620.5 feet. The lower portion of the stilling basin contains baffles 10 feet high and 8 feet wide spaced on 10-foot centers. An unlined pilot discharge channel was constructed downstream of the stilling basin to guide flows to the Missouri River channel. The pilot channel was expected to erode and adjust itself to the flow conditions. The spillway was used for regulation purposes for the first time in 2011. Spillway flows cut a very uniform channel downstream to the river channel. See Section 4-03 of the Garrison WCM for more details on the Garrison spillway and the pilot channel.

4-04.2.3. Garrison Outlet Works and Power Tunnels. The outlet works and power tunnels include an approach channel, an intake structure, eight concrete lined tunnels, of which three are for flood control and five for water supply to power units, a stilling basin at the downstream end of the flood control tunnels and a discharge channel leading to the old river channel. Tunnels through the dam are approximately 1,320 feet long with invert elevations of 1672.0 feet at the upstream end and 1662.0 feet at the downstream exit. Tunnel Nos. 1 through 5, which are on the east side, serve as conduits for the penstocks supplying the power units. The remaining three tunnels, Nos. 6, 7 and 8, are for flood control and discharge into a stilling basin. The five power tunnels have an inside diameter of 29 feet, except for a short distance of Tunnel No. 4, which has a 30-foot inside diameter. Tunnel Nos. 6, 7, and 8 are for flood control; Tunnel No. 6 has an inside diameter of 26 feet and Tunnel Nos. 7 and 8 have inside diameters of 22 feet. A stilling basin extends below the three flood control tunnels. The discharge channel extends from the downstream edge of the tailrace and stilling basin to the Missouri River channel, a distance of almost 4,000 feet. The combined discharge capacity of Tunnels Nos. 6, 7, and 8 is 98,000 cfs at elevation 1854.0 feet. See Section 4-04 of the Garrison WCM for more details on the Garrison outlet works and power tunnels.

4-04.2.4. Garrison Powerplant. The powerhouse structure encloses five generating bays, an erection bay, and an office and control bay and is located in the right abutment of the dam. Five hydraulic turbines of the vertical shaft, single-runner Francis type, with riveted plate steel scroll casings and elbow-type draft tubes are installed in the powerhouse. Each turbine is supplied water by an individual steel penstock extending from the intake structure to the spiral case extension at the upstream face of the powerhouse. Two surge tanks are provided with each unit. Penstocks are provided with vertical lift gates in the intake structure. The tailrace extends from the downstream face of the powerhouse through a distance of about 150 feet to the discharge channel. The generators for Unit Nos. 1, 2 and 3 are each rated at 121,600 kW and Unit Nos. 4 and 5 are each rated at 109,2500 kW. See Sections 4-05, 4-06 and 4-07 of the Garrison WCM for more details on the Garrison powerplant and switchyard, intake and powerhouse, respectively.

4-04.2.5. Garrison Water Supply Facilities. A 12-inch water line supplies the water treatment facility located in Riverdale. The treated water is distributed to the Corps' maintenance facility, downstream campgrounds, powerplant, Garrison National Fish Hatchery, Sakakawea State Park, and the cities of Riverdale, Underwood and Pick City, ND. The Garrison National Fish Hatchery is located downstream from Garrison Dam and receives raw water from a 16-inch line extending from the penstocks of Unit Nos. 4 and 5. See Section 4-18 of the Garrison WCM for more details on the Garrison water supply facilities.

4-04.3. Oahe Dam. The following sections describe the physical features of the System project, Oahe Dam.

4-04.3.1. Oahe Embankment. Oahe Dam consists of rolled earthfill embankment with the outlet works tunnels in the right abutment and the power tunnels in the left abutment. State Highway 204 crosses the Missouri River on top of the dam. The embankment has a total length of 9,300 feet, a maximum height of 245 feet and a top elevation of 1660.0 feet. The total volume of fill in the embankment is approximately 92 million cubic yards. The maximum base width is 3,500 feet and the top width is 60 feet. Embankment freeboard was based on an Oahe reservoir level of 1644.4 feet, the maximum level attained during routing of the Spillway Design Flood (SDF). A set-up allowance of 1.8 feet and wave height plus ride-up allowance of 7.3 feet was developed in design studies. An additional safety factor of 6.5 feet resulted in a total freeboard allowance of 15.6 feet, establishing the embankment crest at elevation 1660.0 feet. See Section 4-02 in the Oahe WCM for more details on the Oahe embankment.

4-04.3.2. Oahe Spillway. The Oahe spillway is a remote spillway located on the right bank of the Missouri River about a mile west of the right abutment of the dam. An unlined approach channel has been excavated in shale to elevation 1590.0 feet for a distance of approximately 1,300 feet upstream of the weir. The width of the channel in the weir area is about 472 feet. Upstream of the shale excavation, the approach channel widens considerably due to the slope of the natural ground. An unlined discharge channel extends approximately two miles downstream of the spillway structure. The spillway is controlled by eight tainter gates, each 50 feet long by 23.5 feet high. The discharge capacity of the spillway is 80,000 cfs at maximum operating pool of 1620.0 feet. Spillway operating criteria, which are available in Section 4-03.3 of the Oahe WCM, have been established to reduce unpaved discharge channel erosion rates. See Section 4-03 in the Oahe WCM for more details on the Oahe spillway.

4-04.3.3. Oahe Outlet Works. The outlet works are located on the right bank of the river and consist of an approach channel, six tunnels with intake structures and control shafts, a stilling basin and a discharge channel. The approach channel from the river channel to the outlet works tunnel intake is excavated in the abutment of the dam and is approximately 2,000 feet long. The upstream portion of the channel is straight for a distance of about 1,300 feet and is on two levels, upper and lower. The intakes are individual submerged-type reinforced structures located at the end of the tunnels. The structures have a top elevation of 1530.0 feet and are submerged to a depth of 10 feet at the minimum operating pool elevation of 1540.0 feet. Six tunnels have been provided in the outlet works for flood control and regulation purposes. The tunnels are parallel to each other and are spaced 85 feet on center. The length of the tunnels from the upstream face of the intake to the downstream face of the tunnel outlet portal varies from 3,496 feet to 3,659 feet. The six control gates include a 13-foot by 22-foot vertical lift cable suspended tractor-type gate installed in each of Tunnel Nos. 1 to 4 inclusive, and 13-foot by 22-foot hydraulic lift, wheeled-type gates installed in Tunnel Nos. 5 and 6 for fine regulation. Each of the six tunnels have 13-foot by 22-foot vertical lift tractor-type emergency gates. The stilling basin is located downstream of the tunnel portals and consists of training piers, drop sections, retaining walls, weir baffles and the end sill. An ogee weir with a crest elevation of 1417.5 feet divides the stilling basin into a double-stage-type with a primary basin and a secondary basin. The overall length of the discharge channel is 9,000 feet. The upper reach of the channel was excavated in shale to a bottom elevation of 1390.0 feet. The discharge channel tapers from a width of 500 feet at the stilling basin to 400 feet about 3,000 feet downstream. See Section 4-04 in the Oahe WCM for more details on the Oahe outlet works.

4-04.3.4. Oahe Powerplant. The seven power tunnels are located in the left abutment of the dam and extend from the downstream edge of the intake structure to the face of the surge tank base structures. The tunnels have a 24-foot inside diameter and are curved in plan. The upstream portions of the power tunnels are concrete lined and extend from the closure monolith at the intake structure to a point near the axis of the dam. The power tunnels vary in overall length: 3,280 feet for Tunnel No. 1, which is the riverward tunnel, to 4,005 feet for Tunnel No. 7, which is the landward tunnel. Downstream from the steel-lined section, each power tunnel consists of an 80-foot long tunnel entry structure, a 96-foot long cut-and-cover section and the 48-foot long tunnel terminal structure. All are included as part of the overall length of the tunnels. Each of the seven penstocks have a 24-foot inside diameter and extend from the end of the embedded steel liners through the cut-and-cover sections, the terminal structures and the surge tanks to connect with the spiral case extensions at the upstream wall of the powerhouse. The intake for the power tunnels is located near the left abutment of the dam, a short distance upstream from the toe of embankment slope at elevation 1520.0 feet. The seven intake towers, spaced 90 feet on center, extend 145 feet above the level of the approach area at elevation 1520.0 feet. The powerhouse structure encloses the seven generator bays, an assembly bay, and a control and service bay. Generator Bay No. 7 is located on the east end and the assembly bay, control bay and service bay are located on the west end. The powerhouse is located in the left abutment of the dam and is oriented so that the flow through the powerhouse is approximately north to south. The seven hydraulic turbines are vertical-shaft, single runner-type, with welded steel scroll cases and elbow-type draft tubes. The seven generators are each rated at 112,300 kW. The tailrace is 508 feet wide and 114 feet long ascending from elevation 1387.0 feet at the draft tube exit to elevation 1404.0 feet. The tailrace is paved with reinforced concrete, which is anchored to the foundation. The Oahe switchyard is an outdoor-type and is located on the right side of the tailrace at elevation 1456.0 feet. See Sections 4-05, 4-06 and 4-07 of the Oahe WCM for more details on the Oahe powerplant and switchyard, intake, and powerhouse, respectively.

4-04.3.5. Oahe Water Supply Facilities. The Oahe reservoir is utilized as water supply directly by four towns: Fort Yates, ND, Wakpala, SD, Mobridge, SD and Huron, SD, and three rural water districts. The intake for the Cheyenne River Tribe Mni Waste´ Water Company is at RM 1110 and serves multiple South Dakota communities. Immediately downstream of Oahe Dam, the municipalities of Pierre and Fort Pierre obtain their water supply from wells. See Section 4-18 of the Oahe WCM for more details on the Oahe water supply facilities.

4-04.4. Big Bend Dam. The following sections describe the physical features of the System project, Big Bend Dam.

4-04.4.1. Big Bend Embankment. Big Bend Dam is a rolled earthfill embankment with the powerhouse at the right abutment and the spillway at the left abutment. The total embankment length, including the spillway, is 10,570 feet. Maximum dam height is 95 feet, top elevation is 1440.0 feet, maximum embankment base width including berms is 1,200 feet and the top of dam width is 50 feet. The embankment makes a gentle S-curve across the valley and is composed of approximately 17 million cubic yards of fill material. The embankment is built on dredged pervious fill, which has a top elevation near 1357.0 feet. A central impervious core along the entire length of the embankment extends from the pervious fill to 5 feet below the top of the dam to control seepage through the embankment. An impervious blanket ties into the central impervious core and extends 425 to 540 feet through the major portion of the embankment. A pervious drain section is located on the downstream side of the impervious core. Embankment freeboard was based on a Big Bend reservoir level of 1433.6 feet, the maximum level attained during routing of the SDF. A set-up allowance of 0.7 foot and wave height plus ride-up allowance of 3.3 feet was developed in design studies. An additional safety factor of 2.4 feet resulted in a total freeboard allowance of 6.4 feet, establishing the embankment crest at elevation 1440.0 feet. See Section 4-02 of the Big Bend WCM for more details on the Big Bend embankment.

4-04.4.2. Big Bend Spillway. The Big Bend spillway is located on the left bank of the river at the end of the embankment section of the dam. The approach channel is about 2,700 feet long and curves through an angle of 90 degrees on the riverward side and 70 degrees on the landward side. The bottom of the approach channel is excavated to elevation 1375.0 feet. The spillway structure consists of an ogee weir with a crest elevation of 1385.0 feet. The spillway crest elevation is 10 feet above the bottom of the approach channel, surmounted by tainter gates, a highway bridge, equipment platforms and service walkways. Eight tainter gates control the spillway. Each tainter gate is 40 feet long and 38 feet high and are all separated by 8-foot wide piers. The net length of the spillway crest is 320 feet. The gates operate individually and may be opened or closed in 1-foot increments. See Section 4-03 of the Big Bend WCM for more details on the Big Bend spillway.

4-04.4.3. Big Bend Outlet Works. Conventional outlet works structures were not provided at Big Bend. Releases must be made either through the spillway or the powerplant.

4-04.4.4. Big Bend Powerplant. Power facilities for Big Bend are located in the right abutment of the dam. The flow of water from the reservoir is guided by an approach channel curving in plan along a circular arc. The width of the channel at elevation 1345.0 feet is 400 feet. At elevation 1355.0 feet the channel width converges from a maximum of 800 feet approximately 600 feet upstream from the intake to 675 feet at the intake. The intake structure contains separate intakes for each of the eight turbines. Each unit intake is divided into three water passages by intermediate piers. Each of the water passages contains two sets of gate slots, one for the service gate and one for the bulkhead gate. Three tractor-type vertical lift service gates are provided for each of the unit intakes. A total of three emergency bulkhead-type gates are provided in any of the upstream bulkhead gate slots. The powerhouse consists of two elements, the main structure and the service bay. The powerhouse is constructed integrally with the intake structure. The main structure provides housing for the power units, service and storage rooms and personnel facilities. The service bay is located along the downstream side and contains the control room, various service rooms, offices and public facilities. Eight hydraulic turbines of the vertical shaft fixed blade propeller-type, with concrete semi-spiral cases and concrete, elbow-type, draft tubes are installed in the powerhouse. The eight generators are each rated at 67,300 kW. The tailrace is 675 feet wide and 140 feet long and is paved with reinforced concrete anchored to the foundation. The tailrace discharge channel is excavated to elevation 1330.0 feet to the chalk outcrop 1,350 feet downstream from the downstream end of the tailrace paving. The bottom width of the tailrace channel widens to 800 feet at the chalk outcrop. The tailrace channel extends for an additional 3,000 feet with a bottom width of 400 feet across an island formed near the chalk outcrop. See Sections 4-05, 4-06 and 4-07 of the Big Bend WCM for more details on the Big Bend powerplant and switchyard, intake and powerhouse, respectively.

4-04.4.5. Big Bend Water Supply Facilities. There are no water supply facilities provided from the Big Bend powerhouse. See Section 4-18 of the Big Bend WCM for more details on Big Bend water supply facilities.

4-04.5. Fort Randall Dam. The following sections describe the physical features of the System project, Fort Randall Dam.

4-04.5.1. Fort Randall Embankment. Fort Randall 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. In late 1997, additional rock was placed to elevation 1381.0 feet. Embankment freeboard was based on a Fort Randall reservoir level of 1379.3 feet, the maximum level attained during routing of the 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 crest at elevation 1395.0 feet. See Section 4-02 of the Fort Randall WCM for more details on the Fort Randall embankment.

4-04.5.2. Fort Randall 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 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. The spillway structure consists of a concrete ogee crest weir with a crest elevation of 1346.0 feet, surmounted by tainter gates, a roadway and service bridge and machinery platforms. The spillway has a total 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 wide piers. The net length of the spillway crest is 840 feet. 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. A 230-foot long stilling basin extends below the concrete spillway chute. The spillway discharge channel 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. Discharge capacity at the maximum operating pool elevation of 1375.0 feet is 508,000 cfs. See Section 4-03 of the Fort Randall WCM for more details on the Fort Randall spillway.

4-04.5.3. Fort Randall Outlet Works and Power Tunnels. 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. 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. 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. Service gates on Tunnel No. 11 were modified in 1999 to allow for fine regulation of flows. The service gates can be operated remotely from the powerplant control room. 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) have 22-foot inside diameters 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 has a 28-foot inside diameter. The remaining flood control tunnels (Nos. 9, 11 and 12) have 22-foot diameters throughout their entire length. Steel pipe penstocks, 22 feet in inside diameter, are installed in the downstream portion of the eight power tunnels and the No. 10 regulating tunnel. 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. The discharge capacity of the flood control tunnels is 128,000 cfs. 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 crest 505 feet downstream of the portal wall of the tunnels. 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. Two rows of baffle piers, for energy dissipation, were 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. See Section 4-04 of the Fort Randall WCM for more details regarding the Fort Randall outlet works.

4-04.5.4. Fort Randall Powerplant. 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 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. 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 powerhouse structure is 561 feet long by 78 feet wide and consists of eight generator bays, an erection bay and a service bay. 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 and heating and air conditioning facilities. Eight hydraulic turbines of the vertical-shaft single runner Francis-type, with plate-steel spiral casings are installed in the powerhouse. The eight generators are each rated at 40,000 kW. The tailrace is approximately 560 feet wide and extends 500 feet downstream from the powerhouse. An outdoor switchyard containing the main transformers and switch gear is located immediately to the right and downstream from the powerhouse. See Sections 4-05, 4-06 and 4-07 of the Fort Randall WCM for more details on the Fort Randall powerplant and switchyard, intake and powerhouse, respectively.

4-04.5.5. Fort Randall Water Supply Facilities. 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. See Section 4-18 of the Fort Randall WCM for more details regarding Fort Randall water supply facilities.

4-04.6. Gavins Point Dam. The following sections describe the physical features of the System project, Gavins Point Dam.

4-04.6.1. Gavins Point Embankment. Gavins Point Dam is a rolled earthfill structure 8,700 feet in length extending from the left bank of the Missouri River valley to the spillway and powerhouse structures located on the right bank of the valley. The embankment contains about 7 million cubic yards of fill consisting largely of compacted and uncompacted chalk obtained from the excavations for the spillway, powerhouse and downstream channels. A core and a blanket extending 300 feet upstream from the core were constructed from impervious material. The crest of the embankment is at elevation 1234.0 feet, representing a maximum height above streambed of 74 feet and an average height above the valley floor of about 60 feet. Between elevations 1203.0 and 1217.0 feet the upstream face of the dam has a slope of 1 vertical on 15 horizontal. The uncompacted chalk forming the gradual slope through this range of elevation, where the level of the reservoir can be expected most of the time, provides protection for wave action on the embankment. Embankment freeboard was based on a Gavins Point pool elevation of 1221.4 feet, the maximum level attained during routing of the SDF. A set-up allowance of 3.1 feet and wave height plus run-up allowance of 8.8 feet was developed in design studies. An additional safety factor of 0.7 foot resulted in a total freeboard allowance of 12.6 feet, establishing the embankment crest at elevation 1234.0 feet. See Section 4-02 of the Gavins Point WCM for more details on the Gavins Point embankment.

4-04.6.2. Gavins Point Spillway. The Gavins Point spillway is located on the right bank between the embankment and the powerhouse. The spillway is a chute type consisting of a short approach channel, a gated ogee crest structure, a concrete paved chute, a stilling basin and a discharge channel. The approach channel from the reservoir is relatively short with a bottom elevation of 1155.0 feet. The spillway structure consists of a concrete ogee crest weir, surmounted by tainter gates, a roadway and service bridge and machinery platforms. The spillway has a gross length of 664 feet and is controlled by 14 tainter gates. Each spillway gate is 40 feet long and 30 feet high and are separated by 13 8-foot reinforced concrete piers. The net length of the spillway crest is 560 feet. The weir has an ogee crest of elevation 1180.0 feet, 25 feet above the approach channel floor. A paved chute, 664 feet in width and 216 feet in length, connects the weir and the stilling basin. The upstream end of the chute is at elevation 1155.0 feet. The downstream end of the chute terminates at the stilling basin floor at elevation 1123.0 feet. The 220-foot long reinforced concrete stilling basin slab extends from the spillway chute to the downstream face of the end sill. The stilling basin's floor is at elevation 1123.0 feet and has a width of 638 feet. The unpaved spillway discharge channel begins at the stilling basin sill. From elevation 1132.0 feet at the end sill, the channel bottom slopes upward to a uniform elevation of 1140.0 feet. The stilling basin wall on the riverward side extends approximately 127 feet downstream. The landward side wall terminates at the stilling basin. The spillway can discharge 345,000 cfs at a maximum operating pool of 1210.0 feet. See Section 4-03 of the Gavins Point WCM for more details on the Gavins Point spillway.

4-04.6.3. Outlet Works. Conventional outlet works structures were not provided at Gavins Point. Releases must be made either through the spillway or the powerplant.

4-04.6.4. Gavins Point Powerplant. The flow of water from the reservoir to the powerhouse intake is guided by a relatively short approach channel located at the right end of the dam. The sides of the approach channel at the intake to the powerhouse are closed off by the concrete abutment walls. The intake structure contains three separate intakes for each of the three turbines. Each unit intake is subdivided into three gate passages each having five removable trash rack sections of welded steel construction. Each passage contains two sets of gate slots. Nine tractor-type, vertical lift service gates operate in the downstream gate slots. One slide, vertical lift-type gate can be operated in any one of the upstream or bulkhead gate slots. The powerhouse contains three hydraulic turbines of the vertical shaft, single runner, adjustable-blade propeller, Kaplan type, with governor-controlled runner blades, concrete semi-spiral cases and concrete elbow-type draft tubes. The generators were rewound from 1987 through 1989 and have a nameplate capacity of 44,100 kW. The tailrace channel conveys flow from the draft tube outlets to the spillway discharge channel. A concrete slab extends 99 feet downstream from the draft tube outlets. The transformer yard is located outside the powerhouse adjacent to the erection bay. The switchyard is located above and south of the transformer yard and contains transformer switching bays, a bus tie bay, and four outgoing line bays. See Sections 4-05, 4-06 and 4-07 of the Gavins Point WCM for more details on the Gavins Point powerplant and switchyard, intake and powerhouse, respectively.

4-04.6.5. Gavins Point Water Supply Facilities. There are no water supply facilities provided from the Gavins Point powerhouse.

4-05. Missouri River Channel and Floodway Characteristics. The System, intervening river reaches and lower river reaches extend from Fort Peck in eastern Montana downstream to the confluence with the Mississippi River at St. Louis, MO, as shown on Plate III-1. Plate IV-1 presents the usual time of travel of within-bank, open-water flows for the Missouri River and its major tributaries. It should be noted that these are general approximations that may be affected by many factors. For purposes of scheduling System releases, approximate open water travel times from Gavins Point Dam are 1.5 days to Sioux City, 3 days to Omaha, 3.5 days to Nebraska City, 5.5 days to Kansas City, and 10 days to the mouth of the Missouri River.

4-05.1. Maximum Non-Damaging Flow. The maximum flow that may be passed through a specific river reach without damage, or the channel capacity, varies throughout the length of the Missouri River and is dependent upon channel dimensions, the degree of encroachment upon the floodplain and improvements such as levees and channel modifications. Channel capacities at specific locations also vary from season to season, especially in the middle and upper reaches. In these two reaches, a decrease in channel capacity due to the formation of an ice cover is common through the winter and early spring months. Generally, the capacity of the Missouri River channel usually increases progressively downstream, although instances do occur where this trend is reversed. Between and below the System dams are reaches of the Missouri River that range in length from 811 miles for the lower Missouri River below Gavins Point Dam to 0 miles between Big Bend Dam and the Fort Randall reservoir. Descriptions of each of these reaches follow.

4-05.2. Missouri River Reach - Fort Peck Dam to Garrison Reservoir. The Missouri River from Fort Peck Dam flows in an easterly direction for about 204 miles as an unchannelized river before entering the headwaters of Garrison reservoir near Williston, ND. Major tributaries include the Milk, Poplar and Yellowstone Rivers. The Yellowstone River enters the Missouri

River just upstream of the Garrison reservoir delta and influences only a short segment of the Fort Peck reach.

4-05.2.1. Channel characteristics of this river reach include many sandbars, islands and side channels. Abandoned channels and several oxbow lakes remain in the floodplain. Upstream of Brockton, MT (RM 1660), the floodplain is about 4 miles wide and is bordered by rolling grasslands, dryland crops and rangelands. Downstream from this point, the floodplain narrows to a 1-mile wide valley surrounded by badlands. Most of the floodplain consists of croplands, pastures and hayfields in private ownership or in the Fort Peck Reservation. The total reach contains approximately 100,000 acres of agricultural land subject to flooding.

4-05.2.2. Damage Levels. Flood damages begin with open water flows of approximately 35,000 cfs. For flows ranging from 50,000 cfs in the upper portion (Fort Peck Dam to mouth of Yellowstone River) to 70,000 cfs in the lower portion (mouth of Yellowstone River to the headwaters of the Garrison reservoir) of the reach, damages are relatively minor and limited mainly to pasture and low-lying areas. Historical regulation has shown that stages at Wolf Point and Culbertson up to 21 feet and 13 feet, respectively, do not cause significant flood damages. During the winter season, the ice-covered channel capacity through this Missouri River reach is limited to 10,000 cfs at the time of ice formation, increasing to over 15,000 cfs after the ice cover has stabilized.

4-05.2.3. Channel Degradation. The valley width is relatively uniform and is well entrenched in the terrain of the Montana prairies. Since Fort Peck Dam entraps all upstream contributed sediment, the downstream river remains relatively free of suspended sediment until the Milk River, which enters the Missouri River about 10 miles downstream of the dam, and other tributaries introduce their individual load contributions into the Missouri River. An Omaha District study completed in 2013 titled *Fort Peck Downstream Sediment Trends Study* analyzed degradation and bank erosion rates. Overall, the water surface elevation has decreased between 1950 and 2012. However, the decrease has not been steady over the entire period or constant for the entire 175-mile reach. Changes are influenced by Fort Peck releases and flows from tributaries that enter the Missouri River downstream of Fort Peck. Recent major decreases occurred as a result of the high releases made in 1997 and the record releases made in 2011. Slight increases have occurred in some areas during the low flow periods such as the 1980s. The report showed that from 1950 to 2012 at the 10,000 cfs flow level, the reach’s average decrease was 2.4 feet, of which 1.3 feet (54 percent) occurred in the period from 1995 to 2012. Degradation is projected to continue at a diminishing rate as the channel geometry adjusts and the bed surface develops an armored layer. Similar to what occurred in 1997, additional degradation is expected during periods of sustained high project releases.

4-05.2.4. Channel Width. There has been very little increased channel width due to streambank erosion, except in isolated stretches between RM 1612 and RM 1746. Streambank erosion rates for the 204-mile reach averaged about 88 acres per year from 1975 to 1983 and 107 acres per year from 1983 to 1990. Sediment deposition begins in the vicinity of the Yellowstone River confluence and continues downstream into the Garrison reservoir. A visible delta of sediment deposition has formed as Missouri River flows enter the Garrison reservoir. The associated increase in the elevation of the Missouri and Yellowstone River channels in this area has led to higher river water levels, localized flooding and higher water tables.

4-05.3. Missouri River Reach - Garrison Dam to Oahe Reservoir. Below Garrison Dam, the Missouri River flows 87 miles in a south-southeasterly direction, passing the North Dakota cities of Bismarck and Mandan before entering the Oahe reservoir. Significant tributaries include the Knife River near Stanton, ND, and the Heart River just upstream of the Oahe reservoir delta and downstream of Mandan.

4-05.3.1. Channel Characteristics. Within the Missouri River floodplain in the Garrison Dam to Oahe reach, terraces form a complex of different low-lying landforms, many at an elevation within 3 feet above the river. The river is restricted to one main channel in this reach with very few side channels, old channels or oxbow lakes. The floodplain in this reach contains 34,600 acres of agricultural land subject to flooding. Main damage centers in this reach are the cities of Bismarck and Mandan. At the time Garrison Dam was constructed, a 13-foot stage at Bismarck represented an open water channel capacity of about 90,000 cfs; however, in 1975 after 22 years of reservoir operation, the channel had deteriorated to the extent that open water flows of about 50,000 cfs resulted in a stage of 13.0 feet. During 1997, releases of 59,000 cfs were made from Garrison Dam, resulting in a stage at Bismarck of about 14 feet. Some erosion and minor flood damage from water ponding in the yards of homes occurred as a result of this release. With the scouring effects of flood flows in 2011, recent trends show a flow of 63,000 cfs at stage of 13.0 feet. A substantial amount of floodplain development at low-lying levels has occurred in the Bismarck and Mandan metropolitan areas. Winter operational experience has shown that at the time an initial ice cover forms the Bismarck stage typically increases 4 to 6 feet, and a stage of about 13 feet may be reached at a flow of about 20,000 cfs. This is a reduction from the original Garrison powerplant capacity of 35,000 cfs due to ice effects and aggradation in the upper end of the Oahe reservoir. After the ice-cover stabilizes, the discharge capacity of the channel can be expected to increase, allowing for gradual increases in Garrison releases.

4-05.3.2. Channel Degradation. Degradation of the riverbed below Garrison Dam (RM 1390) occurs primarily in the initial 35- to 50-mile long reach downstream from the dam. The magnitude of the bed lowering generally decreases with distance from the dam. A study completed in 2012 titled *Garrison Project Downstream Channel and Sediment Trends Study* analyzed degradation and bank erosion rates. An annual evaluation of the Garrison tailwater trends was also conducted in this study. About 11.5 feet of tailwater degradation has occurred at Garrison between 1953 and 2015. This degradation tapers to about 2 feet at RM 1335. Most of the degradation occurred within the first 30 years of dam closure. By 1985 the tailwater had decreased by about 9 feet from the mid-1950s. Tailwater levels appeared to be stabilizing in the mid-1980s, but high releases in 1996 and 1997 caused about 1 foot of degradation. The tailwater trend appeared to stabilize again after 1997, but high releases in 2011 resulted in another period of channel degradation. Channel bed grain size has increased in the downstream channel, mostly within the initial 25 miles below Garrison Dam, as a gradual armoring of the channel bed has occurred. Degradation is projected to continue at a diminishing rate as the channel geometry adjusts and the bed surface develops an armored layer. Similar to what occurred in 1997 and 2011, additional degradation is expected during periods of sustained high project releases.

4-05.3.3. Channel Width. The channel widths for the initial 20 miles below Garrison Dam have remained fairly constant. Only near the mouth of the Knife River (RM 1378) is the channel width decreasing. This decrease is due to a buildup of Knife River deposits resulting from a reduction in flood flows as a result of regulation of Garrison releases. Farther downstream, the channel is widening.

4-05.3.4. Bank Erosion. Bank erosion continues in the reach, however, the rate of bank erosion has declined since dam closure in 1953. Streambank erosion rates average 60 acres per year from 1954 to 1964 for the 87-mile reach. Bank erosion rates decreased to less than 20 acres per year from 1975 to 1997. The pre-dam closure bank erosion rate from 1938 to 1954 was 3 to 4 times greater. The Corps constructed many bank protection projects in this reach from the 1960s through the 1980s, as authorized by the flood control acts of 1963 and 1968. These bank protection projects have limited the erosion in many areas.

4-05.3.5. Damage Levels. This reach has 34,500 acres of cropland subject to flood damage. The Missouri River area most subject to flooding in this reach, however, is the urban area near Bismarck. Expensive homes constructed in the bottomlands located along the Missouri River are subject to flooding during the winter freeze-in period as well as during significant System inflow events that require releases greater than 60,000 cfs from Garrison Dam. The floodplain construction in the Bismarck area during the past 35 years represents an area of considerable concern that has become more susceptible to future flood control storage evacuation. Damage in this reach will be very high when higher project releases, that are required to evacuate flood storage, occur. Also, this area of Bismarck is subject to potential damage if an ice jam occurs just downstream that backs water into these housing developments. The 2-day water travel time from Garrison Dam to this vicinity prevents any significant control by Garrison Dam during ice jam events.

4-05.4. Missouri River Reach - Oahe Dam to Big Bend Reservoir. This short reach extends from Oahe Dam (RM 1072) five miles downstream to Big Bend reservoir (RM 1067), near the city of Pierre, SD. Due to the influence of the downstream Big Bend reservoir (Lake Sharpe), no significant degradation occurs in this reach.

4-05.4.1. Channel Characteristics. This reach is relatively straight and confined to one channel, with no large tributary flows dominating the reach. The Bad River enters near the downstream end of this reach. A large amount of sediment enters the Missouri River from the Bad River. An Environmental Protection Agency (EPA)-funded Section 319 project in the Bad River basin has reduced this sediment load in recent years.

4-05.4.2. Damage Levels. Flooding in the Pierre-Fort Pierre area, especially at street intersections in the Stoeser Addition of Pierre, has been a recurring problem since 1979. Prior to the installation of an emergency gate, high Oahe releases, coupled with the formation of river ice in the LaFramboise Island area, caused water to back up into a storm sewer outlet, flooding street intersections. Public Law 105-277, as amended by Public Law 106-224, authorized and funded the design and modification of infrastructure changes, acquisition of the most flood-prone properties and flood-proofing of other properties in the Fort Pierre and Pierre areas. Release restrictions have been implemented in previous years to prevent flooding. Peak hourly releases, as well as daily energy generation, will be constrained to prevent urban flooding in the Pierre and Fort Pierre areas if severe ice problems develop downstream of Oahe Dam. This potential reduction has been coordinated with Western. The urban areas of Pierre and Fort Pierre are subject to potentially high damages if higher-than-average releases are required from Oahe for flood storage evacuation.

4-05.5. Missouri River Reach – Big Bend Dam to Fort Randall Dam. This reach extends from the Big Bend Dam (RM 987) 107 miles downstream to Fort Randall Dam (RM 880). The Fort Randall reservoir (Lake Francis Case) forms the entirety of this reach and limits degradation.

4-05.5.1. Channel Characteristics. This reach is dominated by the Fort Randall reservoir. Pool levels typically vary throughout the year by about 15 to 20 feet, which can result in some open river characteristics in the upstream reach. The White River confluence at RM 954 is about 10 river miles downstream of Chamberlain, SD and over 30 river miles downstream of Big Bend Dam. A large amount of sediment enters the Missouri River from the White River. The White River delta extends across the Fort Randall reservoir and has a damming effect, which can alter the reservoir elevation upstream of the delta. The reservoir elevation upstream of the delta has been observed to be up to 6 feet higher than the downstream reservoir level. The delta has also caused channel narrowing, overbank deposition and a decrease in channel capacity, subjecting the adjacent land to a higher risk of flooding.

4-05.6. Missouri River Reach - Fort Randall Dam to Gavins Point Reservoir. The Missouri River below Fort Randall Dam (RM 880) flows in a southeasterly direction for approximately 44 miles in an unchannelized river to the Gavins Point reservoir. The major tributary in this reach is the Niobrara River, a right bank tributary that enters the Missouri River at RM 843.5. In this reach, the Missouri River meanders in a wide channel with the flow restricted to generally one main channel. Only a few side channels and backwaters are present, except at the lower end of the reach in the Gavins Point reservoir delta. The 39-mile reach of Missouri River from Fort Randall Dam (RM 880) to Running Water, SD has been designated a National Recreational River under the National Wild and Scenic Rivers Act.

4-05.6.1. Channel Characteristics. A study completed in 2012 titled *Fort Randall Project Downstream Channel and Sediment Trends Study* analyzed degradation and bank erosion rates. The degradation reach downstream of Fort Randall Dam, from RM 880 to 860, has experienced channel widening and up to 6 feet of riverbed degradation from 1953 to 1997. Channel bed elevations shows the approximately 6 feet of degradation downstream of the dam transitions to minor change at RM 865. Shortly downstream of this location, aggradation begins due to influence from the Niobrara River and the Gavins Point reservoir headwaters. The average downstream progression of the delta into the Gavins Point reservoir is approximately 550 feet per year. The face of the delta was located at about RM 826 in 2012. Streambank erosion averaged over 60 acres per year initially after closure of the dam from 1953 to 1966. Erosion rates averaged 40 acres per year from 1976 to 1984. This compares to a pre-dam rate of 135 acres per year. Bank erosion rates have not been updated since 1984. The Missouri River has coarser bed material from the dam downstream to about RM 870 than downstream, indicating some armoring of the channel has occurred in the reach immediately downstream of the dam. The average grain size for this reach was 0.48 mm in 1956 and 0.91 mm in 2007.

4-05.6.2. Damage Levels. Since the Gavins Point reservoir first filled, a delta has formed at the mouth of the Niobrara River (RM 843.5) to near Springfield, SD. This delta formation has restricted reservoir access at Springfield and caused problems for the city’s water intake. While this reach of the Missouri River was capable of passing flows in excess of 150,000 cfs prior to construction of the System, Fort Randall open water releases near full powerplant capacity may result in groundwater and flood problems. High Fort Randall releases, coupled with diminished channel capacity, caused lowland flooding in this reach during the period from 1995 to 1997 and again in 2010 and 2011. The historic record high releases in 2011 caused a notable increase in the channel capacity in this reach of the Missouri River of over 4 feet at a flow of 30,000 cfs. However, similar to the river stage progression that occurred following previous high flow events, aggradation will resume and any channel capacity increase that occurred in 2011 should be regarded as temporary. The reach contains approximately 2,200 acres of agricultural land and 62 residential buildings subject to flooding. Corn and soybeans are the primary crops grown. With the severely restricted channel capacity in this reach, inundation of some of the bottomlands adjacent to the channel will likely be necessary in years that above-average System inflows must be evacuated.

4-05.7. Missouri River Reach - Gavins Point Dam to Sioux City. The Missouri River between Gavins Point Dam (RM 811.1) and Sioux City (732.3) flows in an east-southeasterly direction and is comprised of three sub reaches: Missouri River National Recreational River, Kensler's Bend, and the start of the Missouri River Navigation Channel.

4-05.7.1. Missouri River National Recreation River Reach. The 59-mile reach extends downstream from Gavins Point Dam at RM 811.1 to Ponca, NE at RM 752 and is designated as the Missouri River National Recreational River. The National Recreational River reach below Gavins Point Dam has not been channelized by the construction of dikes and revetments. Multiple bank erosion projects were federally constructed in the 1960s and 1970s, which has reduced bank erosion rates in many areas. This portion of the river is a meandering channel with many chutes, backwater marshes, sandbars, islands and variable current velocities. Snags and deep pools are common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide.

4-05.7.2. Kensler's Bend Reach. The Kensler's Bend reach extends from Ponca, NE at RM 752 to above Sioux City, IA at RM 735. The Kensler's Bend Project provided for the construction of dikes, revetment and channel improvements for the protection of adjacent lands from bank erosion. The project was started in 1946 and completed in 1961.

4-05.7.3. Missouri River Navigation Channel Reach. This 2.7-mile reach extends from the downstream end of the Kensler's Bend Project (RM 735) to the mouth of the Big Sioux River in Sioux City, IA (RM 732.3) and is the upstream portion of the Missouri River BSNP. The entire BSNP channelized 735-mile reach extends to the mouth of the Missouri River near St. Louis, MO.

4-05.7.4. Channel Characteristics. The main tributaries in the Gavins Point to Sioux City reach are the James River (RM 800.8), Vermillion River (RM 772), and Big Sioux River (RM 735). All are left bank tributaries. Prior to construction of the System, the open water channel capacity through this reach of the Missouri River was well in excess of 100,000 cfs. There is evidence of channel deterioration due largely to floodplain encroachment in backwater areas and along old river meander chutes. This is offset by the extensive channel degradation that has occurred downstream of Gavins Point. Degradation is due to both sediment trapping within the upstream dams, which results in clear water releases from Gavins Point Dam, and the substantial Missouri River channel shortening that occurred during construction of the Missouri River BSNP. Gradual armoring of the riverbed, mostly within the initial 20 miles downstream of Gavins Point Dam, has reduced the rate of channel degradation. A study completed in 2014 titled *Gavins Point Dam Degradation Trend Study* analyzed degradation and bank erosion rates. Over 12 feet and 10 feet of degradation has occurred at the Gavins Point tailwaters and at Ponca, NE, respectively, during the period between 1955 and 2016. Degradation does not occur at a steady rate. Large declines occurred in both 1997 and 2011, which correspond to high flow years. Bank erosion rates since closure of the Gavins Point in 1956 have averaged over 120 acres per year between Gavins Pont and Ponca State Park, compared to a pre-dam erosion rate of about 190 to 200 acres per year. The rate of erosion had been declining since 1975. The erosion rate dramatically increased during the 1995-1997 and 2008-2011 periods.

4-05.7.5. Damage Levels. The regulation of the System provides a great amount of flood protection to this Missouri River reach because of the close proximity of this reach to Gavins Point, the lowermost System project. In 1997, flows of 70,000 cfs in this reach caused no significant damage because of the channel degradation that has occurred in this reach. Flows in 2011 that persisted in excess of 160,000 cfs resulted in some areas of overbank flooding, and significant damage occurred with bank erosion, rock structure damage, and impacts to adjacent floodplain structures. Advanced measure construction actions occurred in the Sioux City and Dakota Dunes areas. The maximum flow with a stabilized ice cover at which there would be no flood damage is believed to be near 30,000 cfs. The reach contains approximately 1,900 acres of agricultural land and approximately 4,000 residential and nonresidential buildings subject to flooding.

4-05.8. Missouri River Reach - Sioux City to Omaha. The 116-mile reach between Sioux City, IA (RM 732.3) and Omaha, NE (RM 615.9) is part of the upper Missouri River BSNP. Major tributaries in this reach include the Floyd River (RM 731.1), the Little Sioux River (RM 669.2) and the Boyer River (RM 635).

4-05.8.1. Channel Characteristics. The Missouri River flows in a south-southeasterly direction through this channelized reach. Open water channel capacities in this reach prior to construction of the System were in excess of 100,000 cfs. During recent years, there has been considerable encroachment on the channel area. Fixed boat docks have been constructed in numerous locations through this reach and low areas are now being farmed. Much of this development is on or adjacent to river stabilization structures and takes advantage of sand deposition encouraged by this stabilization. A study completed in 2014 titled *Investigation of Channel Degradation, Gavins Point Dam to the Platte River Confluence* analyzed degradation rates within this reach. Degradation at Sioux City is over 12 feet since 1955 at a flow of 30,000 cfs. The degradation rate is not as pronounced in the river reach closer to Omaha. Stages for equivalent flow at Omaha had declined more slightly over the 1955-2011 period; this resulted in a total decrease of about 3 feet. Stage recovery of over 1 foot has occurred since 2010.

4-05.8.2. Damage Levels. Flows of 65,000 cfs in 1975 and 70,000 cfs in 1997 resulted in inundation of some of the cropped land and interrupted access to some marinas constructed along the banks. Flows in 2011 that persisted in excess of 160,000 cfs resulted in significant areas of overbank flooding and damage occurred with bank erosion, rock structure damage and impacts to adjacent floodplain structures, and inundation of agricultural lands. Some agricultural lands experience interior drainage problems at the higher flow levels. Winter flows of up to 30,000 cfs with a stable ice cover appear possible without flooding. During river freeze-in and ice break-up periods, which can occur at any time during the winter season, flows in excess of 25,000 cfs could result in lowland inundation. Based on the 1996 land survey, the reach contains about 415,000 acres of agricultural land and about 18,500 residential and nonresidential buildings subject to flooding.

4-05.9. Missouri River Reach - Omaha to Kansas City. The Missouri River reach from Omaha, NE (RM 615.9) to Kansas City, MO (RM 366.1) flows in a south-southeasterly direction for approximately 250 miles. Major tributaries in this reach include the Platte River (RM 494.8), Nishnabotna River (RM 542) and Kansas River (RM 367.5). Deterioration of the channel and flood capacity has occurred throughout this reach. Recent experience indicates that mid-summer Missouri River flows exceeding 90,000 cfs will result in river levels above flood stage at Nebraska City, Rulo and St. Joseph. Complaints are received from adjacent landowners concerning water logging of cultivated fields and impacts to interior drainage structures from levee protected areas with stages at 2 feet below flood stage. During the winter months, stages in this reach have gone as much as 5 feet above flood stage due to ice jams even though Gavins Point Dam releases were limited to 20,000 cfs and there was little incremental inflow occurring below Gavins Point Dam. This reach contains about 360,000 acres of agricultural land and about 2,650 residential and commercial buildings subject to flooding.

4-05.10. Missouri River Reach - Kansas City to Mouth of Missouri River. From Kansas City (RM 366.1), the Missouri River flows 366 miles in an easterly direction to its confluence with the Mississippi River (RM 0). Major tributaries in this reach include the Grand (RM 250), Chariton (RM 238.9), Osage (RM 130) and Gasconade (RM 104.5) Rivers. Missouri River flows of about 150,000 cfs will result in minor agricultural damages in this reach. In the vicinity of Kansas City, the channel is experiencing both a deterioration of the flood conveyance capacity in the overbank area and, simultaneously, increased channel capacity through channel degradation. This channel degradation has adversely impacted water intakes in this reach during low winter stages. In recent years, the established flood stage on the Missouri River at Waverly, MO has been exceeded when flows were greater than 115,000 cfs. This lowest reach of the Missouri River has historically experienced a deterioration of the flood conveyance capacity. The reach contains about 472,000 acres of agricultural land and about 4,800 residential and commercial buildings subject to flooding. Ice jams can cause flooding with flows of less than 30,000 cfs on this reach of the Missouri River.

4-05.11. System Flood Damage Levels. The three primary resources directly affected by the System's ability to control floods are agricultural resources, non-agricultural resources and navigation.

4-05.11.1. Agricultural Resources. Approximately 1.4 million acres of agricultural land is subject to flooding along the Missouri River. Ninety percent of these acres are located downstream of Gavins Point Dam. Corn is the primary crop cultivated, followed by soybeans and wheat. In total, approximately 42,800 acres of Tribal lands are also subject to flooding. Most of the Tribal lands are on the Fort Peck Reservation. Grassland is not included in the aforementioned acreage figures.

4-05.11.2. Non-agricultural Resources. Non-agricultural resources include residential and nonresidential structures (and their contents) located in areas along the Missouri River that are subject to flooding. There are about 62,000 residential buildings worth approximately $23.8 billion located within the Missouri River floodplain as described in the MRRMP-EIS. For the purposes of this study, the floodplain consists of the entire area from bluff to bluff along the Missouri River between Fort Peck Dam and St. Louis, MO. There are 11,467 nonresidential buildings subject to flooding, with a total value of approximately $35.7 billion. All values are updated to 2018 price levels. Residential development is characterized according to 16 general classes of residential buildings including farmsteads. For nonresidential structures, 20 building categories were used for the initial classification. Development on Tribal lands adjacent to the Missouri River floodplain includes about 343 buildings worth an estimated $129 million.

4-05.12. Navigation. Flood flows greater than a 25-year flood event have the potential to adversely affect navigation on the Missouri River. Navigation losses result from interrupted service. The duration of the interruption depends on the length of river affected and the magnitude of the flood. Losses are based on daily barge and towboat costs and the average daily tonnage moved during the month that a flood occurs.

4-05.13. System Flood Damages Prevented Report. On an annual basis, and more often if needed, the MRBWM office provides the Omaha District and Kansas City District planning offices the basic hydrologic data (e.g., regulated and unregulated stages) to determine the damages prevented of both actual and without dams (unregulated) conditions by the System. The districts then apply the hydrologic data using stage-damage curves for the various reaches of the System. The computed damages prevented are then provided to the MRBWM office and higher Corps authority. The flood control effects of the Missouri River levee system are included in the determination and the System fair-shares the benefits with the levee system. Fair-sharing occurs unless the levee system would have been overtopped by the natural events. In the case of levee overtopping, the System gets the full credit for damages prevented for the river reach for that flood event. Tributary reservoir effects are accounted for, and if the tributary projects have authorized flood control storage, they receive credit for damages prevented. If they do not have authorized flood control, the benefits are assigned to the System. As shown on Plate IV-2, the estimated accumulated flood damages prevented by the System from 1938 to 2017 (indexed to 2017 dollars) is $62.5 billion, or $781 million annually. Unindexed, the damages prevented by the System from 1938 to 2017 totals $35.7 billion, or $446 million annually.

4-05.14. System Rating and Damage Curves. Rating (stage-discharge) and damage (stage-damage) curves, relate stages at particular locations with open-river flows and stages with damages through an adjacent reach along the Missouri River. Examples of typical stage-damage and area-damage curves for the Missouri River at Bismarck, ND and Omaha, NE are shown on Plates IV-3 and IV-4, respectively. The Omaha and Kansas City Districts are responsible for maintaining and updating stage-damage curves as updated information becomes available. Stage-damage curves have been developed for both existing and natural (without levees) conditions. This was done to determine the effect of protective levees that have been built in many reaches of the lower Missouri River. Stage-damage curves for the Missouri River are available for Culbertson and Wolf Point, MT; Bismarck, ND; Yankton, SD; Sioux City, IA, Decatur, Omaha, Nebraska City and Rulo, NE; and St. Joseph, Kansas City, Waverly, Boonville and Hermann, MO.

4-06. System Related Control Facilities. The following facilities were designed to work in concert with the System to provide an improved Missouri River basin water management condition. The following sections describe the projects, other than the System, that affect or influence water management in the Missouri River basin.

4-06.1. Missouri River Basin - Tributary Reservoirs. The facilities that have the greatest effect on the System are the tributary reservoirs. A significant number of tributary reservoirs have been constructed in the Missouri River basin, many as a result of the 1944 Flood Control Act and others for general water resource development purposes. The cumulative effect provided by these tributary reservoirs on the System is significant. As of 2018, the 529,350-square mile Missouri River basin contains approximately 17,200 reservoirs. In the aggregate, these reservoirs provide a total of almost 200 MAF and 130 MAF of maximum and normal storage capacity, respectively. The investment cost for this storage capacity exceeds $15 billion. Almost 99 percent of the total storage capacity serves multiple-purpose functions. Purposes served by individual multiple-purpose reservoirs may include any combination of the purposes of flood control, municipal and industrial water supply, water quality control, irrigation, navigation, hydroelectric power, fish and wildlife enhancement and recreation. In contrast, the function of most single-purpose reservoirs is either flood control or water supply. Pertinent data from reservoirs in the basin, including all of the reservoirs in which the Corps has an operational responsibility, are listed in Tables IV-1 and IV-2. Locations of federal reservoirs in the Missouri River basin are shown on Plate III-26. The tributary reservoirs are divided into two groups for purposes of discussion; those above the System are called Upstream Tributary Reservoirs and those below the System are called Downstream Tributary Reservoirs.

4-06.1.1. Missouri River Basin – Upstream Tributary Reservoirs. Although it is relatively simple to approximate the effects of a single tributary reservoir on specific streamflow occurrences, provided flow and storage data are available, such a process becomes exceedingly complex with the large number of reservoirs in the Missouri River basin. The approximation process becomes further complicated when including the numerous small reservoirs for which no hydrologic data are available. Individually, these small projects have insignificant effects on Missouri River flows; however, when considered in the aggregate, this effect may be very significant. Certain general conclusions, as given below, may be deduced relative to the effect on streamflow of these projects. Many of these projects are not regulated specifically for flood control; however, their releases are integral to total System regulation.

4-06.1.1.1. On an annual or other long-term basis, the existence of tributary reservoir storage will generally result in a decrease in Missouri River streamflow. In addition to the consumptive use of water from the projects, nearly all are located in regions where the volume of evaporation from the reservoir will exceed the volume of precipitation that may fall directly on the pool. During any flood season, the existence of upstream tributary storage will almost certainly reduce System flood volumes to some extent, the amount being dependent on antecedent conditions. Although specific flood control storage may not be allocated, these reservoirs are located in regions where flows are of a distinct seasonal nature. Reservoir regulation to achieve the purposes that the reservoirs serve results in storing water during periods of excess flows. The stored water is then used later during periods of low runoff. This stored water will reduce flood volumes and peak inflows into the System and augment the amount of water in System storage during low-inflow periods into the System later in the season.

4-06.1.1.2. Normally, the natural peak flows on the Missouri River will also be reduced by the existence of tributary reservoir storage, provided significant runoff contributing to the peak flow originates above the tributary projects. Reasons for this are discussed in the preceding sections, plus the additional effects of the tributary reservoirs in smoothing and delaying sharp peaks even if there were no appreciable vacant storage space remaining at the time of the peak. It is realized that, in certain instances, a reservoir project can increase the size of the peak below the project over that which would have occurred naturally. This is due to the reservoir decreasing the travel time of the peak flow or by delaying a portion of the runoff from a drainage area that is later contributing to a major upstream peak on the Missouri River when releases from the tributary reservoir are made. With a single tributary reservoir, or only a few projects, such an increase in peak flows might occasionally be expected. With the large number of projects tributary to the Missouri River, it is not likely that their aggregate effect would increase Missouri River peak flows.

4-06.1.1.3. The Corps is responsible for flood control regulation of all federal reservoirs with allocated flood control space. Many of these reservoirs will be regulated, insofar as practical, to prevent local flood damages along both the tributary streams and on the Missouri River downstream from the reservoirs. Regulation of the tributary reservoirs will be coordinated with regulation of the System at times of large flood flows or large quantities of water in System storage. Table IV-1 provides pertinent data of larger reservoirs above Gavins Point Dam. One USBR project, Canyon Ferry, is located on the Missouri River above the System while all others are tributary reservoirs regulated by either the Corps or the USBR.

4-06.1.2. Missouri River Basin – Downstream Tributary Reservoirs. There are no reservoirs located on the main stem of the Missouri River below the System. Many tributary reservoirs provide some control of the flows to the Missouri River and, at times, have a significant effect on Missouri River levels and regulation of the System. Section 7-04.18 of this manual provides some insight on how the lower basin tributary reservoirs effect System regulation. One difference is that three Kansas City District projects, Perry, Tuttle Creek and Milford, located in the Kansas River basin, are sometimes used to provide navigation support on the Missouri River, as described in Section 7-09 of the Gavins Point WCM. Table IV-2 provides a list of the larger tributary reservoirs located below the System.

4-06.2. Missouri River Basin – Upstream Tributary Levee Projects. In addition to levee protection along the Missouri River, the comprehensive plan for basin development included many protection projects for localities in the upstream reaches of the Missouri River or on tributary streams. Some of the projects are designed to provide protection in combination with flood control reservoirs constructed upstream from the affected locality. Description of each of these projects is beyond the scope of this manual and reference is made to individual System project WCMs or tributary reservoir WCMs for descriptions of these projects.

4-06.3. Missouri River Basin - Downstream Levee Structures. The drainage area above Gavins Point Dam is 279,480 square miles, 52 percent of the basin total of 529,350 square miles. The ability to control the movement of water in the lower Missouri River decreases the farther downstream from Gavins Point Dam a particular location is. Sioux City has 88 percent of the drainage area controlled by the System while Omaha has 86 percent. Values continue to drop to 68, 66, 57, 55 and 53 percent for Nebraska City, St. Joseph, Kansas City, Boonville and Hermann, respectively. The production of food is the major industry in the large agricultural region that makes up the Missouri River basin. More than 1.5 million acres of the most productive farm land within the basin, the associated livestock, equipment, farm buildings and numerous rural communities are located on the floodplain of the Missouri River between Sioux City and the Missouri River's mouth.

4-06.3.1. Missouri River Basin – Downstream Federal Agricultural Levee Projects. Federal levee construction in accordance with the 1941 and 1944 Flood Control Acts was started in 1947. The levees are designed to function as a team with System and tributary reservoirs. Neither the reservoirs alone nor the levees alone provide the desired degree of protection, but operating to supplement each other, they provide significant flood risk reduction. The whole system of federal levees is constructed in individual units. Older levees were built of semi-compacted earth fill with a top width of 10 feet, side slopes of 1 vertical on 3 horizontal, and a freeboard of 2 to 3 feet above the water surface of the design flood. New construction of the levees remains similar, but the design is based on risk analysis at a 90 percent confidence level. Landside berms or seepage wells are provided where foundation conditions require such measures. Drainage structures extend through the levees to provide internal drainage.

4-06.3.2. At the end of 2001, twenty nine federal units were either constructed or under construction. With the exception of two units between Kansas City and Boonville, Missouri, all federal levees now constructed are in the reach located between Omaha and Kansas City. While additional units appear economically feasible, they presently are in an inactive status. Design discharges of these federal levees range from 250,000 cfs at Omaha, 295,000 cfs at Nebraska City, 325,000 cfs at St. Joseph, 460,000 cfs at Kansas City, and up to 620,000 cfs at Hermann, Missouri, near the mouth of the Missouri River. Detailed locations of these levees and their protected areas, are shown in the Project Maps, as published and revised annually by the Corps' Omaha and Kansas City District offices.

Table IV-1
Large Reservoir Projects in the Upper Missouri River Basin– Pertinent Data

Project Name	Location (City, State)	Drainage Area (sq. mi).	Regulated By
Gavins Point Dam	Yankton, SD	16,000	Corps
Fort Randall Dam	Pickstown, SD	14,150	Corps
Big Bend Dam	Fort Thompson, SD	5,840	Corps
Oahe Dam	Pierre, SD	62,090	Corps
Garrison Dam	Riverdale, ND	123,900	Corps
Fort Peck Dam	Fort Peck, MT	57,500	Corps
Clark Canyon[1]	Dillon, MT	2,320	USBR
Canyon Ferry[1]	Helena, MT	13,580	USBR
Gibson	Augusta, MT	575	USBR
Tiber[1]	Chester, MT	4,920	USBR
Fresno	Havre, MT	3,776	USBR
Bull Hook	Havre, MT	54	Corps
Buffalo Bill	Cody, WY	1,500	USBR
Boysen[1]	Thermopolis, WY	7,710	USBR
Yellowtail[1]	St. Xavier, MT	10,420	USBR
Dickinson	Dickinson, ND	400	USBR
Heart Butte[1]	Glen Ullin, ND	3,400	USBR
Bowman Haley	Scranton, ND	446	Corps
Shadehill[1]	Lemmon, SD	3,070	USBR
Keyhole[1]	Moorcroft, WY	1950	USBR
Belle Fourche	Belle Fourche, SD	205	USBR
Deerfield	Rapid City, SD	95	USBR
Pactola[1]	Rapid City, SD	214	USBR
Coldbrook	Hot Springs, SD	71	Corps
Cottonwood Springs	Hot Springs, SD	26	Corps
Angostura	Hot Springs, SD	9,100	USBR
[1]USBR Section 7 project			

Table IV-2
Reservoir Projects Located in the Lower Missouri River Basin

Project Name	Location (City, State)	Drainage Area (Sq. Mi.)	Regulated By
Milford Lake	Junction City, KS	3,620	Corps
Wilson Reservoir	Russell, KS	1,917	Corps
Glen Elder Dam[1]	Beloit, KS	5,076	USBR
Kirwin Dam[1]	Kirwin, KS	1,409	USBR
Webster Dam[1]	Stockton, KS	1,150	USBR
Cedar Bluff Dam[1]	Ellis, KS	5,365	USBR
Bonny Dam[1]	Hale, CO	1,435	USBR
Enders Dam[1]	Imperial, NE	951	USBR
Trenton Dam[1]	Trenton, NE	8,624	USBR
Kanopolis Reservoir	Lindsborg, KS	2,330	Corps
Tuttle Creek Reservoir	Manhattan, KS	9,556	Corps
Harlan County Dam	Republican City, NE	20,751	Corps
Medicine Creek Dam[1]	Cambridge, NE	642	USBR
Perry Reservoir	Topeka, KS	1,117	Corps
Clinton Reservoir	Lawrence, KS	367	Corps
Smithville Reservoir	Platte City, MO	213	Corps
Longview Lake	Lee’s Summit, MO	50.3	Corps
Blue Springs Lake	Lee’s Summit, MO	32.8	Corps
Pomona Reservoir	Osage City, MO	322	Corps
Melvern Reservoir	Osage City, MO	349	Corps
Hillsdale Lake	Paola, KS	144	Corps
Stockton Lake	Stockton, MO	1,160	Corps
Pomme De Terre Lake	Hermitage, MO	611	Corps
Harry S Truman Reservoir	Warsaw, MO	11,500	Corps
Lake of the Ozarks	Lake Ozark, MO		Ameren
Lovewell[1]	Lovewell, KS	358	USBR
Long Branch Lake	Macon, MO	109	Corps
Rathbun Lake	Rathbun, IA	549	Corps
Red Willow Dam[1]	McCook, NE	310	USBR
Norton[1]	Norton, KS	688	USBR
Jamestown Dam[1]	Jamestown, ND	1,300	USBR
Pipestem Dam	Jamestown, ND	400	Corps
Chatfield Dam	Denver, CO	3,018	Corps
Bear Creek Dam	Denver, CO	261	Corps
Cherry Creek Dam	Denver, CO	386	Corps
Glendo Dam[1]	Glendo, WY	14,330	USBR
Pathfinder Dam	Alcova, WY	14,600	USBR
Seminoe Reservoir	Sinclair, WY	7,210	USBR
[1]USBR Section 7 project			

4-06.3.3. Missouri River Basin - Downstream Federal Urban Levee Projects. Levee projects for the protection of large urban areas along the Missouri River have been constructed at Omaha, NE; Council Bluffs, IA; and Kansas City, MO. The Kansas City project was authorized by the 1936 Flood Control Act and modified and extended by the Acts of 1944 and 1954. The authorizations for the Omaha and Council Bluffs projects were included in the 1944 Flood Control Act. These projects are designed to operate in conjunction with the System and tributary reservoirs to prevent flooding of these localities from the most severe flood events of record. Design discharge of the Omaha-Council Bluffs project is 250,000 cfs, while levees in the Kansas City area are designed for Missouri River flows ranging from 460,000 cfs to 540,000 cfs. In addition to the large projects, a short levee constructed by the Corps under Section 212 protects the town of New Haven, MO from Missouri River floods.

4-06.3.4. Missouri River Basin - Downstream Private Levee Projects. Railroads, highways, bridges, municipal developments and farmland within the floodplain increase the necessity for adequate flood protection in the non-urban Missouri River bottom areas. Local interests have built over 500 miles of levees, which comprise nearly 100 non-federal levee systems, through this reach of the river. Most of these are active in the Corps' P.L. 84-99 rehabilitation program and listed in appropriate flood emergency plans. While these levees provide protection during the majority of events, in general, they are inadequate to withstand major floods.

4-06.4. Missouri River Basin – Missouri River Streambank Stabilization. The following sections discuss the programs implemented to stabilize the banks of the Missouri River. Streambank erosion is a continuing problem along most of the main stem and many tributaries in the Missouri River basin. Most bank protection projects now in existence are comparatively small and many were constructed as part of an emergency measure. This is particularly true for tributary streams and the main stem Missouri River upstream of the BSNP (e.g., Ponca State Park). Numerous bank protection projects have been installed below the Garrison, Fort Randall and Gavins Point dams and additional revetments will probably be required in future years below all of the projects due to increased riverfront development. These projects are very small compared to the most significant bank-erosion control achievements in the basin, such as the Missouri River BSNP and the Kensler's Bend Project. Prior to stabilization, the Missouri River banks were subject to significant erosion. Development along the Missouri River was very limited because of this bank erosion in combination with serious flooding. Prior to System regulation, high bank erosion and high bank accretions would be comparable over time. However, since the reservoirs now act as a sediment trap, this is no longer the case. Downstream of the System, near Ponca State Park at the upstream end of the Kensler's Bend Project, the flow of the Missouri River during moderate and low flow periods is confined to one designed alignment, stabilized by permanent rock dikes and bank revetments. Although some natural side channels exist and some historic side channels have been recently restored to provide fish and wildlife habitat, the lower one-third of the main stem of the Missouri River remains highly channelized.

4-06.4.1. Missouri River Basin – Upstream Bank Stabilization. There are numerous bank stabilization projects located in and above the System that provide bank stabilization along the Missouri River and its tributaries. These projects are not addressed in detail in this manual but the larger projects are discussed in the individual System projects' and tributary projects' WCMs.

4-06.4.2. Missouri River Basin – Downstream Bank Stabilization. This reach of the river has been modified over its entire length by an intricate system of dikes and revetments designed to provide a continuous navigation channel without the use of locks and dams. Authorized channel dimensions are achieved through supplementary releases from the large upstream reservoirs and occasional dredging and maintenance. In addition, when certain conditions warrant, supplemental flows are provided from specific tributary reservoirs to support Missouri River navigation to conserve System storage. The Missouri River reach from Gavins Point Dam to St. Louis includes numerous authorized projects that provide bank stabilization and a navigation channel. In addition to the primary authorization to maintain a 9-foot deep by 300-foot wide navigation channel from Sioux City to the mouth, there are authorizations to stabilize the riverbanks. The 735-mile Missouri River BSNP extends from the confluence of the Big Sioux and Missouri Rivers near Sioux City, IA to the mouth of the Missouri River.

4-06.4.2.1. The Missouri River BSNP was designed to prevent general bank erosion and channel meandering and to provide reliable Missouri River navigation. This project, authorized by Congress in the Rivers and Harbors Act of 1945, provides for a 735-mile 9-foot deep channel with a minimum width of 300 feet from Sioux City, IA to the mouth of the river near St. Louis, MO. Construction of the navigation works was declared complete in September 1981, although corrective work will be required as the Missouri River continues to form its channel in response to the altered flow and sediment regime. The navigation project is not accomplished by using locks, as is the case on most of the inland waterway systems, but by using river structures placed to confine and control the navigation channel. The use of these structures produces velocities high enough to prevent the accumulation of sediment in the navigation channel and permits an open condition for the entire length of the project with no regular dredging required under normal water supply conditions.

4-06.4.2.2. Commercial navigation in the Missouri River is confined to the main stem of the Missouri River between Sioux City and the mouth of the Missouri River near St. Louis. The Missouri River BSNP is designed to secure a permanent, continuous, open-river navigation channel with a 9-foot depth and a width of at least 300 feet under full navigation service conditions. Maintenance of these dimensions requires releases from the System, as well as some infrequent dredging activities, particularly during periods of below-average water supply. This navigation project is an important link with the Mississippi River waterway system. Low-cost transportation, particularly for bulk commodities, is available at many localities in the Missouri River valley. Cities and commercial interests have provided facilities along the banks of the river for both handling and managing navigation traffic.

4-06.4.3. Bank Stabilization on Tribal Cultural Resource and Archeological Sites. In addition to the aforementioned bank stabilization efforts there is an ongoing effort to stabilize portions of the System to protect Tribal cultural resource and archaeological sites. The Corps, through the Corps' Operations and Maintenance (O&M) appropriations, continues to make progress in Missouri River bank stabilization efforts for the protection of archaeological sites. The Corps consults with Tribal Nations, Tribal Historic Preservation Offices and State Historic Preservation Offices to prioritize sites where bank stabilization efforts should be focused. Site-stabilization work is contingent upon available funds. Additional sites will be protected as funding becomes available.

4-06.5. Missouri River Basin – National Recreational River Designations. Two sections of the Missouri River have been declared National Recreational River reaches, as described in the following sections.

4-06.5.1. Missouri River Basin - National Recreational River. The 36-mile river reach from Fort Randall Dam (RM 880) to the Gavins Point reservoir delta (RM 844) is designated a National Recreational River under the National Wild and Scenic Rivers Act. The banks along this reach tend to restrict flow to one main channel. There are only a few side channels and backwaters, except at the lower end in the Gavins Point reservoir delta. The Missouri River bank line that borders the Yankton Reservation is located adjacent to this reach, from RM 880 to RM 845. This reach receives no significant inflow from tributaries other than the Niobrara River.

4-06.5.2. Missouri River Basin - Downstream National Recreational River. The 59-mile river reach between Gavins Point Dam (RM 811) and Ponca (RM 752) is designated a National Recreational River under the National Wild and Scenic Rivers Act. It is also the only river reach downstream of Gavins Point Dam that has not been channelized by dikes and revetments. A wide, braided channel and numerous islands, chutes and backwaters favor a variety of wetlands. This river reach resembles the original undeveloped Missouri River more than any other reach. Compared to the other river reaches, it displays the greatest density of wetlands, approximately 90 acres per mile. Wetland acreage, however, has undoubtedly declined in the years following the designation due to channel degradation. Major tributaries in this river reach are the James River and the Vermillion River.

4-06.6. Missouri River Basin - Federal and State Fish Hatcheries. Three fish hatcheries are located on or adjacent to System projects and are described in the following sections. Refer to the MRRMP-EIS for more details regarding fish propagation activities of both federal and state fish hatcheries for native and T&E species with regard to the Missouri River and the System.

4-06.6.1. Fort Peck State Fish Hatchery. This fish hatchery was constructed adjacent to Fort Peck Dam. The Fort Peck Multi-Species Fish Hatchery is owned by the Corps but is staffed and operated by Montana Fish, Wildlife and Parks. Opened in the spring of 2006, this facility is capable of rearing a wide variety of warmwater and coldwater fish including walleye, northern pike, Chinook salmon and rainbow trout. The facility has 64 rearing tanks and incubation capacity for up to 125 million walleye eggs, 500,000 Chinook salmon eggs and 350,000 rainbow trout eggs. Forty outdoor ponds are used in the spring and summer for raising fingerling warm water fish. Eight concrete raceways are used for rearing spring-released Chinook salmon and rainbow trout.

4-06.6.2. Garrison Dam National Fish Hatchery. This hatchery was originally established in 1957 to provide fish for recreational fishing in the new reservoirs created by federal water development projects in the Midwest. The USFWS operates this hatchery. Currently, the hatchery provides management and production of many freshwater fish for the System, National Wildlife Refuges, American Indian waters and programs of the State of North Dakota. As many of the native fish struggle with the changes in the Missouri River aquatic ecosystems, the hatchery's role has changed to include maintaining migratory fish, such as the paddlefish, and restoring T&E species, such as the pallid sturgeon. To meet the high fish production demands, Garrison Dam National Fish Hatchery encompasses 209 acres of land and has a total of 64 rearing ponds.

4-06.6.3. Gavins Point National Fish Hatchery. The Gavins Point National Fish Hatchery is located just downstream of Gavins Point Dam on the South Dakota side of the Missouri River. The hatchery began operations in 1961, raises 12 to 16 species of sport fish, and has produced more than 5 billion fish for stocking or release in Midwestern waters. The hatchery raises the endangered pallid sturgeon and the paddlefish, both of which are native to the Missouri River. The hatchery, which is operated by the USFWS, has 36 rearing ponds that cover 40 acres.

4-06.7. System Public Recreation Facilities. 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. The number of recreation areas by System projects includes 27 at Fort Peck, 37 at Garrison, 52 at Oahe, 24 at Big Bend, 25 at Fort Randall and 23 at Gavins Point. 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, which holds the areas in trust for the Lower Brule Sioux Tribe and the Cheyenne River Sioux Tribe, under Title VI of P.L. 105-53, Water Resources Development Act of 1999 as amended by P.L. 106-541, Water Resources Development Act of 2000. The 65 recreation areas transferred in fee title, along with the nine recreation areas leased in perpetuity, will be managed for the restoration of terrestrial wildlife habitat loss that occurred as a result of the flooding of lands related to the construction of the Oahe, Big Bend, Fort Randall and Gavins Point projects. Table IV-3 presents the Natural Resource Management System reporting area recreation sites, marinas, camping sites and swimming areas for each System project.

Table IV-3
Missouri River System Recreation

Mainstem Reservoir	NRMS Recreation Areas[1]	Marinas	Camping Sites	Swimming Areas
Fort Peck	26	3	231	3
Garrison	45	9	1,111	4
Oahe	52	4	995	5
Big Bend	31	1	371	7
Fort Randall	31	3	578	6
Gavins Point	28	2	1,022	7
Total	**213**	**22**	**4,308**	**32**

[1] The Natural Resource Management System (NRMS) reporting areas include sites where visitor use occurs and may include visitor centers, powerplant exhibit areas, cabin sites, fishing access areas, campgrounds, multiple-use areas and day-use facilities. These areas are located both upstream and immediately downstream of the dam within the project boundary. The 188 total sites referred to in Section 4-06.7 are just public recreation areas on the respective System projects.

4-06.8. Missouri River Basin - Irrigation Facilities. Irrigation is the largest single consumptive use of water in the Missouri River basin. As of 2012, about 14.2 million acres of irrigated land required an annual farm delivery of nearly 13 MAF of surface water. The USBR estimates water use in the Missouri Basin and updates those estimates every five years following the publication of the Agricultural Census from the USDA. The next update is anticipated in 2019 (based on data through 2017). State and local agencies have detailed information on the types of water users and group irrigation systems operated in the Missouri River basin. About 70 percent of the irrigated area is served by surface water and about 30 percent is served by groundwater. In years of deficient water supply, a significant portion of the area normally irrigated cannot be furnished the water required. Since 1965, an estimated additional 6.7 million acres have been placed under irrigation in the Missouri River basin, predominantly from groundwater sources and by private enterprise.

4-07. System Real Estate Acquisition. Construction of the System required the acquisition of approximately 1.7 million acres in fee, public domain transfers and easements. The individual System projects' WCMs contain additional details regarding real estate acquisition and relocations for that specific project. The following sections contain a brief description of the acquisitions for the System, the largest reservoir system in the United States.

4-07.1. Fort Peck Real Estate Acquisition. Approximately 590,085 acres were acquired for the Fort Peck project: 167,705 acres in fee, 422,069 acres from public domain and 311 acres in easement. Land acquisition was based on a guide-taking line at an elevation of 2250 feet, which is the top of the Exclusive Flood Control Zone, from the dam to RM 1863, approximately 3 miles downstream of the confluence of the Musselshell and Missouri Rivers. Land was acquired to a guide-taking line at an elevation of 2270 feet from RM 1863 to RM 1932. Land was acquired at this elevation due to the flatness of the terrain and the issues with winter ice-jam flooding in this reach.

4-07.2. Garrison Real Estate Acquisition. Almost 500,000 acres of real estate in fee and just less than 3,000 acres in easement were acquired for the Garrison project. Land acquisition was based on a guide-taking line at an elevation of 1855 feet, which is 1 foot higher than the top of the Exclusive Flood Control Zone, for a major portion of the reservoir area. In the upstream portion of the Garrison reservoir, the high potential for aggradation and backwater effects was recognized; therefore, land was acquired to an elevation of 1860 feet.

4-07.3. Oahe Real Estate Acquisition. Over 400,000 acres of real estate in fee and 2,417 acres in easement were acquired for the Oahe project. Land acquisition was based on a guide-taking line at an elevation of 1620 feet, which is the top of the Exclusive Flood Control Zone, with allowances for wave heights, set-up, wave run-up, erosion and bank caving. In the upstream portion of the Oahe reservoir, aggradation and backwater effects were recognized; therefore, land was acquired to an elevation of 1630 feet.

4-07.4. Big Bend Real Estate Acquisition. Approximately 45,412 acres in fee and 169 acres in easements were acquired for the Big Bend project. Land acquisition was based on a guide-taking line at an elevation of 1423 feet, which is the top of the Exclusive Flood Control Zone, with allowances for wave heights, set-up, wave run-up, erosion and bank caving, or a 300-foot setback from the 1423-foot contour, whichever was the greater. Flowage easements were acquired on four tracts of land having a total area of less than 10 acres.

4-07.5. Fort Randall Real Estate Acquisition. Approximately 114,163 acres in fee and 649 acres in easements were acquired for the Fort Randall project, including 514 acres of flowage easements at 15 locations. In addition, Public Land Order transferred 173 acres from the public domain. Of the total originally acquired for Fort Randall, approximately 15,000 acres were later included as necessary real estate for the Big Bend project. A guide-taking line at an elevation of 1375 feet, which is the top of the Exclusive Flood Control Zone, was the basis of the acquisition over most of the reservoir area.

4-07.6. Gavins Point Real Estate Acquisition. Approximately 34,474 acres in fee and 212 acres in easements were acquired for the Gavins Point project. No public domain land was involved at this project. The guide-taking line for the main body of the reservoir was to an elevation of 1210 feet, which is the top of the Exclusive Flood Control Zone, with a provision for wave heights, erosion, bank caving, set-up and wave run-up. A provision was also made for raising the elevation of the guide-taking line in upper reaches of the reservoir to allow for sedimentation and backwater effects.

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V - Data Collection and Communication Networks

5-01. Data and Communication. This chapter describes the data collection and storage as well as the communication methods used to meet the Corps' mission of managing the Nation's water resources in the Missouri River basin.

5-02. Hydro-meteorological Data. Hydro-meteorological data is collected throughout the basin through a variety of sources and integrated into the verified and validated centrally-located Corps Water Management System (CWMS) Oracle database of the Missouri River Region's (MRR) Water Management System (WMS). The collected data includes, but is not limited to, river stages and flows, reservoir elevations, inflows and releases, water and air temperature and precipitation, which are collected and transmitted via data collection platforms (DCP) and other telemetered devices. Gridded data, including precipitation, air temperature and plains snowpack and location-specific data, including air temperature and precipitation, plains and mountain snowpack, as well as non-Corps reservoir and various other hydro-meteorological data from other agencies such as the USBR, USGS, NWS, NRCS and state agencies, are collected, verified, validated and stored in the MRR CWMS Oracle database or the MRR WMS. The MRR consists of the three Missouri River basin water management offices: Omaha District, Kansas City District and MRBWM. The CWMS Oracle database and MRR WMS are discussed in detail in Section 5-11 of this manual.

5-03. Precipitation Data. Precipitation data is available through automated precipitation gages at real-time DCP stations and observer precipitation stations. Spatially-distributed observed precipitation data is provided by the NWS through its quantitative precipitation estimates (QPE). The precipitation grids are used as one of the primary data sources for watershed Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) runoff models. The hourly QPE files are automatically retrieved from the NWS Missouri Basin River Forecast Center (MBRFC) and converted into 4-km x 4-km resolution grids and stored in gridded format on the MRR WMS at 1-hour and daily total intervals. Forecasted precipitation grids are also available for NWS quantitative precipitation forecasts (QPF) products. Like the QPE products, the QPF products are retrieved from the MBRFC and converted into 4-km x 4-km resolution grids and stored in gridded format at 6-hour time steps for five days into the future for almost all areas of the basin. The primary purpose of the DCP real-time and observer precipitation networks is for validation of the QPE data, for use as primary data during that portion of the runoff season when QPE data are not considered accurate and for reporting purposes on MRBWM bulletins.

5-03.1. Precipitation Station Locations. The individual mainstem WCMs contain maps of key hydro-meteorological stations in the upper Missouri River basin. Plate V-1 shows the locations of the NWS Weather Surveillance Radar 1988 Doppler (WSR-88D) sites from which spatially-distributed observed precipitation is estimated for the MBRFC QPE precipitations grids. Data gathered through this basic network is augmented by numerous additional reports from the NWS and Corps' Districts at times of significant precipitation.

5-04. Air Temperature Data. 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 several data exchange methods, including the University Corporation for Atmospheric Research's Unidata local data manager (LDM) and methods developed and supported by the Corps' Cold Regions Research and Engineering Laboratory (CRREL) and HEC. The air temperature data is converted into 4-km x 4-km square pixels and stored in 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. The air temperature grids are used as one of the primary data sources for watershed HEC-HMS snowmelt runoff models. 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 via a Corps-developed and supported data exchange routine.

5-05. Water Temperature Data. Each mainstem project has a thermometer located in a turbine unit to record hourly tailwater temperatures. See Section 5-02 of the individual WCMs for a description of how that water temperature data is collected, transmitted and stored in the WMS. Real-time river water temperature data is available via select real-time DCP stations. The USGS has installed thermistors at several key Missouri River and tributary DCP stations at locations throughout the basin. The MRBWM office references the river water temperature data throughout the winter season as they adjust mainstem releases to reduce the risk of ice-induced flooding.

5-06. Snow Data. Nearly 75 percent of the total annual runoff that enters the System occurs during the 5-month March-July period. The runoff is from rainfall events and the melting of the winter's snow accumulation over the northern plains area during the spring (March-April) and from rainfall events and the mountain snowmelt during the late spring and early summer (May-July). Spring and summer flooding in the upper basin is usually associated with these events when there is above-average plains and/or mountain snow accumulation. Snowmelt also contributes to flood flows that occur throughout the lower basin. Measurement of the snow depth and water content of the snow cover, in combination with quantitative as well as qualitative assessments of other related data, provide insight into the potential magnitude of runoff events. This, in turn, enables System regulation to be adjusted accordingly so that flood control, as well as the other authorized project purposes, may be accomplished according to the operational objectives stated in this manual.

5-06.1. Plains Snow. In many years a major portion of the annual runoff from the plains area is a result of the melting of the plains snowpack accumulated during the winter months. This melt usually occurs during March or April, but can occur in February and even as early as January. During March and April, the 2-month period when plains snow is normally melting and spring rainfall is occurring, the runoff in the upper basin totals about 25 percent of its annual total. Determining runoff from plains snowpack is extremely challenging because it is dependent on many factors, primarily 1) soil moisture and infiltration capacity during the snowpack accumulation period and during the snowmelt, 2) water content of the accumulated snowpack prior to the melt period, 3) rainfall amount and intensity occurring during the snowmelt, and 4) daily high and low air temperatures before and during the snowmelt. Plates III-16 through III-19 show the Missouri River basin annual mean snowfall, annual maximum snowfall, extreme minimum snowfall and extreme maximum snowfall, respectively.

5-06.1.1. Plains Snow Surveys. Since 1948, plains-area winter ground surveys that determine the snow water equivalent (SWE) of the plains snowpack have been conducted in the Missouri River basin by Omaha District personnel during years of high plains snowmelt runoff potential. Plains snow surveys within the Omaha and Kansas City District boundaries can be made at their discretion, with inter-District coordination by the MRBWM office. Basin-wide surveys are normally conducted from mid-February to mid-March during those years that a moderate to heavy plains snowpack is noted. Since 2010, the MRBWM office has overseen a cooperative plains snow survey to characterize the plains snowpack and estimate plains SWE during the plains snow accumulation season. The cooperative survey, which was developed and is managed by the MRBWM office, utilizes volunteers from federal and state agencies, county and city government and private citizens to make standardized periodic measurements of plains snow characteristics. Data pertinent to estimating runoff potential are observed at specific locations and include SWE, snow depth, amount of ice layer present on the ground surface, a qualitative estimate of surface ground saturation, amount of drifting and the condition of the ground surface with regard to frost penetration. Reports of plains snow surveys are submitted to the MRBWM office, which collects and distributes all cooperative snow survey data to all participants, the Omaha and Kansas City Districts, the NWS MBRFC and NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) via email and the MRBWM external website. One of the primary uses of the snow survey data is to verify and adjust model snowpack assessments conducted by the MBRFC and NOHRSC. Ultimately, the snow data is analyzed by appropriate District water control offices, the MRBWM office, the NWS and other agencies and used to assess flood potential throughout the basin.

5-06.1.2. NWS National Snow Analysis. The NOHRSC incorporates all measured snow observations from the Corps' cooperative snow survey and many other sources into its National Snow Analysis. The National Snow Analysis provides a nation-wide modeled snow assessment of all plains and mountain snowpack using ground observations, airborne gamma radiation surveys and the Snow Data Assimilation model. This product is used by the NWS, the Corps and other agencies to model snowmelt runoff and forecast streamflow and runoff volumes for localized flooding and reservoir inflow forecasts.

5-06.1.3. Corps' Missouri Basin Snow Tool. The Missouri Basin Snow Tool (MBST) is a web-based application designed by CRREL and the MRBWM office to provide real-time and historical information for upper basin plains snowpack. The tool is used to assist the MRBWM office in determining 1) potential plains snowpack runoff volumes and 2) the likelihood of snowmelt-based floods. Ultimately, it is used to inform reservoir management decisions for the System. SWE can be estimated using empirical relationships between SWE and remotely-sensed passive microwave radiation naturally emitted from the earth's surface. Daily SWE data from two sources are used for comparison: the National Snow and Ice Data Center and the Global Snow Monitoring for Climate Research. Both SWE products are based on passive microwave data from the Special Sensor Microwave/Imager (SSM/I). The MBST provides near real-time weekly SWE estimates throughout the winter season and is available through the Corps' network. SWE estimates can be viewed by Hydrologic Unit Code 2 (HUC-2) or HUC-8 basins or by System reach areas. The real-time SWE estimates are provided along with statistics computed from approximately 30 years of SSM/I data. This tool provides historical context by comparing real-time estimates of basin SWE with historical years of basin SWE. Statistical categories of basin SWE based on the 30 years of SWE data allows forecasters to assess the magnitude and severity of plains snowpack, both spatially and temporally, for all watersheds in the Missouri River basin. This tool may be used to determine plains snow cover categories described in the MRBWM technical report, *Long-Term Runoff Forecasting*, February 2017.

5-06.1.4. Plains Snowmelt Runoff Modeling. The NOHRSC model results are converted into spatially-distributed observed daily plains snow SWE estimates for the entire basin by the Corps' CRREL and HEC offices and provided to the MRBWM office (see Section 5-04). The plains snow grids have a daily time step and are in 4-km x 4-km square pixel formats. The plains snow grids, in addition to precipitation and air temperature grids, are used as one of the primary data sources for watershed HEC-HMS snowmelt runoff models.

5-06.2. Mountain Snow. During May, June and July, the 3-month period when mountain snow is normally melting and spring rainfall is occurring, the runoff in the upper basin totals about 50 percent of its annual total. Mountain snowpack accumulation occurs above Fort Peck and Garrison and is tracked by the MRBWM office. Historically, runoff from the Fort Peck and Garrison reaches during the May-July period accounts for about 40 percent of the annual runoff in the upper basin. Mountain snowpack accumulation is the primary factor that the MRBWM office uses to forecast the May-July runoff in the Fort Peck and Garrison reaches, as described in the MRBWM technical report, *Long-Term Runoff Forecasting*, February 2017. As part of the Snow Survey and Water Supply Forecasting program, the USDA-NRCS National Water and Climate Center (NWCC) administers an automated snow monitoring program consisting of several types of automated and semi-automated data collection methods. The USDA-NRCS Snow Telemetry (SNOTEL) network is comprised of over 800 automated data collection sites located in remote, high-elevation mountain watersheds in the western U.S. The sites are used to monitor snowpack, precipitation, temperature and other climatic conditions. In addition, the NWCC administers a manual snow monitoring program for the western U.S. Manual monitoring consists of monthly snow course measurements and aerial marker observations of mountain snowpack. Additional information regarding the USDA-NRCS snow monitoring program can be found on their website: https://www.wcc.nrcs.usda.gov/.

5-06.2.1. USDA-NRCS Manually Measured Snow Courses. Snow courses are locations where manual snow measurements are taken by the USDA-NRCS during the winter season to determine the depth and water content of the snowpack. Snow courses are permanent locations and represent the snowpack conditions at a given elevation in a given area. Generally, snow courses are about 1,000 feet long and situated in small meadows protected from the wind. They consist of a variable number of equally-spaced individual sample points, typically five to ten. Once onsite, the surveyors use snow samplers at each sample point to measure the depth of the snowpack and then weigh the snow to determine the SWE. The data collected are then entered in the NWCC's database.

5-06.2.2. USDA-NRCS Automated SNOTEL Stations. For the two mainstem reaches that are impacted by mountain snowmelt, above Fort Peck and Fort Peck to Garrison, data from approximately 100 SNOTEL stations are used (about 50 per reach) in the MRBWM long-term runoff forecasting model. The data collected at SNOTEL sites are transmitted to the NWCC's database and used for water supply forecasting, maps and reports. The SNOTEL sites are designed to operate unattended and without maintenance for a year or more. A typical SNOTEL remote site consists of measuring devices and sensors, an equipment shelter for the radio telemetry equipment and an antenna that also supports the solar panels used to keep batteries charged. A standard sensor configuration includes a snow pillow, a storage precipitation gage and a temperature sensor. The snow pillow measures how much water is in the snowpack by weighing the snow with a pressure transducer. Devices in the shelter convert the weight of the snow into SWE. SNOTEL stations also collect data on snow depth, all-season precipitation accumulation and air temperature with daily maximums, minimums and averages. The data collected at SNOTEL sites are generally reported multiple times per day, with some sensors reporting hourly. The SNOTEL data is available via the NWCC website, which is accessed by the MRBWM office. This network of data provides information to determine the amount of SWE in the mountain snowpack in the Missouri River basin. Once the SWE is known, various techniques are used to determine the expected volume of May-July runoff that will occur above Fort Peck and Garrison. Over the years, real-time SNOTEL stations have replaced the manually measured snow courses to the extent that the MRBWM office exclusively uses real-time SNOTEL data in their Missouri River upper basin runoff forecast as outlined in the *Long-Term Runoff Forecasting* MRBWM technical report. A more detailed description of the USDA-NRCS and the SNOTEL system's role in hydrologic forecasting is available in Section 6-06 of this manual.

5-07. River Stages and Flows. River stage and flow information reported to the MRBWM office are supplemented by reports from many tributary locations, particularly during the March-July flood season or other times of the year when unusual stages or flows are occurring. Refer to the individual mainstem WCMs for key locations within each incremental drainage area, as well as the reach from Gavins Point to Sioux City, IA, where streamgaging stations (DCPs) are located.

5-07.1. Historical River Data. In the 1950s, river stage data were recorded onsite by observers and that data sent to the Corps on a weekly basis by U.S. mail. In the early 1960s, the Corps contracted directly with individual observers and collected the river stage by phone on a daily basis. This data collection effort was necessary to effectively regulate the System and tributary reservoirs.

5-07.2. USGS Cooperative Program. Beginning in the late 1960s, the Corps began to contract out the river data collection and maintenance effort to the USGS and NWS through cooperative streamgaging and precipitation network (Co-op) programs. The USGS, in cooperation with other federal and state agencies, currently maintains a network of real-time DCP streamgaging stations throughout the Missouri River basin. The USGS is responsible for the supervision and maintenance of the real-time DCP streamgaging stations and the collection and distribution of streamflow data. In addition, the USGS maintains a stage-discharge measurement program at the stations so that the stage-discharge relationship (i.e., rating curve) for each station is current. Through cooperative arrangements with the USGS, stage-discharge measurements at key Missouri River locations downstream of Gavins Point are made at a greater frequency than is normally considered adequate for historic streamflow records. The increased number of stage-discharge measurements at these locations are necessary to maintain the most current stage-discharge relationships at these stations. Current Missouri River rating curves are required to ensure that System regulation, whether geared to flood control or other authorized purposes, may proceed as efficiently as possible. Results of stage-discharge measurements at key stations are furnished by the USGS to the MRBWM office and the NWS as soon as available. The stage-discharge measurements are also posted on the MRBWM website for District and public dissemination. Upon special request, the appropriate District arranges and furnishes discharge data for stations not included in the basic network. In addition to the stations maintained by the USGS, other federal and state agencies, including the Corps, NWS, and USBR, and private entities, collect stage, and occasionally discharge, data at certain locations. These additional data, if deemed useful or pertinent to System regulation, can usually be obtained from these parties by establishing appropriate data retrieval means.

5-07.3. Non-DCP River Data. The MRBWM office obtains most of the daily precipitation and stage data it needs for real-time System regulation directly from satellite DCPs using the Geostationary Operational Environmental Satellite system. The NWS also distributes most of the hourly stage information used for regulation of the System over its data networks and websites. Arrangements for the NWS reporting of stage data pertinent to System regulation are made through the NWS MBRFC, located in Pleasant Hill, MO and provided directly to the MRBWM via data exchange methods described in Section 5-04. Most of this information is available to the public via either the internet or through private vendors who redistribute the information. The MRBWM office uses graphical- and text-based weather data for regulation of the System and for in-house briefing purposes. Graphics and text are updated automatically as products are prepared and transferred on a scheduled basis. Important streamgaging stations and key reservoir reporting stations are located within the Missouri River basin. Refer to the individual WCMs for detailed station maps pertinent to the regulation of the individual reservoirs. In addition to the basic network, ad-hoc stream-related data are received, often on a seasonal or emergency basis, directly from the MBRFC. Listings and locations of these stations are presented in individual project WCMs and in appropriate disaster manuals for flood emergency operations.

5-08. Reservoir Data. Hourly data are automatically transmitted from the each mainstem project's PPCS via satellite telemetry from a 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 speed and direction. The daily data files include daily maximum and minimum air temperatures, precipitation, manually-entered pan evaporation and tailwater temperatures. Precipitation, air temperature and wind data are obtained from a weather station at some locations. In the event the automatic data collection and transfer is not working, project personnel fax or email hourly and daily project powerplant data to the MRBWM office and the MRBWM staff manually inputs the information into the MRR CWMS Oracle database. Each project's monthly summary is faxed or emailed to the MRBWM office and is used to verify daily data.

5-08.1. Evaporation Data. Evaporation data are particularly significant on the very large System reservoirs. The average annual water loss due to evaporation at the Fort Peck reservoir (Fort Peck Lake) since the System became fully operational (1967 to 2017) is 670,000 acre-feet; Garrison reservoir (Lake Sakakawea) is 877,000 acre-feet; Oahe reservoir (Lake Oahe) is 906,000 acre-feet; Big Bend reservoir (Lake Sharpe) is 183,000 acre-feet; Fort Randall reservoir

(Lake Francis Case) is 252,000 acre-feet; and Gavins Point reservoir (Lewis and Clark Lake) is 95,000 acre-feet.

5-08.1.1. Pan Evaporation Data. Daily manual observations of evaporation depth, pan wind movement and pan temperature are made from April through October. Observations are not made during the other months because the pan water freezes. Based on the observed pan readings, a reservoir evaporation coefficient is computed and used to determine the daily loss of storage due to evaporation. The evaporation rate in inches per day is manually entered into the PPCS at each project.

5-08.1.2. Reservoir Evaporation Model. The MRBWM office and Omaha District partnered with the Corps' CRREL to develop a more accurate real-time model, known as the Omaha District Evaporation Technique, to determine reservoir evaporation. This real-time model uses local hydro-meteorological hourly data, including air temperature, dew point, wind speed, relative humidity, air pressure and cloud cover to calculate solar radiation in addition to water temperature profiles, which are then used to estimate reservoir evaporation. The MRBWM office plans to implement this new technique in 2019.

5-08.2. Air Temperature Data. Air temperature is important hydro-meteorological data used in the regulation of the System. Snowmelt and ice formation can be anticipated by observing air temperature readings. Air temperature, along with wind speed, wind direction and precipitation, are recorded hourly at each project using automated weather equipment. The data are supplied to the MRBWM office as described in Section 5-08. In addition to the data collected at the projects, regional air temperature data are obtained as described in Section 5-04. Air temperature and wind direction and velocity data is critical for the prediction of river ice formation. During the winter, forecasts of river ice formation are considered in the regulation of the System to ensure adequate water supply and to prevent flooding. Air temperature data is also important during the summer months when river water temperatures can exceed established Missouri River water quality standards under low-flow conditions.

5-08.3. Tailwater Temperature Data. The river water temperatures just downstream of the System dams usually vary from the mean air temperatures due to the large amount of water in storage in the System reservoirs. While this tailwater temperature is an important water quality parameter, it is of most concern to the regulation process as an index to surface water temperature, an important element in the development of evaporation estimates. Tailwater temperature is also an important element in predicting downstream water temperatures and for estimating formation and movement of the ice cover below the projects. Each mainstem project has a thermometer located in the tailrace area to record daily tailwater temperatures, as described in Section 5-05. See Section 5-02 of the individual WCMs for a description of how that water temperature data is collected, transmitted and stored in the MRR WMS.

5-09. River Reconnaissance Data Collection. While the conditions expected to result from regulation of the reservoirs can be estimated or modeled through empirical means developed from past experience, verification requires accurate field observations. Project personnel make numerous reconnaissance trips to portions of the Missouri River that are affected by project releases, as well as reservoir areas affected by pool elevation, to obtain current information pertinent to System regulation. During the winter season, project personnel make and report observations of reservoir ice cover and Missouri River ice conditions to the MRBWM office. Video cameras have been installed throughout the basin that can be used to ascertain river and reservoir conditions. These video cameras are owned and maintained by various entities; most are available to the public, but some have a limited access. The MRBWM office uses its website to list the available video cameras. Effects of unusual release rates or reservoir levels are also documented by field observations. Bank erosion below projects and along the reservoir shoreline is also a matter of concern. The reconnaissance trips consist primarily of visual observations and verbal reports to the appropriate Omaha District office and the MRBWM office. The trips are usually supplemented with photographic imagery. When particularly unusual events occur, such as an ice jam or blockage, collection of aerial photography or video imagery may be scheduled. Normally, the Omaha District coordinates and contracts for the acquisition of the aerial photography or video imagery. If aerial photography or video imagery is conducted to observe ice cover, the photography or video is shared with the local NWS Weather Forecast Offices (WFO), the MBRFC and the Corps' national river ice point of contact at CRREL.

5-10. Responsibilities for Data Collection, Analysis and Dissemination. The Omaha and Kansas City Districts are responsible for making appropriate arrangements to ensure adequate hydrologic coverage within their respective boundaries. In addition to the requirements for regulating the System, these data are essential for the Districts to accomplish their water resources mission of tributary reservoir regulation, tributary flow and stage forecasting and emergency operations on both the Missouri River and tributaries. Pertinent data collected by the Districts are immediately forwarded to the MRBWM office through established communication channels. The MRBWM office also maintains direct contact, either by telephone or email, with the NWS, NRCS, USGS, USBR, Western, USFWS, U.S. Coast Guard (USCG) and many other agencies and individuals who provide hydrologic and other data integral to the regulation of the System.

5-10.1. Database. All received data are directly stored in the MRR CWMS Oracle database and/or the MRR WMS, both of which can be accessed by all MRBWM and District water management staff. Water management staff in all three offices cooperatively verify the data accuracy several times each day. These verified data are used to make scheduling decisions regarding release rates from the System and tributary reservoirs. The MRR WMS provides graphical representation of all pertinent data. The graphical representation of river flow hydrographs allows water management staff to quickly determine if the data are accurate and establish basin streamflow patterns. These data are then integrated into various runoff scenarios and/or models so that multiple reservoir simulations can be run to determine the best reservoir regulation schedule to meet the operational objectives stated in this manual. Data can be displayed on individual water manager workstations and are also posted to the MRBWM external website for public dissemination. The CWMS Oracle database and graphics are continually updated to provide the water management staff and the public with the most up-to-date information.

5-11. Water Quality Data. Several water quality monitoring programs have been established for the System reservoirs and the Missouri River. See Appendix C of this manual for details regarding the water quality data collected, the locations where the data is collected and the direct and indirect impacts to water quality as it relates to System regulation. There is no comprehensive, integrated monitoring and reporting program for the entire Missouri River basin between the federal agencies and the individual states. The collection and storage of water quality data has been achieved on an irregular basis by numerous federal and state agencies. As detailed in Appendix C, the Corps has conducted long-term fixed station monitoring, intensive surveys, special studies and investigative monitoring on selected Missouri River reaches and at the six System reservoirs. This monitoring was originally conducted to meet the annual water quality reporting requirement, and recently, is done to facilitate preparation and implementation of project-specific water quality management plans. Water quality data collected by the Corps is available by contacting the Omaha District's Water Control and Water Quality Section. The USGS collects, analyzes and interprets water quality data throughout the Missouri River basin. This data is available on USGS's website: https://water.usgs.gov/owq/index.html. Basin states have collected water quality data in the basin to meet their monitoring and reporting requirements pursuant to the Clean Water Act (CWA). State agencies that can be contacted for water quality information include: Montana Department of Environmental Quality, North Dakota Department of Health, South Dakota Department of Environment and Natural Resources, Nebraska Department of Environmental Quality, Iowa Department of Natural Resources, Missouri Department of Natural Resources and Kansas Department of Health and Environment.

5-12. River Sediment Stations. The Omaha and Kansas City Districts operate 9 suspended-sediment sampling stations. Six of these stations are located on the Missouri River at Sioux City, IA; Omaha, NE; Nebraska City, NE; St. Joseph, MO; Kansas City, MO; and Hermann, MO. The remaining three stations are tributary stations at the Yellowstone River at Sidney, MT; the Bad River at Fort Pierre, SD; and the White River at Oacoma, SD. All sampling is conducted by, or in cooperation with, the USGS.

5-13. Other Project Data. Similar reports from tributary reservoirs that may affect System regulation are furnished on a daily, or as needed, basis by the District offices. Other federal, state and local agencies, primarily the USBR, who are responsible for regulation of non-Corps reservoir projects, furnish reports to the MRBWM office when their operations affect System regulation. Monthly reservoir summary reports are prepared by the MRBWM office for each System project. The reports include tabulations of daily average inflows, releases and evaporation losses and midnight pool elevations and storage. Similar reports are furnished by the Districts for each of the Corps and USBR tributary reservoirs in which the Corps has a regulation responsibility. These reports are prepared on a monthly basis and maintained in electronic and paper form in the MRR WMS and each office's filing system, respectively, and are also available via each office's external website. See Plate V-2 for an example of a monthly reservoir summary report.

5-14. Water Management System. The MRR WMS includes all aspects (hardware and software) of data acquisition, data transformation, data storage (CWMS Oracle database), data dissemination (internal and external websites) and modeling. The MRR CWMS Oracle database is maintained by MRBWM staff and is utilized by all three MRR water management offices as the production database to store, validate and integrate all data.

5-15. MRR WMS Continuity of Operations Plan. The production WMS is physically located in the Omaha federal building, where Omaha District and MRBWM staff are located and is fully backed up in the Kansas City federal building, where Kansas City staff are located, as part of the

MRR WMS Continuity of Operations Plan (COOP). Both WMSs are connect with battery-powered uninterrupted power supplies and diesel-powered emergency generating facilities to ensure continual operation. On a semi-annual basis, the three WM offices conduct a week-long COOP exercise to verify that the WMS located in Kansas City has full functionality and can operate as the production WMS should the WMS in Omaha not be available. Plate V-3 shows the interconnection of the data acquisition, data processing, data storage, data dissemination, data exchange, and watershed modeling within a typical WMS.

5-16. Corps Water Management System (CWMS). CWMS is the automated information system (AIS) developed and supported by HEC and used by the Corps to support its water control management system. CWMS is an integrated system of hardware and software that begins with the receipt of hydro-meteorological, watershed and project data. This data is then processed, stored and made available through a user-friendly interface to the water manager to evaluate and model the watershed. Both modeled and processed data can be displayed and disseminated in tabular, graphical and/or geo-spatial form resulting in an effective design support system. CWMS allows evaluation of any number of operational alternatives before a final forecast scenario and release decision are adopted. For example, various alternative future precipitation amounts may be considered, hydrologic response may be altered, reservoir release rules may be investigated and alternative bridge obstruction, levee integrity, or other river conditions may be evaluated. When an operational decision is made, the results (e.g., project releases, forecasted downstream flows and stages), along with supporting hydro-meteorological, watershed and project data may be disseminated to others via web technology. CWMS has been deployed to over 35 Corps District and Division offices with a water management mission and is currently available only to Corps offices. CWMS is "live" 24/7/365 (24 hours per day, 7 days per week, 365 days per year), continuously providing support during routine high and low flow periods, and during emergencies. CWMS is self-monitoring providing automated status information on components and processes and alerting to service needs.

5-17. Corps - Weekly Briefings and Monthly Calls. Weekly briefings, or more often should conditions warrant, are held in the MRBWM office for key personnel. During these briefings pertinent basin hydro-meteorological information is discussed and short-term and long-term System regulation decisions are made. On a monthly basis, after the draft monthly runoff and regulation studies are completed during the first few business days of each month, the MRBWM office conducts a teleconference with the mainstem Operations Project Managers (OPMs) and various members of the NWD and two district offices. During this monthly call the MRBWM office discusses the latest upper basin runoff forecast and how that forecast was integrated into the draft monthly regulation studies and provides the mainstem OPMs and others the opportunity to provide feedback before the studies are finalized.

5-18. Monthly Webinars. Following the 2011 flood the Corps' NWD committed to better communication basin-wide concerning the current status of the reservoir System and runoff projections. Once the monthly studies are finalized, the MRBWM conducts a monthly webinar with federal, state, county and local officials, Tribes, emergency management officials, independent experts and the media to update all regarding current basin and reservoir conditions, forecasted upper basin runoff, the latest monthly regulation studies and to listen to and respond to any questions or concerns. The monthly webinars are generally held in January through June, and later months should conditions warrant. The monthly webinar is not held in April because the MRBWM semi-annual face-to-face public meetings are conducted in April throughout the Missouri River basin.

5-19. Off-Duty Hours. MRR water control managers have the capability to remotely access the MRR WMS. This capability allows the MRR water management staff to effectively manage the System and tributary projects 24/7/365, including holidays and weekends. The MRBWM Power Production and Reservoir Regulation team leads, as well as the chief of the MRBWM office, are generally available by cell phone as are several of the OPMs. The MRBWM weekend worker also carries a cell phone and has the responsibility of notifying the appropriate MRBWM staff so that proper coordination has occurred before significant changes are made to project releases.

5-20. Communications Network. The following sections describe the general communication network infrastructure between the three Corps offices responsible for regulating the System and tributary reservoirs in the Missouri River basin.

5-20.1. Physical Description. The global network of the Corps consists of a mixture of leased lines and multi-protocol label switching clouds between every Division and District office worldwide. These lines are procured through approved General Services Administration (GSA) telephone vendors. Each office has a minimum of two connections for redundancy. The primary protocol of the entire Corps network is Ethernet. Plate V-4 shows how a typical water management office integrates CWMS into their WMS.

5-20.2. Reliability. The reliability of the Corps' network is considered a command priority and, as such, supports a dedicated 24/7/365 Network Operations Security Center (NOSC). The NOSC, maintains operational status of the network. This team coordinates with all telephone vendors as outages occur and informs local information technology staff of problems and solutions. The NOSC has full control of all routers, firewalls, and any other communication equipment that is required to connect the local office to the Corps' cloud network. This approach mitigates the risk of any office not having access to the global network for command and control purposes. The use of multiple data service vendors supplying the network connections minimizes the risk of a cable cut causing an outage for any office. This redundancy, plus the use of satellite data acquisition, makes for a very reliable water control network infrastructure.

5-20.3. Local Operations. The local office network operations begin at the demarcation point of the global network. For the water management mission, the network is treated as a separate entity. This design allows data acquisition to take place within the finite network of the water management subnet.

5-20.4. Emergency Power. The MRBWM office is a critical component of the emergency operations plans of both Omaha District and Kansas City District. The MRBWM office must be able to function in cases of flooding or other disasters, which typically are followed by the loss of commercial electricity. A GSA-provided diesel-powered generator is physically located in the Zorinsky Federal Building where both the MRBWM and Omaha District offices are located. The generator is regularly tested by GSA to verify operability. Commercial fuel companies or Army fuel depot units, in the case of extended electrical outages, can be used to fuel the generator. The Kansas City District office building does not have a generator. Rather, Kansas

City District has access to large truck-mounted generation equipment that can be rapidly deployed and placed into service should an extended power outage occur.

5-20.5. Typical Equipment. The Corps' network is based on the Ethernet protocol. Thus, many different devices (e.g., switches, routers) are used to implement the physical layer interconnection between device and network. The typical MRBWM office local area network consists of 10/100/1000 megabit unshielded twisted pair cabling to each device. The switches are connected to the corporate firewall appliances, which are then connected to the physical phone network.

5-21. Communication with Projects. The following sections describe the communication between the MRBWM office and the System projects.

5-21.1. Daily Orders. The MRBWM office is responsible for the regulation of the System. Communication between the MRBWM office and System project offices is normally through daily reservoir regulation/power production orders (daily orders), which are emailed from the MRBWM office to the System project offices. The daily orders usually specify the daily average individual System project releases to be made. Scheduled power generation and maximum allowable tolerances or limits are also included in the daily orders. Maximum hourly generation is also included, recognizing current head conditions and the number of available units. Any additional release requirements, such as minimums, steady releases, or release patterns for T&E species operations, are also outlined in the daily orders. In some cases, when no changes in releases are likely to occur at a particular project, daily orders may be sent to cover a period of several days. Normally, the daily orders are sent on Friday to cover the weekend period of project regulation, but the MRBWM weekend worker will change the daily orders if deemed appropriate. In the event of loss of network communications, daily orders can be transmitted verbally via telephone.

5-21.2. Public Requests and Complaints. Throughout the year the project personnel investigate requests and complaints that occur as a result of System regulation and report their recommendations and findings to the MRBWM office. The MRBWM office keeps the 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 individual WCMs and also in Section 7-04.18 of this manual.

5-21.3. Standing Orders. Standing orders are reservoir regulation/power production orders that provide general and continuing guidance to the System projects above and beyond that contained in the daily orders described in Section 5-21.1. For example, standing orders may specify minimum permissible generation for varying durations of time from 1 to 12 hours, maximum release fluctuations and similar regulating limitations. When appropriate, standing orders are referenced in the daily orders to avoid repeating this guidance in each order.

5-21.4. Critical Regulation Periods. During critical reservoir regulation periods and to ensure timely response, significant coordination is often conducted by telephone between the project office and the MRBWM office. See Section 5-19 regarding coordination during off-duty hours.

5-21.5. Between the Project Office and Others. Each System project office is generally responsible for local notification and for maintaining lists of those individuals who require notification under various project regulation changes. In addition, each System project office is responsible for notifying the public using project recreation areas, campsites and other facilities that could be affected by various project release changes. A more complete discussion of project notification procedures is located in each individual project WCM and each project's specific Mainstem O&M Manual, Appendix E, Contingency Plan for Emergencies.

5-22. Project Reporting Instructions. As described in Section 5-08, hourly and daily hydrologic data from the System projects are automatically transferred to the MRR WMS. In the event the automatic data collection and transfer is not working, projects are required to fax or email hourly and daily project powerplant data to the MRBWM office. Once received, the MRBWM staff manually input the powerplant data into the MRR WMS. The System project personnel fax or email monthly summaries to the MRBWM office, which are used to verify daily data.

5-23. Reporting of Unit Outages. Project personnel are responsible for requesting any scheduled System hydropower unit outages in excess of two hours. The Power Production team of the MRBWM office, following coordination with Western and any other affected entities, will approve or deny the request. Out-of-service times are reported back to the MRBWM office upon completion of outages. Forced outages are also reported with an estimated return time, if possible. Any forced or scheduled outages causing the project to miss scheduled water release targets must be immediately reported to the MRBWM office. The mainstem project staff has been advised to contact the MRBWM's Power Production team when any unusual occurrence happens at the specific project that may affect project operations. This includes any confusion over project release schedules that have been coordinated between Western and the MRBWM office. It is imperative that the System projects release the amount of water ordered by the MRBWM within the authorized tolerances, as outlined in the daily and/or standing orders, which are described in Sections 5-21.1 and 5-21.3, respectively.

5-24. Warnings to the Public. Each project's O&M Manual, Appendix E, Contingency Plan for Emergencies, contains information regarding responsibilities, authority and notification lists in the event that any warnings need to be issued to the public. In the case of an emergency, initial in-house notification is to the District Emergency Operations Center (EOC). The District EOC will, in turn, notify the District Engineer, appropriate division chiefs in the District, the Public Affairs Office, the NWD Readiness and Contingency Office, and the appropriate state Civil Defense directors. Appendix E of each project's O&M Manual contains state Civil Defense contact information, maps of immediate downstream notification areas, flood inundation maps and other pertinent information.

5-25. Downstream Users. Additionally, the MRBWM office and System project staff maintain awareness of water intakes, marinas and other river users that could be affected by river flow and stage changes and/or changes in river conditions. Each District's Operations Division is responsible for maintaining a contact list of navigation interests. The MRBWM works closely with the NWS MBRFC staff, which has the responsibility for issuing flood forecasts and warnings to the public. The Corps provides System regulation information directly to the NWS, to allow it to fulfill its responsibility to notify the public of current and expected future river conditions. In addition, the Corps consults with the USCG if it is determined that the Missouri River might be closed for navigation for public safety and to preserve the integrity of the flood protection structures located adjacent to the Missouri River. The final responsibility for closing the river for any purpose rests with the USCG.

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VI - Hydrologic Forecasts

6-01. General. The Corps has developed techniques and maintains water management staff at the MRBWM office and at the Omaha and Kansas City Districts to conduct forecasting in support of the regulation of the System. Daily forecasting of river flow and stage is a challenging task due to the large size (529,350 square miles) of the Missouri River basin, along with the basin's hydrologic variability in climate. The Corps has developed runoff simulation and streamflow prediction models for those areas of the Missouri River basin that have the most significant impact on the Corps' System regulation responsibilities. The System has the largest amount of storage of any reservoir system in North America. The regulation of the multi-purpose System, therefore, requires the scheduling of releases and storages on the basis of both observed and forecasted runoff throughout the basin. Releases to provide downstream flow support are based on providing flow levels at designated downstream locations. The accumulation and evacuation of storage for the authorized purpose of flood control is accomplished in a manner that will lessen, insofar as possible, flows exceeding those which will cause direct flood damage downstream. Flood risk must be considered at all times. During both normal and below-normal runoff conditions, releases through the powerplants are scheduled, to the extent reasonably possible, at the times and rates that will maximize revenue returned to the federal government. The release level and schedules are very dependent on current and anticipated hydrologic events. The most efficient use of water is always a goal, especially during the course of a hydrologic cycle when below-normal streamflow is occurring. Reliable forecasts of reservoir inflow and other hydrologic events that influence streamflow are critical to the efficient regulation of the System.

6-02. Role of the Corps in Hydrologic Forecasting. The System was designed for long-term conservation regulation spanning many successive drought years. The flood control and drought conservation System regulation requires accurate and continual short-range and long-range runoff forecasting as well as river flow and stage forecasting. The runoff forecasts are used as input in MRBWM's System computer model simulations so that project release determinations can be optimized to achieve the regulation objectives stated in this manual. The MRBWM office continuously monitors the weather conditions occurring throughout the Missouri River basin and the forecasts issued by the NWS. The National Oceanic and Atmospheric Administration (NOAA)/NWS weather and hydrologic forecasts are integrated, in accordance with current Corps policy, into the MRBWM runoff and regulation forecasts. The MRBWM office develops these forecasts to meet the objectives of regulating the System and tributary reservoirs. The MRBWM office prepares long-range runoff forecasts based on estimates of rainfall and snowmelt runoff in the basin. In addition to long-range runoff forecasting, the MRBWM office performs short-range river flow and stage forecasting to assist in scheduling System and individual project releases.

6-03. Role of Other Agencies in Hydrologic Forecasting. Several other federal agencies have hydrologic forecasting responsibilities in the Missouri River basin, including the NWS, USBR and USDA-NRCS. In addition, there are other federal, state and local agencies involved in drought and emergency operations that are, at times, providing information that is of particular interest in regulating the System.

6-04. Role of the NWS in Mainstem Regulation. The NWS is responsible for all preparation and public dissemination of forecasts relating to precipitation, temperature and other meteorological elements related to weather and weather-related forecasting in the Missouri River basin. The NWS offices include the MBRFC and various WFOs in the Missouri River basin, as well as the NWS's Climate Prediction Center and Weather Prediction Center. The MRBWM considers the NWS its sole source of information for weather and climate forecasts. The meteorological forecasting provided by the NWS is considered critical to the Corps' water resources management mission. The use of basin condition and climate outlooks and subsequent runoff directly relates to project release decisions. Equally important, at certain times, are temperature forecasts related to snowmelt and ice-jam formation. The NWS has WFOs located throughout the Missouri River basin that can be contacted directly by MRBWM staff for weather-related information required to regulate the System. See Table VI-1 for a listing WFOs that issue or disseminate local weather forecasts that include portions of the Missouri River basin.

Table VI-1
Missouri Basin NWS Weather Forecast Offices

Montana	North Dakota	South Dakota	Nebraska	Colorado	Iowa	Missouri	Kansas
Great Falls	Bismarck	Aberdeen	Hastings	Denver/Boulder	Des Moines	Kansas City	Goodland
Glasgow		Rapid City	North Platte	Grand Junction		Springfield	Topeka
Billings		Sioux Falls	Omaha/Valley			St. Louis	Wichita
Missoula							

6-04.1. Forecasting Responsibility of the NWS. The NWS is the federal agency responsible for the preparation and issuance of river flow and stage forecasts for public dissemination. Because project regulation affects river flow and stage and vice versa, a close liaison is maintained between the Corps and the NWS as it relates to real-time regulation of the System. The MBRFC prepares forecasts for specified locations on the Missouri River as well as tributaries throughout the Missouri River basin. The MBRFC is also responsible for the supervision and coordination of river flow and stage forecasting services provided by the WFOs located throughout the Missouri River basin. The MBRFC routinely prepares and distributes 5-day river flow and stage forecasts at key streamgaging stations along the Missouri River from Sioux City, IA to the mouth. The MBRFC also provides the Corps' District offices with river flow and stage forecasts and reservoir inflow forecasts for selected locations and projects on request. On a weekly basis, the MBRFC prepares a monthly forecast of river flows and stages for the Missouri River. While both the Corps and the NWS prepare short-range river flow and stage forecasts, they do so for different purposes. The NWS forecasts include runoff from potential future precipitation to ensure that people in flood prone areas are provided the maximum warning possible of potential flooding. In some cases, if potential precipitation does not occur, the NWS forecast may over-estimate river flow and stage. Per Corps policy, the MRBWM forecasts only use runoff that is already being registered at the numerous streamgaging sites in the basin, coupled with an estimate of the ungaged runoff in the numerous river reaches based on water on the ground (i.e., observed rainfall or snowpack that has not yet been observed as flow at a streamgaging site). If the NWS-forecasted precipitation does occur, the MRBWM forecast may underestimate river flow and stage. Use of both the NWS and MRBWM forecasts can usually provide a reasonable range of future river flow and stage. The NWS is responsible for public dissemination of weather-related forecasts. The Corps' forecast, which is used to make System regulation decisions, is provided to the public via their website as information only.

6-04.2. Data Exchange with NWS Regarding Hydrologic Forecasting. The MRBWM office obtains most of the NWS information it uses through the internet or directly from the MBRFC via LDM or email. The agencies also actively participate in various monthly webinars and state-based flood/emergency awareness face-to-face meetings, and provide information to supplement the High Plains Regional Climate Center's quarterly climate impacts report, the Corps' seasonal flood outlook, or the NWS's winter and spring flood outlooks. This collaborative approach between the NWS and MRBWM has resulted in the streamlining of data collection and the improvement of data exchange processes in both agencies. When questions arise concerning the validity of data or forecasts, a telephone call or email between respective NWS and MRBWM forecasters normally resolves the issues.

6-04.3. NWS Forecasted Precipitation. The information provided by the MBRFC office and the WFOs are used to the maximum extent possible for regulation of both System and tributary reservoirs. These services are particularly useful when significant flood conditions are occurring or are imminent within the basin. The NWS generates QPF ranging from 24 to 120 hours, usually in 6-hour time steps. The NWS normally uses at least 24 hours of forecasted precipitation, and may choose to use more, in their river flow and stage forecasts. The QPF, as well as severe storm forecasts, provide qualitative information to the MRBWM office regarding its System release determinations. During periods of significant basin flooding, the frequency of contact between the MRBWM and NWS offices is increased to allow for a complete exchange of available data upon which the most reliable forecasts and subsequent project regulation can be based. As noted in Section 6-04.1, river flow and stage forecasts disseminated to the public are a NWS responsibility. The MRBWM conducts its own river flow and stage forecasting for System and tributary reservoir project release determinations. Not all Corps forecast results are made available to the general public, but are normally shared with the NWS. The NWS also makes its internal forecasts available to the MRBWM office as well as the Corps' District offices.

6-05. Role of the USBR in Hydrologic Forecasting. Several offices in the Great Plains Region of the USBR make long-range hydrologic forecasts of runoff volume that are used for the regulation of their tributary reservoir projects in the upper Missouri River basin. The USBR offices in Billings, MT; Casper, WY; and Loveland, CO prepare seasonal runoff forecasts for the basins in their states east of the Continental Divide in the Missouri River basin. The USBR uses SNOTEL and precipitation data collected by the NRCS and NWS. The USBR's seasonal runoff forecast models, which are based on multiple linear regressions, are developed in a similar manner to the NRCS's and Corps' models. All three agencies develop their models independently to ensure objectivity. All three agencies' models can subjectively incorporate basin conditions (e.g., dry, normal or wet soil conditions, streamflow conditions) and anticipated future spring precipitation (rainfall and/or snowfall) and temperature. The three agencies readily share and compare their seasonal runoff forecasts. The NRCS and the USBR develop and disseminate runoff forecast reports at the beginning of each month from January through June. Each office computes a January 1, February 1, March 1 and April 1 forecast report that indicates most probable April through July inflows for all their major tributary basins east of the Continental Divide. The USBR does not publish its seasonal runoff forecasts for public dissemination. Both offices exchange their results internally to the Corps via email or phone. These forecasts are furnished to the Corps District offices and the MRBWM office. These forecasts are used by the districts and MRBWM office in the regulation of tributary reservoir projects and in the integration of water supply forecasts for the Missouri River basin. The procedure of exchanging these runoff forecasts, beginning in January and extending through June of each year, has been long established in the Missouri River basin, dating back to the 1960s. The USBR is the federal agency responsible for providing the Corps with depletion estimates (e.g., monthly estimates of consumptive use and diversion of water from and return of water to the Missouri River) for the System that are used in long-term model simulations and to adjust current calendar year projections.

6-06. Role of the NRCS in Hydrologic Forecasting. The NWCC, located in Portland, OR, is responsible for producing seasonal runoff forecasts for the western United States, including the upper Missouri River basin. The NRCS field offices in Bozeman, MT; Casper, WY and Denver, CO; are responsible for the installation, maintenance, monitoring and data collection at snow courses and SNOTEL sites in the Missouri River basin, as discussed in Section 5-06.2. Data for the Missouri River basin are transmitted and stored in the Snow Survey and Water Supply Forecasting Program database in Kansas City, MO. Data review is conducted by personnel at the Bozeman and Denver offices. These offices, and the Casper office, are responsible for distributing the seasonal forecasts and working directly with water users and interests. All snow courses and SNOTEL data are currently available to the public via the NWCC website: https://www.nrcs.usda.gov/wps/portal/wcc/home. The forecasts are computed at the first of each month from January through June. Updated forecasts are available upon request. For the January 1, February 1, March 1 and April 1 forecasts, the NWCC office issues 4-month (April-July) and 6-month (April-September) forecasts of inflow volumes for all major tributary basins in the upper Missouri River watershed. On May 1, 3-month (May-July) and 5-month (May-September) forecasts of inflow volumes are issued. On June 1, 2-month (June-July) and 4-month (June-September) forecasts of inflow volumes are issued. The forecasts, along with information about current conditions, are distributed in a *Water Supply Outlook Report*, available via the NWCC website and at NRCS Snow Survey state office websites. Observed mountain SWE and water year precipitation are the primary parameters used in the forecast models. Generally, the NRCS only uses recently-observed data in their forecasts. The NRCS develops statistical forecast models using principal components regression analysis. Principal components regression analysis allows for the use of correlated input parameters, which can occur with closely-located stations measuring similar elements to be weighted appropriately and used in the forecast. If unusual conditions during the forecast year result in unreasonable forecast guidance, the NRCS hydrologist may update the model during operations, adjusting the forecast parameters. An example is the use of fall precipitation in the model, a surrogate for antecedent soil moisture and often improving the predictability of the spring and summer runoff. During operational forecasting of an extremely dry winter and spring, heavy early fall precipitation may be removed from the model. Preferably, the models are based on the most recent 30 years of snow, precipitation and streamflow data. Through streamflow analysis and historical observations, the NRCS hydrologists have found that, for basins that are primarily snowmelt-driven, the greatest predictability of seasonal runoff volumes occurs toward the end of the snow accumulation season, which typically in the upper Missouri River basin, is around mid-April.

6-07. Flood Forecasts. When hydrologic conditions exist so that all or portions of the Missouri River basin are considered to be flooding, the MRBWM office may run their short-range river flow and stage forecast model and short- and long-range reservoir regulation models, all described in Sections 6-10 through 6-12, on a more frequent basis. The model results are generally made available to the entire Corps and the public via the MRBWM website. While the Missouri River basin is very large and travel times are relatively long, many sub-basins respond quickly. Geographic diversity within such a large basin must be accounted for in any Missouri River basin-wide modeling approach. Travel time from Gavins Point, the lowermost System project, to the mouth is 10 days for full service navigation support flows, as shown on Plate IV-1. Very high-runoff-producing areas exist along the Missouri River in the Big Sioux, Little Sioux, Platte, Kansas, Grand and Osage River basins. These basins have relatively short travel times, in comparison to the Missouri River and require continuous modeling to provide effective downstream flood control. As part of their normal and off-duty duties, the MRBWM staff continuously assess basin and river conditions in the event that they need to run appropriate river and/or reservoir models to prepare short-range forecasts during times of flooding or for other purposes. The river and reservoir models can all be run within a relatively short period of time, generally less than 30 minutes. Noting that the System and basin are very large and complicated, many simulations may need to be run and evaluated to find the best approach to regulating the System under a range of forecasted hydrologic and basin conditions.

6-07.1. Ice Jam/Blockage Information. During the winter when Missouri River ice blockages and jams are possible, the Corps may request field surveys and use data from reconnaissance flights to determine the nature and extent of the ice jam and/or blockage to make better-informed release decisions. This information is shared with other federal agencies and the public through reports and photographs, normally made available via the MRBWM website. The Corps' CRREL Ice Engineering Research Group also maintains an ice jam database. Data from plains snow surveys are used to anticipate high runoff and the potential for flooding in the basin. The plains snow surveys, which are described in Section 5-06.1.1, are used by the MRBWM office to improve the regulation of the System and by the Corps' Districts for emergency operations and effective tributary reservoir regulation.

6-07.2. Flood Control Zones. Each mainstem project has two zones designated for flood control storage, the Annual Flood Control and Multiple Use Zone and the Exclusive Flood Control Zone. The Annual Flood Control and Multiple Use Zone is the range of elevations in which projects normally operate under a wide range of runoff conditions. The waters in this zone are used to meet all authorized purposes. The zone designated as Exclusive Flood Control Zone is reserved exclusively for flood control regulation. When an individual project or System storage as a whole is great enough to occupy the Exclusive Flood Control Zone or the Corps' simulation models forecast the projects to rise to an elevation to enter this zone, the projects are considered to be in a flood control state. When the System is in a flood control state, the MRBWM office increases the frequency of forecast runs that includes an examination of additional reservoir regulation alternatives that would return the System to a normal condition (e.g., storage in the individual and/or System Annual Flood Control and Multiple Use Zone). The flood control purpose is considered foremost in this situation because of the health and human safety issues, as well as the goal of minimizing loss of property.

6-07.3. Historical Flood Control Regulation. Several MRBWM reports have been published that reflect past System regulation during significant Missouri River basin floods (e.g., 1975, 1978 and 1997). While these reports should be referred to for guidance, it should be noted that no flood is the same. Plate VI-1 is used for guidance by the MRBWM in determining the service level and subsequent System release for flood storage evacuation purposes. Experience demonstrates that the sooner significant runoff from snowmelt can be recognized and the appropriate release of flows scheduled, an improvement in overall flood control can be achieved. In the case of the accumulation of significant mountain or plains snowpack that normally melts well after their respective peaking dates, a longer period of time to prepare the System reservoirs for significant snowmelt runoff has proved beneficial. To provide effective flood control and prepare the System for runoff from future suddenly-developing rainfall events, System storage that has accumulated from significant rainfall events must be evacuated following the event as downstream conditions permit. While each individual System project has flood control capability, Fort Peck, Garrison and Oahe reservoirs contain nearly 90 percent of the total storage, and about 85 percent of the total flood control storage, which makes them the most effective projects in the System in providing flood control. Also critical is the quick response needed in scheduling System release changes. This makes the small amount of flood control storage available in Fort Randall (about 14 percent) important as it is used to absorb these changes for a short period of time. Big Bend and Gavins Point have less than 2 percent of the total System flood control storage. These projects are considered run-of-the-river projects and are generally not considered in discussions regarding System flood control. The System has an effective regulation plan to optimize downstream flood control, one of the System's authorized purposes. Flood control carries the highest priority during significant runoff events that pose a threat to human health and safety and, as indicated by Plate IV-2, has provided many benefits to the Nation. Still, the area below the System, as well as between the projects, is not a flood-free zone. As shown on Plate VI-2, there are large portions of the basin not controlled by any flood control reservoirs, which results in diminished flood control effectiveness.

6-08. River and Reservoir Data Needed for Forecasts. The hydro-meteorological data received via DCPs (see Section 5-02) needs to be transformed (e.g., stage to flow, elevation to area and storage) for river and reservoir forecasting purposes. As described in Section 5-07.2, the USGS maintains a stage-discharge measurement program so that the stage-discharge relationship (i.e., rating curve) for each streamgaging station is current. While river stage information is important, the System is regulated based, primarily, on reservoir releases and river streamflow with downstream flow targets for both flood control and other multi-purpose regulation. The determination of the correct streamflow is, therefore, critical to consistent System regulation for the Missouri River. For the reservoir models, inflows are calculated based on change of reservoir storage, project releases and estimated reservoir evaporation. The Omaha District's River and Reservoir Engineering Section is responsible for updating each mainstem reservoir's elevation-area and elevation-capacity relationship, which are implemented by the MRBWM office.

6-09. Conservation Forecasts. Most of the time the System is regulated for average or below-average runoff conditions; therefore, the majority of the forecasting and runoff modeling simulation is for conservation regulation decisions. The following sections discuss the forecasting and associated System modeling simulations that the Corps has developed and performs on a routine basis to meet its water resources management mission. The Corps has integrated short- and long-range forecasting as well as flood and drought System regulation into all real-time simulation models. The System is the largest reservoir system in North America and as such, requires significant forecasting and modeling simulation efforts to achieve the operational objectives stated in this manual. The data collection system discussed in the previous chapter allows for the rapid collection and assimilation of large amounts of real-time data for input into these models. The automated input of verified hydrologic data into the forecasting and simulation models is significant in allowing a greater amount of time for the MRBWM staff to focus on alternative regulation to achieve maximum benefits for the System.

6-09.1. Short-Range Water Supply Forecasts. Due to the meteorological variability of conditions in the Missouri River basin and the critical need to adjust runoff based on precipitation that has occurred at unexpected rates, short-range water supply forecasts are frequently developed. The need of these forecasts varies, based on reservoir status and time-of-year considerations. Spring fish spawn and plains and mountain snowmelt periods often require more frequent than once-monthly water supply forecasts as does the System regulation for T&E bird species during the nesting season. Large deviations in precipitation, both above and below the System, often create a need to make a mid-month or more frequent adjustments to System regulation. These forecasts generally serve the purpose of improved intra-System regulation and provide more accurate reservoir elevation and project release criteria than would be available by waiting for monthly forecasts. These forecasts are normally provided as input to the Three-Week Forecast Simulation Model, which is discussed in Section 6-12.1. The techniques used for short-range water supply forecasting are based primarily on current basin conditions integrated with forecasted runoff, which is based on engineering judgment and experience regarding the specific basin runoff responses. The techniques used are a refinement of the previously mentioned long-range water supply forecasting techniques. This refinement could be expected to include a greater in-depth analysis of the effects of temperature variability on expected plains and mountain snowmelt runoff and basin-wide hydrologic conditions with regard to precipitation and associated runoff. The shorter time period also allows for an adjustment for the current month of runoff because weekly runoff volumes are determined and can be integrated into the current month's forecasted runoff as a refinement. The integration of anticipated precipitation into the current HEC-HMS runoff forecasting model is an example of an often utilized short-range forecasting technique to determine the proper System release to meet the flood control objectives stated in this manual.

6-09.2. Short-Range Runoff Forecasts. Day-to-day scheduling of releases necessary for regulation of the System on an integrated basis requires the Corps to develop daily forecasts of flow at key streamgaging locations throughout the basin. These forecasts are based on observed and anticipated precipitation, temperature, temperature-snowmelt relationships, rainfall-runoff relationships, observed streamflow in the main stem of the Missouri River and tributaries, antecedent precipitation and other factors that often may be subject to only qualitative analysis.

6-09.3. District Forecasts of Tributary Flows. The Corps' Omaha and Kansas City District water management offices also have a forecast capability and responsibility for aiding in the regulation of the System. This includes the forecasting of expected peak flows from tributary streams during periods of flood runoff. Most of these forecasts also serve the Districts in their regulation of tributary reservoir projects or in their flood emergency activities. When the MRBWM office is providing Missouri River navigation flow support, the Kansas City District furnishes the MRBWM office a daily flow forecast for the next 14 days for the mouth of the Kansas River (Kansas River at Desoto, KS) each morning. The Kansas City District also forecasts daily flows for the next 14 days from the Osage River basin during periods of high streamflow in that basin.

6-10. Lower Missouri River Streamflow Forecasting. The scheduling of releases from the System throughout the open-water season (generally late March through mid-December) is based on maintaining prescribed flows at downstream control points on the Missouri River referred to as “target locations” at: Sioux City, IA; Omaha, NE; Nebraska City, NE; and Kansas City, MO. The MRBWM office is responsible for scheduling Gavins Point releases. The proper scheduling of Gavins Point releases requires the MRBWM office to develop accurate forecasts of lower Missouri River reach inflows between Gavins Point, the lowermost System dam, and forecasts of flows at the four downstream target locations. These forecasts are developed daily for the next 14 days in the future and are compared to daily forecasts developed by the MBRFC. If significant differences in forecasts occur, an attempt is made to reconcile the differences prior to release scheduling. The ultimate forecast and scheduling responsibility for the System regulation is, however, with the MRBWM office.

6-10.1. Lower River Reach Inflow Forecasts. When the System was closed in 1967, reach inflow forecasts for the lower Missouri River, from Gavins Point Dam to the mouth, were determined via hand computations. These computations involved a procedure of recording observed flows at gaging locations, routing these flows to a target location, and subtracting those combined flows from the actual flow at that target location to get an “ungaged” inflow for the river reach between target locations. This procedure was carried out for five previous days of actual data and then a 14-day forecast was made of both future tributary flows at known streamgaging points and for the ungaged inflow into the reach. These forecasts were combined to make a 14-day Missouri River forecast that included anticipated System releases to meet flows at the four downstream target locations described in Section 6-10. The procedure came to be known as the Forecasting Unregulated Inflow (FUI) method and, subsequently, the computer simulation model came to be known as the FUI model. The FUI model has since been replaced with an HEC-ResSim model referred to as the Gavins Release Forecasting Tool (GRFT). The GRFT HEC-ResSim model is an integral part of the real-time regulation of the System. A typical example of the GRFT output for the tributary, ungaged and combined flows and resultant stages for the combined flows is shown on Plates VI-3 to VI-6. The FUI and GRFT models use a river routing method, developed in the then-North Pacific Division (now NWD) Streamflow Synthesis and Reservoir Regulation model study, and documented in MRD-RCC Technical Study *O-78 Computer Program for FUI*, October 1978. The GRFT model provides flexibility for the forecaster to adjust forecasted tributary and ungaged flows based on engineering judgment, experience of forecasting reach inflows, and from HEC-HMS model simulations of reach inflows. The GRFT model initially takes into account water that has reached a streamgaging point. The streamflow from a significant rain that has not reached a gaging location due to water travel time to that location is not automatically included in the GRFT model forecast. Streamflow from rainfall that has just occurred or is currently occurring can be integrated into the forecast if the forecaster has performed HEC-HMS tributary model simulations and/or the experience to estimate anticipated streamflow. A big advantage of the

GRFT model is that a detailed forecast for the Missouri River from Gavins Point Dam to the mouth of the Missouri River can generally be run in less than 30 minutes. This relatively short time period allows for the updating and running of additional forecasts as river and weather conditions change.

6-10.2. Hydrologic Modeling System (HMS) Streamflow Forecasting. Starting in 2012 as part of a nationwide 10-year effort, the entire Missouri River basin is being modeled with the Corps' HEC-HMS surface runoff model. The upper basin has been separated into six HEC-HMS reaches – above Fort Peck, Fort Peck to Garrison, Garrison to Oahe, Oahe to Fort Randall, Fort Randall to Gavins Point and Gavins Point to Sioux City, IA – to align with the runoff reaches described in Section 6-11. The lower basin has been separated into two HEC-HMS reaches, Sioux City, IA to Rulo, NE and Rulo, NE to St. Charles, MO. The district boundaries for Omaha-Kansas City and Kansas City-St. Louis Districts are at Rulo and St. Charles, respectively. For the seven watersheds in the Omaha District, the HEC-HMS models include a plains snowmelt model, as described in detail in Section 5-06.1. The Rulo to St. Charles HEC-HMS model simulates rainfall only, since plains snowmelt is rarely a System regulation factor in this reach. The HEC-HMS models can be run in a real-time mode using observed flow from streamgaging stations, described in Section 5-07, and observed gridded QPE data, described in Section 5-03, as input. The ability to run and calibrate these models in a fairly short time period (less than two hours) allows the MRBWM reservoir regulators to consider these model results when determining System releases to meet the authorized purposes, including, but not limited to, flood control, navigation and water supply. HEC-HMS results from the lower three watersheds, Gavins Point to Sioux City, Sioux City to Rulo, and Rulo to St. Charles, can be used as input in the GRFT HEC-ResSim model, which is described in detail in Section 6-10.1, for the purpose of lower Missouri River flow forecasting to determine Gavins Point releases.

6-11. Monthly Reach Inflow (Runoff) Forecasts. Soon after the first of each month throughout the year a forecast of incremental monthly inflows is prepared by the MRBWM office for six System reservoir reaches: above Fort Peck, Fort Peck to Garrison, Garrison to Oahe, Oahe to Fort Randall, Fort Randall to Gavins Point and Gavins Point to Sioux City. Forecasts of monthly reach inflow or runoff extend from the current date through the remainder of the calendar year to March 1 of the succeeding year. Details and techniques currently applicable for reach inflow or runoff forecast development are contained in the MRBWM Technical Report, *Long-Term Runoff Forecasting*, February 2017. These forecasts of reach inflow or runoff, as shown on Plate VI-7, are utilized to develop System regulation studies, as described in Section 6-12 of this manual.

6-11.1. Runoff Forecast Factors. The monthly reach inflow forecasts are based on, but are not limited to, the following factors: 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, accumulated snow over the incremental drainage area, and accumulated mountain SWE. In the two reaches above Garrison, above Fort Peck and Fort Peck to Garrison, snow contributions include mountain and plains snowmelt. For the four reaches below Garrison, snow contributions only include plains snowmelt. Estimation of this snowmelt runoff is important during the early spring (March-April), the period of plains snowmelt runoff, as well as during the late spring and early summer (May-July), the period of mountain 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 the spring and early summer periods consist primarily of modifying the long-term normal runoff volume by observed antecedent basin conditions.

6-12. Reservoir System Real-Time Simulation Model. An HEC-ResSim real-time model, referred to as the "Upper Basin Model", is used for short- and long-range reservoir forecasts and for long-range studies. The upper basin HEC-ResSim model replaced several models that are described in Sections 6-03 and 6-04 of the 2004/2006 Master Manual.

6-12.1. Three-Week System Forecast. The MRBWM office uses the upper basin HEC-ResSim model to develop forecasts of future daily inflows to each System reservoir at weekly, and sometimes more frequent, intervals. Each week, daily inflow forecasts extending three weeks or more into the future are developed. Experience has indicated that the most satisfactory method of anticipating the reservoir inflows for periods of up to a week or two beyond the current data is a combination of routing observed flow from upstream and tributary locations and extrapolating incremental inflows above or between observation points. With the large amount of storage space available in the upper two reservoirs, Fort Peck and Garrison, the forecast emphasis for these two reservoirs is not toward exact definition of the incremental inflow hydrograph, but rather toward a definition of incremental inflow volumes over a relatively longer period of time (a week or more) so that release adjustments from these two reservoirs can be scheduled to meet regulation objectives. For Oahe and Big Bend, the forecast emphasis includes daily hydropower generation for these hydropower peaking plants. For Fort Randall and Gavins Point, the forecast emphasis includes System (Gavins Point) releases needed to support lower Missouri River purposes, such as flood control, navigation and water supply. The forecast results include daily inflows, releases, reservoir elevations and hydropower generation for a 3- to 5-week period at each of the System projects. The forecast serves as a guide for short-range System modifications and is used to make regulation adjustments within the range normally determined by the long-range monthly studies.

6-12.2. Monthly System Study. The MRBWM office uses the upper basin HEC-ResSim model and the monthly reach inflow forecasts on the first of each month to update monthly System regulation studies. The studies extend from the current month through March 1 of the following year. The study results include end-of-month reservoir elevations and System storage, average monthly inflows and releases and monthly hydropower generation. The monthly study includes the three System storage checks to determine System (Gavins Point) releases: March 15, to provide flow support for the first half of the navigation season; July 1, to provide flow support for the second half of the navigation season and to determine the navigation season length; and September 1, to determine minimum System winter releases. Refer to Section 7-03.2.1.1 of this manual for more details regarding the System storage checks.

6-12.3. AOP and 5-Year Extension Studies. The MRBWM office uses the upper basin HEC-ResSim model to conduct the Annual Operating Plan (AOP) and 5-Year Extension studies. The AOP study period is 19 months, starting on August 1 of Year 0 (current year) and extending to the end-of-month (EOM) February of Year 2. The 5-Year Extension study period is EOM February of Year 2 to EOM February of Year 7. The AOP studies are prepared on August 1 with initial conditions based on Year 0: EOM July reservoir elevations/storages, the remaining five months of the calendar year runoff forecast and current year's monthly depletion estimates. The runoff for Year 1 through Year 7 are based on the MRBWM Technical Report, *Runoff Volumes for AOP Studies*, August 2013. The technical report utilizes statistically-derived runoff based on the 114-year historical record of runoff above Sioux City, IA during the period 1898-2011. Five runoff levels with statistical significance (implied by their titles) are used in the AOP studies: upper decile, upper quartile, median, lower quartile and lower decile. These runoff levels encompass 80 percent of the historic runoff (lower decile to upper decile). Two additional runoff volume scenarios are available, the 2 and 98 percent non-exceedances, that encompasses 96 percent of the historic runoff records. Both have a 1 in 50 chance of occurring. Neither of these "2 percent" runoff volumes are included in the AOP and 5-Year study scenarios, but could be implemented for any given runoff season should the runoff forecast exceed the upper decile runoff scenario or be less than the lower decile runoff scenario. The 5-Year Extension studies are prepared to serve as a guide for Western's marketing activities and to provide data to allow basin interests to conduct long-range planning activities. The 5-Year Extension studies use the median, lower quartile and lower decile runoff scenarios. The 5-Year Extension studies are generally finalized in December and included in the final AOP. All the runoff volumes for both studies are adjusted to 1949 level of water resources development in the Missouri River basin.

6-13. Reservoir System Planning Model. The Missouri River HEC-ResSim planning model was developed to simulate and evaluate alternative System regulation for all authorized purposes under a widely varying long-term hydrologic record. The model's extent spans the Missouri River near Landusky, MT to the Ohio-Mississippi River confluence, including portions of some tributaries. Although the model covers a large portion of the basin, the main computation points are the six mainstem dams, four Missouri River streamgaging stations between mainstem dams (Landusky, MT; Wolf Point, MT; Culbertson, MT and Bismarck, ND), and nine Missouri River streamgaging locations below the System (Sioux City, IA; Omaha, NE; Nebraska City, NE; Rulo, NE; St. Joseph, MO; Kansas City, MO; Waverly, MO; Boonville, MO and Hermann, MO).

6-13.1. Planning Model Dataset. The period-of-record datasets (1930-2012) used in the HEC-ResSim planning model were developed using data from the CWMS Oracle database, USGS gaging records, USBR depletions, daily routing model (DRM) evaporation, and Kansas River HEC-ResSim model. Historic reach inflow datasets were calculated from observed data (CWMS Oracle database and USGS gaging records) and then combined with USBR depletions and the Kansas River HEC-ResSim model output to create homogeneous reach inflow datasets representative of current basin conditions. As part of on-going studies, this dataset will be expanded as additional years become available.

6-13.2. Planning Model Output. The HEC-ResSim planning model writes detailed output to a database for all of the computation points within the model. The model creates detailed output for each dam and reservoir, including, but not limited to, daily pool elevation, storage, reservoir zones, project releases, active reservoir rules, and hydropower generation. At river streamgaging locations, streamflow is currently the only output; however, there is an option to include rating curves at river gage locations, which would allow the model to calculate stage.

6-14. Depletions. Depletions are the volume of runoff water that is diverted for consumptive uses, such as irrigation, municipal and industrial uses. Depletions can also reflect the effects of tributary reservoirs including evaporation. For this discussion, depletions do not include evaporation from the System projects, which are accounted for separately. For the purposes of planning studies, depletions are consumptive uses, or as defined by the USBR, a loss of water from a surface water system resulting from man-induced activity. Approximately 94 percent of the total estimated depletions in the basin are from agriculture irrigation and municipal water supply. The USBR prepares estimates of these streamflow depletions, both historic- and present-level, for the Missouri River and also of future depletions based on historic trends of water uses along the System. Depletions are calculated on a monthly basis by HUC and are generally updated every 5 years. For the purposes of long-term studies, such as the AOP and monthly studies, the USBR annually provides depletions including the effects of tributary reservoirs. The MRBWM office uses the USBR projections and actual depletions in their forecasting and planning for System regulation.

6-15. Unregulated Flows (Holdouts). Throughout the year MRBWM staff conduct analyses to reconstitute unregulated flows that would have occurred without the System for the purpose of determining reservoir regulation effects of System and tributary reservoir regulation (i.e. holdouts). The analysis uses a simple lag-average procedure to route the six System reservoir and 15 USBR tributary reservoir (five upstream of Fort Peck, five between Fort Peck and Garrison, and five between Garrison and Oahe) effects downstream to ten Missouri River locations where reconstituted, or unregulated flows, are desired: Wolf Point and Culbertson, MT; Bismarck, ND; Yankton, SD; Sioux City, IA; Decatur, Omaha, Nebraska City and Rulo, NE; and St. Joseph, MO. The Kansas City District conducts analysis to determine Missouri River unregulated flows at the four Missouri River locations downstream of St. Joseph: Kansas City, Waverly, Boonville and Hermann, MO. Coefficients considered to be applicable, based on examination of flood events, are presented in MRD Technical Study S-73, *Upper Missouri River, Unregulated Flow Development*. The reach locations are chosen based on length of river, taking into account streamflow attenuation, and are basically the same as those presented in the stage-damage curve reduction discussion in Section 4-05.13. The unregulated flows are used to compute annual flood damages prevented and to explain stage reductions resulting from regulation of the System to the public and other interested parties.

6-16. Annual Report on Project Benefits. Per Section 8-6.11 of EM 1110-2-3600, each water management office is responsible for annually determining monetary benefits for project purposes that produce tangible benefits. The District economics teams collaborate with engineering and operations personnel to routinely compute the benefits attributable to flood risk management, navigation, hydroelectric power generation, water supply and recreation. The information is then provided to HQUSACE for preparation of the Annual Report of the Chief of Engineers, Civil Works Activities. An annual flood damage report, which includes damages prevented and damages incurred in each state, is prepared by CECW-CE with significant input from partner agencies. The report is submitted to Congress according to House Committee Report 98-217, Energy and Water Appropriations Act, 1984.

6-17. Downstream Flow and Stage Forecasting. The MRBWM staff run unsteady HEC-RAS models, which were developed and provided by the Omaha District. The models are in the Missouri River reaches downstream of Garrison, Fort Randall and Gavins Point and are run to determine downstream flow and stage impacts from System operations during the T&E species nesting season. The HEC-RAS models downstream of Garrison and Fort Randall are run to determine stage fluctuations from planned hydropeaking operations and the HEC-RAS model downstream of Gavins Point is run to determine stage fluctuations from planned release cycling operations (e.g., 1 day up, 2 days down). The HEC-RAS models are also used to determine the effects of special operations.

6-18. System Water Quality Modeling. The MRBWM office, cooperating with the Omaha District Water Control and Water Quality Section, developed a CE-QUAL-W2 water quality model for the larger System reservoirs. CE-QUAL-W2 is a two-dimensional, unsteady flow hydrodynamic and water-quality model developed and supported by the Corps' Engineering Research and Development Center located in Vicksburg, Mississippi. This model has been widely applied to stratified surface water systems such as lakes, reservoirs, rivers and estuaries. This water quality model computes water levels, horizontal and vertical velocities, temperatures, and 21 other water quality parameters such as dissolved oxygen, nutrients, organic matter, algae, pH, carbonate cycle, bacteria, and dissolved and suspended solids. The model has shown that it could facilitate evaluating the effects on water quality of changes in reservoir regulation and other adaptive management actions. This model can quickly demonstrate or clarify how, by changing regulation of projects' storage levels, release rates and timing, the reservoir and downstream river water quality parameters vary. Certain real-time water quality conditions can be predicted at System projects, using real-time flows and meteorological conditions. The model can also forecast future water quality conditions based on projected future reservoir regulation scenarios using either synthetic or historic inflows and meteorological data. Finally, the model can be used to simulate water quality conditions due to System regulation changes due to changes in runoff scenarios or structural changes such as intake modifications. The aspects of System regulation evaluated could include distribution of storage volumes between several reservoirs and drawing water from different elevations in the reservoir. The CE-QUAL-W2 model could then be used to measure the impact on water quality in the reservoirs by evaluating alternative types of regulation. This model could also aid in water quality data collection by identifying expected critical or sensitive water quality situations in advance that would require more extensive water quality monitoring. The model could be useful in focusing data collection on that part of the reservoir for those water quality parameters that would provide the desired information. This is especially significant on the large upper three System reservoirs.

6-19. Drought Forecast Simulation. Over the regulation history of the System, various products have been used to detect the extent and severity of basin drought conditions. Since the System was developed to meet authorized purposes during consecutive years of long-term drought, no specific drought forecast has been developed. The System was designed, and the water control plan was selected, to serve authorized purposes during a 12-year drought such as that experienced during 1930-1941. The consideration of drought for short- and long-range forecasting and System regulation is part of the normal forecasting process used by the MRBWM office. Currently, the National Drought Mitigation Center's Drought Monitor is used to generally determine the extent and severity of drought in the Missouri River basin. The runoff forecasts developed for both short- and long-range time periods reflect drought conditions when appropriate. The normal banding of runoff to address 80 percent of the expected runoff conditions covers significant drought and provides a reliable tool to assess the effects of drought and the anticipated System regulation. The period of record contains four significant droughts, including the two droughts contained in the record since the System first filled in 1967. This provides a good data set to guide real-time regulation during significant drought periods. As various new techniques become available and improvements are made to existing drought indicators, they will be integrated into the System runoff forecasts. Improved forecasting and the development of simulation tools will be an ongoing process in which better techniques will become available and used in all forecasting areas. The primary data source used to demonstrate System regulation during drought is the Corps' statistical runoff volumes representing lower quartile and lower decile runoffs. This data set is used as input for the System reservoir simulation model to show long-term effects of System regulation under very low basin runoff. This is particularly true for AOP period simulations that include the 5-year extensions of lower quartile and lower decile runoffs, as described in Section 6-12.3 of this manual.

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VII - Current Water Control Plan for the System

7-01. System Water Control Plan. In enacting the 1944 Flood Control Act, Congress adopted the recommendations contained in the underlying Pick-Sloan documents. These documents identified flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife as project purposes and also provided for the protection of beneficial consumptive uses in the upper basin. Congress did not assign a priority to these purposes. Instead, it was contemplated that the Corps, in consultation with affected interests and other agencies, would appropriately consider these functions in order to obtain the optimum development and utilization of the water resources of the Missouri River basin to best serve the needs of the people. The Missouri River Master Water Control Manual Review and Update Study (Master Manual Study), which was started in 1989 and was completed in 2004 and 2006, was conducted without bias toward any project purpose. Therefore, no priority was assumed for any economic use or environmental resource in the conduct of that study. The result of the 2004/2006 Master Manual Study was the identification of the Missouri River Mainstem Reservoir System water control plan (2004/2006 water control plan). As part of analyzing potential management actions the Corps could take to avoid jeopardizing T&E species, the MRRMP-EIS analyzed various modifications to the water control plan. The selected alternative in the MRRMP-EIS ROD maintained all elements of the 2004/2006 water control plan, except for removing the criteria for the bimodal spring pulse and reservoir unbalancing that were added for ESA species in the 2004/2006 updates. This chapter sets forth the detailed provisions of the CWCP. **In the event of any inconsistencies between the provisions of this Chapter VII and any other provisions of this manual or individual System project WCMs, this Chapter VII shall take precedence.**

7-01.1. Objectives of Current Water Control Plan. The CWCP presented in this manual was developed with four objectives in mind: first, to serve the contemporary needs of the basin and the Nation; second, to serve the Congressionally authorized project purposes; third to comply with other applicable statutory and regulatory requirements including environmental laws such as the ESA; and fourth, to fulfill the Corps' responsibilities to federally-recognized Tribes. The application of the CWCP presented in this manual is designed to meet certain operational objectives during drought, flood and normal runoff periods. Many assumptions were necessary in order to effectively analyze the effects of the application of this water control plan. If these assumptions are no longer valid in the future due to changed conditions or unforeseen circumstances, the Corps will adjust the CWCP presented in this manual in an attempt to continue to meet the intended operational objectives. The following sections describe how the CWCP will meet the operational objectives of this manual for each of the Congressionally authorized project purposes. The CWCP described in this chapter meets the objective of serving all of the Congressionally authorized project purposes of the System while considering the other short- and long-term factors affecting the regulation of the System. Optimizing service to all of the Congressionally authorized purposes may be impossible at times because of conflicts between the individual authorized purposes. Therefore, optimization of benefits to individual project purposes will be pursued to the extent reasonably possible.

7-01.2. Regulation Objectives. As an introduction to a discussion on regulation objectives of the CWCP, the need to conform to certain basic water-in-storage provisions and basic principles of reservoir regulation of the System should be recognized, except in unusual circumstances. The Permanent Pool Zones of the System reservoirs are intended to remain permanently filled with water. This will ensure the maintenance of minimum power heads, minimum irrigation diversion levels, and minimum reservoir elevations for the water supply, recreation and fish and wildlife purposes. Similarly, the Exclusive Flood Control Zones at the System reservoirs are provided for the regulation of the largest of floods. These zones will be reserved exclusively for this purpose and generally be empty. The two other storage zones that are intermediate to the Permanent Pool and the Exclusive Flood Control Zones provide active storage for project purposes. These storage zones are called the Annual Flood Control and Multiple Use and the Carryover Multiple Use Zones. These also provide storage space for the control of moderate floods and, when combined with the upper Exclusive Flood Control Zone, provide control of major floods.

7-02. System Regulation Summary. System regulation is, in many ways, a repetitive annual cycle. The melting of plains and mountain snow produces most of the year's runoff into the System, and runoff from spring and summer rains adds to the total. After reaching a peak, usually during July, the amount of water stored in the System declines as releases are made to meet authorized purposes during the drier summer, fall and winter months. During the late fall and winter, the mountain and plains snowpack begins to accumulate and the cycle begins anew. A similar pattern may be found in rates of releases from the System, with the higher levels of flow from mid-March to late November, followed by low rates of winter release from late November until mid-March, after which the cycle repeats. The Water Control Calendar of Events, shown on Plate VII-1, presents the time sequence of many of these cyclic events.

7-02.1. System Regulation. Variations in runoff into the System necessitates the varied regulation plans to accommodate the multi-purpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period extends from mid-December through February. The highest average hydropower generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air-conditioning season (mid-June to mid-August). The energy needs during the winter are supplied primarily with Fort Peck and Garrison releases and the peaking capacity of Oahe and Big Bend. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, the Fort Randall pool elevation is normally drawn down to increase System hydropower generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The major maintenance periods for the System hydropower facilities extend from March through mid-May and September through November, which normally are the lower demand and off-peak energy periods. The exception is Gavins Point, where maintenance is generally performed after the end of the navigation season because all three power units are normally required to provide flow support for navigation and other downstream flow support needs. The normal 8-month navigation season extends from April 1 through December 1, during which time System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases are much lower and vary depending on the need to conserve or evacuate System storage volumes, downstream ice conditions permitting. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April 1 through June. T&E species nesting occurs from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All of these factors will affect the timing and magnitude of project releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate hydropower. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation. The following sections discuss the regulation of the individual System dams to accomplish the System reservoir regulation objectives.

7-02.2. Fort Peck Dam (Fort Peck Reservoir). Fort Peck's primary water management functions are (1) to capture the runoff from mountain and plains snowmelt and localized rainfall runoffs from the large drainage area above Fort Peck Dam, which are then metered out at controlled release rates to meet the System's authorized purposes while reducing flood damages in the Fort Peck Dam to Garrison reservoir reach; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Garrison, Oahe and Fort Randall; and (3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low-water years.

7-02.3. Garrison Dam (Garrison Reservoir). Garrison, the largest Corps storage reservoir, is another key player in the regulation of the System. Its primary water management functions are (1) to capture the runoff from mountain and plains snowmelt and localized rainfall runoffs from the large drainage area between Fort Peck and Garrison dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Garrison Dam to the Oahe reservoir reach, particularly the urban Bismarck and Mandan area; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Oahe and Fort Randall; and (3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low-water years.

7-02.4. Oahe Dam (Oahe Reservoir). Oahe's primary water management functions are (1) to capture plains snowmelt and localized rainfall runoffs from the large drainage area between Garrison and Oahe dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Oahe Dam to Big Bend reach, especially in the urban Pierre and Fort Pierre areas; (2) to serve as a primary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Big Bend, Fort Randall and Gavins Point; and (3) to provide the extra water needed to meet project purposes that draft storage during low-water years, particularly downstream water supply and navigation. In addition, hourly and daily releases from Big Bend and Oahe dams fluctuate widely to meet varying power loads. Over the long term, their release rates are geared to back up navigation releases from Fort Randall and Gavins Point dams in addition to providing storage space to permit a smooth transition in the scheduled annual fall drawdown of the Fort Randall reservoir. Big Bend, with less than 2 MAF of storage, is primarily used for hydropower production, so releases from Oahe are generally passed directly through Big Bend.

7-02.5. Fort Randall Dam (Fort Randall Reservoir). Fort Randall's primary functions are (1) to capture plains snowmelt and localized rainfall runoffs in the drainage area from Big Bend Dam to Fort Randall Dam that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Fort Randall reach, where several areas have homes and cabins in close proximity to the river; (2) to serve as a primary storage location, along with Oahe, for water accumulated in the System when System releases are reduced due to major downstream flood control regulation, thus helping to alleviate large pool increases in the very small Gavins Point project; (3) to provide a location to store the water necessary to provide increased winter energy to the basin by allowing an annual fall drawdown of the reservoir to occur with a winter reservoir refilling that is unique to Fort Randall; and (4) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes, particularly navigation and downstream water supply, that draft storage during low-water years.

7-02.6. Gavins Point Dam (Gavins Point Reservoir). Gavins Point Dam, the most downstream of the System dams, is primarily used as a re-regulating dam to level out the release fluctuations from the upper System dams to better serve System requirements. With a total reservoir storage volume of less than 500,000 acre-feet, it provides very little flood control and is generally maintained in a narrow reservoir elevation band between 1205 and 1207 feet. Due to the limited storage, releases from Gavins Point Dam must be backed up with corresponding release changes out of the upper projects. Gavins Point is the key location in the initiation of release reductions for downstream flood control. Even though it has only a small amount of storage space for flood control, this volume is usually adequate to perform downstream flood control by coordinating Gavins Point release reductions with Fort Randall's. Releases greater than the powerplant capacity are passed through the spillway.

7-03. System Regulation Techniques. The following discussion provides basic information related to the CWCP presented in this manual. The concepts discussed are the division of the individual System reservoirs into regulation zones; the provision of a level of service to meet the Congressionally authorized purposes and the associated flow targets to achieve that level of service; System water-in-storage checks; and seasonal release considerations, which include regulation during the winter and regulation for T&E species. The process of implementing the CWCP is based on selecting the appropriate System regulation criteria described in this chapter for the appropriate time of year and System water-in-storage (storage) or water supply (System and tributary storage plus anticipated runoff for the remainder of the year) condition. Normal and conservation System regulation involves a check on the amount of System storage on March 15 to determine if a navigation season will be provided that year, and if so, the service level to provide for the first part of the navigation season (Table VII-2). Downstream target flows at four designated locations are used to guide System releases (Table VII-1). The System storage is checked again on July 1 to determine the service level for the remainder of the navigation season (Table VII-2) and the ending date or length of the navigation season (Table VII-3). Finally the System storage is checked on September 1 (Table VII-5) to determine the System winter release rate. The above sequence is altered slightly if the System water supply is above normal or if the System is performing a major flood control action. In that case, the service level is determined as often as required (Plate VI-1) based on actual System storage and forecasted water supply so that the System release rate can be scheduled to minimize downstream flood risk and reduce flood damages. The navigation season is extended for 10 days in higher runoff years to facilitate evacuation of stored flood waters before the next flood season. Navigation service level is defined as “full”, “minimum”, or “intermediate”. Full service navigation flow support (see Table VII-2) is provided in near-normal runoff years to provide for evacuation of flood control storage before the next flood season, while serving navigation to the full capability of the authorized 9-foot downstream channel (8.5-foot draft). Minimum service navigation flow support (see Table VII-2) is usually provided in drought times to provide a minimum level of navigation service (7.5 feet of draft) while conserving water in the System in case of an extended drought. Intermediate service navigation flow support is described in Section 7-03.2.1.1. Consideration is also given to using Replacement System Flood Control Storage in cooperation with the USBR, which is discussed in Section 7-04.4.4.1. Also, within the framework of the overall goals, previously described, there are seasonal decisions to optimize the benefits obtained for the various authorized purposes, such as fish spawning, T&E species nesting and releases during river ice formation periods.

7-03.1. System Regulation Zones. The storage capacity of the System has been developed to provide beneficial service to the Congressionally authorized purposes. Regulation of a particular project for one authorized purpose may be compatible, to a varying degree, with regulation for most of the other authorized purposes. For another authorized purpose, this regulation may be detrimental. For example, the vacating of storage capacity after a flood event to assure control of possible future flood events is compatible with providing releases for power, navigation and water supply; however, it is incompatible with the objective of providing stored reserves for continuation of these purposes during a subsequent drought period. These factors made it advisable to divide the storage in individual System reservoirs into regulation zones to obtain the maximum possible service to all of the purposes consistent with the physical and authorizing limitations of the System. Totaling the storage capacity in the respective zones of the individual projects provides the total System storage capacity available in each regulation zone for use in System regulation. These values are not fixed but vary slightly over time according to changes in reservoir capacity from sediment collection in the reservoirs and shoreline erosion. For example, when the System was first considered filled in 1967, the total storage capacity was 75.4 MAF, and as of November 2018, total storage capacity is 72.4 MAF. This change in storage capacity has been reflected in the System storage zones by adjusting the elevations of the various storage zones within the individual projects to reflect the correct amount of storage according to the change that has occurred. In some cases, the elevations have not changed but the actual System storage number has been adjusted for that zone. The sizes of the Exclusive Flood Control Zone and the Annual Flood Control and Multiple Use Zone of 4.7 MAF and 11.6 MAF, respectively, are maintained as the System’s total storage capacity continues to lessen due to sediment collection in the reservoirs. The regulation zones, and the guidance criteria for regulation in these zones considered necessary to achieve the multi-purpose benefits and operational objectives for which the reservoirs were authorized, are described in the following sections.

7-03.1.1. Exclusive Flood Control Zone. Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. The Exclusive Flood Control Zone in each System reservoir is reserved for use to meet the flood control requirements. The storage space therein is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as soon as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. Considerations to achieve the flood control objective include a release limitation for each of the projects, status of storage in the other projects and the level of System or the Gavins Point release being maintained, as designated by criteria discussed later in this chapter. The Exclusive Flood Control Zone represents 4.7 MAF (the upper 7 percent) of the total System storage volume, and this zone, from 72.4 MAF to 67.7 MAF, is normally empty. The large four reservoirs, Fort Peck, Garrison Oahe and Fort Randall, contain 98 percent of the total storage reserved for the Exclusive Flood Control Zone.

7-03.1.2. Annual Flood Control and Multiple Use Zone. An upper "normal operating zone" is reserved annually for the capture and retention of normal and flood runoff and for annual multiple-purpose regulation of this impounded water. The System storage capacity in this zone represents 11.6 MAF (16 percent) of the total System storage volume, and extends from 67.7 MAF to 56.1 MAF. This storage zone, located immediately below the Exclusive Flood Control Zone, will normally be evacuated to the base of this zone by about March 1 to provide adequate storage capacity for capturing runoff during the next flood season. Exceptions may occur. One example would be if Replacement System Flood Control Storage were requested in conjunction with regulation of the USBR reservoirs in the upper Missouri River basin. On an annual basis, water will be impounded in this zone as required to achieve the System flood control purpose and also be stored in the interest of general water conservation to serve all the other Congressionally authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on the release of water from the System. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit System release rates during the December through March period.

7-03.1.3. Carryover Multiple Use Zone. A second lower intermediate zone provides a storage reserve for irrigation, navigation, hydropower production, water supply, recreation and fish and wildlife. The water stored in this zone at the three larger reservoirs (Fort Peck, Garrison and Oahe) will maintain downstream flows through a succession of well-below-normal runoff years into the System. Serving the authorized purposes during an extended drought is an important regulation objective of the System and the primary reason the upper three System reservoirs are so large compared to other federal water resource projects. The System storage capacity in this the largest storage zone represents 38.5 MAF (53 percent) of the total System storage volume and extends from a volume of 56.1 MAF to 17.6 MAF. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the System because of its role in providing assistance to the basin during critical dry periods. Water stored in the Carryover Multiple Use Zone will be used to meet project purposes in the event that the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only Fort Peck, Garrison, Oahe and Fort Randall have this storage as a designated storage zone. The three larger projects of Fort Peck, Garrison and Oahe serve the Missouri River basin during drought periods and water from this zone is called upon to meet operational objectives stated in this plan. The storage space assigned to this zone in Fort Randall serves a different purpose. A portion of the Fort Randall space is normally evacuated each year during the fall season to provide recapture space for upstream winter hydropower releases. The recapture results in complete refill of the space during the winter months. Deliberate, long-term drawdown into the Fort Randall Carryover Multiple Use Zone is not contemplated. During drought periods, the three smaller System projects (Big Bend, Fort Randall and Gavins Point) are maintained at the same elevation they would be at if runoff conditions were normal. While a minor amount of space in Big Bend and Gavins Point was initially provided in this zone, deliberate drawdown into this zone is generally not contemplated.

7-03.1.4. Permanent Pool Zone. A bottom inactive zone, called the Permanent Pool Zone, provides for a minimum hydropower head and for future sediment storage capacity. It also serves as a minimum pool for recreation, fish and wildlife, and as an assured minimum level for water access from the reservoir. A drawdown into this zone is generally not scheduled except in unusual conditions. The System storage capacity in this the lowermost storage zone represents 17.6 MAF (24 percent) of the total System storage volume (extends from 17.6 MAF to 0 MAF). The regulation of System in the Permanent Pool Zone has been changed slightly due to the changes in the storage used in the Carryover Multiple Use Zone.

7-03.1.5. Current System Storage Zone Allocations. The System has been regulated as an integrated system since 1967. Since 1967, many regulation techniques have been evaluated. System regulation procedures have been modified to provide a plan for sustaining and balancing all the Congressionally authorized project purposes. A basic method of evaluating proposed changes in System reservoir regulation has been the long-range System regulation study, as described in Chapter VI of this manual. Numerous long-range studies have been made since 1964, and long-range study criteria have been modified so that release restrictions imposed by the flood control purpose are reflected in the studies. These many long-range studies have been supplemented by detailed examination of particularly severe flood events, which are described in Appendix A of this manual. The Master Manual Study, which concluded with the 2004/2006 water control plan and the 2004/2006 Master Manual, included over 500 long-range studies, exceeding the total number of studies conducted prior to that time.

7-03.1.5.1. Long-term studies have also been made to investigate the effects of continued water resource development in the Missouri River basin. In general, these studies indicate that the flood control zone elevations currently used will continue being applicable well into the future. The loss of storage in the flood control zones of the System reservoirs due to sedimentation will be balanced by the reductions of flood runoff resulting from continuing water resource development, land treatment and depletions that includes future appropriation of Tribal water rights. Studies will continue to be made to determine the effects of such changes in Missouri River basin water resource development and in associated System regulation techniques. A major purpose of these studies will be the re-evaluation of System and individual System project storage zone allocations. If deemed necessary, appropriate action toward modification of System project storage zones will be initiated.

7-03.1.5.2. The current storage allocations and associated elevations in each of the zones of individual System projects, as well as for the System as a whole, is shown on Plates II-1 and II-2. Elevations associated with each of those zones are listed in the following sections. Storages given in this table reflect the November 2018 elevation-storage relationships.

7-03.1.5.2.1. Fort Peck. The Permanent Pool Zone at Fort Peck extends from elevation 2030.0 feet to 2160.0 feet. The Carryover Multiple Use Zone at Fort Peck spans elevation 2130.0 feet to 2234.0 feet. The Annual Flood Control and Multiple Use Zone is between elevation 2234.0 feet and 2246.0 feet. The Exclusive Flood Control Zone extends from elevation 2246.0 feet to 2250.0 feet. Section 7-01.2 describes the regulation objectives of each of the zones.

7-03.1.5.2.2. Garrison. The Permanent Pool Zone at Garrison extends from elevation 1673.0 feet to 1775.0 feet. The Carryover Multiple Use Zone at Garrison extends from elevation 1775.0 feet to 1837.5 feet. The Annual Flood Control and Multiple Use Zone is between elevation 1837.5 feet and 1850.0 feet. The Exclusive Flood Control Zone spans elevation 1850.0 feet to 1854.0 feet. Section 7-01.2 describes the regulation objectives of each of the zones.

7-03.1.5.2.3. Oahe. The Permanent Pool Zone at Oahe extends from elevation 1415.0 feet to 1540.0 feet. The Carryover Multiple Use Zone spans elevation 1540.0 feet to 1607.5 feet. The Annual Flood Control and Multiple Use Zone is between elevation 1607.5 feet and 1617.0 feet. The Exclusive Flood Control Zone extends from elevation 1617.0 feet to 1620.0 feet. Section 7-01.2 describes the regulation objectives of each of the zones.

7-03.1.5.2.4. Big Bend. The top and bottom elevations of the Permanent Pool Zone at Big Bend are 1345.0 and 1420.0 feet, respectively. The Annual Flood Control and Multiple Use Zone extends from elevations 1420.0 and 1422.0 feet and the Exclusive Flood Control Zone extends from elevations 1422.0 and 1423.0 feet. The Annual Flood Control and Multiple Use Zone in Big Bend is not provided for seasonal regulation of flood inflows like the other major upstream projects, but the zone is used for day-to-day and week-to-week hydropower operations. A settlement agreement approved in an order of dismissal by the U.S. District Court, District of South Dakota, in the case of Lower Brule Sioux Tribe et al. v. Rumsfeld, et al. (Civil No. 02-3014 (D.S.D.)) provides that the Corps will consult with the Lower Brule Tribe and the Crow Creek Sioux Tribe during any review and revision of the Missouri River Master Water Control Manual. This agreement also provides that the Corps will coordinate the regulation of the Big Bend Project and the water level of Lake Sharpe with the two Tribes to include the following: the Corps will normally strive to maintain a level at Lake Sharpe between elevation 1419 feet and 1421.5 feet; when the level of Lake Sharpe drops below elevation 1419 feet or exceeds elevation 1421.5 feet, the MRBWM office will provide notice to such persons as the Tribes shall designate in writing; when it is anticipated that the water level will drop below 1418 feet or rise above 1422 feet, or in the event the water level falls below 1418 feet or rises above 1422 feet, the Commander, Northwestern Division, or his designee, shall immediately contact the Chairpersons of the Tribes or their designees to notify them of the situation and discuss proposed actions to remedy the situation.

7-03.1.5.2.5. Fort Randall. The Permanent Pool Zone at Fort Randall extends from elevation 1240.0 feet to 1320.0 feet. The Carryover Multiple Use Zone spans elevation 1320.0 feet to 1350.0 feet. Fort Randall is drawn down near elevation 1337.5 feet during the fall allowing the Carryover Multiple Use Zone to recapture upstream winter hydropower releases rather than for the maintenance of a storage reserve for long-term droughts, as is provided in the three major upstream System projects. This target elevation has been a regulation objective since it was first instituted in 1972. Additional details of this change are available in an MRBWM report titled, *Modification of Operation of Lake Francis Case, South Dakota*. The water stored in the Fort Randall Carryover Multiple Use Zone from 1320 to 1337.5 feet may be used and withdrawn during a drought that is more severe than the drought of the 1930s. This storage volume remains as part of the Carryover Multiple Use Zone for this purpose. The Annual Flood Control and Multiple Use Zone spans elevation 1350.0 feet and 1365.0 feet and the Exclusive Flood Control Zone extends from elevation 1365.0 feet to 1375.0 feet.

7-03.1.5.2.6. Gavins Point. The Permanent Pool Zone at Gavins Point extends from 1160.0 to 1204.5 feet. The Annual Flood Control and Multiple Use Zone from 1204.5 to 1208.0 feet is the zone the project normally is regulated. The Exclusive Flood Control Zone from 1208.0 to 1210.0 feet is kept vacant except during flood control events. Gavins Point reservoir is normally regulated near 1206.0 feet in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 feet following the T&E nesting season for reservoir recreation enhancement.

7-03.2. System Service Level. To facilitate appropriate application of System multi-purpose regulation criteria, a numeric "service level" has been adopted since the System was first filled in 1967. Quantitatively, this service level approximates the water volume necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For the "full service" level, the numeric service level value is 35,000 cfs. For the "minimum service" level, the numeric service level value is 29,000 cfs. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. Because of the fluvial nature of the bed of the Missouri River, flow targets are used rather than river stage targets at the control point locations. The discharge approach has resulted in a consistency in regulation over time as aggradation and degradation previously discussed has occurred at some of the System control point locations, which has changed river stage values for the same flow. The specific technical criteria for the relationship between service level and control point target discharge are as shown in Table VII-1. The service level determination has a range much greater than the minimum and full service discussed so far. The application of the service level concept is also used in the evacuation of flood runoff accumulated in the System by establishing service levels much greater than 35,000 cfs, as shown on Plate VI-1. The specific use of the service levels technique for System flood control evacuation is fully discussed in Section 7-04.13.4.

Table VII-1
Relation of Target Discharges to Service Level

Control Point Location	Flow Target Discharge Deviation from Service Level
Sioux City	-4,000 cfs
Omaha	-4,000 cfs
Nebraska City	+2,000 cfs
Kansas City	+6,000 cfs

7-03.2.1. Service Level for Conservation and Normal System regulation. A full service level of 35,000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a “minimum service” level of 29,000 cfs results in target values of 6,000 cfs less than the full service levels at the four System control points identified above. Selection of the appropriate service level to be maintained is based on the actual volume of water-in-storage in the System. The use of actual water-in-storage means that forecasting is not relied upon when the volume of water in System storage is below normal.

7-03.2.1.1. System Water-in-Storage Checks. The System water-in-storage checks to determine the navigation service level occur on constant key dates (March 15 and July 1) of each year. The volumes selected have been derived from long-range model simulations that allow the System to function to meet authorized purposes during significant multi-year drought periods. The specific technical criteria for navigation service level are as shown in Table VII-2. Straight-line interpolation defines intermediate service levels between full and minimum service. These navigation service level determinations are for conservation and normal System regulation. During years when flood evacuation is required, the service level will be calculated monthly, and mid-monthly should conditions dictate, to facilitate a smooth transition in System release rather than a stepped approach at the March 15 and July 1 dates. Further details related to System regulation during flood events are provided later in this chapter.

Table VII-2
Relation of Navigation Service Level to the Volume of Water in System Storage

Date	Service Level (cfs)	Water in System Storage (MAF)
March 15	35,000 cfs (full service)	54.5 or more
March 15	29,000 cfs (minimum service)	49.0 to 31.0
March 15	(no service)	31.0 or less
July 1	35,000 cfs (full service)	57.0 or more
July 1	29,000 cfs (minimum service)	50.5 or less

7-03.3. Non-navigation Years. As shown in Table VII-2, the CWCP presented in this manual calls for suspension of navigation flow support if System water-in-storage is at or below 31.0 MAF on March 15 of any year. It should be noted that the occurrence of System storage at or below 31.0 MAF would most likely coincide with a national drought emergency. If any of the reservoir regulation studies performed for the development of the AOP indicate that System storage will be at or below 31.0 MAF by the upcoming March 15, the Corps of Engineers will notify the Secretary of the Army. Approval from the Secretary of the Army will be required prior to suspension of Missouri River navigation for the second of two consecutive years. The Corps will ensure that basin stakeholders are promptly informed of the notification to the Secretary of the Army and of the Secretary's decision regarding suspension of navigation flow support.

7-03.4. Season Length Determination. The water-in-storage check for navigation season length is taken on July 1 of each year. Assuming System water-in-storage is above 31.0 MAF on March 15, navigation flow support will be provided. As shown in Table VII-3, if System water-in-storage is at or above 51.5 MAF on July 1, flow support for a full 8-month navigation season would be provided, unless the season is extended to evacuate System flood control storage. However, if System water-in-storage falls below 51.5 MAF on any July 1, flow support for a shortened navigation season would be provided to conserve water stored in the System to extend availability of water-in-storage in the case of an extended drought. The specific technical criteria for navigation season length are shown in Table VII-3. Straight-line interpolation between 51.5 and 46.8 MAF of water-in-storage on July 1 provides the ending date for flow support for a navigation season length between 8 and 7 months. If System water-in-storage on July 1 is between 46.8 and 41.0 MAF, flow support for a 7-month navigation season is provided. A straight-line interpolation is again used between 41.0 and 36.5 MAF, providing flow support for a navigation season length between 7 and 6 months. For System water-in-storage on July 1 below 36.5 MAF, flow support for a 6-month navigation season is provided.

Table VII-3
Relation of System Storage to Season Length

Date	System Storage (MAF)	Season Closure Date at Mouth of the Missouri River
March 15	31.0 or less	No season
July 1	51.5 or more	December 1 - 8-month season
July 1	46.8 through 41.0	November 1 - 7-month season
July 1	36.5 or less	October 1 - 6-month season

7-03.4.1. Season Opening and Closing Dates. Navigation on the Missouri River is limited to the normal ice-free season, with a full-length flow support season of 8 months. Successful commercial navigation on the Missouri River from Sioux City to the mouth is dependent on low-flow supplementation from the System, with occasional assistance from tributary reservoirs authorized to support Missouri River navigation. Navigation is limited to the ice-free season and, based on historical records of ice formation on the Missouri River together with experience gained in System regulation to date, the opening and closing dates of a normal 8-month navigation season have been scheduled as shown in Table VII-4. While flow support for navigation may not be provided during the non-navigation periods of the year, the Missouri River is still available to navigators.

Table VII-4
Navigation Season Opening and Closing Dates for a Normal 8-Month Season

Location	Opening Date	Closing Date
Sioux City	March 23	November 22
Omaha	March 25	November 24
Kansas City	March 28	November 27
Mouth	April 1	December 1

In some years, ice conditions may delay the opening of the season; in other years, ice conditions may result in an early end to the season.

7-03.4.2. Extension of the navigation season in the fall beyond the normal 8-month length will normally be scheduled, river ice conditions permitting, in years with above-normal water supply and when such extensions will not result in a drawdown into the System's Carryover Multiple Use Zone. Based on experience to date, these season extensions will normally be limited to 10 days beyond the normal closure date, resulting in a season closing on December 11 at the mouth of the Missouri River. In addition to enhancing navigation and water supply, the 10-day extension of the navigation season also enhances hydropower production by transferring an additional block of power from the normal navigation season to the more critical, for hydropower generation purposes, winter season.

7-03.5. System Seasonal Considerations. For a portion of some years, deviations may be made from the aforementioned specific technical criteria to achieve the operational objectives of the CWCP or to comply with other statutory or regulatory obligations such as the ESA. In such circumstances, the AOP will explain the deviation from the specific technical criteria and the rationale for that deviation related to the operational objectives of the CWCP or applicable statutory and regulatory requirements. Other seasonal considerations and the corresponding reservoir regulation are further discussed elsewhere, as appropriate, in this manual.

7-03.6. System Winter Release Determination. Another seasonal consideration is regulation in the winter period, which extends from December through February, to support the Congressionally authorized project purposes of hydropower production and downstream water supply and water quality control. The specific technical criteria for Gavins Point Dam or System winter release rate is shown in Table VII-5. The System water-in-storage check for System winter release rate is taken on September 1 of each year. A straight-line interpolation is used between 58.0 and 55.0 MAF.

Table VII-5
Relation of System Winter Release Level to System Storage

September 1 System Storage (MAF)	Average Winter Release from Gavins Point (cfs)
58.0 or more	17,000 cfs
55.0 or less	12,000 cfs

7-03.6.1. A modification to the Gavins Point winter release rate generally occurs when the evacuation of System flood control storage cannot be accomplished by providing a full service navigation season with a 10-day extension of the navigation season. With an above-average upper basin runoff, the winter season Gavins Point release may be scheduled at a rate of up to 25,000 cfs to continue to evacuate the remaining excess water in System flood control storage. When extremely high upper basin runoff has not been previously evacuated due to downstream flood control regulation, consideration will be given to scheduling Gavins Point Dam winter releases in the 25,000 to 30,000 cfs range to accomplish the flood control objective of evacuating the stored flood waters in the Annual Flood Control and Multiple Use Zone prior to the beginning of the next flood season.

7-03.7. Integration of Downstream Requirements. Gavins Point Dam releases are regulated to provide service to all multiple-use purposes, while at the same time recognizing the important flood control function of the System. In years of excess water supply, Gavins Point Dam releases in excess of full service requirements may be necessary to evacuate stored flood water. In recognition that these higher-than-average releases may have an adverse effect on downstream floods, should unexpected rainfall occur in the lower basin, the higher-than-average releases should be made, to the extent possible, when floods from downstream tributaries are less likely. Also, the magnitude of these releases during the open-water season can be reduced somewhat by scheduling winter releases at a higher rate than would be the case with an average water supply. While this may have the effect of slightly increasing the flood risk during the winter months, it reduces the flood risk during the open-water season when the flood potential is greatest. In addition, it may also increase the service provided to the hydropower and navigation purposes by extending the navigation season length up to 10 days and increasing the amount of winter hydropower generation. Also, flood storage evacuation releases slightly above full service requirements during the open-water season usually have a beneficial effect on navigation and hydropower generation.

7-03.7.1. With an average or less-than-average water supply, navigation and hydropower releases during the open-water season are made taking into account the existing System water-in-storage and less-than-full service level releases may be provided when water-in-storage indicates water conservation measures are in effect. Under such conditions, winter hydropower generation releases may also be reduced. Table VII-5 shows that for System water-in-storage of 58.0 MAF a winter release from Gavins Point would be approximately 17,000 cfs. This release rate equates to fully serving the winter System hydropower generation purpose and meeting all downstream water supply requirements. If, due to a depletion in System water-in-storage reserves down to the levels identified in Table VII-3, navigation season lengths need to be reduced to less than 8 months, winter releases from Gavins Point may be reduced to the minimum necessary for water intake or water quality control requirements. The minimum System releases considered applicable at this time are 9,000 cfs during the non-summer open-water season (March-April and September-November), 18,000 cfs during the summer open-water season (May-August) and 12,000 cfs during the winter period (December-February).

7-03.8. System Conservation or Drought Reservoir Regulation Considerations. From 2000-2007, the basin experienced its second extended drought since the System became fully operational in 1967. The System storage reached its historic low of 33.9 MAF in February 2007. All authorized purposes, except for flood control, are negatively affected during extended drought; the impacts range from minor to very severe. Those most severely affected are recreation in the upper three large System reservoirs and below the System; navigation; intake access on the upper three large System reservoirs, in the river reaches between the reservoirs, and below the System; coldwater reservoir fishery species; reservoir and river water quality including thermal powerplants; irrigation; and hydropower generation.

7-04. System Regulation for Flood Control. The regulation of the System for flood control is provided in the following sections.

7-04.1. Objectives of Flood Control Regulation. The System is regulated, insofar as practicable, to prevent flows originating above or within the System from contributing to damaging flows through the downstream reaches of the Missouri River. Regulation of individual System projects is integrated to successfully meet this regulation objective. In addition, each individual System project is regulated to prevent, insofar as practicable, project releases from contributing to damaging flows through the downstream reaches in which that particular project affords a significant degree of control.

7-04.2. Method of Flood Control Regulation. In general, the developed method of regulation of the System as described in subsequent sections 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 reservoir storage space during each flood event with regulation procedures based on the control of floods of approximate reservoir design magnitude. Specific procedures for the accomplishment of flood control regulation and examples are given in the succeeding sections.

7-04.3. Mainstem System Storage Space Available for Flood Control. During any specific major flood event, all available storage space within the System will be used to the maximum extent practicable for flood control. This control will be provided in combination with other beneficial water uses for which the System was authorized. Approximately 16.3 MAF of System storage space are allocated for flood control purposes, of which 4.7 MAF are for this purpose exclusively; the remainder combines flood control with other authorized purposes. More than 98 percent of the System flood control storage space is located in the Fort Peck, Garrison, Oahe and Fort Randall projects. The flood storage in the Big Bend and Gavins Point projects is relatively minor in magnitude. In addition to allocated flood control storage space, surcharge space is available in each of the System reservoirs, primarily to ensure the safety of the project, but the use of that space will provide downstream flood reductions during extreme flood events. The Carryover Multiple Use Zone storage space, when evacuated, will also serve to benefit the flood control purpose; however, deliberate evacuation of this zone to serve flood control will not be normally scheduled. As discussed in Appendix A of this manual, determination of the current flood control storage allocation of the System is based, to a large degree, on the vacated space required to control the 1881 flood. The 1881 flood is discussed in greater detail in Appendix A of this manual. The System flood control storage allocation was examined and confirmed as adequate by numerous long-range regulation studies conducted as part of the 2004/2006 Master Manual update.

7-04.4. Amount of Tributary Reservoir Space Available for Flood Control. The availability of upstream tributary reservoir flood control storage space was not recognized in the early flood studies. Early long-range System regulation studies also did not consider tributary reservoirs regulated specifically for flood control along the main stem of the Missouri River. Tributary reservoir storage space upstream from the System, if regulated for that purpose, can be effective in reducing flood peaks in the lower Missouri River. Certain Missouri River basin tributary reservoirs, therefore, have a portion of their available storage space allocated to flood control use on a “replacement” basis. Replacement storage is defined as tributary reservoir storage space that is regulated in close coordination with the System and, as a consequence, can replace a portion of the System’s Annual Flood Control and Multiple Use Zone space. Replacement storage effectively allows for an increase in the amount of Carryover Multiple Use Zone storage that can be retained in the System projects. This greater amount of Carryover Multiple Use Zone storage results in increased multiple-use benefits while continuing the same degree of downstream flood protection that the System was designed to achieve. Past long-range regulation studies have incorporated this replacement storage concept and have demonstrated the resulting increased multiple-purpose benefits and continued flood control effectiveness of the expanded system of reservoirs. The use of replacement storage was last integrated into the System regulation in the 1980s. Basin hydrologic conditions determine if use of tributary replacement storage is warranted.

7-04.4.1. Replacement System Flood Control Storage Space. Replacement flood control storage has been provided in three USBR projects in the upstream basin: Clark Canyon, Canyon Ferry and Tiber. These projects control drainage areas upstream of Fort Peck. The Corps’ NWD Commander is responsible for the flood control regulation of these projects under Section 7 of the 1944 Flood Control Act. The NWD Commander has delegated the flood control regulation of these USBR projects to the Corps’ Omaha District Commander. The drainage areas of these three projects all have relatively high runoff yields that produce significant volumes of the flood season runoff above the System. It is expected that, in years of large runoff that could conceivably tax the flood control abilities of the System, the replacement storage space in these projects would be used for the control of flooding on the Missouri River. The three USBR projects have the use of replacement System flood control storage outlined in their respective tributary WCMs. Each WCM details the procedures for the Corps to follow in computing the amount of replacement storage available for each runoff season. When replacement storage for any or all of the projects is used, the actual regulation of the System proceeds as if this upstream tributary replacement storage space was a part of the System’s Annual Flood Control and Multiple Use Zone. When replacement storage is used, the total System storage, or storage in a particular System project, could enter the flood season on March 1 above the base of the Annual Flood Control and Multiple Use Zone. This storage may appear to exceed the amount suggested by flood control objective criteria stated in this manual. Because the vacated space in the upstream reservoirs is being used as tributary replacement storage, what is initially seen as excess flood control storage in the System is actually consistent with criteria outlined in this manual. If replacement storage is used, the affected USBR tributary project(s) is credited with extra flood control benefits for a portion of System damages prevented on the Missouri River. The MRBWM office is responsible for requesting, in writing, that the Omaha District Water Control Office initiate the process to use tributary replacement storage to benefit the System. The Omaha District in turn notifies the USBR that tributary replacement storage is being requested by the MRBWM office. The USBR must then assure that the space is evacuated in the tributary project prior to flood season in accordance with the procedures written in the tributary WCMs. The volume of replacement storage space available in the USBR tributary projects, as stated in the tributary project WCMs, is shown in Table VII-6.

Table VII-6
System Replacement Flood Control Storage

Tributary Project	System Replacement Storage[1] (acre-feet)	Elevation Range (feet)	
Tiber	562,160	2993.0	3008.1
Clark Canyon	106,662	5535.7	5556.6
Canyon Ferry	445,564	3783.0	3797.0
Total	1,114,386		

[1]Storages are based on elevation-capacity surveys: Tiber (2002), Clark Canyon (2000), and Canyon Ferry (1998).

7-04.4.2. Other Tributary Reservoir Flood Control Storage Space. In addition to the aforementioned USBR tributary projects that have assigned replacement flood control storage space, there are many other tributary reservoirs upstream of the System projects. Many of these tributary reservoirs have no Congressionally authorized flood control space or have flood control space assigned only for the purpose of local flood control in the immediate downstream river reach. At times, these reservoirs are drawn well below their normal full level prior to the flood season. Efficient Missouri River basin water resources management requires that the status of storage in all significant tributary reservoirs be considered and integrated into the overall regulation of the System, to the extent practical, while maintaining the overall flood control capability originally designed into the System.

7-04.5. System Project Regulation Features. Releases from individual System projects can be made through their respective powerplants, outlet works and spillways. The powerplants will be used to the fullest extent possible to achieve the maximum benefit. During normal operating conditions, the greatest portion of project releases is made through the powerplants. When releases greater than the powerplant capacity or power demand are necessary, the outlet works and spillways will be used. The spillway, in combination with surcharge storage provided, ensures the safety of the dam in the case of extreme floods. Capacities of flow regulating devices at the System projects are indicated on rating curves represented on Plates II-5 through II-9 for Fort Peck, Plates II-20 through II-23 for Garrison, Plates II-34 through II-37 for Oahe, Plates II-47 through II-49 for Big Bend, Plates II-59 through II-62 for Fort Randall and Plates II-72 through II-74 for Gavins Point. Additional information can be found in the individual System project WCMs.

7-04.6. System Flood Control Regulation. Flood control regulation of the System projects, as per the objectives stated in Section 7-04.1, is based on careful consideration of the following factors: river channel capacities downstream from individual System projects; observed and forecasted tributary flows to those portions of the Missouri River through which the System and individual System reservoirs afford a positive degree of flood control; observed and forecasted inflows into the System and the individual System reservoirs; amount of vacated individual System projects and total System storage space for controlling current and forecasted runoff; flood-producing potential of the drainage area both above and below the System and its relationship to individual System projects within the System; release requirements from the System and also from the individual System projects for purposes other than flood control; and available tributary reservoir flood control storage space above the System. The desired System water-in-storage at the start of the runoff season, which is on or about March 1, is 56.1 MAF, equivalent to having each individual System reservoir at the base of its respective Annual Flood Control and Multiple Use Zone. When median or greater runoff occurs with System storage at 56.1 MAF or above on March 1, System releases are adjusted by computing the appropriate service level to draft storage to 56.1 MAF by March 1 of the following year. The three large reservoirs can either be balanced or unbalanced in terms of the amount of water in the Carryover Multiple Use Zone remaining on March 1 by specifying target storages; however the overall goal for the System is to have the stored flood waters evacuated to the base of the Annual Flood Control and Multiple Use Zone (56.1 MAF) by March 1 each season to fully serve the flood control purpose for the upcoming runoff season.

7-04.6.1. Use of Annual Flood Control Storage. The flood control storage space in the System is normally evacuated prior to the start of the next flood season, which generally starts in March or early April. The runoff season could begin as early as January if warmer-than-normal temperatures occur in January and February in the upper basin that result in the melting and subsequent runoff of accumulated plains snowpack. The Annual Flood Control and Multiple Use Zone will be allowed to fill or partially fill through the flood season, with the rate and amount of fill largely determined by actual and anticipated hydrologic conditions. Optimum System regulation requires the filling of a portion of this zone during the spring and early summer when plains and mountain snowpack is melting and rainfall runoff is occurring. The storage of water in this zone allows for System releases that exceed inflows to be made in the summer, fall and winter to fully meet the regulation objectives of this CWCP. This is accomplished provided that inflows exceed the releases required to meet all authorized purposes.

7-04.6.2. Use of Exclusive and Surcharge Flood Control Storage. The space provide in each project's respective Exclusive Flood Control Zone is reserved entirely for the control of floods and is not to be encroached on except for that specific purpose. Surcharge storage space is provided at each project to assure project integrity and will be used only in the case of extreme floods.

7-04.7. Individual System Project Flood Control Regulation. Seasonal regulation of the storage within the individual System projects of the System will, to a degree, parallel that for the System, which is described in previous sections. The individual System projects have two zones designated for flood control, the Annual Flood Control and Multiple Use and the Exclusive Flood Control zones. The Annual Flood Control and Multiple Use Zone is the zone where the projects normally operate under a wide range of runoff conditions. The zone designated as Exclusive Flood Control Zone is vacated most of the time and encroached upon only during significant runoff events. When the amount of water in an individual project or System storage is great enough to occupy this zone or the Corps' simulation models forecast the projects to rise into this zone, the projects are considered to be in a flood control state. Downstream runoff and streamflow conditions can also cause the System to be considered in a flood control state. The flood control state results in an increased frequency of forecasts and an examination of additional alternatives to return the System to a non-flood control condition. During a flood control state, the flood control purpose is considered foremost in making release determinations.

7-04.7.1. Fort Peck and Garrison Flood Control Considerations. The winter season is the time period when the firm power demand from the System is the greatest. To enhance winter energy generation, winter releases from the upstream Fort Peck and Garrison reservoirs are often maintained at the maximum level possible that is consistent with downstream channel capacity. During the winter, channel capacity is reduced because of the threat of flooding during river ice formation or when an established Missouri River ice cover raises Missouri River stages. Because of the somewhat unpredictable behavior of a downstream ice cover, the exact potential volume of winter releases from these upstream projects cannot be estimated accurately. Pre-winter System reservoir storage levels are scheduled on the basis that the established winter release rate will be made most of the time through these upstream powerplants. If channel conditions during the winter are such that the established winter release rate assumed in pre-winter scheduling is not possible, a release modification will be implemented. The changed release rate may result in some imbalance in the amount of water-in-storage in individual System reservoirs by the following spring. This storage imbalance will favor the downstream flood control purpose, with additional evacuated storage space located in Oahe, the farthest downstream of the three largest System projects. This is not a matter of great concern because open-water channel capacities below Fort Peck and Garrison are sufficient to allow a relatively fast restoration of System storage balance following the ice breakup if attaining a balance in the amount of water-in-storage at the large three reservoirs is still a goal at that time of the season.

7-04.7.2. Fort Randall Flood Control Considerations. The early spring flood potential is defined by the amount of accumulation of plains snow and the ground conditions in the incremental areas above and between the System reservoirs. Manipulation of the Fort Randall reservoir level prior to the start of the flood season is based on the spring flood potential. In years when the early-spring flood potential between Oahe and Fort Randall is high because of plains snow accumulation or the flooding potential below Fort Randall is high, the Fort Randall reservoir level may be held below its base of the Annual Flood Control and Multiple Use Zone prior to the onset of spring runoff. This reservoir level manipulation is achieved by reducing late winter hydropower releases from the Oahe and Big Bend projects. The additional vacated storage space in Fort Randall allows for the capture of flood flows with a less severe disruption of hydropower releases from upstream projects through the spring runoff period. During normal runoff situations, the reservoir will be maintained at the base of Annual Flood Control and Multiple Use Zone, elevation 1350.0 feet. During those years that the flood potential below Oahe is low, it may be desirable to raise the Fort Randall reservoir level above the base of the Annual Flood Control and Multiple Use Zone prior to March 1. This allows for an increased amount of energy to be generated during the high-demand winter period. Additionally, the higher reservoir level provides a reserve of additional water that may be used to satisfy short-term demands for increased System releases during the following navigation season for downstream flow support. Experience has indicated that a Fort Randall reservoir level of about 1355.0 feet, 5 feet above the base of the Annual Flood Control and Multiple Use Zone, is satisfactory for meeting the short-term downstream flow support demands. Experience has also indicated that maintaining a minimum pool elevation of 1353.0 feet will meet the recreational and irrigation purposes during the April to September timeframe. Consequently, any deliberate fill of the Fort Randall reservoir, based on low flood potential prior to March 1, will normally be limited to an elevation of 1355.0 feet.

7-04.7.3. Gavins Point Flood Control Considerations. Consideration of the early spring flood potential in the drainage area between Fort Randall Dam and Gavins Point Dam is similar to that outlined in Section 7-04.7.2 for the area between the Oahe and Fort Randall projects. Because it is possible to manipulate the Gavins Point reservoir level in a relatively short period of time, the reservoir level at the start of the flood season will be somewhat dependent on the spring flood potential. When the spring flood potential between Fort Randall Dam and Gavins Point Dam is high, the Gavins Point reservoir level will be drawn down well below its base of Annual Flood Control and Multiple Use Zone immediately prior to the start of the snowmelt period and allowed to refill from the snowmelt runoff. The limit of this drawdown will be dependent on the potential for flooding based on the forecasted runoff in the Fort Randall Dam to Gavins Point Dam reach. When the runoff potential between Fort Randall and Gavins Point Dam is very low, as evidenced by the lack of a plains snow cover or by a lack of antecedent rainfall over the incremental drainage area, complete evacuation of the Gavins Point Annual Flood Control and Multiple Use Zone may not be necessary. Continued surveillance of the runoff potential in this incremental area is required. If the runoff potential increases during the March through July flood season, appropriate measures will be taken to lower the level of the Gavins Point reservoir to near the base of its Annual Flood Control and Multiple Use Zone, which is 1204.5 feet; however, consideration of the state of T&E nesting must be made prior to lowering the reservoir. The potential effects on the recreational use of the Gavins Point reservoir will be a consideration in any decision made to reduce the elevation of Gavins Point to capture additional runoff. In this area, there is continued pressure from recreation specific interests to maintain Gavins Point reservoir levels at the highest practical level consistent with the flood runoff potential. Additionally, keeping the Gavins Point reservoir level high, along with a corresponding storage decrease in upstream reservoirs, increases System hydropower generation because the small size of Gavins Point provides a greater amount of power per unit of storage than any of the other System projects. Because releases from this project are normally greater than from other System projects, the additional head is more effective for increased energy production than a corresponding head increase at other System projects. The Gavins Point reservoir level following the March through July flood season and the completion of the T&E nesting season will normally be maintained at 1207.5 feet to enhance both recreation and hydropower generation. The base of the Gavins Point Exclusive Flood Control Zone is 1208.0 feet. Manipulation of the Gavins Point and Fort Randall reservoir levels, as described in this and the preceding sections, has no effect on the overall availability of evacuated flood control storage space in the System prior to early spring floods. This is because desired reservoir levels are realized by scheduling releases from upstream projects. Downstream System release rates are also not affected by any System reservoir level manipulations discussed in the subsections of Section 7-04.7.

7-04.8. System Flood Control Regulation Criteria. In order to conduct System flood control regulation in an optimum manner, while at the same time providing the maximum possible service to the other multiple-use purposes of the System, storage space allocated for flood control in the downstream System reservoirs of Big Bend, Fort Randall and Gavins Point should be maintained as near to the base of their respective Annual Flood Control and Multiple Use Zones as possible, which is consistent with the discussion in Section 7-04.7. The basis for this type of System regulation is explained in the following subsections.

7-04.8.1. Vacant space in the three smaller downstream System projects provides an additional measure of flood control for the large urban damage centers below the System than the same amount of vacated space in the upper three larger System projects.

7-04.8.2. When the levels of the Big Bend and Fort Randall reservoirs are near the base of their respective Annual Flood Control and Multiple Use Zones, tailwater levels at the immediately upstream Oahe and Big Bend projects will provide maximum hydropower heads. This will result in improved hydropower generation.

7-04.8.3. In the case of heavy runoff originating below the System, vacant Annual Flood Control and Multiple Use Zone space in the downstream three smaller System projects helps both flood control and hydropower generation. These smaller projects then have the space to store the upstream project releases necessary to maintain the optimum System hydropower generation from the upstream three larger System projects, while releases can be reduced from the smaller downstream projects to provide the maximum practical flood reductions.

7-04.8.4. Flood control releases from the System will be made in such a manner as to satisfy the following general requirement: when allocated flood control storage space in Fort Randall is available to capture existing or forecasted flood events, maximum System releases will normally be limited to a rate that will not contribute to flows that exceed 120,000 cfs at Sioux City, IA. If insufficient storage is available in Fort Randall reservoir for controlling the existing or forecasted runoff, System releases will be increased as necessary to ensure project safety while at the same time providing significant downstream flood reductions.

7-04.9. System Regulation Considerations During Winter Ice Season. The maximum flow that may be passed without damage varies through the length of the Missouri River and is dependent on channel dimensions, the degree of encroachment onto the floodplain, and improvements such as levees and channel modifications. Capacities at specific locations also vary from season to season, especially in the middle and upper river reaches, where a decrease in capacity due to the formation of an ice cover is common through the winter and early spring months. Like with most streams, the capacity of the Missouri River channel usually increases progressively downstream, although instances occur where this trend is reversed.

7-04.9.1. Above Sioux City, the Missouri River and its tributaries can be expected to freeze over each year. An intermittent ice cover will also usually form on the Missouri River as far downstream as St. Joseph. In the downstream reaches of the Missouri River below St. Joseph, an ice cover may occasionally form as a result of severe and extended cold temperatures. The time of formation and breakup of the ice cover varies widely from year to year, but an ice cover may be expected over some reaches from early December to about mid-March. MRBWM Technical Report No. SS-N-71, *Missouri River Freeze and Breakup*, November 1971, presents detailed historical data on this subject.

7-04.9.2. An ice cover greatly decreases the river conveyance at any given stage and, consequently, the channel capacities are significantly reduced. The formation and breakup of the ice cover through any reach or series of reaches often causes ice jams. Substantial volumes of water are stored temporarily by these ice jams or by a solid ice cover due to flow restriction by the ice. This phenomenon has a marked effect on streamflow and river stages. Downstream flows and accompanying stages may be markedly reduced at the onset of the jam, while stages just upstream or in the upstream portions of ice-covered sections of the river may rise to damaging levels. The volume of ice in any particular reach of the Missouri River that may contribute to jamming is a function of the thickness of ice, the width of the river and the length of the reach. With low stages, the river width and the ice volume within the reach are reduced from what they would have been with higher stages. Most of the maximum stages of record in the upper Missouri River resulted from ice jams and occurred prior to regulation provided by the System. The System projects tend to act as a trap to flowing ice and reduce the possibility of severe ice jam formation in downstream areas, both during the period of ice formation and ice breakup.

7-04.9.3. In the downstream portions of the Missouri River, ice jamming or ice bridging is likely to occur during periods of extremely cold weather. Large cakes of ice form and float downstream to a restricted reach where they sometimes lodge. The resulting blockages are fed by additional floating ice. Usually, such blockages in the downstream reaches are temporary in nature and continue until such time that temperatures moderate. Because temperature conditions can be forecast several days in advance with a reasonable amount of accuracy, experience has shown that slowly increasing Gavins Point releases prior to a cold snap entering the region can reduce the formation of ice jams in the Missouri River reach from Gavins Point Dam to Kansas City. Release increases are generally made a rate of no more than 1,000 cfs/day over a several day period before the cold snap enters the region. The increase in releases results in a slightly faster flowrate as well as a slightly larger surface area. Once the cold snap has left the region, Gavins Point releases are decreased at generally the same rate of 1,000 cfs/day until the steady winter release rate is achieved.

7-04.9.4. On several occasions, blockages have formed in the Nebraska City to St. Joseph reach of the Missouri River and have caused stages to exceed established flood stage, in spite of low releases from Gavins Point. In recent years, the Missouri River normally freezes first below Gavins Point Dam in the Ponca area above Sioux City; below Decatur, NE; below Fort Calhoun, NE; below the Platte River confluence with the Missouri River and near Leavenworth, KS. During severely cold Midwest winters, over 400 miles of the Missouri River have been covered by ice below Gavins Point Dam. Generally, the long travel times to most locations prevent the Corps from making significant changes in Gavins Point releases to correct stage fluctuations from ice jam events below the System.

7-04.9.5. Ice cover forming on the Missouri River below Fort Peck and Garrison has a marked effect on the winter regulation of these projects. At the time the ice cover first forms below Fort Peck and Garrison dams, the downstream channel capacities are at a minimum. As the river ice cover stabilizes, Fort Peck and Garrison releases are normally slowly increased followed by a progressive increase in the channel conveyance capacity that continues until just prior to the end of the winter season. It is often possible to increase Fort Peck and Garrison releases while maintaining relatively constant downstream stages. This phenomenon is discussed in more detail in two MRBWM Technical Reports, F-73, *Freezing of the Missouri River Below Garrison Dam*, February 1973, and JY-73, *Freezing of the Missouri River Below Fort Peck Dam*, July 1973.

7-04.9.6. Ice cover forming on the Missouri River below the Oahe Dam also has a marked effect upon the winter regulation of this project. During very cold periods, minimum releases are maintained at a "one unit minimum" level, which is approximately 7,000 cfs. This is discussed in more detail in the CRREL Technical Report, *Ice-Affected Flooding, Oahe Dam to Lake Sharpe*, *South Dakota*, March 2000 and the Oahe WCM. As discussed in Section 7-20.10 of this manual, federal funds were used in the late 1990s into the mid-2000s to acquire and/or flood-proof properties most susceptible to ice-affected flooding in Pierre and Fort Pierre, SD.

7-04.9.7. System Winter Season Flood Control Releases. Due to restricted channel capacities under ice conditions, releases from specific projects during the winter river ice-cover period will be limited at all six System projects.

7-04.9.7.1. Fort Peck. At the time when active downstream river ice formation is anticipated or occurring in the reach between Fort Peck Dam and the mouth of the Yellowstone River, mean daily releases from Fort Peck are limited to a maximum of 10,000 cfs unless higher releases are needed for flood control evacuation. After a river ice-cover has formed, releases will be limited to prevent Missouri River stages from exceeding 21 feet at Wolf Point, which is 2 feet below the flood stage, or 13 feet at Culbertson, which is 6 feet below the flood stage, unless higher release rates are required for flood control evacuation. Experience indicates that, after the downstream ice cover has formed and stabilized, mean daily releases can be increased up to 15,000 cfs, which is the Fort Peck powerplant capacity. However, increases in releases from the normal freeze-in level to the maximum winter ice-covered level should normally be made in gradual increments. Additionally, tributary runoff between Fort Peck and Wolf Point and Culbertson streamgaging stations due to plains snowmelt prior to the time the river becomes ice-free is a consideration in scheduling Fort Peck releases.

7-04.9.7.2. Garrison. Garrison releases are normally not scheduled above 20,000 cfs in December to prevent the Missouri River at the Bismarck streamgaging site from exceeding a stage of 13 feet, which is 1.5 feet below the flood stage, during the winter freeze-in period. Releases are typically set at 16,000 to 18,000 cfs prior to the river freeze-in. This action is taken to prevent flooding of housing developments adjacent to the Missouri River in Bismarck and Mandan, ND. After the river ice cover has stabilized in the downstream Missouri River reach around Bismarck, Garrison releases can be gradually increased without increasing the river stage. Experience has shown that approximately one month after the initial freeze-in at Bismarck, Garrison releases up to 27,000 cfs are possible. Tributary runoff between Garrison Dam and Bismarck prior to the time the Missouri River becomes ice-free must be considered in scheduling Garrison releases. The 27,000 cfs winter release rate is less than original Garrison powerplant capacity winter release rate of 35,000 cfs. This reduction is attributed to aggradation in the upper end of the Oahe reservoir, which has caused a reduction in channel capacity through the Bismarck/Mandan reach of the Missouri River.

7-04.9.7.3. Oahe. Experience has indicated that the normal powerplant peaking at Oahe maintains the 7-mile reach between Oahe Dam and the head of the Big Bend reservoir largely in an ice-free condition under all but the most severe weather conditions. Therefore, the channel capacity available requires no restrictions on winter discharges through the Oahe powerplant except during the most severely cold conditions. The formation of this ice cover, at times, has resulted in street flooding. The Bad River delta, which has raised the Missouri River stage for both open-water and ice-affected flows, exacerbates this problem. As described in Section 7-

04.9.6, a “one unit minimum” operation may be required on Oahe generation when extremely cold conditions are occurring or expected to occur.

7-04.9.7.4. Big Bend. Big Bend releases directly enter the Fort Randall reservoir, consequently, no restrictions on winter releases are necessary.

7-04.9.7.5. Fort Randall. Although the ice-covered Missouri River channel between Fort Randall Dam and the headwaters of the Gavins Point reservoir could sustain higher discharges without resulting in damages, the average winter season release from Fort Randall is about 15,000 cfs. This release restriction is due to the restricted ice-covered channel capacity below Gavins Point Dam combined with the small amount of storage space available in the Gavins Point reservoir to re-regulate releases from Fort Randall. Additionally, System regulation associated with an average winter release of 15,000 cfs from Fort Randall represents full winter service to the hydropower generation function of the System. When the Missouri River channel is ice-covered, Fort Randall winter releases may be increased gradually to average 25,000 cfs, or slightly more when it is deemed necessary to evacuate accumulated flood storage.

7-04.9.7.6. Gavins Point. In the Missouri River reach from Gavins Point Dam to Kansas City, MO, ice jams can and have resulted in flood damage. This Missouri River reach is particularly vulnerable due to intermittent freeze-ups and breakups of Missouri River ice cover throughout the winter. This reach of the river valley is also highly developed relative to the rest of the basin; therefore, there is a high flood damage potential related to serious ice jams. There has been ice-jam-related flooding during extremely cold winters when much of the Missouri River below the System is ice-covered. The long travel time in this reach of the river makes river-icing problems particularly difficult, if not impossible, to resolve with System release changes. Generally, any attempt to modify the result of the river icing this far downstream results in a risk to upstream ice cover and potential flooding. Experience has demonstrated that the river icing situation normally resolves itself before the System release change arrives at the problem location. The flow travel time from Gavins Point Dam to Kansas City during open-water periods varies from 5 to 10 days, depending on the amount of water in the river. When ice cover is present, these times are extended considerably. Additional degradation of the Missouri River in the Sioux City vicinity has permitted the maximum Gavins Point winter release rate to be increased from 20,000 cfs up to 30,000 cfs. Open-water Missouri River stages corresponding to a Gavins Point release of 30,000 cfs today are essentially the same as they were previously with a 20,000 cfs release. At times, reductions below the 25,000 cfs level may be necessary due to the formation of severe ice blockages in the Gavins Point Dam to Sioux City reach.

7-04.9.7.6.1. During any non-navigation period, project releases will be made to ensure adequate Missouri River flows to serve water supply in the river reaches downstream of the System and between the System dams, to the extent reasonably possible. During periods of extended drought, recent experience indicates an average Gavins Point winter release of 12,000 cfs with increases up to 18,000 cfs during river ice formation periods is required to meet winter water supply needs downstream of Gavins Point Dam extending as far as the Kansas City metropolitan area. When the System was first filled, the downstream reach of concern during the winter was much shorter, mostly confined to the Missouri River reach from Gavins Point Dam to Omaha, NE. Additional years of degradation have, however, resulted in moving the most affected area downstream to at least Kansas City. It should be noted that most of these winter water supply problems are related to intake access problems that need to be corrected by the intake owners; however, a large number of problem areas may be an indication that it is more than just an access problem. The Corps updates a *Missouri River Stage Trends Report* every few years. The report, which is available on the MRBWM website, details the degradation and aggradation that is occurring on the Missouri River. The report graphically depicts the effects of degradation or aggradation for specific Missouri River locations at various levels of Missouri River flow. Some intake owners have used this report in planning for adequate water supply access.

7-04.10. System Flood Control Considerations During the Open-Water Season. When flood control storage space is available to control existing or forecasted inflows, maximum releases during the open-water season are based on downstream channel capacity.

7-04.10.1. Use of Upper Three Reservoirs. To the extent reasonably possible, the available flood control storage space available in the three upper System reservoirs, Fort Peck, Garrison and Oahe, will be used for the control of floods in preference to the flood control storage space available in the three lower System reservoirs. The allocated flood control space in the downstream Big Bend, Fort Randall and Gavins Point projects will be used to the degree necessary to re-regulate upstream System reservoir releases and to control runoff originating between the drainage area between Oahe and Gavins Point dams.

7-04.10.2. Balancing Available Flood Control Space. To the extent reasonably possible, a balance of the vacant storage space (in terms of percent of allocated space) within both the Annual Flood Control and Multiple Use Zones and Exclusive Flood Control Zones will be maintained between Fort Peck, Garrison and Oahe, the three larger upper reservoirs, when the flood control storage in the System is taxed or expected to be taxed by forecasted inflows. When flood control storage zones are able to contain forecasted inflows, departures from storage balance criteria will be permitted in the interest of enhancing other Congressionally authorized purposes. It should be recognized that, in the event of extreme deviations in expected runoff at individual System projects, it may take several weeks, and sometimes longer, to achieve a storage balance in the upper three reservoirs without causing downstream damaging flows.

7-04.10.3. System Flood Control Evacuation Priority. Evacuation of System flood control storage immediately following the capture of flood runoff will be accomplished, insofar as practical, on the basis of established priorities in the order as follows:

1st Priority: Evacuating stored water from the Surcharge Storage Zones from all System reservoirs.

2nd Priority: Evacuating stored water from the Exclusive Flood Control Storage Zones in the three lower reservoirs (Big Bend, Fort Randall and Gavins Point).

3rd Priority: Evacuating stored water from the Exclusive Flood Control Storage Zones in the three upper reservoirs (Fort Peck, Garrison and Oahe).

4th Priority: Evacuating stored water from the Annual Flood Control and Multiple Use Zones in Gavins Point, and in Fort Randall above elevation 1360.0 feet. Evacuation of stored water in Fort Randall's Annual Flood Control and Multiple Use Zone storage below elevation 1360.0 feet is greatly influenced by power loads and the required hydropower generation at Oahe and Big Bend.

5th Priority: Evacuating stored water from the Annual Flood Control and Multiple Use Zones in the three upper projects (Fort Peck, Garrison and Oahe). In general, evacuation of at least the upper portions of the Annual Flood Control and Multiple Use Zones in the three upper reservoirs should be conducted in such a manner as to maintain a balance of available allocated space within all three reservoirs. Due to the restricted channel capacity below Fort Peck, it may be necessary, depending on conditions, to distort this balance to assure the evacuation of stored waters from that System project.

6th Priority: Evacuating stored water from the Annual Flood Control and Multiple Use Zones will be made in a manner that, to the extent reasonably possible, will assure complete evacuation of this space prior to the beginning of the next flood runoff season while achieving the maximum beneficial conservation use of the stored water based on the operational objectives stated in this manual. The serious hazard of downstream flood damages in the case of late fall or winter ice conditions may make the complete evacuation of stored water in the Annual Flood Control and Multiple Use Zone prior to the next flood season inadvisable. In certain extreme high water years, there is a lesser risk associated with retaining some water in the Annual Flood Control and Multiple Use Zones as opposed to continuing the evacuation and possibly contributing to downstream flood damages during the late fall and winter months. Even in these high water years, long-term release schedules should indicate that a major portion of the Annual Flood Control and Multiple Use Zone is expected to be evacuated prior to the next runoff season.

7-04.11. Scheduling of System Releases. The flood control purpose of the System continues to be a major consideration in scheduling System releases, irrespective of the amount of water contained in the System or the character of inflows to the System. Multi-purpose regulation techniques described in this manual are consistent with the flood control objectives. During the winter months, multi-purpose releases are restricted due to the possibility of ice formation and consequent severe loss of channel capacity. Downstream flow support releases during the open-water season are based on maintaining specified target flows at downstream control points. This type of multi-purpose regulation serves flood control and the other downstream purposes most of the time.

7-04.11.1. There are times, however, when the service provided to other purposes must be modified in the interest of the flood control objective. During winter months, severe ice jams can form on the Missouri River below Gavins Point Dam, even with the restrictions to System releases that are imposed during the winter season. Because this is the non-crop season, flood damages associated with the resultant high Missouri River stages are, fortunately, usually much less than would occur if similar stages were experienced during the summer season. Particularly severe ice jamming could result in flooding of property susceptible to flood damage; therefore, when severe ice jamming is occurring at downstream locations, a reduction in System releases may be warranted. While past experience indicates that those release reductions will have very little effect on stages associated with the jams, action by the Corps will indicate awareness of the problem and the desire to alleviate the adverse conditions. Such release reductions will usually be only temporary, extending at the most, for a week or two. The overall level of service to other System purposes can usually be maintained by increasing releases after the river ice cover stabilizes. At other times, it is prudent to increase System releases prior to the onset of expected river ice buildup or even during a significant ice jam. Experience during recent years indicates that increasing System releases, as described in Section 7-04.9.3 of this manual, speeds the recovery of the Missouri River to more normal stages and assures that the downstream water intakes are operational sooner or affected less by the icing condition. The Corps will evaluate each ice-jam situation on a case-by-case basis and make a determination regarding the appropriate release.

7-04.12. System Service Level. Because the ability to evacuate System storage is severely restricted during the winter months, the necessary increases in System release rates for storage evacuation purposes above the rates necessary for navigation and other authorized purposes will largely be made during the navigation season. The methodology to determine releases to evacuate flood storage and reduced System releases during periods of downstream flood events is an extension of the "service level" and "target flow" concepts described in Sections 7-03.2 through 7-03.2.1.1 of this manual. Basic to the use of the "service level" concept is a definition of the minimum and maximum service levels that can be maintained while meeting the other regulation objectives.

7-04.12.1. Flood Control Considerations for the System Minimum Service Level. As discussed earlier in this chapter, the minimum open-water level that will sustain the navigation purpose throughout the Missouri River navigation project is the 29,000 cfs service level. Target flows for this service level are 25,000 (29,000 - 4,000) cfs at Sioux City, IA and Omaha, NE; 31,000 (29,000 + 2,000) cfs at Nebraska City, NE; and 35,000 (29,000 + 6,000) cfs at Kansas City, MO. Making release reductions below this service level for flood control purposes could have serious adverse effects on navigation, downstream recreation and water supply. Adverse effects on power production are also quite probable with sharply reduced System releases. Release reductions to below the minimum navigation service level should, therefore, be made only when it is reasonably assured that the reductions will be of significant benefit from the flood control standpoint. Reductions below the minimum service level should only be made after appropriately considering the effects on other authorized purposes.

7-04.12.2. Flood Control Considerations for the System Full Service Level. The full service level of downstream open-water flows is 35,000 cfs. It is important to note that the full service level of 35,000 cfs does not indicate a project release. Rather, this flowrate is part of determining the needed volume (a steady flow of 35,000 cfs over an 8-month period is equivalent to a volume of about 17 MAF) of water needed to meet the navigation channel requirements along with all other Congressionally authorized project purposes, such as water supply and recreation, served below the System. Missouri River target flows for a full service level of 35,000 cfs are 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City, and 41,000 cfs at Kansas City. Navigation and some other authorized purposes, such as water supply for powerplant cooling purposes, are enhanced to some extent by flows in excess of those provided by this full service level. Any enhancement to navigation and power production would be negligible for service levels above 45,000 cfs, or more than 10,000 cfs above the full service level. Service level increases above 45,000 cfs, however, may be necessary for flood storage evacuation purposes.

7-04.12.2.1. During the winter season, a 5,000 cfs or higher release level from Fort Randall Dam can be sustained during all past hydrologic conditions since 1898 with the present level of water resource development. Reductions below this level will generally not be made. The full service winter level corresponds to a 15,000 cfs average winter release from Fort Randall. Previous experience has indicated that the winter release level can be increased to 25,000 cfs from Gavins Point with only a modest increase in the potential for downstream ice-jam flooding. This increased potential is held to a minimum by selective release scheduling through the winter season, based on temperature forecasts and observations of current or forecasted ice conditions. In high runoff years when complete evacuation of the accumulated flood control storage during an extended navigation season would result in release rates that are substantially above normal, consideration will be given to scheduling winter Gavins Point releases ranging from 25,000 to 30,000 cfs to provide the most effective overall System flood control regulation.

7-04.13. System Service Level Selection for Flood Control Evacuation. Selection of the appropriate service level for flood storage evacuation purposes in excess of the full service level is dependent on anticipated runoff from the Missouri River drainage area above the System; depletions to this runoff that can be expected to occur prior to the time this runoff appears as inflows to the System reservoirs; current storage conditions in the System and in the major tributary reservoirs located above the System; and evaporation from the System reservoirs. Plate VI-1 was developed to determine the service level at any time during the year. This plate relates the annual water supply and time of year to the appropriate System service level. If a significant growth in depletions occurs, appropriate revisions should be made to Plate VI-1. The revisions would be necessary because the water supply necessary to maintain the indicated service level is based on depletions expected. Determination of water supply is made based on a combination of (a) forecasted runoff above Gavins Point Dam from the current date through December, (b) current amount of water in System storage, and (c) the tributary reservoir storage deficiency.

7-04.13.1. Forecasted Runoff. The forecasted runoff for the remainder of the current calendar year is developed by procedures described in Section 6-11 of this manual, with specific forecast techniques described in detail in MRBWM Technical Report *Long-Term Runoff Forecasting*, February 2017.

7-04.13.2. Tributary Storage Deficiency. The current tributary water-in-storage deficiency is developed by first accumulating the current reservoir water-in-storage in each of the 10 tributary USBR reservoirs listed in Table VII-7. All of these reservoirs are located above the System. These reservoirs, when filled to levels that can be expected during years of excess runoff, have a storage capacity of over 6 MAF. For the purpose of determining an appropriate System service level, a 5.5 MAF level of tributary reservoir storage was selected as the base level for computation of an acceptable water-in-storage level condition by March 1 of the next year. If there is currently more water than 5.5 MAF, the difference is subtracted from the water supply value computed for use in Plate VI-1, and vice versa, as a second step in the computation.

Table VII-7
USBR Projects Used for Calculating Tributary Storage Deficiency for the Water Supply Computation

Lima	Tiber
Clark Canyon	Bull Lake
Hebgen	Boysen
Canyon Ferry	Buffalo Bill
Gibson	Yellowtail

7-04.13.3. Future Adjustments to Service Level. It can be expected that future adjustments to Plate VI-1 may be required. Several factors and past history indicate that changes in tributary reservoir storage and in System storage due to sedimentation and other factors may require some adjustment when they become significant. Also, significant Missouri River basin depletion changes may require adjustment. A significant change in release patterns for any reason may require the information provided on Plate VI-1 to be adjusted since it assumes a steady flow will be provided throughout the remainder of the period.

7-04.13.4. Determining the Service Level for Flood Control Evacuation. Plate VI-1 presents water supply (System and USBR water-in-storage plus anticipated runoff into the System for the remainder of the year) evacuation curves. System releases, based on the determined service level from Plate VI-1, will result in the evacuation of stored waters from the System to the base of the Annual Flood Control and Multiple Use Zone, provided scheduled winter releases can also be maintained, by the following March 1. Determination of the appropriate service level is accomplished by computing the current tributary reservoir water-in-storage excess or deficiency and adding or subtracting it from the current actual System water-in-storage. The resulting water-in-storage is then added to the forecasted remaining calendar year runoff into the System to obtain the current water supply value. The water supply value in MAF, which is computed as described above, is then used with Plate VI-1. By following the water supply value horizontally to the current date, the appropriate service level on which System releases should be based is determined. Forecasted runoff is an essential (Plate VI-7 shows an example of the calendar year forecast) component in determining the service level. Because forecasts of future runoff (which may not materialize) are basic to the use of Plate VI-1, and because the potential for downstream tributary flood runoff is greater during the spring and early summer months, the service level provided should not be increased above the 35,000 cfs full service level prior to July 1 unless an indicated service level of 40,000 cfs or greater is identified by using Plate VI-1. This limitation provides a factor of safety in favor of the flood control purpose. For service level determinations below full service, release rates are computed based on actual water-in-storage checks discussed in Section 7-03.2.1.1 of this manual. The March 1 date indicators on the curves are consistent with the service level definitions defined in this chapter.

7-04.14. System Expanded Full Service Level. The 35,000 cfs service level is considered to be the full service level for meeting all authorized purposes of the System. The initial increase above this full service level has been designated as the “expanded full service level” and consists of extending the navigation season 10 days beyond its normal closing date of December 1 at the mouth of the Missouri River. Additionally, as a storage evacuation measure, winter releases of

20,000 cfs will be scheduled from Gavins Point Dam. While a primary purpose of this expanded full service is for the evacuation of storage space in the System, it also benefits the other authorized purposes. An additional 10 days of navigation service also results in the transfer of a substantial block of hydropower generation from the normal fall navigation season, when power generation is relatively abundant, to the winter season. In some years, ice conditions may preclude this extension, and if such occurs, it may be necessary to carry a minor amount of excess water over to the succeeding flood season. In recognition of ice problems that may occur, releases during the 10-day extension of the navigation season will be made at the full service level unless storage evacuation requirements are such that higher releases are deemed necessary. The announcement of this expanded service should be made as soon as it is determined to allow the downstream users to take full advantage of the 10 days of higher flows.

7-04.15. System Reservoir System – Missouri River Flood Target Flows. Normally, the difference between the selected service level and target flows at control points below the System will be the same for evacuation of flood storage as for normal navigation or downstream flow support releases. This results in Missouri River flow targets located at Sioux City and Omaha of 4,000 cfs less than the current service level, at Nebraska City of 2,000 cfs greater than the current service level, and at Kansas City of 6,000 cfs greater than the current service level. Similar to navigation or downstream flow support targets, storage evacuation targets are for minimum flows at the controlling flow target location. For example, with a 40,000 cfs service level, a target flow of 42,000 cfs at Nebraska City might be controlling with Sioux City, Omaha and Kansas City forecasted flows in excess of their respective targets of 36,000, 36,000 and 46,000 cfs, respectively. When target flows at the non-controlling locations approach critical levels from a flood damage standpoint, the service level-target flow concept is modified to emphasize System regulation for downstream flood control instead of navigation support or System storage evacuation.

7-04.16. Missouri River Flood Target Flows – Full Service Provided. As a flood control measure, the normal relationship between service levels and target flow levels may be modified when large amounts of tributary inflow are forecasted between Gavins Point Dam and the downstream flow target control points. Criteria for these modifications are presented in Table VII-8. For example, if the current service level were 40,000 cfs, System releases would be reduced consistent with the full service level if it were deemed necessary to maintain flows at or below 46,000 cfs at Omaha, 52,000 cfs at Nebraska City or 76,000 cfs at Kansas City. These target flows may be modified by up to 5,000 cfs after consideration is given to antecedent, current, and projected hydrometeorological conditions. Modification of target flows to the full service levels provides a safety margin for the inability to accurately forecast downstream tributary runoff and from unexpected rainfall. There are, however, conditions during large runoff years similar to 1997 and 2011, when the aforementioned criteria must be replaced with a System regulation approach that will result in the best flood control for the lower river. Repeated reductions in System releases early in the runoff season will likely result in the need to make higher System releases to evacuate accumulated floodwater later in the season. The progressive increase in System releases must be evaluated against the approach of taking some small flood risk over a longer period of time and providing a slightly higher System release initially.

Table VII-8
Criteria for Modifying Target Flows – Full Service

Target flows will be reduced to those consistent with the full service level of 35,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:	
6,000 cfs at Omaha	(target flow plus 10,000 cfs)
12,000 cfs at Nebraska City	(target flow plus 10,000 cfs)
36,000 cfs at Kansas City	(target flow plus 30,000 cfs)

7-04.17. Missouri River Flood Target Flows – Minimum Service Provided. As an additional flood control measure for the lower Missouri River, the normal relationship between minimum service levels and target flow levels will be modified when large amounts of tributary runoff are forecasted or occurring between Gavins Point Dam and the downstream flow target control points. Selected criteria for these modifications are noted in Table VII-9. These target flows may also be modified by up to 5,000 cfs after consideration is given to antecedent, current and projected hydrometeorological conditions. Modification of target flows to the minimum service levels provides even a greater safety margin (than to the full service level) for the inability to accurately forecast downstream tributary runoff and from unexpected rainfall. There are, however, conditions during large runoff years similar to 1997 and 2011, when the aforementioned criteria must sometimes be replaced with a System reservoir regulation approach that will result in the best flood control for the downstream reach for the entire flood runoff season. Repeated reductions in System releases early in the runoff season will result in the need, later in the season, to make higher System releases to evacuate accumulated floodwater. The progressive increase in System releases must be evaluated against the approach of taking some small flood risk over a longer period of time. This System flood control approach is accomplished by providing a slightly higher System release initially or earlier in the flood runoff season; therefore, lower flows are provided later in the year. This flood control reservoir regulation approach is at times the preferred option when it is known the flood runoff season will be extended because a large volume of runoff is expected.

Table VII-9
Criteria for Modifying Target Flows – Minimum Service

Target flows will be reduced to those consistent with the minimum service level of 29,000 cfs in order that one or more of the anticipated resultant downstream flows exceed the current service level flow value by more than:	
11,000 cfs at Omaha	(target flow plus 15,000 cfs)
22,000 cfs at Nebraska City	(target flow plus 20,000 cfs)
66,000 cfs at Kansas City	(target flow plus 60,000 cfs)

7-04.18. Coordination of System and Tributary Reservoir Flood Control Releases. At Kansas City, the farthest downstream control point used for scheduling System releases, control of streamflow is also provided by tributary reservoirs located in the Kansas River basin. Flood control regulation criteria and techniques applicable to the Kansas River basin reservoir projects when this competition does not exist are described in the Kansas River Basin Master Manual and in the WCMs for individual Kansas River basin reservoirs. At times, however, competition will exist between the two reservoir systems for use of the available Missouri River channel capacity at Kansas City and downstream. When storage evacuation is required from the Kansas basin reservoirs, coordinated regulation of the two systems of reservoirs will proceed as described in the following sections.

7-04.18.1. If the System water supply is such that a service level of 35,000 cfs or less is applicable, Kansas River basin reservoirs will have priority for the Missouri River channel capacity below Kansas City. Target flows on the Missouri River upstream from Kansas City will be reduced up to the minimum service level (if required) so that System releases do not contribute to forecasted Kansas City flows in excess of the current System service level flow value plus 66,000 cfs.

7-04.18.2. Releases from Kansas River basin reservoirs with accumulated flood control storage in Phase II or higher will have priority over System releases for the available channel capacity, irrespective of the current System service level. System releases will be scheduled as described in Sections 7-04.16 or 7-04.17 after consideration is made of the effects of Phase II and Phase III releases from Kansas River basin reservoirs on Kansas City target flows.

7-04.18.3. If System storage evacuation requires a service level greater than the 35,000 cfs level, the System release requirements will have priority over releases from Kansas River basin reservoirs with accumulated flood control storage in the Phase I zone. Releases from the Phase I zone of Kansas basin reservoirs will be scheduled on the basis of System releases made in accordance with criteria given in Sections 7-04.16 or 7-04.17.

7-04.18.4. During the period of flood storage evacuation from the Kansas River basin reservoirs, close coordination between the Corps' Kansas City District water control office and the MRBWM office is required for the development of release schedules. This coordination consists of the actions outlined in Section 7-04.18.4.1.

7-04.18.4.1. The Kansas City District Water Control Office will develop release schedules for their tributary reservoirs with storage levels in Phase II or higher and furnish the resultant forecasted flows of the Kansas River at Desoto, KS to the MRBWM office in a timely fashion so that it can be integrated into the MRBWM's daily Missouri River streamflow forecast. Based on that, the MRBWM office will schedule releases from the System and furnish this schedule to the Kansas City District in the form of the MRBWM's Missouri River streamflow forecast. The Kansas City District will then take advantage of any remaining Missouri River channel capacity available at Kansas City and downstream Missouri River locations to schedule releases from reservoirs in the Phase I zone.

7-04.19. Lower Missouri River Flood Flows. The Kansas City flow target location is the most downstream location for which System releases will normally be scheduled based on a forecast. Travel time from Gavins Point to Kansas City is generally between 5 to 6 days, depending on the flow. Generally speaking, the higher the flow, the faster the travel time. Experience has shown that predicted hydrologic conditions (e.g., precipitation forecasts indicating timing, location, intensity and total amount) that could produce large amounts of runoff into the Missouri River become significantly less accurate as the forecast time becomes longer. Experience has shown that a precipitation forecast for the Missouri River Basin for the next 1-2 days is somewhat accurate as to the likelihood of when and where a rainfall event may occur. However, precipitation forecasts for the Missouri Basin 5-7 days in the future are much less accurate regarding the probability of rain occurring, the exact location of that rainfall event, as well as the intensity of and total amount of rain that will fall. Current Corps policy, as outlined in Section 2.2.11.3 of EM 1110-2-3600, states that "[F]orecasts of controlled or uncontrolled tributary inflow may be an important element in the plan, but operational decisions should be made based on water-on-the-ground unless stated in an approved water control plan." If System release reductions will not result in missing flow targets and hydrologic forecasts indicate that System release reductions will result in flood damage reductions below Kansas City, a reduction in System releases will be scheduled. This should not be attempted if it will significantly impact System or tributary reservoir flood storage evacuation. Due to the long-range forecasts required and the current state-of-the-art forecasting technology, such System release reductions for this purpose will seldom be necessary except during severe, prolonged downstream flooding periods. Requests regarding flood control regulation from the System due to Missouri River flooding downstream of Kansas City have been made in the past. These requests have been difficult to achieve because of the long travel time (travel time from Gavins Point Dam to Hermann, MO is 9-11 days), the aforementioned lack of accuracy of precipitation forecasts and the Corps' policy to regulate based on water on-the-ground.

7-04.20. Regulation of the System for the Mississippi River. Requests regarding flood control regulation from the System due to Mississippi River flooding have been made in the past, primarily from the Corps' Mississippi Valley Division. The Corps regulates the System in accordance with its authorized project purposes, which only include purposes related to the Missouri River. While Congress recognized that operating for the authorized Missouri River System project purposes would incidentally benefit the Mississippi River, it did not authorize the Corps to operate the Missouri River System solely for the benefit of the Mississippi River. Thus, there are no provisions in this manual that cover operations solely for the Mississippi River.

7-04.21. Regulation of Kansas City District Tributary Projects for the Mississippi River. Corps projects in the Osage River basin, which are regulated by Kansas City District, do have authorization to operate for the benefit of the Mississippi River. Per Section 9.3 of the Harry S Truman WCM, "[T]he overall objective for flood control regulation is to assure that the benefits estimated in the design and justification of the project are realized during flood situations. The Harry S Truman Reservoir, in conjunction with projects located upstream from Harry S Truman [Pomona, Pomme de Terre and Stockton], is expected to provide flood protection to cities and agricultural lands by reducing flood crest[s] along the lower Osage, the lower Missouri, and the middle and lower Mississippi Rivers." Reference the individual WCMs for additional information.

7-04.22. Individual System Project Reservoir Regulation Techniques. Volumes 2 through 7 of the Mainstem Reservoir Regulation Manual series present the details necessary for integrating regulation of the individual System reservoirs with System regulation described in this volume. Section 1-02.1 in this manual presents an explanation of the Mainstem Reservoir Regulation Manual series. While regulation of many of the tributary reservoirs in the Missouri River basin is independent of System regulation, integrated regulation will, at times, be required. Section 7-04.18 describes the coordination necessary in regulating Kansas River basin reservoirs.

Individual System project WCMs describe coordinated regulation with those tributary reservoirs that are most closely related with each individual System project, particularly those tributary reservoirs that have Replacement System Flood Control Storage, as described in Section 7-04.4.1 of this manual.

7-04.22.1. During extreme floods approaching the magnitude of the greatest floods of historical record, it is quite probable that surcharge regulation will be required at one or more of the System projects. If such an event were to occur, System regulation would be conducted largely on a reservoir-by-reservoir basis and would be based on techniques described in the individual project WCMs. System releases would be as defined by the Gavins Point procedures. In the event of a prolonged communications failure between the MRBWM office and individual projects, System release rates would be scheduled according to the emergency procedures outlined in the individual System project WCMs.

7-04.23. Responsibility for Application of System Reservoir Regulation Techniques. Due to the necessity for integrated regulation to secure the maximum degree of beneficial use from all System storage, the MRBWM office will be responsible for, and will direct, the regulation of all the System reservoirs in accordance with the relationship between the MRBWM office and District offices outlined in Chapter VIII of this manual. Such direction will normally be in the form of power production/reservoir regulation orders to the System projects that specify releases to be maintained, the permissible fluctuations in this release rate, and the period through which the order will be applicable. The respective District offices provide personnel for O&M of the projects and are responsible for the physical manipulations necessary to carry out the directives.

7-04.24. Responsibility for System Dam Safety and Emergency Regulation. Although regulation procedures for the System and individual System reservoirs are normally developed in the MRBWM office, it is the responsibility of the District to maintain adequate provisions for maintaining the integrity of the System dams at all times. The MRBWM office will be informed, and a specific method of System or individual reservoir regulation may be recommended by the District, at any time it is believed that any part of a project's dam structure may be endangered by existing or anticipated conditions. In addition, the MRBWM office will be advised when local flood conditions are such that improved conditions may result by specific methods of System reservoir regulation. The MRBWM office will consider this information and field recommendations in conjunction with other known existing conditions prior to issuing System project regulation instructions. If Corps staff believes that the integrity of a dam is endangered and communications with the MRBWM office are not possible, the project office and/or the District office may modify instructions (power production/reservoir regulation orders) to ensure the safety of the structure. When communication with the MRBWM office is impossible and the projects are under emergency conditions, the District or project staff are entirely responsible for application of emergency regulation techniques. Section 7-16 of this manual contains a more detailed discussion regarding System emergency regulation procedures.

7-04.25. Responsibility for Flood Control Reservoir Regulation Coordination in Missouri River Basin. Normally, tributary reservoir regulation is a function of the Districts with pertinent reservoir regulation information furnished to the MRBWM office. When tributary reservoir regulation affects Missouri River flood flows or navigation on the Missouri River, tributary reservoir regulation will, however, become a direct concern of the MRBWM office. During such periods, the MRBWM office will issue pertinent tributary reservoir regulating instructions so that flood damages may be held to a minimum through integrated regulation of all flood control reservoirs in the Missouri River basin. The appropriate District, with NWD oversight, will direct tributary reservoir regulation during periods of tributary floods not extending to the Missouri River. The provisions of Section 7-04.22 of this manual regarding safety of the project and conflicts between local and general flood protection will also apply to tributary reservoirs during periods when they are regulated as directed by the MRBWM office. The Corps' Guidance Memorandum titled, *Reservoir Control Center (RCC) Guidance Memorandum*, dated March 1972, serves as the document that details the role and responsibilities of the MRBWM, formerly the RCC, in managing and regulating the System, including the coordination responsibilities for the regulation of tributary reservoirs during major flood control events.

7-04.26. Reporting of System Flood Control Operations. Status reports regarding System flood control operations are prepared by the MRBWM office and provided to key NWD and District offices on an immediate basis. The reports are normally distributed by email and/or posted to the internal Corps website. The PPCS provides near real-time System data such as hourly releases from each power unit, spillway releases, outlet tunnel flows and reservoir elevations. This information is transmitted automatically to the MRR database on an hourly basis. Once these data are received in the MRBWM office, reservoir storages and inflows are calculated. Even with all the project data available to the MRBWM office, it is sometimes necessary and prudent for MRBWM staff to speak directly to the project staff to assess any potential problems with the project, its major features, or any matter that could affect future project release decisions. During severe flood periods, daily summaries of hydrologic conditions and reservoir regulation will be furnished to the Office of the Chief of Engineers by the District Engineer. Various types of information relative to floods are required in the flood control operations status reports including reservoir name, reservoir elevation, forecasted maximum elevation and associated date, current and forecasted rates of inflow and outflow in cfs, percent of flood control storage used to date, and any other specific information pertinent to the flood situation. Coordination is required with the MRBWM office prior to the Districts furnishing this information relating to the System to the Office of the Chief of Engineers.

7-04.27. Monthly System and Tributary Reservoir Reports. Each month, the MRBWM office prepares a reservoir summary report for each System project that includes daily reservoir elevation, storage, inflow, release and estimated evaporation. The appropriate District office prepares the same report for each of the Corps' tributary reservoirs and all USBR tributary reservoir projects having flood control as an authorized purpose. The District reports are either provided to the MRBWM office electronically or the data to create the report is available in the MRBWM database.

7-04.28. Historical Examples of System Regulation During Major Floods. Although Fort Peck was placed in operation in 1937, additional projects on the System were not operable prior to the 1950s and early 1960s. Limited System regulation was initiated in 1953, following the closure of Fort Randall in 1952 and Garrison in 1953. Gavins Point was closed in 1955, Oahe in 1958, and Big Bend in 1963. Although this completed the embankment closures on the System, regulation of the System was somewhat limited in the early years of regulation by project construction and the completion of real estate activities. In July 1966, installation of all of the present power units was completed, and the following summer each of the System reservoirs reached their respective base of the Annual Flood Control and Multiple Use Zone for the first time. Only since June 1967 have the individual System reservoirs, therefore, been regulated as a completely integrated System. Appendix A contains the historical examples of flood since June 1967.

7-04.28.1. System Storage Accumulation. Initial fill of the System was accompanied during a period of below-average runoff from the Missouri River drainage area above the System. Runoff was well below average during each year of the 8-year period, extending from 1954 through 1961. The cumulative effect of these low-runoff years resulted in the second most severe drought period for the Missouri River basin for the period of record (1898-2017). Runoff above the System averaged slightly above average from 1962 through the mid-1980s with well-above-average amounts occurring in some years. The 6-year drought extending from 1987 through 1992, represented a particularly challenging System regulation period. This drought was followed by some much-above-average runoff years in the 1990s. The second extended drought since the System was closed was experienced from 2000 through 2007. Plate VII-2 illustrates month-by-month accumulation of water in the System since 1953. As shown on Plate VII-2, the Carryover Multiple Use Zone was first filled in 1967. The historical minimum and maximum System storages since 1967 were observed in 2007 and 2011, respectively. Plate VII-3 presents the System storage zones since 1967. From 1967 (75.4 MAF) to 2018 (72.4 MAF), total System storage capacity has decreased 3.0 MAF due to sedimentation.

7-04.28.2. System Regulation Effects on Streamflow. The accumulation and evacuation of water in System storage has had a major effect on streamflow below the System. Plates VII-4 through VII-11 presents hydrographs of regulated and unregulated flows for 1967, 1972, 1975, 1978, 1993, 1997, 2010 and 2011 at Gavins Point. Unregulated flows are determined at various sites for the purpose of calculating flood damages prevented. Unregulated daily flows are determined by representing the regulated flows adjusted for upstream reservoir effects. The upstream reservoir effects include storage of runoff, evaporation from the reservoir surface and precipitation directly on the reservoirs. The reservoir effects used in the development of unregulated flows include those from major tributary reservoirs and the System projects. The major portion of the reservoir effects results from regulation provided by the System.

7-04.28.3. Plates VII-4 through VII-11 illustrate characteristic patterns of releases from the System. Data to produce similar hydrographs that indicate System regulated versus unregulated flows are stored on the MRBWM database. The data are available for all years of regulation since 1950 and for other locations within and below the System. Complete write-ups for each year are on file as separate reports in the MRBWM office.

7-04.29. Regulation During Extreme Floods and During Emergencies. The following sections briefly describe the System flood control regulation procedures for extreme floods and during emergencies.

7-04.29.1. System Regulation During Extreme Floods. During extremely large floods that may use all of the flood control storage zone capacity provided in any of the individual System projects, regulation will primarily be based on conditions affecting that particular project rather than the System as a whole. Examples of regulation during this type of flood are, consequently, not included in this manual. Individual System project WCMs address this subject with the

Gavins Point manual providing the best example of System releases that could be expected to occur during such events. The effects from individual project regulation will be integrated into a System model to balance the effects throughout the System and afford greater flood control downstream than that provided by any one project. Section 7-04.10.2 of this manual describes the flood storage evacuation priority order for the System and individual projects. The System daily and long-range study simulation models discussed in Chapter VI include this evacuation priority as a normal regulation procedure. Further model refinement is provided by manually adjusting individual project and System releases to achieve the desired result.

7-04.30. Emergency Procedures. Regulation criteria in the event of a communications failure with the MRBWM office are detailed in individual project WCMs and their associated instructions to project personnel for such events. Examples of their application are contained in individual System project WCMs.

7-04.31. System Flood Control Storage Analysis. The 2004/2006 Master Manual update included the 2004/2006 water control plan, which included changes to the drought conservation measures used for System regulation. Normal and flood control System reservoir regulation procedures were not changed during that update, but they were updated to reflect current reservoir storage conditions. The amount of System flood control storage space required was analyzed in depth for the Master Manual Study. Results indicate that very little additional flood control benefit could be obtained from additional flood control storage space in the System, thus it was not changed. About half of the basin lies below the System. That fact has prevented, and will continue to prevent, the System from controlling all flooding along the Missouri River. Normally, enough vacant space exists in the System prior to the runoff season to capture the runoff and control the significant floods, such as in 1997. However, during 2011 the runoff volume exceeded the System's flood storage design event by more than 20 percent, as described in Section A-02.2, and resulted in record releases being made from the System and significant downstream flooding. Nine of the highest ten upper basin runoff years since record-keeping began (1898-2017) have occurred since the System closed in 1967. Regulation of these runoffs has refined the System flood control techniques described in this chapter and provided many examples of successful System flood control regulation. Study and refinement of System flood regulation techniques will continue along with research and development to improve the long-range forecasting of expected runoff in the Missouri River basin.

7-05. Multi-purpose Regulation Plans. In the course of the planning, design, construction and regulation of the System, many long-range regulation studies have been made to establish and demonstrate the capabilities of the System to meet the many project purposes and to establish criteria for planning, design and regulation purposes. Other shorter-term studies, on a continuing basis, lead to AOPs, 5-year projections and many other special purpose plans. These studies provide a sufficient volume of predetermined vacant storage capacity at each of the System reservoirs at the beginning of the flood season; therefore, they recognize the flood control purpose. The DRM, which uses a daily time-step, served as a useful tool in the examination of detailed flood control regulation criteria and the other project purposes in determining the 2004/2006 water control plan. In subsequent studies, such as the MRRMP-EIS, which was the impetus of this Master Manual modification, an HEC-ResSim model was used to examine project purposes, including flood control regulation criteria.

7-05.1. Long-Range Regulation Studies. Long-range regulation studies of the System encompassing the hydrologic period from 1898 to the time of the study have been referred to previously in this manual, particularly in Section 6-13, where some of the limitations of these studies were discussed. Major studies have been published and distributed to interested Corps offices, USBR, Western and others. The MRBWM office has a list of the major studies performed in the past and pertinent data as to the basic conditions assumed in their performance. Future studies by the MRBWM office will be needed to evaluate proposed regulation considerations as the System matures under this updated water control plan.

7-05.2. Service to System Authorized Purposes. The long-range regulation studies completed during the Master Manual Study demonstrated the service (e.g., flows, reservoir levels, hydropower generation values) that the System is expected to provide for the basic purposes under various scenarios with differing levels of basin development and conditions of water supply. The studies also served to examine variations in regulation criteria and in this manner keep criteria consistent with changing emphasis upon specific purposes through the years. These studies reflect the service to purposes provided by the System under current criteria included in the Master Manual.

7-06. Emergency Regulation Procedures (Standing Instructions to Dam Tender). The Standing Instructions to the dam tender that would be used in the event that communication is lost with the MRBWM office are contained in the individual System project WCMs and are not repeated in this manual. Those instructions are to be used only in the event of a significant communication failure over an extended period of time that results from a catastrophic event. The MRBWM office uses real-time simulation modeling to effectively regulate the System and this cannot be replicated in the instructions to the dam tenders. These orders serve only as a temporary way of bridging the time period between not having power production/reservoir regulation orders and until MRBWM staff can run their models and issue new orders. The MRBWM office normally schedules each of the System projects for the next several days into the future, and in some cases as long as the next week. It is unlikely, even in a significant communications failure, that the System projects would not have current power production/reservoir regulation orders with which to regulate the project.

7-07. Flood Control Purpose System Regulation. The discussion of the planning and subsequent regulation for the flood control purpose of the System constitutes a major portion of this manual. The planning of the sizing of the individual Mainstem project flood control zones is described in Section 7-03.1 and in Appendix A. The reservoir regulation of the System for flood control is detailed in previous sections in this chapter. Storage of large runoffs in the System for multi-purpose use later by releasing during low-flow periods is consistent with the Congressionally authorized flood control purpose. Similarly, storage of water for the control of floods is also compatible, to a great extent, with multi-purpose regulation of the System. The flood control purpose of the System will be given the highest System priority during periods of significant runoff when loss of life and property could occur. Regulation efforts will be made to minimize these losses. The flood damage prevention provided by the System has been greater than originally envisioned because of the protection provided to the critical urban areas in the basin during major flood events. Plate VI-2 identifies the flood damages prevented by the System from 1938 to 2017. The $35.7 billion (in original price levels, which equates to $62.5 billion indexed to 2017 levels) in cumulative damages prevented by the System exceeds the cost of constructing the entire System of $1.2 billion (in original price levels, which equates to $27.7 billion indexed to 2017 levels). The bulk of the damages prevented occurred during the 7-year period from 1993 to 1999 and the 4-year period from 2008 to 2011. The unpredictability of these major flood events means that, to fulfill the flood control operational objective of the System, the Exclusive Flood Control Zone should be kept empty except during major flood events. This unpredictability also means that the System should normally be at the base of the Annual Flood Control and Multiple Use Zone (56.1 MAF) prior to the beginning of the flood season. The use of Plate VI-1 as a guide in determining the service level for evacuation of water captured in the Exclusive Flood Control and the Annual Flood Control and Multiple Use zones and for normal and conservation regulation is discussed in Chapter VI of this manual as well as in this chapter. This plan was developed with the intent of fully meeting the Congressionally authorized flood control purpose.

7-07.1. Flood Control Regulation Problems Associated with Stage-Discharge Variation and Channel Capacity Deterioration. The following sections discuss the problems associated with System regulation during flooding with regard to channel degradation and variation in the stage-discharge relationship on a seasonal basis.

7-07.1.1. Seasonal Variations in the Stage-Discharge Relationships. The Missouri River is an alluvial stream with a movable sand bed. Consequently, marked variations in the relationship between stages and corresponding discharges occur. While some of these variations may be more or less permanent in nature due to changes in channel regime, there is a seasonal shift in this relationship, particularly in the reach extending from Sioux City to Kansas City. Previous and ongoing analyses indicate that this shift is related to water temperature and consequent bedform configuration. Measurements both in the laboratory and in the field show that the rate at which sediment is transported in suspension varies significantly with water temperature. The colder the water, the more viscous it becomes and the slower a particle will settle out. Thus, sediment will be transported more easily at colder temperatures. In short, the typical seasonal shift results in higher stages during the mid-summer months than during the early spring and fall months for similar rates of flow. Stage variations of approximately one foot may occur as a result of these seasonal rating curve shifts. Gavins Point Dam releases are made to meet a downstream level of service (target flows) at Sioux City, Omaha, Nebraska City and Kansas City. Evaluation of these service level requirements is based on the stage-discharge relationship at these target locations, which are also USGS streamgaging station locations. Accurate and near real-time determination of flow based on observed stage at the target and streamgaging stations is very challenging during the spring and fall when the water temperature shifts are occurring. This requires frequent Missouri River discharge measurements from the USGS and associated rating curve adjustments by both the USGS and the MRBWM office.

7-07.1.2. River Channel Deterioration. Ongoing field measurements and analysis indicate that a permanent shift exists in the stage-discharge relationship at numerous locations in the Missouri River. In some instances, the shift results in reduced channel conveyance capacity for higher flows. In some areas, this reduced channel conveyance capacity has been significant. For example, in the Missouri River reach between Fort Randall Dam and the headwaters of the Gavins Point reservoir (just upstream from the mouth of the Niobrara River), land areas adjacent to the Missouri River are now being inundated with Missouri River flows of less than 50,000 cfs. Prior to 1967 when System regulation began, these same areas were dry with Missouri River flows of over 150,000 cfs. By the mid-1970s, the bankfull channel conveyance capacity was reduced to 60,000 cfs, and further reductions continued to 44,000 cfs in 1985 and 35,000 cfs in 1994. The high releases in 1997 and 2011 resulted in a temporary improvement in channel conveyance capacity because some sediment deposits were scoured from the channel. Many similar instances could be cited, although generally not as extreme as those two years. The effects of these channel changes have resulted in reduced channel conveyance capacity, which can be partly attributed to the System's control of annual flood flows and their scouring effects. Some deterioration in channel conveyance capacity at some locations may also be attributed to bank stabilization measures that have been constructed for navigation or streambank erosion control purposes.

7-07.1.2.1. Conversely, in some Missouri River reaches, evidence exists of significant degradation, or lowering, of the Missouri River channel. As expected, degradation has occurred downstream of the System powerplants. In these cases, degradation has been considered beneficial. The degradation has led to increased hydropower heads that result in greater amounts of hydropower generation for the same release. Downstream of Gavins Point Dam, particularly in the reach from the dam to Omaha, Missouri River stages have decreased markedly since Gavins Point Dam was closed in 1955. This degradation has had adverse effects on recreation facilities, water intakes, well fields, navigation docks, tributary channel stability and wetland habitat. The degradation has had a positive effect on flood control; channel conveyance capacity has improved and areas that were once subject to flooding prior to the construction of the System projects are now high and dry during significant release increases. For example, the bankfull channel conveyance capacity has significantly increased in both the Dakota Dunes area near Sioux City and the Kansas City urban area.

7-07.1.3. Flood Control Regulation Problems Associated with Interior Drainage and Groundwater. Higher System releases during prolonged flood evacuation periods impacts interior drainage capability and can result in increased groundwater tables in the reach of the Missouri River below Gavins Point. Higher Missouri River levels below the System make the draining of runoff that falls on low-land cropland difficult, if not impossible. This is because the constructed levee system generally depends on the impounded waters behind the levees gravity-draining into the Missouri River. Higher Missouri River levels also result in higher groundwater levels that make planting and harvesting crops difficult or impossible for farmland located immediately adjacent to the Missouri River. This is especially true in the aggradation reach immediately downstream of the confluence of the Platte and Missouri Rivers near Plattsmouth, NE. Consideration is given to the effects of interior drainage and high groundwater levels in any prolonged flood control System regulation event.

7-07.1.3.1. Development of flood damageable property in flood-prone areas has been extensive throughout the entire reach of the Missouri River, especially in the areas downstream of the System projects. When higher-than-average releases are required from System projects, flooding of floodplain lands and developments can, and should be, expected. The capture and metering of flood flows during the remainder of the year can also result in higher releases during late summer and fall. This period is normally not a high-runoff period, but, for those low-lying areas immediately adjacent to the Missouri River, poor drainage conditions are a continual concern.

7-07.2. Other Flood Control Regulation Challenges. The regulation of the System during years when the annual runoff is approximately equal to or greater than 30 MAF has occurred many times since the System became operational in 1967. The most significant flood runoff years are 1975, 1978, 1984, 1986, 1993, 1995, 1996, 1997, 1999, 2010 and 2011, all of which are documented in detail in Appendix A of this manual. The 1975, 1978, 1997 and 2011 years stand apart from the others in the severity of the events. Most of the concerns arose from high pool elevations and passing the large volumes of water through the existing outlet works and into limited downstream channels to evacuate flood storage. The following should be recognized in a typical flood control situation.

7-07.2.1. During significant flood events, releases will be reduced to a minimum level to protect and minimize the loss of life and property in all Missouri River reaches downstream of the mainstem projects. Oahe, Big Bend and Fort Randall releases are sometimes reduced to zero or close to zero for hydro-peaking generation and flood control. The releases from Fort Peck, Garrison and Gavins Point are rarely reduced to zero, and only under unusual circumstances, because there must be water flowing through these projects to meet other downstream project purposes, such as irrigation, water supply and water quality control. Over-reaction in the form of reducing project releases to extremely low levels early in the runoff season may result in an expedited filling of flood control storage, resulting in significantly less capability to control flooding, should a significant flood event or a succession of lesser flood events occur later. The reservoir System has a significant, yet finite, amount of storage available for flood control; that flood control storage should be used judiciously.

7-07.2.2. All reasonable attempts will be made to evacuate all of the water that is captured or retained in the System above the base of the Annual Flood Control and Multiple Use Zone prior to the following March 1. Most of this volume will be evacuated by December 1, prior to the onset of winter release restrictions due to expected limited winter releases because of river icing.

7-07.2.3. The presence of and regulation of the mainstem System does not guarantee a flood-free zone in the Missouri River reaches between the System reservoirs or below the System. Flooding downstream of the System projects will sometimes occur, even if releases are reduced to minimums. This flooding occurs because there is a significant amount of uncontrolled drainage area downstream from each project that could produce flood-producing runoff from suddenly-developing rainfall events. The potential extent and amount of damage caused by this runoff varies. If the lack of floodplain zoning to discourage development in flood-prone areas continues, higher flood damages, even with the flood protection provided by the System, will result.

7-07.2.4. The two highest populated cities on the Missouri River are located below the System: Kansas City and Omaha. Due to the large population of these cities, as well as their distance from the nearest System project (Omaha and Kansas City are about 200 and 450 river miles downstream of Gavins Point Dam, respectively), if a high runoff-producing rainfall event were to occur upstream of these cities but downstream of the System, the flood damages incurred are likely greater than if the same volume of flood runoff occurred in reaches within the System. The next two highest populated cities on the Missouri River, Bismarck, ND and Pierre, SD, also have the potential to incur flood damages. However, the regulation of the upstream projects –

Garrison for Bismarck and Oahe for Pierre – provide the Corps some capability to better control downstream flows and stages.

7-07.2.5. During major flood events, the upper three System reservoir levels have risen into their respective Exclusive Flood Control Zones. There is some concern from stakeholders concerning the inundation of reservoir lands when the pools are very high. In 1975, a large rainfall event occurred in eastern Montana, and Fort Peck reached its then-maximum elevation of 2251.6 feet, which was 1.6 feet above its maximum operating level, or 1.6 feet into the Surcharge Zone, which is provided for the control of extraordinary floods. In 2011, Fort Peck reached its current maximum elevation of 2252.3 feet, 2.3 feet above its maximum operating level, or 2.3 feet into the Surcharge Zone. Also in 1975, Garrison's maximum level reached elevation 1854.8 feet, or 0.8 foot into the Surcharge Zone but below the 1855.0-foot guide-taking line for land acquisition. The majority of the concerns relating to high reservoir levels were received from the headwaters' area of the Garrison project. Concerns were also voiced over flooding on the Missouri River near the mouth of the Yellowstone River, upstream of the guide-taking line; however, this land was flooded by high river flows, rather than by the Garrison reservoir. During large runoff events in 1997 and 2011, the Garrison reservoir level reached 1854.4 and 1854.6 feet respectively, 0.4 and 0.6 foot into its Surcharge Zone, again exceeding the maximum normal operating level. Oahe has been in its Exclusive Flood Control Zone several times during the 1990s, prompting concerns about high, prolonged reservoir levels at this System project. In 2011, Oahe reached its maximum pool elevation of 1619.7 feet, just 0.3 foot below the top of its Exclusive Flood Control Zone. The MRBWM office recognizes that encroachment has occurred into the Surcharge Zone of some System projects. This, however, has not reduced the effectiveness of these projects to control flood inflows. All studies to date have indicated that there are no long-term issues associated with having the large System projects in their respective Exclusive Flood Control Zones. This zone is designed to store water during major flood events and the maximum project benefits cannot be obtained unless this zone is used, when appropriate. Releases from System projects with water in their Exclusive Flood Control Zones should be increased to the maximum practical in order to use downstream channel capacity so that the Exclusive Flood Control and the Surcharge Zones are vacated as soon as possible to allow storage space for subsequent runoff from future precipitation events, should they occur.

7-07.2.6. Some level of discussion has occurred as to whether or not project releases should be increased to higher levels earlier in the season to lower maximum release rates and reservoir levels. This is a common practice for snowmelt-type flood events, because the snowpack accumulation is water-on-the-ground, albeit in frozen and not-yet-runoff form; however, this approach does not apply to rainfall events that cannot be accurately predicted outside of a few days' notice. With snowmelt events, the actual conditions during the melt (e.g., soil moisture, soil frost depth, liquid content of snow, current and future air temperature, and current and future precipitation) during the snowmelt heavily influence the amount of runoff volume produced. Determination of some these conditions, such as soil moisture, soil frost depth and liquid content of snow, is extremely challenging due to the enormous area of the upper basin and the variation these conditions can have throughout the basin. While determination of current air temperature and precipitation is decidedly easier and fairly accurate, the accuracy of future air temperature and precipitation drastically lessens more than 5-7 days and 1-2 days in the future, respectively. This lack of reliable current and forecasted information results in a wide range of potential runoff volume for the same amount of accumulated snow. Releasing at higher-than-normal rates early in the runoff season, when it cannot be supported by runoff forecasting techniques, is inconsistent with all System purposes other than flood control. All of the other authorized purposes depend on the accumulation of and release of water in and from the System, rather than the availability of vacant storage space. Unnecessary drawdown of water in the System would not achieve the regulation objective of optimizing service to all authorized purposes.

7-07.2.7. Bank erosion along the unstabilized portion of the Missouri River channel, between and downstream of the System projects, has been an ongoing concern. Data available to the Corps indicate that average erosion rates through the unprotected areas since full System regulation began in 1967 are less than during pre-project conditions, although this improvement is small in some Missouri River reaches.

7-07.3. Missouri River Open-Water Channel Capacities. A brief summary of present open-water channel capacities for specific Missouri River reaches is presented in the following sections. Discussion of ice-affected channel capacities is presented in Section 7-04.9 of this manual.

7-07.3.1. Fort Peck Dam to the Mouth of the Yellowstone River. Damages begin with open water flows of approximately 35,000 cfs in the reach from Fort Peck to the mouth of the Yellowstone River. In the upper portion of this reach (dam to Wolf Point), damages are relatively minor when flows are less than 50,000 cfs. In the lower portion of this reach (Wolf Point to mouth of Yellowstone River), damages are relatively minor when flows are less than 50,000 cfs. For both the upper and lower portions of this reach, the damages are limited largely to pasture and low-lying areas.

7-07.3.2. Garrison Dam to the Oahe Reservoir. The main damage center in this reach is Bismarck. If Bismarck stages are not allowed to rise significantly above 13.0 feet, few flood damages are observed. Flood stage at the Bismarck gage is 14.5 feet. At the time Garrison Dam was constructed, a stage of 13.0 feet represented an open-water channel capacity of about 90,000 cfs; however, in 1975, after 22 years of reservoir regulation, the channel had deteriorated to the extent that open-water flows of about 50,000 cfs resulted in a stage of 13.0 feet. This is due in part to the Oahe delta affect just downstream of Bismarck. With the scouring effects of flood flows in 2011, recent trends show a flow of 63,000 cfs at a stage of 13.0 feet. A substantial amount of floodplain development has occurred at low levels in the Bismarck/Mandan vicinity.

7-07.3.3. Big Bend Dam to the Fort Randall Reservoir. During the 1991 fall drawdown of Fort Randall, it was observed that the White River delta, which extends across the Fort Randall reservoir, was having a damming effect that created different reservoir elevations upstream and downstream of the delta. In recent times, the upper reservoir elevation has been as much as 6 feet higher than that for the reservoir downstream from the delta. The Corps has published a revised elevation capacity table for the Fort Randall reservoir reflecting the effect of this sedimentation near elevation 1347 feet and below.

7-07.3.4. Fort Randall Dam to the Gavins Point Reservoir. Since System regulation began, a delta has formed at the mouth of the Niobrara River, a stream that enters the Missouri River just upstream from the Gavins Point reservoir. Prior to System regulation, large flood flows periodically removed the delta material; however, these large floods are now eliminated by upstream System control. While this reach of the Missouri River was capable of passing non-damaging flows in excess of 150,000 cfs prior to construction of the System projects, Fort Randall Dam open-water releases of 40,000 to 50,000 cfs now result in flood problems to adjacent property owners.

7-07.3.5. Gavins Point Dam to Sioux City. Prior to construction of the System, the open-water channel capacity through this reach of the Missouri River was well in excess of 100,000 cfs. There is evidence of channel deterioration due largely to encroachment in backwater areas and along old river meander chutes; however, this is partially offset by channel degradation. In 1997, sustained flows of 70,000 cfs in this reach caused some damage initially. However, by the end of the 1997 the channel was able to pass 100,000 cfs at a stage more than 4 feet below the 30-foot flood stage. Currently, open-water channel capacity at the 30-foot flood stage is about 120,000 cfs and 100,000 cfs can be conveyed at a stage of 27 feet.

7-07.3.6. Sioux City to Omaha. Open-water channel capacity in this reach prior to construction of the System was in excess of 100,000 cfs. During recent years there has been considerable encroachment on the channel area. Fixed boat docks have been constructed in numerous locations through this reach and low-lying areas are now being farmed. Much of this development is on or adjacent to river stabilization structures and takes advantage of sediment deposition encouraged by this stabilization. Channel degradation, while increasing the channel flood capacity, has adversely impacted marinas, water intakes, and tributary channel stability.

7-07.3.7. Omaha to St. Joseph. Deterioration of the channel capacity has occurred through this reach. Recent experience indicates that mid-summer flows exceeding 90,000 cfs will result in river levels above flood stage at Nebraska City and Rulo, NE and St. Joseph, MO. Impacts, such as high groundwater and non-draining interior runoff behind levees in cultivated fields, are felt at stages two or more feet below flood stage.

7-07.3.8. St. Joseph to the Mouth of Missouri River near St. Louis. Historically, open-water flows of about 150,000 cfs will cause only relatively minor agricultural damages in this reach. Currently, the established flood stage at Waverly, MO, has been exceeded when flows were greater than 115,000 cfs.

7-08. Recreation Purpose System Regulation. Historic System regulation to serve the recreation purpose is detailed in Appendix B of this manual. Numerous adjustments of both a temporary and a relatively permanent nature have been made to the regulation of individual System projects to enhance recreational activities. In particular, during the 2000 to 2007 drought, low elevation boat ramps were constructed at Fort Peck, Garrison and Oahe, the projects that are most affected by extended droughts. Another example on how operations are modified to benefit recreation is that a limitation is placed on power peaking during particular periods in order that downstream boating or fishing tournaments may be facilitated. Recreational use of the System steadily increased as each project was constructed and filled. A decrease in recreation visits was observed during the 8-year extended drought from 2000 to 2007. Visitation has been relatively steady over the last several years, averaging about 8 million visits per year.

7-08.1. Upper Three Reservoir Levels during Drought. Reservoir levels in the upper three, larger System reservoirs during drought were a main focus of the Master Manual Study that was the basis for the selection of the 2004/2006 water control plan. Those elements of the 2004/2006 water control plan are still present in the CWCP presented in this manual. The Master Manual Study indicated that application of the specific technical criteria for the 2004/2006 water control plan would improve benefits provided to reservoir recreation as compared to the water control plan in the 1979 Master Manual.

7-08.2. Lower Three Reservoir Levels during Drought. The three smaller System projects are not affected to any significant degree by extended drought because their levels are basically unaffected by changes in the annual water supply and total System storage. Only if a drought were more severe than that experienced in the 1930s, would the Fort Randall reservoir elevation be reduced to levels lower than the normal annual cycle.

7-09. Water Quality Purpose System Regulation. Historic System regulation to serve the water quality purpose is detailed in Appendix C of this manual. Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health, plant and animal life, and the various uses of water by man (e.g., irrigation, domestic and industrial uses); temperatures, which affect 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. Biologic quality and dissolved-oxygen quality have not been considered problems within the basin until recent years. As a result, there has not been a long-term watershed approach in obtaining basin-wide data, but it is known that problems exist below several of the major cities and below industrialized areas on some of the smaller tributary streams. High ambient air temperatures, solar radiation, water depth and thermal discharges from point sources can also affect thermal water quality conditions. Low releases could impact the operation of downstream powerplants.

7-09.1. System Downstream Release Requirements for Water Quality. Generally, System project release levels necessary to meet the downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 *Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River*. These requirements were used in System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality that are given in Table VII-10 were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the EPA in 1974 after consideration of (1) the current status of P.L. 92-500 programs for managing both point and non-point waste sources discharging into the river, and (2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 parts per million (ppm). The minimum daily flow requirements listed in Table VII-10 are to be used for System regulation purposes. The intent of this CWCP is to fully meet applicable water quality requirements and to continue to monitor the reservoirs and releases from the System to assure that this occurs.

Table VII-10
Minimum Daily Flow Requirements Below the System
for Adequate Dissolved Oxygen
(cfs)

Urban Area	December January February	March April	May	June July August September	October November
Sioux City	1,800	1,350	1,800	3,000	1,350
Omaha	4,500	3,375	4,500	7,500	3,375
Kansas City	5,400	4,050	5,400	9,000	4,050

7-09.2. Other Water Quality Considerations. 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 CWA, because the river has become clearer and cooler and improved recreation and sport fishery. Conversely, the water quality has degraded, as seen through the ESA, because the natural turbid, warm river has become clearer and cooler which may affect native river fish. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality. Water quality, therefore, has more than enough flow during all periods of the year in all of the Missouri River reaches with the CWCP. Water quality in the System reservoirs has been deteriorating for some time, essentially since the reservoirs were first filled. The dissolved-oxygen levels in the lower levels of the System reservoirs do not provide water quality conditions conducive to support some types of fish. The number of algae blooms has increased during the life of the System. Water quality has deteriorated in some arms of the large reservoirs for short periods so that the water in these locations is not potable, but these situations have been rare. In general, the water quality in the System reservoirs is considered good and is expected to remain so. Low flows in the reaches downstream from Garrison and Gavins Point dams directly affect the ability of thermal powerplants in these two reaches to meet National Pollutant Discharge Elimination System permit standards for discharging cooling water back into the Missouri River. Low reservoir levels and river stages may increase the sediment content in water supplies and result in depleted dissolved oxygen conditions in powerplant releases and tailwater areas.

7-10. Fish and Wildlife Purpose System Regulation. Historic System regulation to serve the fish and wildlife purpose is detailed in Appendix D of this manual. Declining water levels of the reservoirs are a concern to many project users interested in the reservoir fishery; however, some fluctuation in the reservoir levels is unavoidable if the reservoirs are to serve all authorized purposes. A continuing objective in the regulation of the System is to minimize the departures in reservoir levels from normal, full multi-purpose levels to the maximum practical extent consistent with regulation for other authorized project purposes. The partial elimination of the annual drawdown of the Fort Randall reservoir (Lake Francis Case), which was previously discussed, is a good example of limiting reservoir level fluctuations while continuing to meet authorized purposes.

7-10.1. Release Rates for Fish and Wildlife. The maintenance of relatively uniform release rates during certain times of the year is also an environmental objective to benefit certain riverine species during their spawning period. Minimum releases are required from some of the projects for downstream fisheries. System regulation has reduced high flows and supplementing low flows that still naturally occur on the Missouri River, which allows requests by state game and fish agencies to be met. Relatively constant releases, however, are not desirable for all fish species. Some fluctuations in release rates continue to be unavoidable if all authorized System project purposes are to be served. Additionally, access to the river may be more difficult at times, fishing success may be affected, the sediment load in the river may be increased, and use of fixed boat docks may be inconvenienced. To the extent practical, considering release requirements for other authorized purposes, release fluctuations are being minimized. Refer to the individual project WCMs for details on how each project is regulated for fish and wildlife.

7-10.2. Minimum System Releases for Fish and Wildlife. Establishment of minimum releases and steady-to-rising pools during the spring months have been recognized since the 1950s as beneficial for successful fish spawning and hatching. An ad-hoc committee of the American Fisheries Society first made recommendations to the former MRD RCC, which is now the NWD MRBWM, in 1972 regarding regulation activities beneficial for the fishery. This committee was replaced with the MRNRC, which was established in 1988 to provide the Corps with a coordinated recommendation for fishery enhancement. The MRNRC is comprised of representatives from fish and wildlife conservation agencies from the seven states bordering the Missouri River.

7-10.2.1. Fort Peck Minimum Release. Minimum hourly releases, particularly during fish spawning, have been requested from Fort Peck, Garrison and Fort Randall dams for many years. These requests are implemented if other project purposes are not affected. A year-round instantaneous minimum release of 3,000 cfs was established at Fort Peck in 1992 for the trout fishery located in the dredge cuts immediately below Fort Peck Dam.

7-10.2.2. Garrison Minimum Release. Garrison Dam minimum releases are established by standing orders that call for a minimum generation over a specified number of hours depending on a range of daily average project releases. In most years, the minimum hourly generation resulting from release patterns for T&E nesting is higher than the minimum specified in the standing orders. The minimum daily average Garrison Dam release is 9,000 cfs to avoid excessively low stages at downstream water intakes.

7-10.2.3. Oahe Minimum Release. Reduced daily power demands usually are experienced during weekends, particularly on Sundays, and as a consequence it may be necessary to schedule minimum Oahe releases during weekend daylight hours to satisfy the weekend recreation and fishing demand in the tailwater area.

7-10.2.4. Fort Randall Minimum Release. Minimum hourly releases from Fort Randall Dam are imposed for fish spawning below the project in years when daily average releases are sufficiently high. The most recent MRNRC recommendation is a minimum of 9,000 cfs from April through June.

7-10.2.5. Gavins Point Minimum Release. The minimums under the CWCP for other purposes exceed current fishery minimum requirements.

7-10.3. Modified System Regulation for Threatened and Endangered Species. Releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate T&E nesting since 1986. Releases from Fort Peck were also modified for several years, but no longer are due to the nesting patterns below that project. Peaking may be restricted in both magnitude and duration at both Garrison and Fort Randall. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Planned operations to address ESA requirements will normally be provided in the AOP.

7-10.3.1. Gavins Point Cycling. When System regulation for the T&E birds began in 1986, a technique of increasing project releases, sometimes referred to as "cycling", every third day by 8,000 to 10,000 cfs was used. The purpose of the cycling was to encourage T&E birds to build their nests on higher habitat so that these nests would not be inundated later when System increases were required to meet the regulation objectives of the System. Cycling is used on a limited basis because of the potential harm to native fish and the risk of stranding chicks. Every third day "cycling" of Gavins Point Dam releases during release reductions for downstream flood control has continued to be used to keep birds nesting at sufficiently high elevations to maintain room for release increases when downstream flooding has subsided. The variation in releases is normally limited to 6,000 to 8,000 cfs to minimize adverse effects on downstream river users and fish.

7-10.3.2. Gavins Point Steady Release. Another technique, called "steady release," is to increase the Gavins Point Dam release by early to mid-May when the terns and plovers begin to initiate nesting activities to the amount expected to be needed in August when downstream tributary flows are typically lower. This uses an additional amount of water stored in the System but usually preserves the ability to support downstream flow objectives and meet T&E species objectives as well. This type of release from Gavins Point Dam has been successfully used many times since System regulation for T&E nesting began in 1986.

7-10.3.3. Gavins Point Flow-to-Target Release. Prior to the System being regulated for T&E species, a "flow-to-target" approach was taken where releases from the System were increased as needed to provide downstream flow support. While this approach preserved the most habitat during the initial nesting phase, it normally resulted in the inundation of nests as downstream tributary flows decreased and Gavins Point Dam releases were increased to meet downstream target flows.

7-10.3.4. Gavins Point Steady Release – Flow to Target. During the 2003 T&E nesting season, a new procedure, called "steady release – flow to target" (SR-FTT), was used to set the Gavins Point Dam release. This procedure combined features of the original "flow-to-target" method with the "steady release" plan. It called for an initial steady release high enough to inundate low-lying habitat that would likely be subject to inundation later in the season. Since 2003, the SR-FTT procedure has been identified in the AOPs as the regulation scenario to be followed because it meets the project purposes while minimizing the loss of nesting T&E species. As downstream tributary flows decline through the summer, System releases are increased as needed, within the limits of the Incidental Take Statement as outlined in the 2018 Biological Opinion, to meet other downstream purposes, such as navigation.

7-10.4. Adaptive Management. Adaptive Management for the T&E species through the Missouri River Recovery Program (MRRP) is outlined in the Science and Adaptive Management Plan (SAMP). Refer to Section D-05 of Appendix D of this manual for additional background information.

7-11. Water Supply and Irrigation Purpose System Regulation. Historic System regulation to serve the water supply and irrigation purposes, as well as intake locations, are detailed in Appendix E of this manual. Tribal intakes are presented in Appendix E. Numerous water intakes are located along the Missouri River below the System and in reaches between the projects. These intakes are primarily for the purposes of municipal water supplies, nuclear and thermal powerplant cooling, and irrigation supplies withdrawn directly from the Missouri River. Historically, water access problems have been associated with several of these intakes; however, the problems have been primarily a matter of sandbars or sediment deposition at the intake restricting access to the river rather than insufficient water supply. Other water supply problems can occur during the winter months due to ice jamming on the river. Floating or frazil ice can block the water intake facilities directly, which can reduce the intake flow to unacceptable rates.

7-11.1. System Water Supply Considerations. The minimum daily flow requirements established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes at numerous locations along the Missouri River below the System. The lower Missouri River is significant with regard to water supply. More than 90 percent of the population served, and 75 percent of the thermal power generating capacity using the Missouri River for once-through cooling, are located below the System. Problems that have been experienced within the System are related primarily to intake elevations or river access rather than inadequate water supply. Evaluations are conducted on an on-going basis, specifically during years when non-navigation and lower-than-average winter releases are made, between the Corps and affected water users to determine the minimum stage and flow requirements at each intake location for satisfactory hydraulic operation. During any non-navigation time period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the Systems dams, to the extent reasonably possible. The minimum required summer release below minimum service rates to fully meet the water supply and water quality needs has not been established because this release has not been tested. In 2003, a 21,000 cfs release for only a few days resulted in downstream water supply problems. It is not known if these facilities could be modified to function at lower levels. An 18,000 cfs flow target was modeled during the development of the 2004/2006 water control plan as a potential minimum water supply flow target rate in the summer months, which may result in some adverse impacts to power generation to comply with the water quality requirements for temperature. Lower flow targets of 9,000 cfs are included in the non-summer, open-water-season months, and these releases may not be adequate to meet water supply needs below the System on the Missouri River without modifications to some intakes, particularly those in the degradation reaches at Sioux City and Kansas City.

7-11.2. Water Supply. The growth in the use of the Missouri River for water supply as an authorized purpose has, like recreation, exceeded all original expectations. The MRBWM office recognizes the importance to regulate the System in a manner to provide sufficient streamflow in intervening reaches between the System reservoirs and in the lower Missouri River reach from Gavins Point Dam to the mouth near St. Louis, MO, to sustain public water supplies of the numerous communities along the banks of the Missouri River. More than 1,600 intakes and intake facilities have been identified on the reservoirs and in the river reaches (Table E-3). Of these, 302 intakes and intake facilities are identified for American Indian Tribes. Appendix E discusses water supply intakes using the Missouri River. These intakes are primarily for municipal, industrial, and individual water supplies; fossil and nuclear-fueled powerplant cooling; and irrigation withdrawals directly from the Missouri River. Water users regularly notify the Corps when problems arise with their intakes; however, the problems have been a matter of intake access to the water rather than insufficient water to supply or meet requirements. The following sections discuss water supply for the reaches between the System projects and below the System. The purpose of the CWCP is to fully meet water supply requirements, to the extent reasonably possible. The Corps will continue to obtain the necessary data and make adjustments to the System to assure that this occurs; however, the intake access associated with obtaining Missouri River water is the responsibility of the entity choosing to use this source of water for its supply. Intake access problems are the responsibility of the intake owner, and the Corps will not guarantee access; rather, only that, to the extent practicable, the supply of water in the Missouri River is adequate to meet this project purpose.

7-11.3. Minimum System Release Requirements for Water Supply and Irrigation – Open-Water Season.

7-11.3.1. Fort Peck. Historic regulating experience indicates that a minimum daily average release of 3,000 cfs from Fort Peck Dam is satisfactory for municipal water supply. As stated in Section 7-10.2.1 of this manual, a year-round instantaneous minimum release of 3,000 cfs was established at Fort Peck in 1992 for the trout fishery located in the dredge cuts immediately below Fort Peck Dam. The irrigation demands below Fort Peck Dam during the irrigation season currently call for a flow of 6,000 cfs as a minimum; however, the formation of sandbars has at times restricted flows to some intakes in this reach. The Fort Peck Dam minimum release rate is, therefore, equal to or greater than the minimum water supply release requirement for this reach.

7-11.3.2. Garrison. At Garrison Dam, a minimum average daily release of at least 9,000 cfs during both the open-water and ice-cover seasons is desirable to provide sufficient river depths for satisfactory operation of municipal, irrigation, and powerplant water intakes in North Dakota. In this reach of the river, fluctuations in release levels require, at times, the resetting of irrigation pumping facilities to achieve access to available water or to prevent inundation of pumps.

7-11.3.3. Oahe and Big Bend. No restriction on minimum releases from Oahe and Big Bend is necessary for adequate service to water intakes because the headwaters of downstream reservoirs may extend to near the upstream dam sites. Minimum flows from Oahe of at least 3,000 cfs may be scheduled as needed during the daylight hours during the recreation season.

7-11.3.4. Fort Randall. 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 municipal and industrial 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.

7-11.3.5. Below Gavins Point. When the water-in-storage in the System is at normal or higher levels, releases for the navigation and power production purposes and to evacuate flood control storage during the navigation season and winter period will normally be at levels that are deemed sufficient to meet downstream water supply needs. During extended droughts, Gavins Point Dam releases may be reduced as the service level is reduced, as outlined in Section 7-13.2 of this manual. During any non-navigation time period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the Systems dams, to the extent reasonably possible. The minimum open-water season System release is 9,000 cfs. Some intakes require more than 9,000 cfs during the open-water season for effective operation. The intake owners bear the responsibility to modify their intakes to ensure that they can remain operational at lower System release rates. A winter Gavins Point Dam minimum release rate of 12,000 cfs has been established as the guide in meeting downstream water supply requirements during this period. Intakes typically have higher requirements during the winter period because of the effects of river ice in reducing the capacity of their intakes. If Gavins Point Dam release rates are reduced below 12,000 cfs for water conservation, continued surveillance of these intakes will be required, and, if appropriate, additional releases may be required to assure adequate water levels for uninterrupted intake operation. During the critical and more difficult winter period, release rates may be adjusted according to river icing conditions to assure that the water supply service is provided downstream. During drought years when System storage is low enough to reduce or eliminate the navigation season, a Gavins Point Dam release of 18,000 cfs has been established as meeting the summer water supply requirement. The intake owners bear the responsibility to modify their intakes if a summer Gavins Point Dam release rate of 18,000 cfs will not be adequate to meet their needs.

7-11.4. Irrigation Purpose System Regulation. Federally-developed irrigation projects served directly from the System were envisioned and the pumping plants to support these irrigation projects from Garrison and Oahe were constructed. The federal irrigation projects have not been constructed. The Oahe Diversion project was never officially deauthorized, but Congress prohibited any further construction without its approval. The Garrison Diversion project has been significantly scaled back. Current plans for water resource development in the Missouri River basin do not include significant federal irrigation development from the System. Releases from the reservoirs are used by numerous private irrigators and by federally-financed projects. Private irrigation directly from the reservoirs is ongoing and continues to develop. While the minimum releases established for water quality or for satisfactory operation of Missouri River water supply intakes are usually ample to meet the needs of irrigators, low reservoir levels and low river stages, with their associated exposure of sandbars and drying up of secondary channels, make access to the available supply difficult or inconvenient to obtain. Instances of such occurrences are discussed in the individual System project WCMs. The System will continue to be regulated for this Congressionally authorized project purpose and the Corps will adjust project releases to meet irrigation needs, to the extent reasonably possible. Access is the major problem for all types of intakes along the Missouri River and on the System reservoirs. The intake owners bear the responsibility to modify their intakes if adequate water supplied for irrigation is not accessible.

7-12. Hydropower Purpose System Regulation. Historic System regulation to serve the hydropower purpose is detailed in Appendix F of this manual. Since completion of the power installations at the System projects, most System project releases have been made through the respective powerplants. When release requirements were exceptionally high due to flood control storage evacuation, or one or more of the hydropower generation turbines are off line, spillway releases are necessary at Gavins Point Dam. Some spillway releases have also been required at Fort Peck, Garrison and Fort Randall Dams for these reasons; however, in most years releases from all projects are made through the powerplants at all times. The six System dams support 36 hydropower units with a combined plant capacity of 2,523 megawatts (MW) of potential power generation. These units provide an average of 9.3 million MWh of energy per year, which is marketed by Western. Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System; however, adjustments are made, when possible, to provide maximum power production during the summer and winter when demand and value of this authorized purpose is highest. Hydropower is the only Congressionally authorized purpose of the System that actually returns money to the U.S. Department of the Treasury.

7-12.1. Maximum Power Potential. Realization of the maximum power generation potential provided by water passing through the System dams requires that hydropower operations be carefully integrated into the regulation of the overall System. This requires consideration of many factors, including, but not limited to, generating capacity at each plant, marketability and current market price of generated power, necessary peaking capability, anticipated long-range storage balance requirements, and regional power emergencies. Day-to-day regulation of the System projects is scheduled to develop the maximum power benefits, to the extent reasonably possible.

7-12.2. Hydropower Considerations – Annual Fort Randall Drawdown. A disparity exists between summer power generation, when releases from four of the six System projects are relatively high to provide Missouri River downstream flow support, and winter generation, when System releases must be restricted due to the limited ice-covered channel capacity. The effect of this disparity may be eased by another aspect of System regulation, the draft and refill of a portion of the Fort Randall Carryover Multiple Use Zone storage space. During this regulation, Oahe and Big Bend releases are reduced several weeks before the end of the navigation season. This leaves Fort Randall as the primary source for downstream release requirements for the remainder of the fall season, a process that results in evacuation of a portion of its Carryover Multiple Use Zone storage space. This vacated storage space is then refilled over the winter period via Oahe and Big Bend releases. Whereas, the volume of winter releases from Oahe and Big Bend, in the absence of this recapture, would be about equal to those from Fort Randall, the refill of the evacuated Fort Randall space allows winter releases from these upstream projects to substantially exceed those from Fort Randall Dam.

7-12.2.1. During the period of initial fill and the regulation of the System in years prior to 1971, as much as 2 MAF of storage below the base of the Annual Flood Control and Multiple Use Zone was drawn out of Fort Randall. The recapture of the evacuated storage space allowed Oahe and Big Bend average daily releases to exceed Fort Randall releases by an average of 8,000 cfs for the winter. This regulation resulted in substantially more winter energy generation, exceeding 300,000 MWhs, when Oahe was at its normal level. Offsetting this gain in System generation, the generating capability at Fort Randall Dam was reduced by 60 to 70 MW in early December because of the lower reservoir level; however, this negatively impacted other System authorized purposes. A lowered Fort Randall reservoir level has an adverse effect on recreation in and around the reservoir area while the exposed reservoir floor becomes undesirable in an aesthetic sense. Mud flats in the reservoir headwaters spawned blowing dust storms near Chamberlain, and the lower pool level resulted in boat ramps being out of the water. The effects of this drawdown on the surrounding environment became an increasing concern, particularly when this drawdown proceeded below elevation 1340 feet. Studies conducted in 1971 and 1972 resulted in a compromise being accepted that limited the drawdown of Fort Randall to elevation 1337.5 feet in most years. The drawdown to this level was also delayed as late as possible in the year so that any negative impacts were felt for the shortest possible period of time. This drawdown was also scheduled to coincide with the period during which there is a marked decline in the recreational usage of the reservoir. Fort Randall, at a reservoir level of elevation 1337.5 feet, makes about 800,000 acre-feet of storage space available below the base of the Annual Flood Control and Multiple Use Zone for recapture of winter power releases from Oahe and Big Bend dams. During droughts more extensive than that of the 1930s, when System storage reserves and System releases are reduced, an additional drawdown of Fort Randall to as low as 1320 feet may be scheduled to permit Oahe and Big Bend Dam releases to be maintained at about 15,000 cfs during the winter period.

7-12.3. Other Hydropower Considerations – Annual Oahe Drawdown. While not as significant (in terms of pool level fluctuation) as the Fort Randall recapture, a similar recapture can occur at Oahe. This recapture is coordinated with upstream Fort Peck and Garrison Dam releases. Oahe recapture may also significantly increase the amount of winter energy generation. During the 4-month winter period, Garrison Dam releases normally are scheduled to be at least 1 MAF more than Oahe releases. The recapture of these upstream releases results in an Oahe elevation increase up to 5 feet or more during the winter months.

7-12.4. System Hydropower Coordination. On a daily basis, real-time regulation of the System for hydropower purposes is closely coordinated with Western and with regulation of the System for non-hydropower purposes. Detailed advance planning is essential so that releases from each of the System projects for any of the other authorized project purposes may be used to the fullest extent practicable for optimum power generation. Daily schedules of power generation for each System powerplant are prepared and furnished to Western. Western, in turn, makes such daily changes in the power marketing arrangements as are necessary. Power production/reservoir regulation orders, which include the scheduled daily generation as well as limits of powerplant loading, are issued directly by the MRBWM office to individual System powerplants. Within the limits of the daily schedules, Western controls the actual hourly loadings of the plants, subject to the limitations imposed by load limits in the power production/reservoir regulation orders and discharge limits imposed by concurrent power production/reservoir regulation orders scheduled by the MRBWM office.

7-12.4.1. The Big Bend and Oahe powerplants primarily follow daily load patterns. In the summer cooling season, Big Bend and Oahe generation is patterned to meet peak electricity demands, which generally occur around 6 p.m. In the winter heating season, their generation is patterned to meet morning and evening peak demands. The Fort Randall, Garrison and Fort Peck powerplants are also used for peaking, but to a lesser degree. The relative role of each powerplant in meeting required peaking patterns varies with relative water supply available to each powerplant and other regulation factors. The peaking patterns vary through time, primarily in response to such factors as the demand for power and the average release rate through the System. At individual dams, daily hydropower releases are normally adjusted for other project purposes while considering such things as flood control, water conservation, environmental objectives and physical and seasonal constraints.

7-13. Navigation Purpose System Regulation. Historic System regulation to serve the navigation purpose is detailed in Appendix G of this manual. Service was provided to navigation on the lower Missouri River during the years that Fort Peck was regulated as an individual project. With the construction and filling of additional System projects, this service was expanded. Full length (8-month) seasons were first initiated in 1962 and have continued except in years when flow reductions were required during extended droughts. Flow support for navigation has been provided since June 1967, when the System closed. While flow support for navigation is for a defined period of time each year (e.g., a full-length season is 8 months), navigators can be on the Missouri River all year, if flow and ice conditions permit. The 735-mile Missouri River navigation channel extends from the confluence of the Big Sioux and Missouri Rivers near Sioux City, IA to the river's mouth near St. Louis, MO. As shown on Table G-1, commercial navigation tonnage reached its peak of 3.3 million tons in 1977. In 2001 the peak total navigation tonnage of 9.7 million tons was recorded. Total navigation tonnage includes commercial tonnage, waterway materials, and sand and gravel. Of that total, commercial navigation tonnage accounted for 1.58 million tons. The Missouri River BSNP is authorized to provide a 9-foot deep and 300-foot wide navigation channel. Downstream flow support is provided to meet many of the Congressionally authorized purposes, which includes navigation. Navigation flow support is provided to maintain an 8- to 9-foot depth in the navigation channel for minimum and full service flow support, respectively, depending on the amount of water stored in the System on March 15 and July 1. The determination of minimum, intermediate, or full flow support is based on the criteria presented in Section 7-03.2.1.1 and Table VII-2 of this manual. Table G-3 in Appendix G presents the navigation tonnage on an annual basis.

7-13.1. Navigation and Other Downstream Support Considerations. The BSNP was constructed and is maintained to create a self-scouring channel that provides a 9-foot deep and 300-foot wide navigation channel with full service flows. Occasionally, groundings can be experienced during the early portion of the navigation season. This is because it may take several weeks for the self-scouring navigation channel dimensions to be created as the service level is transitioned from lower winter flows to the higher navigation and downstream support flows. To alleviate this situation, when appropriate and based on available water supply, downstream flow support releases at the beginning of the season may be scheduled for a short period at a level of up to 5,000 cfs higher than the service level requires, to provide channel conditioning provided System storage levels at the time are adequate.

7-13.1.1. Day-by-day regulation of the System to support navigation requires forecasts of inflow to various reaches of the Missouri River below the System. From these forecasts and current flow targets, the control point (either Sioux City, Omaha, Nebraska City or Kansas City) is determined each day. Anticipated traffic or the absence of traffic at the control points will also have a bearing on the control point selection. For this reason, the MRBWM office will continuously monitor traffic movement on the Missouri River. After selection of the control point, releases from the System are adjusted so that, in combination with the anticipated inflows between the System and the control point, they will meet the target flow at the control point.

7-13.2. System Downstream Flow Support. The System releases required to meet the minimum and full service targets vary by month in response to downstream tributary flow, as shown on Table VII-11. These values, which are part of a MRBWM Technical Report, *Releases Needed to Support Navigation*, April 2000, are updated as additional data are accumulated and when a significant change in these values occurs. For this technical report, the relationship between annual runoff upstream of Sioux City and the average Gavins Point Dam release required for the navigation season was analyzed. The analysis showed that, generally, more water was needed downstream to support navigation during years with below-average upper basin runoff than during years with above-average upper basin runoff. Regulation studies performed since 1999, therefore, use two levels of System release requirements; one for median, upper quartile, and upper decile runoff scenarios and another for lower quartile and lower decile scenarios. An examination of the data presented in Table VII-11 reflects that, early in the season, the flow target is at Sioux City with adequate downstream tributary flows to meet flow targets. Normally, as the runoff season progresses, downstream tributary flows recede or cease during the summer, and the flow target moves from Sioux City to Nebraska City and eventually to Kansas City. This requires higher flow support (i.e., higher Gavins Point releases) as the season progresses through the summer. Normally, the target moves upstream during the fall, when higher downstream tributary flows return. This seasonal tributary flow pattern is reflected in the Gavins Point Dam release data presented in Table VII-11. These releases are the average monthly values during the period studied for the various runoff conditions and do not reflect the maximums and minimums required during that month to meet flow targets. Actual regulation requires daily adjustments to fully serve the Congressionally authorized project purpose of navigation. Studies conducted for the ESA consultation in the spring of 2003 concluded that 30,000 cfs would be needed to provide a 90 percent assurance of meeting minimum service flow targets in July and August. That study used all runoff data from the period of analysis of 1898-1997.

Table VII-11
Gavins Point Releases Needed to Meet
Downstream Target Flows for Indicated Service Level (1950-1996 Data)
(Discharges in 1,000 cfs)

Median, Upper Quartile, Upper Decile Runoff								
Service Level	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Full	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1
Lower Quartile, Lower Decile Runoff								
Service Level	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Full	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

7-13.3. Navigation Service Disruptions. The level of service to navigation can be affected by release restrictions at Gavins Point Dam for the T&E nesting season. Release restrictions were first implemented in 1986 to preserve T&E nesting habitat and not inundate T&E nests or birds that could not yet fly. At times during the release restriction period, navigation target flows cannot be met because tributary flows are declining in July and August and flows cannot be augmented by increased releases from Gavins Point Dam beyond the maximum release established prior to T&E nesting. Generally, release restrictions to protect the birds are lifted in mid-August when the young birds are able to fly and leave the area. Beginning in 1995, releases from Gavins Point Dam were adjusted in early May, when the terns and plovers began to initiate nesting. The release rate was based on an assessment of flows needed to support navigation in July and August. The resulting release prevented the inundation of nests and chicks by not requiring increased downstream support later in the summer.

7-13.3.1. High flows on the lower Missouri River can also disrupt navigation. The USCG has the responsibility of officially closing the Missouri River. The Missouri River is generally closed to navigation when stages become so high that towboat prop-wash and the wake from the tows can damage the Missouri River levees. During the flood of 1993, the Missouri River was closed for navigation for seven weeks due to high flows between Kansas City and St. Louis. During the flood of 2011, various sections of the Missouri River were closed to navigation from June 7 through September 27. See Appendix G for details on the closing of the Missouri River in 1993 and 2011 floods. The Corps and the USCG coordinate the closing and reopening so that significant impacts can be minimized both to the levee system and to the navigation industry. During the 1987-1992 and 2000-2007 droughts, navigators experienced hardships and lost revenues due to both reduced Gavins Point releases and shortened navigation seasons, including disruptions caused by court-ordered actions and operations to benefit the T&E species. Table G-3 provides the season lengths and tonnage on the Missouri River since the System filled in 1967.

7-14. Drought Contingency Plan. Regulation of the System during drought was a significant consideration in the development of the 2004/2006 water control plan. The original design of the System, which is the largest reservoir system in the United States, was to serve all authorized project purposes during an extended drought similar to the 12-year drought from 1930-1941. This resulted in the construction of the System with an enormous amount of water normally retained in System storage in anticipation of the onset of extended drought. For this reason, the three upper reservoirs are extremely large compared to other Corps reservoirs, which makes the System very unique. The System was designed to use the stored water in the Carryover Multiple Use Zones of the upper three reservoirs during extended drought periods to meet a diminished level of service to all Congressionally authorized purposes, except flood control. The three annual water-in-storage checks on March 15, July 1 and September 1, and the associated rule curves noted in Tables VII-2, VII-3 and VII-5, outline how water conservation measures will be implemented during extended droughts. As such, no separate Drought Contingency Plan is needed or required for the System, as it is included as part of the CWCP presented in this manual.

7-15. Flood Emergency Action Plans. A stand-alone Emergency Action Plan (EAP) has been formalized for each mainstem project. The EAP identifies potential emergency conditions at each project and outlines specified pre-planned actions to be followed to reduce consequences in the unlikely event of a dam safety emergency. Engineering Circular (EC) 1110-2-6074 establishes key guidance for consistent application of EAPs, incident management and reporting, and inundation mapping requirements for all USACE operated and maintained dams and appurtenant structures. The EAPs, which contain sensitive information including inundation mapping, are For Official Use Only and therefore, are not disseminated to the public. The Omaha District's Geotechnical Engineering Branch is responsible for incorporating inundation maps into the EAPs; developing, disseminating, and updating EAPs; and augmenting inundation mapping beyond established standards, when warranted. In addition, the Omaha District Online Dam Failure Inundation Mapping Viewer provides federal and non-federal emergency management agencies with an additional planning tool and access to up-to-date inundation mapping. To maintain proper operational readiness, dam safety training and emergency preparedness exercises are coordinated and managed by the Omaha District's Geotechnical Engineering Branch. Emergency exercise frequency and complexity requirements are outlined in EC 1110-2-6074 (Guidance for Emergency action Plans for Dam and Levees), ER 1110-2-1156 (Safety of Dams – Policy and Procedures), and in the Homeland Security Exercise and Evaluation Program.

7-16. Other Considerations. Other considerations than just serving the authorized System purposes must be served from the System, as needed. Adjustments are made to System regulation at times for downstream construction and to aid in recovering bodies from drowning accidents. Adjustments in reservoir levels or dam release rates have been made to help reinter cultural artifacts and human remains at Tribal burial sites. Special regulation to determine the effectiveness of moving accumulated sediment below the System projects has also occurred.

7-17. Deviations from the CWCP. The deviations from the operational objectives presented in this manual or the following year's final AOP are discussed during the AOP process. All significant deviations from this CWCP will be coordinated and approved by the NWD Commander, who may also coordinate with higher authority. All deviations of significance are modeled and disseminated to the public through the normal coordination procedures involving public press releases, the MRBWM website and social media. Minor deviations are accomplished by the MRBWM staff through direct coordination with the affected parties.

7-18. Rate of Change in Release. Releases from the System are generally scheduled on a average daily basis. A gradual change is important when releases are being decreased and downstream conditions are very wet, resulting in saturated riverbank conditions. The MRBWM staff is aware that a significant reduction in System releases over a short period can result in some bank sloughing, and release changes are scheduled accordingly when a slower rate of change does not significantly impact downstream flood risk. Overall, the effect of System regulation on streambank erosion has been reduced by the regulation of the System because higher peak-runoff flows into the System are captured and metered out more slowly. Increasing System project releases can be changed more significantly than reductions because streambank erosion due to sloughing is not an issue. Many years of regulation experience have also indicated that a simple transition of releases is normally desirable, when possible.

7-18.1. Criteria Related to Rate of Release Change. Two sets of criteria are used that are related to the rate of release change for the System dams. The rate of release change criteria is adjusted from that for a normal situation if a flood control regulation objective is initiated to protect life and property in downstream areas or to respond if an emergency exists either at the project or in the project vicinity that requires rapid release changes. Table VII-12 lists the normal and flood control daily rate of release change criteria for each System project. If a situation presents itself that has not been contemplated or a change greater than that described below is required to meet the operational objectives of this plan, the appropriate change will be made. A rate of release change guideline at Oahe and Big Bend does not apply because the tailwaters empty into either a very short river reach or the downstream reservoir, respectively. Also Oahe and Big Bend experience daily changes of releases in the range of full powerplant capacity as required for System hydropower generation to meet this authorized project purpose.

Table VII-12
Mainstem Project
Maximum Daily Rate of Release Change

Mainstem Project	Normal Increase (cfs)	Normal Decrease (cfs)	Flood Control Increase (cfs)	Flood Control Decrease (cfs)
Fort Peck	6,000	3,000	9,000	12,000
Garrison	6,000	3,000	9,000	12,000
Oahe	n/a	n/a	n/a	n/a
Big Bend	n/a	n/a	n/a	n/a
Fort Randall	10,000	6,000	12,000	17,000
Gavins Point	8,000	4,000	10,000	15,000

7-18.2. Maximum Daily Release Decrease. While Table VII-12 shows the maximum daily decrease is 4,000 cfs per day at Gavins Point during a normal situation, this assumes no change in tributary flows downstream. If tributary flows in the reach just downstream of a System project are increasing or decreasing, the actual project release increase or decrease can be based on the combination of tributary flow change and release change to provide the same result downstream. For example, if reach increase of tributary flows of 5,000 cfs were forecasted or experienced at gaging locations in the reach just below Gavins Point and the System were in a normal situation, Gavins Point releases could be reduced by 9,000 cfs per day (5,000 cfs more than the 4,000 cfs shown in Table VII-12) to obtain the same downstream result on the Missouri River as would occur with no tributary flow changes and a release change of 4,000 cfs.

7-19. Mainstem System Physical Constraints. The physical constraints of the System projects are relatively minor with a few exceptions. These constraints are detailed for each project in Chapter IV and Exhibit A of the individual WCMs.

7-19.1. Fort Peck – Emergency Flood Tunnels. The three largest System projects have flood control tunnels that served as outlets when the project embankments were constructed. The flood control tunnels at Fort Peck Dam consist of two 24-foot 8-inch diameter concrete-lined tunnels. The regulation of flow through these tunnels is provided by the operation of a cylinder gate in the tunnels, which also have upstream emergency gates. Per Section 4-04.1.4 of this manual, since 1975, supplemental releases above powerplant capacity have been made through the spillway. Additional guidance regarding best practices and/or special considerations and restrictions for use of the outlet works can be found in Section 4-04 and Exhibit A of the Fort Peck WCM. Per Section 1.6.3 of Exhibit A, it is recommended that the ring gates (flood tunnels No. 3 and 4) should not be used except in case of a dam safety emergency in coordination with Omaha District Engineering Division. The emergency gates consist of cable-suspended, tractor gates, which have never been tested under full flow emergency gate closure conditions. A high probability exists that the emergency gates would not close under full flow conditions, and considerable risk would be associated with any attempt to close these gates under design conditions.

7-19.2. Fort Peck – Emergency Spillway. The spillway crest elevation is 2225 feet. The 16 vertical lift spillway gates are each 25 feet high by 40 feet wide. The concrete-lined spillway channel is about 4,800 feet long varying in width from about 700 feet at the end of the training wall section to 120 feet at the downstream end of the cutoff structure. Discharge capacity at elevation of 2250 feet, which is the elevation of the top of the spillway gates when closed and also the top of the Exclusive Flood Control Zone, is 230,000 cfs. Since completion of the emergency spillway, the spillway has been operated approximately a dozen times, never passing discharges greater than 25,000 cfs until 2011. During the 2011 flood, spillway releases were made from May 6-22 and June 2-September 30. Peak spillway releases were 52,200 cfs for several days in June. Scour in the downstream channel reached a maximum depth of more than 40 feet, leaving less than 30 feet of embedment of the spillway cutoff wall structure. As a result, the downstream face of the cutoff structure was determined to be potentially unstable with concerns that the erosion would flank the cutoff structure and ultimately lead to progressive failure of the spillway chute. See Section 4-03 of the Fort Peck WCM for more details on the Fort Peck spillway.

7-19.3. Fort Peck – Spillway Vertical Lift Gates. As noted in Exhibit A of the Fort Peck WCM, 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.

7-19.4. Garrison – Floodplain Development. The primary regulation constraint for releases from Garrison Dam is an increased water surface at Bismarck and Mandan due to aggradation in the upper reaches of the Oahe reservoir. The past two decades have resulted in a considerable amount of residential development along both sides of the Missouri River floodplain in the Bismarck and Mandan, ND areas. Flows at and above flood stage of 14.5 feet will result in a considerable amount of flood damage. The natural Missouri River flows prior to the construction of Garrison Dam were high enough, and the flooding frequent enough, to discourage such floodplain development. When high releases from Garrison are required for flood storage evacuation, local interests will likely express their desires that the Corps maintain flows through Bismarck below flood stage to reduce the amount of damage in the floodplain near Bismarck and Mandan. A Federal Emergency Management Agency (FEMA) Flood Insurance Study FIS for the Bismarck area has been completed. The federal government does not hold the authority to control local floodplain development.

7-19.5. Garrison – Spillway Tainter Gates. Recent engineering analyses have shown that there should not be any continuous overtopping of the tainter gates at Garrison Dam other than wind-induced effects of run-up and setup. This has been an issue in the past when the reservoir nears the top of the Exclusive Flood Control Zone. If use of the spillway is required, additional guidance regarding any operational restrictions and best practices for those facilities can be found in Exhibit A of the Garrison WCM.

7-19.6. Garrison – Spillway Slab. Use of the Garrison Dam spillway is a concern because of the associated spillway structure uplift pressures. An engineering analysis was completed in 1999 that indicates satisfactory factors of safety are achieved up to a reservoir elevation of 1859 feet. Due to the limited amount of data for analysis, a cautious approach should, however, be taken when spillway releases are required. Instrumentation has been installed, and evaluation under higher pools is required to complete the analysis.

7-19.7. Oahe – Spillway. The Oahe spillway empties into a downstream earth channel; therefore, when used, it will incur significant downstream erosion and flood damages. There will be some local resistance to using this project feature whenever it is first used.

7-19.8. Oahe – Spillway Tainter Gates. Recent engineering analyses have shown that there should not be any continuous overtopping of the tainter gates at Oahe Dam other than wind-induced effects of run-up and setup. Additional guidance regarding any operational restrictions and best practices for use of the spillway at Oahe can be found in Exhibit A of the Oahe WCM.

7-19.9. Oahe – High Pool Levels. There has been considerable concern in recent years regarding the use of the Oahe Exclusive Flood Control Zone for controlling major floods (reservoir level above 1617 feet). A Board of Consultants was convened to evaluate the Oahe embankment stability for maximum design pool levels. The primary conclusion of the Board was that "*The dam has sufficient global resistance to operate without restriction to the maximum surcharge pool of elevation 1645 feet. The required safety is provided by the reserve resistance of the potential break-out zone and the three-dimensional restraints.*"

7-19.10. Oahe – Winter Release Rates. Winter release rates in past years during river ice formation have resulted in minor street flooding in the cities of Pierre and Fort Pierre, SD. This flooding has prompted the application of a restriction on releases from Oahe Dam during a period when river ice formation is occurring, which usually coincides with high demands for hydropower production. A study, referred to as the Pierre/Fort Pierre Flood Mitigation Project, was initiated by the Omaha District in the late 1990s and finalized approximately five to seven years later. This project involved the purchase or flood-proofing of homes along the Missouri River that may be impacted by ice-affected Missouri River flows. Approximately 100 home were purchased and removed and about 20 were flood-proofed. Some homeowners chose not to participate in the voluntary project.

7-19.11. Big Bend – Spillway. The Big Bend spillway has only been used once, during the 2011 flood. The powerplant can normally pass the expected flows, but a powerplant failure for more than a short period of time could disrupt the transfer of water downstream requiring supplemental spillway flows.

7-19.12. Fort Randall – Low Pool Levels. The fall drawdown and winter refill at Fort Randall permits increased energy generation from the System during the winter. Complaints during the late 1960s about the fall regulation of Fort Randall reduced the amount of the normal fall drawdown from 1320 to 1337.5 feet. This change in regulation in the early 1970s has reduced overall power benefits. During a very severe drought, as outlined in Section 7-12.2.1, Fort Randall reservoir can be drawn down to 1320 feet to augment water provided by the upper three, larger System reservoirs.

7-19.13. Fort Randall – Flood Tunnel Fine Regulating Gate. The fine-regulating gate at Fort Randall was destroyed in 1975 and has never been replaced. Two gates in Flood Tunnel No. 11 have been modified to dampen gate vibrations and can be used to make fine regulating releases, either individually or in combination with each other. Service gates on Tunnel No. 11 can be operated remotely from the project control room.

7-19.14. Fort Randall – Reduced Channel Capacity. There has been significant loss of channel capacity in the downstream Fort Randall river reach, such that releases to evacuate accumulated flood storage in 1997 caused flooding to some property located adjacent to the Missouri River. The Niobrara River has been depositing sediments at its mouth (near the upper end of the Gavins Point reservoir), which is causing a loss of conveyance capacity in the river channel in this reach. Restricted downstream channel capacity because of aggradation remains a concern. Also some cabins and residences have encroached onto the floodplain in this reach and were, in some cases, flooded during the 1997 and 2011 floods.

7-19.15. Gavins Point – Spillway Tainter Gates. Steady winter releases from Gavins Point Dam are required to meet minimum downstream flow support targets. The spillway is used to ensure steady releases in the case of a planned or forced hydropower unit outage. In the case of a forced hydropower unit outage, spillway releases are initiated immediately to ensure that a reduction in flows below target levels does not occur downstream. In the winter, lower-than-planned downstream flows could cause disruption of established downstream river ice cover by a sudden reduction in flows, which could result in an ice jam. Winter operation of the spillway tainter gates has been hindered by ice formation along the tainter gate seals and the backside of the gates from water spraying over the spillway and freezing. Sidewall heater plates have been installed to alleviate the gate seal problem.

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VIII - Water Management Organization

8-01. Responsibilities and Organization. This chapter describes the personnel and coordination necessary to manage the System. The Corps has the long- and short-term direct responsibility for regulating the System. The System has been regulated as a hydraulically and electrically integrated system since 1953 when Fort Randall Dam (the second System dam constructed) was closed to begin storing water. As each System dam was completed and filled, System regulation procedures were followed and regulation of the new project was immediately integrated into regulation of the System. The System became "full," or filled to the top of all six projects' Carryover Multiple Use Zones in 1967, following a significant 8-year drought (1954-1961) in the Missouri River basin. The year 1967 is, therefore, considered the official beginning of System regulation. The following sections describe the responsibilities for the regulation of the System.

8-01.1. Corps of Engineers. The NWD's MRBWM Division of the Programs Directorate, located in Omaha, NE, is comprised of a 12-person staff of engineers, biologists, information management specialists, and support staff. The MRBWM office is comprised of two teams: Reservoir Regulation and Power Production. The Corps' Guidance Memorandum titled, *Reservoir Control Center*, dated March 1972, serves as the document that details the role and responsibilities of the MRBWM office in managing and regulating the System. The RCC, now known as the 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 constructed the System projects during the period from 1933 to 1966 and is the sole owner and regulator of the six dams that comprise the System. The Corps' Chief of Engineers 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 issues power production/reservoir regulation orders to accomplish this mission. The O&M of the System dams and associated structures are the responsibility of the Omaha District. The Omaha District has staff physically located at the System projects to make the regulation changes stated on the power production/reservoir regulation orders developed and sent by the MRBWM office. The System is the largest reservoir system in the United States, based on storage capacity. The Corps has the responsibility to coordinate the regulation of this System, both within and outside of the Missouri River basin. 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 manual. Each individual System project WCM contains instructions to the dam tender 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 every day of the year. 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 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 this 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 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 NWD Programs Directorate.

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 CWCP, 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 NEPA, ESA and the Flood Control Act of 1944. Additional details regarding adaptive management are presented in Section 7-10 of this 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 this 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 public streamflow forecasts, MRBWM office performs streamflow forecasting at select locations needed to regulate the System. These results are provided as information only. The NWS forecasts are available as a link from the MRBWM website. The website contains both normal monthly new releases and special news releases concerning other significant items that occur on an unscheduled basis. In addition, the Corps produces numerous reports on a daily basis that provide updates of the System's status and regulation changes.

8-02.3. AOP Public Meetings. The Corps follows a public process as part of the AOP preparation and implementation process for regulating the System. This process involves the development and publishing of a draft AOP in the fall of each year. The draft AOP simulates the regulation of the System for five runoff scenarios for the remainder of the current year, plus the following calendar year. The draft AOP is generally provided to all interested stakeholders in late September via hardcopy or the MRBWM website. Public meetings are held at three to six sites within the basin, normally in October, to accept verbal comments from the public and provide a forum for discussion on the draft AOP. Written comments on the draft AOP are also accepted generally through mid-November. After considering the comments from the public meetings and any written comments provided during the comment period, appropriate changes are made to the draft AOP to produce a final AOP, which is normally made available in December. In the spring, the Corps again conducts public meetings to provide information on the current hydrologic conditions in the basin and the expected effects of System regulation for the remainder of the year. 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 river 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, for integration into the MRBWM real-time forecasting models. During years of significant plains snowmelt, additional coordination between the Corps and MBRFC is necessary to ensure proper data exchange between the two agencies for the forecasting of plains snowmelt. In addition, whenever the Corps conducts special reconnaissance surveys of ice conditions on the Missouri River, the obtained information is readily shared with the MBRFC.

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

8-02.6. Western Area Power Administration Coordination. Power production/reservoir regulation 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 with regard to hydropower generation on the Corps' tributary projects in the Kansas City District. 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, as described in Section 7-04.4.1. The MRBWM office has not exercised the option of using this storage since the drought of the 1980s; however, the water control plans for the System and the individual USBR projects describe this storage and how it would be used to enhance overall basin benefits.

8-04. Commissions, River Authorities, Compacts and Committees. The Missouri Basin Survey Commission (MBSC), in a report to President Truman per Executive Order 10318 dated 1953, recommended that a five-member Missouri River Basin Commission (MRBC) be established by Presidential appointment to oversee the water resource development in the Missouri River basin. This commission never came to fruition; however, several committees, some dating from that period, have provided significant guidance to the primary federal agencies in developing Missouri River basin water resources and in regulating those resource projects in the Missouri River basin. The following sections discuss the roles of those committees in providing information for consideration in regulation of the System.

8-04.1. Committee History. This section describes the major committees in the Missouri River basin previously or presently coordinating water resource planning and System regulation guidance to the Corps.

8-04.1.1. Missouri River States Committee. On May 21, 1943, eight basin states formed the Missouri River States Committee (MRSC) for the purpose of lobbying and working collaboratively for water resource development in the Missouri River basin. The MRSC worked with the Corps and the USBR to finalize the Pick-Sloan Plan for the Missouri River basin that led to the construction of the final five dams in the System and made the Fort Peck project a part of the System.

8-04.1.2. Missouri River Basin Inter-Agency Committee. In March 1945, the Missouri River Basin Inter-Agency Committee (MBIAC) was formed by the Federal Interagency River Basin Committee to facilitate progress on the Pick-Sloan Plan and the Missouri River navigation project. The group consisted of the Corps, USBR, USDA and the Federal Power Commission. In addition, the MRSC was invited to provide four representatives. The Corps hosted the first meeting on July 19, 1945 in Omaha, NE. The Committee facilitated the sharing of data and information and provided a format for problem solving in the basin. A revised charter was adopted in 1954 to provide improved facilities and procedures for coordination of the policies, programs, and activities of the various federal departments and the states in water and related land resources investigation, planning, construction, operation and maintenance. The MBIAC had no authority for making policy for water resource development in the Missouri River basin. The MBIAC functioned until June 14, 1972, when its members joined the MRBC.

8-04.1.3. Missouri Basin Survey Commission. On January 3, 1952, President Truman appointed an 11-member MBSC to determine the land and water resources in the Missouri River basin. It also was to provide guidance on the best way to develop the Missouri River basin resources. The MBSC provided a report in 1953 that promoted the formation of a Missouri Valley Authority to regulate and oversee basin water resource development and coordinate the reservoir regulation of the newly constructed projects. As mentioned in Section 8-04 of this manual, this never occurred.

8-04.1.4. Missouri River Coordinating Committee. The Missouri River Coordinating Committee (MRCC) was established at the request of the Corps' MRD Commander in 1953. The Missouri River basin state governors appointed representatives to the MRCC, usually the state engineer or the head of the state's water resources agency. In addition, representatives of the nine affected federal agencies served in an advisory capacity to represent all interests in their state and basin or for their federal agency. This MRCC served to guide the development of the System and collectively suggested changes to the System from 1953 through 1981. In 1981, it was disbanded because it fell under the purview of the Federal Advisory Committee Act. The overall coordination concept was changed because the MRCC had become somewhat less effective and some felt that its members did not always represent all of the interests within their respective state or federal agency. The process adopted at that time to replace the MRCC was the semi-annual AOP public meeting process discussed in Section 8-02.3 of this manual.

8-04.1.5. Missouri River Basin Commission. In March 1972, President Richard Nixon approved a MRBC. Transfer from the MBIAC to the MRBC was completed formally at a joint meeting on June 14, 1972. The thrust of the MRBC in the early years was the completion of several Missouri River basin water resources studies. At the request of the Missouri River basin state governors, this group developed a computerized water accounting system for the Missouri River basin in 1979. This group was disbanded in 1981 as a program that had been created under the Water Resources Act of 1965 and transferred its assets to the Missouri Basin States Association (MBSA).

8-04.1.6. Missouri Basin States Association. Another significant committee was the MBSA, which was formed in October 1981 following termination of the MRBC. The governors of the Missouri River basin states formed the MBSA to provide regional coordination of water resource management. The MBSA was governed by a board of directors composed of one member for each of the ten basin states. The governors generally appointed senior water resource officials to this position. The affected federal agencies and other interested persons attended the meetings as observers. The primary goal, when the MBSA was first formed, was to complete some of the Missouri River basin water resources studies. An office was established in Omaha, NE and was funded through a group effort of the members. The MBSA office in Omaha closed on April 1, 1988.

8-04.1.7. Missouri River Natural Resources Committee. The Missouri River Natural Resources Committee (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.

8-04.1.8. Missouri River Basin Association. In 1993, the MBSA changed its name to the Missouri River Basin Association (MRBA) reflecting the inclusion of the basin Tribes in its membership. The MRBA also expanded its role as providing a single location for resolving water resource issues occurring in the basin. Basin coordination and cooperation on water resource issues were the primary goal of the MRBA.

8-04.1.9. Missouri River Association of States and Tribes. In the fall of 2006, MRBA became the Missouri River Association of States and Tribes (MoRAST). The MoRAST is a regional interstate organization formed by joint resolution of the governors of Wyoming, Montana, North Dakota, South Dakota, Nebraska, Iowa and Kansas and the Mni Sose Intertribal Water Rights Coalition. It was formed to help resolve issues of concern to the basin states and Tribes, to serve as a forum to foster communication and information exchange among the member states, Tribes and various other governmental units, and to facilitate the management of the natural resources of the Missouri River Basin, including water resources, fish and wildlife while considering the impacts to the economic, historical, cultural and social resources. Nebraska and Iowa have since withdrawn from MoRAST. The MoRAST is not currently active.

8-04.1.10. Missouri River Basin Interagency Roundtable. The Missouri River Basin Interagency Roundtable (MRBIR) was re-activated in 2001 to promote interagency cooperation among the federal agencies within the Missouri River basin. The mission is to foster effective communication and coordination among federal agencies, and, when possible and where appropriate, to communicate to other basin interests with a single federal voice. The cooperating agencies include, but are not limited to the Corps, National Park Service, USGS, USFWS, USBR, BIA, EPA, Western, U.S. Forest Service and the NRCS. Members are composed of executives of federal agencies with activities in the basin.

8-04.1.11. Missouri River Recovery Implementation Committee. This group is a 70-member committee made up of federal, state, Tribal, and stakeholder representatives throughout the Missouri River basin. The Missouri River Recovery Implementation Committee (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 MRRP 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.

8-05. Non-Federal Hydropower. All hydropower facilities located either at or in association with the System are federally owned and operated. 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
MRBWM 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	ER Requirement
	Annual Water Quality Report	ER Requirement
	Cooperative Stream Gage Program (Co-op)	ER Requirement

[1] Report required per ER.
[2] Unregulated flows.

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Appendix A - Extreme Events: Historic Floods and Droughts with Regulation Examples

A-01. Introduction. This appendix contains information related to the major historic floods and droughts in the Missouri River basin. These examples include historic floods and droughts that occurred prior to the construction of the System and since the System was first filled in 1967. Examples of actual historic System regulation for flood control are provided along with a discussion of anticipated flood control regulation for a hypothetical event. A summary of the historic sizing of the System storage zones is also presented. A discussion of regulation during past droughts, including those that have occurred since 1967, are included in this appendix.

A-02. Historic Major Basin Floods Prior to System Regulation. This section of this appendix summarizes information on the major floods that occurred on the Missouri River prior to System construction. The earliest major flood with information for water management analysis is the flood of 1844. Flood data on this flood and major floods up to the flood of 1960 are discussed in this section.

A-02.1. Flood of 1844. This flood, of near legendary proportions, is generally considered to be the greatest known flood in the lower Missouri River basin. From stage records at Kansas City and St. Louis, MO, high water marks at Manhattan and Topeka, KS and Boonville and Hermann, MO, and the precipitation records at Ft. Leavenworth and Ft. Scott in Kansas and Jefferson Barracks in St. Louis, the flood has been traced, and the events leading up to it, have been reconstructed. These events do not differ from those that are recognized today as being conducive to major lower Missouri River basin flooding and include prolonged periods of antecedent rainfall saturating the basin followed by sequential bursts of intense storm rainfall. From May 10 to June 6, 1844, Ft. Leavenworth received 5.77 inches of rainfall and Ft. Scott received 14.34 inches. The normal precipitation for that time period and location is 4.5 inches. This antecedent rainfall apparently saturated the Kansas River basin sufficiently that most of the 4 to 8 inches of additional rainfall that fell in numerous bursts from June 7-14 likely became direct runoff. Actual river stages and discharge measurements are not available for this historical event, but the maximum stages and discharges, shown on Table A-1, are believed to be reasonable estimates and have been accepted by most hydrologic investigators. Some evidence exists to indicate that the basin above the System reservoirs probably contributed only a relatively small amount to the 1844 Missouri River peak flow at St. Joseph, MO. A Missouri River down-bound French steamboat captain reported grounding difficulties in the Dakotas with no report of high water until he saw the evidences of a great flood below the mouth of the Platte River. Further mention of a large contribution from the Platte River that year was provided by a wagon train heading west on the Oregon Trail, which reported in its journals a delay while awaiting the passage of a great flood before fording the Platte River.

Table A-1
Peak Stage and Discharge Data for Major Floods

Station	Miles Above Mouth	Flood Stage (feet)	1952 Floods Date	1952 Stage (feet)	1952 Discharge (cfs)	1951 Floods Date	1951 Stage (feet)	1951 Discharge (cfs)	1943 Floods Date	1943 Stage (feet)	1943 Discharge (cfs)	1903 Flood Date	1903 Stage (feet)	1903 Discharge (cfs)	1881 Flood Date	1881 Stage (feet)	1881 Discharge (cfs)	1844 Flood Date	1844 Stage (feet)	1844 Discharge (cfs)	Highest of Record Date	Highest Stage (feet)	Highest Discharge (cfs)
Williston	**1650.2**	**20**	**Apr 1**	**17.8**	**170,000**	**Apr 8**	**16.8**	**110,000**	**Mar 28**	**19.8**											**Mar 28, 1943**	**19.8**	
									Mar 30	**-**	**204,000**										**Apr 4, 1930**	**-**	**231,000**
Elbowoods (a)	**1504.0**	**17**	**Apr 5**	**25.2**	**360,000**	**Apr 6**	**16.0**		**Mar 31**	**21.1**	**241,000**										**Apr 5, 1952**	**25.2**	**360,000**
						Apr 11	**-**	**94,000**															
Garrison (b)	1455.0	1690	Apr 5	1701.6	348,000	Apr 7	1693.6	130,000	Apr	1696.3											Mar 27, 1947	1704.0	
																					Apr 15, 1952		348,000
Bismarck	1377.8	19	Apr 6	27.9	500,000	Apr 4	16.3		Apr 1	22.7					Mar 30	31.6					Mar 30, 1881	31.6	
						Apr 5		130,000	Apr 3	-	282,000										Apr 6, 1952		500,000
Mobridge	1250.6	16	Apr 9	25.1	435,000	Apr 4	14.8	195,000	Mar 28	19.6											Apr 9, 1952	25.1	435,000
									Apr 5	-	282,000												
Pierre	1117.6	15	Apr 10	25.4	440,000	Apr 8	12.3	127,000	Apr 6	19.6	281,000	Jun 25	9.8		Apr	23.0	259,000 (f)				Apr 10, 1952	25.4	440,000
Chamberlain	1012.9	18	Apr 11	25.6	440,000	Apr 8	11.5	113,000	Apr 7	19.3	(e)										Apr 11, 1952	25.6	440,000
Ft Randall (b)	922.0	1250	Apr 12	1258.9	447,000	Apr 8	1246.3	134,000	Apr 8	1252.6											Apr 12, 1952	1258.9	447,000
Yankton	840.4	12	Apr 13,14	15.5	480,000	Mar 28	11.9	134,000	Apr 9	13.6					Apr 5	30.5					Apr 5, 1881	30.5	
									Apr 8	-	282,000										Apr 13,14 1952		480,000
Sioux City	760.0	16	Apr 14	24.3	441,000	Apr 8	13.0	152,000	Apr 10	18.7	212,000	Jul 10,11	12.3		Apr 23	22.5	362,000 (f)				Apr 14, 1952	24.3	441,000
Decatur (b)	715.7		Apr 15	23.3	(e)	Apr 9	16.6	(e)	Apr 11	20.5	(e)										Apr 15, 1952	23.3	
Blair	670.4	19	Apr 17	23.5	(e)	Apr 12	19.0	(e)	Apr 12	21.4	(e)				Apr 24	19.7					Apr 17, 1952	23.5	
Omaha	632.0	19	Apr 18	30.2	396,000	Apr 11	18.2	152,000	Apr 13	22.4	-	Jun 1	14.4		Apr 25	24.6	370,000(f)				Apr 18, 1952	30.2	396,000
									Apr 12	-	200,000												
Plattsmouth (b)	607.5	952.5	Apr 18	961.4	(e)	Apr 11,12	954.5	(e)	Apr 14	957.6	(e)	Jun 1	11.2		Apr 25	957.9					Apr 18, 1952	961.4	
Nebraska City	579.3	18	Apr 18	27.7	414,000	Jun 2	18.5		Apr 14	19.9	181,000				Apr 27	18.1	380,000(f)				Apr 18, 1952	27.7	414,000
						Mar 29		163,000															
Brownville (b)	552.0	15	Apr 17	29.8	(e)	Jun 3	21.5	(e)	Apr 16	19.9	(e)										Apr 17, 1952	29.8	
Rulo	514.4	17	Apr 22	25.6	358,000	Jun 3	21.0	175,000	Apr 17	20.2	(e)										Apr 22, 1952	25.6	358,000
St. Joseph	460.3	17	Apr 22	26.8	397,000	May 3	19.9	198,000	Jun 18	18.5		Jun 2	20.5	252,000(c)	Apr 29	27.2	370,000	Jun	24.5	350,000(e)	Apr 29, 1881	27.2	
									Apr 18	-	154,000										Apr 22, 1952		397,000
Leavenworth (b)	408.2	19	Apr 23	27.6	(e)	Jul 8	20.8	(e)	Jun 19	23.1	(e)				Apr 30	23.1					Apr 23, 1952	27.6	
Kansas City	377.5	22	Apr 24	30.6	400,000	Jul 14	36.2	573,000	Jun 19	29.1		Jun 2	35.0	548,000(c)	Apr 30	27.8	373,000	Jun 16	38.0	625,000(e)	Jun 16, 1844	38.0	625,000 (c)
									Jun 18		336,000												
Napoleon (b)	332.4	17	Apr 24	24.6	(e)	Jul 14	26.8	(e)	Jun 19	22.4	(e)										Jul 14, 1951	26.8	
Waverly	297.2	18	Apr 24	28.1	369,000	Jul 14	28.2		Jun 18	24.4											Jul 14, 1951	28.2	
						Jul 16		549,000	Jun 19	-	310,000										Jul 16, 1951		549,000
Glasgow (b)	226.8	25	Apr 27	32.1	358,000	Jul 17	36.7	550,000	Jun 21	33.3	(e)	Jun 5	32.7(c)		May 3	28.2(c)					Jul 17, 1951	36.7	550,000
Boonville	196.7	21	Apr 27	27.7	360,000	Jul 17	32.8	550,000	Jun 22	28.8	366,000	Jun 6	30.9	612,000(c)	May 3	23.3		Jun 21	32.7	710,000 (c)	Jul 17, 1951	32.8	
																					Jun 21, 1844		710,000 (c)
Jefferson City (b)	143.0	23	Apr 27	26.1	(e)	Jul 18	34.2	(e)	Jun 23	30.1	(e)	Jun 6	33.5		May 4	26.3(c)					Jul 18, 1951	34.2	
Gasconade (b)	103.9	22	Apr 27,28	29.2	(e)	Jul 19	35.4	(e)	May 21	34.2	(e)										Jul 19, 1951	35.4	
Hermann	96.9	21	Apr 28	27.1	368,000	Jul 19	33.3	618,000	May 21	31.1	550,000	Jun 6,7	29.5	676,000(d)	May 4	23.7		Jun	35.6	892,000(d)	Jun 1844	35.6	892,000(d)
Washington (b)	66.8	20	Apr 28	24.4	(e)	Jul 19	31.0	(e)	May 22	28.6	(e)										Jul 19, 1951	31.0	
St. Charles	28.1	25	Apr 29	31.8	(e)	Jul 20	37.3	(e)	May 22	36.6	(e)	Jun 8	36.8	730,000 (c)	May 5	31.6		Jun 27	40.1	900,000 (c)	Jun 27, 1844	40.1	900,000 (c)

Note: Stages are from gage readings reported by the U.S. Weather Bureau unless otherwise noted. Discharge values are those reported or published by the USGS unless otherwise noted. Discharge values are given for the flood of 1903, 1881 and 1844 where such estimates are available.

(a) USGS gage (b) Corps gage (c) Data from 308 Report (d) Estimated by Kansas City District (e) Stage only station (f) Estimated by Omaha District

A-02.2. Floods of 1881. The floods of March-April 1881 include the second greatest flood of record on the Missouri River in the Dakotas, and the "June rise" in 1881 was one of the largest of the late spring rises. The flood year of 1881 had the greatest total cumulative runoff volume of record on the Missouri River between Bismarck, ND and St. Joseph, MO. Following a wet year in 1880, the winter of 1880-81 experienced much-below-normal temperatures accompanied by very heavy plains snow. This resulted in the heaviest known snow blanket on the plains area by the spring of 1881. Spring thaws and ice breakup began in the upper basin in late February and early March while the downstream river was still frozen, resulting in huge ice gorges in the Dakotas. This first rise was checked by a short period of cold weather during which additional precipitation occurred and after which temperatures throughout the plains area rose to well above normal to complete the release of water from snow and ice. The estimated peak stages and discharges of the early spring-type 1881 flood at Missouri River main stem locations are shown on Table A-1. The peak stage of 18.5 feet above flood stage at Yankton, SD is the highest known rise above flood stage on the Missouri River and 15 feet higher than any other known stage at that station. This extremely high stage resulted from a tremendous ice jam extending from below Yankton to Vermillion, SD, filling the river channel for a distance of over 30 miles with solid ice rising in places to a height of over 30 feet above the surface of the water. The total flood volume in March-April 1881 has been estimated at approximately 15 MAF at Pierre and almost 18 MAF at Sioux City, IA. It is known from hydrologic records and gage heights along the Missouri River that the 1881 early spring flood was followed by one of the wettest summers of record. An estimated peak mean daily discharge of 184,000 cfs occurred at Yankton on June 14. An estimated total volume of flood runoff at Sioux City during the March-July 1881 period was more than 40 MAF, which greatly exceeds the volume of runoff for any other year at this location except for 48.4 MAF in 2011. The severe flood sequence, as reconstructed from available stage records, served as the primary basis for the design of the flood control storage space in the System.

A-02.3. Flood of 1903. The severe flood on the lower Missouri River in May and June 1903 resulted from conditions similar to those that caused the flood of 1844. Excessive rainfall occurred through the lower basin during the first half of May, which saturated the soil and resulted in much-above-normal tributary flows. From May 16-31, rainfall occurred almost every day through the lower basin states of Iowa, Nebraska, Kansas and Missouri. More intense bursts were observed from May 21-23. When heavy bursts again occurred from May 28-30, the extreme flood developed. Rainfall for the month of May totaled over 17 inches at stations in Iowa, Nebraska and Kansas. During the period from May 25-31, a total of 16.8 inches of rainfall occurred at Abilene, KS. Flood flows were of only moderate size in the upstream reaches, but below Omaha, NE, the heavy rains resulted in the most damaging flood experienced to that time through the lower reaches of the Missouri River. Although stages were somewhat lower than in 1844, as shown in Table A-1, increased development of the Missouri River valley resulted in greater damages. This flood was also especially severe on the lower Kansas River and its tributaries. At some locations, maximum record stages were established that have never been exceeded.

A-02.4. Flood of 1908. The flood of June 1908 is the greatest ice-free flood known on the Missouri River through Montana and North Dakota. It resulted from general rains in May climaxed by one of the region's greatest rainstorms in June in conjunction with significant mountain snowmelt runoff. Estimated peak discharges during this flood were 155,000 cfs at the

Fort Peck damsite; 240,000 cfs at Williston, ND; 225,000 cfs at Bismarck, ND; 182,000 cfs at Pierre, SD; and 187,000 cfs at Yankton, SD. As the flood peak passed downstream, it coincided with runoff from heavy rainfall in the lower basin. This resulted in extensive flood damage through the downstream reaches, although the peak stages and discharges were not of record proportions.

A-02.5. Flood of 1927. Flooding occurred in April 1927 over the lower Missouri River basin largely as a result of rainfall runoff originating in this portion of the basin. Rainfall over the lower basin during March had been considerably above normal while April was the wettest month recorded for so early in the flood season in the lower basin states of Kansas and Missouri. The resulting flood was unique for a flood at this time of the year in that the upper basin made only minor contributions to peak stages and discharges on the lower Missouri and Mississippi Rivers. In the upper Missouri River basin, the high-altitude snowpack ranged from about normal to slightly above normal at the end of March, although snow cover over the plains area at this time was virtually nonexistent. During April, precipitation in the upper basin ranged from slightly-above to much-above normal. This was followed by an exceedingly wet May through all of the upper basin states. In addition to contributing directly to streamflow, the heavy April and May precipitation resulted in substantial snow accumulations in the mountainous areas of the basin. Maximum floods of record occurred on some tributary streams in South Dakota during May. Missouri River flows at and above Sioux City during the May-July period were notable for their large volume, high flat peaks, and very large recession volumes. The 1927 calendar year runoff above Sioux City was 37.0 MAF, adjusted to the 1949 level of water resource development, and was the greatest known at that time since record-keeping began in 1898. Lower basin runoff during the late spring and summer of 1927 was only moderate and did not compound the flood flows originating from the upstream areas.

A-02.6. Floods of 1943. Above-normal precipitation during the winter of 1942-1943, augmented by a heavy 4-day snowstorm in the middle of March over the Dakotas, resulted in a near-record snow cover by winter’s end in both the northern plains and mountain regions. Above normal temperatures occurring in late March and early April resulted in rapid melt of the plains snow cover over ice-sheathed and frozen ground that, in turn, resulted in a significant flood. The formation of ice jams and subsequent progressive release of the water impounded behind them contributed considerably to high peak discharges through both North Dakota and South Dakota. Missouri River peak discharges above 200,000 cfs occurred from Williston to Omaha, with peaks near 280,000 cfs from Bismarck to Yankton. As the April flood wave progressed downstream from Omaha, flows receded. Serious damages, however, extended to just above Kansas City, with only minor flooding below that point. The total volume of runoff in March and April was comparatively small, amounting to only 8.8 MAF above Sioux City and 1.9 MAF above Fort Peck, which was impounded in Fort Peck reservoir. The March and April flood was closely followed by a flood in May that developed in the lower basin. This flood was a result of heavy rainfall over southeastern Kansas and in the south and central portions of Missouri. At the Mississippi River at St. Louis, stages in May 1943 were higher than any since 1844, although the peak discharge of 840,000 cfs may have been exceeded in 1903. On the Missouri River at Hermann, a peak discharge of 550,000 cfs occurred on May 21. Peak stages and discharges along the Missouri River in 1943 are shown in Table A-1. During June and July 1943, relatively high discharges again prevailed on the Missouri River in the Dakotas as a result of the melt of the heavy mountain snow cover and above-normal rainfall in the upper basin. A total volume of about 8.2 MAF passed Sioux City during the 2-month period, while 3.8 MAF was stored in Fort Peck. During the same period, the lower basin states also experienced heavy rains that considerably augmented the flow originating upstream and resulted in extensive flooding from Rulo, NE to the mouth of the Missouri River. A peak discharge of 236,000 cfs occurred at Kansas City on June 18, where the 2-month volume exceeded 15 MAF.

A-02.7. Flood of 1944. The March and April period of 1944 was characterized by only moderate rises on the Missouri River above Bismarck, where a peak flow of 136,000 cfs was observed. Heavier snow accumulations through southern North Dakota and South Dakota added materially to the flood volume and increased the peak at Sioux City to 180,000 cfs. Downstream of Sioux City, the April 1944 flood is noteworthy because of the synchronizing of the flood wave as it moved down the river with runoff from general rains through the middle Missouri River basin followed by runoff from heavy rains in the lower Missouri River basin. This resulted in peak flows that exceeded any recent record at that time at many of the downstream stations, and even the high flows of 1943 were exceeded on the Missouri at Hermann and on the Mississippi at St. Louis. June 1944 was one of the wettest months of record through the upper Missouri River basin. The combination of excessive rainfall runoff with the melt of the mountain snow accumulation resulted in 10.5 MAF of flow past Sioux City with 2.4 MAF stored in Fort Peck during the June-July period. This represented the greatest volume of runoff originating in the upper Missouri River basin during a comparable late spring period since intensive streamgaging began in 1929. A 2-month volume of 10.5 MAF is equivalent to an average daily flow of about 87,000 cfs.

A-02.8. Flood of 1947. In March and April 1947, a flood was caused by a combination of ice jams and a relatively small amount of snowmelt runoff from streams draining portions of Montana, Wyoming, North Dakota and western South Dakota. Although peak stages were generally less than those of the 1943 flood, Missouri River peak flows at locations in North Dakota exceeded 250,000 cfs while the river stages experienced were the highest up to that time, exceeding both the estimated 1881 and observed 1943 peak stages. High flows on the Missouri River again occurred in June and July in the Dakotas as a result of runoff from heavy rains and mountain snowmelt. Peak flows increased progressively from 104,000 cfs at Bismarck to 171,000 cfs at Sioux City. In the lower Missouri River basin, the months of March through May 1947 were all wetter than normal. June was extremely wet throughout the basin. Runoff from this extraordinary series of excessive rains occurring in June was supplemented by the upstream river rises, which resulted in the highest stages since 1844 at several stations between Plattsmouth, NE and the mouth of the Missouri River and on the Mississippi River at St. Louis.

A-02.9. Flood of 1951. Prior to 1951, the 1844 flood had been the “great” lower Missouri River basin flood. The estimated stages and discharges of that historical flood were generally accepted, although somewhat discounted, for lack of official supporting data. A considerable amount of hydrologic data was assembled prior to, during, and after the rise and fall of the 1951 flood, and these data lend support to the belief that major floods of the magnitude of the 1844 flood were possible. May and June precipitation over the Kansas River basin was above normal by amounts of 2.66 and 5.58 inches, respectively. The intense rains from July 9-13 resulted in sustained and widespread flooding, which was the greatest in recent years. Rainfall accumulated to 18.5 inches at the storm center during this 5-day period and averaged 8 inches over 30,000 square miles of eastern Kansas. Peak stages occurred on the Kansas River and its tributaries within a 4-day period, July 11-14. The Missouri River at Kansas City peaked on July 14. Fortunately, the peak from the Kansas River coincided with relatively low flows from the upper Missouri River. At Kansas City, the Missouri River remained above flood stage until July 21. The Missouri River peak passed the mouth of the Missouri River on July 21. By August 1, the lower river fell below flood stage. Peak discharge at the lowermost Kansas River station, Bonner Springs, KS, was 510,000 cfs on July 13. On the Missouri River at Kansas City, the peak was 573,000 cfs, and at Hermann, the Missouri River peaked at 618,000 cfs on July 19. Other peak stages and discharges are shown in Table A-1.

A-02.10. Flood of 1952. The flood of April 1952 in the Missouri River basin was of exceptional magnitude and severity on the Missouri River and most of the tributary streams that join the Missouri River at and above Sioux City. On the Missouri River, flooding was continuous from the Yellowstone River to the mouth. In most of the reach between Williston, ND and the mouth of the Kansas River, a distance of about 1,250 river miles, this flood was the greatest of record. The 1952 flood established record flows throughout and record stages at all locations from the Yellowstone River to the mouth of the Missouri River, except for a few isolated locations where previously established record stages resulting from severe localized ice jams were not surpassed. Flooding generally occurred on all major tributaries of the Missouri River between, and including, the Milk River in Montana and the Floyd River in Iowa, with the exception of the Niobrara River in Nebraska. On many of these tributaries, stages and discharges approached previously established records, and on some, new record stages and discharges were established. Normal winters in the upper Missouri River basin include periods of warm weather sufficiently mild to permit intermittent thawing of the snow cover over appreciable areas. Of particular significance during the winter of 1951-1952 was the absence of the usual periods of thawing. Thawing periods instead were supplanted by unusually continuous low-temperature periods. At the end of March, one of the heaviest snow covers in the history of the upper plains was present. Snow surveys completed at the time of maximum snow accumulation on March 20 indicated a water content in the snow cover ranging from 2.4 inches over about 10,000 square miles in the Yellowstone River basin up to 3.6 inches over much of the Grand River basin in South Dakota. A water content of over 6 inches was present in the lower Grand and Moreau River basins and on the eastern edge of the Big Sioux River basin. The water content of the 1951-1952 snow cover was approximately equaled over portions of the basin in previous years but not over nearly as extensive an area. For example, the snow cover over eastern South Dakota was nearly as great in 1950-1951 as it was in 1951-1952. Similarly, the snow cover over the right bank tributary basins in North Dakota and South Dakota was nearly as great, and over some localized areas even greater in 1949-1950, as it was in 1951-1952. The heavy snow cover of 1951-1952, however, extended over both of these areas and others as well, including the lower Yellowstone River basin in Montana. Severe flooding along the Missouri River began late in March from rapid melting of snow cover in the lower Yellowstone and Little Missouri River basins and over the upstream portions of the Missouri River tributaries in the western Dakotas. With few exceptions, the peak outflows of the western Dakota tributaries were synchronized with the peak flow on the Missouri River. Coincidence of tributary outflows was, in large part, due to release of tributary water that had been ponded behind ice jams formed against the solid ice cover of the Missouri River. Throughout North Dakota, movement of the floodwater downstream was hampered by successive ice jams, which greatly increased stages and discharges. The Missouri River peaked at Williston, ND on April 1, with a peak stage and discharge below previous records. At Elbowoods, ND, below the mouth of the Little Missouri River, the flood peaked on April 5, establishing a record stage and flow of 25.2 feet and 360,000 cfs, respectively. The Missouri River flood peak occurred on April 6 at Bismarck, establishing a record discharge of 500,000 cfs. This discharge was more than 75 percent higher than the previous record discharge; however, the record stage established in 1881 was not exceeded. The flood peak reached Mobridge, SD on April 9; Pierre, SD on April 10; Chamberlain, SD on April 11; Yankton, SD on April 13; and Sioux City, IA on April 14. The flood peak moved through most of South Dakota, with peak discharges of 440,000 to 450,000 cfs. An even higher peak discharge of 480,000 cfs occurred at Yankton due to additional tributary inflow. Below Yankton, peak discharges reduced gradually as the flood wave moved downstream. Throughout South Dakota, past maximum-recorded discharges were exceeded by as much as 70 percent. Past record stages were similarly exceeded at all stations in South Dakota except Yankton, where the record stage was established by the exceptionally severe ice jam below Yankton during the 1881 flood. Below Sioux City, the flood continued to establish new record stages and discharges as far downstream as St. Joseph. The peak reached Omaha on April 18; Nebraska City on April 18; Rulo on April 22; and St. Joseph on April 23. The coincidence of the peak at Omaha and Nebraska City resulted from the valley storage provided by failure of major levee units that reduced the Omaha peak to less than that prevailing at Nebraska City on April 18. At St. Joseph, the peak discharge exceeded the previous high discharge of record, but the record stage established during the 1881 flood, although approached, was not exceeded. Below St. Joseph, the flood did not equal previously-established record stages or discharges. Throughout the entire reach from St. Joseph to the mouth, however, the 1952 flood continued to be a flood of major proportions. Peak stages and discharges that occurred during the 1952 flood are listed in Table A-1. The flood of April 1952 was a plains snowmelt flood, due entirely to runoff from melting of the winter's accumulation of ice and snow over the plains areas of the upper basin. The great magnitude of the flood was due to several factors that include the unusual areal coverage of the accumulated plains snow cover, the high water content of the snow cover at the time melting began, the rapidity with which melting took place, the frozen conditions of the ground, and the presence of an ice layer beneath the snow cover that resulted in a very high percentage of the snow's water content reaching the stream channels as runoff. Rainfall over the basin prior to and during the flood period was light, and runoff from rainfall did not add to the peak discharges.

A-02.11. Flood of 1960. The 1960 plains-area snowmelt flood was the first major flood occurrence since integrated System operations began in 1954. Fort Randall Dam was closed in July 1952, Garrison Dam in April 1953, and Gavins Point Dam in July 1955. All of these dams, in addition to Fort Peck Dam, contributed to the prevention of downstream flood damages during this flood. Snow accumulations during the winter months prior to the flood were very large, particularly over the plains areas of South Dakota, western Iowa, Nebraska and Kansas. Melting of this snow in late March and early April caused record high floods on some tributary streams in the area and general flooding along the Missouri River downstream from the mouth of the Platte River in Nebraska. Inflows to the System were particularly large downstream from Oahe Dam. In the process of controlling the flood, the Gavins Point reservoir level rose to 1210.7 feet, 0.7 foot into the Surcharge Zone, resulting in overtopping of the closed spillway tainter gates. Outflows from Fort Randall Dam contributed less than 1,000 cfs; however, high inflows between Fort Randall and Gavins Point dams required releases of 32,000 cfs from Gavins Point Dam. System storage gains during late March and April were about 5 MAF. Stages on the lower Missouri River were as much as 8 feet above established flood stages, resulting in damages of approximately $17 million. Without the regulation provided by the System reservoirs that were already in place, peak stages would have been about 5 feet higher throughout the flooded area. The unregulated peak flow at Gavins Point Dam was estimated to be 210,000 cfs, considerably more than the actual maximum release of 32,000 cfs. Flood damages prevented by System reservoirs and local protective works (e.g., levees) were estimated to be about $200 million.

A-03. Major Floods Occurring Since the System Filled in 1967. Several major floods would have occurred or would have been much worse had the construction of the System not been completed. This section of Appendix A provides some information on these events and the effectiveness of the System in reducing flood damages.

A-03.1. Floods of 1967. One flood occurred in the spring of 1967, and a second one was prevented by the System from occurring. During June 1967, intense rains over the lower basin states of Nebraska, Kansas and Missouri caused severe flooding along many Missouri River tributary streams and along the main stem of the Missouri River from the Platte River downstream to the mouth. Some observed Missouri River peak stages were nearly 10 feet above flood stage and over 500,000 acres of agricultural land were inundated. The failure of 171 local levees during the flood contributed to the flooding. During the last half of June, Missouri River stages were so high that navigation was halted to protect water-soaked local levees from the wakes caused by the towboats. In the Missouri River headwaters areas of Wyoming, mountain snows accumulated at a greater-than-norma1 rate. By May 1967, many mountain snow courses were reporting record high total snow water contents. During late May and continuing through June, heavy upper basin rains coincided with the melt of this mountain snow. This resulted in the eighth highest May-July runoff volume (1898-2017) of record above Sioux City. The System eliminated all flood damage that otherwise would have occurred through the reach extending from Fort Peck Dam to the mouth of the Platte River. At Sioux City, the regulation effects resulted in a peak discharge reduction of almost 200,000 cfs. Total actual flood damages along the Missouri River amounted to over $125 million. The damages prevented by all federal reservoirs and downstream federal levees were estimated at about $600 million, of which over $250 million was credited to the System.

A-03.2. Flood of 1975. During 1975, flood runoff from the drainage area controlled by the System exceeded that occurring in any previous year during the period of available record extending from 1898 to 1975, except for 1927. This runoff was the result of the melting of the mountain snowpack and spring and early summer rainfalls in a large area of the upper basin. The March-July runoff volume above Fort Peck was nearly 10 MAF, more than two times average. Runoff above Garrison during the March-July period was nearly 22 MAF, almost two times average. The rainfall event of June 18-20 is often referred to as the “Great Falls Flood.” The center of the storm had rainfall totals of over 14 inches, while a 10,000-square-mile area received an average rainfall exceeding 6 inches, resulting in a considerable amount of flood damage. In the process of regulating this unprecedented runoff, three of the System projects (Fort Peck, Garrison and Oahe) exceeded previous maximum reservoir elevations while sustained releases from all projects were at higher rates than any previous release. All maximum release rates were well below the flow rates that occurred frequently prior to the regulation of the full System; however, continuation of relatively low outflows for over 30 years of System regulation has adversely affected the downstream channel capacity, primarily due to encroachment upon the downstream floodway. Landowners have cleared and placed under cultivation low-lying floodplain areas adjacent to the river, areas that would have been frequently flooded prior to construction of the dams. Another factor affecting the flood damage potential has been deterioration in the capability of the Missouri River channel to pass flows of a moderate magnitude. For example, at Bismarck a stage of 13 feet reflected a flow of about 90,000 cfs prior to the construction of Garrison Dam in the 1950s. In 1975, flows slightly in excess of 50,000 cfs resulted in a stage of that magnitude. Another effect of the low releases was the growth of the Niobrara River delta below Fort Randall Dam that significantly reduced channel capacity through about a 10-mile reach of the Missouri River above the Gavins Point reservoir delta. Maintenance of relatively stable flows through the portions of the Missouri River above the Platte River also resulted in considerable recreational development, such as the construction of boat docking facilities in low lying areas adjacent to the channel. These effects are recognized in the regulation of the reservoirs. In large flood years, such as occurred in 1975, problems associated with higher-than-average releases occur.

A-03.3. Flood of 1978. The volume of runoff into the System during 1978 (40.6 MAF) was the third highest on record (1898-2017). Drought conditions persisted through the first half of 1977 but gave way to normal precipitation during the fall. On January 1, mountain snowpack was 150 percent of average. Extreme cold persisted through February. By March 1, mountain snowpack was 130 percent of average and a heavy plains snowpack had also accumulated. The snow covered an extensive area of the plains and was much greater than normal. Water equivalents were generally 2 inches, but several areas were as high as 6 inches. The persistent cold weather prevented any melt of the plains snowpack. Heavy rains occurred both upstream and downstream of the System during March and April. The three significant runoff-producing events in the upper basin during 1978 were the March and April plains snowmelt (14.0 MAF, 240 percent of average), May rainfall, and June and July mountain snowmelt. While several of the months were very high runoff months, none exceeded historic maximums. The annual runoff totaling 40.6 MAF has a 5 percent chance of occurrence, according to the runoff frequency analysis performed following the 2011 flood. System storage was only 51.6 MAF on March 1, 6.4 MAF below the base of the Annual Flood Control and Multiple Use Zone, due to a below-average water supply in 1977. The March 1 calendar year runoff forecast for 1978 was 31.2 MAF. Even though System storage was below average for that time of year, full service flow support was provided by the beginning of the navigation season. This provided an early evacuation of expected above-average runoff. During March, System storage increased 6.9 MAF, a record monthly increase at that time. The maximum daily gain of 720,000 acre-feet was recorded on March 27, and a maximum weekly gain of 3.9 MAF occurred between March 25 and March 31. System releases were significantly reduced during both March and April due to the large amount of plains snowmelt entering the Missouri River downstream of Gavins Point Dam. During March and April, the runoff summation above Sioux City, IA was 14.0 MAF, about 240 percent of average. By May 1, the runoff forecast was increased to 33.0 MAF, 135 percent of average. Due to runoff from heavy precipitation that fell both upstream and downstream of the System, by the last week in May System releases from Gavins Point Dam were increased to 10,000 cfs above full service to provide adequate evacuation of System storage in the flood control zones prior to the following runoff season (approximately March 1). May runoff was 6.0 MAF, the fourth highest May runoff (1898-2017). The runoff accumulated during March through May totaled 20.0 MAF, 11.0 MAF greater than average and the fourth highest for this 3-month period (1898-2017). The annual runoff forecast, updated on June 1, was raised to 37.5 MAF, 150 percent of normal. System releases from Gavins Point Dam were increased to 42,000 cfs. System storage climbed to 68.0 MAF on July 1, and the runoff into the

System during the first six months of 1978 was 27.6 MAF, the fourth highest on record (1898-2017). At that time it exceeding the previous record of 27.4 MAF established in 1952. System releases were further increased to 48,000 cfs. Higher System releases would have been preferred but provision of downstream flood control necessitated that releases be held to 48,000 cfs. System storage peaked at 69.3 MAF, 0.4 MAF below the base of the Exclusive Flood Control Zone, on July 23. The annual runoff forecast, updated on August 1, was 39.1 MAF. System releases were 50,000 cfs during August and September. The System was out of balance with Fort Peck 3.6 feet into its Exclusive Flood Control Zone, and both Garrison and Oahe slightly below their respective base of Exclusive Flood Control Zones. Refer to Chapter VII and Section A-06 for details on System storage zones. System releases were increased to 52,000 cfs on October 9, based on the October 1 updated annual runoff forecast of 39.3 MAF. The 52,000 cfs System release was maintained until the end of November, when releases were reduced to end flow support for navigation. On December 1, System storage was at 60.4 MAF, 2.4 MAF above the base of the Annual Flood Control and Multiple Use Zone. A winter System release of 23,000 cfs was maintained to evacuate the stored flood waters before the start of the 1979 runoff season. The total runoff for 1978 above Sioux City was originally computed to be 39.5 MAF, but later revised to 40.6 MAF based on some Gavins Point Dam spillway discharge rating adjustments. Extremely cold temperatures entered the basin during the first week of December, and the Fort Peck and Garrison downstream river reaches froze over. Over $450 million in flood damages were prevented by the System in 1978. Basin conditions in early 1978 represented one of the few times that both a large plains snow and large mountain snow occurred at the same time. The 1978 and 1975 runoff events resulted in many operational studies of the System to determine the best System regulation approach to follow to handle such events. Early releases of a greater-than-required magnitude, or pre-releasing, was established as the best method to provide maximum downstream flood protection and assure System project safety during such events. This event, and the 1975 flood event, were evaluated and summarized in great detail for future regulation guidance in System regulation reports.

A-03.4. Floods of 1984. The winter of 1983-84 began with record cold temperatures and a heavy plains snow cover. Over 460 miles of the Missouri River was frozen over from Gavins Point Dam to Jefferson City, MO. The first flood of the year occurred in April 1984. A late March snowstorm dropped heavy snow over a large area spanning from South Dakota to Missouri. Persistent rains of 2 to 4 inches, resulting in near record stages on the James and Vermillion Rivers, followed this storm. April runoff in the reach from Gavins Point to Sioux City was the fourth highest on record (1898-2017). System releases were reduced to an average of 15,500 cfs during the month of April to lessen downstream flooding. Fort Randall Dam minimum daily average releases during the month were 2,300 cfs to support downstream flood control. The Fort Randall reservoir rose to 1363.2 feet, the highest since 1972. A considerable amount of downstream flood control damage was prevented in the Missouri River reach from Omaha to St. Joseph. The Missouri River at Nebraska City peaked at a stage of 19.8 feet, 1.8 feet above flood stage, and the river remained above flood stage for 18 days. The Missouri River stages at St. Joseph and at Hermann were above flood stage for nearly 30 days during this event. The second flood of the season resulted from a series of downstream rainfall events that occurred in June 1984. Three separate storms on saturated soils during June resulted in significant runoff and flooding. Some of the events had 11-inch rainfalls in a single storm. In one case, this high rainfall occurred following a week when over 9 inches of rain fell on the same area. Several rivers experienced record flows during June 1984. Those of greatest significance were the James

River at Scotland, SD; Vermillion River at Vermillion, SD; Little Sioux at Turin, IA; Salt Creek at Greenwood, NE; and Platte River at Louisville, NE. These were the highest flows and resulting flooding that had occurred in the Missouri River basin since the 1952 flood. The System was regulated to provide maximum downstream flood control. The flood peak was reduced by 61,000 cfs by System regulation. Still, much of the runoff occurred in the uncontrolled area below the System. The Oahe reservoir peaked at elevation 1618.3 feet, 1.3 feet into its 3-foot Exclusive Flood Control Zone. This was the highest pool level since the System first filled in 1967 and 0.4 foot higher than the previous maximum in 1975. Garrison peaked 0.5 foot below the base of its Exclusive Flood Control Zone as a result of reduced releases in all of the System projects for downstream flood control. At that time, record monthly low releases were set at Gavins Point Dam for April, May and June. Even with the low System releases, the Missouri River was above flood stage for over a month from Nebraska City to the mouth. Flood damages prevented by the System in 1984 were $203 million. The USCG closed the Missouri River for navigation from June 8 to July 8 in various reaches because of the high downstream flows.

A-03.5. Floods of 1986. Runoff above Sioux City, IA in 1986 was 36.2 MAF, the seventh highest on record (1898-2017) and a greater-than-upper-decile runoff. Based on historical record since 1898, an upper decile runoff is exceeded only 10 percent of the time. Several floods combined to produce the high runoff in 1986. The first flood occurred in late February and early March when unusually warm temperatures caused a rapid melt of the plains snowpack that had accumulated over ground that was frozen, which amplified the peaking and volume of runoff. Runoff into Garrison during March was the second highest on record (1898-2017). Several of the tributaries in Montana and North Dakota nearly reached the record levels established in 1952. The System captured 4.3 MAF of runoff in 21 days. Unregulated flows would have been near 100,000 cfs at Garrison Dam and 150,000 cfs at Gavins Point Dam. The majority of the runoff was captured in the System, but Nebraska City experienced actual peak flows in the 100,000 cfs range from contributions from downstream tributary flow contributions. The unregulated flow at Nebraska City would have been 240,000 cfs and resulted in significant flood damages.

A-03.5.1. The large volume of runoff into the System combined with the below-normal System release resulted in the Oahe reservoir reaching a then-record pool level of 1618.5 feet, 1.5 feet into its 3-foot Exclusive Flood Control Zone. The James River remained above flood stage for 100 consecutive days from March 19 to June 26. The Missouri River ran bluff to bluff above Sioux City. Stage reductions, ranging from a high of 10 feet at Sioux City (unregulated peak stage of 34.0 feet) to 7 feet at Nebraska City (unregulated peak stage of 24.5 feet), were provided by the System during this period. A considerable amount of flood damage was avoided downstream. In September, heavy rainfalls of 7 to 8 inches were reported near Fort Peck and in the Milk River basin during a 24-hour period on September 24-25. Fort Peck inflows increased from 8,000 cfs to 160,000 cfs in one day, the highest one-day inflow ever recorded at Fort Peck. Garrison inflows peaked at 55,000 cfs. These two reservoirs were able to store this runoff and no flooding below Garrison Dam resulted from the heavy rainfall event. Over $15 million in damages were prevented at Wolf Point and Culbertson, MT and Bismarck, ND. Total flood damages prevented in 1986 were $279.3 million.

A-03.6. Floods of 1987. The mountain snowpack accumulation for the winter of 1986-1987 was much below average at 63 and 69 percent of average in the reaches above Fort Peck and

Garrison Dams, respectively. Total runoff for the year was only 21.3 MAF, which is only 84 percent of average. Even under such dry conditions, a flood occurred. The plains snowpack was above normal in November, but the warmest winter since the 1930s in Sioux City and Omaha melted the snow from December through mid-February. During the last week in February, the weather turned cold, and snows and wet conditions prevailed. Over 20, to as much as 30, inches of heavy snow fell in the Bad River basin in western South Dakota during a late February snowstorm. During March, a significant amount of precipitation fell in the form of snow and rain below Gavins Point. March was a record-setting month for precipitation at Norfolk and Grand Island, NE and Concordia, KS. The warm temperatures during the first half of March ripened the snow. By mid-month, the rains came, causing plains snowmelt runoff. Two separate storms produced 1- to 2-inch rains over a considerable amount of North Dakota and South Dakota. In addition, 2 to 3 inches of rain fell from Pickstown, SD to the confluence of the Missouri and Grand Rivers in Missouri. Runoff into Oahe was very high and it reached a daily April maximum of 204,000 cfs. This high inflow was followed by inflows of 170,000 cfs and 147,000 cfs on subsequent days, all of which eclipsed the previous daily inflow record of 122,000 cfs. On March 22, System storage gained 478,000 acre-feet, a record 1-day System storage increase for the period of 1967 to 1987. System regulation resulted in downstream stage reductions of 10 feet at Pierre; 18 feet at Sioux City; 15 feet at Omaha; 9 feet at Kansas City; and 6 feet at Hermann. Several new record stages from Nebraska City, NE to Waverly, MO were averted by the flood control provided by the System. Flood damages prevented were $450.5 million in 1987, all occurring during the month of March.

A-03.6.1. A late May flood occurred on the lower Missouri River. A 5- to 8-inch band of rainfall, centered on southeastern Nebraska, fell in late May. These rains caused the Missouri River to go above flood stage from Plattsmouth to the mouth at St. Louis. Hardest hit areas were the lower Platte River basin in Nebraska and the Nishnabotna River basin in Iowa, which tied its previous record stage set in 1984. System releases were reduced from 30,000 cfs to 20,000 cfs to lessen downstream flooding. However, by the time the release reductions had made their way downstream, the peak stage and flow had already been observed. Because the rainfall occurred so far downstream and so close to the river, no flood damages were prevented. This event demonstrates that the System cannot reduce the impact of all prolonged high, downstream river stages at critical periods, particularly when suddenly-developing rainfall events occur in locations several days' travel time downstream of Gavins Point.

A-03.7. Floods of 1993. The Great Flood of 1993, as it was commonly called, caused a large amount of devastating, downstream flooding that occurred below the System. This flood also provides an example of how quickly the System refilled, or recovered, following a severe 6-year drought. The flood came as a surprise in that the plains and mountain snowpack accumulations were not significant. All indications were that the six previous years of drought would extend into 1993; however, that was not to be the case. The rains that came during the late spring, and persisted all summer, were spectacular in their intensity and duration. The rainstorms followed the same path across the basin repeatedly due to a blocking high-pressure system that persisted offshore in the Atlantic Ocean near the state of Georgia. References to the rainfall amounts were in feet because the rainfall totals for the summer were so high.

A-03.7.1. The regulation of the System in 1993 was fairly simple, in comparison to other floods. Due to the 6-year drought, a great amount of System storage space was available in addition to the 16.3 MAF of designated flood storage space. The March 1 System storage in 1993 was 43.0 MAF, 14.2 MAF below the base of the Annual Flood Control and Multiple Use Zone. The System release was reduced to minimum levels to meet other regulation objectives and to maximize downstream flood control. The secondary purpose of refilling the System was accomplished through record low releases while significant rainfall runoff upstream of the System was occurring. The System release averaged only 8,000 cfs during July. The System stored nearly 10 MAF during June, July and August. Due to high downstream flows, the USCG closed the Missouri River to navigation on July 3 and did not open it until August 20. This 57-day closure was the longest since the System closed in 1967.

A-03.7.2. The flood damages that occurred below the System were very high. The amount of actual damages dramatized the fact that the System provides less flood prevention as the distance downstream of the System increases. Record stages occurred on the Missouri River from St. Joseph to the mouth. Near-record stages occurred from Nebraska City to Rulo. Although the resulting damages totaled nearly $12 billion, the flood damages prevented by the System were a record level at the time. The System prevented over $4.4 billion in damages (original price levels) during 1993. A total of $15 billion in damages were prevented for all reservoirs and levees in the Missouri River basin. The most significant portion of the flood damages prevented occurred in the cities of Kansas City and St. Louis, where an overtopping of the urban levees was prevented due to flow reductions provided by the System. The stage reductions by the System were not dramatic but made the difference from the levees overtopping in these two metropolitan areas. The nearly $12 billion of actual damages makes the 1993 flood one of the worst floods in recent history in terms of actual damages. The 1993 flood resulted in a Congressional Report called the Galloway Report, which reported on analyses of alternative floodplain measures (e.g., levee setbacks or no levees), and effects on the flood stages, including the floodplain development in the Missouri and Mississippi River basins.

A-03.8. Floods of 1995. The first of two flood events resulted from the occurrence of a high plains snow accumulation accompanied by rains in April. The second flood was a result of the late melt of a much-above-average mountain snowpack in combination with heavy downstream precipitation during the melt period. As much as 50 to 60 inches of snow fell in the central plains of South Dakota during mid-April. Runoff from a late April rainfall event added to the flooding problems in the basin above Sioux City as some streams recorded record stages. The mountain snowpack accumulation, up to the normal peak accumulation date in mid-April, was average. Following mid-April, the mountain snowpack continued to accumulate and increased significantly. While the runoff from mountain snowmelt snowpack was stored in the System reservoirs, project releases were held at below-average levels during the mountain snowmelt period to provide downstream flood control. System storage peaked at 68.1 MAF on July 27, 0.7 MAF below the base of the Exclusive Flood Control Zone. Flood damages prevented by the System for 1995 were $1.8 billion, less than half of the 1993 flood damages prevented, and were the second highest annual damages prevented to date. System regulation during this flood event reduced Missouri River flows by over 110,000 cfs from Bismarck to Pierre. Also, System regulation reduced Missouri River flows approximately 100,000 cfs from Sioux City to Kansas City. All locations would have been significantly above flood stage without the regulation of the System. The peak stages would have occurred in late May or early June as a late-melting plains and mountain snowpack would have combined with significant downstream rainfall events to produce very damaging peak flows. The runoff during 1995 totaled 37.2 MAF above Sioux

City, which is 150 percent of average and the second highest runoff from 1898 to 1995. May runoff was the second largest May runoff of record, and the June and July runoff totals were the tenth and eleventh greatest from 1898 to 1995. Spillway releases were initiated from Gavins Point Dam on July 24 and the total release rate was 38,000 cfs, which was increased to 40,000 cfs on August 1. System releases were further increased to 54,000 cfs by mid-August and held for most of the fall period. System releases were eventually increased to 55,000 cfs in November as downstream tributary flows receded. Oahe peaked at an elevation of 1618.7 feet, which was 0.2 foot higher than the previous record set in 1986 and 1.7 feet into its 3-foot Exclusive Flood Control Zone.

A-03.9. Flood of 1996. The 1996 flood event resulted from a major accumulation and melt of late season mountain snowpack and heavy precipitation across the basin, which occurred several times during and after the melt. The System was scheduled to be, and would have been, at the base of the Annual Flood Control Zone on March 1 had not the largest February runoff of record, 340 percent of average, occurred. Record System releases were made from February through April to prepare the System for the anticipated snowmelt runoff. March mountain snowpack percentages were 114 percent of average above Fort Peck Dam and 124 percent of average between Fort Peck and Garrison dams. System releases on April 1 were scheduled at 10,000 cfs above full service. The service level was increased at 5000 cfs increments three times during May, reaching 25,000 cfs above full service on June 1. The late season mountain snowpack accumulation, which peaked the first week of May, delayed mountain snowmelt significantly, which increased the total runoff. Oahe tied a then-record reservoir level of 1618.7 feet, which was previously reached in 1995. This level was attained on June 23, following a prolonged reduction in System releases in response to downstream flooding. Some of the smaller tributaries below the System, such as the Little Sioux River (32,000 cfs), Monona-Harrison Ditch (10,400 cfs), Boyer River (27,000 cfs), Soldier River (21,400 cfs), and Floyd River (13,300 cfs), experienced very high peak flows, which contributed to nearly $13 million in actual damages on the Missouri River between Sioux City and Rulo. During the 1996 flood, System releases were scheduled to evacuate the ninth highest runoff (35.6 MAF) on record (1898-2017). Flood damages prevented by the System during 1996 totaled $1.6 billion.

A-03.10. Floods of 1997. The 1997 floods (spring plains snowmelt and mountain snowmelt floods) combined to form the second largest Missouri River basin flood event since 1898, in terms of total annual runoff volume above Sioux City. The total annual runoff of 49.0 MAF was almost twice average and has a 1 percent chance estimated annual frequency or one in 100-year recurrence interval. The 1997 flood event tested the flood control capabilities of the System and serves as a good example of the critical regulation decisions that the MRBWM office must consider when the runoff in the upper basin is forecast to be much above average.

A-03.10.1. The 1997 flood event, unlike the 1993 flood, was centered above the System; therefore, the System was able to manage and exert significant control over this flood, despite its record volume. Capturing the extremely high runoffs in the System lessened the impacts of the 1997 flood. The stored water was evacuated at release rates that remained within the downstream channel capacity. A team approach among all Corps offices to solve the problems associated with storing and releasing large volumes of water during significant basin-wide flood control events was more fully implemented in 1997. Full briefings of the Omaha District Dam Safety Committee were provided. In addition, close coordination with the Omaha District

Emergency Management office was necessary to assure adequate channel capacity was available by constructing advanced flood protection measures below some projects. A report titled *Summary Report on the Regulation of the Missouri River Main Stem System During the 1997 Flood* was prepared, and it contains significantly greater detail on this event than is presented here. The report also includes a detailed storm history.

A-03.10.2. The 1997 event really began in November-December of 1996 when a saturated upper basin began experiencing significant plains and mountain snowpack accumulations. The MRBWM office recognized in early January that significant snowpack was building in both the plains and mountain areas, and appropriate increases in System releases commenced. While the MRBWM office recognized in January that heavy accumulations were occurring, the actual volume or significance of the plains snowpack accumulation was not officially determined. This did not occur until the Corps' Omaha District staff provided snow water equivalent values for the upper plains following a comprehensive snow survey conducted in March. Once the extent of and amount of snow water equivalent of plains snow was verified through the snow survey, an estimate of runoff from the accumulated plains snow could be ascertained. The main takeaway regarding the regulation of the 1997 flood is the early pre-release of a considerable amount of water from System storage in preparation for the large volume of runoff from plains and mountain snowmelt that would occur in later months. Then-record high monthly System releases were made from February through December. The rapid plains snowmelt, in combination with the uneven distribution of the plains snowpack, required the utilization of a significant portion of the Oahe and Fort Randall Exclusive Flood Control Storage Zones in late March and April. This situation prevailed until water in storage at Oahe and Fort Randall could be balanced between the two upper large reservoirs, Fort Peck and Garrison. This was the first time that it had been necessary to utilize Fort Randall's Exclusive Flood Control Zone to such an extent. Considerable downstream flood control benefits were obtained during the March-April period by not having to increase System releases from Gavins Point above rates that would have caused significant downstream damage. Negative impacts occurred in the Fort Randall reservoir in terms of recreation facility damage and erosion on the embankment face. The embankment had not been protected in all locations to the top of the Exclusive Flood Control Zone. The Fort Randall and Oahe projects entered their respective Exclusive Flood Control Zones in late March, and they remained in this zone until September 1. As a special operation, the Fort Randall reservoir was lowered and then held at an elevation of 1370 feet for an extended period of time so additional riprap could be placed on the embankment. The 1997 runoff volume during March and April nearly mirrored the previous maximum of 15 MAF that occurred in 1952, before five of the System projects were constructed. Maintaining high pool levels in Oahe and Fort Randall reservoirs so early in the season with saturated ground conditions was a major concern to the MRBWM office. With the onset of mountain snowmelt, System releases were gradually increased through the summer and fall. This gradual and slow increase in System releases resulted in a Missouri River channel change that had also occurred in the high release periods of 1975 and 1978. Prolonged high releases from the System created additional downstream channel capacity. The river degradation that occurred after 2 or 3 weeks of releasing water at high rates often resulted in no increase in the river stage as the next increment of flow increase was added to evacuate the unprecedented runoff. In all, over 3 feet of degradation occurred on the Missouri River from 1996 through 1997 in the Sioux City area. This degradation represents over 12,000 cfs of increased channel capacity in this reach. Ultimately, a then-record System release rate of 70,000 cfs was made during November. System storage peaked at 71.7 MAF on July 13, 1.6

MAF below the top of the Exclusive Flood Control Zone, a storage total only exceeded in 1975 and 2011. Flood damages prevented were estimated at $5.2 billion (original price levels), which was a then-record amount, and exceeded the damages prevented in the Great Flood of 1993.

A-03.10.3. Unlike the Great Flood of 1993, where the majority of runoff occurred in the lower basin, the 1997 flood was due to above-normal runoff in the upper basin, except for one lower basin event in April. The actual damages incurred during 1997 were much less than those in 1993. Generally, no above-average downstream tributary flows occurred during the flood storage evacuation period (July-December). This was similar to what occurred during flood storage evacuation in 1975 and 1978, the previous high System release flood events. Stage reductions varied significantly and are shown in Table A-2 for the spring (plains snowmelt) and summer (mountain snowmelt) flood events. The MRBWM office's approach to regulating the 1997 flood was similar to previous floods, with the exception of unprecedented above-average pre-releases from the System. This allowed significant flood control to occur during the peak inflow periods in April and June.

Table A-2
Stage Reductions Due to System Regulation during 1997 (in feet)

	Bismarck	Pierre	Sioux City	Omaha	Kansas City	Boonville	Hermann
Spring	3.8	6.6	16.3	13.1	14.4	5.6	8.6
Summer	6.5	8.4	10.7	8.1	8.6	4.8	1.1

A-03.10.4. Because the MRBWM office followed established procedures and developed the overall release plan by modeling the runoff event, the flood was controlled, and maximum flood control benefits were attained, while the risks for significant later System release increases were managed. The 1997 flood event serves as an excellent example of a successful flood control regulation of the System. All past major flood events that have resulted in an accumulation of a large amount of storage within the System project Exclusive Flood Control Zones have resulted in questions regarding the use of this storage zone versus making higher releases to limit its use. There is no reason to believe that future flood events will not prompt the same.

A-03.11. Flood of 1999. The 1999 flood was the result of the runoff from a slightly above-average mountain snowpack, approximately 110 percent of average, in combination with significant downstream tributary runoff during the April-July period. Annual runoff for 1999 was 31.8 MAF, 124 percent of average. System storage peaked at 65.4 MAF on July 23, more than 3 MAF below the base of the Exclusive Flood Control Zone. The flood damages prevented by the System in 1999 totaled $2.1 billion, of which $2.0 billion were downstream from Rulo. Actual damages incurred in 1999 upstream from Rulo were $13 million. The Corps' tributary reservoirs downstream from Rulo also prevented $2.5 billion in damages during 1999. The large amount of damages prevented was primarily the result of storing plains and mountain snowpack runoff during the April-July period, when downstream heavy rains occurred. The Missouri River from Rulo to the mouth was above flood stage at all downstream locations from mid-April through June and again in July. The USCG closed the Missouri River to navigation in three separate months, April, May and July, due to high stages from downstream rainfall runoff.

Gavins Point Dam releases varied from 28,000 to 32,000 cfs during the period that the Missouri River was at or above flood stage.

A-03.12. Flood of 2010. Total runoff during 2010 was 38.7 MAF, the fourth highest on record (1898-2017). Plains snowfall accumulation began in the fall of 2009, and continued to accumulate through the winter 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 northwestern Iowa, and 3 to 4 inches in surrounding regions of Montana, Nebraska and southwestern Iowa. 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 throughout 2010; however, much greater-than-normal precipitation occurred in April through August.

A-03.13. Flood of 2011. The 2011 runoff year was the highest runoff year of record (1898-2017) 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 120-year period of record (1898-2017). 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). Runoff during the 5-month March-July period was 48.4 MAF. 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-03.13.1. Plains Snow. The winter of 2010-2011 marked the third consecutive year of significant plains snowpack. The plains snowpack peaked about February 25, 2011. The plains snowpack was generally classified as “heavy”, which was very similar to 2010 with SWE amounts varying between 4-6 inches. In some areas of the basin, particularly in the Milk River basin and upper James and Big Sioux River basins, the plains snowpack was classified as “very heavy” with SWE amounts exceeding 6 inches. Upper basin runoff during March and April, when the plains snowpack normally melts, was 6.4 and 7.7 MAF, respectively, nearly 2.5 times average for that 2-month period.

A-03.13.2. Mountain Snow. The mountain SWE was slightly above average on March 1 in the reach above Fort Peck and between Fort Peck and Garrison, 112% and 111%, respectively. On April 1 the mountain SWE was 126% (above Fort Peck) and 121% (Fort Peck to Garrison) in the two reaches. Normally, the mountain SWE peaks around April 15. During 2011, the mountain snowpack continued to accumulate through the month of April in both reaches and peaked on May 2 at 141% (above Fort Peck) and 136% (Fort Peck to Garrison) of the normal April 15 peak.

A-03.13.3. Spring Rainfall. From May 20-22, generally between 5 and 8 inches of rain fell across the regions of eastern Montana, western South Dakota and northern Wyoming, covering an area of 50 million acres, which is the approximate size of the State of South Dakota. In some isolated areas, 10-15 inches of rain fell over 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 reservoirs to record levels.

A-04. System Regulation during the Historic Major Floods. Although Fort Peck was placed into operation in 1937, additional projects on the main stem of the Missouri River were not operable prior to the 1950s and early 1960s. Limited System regulation was initiated in 1953 following the closure of the Fort Randall embankment in 1952 and Garrison in 1953. Gavins Point was closed in 1955, Oahe in 1958, and Big Bend in 1963. Although this completed the embankment closures on the System, regulation of the System was somewhat limited in the early years of regulation by project construction and the completion of real estate activities. In July 1966, installation of all of the present power units was completed, and the following summer, in June 1967, the System reservoirs reached their respective base of the Annual Flood Control and Multiple Use Zones for the first time. Only since that time have the System reservoirs, therefore, been regulated as a completely integrated System. This section of Appendix A discusses the regulation actions taken in the major floods since 1967 to minimize the flooding on the river reaches within the System and the reach downstream from the System.

A-04.1. System Storage Accumulation. Initial fill of the System was accompanied by a period of below-average runoff from the Missouri River drainage area above the System. Runoff was well-below average during each year of the 8-year period, extending from 1954 through 1961. The cumulative effect of these low-runoff years resulted in the second most severe drought period for the Missouri River basin since 1898. Runoff above the System averaged slightly above average from 1962 through the mid-1980s with well-above-average runoff occurring in some years. The 6-year drought, which extended from 1987 through 1992, represented a particularly challenging System regulation period. The 1990s represent the highest runoff decade of the past century. While the 2006 Master Manual was being written, the basin was currently experiencing another extended drought (2000-2007). Plate VII-2 illustrates month-by-month accumulation of water in the System. As shown on Plate VII-2, the Carryover Multiple Use Zone was first filled in 1967. Since 1967, the volume of water in System storage has generally remained within the Annual Flood Control and Multiple Use Zone. The typical annual variation of the amount of water in System storage shown on Plate VII-2 reflects the normal accumulation of water in storage during the March through July flood season and normal evacuation of accumulated water during the remainder of the year. This plate also shows the years in which an above-average amount of runoff into the System was stored in the System reservoirs, as indicated by the higher storage levels in those years.

A-04.2. System Regulation Effects on Streamflow. The accumulation and evacuation of water in System storage has had a major effect on streamflow below the System. Unregulated flows are determined at various sites for the purpose of calculating flood damages prevented. Unregulated daily flows are determined by representing the regulated flows adjusted for upstream reservoir effects. The upstream reservoir effects include storage of runoff, an adjustment of reservoir travel time, evaporation from the reservoir surface, and precipitation directly on the reservoirs. The reservoir effects used in the development of unregulated flows include those from major tributary reservoirs and the System projects. The major portion of the reservoir effects results from regulation provided by the System. Plates VII-4 through VII-11 show regulated and unregulated flows at Gavins Point for eight large runoff years since the System closed in 1967.

A-04.3. System Regulation during Major Events. The 1967, 1972, 1975, 1978, 1993, 1997, 2010 and 2011 hydrographs illustrate the effects of System regulation on substantial flood inflows, as shown on Plates VII-4 through VII-11, respectively. Plates VII-4 through VII-11 also illustrate characteristic patterns of releases from the System. Data to produce similar hydrographs that indicate System regulated versus unregulated flows are stored on the MRR database. The data are available for all years of regulation since 1950 and for other locations within and below the System. Complete write-ups for each year are on file as separate reports in the MRBWM office.

A-04.4. Flood Control Regulation of 1967 Runoff. The initial fill of the System was being completed during 1967. Floods were also occurring in the lower Missouri River basin during this same time period. Measured Missouri River flows at Hermann, MO exceeded 200,000 cfs from June 13 through July 5, with a peak flow of 372,000 cfs occurring on June 28; the peak stage was over 30 feet, 9 feet above flood stage. In early June, System releases were based on maintaining a navigation service level of 32,000 cfs with corresponding target flows of 28,000 cfs at Sioux City and Omaha, 34,000 cfs at Nebraska City, and 38,000 cfs at Kansas City. By June 12, substantial runoff was forecast in the lower Missouri River basin. Inquiries to the navigation industry revealed that no river traffic was scheduled for the Sioux City to Omaha reach of the Missouri River; therefore, the Sioux City target was not met for the period of June 12-18, and System release scheduling was based on maintaining target flows at the remaining downstream locations with resultant Sioux City flows expected to be below the minimum service level for navigation. With the expected recession of downstream flood runoff, full service navigation releases were re-established after June 20. The minimum mean daily release of 14,000 cfs on June 17 from Gavins Point nearly coincided, when taking into account the 10-day travel time from Gavins Point Dam to Hermann, with the 372,000 cfs peak flow at Hermann on June 28. Refer to Plate VII-4 for a graphical display of the regulated and unregulated Gavins Point Dam releases for 1967.

A-04.5. Flood Control Regulation of 1972 Runoff. The 1972 System regulation is illustrated on Plate VII-5. During this year a large volume of runoff was forecast from the drainage area above the System. In early March, System calendar year runoff was forecast to be 115 percent of average, and, in early April, this forecast was increased to 125 percent of average. Actual runoff experienced during 1972 above Sioux City, IA was 133 percent of average.

A-04.5.1. Service Level Determination. Regulation during calendar year 1972, based on procedures described in Chapter VII of this manual, was as follows. The service level was defined periodically throughout the year as described in Section 7-04 of this manual and as listed in Table A-3.

A-04.5.2. System Releases. Gavins Point Dam releases during January, February, and the first half of March 1972 were made at an expanded full service level of 20,000 cfs due to the large available (water in storage in System and USBR reservoirs) and forecast water supply above Gavins Point for the remainder of the calendar year. See Section 7-04 of this manual for a detailed explanation of how an expanded full service level is determined. As indicated in Table A-3, service level determinations on March 1 indicated that flows above the full service level would be required for storage evacuation purposes. As discussed in Chapter X of the 1979 Master Manual, during the beginning of the navigation season when the water supply is ample, a

System release rate of 5,000 cfs above the navigation service level can be made to facilitate conditioning of the Missouri River navigation channel.

Table A-3
Determination of 1972 Service Level

	March 1	April 1	May 1	June 1	July 1
Tributary Storage[1]	4,450	4,550	4,050	4,350	5,700
Tributary Storage Excess[2]	-1,050	-950	-1,450	-1,150	200
System Storage[3]	59,500	64,600	64,400	66,200	68,500
Forecasted Runoff[4]	24,600	20,100	18,350	14,100	8,650
Water Supply[5]	83,050	83,750	81,310	79,150	77,350
Service Level[6]	40.0	45.0	45.0	46.0	49.0

[1] Accumulated tributary storage in 1000 acre-feet (kAF) as per Section 7-04.13.2 of this manual.
[2] Difference between tributary base storage of 5,500 kAF and accumulated tributary storage as per Section 7-04.13.2 of this manual.
[3] Total System storage in kAF.
[4] Forecasted runoff above Gavins Point Dam in kAF from the current date through December 31, as adjusted to the 1949 level of basin development.
[5] Total of tributary storage excess, System storage, and forecasted runoff in kAF.
[6] System service level release in 1000 cfs

A-04.5.3. Strict adherence to the service level guidelines during flood evacuation periods, as outlined in the 1979 Master Manual, would have required System releases based on service levels of 40,000 cfs in April and May and a service level of 41,000 cfs in June. There were some existing issues concerning the channel capacity downstream of Fort Randall Dam that indicated that a service level of 40,000 cfs or greater would result in flood damages. One potential alternative was to decrease the service level from 40,000 cfs to 35,000 cfs. After a considerable amount of study, the MRBWM office concluded that adverse effects would be at a minimum if the 5,000 cfs reduction from the service level was not made. Additionally, the MRBWM office concluded that a relatively uniform release rate at an amount near the downstream channel capacity should be maintained provided that the flood control criteria described in Section 7-04 of this manual could be met. The uniform release supported a service level of 40,000 cfs through most of the April through June period. Reductions to this uniform rate were made at times during this period in order to not exceed the downstream flood control targets of 57,000 cfs at Nebraska City, which is a 45,000 cfs service level plus 12,000 cfs as per Table VII-7.

A-04.5.4. Increasing forecasts of the 1972 water supply along with additional accumulated System storage because of reduced System releases due to downstream runoff resulted in monthly increases in the service level. This resulted in higher adjustments to the System release as the runoff season progressed, as shown in Table A-4. This is a typical pattern with large runoff volumes. Because the runoff potential downstream was reduced after July, the additional release was passed safely below the System with no significant damages. With the large water supply, extended full service flows were provided at the end of the navigation season, which was extended 10 days as an additional water evacuation measure. A winter release rate of 20,000 cfs was maintained during the latter part of November and through December to evacuate a portion of the additional accumulated storage. Plate VII-5 shows the regulated and unregulated releases from Gavins Point.

Table A-4
1972 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1972	59.4	25.3	-0.7	84.0	35.0	20.0	19.9
Feb 1	59.2	24.4	-0.9	82.7	35.0	20.0	20.0
Mar 1	59.5	24.6	-1.0	83.1	35.0	20.0	26.1
Apr 1	64.6	20.1	-0.9	83.8	41.0	38.3	39.9
May 1	64.4	18.4	-1.5	81.3	38.0	38.0	37.3
Jun 1	66.2	14.1	-1.1	79.2	41.0	40.0	39.8
Jul 1	68.5	8.7	0.2	77.4	46.0	40.0	43.1
Aug 1	68.0	4.7	0.1	72.8	45.0	45.0	46.1
Sep 1	66.5	3.6	-0.2	69.9	46.0	46.0	46.3
Oct 1	64.4	2.5	-0.4	66.5	50.0	48.0	48.5
Nov 1	62.4	1.4	-0.6	63.2	50.0	48.5	44.5

[1] Based on a 5,000 cfs reduction from March through June.
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Section VII 7-04.13.4
[3] Actual average monthly System release.

A-04.6. Flood Control Regulation of 1975 Runoff. January and February snow accumulations in the mountain areas of the basin were only about 80 percent of average. Because there was no substantial plains snow cover, runoff during 1975 was expected to be below average. Winter releases from all projects were maintained at full service winter levels. The System release rate at Gavins Point Dam was 20,000 cfs. Runoff conditions had not changed substantially by March 1. Full service navigation releases were maintained through the month of April. During April, mountain snow accumulation increased to 130 percent of average, a large plains snowpack accumulated in North Dakota and South Dakota, and precipitation was extremely heavy over Montana and western North Dakota. Runoff forecasts made in mid-April indicated that calendar year runoff would likely total more than 20 percent above average. System releases were increased from the full service level of 35,000 cfs to 40,000 cfs by mid-May. By mid-June, runoff from mountain snowpack and spring rainfalls in the upper basin resulted in increasing reservoir levels at Fort Peck and Garrison. On June 24, the System release was increased to 50,000 cfs, the maximum System release made since the System had filled in 1967. By mid-June, upstream runoff remained high and it appeared that another System increase, to 55,000 cfs, would be necessary. The basin downstream of the System was, however, experiencing high tributary runoff due to summer storms. The System releases were lowered to 35,000 cfs to lessen downstream flooding impacts. Meanwhile, heavy rainfalls in the upper basin resulted in a then-record maximum Fort Peck release of 35,000 cfs. System releases were increased and then maintained at 48,000 cfs throughout most of July. Higher releases would have caused problems downstream with interior drainage and lowland flooding. On July 20, the System releases were increased to 60,000 cfs, and downstream private levees were monitored on a constant basis. The System release was maintained at 60,000 cfs through the months of August through November. The System release was lowered to 23,000 cfs by December 10 and maintained at that level through the rest of the year. This serves as an example of a System flood control regulation when the primary inflow resulted from a large rainfall in combination with an accumulation of plains and mountain snowpack late in the accumulation period. This type of runoff season is the most difficult to regulate because no pre-releases are warranted or desired. Plate VII-6 shows the regulated and unregulated flows for 1975. Table A-5 presents the month-by-month progression of the regulation of the 1975 runoff.

Table A-5
1975 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1975	59.7	20.8	-0.9	79.6	35.0	17.2	17.2
Feb 1	59.2	21.1	-1.2	79.1	35.0	17.0	17.1
Mar 1	59.1	20.5	-1.4	78.2	35.0	17.2	19.3
Apr 1	59.9	20.3	-1.5	78.7	35.0	27.5	28.2
May 1	63.0	19.7	-1.6	81.1	37.0	28.0	31.9
Jun 1	66.7	16.2	-1.1	81.8	47.0	35.2	37.5
Jul 1	70.1	11.0	0.3	81.4	62.0	42.5	52.6
Aug 1	71.8	6.4	0.6	78.8	70.0	60.0	60.1
Sep 1	69.7	4.4	0.2	74.3	70.0	60.5	60.5
Oct 1	66.7	3.0	-0.2	69.5	70.0	60.6	61.0
Nov	63.9	1.8	-0.2	65.5	80.0	61.0	61.0
[1] Based on a 5,000 cfs reduction from March through June.							
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Section 7-04.13.4.							
[3] Actual average monthly System release.							

A-04.7. Flood Control Regulation of 1978 Runoff. Following a dry year in 1977, the 1978 runoff was forecast in early January to be approximately 107 percent of average. System releases in January, February, and the first half of March averaged 16,000 cfs. During March, mountain snowpack increased to 130 percent of average, and the plains snow cover increased. Based on this information, the runoff forecast was increased to 126 percent of average. System releases in April were increased to 24,000 cfs to support downstream navigation. Reservoir elevations continued to rise in the upper three projects. Lower-than-expected April and May runoff and precipitation resulted in the runoff forecast being lowered to a near-average level. In late May, heavy rainfall and snow events occurred in Wyoming, Montana, and Missouri. These late May storms caused increased tributary inflows to the Missouri River, both upstream and downstream of Gavins Point Dam. In late May, System releases were increased to 35,000 cfs, full service releases. May precipitation in Wyoming and Montana ranged from 150 percent to 600 percent of normal. The runoff during the month of May above Gavins Point Dam was the third highest of record (1898-2017), exceeded only in 1975 and 2011. In June, System releases were increased to 42,000 cfs. Inflows upstream of the System continued to be higher than average in June and July. The total runoff for the January-July period totaled 30.9 MAF, the third highest on record (1898-2017). In July, the System release was increased to 48,000 cfs and maintained at that rate. System releases were increased to 50,000 cfs in August and maintained at or near that level through the end of November to evacuate the accumulated System storage, as shown in Table A-6. Total runoff for 1978 was 40.6 MAF, more than 160 percent of average and third highest since record-keeping began in 1898. Plate VII-7 shows the hydrographs of System regulated and unregulated flows for 1978.

Table A-6
1978 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1978	51.7	24.8	-1.0	75.5	33.0	15.0	15.5
Feb 1	51.4	25.2	-1.1	75.5	33.0	16.0	16.0
Mar 1	51.6	24.3	-1.3	74.6	33.0	16.0	17.5
Apr 1	59.3	20.2	-1.3	78.2	35.0	22.0	21.8
May 1	62.3	16.3	-1.4	77.2	35.0	24.0	27.9
Jun 1	65.9	14.9	-0.6	80.2	43.0	35.0	38.3
Jul 1	68.1	9.5	0.3	77.9	52.0	41.0	44.4
Aug 1	69.1	5.7	0.4	75.2	57.0	48.0	49.6
Sep 1	67.1	3.9	-0.2	70.8	55.0	50.0	50.0
Oct 1	65.5	2.8	-0.3	68.0	60.0	50.0	51.5
Nov 1	62.9	1.6	-0.4	64.1	60.0	52.0	51.9
[1] Based on a 5,000 cfs reduction from March through June.							
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Section 7-04.13.4.							
[3] Actual average monthly System release.							

A-04.8. Flood Control Regulation of 1993 Runoff. The Missouri River basin was experiencing a 6-year drought prior to the 1993 flood. This was the first extended drought that had occurred since the System filled in 1967. During the 1987-1992 drought, the upper three System reservoirs reached their lowest levels since 1967. System storage was 14.2 MAF below the base of the Annual Flood Control and Multiple Use Zone at the start of the 1992-1993 winter season. The regulation plan was to provide the lowest possible System release, about 12,000 cfs, during the winter to conserve as much water as possible in the upper System projects. The expectation was that, under median runoff, it would take five years to refill the System to normal levels. The navigation season opened on March 23 and minimum service level releases were made for navigation purposes. System releases averaged 11,200 cfs in April; 17,600 cfs in May; 17,000 cfs in June; and 8,000 cfs in July. April, May and July monthly average daily releases were the lowest since the System reached normal operating levels in 1967. The Great Flood of 1993 occurred in July. Heavy and constant rains resulted in substantial inflows into and downstream of the System. The System storage level increased 5.3 MAF during the month of July. Downstream of the System, specifically in the Kansas River basin, significant runoff from heavy and persistent rains resulted in the MRBWM office lowering System releases to as low as 6,000 cfs to lessen downstream Missouri River flooding that extended from the Platte River to the mouth of the Missouri River. The System refilled by September 1. During the time period that the Missouri River was experiencing flooding, the System release was maintained at a rate as low as 6,000 cfs to support water supply intake requirements downstream of Gavins Point. Table A-7 presents the System regulation summary for 1993. Over $4.4 billion (actual) in flood damages were prevented by the System. The primary damages prevented from the significant reduction of System releases was that the levees in Kansas City and St. Louis were not overtopped. Plate VII-8 shows hydrographs of System regulated and unregulated flows for 1993.

Table A-7
1993 System Regulation

	Volume in MAF				**Service Level in 1000 cfs**		
Date	**System Storage**	**Forecast Runoff**	**Tributary Storage Departure**	**Water Supply**	**Defined**	**Initial[1]**	**Average[2]**
Jan 1, 1993	42.7	20.4	-1.0	62.1	29.0	15.0	13.3
Feb 1	42.8	18.5	-1.2	60.1	29.0	11.0	13.0
Mar 1	43.0	17.7	-1.2	59.5	29.0	11.4	12.3
Apr 1	45.5	15.6	-1.1	60.0	29.0	6.0	11.2
May 1	46.1	13.5	-1.0	58.6	29.0	19.0	17.6
Jun 1	47.6	10.6	-0.1	58.1	29.0	15.0	17.0
Jul 1	50.4	7.6	0.5	58.5	29.0	13.3	8.0
Aug 1	55.8	5.8	0.5	62.1	29.0	7.0	10.8
Sep 1	57.2	4.6	0.4	62.2	29.0	14.0	18.5
Oct 1	57.1	3.1	0.1	60.3	29.0	19.5	21.0
Nov 1	56.9	2.0	0.0	58.9	29.0	21.8	20.1
[1] System release at the first of the month, as selected after considering flood control criteria discussed in Section 7-04.13.4.							
[2] Actual average monthly System release.							

A-04.9. Flood Control Regulation of 1997 Runoff. The regulation of the System during the 1997 runoff year is considered to be one of the most difficult over the history of the regulation of the System. High runoff conditions were cited very early in the year, and high runoff continued throughout the spring, summer, and fall seasons. The System storage was 57.8 MAF, 0.7 MAF into the Annual Flood Control and Multiple Use Zone, at the end of 1996. The mountain snowpack measured on January 1 was 181 percent of average. In addition, heavy snow cover was reported over eastern Montana and the Dakotas. The January runoff was the highest of record. System releases averaged nearly 25,000 cfs for the month of January. The accumulation of higher-than-average mountain snowpack and plains snow cover continued into February. The February 1 runoff forecast was 33.4 MAF, 136 percent of average. System releases were increased to average 30,300 cfs for February, exceeding the previous record for February. In March, the mountain snowpack and plains snow cover accumulation was higher than average for that time of year. The March 1 runoff forecast increased to 35.5 MAF, 144 percent of average. Average March System releases were 35,600 cfs, a record for March. Melting plains snow during March increased System storage to 64.6 MAF on March 31. The System releases were reduced from 42,000 cfs to 38,000 cfs in response to tributary flooding downstream of the System. Mountain snowpack conditions still remained higher than normal in April, 136 percent of average. The April 1 runoff forecast was raised to 38.5 MAF, 157 percent of average. Blizzards in the plains area in April and subsequent snowmelt caused the System storage to increase to 67.1 MAF by April 30, occupying 10.0 MAF of the designated 16.3 MAF of flood control storage. System releases were increased early in April from 38,000 cfs to 58,000 cfs, averaging 50,300 cfs for the month. System releases were timed and adjusted so as not to coincide with the flood peaks of the James and Big Sioux Rivers. These adjustments minimized downstream Missouri River flooding. Mountain snowpack was estimated to be 135 percent of average on May 1. The May 1 runoff forecast increased to 42.5 MAF, which would have been the largest total runoff since record-keeping began in 1898. System releases averaged 59,600 cfs for May, 16,000 cfs higher than the next highest monthly average (May 1971). The June 1 runoff forecast was increased to 44.5 MAF due to remaining mountain snowpack and persistent tributary runoff in the plains area of the upper basin. During June, unseasonably warm weather led to rapid melting of mountain snowpack. This snowmelt resulted in 9.6 MAF of runoff into the System during June, more than 4 MAF of average. Storage in the System was pushed to a June record high of 71.1 MAF, only 2.3 MAF below the top of the Exclusive Flood Control Zone. Runoff into the System during the first 6 months of 1997 totaled 35.8 MAF, 216 percent of average. System releases for June remained near 60,000 cfs. High, sustained releases from the System had scoured the channel bed and resulted in a degraded Missouri River channel in some critical reaches. The degradation effect on the channel resulted in an increased channel conveyance capacity. This increase in conveyance capacity allowed the MRBWM office to maintain the high System releases to evacuate System flood storage without causing downstream damages. The July 1 runoff forecast was increased to 46.8 MAF, based on the high runoff in June. System storage peaked at 71.7 MAF on July 13, occupying 14.6 of the designated 16.3 MAF of flood control storage. System releases averaged a then-record 61,500 cfs during July, almost 9,000 cfs higher than the previous record set in 1975. During August, the extremely high System storage required that System releases be increased to 65,000 cfs. The September 1 runoff forecast was increased to 49.0 MAF, 198 percent of average. System releases averaged 68,000 cfs for September and October and 70,000 cfs for November to evacuate the System flood storage. The System releases were lowered to 28,000 cfs starting in early December. The total runoff into the System totaled 49.0 MAF, nearly twice the average. Plate VII-9 shows hydrographs of System regulated and unregulated flows for 1997 and Table A-8 presents the System regulation.

Table A-8
1997 System Regulation

	Volume in MAF				Service Level in 1000 cfs		
Date	**System Storage**	**Forecast Runoff**	**Tributary Storage Departure**	**Water Supply**	**Defined[1]**	**Initial[2]**	**Average[3]**
Jan 1, 1997	57.8	27.2	-0.5	84.5	35.0	21.7	24.9
Feb 1	57.8	29.5	-.07	86.6	37.0	28.0	30.3
Mar 1	59.4	28.3	-1.0	86.7	41.0	35.6	35.6
Apr 1	64.8	23.5	-1.2	87.1	47.0	41.9	50.3
May 1	67.1	20.5	-1.5	86.1	50.0	58.0	59.5
Jun 1	67.7	16.6	-0.6	83.7	50.0	60.0	60.0
Jul 1	71.3	9.0	0.9	81.2	62.0	60.0	61.5
Aug 1	71.1	5.8	0.9	77.8	65.0	60.0	64.4
Sep 1	69.0	4.5	0.6	74.1	70.0	65.0	65.4
Oct 1	66.1	2.8	0.3	69.2	70.0	68.0	68.2
Nov 1	62.8	1.7	0.1	64.6	70.0	70.0	70.0

[1] Based on a 5,000-cfs reduction from March through June.
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Section 7-04.13.4.
[3] Actual average monthly System release.

A-04.10. Flood Control Regulation of 2010 Runoff. The 2010 runoff season began with more than the 16.3 MAF of flood control storage available because the System was still recovering from the 2000-2007 drought. System storage on March 1 was 54.6 MAF, 2.2 MAF below the base of the Annual Flood Control and Multiple Use Zone. The melting of a heavy plains snowpack, as well as below-average System releases of 15,000 cfs, increased the System storage to 59.4 MAF by May 1. System releases were also kept at below-average levels in June as heavy precipitation in the lower basin led to high tributary and Missouri River flows. System releases were increased to a maximum of 49,000 cfs in the fall, the navigation season was extended 10 days, and winter releases up to 21,000 cfs were made to evacuate all the stored flood waters prior to the start of the 2011 runoff season. Plate VII-10 shows hydrographs of System regulated and unregulated flows for 2010 and Table A-9 presents the System regulation.

Table A-9
2010 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined	Initial[1]	Average[2]
Jan 1, 2010	54.3	23.3	-0.4	78.2	35.0	15.0	15.9
Feb 1	54.5	23.2	-0.5	78.2	35.0	15.0	15.0
Mar 1	54.6	22.6	-0.6	77.6	35.0	15.0	15.0
Apr 1	58.2	14.8	-0.6	73.4	35.0	15.0	15.3
May 1	59.4	12.7	-0.5	72.6	35.0	24.0	25.2
Jun 1	60.8	10.9	-0.3	72.4	35.0	26.5	27.7
Jul 1	65.0	9.2	0.7	75.9	50.0	34.0	35.1
Aug 1	65.7	5.4	0.4	72.5	48.0	39.5	41.9
Sep 1	63.9	3.8	0.0	68.7	44.0	46.0	47.2
Oct 1	62.1	2.8	-0.2	65.7	41.0	44.5	48.7
Nov 1	59.8	0.7	-0.3	61.2	35.0	49.0	46.1
[1] System release at the first of the month, as selected after considering flood control criteria discussed in Section 7-04.13.4.							
[2] Actual average monthly System release.							

A-04.11. Flood Control Regulation of 2011 Runoff. All 2010 runoff was evacuated from the System by January 28, 2011 when the System storage reach 56.8 MAF, the base of the Annual Flood Control and Multiple Use Zone. As was the case with 2009 and 2010, a heavy plains snowpack blanketed the upper basin. System releases were maintained at 21,000 cfs from February through early April as runoff from the largely unregulated basins downstream of Gavins Point resulted in high tributary and Missouri River flows. In early April, per the Master Manual and based on the System storage, upstream USBR tributary storage and the April 1 annual runoff forecast above Gavins Point, the service level was increased 10,000 cfs to prepare the System for above-average runoff. In mid-April, an additional service level increase of 5,000 cfs was made. The service level increase did not result in an immediate increase in Gavins Point releases due to high flows that were already occurring along the lower river, but it did raise the downstream flood control constraints at Omaha, Nebraska City and Kansas City by 15,000 cfs. Because of high tributary flows from the largely unregulated basin downstream of the System causing high Missouri River flows, Gavins Point releases were not substantially increased during the first part of the runoff season. Gavins Point releases of 32,000 cfs were made in mid-April and were raised to 45,000 cfs in early May. The March and April runoff above Sioux City, which is primarily from plains snowpack and rainfall runoff, was 6.4 MAF and 7.7 MAF, respectively. While much of this runoff was captured and stored in the mainstem reservoirs, the Gavins Point to Sioux City reach, which is largely unregulated, recorded a March-April runoff total of 3.3 MAF. That 2-month total is more than 1.5 times the average annual runoff for that reach. Based on the System storage, upstream USBR tributary storage and the May 1 annual runoff forecast above Gavins Point, the service level was increased an additional 10,000 cfs in early May. Gavins Point releases of 57,000 cfs were being made by mid-month. Heavy rains, generally ranging from 5 to 8 inches and 10 to 15 inches in some isolated areas, fell from May 20-22 across eastern Montana, western South Dakota and northern Wyoming. The runoff from the rain, along with the forecasted runoff from the above-average mountain snowpack, resulted in record releases being made from every System project. A Gavins Point release of 160,000 cfs, more than two times the previous record release, was made from June 25 to July 29. For a detailed timeline of System regulation during the 2011 Flood, refer to the External Independent Review Report, *Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011*. Plate VII-11 shows hydrographs of System regulated and unregulated flows for 2011 and Table A-10 presents the System regulation.

Table A-10
2011 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined	Initial[1]	Average[2]
Jan 1, 2011	57.0	25.0	-0.5	82.5	40.0	17.0	18.5
Feb 1	57.0	24.2	-0.7	81.5	40.0	19.0	20.7
Mar 1	57.6	22.6	-0.9	80.3	40.0	21.0	21.0
Apr 1	61.7	20.4	-0.9	82.2	45.0	21.0	30.3
May 1	65.5	22.1	-1.1	87.5	60.0	45.0	56.3
Jun 1	70.4	23.4	-0.8	94.0	see Note[4]	77.0	139.0
Jul 1	72.8	13.1	0.7	87.6	see Note[4]	160.0	159.7
Aug 1	69.6	7.1	1.2	78.9	see Note[4]	150.0	136.2
Sep 1	63.6	4.4	0.6	69.6	see Note[5]	90.0	81.9
Oct 1	60.1	2.9	0.1	64.1	see Note[5]	51.7	40.1
Nov 1	58.9	1.9	-0.1	61.7	see Note[5]	40.0	40.1

[1] System release at the first of the month, as selected after considering flood control criteria discussed in Section 7-04.13.4.

[2] Actual average monthly System release.

[3] Releases were set based on projected inflows and surcharge storage availability.

[4] Releases were set based on monthly studies and evacuation of stored flood waters.

A-05. Hypothetical Flood Examples for System Regulation. The entire flood history of the Missouri River basin, from 1881 to the present, has been used in planning studies of the System. Significant historic floods, discussed in this appendix, were examined in as great a detail as the available records would permit. Only since 1929 have sufficient measurements of streamflow been obtained to permit a detailed examination of the effects of individual System reservoir regulation. Prior to that year, synthetic flows had to be derived at numerous locations to illustrate System regulation. The development of the synthetic flows, with corresponding associated uncertainties, was necessary to reconstitute the significant floods prior to 1929. This precluded their inclusion in this manual as comprehensive illustrations of System regulation. From the available records, a general examination was made of the past floods, in particular the large floods occurring in 1881 and 1927, to confirm the applicability and reliability of flood control regulation techniques used in this manual. These studies indicated that, with reasonable allowances made for the basin development since the date of flood occurrence, the techniques developed in this manual for the System regulation would provide adequate control, should such floods recur.

A-05.1. System Regulation during a Hypothetical Flood Sequence of 1944, 1951 and 1952. Detailed flow records available since 1929 include the greatest known summer flood event downstream from the System, occurring in 1951, and the greatest known spring runoff event originating from the drainage area controlled by the System, occurring in 1952. Detailed records are also available for the large 1944 flood. Flood flows during 1952 occurred during the March-April period, while the 1944 large amounts of runoff originated above the System reservoirs during the June-July period. Examination of the sources of runoff during the 1951, 1952 and 1944 events indicates that a runoff sequence combining the events extending from March 1951 through May 1952 combined with those events extending from June 1944 through March 1945 is not unreasonable. This runoff sequence was created and regulation studies developed to illustrate regulation techniques and their results during this combination of runoff events. The long-range study results of the combined storms of 1944, 1951 and 1952 are shown on Plates A-1 and A-2. Detailed explanation of the data used, the study procedures, and the study results are described in the following sections.

A-05.1.1. Reach Inflows. The reach inflows used in the studies were developed from the USGS-published hydrologic record. Plates A-1 and A-2 present the monthly inflow volumes for incremental drainage areas between the dams and between Missouri River streamgaging stations downstream of the System to Hermann. Missouri River reach inflows, shown for the System portion of the tables in the two plates, are the accumulated reach inflows above Sioux City. While only monthly reach inflows are shown on these plates, it should be recognized that regulation of the System to meet specified flood control and navigation targets requires the use of daily Missouri River inflows for the Missouri River reaches between Gavins Point Dam and Kansas City, MO.

A-05.1.2. Reservoir Evaporation. The monthly evaporation volumes from each of the System reservoirs during this examined period are also shown on Plates A-1 and A-2. Evaporation depths or rates were assumed to be average and consist of average reservoir evaporation amounts, adjusted for the occurrence of average precipitation on the reservoir surface. The evaporation volume is a function of the evaporation depth and reservoir surface area.

A-05.1.3. Inflow Adjustments. The reach inflows that actually occurred at the time of the runoff events required adjustment. Since that time, water resource development of the Missouri River basin has progressed. The inflows shown on Plates A-1 and A-2 represent estimates of the effects of this basin development on the reach inflows These estimates are based on data furnished by the USBR and consist largely of irrigation effects, including storage effects of tributary reservoirs that have a primary function of irrigation. The adjustments for the Nebraska City to Kansas City reach also contain regulation effects of the Kansas River basin reservoirs.

A-05.1.4. Modified Inflows. The modified inflows into each of the System reservoirs are shown on Plates A-1 and A-2. The modified inflows consist of observed reach inflows plus the reach inflow adjustment and the release from the dam immediately upstream less the evaporation from the System reservoir receiving the inflow. All reach inflows between Oahe and Fort Randall are assumed to originate below Big Bend Dam, because inflows between Oahe and Big Bend are generally quite low. Additionally, it was assumed that the Gavins Point and Big Bend projects operate at a constant reservoir level, with modified inflows equal to releases. No modified inflows were tabulated for the Big Bend project due to its short distance from Oahe Dam. At locations below the System, the modified inflows represent the observed reach inflows plus the reach inflow adjustments.

A-05.1.5. Storage and Reservoir Elevation. Plates A-1 and A-2 display the end-of-month or the end-of-period reservoir elevation and corresponding storage values listed for the individual System projects and the System. System storage values listed include the Big Bend and Gavins Point projects' storage volumes.

A-05.1.6. Releases and Flows. Plates A-1 and A-2 display the average monthly releases and monthly flow volumes for the System reservoirs and downstream control points. These plates indicate average monthly values; daily flows and releases would indicate a much larger range of values.

A-05.1.7. Power Production. Plates A-1 and A-2 display the average power, peak power and energy production for each period for each of the System projects and for the System. The peak power values displayed on Plates A-1 and A-2 represent values at the end of each time interval.

A-05.1.8. Service Level. The service level to be followed by the System at any given time is a function of actual System storage, forecasted runoff above the System, and tributary reservoir storage, taking into consideration the time of the year. Plate VI-1 is used to define the service level. Table A-11 illustrates the service level definition through the 1951-1952-1944 flood sequence period. Forecasted runoff amounts and the departure of total tributary storage from the base level are represented as reasonable values assumed for illustrative purposes.

A-05.1.9. Definition of System Releases. System releases are determined on a daily basis using the GRFT model described in Chapter VI of this manual. The conditions of May 15, 1952 are used for illustrative purposes.

Table A-11
Service Level Determination for 1951-1952-1944 Flood Sequence

Date	Volume in MAF				Service Level in 1000 cfs	
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Selected[2]
Apr 1, 51	59.0	21.5	-1.3	79.2	35.0	35.0
May 1	61.8	17.2	-1.5	77.5	35.0	35.0
Jun 1	62.7	13.6	-0.9	75.4	35.0	35.0
Jul 1	64.5	9.3	0.0	73.8	38.0	38.0
Aug 1	65.3	6.7	-0.3	71.7	41.0	41.0
Sep 1	65.0	5.0	-0.7	69.3	45.0	45.0
Oct 1	64.7	3.5	-0.8	67.4	55.0	55.0
Nov 1	63.3	1.7	-1.0	64.0	60.0	60.0
Dec 1 through Feb 28 . . . . Expanded Full Service						
Mar 1, 52	60.4	34.4	-1.3	93.5	60.0	55.0
Apr 1	61.4	34.0	-1.4	94.0	65.0	60.0
May 1	70.0	23.5	-1.0	92.5	70.0	65.0
Jun 1	70.4	20.1	-0.5	90.0	75.0	70.0
Jul 1	73.6	11.4	-0.2	85.2	75.0	75.0
Aug 1	72.0	5.8	-0.1	77.7	65.0	65.0
Sep 1	69.1	3.1	-0.3	71.9	60.0	60.0
Oct 1	66.3	2.3	-.07	67.9	60.0	60.0
Nov 1	63.8	1.2	-1.0	64.0	60.0	60.0
Dec 1 through Feb 28 . . . . Expanded Full Service						
[1] Based on Plate VI-1.						
[2] Selected after considering flood control criteria discussed in sections Section 7-04.13.4.						

A-05.1.10. Example 1 – Full Service. A service level of 65,000 cfs was deemed appropriate for this period. The service level of 65,000 cfs would result in Missouri River target flows of 61,000 cfs at Sioux City and Omaha, 67,000 cfs at Nebraska City, and 71,000 cfs at Kansas City. The MRBWM FUI model, which was replaced by the GRFT model, was used to route the System releases, tributary flows, and ungaged inflows through the downstream reach. The FUI model indicated that a System release rate of 54,000 cfs would be required to meet the Sioux City target of 61,000 cfs, 50,500 cfs to meet the Omaha target of 61,000 cfs, and 51,000 cfs to meet the Nebraska City target of 67,000 cfs. Additionally, a release of 44,000 cfs would be required to meet the Kansas City target of 71,000 cfs. A System release of 44,000 cfs would result in missed targets at Nebraska City, Omaha and Sioux City; therefore, the System release of 54,000 cfs is tentatively selected, as it is the lowest System release that meets all four targets. The FUI model indicated that the resultant Missouri River downstream flows from the System release of 54,000 cfs were forecasted to be 61,000 cfs at Sioux City, 64,500 cfs at Omaha, 70,000 cfs at Nebraska City, and 81,000 cfs at Kansas City. The variations of these forecasted flows from the target flows, based on the current service level of 65,000 cfs, are shown in Table A-12. These variations were less than those allowed by flood control considerations specified in Table VII-7; therefore, the 54,000 cfs System release rate was considered appropriate for conditions on May 15, 1952.

Table A-12
Variations from System Releases and Target Flows

Target Location	Forecasted Flow with System Release of 54,000 (cfs)	Target Flow with Full-Service Flow of 65,000 (cfs)	Difference (cfs)
Sioux City	61,000	61,000	0
Omaha	64,500	61,000	3,500
Nebraska City	70,000	67,000	3,000
Kansas City	81,000	71,000	10,000

A-05.1.11. Example 2 – Full Service. If forecast variations from the current service level had exceeded those specified in Section 7-04.16, reductions in the System release rate would have been required as a flood control measure. For example, if the resultant flow forecast for Kansas City had been 105,000 cfs instead of 81,000 cfs, the variation at this location from the 65,000 cfs service level (Kansas City target flow of 71,000 cfs) would have been 34,000 cfs (105,000 – 71,000), or 4,000 cfs greater than that allowed by the flood control criteria at the current service level. A System release of 50,000 cfs, 4,000 cfs less than the initially selected release of 54,000 cfs, would then be appropriate. The System release of 50,000 cfs would meet the flood control criteria at Kansas City and result in flows greater than full service at Sioux City, Omaha and Nebraska City. The full service level of 35,000 cfs, as discussed in Section 7-04.14 of this manual, requires target flows of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City, and 41,000 cfs at Kansas City.

A-05.1.12. Example 3 – Full Service. If the Kansas City flows from a 54,000 cfs release had been 135,000 cfs, instead of the 81,000 cfs in Example 1, the Kansas City variation from the 65,000 cfs service level (target flow of 71,000 cfs) would be 64,000 cfs (135,000 – 71,000). This is 34,000 cfs greater than allowed by the criteria given stated in Section 7-04.16 and Table VII-7 of this manual for full service. Reducing System releases by 34,000 cfs to 20,000 cfs would provide Sioux City resultant flows of 27,000 cfs, which is 4,000 cfs below the full service level of 31,000 cfs. In accordance with criteria discussed in Section 7-04.17, a System release of 24,000 cfs would, therefore, be scheduled to result in Sioux City full service flows of 31,000 cfs. The resultant Kansas City flow would be 105,000 cfs, or 34,000 cfs greater than the current target level. Because this variation from the target level is less than the criteria for release reductions to the minimum service level (a variation of 60,000 cfs per Section 7-04.17 and Table VII-8 of this manual), the 24,000 cfs release is satisfactory.

A-05.1.13. Example 4 – Minimum Service. If the resultant Kansas City flow from a release of 54,000 cfs had been 170,000 cfs, instead of the 81,000 cfs in Example 1, the Kansas City flow would exceed the target flow by 99,000 cfs (170,000 – 71,000). This is 69,000 cfs over the full service flood control criteria (+30,000 cfs at Kansas City) and 39,000 cfs over the minimum service flood control criteria (+60,000 cfs at Kansas City), as shown in Tables VII-7 and VII-8, respectively. Because it would be impossible to reduce System releases to meet the full service flood control criteria, the focus is on meeting the minimum service flood control criteria; therefore, as a starting point, a release of 15,000 cfs (54,000 – 39,000) would be considered. The 15,000 cfs release would result in flows of 22,000 cfs at Sioux City, 25,500 cfs at Omaha, 31,000 cfs at Nebraska City, and 131,000 cfs at Kansas City. This release would meet minimum service flow targets at Omaha (25,000 cfs), Nebraska City (31,000 cfs), and Kansas City (35,000 cfs), but would not meet the minimum service flow target of 25,000 cfs at Sioux City. The System release would, therefore, need to be increased by 3,000 cfs (25,000 – 22,000) to meet the Sioux City minimum service flow target. The resulting 18,000 cfs System release (15,000 + 3,000) would result in flows of 25,000 cfs at Sioux City, 28,500 cfs at Omaha, 34,000 cfs at Nebraska City, and 134,000 cfs at Kansas City.

A-05.1.14. Effect of Regulation on Peak Flows. A comparison of observed peak flows and estimated peaks resulting from regulation of the System and tributary reservoirs during the 1951-1952-1944 flood sequence is given in Table A-13. Examination of the peak flows shown in Table A-13 indicates that the System would have had substantial effects on peak flows, particularly those peaks resulting from upper basin runoff. Missouri River floods can continue to occur, particularly in downstream portions of the basin. With the storage evacuation requirements, the long travel times involved to lower basin damage centers, and the lack of reliable, quantitative rainfall forecasts for several days in advance, occasions may occur when System regulation augments downstream flood events. A continuing objective of System regulation will be to reduce any such augmentations to the practicable minimum by improving forecasting procedures as technology improves.

A-06. History of the Sizing of the Storage Zones. Total storage in the System reservoirs is divided into four storage zones, as discussed in Section 7-03.1. These four storage zones are the Exclusive Flood Control Zone, the Annual Flood Control and Multiple Use Zone, the Carryover Multiple Use Zone, and the Permanent Pool Zone. The current distribution of the current System storage of 72.4 MAF has changed over the years (see Plate VII-3). Because two of the zones were established for flood control, the history of the distribution of the storage among the four zones is contained in this appendix.

A-06.1. Original Sizing of the Storage Zones. The ratio of the gross storage capacity of the System to the annual inflow into the System is unusually high for a major river system and is unprecedented elsewhere in this country. The total System storage is just a little less than the volume of three average years of runoff of the Missouri River above Gavins Point Dam. The large amount of storage results largely from the physical characteristics of the reservoirs and the dam sites. Economic studies at the time of project planning indicated the desirability of the maximum practical site development; consequently, all of the major storage sites, except Fort Peck, were constructed to the maximum level permitted by major relocations from the reservoir areas. The relatively flat slope of the Missouri River valley results in a large storage volume for a given dam height.

A-06.2. Permanent Pool Zone Sizing. The top of the Permanent Pool Zones at Fort Peck, Garrison, Oahe and Fort Randall establishes the normal minimum operating pool level as well as the base of the Carryover Multiple Use Zone. At Big Bend and Gavins Point, the base of the Annual Flood Control and Multiple Use Zone is the normal minimum operating pool level. Although competition between the flood control and the other multiple-use purposes was minimal in the establishment of the Permanent Pool Zone levels due to the large amount of storage available, competition between these other multiple uses is apparent, particularly during extended periods of below-average water supply. At the three larger projects and Fort Randall, powerplant and surge tank design established runner cavitation limits, and minimum assured peaking capability were based on the selected top of the minimum operating pool. Future lowering of these Permanent Pool Zones would, therefore, appear very unlikely. While drawing reservoir levels down into the minimum pools is less likely with the CWCP than in previous System water control plans, dropping into this storage zone could occur in a drought that was more severe than the drought of the 1930s. The established minimum level at Big Bend and Gavins Point could be lowered, and reservoir levels could temporarily fall somewhat below the minimum rather frequently. Due to the relatively minor amounts of storage space involved and the lakeshore development that has occurred based on the established minimums, any deliberate, long-term lowering of these reservoirs below presently-established minimums is, however, very unlikely.

Table A-13
1951-1952-1944 Actual and Regulated Flood Peaks

	Actual Observed		**Regulated by System**	
Location	**Peak (1000 cfs)**	**Date**	**Est. Peak (1000 cfs)**	**Date**
	1951 Flood			
Sioux City	152	Apr 8	67	Jun 19
Omaha	152	Apr 11	107	Mar 28
Nebraska City	163	Mar 29	155	Mar 28
Kansas City	573	Jul 24	370	Jul 14
	1952 Flood			
Sioux City	441	Apr 14	65	Apr 11
Omaha	396	Apr 18	85	Apr 1
Nebraska City	414	Apr 19	108	Apr 2
Kansas City	400	Apr 24	120	Apr 24
	1944 Flood			
Sioux City	136	Jul 7	109	Jul 12
Omaha	138	Jun 17	113	Jun 13
Nebraska City	214[1]	Jun 14	180	Jun 14
Kansas City	186[1]	Jun 20	145	Jun 16

[1] Peaks at Nebraska City and Kansas City appear inconsistent; however, they are as reported in USGS Water Supply papers.

A-06.3. Flood Control Storage versus Carryover Multiple Use Storage Sizing. Competition between flood control and the other multiple-use purposes existed, to a degree, in first establishing the zonal boundaries between the Carryover Multiple Use Zone and the Annual Flood Control and Multiple Use Zone. The maximum benefit, in the case of flood control, would be to provide sufficient empty storage space to store runoff from flood events of the most remote probability of occurrence. On the other hand, in the case of navigation, hydropower generation, and other System project purposes, the entire capacity of the System could be used as a Carryover Multiple Use Zone to more closely provide full service to these purposes, if a drought like the 1930s were to occur. In view of the magnitude of the potential flood damages in the Missouri River basin (to urban as well as rural areas and to the extensive transportation and communication facilities in the Missouri River floodplain), the engineers that originally established the volume set aside in each storage zone recognized that the flood control objective of the System should provide for adequate control of a very severe flood that could be expected to recur at only very infrequent intervals. At the time of initial design of the System in the 1940s, it was considered impracticable to establish any single flood event for the System as the Reservoir Design Flood. However, the Great Flood of 1881 comprised the most critical flood series of historic record in the Missouri River basin. Therefore, the 1881 flood served, in large measure, as the signature event for establishing System flood control storage allocations and the associated System reservoir release rates, should such an event occur. Allocation of sufficient flood control storage (within the combined Exclusive Flood Control and Annual Flood Control and Multiple Use Zones) to control the 1881 flood event established the base of these two flood control zones and, thus, the volume of storage that could be used for Carryover Multiple Use and Annual Flood Control and Multiple Use purposes.

A-06.4. Exclusive Flood Control Zone Sizing. The two upper zones are considered the total System flood control storage space. Within this total flood control space, the level separating the Exclusive Flood Control Zone from the Annual Flood Control and Multiple Use Zone was dictated by specific flood control considerations. Sufficient storage was provided in the Exclusive Flood Control Zone to control the flood runoff from a significant rainfall event that could occur late in the flood season after the Annual Flood Control and Multiple Use Zone was already filled. Additionally, it was deemed important that sufficient storage remain in the Annual Flood Control and Multiple Use Zone to assure continuation of full service to non-flood control purposes until the following flood season began without an annual draw down into the Carryover Multiple Use Zone. The top elevation of the Exclusive Flood Control Zone at each of the projects, except Fort Peck, are restricted by upstream System dams or cities and, as such, are not subject to change in the future. Sufficient surcharge storage, freeboard space, and spillway capacity are provided at each project to pass the maximum probable flood for each System project while maintaining the individual integrity of the System and its individual projects.

A-06.5. Summary on Original Zone Sizing. Allocation of storage in the System was essentially a matter of optimally dividing the storage space made available by site development limitations at the individual projects. A total volume of over 76 MAF was initially available in the System below the tops of the Exclusive Flood Control Zones of the individual System projects. Of this total, approximately 18 MAF was considered Permanent Pool Zone storage. This resulted in about 58 MAF of System storage space available for all Congressionally authorized System project purposes. Above the Exclusive Flood Zone lies about 10 MAF of surcharge storage, which is used for regulation of the various spillway design floods, and over 30 MAF of freeboard storage.

A-06.6. Preliminary Individual Project Storage Zone Allocations. During preauthorization System planning in 1943 and 1944, studies were made of flood control storage requirements in the System reservoirs as individual units in the basin program. What is now referred to as a Standard Project Flood was not yet developed; the relatively conservative design inflows to the System used in these studies were based on past flood history. Great emphasis was placed on the reconstructed 1881 flood for which records were very sparse and not subject to refined analysis. At the time, no detailed techniques for flood control regulation had been selected. Regulation studies were based on not exceeding specified release rates, with very little consideration of the potential downstream effects of these releases. As a consequence, the System storage required for the control of flood flows varied over a range from approximately 15 to 21 MAF, depending on the criteria and assumptions chosen. These studies determined that, as a result of continued basin water resource development, the required flood control storage space in the System would in time decrease. This was based on a level of basin water resource development that included additional tributary reservoirs that would have flood control functions and on future irrigation and water supply depletions.

A-06.7. Early Design Studies Regarding Storage Allocation. As planning and design of the System continued after authorization in the 1944 Flood Control Act, many long-range reservoir regulation studies were prepared, some of which were presented in the Definite Project Reports of the mid- to late 1940s. These early, long-range studies primarily demonstrated performance for three of the four basic purposes, namely navigation, hydropower and irrigation. Only very general consideration was given to flood control regulation requirements in these early multiple-purpose regulation studies, which were generally limited to a demonstration of monthly flow regulation at Sioux City during the period of record. What was considered at the time of each study to be sufficient flood control storage space, within the range developed in preauthorization planning, was allocated to flood control on an exclusive and seasonal storage basis. The storage allocations reflected the basic assumptions made at the time of the study and, in retrospect, appear inconsistent, to some degree, in many cases. Variations between, and limitations of, these early studies resulted for three reasons. First, preliminary System project area-capacity curves were used that later changed. Second, in many cases, no allowances were made for future loss of storage to sedimentation. Finally, different levels of basin water resource development with corresponding differences in irrigation depletions were used and early estimates of future streamflow depletions were subsequently revised.

A-06.8. Early Multiple-Purpose Studies. Some of the early multiple-purpose studies for the partially completed System provided for temporary assignment of greater initial flood control allocations at individual projects to provide sufficient System storage pending completion of all System projects. All of the multiple-purpose reservoir regulation studies of the completed six-project system that were made prior to 1956, however, used a common set of elevations for the base of Exclusive Flood Control and Annual Flood Control and Multiple Use Zones in the System reservoirs, as shown in Table A-14.

A-06.9. Project Zone Levels. The selection of these levels was based on the total System storage required for the flood control purpose together with runoff characteristics of the incremental reaches, as defined by the individual System projects. The relationship between the current storage space in the zones defined by these elevations at the major reservoirs and the maximum monthly reach runoff of record is illustrated in Table A-15.

Table A-14
Project Zone Levels

Project	Elevation of Exclusive Flood Control and Annual Flood Control Zone (in feet)	Elevation of Multiple Use Zone (in feet)
Fort Peck	2246.0	2234.7
Garrison	1850.0	1830.0
Oahe	1617.0	1610.0
Big Bend	None	None
Fort Randall	1365.0	1350.0
Gavins Point	1208.0	1204.5

A-06.10. Fort Randall Flood Control Storage. The relatively greater amount of flood control storage space provided in Fort Randall was in recognition of this project's downstream location where re-regulation of upstream projects' flood control releases is required plus Fort Randall's requirement to serve as a temporary storage buffer for significant downstream flood control regulation below the System. The Gavins Point elevations are based on the design studies presented in the Gavins Point Definite Project Report.

Table A-15
Comparison of Current Flood Control Storage Space to the Maximum Monthly Reach Runoff of Record for Each System Project

	Max Monthly Reach Inflow	Total FC Storage	Exclusive FC Storage	Ratio of FC Storage to Monthly Reach Inflow	
Project	(1000 acre-feet)			Total	Exclusive
Fort Peck	4,825	3,675	971	0.76	0.20
Garrison	6,485	5,706	1,495	0.88	0.23
Oahe	3,953	4,315	1,107	1.09	0.28
Fort Randall	1,660	2,292	986	1.38	0.59

A-06.11. Storage Zone Elevations. These elevations were used in regulation studies VII-D, VII-G, VII-J, and IX-A that are presented in Definite Project Reports. They were, subsequently, also used in study PGOR-6, which was completed in 1953. The elevations were held constant for all studies, although there were considerable variations from study to study in the level of irrigation development assumed (from no depletions to as much as one-fourth the annual runoff at Sioux City). Variations in the storage curves and in the estimated growth and ultimate level of depletions were also used.

A-06.12. Determination of Flood Control Storage Needed. The first detailed, long-range regulation study of the System that attempted to systematically reflect the progressive growth of irrigation depletions and the loss of storage to sedimentation, were MRD studies PGOR-10A and 10B, published in April 1956. For those studies, 20.7 MAF of combined exclusive and seasonal flood control storage space (near the maximum developed in preliminary studies of flood control requirements) was assumed to be required under the 1949 level of basin water resource development. Also assumed, the flood control requirements would be reduced to 15 MAF (the minimum requirement developed in preliminary studies) by the year 2010.

A-06.12.1. Long-range System regulation studies that were conducted in 1958 in connection with cost allocation studies were based on the streamflow depletions that had developed prior to 1949. These studies considered the effects of these depletions on historical runoff into the System. They also assumed a System flood control storage capacity of about 17 MAF for the early years of System regulation, with this value reduced to about 15 MAF by the year 2010 to reflect continued water resource development in the basin.

A-06.12.2. All of these early, long-term studies reflected the very substantial multiple benefits derived from the System. They also reflected the basic regulation objectives necessary to obtain these benefits through a relatively large range of possible storage allocation alternatives to the flood control function. They also demonstrated the continued performance of the System over the years when depletion in water supplies due largely to irrigation development would occur; sedimentation in the reservoirs could be expected; and a large number of tributary reservoirs, both upstream and downstream from the System, would be constructed.

A-07. Historic Missouri River Basin Droughts. A drought, for the purposes of this discussion, is defined as those years when less than median runoff occurs for three or more consecutive calendar years. System regulation associated with drought can be challenging. All Congressionally authorized project purposes except flood control are negatively affected during significant drought, and the negative impacts are generally less localized. Also, the drought, and the resultant water conservation that comes with it, persists for years at a time, which compounds and amplifies negative impacts. An examination of the period of record (from 1898 to 2017) of annual runoff above Sioux City, IA indicates that four significant droughts have occurred in the upper basin since 1898 (see Plate A-3). The runoff data on Plate A-3 are adjusted to a consistent depletion level that occurred in 1949 before most of the major water resources were developed in the Missouri River basin. This adjustment is done so that data can be compared on a year-to-year basis throughout the period of record. The drought periods, as defined earlier, are represented in Plate A-3 as yellow bars. The System, aside from Fort Peck, was constructed during the 1950s and early 1960s and first filled in 1967. As shown in Plate A-3 and Plate VII-2, three out of the four droughts in the historic record have directly impacted the storage in the System.

A-07.1. Megadrought. The fact that the Missouri River basin experiences significant drought has been chronicled many times in its historic descriptions. Terms like “The Great Desert” have been used historically to describe the diverse aspect of this semi-arid region. The term “megadrought” is used in describing periods of drought lasting two decades or longer. Past megadroughts have been associated with persistent multiyear La Niña conditions (cooler than normal water surface temperatures in the tropical eastern Pacific Ocean). Only in recent years has the full scope of megadrought in this region been evaluated by climate researchers using scientific methods to verify the temporal and spatial extent of historic droughts.

A-07.2. Research Efforts on Historic Droughts. Recently climate researchers have been examining the impacts of weather phenomena such as El Niño and La Niña on the United States climate, but these effects may pale in comparison to megadroughts of the past. A drought in the

16th century, according to the latest research, could have lasted over 40 years and been the worst in the last 800 years according to tree ring studies. Some drought researchers currently conclude that these types of extensive droughts are linked to ocean currents like those discussed above but on a much larger scale. Drought is currently the most severe type of natural disaster because of its large aerial extent and prolonged duration. Another research effort is ongoing to examine drought in the Sand Hills area of Nebraska, where past droughts have been so severe as to cause all vegetation to disappear and the area to turn to dust. Such a drought occurred in this area 800 to 900 years ago. An examination of this data leads to the conclusion that drought has been a part of the fabric of the Missouri River basin for hundreds of years.

A-08. Historic Major Droughts Prior to System Regulation in 1967. This section of this appendix discusses drought prior to the System being filled in 1967. An examination of Plate A-3 reveals there have been two documented droughts between 1898, when detailed basin runoff record-keeping began, and 1967, when the System filled to normal levels. The first was the 12-year drought that extended from 1930-1941. The other significant drought is the drought that occurred from 1954-1961. Various indicators have identified the potential for droughts much greater than those that have been experienced since 1898.

A-08.1. Drought of 1930-1941. Since detailed record-keeping began in 1898, the first major basin drought was the 12-year drought that extended from 1930-1941. It occurred during what is often labeled the Great Depression era of our country and caused the central plains to turn into what was termed the "dust bowl." Fort Peck, one of the three largest System reservoirs, was constructed during this period. The Great Depression and the 12-year drought forced many farmers and businessmen to leave the Missouri River basin, never to return. During the 1930s federal and state agencies poured more than $1.2 billion into the Missouri River basin for agricultural relief. Avoidance of the tremendous negative impacts of drought and floods was a primary consideration of Congress in the authorization of the construction of the System. System regulation during an extended drought was an integral part of the original water control plan. The System, as designed and constructed, has a great capacity to serve project purposes during droughts. The 1930-1941 drought was the most significant event in the basin hydrologic record at the time that the original water control plan was developed. The Corps designed the System and its storage zones, described in Section A-06, with the 12-year drought in mind. The substantial Carryover Multiple Use Zone was sized to provide continued support to project purposes during a drought similar to the 1930-1941 drought.

A-08.2. Drought of 1954-1961. Fort Peck filled to its normal operating pool level in May 1942, just after the 1930-1941 drought ended. Construction of the remaining five System dams began in 1946. The time to construct each project varied from 5 to 14 years, with the two large upstream projects requiring a longer construction time. When completed, Garrison and Oahe became the world's fourth and tenth largest earthfill dams, respectively. The 1954-1961 drought was the second significant extended drought in the Missouri River basin since record-keeping began in 1898 and occurred during and immediately following the construction of the System when these projects were being filled to their normal operating pools levels. The drought began in 1954 just after Fort Randall and Garrison were closed and extended for eight years, two years before Big Bend, the last System project to be constructed, was closed in 1963. The 1954-1961 drought considerably delayed the filling of the System and prompted a great amount of discussion and changes to the annual System regulation plan in order to promote the filling of the

System. Total System storage available was 75.4 MAF, making the System the largest reservoir system in the United States. The System has the capacity to hold three years of the annual flow of the Missouri River at Sioux City, IA, which is just downstream of the System. It was not until the summer of 1967 that the System storage reached 59.0 MAF, the top of the Carryover Multiple Use Zone.

A-09. Major Droughts since the System Filled in 1967. Sections A-09 through A-13 of this appendix provide information on System regulation during the droughts that have occurred since the System filled in 1967. An examination of Plate A-3 reveals there have been two droughts since the System filled. The first was the 1987-1992 drought. This drought prompted a review of the System water control plan that ultimately resulted in a revision to the Master Manual in March 2004 to include more stringent water conservation measures.

A-09.1. Drought Water Conservation Measures. Regulation of the System is driven by basin runoff. The level to which Congressionally authorized project purposes can be served is based on the amount of water in storage as well as the amount and seasonal distribution of the annual runoff. Because of this, water conservation measures are instituted during dry or drought periods to provide for saving, or conserving, existing water in storage to allow service to project purposes during extended droughts. Generally, only near-average-or-higher runoff can restore the System to its desired state (at the base of the Annual Flood and Multiple Use Zone at the beginning of the runoff season) after System reservoir storage levels are reduced below their respective desired levels due to drought.

A-10. Drought of 1987-1992. The 1987-1992 drought was the first significant Missouri River basin drought since the System was filled in 1967. The annual runoffs for this 6-year drought period are shown in Table A-16. As releases were made to meet authorized purposes throughout the drought, the reservoir levels in the upper three projects dramatically declined. The calendar year runoffs during the drought period are shown on Plate A-3 and in Table A-16.

A-10.1. Water Conservation Measures during the 1987-1992 Drought. The conservation criteria presented in the 1979 Master Manual were in place during this drought; however, some adjustments were made to account for changed circumstances that had occurred since the 1979 Master Manual was finalized. Generally, the System water conservation criteria of the 1979 Master Manual delayed implementation of conservation measures earlier in a drought as compared to the criteria in the 2004/2006 Master Manual. An important feature of both the 1979 and 2004/2006 Master Manuals is that water conservation criteria is based on actual System storage checks, not forecast data. In general, the water conservation criteria is designed to become increasingly more stringent as the drought conditions linger into multiple years.

A-10.2. Regulation during the 1987-1992 Drought. Regulation of the System during this drought is described below. Regulation for T&E species began in 1986 and regulation for this purpose is, therefore, also covered in the description.

A-10.2.1. Regulation during 1987. Based on the March 15 System storage check of 59.4 MAF, 1.9 MAF above the base of the Annual Flood Control and Multiple Use Zone, navigation flow support started at full service on normal opening dates (April 1 at the mouth). From late May through early June, System releases were cycled during a cut-back period for downstream flood control and to prevent T&E birds from nesting on lower elevation sandbars. Based on the July 1 System storage check of 62.9 MAF, full service flow support for a full 8-month navigation season was provided. Based on the September 1 System storage check of 60.9 MAF, a Gavins Point winter release of 18,000 cfs, a normal winter release rate, was scheduled. Thus, no water conservation measures were enacted during 1987. Runoff during 1987 was 23.1 MAF, slightly below average.

A-10.2.2. Regulation during 1988. Based on the March 15 System storage check of 55.8 MAF, 1.7 MAF below the base of the Annual Flood Control and Multiple Use Zone, navigation flow support started at full service on normal opening dates (April 1 at the mouth). The T&E species nesting occurred with a System release rate of 32,000 cfs, the highest System release possible during the T&E nesting season without inundating nests directly downstream of Gavins Point Dam. During late June and early July the System release, combined with downstream tributary flows, did not meet downstream navigation flow targets. The System release was not increased because doing so would cause T&E species nests to be inundated. Missouri River flows were approximately 3,500 cfs lower than needed to meet navigation flow targets. Based on the July 1 System storage check of 54.3 MAF the service level for the second half of the navigation season should have been reduced by 3,000 cfs. Following a series of coordination meetings with basin interests, a decision was made to provide full service navigation flow support during the remainder of the 1988 season in exchange for a one-week delay in the opening of the 1989 navigation season. Dredging on the Missouri River was required during July, September and October 1988. The navigation season was shortened two weeks in the fall as a water conservation measure. Winter System releases were lowered to 12,500 cfs when the navigation season closed in mid-November as another water conservation measure. The runoff in 1988 was 12.4 MAF, the fourth lowest since record-keeping began in 1898. During 1988 (from January 1 to December 31) the pool levels at Fort Peck, Garrison and Oahe, the three System reservoirs that are impacted by drought, declined 12, 14 and 14 feet, respectively.

A-10.3. Regulation during 1989. As discussed in the previous section, downstream flow support began one week later than normal to compensate for the higher service level provided in 1988. The 1989 navigation service level was established at an intermediate service level (3,000 cfs below full service, which is 3,000 cfs above the minimum service level) based on the March 15 System storage check of 45.9 MAF. During the navigation season, navigators experienced many groundings, double-trippings, and bottom bumpings on the lower Missouri River with the less-than-full service flows. In May, the RCC (now known as MRBWM) determined that a System release of 32,000 cfs would be required to meet downstream flow targets later that summer. Based on 1979 Master Manual criteria, a July 1 System storage less than 50.5 MAF calls for navigation flow support at a minimum service level, which is 6,000 cfs less than the full service level, for the remainder of the navigation season. After several coordination meetings with the basin stakeholders, an intermediate service level of 3,000 cfs less, rather than 6,000 cfs less, than full service was provided in exchange for a shortening of the navigation season. Flow support for navigation was stopped four weeks early to offset the higher service level flows provided during the last half of the navigation season. With System releases maintained at 32,000 cfs to protect the T&E species' nests, downstream tributary flows declined to much-lower-than-expected levels during the summer. In August, the downstream flow targets were missed from 1,000 to 3,400 cfs and the navigators experienced many groundings. In this third year of the drought, $3 million in federal funding was expended by the Corps to extend boat ramps on the upper System reservoirs. Based on the September 1 System storage check of 45.4 MAF, the average System winter release rate was set at 10,500 cfs. Fall System releases were reduced to as low as 10,000 cfs, the minimum level to prevent downstream intake problems. System releases during December were reduced from 17,000 cfs, during ice formation, to 12,000 cfs once a stable ice cover was formed. The Missouri River downstream of Gavins Point Dam had a 400-mile stretch that was ice covered during the coldest period of the 1989-1990 winter.

A-10.4. Regulation during 1990. During the fall of 1989 when the draft 1989-1990 AOP was being compiled, many basin stakeholders provided input regarding the plan for System release rates and downstream target flows. The RCC (now MRBWM) decided to open the 1990 navigation season one week later than normal, to compensate for the extra flow service provided in 1989. The 1990 navigation season was closed four weeks early. By mid-January, System releases were lowered to 10,500 cfs. In March, after coordinating with the Missouri River intake owners, System releases were reduced to 9,500 cfs. Based on March 15 storage check of 44.2 MAF, the service level was set at a minimum service level. Navigators loaded tows to 7.5-foot drafts, 1 foot lower than they do with full service flows. The RCC (now MRBWM) determined that a Gavins Point release rate of 30,000 cfs would be needed during August to meet downstream flow targets. In order to encourage T&E species nest creation at elevations that would not be inundated later in the summer, the System releases were increased to 30,000 cfs in May. As a water conservation measure, the releases were “cycled”, meaning that a 30,000 cfs release was made every third day with lower releases being made the other two days. This was the first year for “cycled” System releases aside from the flood control regulation period in 1987. System storage peaked at 45.4 MAF in early July, 11.8 MAF below the base of the Annual Flood Control and Multiple Use Zone. The System release of 30,000 cfs resulted in downstream flow targets being missed a couple times, but not by more than 500 cfs. Missouri River navigation support from Kansas River reservoirs was utilized beginning in September. The Kansas River system provided up to 2,300 cfs above their required water quality flows during October. Flow support for Missouri River navigation ended four weeks earlier than normal. System releases were reduced to 9,000 cfs by November 14. System releases were increased to 16,000 cfs in mid-December to lessen impacts from Missouri River ice formation. During the early winter, several ice jams did form. The jams caused the Missouri River stages to decline considerably for a day or so. As this stage decline moved downstream many intakes lost access to water until the stage reduction moved further downstream and normal winter stages returned.

A-10.5. Regulation during 1991. As the drought continued, water conservation measures intensified. As was done in the previous fall, during the fall of 1990 when the draft 1990-1991 AOP was being compiled, many basin stakeholders provided input regarding the plan for System release rates and downstream target flows. Similar to 1989 and 1990, flow support for navigation began one week later and ended four weeks earlier than normal. System winter releases were as low as 9,000 cfs after the ice cover stabilized in February. Downstream of Gavins Point Dam, 176 miles of the Missouri River was ice covered. In May, the RCC (now MRBWM) determined that a System release rate of 29,000 cfs was needed to meet late summer navigation flow targets. System release cycling was implemented in May with 29,000 cfs released every third day. High flows on the James River required that System releases be reduced for several days to reduce downstream flood risk. During this time some T&E birds nested on low areas on sandbars between Gavins Point Dam and the confluence of the Missouri and James Rivers, about 10 miles downstream of Gavins Point Dam. As a result of the low T&E

species' nesting, the cycle peak was temporarily reduced to 27,500 cfs to prevent nest inundation. Following a reconnaissance by USFWS staff, the peak of the cycle was increased slightly to 28,000 cfs, but was not returned to the 29,000 cfs rate established earlier. Tows were again loaded to 7.5-foot drafts. Supplemental navigation flow support from the Kansas System reservoirs was utilized. Releases to support Missouri River navigation resulted in these reservoir levels declining 6 feet, which is provided for in their respective WCMs. The navigation season closed on November 1. Following the close of the navigation season, System releases were reduced to 9,000 cfs. When extremely cold temperatures entered the basin in late November, System releases were increased to 15,000 cfs. Once an ice cover formed, releases varied between 12,000 and 14,000 cfs.

A-10.6. Regulation during 1992. As was done in the two previous years, several meetings were held during the winter of 1991-1992 to discuss the 1992 navigation flow support. The result of these meetings was that the RCC (now MRBWM): 1) maintained the season opening date at the normal date of April 1 at the mouth, 2) set the navigation flow support level at the minimum service level, and 3) determined that the navigation season closing date would be based on the July 1 System storage check. During February, System releases were reduced to 9,000 cfs and then were further reduced to 6,000 cfs. Releases were 7,000 cfs prior to the increase of the releases in mid-March to support the navigation season. In early May, the RCC (now MRBWM) determined that a System release of 29,000 cfs was needed to meet downstream flow targets during the late summer. Cycling was again implemented as a water conservation measure. The System release rate was later reduced to 27,000 cfs and then to 23,000 cfs as high downstream tributary flows on the Big Sioux River helped provide enough tributary flow to meet navigation flow targets. System storage peaked at 46.1 MAF on March 18. High downstream tributary flows resulted in System releases being maintained at fairly low levels (about 23,000 cfs) during the latter part of the navigation season. Supplemental navigation support was not required from the Kansas Reservoir system. The navigation season was closed five weeks early as a water conservation measure.

A-10.7. Regulation during 1993. For a fourth consecutive year, the basin interests provided input during the fall AOP process for the 1993 navigation season. Flow support for the 1993 season was at minimum levels and the season started at the normal time (April 1 at the mouth). However, 1993 was an extremely wet year in the lower basin. Because of high downstream flows and significant runoff, System storage recovered to normal levels during 1993. The USCG closed navigation on the Missouri River for over seven weeks (53 days) because of extremely high downstream flows. The closing was done as a safety precaution and to reduce wave action on the many levees that were nearly overtopped during the Great Flood of 1993.

Table A-16
Drought of 1987-1992 - Significant System Criteria

Year	Calendar Year Runoff- (MAF)	March 15 System Storage (MAF)	Level of Service (kcfs)	July 1 System Storage (MAF)	Navigation Service Level (kcfs)	Sep 1 System Storage (MAF)	Winter System Release (kcfs)	Actual Winter Release (kcfs)	Navigation Season Shortening (weeks)
1987	23.1	59.4	full	62.9	full	60.9	17.0	18.0	0
1988	12.4	55.8	full	54.3	full	50.5	12.3	13.6	2
1989	17.7	45.3	-3.0	47.8	-3.0	45.3	10.0	13.0	5[1]
1990	16.7	44.3	min	45.2	min	43.9	10.0	12.4	5[1]
1991	22.3	41.7	min	47.7	min	46.8	10.0	12.1	5[1]
1992	16.4	45.4	min	45.1	min	44.7	10.0	13.1	5
[1]Season shortened one week at beginning of season									

A-11. System Regulation during Droughts under the 1979 and 2004/2006 Master Manuals. The 1987-1992 resulted in heated controversy over the adequacy of the 1979 Master Manual regarding service provided to project purposes, especially recreation versus navigation. This resulted in the Master Manual Review and Update Study, which investigated numerous water control plan alternatives. The resulting 2004/2006 Master Manual included more stringent water conservation criteria.

A-12. Drought of 2000-2007. The 2000-2007 drought was the second significant Missouri River basin drought since the System was filled in 1967. The annual runoffs for this 8-year drought period are shown in Table A-17. While none of the annual runoffs were as low as observed during the previous 1987-1992 drought (e.g., 12.4 MAF in 1988), the length of the drought resulted in the System reaching its lowest storage level of 33.9 MAF (February 2007) since the System filled (1967-2017). During this drought, record low elevations were reached at Fort Peck, Garrison and Oahe. The calendar year runoffs during the drought period are shown on Plate A-4 and in Table A-17.

A-12.1. Regulation during 2000. Based on the March 15 System storage check of 57.7 MAF, the 2000 navigation season began on the normal opening date (April 1 at the mouth) with full service flow support. The July 1 System storage check of 57.0 MAF resulted in a reduction in service level (1,500 cfs below full service level) for the second half of the navigation season and a full navigation season (December 1 at the mouth). Per the 1979 Master Manual criteria, water conservation measures were to begin (e.g., less than full service for the second half of the navigation season) when the July 1 System storage check is less than 59.0 MAF.

A-12.2. Regulation during 2001. Based on the March 15 System storage check of 50.3 MAF, the 2001 navigation season began on the normal opening date (April 1 at the mouth) with intermediate service flow support, which was 3,000 cfs below and above full service and minimum service levels, respectively. While there was a good volume of plains snowpack during the 2000-2001 winter, much of plains snow volume was in eastern South Dakota in the Gavins Point to Sioux City reach, which is largely unregulated and empties into the Missouri River downstream of the System. The volume contained in the plains snowpack in that area of the upper basin was not captured by the System reservoirs. This large runoff did allow for reduced System releases through May. The July 1 System storage check of 54.7 MAF resulted in a continuation of the intermediate service level (3,000 cfs less than full service), per the criteria in the 1979 Master Manual. The RCC (now MRBWM) determined that System releases would not need to be increased for T&E bird nesting because adequate T&E habitat was in place at the time. This habitat was created by high releases (60,000 to 70,000 cfs) in 1997 to evacuate System flood storage filled during that then-record runoff year. Because the base tributary flows were expected to remain fairly high and adequate T&E nesting habitat was in place, a "follow target" System release plan was implemented during the 2001 nesting season. The navigation season ended on the normal closing dates (December 1 at the mouth). During 2001 (from January 1 to December 31), the Fort Peck reservoir declined 7 feet as Montana experienced its third consecutive year of drought. Noxious weeds quickly became a serious issue in the Fort Peck reservoir; the exposed and vegetation-free shoreline opened up opportunity for weeds to encroach. Also, a new invasive species, the salt cedar, made this a more serious issue, because of its characteristic to consume tremendous amounts of water. Weed control during this drought tied up significant Omaha District resources that could have been used elsewhere to help alleviate other negative drought impacts. The Corps' Omaha District has since established an ongoing program to control noxious weeds on Corps property with a special focus on salt cedar.

A-12.3. Regulation during 2002. Based on the March 15 System storage check of 48.6 MAF, the 2002 navigation season began on the normal opening date (April 1 at the mouth) with intermediate service flow support, which was 4,000 cfs below and 2,000 cfs above full service and minimum service levels, respectively. The navigation season was impacted in early May when a series of lawsuits from basin states were served to the Corps. The State of South Dakota sued to maintain a level or rising Oahe pool during the rainbow smelt spawn. During the 4-week rainbow smelt spawning period, the intermediate service level was maintained and by intra-system regulation operations, a steady Oahe reservoir level maintained. These operations resulted in reservoir level reductions at the other five System reservoirs, which resulted in additional court actions. Reservoir access at the five reservoirs, other than Oahe, were negatively impacted. As was first done in 2001, a "follow target" regulation plan was implemented during the 2002 T&E bird nesting season. The July 1 System storage check of 48.4 MAF resulted in a service level change to minimum service. During July and August, the lower basin tributary runoff reduced such that an increase in System releases was required to meet downstream minimum flow targets. The Corps planned to captively rear T&E eggs and chicks that were in danger of inundation by the "follow target" regulation. The collection of eggs was started, but was later ceased when the Corps was informed by the USFWS that this operation would be considered "take." Therefore, from July 1 through August 15 System releases were not increased, but rather were maintained at 25,500 cfs. Maintaining System releases at 25,500 cfs resulted in serious navigation issues in the lower Missouri River: multiple groundings, a tow was broken open, and the navigation channel essentially closed and all tows had to leave the Missouri River. Dredging was required, at a cost of $465,000 to the Corps, to open two areas of the navigation channel that experienced serious shoaling due to the below-minimum service flows. Missouri River flow were as much as 7,000 cfs below minimum target levels during this period and Missouri River channel depths, in some locations, were less than 7 feet. Once the T&E bird nesting season ended on August 15 System releases were increased to "follow target" levels. The estimated loss to the navigation industry was $3.5 million. A river excursion boat estimated its losses at $1.1 million. The navigation season ended on the normal closing dates (December 1 at the mouth).

A-12.4. Regulation during 2003. Based on the March 15 System storage check of 42.6 MAF, the 2003 navigation season began on the normal opening date (April 1 at the mouth) with minimum service flow support. From August 11 to September 1 downstream navigation flow targets were not met; a court order called for the Corps not to increase System releases, which were approximately 26,000 cfs. The season length was shortened six days because of extra water used for winter 2002-2003 flow support (releases above the minimum winter rate of 12,000 cfs to keep lower river intakes operational). Per the July 1 System storage check of 45.1 MAF, the navigation season was to be shortened an additional 10 days. However, the 2003 navigation season shortening was only six days, rather than 16 days, to "offset" the six-week period in the 2002 navigation season when the Missouri River navigation season was impacted, as described in the previous section. Navigation support flows were required from the Kansas reservoir system during 2003. During 2003 (from January 1 to December 31), the Fort Peck, Garrison and Oahe reservoirs declined 7, 5 and 4 feet, respectively. The water supply intake at Fort Yates, ND, a city in Sioux County where the Tribal headquarters of the Standing Rock Sioux Tribe is located, failed in November 2003 due to the low Oahe reservoir levels. The Corps worked with the USBR to restore the intake as quickly as possible. During 2003, the Corps expended $1.2 million to extend boat ramps on the upper three System reservoirs.

A-12.5. Regulation during 2004. The 2004 Master Manual was finalized per a ROD on March 19, 2004. The modification of the Master Manual included several changes from the 1979 Master Manual: drought conservation measures, unbalancing of the upper three reservoirs, non-navigation flows, and an adaptive management process. All pending lawsuits were combined and the Federal 8th Circuit Court of Appeals ruled that the Master Manual was a "binding" document. Thus, the criteria in the Master Manual, such as determining level of service for navigation flow support and season length based on the System storage checks, should be followed as outlined. Based on the March 15 System storage check of 39.0 MAF, the 2004 navigation season began on the normal opening date (April 1 at the mouth) with a minimum service level for navigation flow support. Navigation flow targets were not met at Sioux City and Omaha in early April, in accordance with the Master Manual since there was no commercial barge traffic scheduled in those reaches during that period. Navigation support flows were required from the Kansas Reservoir system during 2004. The 2004 navigation season ended on October 15 at the mouth. Per the July 1 System storage check of 38.6 MAF and the 2004 Master Manual criteria, the navigation season was shortened by 47 days, which was 30 days shorter than under the 1979 Master Manual criteria. At Garrison, reservoir coldwater fishery issues were a concern as the pool elevations reached record low levels. The Corps spent $600,000 extending boat ramps in the System reservoirs in 2004. Following the end of the 47-day shortened navigation season and per the 2004 Master Manual criteria, System releases were gradually reduced to 9,000 cfs, the minimum non-navigation season release. The reduction of System releases to 9,000 cfs was accomplished over a period of several weeks. During this period, the MRBWM office coordinated with downstream users to ensure that downstream intakes would remain functional with these minimum System releases. The System release of 9,000 cfs was maintained through the fall because downstream tributary flows provided enough supplemental flow to the Missouri River to keep intakes functional. During the winter and per the 2004 Master Manual criteria, System releases averaged 12,000 cfs. The shortening of the navigation season from 17 days (1979 Master Manual) to 47 days (2004 Master Manual) resulted in a conservation of 0.7 MAF of water in the System reservoirs that would have been released by following the 1979 Master Manual criteria.

A-12.6. Regulation during 2005. The average daily System release for the month of February was 9,900 cfs, a record low. Based on the March 15 System storage check of 35.7 MAF, the 2005 navigation season began on the normal opening date (April 1 at the mouth) with a minimum service level for navigation flow support. The July 1 System storage check of 38.4 MAF resulted in a record navigation season reduction of 48 days. Missouri River navigation flow support was required from the Kansas River system in 2005. Downstream flow support for the navigation season ended on October 14 at the mouth. Unlike 2004, System releases were reduced quickly to non-navigation releases to conserve as much water as possible. The travel time from Gavins Point to the mouth is about 10 days. Starting on October 5, the System releases were reduced to 10,000 cfs at a rate of 3,000 cfs per day by October 10. Releases were then slowly stepped down over a 5-day period to the non-navigation flow support rate of 9,000 cfs. Unlike the fall of 2004, downstream tributary flows were lower than normal (below lower quartile levels) during October and November. In order to keep downstream water supply intakes functional, System releases were increased to 12,000 cfs, 3,000 cfs over the minimum non-navigation level of 9,000 cfs. The winter release rate of 12,000 cfs was scheduled once downstream tributary flows increased to more normal winter levels.

A-12.7. Regulation during 2006. Based on the March 15 System storage check of 36.7 MAF, the 2006 navigation season began on the normal opening date (April 1 at the mouth) with a minimum service level for navigation flow support. Winter System releases were 12,000 cfs, the minimum release needed to provide adequate water supply downstream of the System. As a water conservation measure, the navigation flow targets at Sioux City and Omaha were not met in late March and early April since there was no commercial barge traffic in those reaches. The July 1 System storage check of 39.0 MAF resulted in a navigation season reduction of 44 days. With Gavins Point releases at 26,000 cfs in mid-July, the minimum navigation flow target of 35,000 cfs at Kansas City was missed for a few days in late July. The System releases were increased to 31,500 cfs in late July to meet downstream navigation flow targets. The releases were gradually reduced to 25,000 cfs over the next two months as downstream tributary flows increased. Starting on October 7, the System releases were reduced 3,000 cfs per day to a non-navigation open season release of 10,000 cfs. The release was eventually increased to 11,000 cfs in late October to ensure that downstream water supply intakes remained operational.

A-12.8. Regulation during 2007. Winter System releases ranged from 11,000 to 16,000 cfs throughout the 2006-07 winter. As part of the water conservation measures, the System releases were adjusted throughout the winter to release only enough water to keep the downstream water supply intakes operational. The System storage reached its record low of 33.9 MAF on February 8. Based on the March 15 System storage check of 35.0 MAF, the navigation season began on the normal opening date (April 1 at the mouth) with a minimum service level for navigation flow support. Runoff from downstream tributaries was significant during the spring and summer. System releases ranged from 11,000 to 15,000 cfs for most of April and May. During the June-September period, the System releases ranged from 21,000 to 24,500 cfs. The July 1 System storage check of 40.2 MAF resulted in a navigation season reduction of 35 days. Higher-than-normal tributary runoff downstream of the System in October and November allowed for System releases to be set at 9,000 cfs for the non-navigation open season.

A-12.9. Regulation during 2008. Winter System releases ranged from 11,000 and 14,000 cfs throughout the 2007-2008 winter. As part of the water conservation measures, the System releases were adjusted throughout the winter to release only enough water to keep the downstream water supply intakes operational. Runoff during 2008 was 26.6 MAF, slightly more than the long-term average (25.3 MAF). However, water conservation measures were still in effect as the System had not recovered from the 2000-2007 drought. Based on the March 15 System storage check of 36.9 MAF, the 2008 navigation season began on the normal opening date (April 1 at the mouth) with a minimum service level for navigation flow support. System releases during the April-July period ranged from 10,000 to 19,000 cfs because downstream tributary runoff from rainfall events was significant throughout the spring and summer. The July 1 System storage check of 44.2 MAF resulted in a navigation season reduction of 30 days. Higher-than-normal tributary runoff downstream of the System in October and November allowed for System releases to be set at 9,000 cfs for the non-navigation open season.

A-12.10. Regulation during 2009. Winter System releases ranged from 12,000 and 16,000 cfs throughout the 2008-2009 winter. As part of the water conservation measures, the System releases were adjusted throughout the winter to release only enough water to keep the downstream water supply intakes operational. Water conservation measures were still in effect as the System had not yet recovered from the 2000-2007 drought. Based on the March 15 System storage check of 46.0 MAF, the 2009 navigation season began on the normal opening date (April 1 at the mouth) with a minimum service level for navigation flow support. Upper basin runoff during 2009 was 33.4 MAF, almost 8 MAF above the long-term average (25.3 MAF). Downstream of the System, tributary runoff was also significant, resulting in lower-than-average April-June System releases, which ranged from 15,000 to 25,000 cfs. The result of the above-average upper Basin runoff and the below-average System releases resulted in a July 1 System storage of 56.9 MAF and a full recovery from the 2000-2007 drought. Per the Master Manual, this System storage resulted in a full 8-month navigation season with full service navigation flow support for the second half of the season.

Table A-17
Drought of 2000-2007 – Significant System Criteria

Year	Calendar Year Runoff (MAF)	March 15 System Storage (MAF)	Service Level (kcfs)	July 1 System Storage (MAF)	Service Level (kcfs)	Sep 1 System Storage (MAF)	Winter System Release (kcfs)	Actual Winter Release (kcfs)	Navigation Season Shortening (days)
2000	16.5	57.7	Full	57.0	-1.5	54.3	14.4	14.0	0
2001	22.5	50.3	-3.0	54.7	-3.0	53.2	13.6	13.4	0
2002	15.8	48.6	-4.0	48.8	Min	46.9	10.0	13.3	0
2003	17.4	42.6	Min	45.1	Min	42.8	10.0	14.5	6
2004[1]	16.2	39.0	Min	38.6	Min	36.5	12.0	12.0	47
2005	20.1	35.7	Min	38.4	Min	37.3	12.0	13.0	48
2006	18.2	36.7	Min	39.0	Min	40.2	12.0	13.2	44
2007	21.1	35.0[2]	Min	40.2	Min	38.4	12.0	12.3	35
2008	26.6	36.9	Min	44.2	Min	45.0	12.0	12.2	30
2009	33.4	46.0	Min	56.9	Full	Recovered from drought			

[1]2004 Master Manual was finalized on March 19, 2004
[2]Record low System storage of 33.9 MAF reached on February 8, 2007.

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Appendix B - Recreation

B-01. General. The six reservoirs of the System and the Missouri River reaches between and downstream of these reservoirs provide recreation opportunities. Recreational activity is a source of income for businesses catering to boating, hunting, fishing, camping, and other recreational pursuits. Service-related establishments located near the 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 viable 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. Through 2012, the Corps stored the visitation data (in hours) in the Natural Resource Management's Visitation Estimation and Reporting System database. The methodology used for the Corps to determine visitation (visits) was revised in 2013. The new methodology leverages metered data that is collected as vehicles enter and exit the recreation areas. Plate B-1 shows the annual visitation graphically for the total System and the six individual System projects from 1954-2012 (in visitor hours) and from 2014-2017 (in visits). No visitation data is available for 2013. Plate B-1 shows that the trend is upward except during extended drought periods, when the trend levels off or is slightly reversed depending on the year. Other factors also affect the visitation numbers such as the overall United States economy. A survey completed in 1999 showed that of the annual visits made to the six projects, approximately 37 percent are made by sightseers, 29 percent by fishermen, 24 percent by boaters, 10 percent by picnickers, 9 percent by swimmers, 2 percent by campers, 2 percent by water skiers, 2 percent by hunters, and 22 percent by visitors who participate in other activities. The visit percentages total more than 100 percent (137 percent) and indicate that some visits include multiple activities. Refer to the individual mainstem WCMs for specific project visitation information.

B-03. Recreation Economic Impact. In addition to visitation data, economic data reveal the extent of recreation on the System reservoirs. The social, economic, and environmental benefits of recreation at national, division, state, and individual project levels is presented on the Corps' Value to the Nation website (http://www.corpsresults.us and http://www.corpsresults.us/recreation/recfastfacts.cfm).

B-04. Recreation Purpose. The recreation purpose is more fully discussed in Section 3.12 of the Missouri River Master Water Control Manual Final EIS (2004 Final EIS), Section 3.16 of the MRRMP-EIS, and Sections 4-06.7 and 7-08 of this manual.

B-05. System Regulation Problems Associated with Recreation. There is a direct conflict between providing adequate flows to support several other Congressionally authorized purposes and recreation in the upper three large System reservoirs. During high and normal runoff periods when the three large reservoirs are at normal or above-normal reservoir levels, there is enough water so this conflict is minimized. During prolonged drought periods when water is released for downstream flow support for water supply, navigation, powerplant cooling, downstream river recreation and water quality, there is a conflict with reservoir recreation at the Fort Peck, Garrison and Oahe projects. This conflict applies at the upper three large reservoirs because they are the only System projects that have Carryover Multiple Use Zone storage drawn from during drought or below-average water supply periods. This storage zone was sized, as discussed in Chapter VII, to serve the authorized project purposes during successive years of drought.

B-05.1. Recreation during Drought. Usually, the reduced runoff period must be greater than two years and System storage must be lowered below 52 MAF before a drought begins to significantly impact reservoir recreation. Because the recreation industry has performed through two significant droughts since the System filled in 1967, the recreation facilities at some locations on the three larger System reservoirs have been adapted to maintain functionality at lower reservoir levels. There are locations, however, on the three larger reservoirs that have no access during significant drought and cannot adapt other than provide alternative recreation. The three larger System reservoirs were expected to have greatly reduced reservoir levels during extended drought. That is why the upper three reservoirs' Carryover Multiple Use Zone storage is so large compared to other reservoir systems that do not provide water supplementation during significant drought. The federal government did provide funds for extending or constructing boat ramps to provide additional or improved access when the upper three System reservoirs were at lower levels during the two drought periods previously discussed. While this has improved the situation somewhat, reduced recreation benefits at the three larger System reservoirs during drought will continue to be an issue until the recreation facilities are adjusted to function at the lower reservoir levels or alternative recreation opportunities are provided during drought periods.

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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. From a historical perspective, water quality degradation has occurred in the Missouri River basin. 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 CWA because the river has become clearer and cooler and improved recreation and sport fishery. Conversely, the water quality has degraded as seen through the ESA because the natural turbid, warm river has become clearer and cooler, which may affect native river fish. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality.

C-02.1. Coldwater Habitat. The majority of the water quality degradation that is a direct result of System regulation occurs in the upper portion of the Missouri River basin. These direct water quality impacts include temperature changes in the reaches downstream from several of the dams, low concentrations of suspended solids in the releases, and temperature and dissolved oxygen problems when the upper three reservoirs are drawn down during droughts. These impacts are more physical in nature, involving the management of streamflow and water storage in the System. Water temperature is recognized as an important water quality condition affecting the fishery population in the Missouri River reaches downstream of the dams. Because releases from the System dams contain low concentrations of suspended solids, some native riverine fish species may be adversely affected. The drawdown of the three larger reservoirs during extended droughts diminishes the coldwater habitat. The water 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 in Sections C-03.1 through C-03.5.

C-03.1. Droughts. During extended droughts, low reservoir levels in the summer generally lead to lower dissolved oxygen levels in the deeper, cooler portions of the three larger System reservoirs. This volume reduction may cause an increase in the reservoir water temperature and may reduce the total amount of oxygen available to meet demands of sediment and decomposing organic material, such as decaying algae.

C-03.2. Dissolved Oxygen. 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 (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. Major Metals. 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. 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 (i.e., atmospheric deposition), 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. Agricultural practices, both past and present, include the application of pesticides throughout much of the Missouri River basin. The Omaha District Water Control and Water Quality Section scans for the following pesticides: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, deethylatrazine, deisopropylatrazine, dimethenamid, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate and trifluralin.

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

C-04. System Reservoir Water Quality. Specific water quality problems and issues detected in the System reservoirs are presented in Table C-1. This table summarizes the water quality conditions of the reservoirs (inflow, reservoir and outflow locations). This table also provides information on the length, surface area, volume and daily inflow rates. Specific reservoir water quality issues are discussed in Sections C-04.1 through C-04.6.

C-04.1. Fort Peck. The State of Montana has assigned Fort Peck Lake a B-3 classification in the state's water quality standards. As such, the reservoir is to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. The Missouri River downstream of Fort Peck Dam has been designated a B-2 classification from the dam to the confluence of the Milk River, and a B-3 classification from the Milk River confluence to the Montana/North Dakota state line (Montana water quality standards). Both B-2 and B-3 waters are to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming and recreation; waterfowl and furbearers; and agricultural and industrial water supply. Refer to Appendix C of the Fort Peck WCM for additional water quality information for Fort Peck Lake and the Fort Peck tailwater.

C-04.2. Garrison. Lake Sakakawea is on the State of North Dakota's 303(d) List of Impaired Waterbodies citing impairment to the use of fish consumption due to methyl mercury. Currently, low dissolved oxygen and water temperature are not listed as stressors, but this may change during periods with lower-than-normal reservoir levels. Algal blooms occur at times in the reservoir during low reservoir conditions. A toxic algal bloom occurred in the reservoir in 1990 when the reservoir level declined to elevation 1815.0 feet during a drought. Organic materials, such as decaying algae and imported organic matter, contribute to the in-reservoir oxygen demand and result in reduced dissolved oxygen levels in the deeper, cooler portion of the reservoir. Dissolved oxygen concentrations may fall below 5 mg/l in the deeper, cooler portion of the reservoir, and coldwater habitats may be reduced during drought conditions. Refer to Appendix C of the Garrison WCM for additional water quality information for Lake Sakakawea and the Garrison tailwater.

C-04.3. Oahe. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Oahe reservoir in the state's water quality standards: recreation (i.e., immersion and limited contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has placed the Oahe reservoir reach of the Missouri River, which is from the North Dakota/South Dakota state line to the Oahe Dam, on its Section 303(d) list of impaired waters due to mercury in fish tissue. The State of South Dakota does not currently have a fish consumption advisory for mercury in fish tissue issued for this portion of the river. The State of North Dakota has a statewide fish consumption advisory due to mercury concerns. This advisory is applicable to the Oahe reservoir from its headwaters to the North Dakota/South Dakota state line. The State of North Dakota has classified the Oahe reservoir as a Class 1 lake. As such, the reservoir in North Dakota is to be protected for a coldwater fishery, swimming, boating, and other water recreation, irrigation, stock watering, wildlife, and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal CWA, North Dakota has not placed the Oahe reservoir on the state's list of impaired waters. The Cheyenne River Sioux Tribe has issued a fish consumption advisory for the Oahe reservoir and the Cheyenne and Moreau Rivers. Tribal lands of the Cheyenne River Sioux are located along the west side of the Oahe reservoir between the Moreau and Cheyenne Rivers. Refer to Appendix C of the Oahe WCM manual for additional water quality information for Lake Oahe and the Oahe tailwater.

C-04.4. Big Bend. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Big Bend reservoir (Lake Sharpe) in the state's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota listed Lake Sharpe on the state's Section 303(d) list of impaired waters and has targeted the reservoir and given the development of a total maximum daily load for Lake Sharpe a high priority. The reservoir use identified as impaired is coldwater permanent fish life propagation waters and the cause of impairment is identified as warm water temperatures and dissolved oxygen conditions. Lake Sharpe does not regularly form a coldwater hypolimnion and summer water temperatures discharged from Oahe, especially during times when the Oahe reservoir has lower pool levels, do not meet the temperature criteria for a coldwater fishery use. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Missouri River downstream of Big Bend Dam: domestic water supply waters, warmwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. Big Bend is the current demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of Warmwater Permanent Fish Life Propagation applies to Big Bend tailwaters rather than the Coldwater Permanent Fish Life Propagation use that applies to Lake Sharpe. Refer to Appendix C of the Big Bend WCM for additional water quality information for Lake Sharpe and the Big Bend tailwater.

C-04.5. Fort Randall. 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 does not currently have a fish consumption advisory posted 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. 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 does not currently have a fish consumption advisory posted for the reservoir. Refer to Appendix C of the Fort Randall WCM for additional water quality information for Lake Francis Case and the Fort Randall tailwater.

C-04.6. Gavins Point. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Gavins Point 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 Nebraska has designated the following water quality-dependent beneficial uses for the Gavins Point reservoir in the state's water quality standards: primary contact recreation, Class A warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply and aesthetics. The uses designated by the two states are consistent with each other. The State of Nebraska has placed the Gavins Point reservoir on the state's Section 303(d) list of impaired waters for impairment to the aquatic life use due to high levels of chlorophyll-α and impairment of the recreation use due to *E. coli* bacteria. Refer to Appendix C of the Gavins Point WCM for additional water quality information for Lewis and Clark Lake and the Gavins Point tailwater. The states of South Dakota, Nebraska, Iowa and Missouri have designated water quality-dependent beneficial uses for appropriate reaches of the Missouri River downstream of Gavins Point Dam to Rulo, NE:

a. South Dakota – primary contact recreation, warmwater fishery, drinking water supply and industrial water supply.
b. Nebraska – primary contact recreation, warmwater aquatic life, agricultural water supply and aesthetics. Also, the use of drinking water supply to the Missouri River downstream of the confluence of the Niobrara River and industrial water supply to the Missouri River downstream of the confluence of the Big Sioux River.
c. Iowa – primary contact recreation, warmwater fishery, and high quality state resource water. Also, the use of drinking water supply to the Missouri River in the area of Council Bluffs, IA.
d. Missouri – primary contact recreation, warmwater fishery, drinking water supply, agricultural water supply and industrial water supply.

C-05. Water Quality Monitoring at the Mainstem Projects. The Corps has monitored water quality conditions at the mainstem projects since the late 1970s. Water quality monitoring locations have included sites on the reservoirs and on the Missouri River upstream and downstream from the mainstem dams. The USGS monitors inflowing tributaries. Remote monitoring of releases for dissolved oxygen, pH, conductivity and temperature occurs at all of the System projects. Monitoring is conducted to detect water quality problems and determine compliance with federal water quality criteria and state and local water quality standards. 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.

Table C-1
System Reservoir Water Quality and Physical Description Summary

Project	Potential Problem Areas	State Standard Concerns	Length (miles)	Surface Area (acres)	Gross Volume (acre-feet)	Mean Daily Inflow (kcfs)
Fort Peck Lake, MT Missouri River Mainstem	Coal and oil development, algal blooms, nutrients	Inflows: Copper, lead, nutrients Lake: Arsenic, mercury, dissolved oxygen Releases: Temperature	134	210,700	14,788,000	10.0
Lake Sakakawea, ND Missouri River Mainstem	Oil production, strip mining, nutrients, algal blooms	Inflows: *E. coli* Lake: Arsenic, mercury, dissolved oxygen Releases: None identified	178	307,775	17,744,640	22.8
Lake Oahe, SD Missouri River Mainstem	Ag runoff, mercury, bioaccumulation,	Inflows: Nutrients Lake: Mercury Releases: Arsenic, mercury,	231	312,100	18,667,635	25.3
Lake Sharpe, SD Missouri River Mainstem	Ag runoff, atrazine, mercury	Inflows: None identified Lake: Mercury, temperature, dissolved oxygen Releases: Sulfate	80	59,700	1,738,000	23.8
Lake Francis Case, SD Missouri River Mainstem	Intrusion of the white river delta, atrazine	Inflows: Nutrients Lake: Mercury, dissolved oxygen, arsenic Releases: Mercury	107	76,206	3,000,732	25.4
Lewis and Clark Lake, SD Missouri River Mainstem	Emergent aquatic vegetation, atrazine	Inflows: Mercury Lake: Mercury, dissolved oxygen, arsenic Releases: Mercury, arsenic	25	25,081	374,434	27.7

Notes: Length, surface area, and gross volume are at top of Carryover Multiple Use Zone. Mean daily inflow is for the period 1967 to 2016.

Source: NWD, Omaha District Water Quality Annual Report

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Appendix D - Fish and Wildlife

D-01. General. The USFWS has identified three protected species – the endangered interior least tern, the threatened piping plover and the endangered pallid sturgeon – that are affected by the regulation of the System. Development of the System has transformed a major portion of the Missouri River valley extending from eastern Montana through the Dakotas from an area typical of alluvial streams into a chain of long, relatively deep reservoirs. This development, in an area where such a quantity of surface water did not exist naturally and that is characterized as having a relatively dry climate, has had a great effect on the environment of the area. The purchase and subsequent management of lands associated with the individual System projects has changed use patterns of lands adjacent to the System projects from the use experienced prior to projects. Regulation of the reservoirs also has affected the regime of the Missouri River through those reaches below the System and in those reaches between the System reservoirs where the river is still more or less in its natural state. The full impact of each of the reservoirs and its regulation on the environment is constantly changing as they adapt to new conditions. The environmental emphasis has changed since the System was authorized. Current efforts are focused on increased stewardship of the Missouri River and surrounding affected lands by maintaining them in as natural a condition as possible through enhancing and supporting native plants and species. The two basic goals of the Corps stewardship are to manage lands and waters to ensure their availability for future generations and to help maintain healthy ecosystems and biodiversity. Balancing the needs of the people with those of nature is the basic challenge. Through observations and discussion with interested individuals and agencies, many suggestions for environmental enhancement of the System have been received and are being implemented by the Corps. The adaptive management process discussed in Section 7-10 of this manual will provide 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. Effects from System Regulation. 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 practical for improving migratory waterfowl habitat and hunter access along the 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.

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

D-02.1. Missouri River Wildlife Habitat. The Missouri River creates and maintains important forest and wetland habitat for a wide diversity of wildlife, including mammals, birds, reptiles and amphibians. The diversity and abundance of wildlife reflects the diverse mix of habitat classes occurring in the Missouri River valley, which includes riverine; reservoirs, lakes and ponds; emergent, scrub-shrub, and forested wetlands; riparian forests; grasslands; and croplands. The diversity of wildlife include species that live year-round within the river and its floodplain as well as migratory species for which the ecosystem provides vital seasonal habitat (e.g., wintering and breeding), movement corridors, and stopover habitats. Aquatic habitats generally include open water habitats of varying depths (i.e., main channel, secondary channels and chutes, backwaters, floodplain lakes/oxbows). Terrestrial habitats include emergent wetlands, forests, woodlands, grasslands and shrublands.

D-02.1.1. The river hydrology and morphology influence the composition and distribution of vegetation on the floodplain, causing habitat changes on a daily, seasonal, annual and long-term basis. Erosion and sediment transport play an important role in the creation and degradation of sandbar habitat, scouring or elimination of vegetated lands, and creation of suitable substrate for plant germination and the initiation of early-successional plant communities. Seasonal flow patterns dictate the frequency and duration of wetland flooding and maintain oxbow lakes that are important for breeding and foraging wildlife. Reservoir storage levels determine the water depths in wetlands located along the six System reservoirs and the extent of exposed shoreline.

D-02.1.2. The Missouri River, extending from the headwaters of Fort Peck reservoir to Gavins Point Dam, contains a relatively diverse mix of wetlands, riparian habitats, riverine open water, and open water associated with the six System reservoirs. The highly variable water levels of the System reservoirs can produce extensive zones of wetland or weedy herbaceous wildlife habitat that establishes on exposed shoreline sediments. The large wetland/riparian complexes that have developed at the upstream end of each reservoir also provide productive habitat and are actively managed for wildlife. Productive habitat in the lower Missouri River downstream of Ponca is largely restricted to the old oxbows and chutes that were partially or entirely cut off from the river by dikes and revetments. For this reason, many of the larger river bends in Nebraska, Iowa, Missouri, and Kansas are managed as state wildlife management areas.

D-02.2. Fishery Management. Over 150 fish species have been documented in the Missouri River. These species include a wide variety of native species and numerous species that have been introduced into the System reservoirs and riverine stretches of the Missouri River. The habitat classes available and, correspondingly, the species composition of the Missouri River differ considerably between the riverine and reservoir segments. The reservoirs formed by the six dams on the Missouri River changed the character of the river and thus the fish habitat. Even the Missouri River reaches below the dams have changed, particularly in terms of water temperature, clarity, chemical composition, and bottom configuration and substrate. The additional diversity of habitat has led to a greater diversity in the fish community. The river and reservoir fisheries and habitat will be discussed in the following sections.

D-02.2.1. Riverine Fish. The most important sportfish in the open river reaches are walleye, sauger, white bass, yellow perch, channel catfish, paddlefish, shovelnose sturgeon and northern pike. Trout and salmon and smallmouth bass are also targeted in many of the tailrace fisheries below the dams. Until recently, channel catfish, bigmouth buffalo, smallmouth buffalo, flathead catfish, goldeye and suckers were fished commercially in some areas.

D-02.2.2. Native Fish. The native river fishes are the fishery that existed in the Missouri River prior to the construction of the System. Native river fishes including the catfish, sturgeon, sauger, suckers and paddlefish, have declined as a result of migration blockage, loss of habitat, change in habitat, and competition from new species that have taken advantage of these changes. The pallid sturgeon has been listed as an endangered species. Dams, channelization, river channel degradation, farmland reclamation, and reduced peak flood flows have contributed to the loss of important fish habitat in the Missouri River. Other common native species in the river include carp, river carpsucker, shorthead redhorse, freshwater drum and goldeye. Shortnose gar, gizzard shad, flathead chub, blue sucker and several shiners are also common in some parts of the Missouri River.

D-02.2.2.1. Native Fish Habitat. Natural seasonal flow patterns to which many of the native fishes originally adapted have changed on the Missouri River. High spring flows that provided additional shallow water habitat have been nearly eliminated on some sections of the Missouri River and reduced on others. Most riverine fish depend on the remaining low-velocity, shallow-water habitat at some point in their life history. Several species spawn in such habitat, and the juveniles of most species rear in low-velocity regions until they are large enough to maintain themselves and avoid predation in the higher velocity flows of the Missouri River's main channel. Many species spend their entire lifetime in the low-velocity areas of the river. Backwaters, side channels, and other low-velocity habitat are currently limited in some of the remaining river reaches.

D-02.2.3. Coldwater Riverine Fish Habitat. Tailwaters differ from the natural river habitat in temperature, turbidity, substrate, current and flow patterns, food supply, and the ensuing difference in species assemblages. Because of the low sediment load of the Missouri River below the dams, tailwaters frequently exhibit bed degradation, deep pools, coarse bed materials, and high biotic diversity. The coldwater releases from the dams support coldwater fisheries. Trout, salmon, walleye, sauger, northern pike, smallmouth bass, and many other species use the cooler waters below the dams. Most of these populations are self-sustaining, although some, especially trout and salmon, are supported or enhanced by stocking. The quantity of coldwater habitat available downstream of the dams is a function of the quantity of water released from the dams during the summer months and the temperature of that water. When reservoir levels are low, water releases from the dams may be several degrees warmer and provide less coldwater habitat downstream.

D-02.2.4. Endangered Riverine Fish. A native Missouri River fish of primary concern is the endangered pallid sturgeon. The historic range of pallid sturgeon encompassed the Middle and Lower Mississippi River, the Missouri River, and the lower reaches of the Platte, Kansas and Yellowstone Rivers. Because the pallid was not recognized as a distinct species until 1905, little is known about its abundance and distribution prior to this date. They have always been uncommon. Hybrids of the shovelnose and pallid sturgeon have been collected and may be common in the lower Missouri River. Some surveys suggest a probable decline in the abundance of pallid sturgeon from former levels. According to the Pallid Sturgeon Recovery Plan, modification of the natural hydrograph, habitat loss, migration blockage, pollution, hybridization, and over harvesting are possibly all responsible for this decline.

D-02.2.4.1. Blockage of migrations, over harvest, and loss of deep pool habitat are among the key factors believed to be affecting paddlefish populations. Other native fish species are also declining. Several other species have been classified as species of special concern by the various states located along the Missouri River. Little is known about the biology or specific habitat requirements of many of these species, although several recent studies are shedding some light on habitat use. This CWCP recognizes the importance of improving the native river fishery. The Corps will work with others through the adaptive management process discussed in Section 7-10 to implement those steps necessary to contribute to the recovery of the native river fish.

D-02.2.5. System Reservoir Fisheries. The six System reservoirs contain a diverse community of coldwater, coolwater, and warmwater fish. The three larger reservoirs have been stocked with coldwater game and forage fish species to take advantage of the coldwater habitat that is retained through the summer and fall in the lower depths of the lakes. These species include Chinook salmon, brown trout, rainbow trout, lake trout (Fort Peck reservoir only), cisco (forage in Fort Peck reservoir) and rainbow smelt. Species in the three smaller reservoirs and in the warmer waters of the three larger reservoirs include native and non-native species that have adapted to lacustrine conditions. Some of the most common of these species are walleye, sauger, goldeye, carp, channel catfish, river carpsucker, crappie, gizzard shad and emerald shiner. Smallmouth bass have also been stocked in several of the System reservoirs. White bass and northern pike are common in several reservoirs. Many of the species present in the reservoirs support sports fisheries. Water levels, inflow and outflow are important factors in the reservoirs. In the upper three reservoirs, low water levels during droughts limit coldwater fish habitat and shallow spawning and rearing habitat of warmwater and coolwater species.

D-02.2.5.1. Reservoir Fishery Habitat. Natural reproduction of the fish populations of the six System reservoirs is limited by the availability of spawning and young-of-year rearing habitat. The coldwater species generally lack spawning habitat and, thus, are primarily supported by hatcheries. An exception is the lake trout in the Fort Peck reservoir, which spawn naturally in the rock riprap along the dam face. Most of the warmwater and coolwater species spawn in shallow habitat of the reservoir shorelines, in the river above the lakes, or in tributary streams. Walleye and, to a lesser degree, sauger require clean rock in moderately shallow water for suitable spawning habitat. Northern pike and several other warmwater species spawn in submerged vegetation. The effect that the availability of spawning habitat has on the production of fish was evident when the reservoirs were first filled. Rising waters inundated vast areas of terrestrial vegetation. The populations of northern pike and other species requiring vegetated spawning and rearing habitat increased dramatically. These species also prospered from an abundance of small forage fish. Upon the eventual decay of submerged vegetation, the reservoirs declined in productivity and many species began to decline. Other factors that affected the production of fish include the gradual decline of shallow-water habitat as embayments fill with sediment and shorelines are smoothed.

D.02.2.5.1.1. Coincident with the decline in these populations, walleye abundance increased as a result of stocking and improved spawning habitat. During the 1987-1992 drought, the upper three reservoirs were drawn down about 20 to 25 feet below the base of their respective Annual Flood Control and Multiple Use Zones, draining much of the shallow habitat normally found in bays, exposing available clean rock, and limiting the availability of submerged vegetation to support spawning and rearing. Concern arose regarding the System's ability to maintain the productivity of the important game and forage fishes. Stocking was increased to maintain populations of game fish. The high productivity in the upper reservoirs was a result of the System filling following the drought. During the extended drawdown period, vegetation developed along the normally inundated shorelines that now provide new spawning and rearing habitat.

D-02.2.5.2. Reservoir Coldwater Habitat. Coldwater habitat available to support the popular trout and salmon fisheries is decreased during periods of drought. The amount of well-oxygenated cold water retained through the summer and fall is related to the water level in the upper three reservoirs. Habitat in the lower three System reservoirs has been affected very little by drought because these reservoirs are regulated at the same levels regardless of wet, normal or drought conditions. Little coldwater habitat is retained through the summer and fall in these reservoirs due to their smaller size and the high quantity of warm water flowing through the reservoirs. Flow rates through the lower three reservoirs varies considerably from year to year based on runoff conditions. High flows may reduce primary and secondary productivity, spawning success, and could flush fish from the reservoirs. Higher flows, however, are required for the evacuation of accumulated flood storage during high runoff years.

D-03. Fish and Wildlife Purpose Accomplishments. There have been significant benefits provided to fish and wildlife in the reservoirs and river reaches between the projects from the construction of the System. Since the System filled in 1967, the System reservoirs have been regulated to enhance the fish population associated with the reservoirs. Currently, more 150 fish species are known to occur in the Missouri River and the System. These include native species and many others that have been introduced over the years. A diverse community of coldwater and warmwater fish inhabit the six reservoirs of the System. The upper three larger reservoirs have been stocked with coldwater game and forage species to take advantage of the cold water retained through the summer and fall in the deeper waters of the reservoirs when the storage in these reservoir has not been depleted by drought. The past accomplishments in fish and wildlife enhancements could be expressed in many ways. The greater-than-expected improvement in upstream recreation is directly related to the enhancement of the fishing and wildlife activities associated with the System reservoirs. Also, most state fishing records are from the System reservoirs. Large areas are preserved for the diverse basin wildlife on System project lands. Early attempts to manage reservoir levels to inundate reservoir vegetation for fish spawning and control of releases to encourage downstream spawning below reservoirs have been documented. The success of the fish in the System and on the Missouri River below the System depends on habitat conditions. Water levels, inflow and outflow are important factors in the reservoirs.

Native fish in the river reaches are naturally adapted to warm, muddy high spring and early summer flows, and also to the lower late summer and fall flow characteristics of the historic Missouri River. The cold, clearer tailwaters of the upper three large System reservoirs are more conducive to trout and salmon, but not paddlefish, pallid sturgeon and other native river fish. The MRBWM office will continue to work with state and federal interests to optimize the benefit to fish and wildlife through regulation of the System.

D-04. Historic System Regulation for Endangered and Threatened Species - Terns and Plovers. While the Missouri River provides habitat for a wide variety of wildlife species, the endangered interior least tern (tern) and threatened piping plover (plover) are of particular importance. They depend on non-vegetated sandbars and islands in the river for nesting and are directly affected by water level changes. These birds typically nest in colonies on river sandbars, sandy shorelines of reservoirs, or in sandpits along the river. Important nesting reaches are below the Fort Peck, Garrison, Fort Randall and Gavins Point dams, and on the Oahe and Garrison reservoirs. River hydrology and channel characteristics influence the composition and distribution of tern and plover habitat along the river. Seasonal river flow and water level patterns dictate the frequency and duration of habitat flooding and the scouring of sandbar vegetation. Bank erosion and sediment movement in the riverbed also affect the creation and removal of sandbar and island habitat. Declining reservoir levels result in exposed bare shoreline increasing nesting habitat. Specific System regulation criteria used in the past for T&E species nesting is discussed in Section 7-10 of this manual.

D-04.1. System Regulation. The MRBWM office has been regulating the System for T&E nesting since 1986. Real-time streamgages have been installed on the Missouri River in the critical nesting reaches specifically to monitor streamflows during the nesting season. These streamgages provide a check, as well as a stage history, throughout the season to help relate the effects of regulation and natural events at intervals along the Missouri River. The streamgaging data must be supplemented with observations of nesting activities and conditions to provide all the information that is needed for regulation decisions. A dynamic flow routing model has been developed to forecast maximum river stages along the river for different combinations of daily discharge and hourly power peaking characteristics. Beginning in 1999, the Omaha District created a computerized Threatened and Endangered Species Data Management System. Report data, which is updated daily, includes nest records, census and productivity data, site descriptions, field journals and messages. The use of this database is a valuable tool in aiding release decisions benefiting T&E birds. Table D-1 and D-2 show the population distribution and productivity for terns and plovers for 2000 through 2017. Refer to MRBWM Summary Reports for 1986-1999 data. Adult birds in this table are considered breeders even though they may not have had nesting success. The term "fledglings/pair" means the number of young birds produced per breeding pair. This ratio is an estimate, as the fate of every single fledgling is impossible to ascertain.

D-05. U.S. Fish and Wildlife Biological Opinions. Beginning in 1987, the USFWS and USACE have engaged in consultation in compliance with Section 7 of the ESA, concerning the impact of System operations on the piping plover and the interior least tern. That consultation resulted in a 1990 BiOp with a finding of jeopardy. Consultations continued after the pallid sturgeon was listed in 1990 and the scope was expanded to include proposed System operations under the revised Master Manual and the operation and maintenance of the BSNP. In a 2000

BiOp, USFWS concluded that operating the System, operating and maintaining the BSNP, and operating the Kansas River System, as proposed at the time, would jeopardize the continued existence of the federally listed pallid sturgeon, interior least tern, and piping plover. The 2000 BiOp recommended a Reasonable and Prudent Alternative (RPA) to avoid jeopardy. USACE reinitiated formal consultation with the USFWS, providing a Biological Assessment (BA) with new proposed actions. After additional consultation in 2003, USFWS amended its 2000 BiOp with the determination that the new proposed actions would avoid jeopardizing the continued existence of the two listed bird species, but would jeopardize the continued existence of the pallid sturgeon in the wild (USFWS 2003). The Amended 2003 BiOp included an RPA that included provisions for the Corps to develop a plan to implement a bimodal spring pulse from Gavins Point Dam for the benefit of the pallid sturgeon, among other things. Working with the USFWS, Tribes, states and basin stakeholders, the Corps developed technical criteria for the bimodal spring pulse releases. In March 2006 the Master Manual was revised to include technical criteria for a spring pulse.

D-05.1. 2018 Biological Opinion. The Corps has since re-initiated consultation with the USFWS as part of the public MRRMP-EIS process. A Final BA was submitted to USFWS on October 30, 2017, and amended on January 19, 2018, and a new Final BiOp was issued by USFWS on April 13, 2018. The new BiOp determined that implementation of the USACE proposed action in the BA is not likely to jeopardize the pallid sturgeon, interior least tern, or piping plover or destroy or adversely modify piping plover critical habitat. The preferred alternative identified in the MRRMP-EIS (Alternative 3) incorporates the proposed action from the 2017 BA (as amended) and is consistent with the 2018 BiOp. Alternative 3 will meet the species objectives and fulfill the purpose and need of the plan while avoiding and minimizing adverse impacts. Alternative 3 would be implemented within the adaptive management framework detailed in the SAMP. After thorough analysis and input by the public, the Record of Decision for the MRRMP-EIS required the modification of the Master Manual to remove technical criteria for the bimodal spring pulse and reservoir unbalancing.

Table D-1
Missouri River System – Interior Least Tern Survey Data

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013[2]	2014	2015	2016	2017
Fort Peck Lake																		
Adults	0	0	0	2	0	0	2	2	0	0	0	0	0		0	0	0	0
Fledglings/Pair	0	0	0	0	0	0	3	0	0	0	0	0	0		0	0	0	0
Fort Peck to Lake Sakakawea																		
Adults	13	39	34	38	48	34	36	77	22	46	26	0	0		8	12	10	11
Fledglings/Pair	0.15	0.97	0.59	0.63	0.50	2.18	1.17	1.38	1.45	0.87	1.00	0.00	0.00		0.00	0.00	0	0.00
Lake Sakakawea																		
Adults	10	34	21	25	16	26	48	53	14	15	11	3	14		19	18	52	23
Fledglings/Pair	0.20	0.76	0.86	0.56	0.88	0.31	0.71	0.72	2.57	1.07	0.00	0.00	0.29		0.11	0.89	0.38	0.17
Garrison to Lake Oahe																		
Adults	105	125	126	144	142	157	139	123	73	108	134	0	105		131	157	213	197
Fledglings/Pair	1.03	1.26	1.83	1.28	1.13	0.73	0.81	1.06	1.34	0.48	1.36	0.00	0.99		0.55	1.06	0.24	1.22
Lake Oahe/Lake Sharpe																		
Adults	85	94	106	70	73	131	128	186	111	71	48	39	100		89	93	87	101
Fledglings/Pair	1.01	1.34	1.32	1.20	1.26	0.87	1.14	0.48	0.58	0.96	0.17	1.33	1.06		0.29	0.49	0.25	0.51
Fort Randall to Niobrara																		
Adults	72	71	84	50	71	76	55	74	58	23	10	0	87		99	155	138	145
Fledglings/Pair	1.26	0.14	0.71	0.92	0.37	0.47	0.69	0.30	1.14	0.43	0.00	0.00	1.10		0.73	1.63	1.41	1.05
Lewis and Clark Lake																		
Adults	44	58	46	46	13	4	0	85	225	214	272	231	211		131	164	145	142
Fledglings/Pair	0.38	1.17	1.04	0.39	0.00	0.00	0.00	1.58	0.67	0.76	1.01	0.15	1.43		0.52	1.46	0.98	0.56
Gavins Point to Ponca																		
Adults	149	232	314	366	359	476	383	410	278	211	159	0	209		243	318	416	422
Fledglings/Pair	1.72	1.09	1.32	0.75	1.04	1.34	0.63	0.59	1.14	1.00	1.17	0	1.2		0.79	1.46	0.98	0.85
Missouri River System																		
Total Adults	551	653	731	741	722	904	802[1]	1,010	781	696	650	273	726		720	917	1061	1041
Fledglings/Pair	1.22	1.04	1.27	0.87	0.95	1.09	0.80[1]	0.75	0.98	0.80	1.02	0.32	1.19		0.6	1.31	0.8	0.86

[1] Includes adults and fledglings from Lake Francis Case

[2] 2013 data is not added due to survey methodology change. See 2013 MRRP Annual Report for additional information.

Notes: The data do not include least terns and piping plovers raised in captivity from 1995 to 2002. The data represent only wild fledged birds.
From 1990 to 2003 the 10-Year Least Tern Fledge Ratio was 0.70 (1990 and 2000 Biological Opinions).
From 2004 to current 5-year running average goal is 0.94 (2003 Amended Biological Opinion)
Data in this table may differ from previous reports. As information becomes available, this table is updated.
Refer to previous MRBWM Summary Reports for 1986-1999 data.

Table D-2
Missouri River System – Piping Plover Survey Data

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013[2]	2014	2015	2016	2017
Fort Peck Lake																		
Adults	0	4	2	17	9	26	20	16	9	12	3	2	0		0	4	2	0
Fledglings/Pair	0	1	2	0.35	2.22	1.08	1.2	0.5	0.22	0.33	0	0	0		0	0	0	0
Fort Peck to Lake Sakakawea																		
Adults	4	3	2	6	0	2	5	0	0	0	0	0	0		0	0	0	0
Fledglings/Pair	0	1.33	0	2.67	0	4	0.4	0	0	0	0	0	0		0	0	0	0
Lake Sakakawea																		
Adults	277	424	469	528	738	746	430	399	363	85	38	24	200		155	252	400	156
Fledglings/Pair	1.61	1.25	1.65	1.06	1.5	0.89	0.61	0.7	0.68	0.21	0.89	1.67	1.4		0.48	0.73	1	0.31
Garrison to Lake Oahe																		
Adults	99	149	119	149	164	220	175	222	218	275	287	0	98		221	392	336	266
Fledglings/Pair	1.41	1.53	2.03	1.66	1.16	0.8	0.77	0.97	1.37	0.94	0.84	0	1		2.05	1.26	0.36	1.3
Lake Oahe/Lake Sharpe																		
Adults	141	184	203	301	372	364	331	273	281	158	44	20	125		210	251	227	211
Fledglings/Pair	1.45	1.41	2.16	1.84	1.41	1.21	0.99	0.62	0.9	0.47	0.1	0.4	1.76		0.45	0.49	0.56	0.63
Fort Randall to Niobrara																		
Adults	62	38	35	37	42	42	37	21	26	16	6	0	43		106	145	173	170
Fledglings/Pair	0.87	0.74	1.03	1.46	0.71	0.81	0.38	0	1	1	0	0	1.81		1.08	2.34	1.69	1.29
Lewis and Clark Lake																		
Adults	28	34	44	14	0	24	4	20	57	122	152	134	179		186	188	124	194
Fledglings/Pair	0.5	0.71	1.68	1.57	0	0.17	0.5	1.8	1.37	1.8	1.25	0.22	1.35		0.57	1.37	1.05	1.23
Gavins Point to Ponca																		
Adults	186	218	260	286	262	340	309	300	320	238	74	2	137		238	380	570	532
Fledglings/Pair	2.17	1.85	2.29	1.9	1.87	1.97	0.78	0.39	1.39	1.09	1.86	0	1.82		1.73	2.23	1.69	0.95
Missouri River System																		
Total Adults	551	797	1054	1134	1338	1587	1764	1311	1251	1274	906	604	182		782	1116	1612	1832
Fledglings/Pair	1.22	1.58	1.41	1.91	1.5	1.49	1.15	0.78	0.66	1.06	0.94	1.01	0.43		1.49	1.12	1.4	1.12

[2] 2013 data is not added due to survey methodology change. See 2013 MRRP Annual Report for additional information.

Notes:
The data do not include least terns and piping plovers raised in captivity from 1995 to 2002. The data represent only wild fledged birds.
From 1990 to 2000 the 15-Year Piping Plover Fledge Ratio Goal was 1.44 (1990 Biological Opinion).
From 2001 to 2003 the goal was 1.13 (2000 Biological Opinion)
From 2004 to current the 10-year running average goal is 1.22 (2003 Amended Biological Opinion)
Data in this table may differ from previous reports. As information becomes available, this table is updated.
Refer to previous MRBWM Summary Reports for 1986-1999 data.

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MISSOURI RIVER BASIN
MAINSTEM RESERVOIR SYSTEM
MASTER WATER CONTROL 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 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 has resulted in a dependency from many river communities for using the Missouri River as a source for domestic as well as industrial water supply. There have been times when intake access becomes a problem, primarily during release reductions for flood control or because of reduced releases during 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 (Table E-1).

E-01.1. Missouri River Basin – Missouri River Intakes and Water Supply. Water is withdrawn from the Missouri River and its System reservoirs for cooling purposes in the production of electricity; municipal water supply; and commercial, industrial, irrigation, domestic and public uses. More than 1,600 intakes and intake facilities have been identified on the System reservoirs and river reaches (Table E-2 and Table E-3). Of these, 302 intakes and intake facilities are identified for American Indian Tribes.

E-01.1.1. Missouri River Basin – Upstream Water Supply Intakes. Water supply intakes have been constructed on the System projects and river reaches downstream from several of these projects. The major population centers served are Bismarck, ND and Pierre, SD. The dominant category of intake type for the upstream water supply intakes is irrigation, as shown in Table E-3.

E-01.1.1.1. Fort Peck Reservoir. As shown on Table E-3, 109 water supply intakes and intake facilities are located on the Fort Peck reservoir. These include 1 municipal water supply facility, 5 irrigation intakes, 101 domestic intakes and 2 public intakes. The municipal water supply facility serves a population of approximately 580 persons. Cabin owners own the majority of the domestic intakes, which are generally used in lawn watering, car washing and fire protection. Domestic intakes along this reach are not generally used to provide drinking water, which is obtained in neighboring towns.

Table E-1
Municipal Water Supply by River Reach

Reach/Reservoir	Population Served	Share of Total (%)
Fort Peck Reservoir	580	<1
Fort Peck	114,277 (200)	4
Garrison Reservoir	19,212 (1,512)	1
Garrison	69,960	2
Oahe Reservoir	121,515 (11,550)	4
Oahe	0	0
Big Bend Reservoir	900 (600)	<1
Big Bend	0	0
Fort Randall Reservoir	12,100	<1
Fort Randall	0	0
Gavins Point Reservoir	10,377	<1
Gavins Point	15,000	1
Sioux City	88,800	3
Omaha	530,000	16
Nebraska City	0	0
St. Joseph	418,000	13
Kansas City	845,500	26
Boonville	46,740	1
Hermann	940,000	29
Total	**3,232,961 (13,862)**	**100**
Served Above Gavins Point	348,921 (13,862)	11
Served Below Gavins Point	2,884,040 (0)	89
Source: Corps, MRRMP-EIS ( ) Denotes Tribal Reservation population served by municipal intakes.		

Table E-2
Powerplants Using Missouri River for Cooling Water

Reach/Reservoir	Powerplant Nameplate Capacity (MW)	Share of Total (%)
Fort Peck Reservoir	0	0
Fort Peck	0	0
Garrison Reservoir	870	5
Garrison	3,444	20
Oahe Reservoir	0	0
Big Bend Reservoir	0	0
Fort Randall Reservoir	0	0
Gavins Point Reservoir	0	0
Gavins Point	0	0
Sioux City	1,280	8
Omaha	2,303	13
Nebraska City	2,191	13
St. Joseph	1,730	10
Kansas City	1,690	10
Boonville	1,236	7
Hermann	2,390	14
Total	**17,134**	**100**
Above Gavins Point	4,314	25
Below Gavins Point	12,820	75
Source: Corps, MRRMP-EIS		

Table E-3
Missouri River Water Supply Intakes

Reach	River Mile	Intake by Type						Total Intakes
		Power	Municipal	Industrial	Irrigation*	Domestic	Public	
Fort Peck Reservoir	1771.6		1		5	101	2	109
Fort Peck	1547.1		4 (2)	0	283 (94)	162 (14)	1	450 (110)
Garrison Reservoir	1389.9	1	15 (4)	27 (1)	44 (10)	228 (63)	11	326 (78)
Garrison	1317.4	6	7	7	77	28	3	128
Oahe Reservoir	1072.3		8 (3)	0	179 (12)	21 (6)	8 (2)	216 (23)
Oahe	1072.2		1					1
Big Bend Reservoir	987.4		3 (2)		91 (71)	19 (4)	2	115 (77)
Big Bend	987.3							0
Fort Randall Reservoir	841.8		5		72	4	3	84
Fort Randall	836.1				100(4)			100 (4)
Gavins Point Reservoir	811.1		2		27 (5)	6	2 (2)	37 (7)
Gavins Point	734.2		1		33	7	1	42
Sioux City	648.0	2	1	1	42 (3)		2	48 (3)
Omaha	597.2	1	2	1	8	2	5	19
Nebraska City	497.4	2			22	1		25
St. Joseph	374.0	4	4				2	10
Kansas City	249.9	3	4				1	8
Boonville	129.9	1	3				1	5
Hermann	0.0	1	3					4
Total		**21**	**64 (11)**	**35 (1)**	**891 (199)**	**579 (87)**	**44 (4)**	**1,616 (302)**
Above Gavins Point		7	46 (11)	33 (1)	786 (196)	569 (87)	32 (4)	
Below Gavins Point		14	18	2	105 (3)	10	12	

Source: MRRMP-EIS
( ) Denotes intakes located on Reservation land.

E-01.1.1.2. Fort Peck Dam to Garrison Reservoir. As shown on Table E-3, 455 water supply intakes and intake facilities are located on the Missouri River in this reach from Wolf Point, ND to Williston, ND. These include 4 municipal water supply facilities, 283 irrigation intakes, 162 domestic intakes and 1 public intake. The municipal water supply facilities serve a population of approximately 114,277 persons, 80 percent of whom live in the Williston area. Of the 450 water supply intakes and intake facilities, there are 110 water supply intakes and intake facilities located on the Missouri River serving the Fort Peck Reservation. These include 2 municipal water supply facility, 94 irrigation intakes and 14 domestic intakes. The municipal water supply facilities serve a population of approximately 200 persons.

E-01.1.1.3. Garrison Reservoir. As shown on Table E-3, 326 water supply intakes and intake facilities draw water from the Garrison reservoir. These include 1 powerplant, 15 municipal water supply facilities, 27 industrial intakes, 44 irrigation intakes, 228 domestic intakes and 11 public intakes. The powerplant has a nameplate generating capacity of 870 megawatts (MW). The municipal water supply facilities serve a population of approximately 19,212 persons. Of the 326 water supply intakes and intake facilities, there are 78 water supply intakes and intake facilities that serve the Fort Berthold Reservation. These include 4 municipal water supply facilities, 1 industrial intake, 10 irrigation intakes and 63 domestic intakes. The municipal water supply facilities serve a population of approximately 1,512 persons.

E-01.1.1.4. Garrison Dam to Oahe Reservoir. As shown on Table E-3, 128 water supply intakes are located on the Missouri River from Garrison Dam to the upper end of the Oahe reservoir. These include 6 powerplant intakes, 7 municipal water supply facilities, 7 industrial intakes, 77 irrigation intakes, 28 domestic intakes and 3 public intakes. The 3 powerplants served by the 6 intakes have a nameplate generating capacity of 3,444 MW. The municipal water supply facilities serve a population of approximately 69,960 persons.

E-01.1.1.5. Oahe Reservoir. As shown on Table E-3, there are 216 water supply intakes are located on the Oahe reservoir. These include 8 municipal intakes, 179 irrigation intakes, 21 domestic intakes and 8 public intakes. The municipal water supply facilities serve a population of approximately 121,515 persons. Of the 216 water supply intakes, 23 serve the Standing Rock and Cheyenne River reservations.

E-01.1.1.6. Big Bend Reservoir. As shown on Table E-3, 115 water supply intakes are located on the Big Bend reservoir. These include 3 municipal intake facilities, 91 irrigation intakes, 19 domestic intakes and 2 public intakes. The municipal water supply facilities serve a population of approximately 900 persons. Of the 115 water supply intakes, 77 serve the Lower Brule and Crow Creek reservations.

E-01.1.1.7. Fort Randall Reservoir from Fort Randall Dam to Gavins Point Reservoir. As shown on Table E-3, 84 water supply intakes are located on the Fort Randall reservoir. 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 Dam, four are located on the Yankton Reservation.

E-01.1.1.8. Gavins Point Reservoir. As shown on Table E-3, 37 water supply intakes are located on the Gavins Point reservoir. These include 2 municipal water supply facilities, 27 irrigation intakes, 6 domestic intakes and 2 public intakes. The municipal water supply facilities serve a population of approximately 10,377 persons. Of the 37 water supply intakes located on the Gavins Point reservoir, 7 are serving the Santee Reservation. These include 5 irrigation intakes and 2 public intakes.

E-01.1.2. Missouri River Basin – Downstream Water Supply Intakes. The lower river has 161 water supply intakes that depend on the Missouri River as their source of water.

E-01.1.2.1. Gavins Point Reach. As shown on Table E-3, 42 water supply intakes are located on the Missouri River below Gavins Point Dam to Sioux City, IA. These include 1 municipal water supply facility, 33 irrigation intakes, 7 domestic intakes and 1 public intake. The municipal water supply facility serves a population of approximately 15,000 persons.

E-01.1.2.2. Sioux City Reach. As shown on Table E-3, 48 water supply intakes are located on the Missouri River in the Sioux City to Blair, NE reach. These include 2 powerplant intakes, 1 municipal water supply facilities, 1 industrial intake, 42 irrigation intakes and 2 public intakes. The two powerplants have a nameplate generating capacity of 1,280 MW. The municipal water supply facilities serve a population of approximately 88,800 persons. Of the 48 water supply intakes located on the Missouri River in the Sioux City reach, 1 irrigation intake is located on the Winnebago Reservation and 2 irrigation intakes are located on the Omaha Reservation.

E-01.1.2.3. Omaha Reach. As shown on Table E–3, 19 water supply intakes are located on the Missouri River in the Blair to Bellevue, NE reach. These include 1 powerplant (one nuclear) intake, 2 municipal water supply facilities, 1 industrial intake, 8 irrigation intakes, 2 domestic intakes and 5 public intakes. The powerplant has a nameplate generating capacity of 2,303 MW. The municipal water supply facilities serve a population of approximately 530,000 persons.

E-01.1.2.4. Nebraska City Reach. As shown on Table E-3, between Bellevue and Rulo, NE, 25 water supply intakes are located on the Missouri River. These include 2 powerplant (one nuclear) intakes, 22 irrigation intakes and 1 domestic intake. The two powerplants have a nameplate generating capacity of 2,191 MW.

E-01.1.2.5. St. Joseph Reach. As shown on Table E-3, 10 water supply intakes are located on the Missouri River between Rulo and Kansas City, MO. These include 4 powerplant intakes, 4 municipal water supply facilities and 2 public intakes. The 4 powerplants have a nameplate generating capacity of 1,730 MW. The municipal water supply facilities serve a population of approximately 418,000 persons. None of 9 water supply intakes located on the St. Joseph reach of the Missouri River are on the Iowa and the Sac and Fox Reservation.

E-01.1.2.6. Kansas City Reach. As shown on Table E-3, 8 water supply intakes are located on the Missouri River between Kansas City and the Grand River confluence with the Missouri River. These include 3 powerplant intakes, 4 municipal water supply facilities and 1 public intake. The 3 powerplants have a nameplate generating capacity of 1,690 MW. The municipal water supply facilities serve a population of approximately 845,500 persons.

E-01.1.2.7. Boonville Reach. As shown on Table E-3, 5 water supply intakes are located on the Missouri River between the Grand River and Osage River confluences. These include 1 powerplant intake, 3 municipal water supply intakes and 1 public intake. The 1 powerplant has a nameplate generating capacity of 1,236 MW. The municipal water supply intakes serve a population of approximately 46,740 persons.

E-01.1.2.8. Hermann Reach. As shown on Table E-3, 4 water supply intakes are located on the Missouri River between the Osage River and St. Louis. These include 1 powerplant (one nuclear) intake and 3 municipal water supply facilities. The 1 powerplant has a nameplate generating capacity of 2,390 MW. The municipal water supply facilities serve a population of approximately 940,000 persons.

E-02. Historic Municipal and Domestic Water Supply Considerations. Missouri River water is used for municipal water supply uses. Municipal water supply use is for Tribal and public supply of water to Reservations, residents of cities and towns, and rural water districts or associations. Approximately 2.9 million people are served by municipal water supply facilities that withdraw water from the System and the Missouri River below the System. Tribal, public and private water supply facilities provide treated water to households and commercial and industrial establishments. Most of the smaller municipal water supply facilities are located on the reservoirs and upper river reaches and serve about 349,000 persons. The largest municipal water supply facilities are located on the Missouri River reach below the System and serve the major urban areas of the lower basin located near the Missouri River. The larger downstream municipal intakes on the Missouri River were in place well before the construction of the System. Many were in place before the turn of the century, when the cities were first established. Some of the smaller municipal or rural water supply intakes are situated at a relatively high elevation in the System reservoirs. The Corps makes every effort to accommodate serving all water intakes when it is possible to do so without impacting the other project purposes. The water supply purpose is fully served by the System because the quantity of water available has been, and is expected to continue to be, sufficient to meet the needs.

E-02.1. Intake Access. The water supply problem that sometimes occurs is usually related to an intake access problem that is further discussed in Section E-05. When these problems do occur the cost of obtaining water increases. In addition to the cost of extending intakes, costs may be incurred due to additional strain on equipment, increased sedimentation problems, and the necessity for more frequent and thorough cleaning of intake screens. Other costs include increased pumping costs, costs for additional personnel, and increases in water treatment costs to eliminate taste and odor problems that could occur from heavier algae growth at lower reservoir and river levels. Most municipalities located on the Missouri River or System reservoirs have no alternative sources of water. Some have wells that serve as short-term backup systems only. Even by instituting strict conservation measures, most facilities have only about one to two days of water supply available in storage. To increase the amount of water available, some municipalities have had to drill new wells as an alternative water source or to increase pumping capacity at existing wells.

E-02.2. Community Water Supply. Of the approximately 1,800 communities with public water service, the great majority (over 1,500) obtain their water supply from groundwater sources alone, about 200 communities use surface water sources exclusively, and about 50 communities use combined surface and groundwater sources. The major cities of Omaha, NE and Kansas City and St. Louis, MO depend on the Missouri River as a major source for water supply, as do several other smaller cities along the Missouri River.

E-02.3. Total Water Supply Withdrawal. Currently, the total consumptive use of water for municipal, rural domestic, and industrial purposes in the Missouri River basin is approximately 300,000 acre-feet. Based on information from the 2004 Final EIS, approximately 20 percent of the gross demand is obtained from groundwater, 20 percent from surface water, and 60 percent from re-use of return flows from upstream systems.

E-03. Historic Industrial Water Supply Considerations. Many industrial water users in the Missouri River basin have water supply systems separate from the local municipal water supply systems and use both groundwater and surface water resources. Thermal-electric power generation represents the largest industrial use, with a previous withdrawal estimate of over 1.7 MAF annually. Based on information from the 2004 Final EIS, activities associated with the extraction and primary processing of ores and fuels were estimated to require almost 100,000 acre-feet each year, while other industries in the basin were about 400,000 acre-feet annually. Livestock production is an important part of the agricultural industry within the basin. The estimated use for livestock production was about 400,000 acre-feet annually, exclusive of evaporation from ponds constructed specifically for livestock watering purposes. Total industrial consumptive use in the basin now totals about 200,000 acre-feet annually.

E-04. Missouri River Basin – Irrigation Considerations. Large federally developed irrigation projects have not been served directly from the System reservoirs. Significant increased use of the System for irrigation water supply is not presently contemplated unless developed in association with Tribal water rights. Numerous irrigation intakes are located downstream from individual reservoirs and at certain times of the year their requirements have been a reservoir regulation consideration. The amount of such irrigation made possible by System regulation is not known; however, it is believed that a large amount would not have been practicable without the stabilizing influences upon river flows exerted by the regulation of the System. Table E-3 indicates almost 900 irrigation intakes either in the System reservoirs or on the Missouri with irrigation as the primary use. Historically, intake access is the major System regulation problem with serving this purpose.

E-05. Missouri River Basin – Intake Access Problems. Access to the water rather than the quantity of water available is the primary concern of intake operators along the Missouri River. In periods of average or above-normal rainfall, few problems are experienced because river stages and reservoir levels are sufficiently high for all intakes along the Missouri River. During below-normal rainfall, or drought periods, low reservoir levels and low Missouri River stages have resulted in water access problems at some intakes, causing intake owners extreme difficulties related to pumping the water. Low flows and low reservoir levels also alter sediment deposition and sandbar formation, which may further restrict the flow of water to the intakes. During the winter, ice formation can further complicate water availability, particularly in the Missouri River reaches below the System. During floods, reservoir releases are minimized, which may cause local water access problems downstream. Changes in river flows and reservoir levels affect the cost of operating intake facilities. Low water levels may increase day-to-day operating costs, or, in extreme cases, lead to capital costs for intake modification, location of an alternative water source, or even shutdowns. Low reservoir levels and below-normal reservoir releases during the recent drought forced many intake owners to modify operations and intake structures. The intent of this plan is to fully meet the authorized project purposes of water supply and providing for all irrigation requirements. The Corps will continue to make adjustments to the System to implement this purpose. However the intake access associated with obtaining Missouri River water is the responsibility of the entity choosing to use this source of water for their supply. Therefore intake access problems are the responsibility of the intake owner and the Corps will not guarantee access, only that the supply of water in the Missouri River is adequate to meet this purpose. The Corps does not assure a water supply based on a certain river stage or reservoir level, only that the quantity of water required will be available at that location. As stated in Section E-01, accessing the water is the intake owner's responsibility.

E-06. Missouri River – Tribal Water Rights. Certain Missouri River basin American Indian Tribes are entitled to water rights in streams running through and along their Reservations under the Winters Doctrine. This doctrine refers to the 1908 U.S. Supreme Court decision in the case of *Winters v. U.S.* (207 U.S. 564 1908). These reserved water rights are not forfeited by non-use. The basin's Native American Indian Tribes are in various stages of exercising their water rights. Currently, Tribal Reservation-reserved water rights have not been quantified in an appropriate legal forum or by compact, except in four instances. These are the rights embodied in the Compacts between Montana and the Tribes of the Fort Peck Reservation (awaiting Congressional approval), between Montana and the Tribes of Rocky Boys Reservation, between Montana and the Tribes of the Northern Cheyenne Reservation, and the Wyoming settlement within the Wind River Reservation. The following paragraphs discuss current and ongoing Tribal water right considerations but additional discussion is available in the Tribal Appendices of the 1998 Revised Draft EIS and 2004 Final EIS.

E-06.1. Fort Peck Compact. The Fort Peck Compact proposal now awaiting Congressional approval would entitle the Assiniboine and Sioux Tribes of the Fort Peck Reservation to an annual diversion of 1 MAF with an annual consumptive use of 0.55 MAF. A Wyoming Supreme Court decision held that the United States, as trustee for the Shoshone and Arapahoe Tribes, was entitled to annually divert approximately 0.48 MAF of water. A divided United States Supreme Court affirmed the Wyoming Supreme Court decision without opinion.

E-06.2. Northern Cheyenne Indian Reserved Water Rights Settlement. The Northern Cheyenne Indian Reserved Water Rights Settlement Act (P.L. 102-374), was passed by Congress and signed by the President. This Compact allows the annual use or disposition by the Tribe of 0.03 MAF of stored water in Big Horn Reservoir in Montana per year, as measured at the outlet works of the dam or at the diversion point from the reservoir, for any purpose.

E-06.3. Tribal Water Rights. Native American reserved water rights are rights to divert water from a stream for beneficial use. When a Tribe exercises its water rights, these consumptive uses will then be incorporated as an existing depletion. Accordingly, water must actually be diverted to have an impact on the operation of the System. Further modifications to System operation, in accordance with pertinent legal requirements, will be considered as Tribal water rights are exercised in accordance with applicable law.

E-06.4. Winnebago Reservation. Based on the survey performed by the Mni Sose Intertribal Water Rights Coalition (February 1994), the Winnebago Reservation has indicated that the System and levees “affected wetlands along the river, caused erosion, affected fishing and navigation, and caused willows to dry due to cranes.” Prior to the construction of the dams and levees, the river was used for “navigation, fish, food and transportation, and willows along bank used to build wigwams, feeds, and baskets.” Currently, the Tribal water sources identified in the survey are the Missouri River for agricultural uses and the aquifer/groundwater (Ogalala) for domestic uses. The Winnebago Tribe identified in the survey future water uses as “fisheries, recreation, and irrigation.” Similar to the sentiments of the Santee Sioux Tribe, the Winnebago Tribe indicated in the survey that the water levels fluctuate too much and are too low. The Tribe identified “solid waste, water quality/groundwater contamination, and underground storage tanks” as its top three environmental challenges.

E-06.5. Omaha Reservation. The Mni Sose Intertribal Water Rights Coalition survey indicated that, for the Omaha Reservation, the Missouri River represented “campsites, watering of livestock, fishing, watering gardens, recreation, drinking water, and trading with non-Indians” prior to the construction of the dams and levees. Construction of the dams and levees “dried Lawless Lake and Betsey Bottom Lake where cultural activities took place,” caused “loss of individual allotments and Tribal lands,” and moved the river, thus affecting the Tribe’s sole sources of water. “Tribal ceremonies and religious activities ceased or changed,” according to the survey.

E-06.6. Future Water Use Concerns. Future water use concerns identified by the Omaha Tribe are water quality and quantity and Tribal water code by priority rights. Unlike the Winnebago Tribe, the Omaha Tribe feels that the water levels are about right and that the Reservation does benefit from the current flood control measures. Even so, the survey indicated that the Tribe feels that it would suffer a financial impact as a result of the loss of financial revenue from the alternatives previously evaluated in the RDEIS. The Omaha Tribe currently uses the Tribal Rural System (aquifer/wells system) for its water source. Additionally, the Tribe’s top three environmental challenges were identified as “landfill closure, Tribal utility system, and water rights.” Current land uses on the Omaha Reservation are identified as primarily agricultural, forestry, grazing, recreation, tourism and residential, with minor amounts of commercial uses.

E-06.7. Iowa Reservation. For Iowa Tribal members on the Iowa Reservation, the Missouri River was a source of “fish and fresh water” prior to the construction of the dams and levees. The survey completed by the Iowa Tribe indicated that the “fish population has declined dramatically” to “almost nonexistent” since construction of the dams and levees. Additionally, the Tribe feels that “dams and levees have caused flooding by trying to control and confine the river.” The survey indicated that Tribal members feel that there is too much water level fluctuation and that the Corps should minimize the amount of fluctuation. Currently, the Tribe relies on well water as a Tribal water source and identifies recreation and irrigation as future water uses. “Solid waste, water pollution, and erosion” were identified as the top three environmental challenges facing the Iowa Tribe. Current land uses are identified as agricultural, grazing and forestry.

E-06.8. Sac and Fox Reservations. The survey of the Sac and Fox Reservations indicated that, prior to the construction of the dams and levees, the Missouri River was a source for “navigation, hunting, and fishing.” The construction of the dams “destroyed fish and wildlife habitat,” “decreased navigation,” and “lowered creeks, affecting fishing.” The survey did not indicate any future water uses or environmental challenges for the Sac and Fox Reservation. The current identified land use on the Sac and Fox Reservation was identified primarily as agricultural.

E-07. Missouri River Basin Depletions. Dependence on the System as a source for water supply is continually increasing. Increases in use of the water can result in decreases in the amount of water that is available for use by those downstream from the new users. The USBR prepares estimates of the depletions of river flow for the Missouri River. The USBR also makes estimates of future levels of depletion based on projections of increased water uses along the System. The Corps uses the USBR projections and actual depletions in their forecasting and planning for System regulation.

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Appendix F - Hydropower

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

F-02. Hydropower Capacity. The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20,000 MW, with an annual generation of over 90 million MWh. The investor-owned systems have about 60 percent of the basin's generating capacity. The publicly-owned systems consist of about 40 percent federal hydroelectric capacity and 60 percent thermal capacity owned by non-federal public bodies. Hydropower installations in the basin total about 3,000 MW, of which about 82 percent is federal, 14 percent is investor owned, and 4 percent is publicly owned. The federal power system in the upper Missouri River basin includes the six Corps System powerplants as well as the Canyon Ferry and Yellowtail powerplants constructed by the USBR. Until October 1, 1977, energy 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-02.1. Hydropower Facilities and Historic Regulation. The following sections describe the individual System project hydropower and generation. Chapter IV of this manual contains a more detailed description of the hydropower and powerplant facilities. Table F-1 presents hydropower related information for the System dams.

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

[1] 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-03. Fort Peck Dam. There are five units operating at Fort Peck, with a generating capacity of 185 MW. The powerhouse discharge capacity ranges from 15,000 to 16,000 cfs, and the average flow is 9,200 cfs. The average annual flow plant factor is 58 percent. The powerplant produces an average of approximately 1.0 million MWh of energy per year. The first hydropower unit went on line in 1943 and the first powerhouse was completed with the installation of the third unit in 1951. The second powerhouse with two units was completed in 1961. The Fort Peck powerplant is a semi-peaking plant.

F-04. Fort Peck Releases. Prior to 1956, Fort Peck was the only System project with a major amount of accumulated storage. As a consequence, releases as high as 28,000 cfs were made in the late summer and fall for flood storage evacuation as well as for downstream navigation flow support. After the second powerhouse went on line in 1961, nearly all the releases have been made through the power turbines except in years when releases were very high due to the evacuation of flood waters. Since 1967 when the System filled, releases greater than the combined powerplant capacity of about 16,000 cfs have occurred in 1971, 1976, 1979, 1997 and 2011. Minimum mean daily releases since 1954 have usually been no less than 3,000 cfs; however, mean daily releases as low as zero have occurred.

F-05. Garrison Dam. Five units operate at Garrison, with a generating capacity of 583 MW. Normal powerhouse flow capacity is 41,000 cfs, and the average release is 21,600 cfs. The average annual plant factor is 53 percent. The powerplant produces an average of 2.2 million MWh per year. Power generating units came on line between 1956 and 1960. The Garrison powerplant is a semi-peaking plant.

F-06. Garrison Releases. Since 1956, releases from Garrison have generally been through the power facilities, having a maximum capacity of about 41,000 cfs. Exceptions were in 1975, 1997 and 2011 when releases of 65,000 cfs, 59,000 cfs, and 150,000 cfs, respectively, were required to evacuate accumulated flood storage. The minimum mean daily release since 1956 has been 0 cfs, which occurred in 2009.

F-07. Oahe Dam. Seven units operate at Oahe, with a generating capacity of 786 MW. Normal powerhouse capacity (at rated head) is 54,000 cfs, and the average release is 23,200 cfs. Powerhouse releases up to approximately 57,500 cfs may be made under certain conditions. The average annual flow plant factor is 43 percent. The powerplant produces an average of 2.6 million MWh per year. Power generating units came on line between 1962 and 1963. The Oahe powerplant is a peaking plant.

F-08. Oahe Releases. Due to the control provided by the downstream Big Bend project, Oahe releases have been extremely variable since the project became fully operational. Minimum mean daily out flows of 1,000 cfs or less are not uncommon, while releases near the powerplant capacity of about 54,000 cfs are also frequently made. Since the powerplant became operational, nearly all releases have been made through the power turbines except during 1997 and 2011, when releases were very high to evacuate record runoff.

F-09. Big Bend Dam. Eight units operate at Big Bend, with a generating capacity of 517 MW. At this rating, the powerhouse capacity is 103,000 cfs. The average annual release is 23,700 cfs (1967-2015) and the average annual flow plant factor is 22 percent, the lowest of the six System powerplants. The powerplant produces, on average, 1.0 million MWh per year. Power generating units came on line from 1964 through 1966. Big Bend Dam is primarily a peaking powerplant that normally only fluctuates through a very narrow 1-foot range in reservoir elevation.

F-10. Big Bend Releases. Releases experienced from this project have been very similar to that described for Oahe Dam, with a maximum mean daily outflow of 166,300 cfs occurring during 2011, a combination of powerplant and spillway releases. Prior to 2011, releases had been entirely through the powerplant since the facilities became fully operational. A mean daily release of 0 cfs is frequently made from the project, usually on a Sunday to facilitate refilling the project for the next week's releases. On October 8, 1997, releases were made through the powerhouse without any associated generation. Generation was suspended for part of the day for replacement of equipment that was damaged during a spring ice storm. Water was released through the units at "speed no load" during the outage, with hourly discharges ranging from approximately 20,000 to 29,000 cfs.

F-11. Fort Randall Dam. Eight units operate at Fort Randall, with a generating capacity of 320 MW. Normal powerhouse capacity is 44,500 cfs, and the average release is 25,100 cfs. 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-12. Fort Randall 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 level 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-13. Gavins Point Dam. Three units operate at Gavins Point, with a generating capacity of 132 MW. These units came on line in 1956 and 1957. The powerhouse capacity is approximately 36,000 cfs, but under varying conditions 33,000 cfs to 35,000 cfs may be expected, and the average release is 27,600 cfs (1967-2015). The average annual flow plant factor is 77 percent, which is the highest of the six System powerplants. On average, the powerplant produces 0.7 million MWh of energy per year. Gavins Point is the only dam that is not operated to provide peaking power. Generally, daily releases from Gavins Point are constant to allow for stable downstream navigation and other project purposes.

F-14. Gavins Point Releases. Since full regulation began, the reservoir has usually been regulated in the narrow zone extending from elevations 1204.5 to 1208.0 feet. A maximum reservoir level of 1210.7 feet occurred in 1960. Since the System filled in 1967, a maximum elevation of 1209.7 feet was observed in 2010. Also, the Gavins Point reservoir was drawn down to elevation 1199.8 feet in 1969 in anticipation of large amounts of inflow from plains snowmelt. Since 1967, minimum mean daily releases from the project were as low as 6,000 cfs in 1993 and as high as 160,700 cfs in 2011.

F-15. Benefits of Hydropower. The System powerplants provide three principal hydropower benefits:

1. The powerplants provide dependable capacity to meet annual peak power demands; System hydropower helps ensure the reliability of the electrical power system. This reduces the need for additional coal, gas, oil or nuclear generating capacity.
2. The powerplants provide a large amount of energy at a very small cost relative to thermal electric generating stations, reducing the overall cost of electricity. Hydropower facilities reduce the burning of fossil fuels, thereby reducing air pollution, acid rain and the greenhouse effect.
3. The hydropower generated by the System powerplants has several valuable operating characteristics that improve the reliability and efficiency of the electric power supply system, including efficient peaking, a rapid rate of unit unloading, and rapid power availability for emergencies on the power grid.

F-16. 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 (Lake Francis Case). To allow for this, the Fort Randall reservoir is drawn down during the fall of each year as discussed in Section F-16.2.

F-16.1. Hourly Patterning. Hourly patterning of the average daily releases is also of major importance in realizing the full power potential of the System powerplants. Based on past experience with both open water and a downstream ice cover, in most cases no limits need be placed upon 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 mean 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 upon 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 this manual and other System project WCMs.

F-16.2. Patterning Project Releases. Due to the flexibility inherent in such a large system of reservoirs, it is possible to pattern project releases (with the exception of Gavins Point) to cycles extending for periods longer than a day in duration for maximum power production while still providing full service to the authorized project purposes other than hydropower. During the navigation season when downstream flow requirements are high, large amounts of water are normally released from Gavins Point. This requires that large volumes of inflow to Gavins Point be supplied from Fort Randall. Fort Randall, in turn, requires similar support from Big Bend, and Big Bend from Oahe. Here the chain can be interrupted because Oahe is large enough to support high upstream releases for extended periods without correspondingly high inflows. High summer releases from Gavins Point, Fort Randall, Big Bend and Oahe result in high generation rates at these plants. To avoid generating more power than can be marketed advantageously under these circumstances and to provide more winter hydropower, the usual practice during this time of year is to hold releases and generation at Fort Peck and Garrison at lower levels unless the evacuation of flood control storage space or the desire to balance storages between projects becomes an overriding consideration. With the end of the navigation season, conditions are reversed. Releases from Gavins Point drop to about half of summer levels and the chain reaction proceeds upstream, curtailing releases from Fort Randall, Big Bend and Oahe. A means of partially compensating for the lesser amount of hydroelectric energy associated with lower winter release rates from Fort Randall and other mainstem reservoirs is the pre-winter drawdown of the Fort Randall reservoir. As part of this regulation, Oahe and Big Bend releases are reduced several weeks prior to the end of the navigation season. This leaves the Fort Randall reservoir in the position of supplying a majority of downstream releases requirements from accumulated storage, resulting in a lowering reservoir level. This vacated storage space is refilled during the winter months by releases from Oahe and Big Bend in excess of those that would have been possible if drawdown of the Fort Randall reservoir had not been made. At this time, Fort Peck and Garrison winter releases are usually maintained at relatively higher levels as permitted by the downstream ice cover to partially compensate for the reduction in generation downstream.

F-17. System Hydropower Capacity, Energy and Value. The hydropower generating capacity that is available from the System dams at any time varies with the reservoir elevation, or the amount of “head” on the units. As the reservoir elevations decline during long-term droughts, the generating capacity (capability) of the System is decreased. As seen on Plate F-1, during the 1987-1992 and 2000-2007 droughts, power production fell sharply due to declining pool elevations and reduced releases for water conservation purposes. Even though the 1987-1992 drought had ended, power production in 1993 was even lower than during previous drought years. This was due to the significant reduction in System releases for an extended period of time to lessen downstream flood impacts during the 1993 Flood.

F-17.1. Dependable Capacity. The dependable capacity, or capability, as currently marketed by Western, is based on an adverse storage condition. For the System reservoirs, the adverse storage condition selected by Western was the System storage in the fourth extension year of the 5-year lower decile extension study (2009 AOP). In this scenario the reservoirs start the initial year at the base of the Annual Flood Control and Multiple Use Zone and are then lowered due to successive years of low runoff. The System capability in this fourth extension year was 2,082 MW in summer (August) and 1,997 MW in winter (December).

F-17.2. Value Components. The two major components that determine hydropower value are capacity and energy values. For hydropower, maximum value is achieved when the capacity and energy outputs are maximized. The capacity value reflects the ability of the hydropower units to provide capacity when needed, especially during summer and winter peak demand periods. With potential reduced dependable capacity during these time periods, alternative generation facilities may need to be constructed beyond those currently planned to avoid potential brownouts or blackouts.

F-17.3. Value of Capacity. The value of power produced at a particular powerplant is greatest when the available capacity is maximized. This occurs when the available head is a maximum. For most plants, this condition occurs when the reservoir is at its maximum elevation. As the reservoir elevation drops, the head decreases, and the capacity value drops proportionally. Because sufficient water must be released to make the capacity available through the peak demand period, capacity benefits are also a function of the project’s release.

F-17.4. Value of Energy. The value of the energy produced varies from season to season, depending on runoff and reservoir conditions and the power demand. Generally, the higher the demand, the greater the value of hydropower. Because demand is greatest in summer and winter, energy produced during these seasons is of greater overall value than energy produced in the spring and fall. In general, the energy value represents the value of hydropower that minimizes the cost of operating all available plants (hydropower plus thermal) to meet day-to-day power demand. This value is greatest when the hydropower units have sufficient water to produce a maximum amount of energy.

F-17.5. Maximizing Value. The value of the energy produced by a particular powerplant during a month is generally maximized when the powerplant produces as much energy as possible. Because hydropower units burn no fuel, the cost of production is lower than fuel-burning powerplants. When hydropower is available, generation from more expensive coal- or oil-burning plants can be reduced. The savings hydropower provides depends on the value of the thermal energy it displaces and the amount of hydropower produced. Hence, the true energy value to the consumer is the per-unit cost of the thermal energy displaced.

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Appendix G - Navigation

G-01. Authorization and Design. The Missouri River BSNP was designed to prevent bank erosion and channel meandering and to provide reliable commercial navigation on the Missouri River. The Missouri River BSNP was authorized by Congress in the Rivers and Harbors Act of 1945. The design of the Missouri River BSNP was to secure a permanent, continuous, self-scouring, open-river navigation channel with a 9-foot depth and a width of not less than 300 feet under full navigation service conditions for a distance of 735 miles from the confluence of the Big Sioux and Missouri Rivers near Sioux City, IA to the mouth near St. Louis, MO.

G-02. Construction of BSNP. Construction of the navigation works was declared complete in September 1981, although corrective work will be required as the Missouri River continues to form its channel in response to changing flow conditions. The navigation project is not accomplished by using locks, as is the case on most of the inland waterway systems, but by using river structures placed to confine and control the channel. The use of these structures produces velocities high enough to prevent the accumulation of sediment in the channel (self-scouring channel) and permits an open river channel condition for the entire 735-mile length of the project. Maintenance of these channel dimensions, however, requires releases from the System and some infrequent dredging activities, particularly during periods of below-average water supply and/or System releases. The velocities in the Missouri River are higher than on other inland navigation systems, which can present challenges to navigating the river. This navigation project is an important link with the Mississippi River waterway system. Low-cost transportation, particularly for bulk commodities, is available at many localities in the Missouri River valley. Cities and commercial interests have provided facilities along the banks of the river for both handling and managing navigation traffic.

G-03. Transported Commodities. Major commodities transported on the Missouri River include agricultural products (farm and food products); chemicals, including fertilizers; petroleum products, including asphalt; manufactured goods, including building products such as cement; and crude materials such as sand, gravel and materials used to maintain the Missouri River BSNP. Commercial tonnage, which excludes sand and gravel and waterway materials, peaked in 1977 at 3.3 million tons and has generally declined since then. Table G-1 presents annual tonnage of commodities transported on the Missouri River BSNP.

G-03.1. Commercial Tonnage. In August of 2015, the Port of Kansas City re-opened (having closed since 2007). In the past couple of years, commercial tonnage has increased on the Missouri River, with the opening of the Port of Kansas City and sufficient System storage levels to provide full navigation service in 2015-2017. The Port of Kansas City moved 285,000 tons of freight in 2017. In 2016, the latest year with available data, there were about 113 active docks and ports along the Missouri River. Ninety-nine docks were located around and downstream of Kansas City, MO, while the remaining 14 were located between Kansas City, MO and Omaha, NE. While the Missouri River between Omaha and Sioux City, IA reach does contain docks, none were active in 2016 (MRRMP-EIS).

Table G-1
Missouri River Navigation Freight Traffic
(short tons in 1000s)

	Year							
Commodity	**1940[a/]**	**1950[a/]**	**1960**	**1970**	**1980**	**1990**	**2000[c/]**	**2010[c/]**
Farm Products	53.2	79.9	1,061.3	1,059.0	1,099.8	371.0	488	36
Corn			59.5	143.8	87.8	32.0	198	13
Wheat			649.1	669.0	835.2	171.0	21	0
Soybeans			104.9	208.8	164.1	40.0	153	23
Nonmetallic Minerals	330.0	282.9	1,495.3	2,869.5	2,855.4	4,268.0	7,254	4,388
Sand/Gravel	330.0	282.9	1,462.1	2,677.5	2,715.2	4,240.0	7,225	4,346
Food and Kindred			135.5	370.3	570.8	61.0	42	36
Pulp and Paper			0.0	16.7	3.6	6.0	1	0
Chemicals	0.5	0.8	21.3	526.2	501.8	345.0	289	72
Fertilizer			11.3	460.2	455.9	312.0	281	70
Petroleum	46.5	3.5	17.2	50.4	315.6	345.0	256	118
Stone/Clay/Glass			0.0	157.7	146.7	154.0	163	76
Primary Metals	6.3	58.5	164.8	57.8	95.4	11.0	69	0
Waterway Materials	844.8	1129.5	4,045.8	2,377.2	290.3	272.0	165	105
Other	15.2	54.4	7.7	34.4	35.4	8.0	6	0
Total	**1,296.5**	**1,609.5**	**6,948.9**	**7,519.2**	**5,914.8**	**5,841.0**	**8,733**	**4,831**
Total Commercial [b/]	121.7	197.1	1,441.0	2,464.5	2,909.3	1,329.0	1,343.6	380

a/ Commodity category definition is slightly different before 1960.
b/ Commercial excludes sand and gravel and waterway materials.
c/ Data Source: U.S. Waterborne Commerce
Source: Navigation Economics Technical Report (Corps).

G-04. Service Level. The explanation of the use of service level to serve the authorized System project purposes is located in Section 7-03.2 of this manual. The selection of the service level is based on criteria explained in Section 7-03.2.1.1. The navigation season length is based on a July 1 System water-in-storage check as outlined in Section 7-03.4. Downstream target flows for full service navigation are 31,000 cfs at Sioux City, IA and Omaha, NE; 37,000 cfs at Nebraska City, NE; and 41,000 cfs at Kansas City, MO. The full service flows provide a 9-foot deep channel and allow the capability to load barges to an 8.5-foot draft.

G-05. Historic Service Levels and Season Lengths. Flow support is provided for a normal navigation season of 8 months from April 1 to December 1 at the mouth of the Missouri River. As stated in Sections G-04 and G-12 of this appendix and Section 7-03.4 of this manual, the length of each year's navigation season is based on the July 1 System storage check. Refer to Table G-2 for historic service levels since 1967. Refer to Table G-3 for historic season lengths and the tonnages moved in each year since 1967.

G-06. Minimum Service Level. As shown on Table VII-2, should the System storage be 49.5 MAF or less on March 15 (first half) or 50.5 MAF or less on July 1 (second half), flow support for navigation will be at a minimum service level for the respective navigation season halves. The difference between minimum and full service flow support is 6,000 cfs. Flows for minimum service navigation are 25,000 cfs at Sioux City, IA and Omaha, NE; 31,000 cfs at Nebraska City, NE; and 35,000 cfs at Kansas City, MO. The minimum service level of flow support is generally sufficient to provide an 8-foot deep channel. These flows generally provide a minimum 8-foot channel and barges can be loaded to a 7.5-foot draft.

G-06.1. Impacts of Minimum Service Level. Commercial navigation declines or ceases at flows below the minimum service level of 8 feet due to the decreased loading capability as well as time and profit lost due to bumpings and groundings. Dredging could be required to maintain a satisfactory navigation channel.

G-07. Intermediate Service Level. As shown on Table VII-2, should the System storage be between 49.5 and 55.0 MAF on March 15 (first half) or between 50.5 and 57.0 MAF on July 1 (second half), flow support will be at an intermediate service level for the respective navigation season halves. The difference between minimum and full service flow support is 6,000 cfs. A straight-line interpolation is used to determine the intermediate service level. For example, an intermediate service level for Sioux City will be between full service (31,000 cfs) and minimum service (25,000 cfs) based on March 15 and July 1 System water-in-storage and the storage ranges outlined in Table VII-2.

G-08. Expanded Service Level. In years when there is above-average upper Basin runoff, and when stored flood waters in the Annual Flood Control and Multiple Use Zone is being evacuated, System releases that exceed full service levels may provide some additional benefit to navigation and also benefit System hydropower production. Table G-2 indicates the System service levels since the System filled in 1967. The determination of an expanded service level is outlined in Section 7-04.13. As noted in Section 7-04.14, an expanded service consists of extending the navigation season 10 days beyond its normal closing date of December 1 at the mouth of the Missouri River. In some years, ice conditions may preclude this extension, and if such occurs, it may be necessary to carry a minor amount of excess water over to the succeeding flood season.

G-09. Closure of Missouri River to Navigation Traffic. Above-average flows on the lower Missouri River flow can disrupt navigation. The Missouri River has been closed to navigation for extended periods due to high river flows during the 1993 and 2011 floods. During the flood of 1993, the Missouri River was closed by the USCG for navigation for seven weeks due to high flows between Kansas City and St. Louis. As detailed in the MRBWM report 1993-1994 *Annual Operating Plan and Summary of Actual 1992-1993 Operations*, the Missouri River was closed from RM 144 to RM 293 on July 3, 1993. By July 6 the entire stretch from the mouth of RM 593 was closed to navigation. The reach from RM 593 to RM 352 was reopened to navigation traffic on August 6 and RM 351 to RM 185 was opened on August 12. The final reach from RM 185 to the mouth opened on August 20. As detailed in Table 13 of the MRBWM report *Summary of Actual 2011 Regulation*, due to the record releases being made from Gavins Point Dam, the USCG, in coordination with the Corps and basin responders, closed the Missouri River to all traffic from RM 811 to RM 550. By July 11, the USCG closed the Missouri River in reach phases and finally closed the river to all traffic from RM 88 to RM 226.3. The USCG opened the river to traffic in reach phases, eventually opening the entire river to traffic on September 27.

G-10. Waterway Action Plan. The navigation industry, USCG and the Corps have collaboratively developed navigation waterways action plans (WAP) for high water and low water conditions. During very high or low water conditions, the WAPs are updated, usually on a daily basis by a navigation industry designee, based on the current and forecast river conditions and disseminated to all interested parties. Both WAPs designate "watch" and "action" phases. For high water conditions, the phases indicate high (watch) or extreme high (action) flows and stages. For low water conditions, the phases indicate low (watch) or extreme low (action) flows and stages.

G-11. Navigation Season Length. The navigation season length is based on the July 1 System storage check and criteria set forth in Table VII-3. The normal navigation season length is 8 months, from April 1 to December 1 at the mouth of the Missouri River. During years when above-average upper Basin runoff has occurred, the December 1 end date may be extended up to 10 days (December 11), Missouri River conditions permitting. Past experience has shown that extensions and attempted extensions prior to the normal opening dates of the navigation season (April 1 at the mouth) were not plausible. In many years, the Missouri River ice cover below Gavins Point was still in place at the time it was necessary to schedule increased releases from the System to provide the extension. The presence of this ice cover prohibited the early opening because it increased downstream flood risk. Additionally, in those years when earlier-than-normal navigation releases are possible due to lack of ice cover, experience has indicated that towboat groundings during this early period are much more frequent than during the remainder of the season. The increased incidence of groundings appears to be related to the cold water temperatures and their effect on channel topography. Although early opening of the navigation season is faced with problems, market conditions favor early transport of grain, fertilizer, and other commodities on the river, and Gavins Point releases necessary to provide satisfactory depths are generally much smaller than for a fall extension. Provision of an early opening to the navigation season will, therefore, continue to be explored, as conditions warrant. With an adequate amount of water in the System, consideration will also be given to extensions beyond the normal closing date. The shortening of the season for water conservation purposes is considered preferable to reducing releases below what are considered minimum service levels. Shortening of the season in these extended drought periods is done in accordance with the criteria in Table VII-3 of this manual. The season lengths provided historically and the tonnages moved in each year since the System first filled in 1967 are shown in Table G-3.

G-12. Navigation Season Shortening. Shortening of the normal 8-month navigation season since the System first filled in 1967 occurred in 1981, 1988-1992, and 2003-2008. See Sections A-09 through A-12 in Appendix A, of this manual for a full description of how water conservation measures have been implemented during droughts since the System closed. Prior to the finalization of the 2004/2006 Master Manual, the MRBWM office exercised flexibility as it related to service level and the opening and closing dates of the navigation season. Once the 2004/2006 Master Manual was implemented, as detailed in Section A-12.5, the criteria as outlined in Tables VII-2 (service level) and VII-3 (season length) was strictly followed. If the July 1 water-in-storage check is less than 51.5 MAF, a shortening of the navigation season will occur. Straight-line interpolation between 51.5 and 46.8 MAF of water-in-storage on July 1 provides the closure date for a navigation season length between 8 and 7 months. If System water-in-storage on July 1 is between 46.8 and 41.0 MAF, a 7-month navigation season is provided. A straight-line interpolation is again used between 41.0 and 36.5 MAF, providing a navigation season length between 7 and 6 months. For System water-in-storage on July 1 below 36.5 MAF, a 6-month navigation season is provided.

Table G-2
Navigation Season Target Flows
(1,000 cfs)

Year	Months	Sioux City	Omaha	Nebraska City	Kansas City
1967	Apr-Jun	28	28	34	38
	Jul-Nov	31	31	37	41
1968	Apr-Nov	31	31	37	41
1969	Apr-Jun(1)	35-40	35-40	41-46	45-50
	Jul(1)	36	36	42	46
	Aug-Sep(1)	50-55	50-55	55-60	55-60
	Oct-Nov(1)	40-45	40-45	45-50	50-55
1970	Apr-May	31	31	37	41
	May-Sep(1)	36	36	42	46
	Oct-Nov(1)	40	40	46	50
1971	Apr-May(1)	36	36	42	46
	May-Nov(1)	45-50	45-50	50-55	55-60
1972	Apr-Nov(1)	40-50	40-50	45-55	50-60
1973-74	Apr-Nov	31	31	37	41
1975	Apr	31	31	37	41
	May-Nov(1)	35-60	35-60	41-66	45-70
1976	Apr-Jul(1)	34-38	34-38	40-44	44-48
	Aug-Dec(1)	31-34	31-34	37-40	41-44
1977	Apr-Nov	31	31	37	41
1978	Apr	31	31	37	41
	May-Jul(1)	35-46	35-46	41-52	45-56
	Aug-Nov(1)	46-51	46-51	52-57	56-61
1979	Apr-Jul(1)	36-42	36-42	42-48	46-52
	Aug-Nov(1)	31-36	31-36	37-42	41-46
1980	Apr-Nov	31	31	37	41
1981	Apr-Nov(2)	31	31	37	41
1982	Apr-Sep	31	31	37	41
	Oct	31-36	31-36	37-42	41-46
	Nov-Dec(1)	36-46	36-46	42-52	46-56
1983	Apr-Jun	31	31	37	41
	Jul	31-36	31-36	37-42	41-46
	Aug-Nov(1)	36	36	42	46
1984	Apr-Jun	31	31	37	41
	Jul-Dec(1)	31-44	31-44	37-50	41-54
1985	Apr-Dec	31	31	37	41
1986	Apr(1)	36-41	36-41	42-47	46-51
	May-Dec(1)	41-46	41-46	47-52	51-56
1987	Apr-Nov	31	31	37	41
1988	Apr-Nov(2)	31	31	37	41
1989	Apr-Aug(3)	28	28	34	38
	Sep-Oct(3)	28	28	34	35
1990-93	Apr-Oct(4)	25	25	31	35
1994	Apr-Dec	31	31	37	41
1995	Apr-May	31	31	37	41
	Jun-Dec(1)	46-56	46-56	52-62	56-66
1996	Apr(1)	41	41	47	51
	May(1)	41-51	41-51	47-57	51-61
	Jun-Dec(1)	56	56	62	66
1997	Apr-Dec(5)	*	*	*	*
1998	Apr-Dec(5)	31	31	37	41
1999	Apr-Dec(1)	31-43	31-43	37-49	41-53
2000	Apr-Jun	31	31	37	41
	Jul-Dec(3)	29.5	29.5	35.5	39.5
2001	Apr-Dec(3)	28	28	34	38
2002	Apr-Jun(3)	27	27	33	37
	Jul-Dec(3)	25	25	31	35
2003	Apr-Nov(4)	25	25	31	35
2004-08	Apr-Oct(6)	25	25	31	35
2009	Apr-Nov(7)	25/31	25/31	31/37	35/41
2010	Apr-Dec(1)	31-43	31-43	37-49	41-53
2011	Apr(1)	31-41	31-41	37-47	41-51
	mid-Apr(1)	41-46	41-46	47-52	51-56
	May(1)	46-56	46-56	52-62	56-66
	mid-May(5)	*	*	*	*
2012	Apr-Dec	31	31	37	41
2013	Apr-Jun(6)	25	25	31	35
	Jul-Dec(3)	28	28	34	38
2014	Apr-Jun(3)	28	28	34	38
	Jul-Dec(1)	31-46	31-46	37-52	41-56
2015	Apr-Dec	31	31	37	41
2016	Apr-Dec	31	31	37	41
2017	Apr-Jun(1)	36	36	42	46
	Jul-Dec	31	31	37	41

(1) Downstream flow targets above full service navigation level as a flood control storage evacuation measure.
(2) Full service flows provided for shortened season.
(3) Navigation targets below full service as a water conservation measure.
(4) Navigation targets at minimum service as a water conservation measure.
(5) Releases determined by flood control storage evacuation criteria and not adjusted to meet specific navigation targets.
(6) Minimum service targets at Sioux City and Omaha not met during periods when there was no navigation in those reaches.
(7) Minimum service targets at Sioux City were not met during periods when there was no navigation in those reaches.

Table G-3
Missouri River Navigation Tonnage and Season Length

Year	Length of Season (Months)	Commercial (Tons) (1)	Total Traffic (Tons) (2)	Total Traffic (1,000 Ton-Miles) (2)	Year	Length of Season (Months)	Commercial (Tons) (1)	Total Traffic (Tons) (2)	Total Traffic (1,000 Ton-Miles) (2)
1967 (3)	8	2,562,657	6,659,219	1,179,235	2000	8	1,344,000	8,733,000	628,575
1968	8 (4)	2,254,489	6,724,562	1,047,935	2001	8	1,288,000	9,732,000	566,150
1969	8 (4)	2,123,152	7,001,107	1,053,856	2002	8 (9)	1,009,000	8,266,000	409,980
1970	8 (5)	2,462,935	7,519,251	1,190,232	2003	8 (10)	667,000	8,050,000	256,788
1971	8 (4)	2,791,929	7,483,708	1,329,899	2004	6 1/2 (11)	525,498	8,192,219	181,995
1972	8 (4)	2,665,579	7,182,841	1,280,385	2005	6 1/2 (11)	284,641	7,935,747	129,882
1973	8	1,817,471	6,370,838	844,406	2006	6 1/2 (11)	195,290	8,295,226	84,483
1974	8	2,576,018	7,673,084	1,227,525	2007	6 3/4 (11)	302,769	6,684,625	119,177
1975	8 (4)	2,317,321	6,208,426	1,105,811	2008	7 (11)	174,800	5,670,968	86,203
1976	8 (4)	3,111,376	6,552,949	1,535,912	2009	8	269,563	5,035,744	114,865
1977	8	3,335,780	6,734,850	1,596,284	2010	8(4)	379,492	4,829,714	132,747
1978	8 (4)	3,202,822	7,929,184	1,528,614	2011	8(4)	230,439	3,831,925	62,253
1979	8 (4)	3,145,902	7,684,738	1,518,549	2012	8	197,000	3,906,000	56,631
1980	8	2,909,279	5,914,775	1,335,309	2013	8	244,576	4,104,505	110,280
1981	7 1/4 (6)	2,466,619	5,251,952	1,130,787	2014	8(4)	293,125	4,670,661	89,932
1982	8 (4)	2,513,166	4,880,527	1,131,249	2015	8	269,200	4,402,000	78,300
1983	8 (4)	2,925,384	6,301,465	1,300,000	2016	8	559,020	4,655,884	201,943
1984	8 (4)	2,878,720	6,386,205	1,338,939	2017	8	633,620 (13)	4,918,000 (13)	120,000 (12)
1985	8 (4) (7)	2,606,461	6,471,418	1,201,854					
1986	8 (4) (7)	2,343,899	6,990,778	1,044,299					
1987	8	2,405,212	6,735,968	1,057,526					
1988	7 ½	2,156,387	6,680,878	949,356					
1989	6 ¾	1,906,508	5,352,282	796,799					
1990	6 ¾	1,329,000	5,841,000	552,509					
1991	6 ¾	1,563,000	5,729,000	537,498					
1992	6 ¾	1,403,000	5,783,000	593,790					
1993	8 (8)	1,570,000	5,631,000	615,541					
1994	8	1,800,000	8,501,000	774,491					
1995	8 (4)	1,439,000	6,884,000	604,171					
1996	8 (4)	1,547,000	8,165,000	680,872					
1997	8 (4)	1,651,000	8,172,000	725,268					
1998	8 (4)	1,735,000	8,379,000	777,727					
1999	8 (4)	1,576,000	9,252,000	699,744					

(1) Includes commercial tonnage except for sand and gravel or waterway materials. Tonnage compiled by Waterborne Commerce Statistics Center (WCSC).
(2) Includes commodities; sand, gravel, and crushed rock; and waterway improvement materials Tonnage by WCSC.
(3) Mainstem Reservoir System first reached normal operating storage level in 1967.
(4) 10-day extension of season provided.
(5) 10-day extension and 10-day early opening provided.
(6) Full service flows for shortened season in preference to reduced service.
(7) 10-day extension provided for 1985 season in trade for 10-day delayed support of 1986 season.
(8) Lower Missouri River closed: 57 days in 1993, 20 days in 1995, and 18 days in 1999.
(9) To protect T&E shore birds below Gavins Point Dam, the Corps did not support navigation from July 3 to August 14, 2002. Average days towing industry off the river was 23 days.
(10) 6-day shortening of season to follow CWCP. From Aug 11 to Sep 1 Corps did not support navigation flows to comply with lawsuit to follow 2000 Biological Opinion. Navigation industry left the river during this period.
(11) Season shortening; 47 days, 2004; 48 days, 2005; 44 days, 2006; 35 days, 2007; 30 days, 2008
(12) Estimated using boat report barge counts
(13) Estimated using WCSC preliminary projections.

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Missouri River Basin
Mainstem Reservoir System
Master Water Control Manual

Appendix H - Continuing Studies

H-01. Introduction. This appendix presents and discusses the areas related to the regulation of the System that are candidates for continuing studies. The Corps recognizes that the regulation of the System under the CWCP may not be appropriate in the future. It is impossible to foresee the future sequences of floods and droughts; future regulation requirements for T&E species; the time and conditions under which water conservation measures may be implemented on tributaries and their effects on streamflow; the future amounts of flow depletions, whether by the implementation of Tribal water rights or by other factors; changes in power market characteristics; changes in future water requirements for navigation; and possible changes in emphasis on one or more of the authorized purposes due to changing national policies and/or economic conditions. Regardless, studies could be undertaken, when appropriate, for improvement of the methods of regulation proposed in this manual using fairly firm forecasts of future development.

H-02. Forecasting Techniques and Procedures. As the demand for water supply continues to increase, the value of water stored in the System will also increase. In an "ideal world", future weather, climate and streamflows could be accurately known many months in advance so that a reduction in the amount of the storage space specifically set aside for flood control purposes could be accomplished such that the storage could be distributed to increase the benefits to the other authorized purposes. Unfortunately, that "ideal world" does not currently exist. Due to the inability to accurately forecast future weather, climate and streamflows many months in advance, such procedures are not possible at this time; however, it is evident that any indication of future runoff could lead to an improved System regulation. The more accurately and further in advance that runoff can be forecasted, the greater will be the benefits derived from adjustments to System regulation. Current Corps policy, ER 1110-2-240, calls for reservoir regulators "…making decisions based on the principle of water on the ground, which is observed precipitation or observed snowpack. Forecasted conditions may be used for planning future operations, but releases should follow the water control operations plan based on observed conditions within the watershed to the extent practicable." For this reason, major emphasis has been placed on continuing studies designed to improve forecasts of runoff into the System reservoirs and into the Missouri River below the System, based on basin conditions and observed precipitation or observed snowpack.

H-03. Optimum Evacuation Schedules. Flood storage evacuation following a major flood runoff into the System may be accomplished at rates greater than required for conservation purposes to ensure that adequate space is available for the control of future flood events. This evacuation should be made in an orderly manner that will ensure the maximum beneficial use of the stored water and should minimize the risk of contributing to damaging flows in the lower reaches. Sufficient water in storage in the Annual Flood Control and Multiple Use Zone should be retained to provide for optimum conservation regulation through subsequent low-flow periods insofar as consistent with future flood control regulation. Evacuation schedules will be evaluated, when appropriate, through additional studies. For example, the development of more accurate plains snowmelt runoff models could lead to the earlier pre-release of water in storage prior to large spring runoff from mountain snowmelt and/or spring rainstorms, which could allow the System to further reduce flood damages.

H-04. Recommendations from 2011 Independent Review Panel. Three of the six recommendations for future management of the System from the Independent Review Panel (IRP) of the 2011 Flood, *Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011*, apply to this appendix.

H-04.1. Efforts to Improve Forecasting. Recommendation #4 calls for improved cooperation and collaboration with the NWS and its already-established forecast systems as well as with the USGS, possibly through the Integrated Water Resources Science and Services initiative. Coordination meetings should be held with the other agencies that produce water supply forecasts, specifically the NWS and NRCS. State, local, city officials, and other emergency managers, such as FEMA and Sheriff's departments, should be included in these meetings during periods of heightened flood risk. Communication systems (should be developed) for awareness of other agency forecasts and distribution of current conditions, forecasts, and planned releases for the System to all local officials and emergency managers.

H-04.2. Plains Snow Runoff Forecasting. Recommendation #5 calls for studies to enhance data collection, forecasting, and resulting runoff from plains snow. Suggested activities include establishment of additional permanent plains snow measurement stations (using already established snow measurement standards), focused on the development of improved historical record at permanent stations; and research on the effects of prairie soils, geomorphology, and hydrology on snowmelt runoff. Also, the Corps should work to improve collaboration with other groups that collect and analyze snow data, for example, the Community Collaborative Rain, Hail, and Snow network.

H-04.3. Decision Support System. Recommendation #6 calls for the Corps to develop and implement a decision support system that includes real-time status information on tributary reservoirs and inflows that is linked to a modern interactive graphic forecast system. In noting the complexity of the communications systems required to manage the mainstem reservoirs, while considering the status of weather, downstream flooding, inflows, and storage in tributary reservoirs, the panel observed that a program of modernization is needed to create an effective decision support system linked to a modern interactive graphic forecast system.

H-05. Response to IRP Recommendations. Since the 2011 Flood the MRBWM has made considerable improvements to their 1) forecasting cooperation and collaboration efforts, 2) forecasting techniques for plains snow runoff, and 3) decision support system.

H-05.1. Forecasting Cooperation and Collaboration Efforts. Following the 2011 Flood, the Corps committed to communicating more broadly and frequently by holding monthly conference calls from January to July with federal, state, county and local officials, Tribes, emergency management officials, independent experts and the media to discuss conditions on the ground and the current System release plans and forecasts. MRBWM personnel actively participate in various NOAA-led webinars and in-person meetings that focus on Missouri River basin streamflow and soil conditions, flood potential and drought impacts. In addition, the MRBWM office continues to participate in a variety of regional and national climate change teams. The NOAA also collaborated with the Corps and other agencies on a three-part study. The first part, which was completed in December 2013, was a climate attribution effort focusing on the 2011 event. The second part of the study, which was completed in August 2013, was an assessment of the skill and reliability of predictions of seasonal climate and the ability to predict rapid transitions of cycles from wet to dry and dry to wet. In July 2016, NOAA and the University of Colorado's Cooperative Institute for Research in Environmental Sciences completed the third part of the study, which consisted of an expert scientific analysis on why 9 of the highest 10 historic annual runoff years (1898-2015) in the upper Missouri River basin have occurred since 1970. The Corps and NOAA remain committed to sharing their respective modeling tools and analyses as forecasting and analytical methodologies continue to improve.

H-05.2. Forecasting Techniques for Plains Snow Runoff. The Corps continues to collaborate with other federal, state and local agencies and our field offices to improve runoff forecasts, particularly as it relates to plains snowpack.

H-05.2.1. Cooperative Observer Network. In 2009 the MRBWM office established an upper basin plains snow field measurement network. The network consists of federal, state and local officials, and private citizens. The network consists of approximately 200 identified sites that are distributed throughout the plains area of Montana, North Dakota, South Dakota and Wyoming. Starting in January and ending in late March, the snow observers make bi-monthly field measurements of snow depth and snow water equivalent. This information is incorporated into the MRBWM's technical analysis, detailed in Section H-05.2.2, and is also shared with the NWS NOHRSC and MBRFC offices to be incorporated into their respective products. The network still has sites that need observers. The MRBWM office will continue to reach out to basin stakeholders so that the entire plains area of the upper basin is covered.

H-05.2.2. Technical Analysis. The MRBWM office continues to update a number of technical reports used in the regulation of the System. The *Long-Term Runoff Forecasting* report was completed in February 2017. The report includes methodology regarding forecasting March-April runoff in the upper basin, which is the period when plains snow normally melts. The report includes the methodology for determining the current plains snowpack conditions and then comparing current snowpack measurements and modeled maps to historic measurements and maps. Through this analysis, the reservoir regulator is able to forecast a total March-April runoff into the upper basin from plains snowmelt and rainfall runoff. This technical analysis will be continuously updated as plains snow measurements, soil moisture, and observed and forecast precipitation and temperature data become more extensive and available throughout the entire upper basin.

H-05.2.3. Runoff and Reservoir Simulation Models. The Corps continues to improve their real-time modeling techniques regarding snowmelt modeling with HEC-HMS and reservoir modeling with HEC-ResSim. With the assistance of the Corps' HEC and CRREL offices, the MRBWM office continues to develop and calibrate snowmelt HEC-HMS models that use gridded precipitation, air temperature and snow data to forecast runoff from plains snow and rainfall. A HEC-ResSim model has been developed, and continues to be improved on, that simulates reservoir regulation of the entire System. The HEC-ResSim model can perform a period-of-record analysis as well as short- and long-term regulation forecasts based on observed and forecasted inflows. In the future, the HEC-ResSim model will improve incorporation of tributary storage and release information. Improvement of the HEC-HMS and HEC-ResSim models, including the input data, is an ongoing process.

H-05.2.4. Satellite-Based Plains Snow Assessment. The MBST, described in Section 5-06.1.3, is a web-based application designed by CRREL and the MRBWM office to provide real-time and historical information for upper basin plains snowpack. The tool is used to assist the MRBWM office in determining 1) potential plains snowpack runoff volumes and 2) the likelihood of snowmelt-based floods. Plains SWE displayed by the MBST is estimated using empirical relationships for remotely-sensed passive microwave radiation naturally emitted from the earth's surface. The MBST uses SWE data from two sources: the National Snow and Ice Data Center and the Global Snow Monitoring for Climate Research. The MBST provides weekly SWE estimates in the Missouri Basin by HUC-8 basins and reservoir reaches throughout the winter season, and the tool is available through the Corps' internal research computer network. In the future, CRREL and MRBWM will improve the tool by transferring the MBST from its current web platform to the Corpsmap platform, which is a nationwide Corps platform for displaying water-resource related data and products. Furthermore, CRREL and MRBWM plan to add additional snow and basin conditions data to the MBST in order to improve the ability to forecast potential plains snowpack runoff volumes and the likelihood of snowmelt-based floods.

H-05.2.5. Basin Monitoring Network. Improvement of forecasting plains snowpack runoff will require a collaborative effort to improve both data collection (i.e., plains snowpack SWE, soil moisture and frost depth) and hydrologic modeling. In 2013 a proposal for the Missouri River basin plains snow and basin condition network was prepared by subject matter experts from various federal and state agencies. The proposal outlined timelines, costs, and agency responsibilities. The 2014 Water Resources and Reform Development Act (WRRDA 2014, Section 4003a) included authorization, but not funding, for the establishment of the basin monitoring network. Implementation guidance was provided in October 2015, which stated that activities under Section 4003(a) may not be undertaken until funds are specifically appropriated for such purpose. The Water Resources Development Act of 2016 (WRDA 2016, Section 1179a) amended WRRDA 2014, Section 4003a, and established the Corps as the lead agency for snowpack and drought monitoring in the upper Missouri River basin. The Government Accountability Office submitted a report to Congress in June 2015 stating that the progress has been limited, primarily due to lack of funding. In 2018 the Corps allocated $100,000 to update the proposal with new equipment and costs, as well as to develop interagency agreements with partner federal, state and research/extension agencies regarding the purchase, installation and ongoing maintenance of equipment, retrieval, QA/QC, storage and dissemination of data, and development of soil moisture and plains snow products that could be integrated into runoff and water supply models and forecasting techniques.

H-05.3. Decision Support System. Starting in 2012, the Corps has been actively developing a suite of models to be integrated into the CWMS AIS. This 10-year effort consists of developing and implementing a suite of models for over 200 watersheds in the contiguous United States, 19 of which are in the Missouri River basin. The modeling suite consists of 1) a CWMS database storage/exchange for acquired data and model results; 2) an HEC-HMS model that produces flow forecasts from spatial precipitation, including plains snow, at common computation points for the entire watershed; 3) an HEC-ResSim model that includes stream alignment, physical water components, and any operational rule sets for all reservoirs within the watershed; 4) an HEC-RAS model that determines river flow and stage, including inundation maps, based on HEC-ResSim and HEC-HMS results; and 5) an HEC-FIA model that computes impacts, such as structural and agricultural damages, based on HEC-RAS results. The modeling suites for the entire Missouri River basin are currently being developed and implemented in a phased approach. All models are expected to be completed and implemented by 2022.

H-06. Tributary Development. Several different categories of future development on the tributaries will affect the System that, when appropriate, need appraisal. The amount of storage available for flood control in tributary reservoirs or how the regulation of these reservoirs may change, could lead to effects on System regulation. Additional evaluation of these changes is also essential for estimating flood control benefits to be assigned to tributary reservoirs. Effects of land use changes, soil conservation, and/or forestry practices on flood flows and water yields may also need further appraisal. The growth of privately-developed irrigation pumping on some tributaries may affect the water yield to the point during future low water years that future studies may be needed to assess the effect on System regulation.

H-07. Channel Characteristics. The channel characteristics of the Missouri River, such as channel capacities, water travel times, and ice formation, will need to be the subject of continuing studies insofar as changes to them affect System regulation. The results of changes in the flow regime caused by System and tributary reservoir development can be fully determined only through continuous observation and study. While most channel and adjacent improvements, such as channel realignments, bank stabilization, and levee construction, have already occurred that could substantially affect System regulation, channel capacity changes continue to occur. Studies relating to the maximum permissible flow rates under ice-cover conditions should be continued. Any change in the estimated capacities would be of importance not only from the standpoint of flood control but also from the standpoint of winter power generation. Also, downstream Missouri River degradation has increased channel capacity in some reaches. Conversely, aggradation has reduced the channel capacity in other reaches. The effects of these changes need continued monitoring and study.

H-08. Sedimentation. The Missouri River normally carries a great sediment load through its entire length. Most of the sediment originating upstream from the System will be deposited into each of the mainstem reservoirs. Analysis of historical data of the sediment deposition in the individual reservoirs have been made to quantify the manner, location and amount of deposition. These analyses will be corroborated by continuing monitoring of actual deposition in the reservoirs. Sediment monitoring for this purpose have been established in each of the reservoirs, as described in the individual project manuals. Continuing analysis of the distribution of the capacity in each of the storage zones will take into consideration lost capacity due to continued sediment deposition. Plate H-1 presents the mainstem reservoir capacity lost by project and by the total System. Plate H-2 presents the reservoir capacity lost by project. Plate H-3 presents a schematic of typical reservoir deposition.

H-09. Channel Degradation. While there is sedimentation occurring within the reservoirs, there is channel degradation occurring below the dams. The anticipated degradation below each project was taken into account when establishing the elevation of stilling basins and hydropower draft tubes. Continuing surveys of channel degradation will be made so that its extent may be defined. If necessary, remedial measures may be taken to ensure the maximum economic return from power production of the project. Channel degradation has also resulted in adverse impacts to the Missouri River below the System. In addition to sediment trapping within the reservoir System, degradation has also been caused by the shortening of the Missouri River during construction of the navigation channel from Sioux City to its mouth. The channel shortening has resulted in the loss of oxbow and chute habitat for the native fishery. One positive affect of channel degradation is an increase in carrying capacity of the Missouri River in some reaches. This additional capacity results in additional damages prevented during periods when evacuation of water from major runoffs has occurred. Potential effects of degradation in some of the lower river reaches need to be studied so water supply interests can plan for future Missouri River access.

H-10. Flood Control Storage Zone Allocations. As discussed in Appendix A, the storage allocations used in this manual have gone through a long history of analysis over time and have been changed slightly, primarily the result of the aggradation that has occurred in the reservoirs. The CWCP has not substantially changed the storage zone elevations but has resulted in some changes primarily to the Carryover Multiple Use Zone. As noted in Section 7-04.3 of this manual, the System flood control storage allocation was examined and confirmed as adequate by numerous long-range regulation studies conducted as part of the 2004/2006 Master Manual update. Future studies will be conducted, as warranted, to examine the storage zone allocations. These studies are necessary not only for the definition of total System flood control at locations but also for the optimum distribution of the total flood control storage included in reservoirs comprising the System. In these studies, consideration should be given to the effects of present tributary reservoir development, including the effects of those projects with specifically allocated flood control space and those projects regulated entirely for conservation purposes. Depletions to streamflow resulting from evaporation on System and tributary reservoirs, irrigation, implementation of Tribal water rights, conservation practices in the basin, and development of the multitude of stock and farm ponds will also be considered. With these and other considerations, as may be deemed appropriate, design inflows to the System and each reservoir comprising the System will be developed on the basis of past flood history and the flood potential of the basin.

H-11. Release Restrictions. Restrictions on releases from individual reservoirs affecting flood control considerations will be analyzed in greater detail. Studies concerning evacuation schedules and channel characteristics, as discussed earlier in this appendix, will be necessary. Restrictions imposed by the downstream flood potential will be further evaluated. Consideration will also be given to necessary service to authorized purposes other than flood control that must be maintained at the time of flood control regulation.

H-12. Design Flood Storage. With the detailed analysis of design flood inflows to the System and permissible releases from the System during the inflows, the storage required for control of the design flood could be re-examined. Such determination will take into account allocations for both seasonal and exclusive flood control functions and their corresponding differing regulation criteria. This could lead to the redistribution of the storage space between the Permanent Pool Zone and the base of required surcharge storage in each System reservoir. As part of the Dam Safety Program USACE has tasked its Hydraulics and Hydrology (H&H) Community of Practice to analyze extreme storm data and update hydrology for various USACE water resources projects. Currently, there are ongoing studies for the Fort Peck and Garrison reaches that are primarily focused on hydrologic adequacy and include efforts on extreme storm analysis, Probable Maximum Precipitation (PMP) analysis, and Probable Maximum Flood (PMF) analysis. The updating of the hydrology may expand to include the other four Mainstem projects in the future.

H-13. Ongoing Basin Development. As basin development continues, further analysis will need to be made of developed storage at all locations. Other continuing studies, as discussed in this appendix, will also have a bearing on the analysis. Only by keeping current with developments and making appropriate adjustments in reservoir regulating procedures and allocations can the full potential benefits of the System be realized. An anticipation of future development with associated studies is also essential, not only for orderly long-range planning of System regulation but also for planning tributary reservoir regulation and future benefits evaluations. Consequently, the Corps envisions that periodic reanalysis of System storage distribution will be necessary.

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Missouri River Mainstem Reservoir System

Master Water Control Manual

Plates

Item No.	Summary of Engineering Data -- Missouri River Mainstem System 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)	1,027	2,255	2,610
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.	75,545	37
	Left Bank			38
None (7)	4 - 22' diameter	None (7)		39
	1013			40
	2 - 11' x 23' per conduit, vertical lift, cable suspension			41
1385 (11)	1229	1180 (11)		42
	Elev 1375 32,000 cfs - 128,000 cfs			43
1351-1355(10) 25,000-100,000 cfs	1228-1237 10,000-60,000 cfs	1153-1161 15,000-60,000 cfs		44
70	117	48	764 feet	45
None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46
	1,074		55,083	47
None	59' dia, 2 per alternate penstock	None		48
8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49
67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50
67,275 (15)	40,000	44,100		51
517,470	320,000	132,300	2,524,350 kw	52
497,000	293,000	74,000	1,967,000 kw	53
974	1,719	726	9,310 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) 1967-2017 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
(15) 67,275 kW on per unit basis 64,684 kW on facility basis

Corps of Engineers, U.S. Army
Compiled by
Northwestern Division
Missouri River Region
August 2018

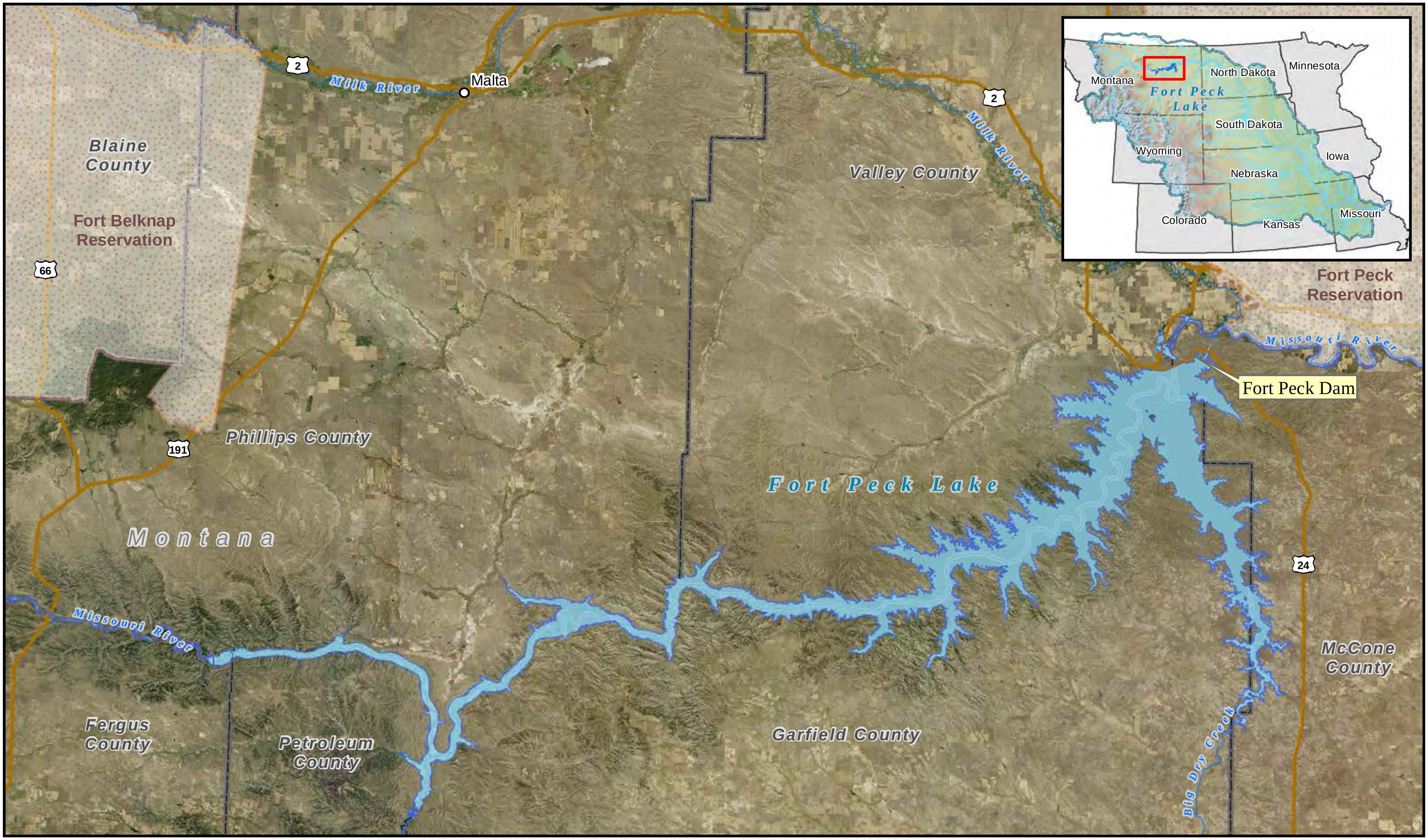

Plate II-3

US Army Corps of Engineers®
Northwestern Division

- Cities
- Rivers
- Roads
- Reservations
- Reservoirs/Lakes
- State Boundaries
- County Boundaries

0 5 10 20 30 Miles

N S W E

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

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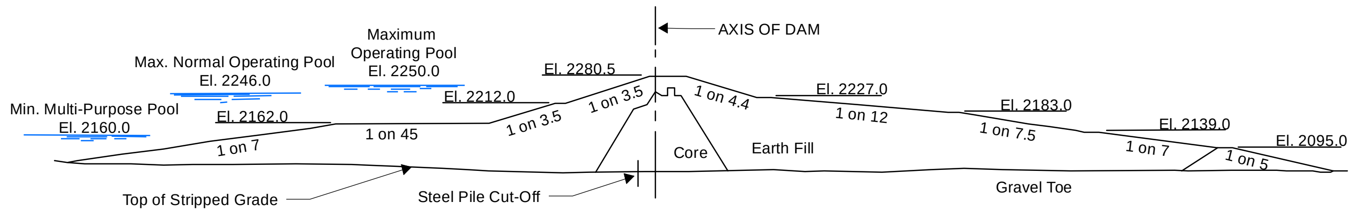
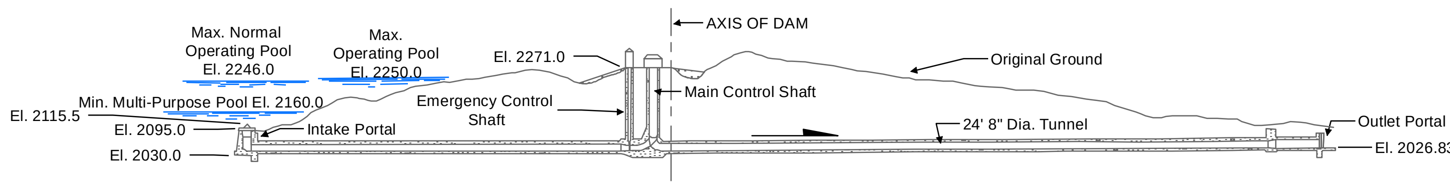
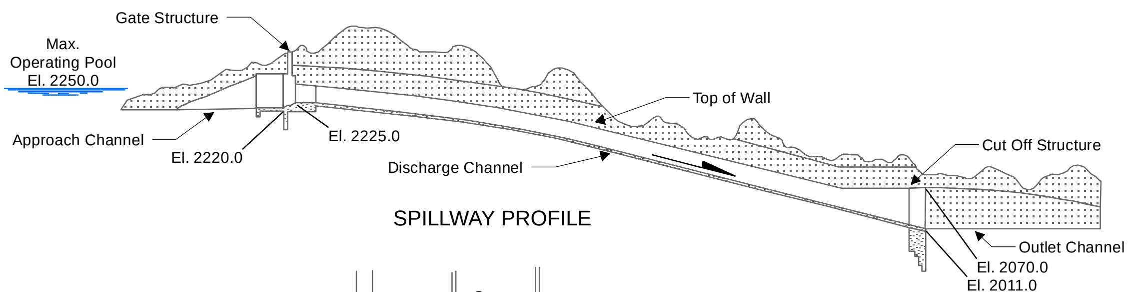
Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Project Map
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



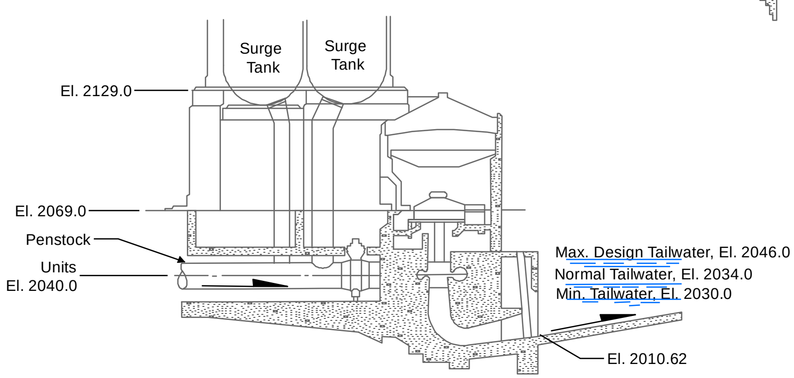
MAXIMUM EMBANKMENT SECTION



OUTLET WORKS PROFILE



SPILLWAY PROFILE



POWERHOUSE SECTION
First Power Plant

PLAN VIEW

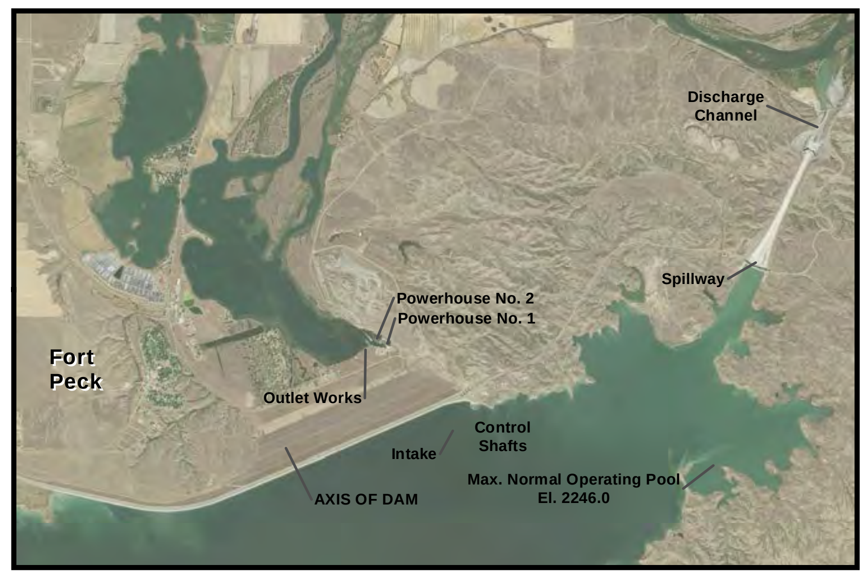


Plate II-4

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

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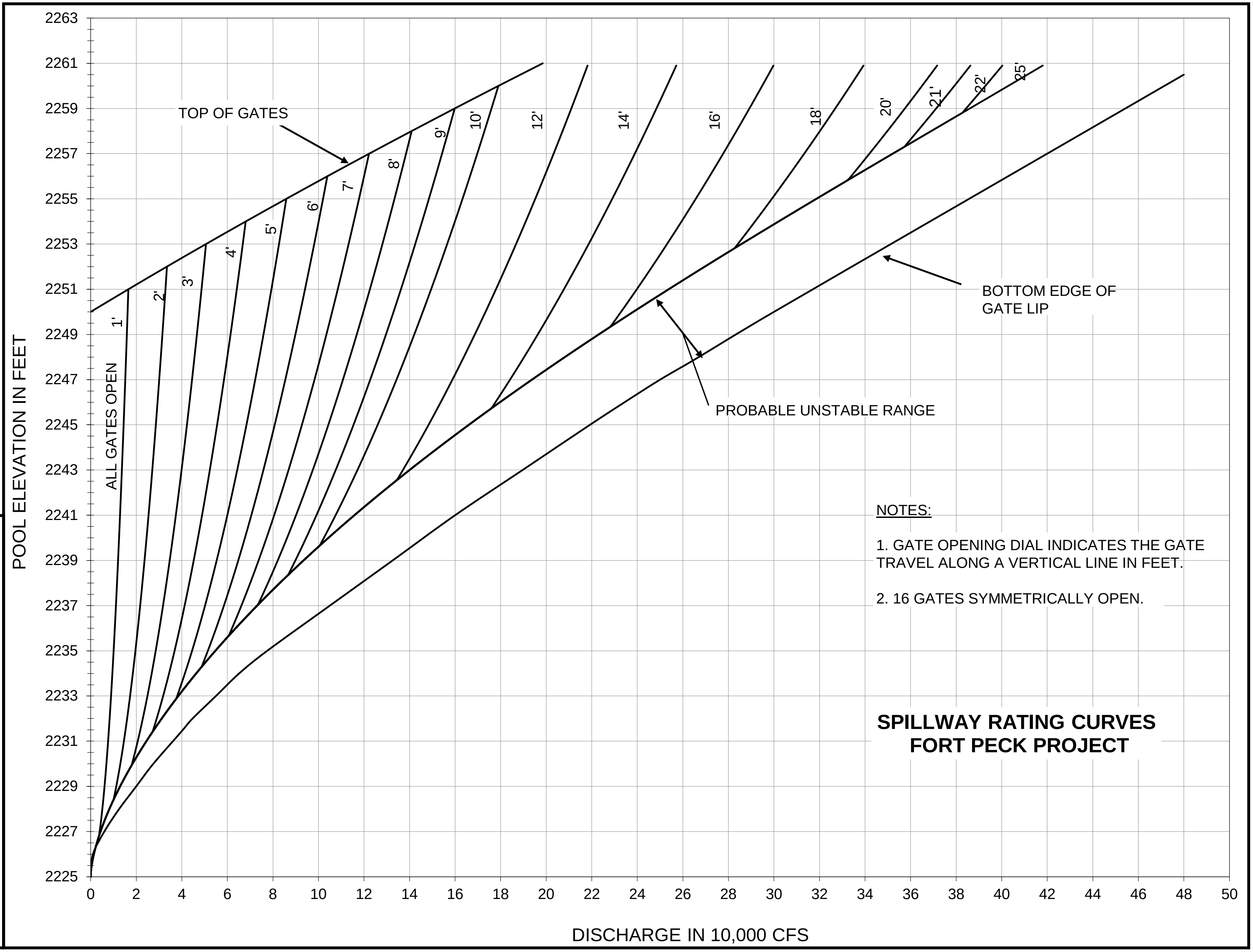
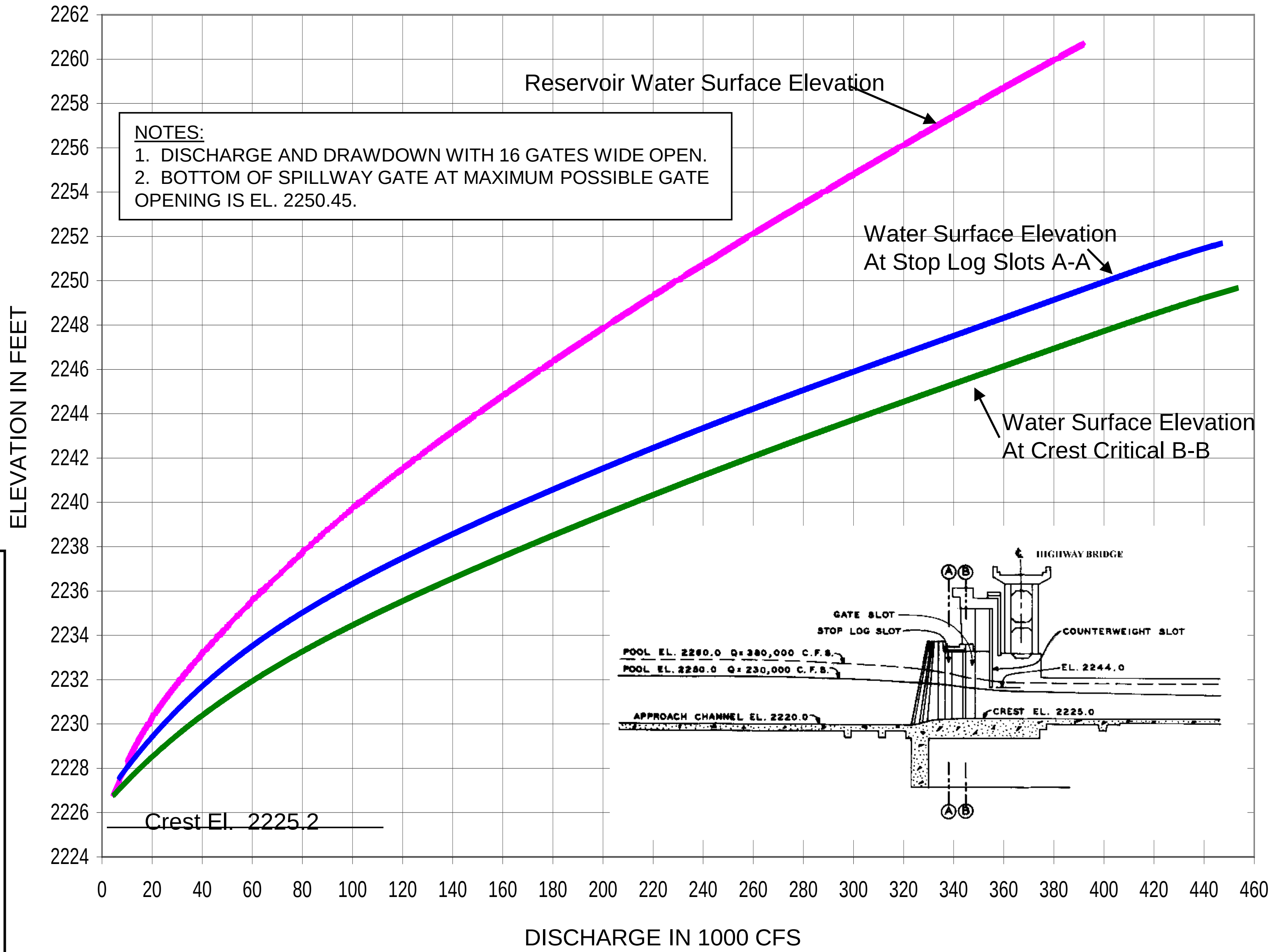
Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Plan and Sections
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Fort Peck Spillway Rating Curves



Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Spillway Rating Curves
U.S. Army Engineer Division, Northwestern Corps of Engineers, Omaha, Nebraska
November 2018

Plate II-5



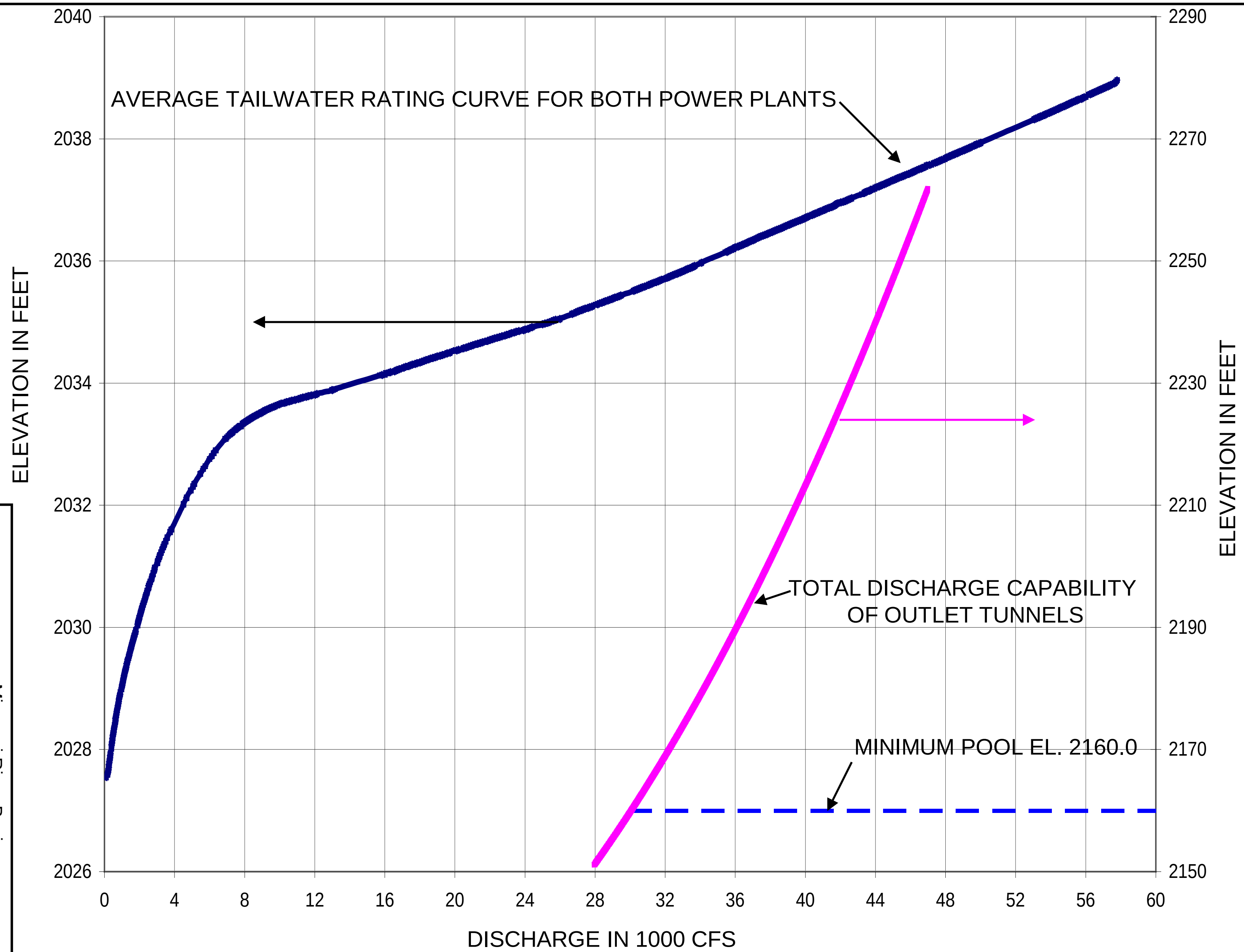
NOTES: 1. DISCHARGE AND DRAWDOWN WITH 16 GATES WIDE OPEN.
2. BOTTOM OF SPILLWAY GATE AT MAXIMUM POSSIBLE GATE OPENING IS EL. 2250.45

Missouri River Basin

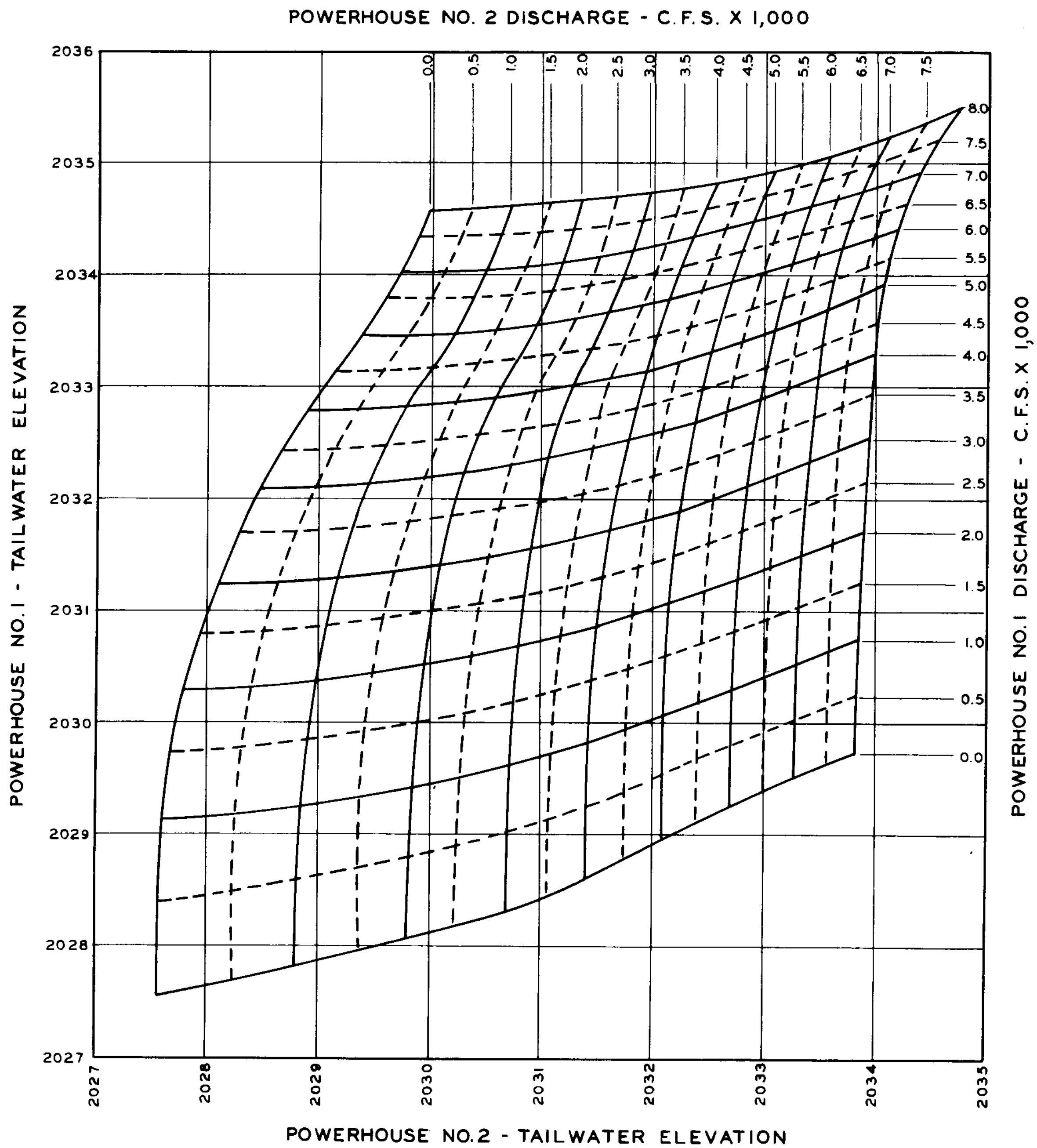
Mainstem Master Water Control Manual

Fort Peck - Discharge Rating Curve and Drawdown at Spillway Gates

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck - Powerplant, Tailwater Rating Curve and Discharge Capability of Outlet Tunnels
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018



Directions:

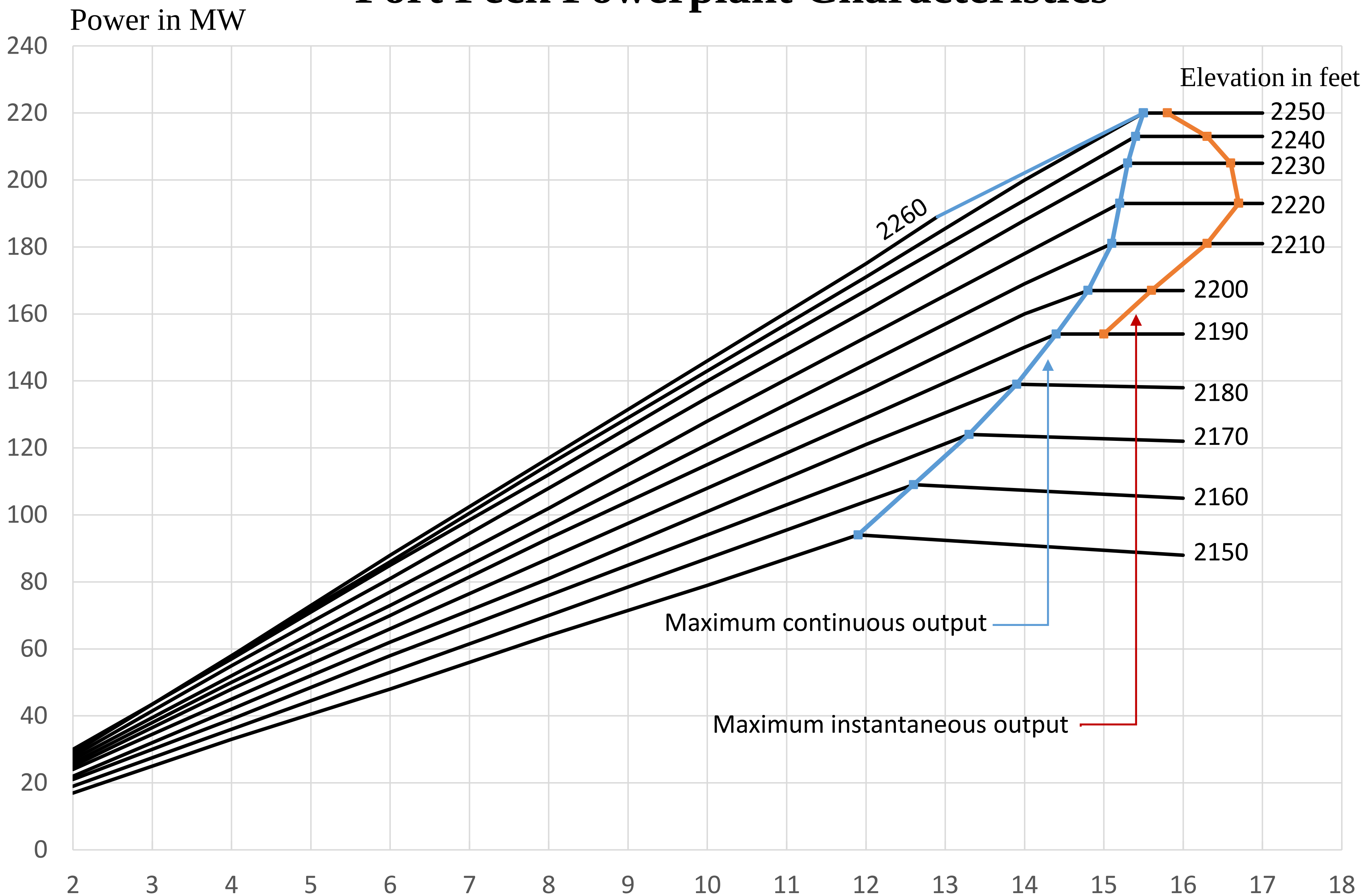
Tailwater elevation can be determined by following the Powerhouse No. 1 discharge curve to the left until the correct Powerhouse No. 2 discharge is reached. From this point read directly to the left for Powerhouse No. 1 tailwater elevation and straight down for Powerhouse No. 2 tailwater elevation.

Notes:

1. These curves are only good when steady state flow conditions exist at both powerhouses.
2. The curves are based on steady state flow period determined from the 1963 through 1965 stage recorder charts of both powerhouses. Discharges for these period were obtained from the hourly powerhouse releases.

Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Tailwater Rating Curves for
Powerhouse No .1 and No. 2
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Fort Peck Powerplant Characteristics



October 1995

Missouri River Basin

Mainstem Master Water Control Manual

Fort Peck Powerplant Characteristics

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

FORT PECK PROJECT - Effecitve Date January 2099
RESERVOIR SURFACE AREA IN ACRES
(2007 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
2030	0	0	0	0	0	50	87	108	129	151
2040	292	462	546	638	740	850	970	1,098	1,235	1,381
2050	1,479	1,489	1,498	1,573	1,714	1,921	2,193	2,530	2,934	3,404
2060	3,802	4,004	4,165	4,428	4,794	5,263	5,834	6,507	7,283	8,161
2070	9,100	10,002	10,820	11,569	12,248	12,857	13,397	13,866	14,265	14,596
2080	14,882	15,190	15,555	15,970	16,436	16,954	17,522	18,141	18,812	19,533
2090	20,221	20,791	21,328	21,915	22,550	23,236	23,972	24,757	25,591	26,476
2100	27,343	28,119	28,861	29,630	30,428	31,255	32,110	32,993	33,905	34,845
2110	35,709	36,418	37,115	37,917	38,822	39,831	40,946	42,164	43,486	44,913
2120	46,360	47,704	48,967	50,215	51,449	52,667	53,869	55,057	56,229	57,386
2130	58,579	59,849	61,126	62,353	63,530	64,656	65,731	66,757	67,733	68,658
3140	69,608	70,661	71,750	72,799	73,810	74,782	75,716	76,610	77,466	78,283
2150	79,022	79,691	80,396	81,201	82,106	83,110	84,214	85,418	86,721	88,124
2160	89,461	90,567	91,606	92,745	93,981	95,316	96,749	98,281	99,911	101,640
2170	103,394	105,061	106,652	108,219	109,763	111,285	112,782	114,256	115,708	117,136
2180	118,608	120,181	121,766	123,288	124,748	126,146	127,482	128,755	129,966	131,115
2190	132,175	133,178	134,237	135,407	136,688	138,081	139,585	141,201	142,928	144,765
2200	146,595	148,268	149,860	151,474	153,112	154,773	156,457	158,166	159,893	161,650
2210	163,400	165,100	166,790	168,495	170,210	171,930	173,670	175,420	177,175	178,950
2220	180,590	182,005	183,420	185,015	186,800	188,765	190,905	193,230	195,740	198,430
2230	201,130	203,610	205,955	208,310	210,665	213,025	215,395	217,765	220,145	222,530
2240	225,065	227,835	230,585	233,130	235,470	237,605	239,530	241,260	242,785	244,100
2250	245,405	246,945	248,635	250,330	252,025	253,715	255,410	257,105	258,795	260,485
2260	262,180									

FORT PECK PROJECT - Effecitve Date January 2009
RESERVOIR CAPACITY IN ACRE-FEET
(2007 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
2030	0	0	0	0	0	25	101	199	318	458
2040	620	1,042	1,544	2,134	2,821	3,614	4,522	5,554	6,719	8,025
2050	9,482	10,983	12,461	13,980	15,607	17,408	19,449	21,794	24,510	27,663
2060	31,318	35,267	39,326	43,597	48,182	53,185	58,708	64,853	71,723	79,420
2070	88,046	97,621	108,050	119,262	131,188	143,758	156,903	170,552	184,635	199,083
2080	213,827	228,847	244,207	259,957	276,147	292,830	310,055	327,874	346,338	365,498
2090	385,404	405,940	426,987	448,597	470,817	493,698	517,290	541,642	566,804	592,825
2100	619,756	647,512	675,995	705,234	735,256	766,091	797,766	830,311	863,753	898,121
2110	933,443	969,539	1,006,280	1,043,770	1,082,114	1,121,414	1,161,777	1,203,306	1,246,105	1,290,279
2120	1,335,932	1,383,000	1,431,340	1,480,935	1,531,771	1,583,833	1,637,105	1,691,572	1,747,219	1,804,030
2130	1,861,991	1,921,189	1,981,690	2,043,442	2,106,396	2,170,502	2,235,708	2,301,965	2,369,223	2,437,431
2140	2,506,539	2,576,647	2,647,862	2,720,147	2,793,461	2,867,767	2,943,026	3,019,199	3,096,246	3,174,131
2150	3,252,813	3,332,176	3,412,195	3,492,969	3,574,598	3,657,182	3,740,819	3,825,611	3,911,655	3,999,053
2160	4,087,903	4,177,975	4,269,037	4,361,188	4,454,527	4,549,151	4,645,159	4,742,650	4,841,722	4,942,473
2170	5,045,002	5,149,262	5,255,124	5,362,566	5,471,563	5,582,093	5,694,133	5,807,658	5,922,646	6,039,074
2180	6,156,918	6,276,291	6,397,280	6,519,823	6,643,856	6,769,319	6,896,149	7,024,283	7,153,659	7,284,215
2190	7,415,889	7,548,566	7,682,245	7,817,040	7,953,060	8,090,417	8,229,223	8,369,588	8,511,625	8,655,444
2200	8,801,156	8,948,634	9,097,693	9,248,354	9,400,641	9,554,578	9,710,187	9,867,493	10,026,520	10,187,280
2210	10,349,820	10,514,080	10,680,020	10,847,660	11,017,010	11,188,080	11,360,870	11,535,420	11,711,710	11,889,770
2220	12,069,610	12,250,950	12,433,620	12,617,790	12,803,650	12,991,390	13,181,180	13,373,200	13,567,640	13,764,680
2230	13,964,500	14,166,940	14,371,720	14,578,850	14,788,340	15,000,180	15,214,390	15,430,970	15,649,920	15,871,260
2240	16,094,980	16,321,390	16,550,650	16,782,560	17,016,910	17,253,500	17,492,120	17,732,560	17,974,640	18,218,130
2250	18,462,840	18,708,940	18,956,730	19,206,210	19,457,390	19,710,260	19,964,820	20,221,080	20,479,030	20,738,670
2260	21,000,000									

Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Area
and Capacity Tables
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate II-11

Missouri River Basin

Mainstem Master Water Control Manual

Fort Peck

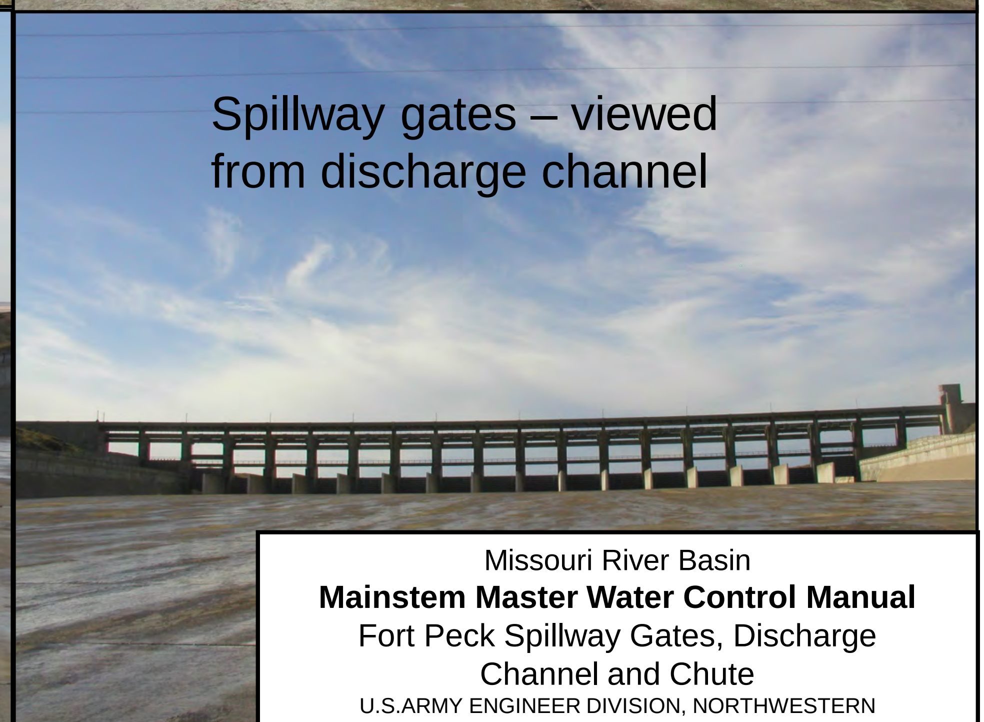
Embankment, Reservoir and Powerhouses

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Spillway gates – viewed from approach channel

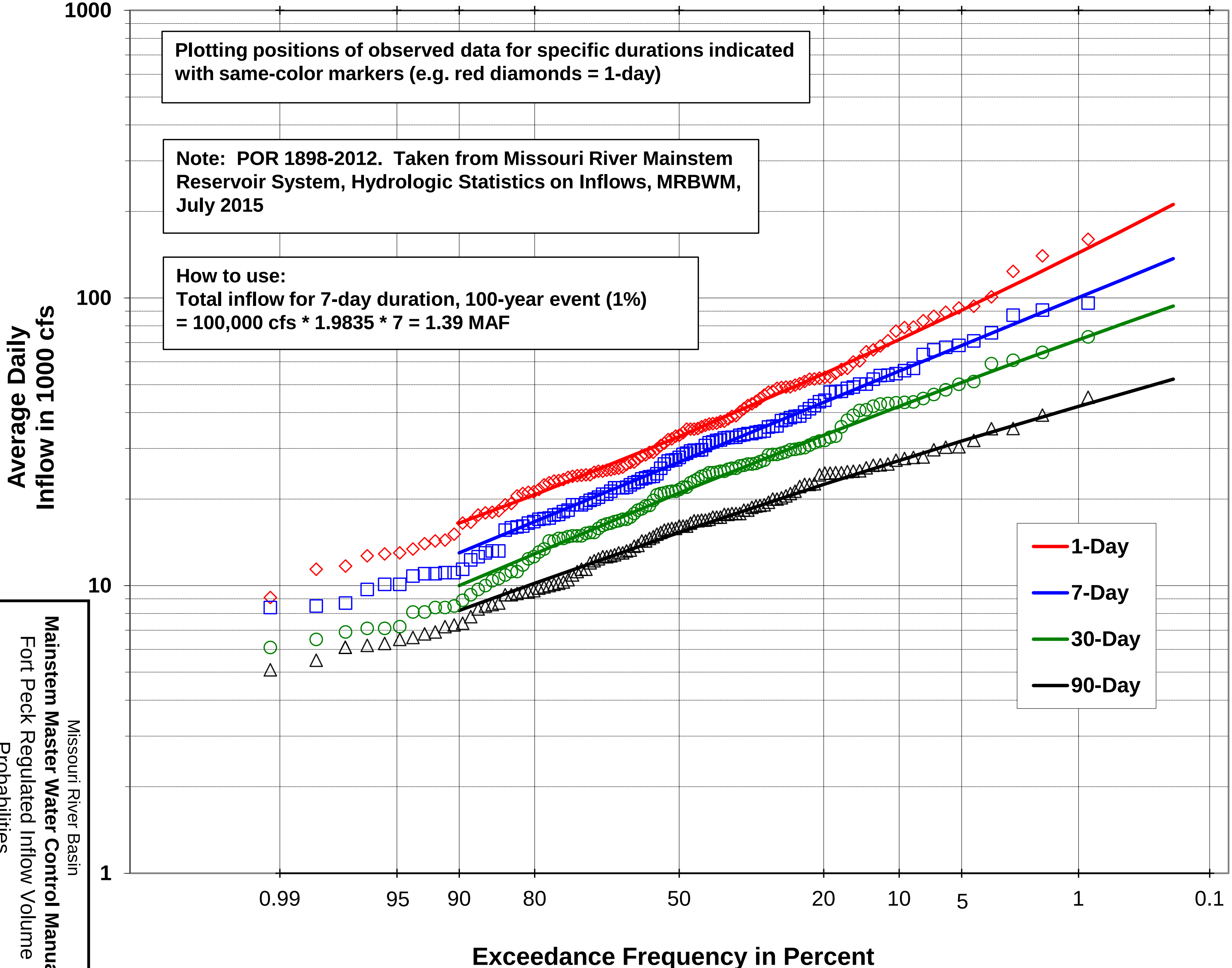
Spillway gate – viewed from discharge channel

Spillway discharge channel



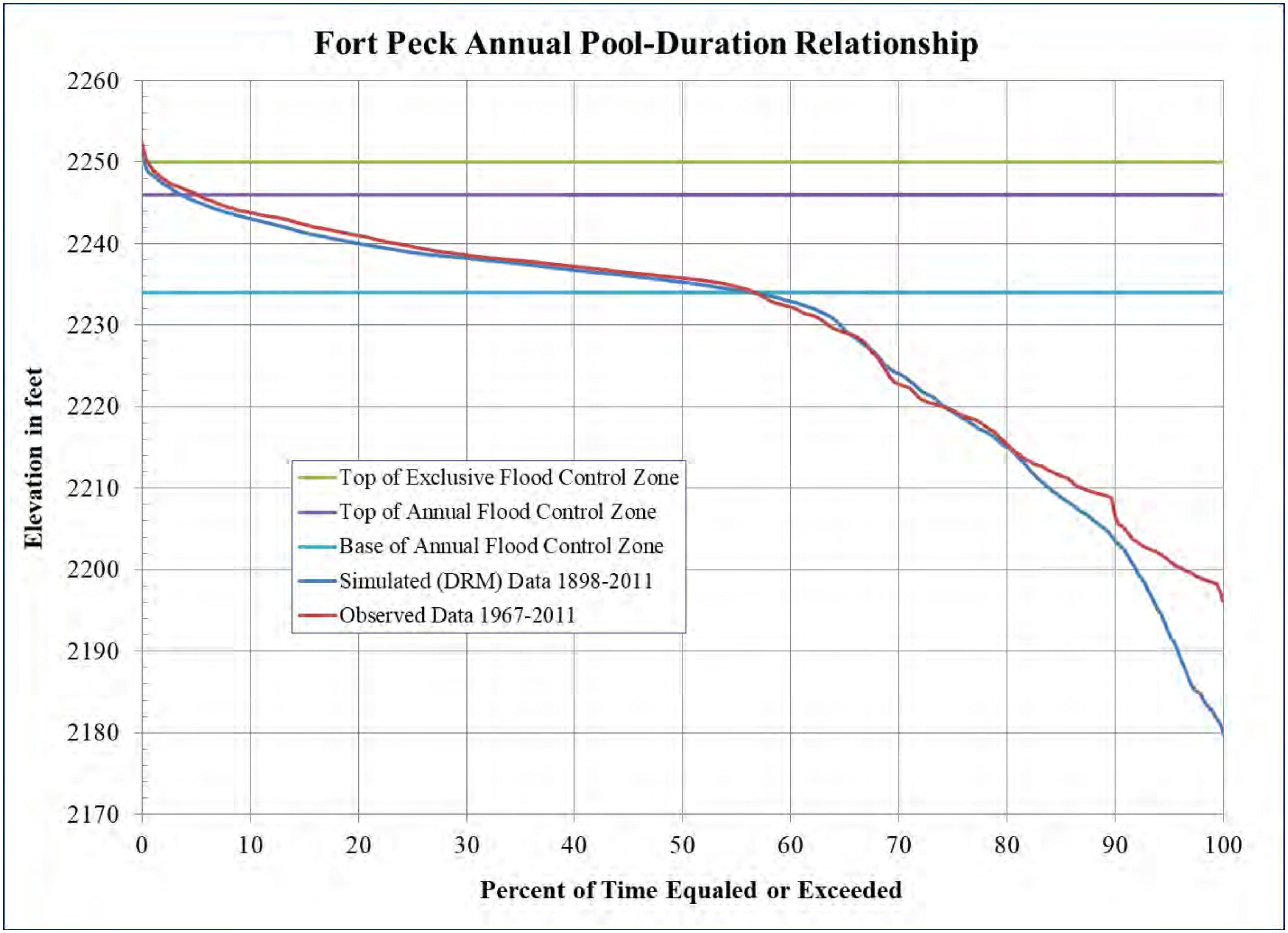
Spillway gates – viewed from discharge channel

Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Spillway Gates, Discharge Channel and Chute
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

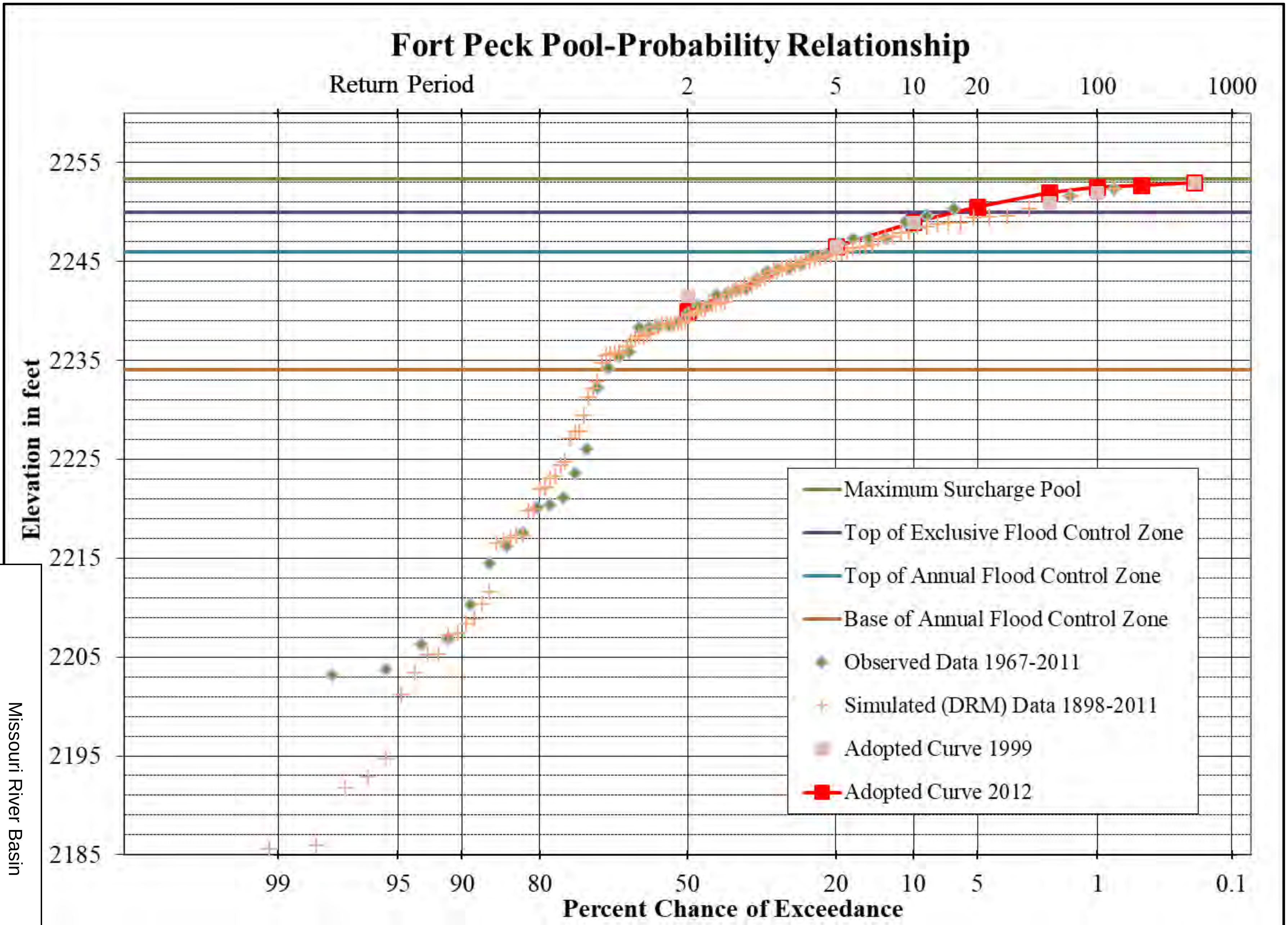


Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Regulated Inflow Volume
Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

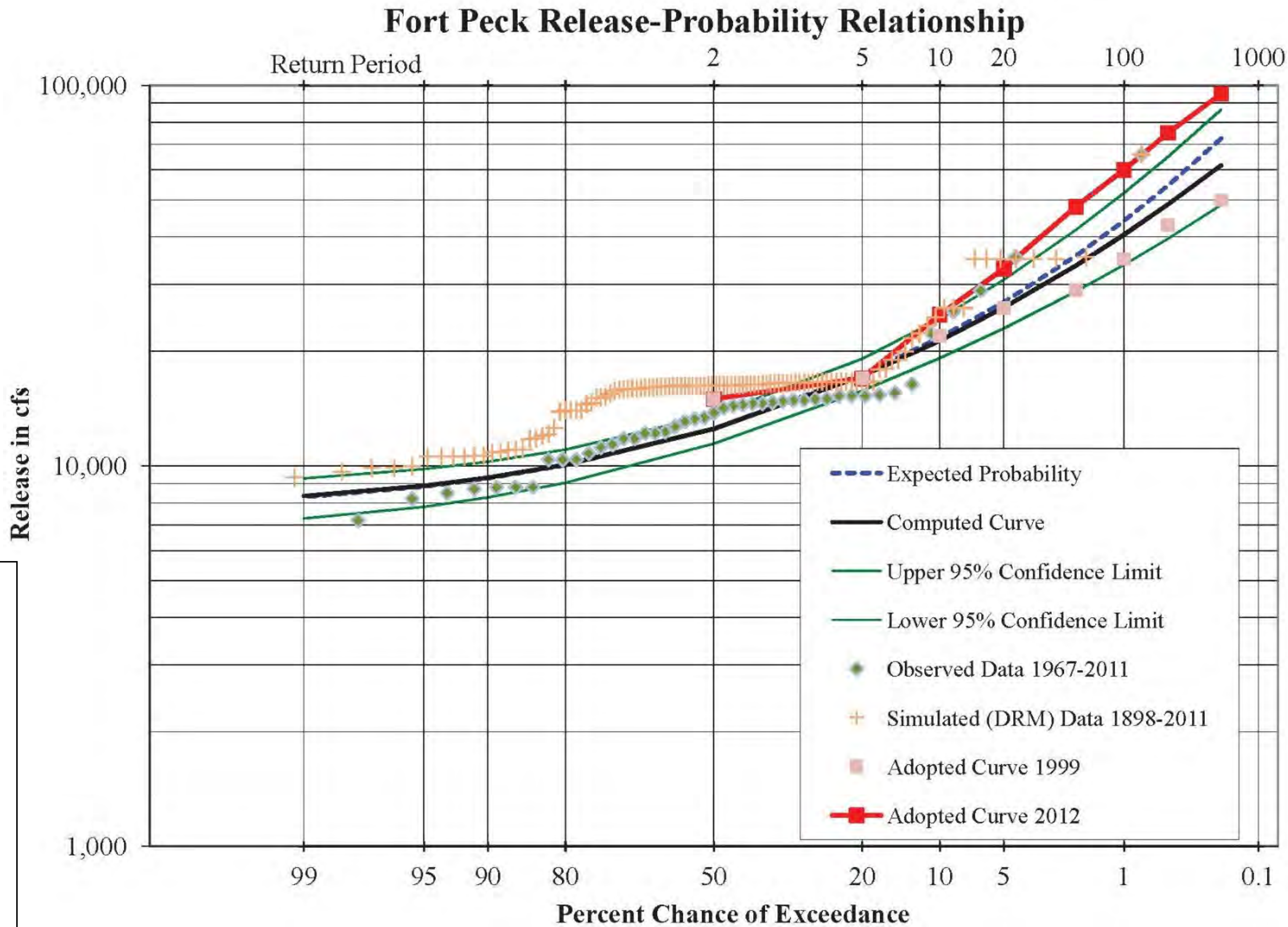
Plate II-13



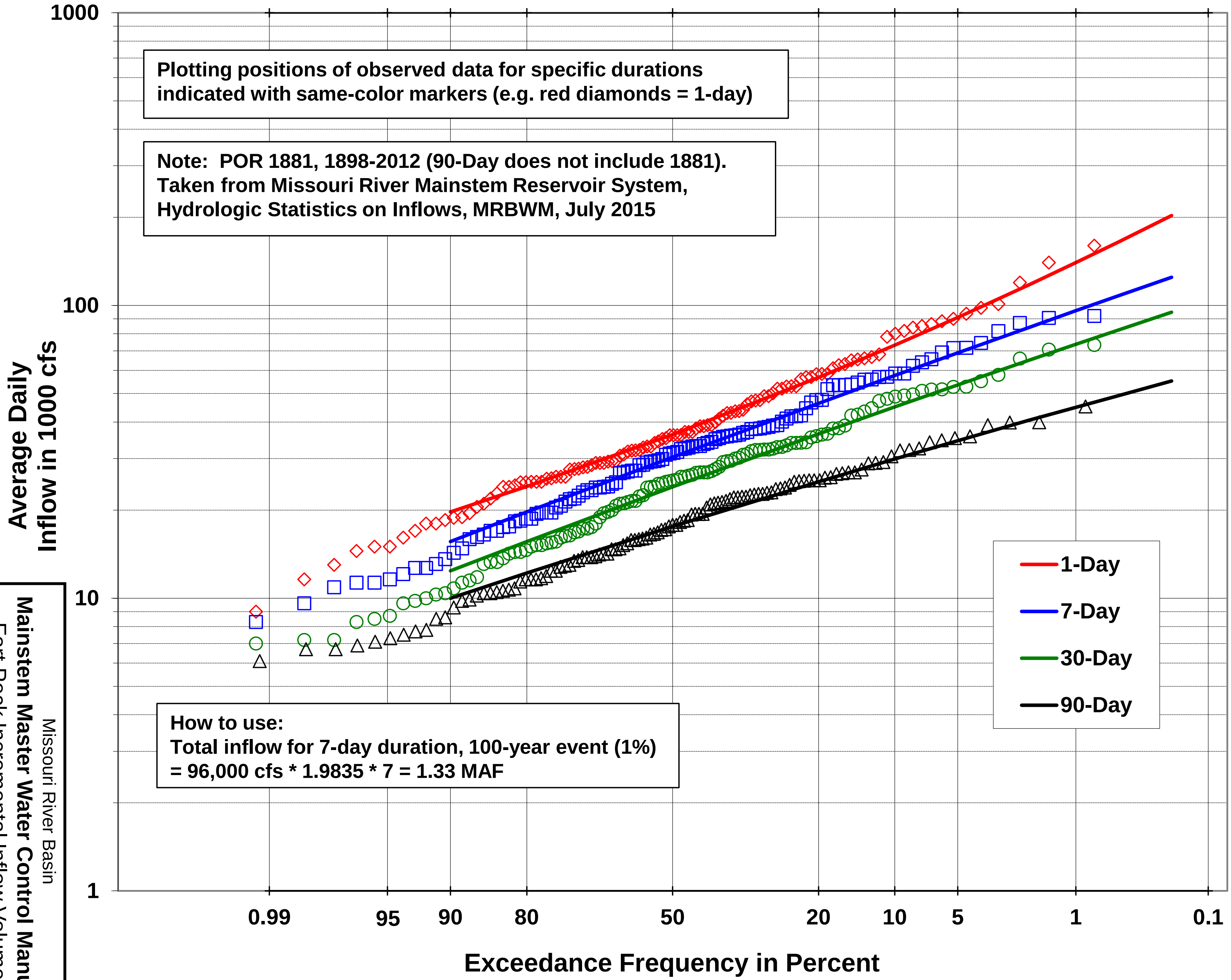
Source: Hydrologic Statistics, MRBWM, September 2013



Source: Hydrologic Statistics, MRBWM, September 2013



Missouri River Basin
Mainstem Master Water Control Manual
Fort Peck Release-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin

Mainstem Master Water Control Manual

Fort Peck Incremental Inflow Volume Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-17

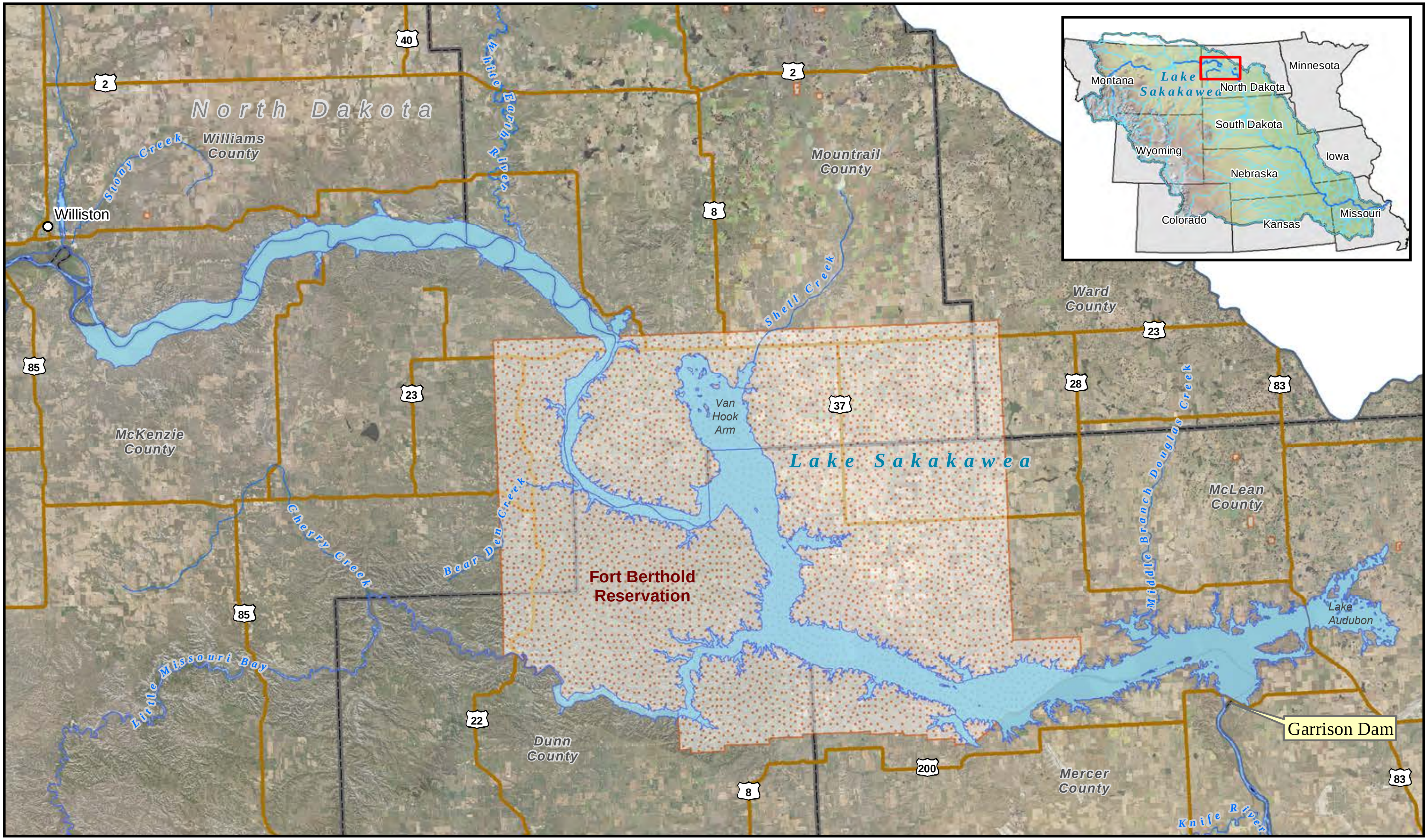


Plate II-18

US Army Corps of Engineers®
Northwestern Division

Cities
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 5 10 20 30 Miles

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

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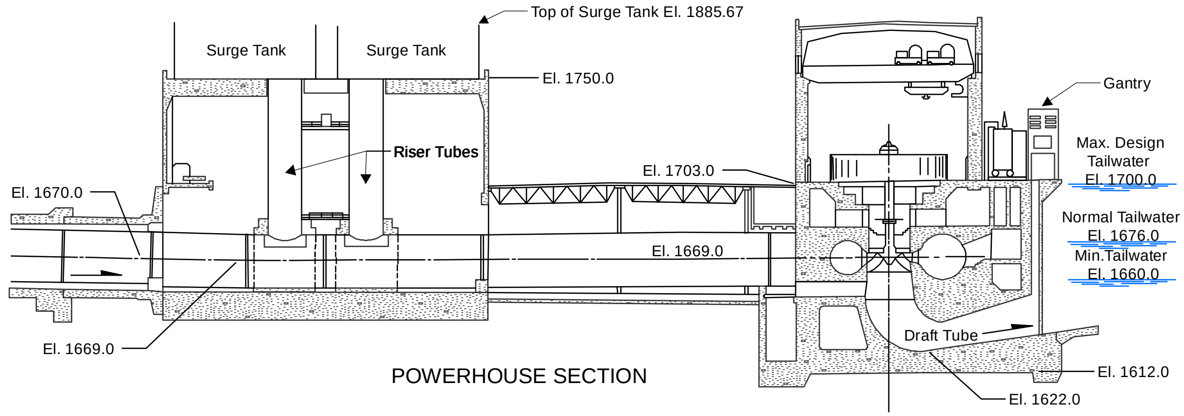
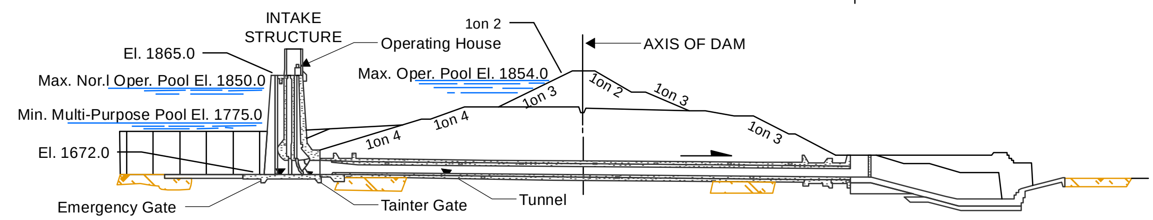
Missouri River Basin
Mainstem Master Water Control Manual
Garrison Project Map
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

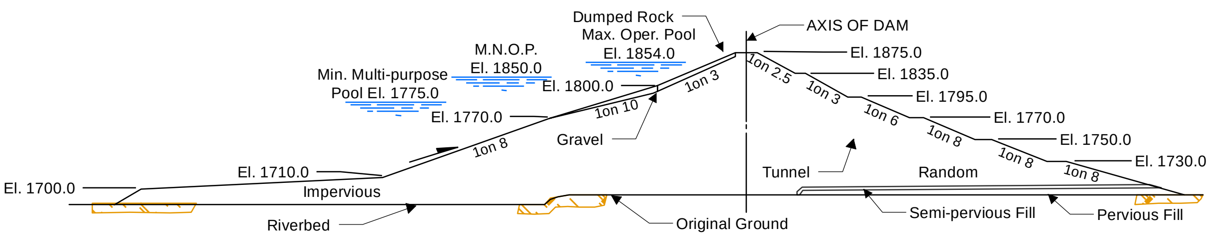
PLAN VIEW



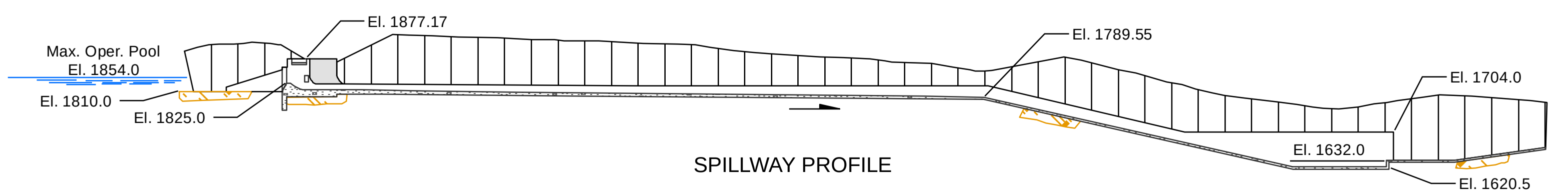
POWERHOUSE SECTION



OUTLET WORKS PROFILE



EMBANKMENT SECTION



SPILLWAY PROFILE

Plate II-19

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

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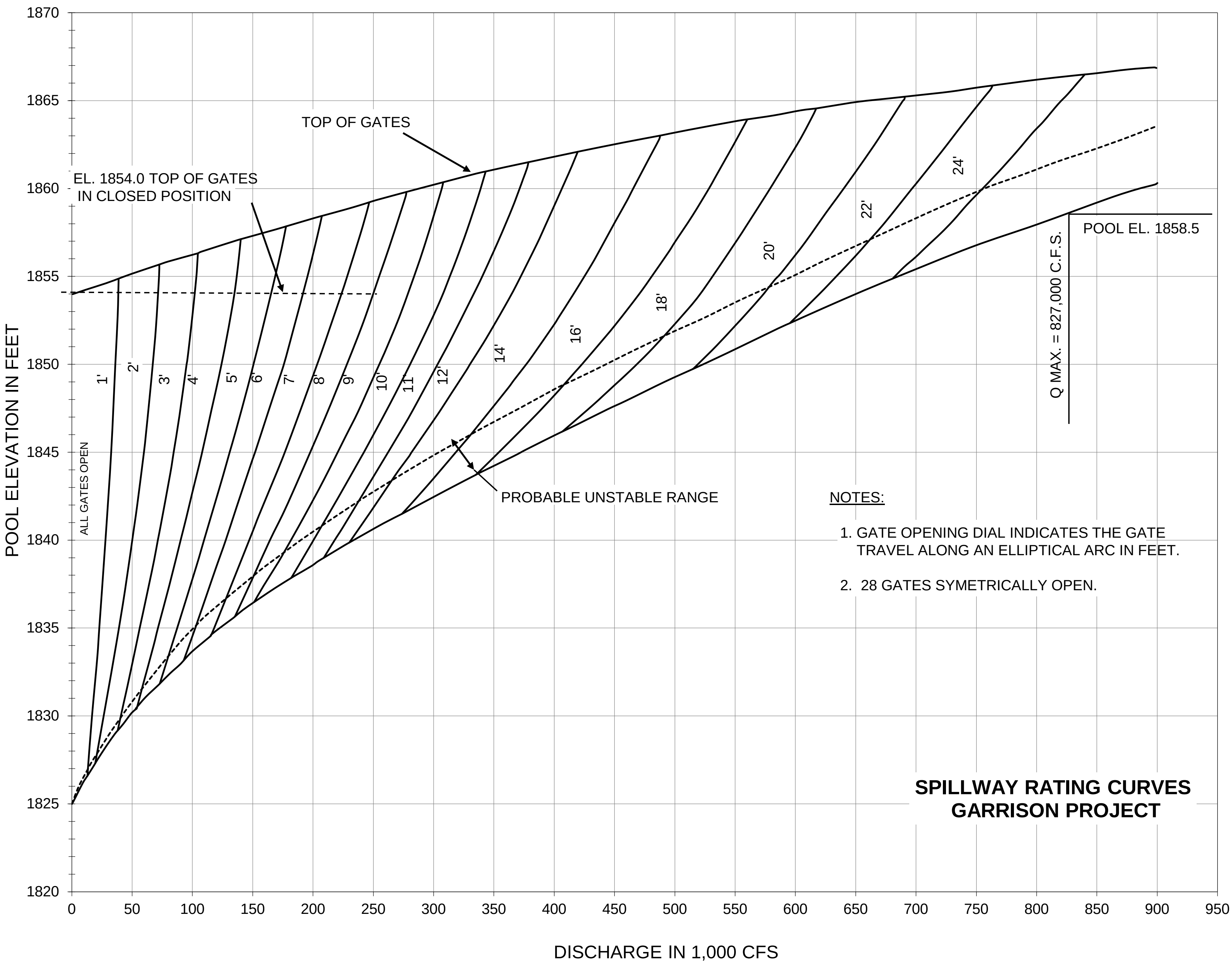
Missouri River Basin
Mainstem Master Water Control Manual
Garrison Plan and Sections
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Garrison Spillway Rating Curves



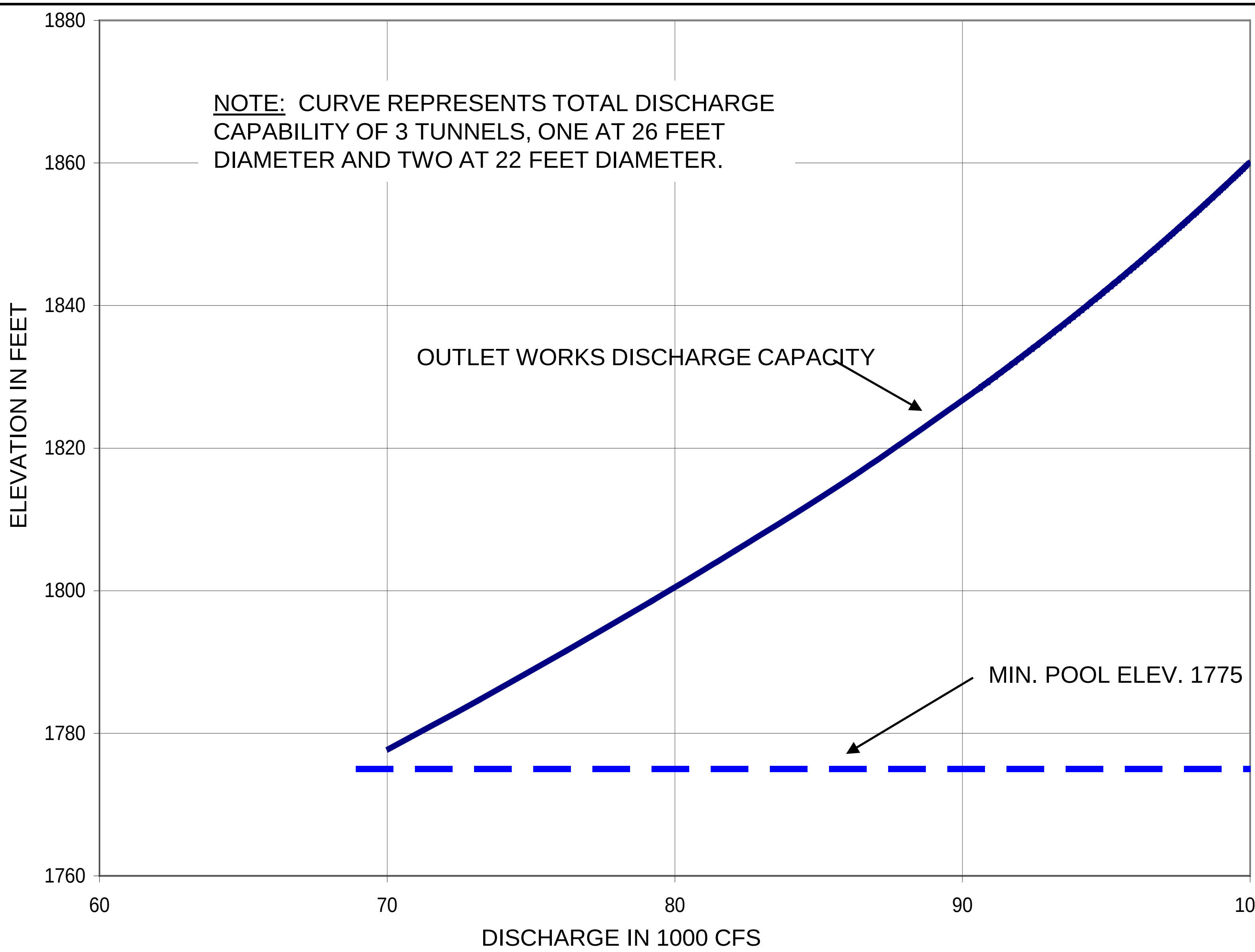
NOTES:

1. GATE OPENING DIAL INDICATES THE GATE TRAVEL ALONG AN ELLIPTICAL ARC IN FEET.
2. 28 GATES SYMETRICALLY OPEN.

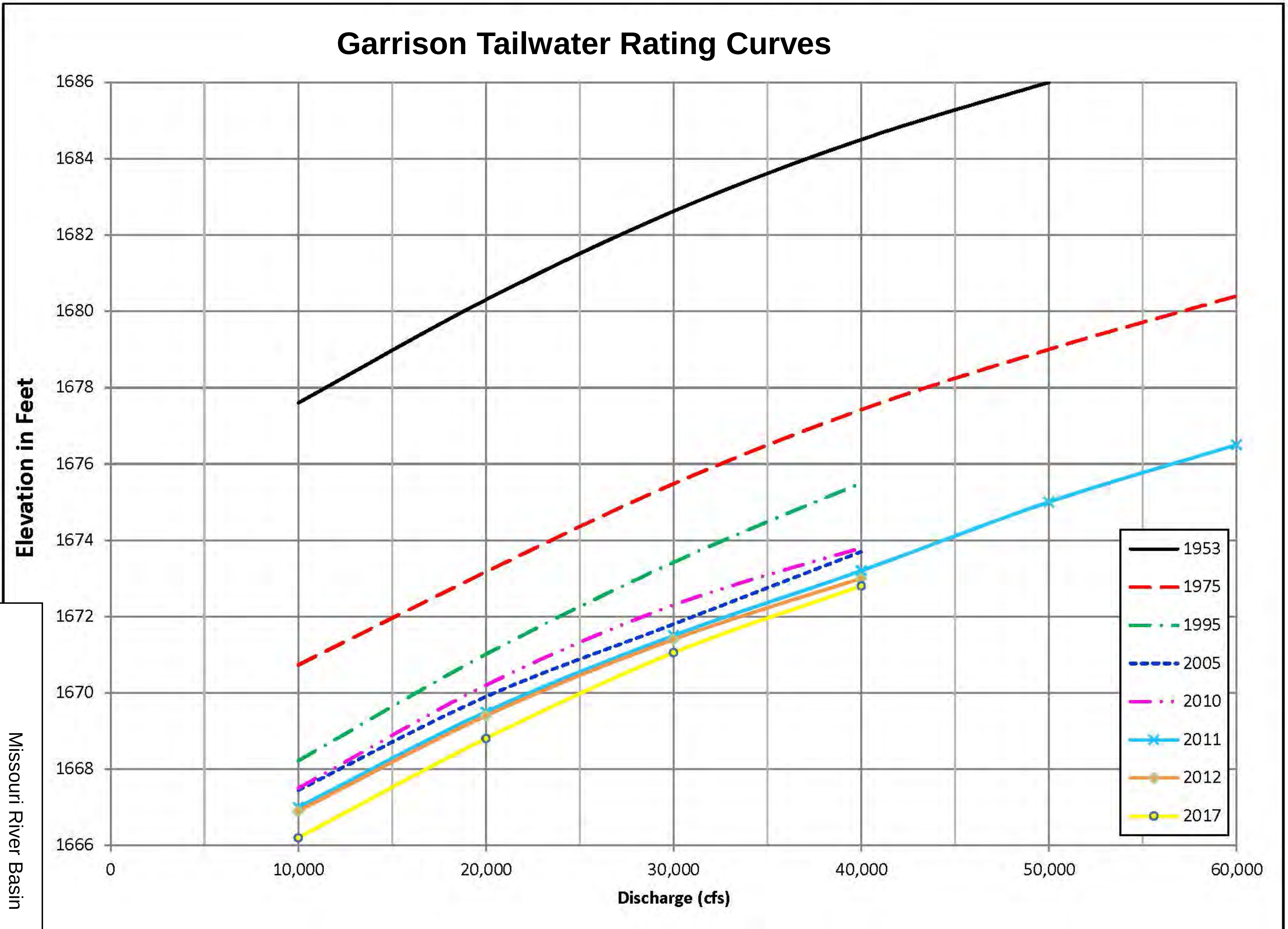
SPILLWAY RATING CURVES
GARRISON PROJECT

Missouri River Basin
Mainstem Master Water Control Manual
Garrison Spillway Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate II-20



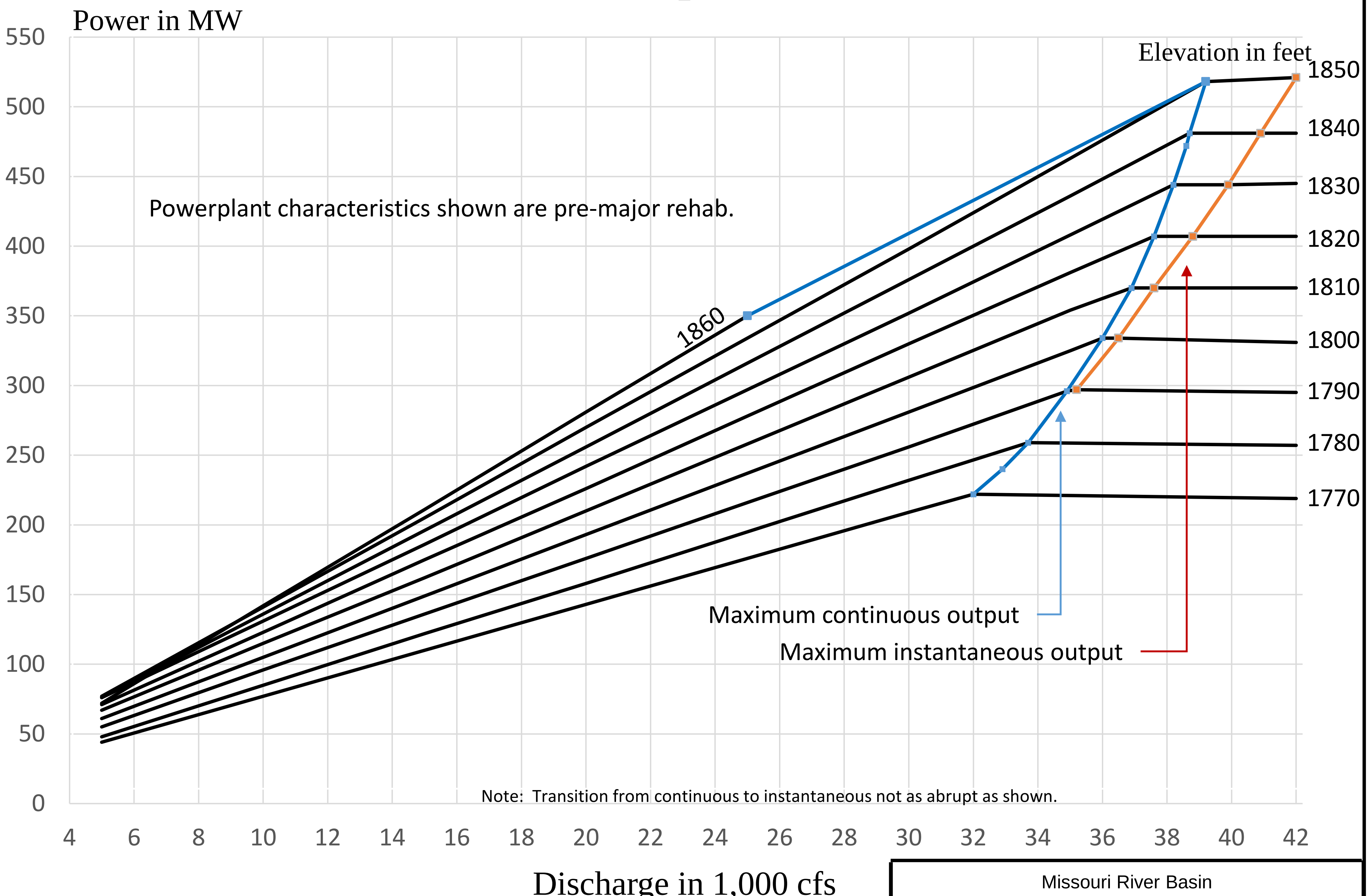
Missouri River Basin
Mainstem Master Water Control Manual
Garrison - Discharge Rating Curve for Flood Control Tunnels
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018



January 2018

Missouri River Basin
Mainstem System Master Manual
Garrison Tailwater Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Garrison Powerplant Characteristics



October 1995

Missouri River Basin

Mainstem Master Water Control Manual

Garrison Powerplant Characteristics

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

GARRISON PROJECT - Effective August 2013 RESERVOIR SURFACE IN ACRES (2010-2012 Survey Data)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1660	0	0	0	0	0	0	0	0	0	0
1670	7	6	6	22	52	97	156	231	320	424
1680	460	374	285	286	378	561	834	1198	1654	2199
1690	2632	2770	2853	3098	3504	4072	4802	5693	6745	7959
1700	9136	10046	10840	11702	12631	13628	14691	15823	17023	18289
1710	19492	20509	21482	22548	23707	24957	26300	27735	29263	30882
1720	32467	33880	35228	36632	38092	39608	41179	42807	44491	46231
1730	47931	49495	51023	52610	54257	55964	57731	59558	61443	63389
1740	65344	67235	69081	70921	72757	74587	76413	78233	80048	81858
1750	83684	85542	87400	89238	91054	92848	94621	96372	98101	99808
1760	101552	103378	105217	107006	108745	110434	112074	113663	115203	116693
1770	118070	119337	120653	122114	123719	125469	127364	129403	131587	133915
1780	136204	138246	140185	142191	144266	146409	148619	150897	153243	155658
1790	157953	159974	161958	164109	166427	168911	171561	174379	177362	180513
1800	183545	186177	188699	191397	194272	197322	200549	203949	207531	211285
1810	215125	218875	222480	225995	229410	232725	235955	239085	242115	245055
1820	247910	250750	253670	256700	259830	263065	266405	269850	273395	277050
1830	280485	283445	286360	289570	293080	296890	301000	305415	310135	315145
1840	320190	324895	329365	333835	338300	342750	347200	351645	356080	360510
1850	364935	369370	373810	378255	382695	387135	391580	396015	400455	404900
1860	409343									

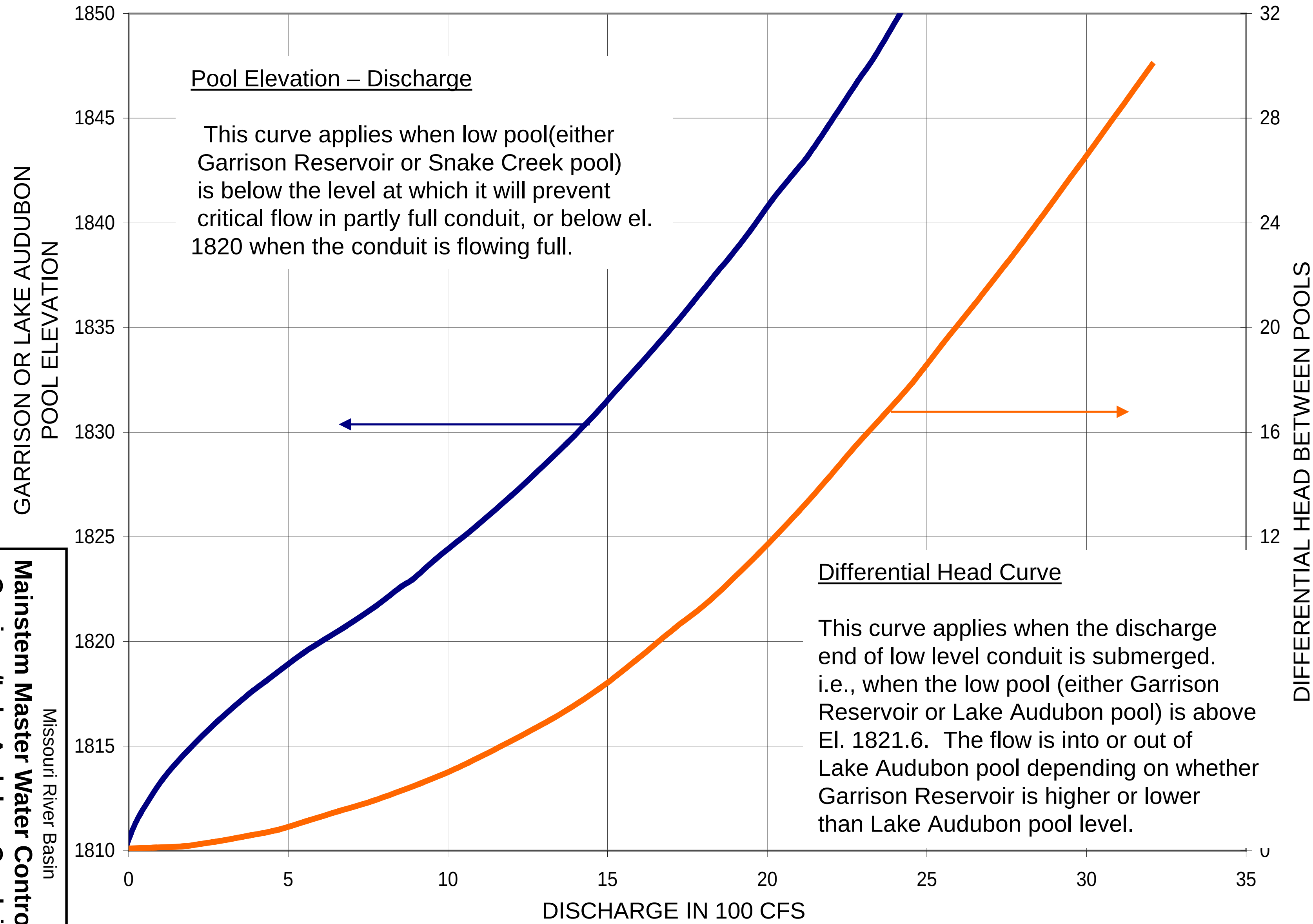
GARRISON PROJECT - Effective August 2013 RESERVOIR CAPACITY IN ACRE-FEET (2010-2012 Survey Data)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1660	0	0	0	0	0	0	0	0	0	0
1670	5	15	18	28	62	133	256	446	718	1087
1680	1566	2008	2315	2578	2887	3334	4009	5002	6406	8310
1690	10805	13574	16345	19281	22542	26290	30687	35895	42074	49386
1700	57993	67659	78085	89340	101489	114602	128745	143985	160392	178031
1710	196970	217015	237988	259980	283085	307394	332999	359994	388470	418520
1720	450235	483455	517996	553912	591260	630096	670476	712455	756091	801438
1730	848553	897300	947544	999346	1052765	1107861	1164694	1223324	1283810	1346211
1740	1410589	1476900	1545060	1615062	1686903	1760577	1836078	1913403	1992545	2073500
1750	2156262	2240869	2327346	2415670	2505822	2597779	2691519	2787021	2884263	2983223
1760	3083880	3186327	3290637	3396761	3504649	3614251	3725518	3838399	3952844	4068805
1770	4186230	4304945	4424905	4546252	4669133	4793691	4920072	5048420	5178879	5311594
1780	5446709	5584003	5723202	5864373	6007584	6152905	6300402	6450143	6602196	6756630
1790	6913512	7072536	7233461	7396453	7561680	7729308	7899502	8072431	8248260	8427156
1800	8609286	8794246	8981641	9171645	9364436	9560189	9759081	9961287	10166980	10376350
1810	10589550	10806600	11027300	11251560	11479290	11710380	11944740	12182290	12422910	12666520
1820	12913020	13162340	13414520	13669680	13927920	14189340	14454050	14722150	14993750	15268940
1830	15547850	15829910	16114740	16402630	16693880	16988790	17287660	17590790	17898490	18211060
1840	18528780	18851440	19178570	19510170	19846240	20186770	20531740	20881170	21235030	21593330
1850	21956050	22323200	22694790	23070820	23451300	23836210	24225570	24619370	25017600	25420280
1860	25827400									

Missouri River Basin

Mainstem Master Water Control Manual

Garrison Area
and Capacity Tables

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin

Mainstem Master Water Control Manual

Garrison/Lake Audubon Conduit Rating Curves for Snake Creek Embankment

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003

Missouri River Basin

Mainstem Master Water Control Manual

Garrison Project

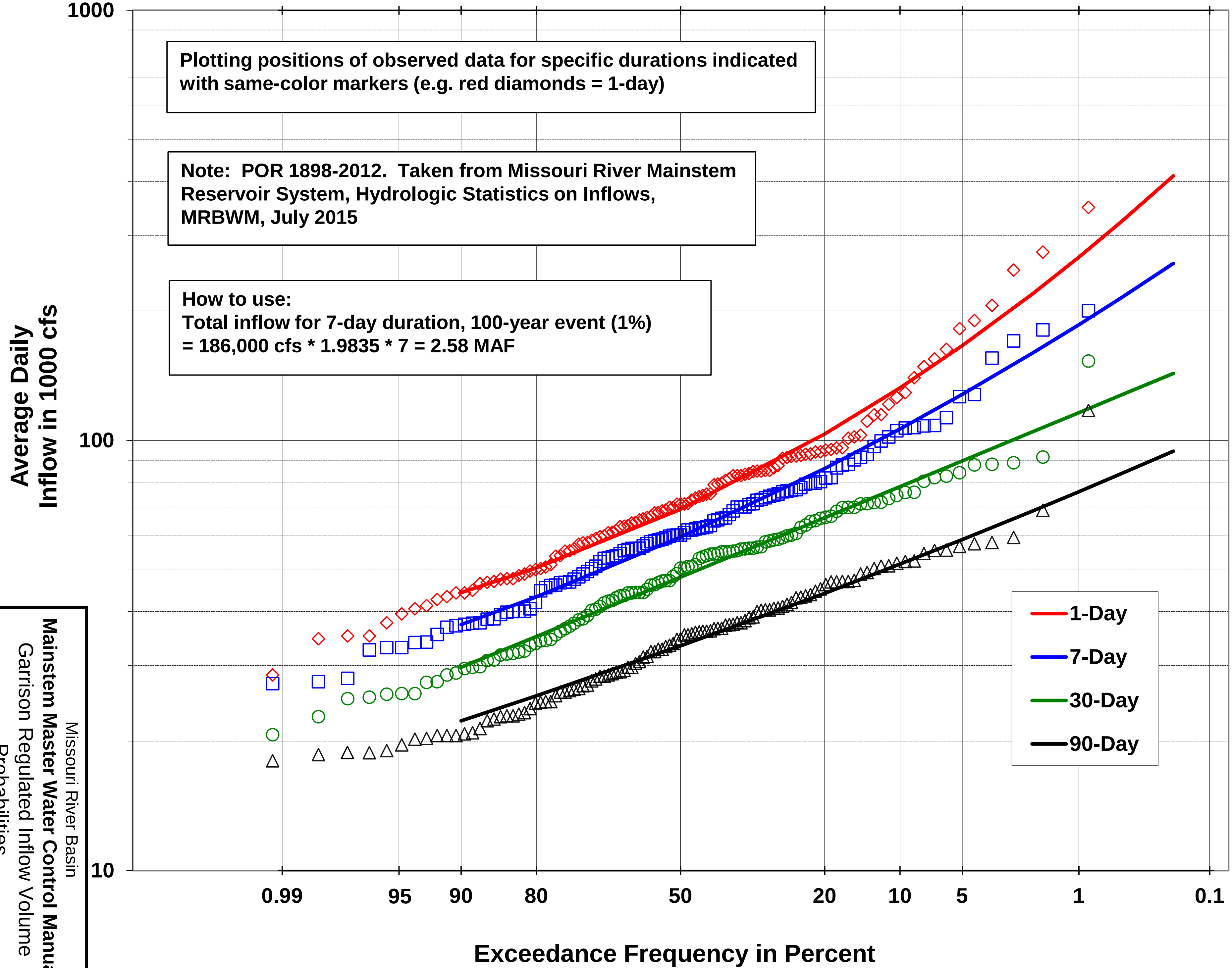
Reservoir, Embankment,

Intakes, Powerhouse and Spillway

U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

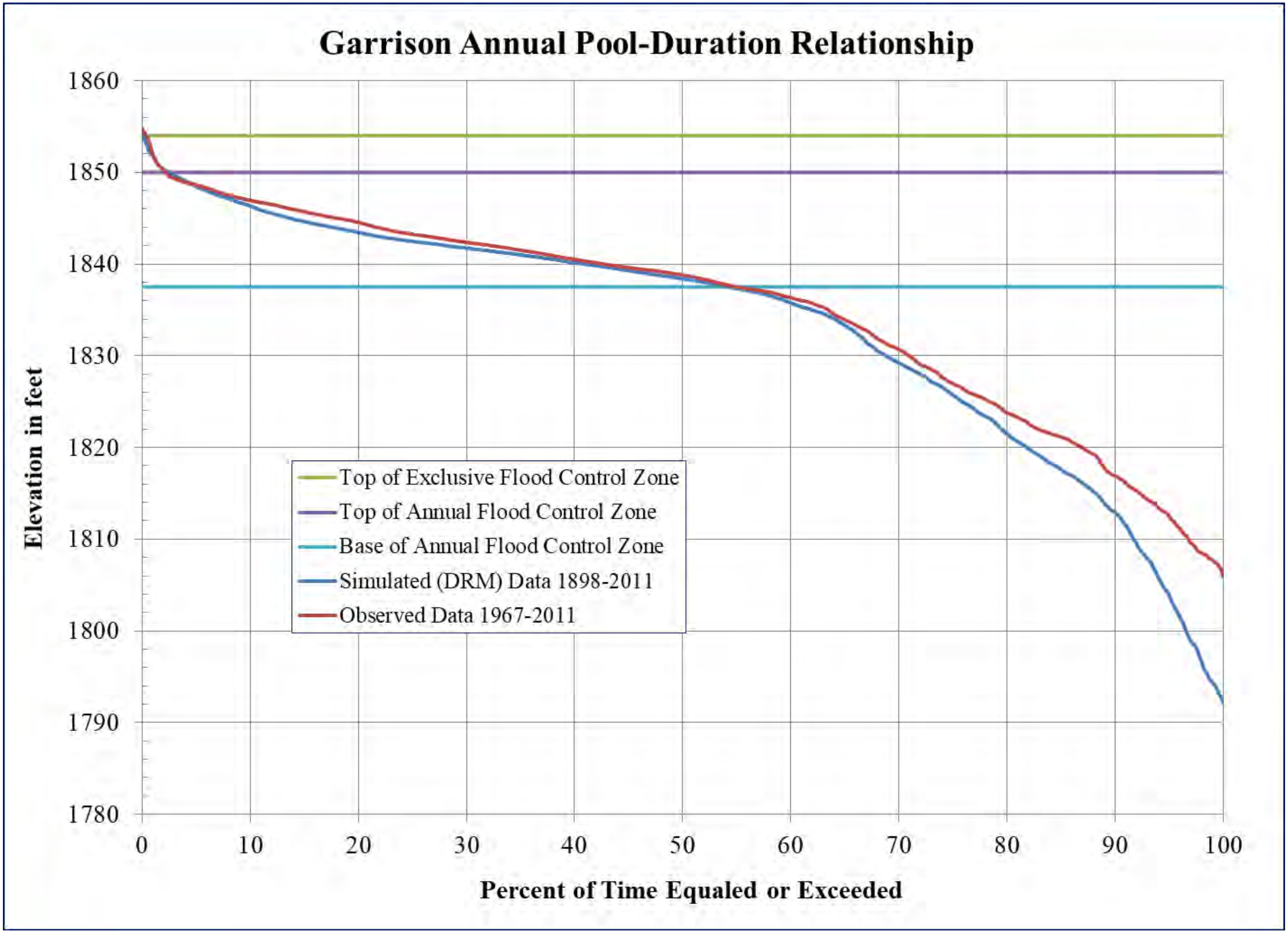
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
Garrison Regulated Inflow Volume Probabilities

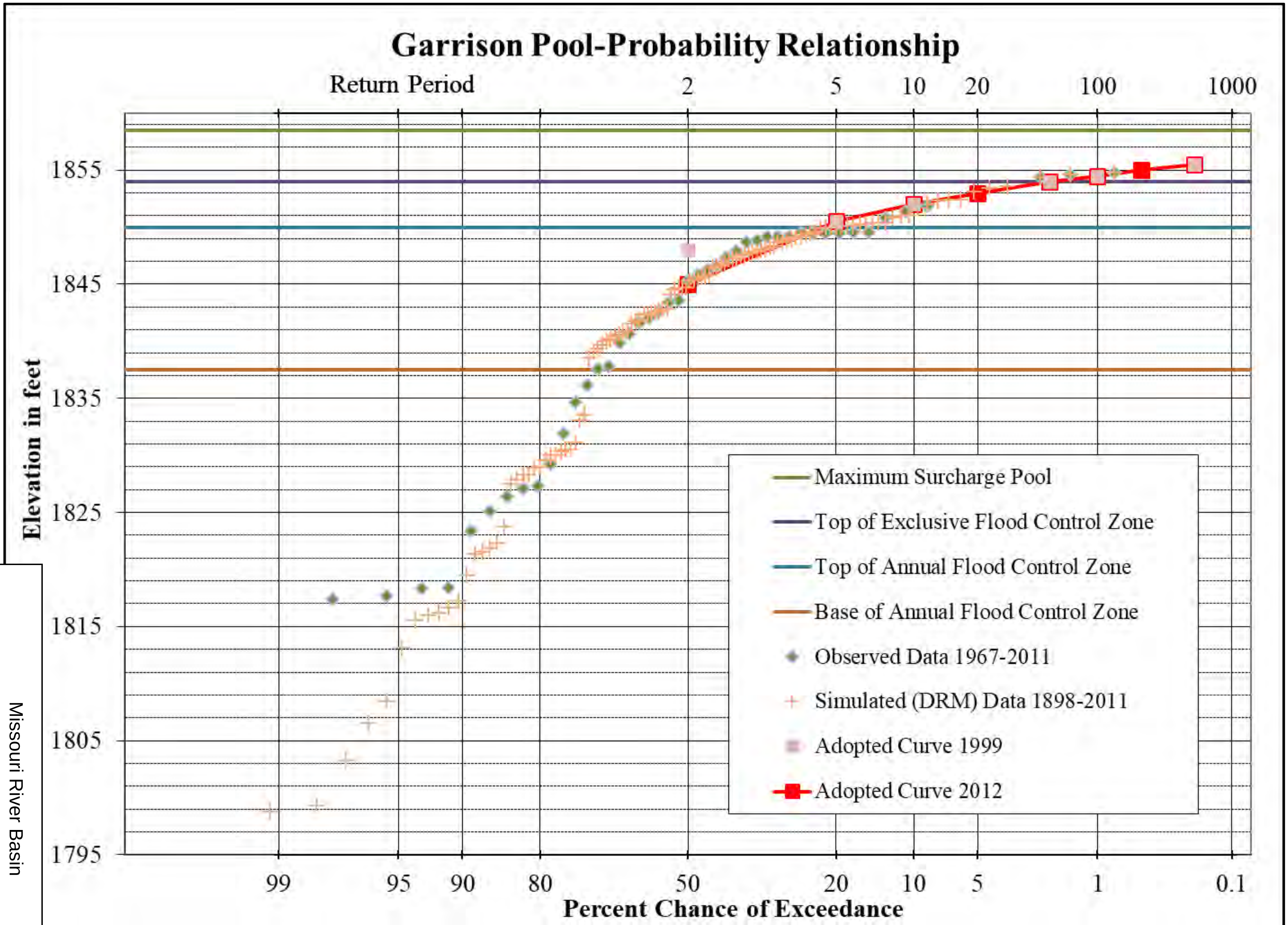
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-27

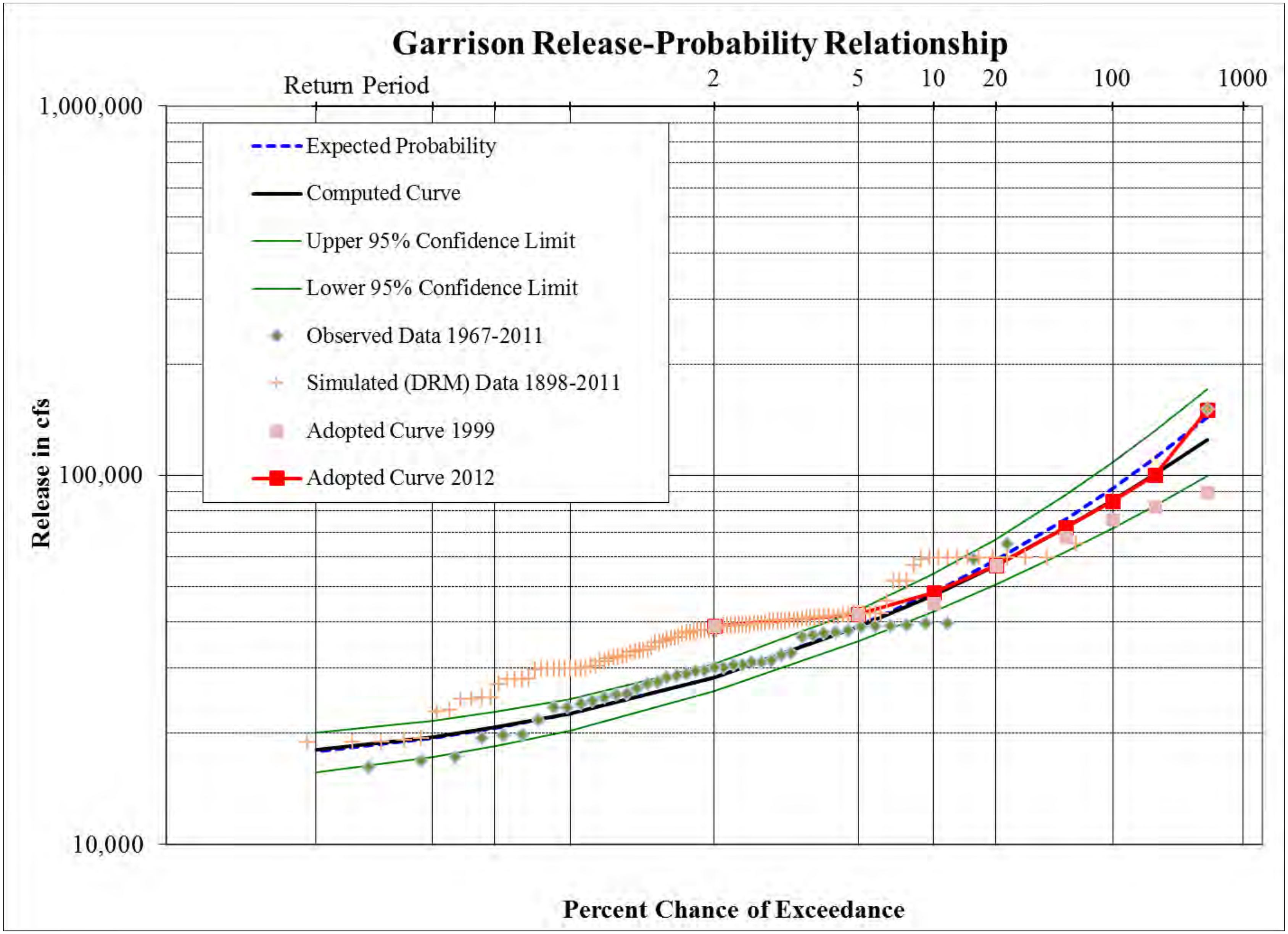


Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin
Mainstem Master Water Control Manual
Garrison Pool-Duration Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

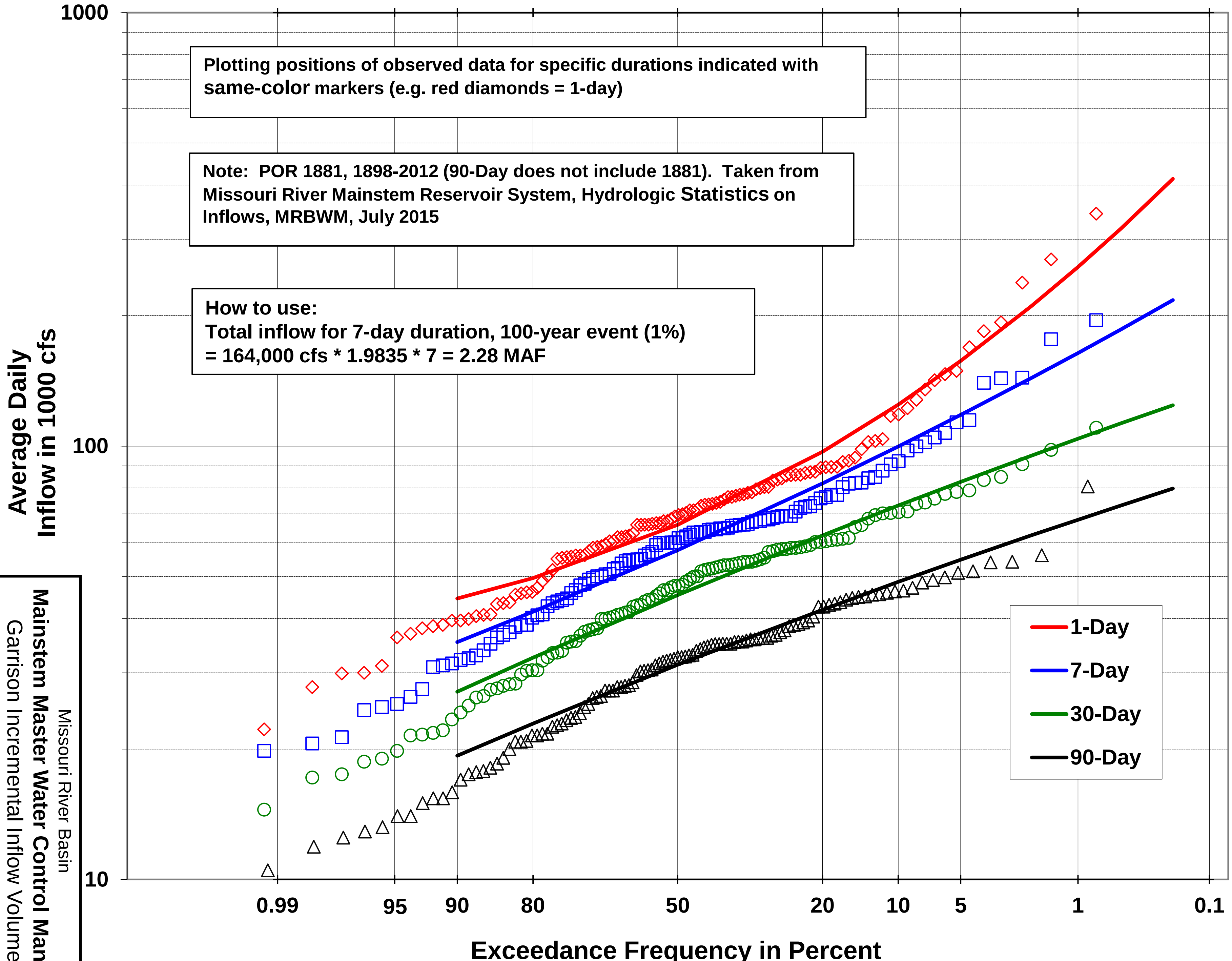


Source: Hydrologic Statistics, MRBWM, September 2013



Missouri River Basin
Mainstem Master Water Control Manual
Garrison Release-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate 30



Missouri River Basin
Mainstem Master Water Control Manual
Garrison Incremental Inflow Volume
Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-31

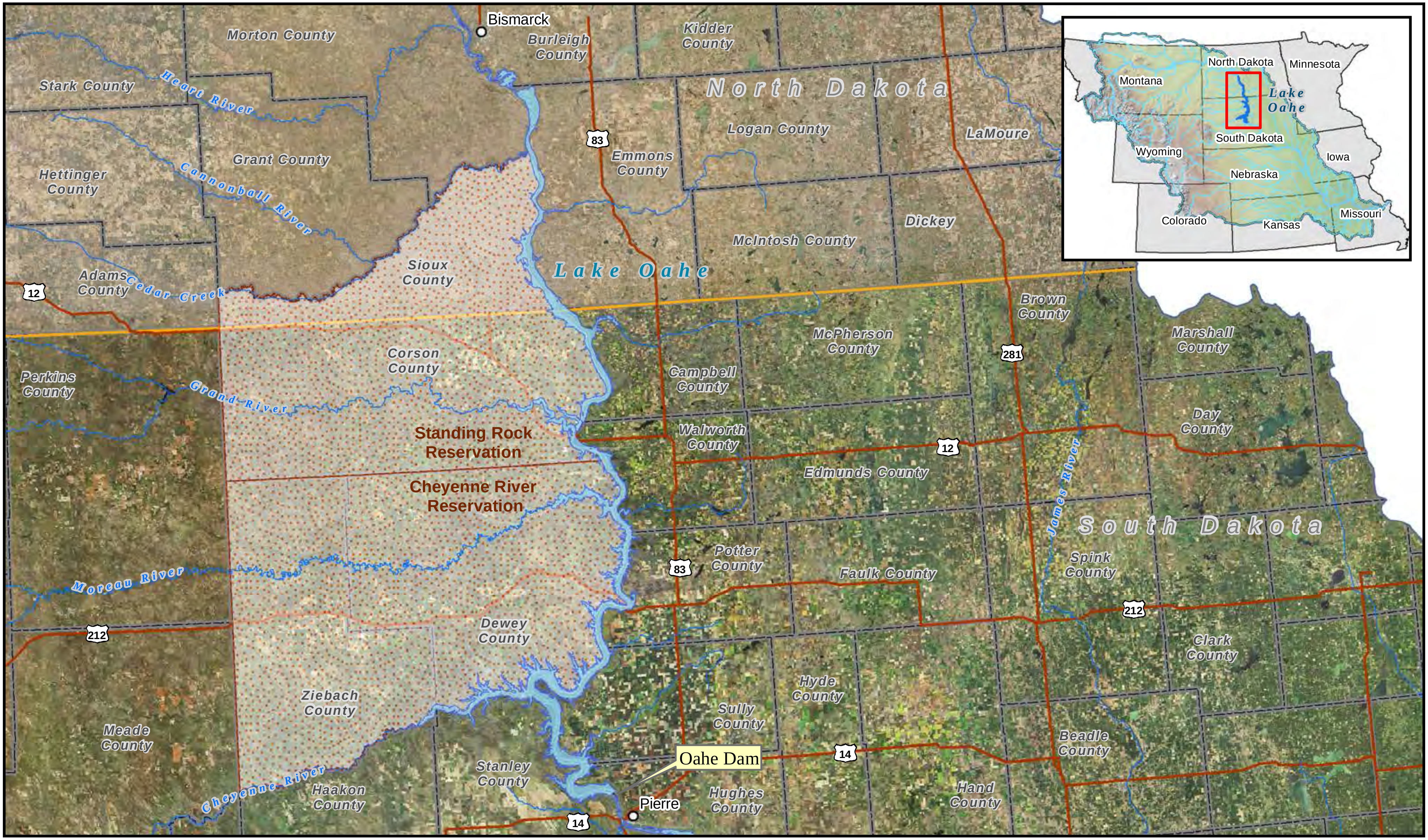


Plate II-32

US Army Corps of Engineers®
Northwestern Division

Cities
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 10 20 40 60 Miles

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

N S W E

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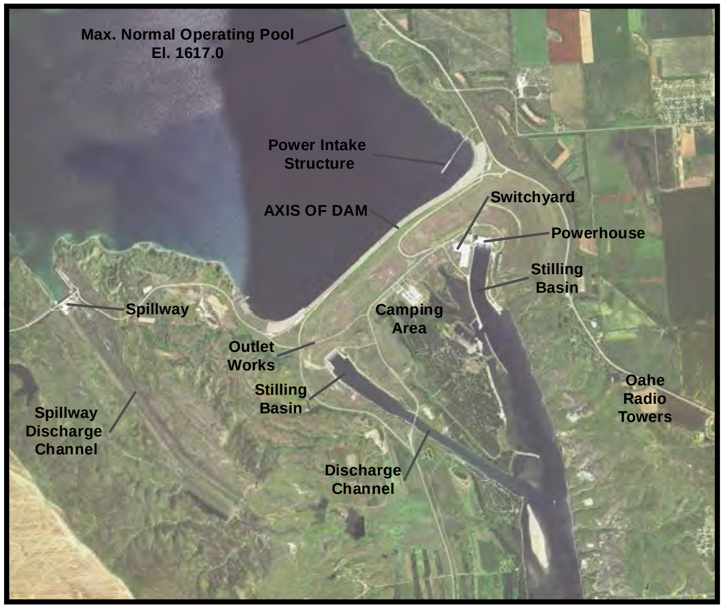
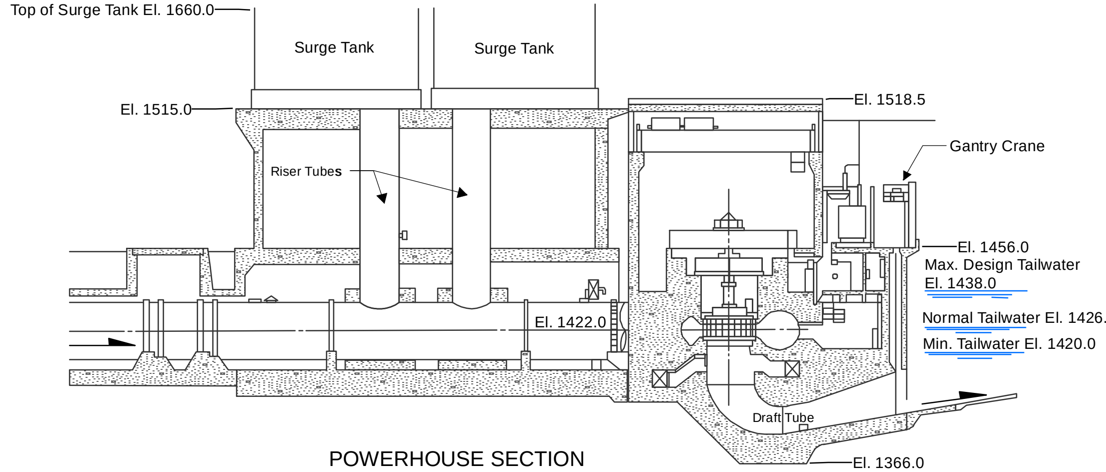
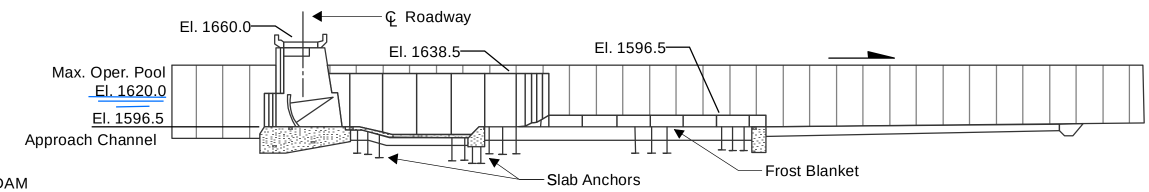
Missouri River Basin
Mainstem Master Water Control Manual
Oahe Project Map
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



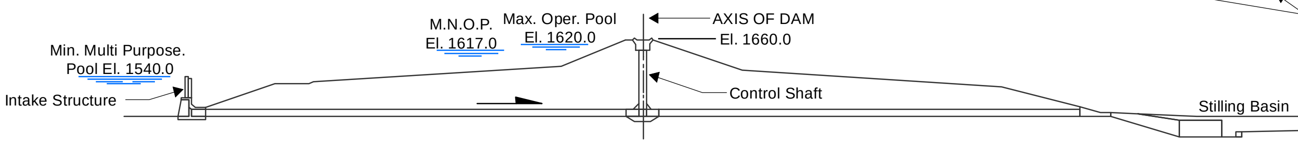
PLAN VIEW



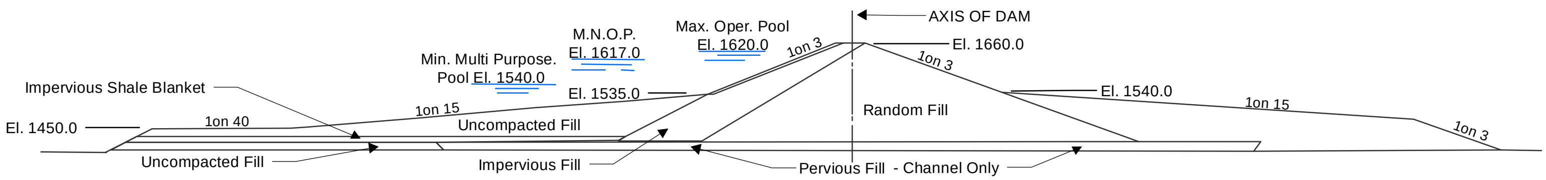
POWERHOUSE SECTION



SPILLWAY PROFILE



OUTLET WORKS PROFILE
FLOOD CONTROL TUNNELS



EMBANKMENT SECTION

SPILLWAY PROFILE

Plate II-33

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

N W E S

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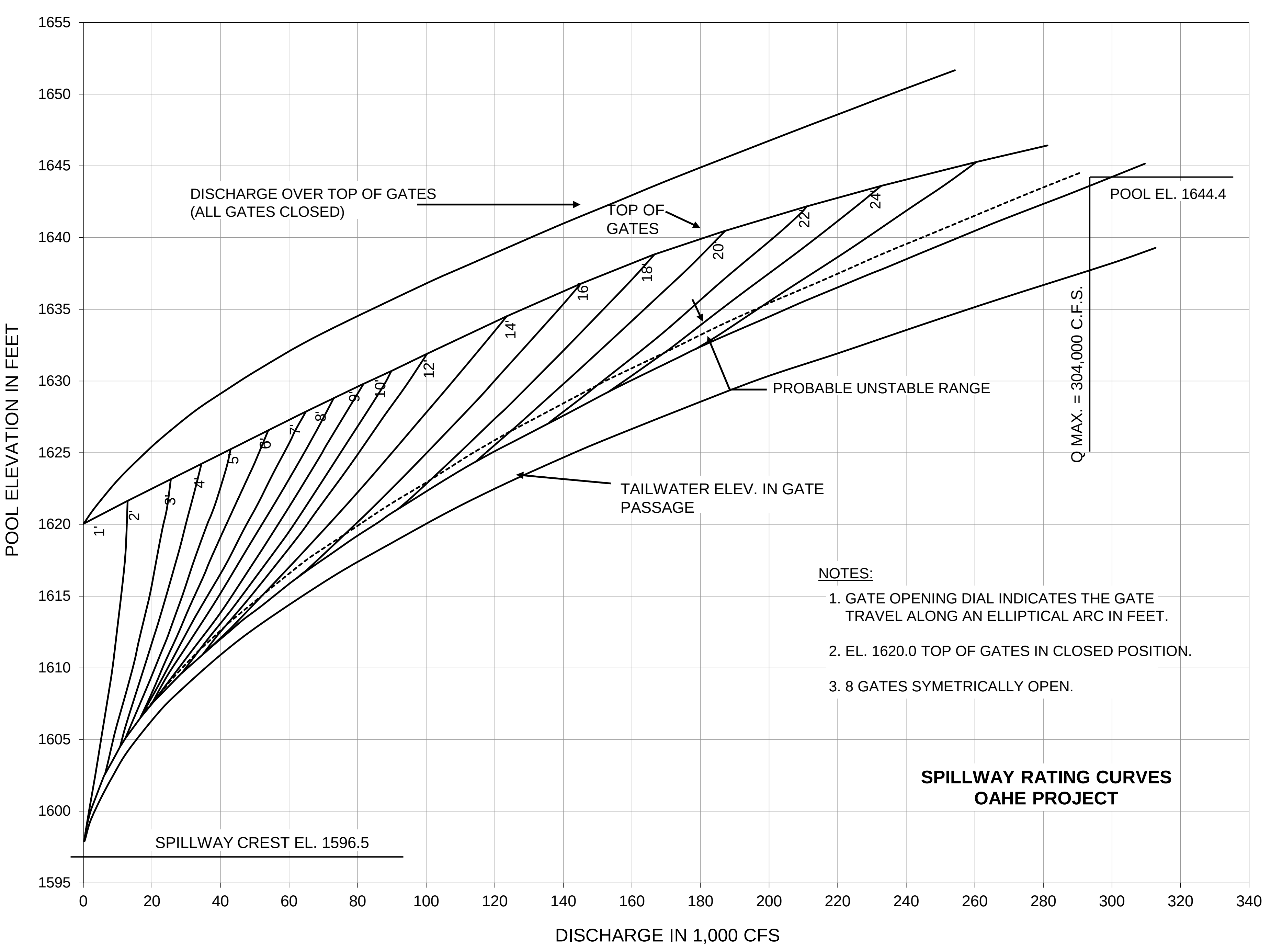
Missouri River Basin
Mainstem Master Water Control Manual
Oahe Plan and Sections
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Oahe Spillway Rating Curves



Missouri River Basin

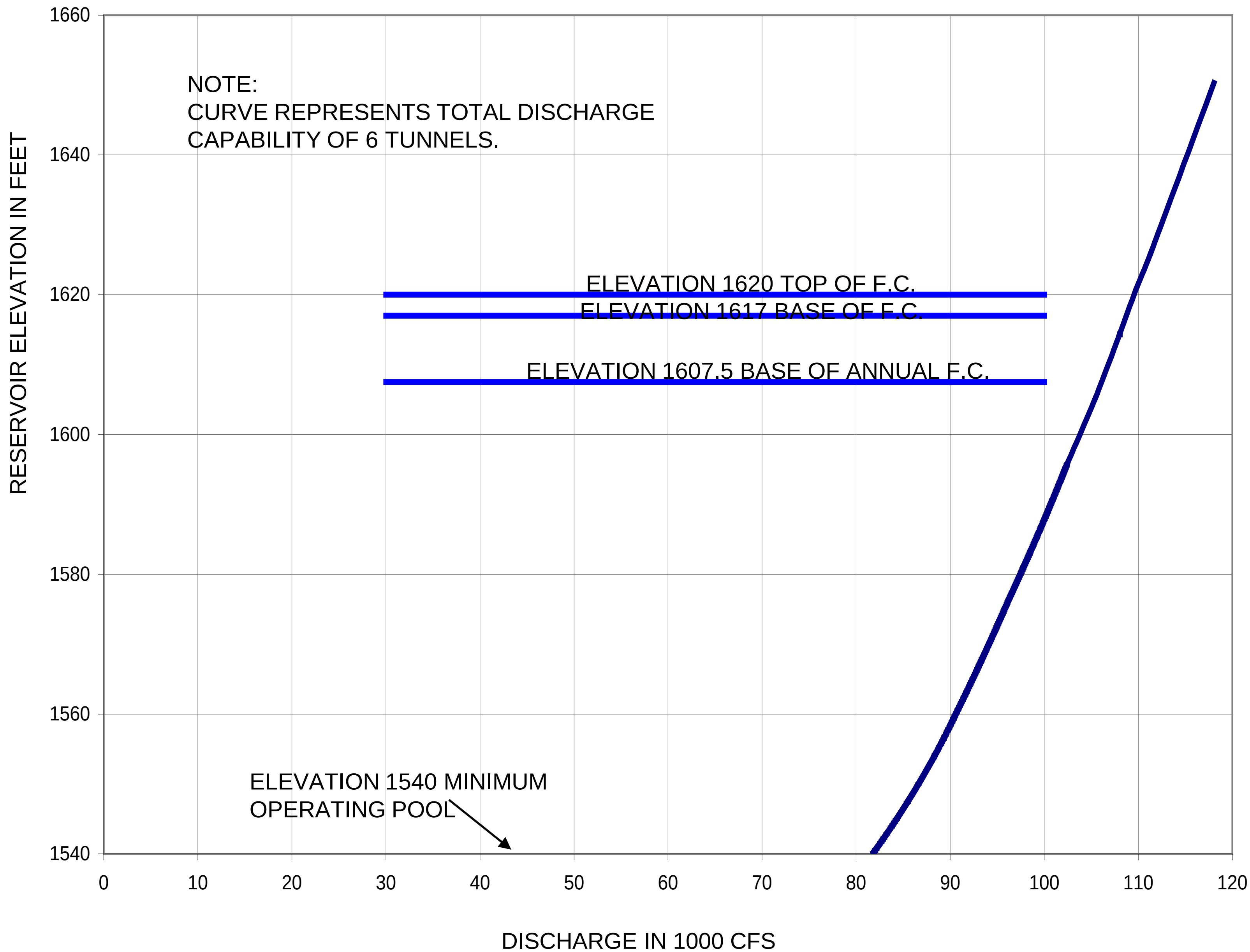
Mainstem Master Water Control Manual

Oahe Spillway Rating Curves

U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

November 2018

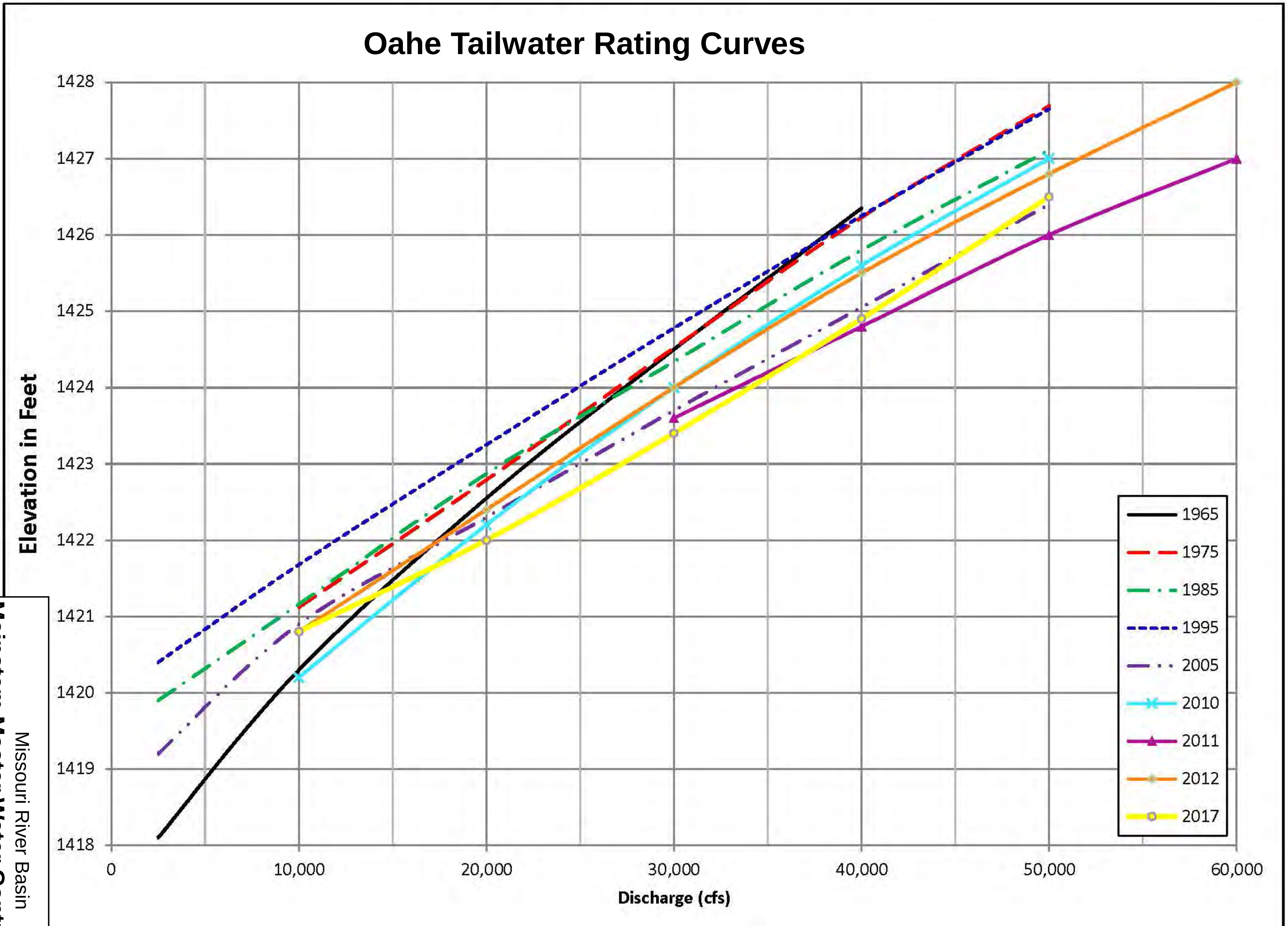


Missouri River Basin

Mainstem Master Water Control Manual

Oahe - Outlet Works Rating Curve

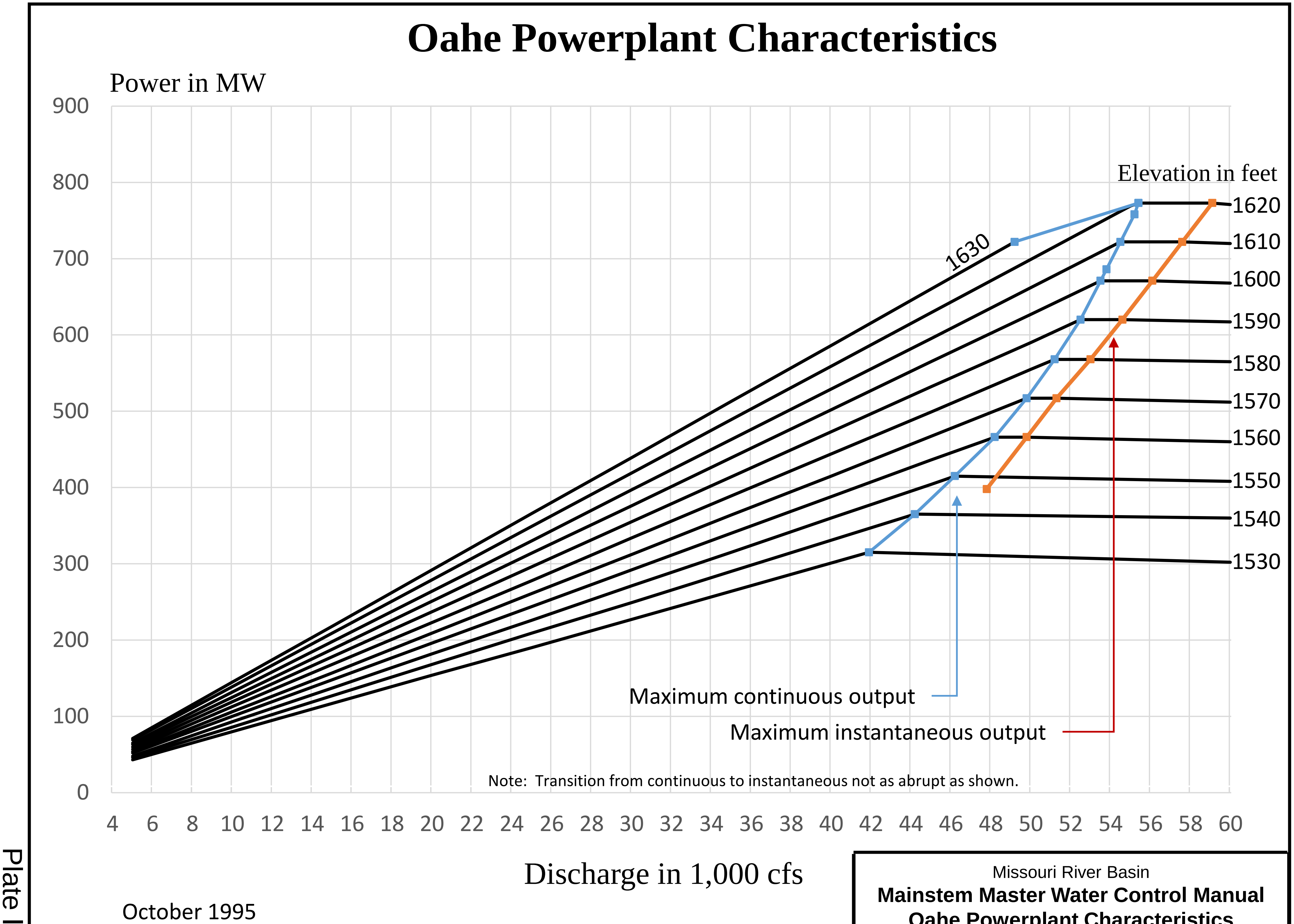
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018



January 2018

Missouri River Basin
Mainstem Master Water Control Manual
Oahe Tailwater Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate II-36



Missouri River Basin
Mainstem Master Water Control Manual
Oahe Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

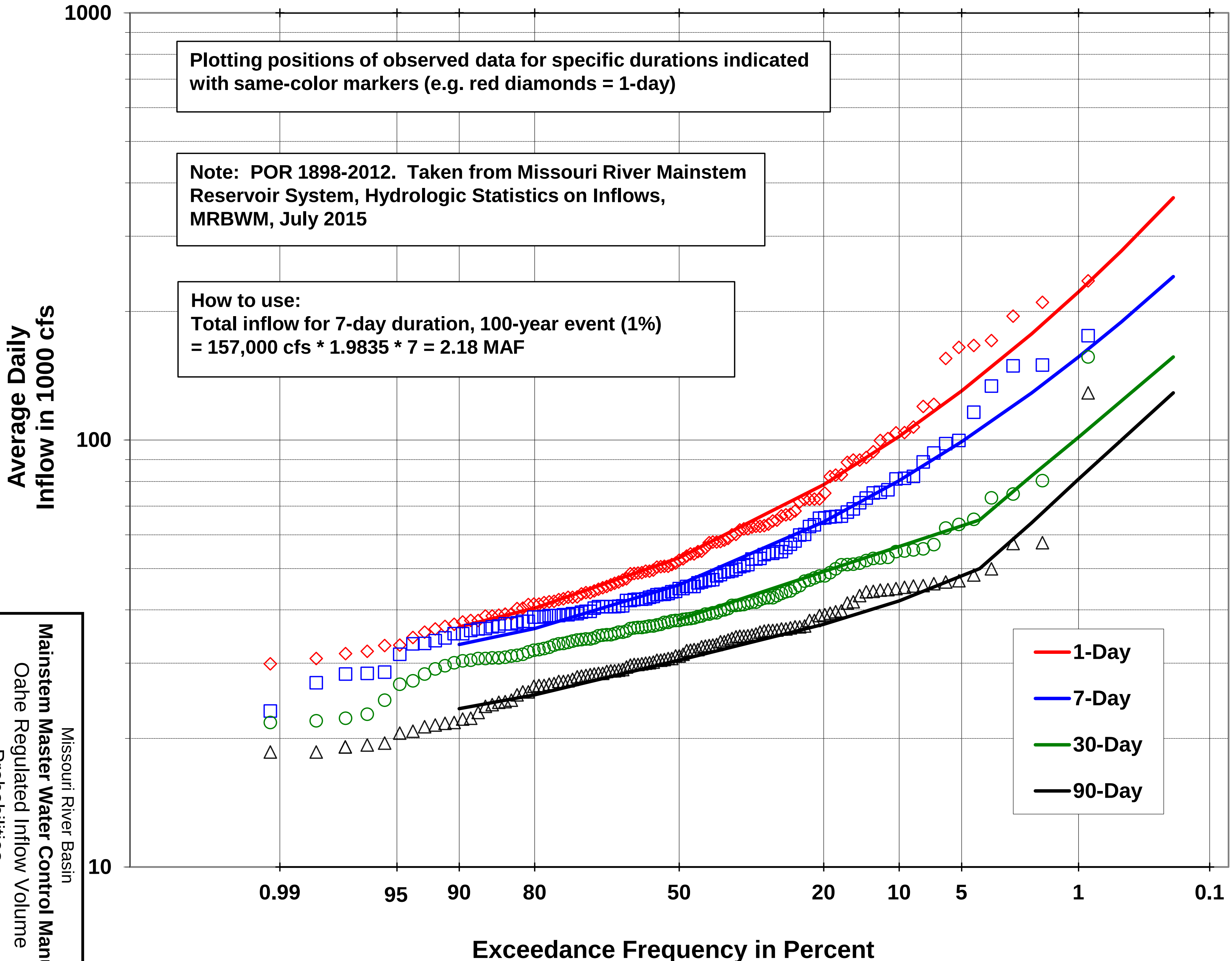
LAKE OAHE - Effective date August 2013
RESERVOIR SURFACE AREA IN ACRES
(From 2010 Hydrographic Survey Data - NGVD1929)

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

LAKE OAHE - Effective date August 2013
RESERVOIR CAPACITY IN ACRE-FEET
(From 2010 Hydrographic Survey Data - NGVD1929)

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

Missouri River Basin
Mainstem Master Water Control Manual
Oahe Project
Reservoir, Embankment, Intakes,
Powerhouse and Outlet Tunnels
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



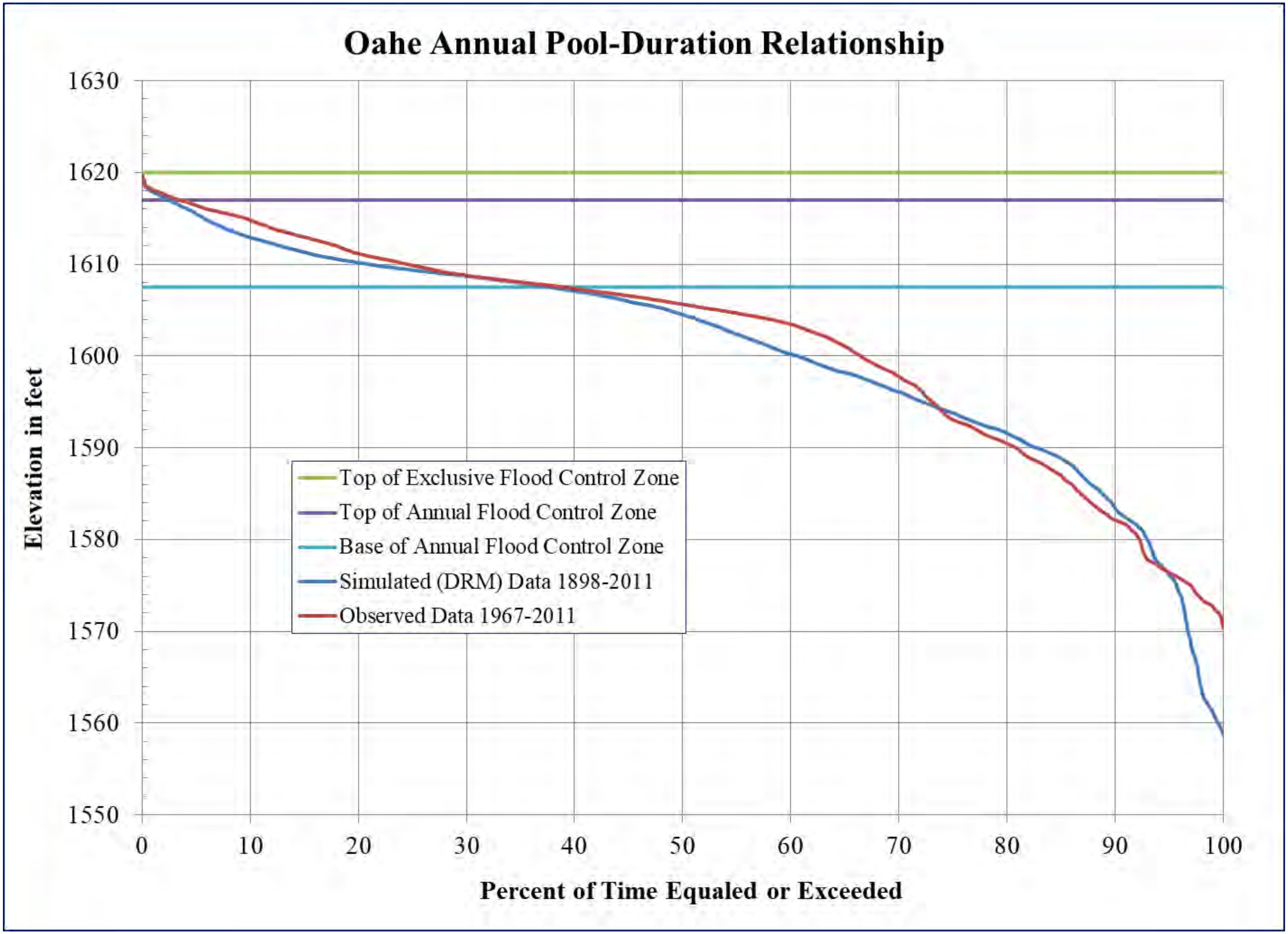
Missouri River Basin

Mainstem Master Water Control Manual

Oahe Regulated Inflow Volume
Probabilities

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-40



Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin

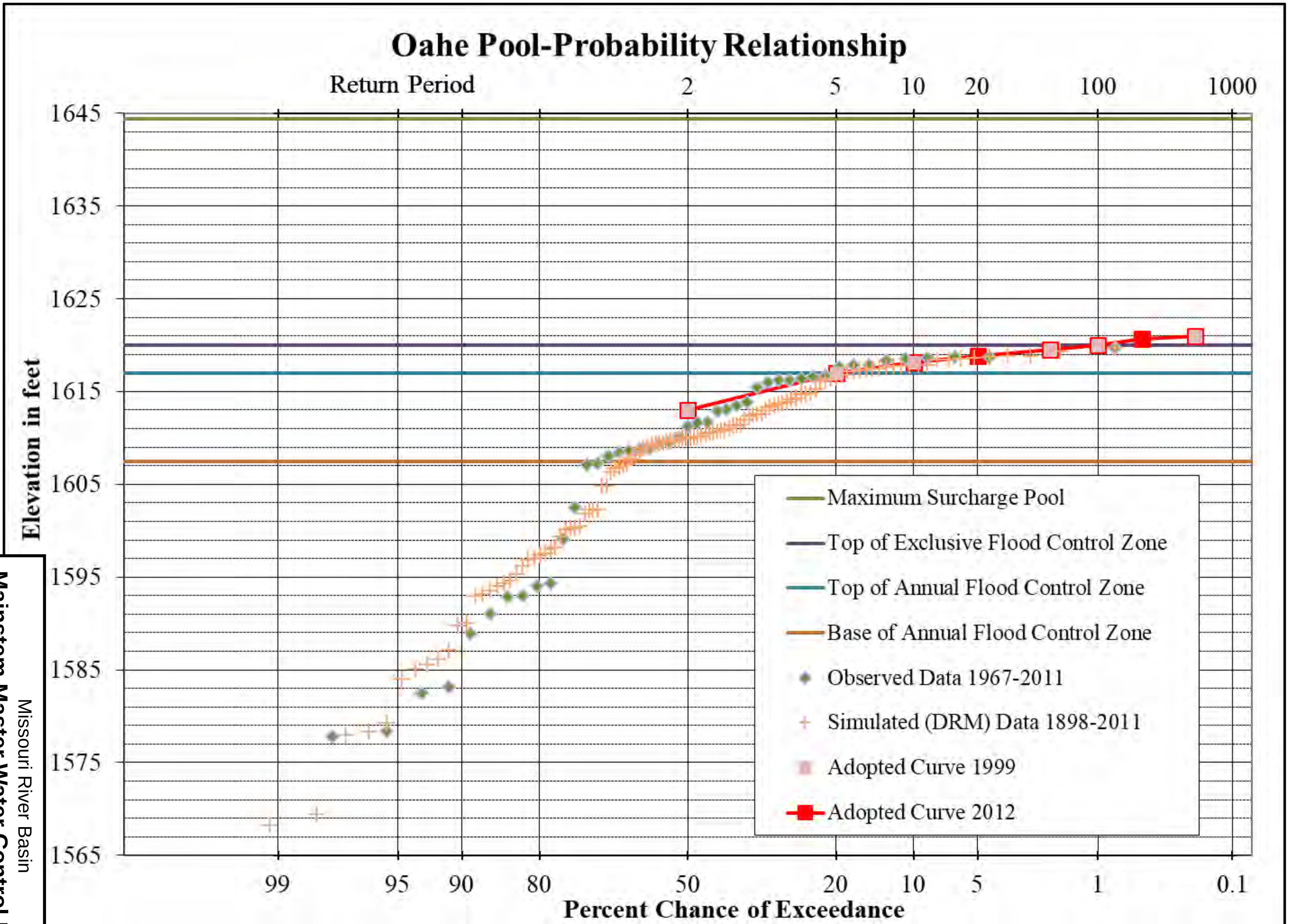
Mainstem Master Water Control Manual

Oahe Pool-Duration Relationship

U.S. Army Engineer Division, Northwestern

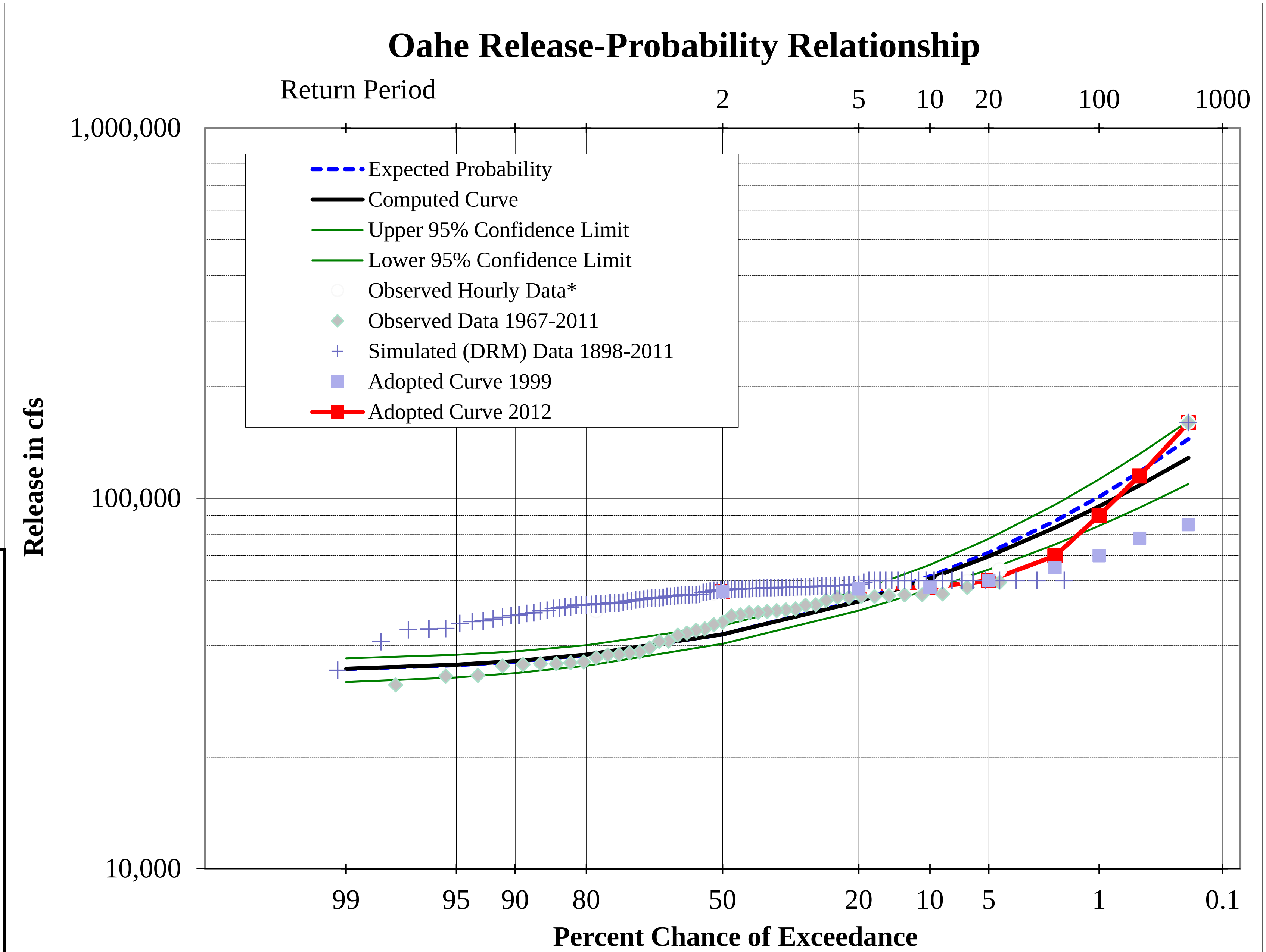
Corps of Engineers, Omaha, Nebraska

November 2018

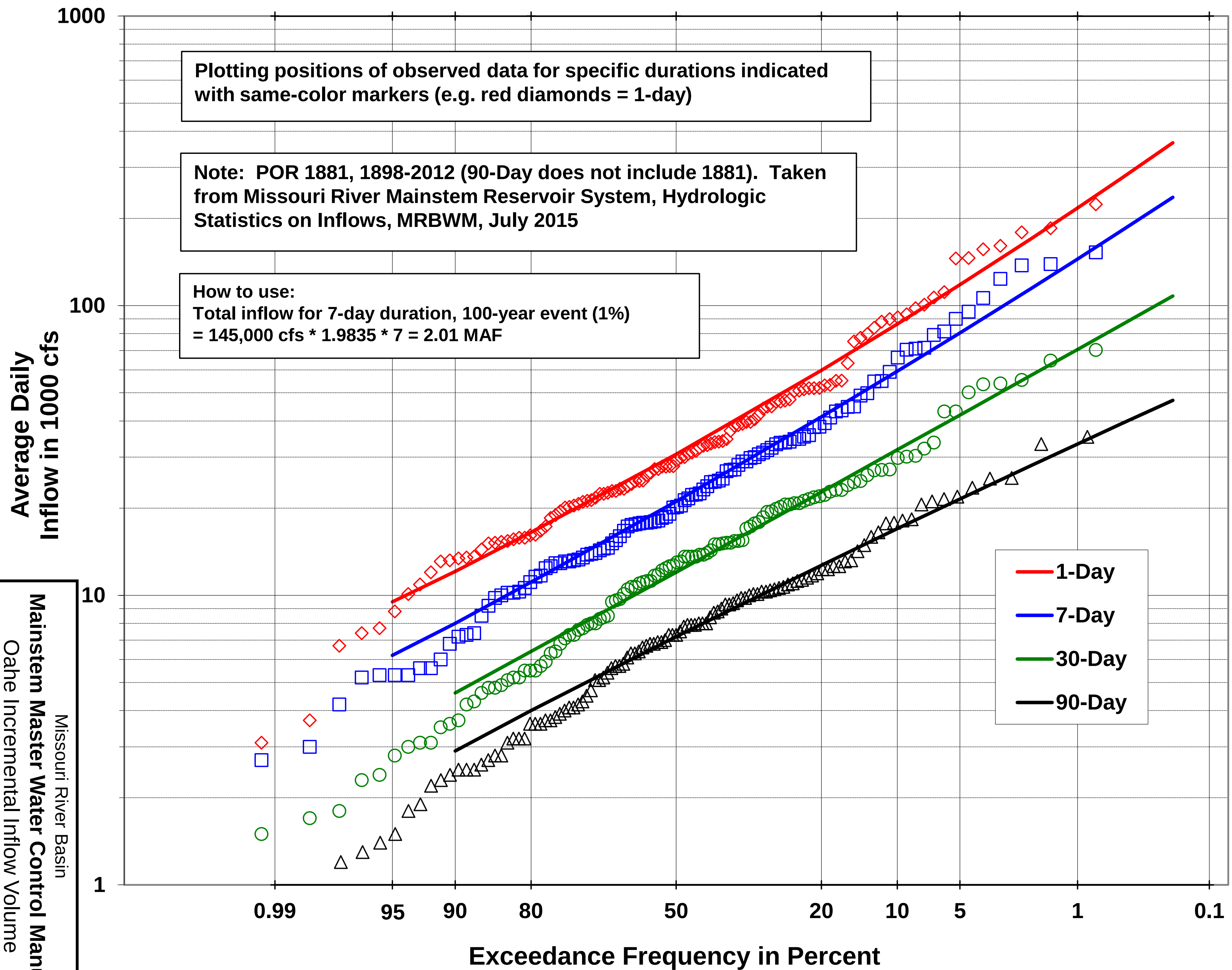


Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin
Mainstem Master Water Control Manual
Oahe Pool-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
Oahe Release-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin

Mainstem Master Water Control Manual

Oahe Incremental Inflow Volume

Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-44

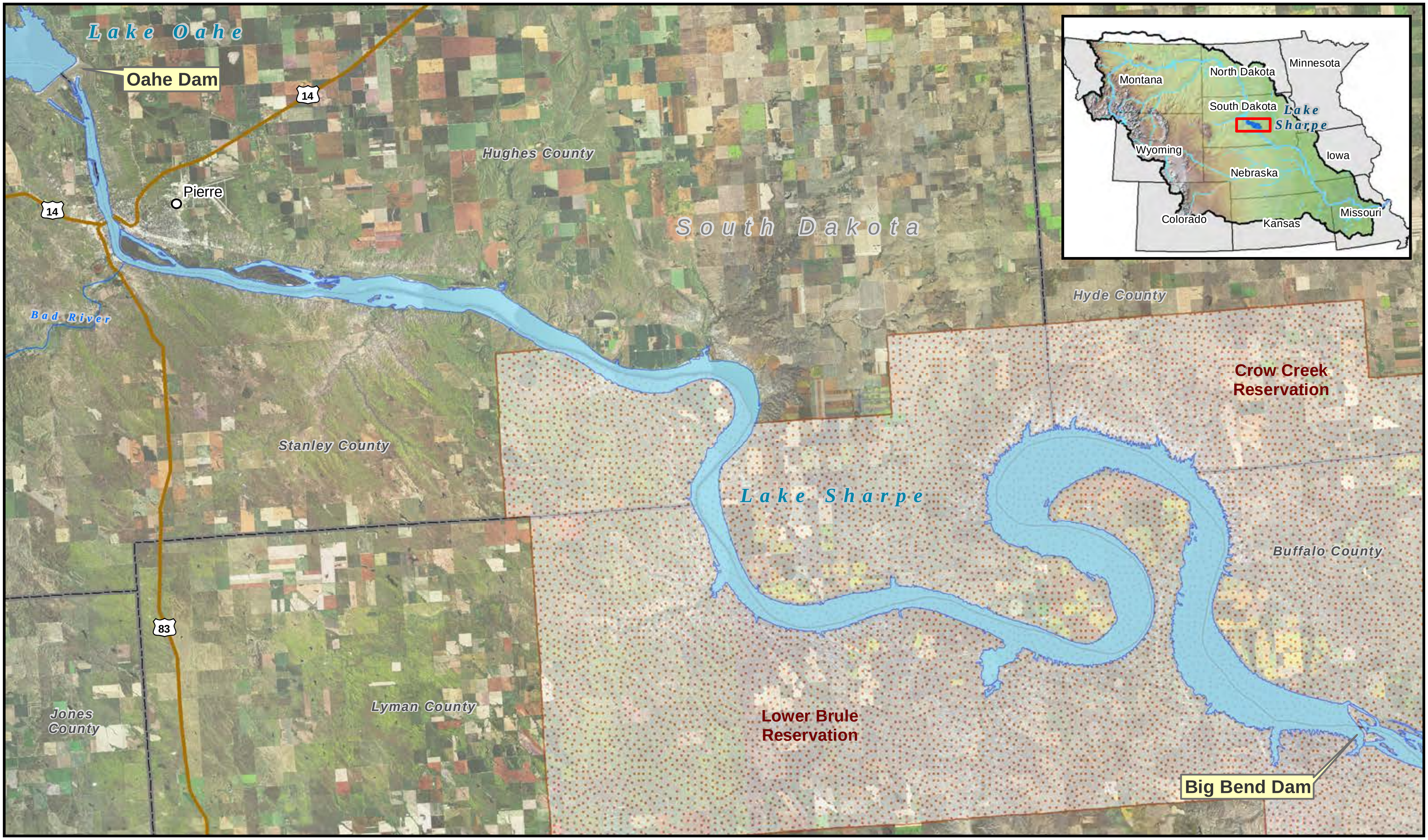


Plate II-45

US Army Corps of Engineers® Northwestern Division

Cities
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

Miles 0 2 4 8 12

N S E W

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

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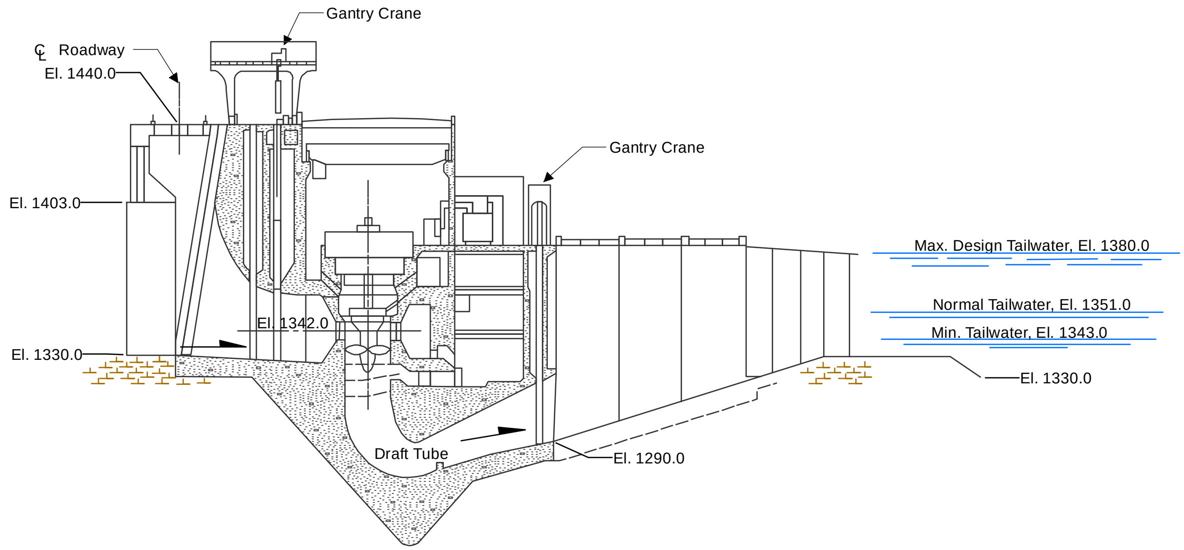
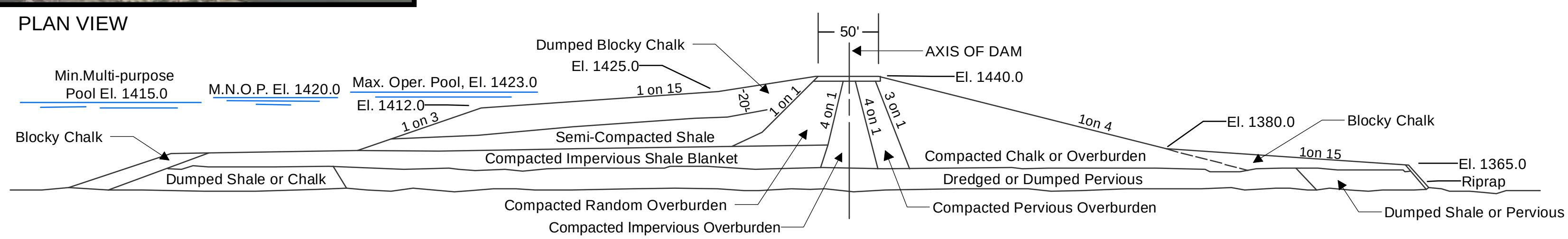
Missouri River Basin
Mainstem Master Water Control Manual
Big Bend Project Map
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

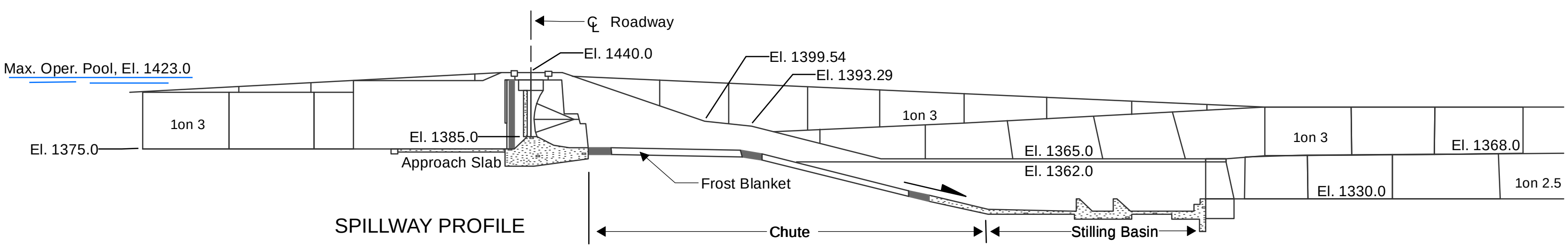
PLAN VIEW



POWERHOUSE SECTION



EMBANKMENT SECTION



SPILLWAY PROFILE

Plate II-46

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

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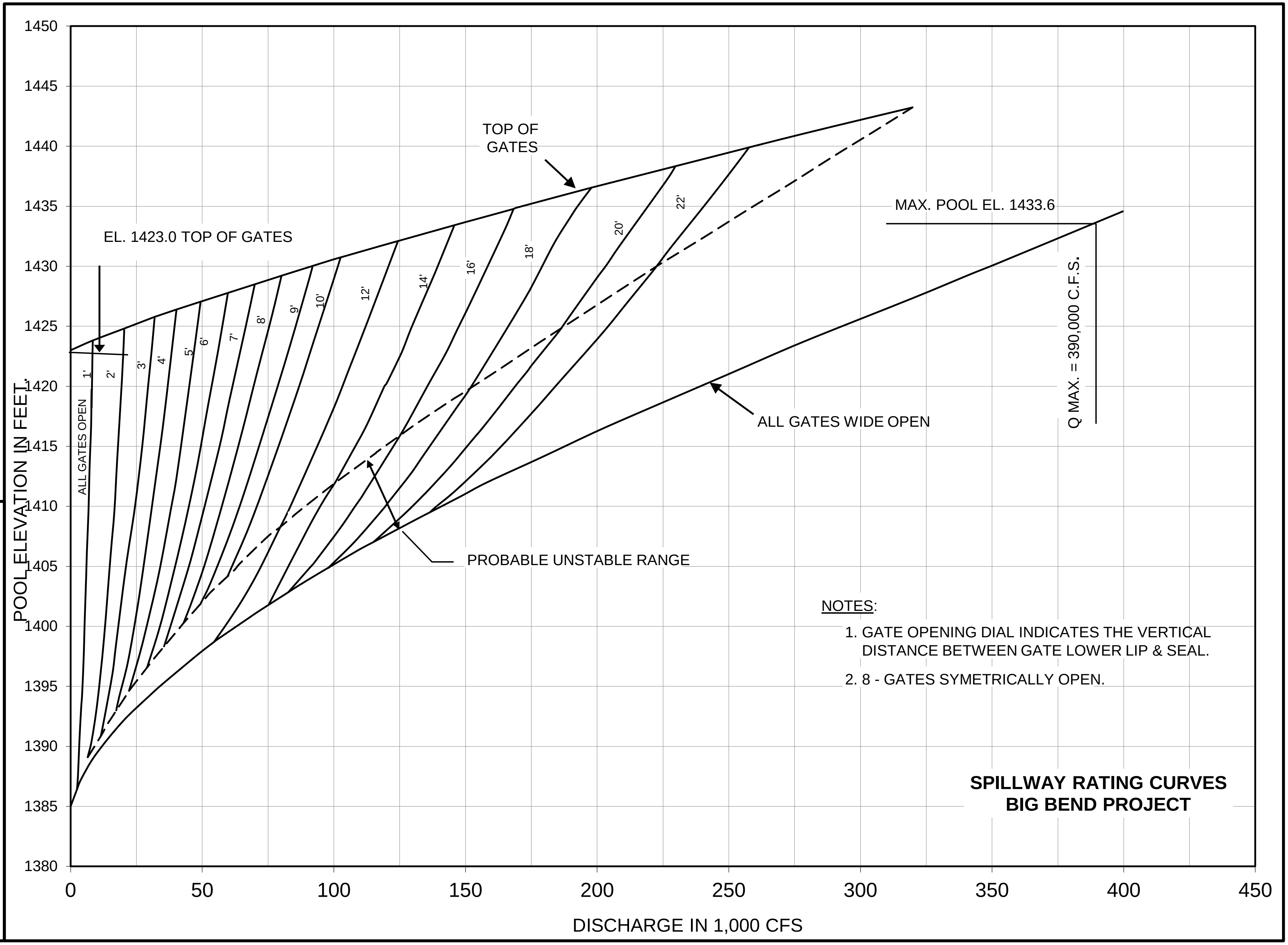
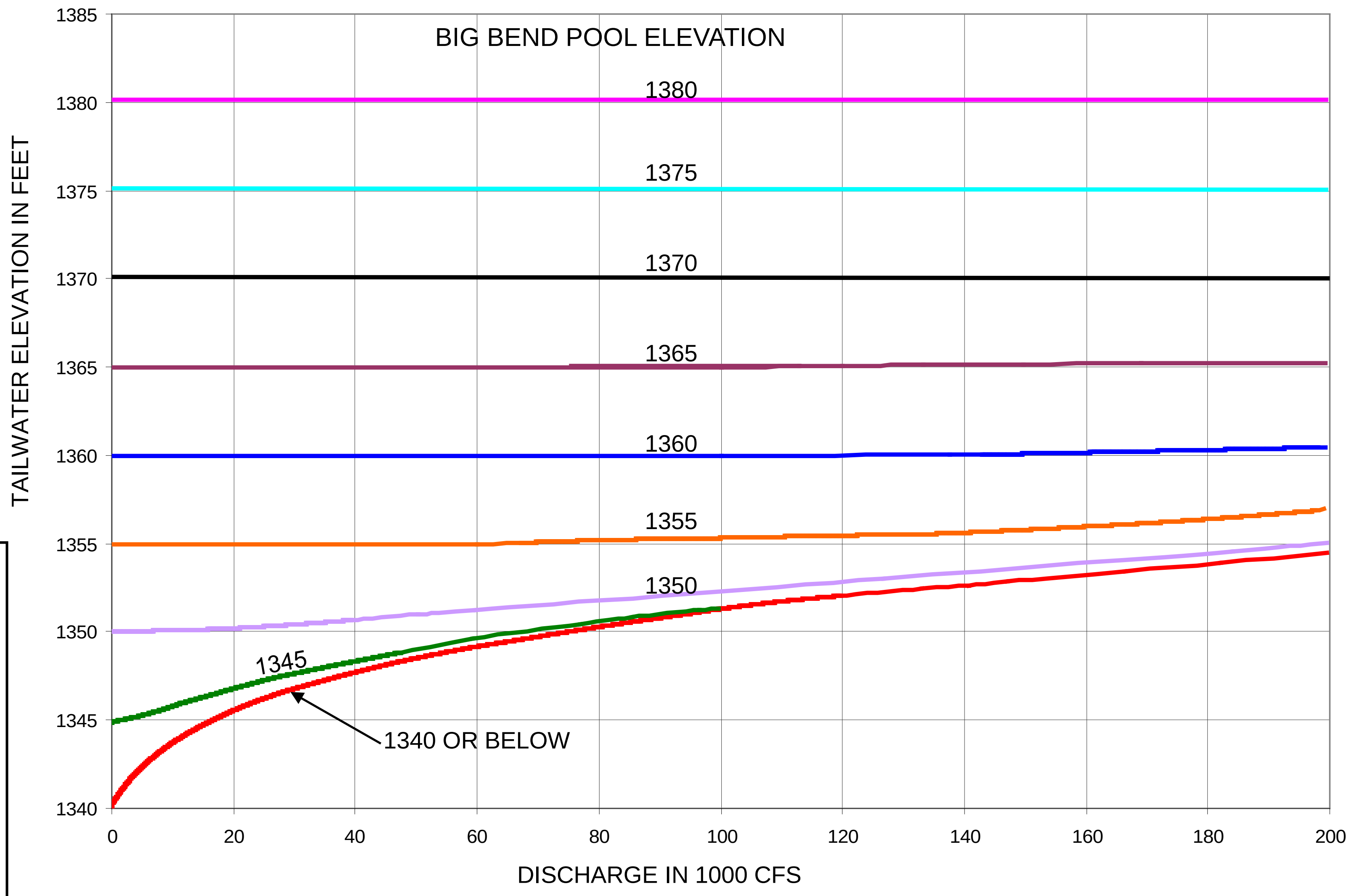
Missouri River Basin
Mainstem Master Water Control Manual
Big Bend Plan and Sections
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

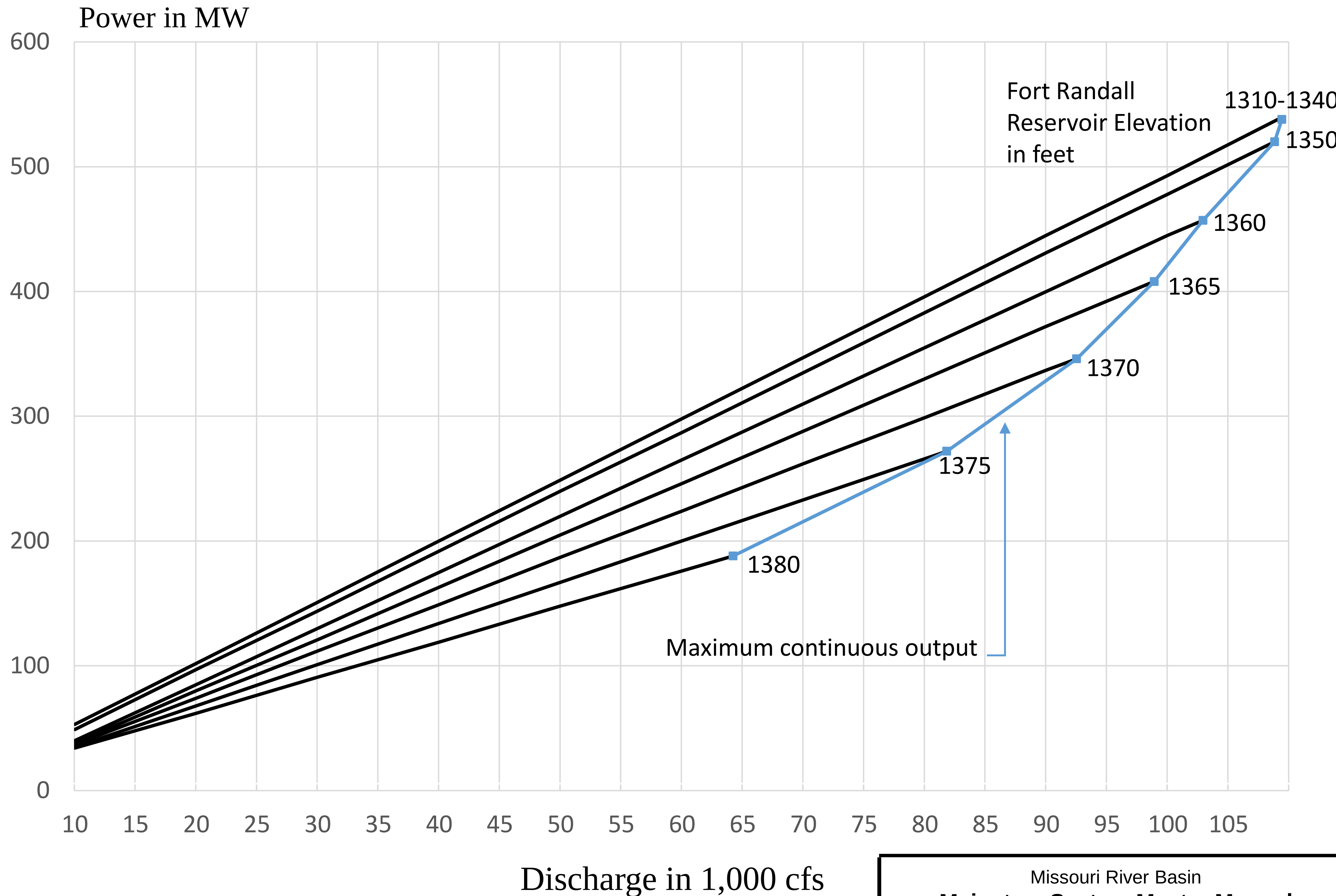
Big Bend Spillway Rating Curves





Missouri River Basin
Mainstem Master Water Control Manual
Big Bend - Tailwater Rating Curves
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Big Bend Powerplant Characteristics



October 1995

Missouri River Basin
Mainstem System Master Manual
Big Bend Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Big Bend (Lake Sharpe) Surface Area in Acres Effective date 08 January 2014 (2012 Surveys)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1340	0	0	0	180	211	251	291	331	371	411
1350	816	1,193	1,235	1,392	1,663	2,049	2,550	3,166	3,897	4,742
1360	5,597	6,318	6,952	7,587	8,222	8,857	9,493	10,129	10,765	11,401
1370	12,035	12,665	13,295	13,929	14,565	15,205	15,848	16,494	17,143	17,796
1380	18,464	19,151	19,835	20,498	21,141	21,765	22,368	22,951	23,515	24,058
1390	24,532	24,924	25,339	25,844	26,439	27,124	27,900	28,766	29,722	30,768
1400	31,692	32,309	32,873	33,609	34,519	35,602	36,858	38,287	39,889	41,664
1410	43,478	45,128	46,645	48,130	49,583	51,003	52,390	53,745	55,068	56,359
1420	57,646	58,972	60,322	61,671	63,021	64,371	65,721	67,071	68,420	69,770
1430	71,120									

Big Bend (Lake Sharpe) Capacity in Acre-Feet Effective date 08 January 2014 (2012 Surveys)										
ELEV	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1340	0	0	0	80	271	501	772	1,083	1,434	1,825
1350	2,256	3,457	4,642	5,927	7,425	9,253	11,524	14,353	17,856	22,147
1360	27,341	33,341	39,976	47,246	55,150	63,690	72,865	82,675	93,122	104,205
1370	115,925	128,276	141,256	154,867	169,113	183,998	199,523	215,693	232,511	249,980
1380	268,103	286,907	306,405	326,576	347,401	368,859	390,930	413,595	436,833	460,624
1390	484,949	509,689	534,798	560,367	586,486	613,245	640,735	669,045	698,266	728,489
1400	759,803	791,874	824,421	857,619	891,640	926,657	962,843	1,000,372	1,039,417	1,080,150
1410	1,122,745	1,167,106	1,213,001	1,260,397	1,309,261	1,359,562	1,411,266	1,464,342	1,518,757	1,574,478
1420	1,631,474	1,689,771	1,749,418	1,810,414	1,872,760	1,936,456	2,001,502	2,067,898	2,135,643	2,204,739
1430	2,275,184									

Missouri River Basin

Mainstem Master Water Control Manual

Big Bend Project

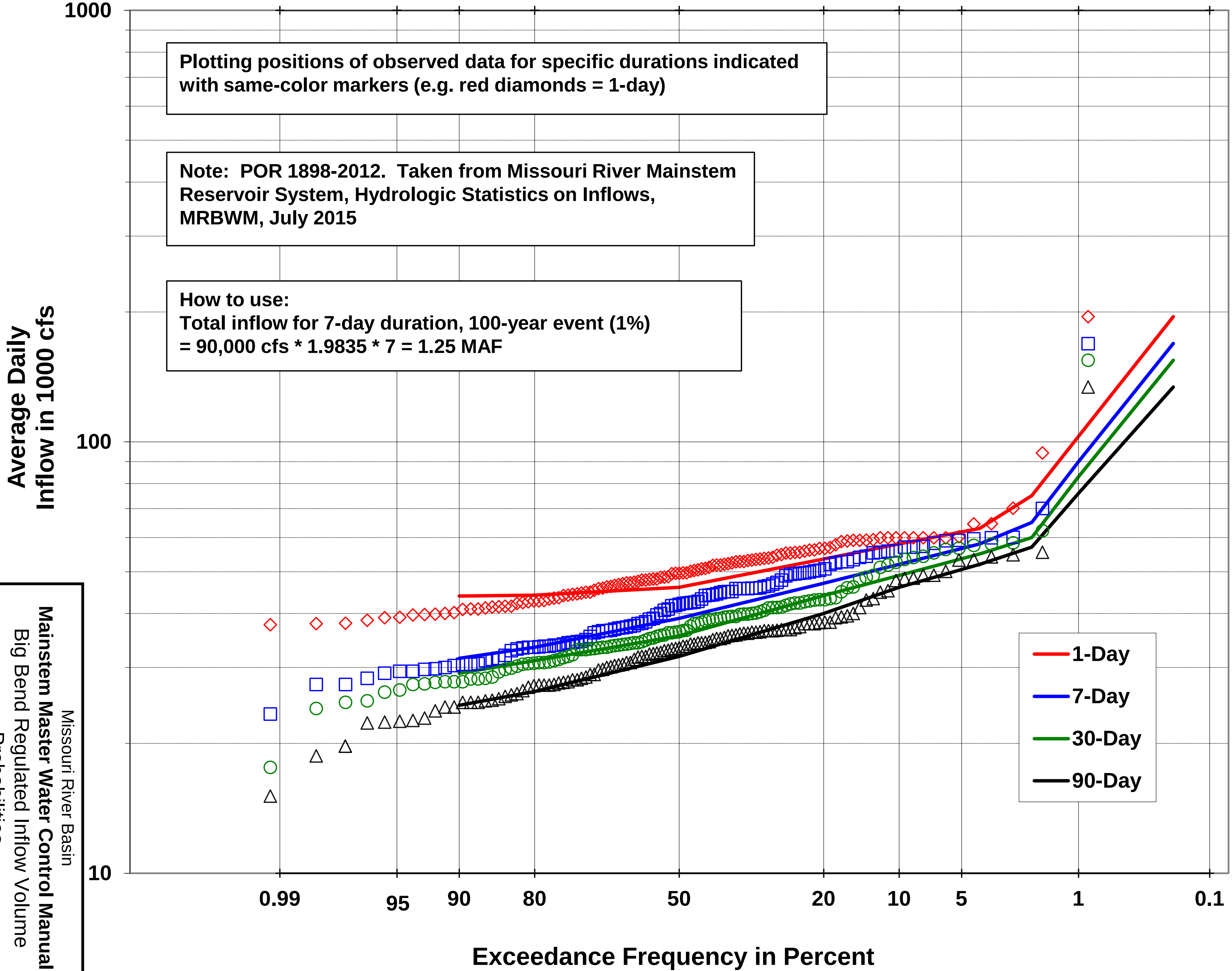
Area and Capacity Tables

U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

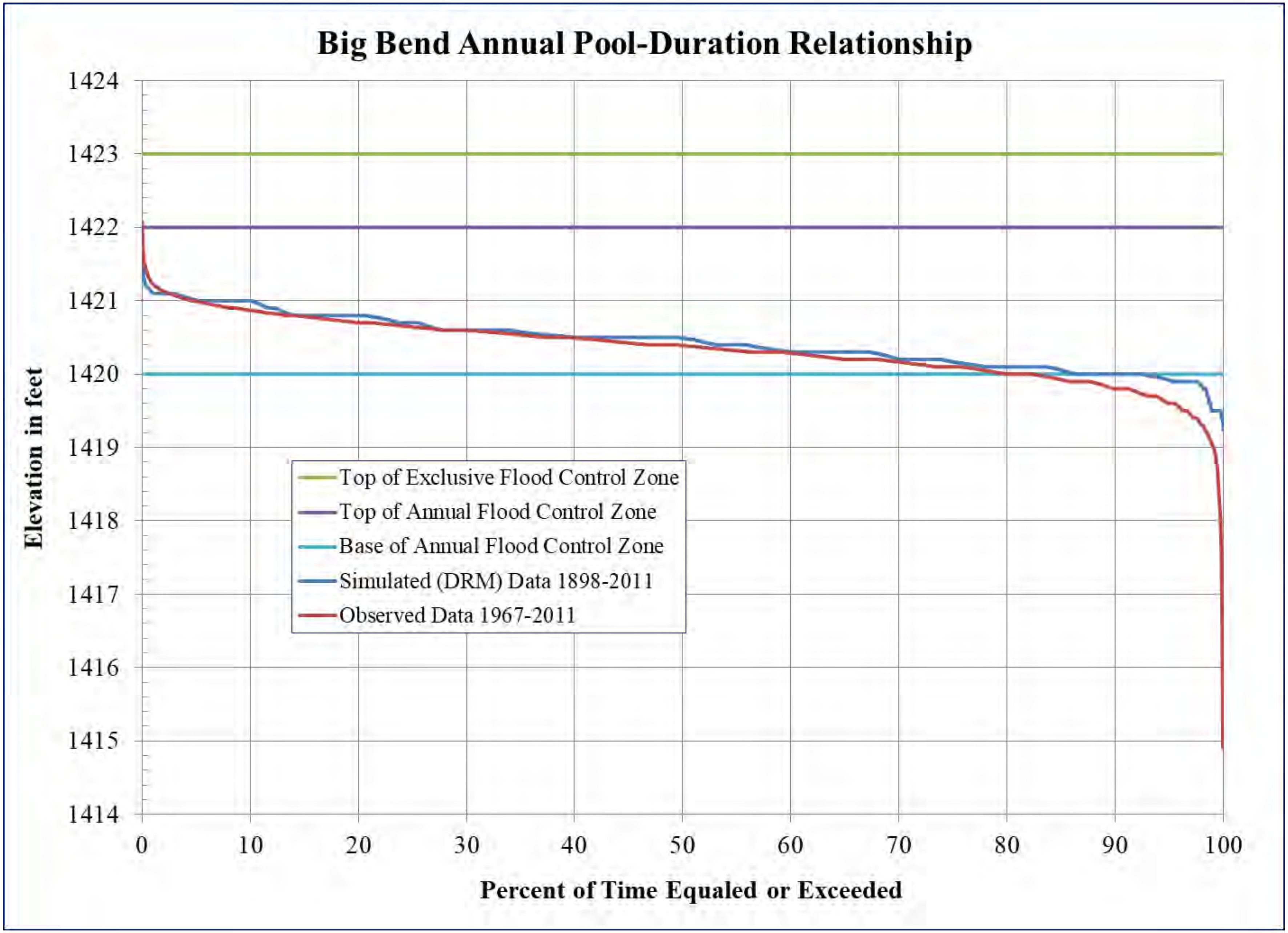
November 2018

Missouri River Basin
Mainstem Master Water Control Manual
Big Bend Powerhouse, Spillway,
Reservoir and Embankment
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2016

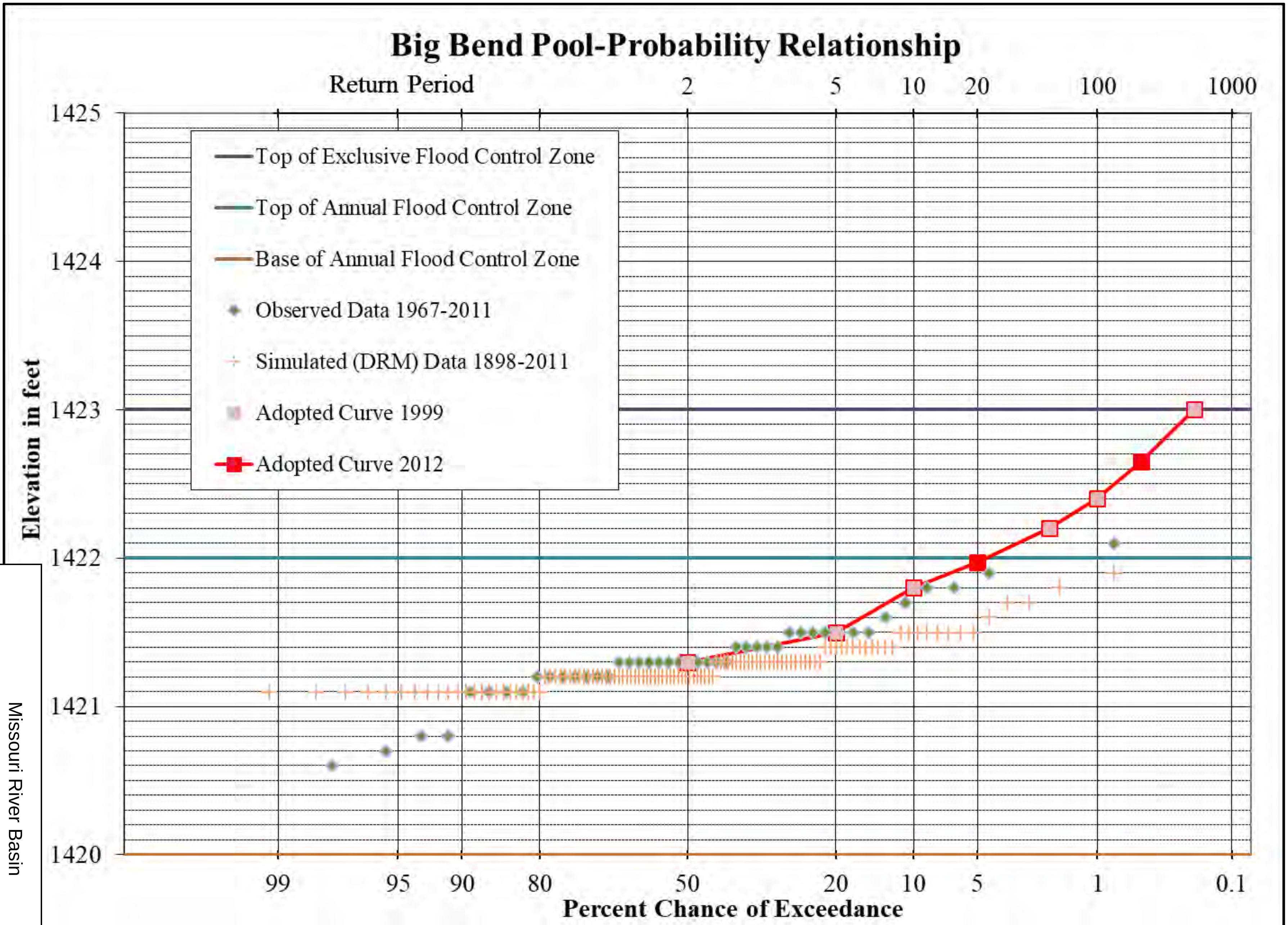


Missouri River Basin
Mainstem Master Water Control Manual
Big Bend Regulated Inflow Volume
Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-52

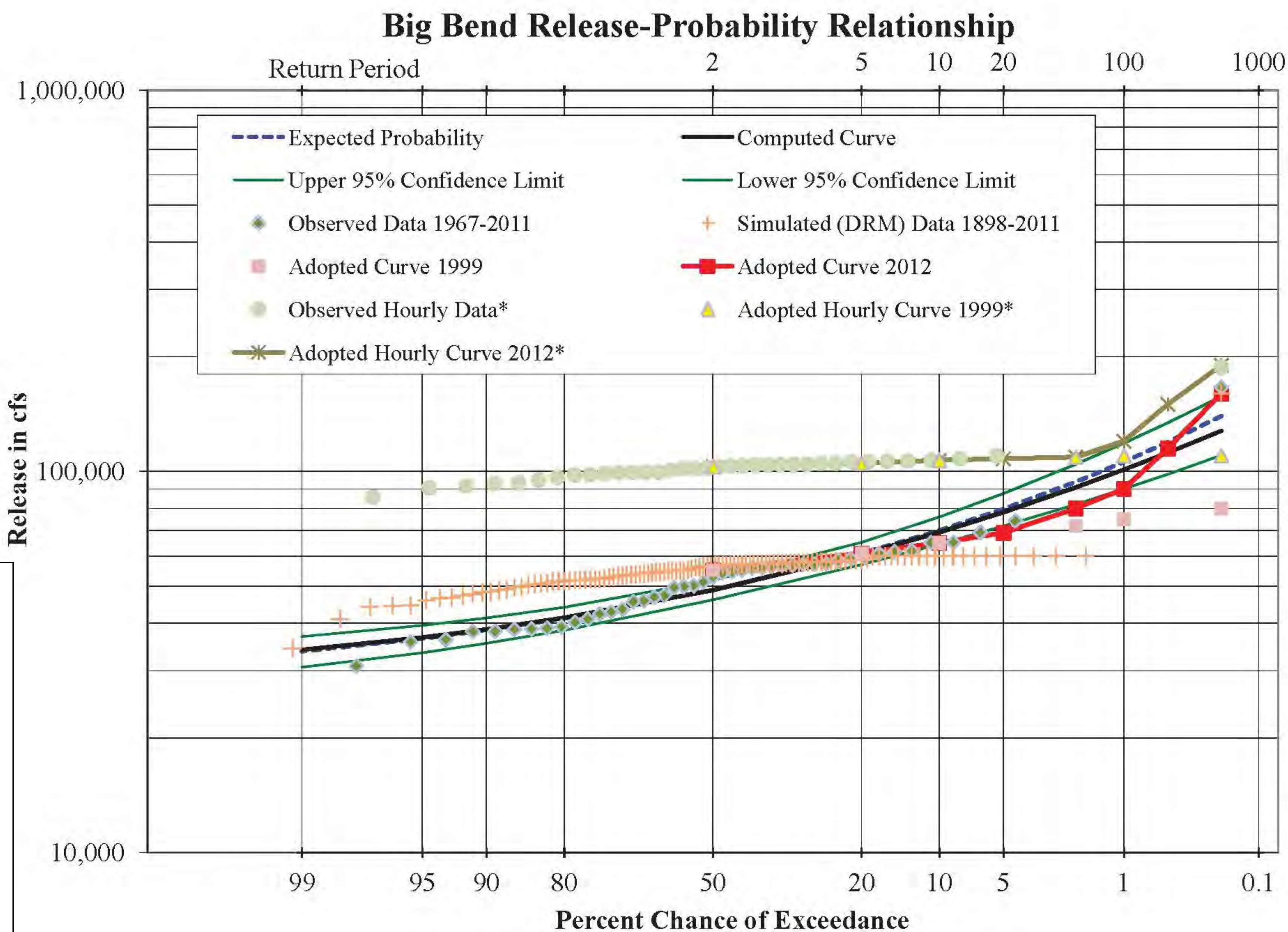


Source: Hydrologic Statistics, MRBWM, September 2013



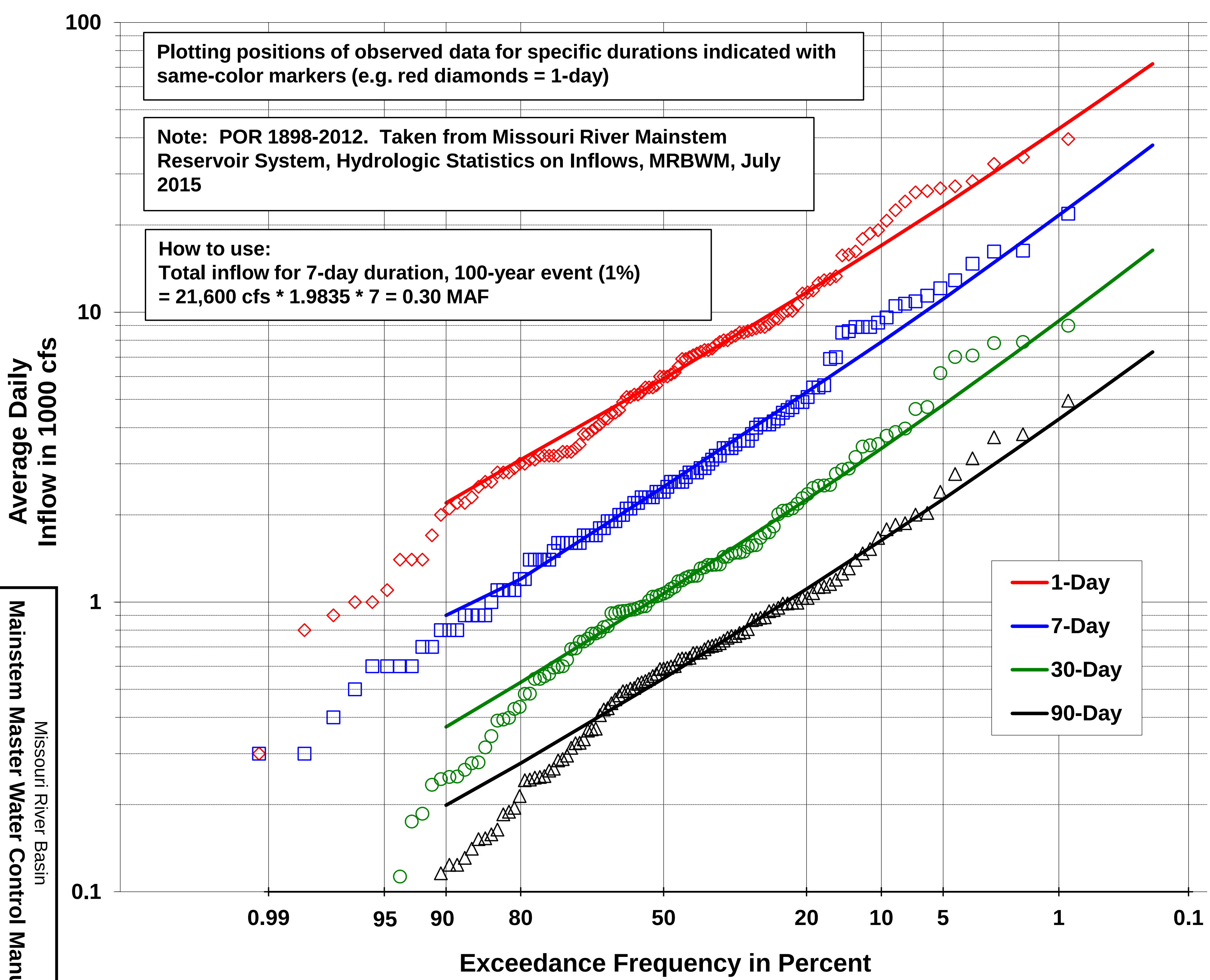
Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin
Mainstem Master Water Control Manual
Big Bend Pool-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
Big Bend Release-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate II-55



Missouri River Basin

Mainstem Master Water Control Manual

Big Bend Incremental Inflow Volume

Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN

CORPS OF ENGINEERS, OMAHA, NEBRASKA

November 2018

Plate II-56

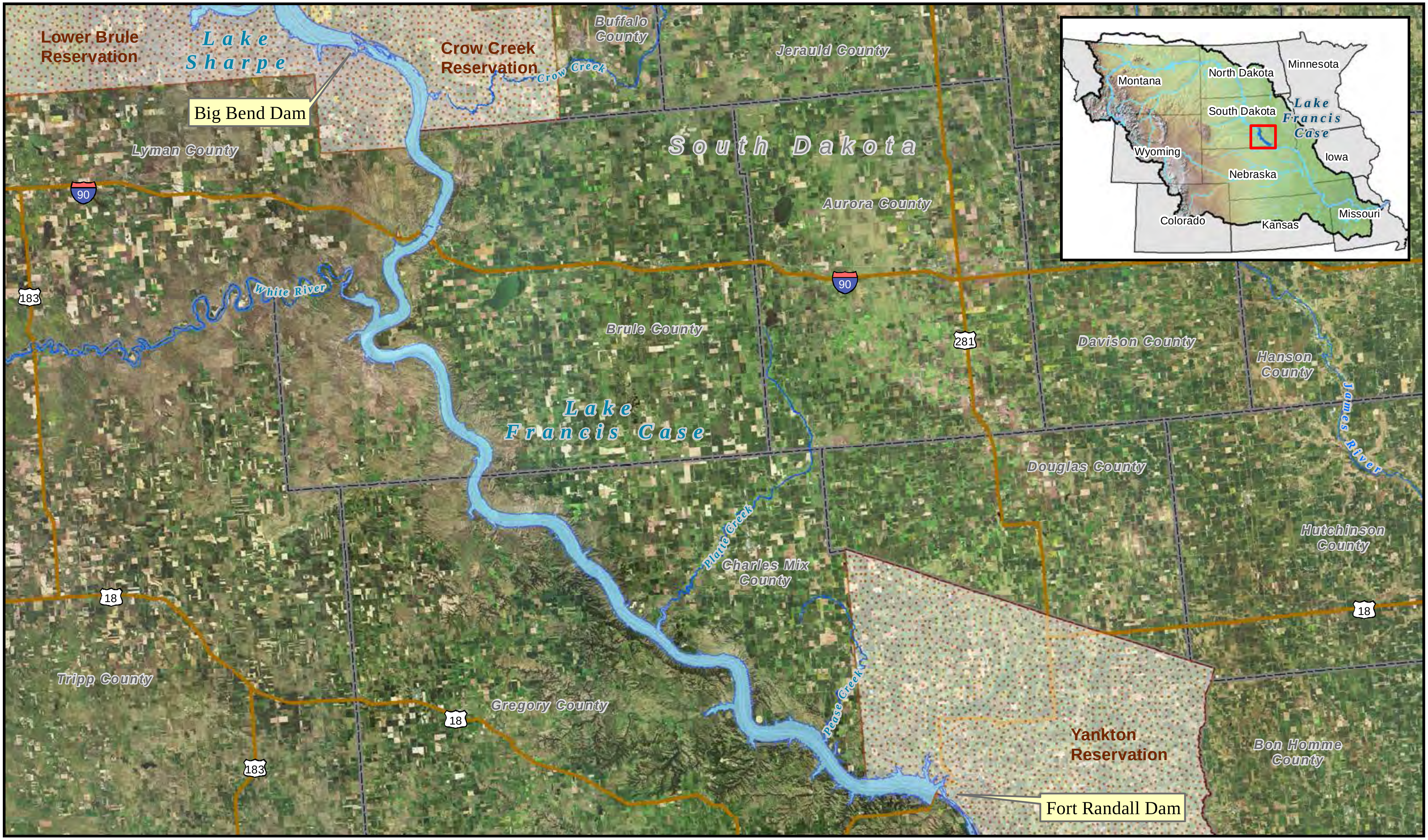


Plate II-57

US Army Corps of Engineers®
Northwestern Division

Cities	Reservoirs/Lakes
Rivers	State Boundaries
Roads	County Boundaries
Reservations	

0 5 10 20 30 Miles

N S W E

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

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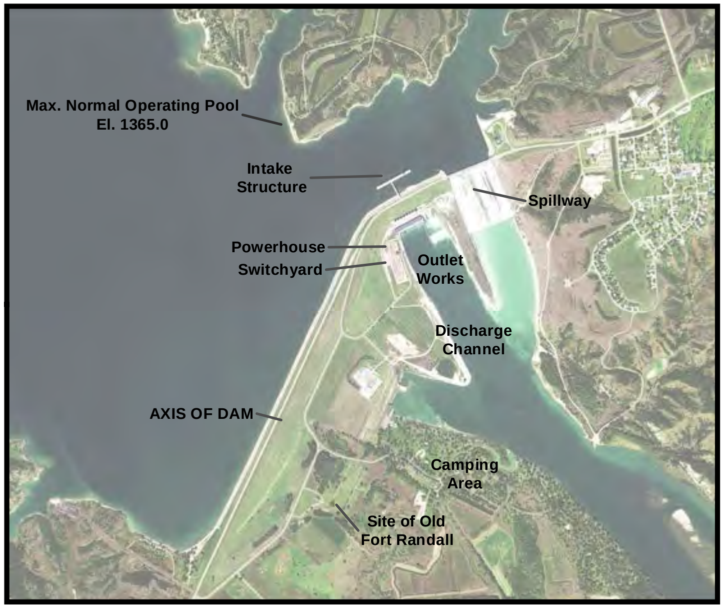
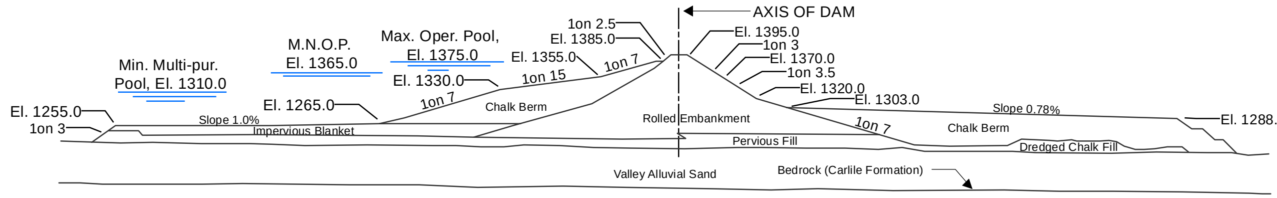
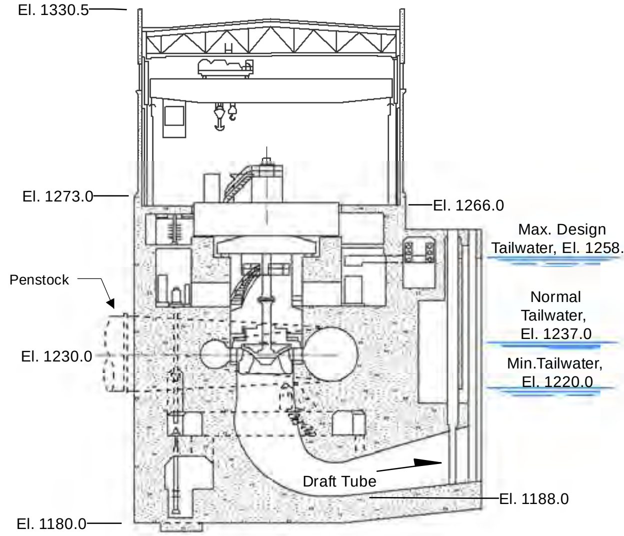
Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall Project Map
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



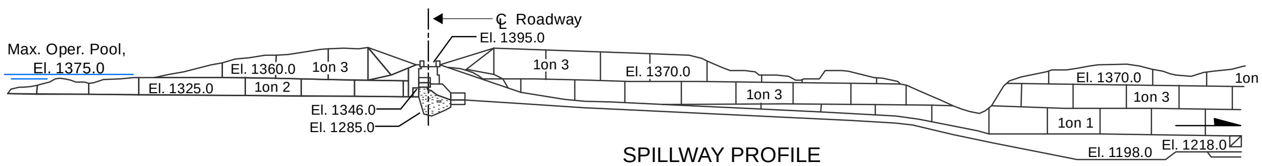
PLAN VIEW



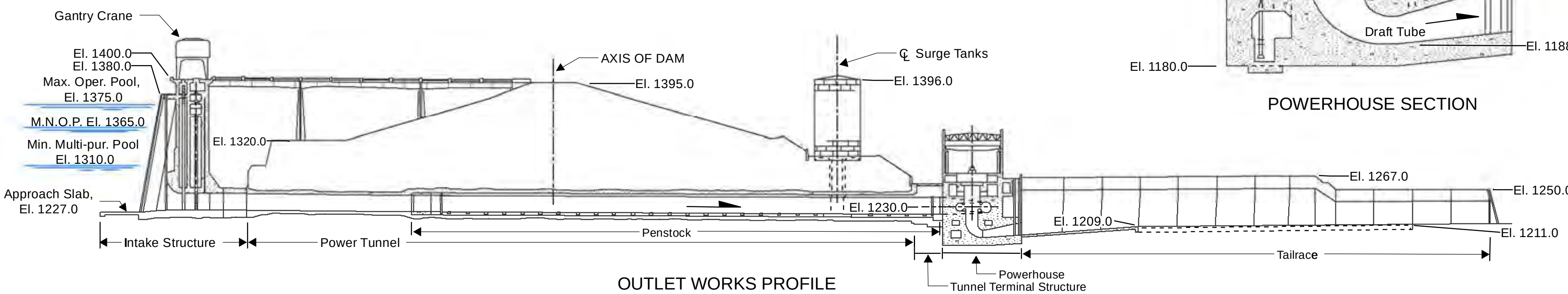
EMBANKMENT SECTION



POWERHOUSE SECTION



SPILLWAY PROFILE



OUTLET WORKS PROFILE

Plate II-58

US Army Corps of Engineers®
Northwestern Division

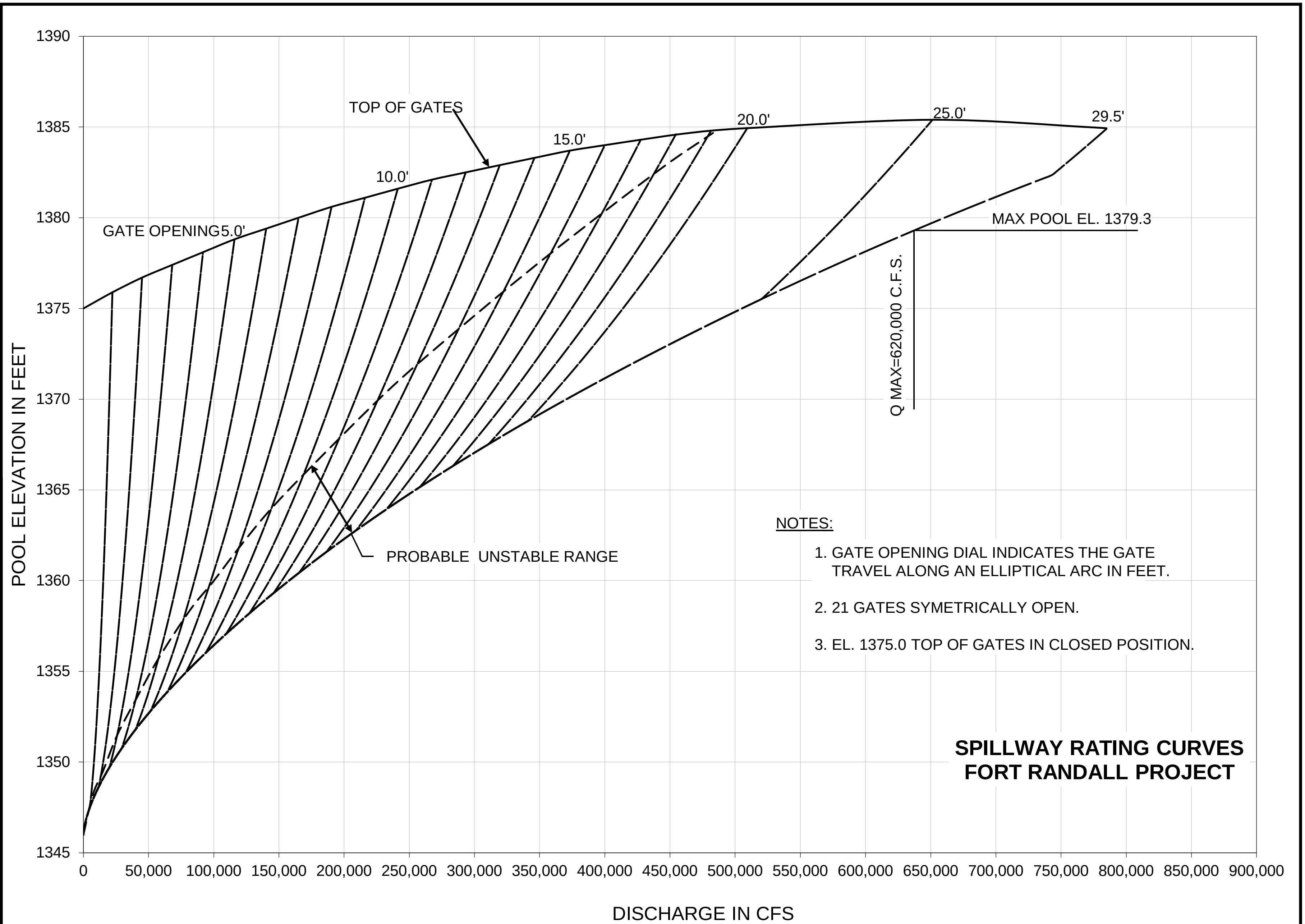
PLAN & SECTIONS DETAIL

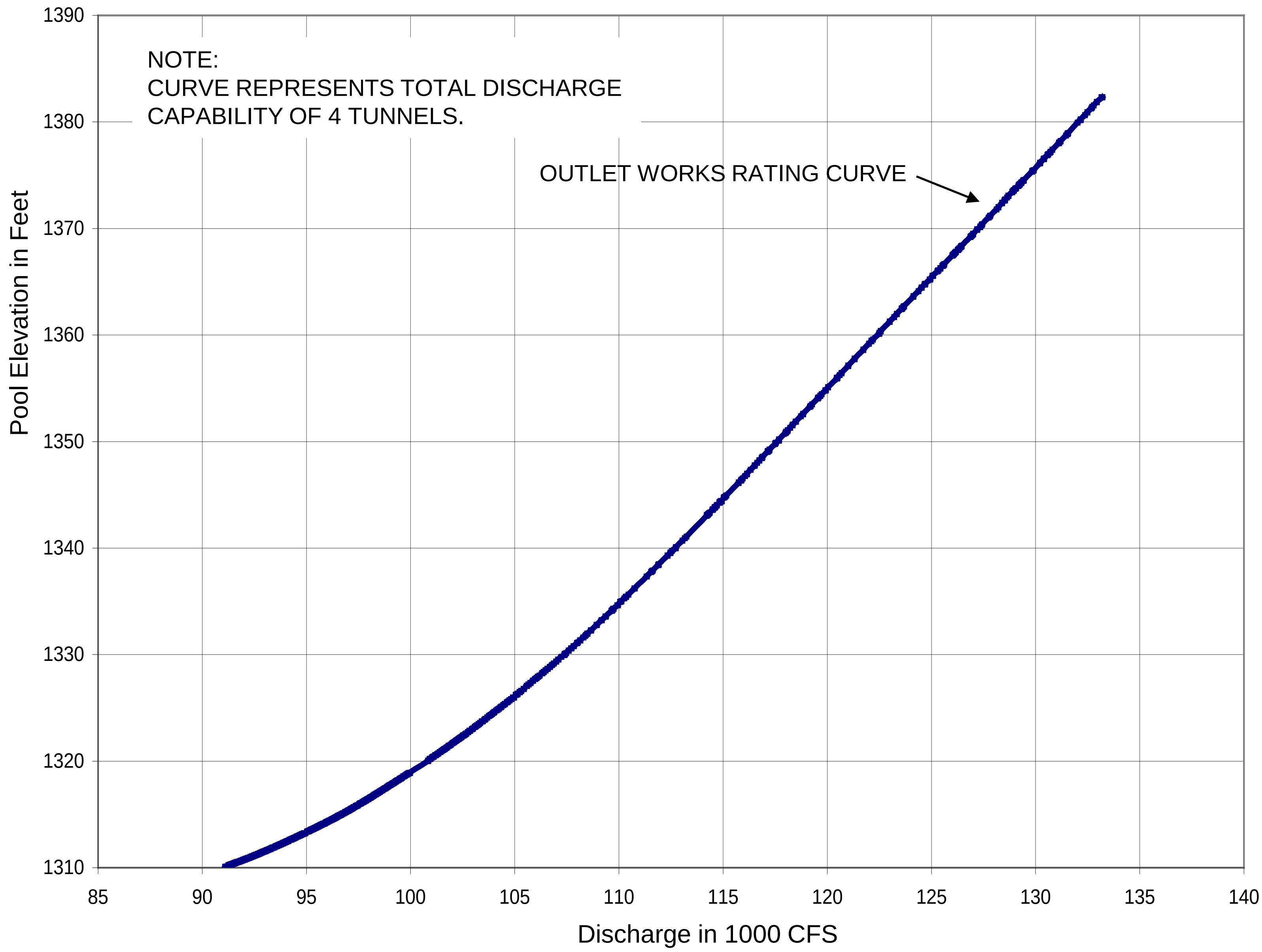
N W E S

G:\2016_DivisionMaps\Dam_Detail\mxd\Fort_Randall_Water_Control_Map.mxd

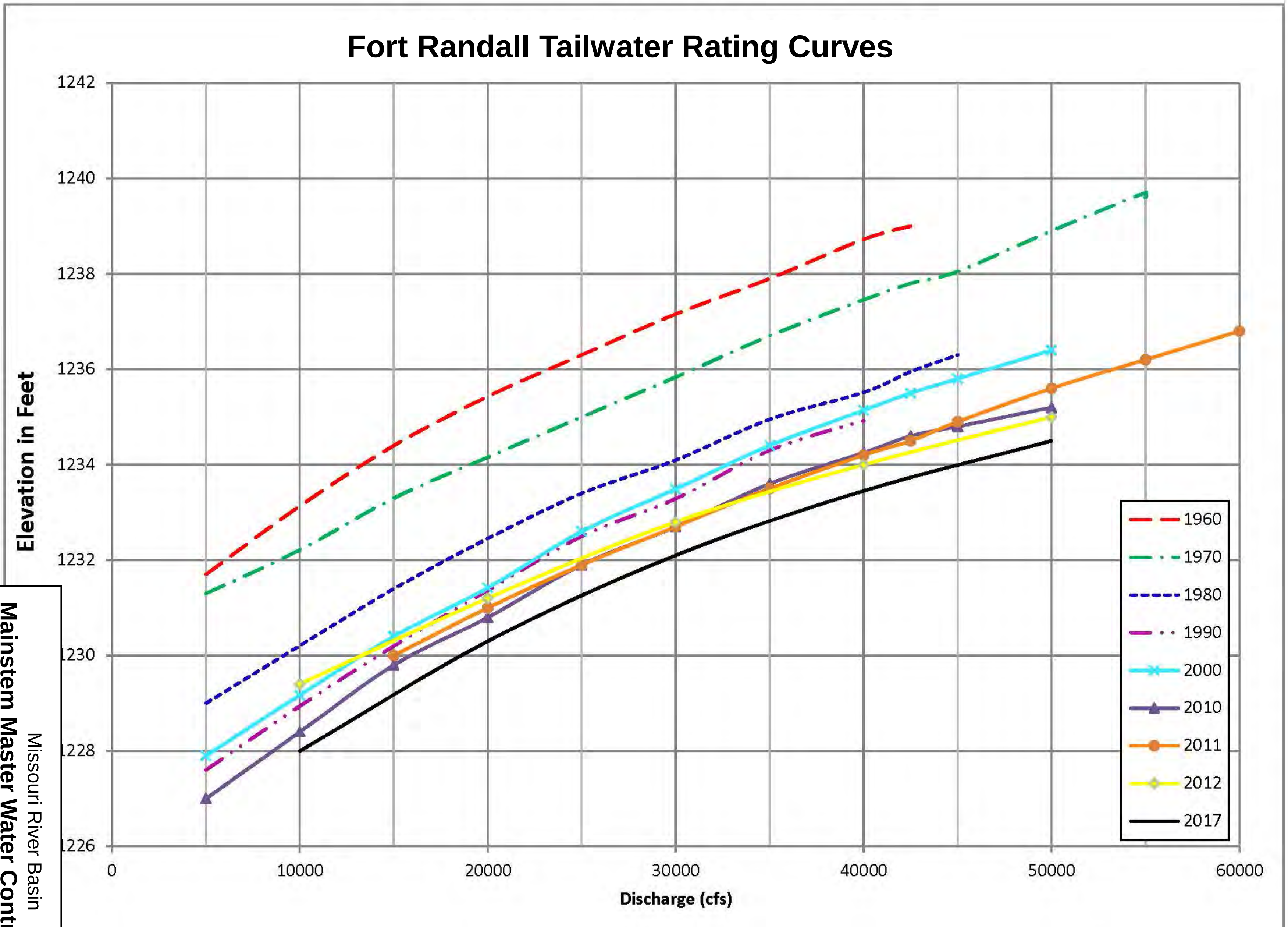
Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall Plan and Sections
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Fort Randall Spillway Rating Curves





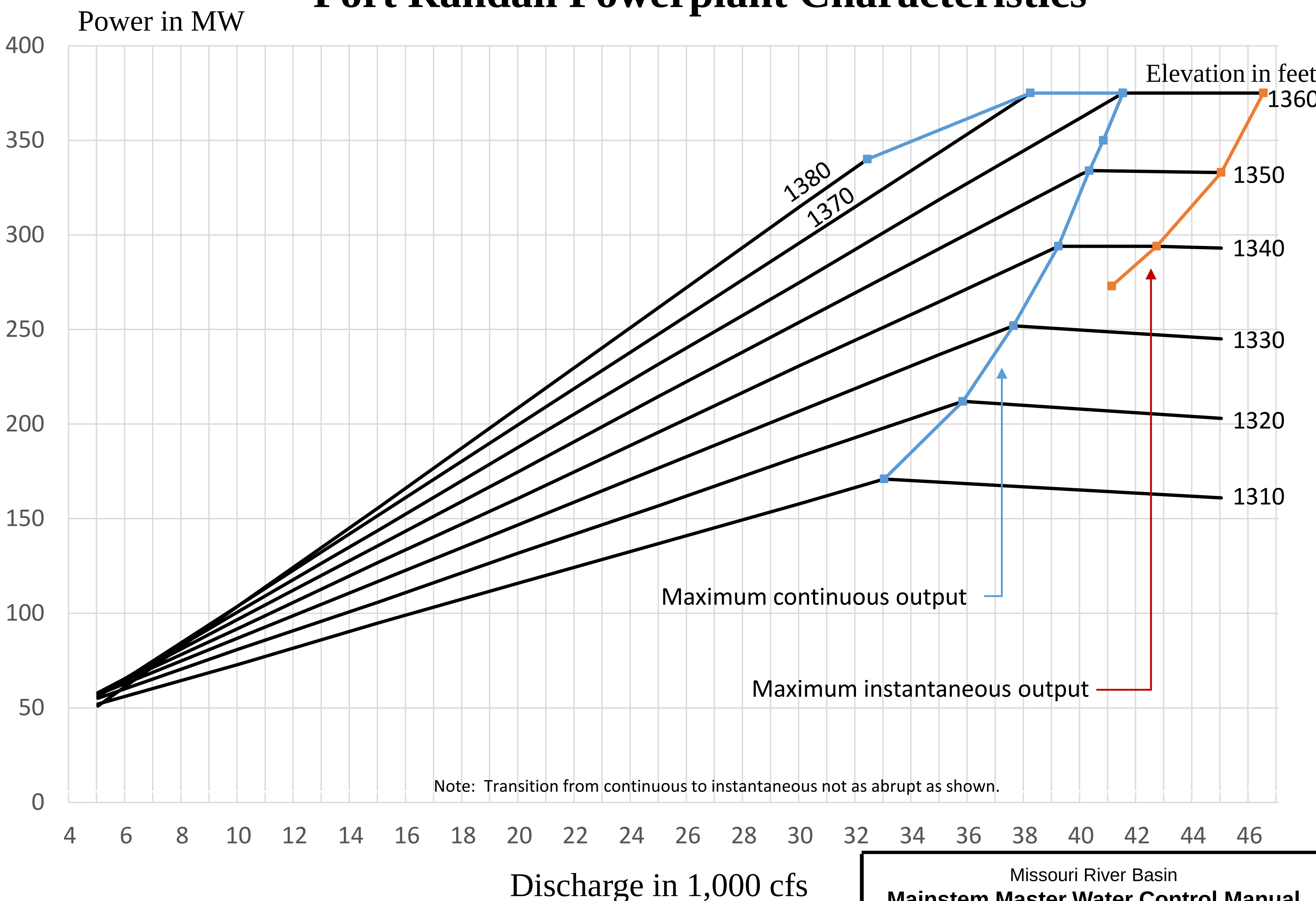
Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall - Outlet Works Rating Curve
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018



January 2018

Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall Tailwater Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Fort Randall Powerplant Characteristics



October 1995

Missouri River Basin

Mainstem Master Water Control Manual

Fort Randall Powerplant Characteristics

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN

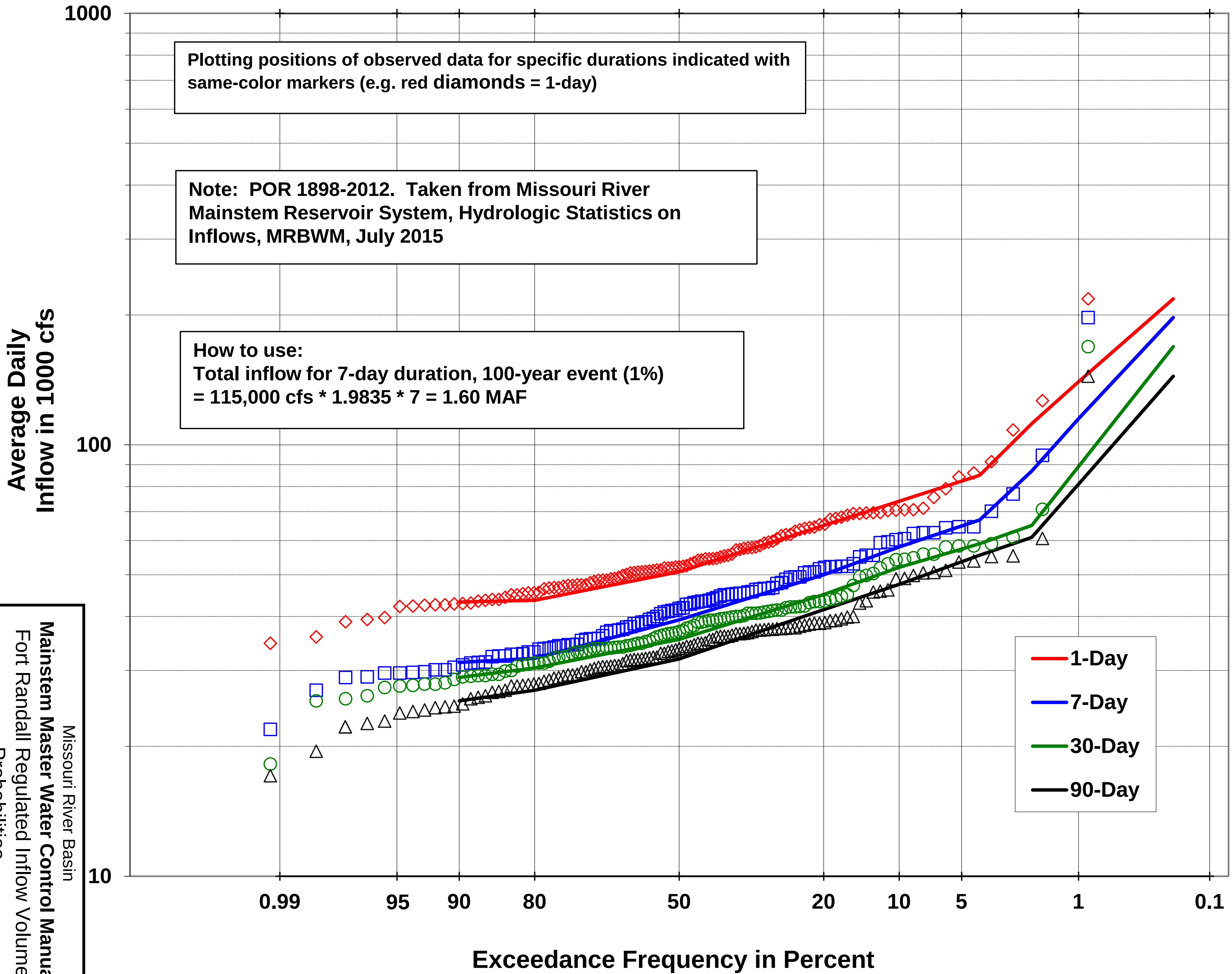
CORPS OF ENGINEERS, OMAHA, NEBRASKA

November 2018

Fort Randall (Lake Francis Case) 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									

Fort Randall (Lake Francis Case) 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									

Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall Reservoir, Embankment,
Intakes, Powerhouse and Spillway
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



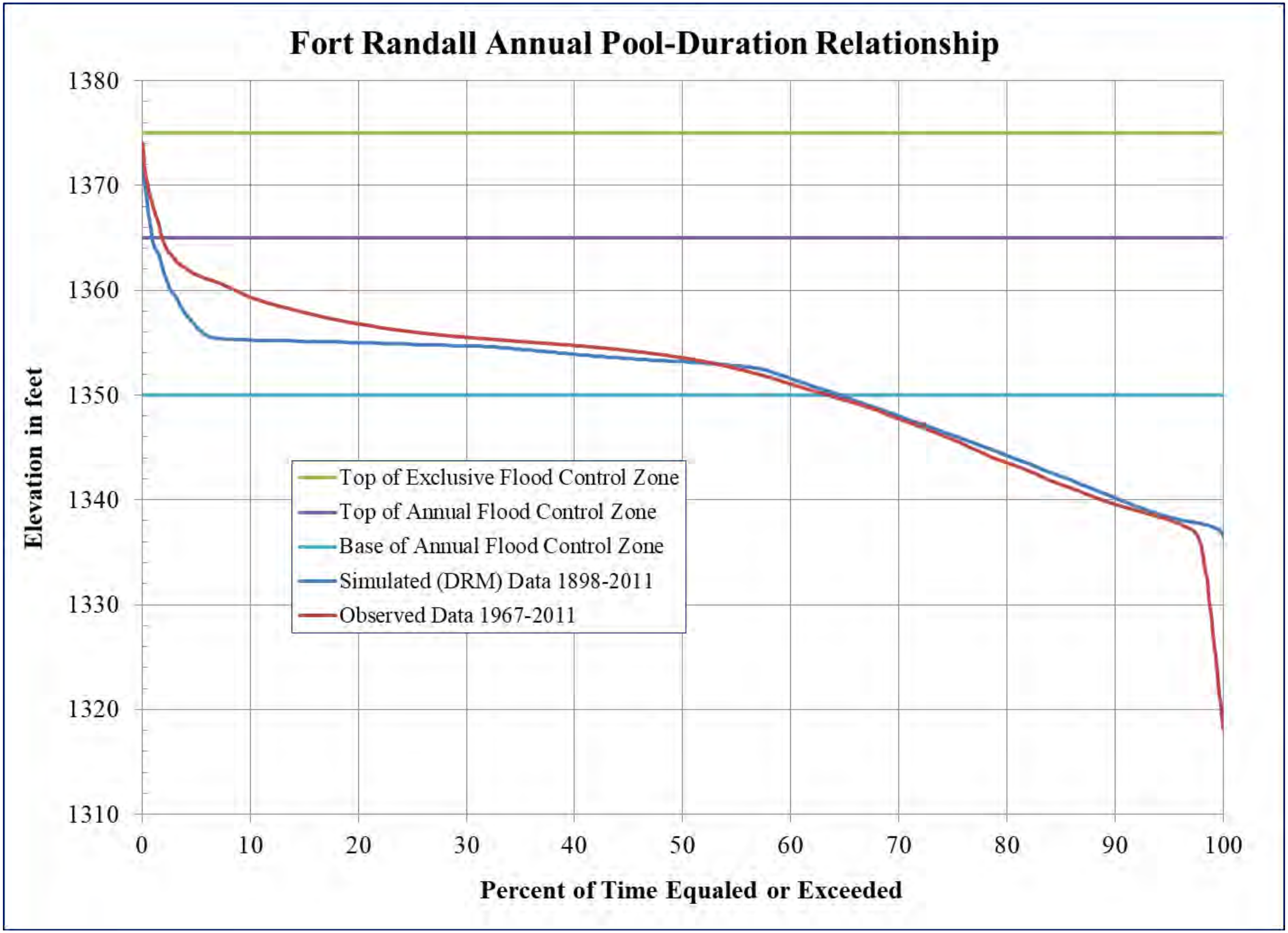
Missouri River Basin

Mainstem Master Water Control Manual

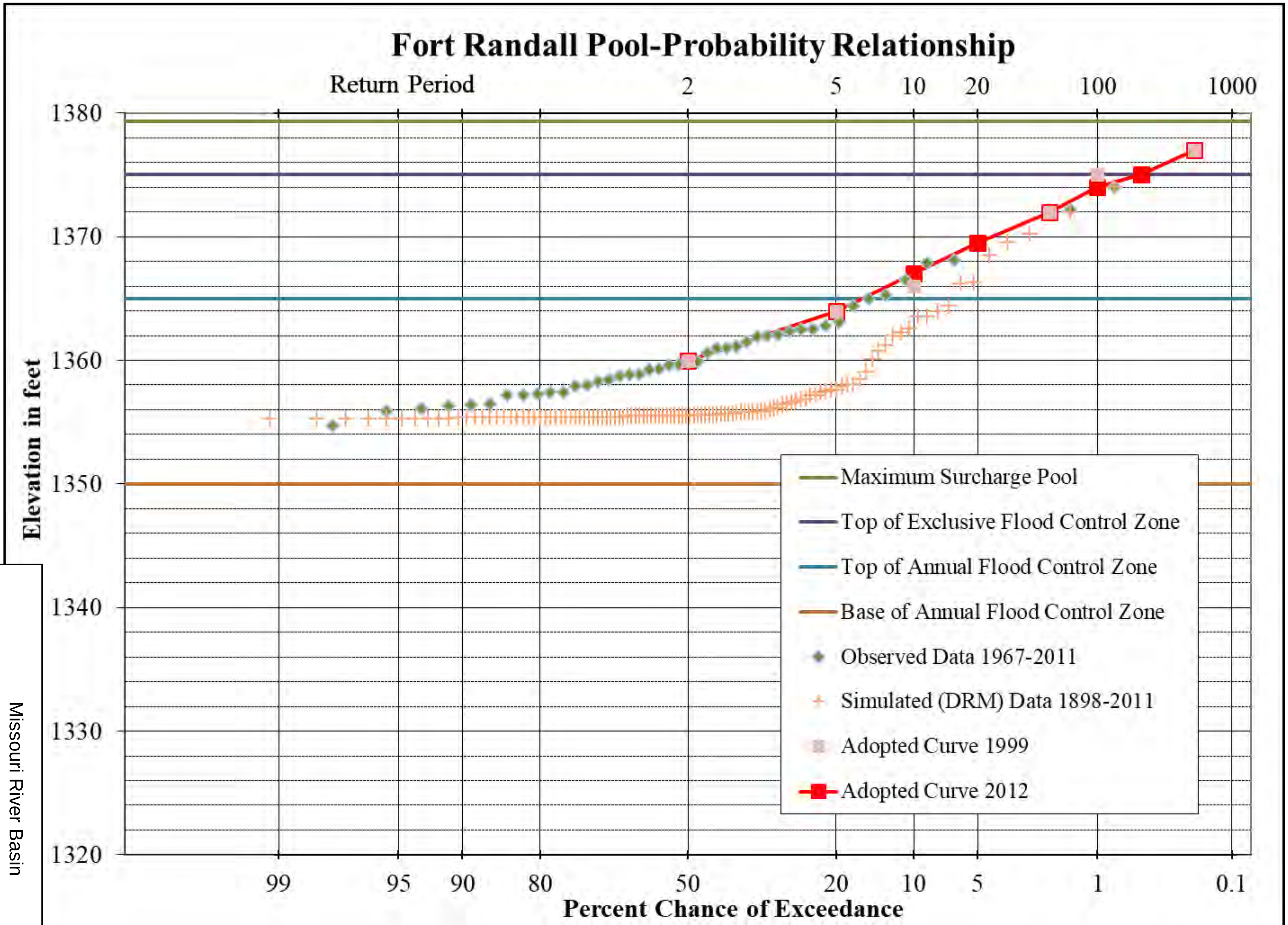
Fort Randall Regulated Inflow Volume Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-65



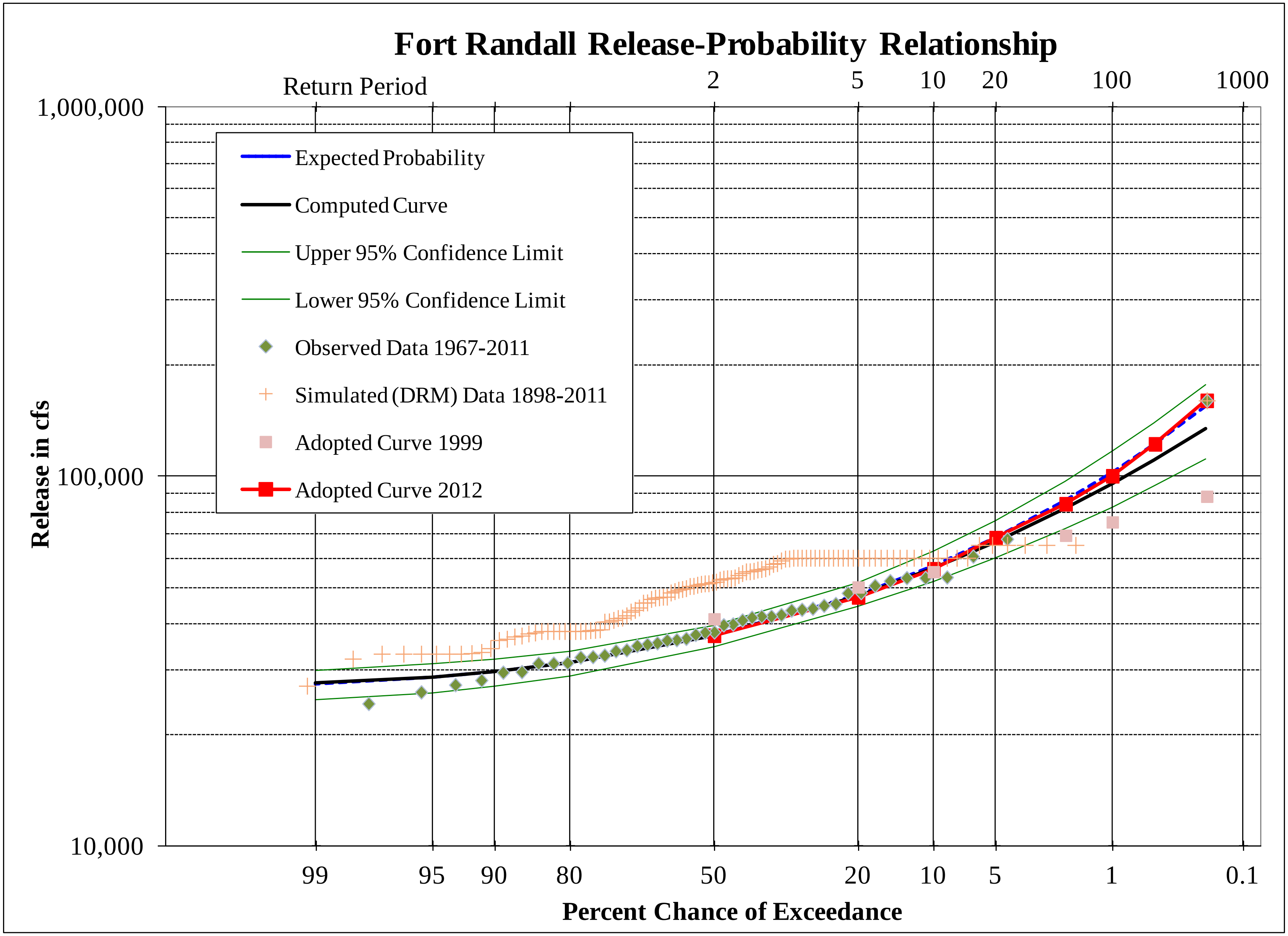
Source: Hydrologic Statistics, MRBWM, September 2013



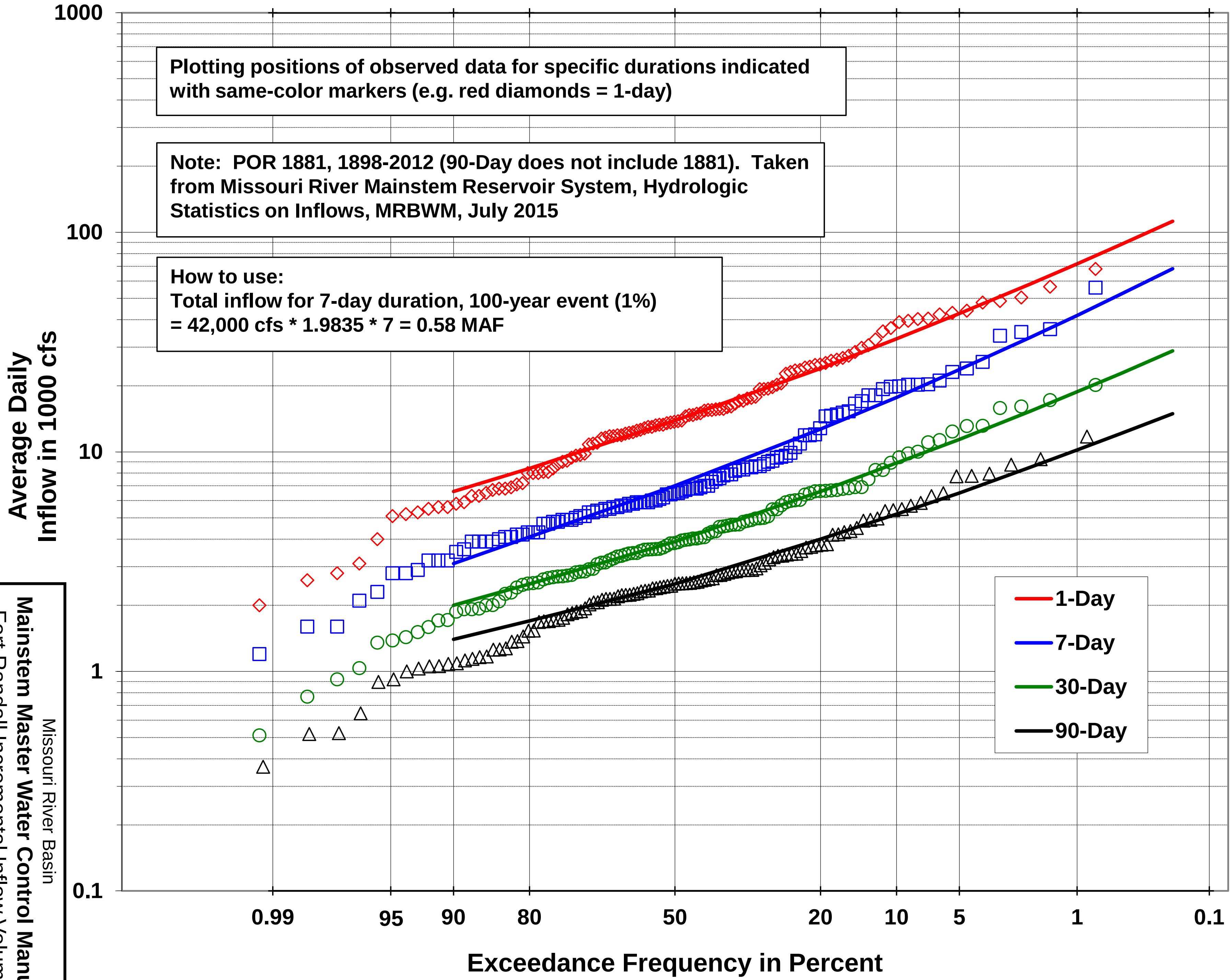
Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall Pool-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate II-67



Missouri River Basin
Mainstem Master Water Control Manual
Fort Randall Release-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin

Mainstem Master Water Control Manual

Fort Randall Incremental Inflow Volume Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-69

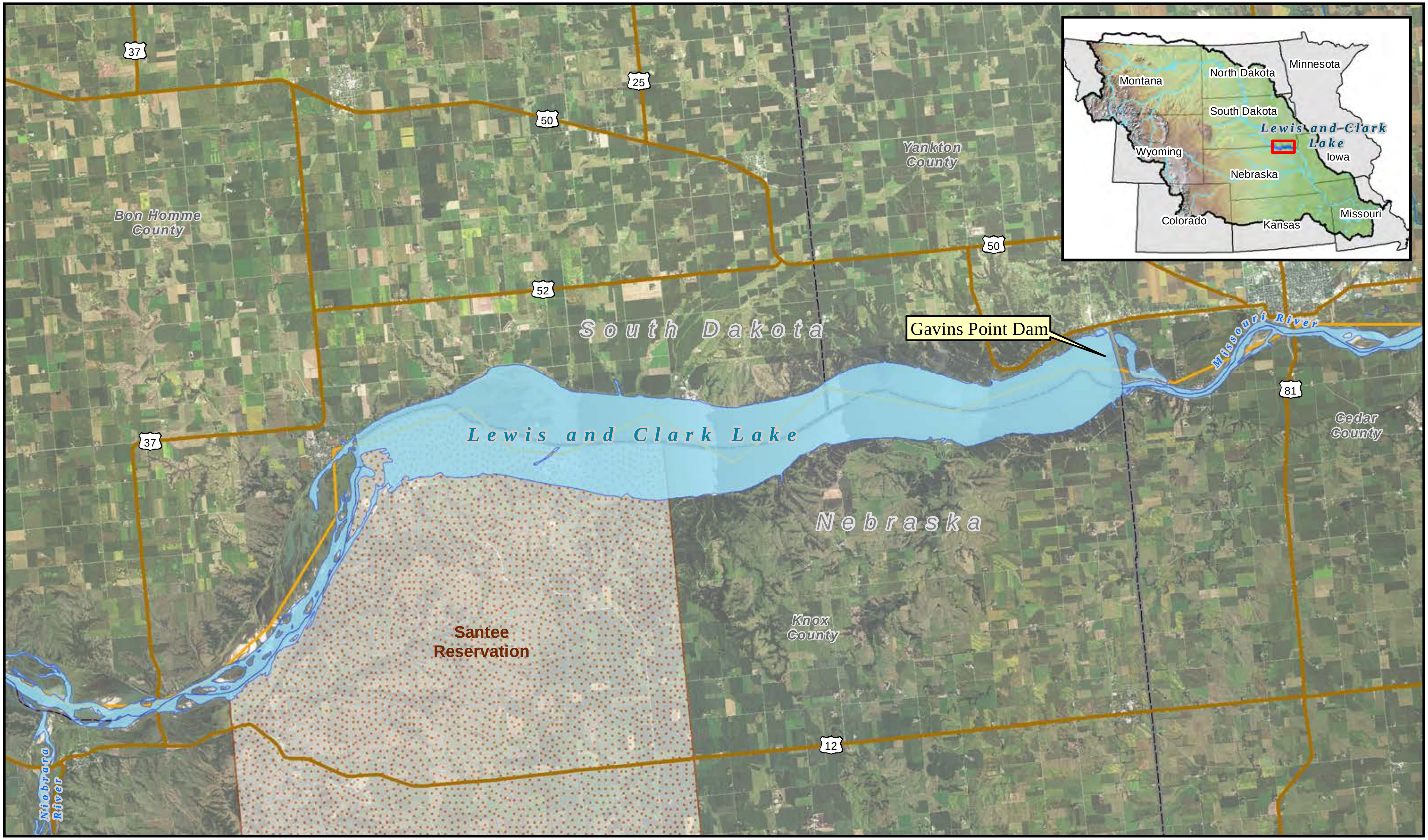


Plate II-70

US Army Corps of Engineers®
Northwestern Division

Legend			
Cities		Reservoirs/Lakes	
Rivers		State Boundaries	
Roads		County Boundaries	
Reservations			

0 2.5 5 10 Miles

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

N W E S

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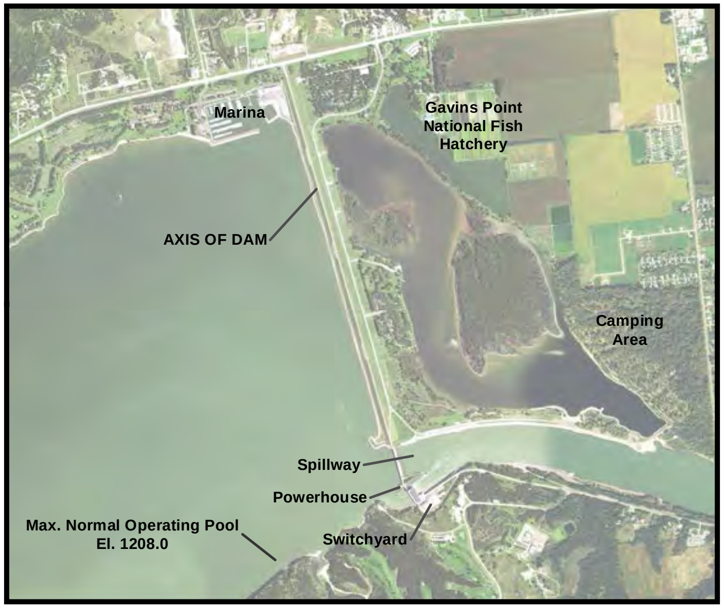
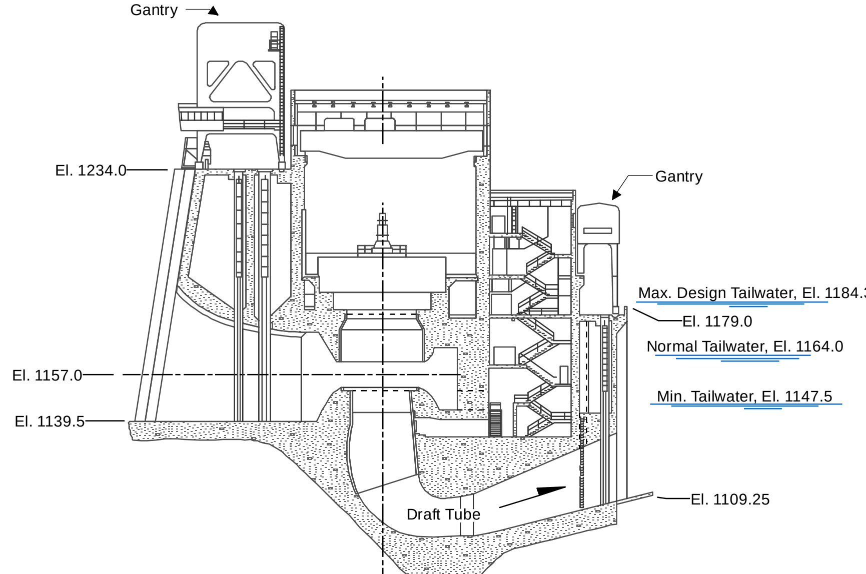
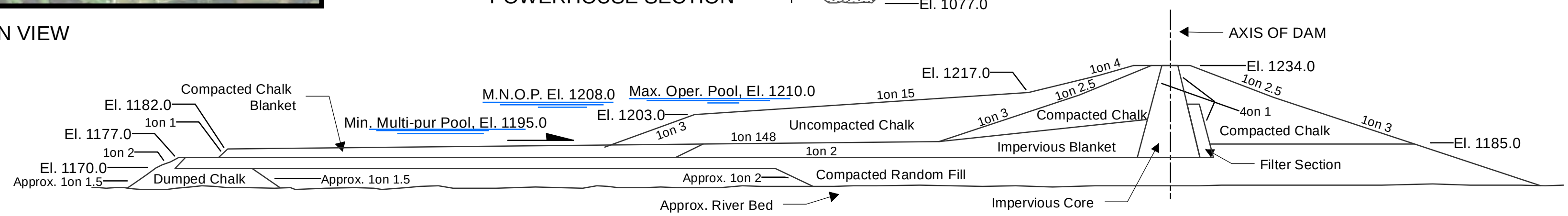
Missouri River Basin
Mainstem Master Water Control Manual
Gavins Point Project Map
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



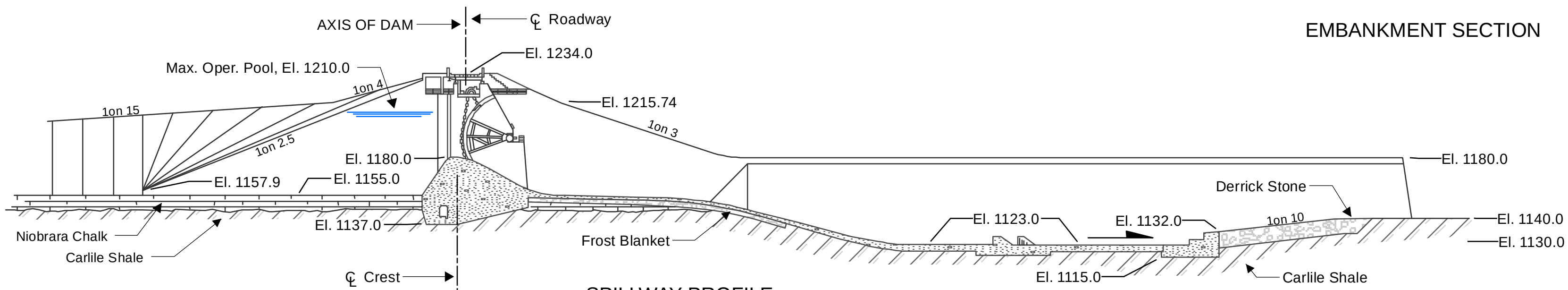
PLAN VIEW



POWERHOUSE SECTION



EMBANKMENT SECTION



SPILLWAY PROFILE

Plate II-71

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

N W E S

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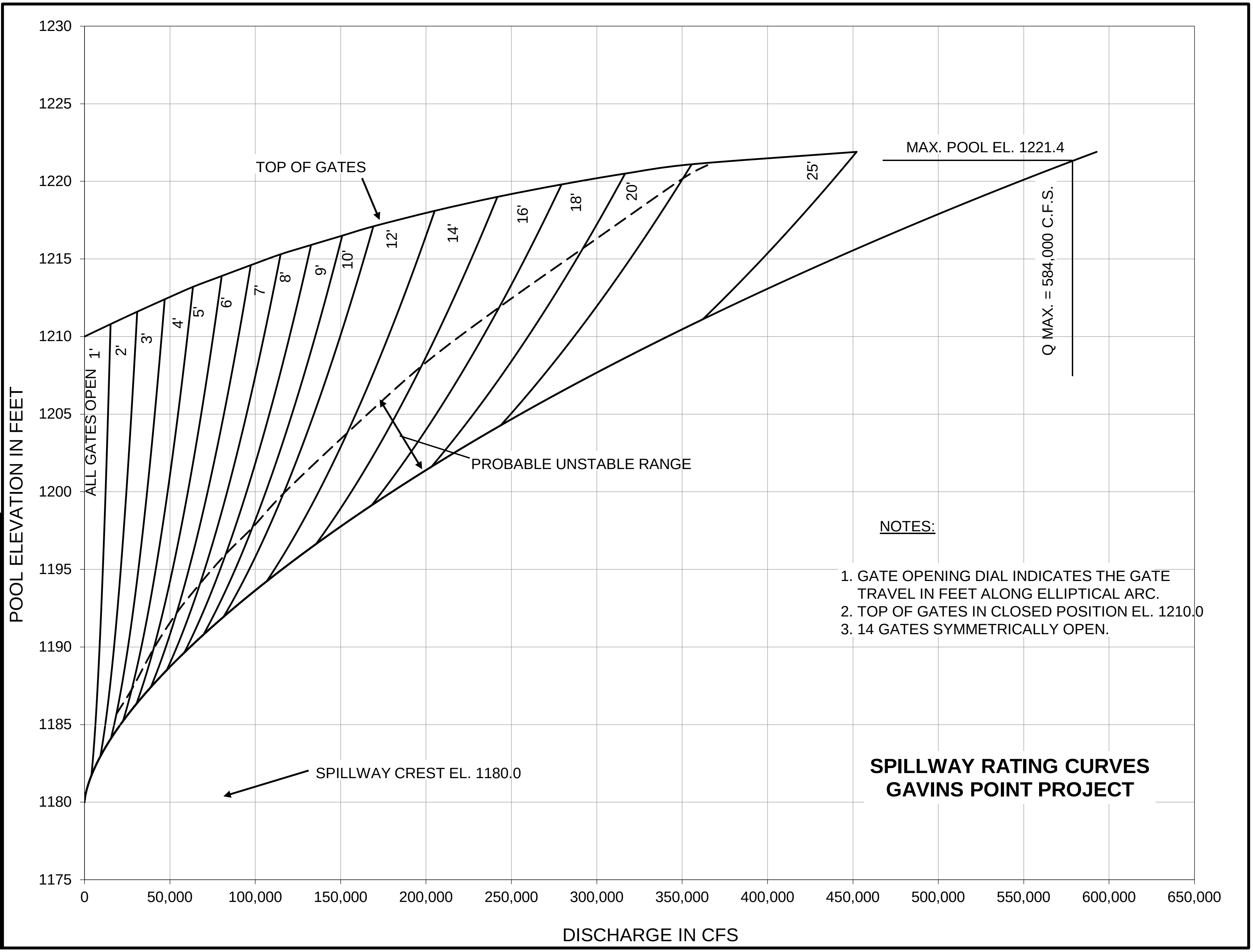
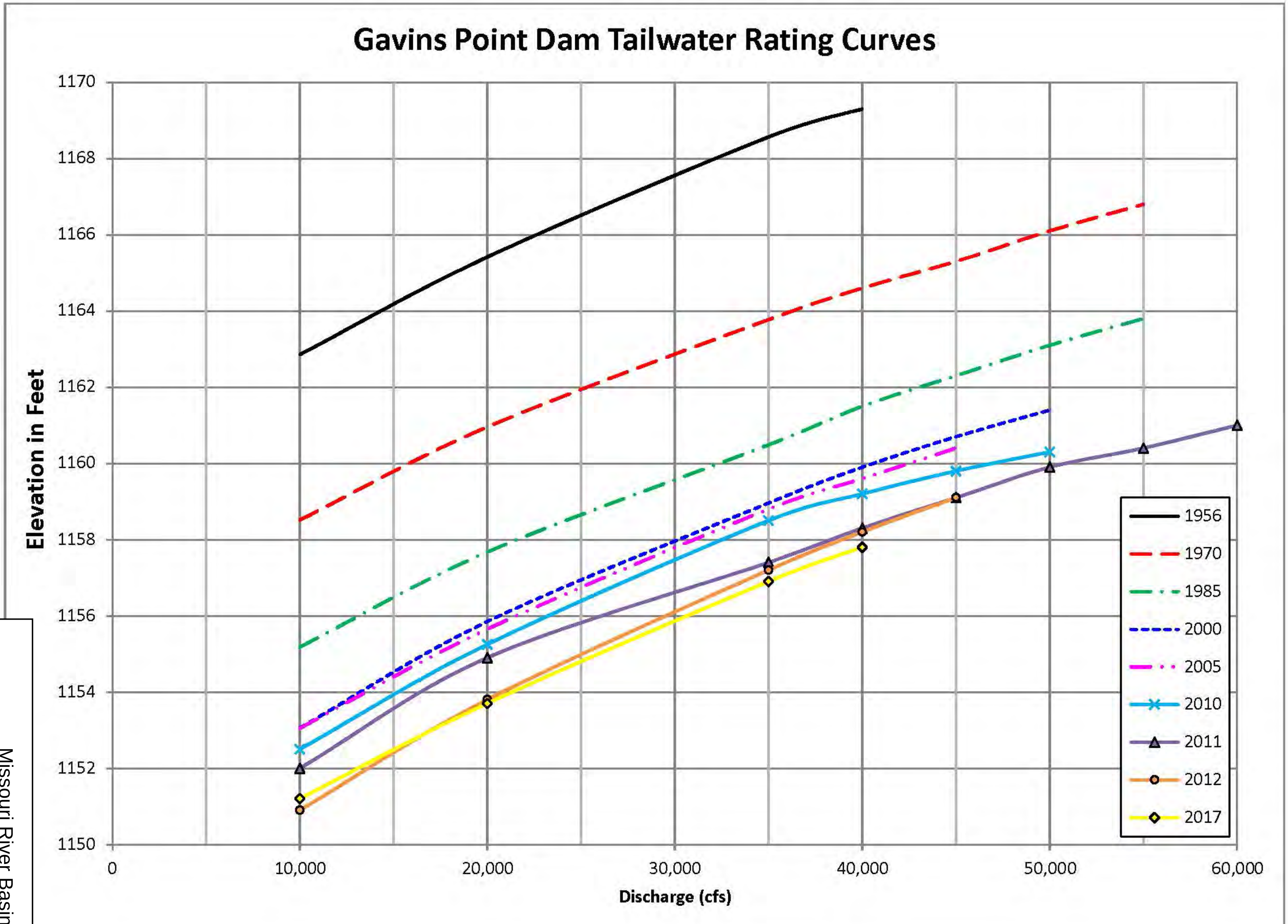
Mainstem Master Water Control Manual
Gavins Point Plan and Sections
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

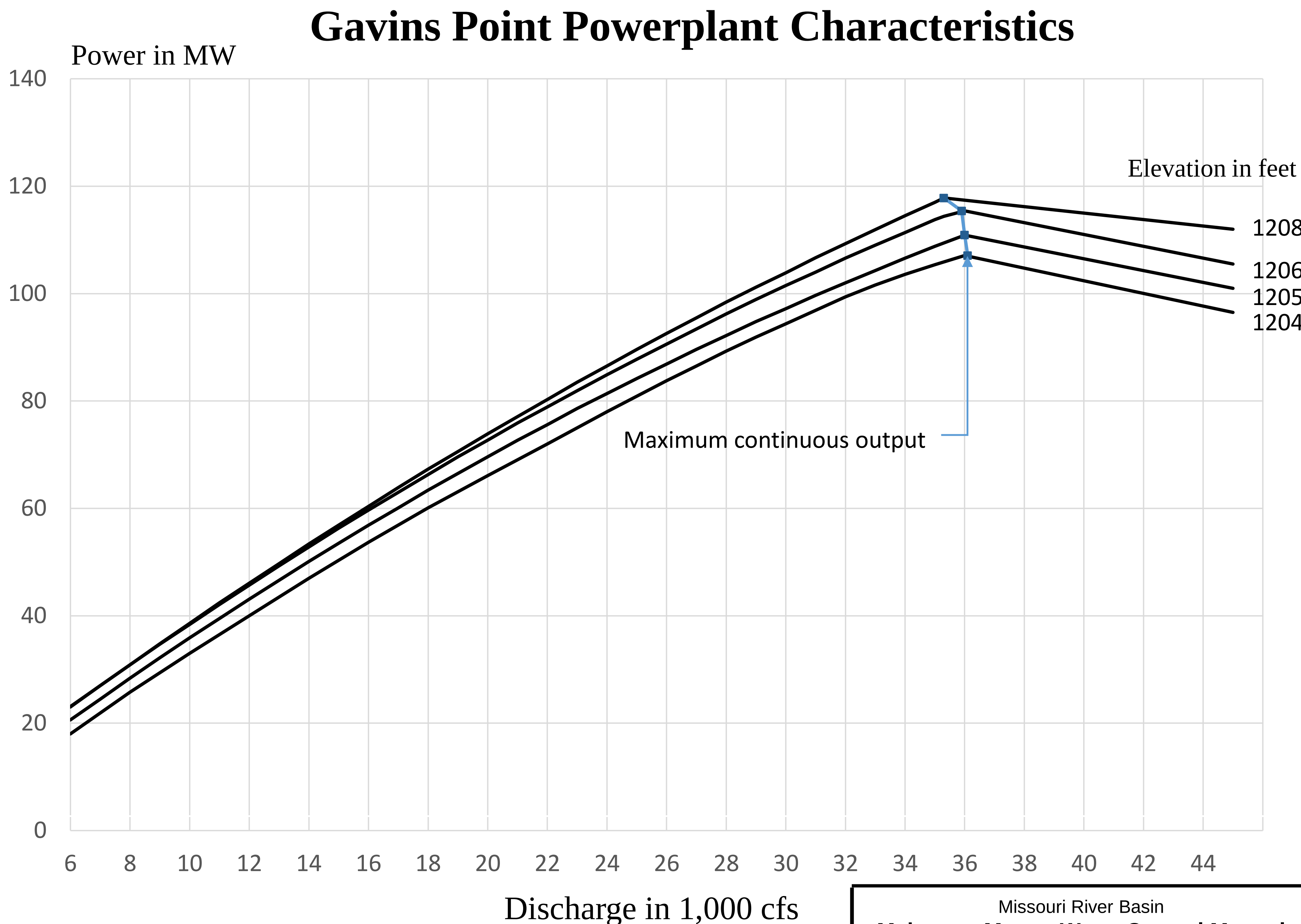
Gavins Point Spillway Rating Curves





January 2018

Missouri River Basin
Mainstem System Master Manual
Gavins Point Tailwater Rating Curves
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



October 1995

Missouri River Basin
Mainstem Master Water Control Manual
Gavins Point Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Gavins Point (Lewis and Clark Lake) Surface Area in Acres Implemented by MRBWM August 2013 (2011 Surveys)										
ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	0	0	0	0	0	75	146
1170	232	284	308	402	567	804	1112	1491	1940	2461
1180	2855	2959	3024	3267	3687	4285	5059	6011	7140	8446
1190	9828	11099	12231	13280	14248	15134	15937	16658	17298	17855
1200	18259	18530	18880	19425	20165	21101	22232	23559	25081	26799
1210	28552	30106	31511	32891	34246	35577	36882	38163	39419	40650
1220	41878	43136	44413	45690	46966	48242	49519	50796	52072	53349
1230	54625									

Gavins Point (Lewis and Clark Lake) Capacity in Acre-Feet Implemented by MRBWM August 2013 (2011 Surveys)										
ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	0	0	0	0	0	32	150
1170	325	615	893	1231	1698	2366	3307	4591	6289	8472
1180	11211	14182	17129	20231	23664	27606	32234	37725	44256	52005
1190	61148	71661	83347	96123	109908	124620	140176	156494	173493	191090
1200	209203	227608	246264	265368	285114	305698	327316	350163	374434	400326
1210	428033	457430	488245	520452	554027	588945	625181	662710	701507	741548
1220	782807	825305	869080	914132	960460	1008064	1056945	1107103	1158537	1211248
1230	1265235									

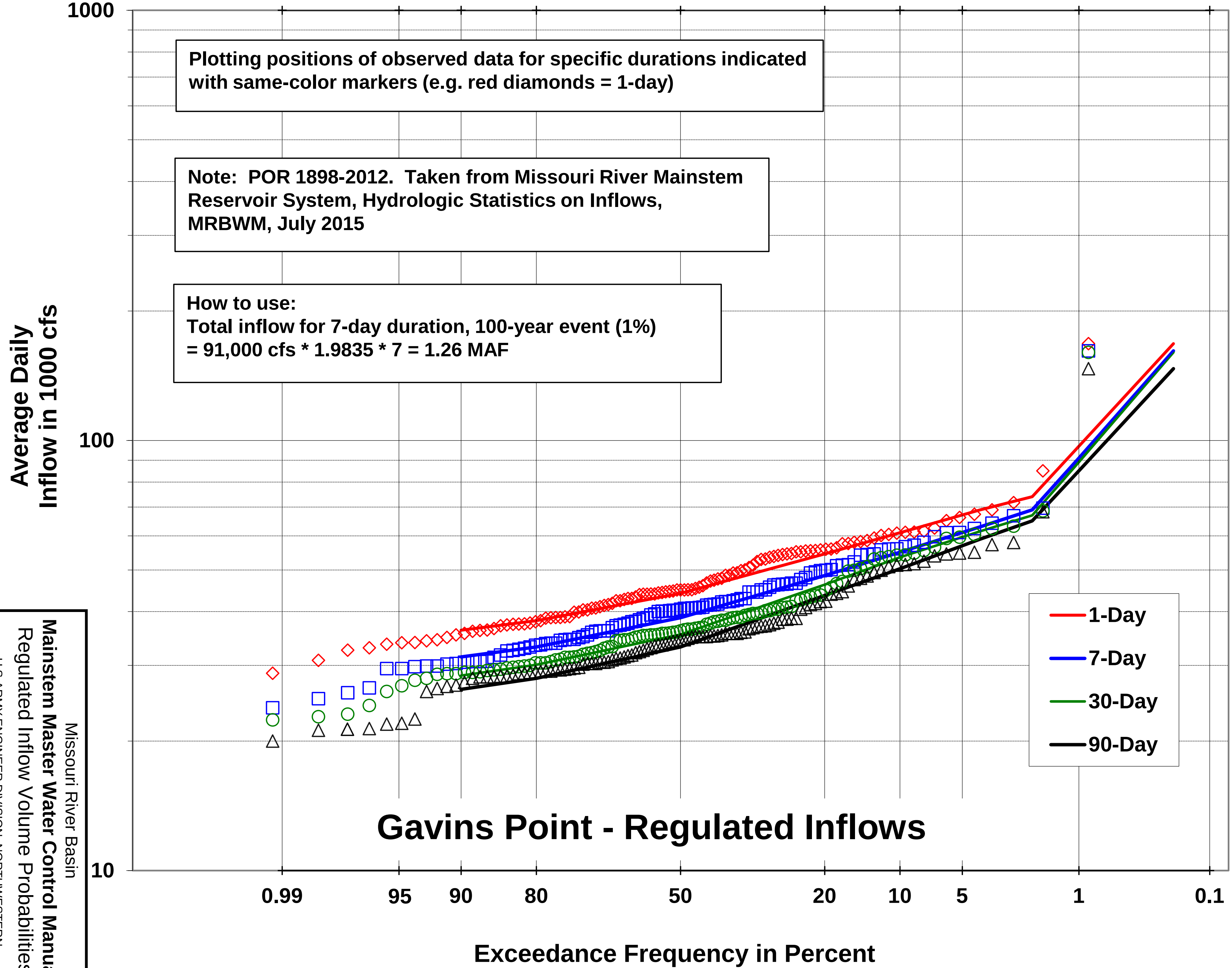
Missouri River Basin
Mainstem Master Water Control Manual
Gavins Point
Area and Capacity Tables
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Missouri River Basin

Mainstem Master Water Control Manual

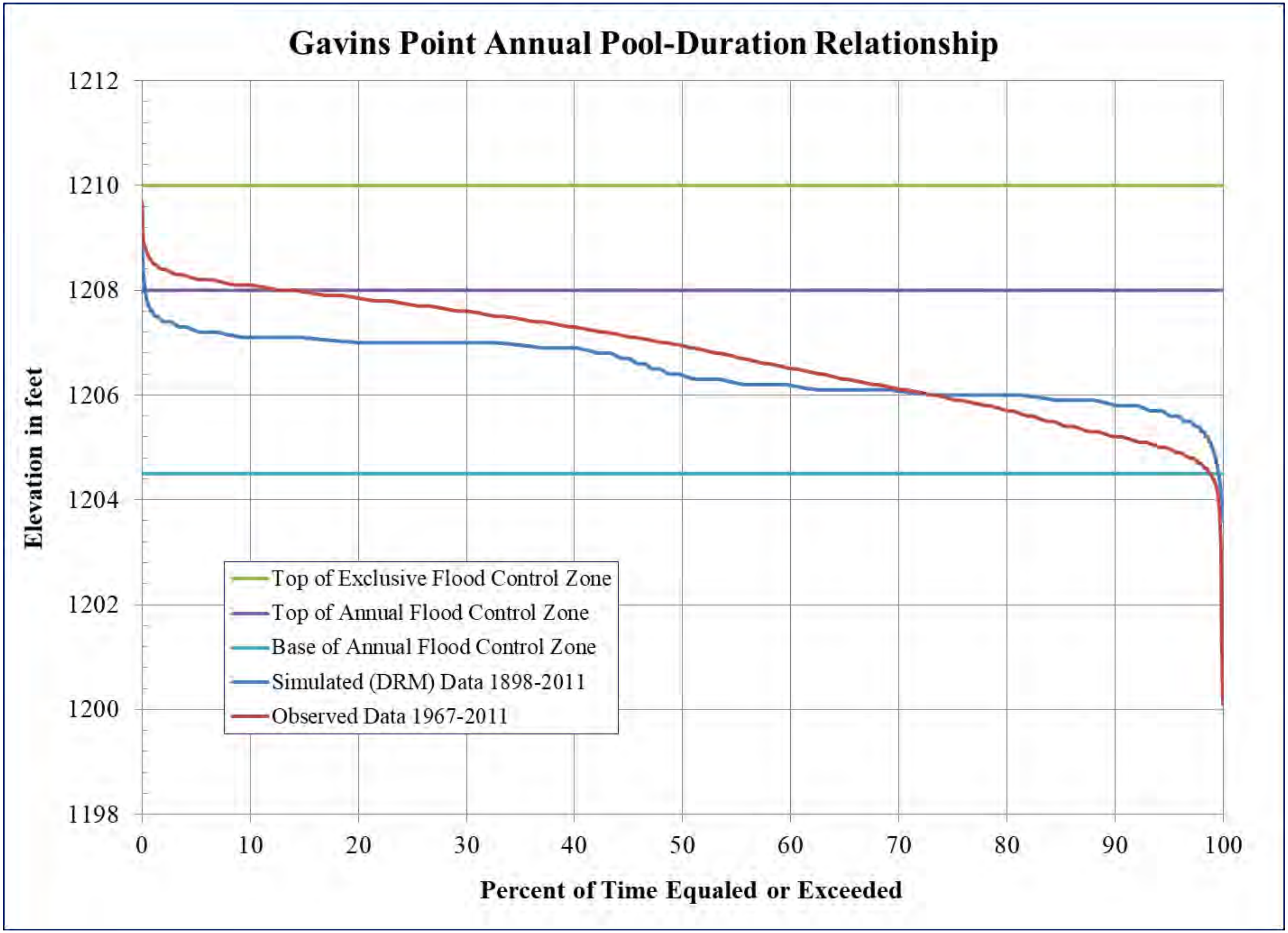
Gavins Point Reservoir, Embankment, Intakes, Powerhouse and Spillway

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



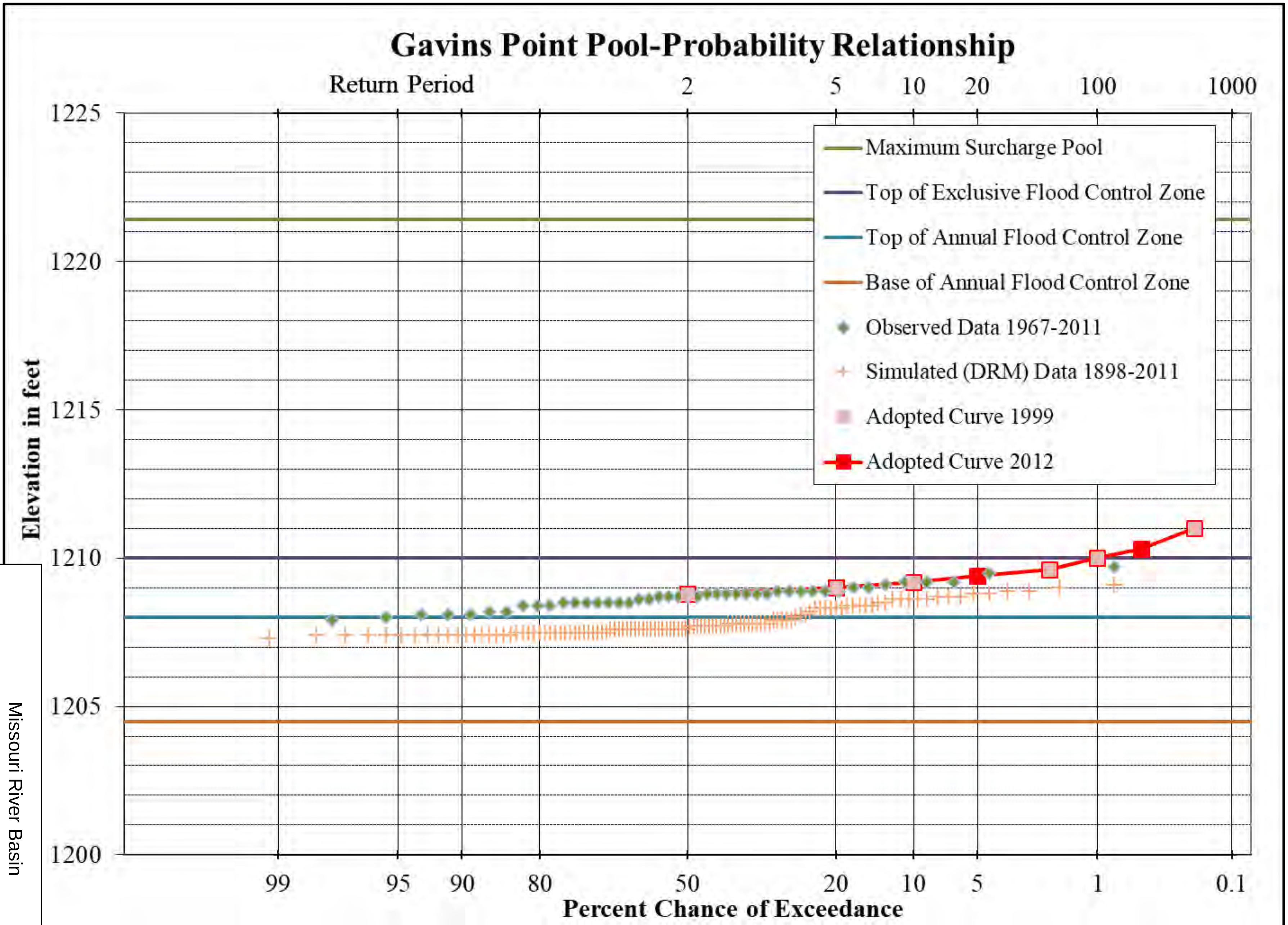
Missouri River Basin
Mainstem Master Water Control Manual
Regulated Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-77



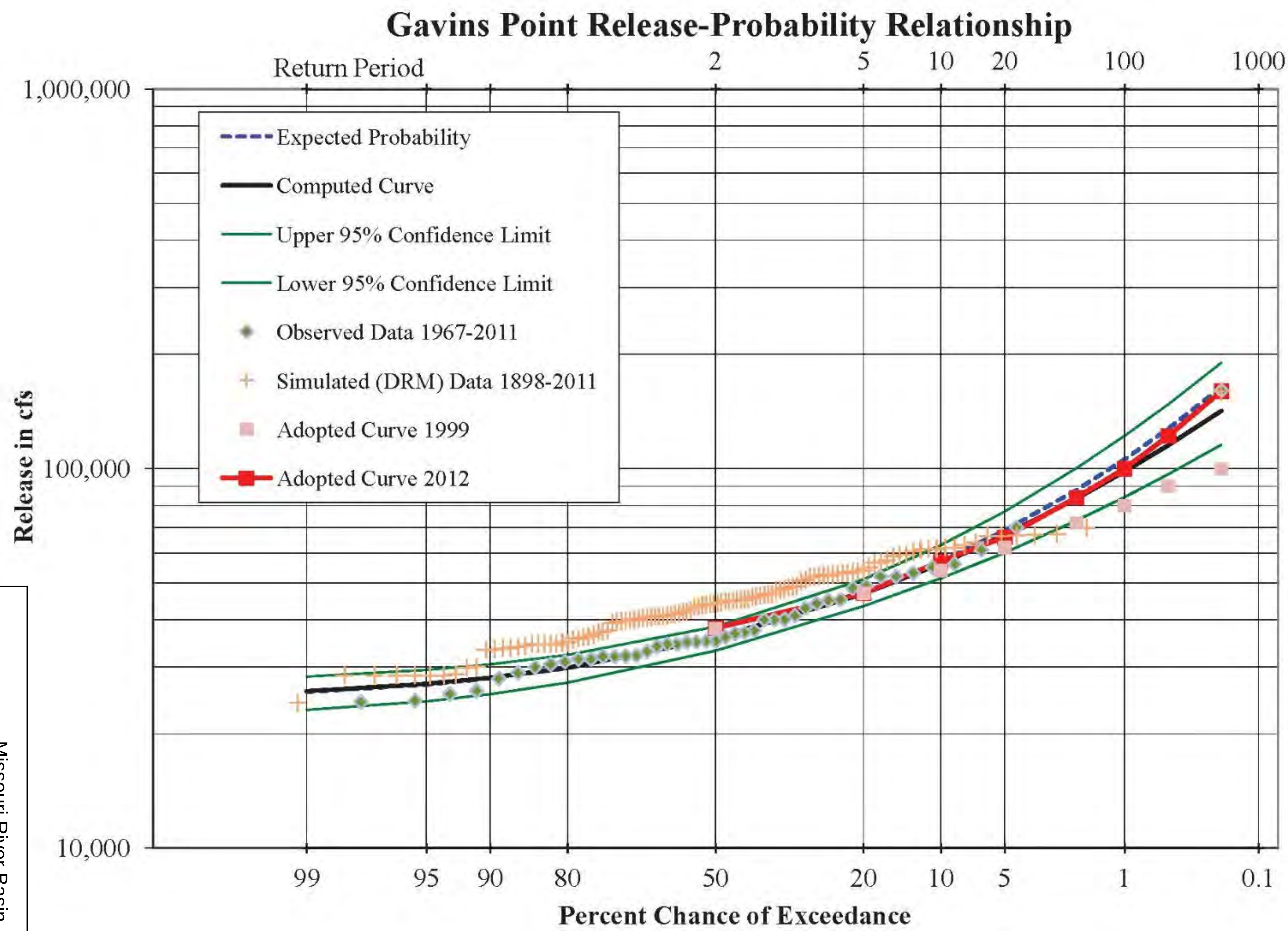
Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin
Mainstem Master Water Control Manual
Gavins Point Pool-Duration Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

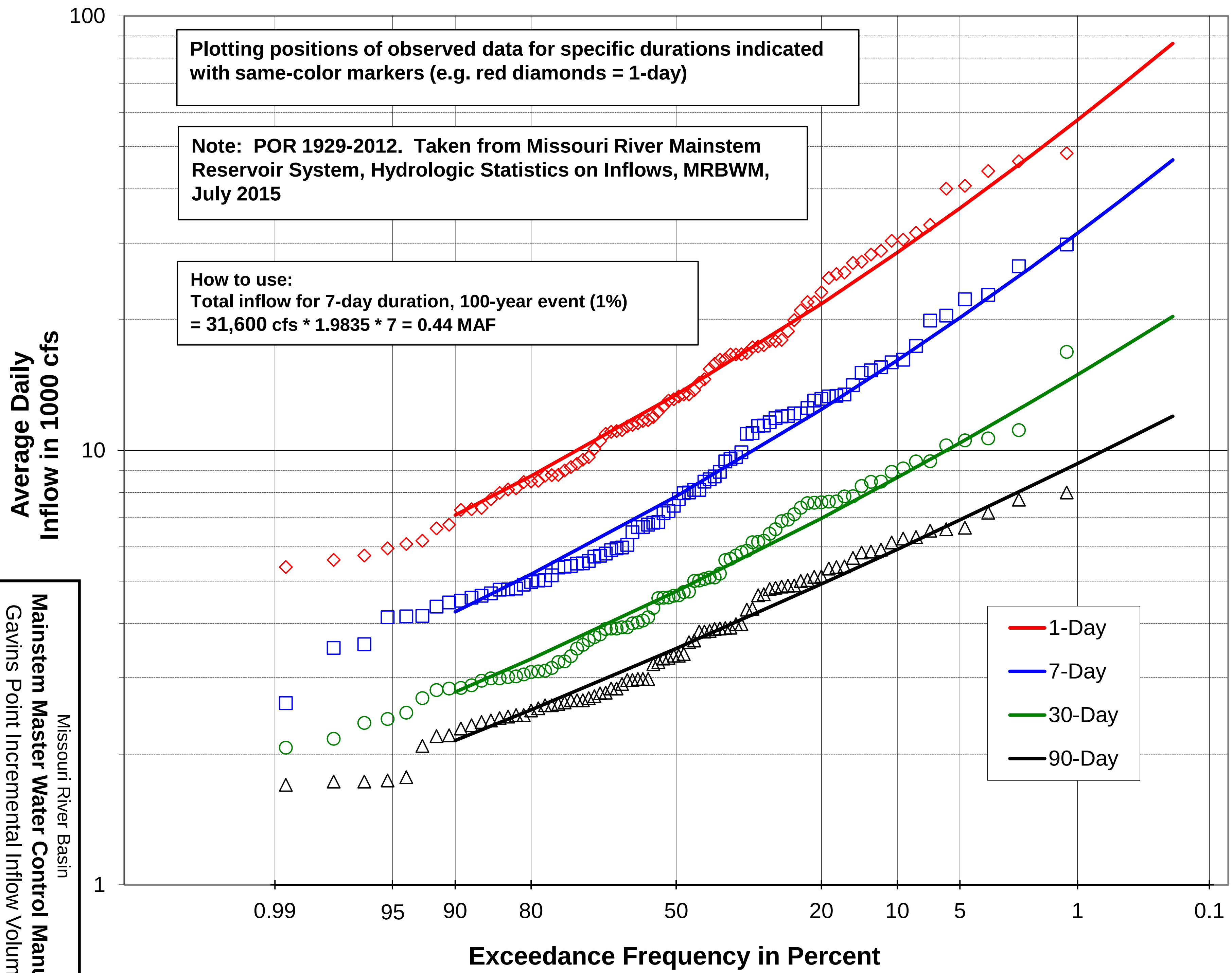


Source: Hydrologic Statistics, MRBWM, September 2013

Missouri River Basin
Mainstem Master Water Control Manual
Gavins Point Pool-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
Gavins Point Release-Probability Relationship
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Incremental Inflow Volume Probabilities

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate II-81

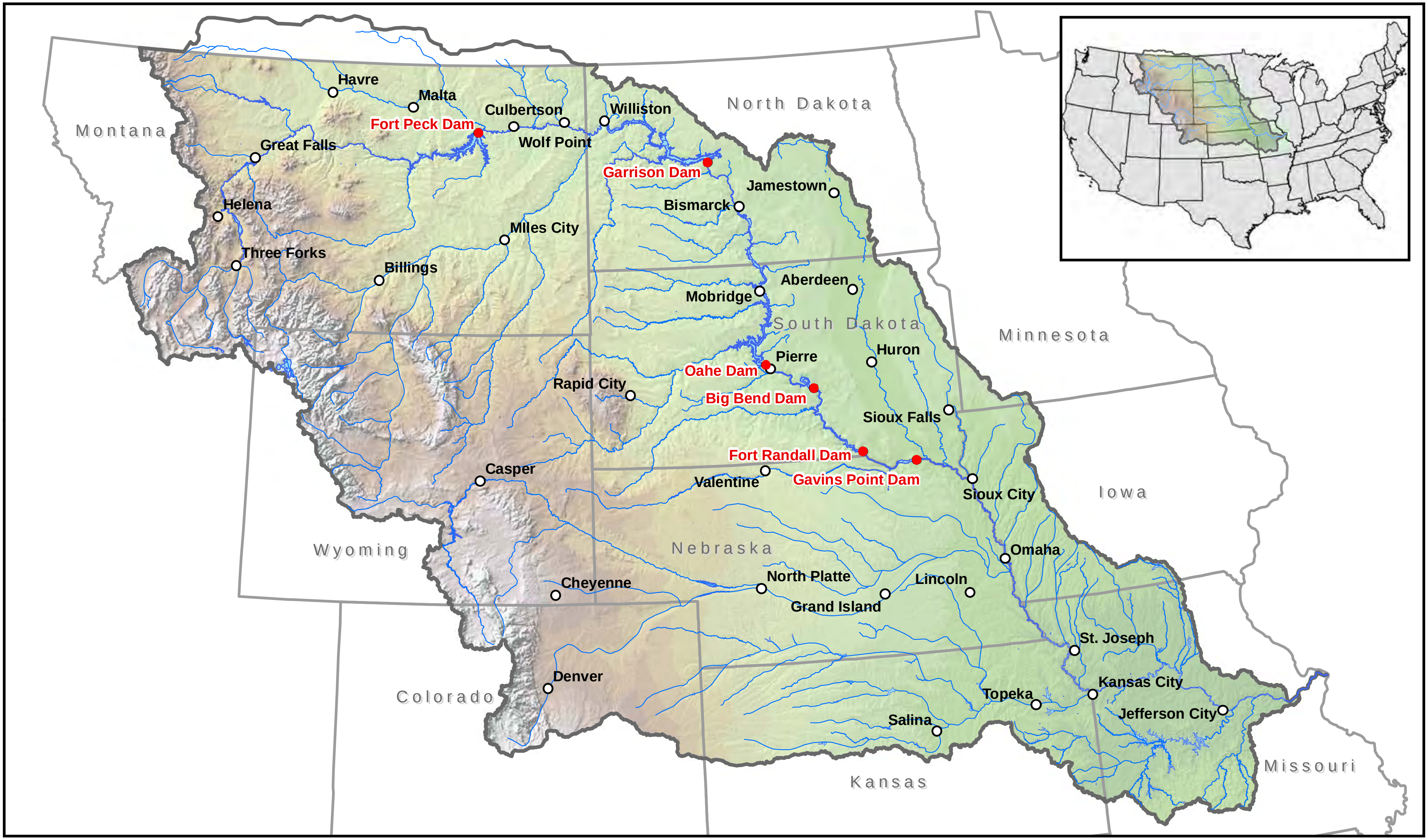


Plate III-1

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

N W E S

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

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Missouri River Basin
Mainstem Master Water Control Manual
General Location
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

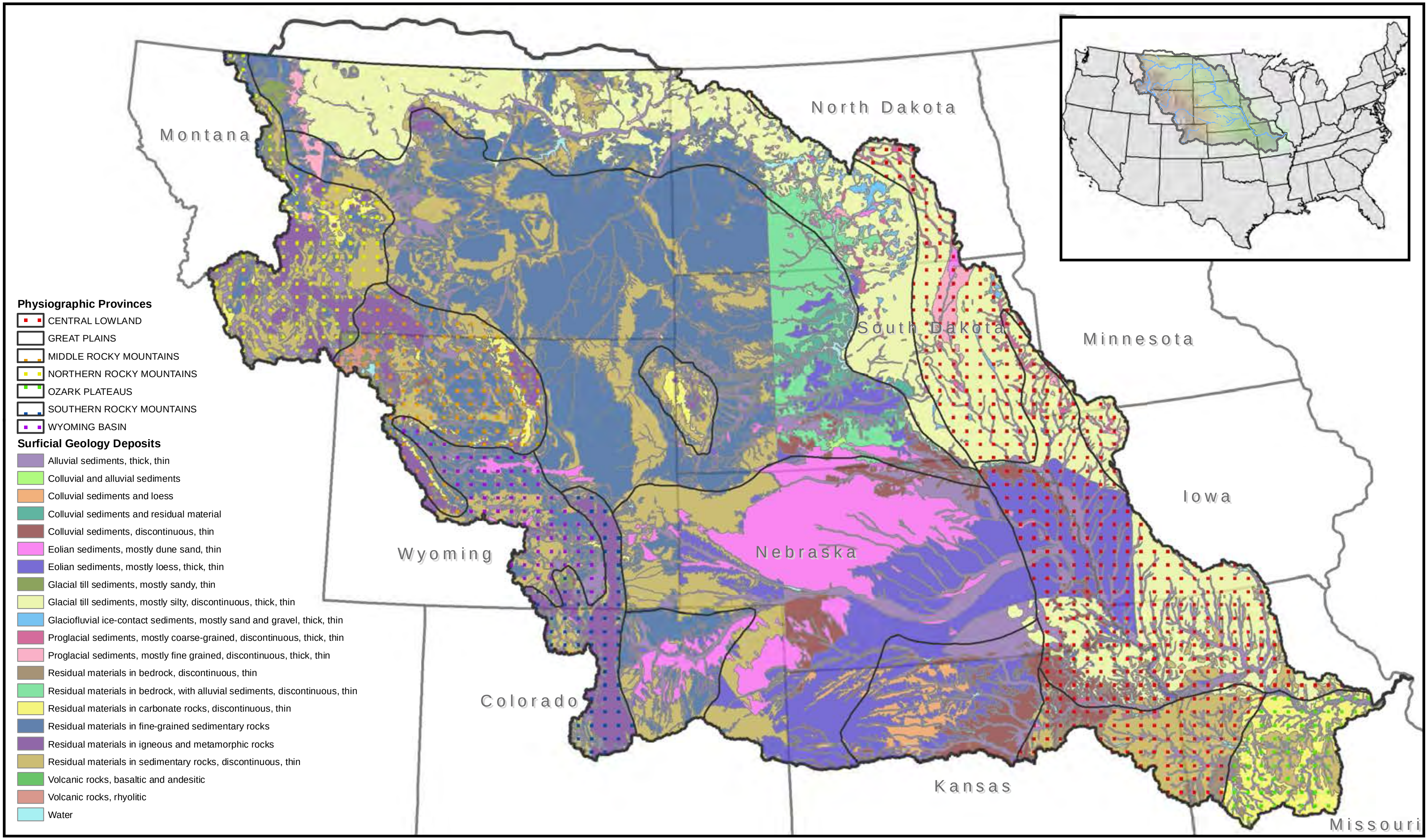

Plate III-2

US Army Corps of Engineers®
Northwestern Division

Omaha/Kansas City District Boundaries
State Boundaries

0 50 100 200 300 Miles

N W E S

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

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Missouri River Basin
Mainstem Master Water Control Manual
PHYSIOGRAPHIC PROVINCES &
SURFICIAL GEOLOGY DEPOSITS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate III-3

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

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

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Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

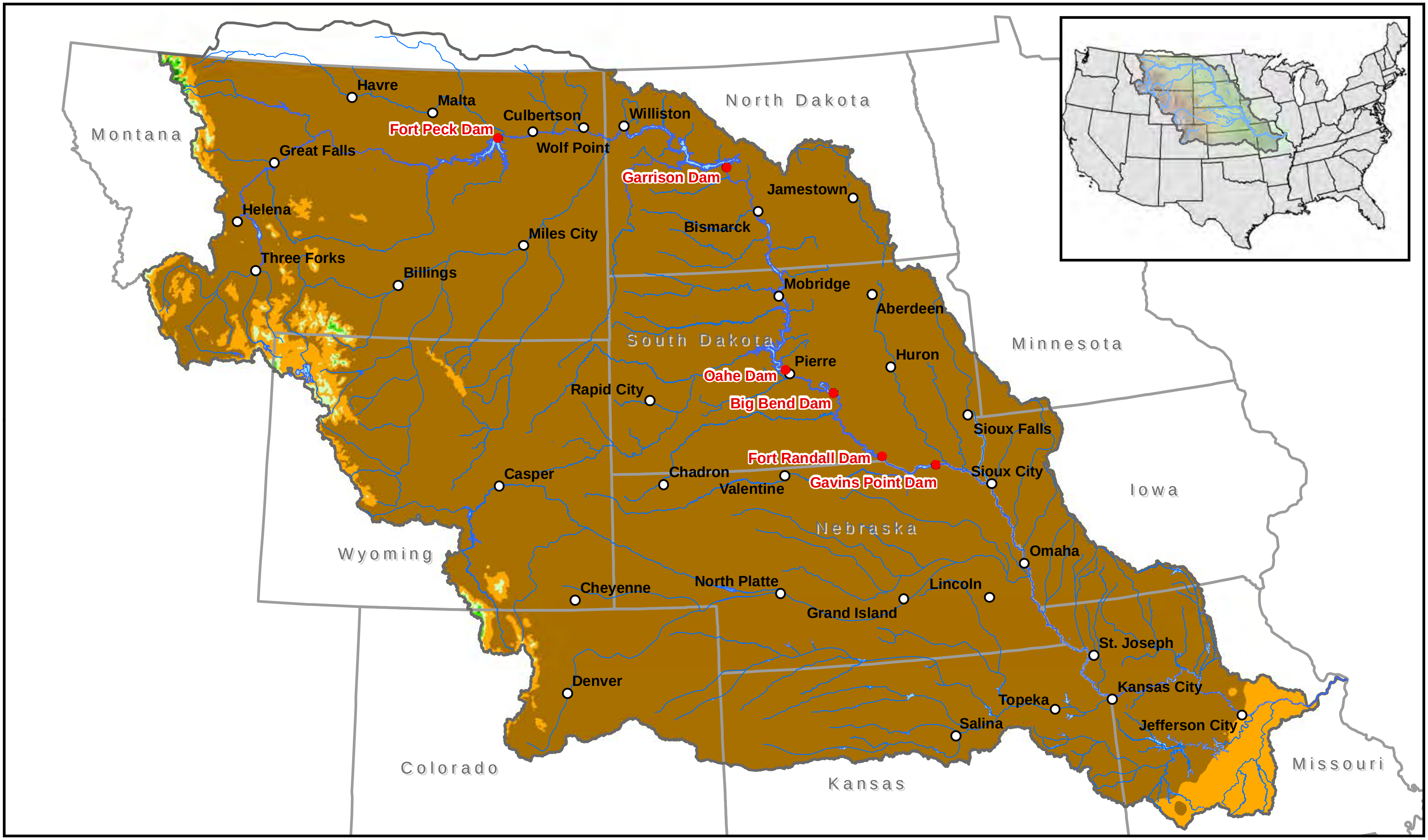


Plate III-4

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - January

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

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

N W E S

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - JANUARY
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

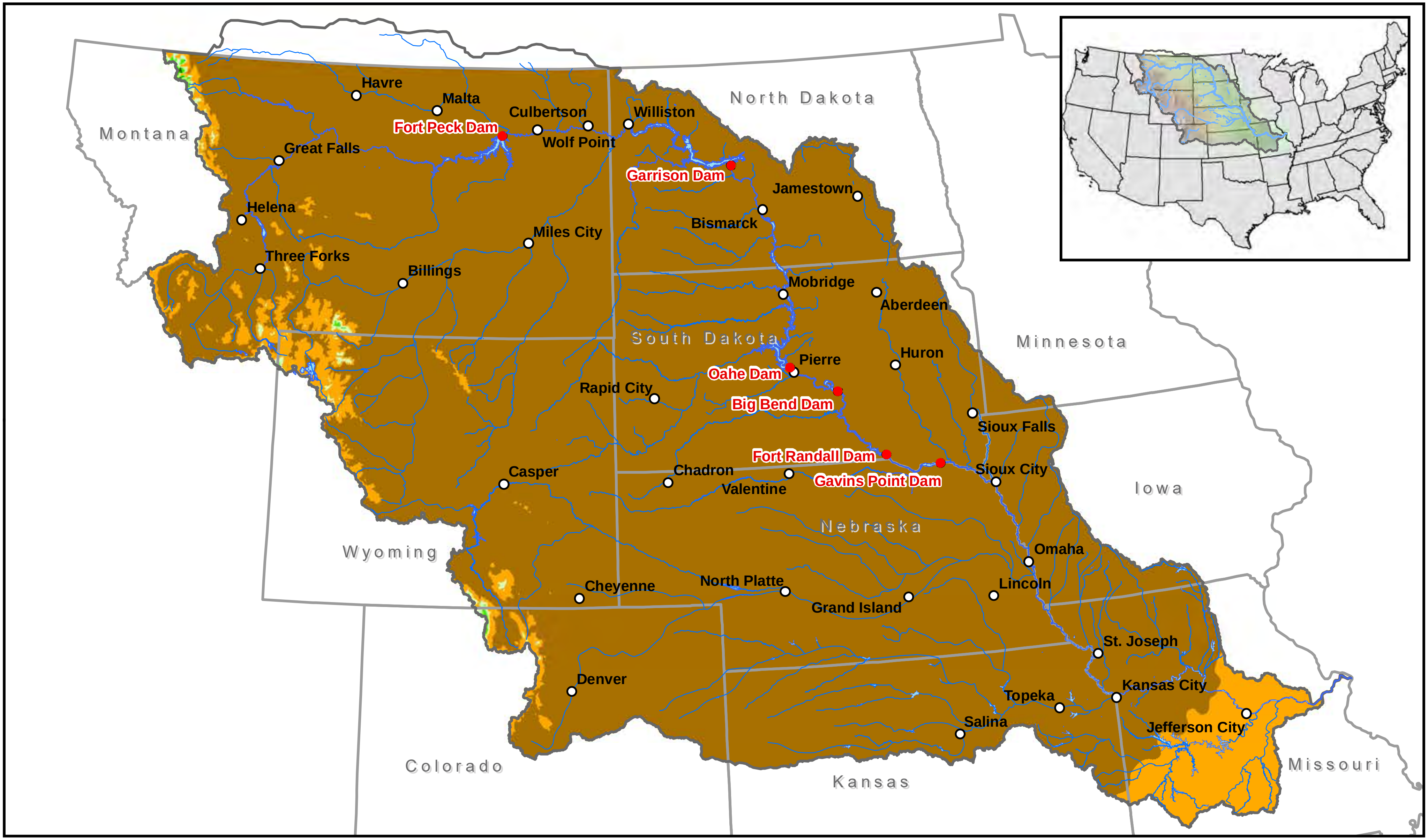


Plate III-5

US Army Corps of Engineers®
Northwestern Division

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - FEBRUARY
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

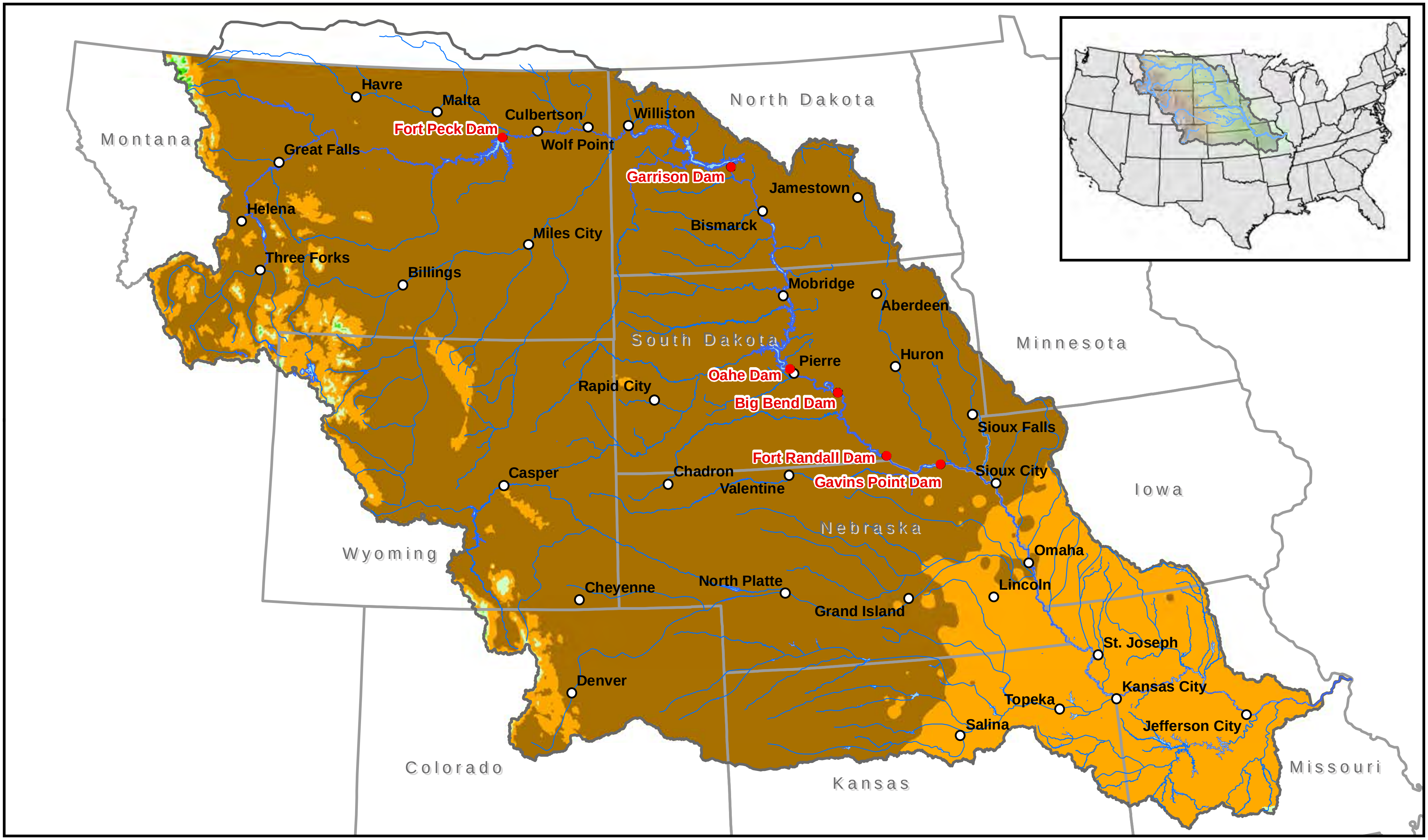


Plate III-6

US Army Corps of Engineers® Northwestern Division

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

Average Precipitation - March

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

N E S W

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - MARCH
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate III-7

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - April

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - APRIL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

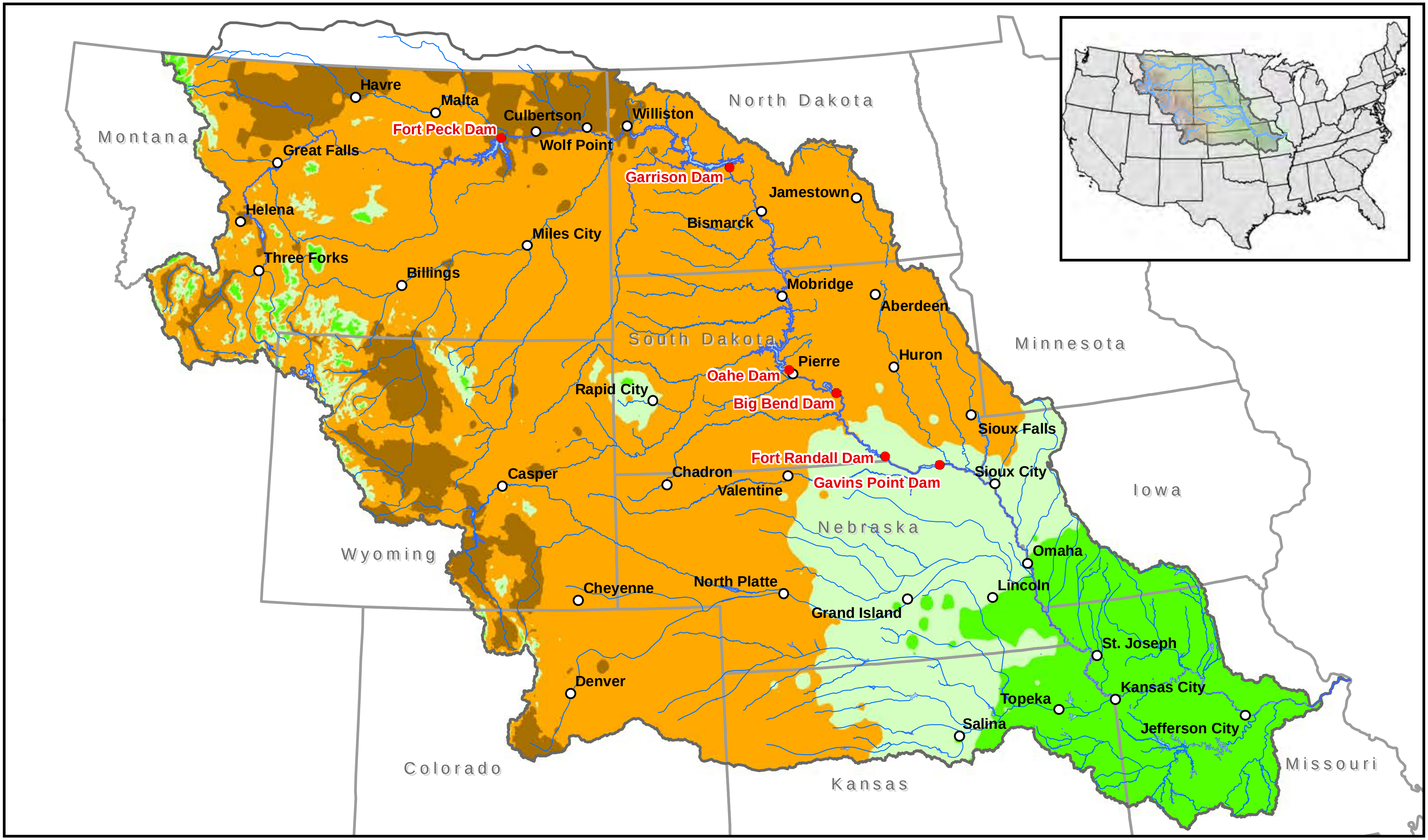


Plate III-8

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - May

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - MAY
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

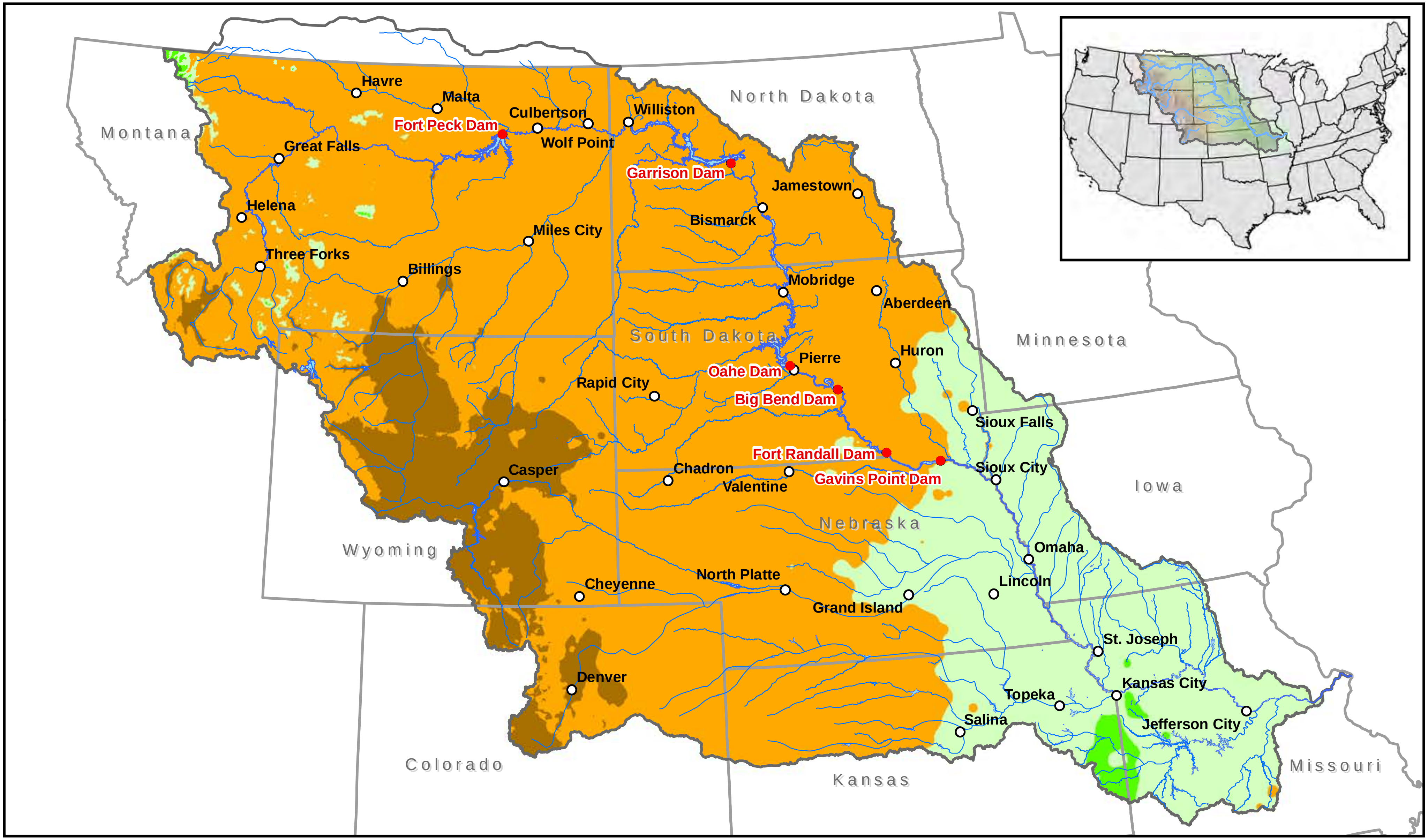


Plate III-9

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - June

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - JUNE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

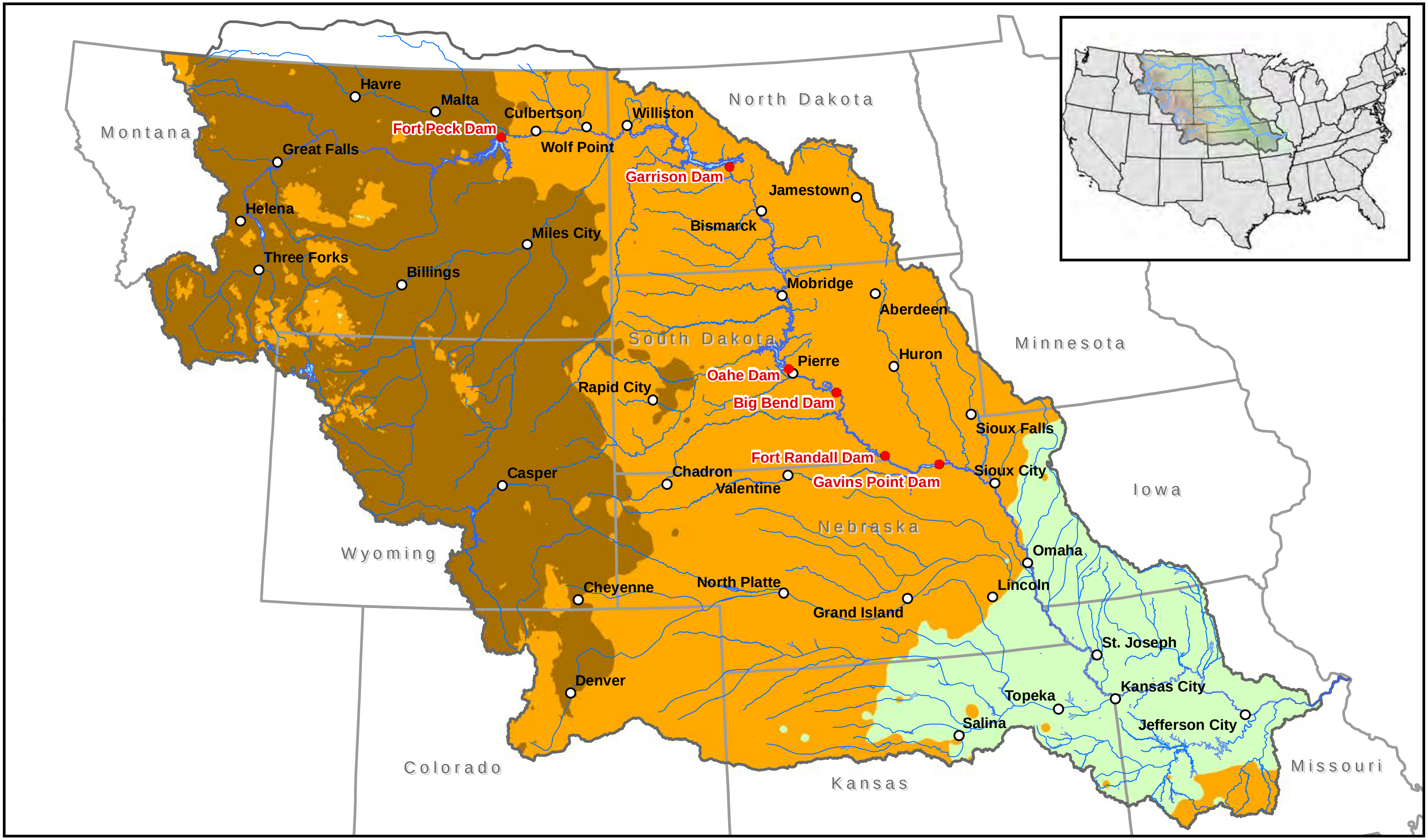


Plate III-10

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - July

< 2.0"
2.0" - 4.0"
4.0" - 6.0"
6.0" - 8.0"
> 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - JULY
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

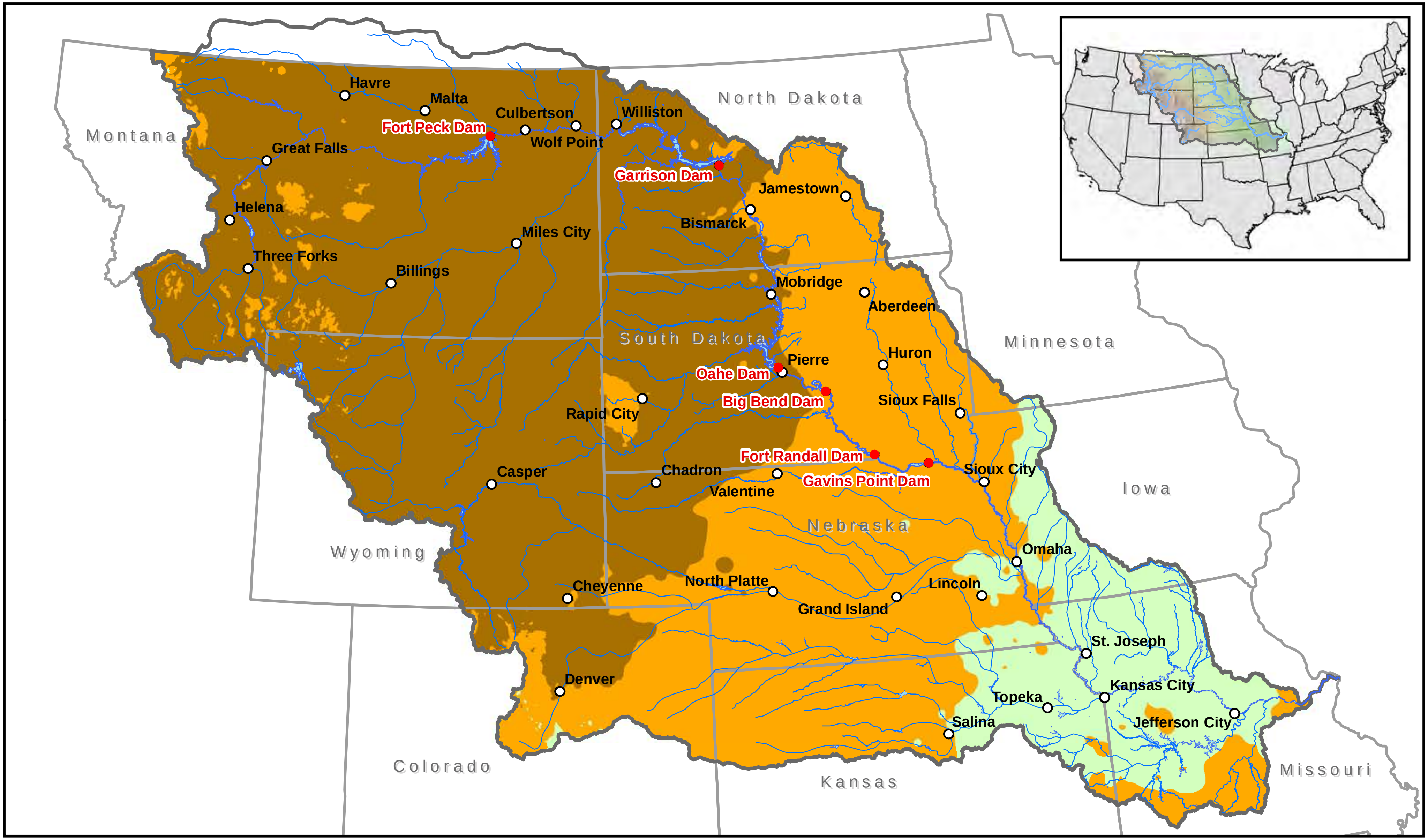


Plate III-11

US Army Corps of Engineers® Northwestern Division

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

Average Precipitation - August

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - AUGUST
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

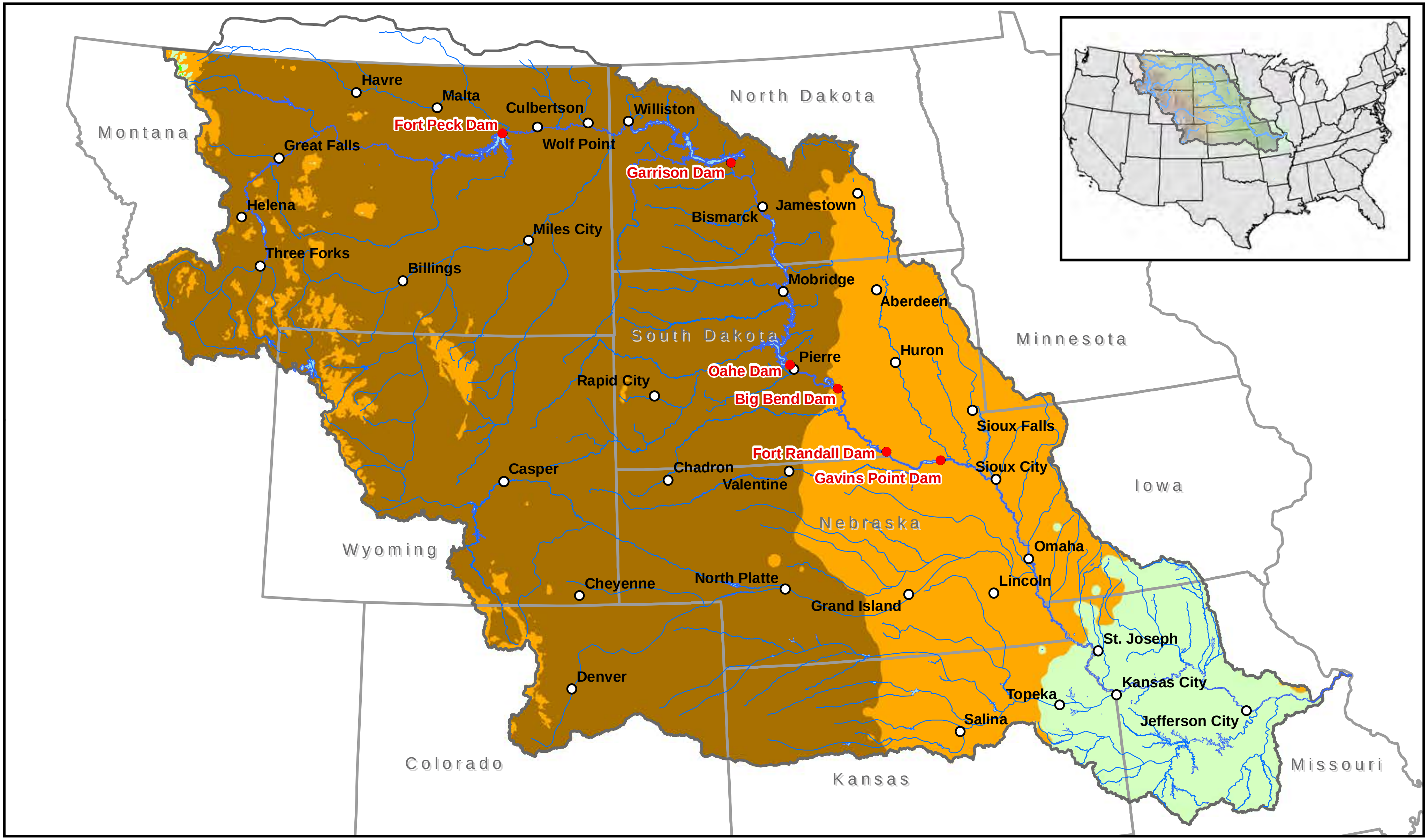


Plate III-12

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - September

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- > 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - SEPTEMBER
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

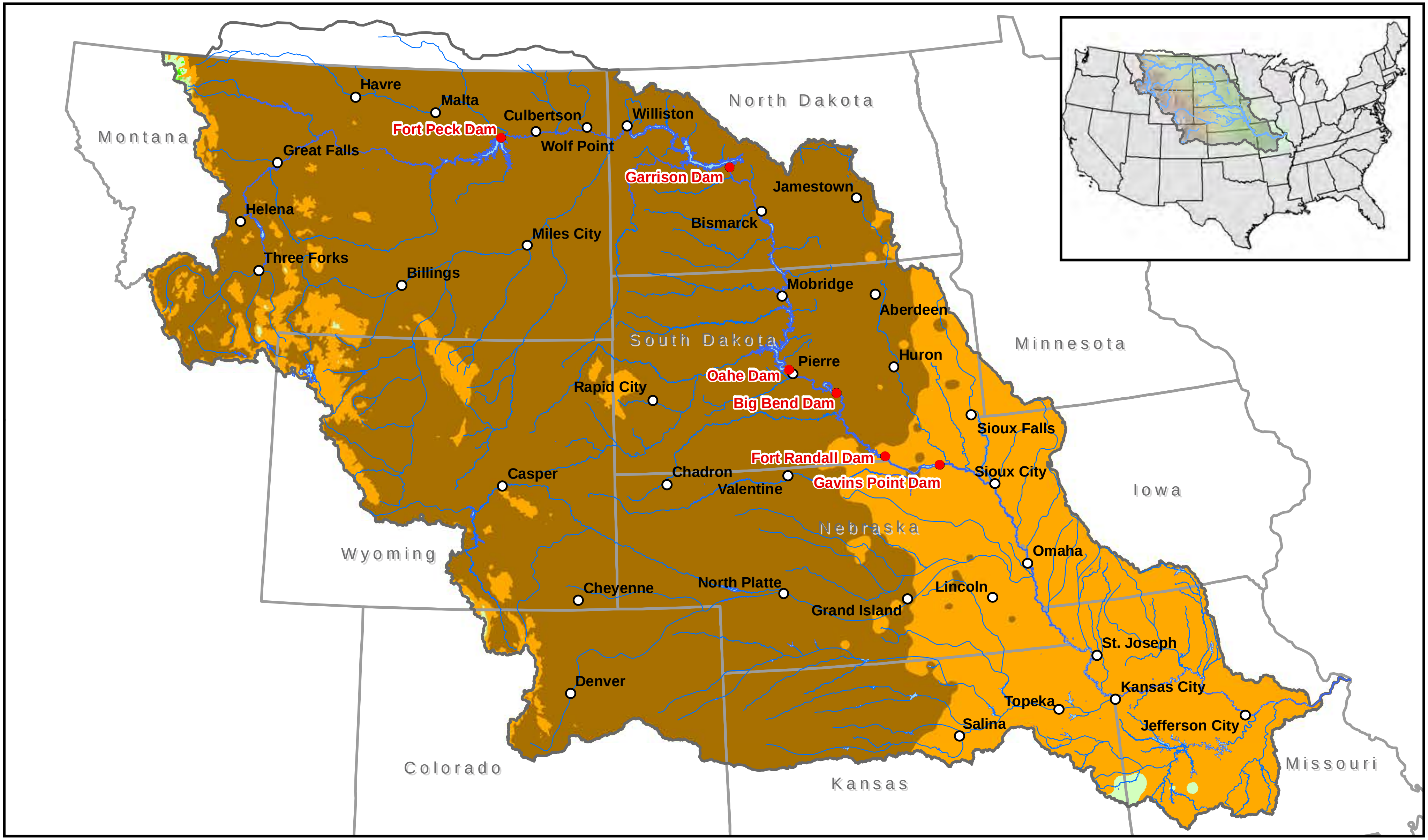


Plate III-13

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - October

< 2.0"
2.0" - 4.0"
4.0" - 6.0"
6.0" - 8.0"
> 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - OCTOBER
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

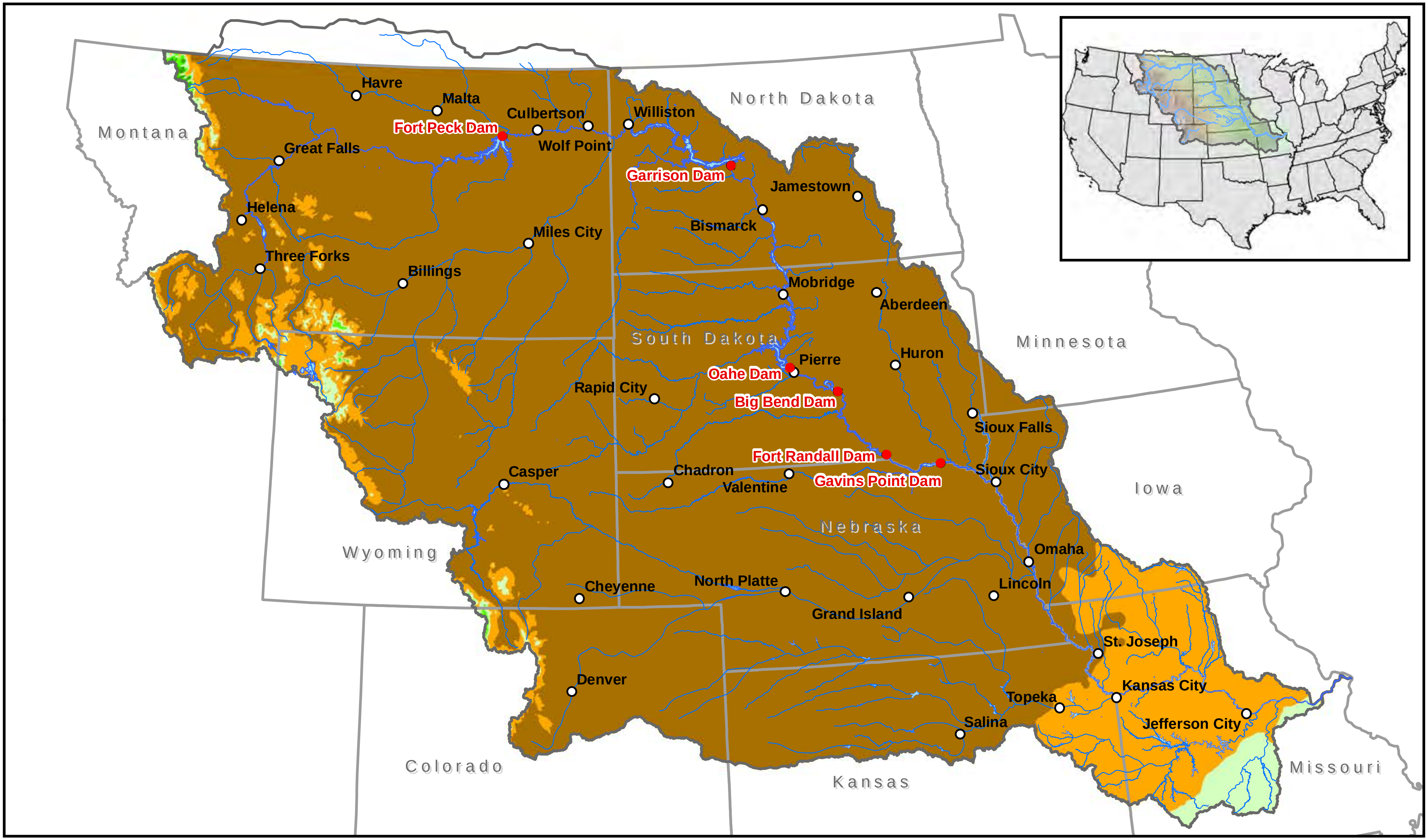


Plate III-14

US Army Corps of Engineers®
Northwestern Division

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

Average Precipitation - November

- < 2.0"
- 2.0" - 4.0"
- 4.0" - 6.0"
- 6.0" - 8.0"
- < 8.0"

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - NOVEMBER
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

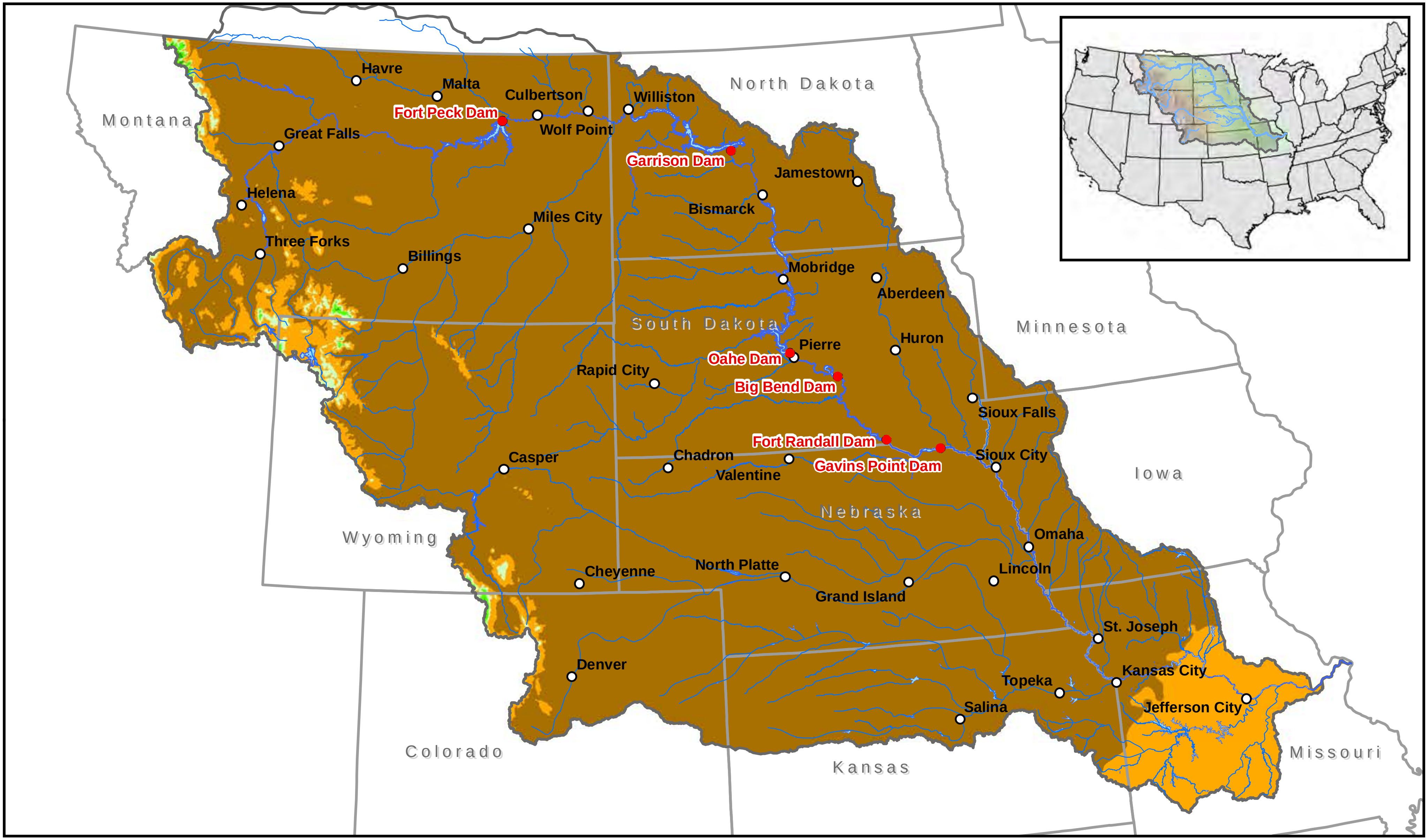


Plate III-15

US Army Corps of Engineers®
Northwestern Division

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

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

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE PRECIPITATION - DECEMBER
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

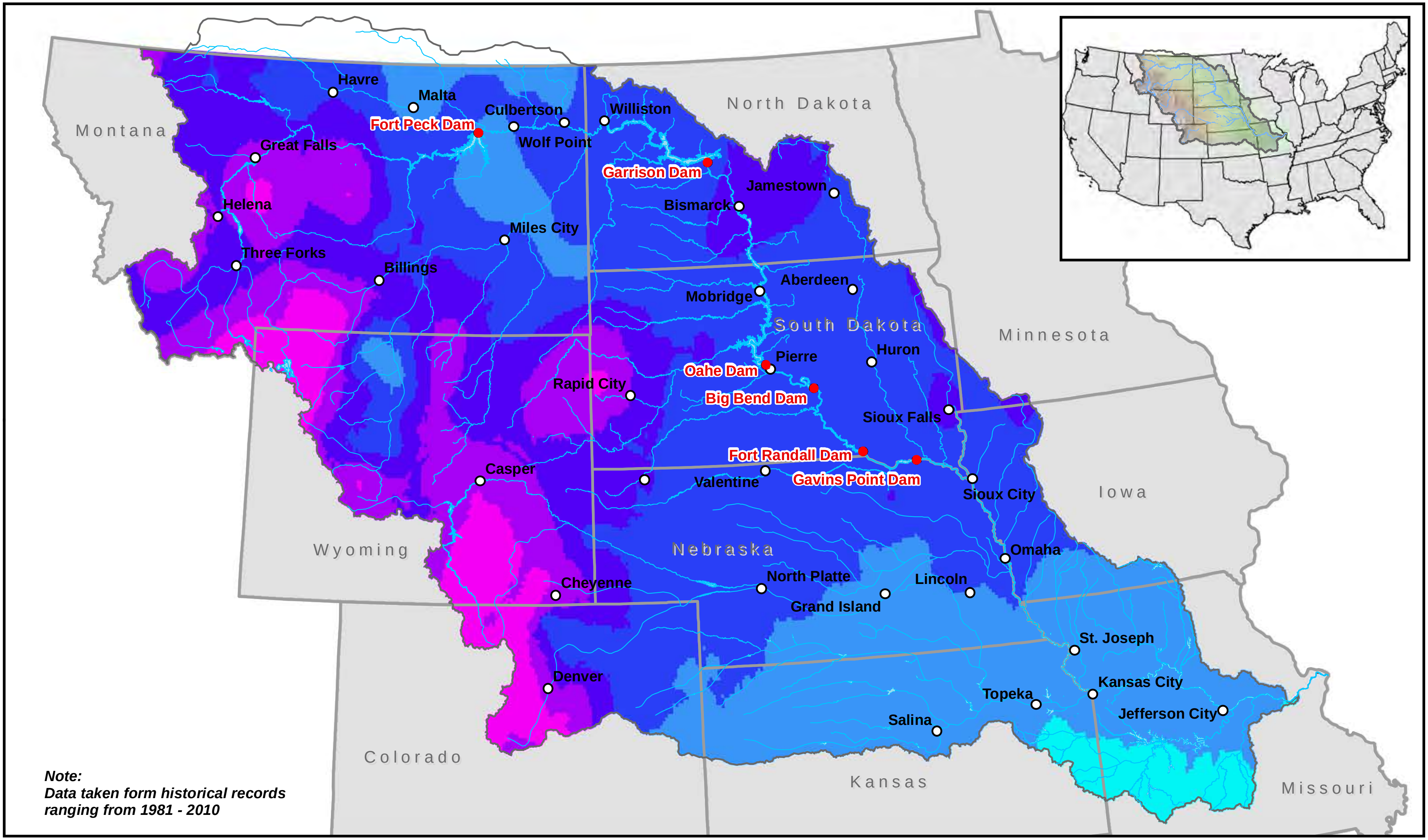


Plate III-16

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

G:\2016_DivisionMaps\MO_Snow\mxd\Annual_Mean_Snowfall.mxd

Missouri River Basin
Mainstem Master Water Control Manual
ANNUAL MEAN SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

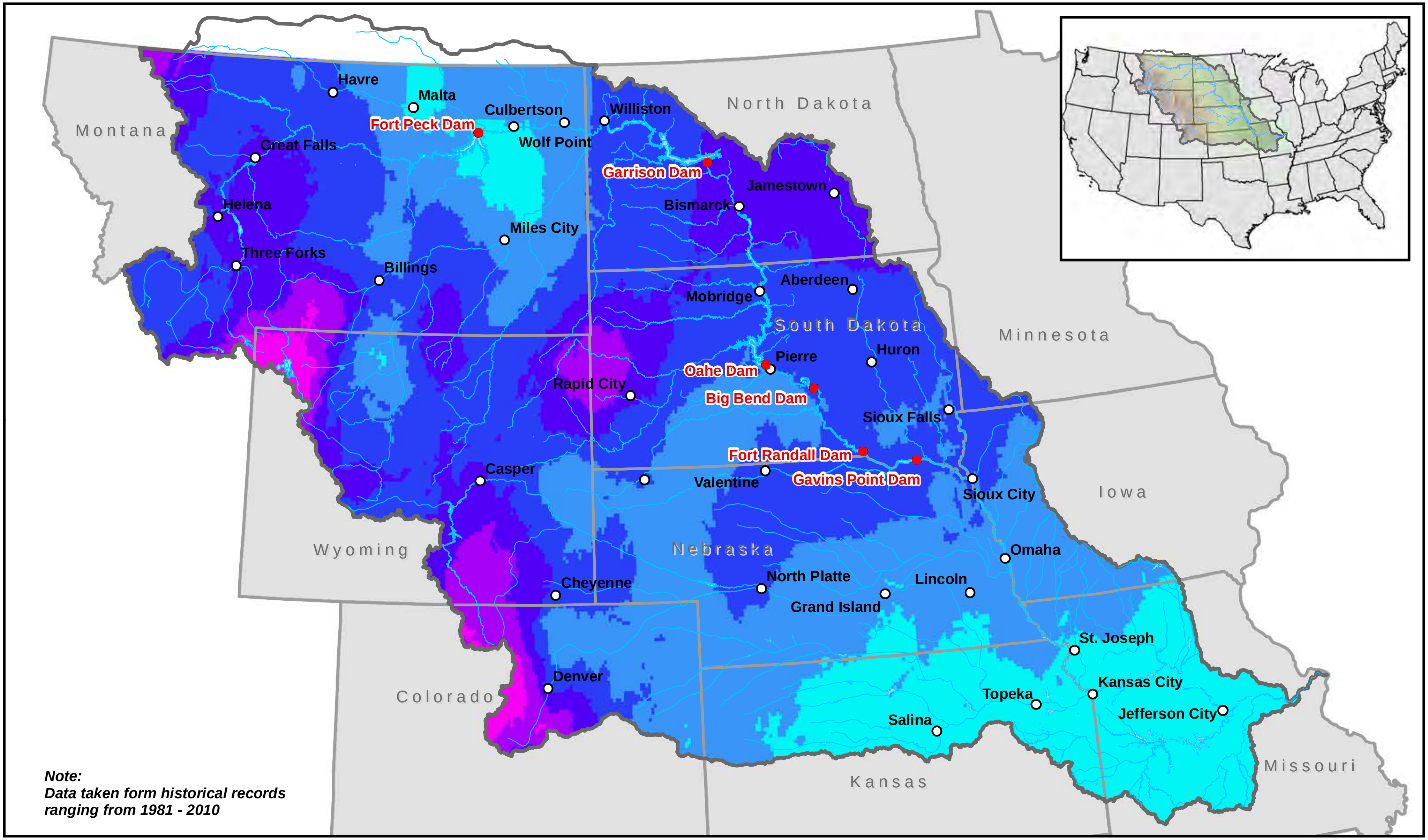


Plate III-17

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

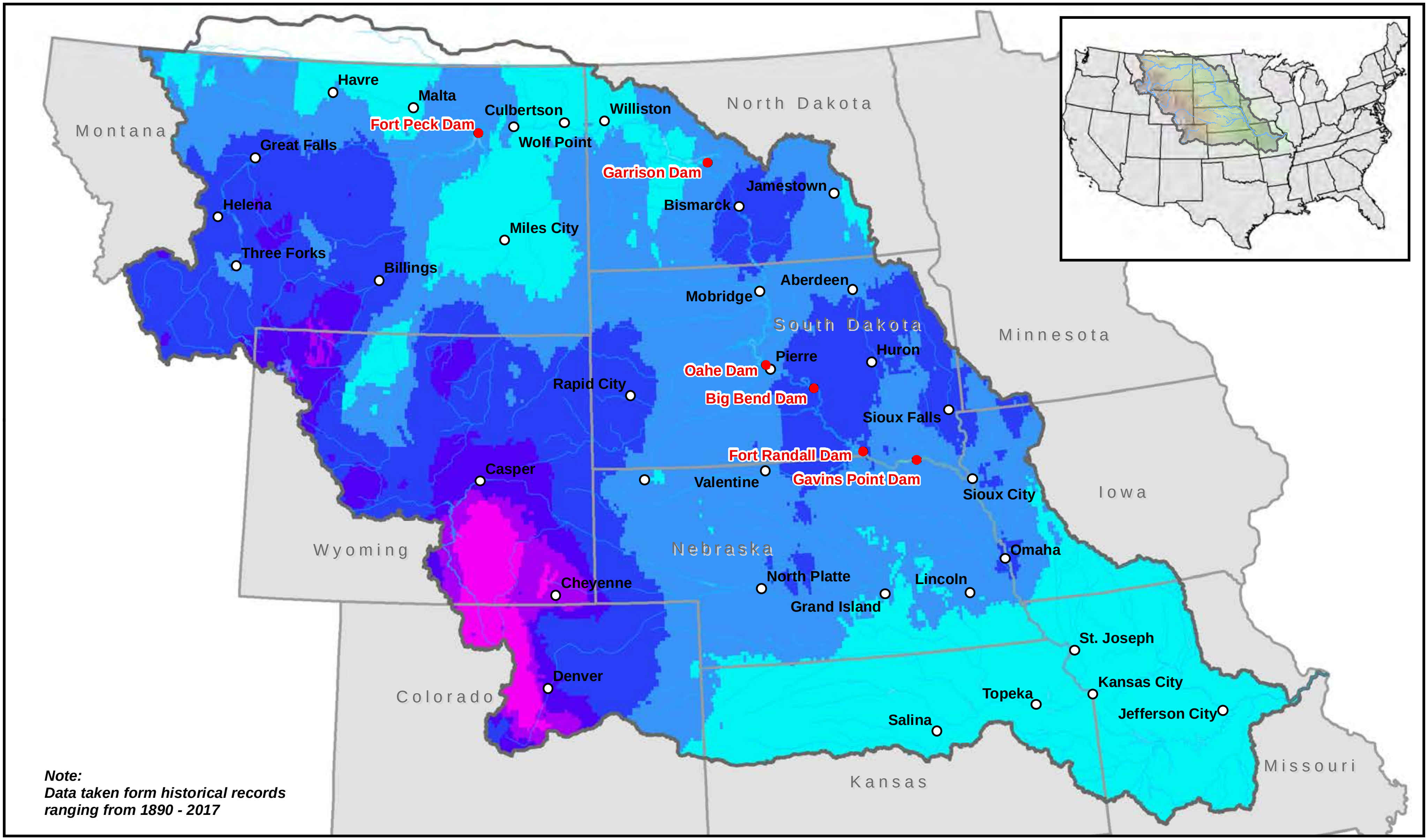
0 50 100 200 300 Miles

N W E S

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

G:\2016_DivisionMaps\MO_Snow\mxd\Annual_Max_Snowfall.mxd

Missouri River Basin
Mainstem Master Water Control Manual
ANNUAL MAXIMUM SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Note:
Data taken form historical records ranging from 1890 - 2017

Plate III-18

US Army Corps of Engineers®
Northwestern Division

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

Extreme Minimum Snowfall

- < 5 Inches
- 5 - 10 Inches
- 10 - 20 Inches
- 20 - 30 Inches
- 30 - 40 Inches
- < 40 Inches

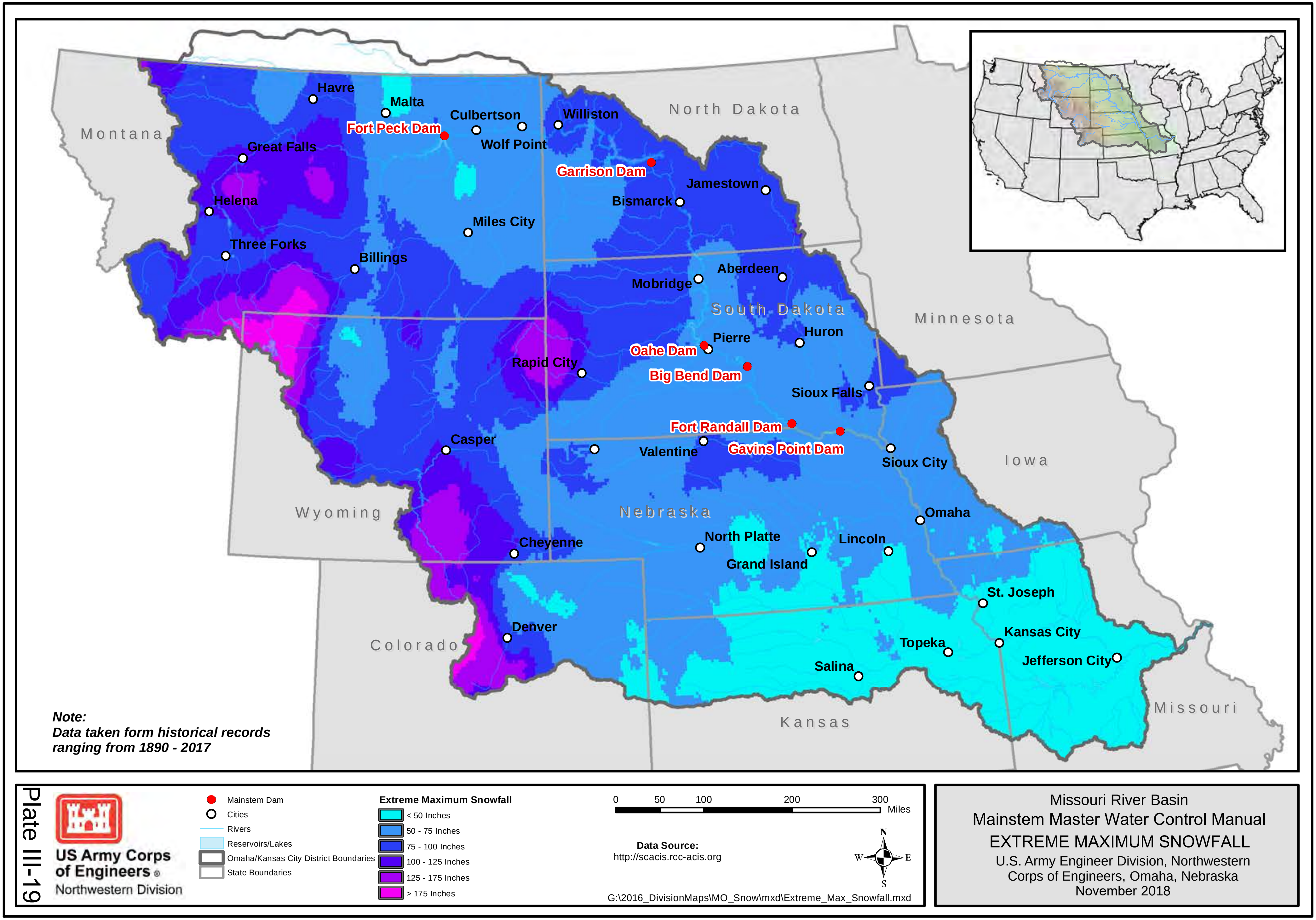
0 50 100 200 300 Miles

N W E S

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

G:\2016_DivisionMaps\MO_Snow\mxd\Extreme_Min_Snowfall.mxd

Missouri River Basin
Mainstem Master Water Control Manual
EXTREME MINIMUM SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
EXTREME MAXIMUM SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

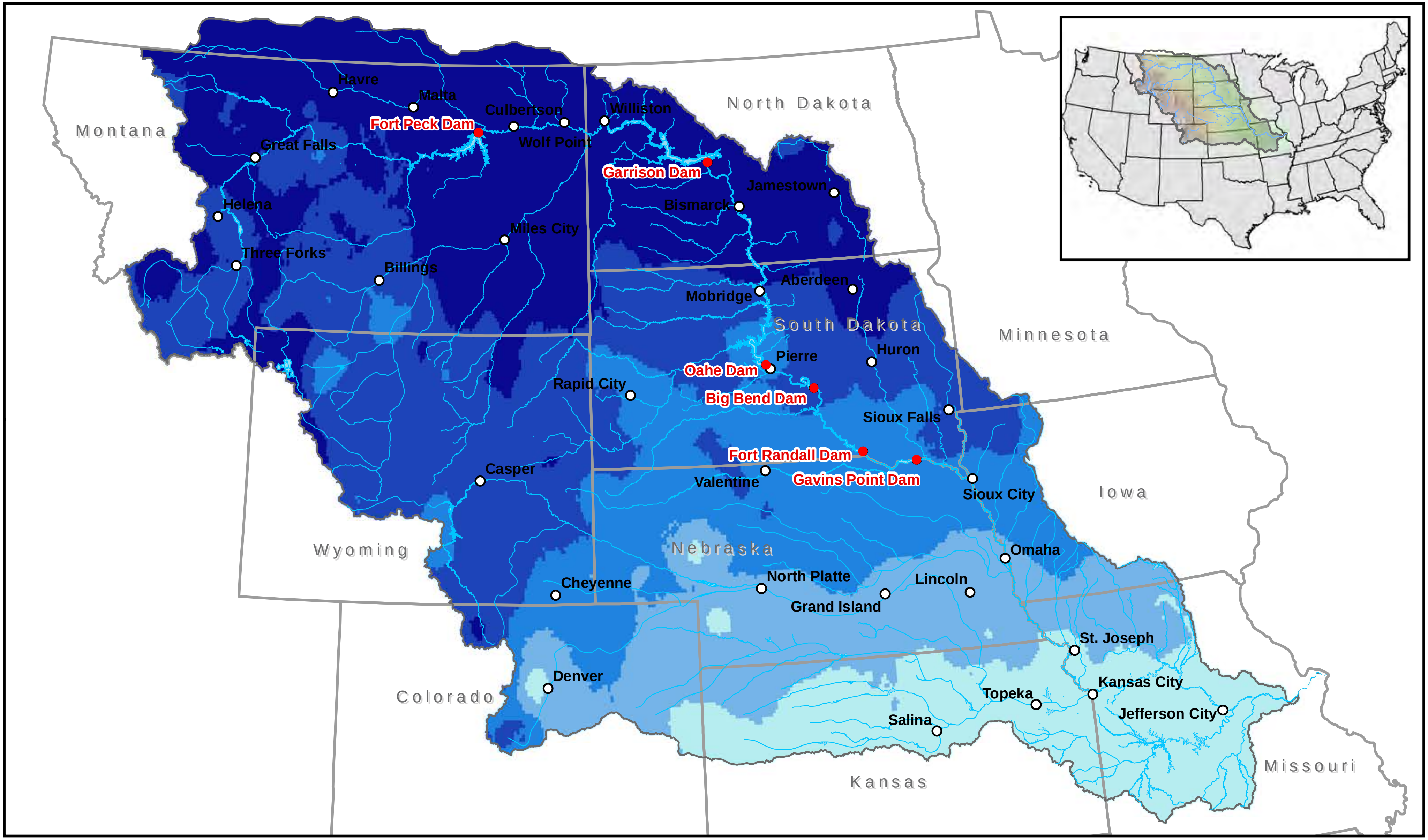


Plate III-20

US Army Corps of Engineers®
Northwestern Division

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

G:\2016_DivisionMaps\MO_Temp\mxd\Annual_Average_Min_Temp.mxd

Missouri River Basin
Mainstem Master Water Control Manual
AVERAGE MINIMUM TEMPERATURE - ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

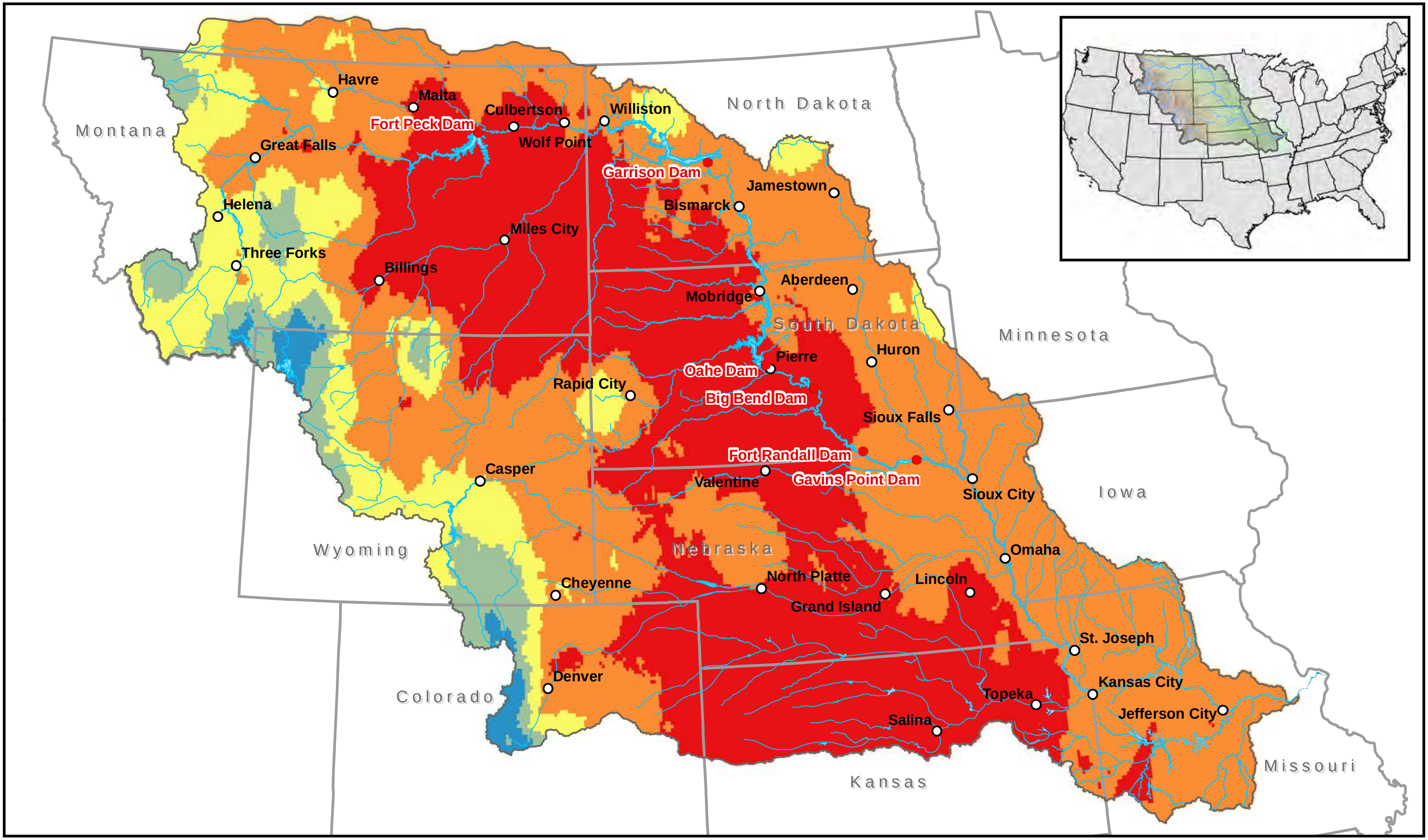


Plate III-21

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 W E S

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

G:\2016_DivisionMaps\MO_Temp\mxd\Annual_Average_Max_Temp.mxd

Missouri River Basin
Mainstem Master Water Control Manual

AVERAGE MAXIMUM TEMPERATURE - ANNUAL

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

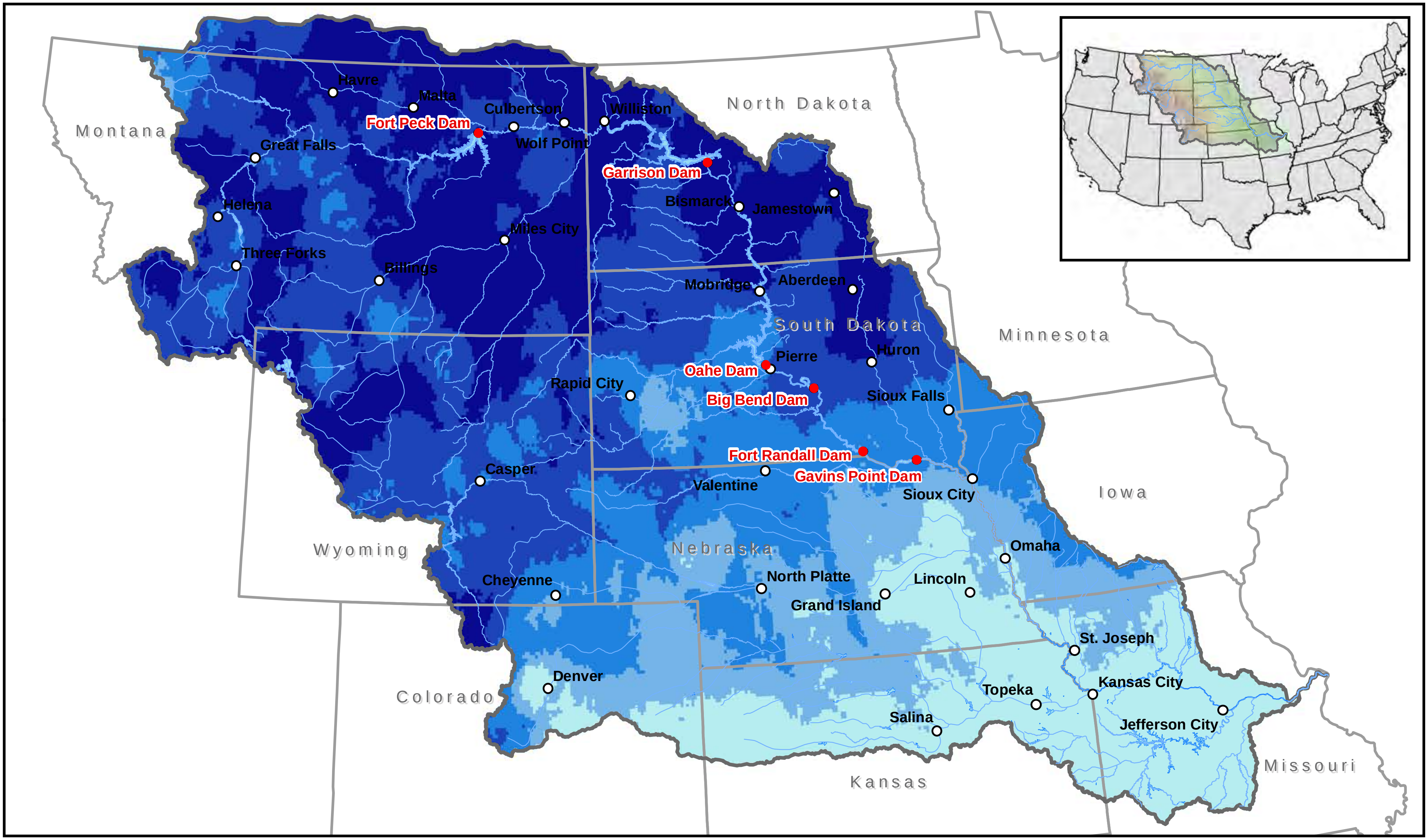


Plate III-22

US Army Corps of Engineers®
Northwestern Division

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

Extreme Minimum Temperature - Annual

- -47°F to -38°F
- -38°F to -33°F
- -33°F to -28°F
- -28°F to -23°F
- -23°F to -13°F

0 50 100 200 300 Miles

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

N W E S

G:\2016_DivisionMaps\MO_Temp\mxd\Annual_Extreme_Min_Temp.mxd

Missouri River Basin
Mainstem Master Water Control Manual
EXTREME MINIMUM TEMPERATURE - ANNUAL

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

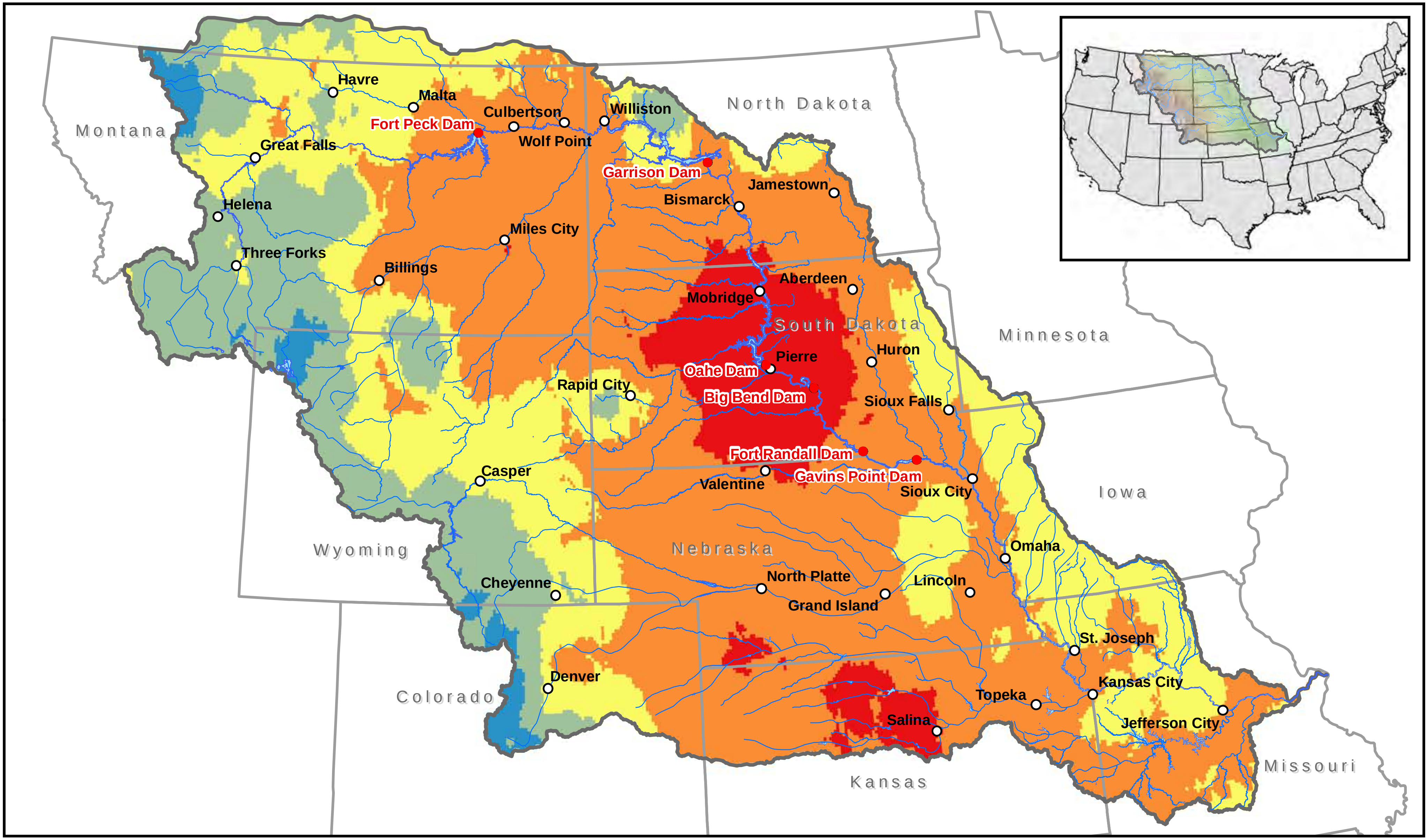


Plate III-23

US Army Corps of Engineers®
Northwestern Division

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

Extreme Maximum Temperature - Annual

- 79°F - 90°F
- 90°F - 100°F
- 100°F - 105°F
- 105°F - 110°F
- 110°F - 114°F

0 50 100 200 300 Miles

N S E W

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

G:\2016_DivisionMaps\MO_Temp\mxd\Annual_Extreme_Max_Temp.mxd

Missouri River Basin
Mainstem Master Water Control Manual
EXTREME MAXIMUM TEMPERATURE - ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Missouri River Mainstem Reservoir System

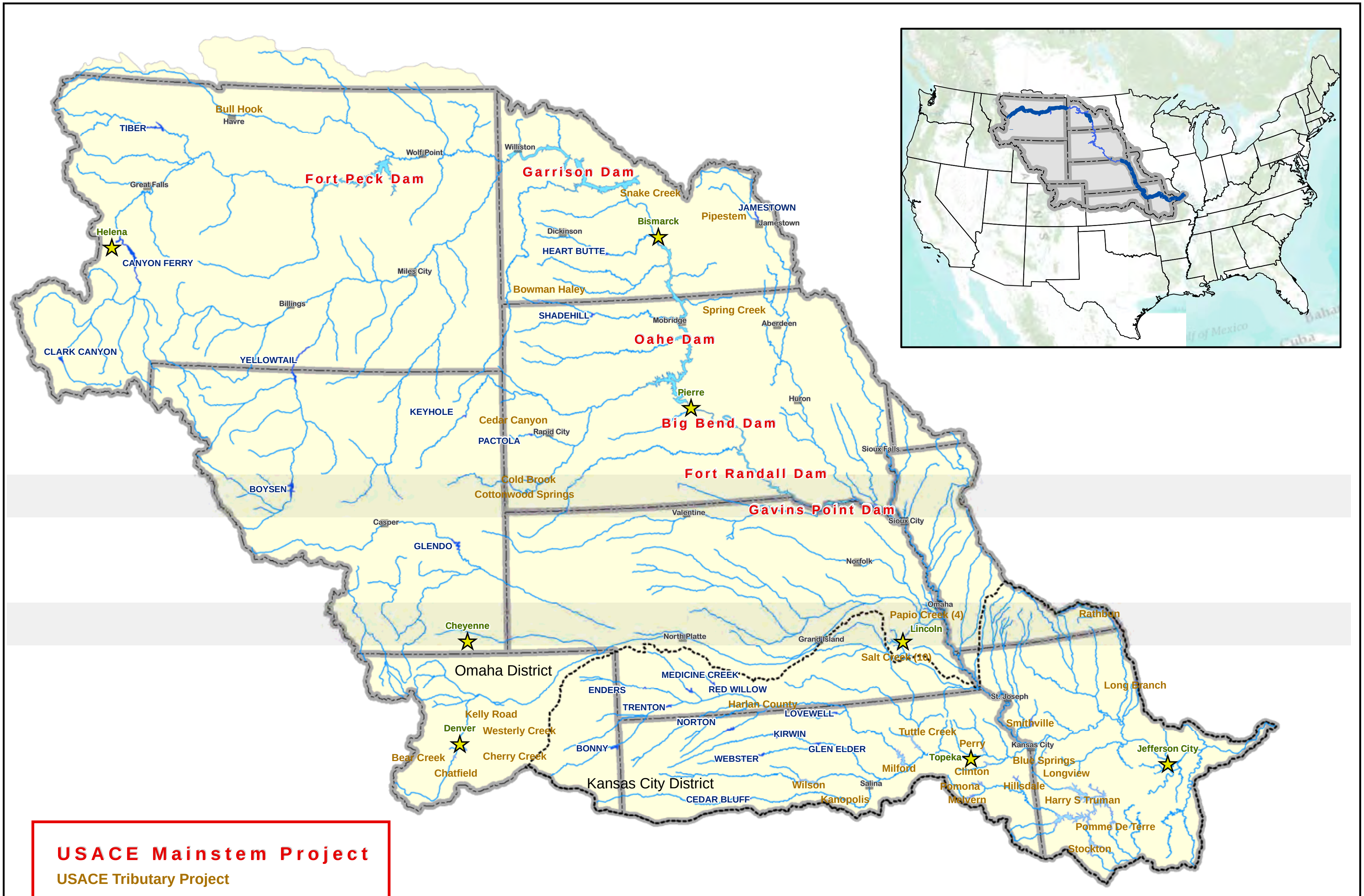
Normal Monthly Net Lake Evaporation
Inches of Depth

Month	Missouri River Mainstem Project					
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
January	0.39	-0.07	0.34	0.11	0.26	0.15
February	0.21	0.01	0.19	0.09	0.22	0.06
March	0.48	0.38	0.32	0.17	0.32	0.15
April	-0.34	-0.45	-0.46	0.66	-0.92	0.36
May	0.20	-0.10	-0.62	0.59	-0.31	0.86
June	0.06	-1.21	-1.12	0.62	-0.15	0.74
July	2.68	0.53	0.59	3.92	1.83	3.02
August	4.90	3.72	3.27	4.94	3.84	2.89
September	5.72	4.82	4.94	4.40	4.74	3.01
October	4.26	4.73	4.58	3.14	4.73	2.90
November	4.18	4.19	4.10	2.07	2.86	1.88
December	2.83	2.85	3.38	0.97	1.23	0.87
Annual	25.57	19.40	19.51	21.68	18.65	16.89

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 16.

Net Lake Evaporation = Lake Evaporation - Precipitation.

Missouri River Basin
Mainstem Master Manual Control Manual
Average Monthly Net Lake Evaporation
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN CORPS OF ENGINEERS, OMAHA, NEBRASKA November 2018



Missouri River Basin

Mainstem Master Water Control Manual

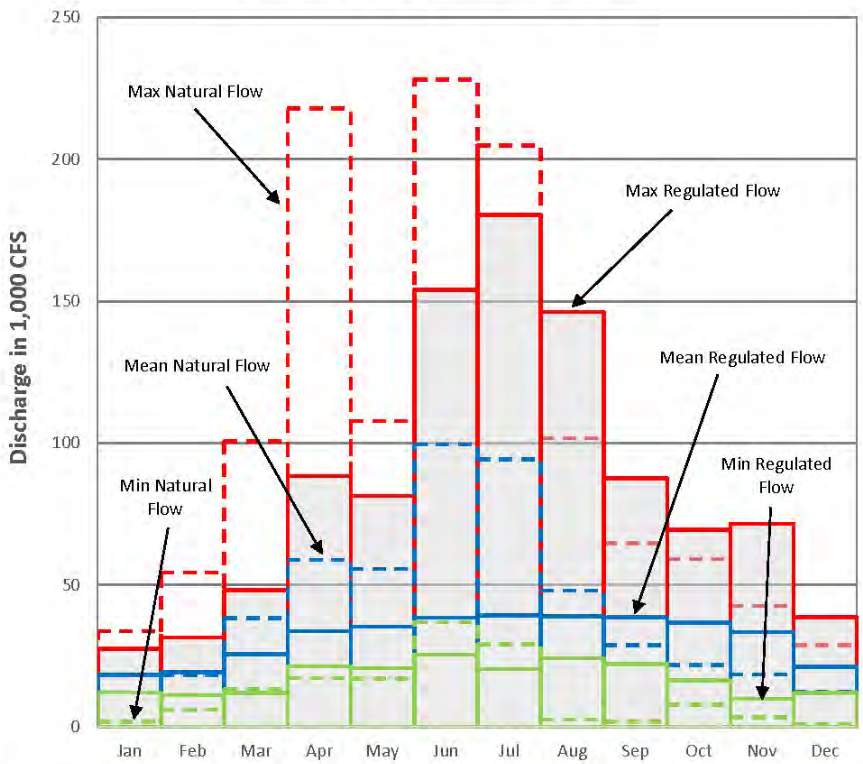
Federal Reservoir Projects

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Notes:

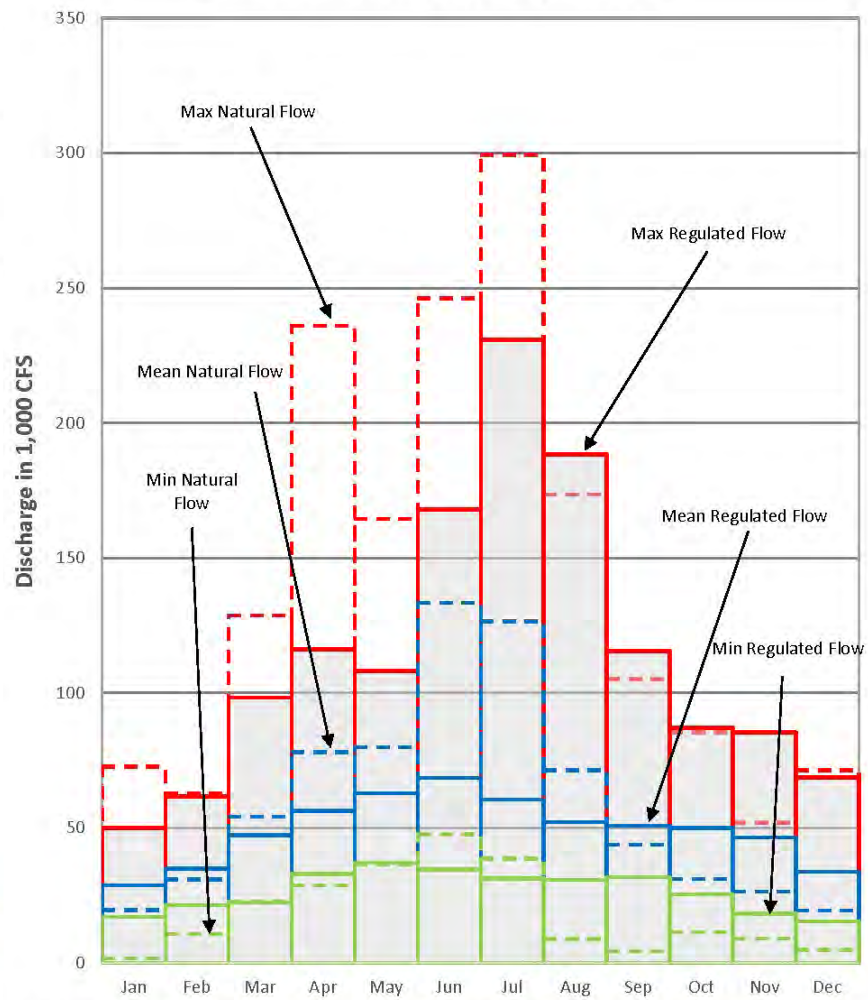
1. Natural flows refer to Missouri River flows from 1898 - 2017 (source: USACE).
2. Regulated flows refer to Missouri River flows from June 1967 - December 2017 (source: USGS).

Missouri River at Sioux City, Iowa



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Natural	1919	1928	1986	1952	1975	2011	2011	1993	1915	1923	1914	1911
Max Regulated	1987	1997	1997	1997	2011	2011	2011	2011	2011	1997	1997	1997
Min Natural	1988	1937	1940	1992	2004	2004	2006	2003	2012	2012	1935	1963
Min Regulated	1990	2005	1991	2013	2008	2007	2008	1993	2008	2006	1990	1990

Missouri River at St. Joseph, Missouri



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Natural	1910	1984	1986	1952	1995	1908	1993	1993	1903	1986	1998	2015
Max Regulated	2016	1983	1979	1984	2011	2011	2011	2011	2011	1986	1997	2015
Min Natural	1908	1936	1940	1935	2002	2002	2006	2006	2012	2012	1936	1963
Min Regulated	1968	1990	2005	1990	1989	2006	2002	2003	2005	2006	1990	1989

Missouri River Basin
Mainstem Master Water Control Manual
Monthly Regulated and Natural Flows
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate III-27

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Omaha/Kansas District Boundaries
State Boundaries

0 50 100 200 300 Miles

N W E S

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

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

Missouri River Basin
Mainstem Master Water Control Manual
Land Use
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

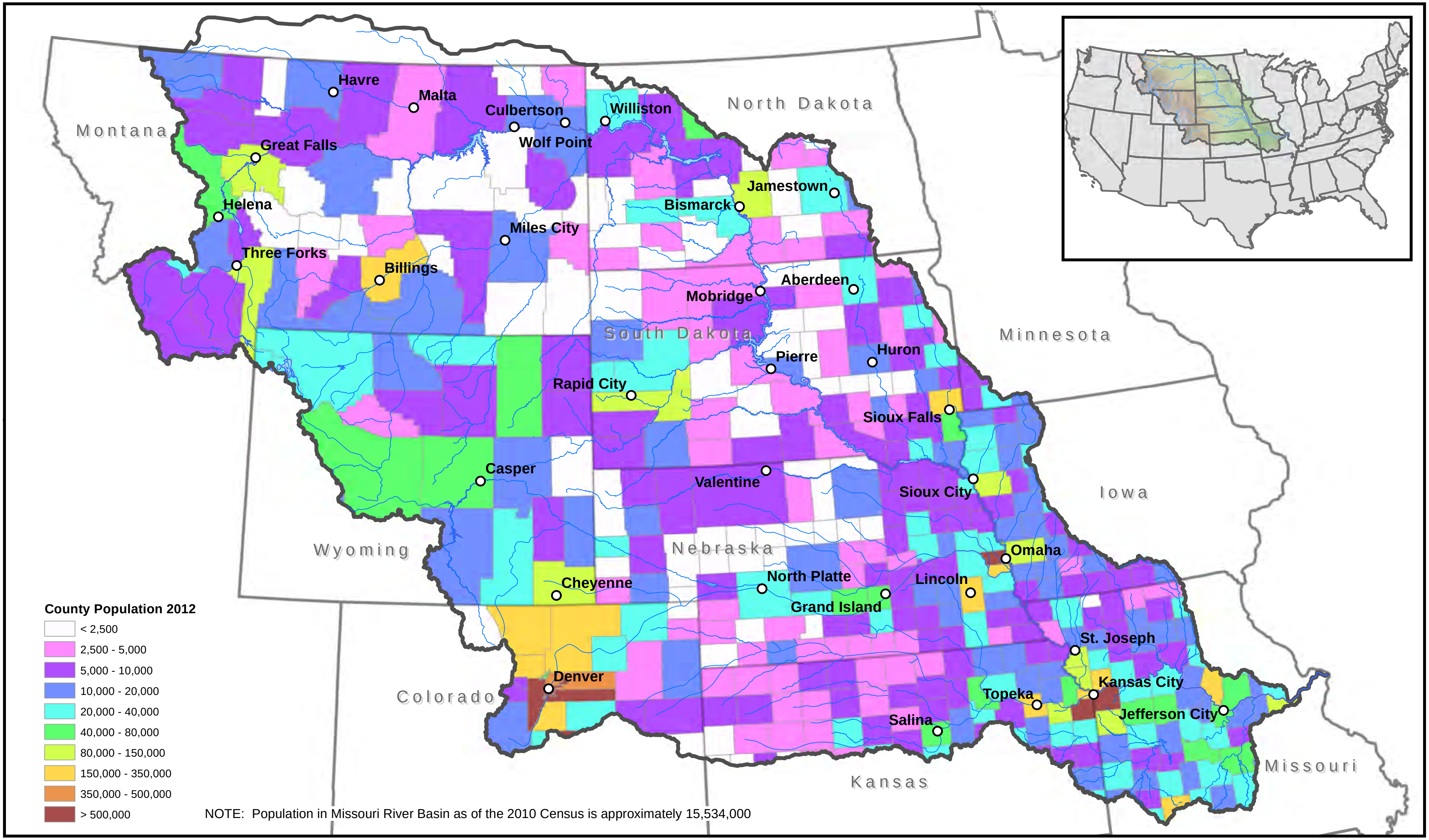


Plate III-28

US Army Corps of Engineers®
Northwestern Division

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

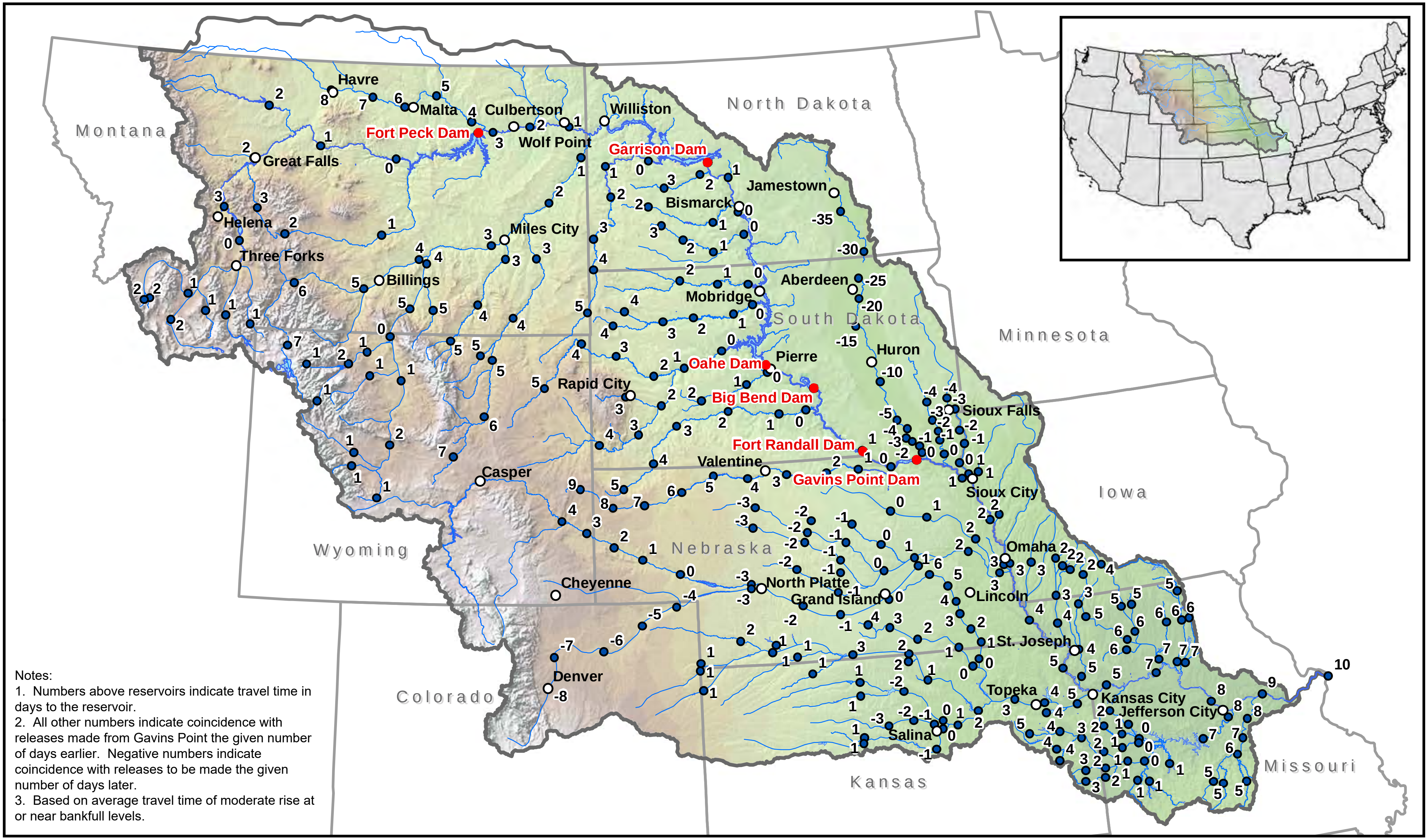
0 50 100 200 300 Miles

N W E S

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

G:\2016_DivisionMaps\Cnty_Population\County_Pop_Map.mxd

Missouri River Basin
Mainstem Master Water Control Manual
Population
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Notes:
1. Numbers above reservoirs indicate travel time in days to the reservoir.
2. All other numbers indicate coincidence with releases made from Gavins Point the given number of days earlier. Negative numbers indicate coincidence with releases to be made the given number of days later.
3. Based on average travel time of moderate rise at or near bankfull levels.

Plate IV-1

US Army Corps of Engineers®
Northwestern Division

- Mainstem Dam
- Cities
- Travel Time - Days
- 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

N W E S

G:\2016_DivisionMaps\MO_Time_travel\mxd\Basin_Wide_Travel_Times_Map.mxd

Missouri River Basin
Mainstem Master Water Control Manual
Water Travel Time
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

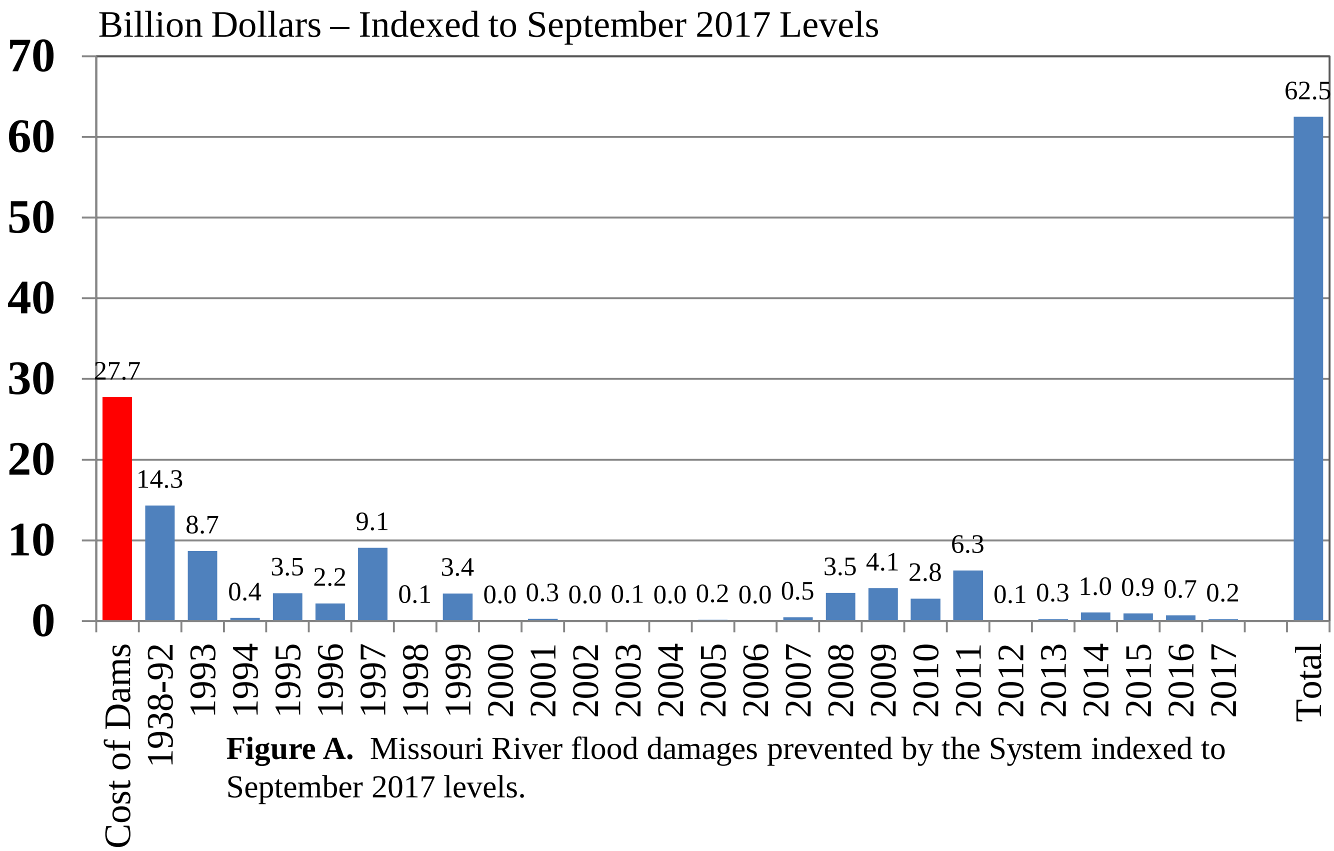


Figure A. Missouri River flood damages prevented by the System indexed to September 2017 levels.

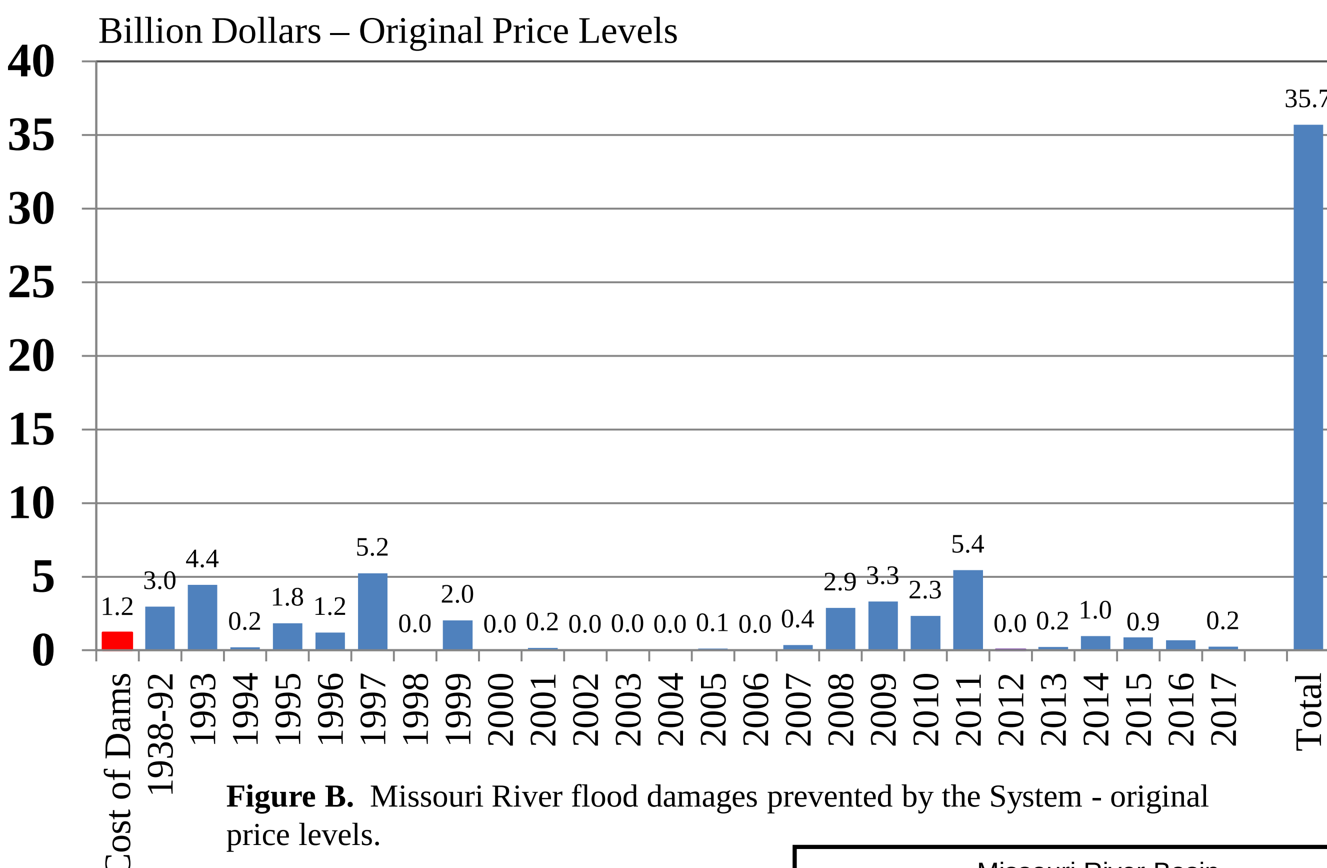
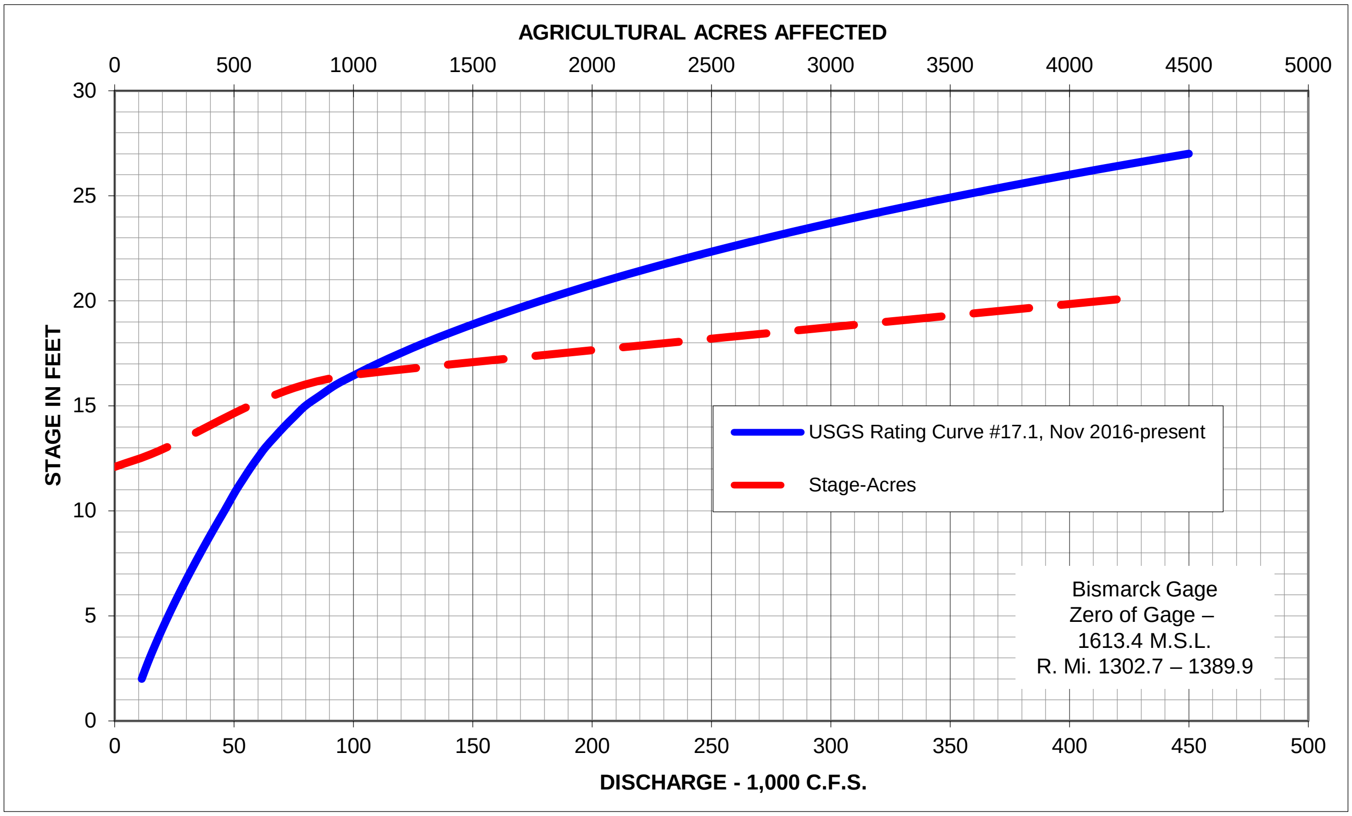
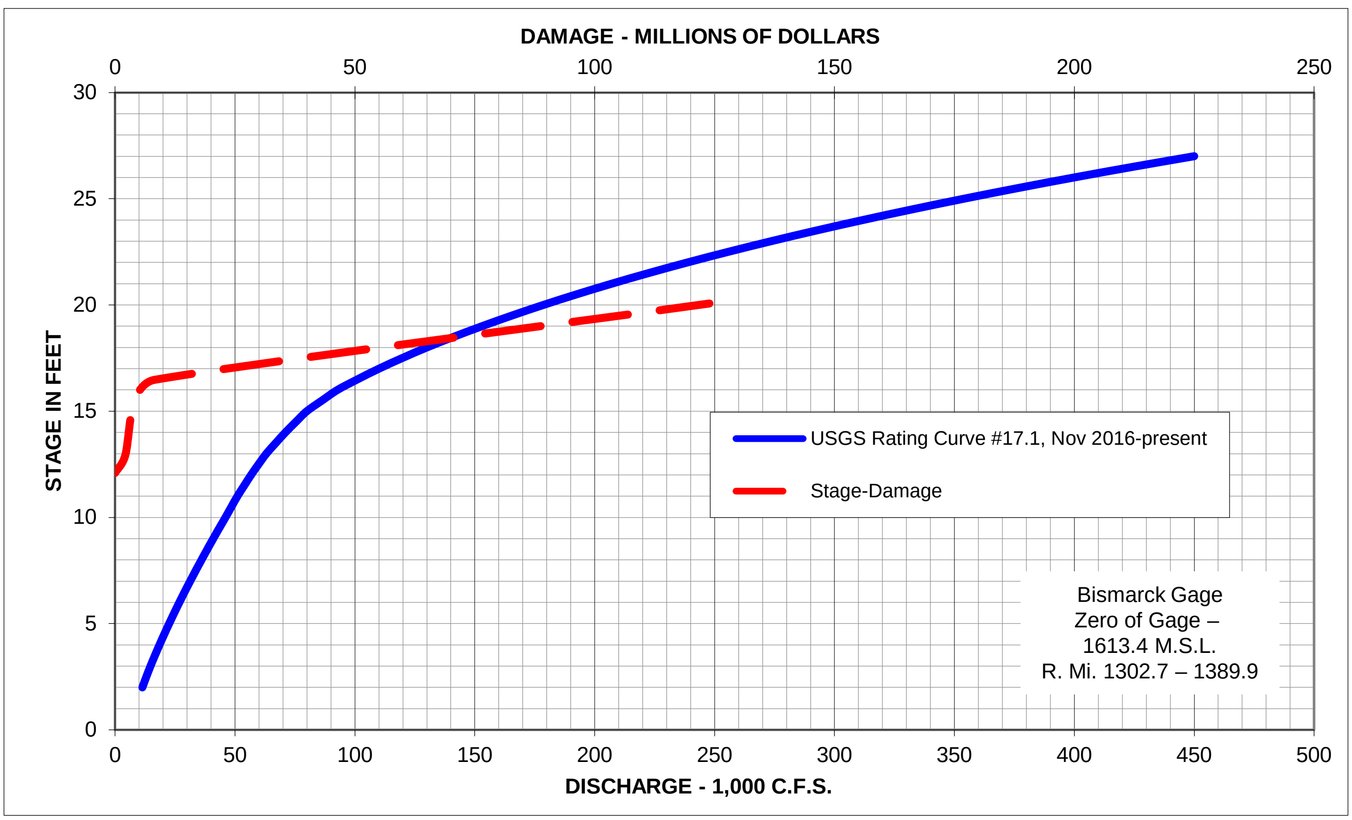


Figure B. Missouri River flood damages prevented by the System - original price levels.

Missouri River Basin
Mainstem Master Water Control Manual
Flood Damages Prevented
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018





Note: Curves shown are approximate. Omaha or Kansas City Planning Branch (Economics Section) maintains current curves, which are updated as new information is made available.

Missouri River Basin

Mainstem Master Water Control Manual

Stage-Discharge-Area-Damage Curves

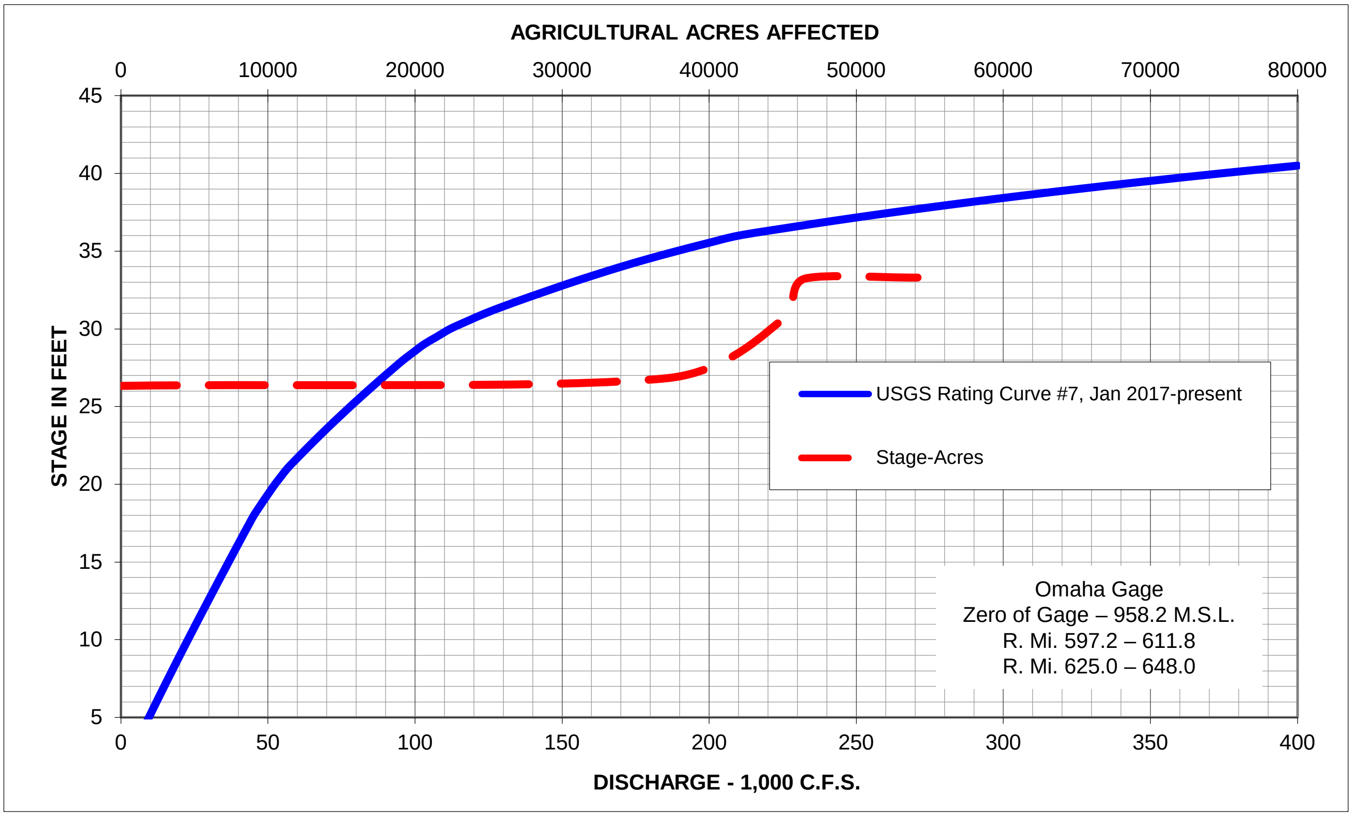
Missouri River at Bismarck, ND

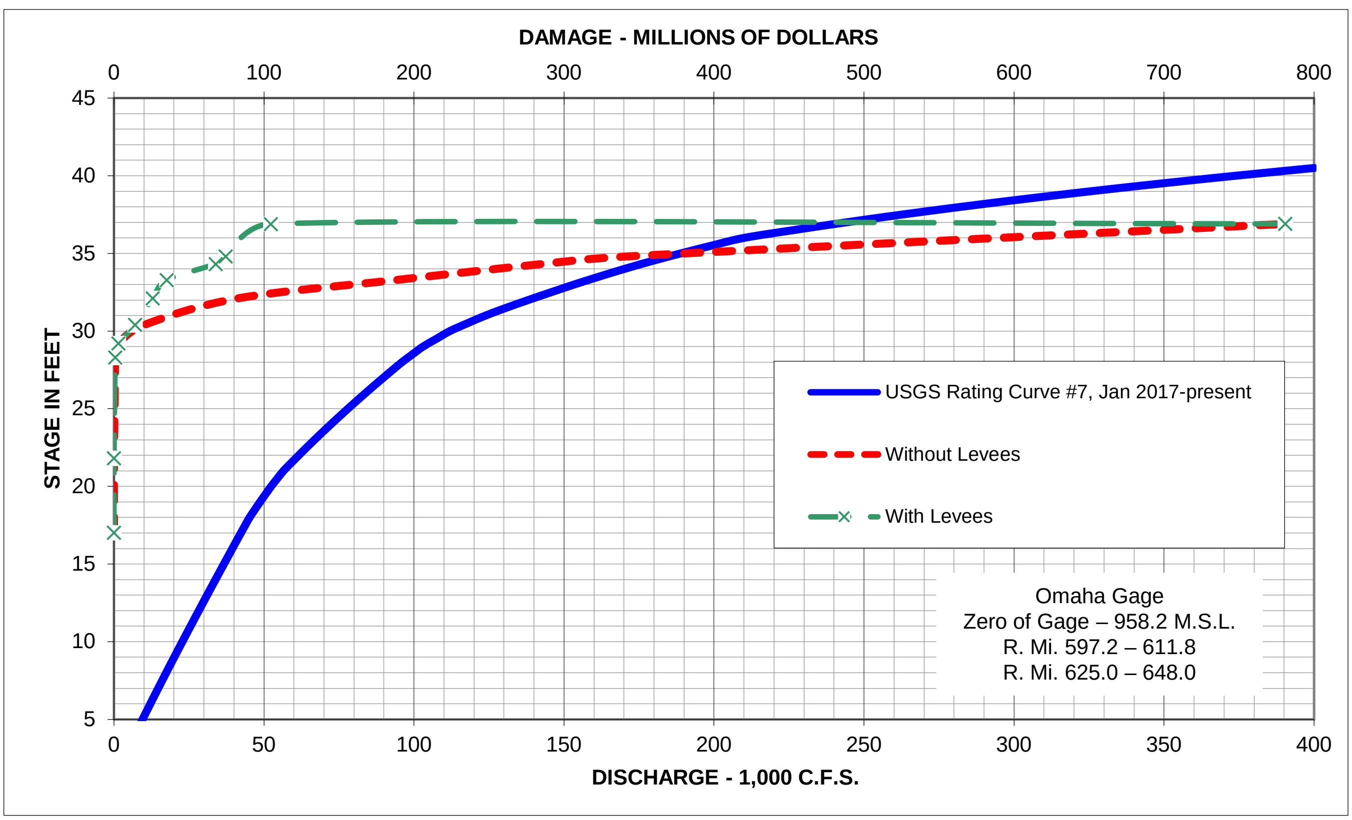
U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

November 2018

Plate IV-3





Note: Curves shown are approximate. Omaha or Kansas City Planning Branch (Economics Section) maintains current curves, which are updated as new information is made available.

Missouri River Basin

Mainstem Master Water Control Manual

Stage-Discharge-Area-Damage Curves

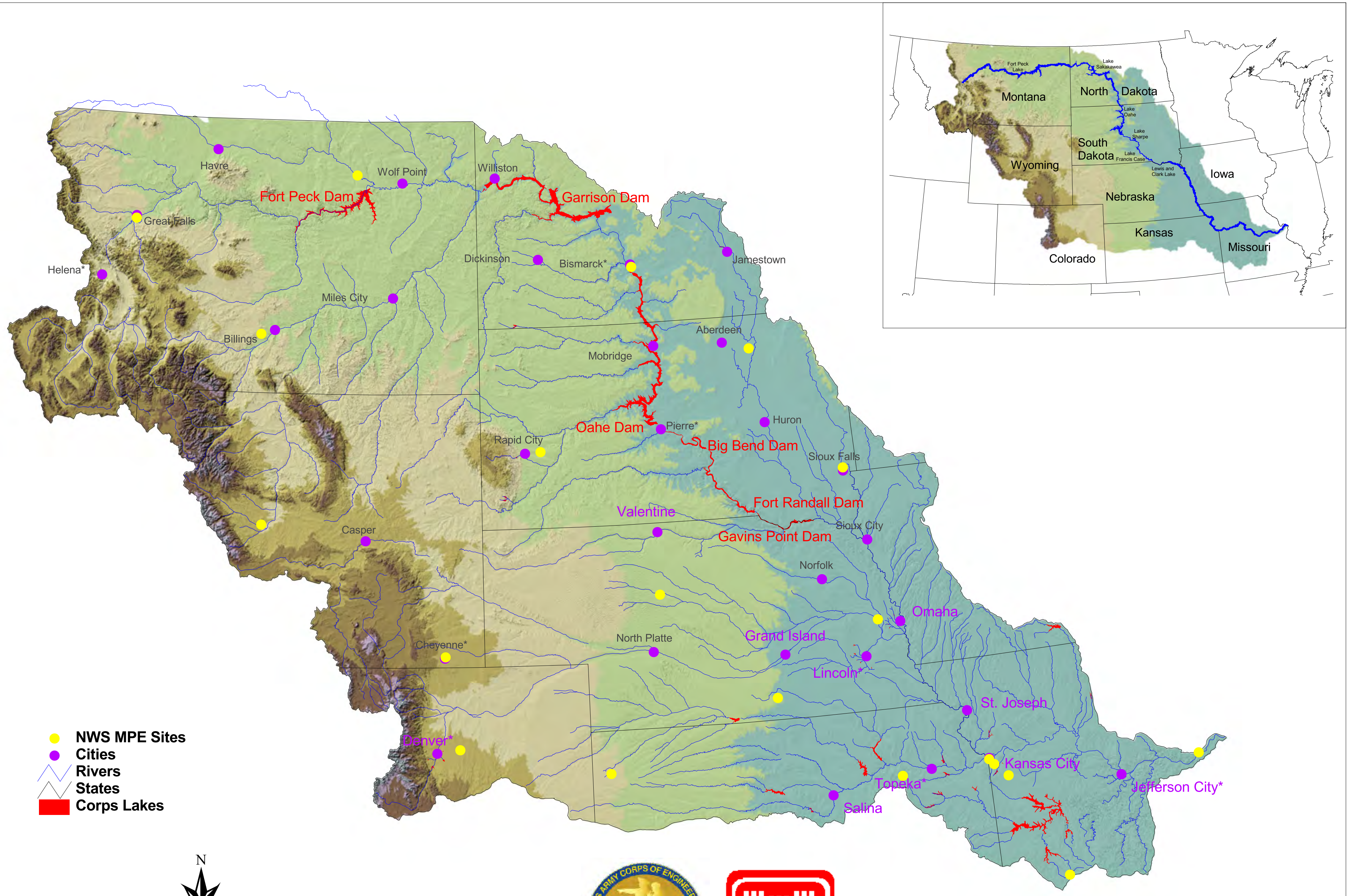
Missouri River at Omaha, NE

U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

November 2018

Plate IV-4



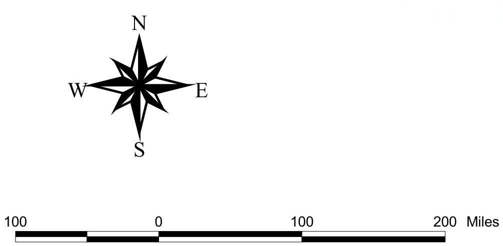


Plate V-1

U.S. Army Corps of Engineers

Missouri River Basin
Mainstem Master Water Control Manual
NWS Radar (WSR-88D) Sites
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

MONTHLY RESERVOIR OPERATION

FORT PECK — **MISSOURI RIVER**

MISSOURI RIVER REGION — **Apr-2018** — **US ARMY CORPS OF ENGINEERS**

Apr 2018	ELEVATION FEET-MSL	EVAP PAN INCH	EVAP FLOW CFS	MEAN DISCHARGE IN CFS OUTFLOW POWER	OUTFLOW SPILL	OUTFLOW TOTAL	INFLOW
4/1	2236.04 -	0.10	0 -	9,400	0 +	9,400	20,000
4/2	2236.18	0.10	0	9,000	0 -	9,000	18,000
4/3	2236.23	0.10	0	8,500	0	8,500	17,000
4/4	2236.28	0.10	100 +	8,500	0	8,500	14,000
4/5	2236.34	0.10	100	8,400 -	0	8,400 -	14,000
4/6	2236.34	0.10	100	8,700	0	8,700	14,000
4/7	2236.43	0.10	100	8,600	0	8,600	14,000
4/8	2236.47	0.10	100	8,400	0	8,400	13,000 -
4/9	2236.52	0.10	100	8,400	0	8,400	13,000
4/10	2236.57	0.10	100	8,500	0	8,500	15,000
4/11	2236.74	0.10	100	8,700	0	8,700	25,000
4/12	2236.98	0.10	100	8,900	0	8,900	36,000
4/13	2237.19	0.10	100	8,800	0	8,800	34,000
4/14	2237.39	0.10	100	8,700	0	8,700	31,000
4/15	2237.58	0.10	100	8,600	0	8,600	32,000
4/16	2237.95	0.10	100	8,600	0	8,600	40,000
4/17	2238.24	0.10	100	8,800	0	8,800	45,000 +
4/18	2238.48	0.10	100	8,800	0	8,800	39,000
4/19	2238.73	0.10	100	8,700	0	8,700	36,000
4/20	2238.96	0.10	100	8,800	0	8,800	34,000
4/21	2239.05	0.10	100	11,100	0	11,100	30,000
4/22	2239.23	0.10	100	10,700	0	10,700	23,000
4/23	2239.34	0.10	100	10,700	0	10,700	23,000
4/24	2239.38	0.10	100	10,800	0	10,800	20,000
4/25	2239.48	0.10	100	11,500 +	0	11,500 +	20,000
4/26	2239.59	0.10	100	11,300	0	11,300	20,000
4/27	2239.60	0.10	100	11,200	0	11,200	20,000
4/28	2239.66	0.10	100	11,000	0	11,000	20,000
4/29	2239.84	0.10	100	9,500	0	9,500	20,000
4/30	2239.88 +	0.10	100	11,100	0	11,100	20,000
Total (DSF)		3.00	2,700	282,700	0	282,700	720,000
Total (ac-ft)			5,400	561,000	0	561,000	1,428,000
Mean	2237.89	0.10	100	9,400	0	9,400	24,000

Monthly Reservoir Storage: **EOM =** 16,070,000 **Change =** 862,000

+ Max **Monthly Max =** 16,070,000 **Min =** 15,229,000

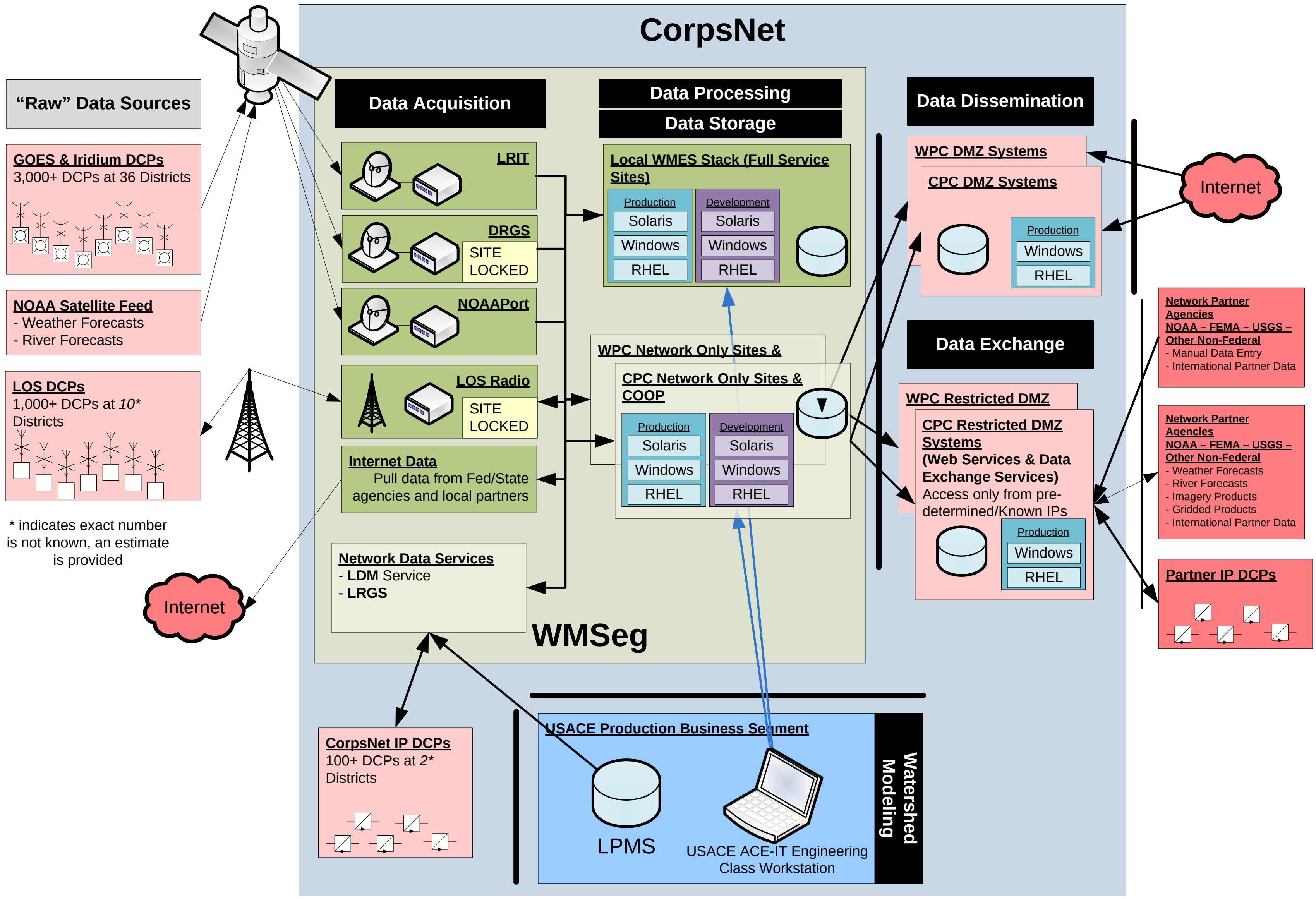
- Min **Monthly Precip =** 1.07 inches

Notes: Lake is ice free as of 30Apr

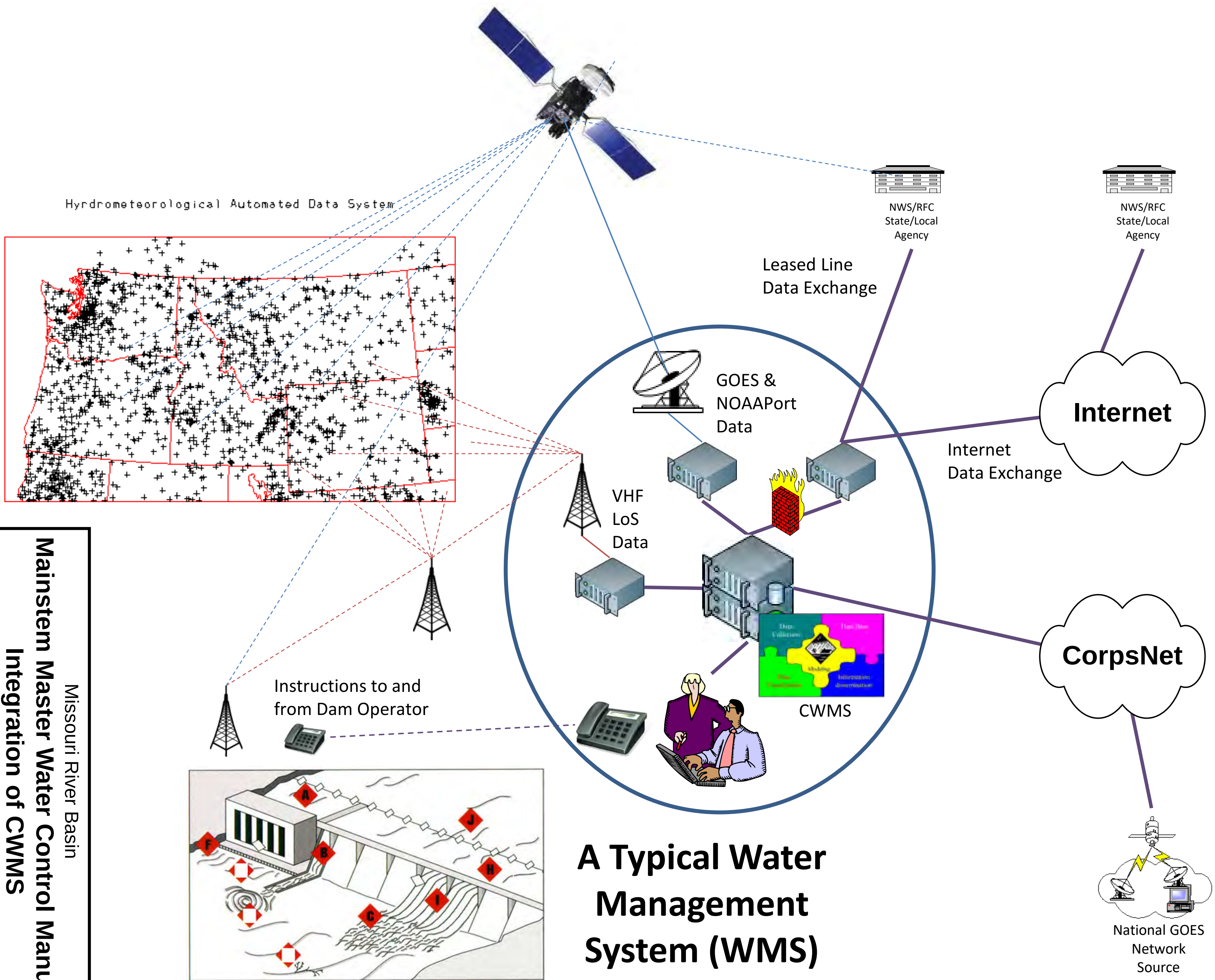
Apr 2018

Missouri River Basin
Mainstem Master Water Control Manual
Monthly Reservoir Summary Report
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Major Elements of the USACE Water Management Enterprise System (WMES)



Missouri River Basin
Mainstem Master Water Control Manual
Major Elements of a WMES
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



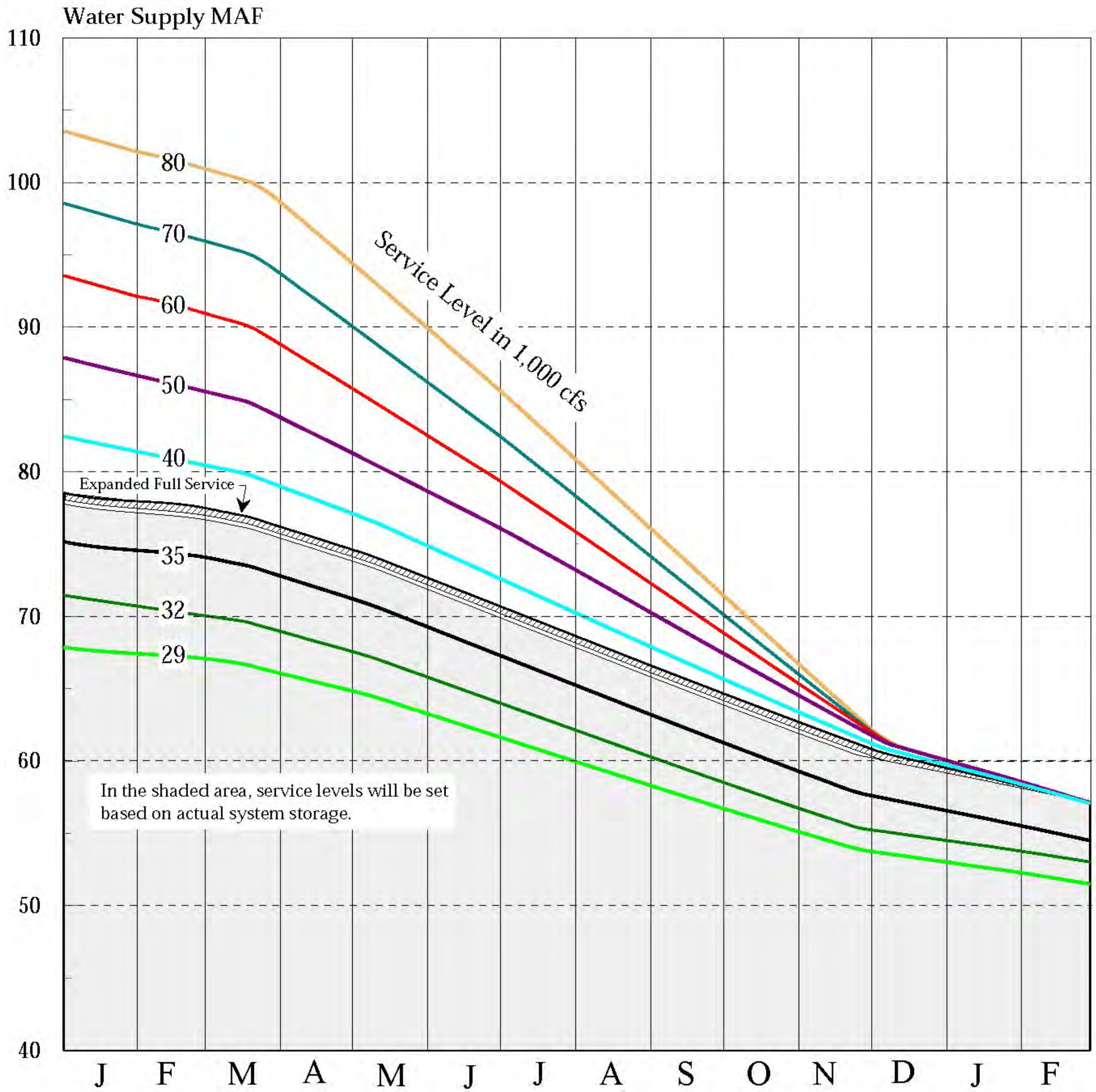
Missouri River Basin

Mainstem Master Water Control Manual

Integration of CWMS into a Typical WMS

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate V-4



Notes:

1. Water supply consists of the accumulation of the following:
   a. Actual system storage
   b. Forecast remaining calendar year runoff volume (1949 basin development level) above Gavins Point Dam.
   c. Departure of total tributary storage from base level. (See text.)

2. Expanded full service consists of the following:
   a. Maintenance of 35,000 cfs service level through the navigation season.
   b. Extension of the navigation season for up to 10 days beyond the normal closing date of 1 December at the mouth of the Missouri River.
   c. Winter releases averaging 20,000 cfs from Gavins Point.

3. The relationship between the service level and target flow is as given in the table below:

	Target Flows - 1,000 cfs		
Service Level	Sioux City & Omaha	Nebraska City	Kansas City
29.0 1/	25.0	31.0	35.0
35.0 2/	31.0	37.0	41.0
40.0 3/	36.0	42.0	46.0
50.0 3/	46.0	52.0	56.0

1/ Minimum service level
2/ Full service level
3/ Storage evacuation service level

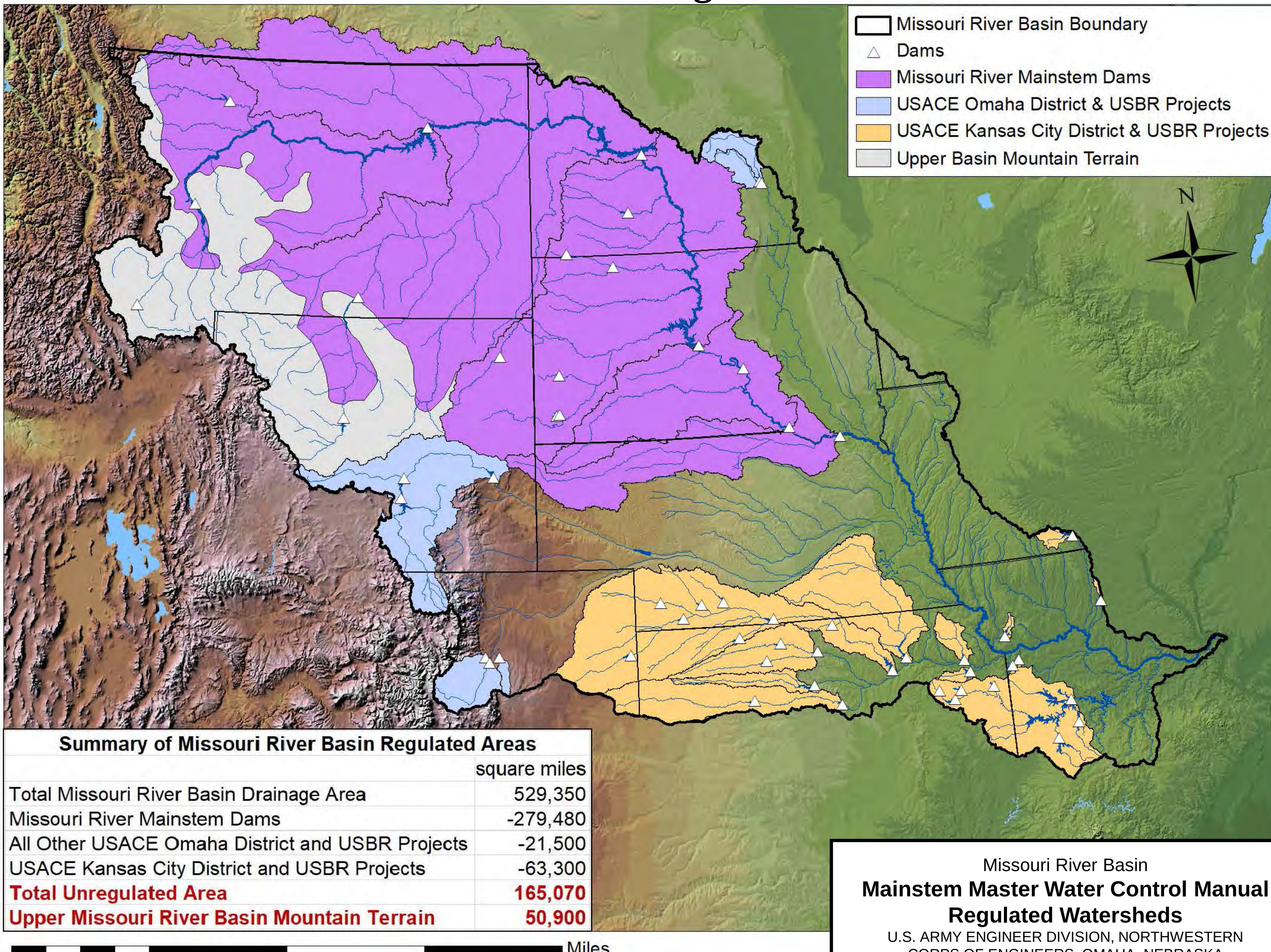
Missouri River Basin

Mainstem Master Water Control Manual

Mainstem Reservoir System Service Level

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Missouri River Basin Regulated Watersheds



Summary of Missouri River Basin Regulated Areas	
	square miles
Total Missouri River Basin Drainage Area	529,350
Missouri River Mainstem Dams	-279,480
All Other USACE Omaha District and USBR Projects	-21,500
USACE Kansas City District and USBR Projects	-63,300
Total Unregulated Area	**165,070**
Upper Missouri River Basin Mountain Terrain	**50,900**

Missouri River Basin

Mainstem Master Water Control Manual

Regulated Watersheds

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Missouri River below Gavins Point Dam Forecast

** All flows in 1000 cfs ** as of: 8/1/2017

date	GAPT	AKIA	SUX	DENE	TUIA	OMA	GRNE	WTNE	LUNE	NCNE	
7/29	**31.0**	1.3	**33.0**	33.8	1.0	**36.5**	0.5	1.4	5.4	**41.9**	
7/30	**30.8**	1.2	**33.1**	33.9	1.0	**36.1**	0.5	1.3	4.7	**40.5**	
7/31	**31.0**	1.2	**32.9**	33.9	0.9	**36.0**	0.7	1.3	4.4	**39.8**	
8/1	**30.9**	1.2	**33.0**	34.0	0.8	**35.8**	0.6	1.3	4.3	**40.2**	Observed
8/2	**31.0**	1.3	**33.2**	33.9	0.8	**35.7**	0.6	1.3	4.0	**39.9**	Forecast
8/3	**31.0**	1.3	**33.2**	34.0	0.8	**35.7**	0.7	1.3	3.9	**39.9**	
8/4	**31.0**	1.2	**33.2**	34.0	0.8	**35.7**	0.7	1.3	3.9	**39.8**	
8/5	**31.0**	1.1	**33.2**	34.0	0.8	**35.7**	0.7	1.3	3.8	**39.8**	
8/6	**31.0**	1.1	**33.2**	34.0	0.8	**35.7**	0.7	1.3	3.7	**39.7**	
8/7	**31.0**	1.0	**33.1**	33.9	0.7	**35.6**	0.7	1.2	3.7	**39.5**	
8/8	**31.0**	1.0	**33.0**	33.8	0.7	**35.5**	0.7	1.2	3.7	**39.4**	
8/9	**31.0**	1.0	**32.9**	33.7	0.7	**35.3**	0.7	1.2	3.7	**39.2**	
8/10	**31.0**	1.0	**32.9**	33.6	0.7	**35.2**	0.7	1.2	3.7	**39.1**	
8/11	**31.0**	0.9	**32.8**	33.5	0.7	**35.2**	0.7	1.2	3.6	**39.0**	
8/12	**31.0**	0.9	**32.8**	33.5	0.7	**35.1**	0.7	1.2	3.6	**38.9**	
8/13	**31.0**	0.9	**32.8**	33.4	0.7	**35.0**	0.7	1.2	3.6	**38.8**	
8/14	**31.0**	0.9	**32.7**	33.4	0.7	**35.0**	0.7	1.1	3.5	**38.7**	
8/15	**31.0**	0.9	**32.7**	33.3	0.7	**34.9**	0.7	1.1	3.5	**38.6**	

date	HAIA	RUNE	STJ	SSMO	MKC	WVMO	SMNM	BNMO	BAGL	HEMO	
7/29	1.4	45.3	44.9	0.4	**53.1**	79.6	0.8	127.6	2.2	64.6	
7/30	1.3	44.2	46.0	0.3	**52.1**	60.2	0.7	87.2	1.1	114.3	
7/31	1.2	42.2	44.0	0.3	**51.1**	56.8	0.7	72.2	1.5	88.9	
8/1	1.2	41.7	42.8	0.3	**48.6**	54.5	0.6	69.5	7.5	74.0	Observed
8/2	1.2	41.6	42.7	0.2	**47.5**	51.8	0.6	66.4	7.3	72.3	Forecast
8/3	1.1	41.3	42.5	0.2	**47.2**	50.8	0.6	60.0	14.5	73.0	
8/4	1.1	41.3	42.4	0.2	**46.9**	50.3	0.5	57.2	13.7	73.4	
8/5	1.1	41.2	42.3	0.2	**46.7**	49.8	0.5	55.7	1.6	69.5	
8/6	1.1	41.1	42.2	0.2	**46.5**	49.5	0.5	54.7	1.6	60.7	
8/7	1.1	40.9	42.1	0.2	**46.3**	49.2	0.5	54.0	45.7	59.3	
8/8	1.1	40.8	41.9	0.2	**46.1**	48.9	0.5	53.4	37.2	94.2	
8/9	1.1	40.6	41.7	0.2	**45.8**	48.5	0.5	52.9	20.9	84.9	
8/10	1.0	40.5	41.6	0.2	**45.5**	48.2	0.5	52.3	19.5	73.6	
8/11	1.0	40.3	41.4	0.2	**45.3**	47.8	0.5	51.7	19.0	71.6	
8/12	1.0	40.2	41.3	0.2	**45.0**	47.5	0.4	51.2	19.0	70.6	
8/13	1.0	40.0	41.1	0.2	**44.7**	47.2	0.4	50.6	16.5	69.6	
8/14	1.0	39.9	41.0	0.2	**44.5**	46.8	0.4	50.0	16.5	67.2	
8/15	1.0	39.8	40.9	0.2	**44.3**	46.5	0.4	49.5	16.5	66.5	

	Results of Release for Date				Service Level Exceeded			
Date	SUX	OMA	NCNE	MKC	SUX	OMA	NCNE	MKC
8/1	33.2	35.7	39.8	46.3	2.2	4.7	2.8	5.3
8/2	33.2	35.7	39.7	46.1	2.2	4.7	2.7	5.1
8/3	33.2	35.7	39.5	45.8	2.2	4.7	2.5	4.8
8/4	33.2	35.6	39.4	45.5	2.2	4.6	2.4	4.5
8/5	33.1	35.5	39.2	45.3	2.1	4.5	2.2	4.3
8/6	33.0	35.3	39.1	45.0	2.0	4.3	2.1	4.0
8/7	32.9	35.2	39.0	44.7	1.9	4.2	2.0	3.7
8/8	32.9	35.2	38.9	44.5	1.9	4.2	1.9	3.5
8/9	32.8	35.1	38.8	44.3	1.8	4.1	1.8	3.3

Flood Targets:

Full Service		
OMA	NCNE	MKC
41.0	47.0	71.0
Minimum Service		
OMA	NCNE	MKC
46.0	57.0	101.0

Current Service Level: 35.0 kcfs

This forecast is prepared by the Corps of Engineers Missouri River Basin Water Management Division for regulation of reservoir releases and is for internal use and not for general distribution.
The National Weather Service prepares and distributes river stage forecasts for the general public.

Missouri River below Gavins Point Dam Forecast - Ungaged Flows

** All flows in 1000 cfs ** as of: 8/1/2017

date	AKIA	SUX	JMIA	DENE	CEIA	TUIA	OMA	GRNE	WSNE	WTNE	LUNE	NCNE	
7/29	0.3	0.5	0.1	0.6	0.4	0.0	0.3	0.1	0.2	0.5	1.8	-1.5	
7/30	0.3	0.6	0.1	0.7	0.4	0.0	0.0	0.1	0.2	0.5	1.3	-0.7	
7/31	0.3	0.5	0.1	0.6	0.3	0.0	-0.1	0.2	0.1	0.5	1.2	-0.4	
8/1	0.3	0.7	0.1	0.8	0.3	0.0	0.0	0.1	0.1	0.5	1.0	0.2	Observed
8/2	0.3	0.8	0.1	0.7	0.3	0.1	-0.1	0.0	0.1	0.5	0.8	0.1	Forecast
8/3	0.3	0.8	0.1	0.7	0.3	0.1	-0.1	0.0	0.1	0.5	0.7	0.1	
8/4	0.3	0.8	0.1	0.7	0.3	0.1	-0.1	0.0	0.1	0.5	0.6	0.1	
8/5	0.3	0.8	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.5	0.6	0.1	
8/6	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.5	0.5	0.1	
8/7	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.4	0.4	0.1	
8/8	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.4	0.4	0.1	
8/9	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.4	0.4	0.1	
8/10	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.4	0.4	0.1	
8/11	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.4	0.4	0.1	
8/12	0.3	0.7	0.1	0.6	0.3	0.1	-0.1	0.0	0.1	0.4	0.4	0.1	
8/13	0.3	0.7	0.1	0.5	0.3	0.1	0.0	0.0	0.1	0.4	0.4	0.1	
8/14	0.3	0.6	0.1	0.5	0.3	0.1	0.0	0.0	0.1	0.4	0.4	0.1	
8/15	0.3	0.6	0.1	0.5	0.3	0.1	0.0	0.0	0.1	0.4	0.4	0.1	

date	ROIA	RNIA	HAIA	RUNE	STJ	SSMO	MKC	WVMO	CHMO	SMNM	BNMO	HEMO	
7/29	0.3	0.5	0.1	1.1	0.3	0.1	2.0	14.8	0.7	-0.5	15.8	-11.9	
7/30	0.3	0.5	0.1	1.1	0.6	0.0	1.1	5.4	0.7	-0.5	10.5	-5.3	
7/31	0.3	0.5	0.1	0.6	0.4	0.0	1.7	3.4	0.7	-0.5	3.6	-2.5	
8/1	0.3	0.4	0.1	0.5	0.5	0.0	1.4	3.1	0.7	-0.5	2.6	-1.5	Observed
8/2	0.3	0.4	0.1	0.2	0.8	0.0	1.1	2.9	0.7	-0.5	4.1	-2.1	Forecast
8/3	0.3	0.4	0.1	0.2	0.8	0.0	1.0	2.8	0.7	-0.5	4.0	-1.7	
8/4	0.3	0.4	0.1	0.1	0.8	0.0	1.0	2.8	0.7	-0.5	3.8	-1.4	
8/5	0.3	0.4	0.1	0.1	0.8	0.0	1.0	2.7	0.7	-0.5	3.6	-1.3	
8/6	0.3	0.4	0.1	0.1	0.8	0.0	0.9	2.6	0.7	-0.5	3.4	-1.3	
8/7	0.3	0.4	0.1	0.1	0.8	0.0	0.9	2.6	0.7	-0.5	3.2	-1.2	
8/8	0.3	0.4	0.1	0.1	0.8	0.0	0.9	2.5	0.7	-0.5	3.0	-1.2	
8/9	0.3	0.4	0.1	0.1	0.8	0.0	0.8	2.4	0.7	-0.5	2.8	-1.1	
8/10	0.3	0.4	0.1	0.1	0.7	0.0	0.8	2.3	0.7	-0.5	2.7	-1.1	
8/11	0.3	0.4	0.1	0.1	0.7	0.0	0.8	2.3	0.6	-0.5	2.5	-1.0	
8/12	0.3	0.4	0.1	0.1	0.7	0.0	0.7	2.2	0.6	-0.5	2.3	-1.0	
8/13	0.3	0.3	0.1	0.1	0.7	0.0	0.7	2.1	0.6	-0.5	2.1	-0.9	
8/14	0.2	0.3	0.0	0.1	0.7	0.0	0.7	2.1	0.6	-0.5	1.9	-0.9	
8/15	0.2	0.3	0.0	0.1	0.7	0.0	0.6	2.0	0.6	-0.5	1.7	-0.8	

Missouri River below Gavins Point Dam Forecast - Tributary Flows

** All flows in 1000 cfs **   as of: 8/1/2017

date	GAPT	SCSD	VRSD	NCSD	RVIA	ANIA	MPIA	LVIA	MHIA	LGIA	PSIA	KENE	MLNE	NLNE	OFK	UENE	
7/29	**30.9**	0.1	0.1	0.7	0.2	0.0	0.3	0.2	0.3	0.6	0.2	0.3	0.3	0.9	0.4	0.3	
7/30	**31.0**	0.1	0.1	0.7	0.2	0.0	0.3	0.2	0.3	0.6	0.2	0.4	0.3	0.9	0.4	0.3	
7/31	**30.8**	0.1	0.1	0.8	0.2	0.0	0.3	0.2	0.3	0.5	0.2	0.4	0.4	0.9	0.4	0.3	
8/1	**31.0**	0.1	0.1	0.8	0.2	0.0	0.2	0.2	0.3	0.5	0.2	0.6	0.3	0.8	0.4	0.3	Observed
8/2	**31.0**	0.1	0.1	0.7	0.2	0.0	0.2	0.2	0.3	0.5	0.2	0.7	0.3	0.8	0.4	0.3	Forecast
8/3	**31.0**	0.1	0.1	0.6	0.2	0.0	0.2	0.2	0.3	0.5	0.2	0.7	0.3	0.8	0.4	0.3	
8/4	**31.0**	0.1	0.1	0.6	0.2	0.0	0.2	0.2	0.3	0.5	0.2	0.7	0.3	0.8	0.4	0.3	
8/5	**31.0**	0.1	0.1	0.5	0.2	0.0	0.2	0.2	0.3	0.5	0.1	0.7	0.3	0.8	0.4	0.3	
8/6	**31.0**	0.1	0.1	0.5	0.2	0.0	0.2	0.2	0.3	0.5	0.1	0.7	0.3	0.8	0.4	0.3	
8/7	**31.0**	0.1	0.1	0.5	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.8	0.4	0.2	
8/8	**31.0**	0.1	0.1	0.5	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.8	0.4	0.2	
8/9	**31.0**	0.1	0.1	0.5	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.8	0.4	0.2	
8/10	**31.0**	0.1	0.1	0.5	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.7	0.4	0.2	
8/11	**31.0**	0.1	0.1	0.4	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.7	0.3	0.2	
8/12	**31.0**	0.1	0.1	0.4	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.7	0.3	0.2	
8/13	**31.0**	0.1	0.1	0.4	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.7	0.3	0.2	
8/14	**31.0**	0.1	0.1	0.4	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.7	0.3	0.2	
8/15	**31.0**	0.1	0.1	0.4	0.2	0.0	0.2	0.1	0.3	0.5	0.1	0.7	0.3	0.7	0.3	0.2	

date	GWNE	UNNE	ACIA	HCIA	AUNE	FLNE	GRAM	AGYM	DESO	LCTM	TTNM	GLLM	PRIM	BLCM	BAGL	RIFM	
7/29	0.4	0.1	0.1	0.3	0.3	0.1	0.3	0.3	4.7	1.5	0.2	0.3	0.1	5.6	2.2	0.8	
7/30	0.3	0.1	0.1	0.3	0.2	0.1	0.3	0.3	4.0	1.3	0.2	0.3	0.1	7.4	1.1	0.8	
7/31	0.2	0.1	0.1	0.3	0.2	0.1	0.3	0.2	3.4	0.9	0.2	0.2	0.1	9.9	1.5	0.8	
8/1	0.2	0.1	0.1	0.3	0.2	0.0	0.3	0.2	3.4	0.5	0.2	0.2	0.1	9.5	7.5	0.8	Observed
8/2	0.2	0.1	0.1	0.3	0.1	0.1	0.2	0.2	3.4	0.4	0.1	0.2	0.1	6.5	7.3	0.8	Forecast
8/3	0.2	0.1	0.1	0.3	0.1	0.1	0.2	0.2	3.3	0.3	0.1	0.2	0.1	2.6	14.5	0.8	
8/4	0.2	0.1	0.1	0.3	0.1	0.1	0.2	0.2	3.2	0.2	0.1	0.2	0.1	1.6	13.7	0.8	
8/5	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.2	3.2	0.1	0.1	0.2	0.1	1.1	1.6	0.8	
8/6	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.2	3.1	0.1	0.1	0.2	0.1	0.8	1.6	0.8	
8/7	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.2	3.0	0.1	0.1	0.2	0.1	0.7	45.7	0.8	
8/8	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.2	3.0	0.1	0.1	0.2	0.1	0.7	37.2	0.8	
8/9	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.9	0.1	0.1	0.2	0.1	0.7	20.9	0.8	
8/10	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.8	0.1	0.1	0.2	0.1	0.6	19.5	0.8	
8/11	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.8	0.1	0.1	0.2	0.1	0.6	19.0	0.8	
8/12	0.1	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.7	0.1	0.1	0.1	0.1	0.6	19.0	0.8	
8/13	0.1	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.6	0.1	0.1	0.1	0.1	0.5	16.5	0.8	
8/14	0.1	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.5	0.1	0.1	0.1	0.1	0.5	16.5	0.8	
8/15	0.1	0.1	0.1	0.2	0.1	0.0	0.2	0.2	2.5	0.1	0.1	0.1	0.1	0.5	16.5	0.8	

Missouri River below Gavins Point Dam
Stage Forecast

** All stages in feet ** as of: 8/1/2017

date	SUX	DENE	OMA	NCNE	RUNE	STJ	MKC	WVMO	BNMO	HEMO	
7/29	13.4	21.7	15.8	10.8	10.1	8.1	12.5	18.2	18.2	8.5	
7/30	13.5	21.7	15.7	10.4	9.9	8.3	12.4	15.7	14.2	14.6	
7/31	13.4	21.7	15.7	10.3	9.5	7.9	12.2	15.2	12.4	11.8	
8/1	13.4	21.7	15.6	10.4	9.4	7.6	11.7	14.9	12.0	9.9	Observed
8/2	13.5	21.7	15.5	10.3	9.4	7.6	11.5	14.4	11.6	9.6	Forecast
8/3	13.5	21.7	15.6	10.3	9.3	7.5	11.5	14.3	10.7	9.8	
8/4	13.6	21.8	15.6	10.3	9.3	7.4	11.4	14.2	10.2	9.8	
8/5	13.6	21.8	15.6	10.2	9.3	7.4	11.4	14.1	10.0	9.3	
8/6	13.6	21.8	15.5	10.2	9.3	7.4	11.4	14.1	9.8	8.0	
8/7	13.6	21.7	15.5	10.2	9.3	7.3	11.3	14.0	9.7	7.8	
8/8	13.6	21.7	15.5	10.1	9.2	7.3	11.3	14.0	9.6	12.5	
8/9	13.6	21.7	15.4	10.1	9.2	7.2	11.2	13.9	9.5	11.4	
8/10	13.6	21.7	15.4	10.1	9.2	7.2	11.2	13.9	9.4	10.0	
8/11	13.6	21.6	15.4	10.0	9.2	7.1	11.1	13.8	9.3	9.7	
8/12	13.6	21.6	15.3	10.0	9.1	7.1	11.1	13.7	9.2	9.6	
8/13	13.6	21.6	15.3	10.0	9.1	7.0	11.1	13.7	9.1	9.5	
8/14	13.6	21.6	15.3	10.0	9.1	7.0	11.0	13.6	9.0	9.1	
8/15	13.6	21.6	15.3	9.9	9.1	6.9	11.0	13.6	8.9	9.1	

Flood stages at the above stations are shown below

30.0	35.0	29.0	18.0	17.0	17.0	32.0	20.0	21.0	21.0

Missouri River Basin
Mainstem Master Water Control Manual
Gavins Release Forecasting Tool
Missouri River Stages
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate VI-6

Missouri River Basin
Calendar Year 2018
Runoff Forecast

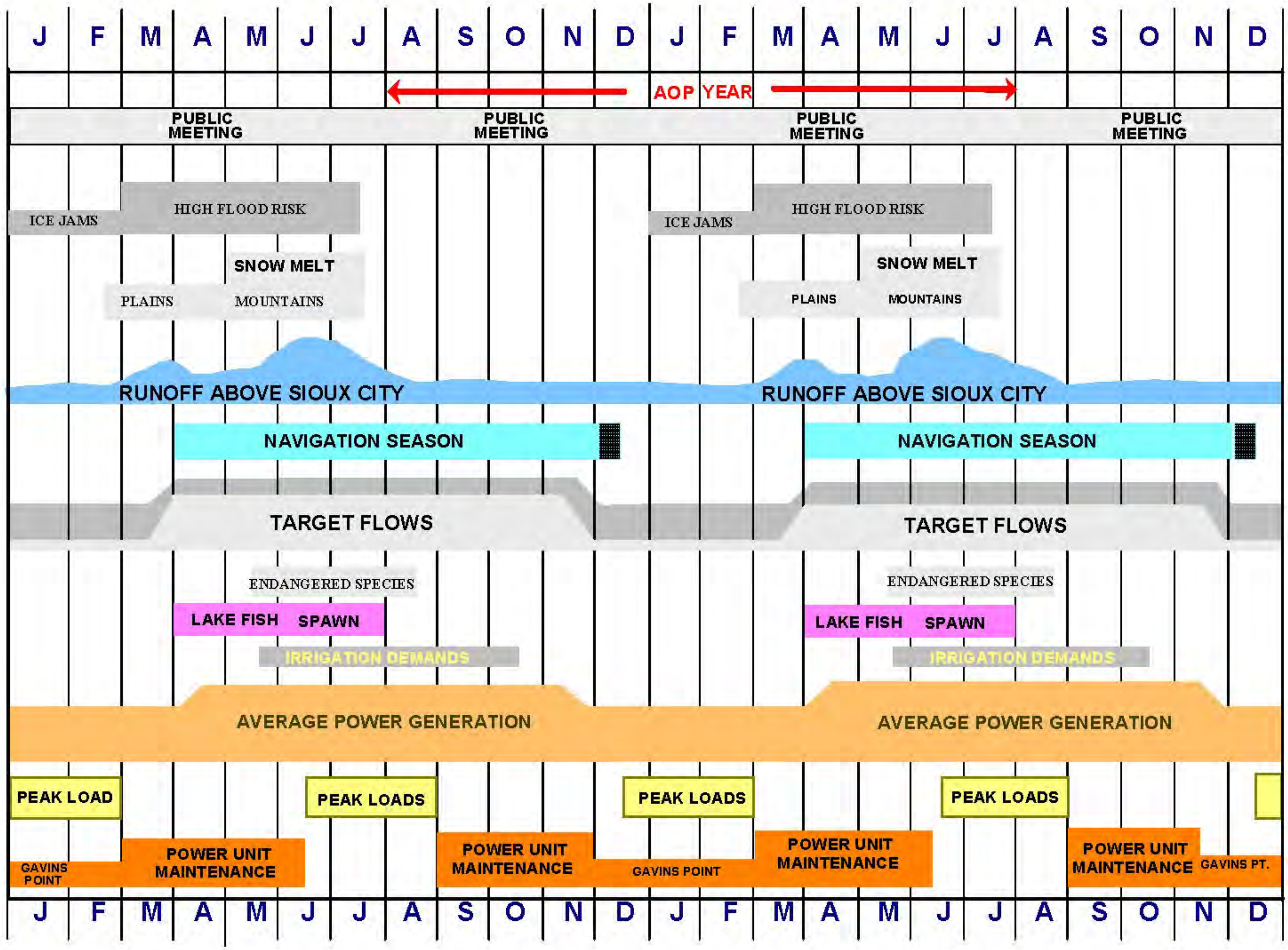
*1898-2017 Averages

1-May-18

	Incremental Runoff in Reaches								
	Fort Peck	Garrison	Oahe	Fort Randall	Gavins Point	Sioux City	Summation above Gavins Point	Summation above Sioux City	End-of-Month Accumulated Runoff above Sioux City
				Values in 1000 Acre Feet					
JAN 2018	296	338	-9	181	178	156	984	1,141	1,141
AVERAGE*	312	264	13	31	100	55	720	775	775
DEPARTURE	-16	74	-21	150	78	101	264	365	365
% OF AVG	95%	128%	-67%	583%	178%	284%	137%	147%	147%
FEB 2018	354	344	89	43	127	189	957	1,146	2,286
AVERAGE*	364	362	100	58	134	105	1,018	1,123	1,898
DEPARTURE	-10	-18	-11	-15	-7	84	-61	23	388
% OF AVG	97%	95%	89%	73%	95%	180%	94%	102%	120%
MAR 2018	907	1,196	453	361	336	559	3,252	3,811	6,097
AVERAGE*	596	1,002	579	211	209	326	2,597	2,923	4,821
DEPARTURE	311	194	-126	150	127	233	655	888	1,276
% OF AVG	152%	119%	78%	171%	161%	171%	125%	130%	126%
APR 2018	1,490	2,119	440	224	251	783	4,524	5,307	11,404
AVERAGE*	639	1,073	501	145	179	382	2,537	2,919	7,741
DEPARTURE	851	1,046	-61	79	72	401	1,987	2,388	3,664
% OF AVG	233%	197%	88%	155%	140%	205%	178%	182%	147%
	(Forecast)								
MAY 2018	1,575	1,900	300	160	210	400	4,145	4,545	15,949
AVERAGE*	1,079	1,270	324	149	187	328	3,009	3,337	11,077
DEPARTURE	496	630	-24	11	23	72	1,136	1,208	4,872
% OF AVG	146%	150%	93%	107%	113%	122%	138%	136%	144%
JUN 2018	2,300	3,750	446	161	184	340	6,841	7,181	23,130
AVERAGE*	1,628	2,727	446	161	184	327	5,146	5,473	16,550
DEPARTURE	672	1,023	0	0	0	13	1,695	1,708	6,580
% OF AVG	141%	138%	100%	100%	100%	104%	133%	131%	140%
JUL 2018	1,125	2,450	191	58	138	247	3,962	4,209	27,340
AVERAGE*	825	1,818	191	58	138	247	3,031	3,278	19,828
DEPARTURE	300	632	0	0	0	0	932	932	7,512
% OF AVG	136%	135%	100%	100%	100%	100%	131%	128%	138%
AUG 2018	475	775	81	43	116	152	1,490	1,642	28,982
AVERAGE*	360	613	81	43	116	152	1,213	1,365	21,193
DEPARTURE	115	162	0	0	0	0	277	277	7,789
% OF AVG	132%	126%	100%	100%	100%	100%	123%	120%	137%
SEP 2018	350	475	112	38	110	112	1,085	1,197	30,178
AVERAGE*	327	450	112	38	110	112	1,036	1,148	22,341
DEPARTURE	23	25	0	0	0	0	49	49	7,837
% OF AVG	107%	106%	100%	100%	100%	100%	105%	104%	135%
OCT 2018	390	533	71	4	119	95	1,117	1,212	31,391
AVERAGE*	380	533	71	4	119	95	1,107	1,202	23,543
DEPARTURE	10	0	0	0	0	0	10	10	7,848
% OF AVG	103%	100%	100%	100%	100%	100%	101%	101%	133%
NOV 2018	380	391	68	4	118	85	961	1,046	32,437
AVERAGE*	380	391	68	4	118	85	961	1,046	24,589
DEPARTURE	0	0	0	0	0	0	0	0	7,848
% OF AVG	100%	100%	100%	100%	100%	100%	100%	100%	132%
DEC 2018	327	253	5	12	100	63	698	761	33,197
AVERAGE*	327	253	5	12	100	63	698	761	25,350
DEPARTURE	0	0	0	0	0	0	0	0	7,848
% OF AVG	100%	100%	100%	100%	100%	100%	100%	100%	131%
				Calendar Year Totals					
	9,969	14,524	2,247	1,289	1,987	3,181	30,016	33,197	
AVERAGE*	7,217	10,756	2,491	912	1,693	2,277	23,069	25,346	
DEPARTURE	2,752	3,768	-244	377	294	904	6,947	7,851	
% OF NORM	138%	135%	90%	141%	117%	140%	130%	131%	

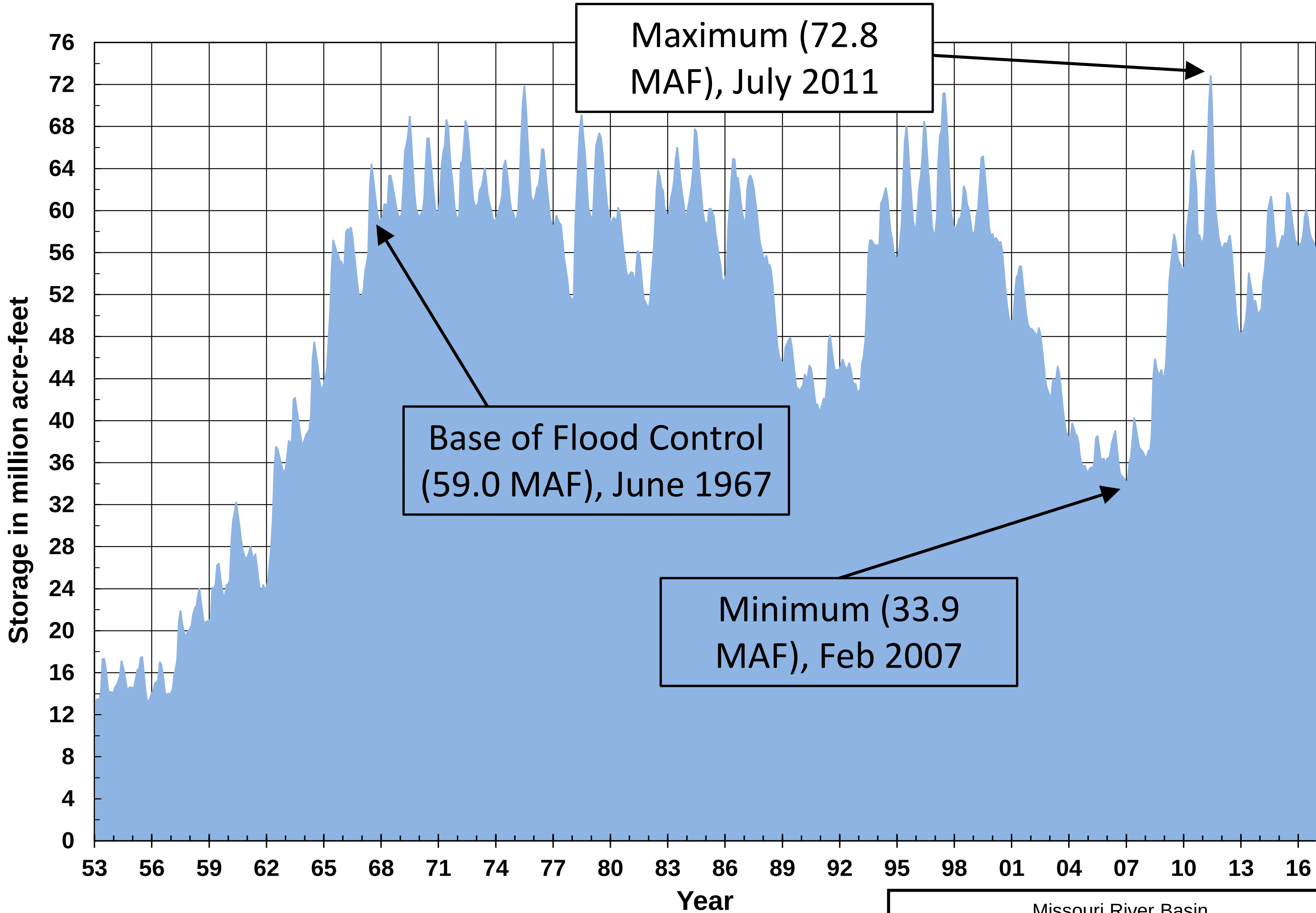
Missouri River Basin
Mainstem Master Water Control Manual
Upper Basin Runoff Forecast
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Water Control Calendar of Events



Missouri River Basin
Mainstem Master Water Control Manual
Calendar of Events
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

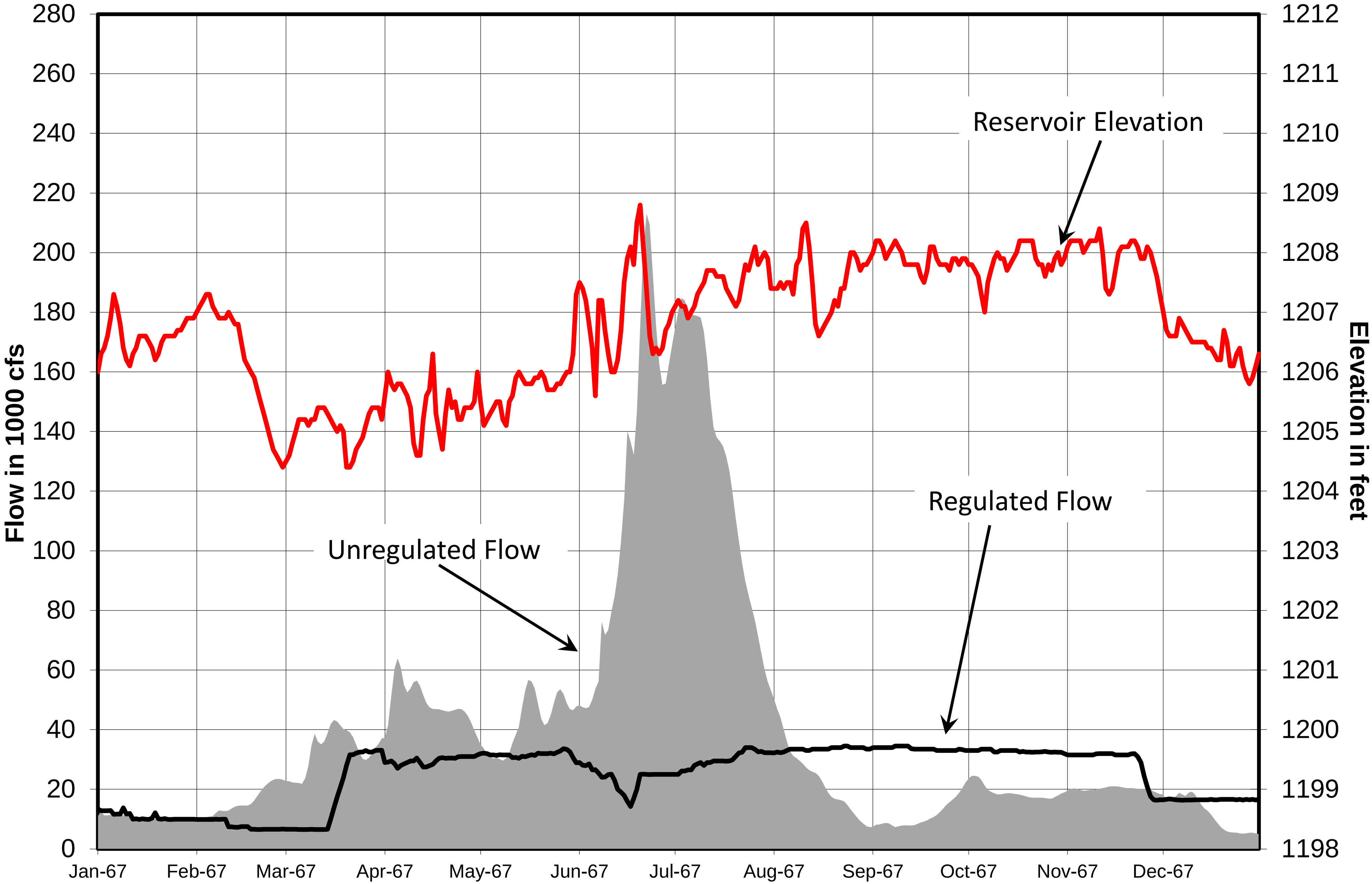
Plate VII-1



Missouri River Basin
Mainstem Master Water Control Manual
System Storage (1953-2017)
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

	System Storage (1000 AF)				Storage Zones (in MAF)			
	Top of Exclusive Flood Control Zone	Top of Annual Flood Control and Multiple Use Zone	Top of Carryover Multiple Use Zone	Top of Permanent Pool Zone	Exclusive Flood Control Storage	Annual Flood Control and Multiple Use Storage	Total Flood Control Storage	Carryover and Multiple Use Storage
1967	75,406	70,718	58,973	18,720	4.69	11.75	16.4	40.3
1968	75,266	70,589	58,826	18,666	4.68	11.76	16.4	40.2
1969	75,048	70,378	58,657	18,661	4.67	11.72	16.4	40.0
1970	75,034	70,365	58,645	18,649	4.67	11.72	16.4	40.0
1971	74,969	70,300	58,579	18,583	4.67	11.72	16.4	40.0
1972	74,740	70,065	58,362	18,520	4.68	11.70	16.4	39.8
1973	74,624	69,948	58,249	18,453	4.68	11.70	16.4	39.8
1974	74,624	69,948	58,249	18,453	4.68	11.70	16.4	39.8
1975	74,612	69,935	58,237	18,441	4.68	11.70	16.4	39.8
1976	74,442	69,759	58,052	18,371	4.68	11.71	16.4	39.7
1977	74,411	69,728	58,019	18,368	4.68	11.71	16.4	39.7
1978	74,411	69,728	58,019	18,368	4.68	11.71	16.4	39.7
1979	74,160	69,494	57,851	18,353	4.67	11.64	16.3	39.5
1980	74,160	69,494	57,851	18,353	4.67	11.64	16.3	39.5
1981	74,131	69,464	57,817	18,351	4.67	11.65	16.3	39.5
1982	74,131	69,464	57,817	18,351	4.67	11.65	16.3	39.5
1983	74,121	69,457	57,815	18,349	4.66	11.64	16.3	39.5
1984	74,121	69,457	57,815	18,349	4.66	11.64	16.3	39.5
1985	74,109	69,446	57,807	18,341	4.66	11.64	16.3	39.5
1986	73,808	69,146	57,501	18,246	4.66	11.65	16.3	39.3
1987	73,808	69,146	57,501	18,246	4.66	11.65	16.3	39.3
1988	73,706	69,039	57,402	18,236	4.67	11.64	16.3	39.2
1989	73,506	68,834	57,182	18,158	4.67	11.65	16.3	39.0
1990	73,506	68,834	57,182	18,158	4.67	11.65	16.3	39.0
1991	73,491	68,819	57,167	18,143	4.67	11.65	16.3	39.0
1992	73,491	68,819	57,167	18,143	4.67	11.65	16.3	39.0
1993	73,491	68,819	57,167	18,143	4.67	11.65	16.3	39.0
1994	73,491	68,819	57,167	18,143	4.67	11.65	16.3	39.0
1995	73,469	68,798	57,136	18,112	4.67	11.66	16.3	39.0
1996	73,393	68,723	57,067	18,084	4.67	11.66	16.3	39.0
1997	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
1998	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
1999	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2000	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2001	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2002	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2003	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2004	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2005	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2006	73,332	68,662	57,006	18,023	4.67	11.66	16.3	39.0
2007	73,312	68,644	56,992	18,009	4.67	11.65	16.3	39.0
2008	73,312	68,644	56,992	18,009	4.67	11.65	16.3	39.0
2009	73,087	68,423	56,784	17,886	4.66	11.64	16.3	38.9
2010	72,933	68,264	56,618	17,828	4.67	11.65	16.3	38.8
2011	72,786	68,119	56,483	17,768	4.67	11.64	16.3	38.7
2012	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5
2013	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5
2014	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5
2015	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5
2016	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5
2017	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5
2018	72,428	67,754	56,128	17,592	4.67	11.63	16.3	38.5

Missouri River Basin
Mainstem Master Water Control Manual
System Storage Zones by Year
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
March 2018

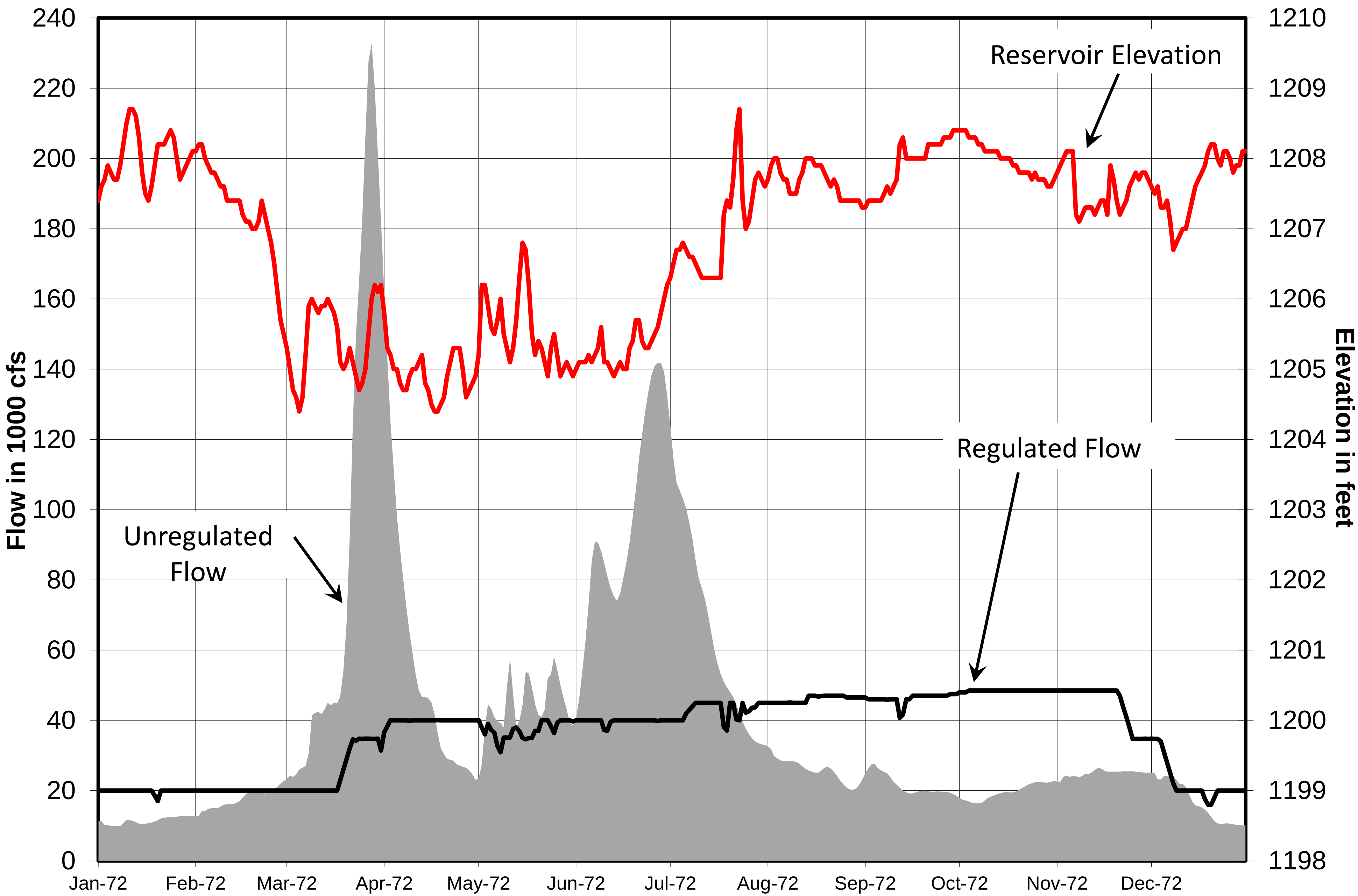


Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 1967

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018



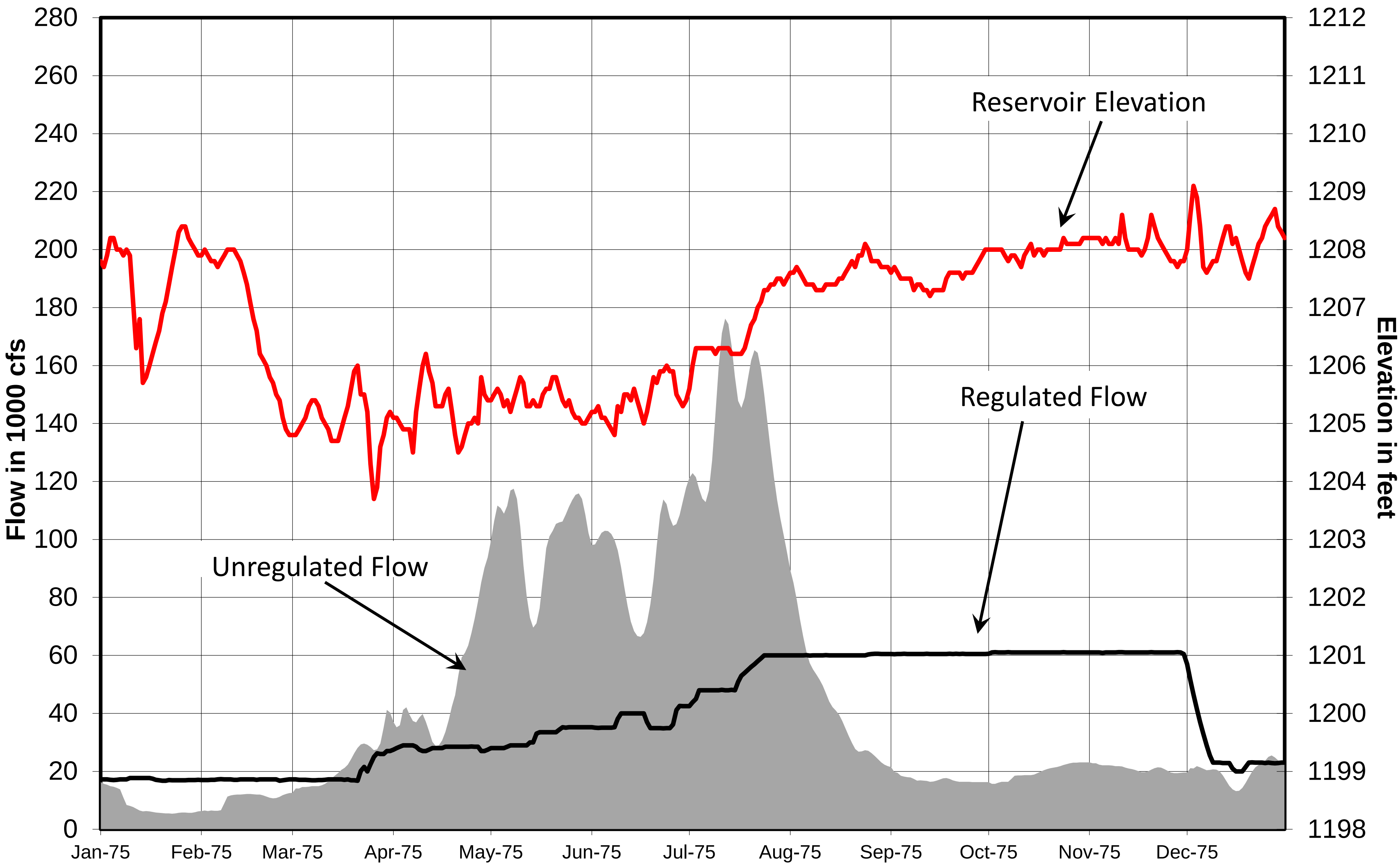
Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 1972

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

November 2018



Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 1975

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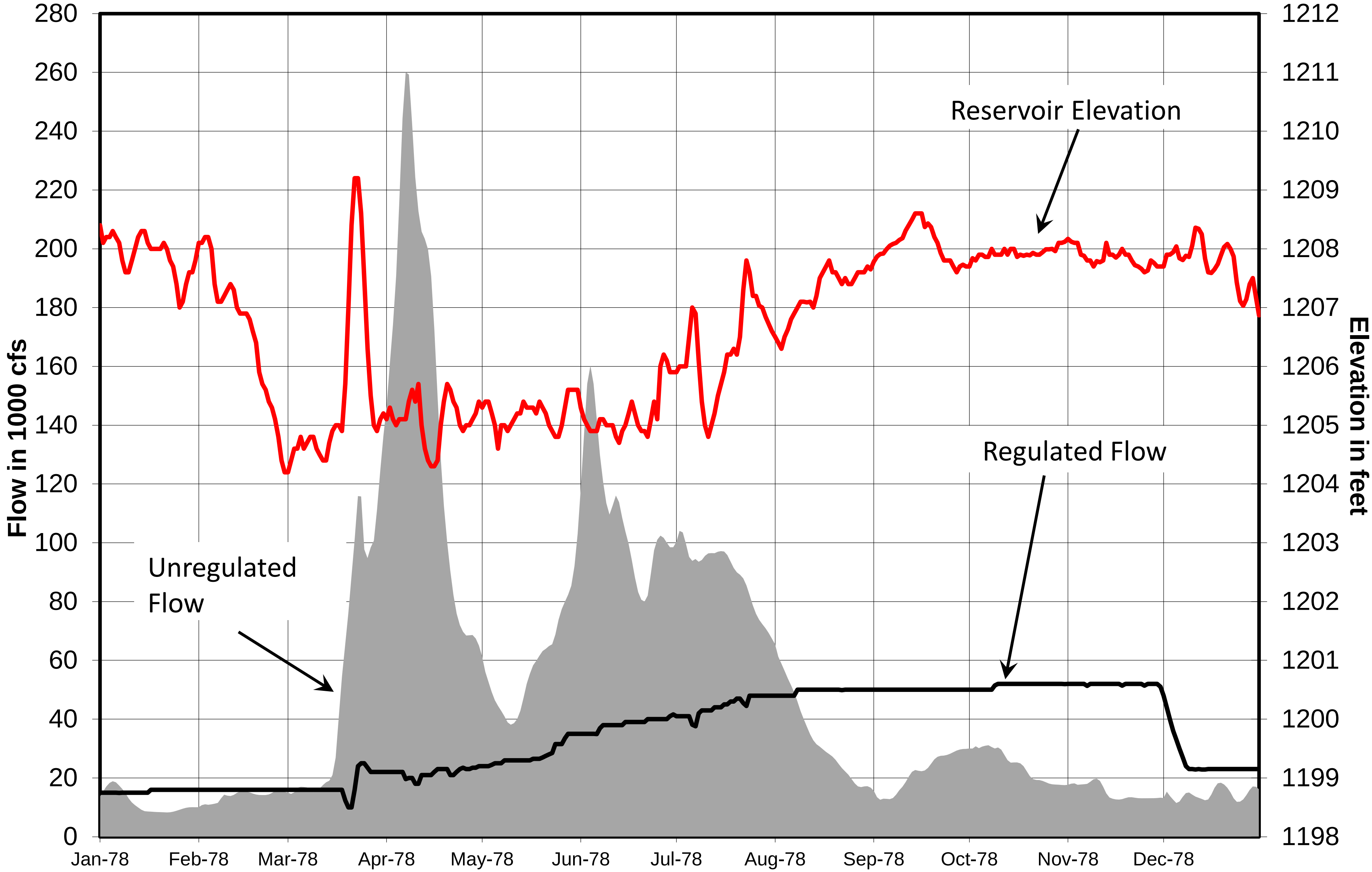

Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 1978

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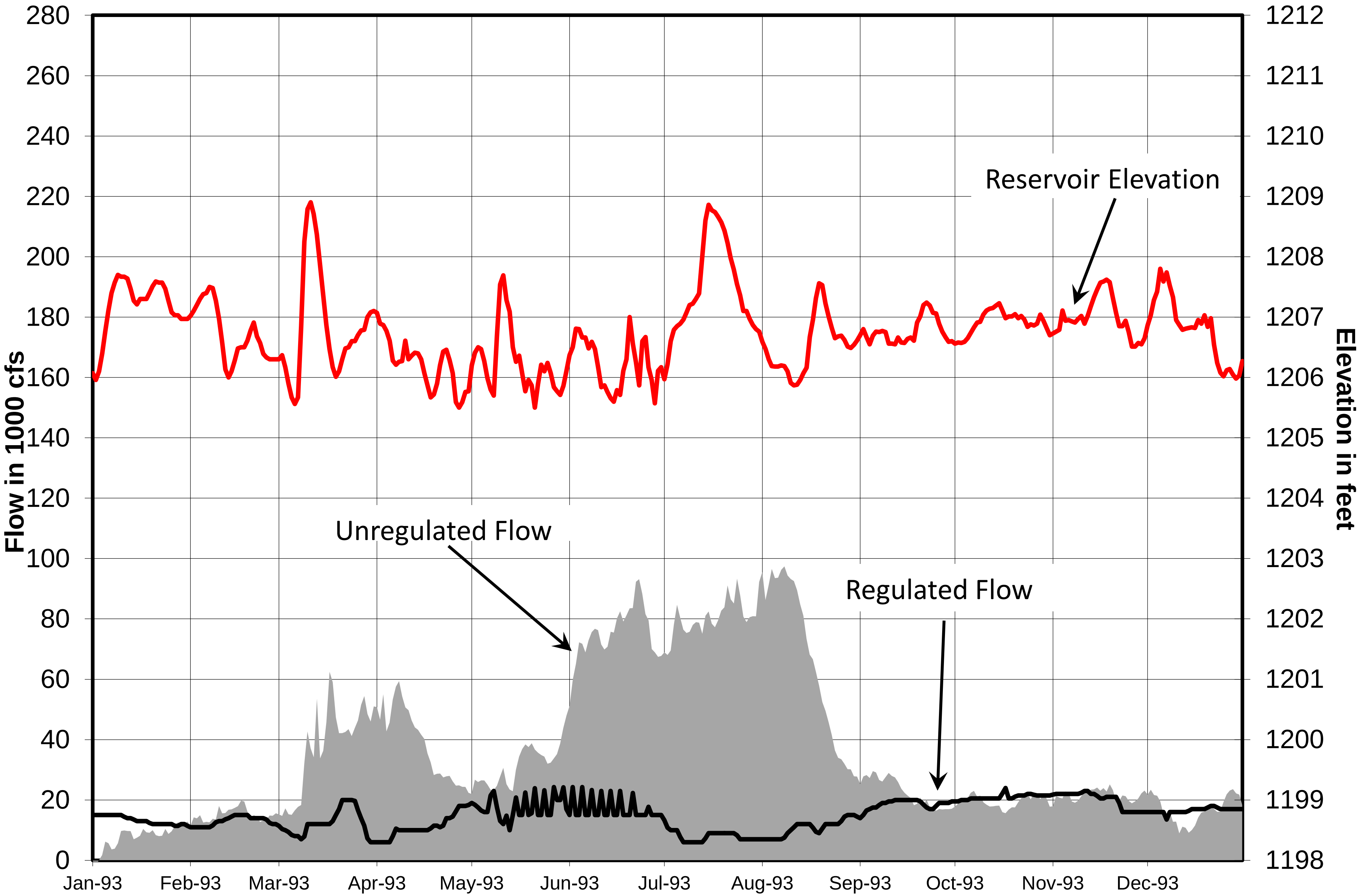

Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 1993

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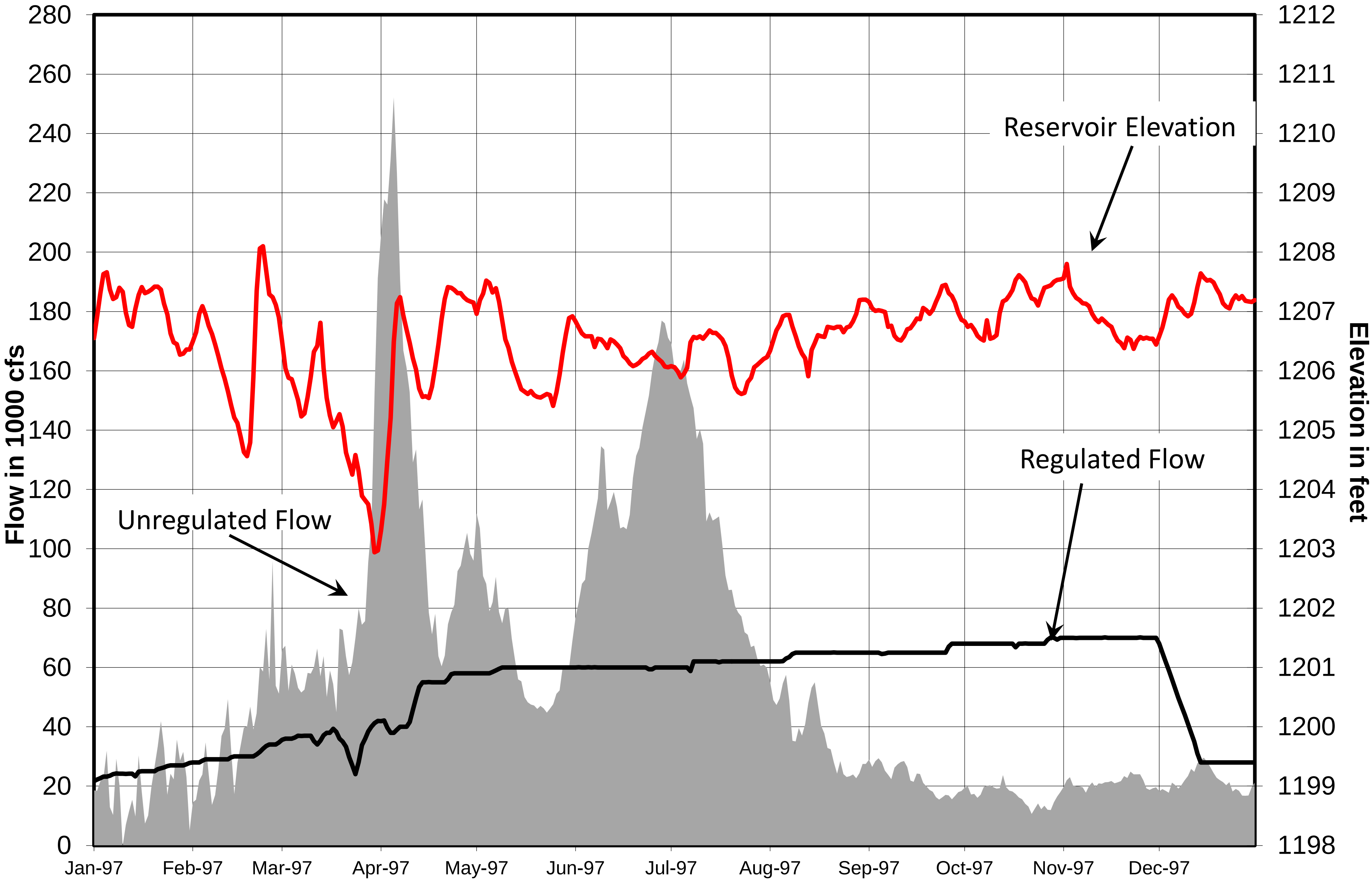

Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 1997

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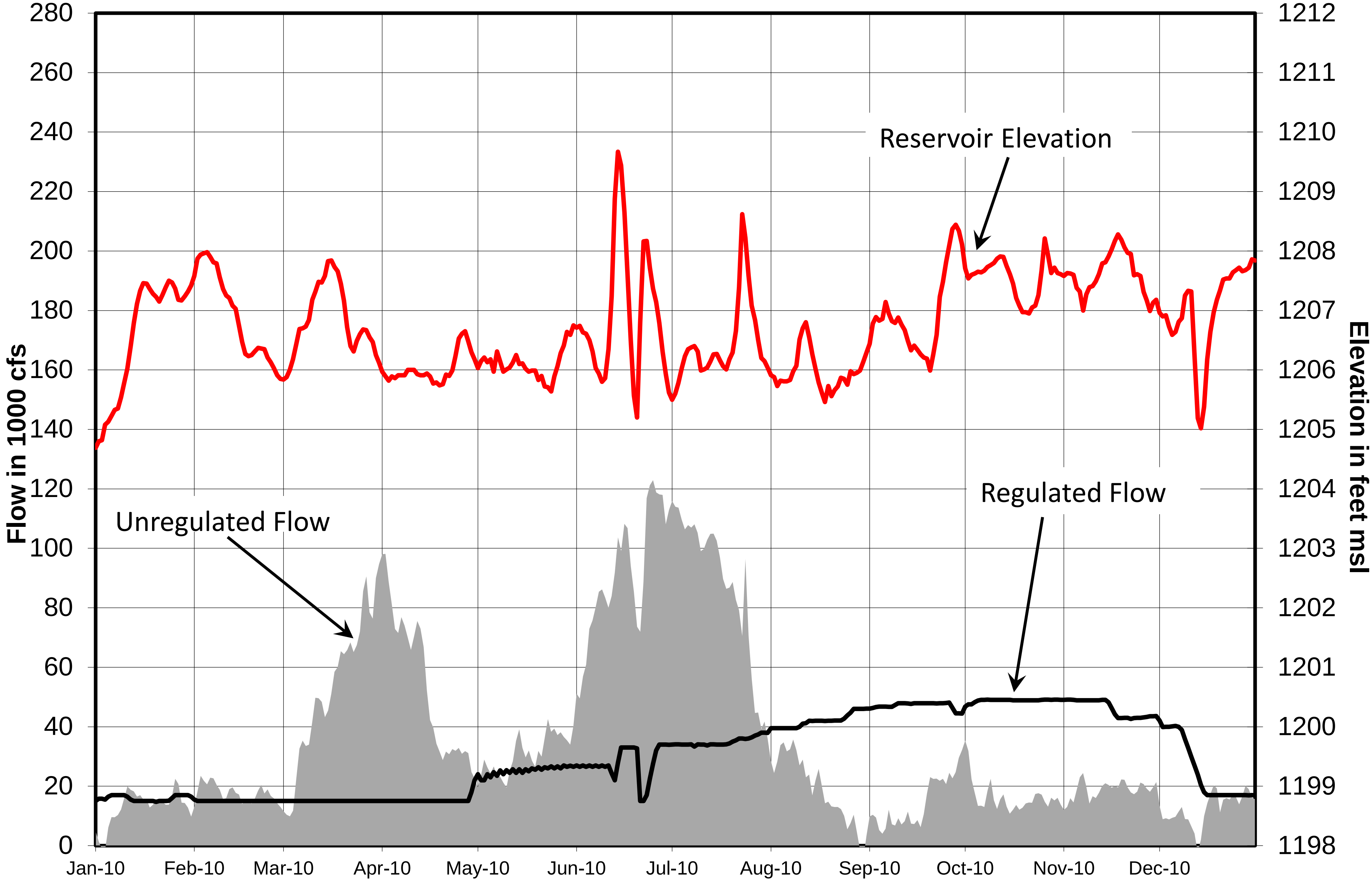

Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 2010

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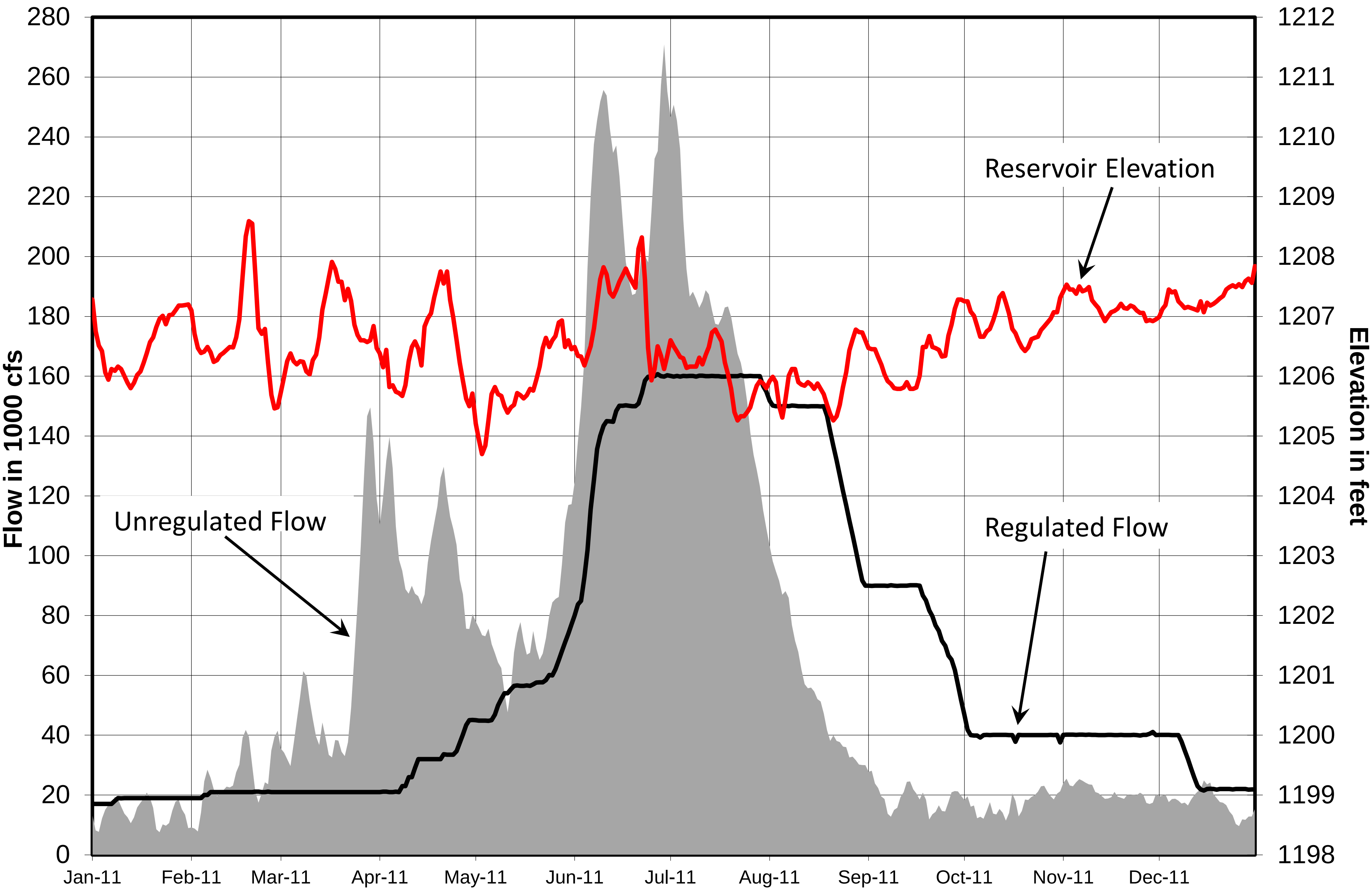
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2018

Plate VII-10



Missouri River Basin

Mainstem Master Water Control Manual

Gavins Point Elevation, Regulated and Unregulated Flows, 2011

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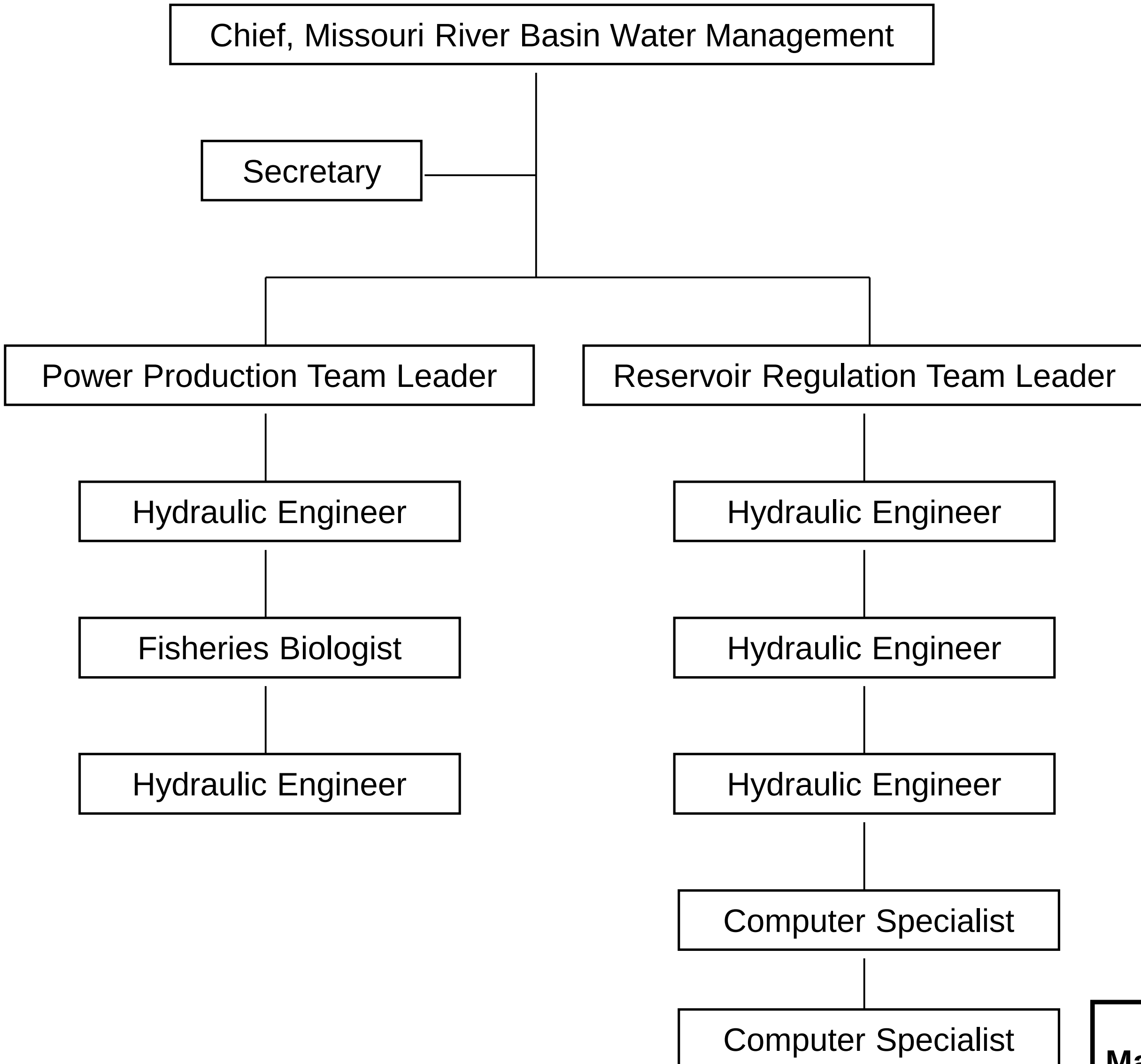
Missouri River Basin Water Management Division



Budget Analyst is shared with Columbia River Basin Water Management

Missouri River Basin
Mainstem Master Water Control Manual
MRBWM Division Organization Chart

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

November 2018

Simulated Regulation For 1951-1952-1944-1945 Flood Combination - Sheet 1

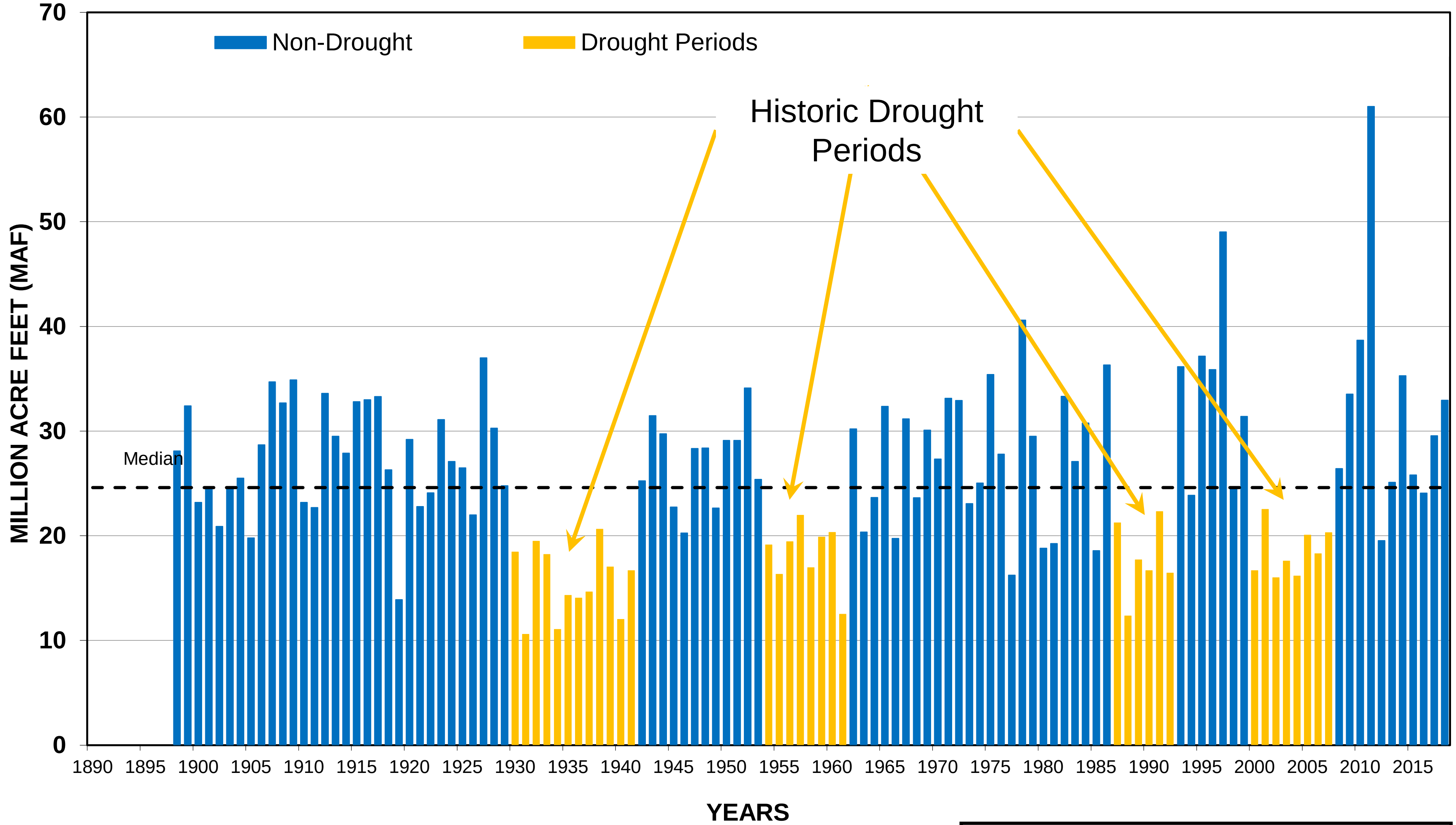
							1951								1952	
		22-Mar	31-Mar	30-Apr	31-May	30-Jun	31-Jul	31-Aug	30-Sep	31-Oct	15-Nov	30-Nov	31-Dec	31-Jan	28-Feb	15-Mar
Fort Peck																
Reach Inflow, 1000 AF	8773	223	287	911	1499	1508	881	434	489	522	233	233	318	384	526	323
Evap, 1000 AF	481	0	0	0	33	24	93	96	90	62	28	28	24	0	0	0
Inflow Adjust, 1000 AF	-824	13	16	3	-465	-470	-294	43	133	-71	24	24	-34	162	88	2
Modified Inflow, 1000 AF	7467	236	304	914	1000	1013	493	380	531	388	228	226	259	546	614	325
Storage, 1000 AF	15300	15453	15669	16285	16610	16969	16725	16367	16453	16534	16614	16694	16259	16036	15950	15904
Pool Elev, FT-MSL	2234.4	2235.1	2236.1	2238.8	2240.2	2241.5	2240.7	2239.2	2239.6	2239.9	2240.3	2240.6	2238.7	2237.7	2237.4	2237.2
Release, 1000 AF	6863	83	89	297	676	654	737	737	446	307	148	148	694	768	700	371
Release, 1000 CFS	9.5	6.0	5.0	5.0	11.0	11.0	12.0	12.0	7.5	5.0	5.0	5.0	11.3	12.5	12.5	12.5
Ave Power, MW	132	82	69	69	153	154	168	167	105	70	70	70	157	173	173	173
Peak Power, MW		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Energy, 1000 MWH	1160.1	13.9	15.0	50.4	114.3	111.0	125.1	124.8	75.6	52.4	25.4	25.4	117.5	129.3	117.6	62.4
Garrison																
Reach Inflow, 1000 AF	11939	187	240	1969	1374	2201	1702	1044	822	717	321	321	90	319	484	147
Evap, 1000 AF	549	0	0	0	36	26	105	112	105	70	32	32	27	0	0	0
Inflow Adjust, 1000 AF	-606	33	43	55	-161	-492	-120	-165	-65	84	20	20	21	25	29	65
Modified Inflow, 1000 AF	17646	303	372	2321	1852	2337	2214	1504	1097	1038	456	456	778	1112	1213	585
Storage, 1000 AF	18200	18334	18261	19005	19411	20498	20868	20528	19841	20264	20423	20583	19977	19399	18931	18624
Pool Elev, FT-MSL	1837.0	1837.5	1837.2	1839.8	1840.8	1844.0	1845.0	1844.1	1842.2	1843.4	1843.8	1844.2	1842.5	1840.8	1839.3	1838.4
Release, 1000 AF	17221	168	446	1487	1537	1249	1844	1844	1785	614	297	297	1383	1690	1681	892
Release, 1000 CFS	23.8	12.2	25.0	25.0	25.0	21.0	30.0	30.0	30.0	10.0	10.0	10.0	22.5	27.5	30.0	30.0
Ave Power, MW	294	150	300	302	306	261	374	374	371	129	130	130	281	338	364	362
Peak Power, MW		446	445	455	459	460	460	460	460	460	460	460	460	459	453	449
Energy, 1000 MWH	2577.8	25.3	64.8	217.8	227.7	188.5	278.5	278.6	267.5	96.4	46.9	47.0	209.3	251.8	247.4	130.3
Oahe																
Reach Inflow, 1000 AF	1266	53	68	933	-78	185	50	20	105	44	-54	-54	-68	-71	78	53
Evap, 1000 AF	481	0	0	0	32	23	89	96	94	66	28	27	22	0	0	0
Inflow Adjust, 1000 AF	88	-14	-16	-39	80	-62	-37	-24	-37	-13	61	61	82	85	-22	-14
Modified Inflow, 1000 AF	18095	208	490	2381	1506	1349	1768	1744	1758	579	275	276	1375	1704	1737	932
Storage, 1000 AF	19100	18982	19122	20135	20412	20571	21110	21821	22495	21077	20249	9397	18659	18867	19610	20131
Pool Elev, FT-MSL	1607.1	1606.7	1607.1	1610.2	1611.1	1611.6	1613.2	1615.4	1617.2	1613.1	1610.6	1608.0	1605.7	1606.4	1608.6	1610.2
Release, 1000 AF	17063	325	357	1368	1229	1190	1229	1033	1084	1998	1103	1128	2112	1497	994	411
Release, 1000 CFS	23.6	23.4	20.0	23.0	20.0	20.0	20.0	16.8	18.2	32.5	37.1	37.9	34.4	24.4	17.7	13.8
Ave Power, MW	311	302	258	300	265	266	267	227	249	438	492	495	441	312	231	183
Peak Power, MW		685	685	685	685	685	685	685	685	685	685	685	685	685	685	685
Energy, 1000 MWH	2726.8	50.9	55.9	216.6	197.5	191.8	199.4	169.6	179.3	326.6	177.2	278.3	328.7	232.4	156.7	66.0
Big Bend																
Evap, 1000 AF	60	0	0	0	4	3	11	12	11	7	3	3	3	0	0	0
Ave Power, MW	107	106	89	100	85	84	82	69	79	155	181	185	168	116	81	61
Peak Power, MW		487	487	454	459	440	426	454	491	529	537	538	531	506	495	495
Energy, 1000 MWH	941.5	17.9	19.4	72.6	63.5	60.8	61.3	51.8	57.2	115.6	65.3	66.9	125.1	86.8	55.0	22.3
Fort Randall																
Reach Inflow 1000 AF	1181	33	42	103	131	218	77	23	56	100	60	60	6	24	119	128
Evap, 1000 AF	70	0	0	0	5	3	14	15	13	8	3	3	2	0	0	0
Inflow Adjust, 1000 AF	-161	-3	-4	-21	-19	-34	-33	-17	-17	-4	0	0	-1	-1	-1	-3
Modified Inflow, 1000 AF	17953	354	394	1450	1332	1367	1248	1011	1098	2077	1155	1180	2112	1520	1112	535
Storage, 1000 AF	3700	3783	3780	4116	4072	4262	4392	4115	3746	3218	2868	2543	3184	3598	3701	3701
Pool Elev, FT-MSL	1353.0	1354.0	1354.0	1357.9	1357.4	1359.5	1360.9	1357.9	1353.6	1346.9	1342.2	1337.5	1346.5	1351.8	1353.0	1353.0
Release, 1000 AF	17951	271	397	1115	1376	1177	1118	1288	1467	2606	1505	1505	1471	1106	1008	535
Release, 1000 CFS	24.8	19.6	22.3	18.7	22.4	19.8	18.2	21.0	24.7	42.4	50.6	50.6	23.9	18.0	18.0	18.0
Ave Power, MW	192	161	183	157	190	170	159	181	204	322	299	277	176	143	147	148
Peak Power, MW		338	338	353	352	360	365	353	337	307	285	264	305	329	334	334
Energy, 1000 MWH	1684.7	27.1	39.6	113.7	141.4	122.5	118.4	134.7	147.5	240.0	107.7	100.0	131.3	107.1	100.3	53.5
Gavins Point																
Reach Inflow, 1000 AF	2363	65	84	296	235	343	19.0	289	242	171	13	13	63	115	171	242
Evap, 1000 AF	31	0	0	0	2	1	6	6	6	4	1	1	1	0	0	0
Inflow Adjust, 1000 AF	-140	-4	-5	-5	-10	-24	-26	-38	-23	-14	6	6	1	1	0	-4
Release, 1000 AF	20143	332	476	1406	1599	1494	1104	1532	1679	2758	1523	1523	1533	1222	1179	773
Release, 1000 CFS	27.8	24.0	26.7	23.6	26.0	25.1	18.0	24.9	28.2	44.9	51.2	51.2	24.9	19.9	21.1	26.0
Ave Power, MW	75	72	79	71	77	75	56	75	83	95	92	92	75	61	64	77
Peak Power, MW		97	99	96	99	99	75	99	99	95	92	92	99	82	86	99
Energy, 1000 MWH	662.3	12.2	17.2	51.5	57.9	54.4	41.8	55.8	60.3	70.7	33.4	33.4	55.9	45.9	43.9	28.0
Mainstem System																
Reach Inflow, 1000 AF	29276	656	843	4989	3568	5089	3322	2092	2032	1721	562	562	431	725	1619	1044
Evap, 1000 AF	1675	0	0	0	113	82	319	339	321	219	99	98	81	0	0	0
Inflow Adjust, 1000 AF	-1872	21	27	-40	-595	-1114	-556	-240	-40	-27	110	110	68	271	90	41
Storage, 1000 AF	58300	58721	59001	61800	62673	64469	65264	65000	64703	63261	62323	61385	60248	60068	60360	60529
Ave Power, MW	1112	876	980	1003	1078	1012	1108	1095	1093	1211	1266	1252	1300	1146	1063	1006
Peak Power, MW		2255	2256	2246	2255	2244	2213	2252	2272	2277	2260	2240	2280	2263	2256	2264
Energy, 1000 MWH	9753.3	147.2	211.9	722.7	802.3	729.0	824.5	815.3	787.5	901.7	455.8	451.0	967.7	853.3	720.9	362.5
Service Level, 1000 CFS		35.0	35.0	35.0	35.0	35.0	38.0	41.0	45.0	55.0	60.0	60.0				
Navigation Season Length		20	20	20	20	20.0	20	20	20	20	20	20	20	20	20	20
Control Point		11	992	992	9992	9992	9992	9992	9992	994	994	994	11	11	11	11
Sioux City																
Reach Inflow, 1000 AF	3751	93	119	777	427	634	593	282	318	167	-12	-12	22	-46	241	147
Inflow Adjust, 1000 AF	-229	-3	-4	-33	-20	-32	-46	-39	-31	-9	0	0	-1	-1	-4	-3
Modified Inflow, 1000 AF	3522	89	115	744	407	602	547	243	287	158	-12	-12	21	-47	237	143
Flow, 1000 AF	23666	422	591	2149	2005	2096	1651	1775	1966	2916	1511	1511	1554	1175	1416	917
Flow, 1000 CFS	32.7	30.4	33.1	36.1	32.6	35.2	26.9	28.9	33.1	47.4	50.8	50.8	25.3	19.1	25.3	30.8
Omaha																
Reach Inflow, 1000 AF	3879	132	170	755	545	392	444	552	284	28	30	30	79	90	291	54
Inflow Adjust, 1000 AF	-33	-1	-2	-6	-6	-8	-6	-2	0	0	0	0	0	0	0	-1
Modified Inflow, 1000 AF	3846	131	168	749	539	384	438	550	284	28	30	30	79	90	291	53
Flow, 1000 AF	27485	528	751	2889	2555	2473	2115	2319	2238	2901	1531	1541	1710	1284	1689	954
Flow, 1000 CFS	37.9	38.0	42.1	48.6	41.6	41.6	34.4	37.7	37.6	47.2	51.5	51.8	27.8	20.9	30.1	32.1
Nebraska City																
Reach Inflow, 1000 AF	8035	275	354	573	912	1331	781	562	537	496	227	227	345	406	732	276
Inflow Adjust, 1000 AF	-947	-2	-3	7	-21	-87	-129	-129	-119	-84	-31	-31	3	-60	-182	-79
Modified Inflow, 1000 AF	7087	273	351	580	891	1244	652	433	418	412	196	196	348	346	550	197
Flow, 1000 AF	34564	792	1100	3466	3450	3714	2775	2750	2652	3299	1724	1737	2083	1636	2232	1145
Flow, 1000 CFS	47.7	57.1	61.6	58.3	56.1	62.4	45.1	44.7	44.6	53.7	58.0	58.4	33.9	26.6	39.9	38.5
Kansas City																
Reach Inflow, 1000 AF	28938	125	160	755	3153	5906	9363	2207	3460	1110	472	472	355	381	518	500
Inflow Adjust, 1000 AF	-333	0	-1	-50	-34	-1019	-808	802	-5	884	77	77	-6	-9	-30	-10
Modified Inflow, 1000 AF	28605	124	159	705	3119	4887	8555	3009	3455	1794	549	549	349	372	488	489
Flow, 1000 AF	63134	883	1249	4159	6583	8591	11363	5751	6090	5035	2260	2286	2534	2033	2696	1613
Flow, 1000 CFS	87.1	63.6	70.0	69.9	107.1	144.4	184.8	93.5	102.4	81.9	76.0	76.9	41.2	33.1	48.1	54.2
Boonville																
Reach Inflow, 1000 AF	13785	149	192	1490	845	1035	4722	939	1215	851	355	355	562	499	452	623
Inflow Adjust, 1000 AF	-93	-5	-7	-19	-19	-28	0	0	0	0	0	0	0	0	-9	-5
Modified Inflow, 1000 AF	13692	144	185	1471	826	1007	4722	939	1215	351	355	355	562	499	443	617
Flow, 1000 AF	76791	993	1423	5618	7423	9587	16119	6682	7288	5329	2601	2641	3199	2556	3114	2209
Flow, 1000 CFS	106.0	71.6	79.8	94.4	120.7	161.1	262.2	108.7	122.5	86.7	87.4	88.8	52.0	41.6	55.6	74.3
Hermann																
Reach Inflow, 1000 AF	28844	643	826	1778	1310	1440	8947	974	3993	1547	1262	1262	1326	1121	1703	710
Inflow Adjust, 1000 AF	-89	-22	-29	-86	-88	47	74	89	150	-82	-22	-22	-20	-19	-33	-24
Modified Inflow, 1000 AF	28754	620	797	1692	1222	1487	9021	1063	4143	1465	1240	1240	1306	1102	1670	685
Flow, 1000 AF	105528	1597	2216	7304	8652	11069	25157	7741	11423	6765	3834	3881	4556	3671	4772	2883
Flow, 1000 CFS	145.7	115.1	124.1	122.8	140.7	186.0	409.1	125.9	192.0	110.0	128.9	130.5	74.1	59.7	85.2	96.9

Missouri River Basin
Mainstem Master Water Control Manual
Simulated Regulation for
1951-1952-1944-1945 Flood Combination
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Simulated Regulation For 1951-1952-1944-1945 Flood Combination - Sheet 2

		1952				1944								1945		
		22-Mar	31-Mar	30-Apr	31-May	30-Jun	31-Jul	31-Aug	30-Sep	31-Oct	15-Nov	30-Nov	31-Dec	31-Jan	28-Feb	15-Mar
Fort Peck																
Reach Inflow, 1000 AF	9036	283	363	1541	1693	1740	914	375	309	339	163	163	270	375	343	163
Evap, 1000 AF	518	0	0	0	34	25	101	107	99	66	29	29	24	0	0	0
Inflow Adjust, 1000 AF	-1251	2	3	-162	-523	-540	-304	-46	136	12	25	25	-5	38	67	18
Modified Inflow, 1000 AF	7266	285	366	1379	1135	1174	508	221	345	284	159	159	240	413	410	182
Storage, 1000 AF	15644	15846	16123	17205	18033	18909	18928	18298	17799	17313	17071	16828	16374	16018	15728	15539
Pool Elev, FT-MSL	2236.0	2236.9	2238.1	2242.8	2246.4	2250.0	2250.1	2247.5	2245.4	2243.3	2242.3	2241.2	2239.2	2237.7	2236.4	2235.5
Release, 1000 AF	7371	83	89	297	307	297	489	851	844	770	401	402	694	768	700	371
Release, 1000 CFS	10.2	6.0	5.0	5.0	5.0	5.0	8.0	13.9	14.2	12.5	13.5	13.5	11.3	12.5	12.5	12.5
Ave Power, MW	142	83	69	70	71	71	112	195	200	176	189	189	158	173	173	172
Peak Power, MW		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Energy, 1000 MWH	1251.3	14.0	15.1	50.8	52.8	51.2	83.8	145.3	144.0	131.2	68.3	68.2	117.6	129.4	117.4	62.1
Garrison																
Reach Inflow, 1000 AF	17222	129	166	4802	2097	4346	2469	567	395	460	214	214	250	238	365	508
Evap, 1000 AF	603	0	0	0	41	29	119	125	115	76	34	33	27	0	0	0
Inflow Adjust, 1000 AF	-929	57	73	131	-54	-749	-345	-64	-37	18	4	4	35	1	-6	0
Modified Inflow, 1000 AF	23060	270	329	5230	2309	3864	2494	1229	1087	1171	585	586	952	1007	1059	881
Storage, 1000 AF	18861	18962	18845	21969	22102	23664	23695	22898	22101	21315	20934	20555	20124	19440	18819	18808
Pool Elev, FT-MSL	1839.1	1839.4	1839.1	1848.1	1848.5	1852.7	1852.8	1850.7	1848.5	1846.3	1845.2	1844.2	1843.0	1840.9	1839.0	1838.9
Release, 1000 AF	23113	168	446	2106	2176	2302	2464	2025	1884	1958	965	965	1383	1690	1681	892
Release, 1000 CFS	31.9	12.2	25.0	35.4	35.4	38.7	40.1	32.9	31.7	31.8	32.5	32.5	22.5	27.5	30.0	30.0
Ave Power, MW	393	152	303	438	447	460	460	421	402	402	406	404	281	339	364	362
Peak Power, MW		454	452	460	460	460	460	460	460	460	460	460	460	460	452	452
Energy, 1000 MWH	3447.0	25.6	65.7	315.6	332.8	331.2	342.2	313.3	290.0	299.1	146.4	145.7	209.5	252.3	247.2	130.4
Oahe																
Reach Inflow, 1000 AF	6456	47	60	3650	230	1299	40	145	61	30	76	76	-105	16	365	463
Evap, 1000 AF	504	0	0	0	37	26	101	106	95	61	27	27	22	0	0	0
Inflow Adjust, 1000 AF	-529	-12	-16	-288	-18	-70	-34	-48	-18	-3	-2	-2	119	-2	-93	-41
Modified Inflow, 1000 AF	28535	203	490	5468	2351	3505	2369	2016	1831	1924	1012	1013	1374	1704	1953	1314
Storage, 1000 AF	20153	20007	20141	23506	23506	23506	23431	22010	20498	19827	19806	19762	18872	18989	19884	20797
Pool Elev, FT-MSL	1610.3	1609.9	1610.3	1620.0	1620.0	1620.0	1619.8	1615.9	1611.4	1609.3	1609.2	1609.1	1606.4	1606.7	1609.5	1612.3
Release, 1000 AF	27890	349	357	2103	2351	3505	2443	3437	3343	2596	1033	1057	2264	1588	1058	401
Release, 1000 CFS	38.5	25.1	20.0	35.4	38.2	58.9	39.7	55.9	56.2	42.2	34.7	35.6	36.8	25.8	18.9	13.5
Ave Power, MW	493	331	264	477	525	685	545	685	685	554	453	464	476	332	246	180
Peak Power, MW		685	685	685	685	685	685	685	685	685	685	685	685	685	685	685
Energy, 1000 MWH	4326.7	55.7	57.1	343.8	390.9	493.2	406.0	509.6	493.2	412.7	163.4	167.1	354.3	247.3	167.3	65.1
Big Bend																
Evap, 1000 AF	60	0	0	0	4	3	11	12	11	7	3	3	3	0	0	0
Ave Power, MW	168	112	86	139	144	219	159	257	258	202	169	174	180	123	86	60
Peak Power, MW		471	459	349	410	331	491	491	491	529	537	538	531	506	495	495
Energy, 1000 MWH	1480.8	18.9	18.7	100.5	107.2	157.9	118.8	191.2	186.0	150.8	61.1	62.7	134.2	92.2	58.6	21.8
Fort Randall																
Reach Inflow, 1000 AF	2598	112	144	1305	139	490	179	180	54	-8	25	25	-174	-69	55	140
Evap, 1000 AF	71	0	0	0	6	3	17	13	12	8	3	3	2	0	0	0
Inflow Adjust, 1000 AF	-187	-3	-4	-19	-28	-41	-35	-33	-18	1	-1	-1	1	1	-1	-6
Modified Inflow, 1000 AF	30169	458	497	3389	2452	3947	2559	3559	3355	2572	1049	1074	2085	1520	1112	535
Storage, 1000 AF	3701	3950	4072	5131	4549	5306	3746	3746	3746	3218	2868	2543	3184	3598	3701	3701
Pool Elev, FT-MSL	1353.0	1356.0	1357.4	1368.6	1362.6	1370.3	1353.6	1353.6	1353.6	1346.9	1342.2	1337.5	1346.5	1351.8	1353.0	1353.0
Release, 1000 AF	30168	208	375	2331	3034	3190	4118	3559	3355	3101	1399	1399	1444	1106	1008	535
Release, 1000 CFS	41.6	15.0	21.0	39.2	49.3	53.6	67.0	57.9	56.4	50.4	47.1	47.1	23.5	18.0	18.0	18.0
Ave Power, MW	277	126	177	340	360	360	360	336	336	322	299	277	173	143	147	148
Peak Power, MW		346	352	368	368	368	337	337	337	307	285	264	305	329	334	334
Energy, 1000 MWH	2430	21.2	38.4	245.3	267.8	259.2	267.8	250.4	242.3	240.0	107.7	100.0	129.0	107.1	100.3	53.5
Gavins Point																
Reach Inflow, 1000 AF	2060	212	273	271	155	218	137	103	79	101	53	53	87	113	133	71
Evap, 1000 AF	31	0	0	0	2	1	6	6	6	4	1	1	1	0	0	0
Inflow Adjust, 1000 AF	-152	-4	-5	-6	-9	-24	-32	-30	-22	-14	-2	-2	2	2	1	-4
Release, 1000 AF	32045	416	643	2596	3178	3382	4216	3625	3405	3183	1448	1448	1532	1221	1142	601
Release, 1000 CFS	44.2	30.0	36.0	43.6	51.7	56.9	68.6	59.0	57.2	51.8	48.7	48.7	24.9	19.9	20.4	20.2
Ave Power, MW	84	88	98	95	92	90	86	89	90	92	93	93	74	61	63	62
Peak Power, MW		99	98	95	92	90	86	89	90	92	93	93	99	82	84	83
Energy, 1000 MWH	738.5	14.8	21.2	68.8	68.9	65.3	64.3	66.9	65.2	68.8	33.7	33.7	55.8	45.8	42.7	22.5
Mainstem System																
Reach Inflow, 1000 AF	41390	914	1175	12600	4915	8162	4659	1800	1124	1067	571	571	326	679	1346	1481
Evap, 1000 AF	1790	0	0	0	125	90	356	370	340	224	100	99	81	0	0	0
Inflow Adjust, 1000 AF	-3291	36	46	-375	-652	-1430	-799	-268	-4	3	19	19	151	39	-38	-40
Storage, 1000 AF	60528	60934	61350	69979	70358	73553	71968	69121	66314	63841	62848	61856	60722	60213	60300	61013
Ave Power, MW	1559	894	1000	1562	1640	1886	1724	1984	1973	1750	1612	1604	1344	1174	1081	987
Peak Power, MW		2256	2247	2157	2215	2135	2259	2263	2263	2274	2260	2241	2280	2263	2252	2251
Energy, 1000 MWH	13674.3	150.3	216.1	1124.8	1220.5	1358.0	1283.0	1476.8	1420.7	1302.6	580.6	577.5	1000.4	874.1	733.6	355.4
Service Level, 1000 CFS		55.0	55.0	60.0	65.0	70.0	75.0	65.0	60.0	60.0	60.0	60.0				
Navigation Season Length		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Control Point		11	992	992	992	992	992	994	994	994	994	994	11	11	11	11
Sioux City																
Reach Inflow, 1000 AF	4016	129	166	1031	601	69	920	430	226	145	38	38	-2	6	85	132
Inflow Adjust, 1000 AF	-241	-3	-4	-31	-20	-6	-49	-47	-45	-11	-4	-4	-1	-1	-6	-7
Modified Inflow, 1000 AF	3775	126	162	1000	581	63	871	383	181	134	34	34	-3	5	79	125
Flow, 1000 AF	35821	542	805	3595	3758	3445	5087	4008	3586	3317	1482	1482	1529	1226	1221	727
Flow, 1000 CFS	49.4	39.1	45.1	60.4	61.1	57.9	82.7	65.2	60.3	54.0	49.8	49.8	24.9	20.0	21.8	24.4
Omaha																
Reach Inflow, 1000 AF	1520	48	61	109	128	512	140	147	73	-1	19	19	-26	17	148	125
Inflow Adjust, 1000 AF	-35	-1	-1	-4	-4	-8	-6	-2	0	0	0	0	0	0	0	-8
Modified Inflow, 1000 AF	1485	46	60	105	124	504	134	145	73	-1	19	19	-26	17	148	117
Flow, 1000 AF	37326	564	847	3655	3880	3959	5147	4206	3674	3335	1514	1501	1578	1258	1364	836
Flow, 1000 CFS	51.5	40.7	47.5	61.4	63.1	66.5	83.7	68.4	61.8	54.3	50.9	50.5	25.7	20.5	24.3	28.1
Nebraska City																
Reach Inflow, 1000 AF	5708	242	311	644	886	1377	508	307	187	148	92	92	126	251	337	200
Inflow Adjust, 1000 AF	-916	-69	-89	-131	-118	-69	-2	-110	-75	-59	-37	-37	-50	-100	23	7
Modified Inflow, 1000 AF	4792	172	222	513	768	1308	506	197	112	89	55	55	76	151	360	207
Flow, 1000 AF	42125	729	1063	4152	4648	5270	5628	4421	3791	3431	1573	1556	1679	1414	1722	1041
Flow, 1000 CFS	58.1	52.5	59.6	69.8	75.6	88.6	91.5	71.9	63.7	55.8	52.9	52.3	27.3	23.0	30.7	35.0
Kansas City																
Reach Inflow, 1000 AF	12903	437	563	914	1638	1117	1596	1755	1209	549	206	206	1197	433	542	539
Inflow Adjust, 1000 AF	-956	-9	-11	-36	-116	-402	-251	-131	0	0	0	0	0	0	0	0
Modified Inflow, 1000 AF	11946	428	551	878	1522	715	1345	1624	1209	549	206	206	1197	433	542	539
Flow, 1000 AF	54097	1124	1590	4969	6167	5998	6874	6115	5020	4005	1795	1762	2975	1867	2256	1571
Flow, 1000 CFS	74.7	81.0	89.1	83.5	100.3	100.8	111.8	99.5	84.4	65.1	60.4	59.3	48.4	30.4	40.3	52.8
Boonville																
Reach Inflow, 1000 AF	5717	545	701	544	1382	-36	26	383	339	255	67	67	587	32	408	415
Inflow Adjust, 1000 AF	-107	-5	-6	-18	-18	66	4	-38	-34	-26	-5	-5	0	0	-13	-7
Modified Inflow, 1000 AF	5610	540	695	526	1364	30	30	345	305	229	62	62	587	32	395	407
Flow, 1000 AF	59733	1632	2262	5434	7528	6041	6804	6530	5345	4259	1874	1824	3662	1918	2644	1968
Flow, 1000 CFS	82.5	117.6	126.7	91.3	122.4	101.5	110.7	106.2	89.8	69.3	63.0	61.3	59.6	31.2	47.2	66.2
Hermann																
Reach Inflow, 1000 AF	11392	621	799	1729	1156	436	489	995	1036	893	142	142	687	400	737	1129
Inflow Adjust, 1000 AF	-28	-21	-27	-82	-83	64	100	122	205	-112	-30	-30	-27	-26	-45	-33
Modified Inflow, 1000 AF	11364	600	771	1647	1073	500	589	1117	1241	781	111	111	660	374	692	1095
Flow, 1000 AF	71110	2216	3021	7050	8600	6548	7344	7682	6595	5053	1994	1936	4372	2302	3332	3058
Flow, 1000 CFS	98.2	159.6	169.3	118.5	139.9	110.0	119.4	124.9	110.8	82.2	67.0	65.1	71.1	37.4	59.5	102.8

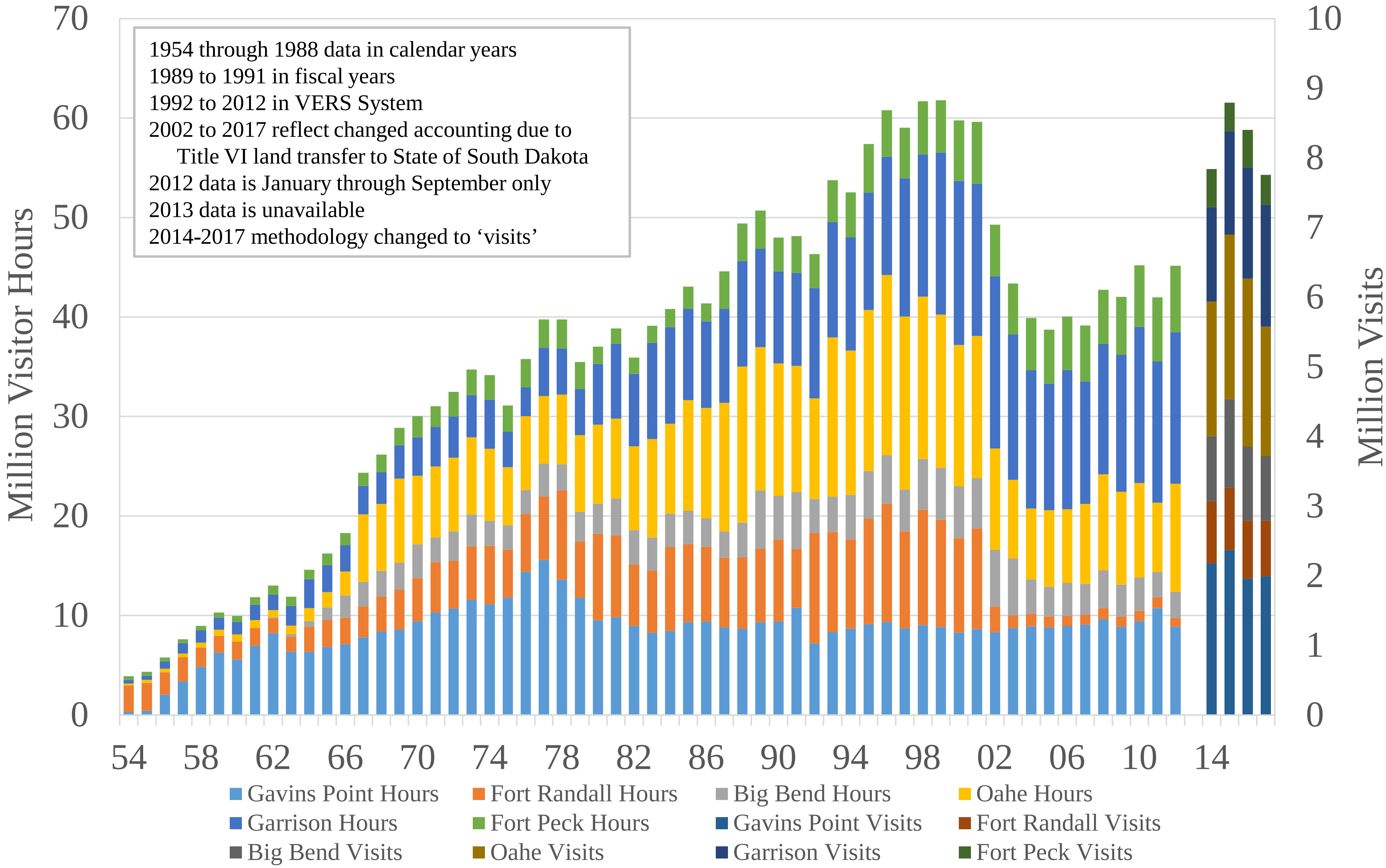
Missouri River Basin
Mainstem Master Water Control Manual
Simulated Regulation for
1951-1952-1944-1945 Flood Combination
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



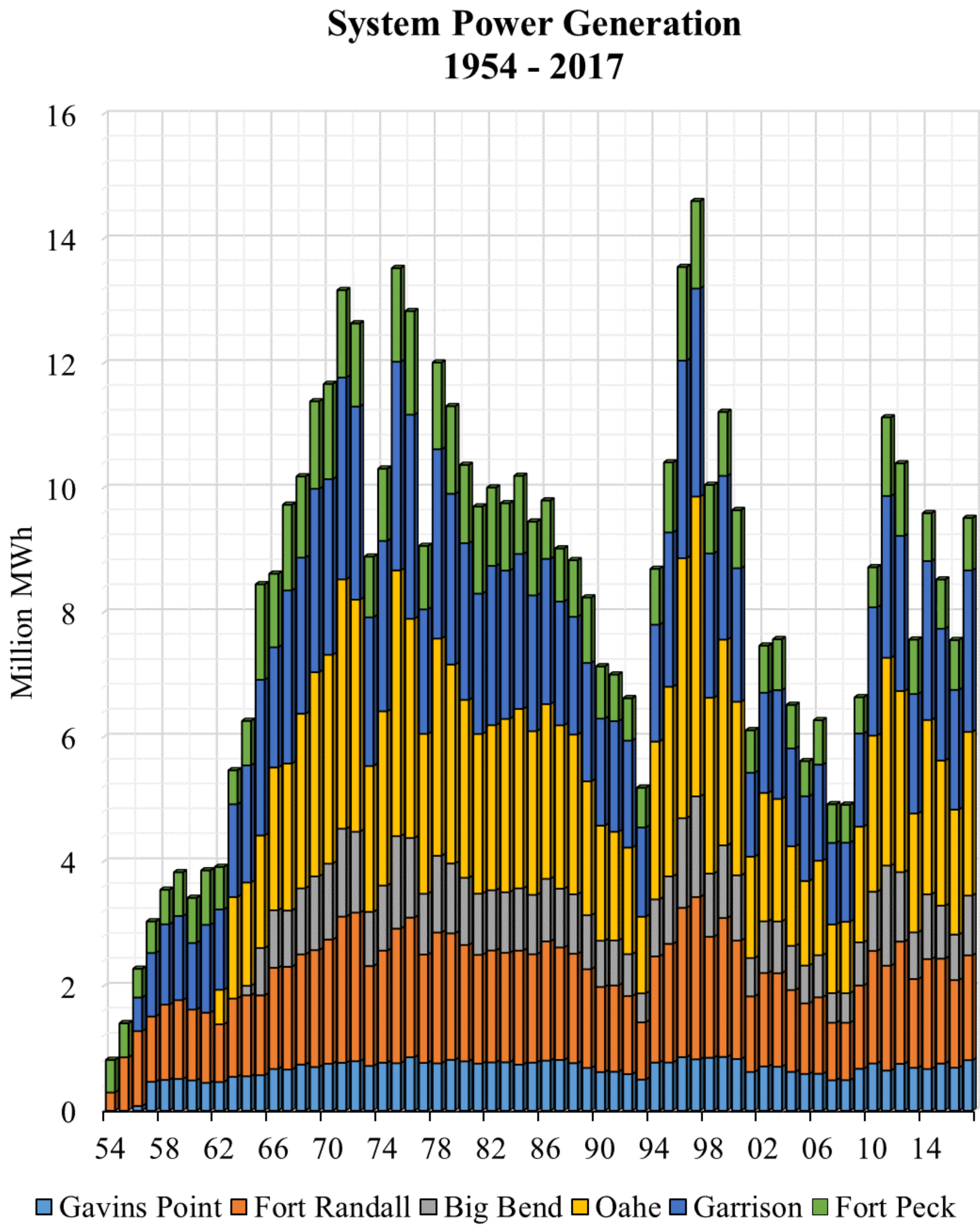
Missouri River Basin

Mainstem Master Water Control Manual
Annual Runoff above Sioux City, IA

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin
Mainstem Master Water Control Manual
System Visitation by Project
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Missouri River Basin

Mainstem Master Water Control Manual

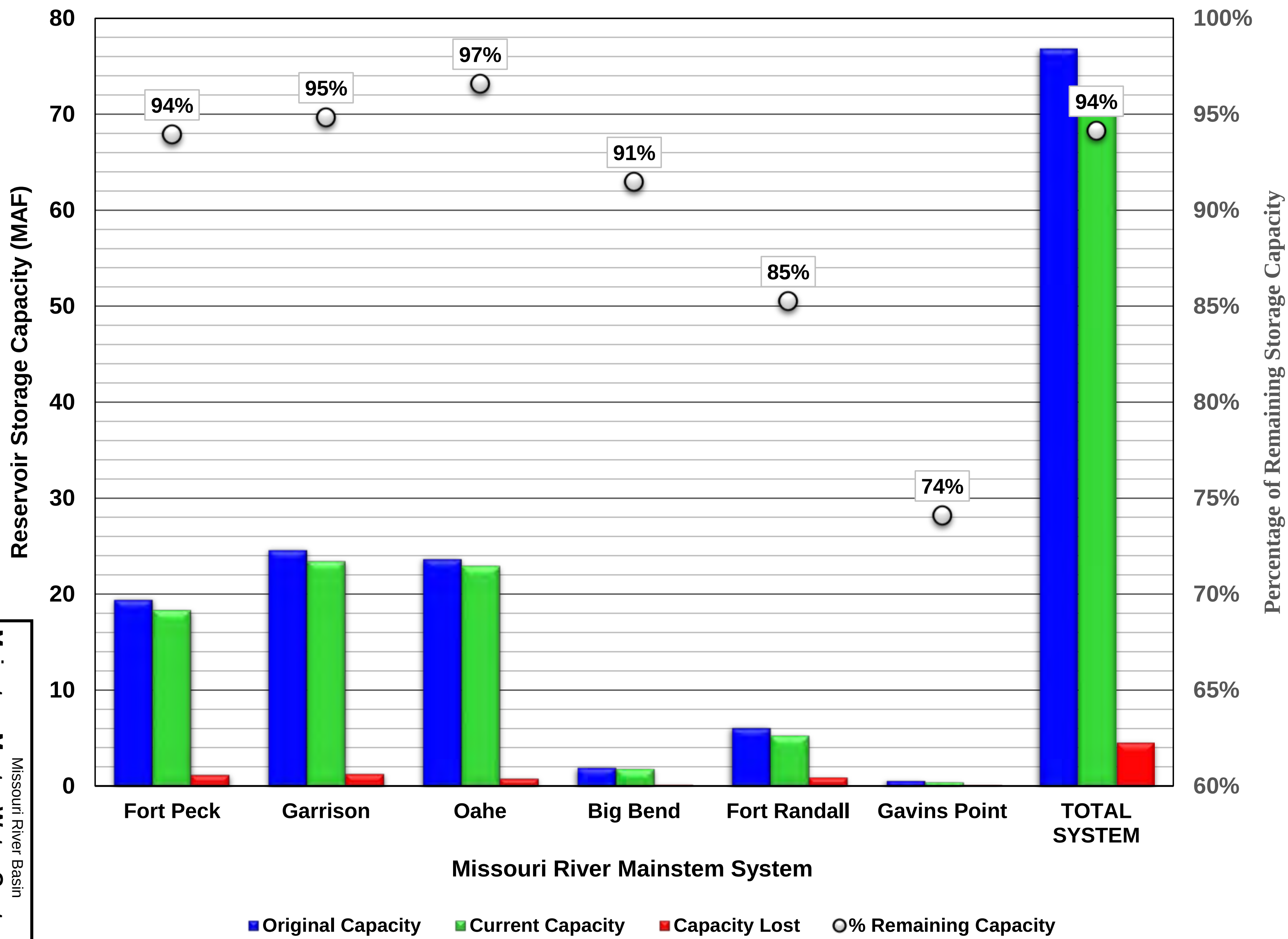
System Hydropower Generation

U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

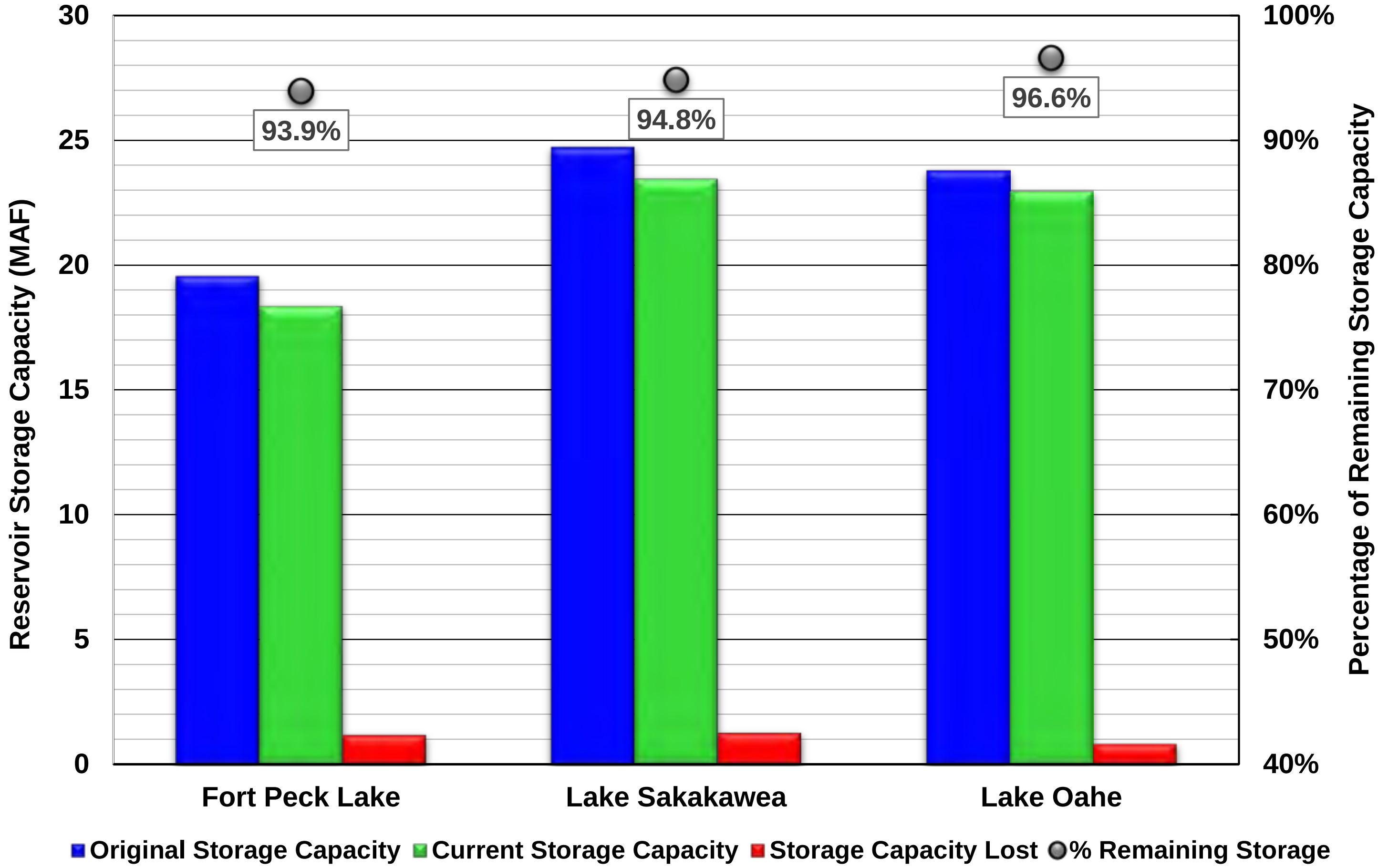
November 2018

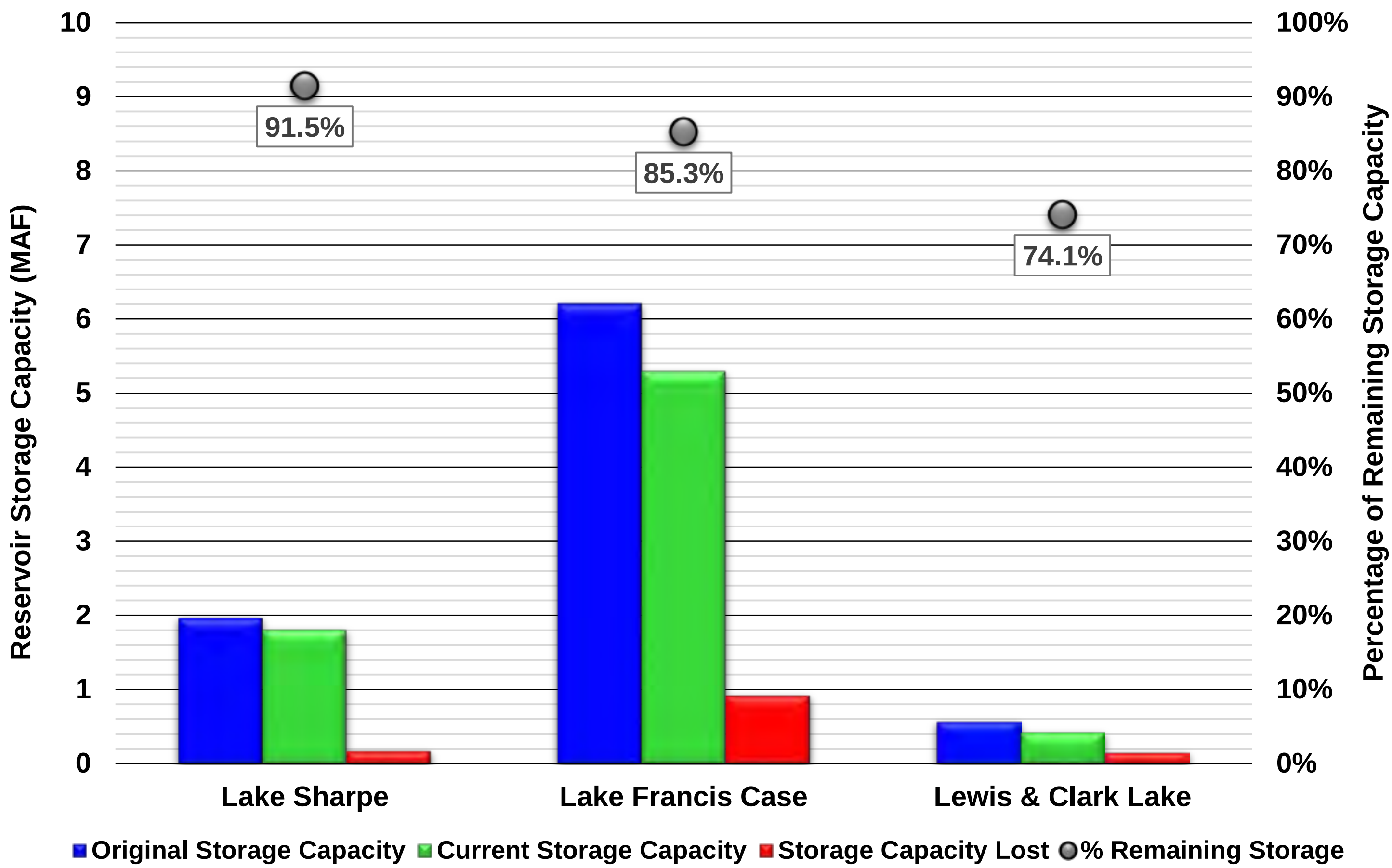
Plate F-1



Missouri River Basin
Mainstem Master Water Control Manual
Reservoir Capacity Lost
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate H-1

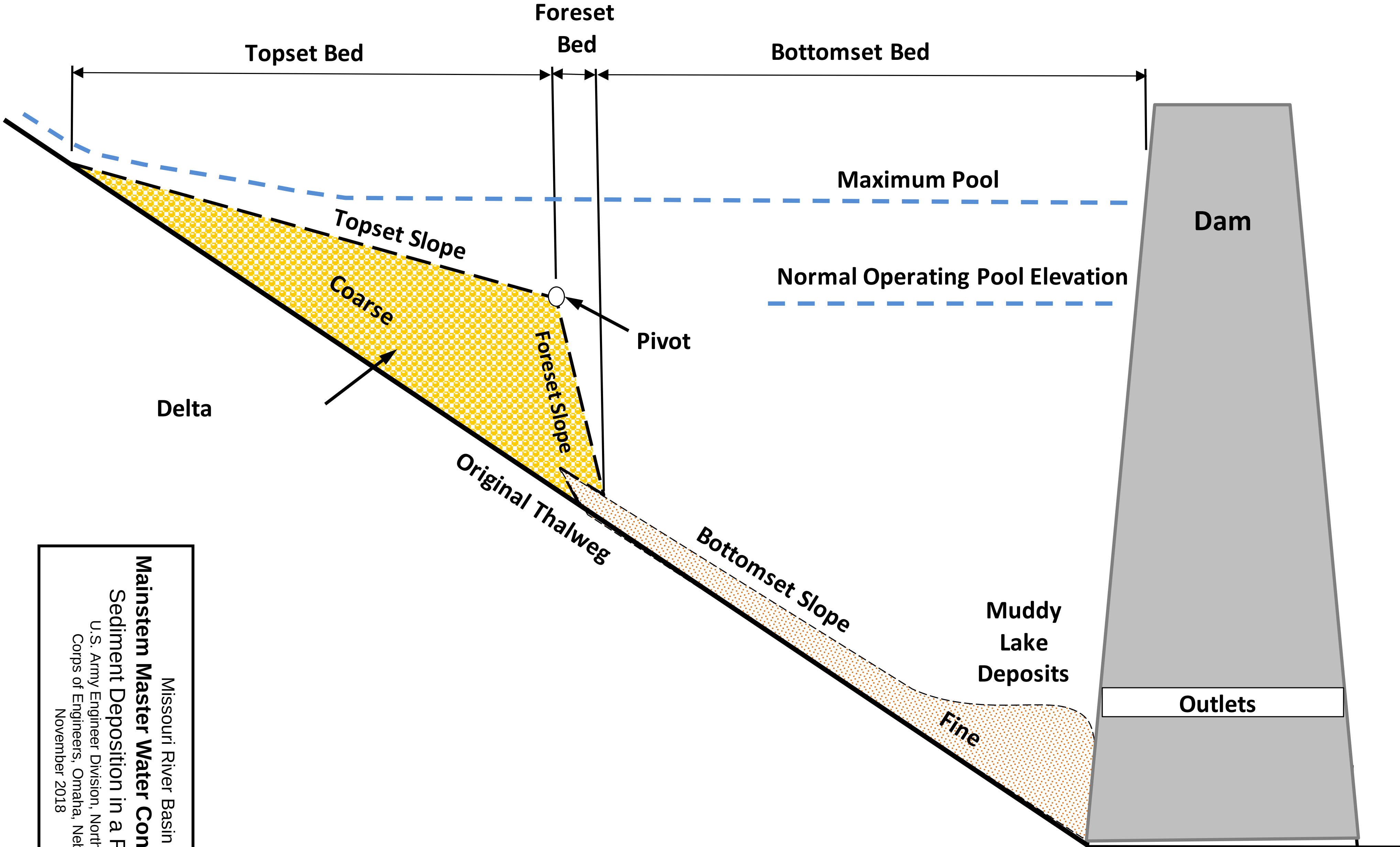




Missouri River Basin

Mainstem Master Water Control Manual
Reservoir Capacity Lost – Upper and Lower

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018



Depositional Zones in a Reservoir

Missouri River Basin
Mainstem Master Water Control Manual
Sediment Deposition in a Reservoir
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
November 2018

Plate H-3