Water Control Manual

Boysen Dam and Reservoir

Wind River
Wyoming

U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

July 2020

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, NORTHWESTERN DIVISION
1616 CAPITOL AVENUE, STE 365
OMAHA NE 68102

CENWD-PDR 10 August 2020

MEMORANDUM FOR Commander, Omaha District (CENWO-ED-HA, Attn: Nelson)

SUBJECT: Request for Review and Approval Water Control Manual, Boysen Dam and Reservoir, Missouri River Basin

1. Reference memorandum dated 28 July 2020, CENWO-EDH-A, subject as above.

2. The subject water control manual is approved.

3. It should be noted that the Boysen Field Working Agreement between the U.S. Bureau of Reclamation and the Corps is being finalized. Please provide a paper copy to this office upon its finalization.

4. We commend your staff for their professional and dedicated effort in updating this manual. We realize that updating any water control manual is a considerable undertaking.

5. Thank you for providing a hardcopy to this office. Please provide an electronic version of the manual to HQUSACE for Continuity of Operations (COOP) purposes, and a redacted electronic version for the national public-facing website.

6. If you have any questions concerning this reply, please contact me at [redacted] [redacted] of my staff at [redacted]

FOR THE COMMANDER:

[redacted]

Chief, Missouri River Basin Water Management Division

CENWO-ED-HA

28 July 2020

MEMORANDUM FOR CENWD-PDR/Remus, Suite 3300, 1616 Capitol Avenue, Omaha, NE 68102

SUBJECT: Request for Review and Approval of Final Draft Water Control Manual, Boysen Dam and Reservoir, Missouri River Basin

1. Enclosed for your review and approval is a copy of the final draft of Water Control Manual, Boysen Dam and Reservoir, Missouri River Basin, including recommended edits. An electronic version of this document can be accessed in the following directory: V:\Public\NWO WCMs - Mar2013\Boysen_WCM_May2020\WCM_Boysen-July2020.pdf.

2. This update did not contain any major changes to the water control plan. An updated field working agreement written by the Corps of Engineers and the Bureau of Reclamation is included in this Water Control Manual update. The Field Working Agreement will be signed by the District Engineer and the Regional Director following approval of the manual.

3. Please contact me at [redacted] questions.

Encls

Chief, Water Control & Water Quality Section
Hydrologic Engineering Branch
Engineering Division

Boysen Dam

Boysen Dam and Reservoir

Boysen Reservoir - Aerial View

NOTICE TO USERS OF THIS MANUAL

Regulations specify this Water Control Manual be published in a hard copy binder with loose leaf form, and only those sections, or parts thereof, requiring changes will be revised and printed. Therefore, this copy should be preserved in good condition so that inserts can be made to keep the manual current. Changes to individual pages must carry the date of revision, which is the Division's approval date.

All elevations stated in this section are at the Boysen Dam and are referred to a datum giving 4700.0 feet as the elevation of the spillway crest.

In the original design and construction of Boysen Dam, elevations on design drawings and reservoir levels referenced the Sea Level Datum of 1929. This was based on measured water levels at 26 tide stations in the United States and Canada, and commonly referred to as "feet above mean sea level”. In 1973 the Sea Level Datum of 1929 was renamed the National Geodetic Vertical Datum of 1929 (NGVD29). **Unless specifically noted, all elevations in this manual are referenced to NGVD29**. The NGVD29 datum was subsequently replaced by the North American Vertical Datum of 1988 (NAVD88) as the current vertical reference datum used by the National Oceanic and Atmospheric Administration (NOAA). The NAVD88 is based on a single point as the reference point from which all other elevations are measured. As such, the conversion from the NGVD29 to the NAVD88 varies depending on location. As specified in ER 1110-2-8160, long-term efforts shall be programmed to transition from older datums to NAVD88.

In this water control manual, elevations for reservoir levels and project drawings are based upon the NGVD29 datum and have not been converted to the NAVD88 datum because of the desire to provide elevation data that is consistent with historical events and the original design drawings for the project. If elevations referenced to the NAVD88 datum are needed at Boysen Dam, the following conversion of 2.96 feet applies: NGVD29 elevation + 2.96 feet = NAVD88 elevation.

REGULATION ASSISTANCE PROCEDURES

In the event unusual conditions arise during non-duty hours, communication can be achieved by contacting, in the order listed, one of the following personnel:

Directory of Regulation Personnel

[redacted]

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PLATES

EXHIBITS

Boysen Dam and Reservoir Pertinent Data

GENERAL	
Location of Dam	20 miles South of Thermopolis, WY
County	Fremont County
River and River Mile	Wind/Bighorn River at river mile 295
Drainage Areas	
Bighorn River above Boysen Dam (sq. mi)	7,710
Bighorn River above Thermopolis, WY (sq. mi)	8,080
Bighorn River above Kane, WY (sq. mi)	15,800
Bighorn River above Hardin, MT (sq. mi)	20,700
Bighorn River above mouth (sq. mi)	22,940
Yellowstone River above Miles City, MT (sq. mi)	47,596
Yellowstone River above mouth (sq. mi)	70,400
DAM	
Type	Rolled earthfill
Crest Elevation (NGVD 29)	4758.0 feet
Top width (feet)	30 feet
Height above Streambed (feet)	150 feet
Length (feet)	1,143 feet
Date of Closure	October 1951
SPILLWAY	
Location	Right abutment
Type	Gated concrete chute
Crest Elevation (NGVD 29) (feet)	4700.0 feet
Number of Gates	2
Type of Gates	Radial
Width of Gates (feet)	30 feet
Height of Gates (feet)	25 feet
Type of Gate Operating Machinery Hoist	Motor operated individual hoists
Discharge Capacity at Water Surface Elevation 4,725.0 feet (cfs)	20,000 cfs
OUTLET WORKS	
[redacted]	
POWER PLANT	
Turbines	2–Francis @ 10,500 HP
Generators	2–Vertical Shaft @ 7,500 kW
Plant Capacity (kW)	15,000
Maximum Head (ft)	120

Boysen Dam and Reservoir Pertinent Data

RESERVOIR POOL ALLOCATIONS	ELEVATION LIMITS	CAPACITY (af)	
Surcharge Zone	4732.2 - 4752.0 feet	520,679	
Exclusive Flood Zone	4725.0 - 4732.2 feet	150,632	
Joint Use Zone	4717.0 - 4725.0 feet	144,229	
Active Conservation Zone	4685.0 - 4717.0 feet	378,184	
Inactive Conservation Zone	4657.0 - 4685.0 feet	179,097	
Dead Zone	4608.0 - 4657.0 feet	40,084	
RESERVOIR POOLS	**Elevation feet**	**Gross Area (acres)**	**Gross Storage (af)**
Top of Surcharge	4752.0	30,850	1,412,905
Top of Exclusive Flood Control Storage	4732.2	22,190	892,226
Top of Joint Use Storage	4725.0	19,500	741,594
Top of Active Conservation Storage	4717.0	17,300	597,365
Top of Inactive Conservation Storage	4685.0	8710	219,181
Top of Dead Storage	4657.0	4,100	40,084
Streambed Elevation	4608.0	0	0

ABBREVIATIONS

af	Acre-Feet
CCC	Casper Control Center
cfs	Cubic Feet per Second
Corps	Corps of Engineers
CWMS	Corps Water Management System
DCP	Data Collection Platform
EM	Engineering Manual
ER	Engineering Regulation
GOES	Geostationary Operational Environmental Satellite
HEC	Hydrologic Engineering Center
ID	Inner Diameter
kW	kilo Watt
MRBWM	Missouri River Basin Water Management
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
PMF	Probable Maximum Flood
Reclamation	United States Bureau of Reclamation
SNOTEL	SNOw TELemetry (Operated by NRCS)
SPHS	Wyoming State Park, Historic Sites and Trails
WAPA	Western Area Power Administration
WCWQS	Water Control and Water Quality Section
WCP	Water Control Plan
WCM	Water Control Manual
WYAO	Wyoming Area Office

CHAPTER 1—INTRODUCTION

1-01 AUTHORIZATION

This manual was prepared in compliance with the following authorities and directives:

- Engineering Regulation (ER) 1110-2-240, Water Control Management, 30 May 2016
- Section 7 of the Flood Control Act, 22 December 1944
- 33 CFR Chapter II Part 208, Flood Control Regulations, Section 208.11.

1-02 PURPOSE AND SCOPE

Boysen Dam and Reservoir was constructed by the Bureau of Reclamation (Reclamation) and was completed in 1952. This Water Control Manual (WCM) covers the regulation of the reservoir only for flood control purposes as designated in ER 1110-2-240. This manual also contains current information about the dam and reservoir as well as descriptions of the project and its history, watershed characteristics, the data collection and communications network, and the organizations responsible for collecting data and regulating the reservoir. This report follows the guidance presented in Engineering Manual (EM) 1110-2-3600 “Management of Water Control Systems”, 10 Oct 2017 and ER 1110-2-8156 “Preparation of Water Control Manuals”, 30 September 2018.

1-03 RELATED MANUALS AND REPORTS

a. Boysen Dam and Reservoir – Reservoir Regulation Manual – Flood Regulation Only, March 1963.

b. Field Working Agreement for water control between Reclamation and U.S. Army Corps of Engineers (Corps), 5 May 1967.

c. Field Working Agreement for water control between Reclamation and Corps, 13 Jul 2021.

The plan of regulation presented in this manual is classified as “Method C” of the methods outlined in EM 1110-2-3600.

1-04 PROJECT OWNER

Boysen Reservoir was constructed by Reclamation.

1-05 OPERATING AGENCY

Reclamation’s Wyoming Area Office (WYOA) is responsible for the operation and maintenance of Boysen Dam. Forecasting reservoir inflows and directing water releases associated with the reservoir during normal operations is performed by the Resources Management Division of the WYAO. The Casper Control Center (CCC) is responsible for the remote daily operation of the generating units, river outlet gates, and for monitoring and reporting reservoir level, inflow, river releases and power generation. The CCC is reporting reservoir level, inflow, river releases and power generation. The CCC is responsible for the remote changes which are scheduled and directed by the Resources Management Division of the WYAO. The spillway gates cannot be remotely operated from the CCC and must be manually operated from the dam. All releases for power generation and river flows are closely coordinated with Western Area Power Administration (WAPA).

1-06 REGULATING AGENCIES

Reclamation is the regulating agency for Boysen Dam. During periods of flood control regulation, it becomes the responsibility of the Corps to regulate the reservoir according to the Water Control Plan (WCP). See Section 9-01.a for further explanation of the Corps' responsibilities and authorities. All other regulatory functions are the responsibility of Reclamation's WYAO. Personnel from these offices are listed in the directory of regulation personnel on page vi, Regulation Assistance Procedures.

CHAPTER 2—DESCRIPTION OF PROJECT

2-01 LOCATION

Boysen Dam is located on the Bighorn River in Wyoming about twenty miles upstream from Thermopolis, WY (Plate 2-1). The project is in Fremont County, WY on the Wind River, 295 miles upstream from the confluence of the Bighorn River with the Yellowstone River near Bighorn, MT.

2-02 PURPOSE

The Boysen Unit of the Pick-Sloan Missouri Basin Program (P-SMBP) was authorized through the Flood Control Act of 1944 as a multiple-purpose project providing hydropower generation, flood control, and irrigation in the Upper Missouri River Basin. Additional benefits include fish and wildlife enhancement, recreation, and municipal and industrial water supply. Flood control storage in Boysen is allocated in an exclusive zone only used for flood control and a joint use zone, which is utilized for both flood control and conservation.

a. Purposes Assigned by Congress

1) Irrigation
2) Hydropower
3) Flood control
4) Recreation
5) Fish and Wildlife
6) Municipal and Industrial

b. Purposes Subsequently Assigned by Congress

None applicable.

c. Incidental Benefits

The major benefits provided by Boysen Dam and Reservoir are attributed to the authorized purposes.

2-03 PHYSICAL COMPONENTS

The physical components of Boysen Dam are shown on Plates 2-2 through 2-15 and described below.

a. Embankment

Boysen Dam is a rolled earthfill structure, with a crest length of 1,143 feet, top width of 30 feet, and a maximum height above the streambed of 150 feet. The dam is located approximately 20 miles south of Thermopolis, WY. General plan and sections are shown on Plate 2-2.

b. Dikes

Dikes are not included as project features.

c. Barriers

Barriers are not included as project features.

d. Spillway

The spillway is a concrete structure located in the right abutment. It consists of a weir with crest at elevation 4700.0 feet, two radial gates, each 30 feet wide and 25 feet high, a concrete chute, and a stilling basin with two rows of baffle blocks and an upward sloping outlet channel. The theoretical release capacity of the spillway gates is 35,000 cfs. The normal spillway capacity is 20,000 cfs. The top of the spillway gates in closed position is at elevation of base of exclusive flood control zone. No spillway discharges are made over the top of the gates. Details of the spillway are shown on Plates 2-3, 2-4 and 2-5.

e. Outlet Works

[redacted]

f. Hydroelectric Power Facilities

[redacted]

2) The power plant has an installed capacity of 15,000 KW. Each penstock leads to a 10,500 horsepower turbine, which drives a 7,500 kilowatt generator. Each turbine is protected by a ring seal gate. Plates 2-10 through 2-13 show features of the Boysen power plant.

g. Water Supply Facilities

There are a number of diversions for irrigation located downstream from Boysen. See Section 3-04 for more information regarding upstream and downstream irrigation and facilities.

A number of cities downstream from Boysen Reservoir use the river for domestic and wastewater purposes. Several sugar factories operate along the river during the autumn months. For pollution abatement a minimum daily average release of 300 cfs is required from the reservoir during period of sugar factory operation. After the end of sugar factory operation minimum flows may be decreased to 100 cfs.

h. Reservoir

Boysen Reservoir is located on the south, or upstream, end of Wind River Canyon. At the maximum water surface elevation of 4752.0 feet, the reservoir extends upstream a distance of approximately 20 miles, and up six tributaries for distances which vary from two to six miles. At that elevation, the reservoir area is 30,850 acres and the total storage capacity is 1,412,905 acre-feet (af). A map of reservoir and inundations at multiple pool elevations is shown on Plate 2-14. Storage capacity allocated to the various purposes seen in the Pertinent Data and a plot of the storage vs. elevation relationship is shown on Plate 2-15.

2-04 RELATED CONTROL FACILITIES

There are several reservoirs in the area which will affect Boysen’s operation. Releases from reservoirs on downstream tributaries will affect flow at downstream control points. See Section 3-04 for more information on reservoir and irrigation projects in the area.

2-05 REAL ESTATE ACQUISITION

All real estate acquisitions are managed by Reclamation.

2-06 PUBLIC FACILITIES

According to Reclamation’s Standing Operating Procedures Manual for Boysen Dam and Reservoir, “The reservoir is popular for camping, fishing, boating, and sightseeing. The recreational area is administered by the Wyoming State Park, Historic Sites and Trails, known as SPHS. The Wind River Canyon is a spectacular gorge in the Owl Creek Range below Boysen Dam and Reservoir, is a special attraction. The Wind River in the gorge furnishes excellent cold water fishing. Winter time activities include snowmobiling and fishing for ling and trout through the ice on the reservoir.”

CHAPTER 3—HISTORY OF PROJECT

3-01 AUTHORIZATION

The plans contained in House Document No. 475 and Senate Document No. 191 were reviewed and brought into agreement in a joint agency report published as Senate Document No. 247, 78th Congress, 2nd Session, which was approved and made a part of Public Law 534, 78th congress, 2nd Session, which law is known as the 1944 Flood Control Act. The plan described in Senate Document No. 191, in regard to the Yellowstone River Basin, was thus authorized, with construction to be accomplished at Boysen by Reclamation. The Corps was made responsible for determining reservoir capacities for flood control and navigation and for prescribing regulations for the use of storage allocated to flood control or navigation.

3-02 PLANNING AND DESIGN

The present Boysen Dam was constructed during the period, 1945–1952, by Reclamation. A previous dam was located a short distance downstream from the present site. This dam, also called Boysen, was constructed by the Wyoming Power Company in 1910 with an original reservoir capacity of 23,000 af. Sediment deposits during the period 1921–1928 caused powerplant operation to be discontinued on May 22, 1928 and the project was dismantled and abandoned. This dam was removed during construction of the current Boysen Dam.

The first Federal interest in flood control in the Bighorn and Yellowstone basins was expressed in the “308 Report” on the Yellowstone River, issued by the Kansas City District of the Corps, and published as House document 256, 73rd Congress, 2nd Session, in 1934. The need of Bighorn River storage for flood control on the Yellowstone River was recognized, and the report stated storage in a combination of reservoirs, including 479,000 af in the proposed Upper Bighorn Reservoir to be located near the Montana-Wyoming state line, and 393,000 af in the proposed Cave Canyon Reservoir to be located some 20 miles south of the state line, would provide effective flood protection.

In the “Survey Report on Flood Control on Bighorn River and Tributaries, Wyoming,” prepared in 1940 by the Omaha District of the Corps, the provision of 1,000,000 af of multiple use flood control and conservation storage in the proposed Boysen Reservoir and 1,440,000 af for the same uses in the proposed Upper Bighorn Canyon Reservoir was found practicable, but only the latter reservoir was recommended, since flood control on the Bighorn River above that site could be furnished by other means.

In a review of reports on the Missouri River Basin, prepared by the Missouri River Division of the Corps, and published as House Document No. 475, 78th Congress, 2nd Session, construction of Boysen Reservoir, with a capacity of 3,500,000 af, was recommended as a unit in the plan of improvement for the Missouri Basin.

In a report on the conservation, control, and use of water resources of the Missouri River basin, which was published as Senate Document No. 191, 78th Congress, 2nd Session, Reclamation proposed the construction of Boysen Reservoir with a capacity of 730,000 af. This report stated that “regulation of the reservoir, based upon runoff forecasts from snow surveys, will permit the reduction of flood flows, such as have occurred in the past, to safe channel capacities." In addition, Reclamation proposed the construction of Kane Reservoir, with a capacity of 750,000 af, at the upper end of Bighorn Canyon, and Yellowtail Reservoir, with a capacity of 470,000 af, near the downstream end of Bighorn Canyon.

3-03 CONSTRUCTION

Award of the major contract for construction of Boysen Dam and Power Plant was made in 1947. Construction was initiated on October 1, 1947 and impoundment of streamflow began on October 11, 1951. Construction was completed in 1952. Initial fill of reservoir to top of joint use storage pool was made in 1954. The project was placed in operation and maintenance status on January 1, 1953.

3-04 RELATED PROJECTS

a. Yellowtail Dam and Bighorn Reservoir

Reclamation completed Yellowtail Dam on the Bighorn River below Boysen Dam in December 1966. Yellowtail Dam is located approximately 45 miles south and west of Hardin, MT. The dam and reservoir regulate runoff for irrigation, flood control, power generation and other uses. Storage allocations include 240,000 af of joint-use storage used for flood control and conservation. There is also 258,000 af of exclusive flood control used to minimize flood damages along the Bighorn and Yellowstone River. The project has an installed power capacity of 250,000 kilowatts and is one of the major hydroelectric powerplants in the upper Missouri River. The Corps has flood control release responsibility at Yellowtail Dam and Boysen Dam.

b. Original Boysen Dam

A previous dam was located a short distance downstream of the present site. See Section 3-02 for further details on the original Boysen Dam.

c. Buffalo Bill Reservoir

The Buffalo Bill Reservoir, on the Shoshone River, with a capacity of 646,565 af at the top of conservation, is one of the larger reservoirs in the Boysen operational area. The Corps has no operational authority at Buffalo Bill.

d. Bull Lake

Bull Lake, with a capacity of 152,000 af, is the largest upstream reservoirs with a regulating effect on inflow to Boysen. The Corps has no operational authority at Bull Lake.

e. Pilot Butte

With a capacity of 33,000 af, is one of the larger upstream reservoirs with a regulating effect on inflow to Boysen. Pilot Butte is an off-stream storage project whose inflows are fed via Midvale Irrigation District's Wyoming Canal on the Wind River. The Corps has no operational authority over this reservoir.

f. Sunshine Reservoir

Sunshine Reservoir is on the Wood River below Boysen Dam. The Wood River is a tributary of the Greybull River.

g. Garrison Dam and Lake Sakakawea

Garrison Dam is on the Missouri River downstream of the mouth of the Yellowstone River. Releases from Boysen Dam take 5-7 days to reach Garrison Dam.

h. Irrigation Projects

No water is diverted directly from Boysen Reservoir for irrigation. A number of irrigation units are located upstream and downstream from the reservoir with diversion from the river used to obtain water for the irrigation projects. Approximately 900-1,200 cfs flow is needed in the river during the peak of the irrigation season for projects in the reach from Boysen to the mouth of the Shoshone River. During the irrigation season a minimum release rate from this reservoir is set by the State Water Commissioner. The allowable maximum diurnal fluctuation is 30 percent from the daily average. Increases or decreases in release rate by more than 500 cfs require notice to downstream users.

Beside losses resulting directly from irrigation, sizeable storage developments exist in Bull Lake Reservoir on Bull Lake Creek, the off stream Pilot Butte Reservoir, and other smaller reservoirs. The loss of substantial portion of the return flows from irrigated lands occurs in large relatively impervious “sinks” such as Ocean Lake, where a balance appears to have been attained between high evaporative rates and inflows and outflows (where any exist). Although it is relatively easy to determine the effects of upstream reservoirs upon the inflows to Boysen, determination of the losses to stream flow resulting from application of water to the irrigated land and subsequent return flow is very complex.

Table 3-1 is a list of the irrigation projects on the Wind River and the Bighorn River above Yellowtail Dam. The average monthly diversions from April-October are shown. These diversions occur in most all years, except after large rainfall events. Heavy winter snowpack can also delay and decrease diversions. The effects of diversions should be taken into account during runoff events.

Table 3-1. Irrigation Projects and Average Diversions

Diversion Name			Average Monthly Diversion, cfs						
Wind River	lat	long	Apr	May	Jun	Jul	Aug	Sep	Oct
LeClair Canal at Headworks	43.108°	-108.663°	52	165	230	284	243	191	135
Upper Wind River A Canal at Headworks, near Burris, WY	43.408°	-109.312°	4	47	54	57	66	55	34
Riverton Valley Irrigation District Canal at Headworks	43.026°	-108.495°	29	92	118	126	120	105	36
Midvale Irrigation District (Wyoming Canal) near the Headworks, near Diversion Dam	43.226°	-108.950°	298	839	1,130	1,240	1,061	935	383
Johnstown Ditch at Headworks, near Kinnear, WY	43.150°	-108.728°	4	17	28	29	30	26	1
Aragon Ditch at Headworks	43.191°	-108.784°	-	22	39	29	28	21	12
Winchester Ditch at Headworks	43.231°	-109.025°	4	8	15	16	23	20	-
Bighorn River above Yellowtail									
Upper Lucerne Canal	43.697°	-108.178°	28	32	36	39	39	33	26
Lower Hanover Canal	43.974°	-107.991°	74	162	188	200	175	133	81
Upper Hanover Canal	43.853°	-108.174°	282	291	298	285	255	212	198
Bighorn Canal near Worland, WY	43.945°	-108.016°	289	429	476	509	445	375	241
Kirby Canal at Headworks	43.679°	-108.182°	26	47	54	67	65	61	32

Note: Some small irrigations begin before April, especially from Midvale. Diversions during the winter and early spring are small and will minimally affect flood hydrographs.

3-05 MODIFICATION TO REGULATIONS

Under the provisions of Section 9 of the 1944 Flood Control Act, the Corps determined the storage required for flood control purposes. Since the desired volume of exclusive flood control storage could not be furnished because of site limitations, an agreement was reached between the Corps and Reclamation that 150,000 af of exclusive flood control storage would be provided, with an additional 150,000 af which would be made available, in whole or in part, as needed on the basis of forecasts of seasonal runoff into the reservoir. Under the provisions of Section 7 of the 1944 Flood Control Act, regulations for the operation of flood control storage in the reservoir have been prepared by the Omaha District, and will be published in the Federal Register. These regulations, supplemented by a letter agreement covering details of reservoir operation, are included herewith as Exhibit II. Operation of Boysen Reservoir for flood control will be accomplished by the Corps when the reservoir pool level reaches the zone of responsibility of the Corps, as outlined in paragraph "c" of the regulations in Exhibit I. Plates 7-1 and 7-2 also display the zones and a brief description of responsibility. Joint storage space will only be vacated for flood control from 1 February to 31 July.

a. Reservoir Regulation Technique for Floods Exceeding Project Size.

When it becomes apparent the pool elevation will exceed the top of the exclusive flood control zone, Reclamation will be notified. Operation of the reservoir will be the responsibility of Reclamation when the reservoir level is in the surcharge pool. The exact plan to be followed by Reclamation for operation in the surcharge pool will be dependent on the event. However, emergency instructions for operating the spillway gates indicate flow will be held to 20,000 cfs until the reservoir pool reaches 4752.0 feet and the spillway gates will be opened as necessary to maintain pool level at 4752.0 feet. The Field Working Agreement between Reclamation and the Corps states "when the reservoir level is above the exclusive flood control zone or below the joint use pool level of responsibility during conservation operations, the District Engineer may make recommendation to the Regional Director for operation in the interest of flood control, but such recommendations shall not be considered mandatory." Operation by maintaining a maximum of 20,000 cfs release on the rising side of the hydrograph is considered satisfactory for most cases. Minimum spillway release at the top of the exclusive flood control zone 4732.0 feet is 13,000 cfs and 15,500 cfs at 4752.0 feet. However, each event would be analyzed on a daily basis to optimize risk to the project and downstream damages within the prescribed release schedules.

b. Field Working Agreement for Water Control Between Bureau of Reclamation and U.S. Army Corps of Engineers, 5 May 1967

The original Field Working Agreement set elevation and storage volumes of exclusive flood control and joint use storage as well as the other pool zones. It also outlines the release responsibility in the joint use zone as it pertains to flood control and conservation.

c. Current Field Working Agreement

The current Field Working Agreement further outlines Missouri River System Flood Control Operations as seen in Section 7-05.

3-06 PRINCIPAL REGULATION PROBLEMS

Due to site limitations at Boysen Dam, the elevation of the base of the exclusive flood control pool is the same elevation as the top of the spillway gates. This means storing a significant volume of water in the exclusive flood control pool requires making damaging releases downstream. In a local flood operation or system-wide flood control operation the risk of downstream damages must be weighed against plans to store large volumes in the flood control pool.

Reclamation prefers to maintain 0.5 foot of freeboard on the spillway gates when storing in the exclusive flood control pool. This precaution is taken when possible to minimize waves from spilling over the tops of the gates. If the spillway gates must be opened while the river is ice covered downstream, the freeboard on the spillway gates will be taken to zero.

Boysen can only pass approximately 48% of the Probable Maximum Flood (PMF). This PMF was determined by Reclamation to be the largest flood that could be experienced at Boysen Dam. The PMF has a peak discharge of 864,967 cfs and a volume of over 3,000,000 af. The maximum depth of overtopping is 18 feet. Boysen Dam would fail upon overtopping.

CHAPTER 4—WATERSHED CHARACTERISTICS

4-01 GENERAL CHARACTERISTICS

The Bighorn River is a tributary of the Yellowstone River, which in turn is a tributary of the Missouri River. The Missouri River has a drainage area of 529,350 square miles, the Yellowstone River has a drainage area of 70,400 square miles, and the Bighorn River has a drainage area of 22,940 square miles. The drainage area above Boysen Dam is 7,710 square miles.

The Yellowstone River Basin is located in north-central Wyoming, southeastern Montana, and extreme western North Dakota. The basin is roughly pear-shaped, with a length of about 440 miles and a maximum width of about 310 miles. Of the total drainage area, 70,400 square miles, roughly half is in Montana and half is in Wyoming, with 740 square miles in North Dakota.

The Yellowstone River originates in Yellowstone National Park and flows in a northeasterly direction to its confluence with the Missouri River near Williston, ND. There are four main tributaries, all of which flow from the south: Clarks Fork, entering near Laurel, MT; Bighorn River, entering near Custer, MT; Tongue River, entering at Miles City, MT; and the Powder River entering near Terry, MT. Drainage areas, lengths, and slopes of the main stem and the principal tributaries are shown in Table 4-1.

Table 4-1. Main Stem and Principal Tributaries

Stream	Drainage Area Square Miles	Length Miles	Average Slope Feet per Mile
Yellowstone	70,400	671	13
Clarks Fork	2,850	151	28
Wind	7,750	160	17
Bighorn	22,940	461	15
Tongue	5,440	265	27
Powder	13,410	486	16

The main stem of the Yellowstone River below the mouth of the Bighorn flows in a meandering channel through an alluvial flood plain from 1.5 to 7 miles in width. The flood plain is mostly farmland, with a large part of it irrigated.

The Bighorn River drains an oval-shaped area between the Wind River and the Absaroka Mountain Ranges on the west and the Bighorn Mountains on the east. The basin is about 260 miles long in a north-south direction and 160 miles in maximum width, and is 22,940 square miles in area, of which 18,880 square miles are in Wyoming and 4,060 square miles are in Montana.

The Bighorn River from the headwaters near Togwotee Pass to the mouth of the Wind River Canyon is named the Wind River. Immediately downstream of Wind River Canyon at a historic site known as the “Wedding of the Waters” the river changes names to the Bighorn

River. The Wind River basin is approximately 140 miles wide in the east-west direction and 70 miles in the north-south direction. The river flows to the southeast from the headwaters to Riverton, WY where it turns and flows north. The drainage area is 7,750 square miles all in Wyoming.

The Bighorn River Basin is divided topographically into three sub-basins: 1) the Wind River basin, 2) the Bighorn basin, and 3) the Lower Bighorn Basin. The Wind River and Bighorn basins are located in Wyoming and the Lower Bighorn Basin is located in Montana. The sub-basins are separated by mountain ranges, through which the river has cut steep canyons. Boysen Dam is located at the south or upstream end of one of these canyons, the Wind River Canyon, which separates the Wind River Basin from the lower portions of the Bighorn Basin. Further detail of the topography above the outlet of Wind River Canyon is found in Section 4-02.

4-02 TOPOGRAPHY

The Wind River Basin can be divided into four geologic regions: 1) the Washakie Range, 2) the Wind River Range, 3) the Southern Bighorn Mountains-Casper Arch-Granite Mountains, and 4) the Wind River Valley (**Rieke, 1981**). Within these geologic regions are various watershed sub-basins: the Upper Wind sub-basin, Little Wind sub-basin, Popo Agie sub-basin, Muskrat Creek sub-basin, Badwater Creek sub-basin, and the Lower Wind sub-basin (**WDEQ, 2010**). The geologic regions and their associated watershed sub-basins are discussed separately below and shown on Plate 4-1.

a. Washakie Range

The Washakie Range is located along the northwest corner of the Upper Wind basin and is a series of faulted folds in Precambrian, Paleozoic, and lower Mesozoic rocks that were completely buried by volcanic debris of the Absaroka Range during post-early Eocene time. This uplift reaches altitudes of more than 10,000 feet. The range extends 70 miles northwest of the western end of the Owl Creek Mountains, and ends with the western flank of Buffalo Fork Mountain west of Togwotee Pass. The structures have now been partly exhumed along the major drainages. A continuous reverse fault probably separates the steep south flank of the range from the adjacent northwest margin of the basin (**Rieke, 1981**).

The Washakie Range contains the headwaters of the Upper Wind sub-basin, which forms the Wind River that flows east to southeast into Boysen Reservoir. Land uses in the upper watersheds are primarily recreation, livestock grazing, wildlife habitat, and timber production (**WDEQ, 2010**).

b. Wind River Range

The Wind River Range, located along the southern edge of the Wind River Basin culminates at the 13,785-foot Gannett Peak and is one of the most extensive mountain uplifts in Wyoming. The range trends northwest along the West side of the Wind River Basin for about 100 miles and has a maximum width of about 50 miles. The broadly exposed Precambrian core is composed chiefly of gneissic and massive granitic rocks. Along the east flank of the Wind River Range, Paleozoic and Mesozoic strata form a nearly linear outcrop pattern trending N. 40° W. These rocks dip uniformly at 12°-15° NE. (basinward), and descend from the higher parts of the range along a series of prominent dip slopes to the floor of the Wind River Basin. Resistant cherty limestones of the Permian Park City Formation form the outermost series of conspicuous flatirons along the mountain front; less resistant Mesozoic rocks form hogbacks and strike valleys in the lower foothills regions (**Keefer, 1970**).

The Wind River Range contains the headwaters of the Upper Wind, Little Wind, and Popo Agie sub-basins. Land uses in the upper watersheds are primarily used for recreation, livestock grazing, wildlife habitat, and timber production (**WDEQ, 2010**).

c. Southern Bighorn Mountains-Casper Arch-Granite Mountains

The Southern Bighorn Mountains, Casper Arch and Granite Mountains comprise the eastern to southeastern edge of the Wind River Basin. The southwest end of the Bighorn Mountains forms approximately 30 miles of the northeast margin of the Wind River Basin with elevations ranging from 5,800 to 6,600 feet. The broadly exposed pre-Cambrian core of the Bighorn Mountains consists of highly contorted gneisses and schists cut by numerous irregular pegmatite dikes. The Casper Arch comprises approximately 40 miles of the eastern margin of the Wind River Basin with elevations of 6,000 to 6,200 feet. The Casper Arch is a major, but not deeply eroded, structural upwarp with steep to overturned west limb that forms the east margin of the Wind River Basin. The Upper Cretaceous Cody Shale underlies the broad central part of the arch, and younger Cretaceous and Paleocene strata are exposed in a linear belt along the west flank. The Granite Mountains comprise approximately 45 miles of the southeast corner of the Wind River Basin with elevations ranging from 6,000 to 6,300 feet. The Granite Mountains were formed during the Laramide deformation and the core of the mountains (pre-Cambrian granite and gneiss) were uplifted several thousand feet and subsequently deeply eroded. Then, due to a series of downfolding and downfaulting movements, the pre-Cambrian core collapsed and was buried by a thick sequence of middle and upper Tertiary sediments.

These eastern flanking mountains comprise the headwaters of the Badwater Creek sub-basin (primarily Bighorn Mountains), the eastern headwaters of the Lower Wind sub-basin (Primarily Casper Arch), and the Muskrat Creek sub-basin (primarily Granite Mountains). Land uses in these areas are primarily livestock grazing and oil and gas production.

d. Wind River Valley

The Wind River Valley is a topographic low for the entire drainage basin with elevations ranging between 4,800 and 7,000 feet. Upturned rocks of Paleozoic and Mesozoic age form distinct cuestas and hogbacks along the mountain fronts, and nearly horizontal rocks of Tertiary age form generally broad valleys and prominent gravel-capped mesas and buttes in the central part of the basin. The Wind River Valley is relatively deep compared to most other stream valleys in the basin, and high bluffs border the river in many places. Mesas and buttes form drainage divides between the smaller streams. Along the flanks of the Wind River Basin, where older strata dip rather steeply, the topography is marked by conspicuous strike valleys with intervening sandstone ridges.

In the basin's interior portion where younger, more gently dipping rocks rest with angular unconformity upon older rocks, the terrain is generally a rolling, less rugged plain. Occasionally, however, erosion has turned these rolling plains into rugged badlands. The topography of the northern part is very irregular owing to the alternating succession of resistant and nonresistant rocks. This area erodes rapidly during flash floods (**Rieke, 1981**).

The Wind River Basin contains the topographically low portions of the Upper Wind, Little Wind, Popo Agie, Muskrat Creek, Badwater Creek, and the Lower Wind sub-basins as they all flow into the central portion of the basin. All six of the sub-basins converge and form the Boysen Reservoir. The Muskrat Creek and Badwater Creek sub-basins have been identified as having limited flow. However, United States Geological Survey (USGS) data suggest that the Badwater Creek sub-basin can transport large sediment loads to the Boysen Reservoir during stormwater runoff events. Land uses in the lower watersheds are used for grazing, irrigated agriculture, residential development, and oil and gas production primarily in the Little Wind, Muskrat Creek, and Badwater Creek sub-basins (**WDEQ, 2010**).

4-03 GEOLOGY AND SOILS

a. Geology

Boysen Dam is located on the southern flank of the Owl Creek Mountains within a narrow section of the Wind River Canyon at the head of Boysen Reservoir. The Owl Creek Mountains were formed during the Laramide orogeny between post-Paleocene to pre-early Eocene time with the Wind River Canyon being formed in recent geologic time by the Bighorn River carving a narrow deep gorge through the Owl Creek Mountains. At the base of the Wind River Canyon is the older pre-Cambrian diorite (schist and granite cut by numerous pegmatite dikes [**Keefer, 1970**]) that is mostly unweathered but jointed, with the joints being tight and discontinuous and filled with calcite and pyrite. The pre-Cambrian diorite is unconformably overlain by Cambrian sandstones (Flathead Formation) and shales (Gros Ventre Formation) and Quaternary river alluvium of the Bighorn River. The Flathead Formation sits on top of the pre-Cambrian diorite and is approximately 110 feet thick of moderately hard (mostly unweathered), brittle, dull-red quartzitic sandstone and contains open joints. Overlying that is several hundred feet of the Gros Ventre Formation composed of soft green micaceous shale of the Park Shale Member and is underlain by blue-grey and yellow mottled hard dense limestone and sandstone of the Death Canyon Limestone Member (**Love and Christiansen, 1985**) and (**Rieke, 1981**). The Gros Ventre Formation is made even less competent in the vicinity of the dam site due to faulting and folding.

Due to the location of the Boysen Dam, it rests in an area along the Owl Creek Mountains that have an abundance of accessory faults and folds associated with the major Owl Creek Thrust fault that has been exposed about a half mile upstream with dips of 10° to 60° N (Dowling, 1952). An exposed fault along the left abutment, downstream of the dam, can be traced with an east-west strike, a dip of 40° to 60° N, and has a vertical displacement between 300 and 500 feet and is most likely an accessory normal fault associated with the Owl Creek Thrust fault. The fault gouge consists of crushed shale, sandstone, and limestone (**Rieke, 1981**).

West of the Boysen Dam, parallel to the foothill of the Owl Creek Mountains and south of the major Owl Creek Mountain thrust fault, is the Stagner Creek fault (Holocene aged, post glaciation [<15,000 years]) consisting of normal faults that dip to the south with a slip rate of <0.2 mm/yr. Mapping of these faults is inferred to pass along the approximate area of the dam (**USGS, 2001**).

Overall geology for the pool area of the Boysen Reservoir appears to primarily consist of the Wind River Formation (Eocene) containing variegated claystone and sandstone with lenticular discontinuous conglomerates, is up to 600 feet thick in some places, and is known to have low yields for aquifer use. Based on the description of the Wind River Formation, serious reservoir leakage should not be anticipated and based on available research of the reservoir, leakage does not appear to have been an issue throughout the dams 64 years of operation.

b. Soils

Central Wyoming is ecologically diverse and contains a wide range of environments; including shrub and grassland plains, alluvial valleys, volcanic plateaus, forested mountains, woodland and shrub land hills, glacial peaks, lava fields, and wetlands. These environments coupled with topographic gradients largely influence overall water flow, rates of infiltration, runoff response, and flow velocity to Boysen Reservoir. The headwaters of the mountainous regions should be expected to be largely influenced by steep topographic gradients owing to high velocity flow rates of stormwater runoff and snow melt. Although the mountainous regions are predominantly forested and heavily vegetated, data gathered by the WDEQ in the mountainous watersheds indicates that sedimentation in the mountainous streams may be caused by high flow velocities and uncontrolled erosion (**WDEQ, 2010**). As the smaller tributary creeks transition from the headwaters of the mountainous areas, they converge into the Wind River Valley culminating in larger flow volumes but with shallower topographic gradients. The Wind River Valley is primarily an arid zone sparsely vegetated with sage brush except for the areas of major streams and rivers where trees line the banks. Surface geology of the Wind River Valley primarily consists of the Wind River Formation (Eocene) containing variegated claystone and sandstone with lenticular discontinuous conglomerates, is up to 600 feet thick in some places, and is known to have low yields for aquifer use. Based on the description of the Wind River Formation, infiltration from streams or rivers into the surrounding formation would be limited, thus confining stormwater runoff or snow melt to the topographic drainage features. Because vegetation is sparse and infiltration rates are anticipated to be low within the Wind River Valley, stormwater runoff response times would be relatively quick with the potential for flash flooding or high volume flows. The Badwater Creek sub-basin was identified as a watershed with low flow, however, USGS data suggests that this watershed transports large sediment loads to the Boysen Reservoir during runoff events (**WDEQ, 2010**).

4-04 SEDIMENT

Sediment accumulation in Boysen Reservoir has not affected the flood control storage allocation.

4-05 CLIMATE

The climate of the Yellowstone River Basin is characterized by cold winters and hot summers. The average annual precipitation ranges from as little as 8 inches in areas below the Bighorn River confluence to 30 inches in the mountainous areas near the headwaters. The mountainous areas accumulate heavy snowfall during the winter months. Most of the lower valley's annual precipitation occurs as rain during the April–September period. In the mountains, however, most of the precipitation occurs as snow, which usually reaches its maximum accumulation on the ground during the first half of April.

Table 4-2. Normal Climate Values for Boysen Dam Aug 1948 – Jun 2016

Month	Average Max Temperature (°F)	Average Min Temperature (°F)	Average Precipitation (inches)	Average Snowfall Depth (inches)
January	29.6	6.4	.25	1.7
February	37.9	12.9	.28	2.1
March	49.4	23.8	.56	3.1
April	59.7	33.8	1.28	1.0
May	70.1	43.6	1.82	0.0
June	81.1	52.8	1.34	0.0
July	90.3	60.1	0.72	0.0
August	88.2	58.3	0.51	0.0
September	76.5	47.7	0.79	0.0
October	62.2	36.3	0.80	0.3
November	44.0	23.1	0.33	1.5
December	31.3	10.8	0.28	1.9
Annual	**60.0**	**34.1**	**8.96**	**11.6**

Source: Western Regional Climate Center Temperature and Precipitation data is at Boysen Dam station
http://www.wrcc.dri.edu/summary/Climsmwy.html

a. Evaporation

Evaporation was historically estimated using a 4-foot Class A evaporation pan. Evaporation is now calculated using a bulk flux evaporation estimate. This estimate uses real-time hydrometeorological data collected at the Riverton Regional Airport along with Boysen's physical properties to calculate an evaporated volume. Table 4-3 lists the input and output parameters needed to calculate evaporation.

Table 4-3. Boysen Reservoir Evaporation Estimate Input and Output

Inputs	Unit	Parameter Name
Percentage of sky covered by high level clouds	%	%-Cloud-High
Percentage of sky covered by mid-level clouds	%	%-Cloud-Mid
Percentage of sky covered by low level clouds	%	%-Cloud-Low
Relative Humidity	%	%-Rel-Hum
Elevation of high level clouds	meters	Elev-Cloud-High
Elevation of mid-level clouds	meters	Elev-Cloud-Mid
Elevation of low-level clouds	meters	Elev-Cloud-Low
Air pressure	kPa	Pres-Air
Wind Speed	m/s	Speed-Wind
Air Temperature	C	Temp-Air
Reservoir Area	meters	Area
Reservoir Elevation	meters	Elev
Outputs		
Irrad Sensible Heat	W/m^2	Irrad-Heat-Sensible
Irrad Latent Heat	W/m^2	Irrad-Heat-Latent
Short Wave Radiation Flux	W/m^2	Irrad-Flux-Solar
Long Wave Radiation Flux in	W/m^2	Irrad-Flux-IR
Long Wave Radiation Flux out	W/m^2	Irrad-Flux-IR-Out
Water Temperature (estimated at every half meter)	C	Temp-Water-Surface or Temp-Water-x,xm
Hourly Evaporation	mm	Evap
Daily Evaporation	mm	Evap
Daily Evaporated Volume	cms	Flow-Evap

4-06 STORMS AND FLOODS

Floods in the Yellowstone River Basin fall into three distinct types: floods caused by ice jams, accompanied by runoff from snowmelt in the lower areas of the basin; floods caused by the melting of the mountain snow cover, frequently in combination with rain in the foothills or plains areas; and floods caused by intense rains, which usually occur as summer thunderstorms.

Because of a combination of factors, including the northerly direction of flow of streams in the basin, the location of the mountain ranges, and the prevailing winds, snowmelt in the

Yellowstone Basin usually begins in February or March in the upper reaches of the main stem in the vicinity of Livingston and Billings, MT, and progresses downstream over a period of about one month before the final breakup of ice at the mouth of the river. The snowmelt in the Wyoming portion of the basin usually occurs somewhat later in the spring than that along the main stem, and usually begins in the lower or northerly reaches of the streams. As a result of this melting of snow at the lower elevations, the ice cover breaks up and severe ice jams can occur. The reach from Miles City to the mouth of the Yellowstone River has suffered the most severe damage from floods of this type. Areas along the Bighorn near Worland and Greybull, WY, have also suffered from ice jam floods. Examples of this type of flood are those which occurred during March or April in 1943 on the Yellowstone and in March and April 1929 on the Bighorn.

Melting of the mountain snow cover causes the second and largest general rise in streamflow, known as the June rise. Occasionally this snowmelt runoff is augmented by general rains throughout the basin. During this period, flood stages occur almost every year on some of the streams in the basin. Examples of major floods of this type are the floods of 1918, 1967, 1991, 1997, 2011, 2017, and 2018.

Periods of thunderstorm activity are quite common during the summer, and flash floods occur practically every year in some part of the Yellowstone Basin. The thunderstorms usually occur on the plains area and on the mountain slopes up to 7,000 feet elevation, but have occurred at elevations as high as 10,000 feet. An example of the rainstorm type of flood is the one of July 1923, which resulted from a cloudburst in the area surrounding Boysen Dam and which was the greatest flood of record at Thermopolis, WY. In September of the same year, another storm, with several centers of cloudburst intensity, caused major floods in the Bighorn and Powder basins. The rain driven flood of 1957 caused Boysen Reservoir to store significant floodwater.

Graphics showing the operations of Boysen Dam are shown in Plates 4-2 through 4-8. No graphics were generated for the events before the dam was closed in 1951.

a. Flood of 1917

The 1917 flood, caused by melt of a heavy mountain snow cover, was one of the largest snowmelt floods that occurred before Boysen Dam was constructed. Peak flows past the Boysen damsite were approximately 18,000 cfs and flows below the Shoshone River were over 32,000 cfs. Significant flooding occurred along the Wind and Bighorn rivers.

b. Flood of 1918

The open-water flood of 1918, which is one of the greatest general floods of record in the Yellowstone River Basin, caused significant damage in both rural areas and river communities. Floodwaters along the Yellowstone River inundated nearly all the business and residential property in Forsyth, MT. Peak flow at Boysen damsite peaked at over 17,000 cfs and remained above 14,000 cfs for two weeks.

c. Flood of 1923

The town of Thermopolis, WY has experienced two major floods dating back to 1900. Both floods occurred in 1923 and were caused by intense rains. The July 1923 event was a result of thunderstorm activity and is the flood of record at Thermopolis. In September 1923 a second intense rainstorm occurred above and below the Boysen damsite. Approximately half of the town of Greybull, WY was flooded to an average depth of three feet. No gage exists at Greybull, but the September 1923 estimated discharge was 36,000 cfs.

d. Flood of 1929

The ice-jam flood of March 1929 in Greybull, WY was the most damaging flood to occur in Greybull.

e. Flood of 1948

Significant ice-jam flooding occurred on the Bighorn River in Worland, WY and Manderson, WY.

f. Flood of 1957

The flood of 1957 was caused by heavy rains in May and June following a winter with below normal snowfall. Boysen Reservoir's peak inflow of 15,000 cfs was recorded on 9 June. Inflows had receded by late June before inflows peaked a second time near 12,500 cfs. As a result the pool elevation peaked at 4729.8 feet, which increased releases to 8,000 cfs. See Plate 4-2 for a graphical depiction of the 1957 flood routing.

g. Flood of 1967

Heavy mountain snowpack accumulated in the Bighorn Basin from January through March. A cold April and May delayed the start of the runoff season and allowed for continued snowpack accumulation. Heavy rains fell in June, amplifying the delayed snowmelt. Boysen releases were increased throughout the winter and spring to evacuate storage for the snowmelt runoff. The joint-use storage zone was completely evacuated and Reclamation chose to draw the pool down further to provide further flood risk reduction. Boysen pool elevation reached 4706.9 feet, the low pool elevation for the year, in mid-May. A large rainfall event on June 13-15 brought heavy rain above and below Boysen Dam bringing large inflows to the reservoir and the downstream area. The reservoir entered the exclusive flood control zone on June 18. Inflows reached 19,250 cfs on June 23, the record inflow that stood until 2017. Peak pool elevation of 4730.8 feet and peak release of 14,200 cfs occurred on July 8. Record pool elevation and release was set during this event. Peak discharge at the Bighorn River at Kane was 25,000 cfs on June 24. Boysen releases of approximately 9,000 cfs contributed to the June 24 flow at Kane. See Plate 4-3 for a graphical depiction of the 1967 flood routing.

Yellowtail Dam had recently been completed and the reservoir pool was being filled during the 1967 event. Yellowtail set a record pool elevation and release during this event. Peak pool elevation was 3656.3 feet and peak release was 24,700 cfs. The Yellowtail afterbay dam was designed to release 20,000 cfs, and releases above 20,000 cfs could force the afterbay dam to be breached. But the afterbay spillway was able to pass the peak release without failure.

h. Flood of 1991

During the last part of April and the first part of May, the snowpack in the Wind River basin above Boysen Reservoir increased dramatically. The snowpack peaked near the start of the second week in May, approximately three weeks later than normal and was well above normal. On May 29, spillway flow was initiated by Reclamation in anticipation of high runoff. On June 2 and 3 heavy rainfall on an isothermal snowpack resulted in a substantial rise in inflow rates. The Wind River and Little Wind River at Riverton both rose above flood stage.

On June 9, the pool level entered the exclusive flood control zone and the operation of the spillway gates became closely coordinated between the USBR's Montana Area Office and Omaha District's WCWQS. Three-day forecasted inflows were received daily from the National Weather Service (NWS) River Forecast Center and routed through the reservoir to determine recommended gate settings.

Inflows remained steady until additional rainfall and temperatures in the 60's on June 12 and 13 resulted in a rapid melt of the remaining snowpack. Runoff added to the already swollen Wind and Little Wind rivers, causing flooding in the Arapahoe and Riverton areas. Peak inflow of 16,500 cfs occurred on June 15. Based on NWS forecasts of continued high inflows, the release out of Boysen was increased to a peak 10,700 cfs on June 16. However, inflows began to drop and releases were reduced. The pool level dropped below the exclusive flood control zone on July 4.

Boysen Reservoir was operated to reduce flood damages. When the pool level entered the exclusive flood control zone, floodwater was stored and releases were limited to the maximum non-damaging downstream channel capacity, consistent with regulation procedures outlined in the Boysen Reservoir Regulation Manual. See Plate 4-4 for a graphical depiction of the 1991 flood routing.

i. Flood of 1997

The winter and spring brought the snowpack of record entering the 1997 runoff season. Numerous SNOw TELemetry (SNOTEL) stations in the Bighorn Basin reached record levels and a large runoff was expected. Releases were increased in March and April to evacuate conservation storage in expectation of a high runoff year. The pool reached a low of 4705.3 feet in mid-May. Releases were increased to 4,000 cfs on May 23 as inflow began to climb. By May 30 floodwaters were filling Garrison Dam as well as Yellowtail Dam and there was concern both projects could have their spillway gates overtopped. Boysen releases were cut in response to the downstream conditions. Releases were cut to 3,000 cfs on May 31 and held until June 15. Peak inflows of 15,400 occurred on June 11. Peak release for the year reached 6,450 cfs in late June. The peak pool elevation of 4727.3 feet was reached on June 27. Both Boysen Dam and Yellowtail Dam were integral parts of the flood control mission during the record 1997 snowmelt runoff event. See Plate 4-5 for a graphical depiction of the 1997 flood routing.

j. Flood of 2011

Snowpack above Boysen Reservoir was near the 30-year average from December 2010 through the end of March 2011. Large snowstorms in April and May increased the snowpack to over 170% of normal. Figure 4-1 shows the 2011 snow water equivalent (SWE) compared to the 30-year average.

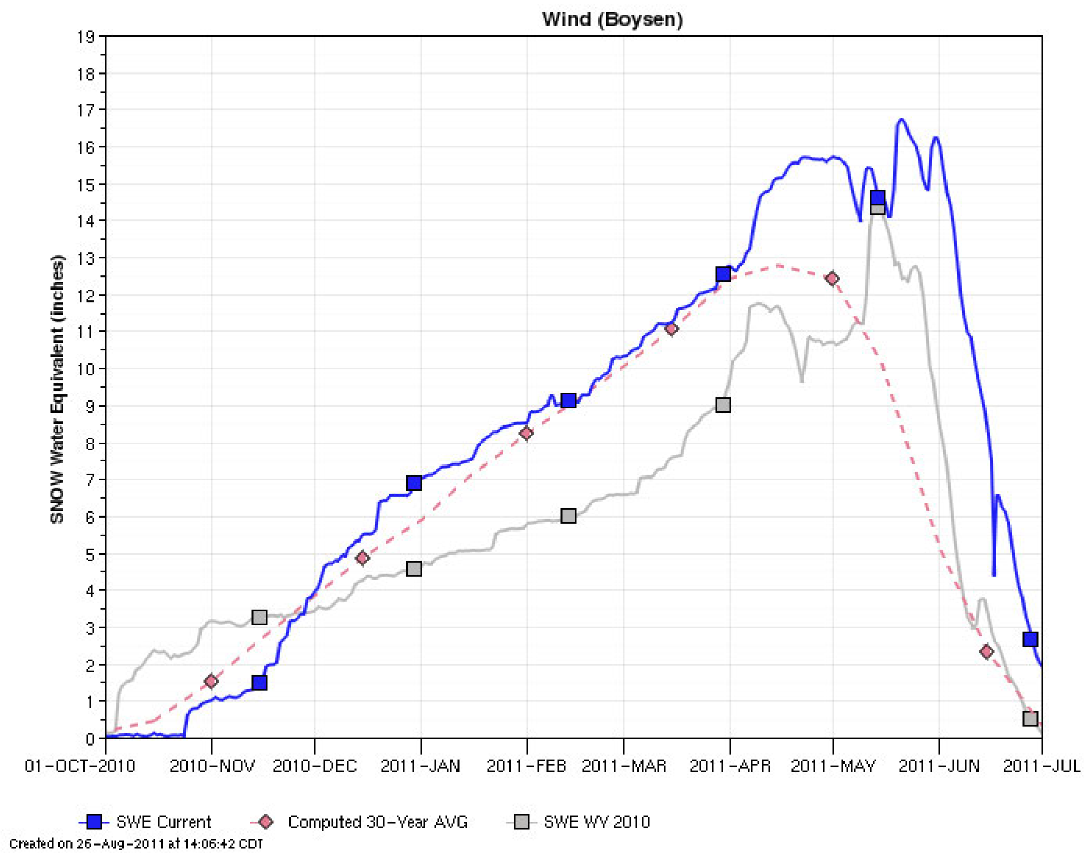

Figure 4-1. 2011 Wind River Snowpack

The snow began to melt in mid-May, but new snow continued to fall as the snowmelt began. The snowfall on top of melting snow can be seen in Figure 4-1. The saw-toothed pattern in late May is a reflection of these snowfall events. The saw-toothed pattern does not increase the peak SWE estimate, but each oscillation adds more snowmelt volume to the runoff event. Reclamation continued to lower Boysen's pool in expectation of an increasing runoff volume. Both the Corps and Reclamation predicted a May-July inflow volume above 1 MAF, which would be one of the highest on record. The actual May-July runoff volume was near 960,000 af, which was the 8th highest on record.

Release plan coordination between the Omaha District, Reclamation and Missouri River Basin Water Management (MRBWM) began in May. In response to historic late May rainfall in eastern Montana, MRBWM requested the immediate utilization of all available storage at Section 7 projects. Boysen's available flood control storage had been vacated to accommodate the heavy snowpack above Boysen. Storing floodwater ahead of the peak snowmelt runoff would fill the conservation pool more quickly, likely forcing damaging releases when Boysen entered the flood control pool.

It was agreed upon that Boysen would most effectively benefit the Missouri River mainstem reservoir system by storing water during the peak snowmelt runoff. In mid-June, an elevation of 4727.5 to 4728.5 feet was targeted at Boysen, storing 50,000 - 70,000 af in the exclusive flood control zone. This goal for the portion of flood control space occupied was much less than many of the other Section 7 projects, but any higher goal would force increasing Boysen's gate opening and release near damaging river flows downstream of Boysen. The goal of 50,000 – 70,000 af optimized reducing the risks of damaging flows locally and reducing inflows into Yellowtail and Garrison. Releases and reservoir forecasts were coordinated with Reclamation on a daily basis. All releases from Boysen were coordinated to best balance risk between Boysen and Yellowtail.

The low elevation snow melted in May and early June. The SNOTEL gages reported that most of the snow had melted by mid-June. Boysen's inflows were not reaching forecasted levels, which had some concerned the Corps' and USBR's inflow volume forecasts were too high. But high temperatures exceeding 90 degrees in late June and early July melted the remaining snow and increased inflows dramatically. The peak daily inflow of 16,500 cfs on July 2 was the 3rd highest on record.

Releases were made to draft Boysen's pool until June 8. From June 9 through June 22, releases were increased to retain storage for the forecasted peak inflow. Releases were decreased on June 23 to begin storing water and to reduce Yellowtail inflows. Boysen entered the exclusive flood control pool on July 9. Once in the exclusive flood control pool, the spillway gates were adjusted to maintain at least 0.5 feet of freeboard on the spillway gates. Boysen spent 26 days in the exclusive flood control zone and reduced peak inflows to Yellowtail Reservoir and to the Missouri River. See Plate 4-6 for a graphical depiction of the 2011 flood routing.

k. Flood of 2017

Following a dry fall, Reclamation held the pool near 4720 feet into December. Repeated snowstorms in December, January, February and March produced a record snowpack in the Wind River basin. The 30-year average peak snowpack above Boysen is 12 inches. 2017 snowpack exceeded 12 inches in mid-February.

Based on the February 1 May-July runoff forecast, approximately 110 kaf of joint use storage evacuation was required by May 1. Reclamation's Most Probable Operation Plan evacuated the entire joint use storage zone by May 1.

By March 1 snowpack was nearly 200% of normal and the runoff forecast was increased to 1,195 kaf. This large runoff required Reclamation to evacuate all 150 kaf of joint use storage by May 1. Reclamation's Most Probable Operation Plan evacuated the entire joint use storage zone by May 1.

Additional coordination with Reclamation began in mid-March to plan for the large runoff. The Corps, the WYAO, the Missouri Basin and Arkansas-Rio Grande-Texas Gulf Regions, and the Montana Area Office began having ad-hoc conference calls to discuss different runoff and release scenarios. This elevated coordination continued through the remainder of the event.

Following ice-out in late March, releases were increased to approximately 5,500 cfs and were held near this level until late May. This release was made to evacuate the remainder of the joint use zone as well as part of the conservation zone. The April 1, May-July runoff forecast increased again to 1,356 kaf. This large runoff required Reclamation to evacuate all 150 kaf of joint use storage by May 1. Reclamation's Most Probable Operation Plan evacuated the entire joint use storage zone by May 1, planning to reach pool elevations as low as 4705 feet.

The May 1, May-July runoff forecast increased to 1,517 kaf. The pool elevation had been drawn down over the previous month reaching 4708.0 feet on May 1 with a minimum pool elevation of 4705.1 feet on May 9. Reclamation sent a press release in late April notifying locals of the expectation to release at least 6,500 cfs. Inflows increased in early May as low elevation snow melted and entered the river system. Boysen's May inflows peaked on May 15 at approximately 10,500 cfs before a cool down slowed the melt. Inflows decreased over the next 10 days and there were discussions with Reclamation that the forecasted runoff may have been overestimated. But warm temperatures returned in early June, setting a new record daily inflow of 20,400 cfs on June 11.

Releases were stepped up from 5,500 cfs in May to 9,000 cfs by the end of June. Releases were held lower in early June while high flows from the downstream tributaries peaked. Flows were kept below the 15,000 cfs flood target at Kane throughout this period, with the exception of June 10 and 11 when flows reached 15,800 cfs for a short time. Releases were not cut during this time due to the risk of higher releases later if the runoff volume was underestimated. The 9,000 cfs release reached on June 21 was the highest release at Boysen since 1995. All releases were coordinated with the Reclamation's Wyoming and Montana Area Offices to best balance the flood control risk between Boysen and Yellowtail.

The pool elevation peaked on June 28 at 4728.9 feet, 3.9 feet into the exclusive flood control zone. Releases were held at 9,000 cfs until July 5 when releases were cut to 8,500 cfs. This cut was made to relieve flooding pressure on irrigation structures downstream of Boysen and to Thermopolis' water supply, waste water, and bridge infrastructure. Releases were further decreased as the exclusive flood control zone was evacuated on July 26.

2017 set a new record May-July runoff volume at 1,503,000 af. This is particularly surprising considering the May and June precipitation were both below normal in the Wind River basin (NOAA Climate Division 9). Had rainfall during May and June followed a more normal pattern, releases from Boysen would have been significantly higher. See Plate 4-7 for a graphical depiction of the 2017 flood routing.

I. Flood of 2018

Boysen's pool elevation was steadily drawn down over the winter as part of Reclamation's normal operations. The snowpack as of February 1 was near 100% of average. The inflow regression forecast was predicting 891 kaf, 154% of normal May-July runoff. This was primarily due to high fall runoff and high previous year's precipitation, not an above normal snowpack above Boysen. Based on the February 1, May-July runoff forecast, evacuation of all the joint use storage was required by May 1. Reclamation's Most Probable Operation Plan evacuated the entire joint use storage zone by May 1.

March 1, snowpack remained near average and the runoff forecast was 874 kaf. This required Reclamation to evacuate all joint use storage by May 1. Reclamation's Most Probable Operation Plan evacuated the entire joint use storage zone by May 1.

Reclamation increased releases in mid-March to evacuate storage ahead of the runoff season. Releases reached nearly 3,000 cfs in early April and were held near this level into May. The April 1, May-July runoff forecast decreased to 754 kaf. This forecasted runoff required Reclamation to evacuate 122 kaf of joint use storage by May 1. Reclamation's Most Probable Operation Plan evacuated the entire joint use storage zone by May 1, planning to reach pool elevations as low as 4708 feet.

The May 1, May-July runoff forecast was 659 kaf. The pool elevation had been drawn down over the previous month reaching 4706.9 feet on May 9. The required joint use drawdown was 84 kaf, which was exceeded by Reclamation's operations.

After below normal April temperatures delayed the snowmelt season, May temperatures were above normal and quickly increased inflows into the projects. Repeated rainstorms across Montana and Wyoming from May 22-27 combined with high snowmelt runoff to dramatically increased Yellowstone River flows. Ahead of these events the Corps and Reclamation's Missouri Basin and Arkansas-Rio Grande-Texas Gulf Regions, Wyoming and Montana Area Offices began coordinating operations from Boysen, Buffalo Bill, and Yellowtail. This coordination occurred daily and continued into mid-July to assure the optimal operation was achieved. Flows at Miles City were forecast to reach above 70,000 cfs in late May. In response to above flood target flows at Miles City releases were cut from Yellowtail and Boysen. Releases were cut starting May 23 from 2,300 cfs to 1,800 cfs while flows near Miles City receded. Releases were increased beginning on May 28 and reached approximately 4,000 cfs by June 1. Inflows peak at 12,500 cfs on May 29 and slowly receded into June. During this time large inflows from snowmelt and rainfall also accumulated in Boysen Reservoir.

The large May precipitation totals increased the June runoff forecast. June 1, May-July runoff forecast was increased to 832 kaf. The June 1 joint use storage requirements for this runoff and the expected releases was 140 kaf below the top of joint use storage. But providing flood risk reduction at Miles City superseded the joint use evacuation requirement. Releases increased to 6,000 cfs by June 7 in anticipation of utilizing the Exclusive Flood Control Zone. Inflows during this period continued to recede, but remained above outflows. By June 11 inflows had fallen below 7,000 cfs as much of the snow had melted. Releases were cut from 6,000 cfs to 4,500 cfs between June 12 and 14 to reduce inflows into Yellowtail. On June 18 1.5 inches to3 inches of rain fell above Kinnear. This melted much of the remaining snow and increased Boysen inflows dramatically. Inflows increased from 3,700 cfs on June 14 to a peak of 13,000 cfs June 21. To avoid overtopping the spillway gates, releases were increased from 4,500 cfs on June 16 to 7,000 cfs by June 24. Additional heavy rains June 17-25 in Montana, Wyoming, and North Dakota created excessive runoff into the Missouri River mainstem flood control system. The MRBWM requested Boysen and other Section 7 projects delay release increases or cut releases in an effort to curtail inflows to the mainstem reservoirs. Releases were held at 7,000 cfs as the pool elevation peaked at 4727.5 feet June 23.

Following the peak pool elevation releases were quickly cut to closely match inflows to minimize Boysen's contribution to downstream flows. These cuts were made starting June 25 and the cuts continued into July. Releases reached 3,500 cfs by July 5 and were held there until cutting to 3,000 cfs July 18. Boysen exited the Exclusive Flood Control Zone on July 19. It should be noted without MRBMWD's request to reduce releases, releases would likely have been held at higher levels already experienced and for longer durations. This would have resulted in a quicker evacuation of the flood pool. But the operation as implemented provided additional flood risk reduction benefits to the Missouri River flood control system. See Plate 4-8 for a graphical depiction of the 2018 flood routing.

4-07 RUNOFF CHARACTERISTICS

A majority of the runoff above Boysen Dam is derived from melting snow in the mountains during early summer. Over one half of the annual runoff occurs during the May-July 3-month period. Plate 4-9 shows a graph of Boysen's historical monthly inflow volume and Plates 4-10 to 4-12 present this data in tabular form. The historic annual inflow volume for the period of record is graphically represented in Plate 4-13.

4-08 WATER QUALITY

According the State of Wyoming SPHS, Boysen Reservoir is suitable for fishing, swimming, boating and other lake activities. Reclamation is responsible for coordinating water quality at Boysen.

4-09 CHANNEL AND FLOODWAY CHARACTERISTICS

Channel capacities for the damage reaches below Boysen Dam were determined by analysis of flows and stages with and without flooding. Channel capacity was found to be approximately 15,000 cfs at the Kane gage station, gage height currently of 8 to 9 feet. During ice cover or ice flow conditions, flows would be substantially lower at the same stage, considering the backwater effect of ice. Thermopolis' channel capacity during the 2017 Flood appeared to be between 9,000 cfs and 10,500 cfs. The peak release in 2017 was approximately 9,000 cfs. Bankfull travel times are shown on Plate 4-14. Rating curves for major streamgaging stations in the Boysen Dam area are shown on Plates 4-15 through 4-28.

4-10 UPSTREAM STRUCTURES

See Section 3-04, Related Projects.

4-11 DOWNSTREAM STRUCTURES

See Section 3-04, Related Projects.

4-12 ECONOMIC DATA

a. Population

The majority of the towns and the areas having the greatest density of rural population are located along the larger rivers and streams. The upland areas are used mostly for grazing and dry land farming, and the mountain areas are sparsely settled.

The largest cities in the Yellowstone basin include Billings, Miles City, Glendive, and Sidney. All of the cities named above except Billings are downstream from the mouth of the Bighorn River and in Montana. The centers of population in the Bighorn Basin are found along the streams, while the upland and mountainous areas are sparsely settled. The largest cities in the Bighorn basin are Worland, Riverton, Cody, Powell, Lander, and Thermopolis. Table 4-4 lists the populations and counties of each city.

Table 4-4 Cities in the Bighorn Basin

City	Population	County
Cody, WY	9,740	Park
Lander, WY	7,642	Fremont
Powell, WY	6,407	Park
Thermopolis, WY	3,020	Hot Springs
Riverton, WY	10,953	Fremont
Worland, WY	5,366	Washakie

Source: city-data.com: 2014 data

b. Agriculture

Stock raising has long been a major industry of the Yellowstone Basin. Irrigation farming is of great importance, and the two activities have become well-coordinated, particularly in the production of hay for winter feeding. Several large irrigation developments are located along the Yellowstone River below the mouth of the Bighorn River.

Stock raising and irrigation farming are the principal activities in the Bighorn Basin, with coal and oil production also of considerable importance. Several large irrigation developments are found in the basin, notable among them being the Riverton Project in the Wind River Basin and areas along the Greybull and the Shoshone Rivers.

See Section 3-04, Related Structures for more information on irrigation diversions.

c. Industry

The cities of Billings, Miles City, Glendive, and Sidney constitute the center of the manufacturing industries in the basin. Oil is an important product of the Yellowstone and

Bighorn Basins. Recent developments in the Williston area, which includes the lower part of the main stem of the Yellowstone River, has become one of the largest oil-producing areas in the country. Coal is the principal mineral resource and is mined extensively in Rosebud County, Montana, and in most of the counties of Wyoming.

d. Flood Damages

The Bighorn and Yellowstone River downstream from Boysen Dam has been divided into several reaches for computation of flood damages as follows. Note that Bighorn Reach 4 was from the Shoshone River to Yellowtail Dam. This reach was removed following the federal purchase of land for Yellowtail Dam.

Bighorn Reach 1 - Boysen Dam to Worland

Bighorn Reach 2 - Worland to mouth of Greybull River

Bighorn Reach 3 - Greybull River to Shoshone River

Bighorn Reach 5 - Yellowtail Dam to mouth of Little Bighorn River

Bighorn Reach 6 - Little Bighorn River to mouth of Bighorn River

Yellowstone Reach 1 - Bighorn River to Miles City

Yellowstone Reach 2 - Miles City to Glendive

Yellowstone Reach 3 - Glendive to mouth of Yellowstone

Index stations for each reach were selected to reflect discharges within the reach. Discharge damage curves were developed from field surveys and floods of record. Zero damage discharges were selected for each reach from a study of recorded stream discharges and flood records. This survey was made prior to 1963. However, the curves were indexed to inflation as of 2015. The discharge damage curves can be seen on Plates 4-29 and 4-30. Annual flood damages prevented by Boysen Dam since construction for both local and the Missouri River Mainstem System are shown Plate 4-31. Total damages prevented by Boysen Dam since its construction is $291,303,000 in September 2018 dollars.

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CHAPTER 5—DATA COLLECTION AND COMMUNICATION NETWORKS

5-01 HYDROMETEOROLOGICAL STATIONS

a. Facilities

Maps of stream gaging stations upstream and downstream of Boysen Dam are presented on Plate 5-1.

The Cooperative Stream Gaging (Co-op) Program is a joint effort between the Corps, Reclamation, and the USGS providing remote site, satellite data transmissions utilized for water management. Plate 5-2 displays a table of several reservoirs and hydrologic stations relevant to Boysen Dam with various organizations' identification names, drainage areas, mean values, and periods of record.

Reclamation's HydroMet system forms a complementary network of nearly 400 real-time hydrologic and meteorological data stations dedicated to forecasting and managing the water supply in the western U.S. HydroMet stations at various locations within the Bighorn Basin associated with the regulation of Boysen Reservoir are identified on Plate 5-2.

Since 1964 the Natural Resources Conservation Service (NRCS) has also established automated SNOTEL stations or snow pillows in the mountain areas. The locations of these SNOTEL stations are shown on Plate 5-3. Plate 5-4 contains a table of average bi-weekly SWE values for SNOTEL stations located in the upstream basin of Boysen Dam. It can be used to track the progress of the snowpack accumulation, as well as precipitation.

Real-time rainfall gages located in area are listed in Table 5-1 and their locations are shown on a map in Plate 5-2. The monthly precipitation totals are shown in Plate 5-5.

Table 5-1 Real-Time Precipitation Stations

Station Name	Elevation (feet NGVD29)	NESDIS ID	NWS ID	Period of Record
Crandall	6612			1993-
Elk Horn RAWS	8325	323A114E	ELKW4	1989-
Fales Rock RAWS	6380	3265139E	RSNW4	1997-
Grass Creek Divide	7100			1991-
Lander Airport*	5587	-		1990-
Leigh Creek	8202			1999-
Pistol Draw	4520			2016-
Raspberry RAWS	10,040	325F44C0	RASW4	1985-
Rattlesnake Mtn	6800			1988-
Riverton Regional Airport*	5475	-		1990-
Sharpnose RAWS	5555	AAB716BE	SHPW4	2015-
Split Rock Creek RAWS	6000	3278B79E	SPLW4	1988-
Wind River RAWS	9235	52117480	WRVW4	1991-

* Precipitation data used in the Corps' long-range runoff volume forecast described in Section 6-04. RAWS = National Interagency Remote Automated Weather Stations (mostly used for fire related forecasting)

Sources: http://amazon.nws.noaa.gov/hads/charts/MT.html http://www.wrcc.dri.edu/wraws/wyF.html

b. Reporting

Data from hydrologic gages for water management are obtained from various sources including contract observers, project offices, NWS, USGS, Reclamation, and state offices. The NWS provides current weather conditions, temperature, river stage and flow forecasts, observed precipitation reports, river level data, and special hydrologic forecasts including flood warnings.

There are many websites that provide a variety of weather products including universities, NWS, and commercial vendors of weather products. Products range from raw data (i.e., precipitation, temperature) to upper air maps and forecast products.

Periodic discharge measurements made by the USGS are normally furnished to the Omaha District WCWQS through automated computer exchange but can also be obtained by email, or telephone for various stations. These are used to maintain current stage-discharge relationships. Collection and publication of data such as stage, discharge, sediment, water quality, and groundwater records are the primary functions of the Co-op program.

The NRCS publishes real-time SNOTEL updates to the NRCS website.

Reclamation's HydroMet data is integrated with other sources of information to provide streamflow, forecasts, and current runoff conditions for river and reservoir operations. Reclamation uses the internet to share streamflow, weather, and runoff forecast data with the Corps that is used, in turn, to determine reservoir releases. Real-time provisional data is accessible on Reclamation's website.

c. Maintenance

The Corps and Reclamation support individual database systems by contributing personnel, funds, and equipment. Streamgaging sites are maintained by Reclamation, the Corps, and USGS. SNOTEL sites are maintained by the NRCS.

Omaha District personnel complete the District's streamgaging program with assistance from the USGS. The USGS's activities are funded through the Co-op Program (FC-33) executed by the WCWQS. The Co-op Program provides financial support for operation and maintenance of multiple streamgaging stations.

DCPs are installed and maintained by the USGS, Reclamation, and the Corps WCWQS personnel.

5-02 WATER QUALITY STATIONS

a. Facilities

Water temperature is measured at numerous stream gages throughout the basin and at Boysen Dam and Yellowtail Dam.

b. Reporting

Data is transmitted as described in Section 5-01.b via the GOES satellite.

c. Maintenance

No water quality stations are currently operated in concert with Boysen Dam and Reservoir.

5-03 SEDIMENT STATIONS

The Corps has not operated or funded sediment stations in the Bighorn basin.

5-04 RECORDING HYDROLOGIC DATA

The Corps Water Management System (CWMS) is the Omaha District's primary data management system. CWMS was developed by the Hydrologic Engineering Center (HEC) and utilizes an Oracle database to store river, reservoir and weather data. Another feature of CWMS is the ability to collect data from other Corps districts as a source of backup.

CWMS collects and presents the District's data in a clear, concise, and comprehensive manner. It provides access to both the current observed data and the results from forecast scenarios. Observed and forecasted information are displayed in two-dimensional plots and in special graphics using schematic, map or image backgrounds.

5-05 COMMUNICATION NETWORK

According to Reclamation's Boysen Standing Operating Procedure, Boysen Powerplant is equipped with telephone service. There is also a Western Area Power Administration PBX extension at the power plant. Other Reclamation telephone services connect by microwave to the CCC. Most Reclamation management personnel are also equipped with cellular phones.

Boysen power plant is equipped with a radio operating at a frequency of 41.020 MHZ. Reclamation area mobile radios and the CCC also operate under 41.020 MHZ frequency. Call letters for Boysen are KAC-845.

a. Emergency Warning

The WYAO, dam operating personnel, and/or the CCC are responsible for emergency notification. These Reclamation entities will follow the warning response detailed in the Boysen Emergency Action Plan. As a minimum, notification must be made to the Corps. In the event of flooding concerns, the NWS is federally mandated to issue flood warnings.

b. Emergency Situations

Section 7-15 describes deviations from normal regulation during emergency situations. When these or any other emergency situations arise, the WYAO Area Manager and Resources Management Division should be immediately notified and informed of all information pertaining to the incident. If the incident should occur after normal office hours, individuals listed as emergency contacts for WYAO in the Communications Directory shall be contacted by calling their cell or home telephone numbers. The local county sheriff and state emergency offices shall also be immediately notified of the accident. Additional local contact information is available in Reclamation's Boysen Standing Operating Procedures. During an emergency activity when the reservoir is in the flood control pool, the District will inform the MRBWM of its activities as soon as possible. Written confirmation of the deviation, including a description of the cause of the emergency, will be furnished to the MRBWM.

c. Remote Control

The remote supervision of the Boysen power plant and the outlet works is set up to be controlled from the CCC in Mills, WY and/or the control room of the Boysen power plant. This has resulted in the power plant being completely unattended most of the time, with the exception of Monday through Thursday when the dam operating personnel are on duty between 0700 and 1730 hours Mountain Time.

5-06 COMMUNICATION WITH PROJECT

a. Corps of Engineers with Bureau of Reclamation

Telephone and email are available for communication between the Boysen power plant, The WYAO in Mills, Wyoming, and the Omaha District WCWQS.

Except for emergency conditions outlined in the Standing Instructions to Dam Tender in Exhibit III, issuance of regulation orders during flood control operations is the function of the Corps' Omaha District WCWQS. Verbal regulation orders issued by the Omaha District WCWQS to Reclamation's WYAO or Boysen's Facility Manager will be confirmed in writing as soon as practicable. The written orders will be sent via email to the WYAO Resources Management Division who shares the information with the Facility Manager and the Missouri Basin and Arkansas-Rio Grande-Texas Gulf Regions. During the runoff season, release forecasts are shared with the MRBWM.

Dam operating personnel are required to report rapidly rising pool levels and heavy rainfall to the WYAO Resources Management Division. In the event the WYAO cannot be reached, the Dam Operator will notify the Omaha District WCWQS or the Corps' Garrison Project Manager. The method, time, and items to be reported are detailed in the Standing Instructions to the Dam Operator in Exhibit III.

b. Reclamation with Other

Reclamation communicates with state and local agencies regarding water supply, fish and wildlife, flooding, and other items of concern.

5-07 PROJECT REPORTING INSTRUCTIONS

The Boysen staff collects data as requested by the WYAO. Generally Current pool elevation, recent precipitation, discharge amounts through the various gates and tunnels and any other information pertinent to the operation of the project is shared with the WYAO who relays this information to the Corps via computer exchange.

5-08 WARNINGS

The procedure for the dissemination of Emergency Public Information is detailed in the Boysen Dam and Reservoir Emergency Action Plan (EAP).

The NWS is federally mandated to issue flood warnings.

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CHAPTER 6—HYDROLOGIC FORECASTS

6-01 ROLE OF DIFFERENT AGENCIES

a. Role of Corps

Forecasting the volume of runoff expected from the spring snowmelt is done independently by Reclamation, NRCS, and the Corps. The Corps is required to prepare forecasts of the expected May-July runoff volume once per month from February through July. The Corps' forecast as described in Section 6-04 with consideration of the Reclamation and NRCS forecasts is used when determining the joint use space requirements. The Corps also forecasts event based runoff when the pool elevation is above the joint use elevation of responsibility or in the exclusive flood control zone or anytime downstream flood targets are exceeded.

b. Role of Other Agencies

Reclamation takes all three forecasts into consideration when scheduling conservation or multi-purpose releases and development of their monthly operation plans. Reclamation also does event based forecasting at all pool elevations.

The NWS releases short-term inflow forecasts as part of their mission as official forecaster. This forecast is generally limited to an inflow forecast with a less than two week forecast window. Both Reclamation and the Corps use this information as a guide when forecasting inflow and making operational decisions.

6-02 FLOOD CONDITION FORECASTS

a. Requirements

Boysen Dam requires short range, event based forecasting as well as long range runoff forecasts. The seasonal May-Jul runoff forecasts are further described in Section 6-04.

b. Methods

Quantitatively forecasting rainfall runoff from the contributing areas above the reservoir is difficult due to the large areas involved, the variation in terrain, and the scarcity of precipitation reporting stations. Precipitation reports form a basis for qualitative estimates and serve as an alert for increased stream flow both above and below the dam. This information is used along with NWS Doppler radar to provide observed precipitation estimates.

The Corps has a HEC-HMS runoff model to aid in Bighorn runoff forecasting. The HMS model uses observed precipitation, snowpack conditions, streamflow and predicted precipitation and predicted temperatures to forecast runoff.

Forecasts will also be made of river stages at control points on the Bighorn and Yellowstone Rivers. In general, during the mountain snowmelt or "June rise" period, the forecasts can be made by the application of time and duration relationships which have been found to exist between certain upstream and downstream stations. The control points for flood control operations are Kane, WY, Bighorn, MT and Miles City, MT. The travel time from Boysen to Kane, WY is approximately one day and from Boysen to Bighorn, MT three days. The travel time from Boysen to Miles City, MT is four days. In order to affect flood control or flood reduction, the flows must be predicted for the number of days in advance that it takes the release from Boysen to reach each control point. Thus, the flows at Kane, WY must be predicted for one day in advance, Bighorn, MT three days in advance and Miles City, MT four days in advance. A map depicting travel time is shown on Plate 4-14.

Short-range estimates of inflows resulting from mountain snowmelt runoff can still be made by translating and extrapolating flows observed at the tributary gaging stations, coupled with the total volume forecast. In the absence of numerical runoff modeling the following method can be used for forecasting flows at the Bighorn River at Kane.

The local inflow between Boysen Dam and Kane can be estimated using flows on the Wind River at Riverton and Little Wind River at Riverton as an index. One-half of the combined flows of the Wind River at Riverton and Little Wind River at Riverton is used as the local inflow between Boysen Dam and Kane. An adjustment is made based on variation shown by previous day's data. The predicted flow at Kane is the predicted local inflow from Boysen Dam to Kane plus the release from Boysen Reservoir lagged one day. This forecast method provides an approximate estimate for Kane flows, but can be affected by uneven runoff distribution above and below Boysen Dam.

6-03 CONSERVATION PURPOSE FORECASTS

Reclamation has responsibility for preparing water conservation forecasts, which are sometimes referred to as drought contingency forecasts.

6-04 LONG RANGE FORECASTS

a. Requirements

A major portion of the annual inflow into Boysen Reservoir results from the mountain snowmelt. On a monthly basis from February through July, the Corps prepares an inflow forecast for the May-July 3-month period. The May-July forecast is used to determine the required joint use storage evacuation volume.

b. Methods

The long-range runoff volume forecast method, which is presented in Exhibit VI, utilizes historical and current SNOTEL station data, daily precipitation data (see Section 5-01), and historical May-July and October-November Boysen inflow. Similar long-range runoff forecasts are independently prepared by Reclamation and the NRCS. The Corps evaluates all three forecasts to determine the joint use evacuation required to meet the flood control mission. A more detailed explanation of how to calculate the required evacuation is in Exhibit VII.

6-05 DROUGHT FORECAST

Reclamation has responsibility for preparing water conservation forecasts, which are sometimes referred to as drought contingency forecasts.

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CHAPTER 7—WATER CONTROL PLAN

7-01 GENERAL OBJECTIVES

The operating objectives at Boysen Dam and Reservoir are to provide desired river and reservoir regulation to maximize the power generation benefit; provide water for irrigation, municipal, and industrial use; provide desired river flow conditions to meet the needs of the downstream river fishery; provide desired conditions for fish, wildlife, and recreational use in the reservoir; and regulate river flow to mitigate downstream flood risk. Flood regulation will be coordinated between Reclamation and the Corps as specified in this manual.

7-02 CONSTRAINTS

The exclusive flood control zone at Boysen Dam begins at elevation 4725.0 feet, which is the top of the spillway gates. For this reason the spillway gates must be opened whenever water is stored in the exclusive flood control zone. The resulting releases made by storing water into the upper levels of the exclusive flood control zone increase the risk of flooding between Boysen Dam and Yellowtail Dam. The gates and valves in Boysen Dam used to regulate outflow from the reservoir are summarized as follows:

a. Operation of Spillway Radial Gates

Two radial-type gates, each 30 by 25 feet, with individual hoists control spillway releases. The invert elevation of the spillway is 4700.0 feet with top of gates at 4725.0 feet. Capacity of the spillway at elevation 4725.0 feet is 20,000 cfs. Flow over the top of the gates is not permitted. It’s preferred that six inches of freeboard be maintained on the spillway gates when the downstream channel is ice free.

b. Operation of River Outlet Works

Normal releases will be made through the power plant. When the power plant is not operating, by-pass outlets are provided to release water. Due to design limitations, do not operate the 48-inch hollow jet valves when the tailwater exceeds elevation 4619.0 feet.

During the 1991 event, it was determined the Sixth Street bridge in Thermopolis, WY would be one of the first structures affected by high release rates. At the maximum release of 10,688 cfs, water was just touching the superstructure of the bridge. With a maximum release of 9,000 cfs in 2017 water levels at the Sixth Street bridge was near the bridge superstructure, but did not reach it. Flows in excess of this amount would threaten the bridge along with the local water and natural gas line associated with it.

7-03 OVERALL PLAN FOR WATER CONTROL

a. Storage Allocations

The storage space in Boysen Reservoir has been allocated as shown in Pertinent Data Sheet on page XV and seen graphically in Plate 7-1. See Plate 7-2 for a graphical depiction of Corps and Reclamation release responsibilities at different storage levels and operating conditions.

The exclusive flood control zone consists of over 150,000 af of storage that is normally left vacant and is only used when current release rates or release increases would cause flows at the downstream control points to exceed flood targets described in this manual or during large Yellowstone or Missouri basin-wide events.

The joint use zone is over 144,000 af of storage vacated seasonally to maximize flood risk reduction during high snowpack years. This space can also remain full during the spring if water supply is forecasted to be less than needed to meet the conservation requirement as described in Exhibit VII. If the discharge at the control points downstream exceed the flood levels described in this manual, the joint use zone can also be filled to maximize flood risk reduction, so long as filling the joint use zone is not forecasted to cause higher discharges at the control points later in the runoff year.

Storage in the conservation zone is used to meet release requirements for irrigation, hydropower, fish and wildlife, water supply and other water uses. Evacuation of the conservation zone for flood risk reduction can be recommended to Reclamation by the Corps, but these recommendations are not considered mandatory.

The inactive zone is a level above which the pool will be maintained to provide minimum hydropower, fisheries, and other reservoir related benefits.

The dead zone is the pool below which no water can be released. This elevation is at the invert elevation to the penstock intake.

7-04 STANDING INSTRUCTIONS TO DAM TENDER

a. Flood Control Operation

When the pool is in the exclusive flood control zone, or when the vacated joint use zone is encroached, or when downstream flood targets are exceeded, instructions for releases will be issued by the Corps to the WYAO, who will in turn transmit the instructions to the dam tender. The WYOA will coordinate the minimum spillway release required at the current pool elevation. If communications cannot be made between the Corps and the WYAO, the Corps will communicate instructions directly to the dam tender.

b. Emergency Instructions

Reclamation has drawn up emergency instructions for operation of the spillway gates, a copy of which is included in Exhibit III. Instructions to the dam tender for flood control operation under emergency conditions have also been prepared by the Corps and included in Exhibit III.

7-05 FLOOD CONTROL

a. Local Flood Control.

Regulation of storage of Boysen Reservoir will be made to prevent, insofar as possible, the flow at Kane, WY, gage from exceeding 15,000 cfs. In general, holding flow at Kane to 15,000 cfs will result in non-damaging flow in damage reaches 1, 2, and 3 as defined in Section 4-12.b. Water travel time on the Bighorn River from Boysen Dam to Kane is approximately one day. The flow at Kane will be forecast one day in advance and releases from Boysen reduced to prevent discharge at Kane in excess of 15,000 cfs unless greater release is needed to meet another authorized purpose. Effectiveness of operation may be restricted by the limited volume of storage space available below the top of the spillway gates. If during the above operation the reservoir rises into the exclusive flood control zone releases can be increased up to the level indicated by the regulation curves (Plate 7-3) allowing for power releases and providing that such releases will not, when physically feasible, contribute to flows in excess of 20,000 cfs at Kane. As inflows decrease, these regulation curves will continue to serve as a guide for making releases until such time downstream conditions permit making releases in excess of those indicated without contributing to over 15,000 cfs at Kane. It should be noted the spillway characteristics are such that spillway releases must be made when the pool elevation exceeds 4725.0 feet. Releases may be made for power throughout the flood period, depending on the size and severity of the flooding. Conditions during any particular flood event may require some modification from the above schedule.

b. Lower Bighorn and Yellowstone Flood Control

In coordination with Yellowtail Dam, the storage in Boysen Reservoir will be regulated to prevent, insofar as practical, flows at the gaging station at Bighorn, MT from exceeding 25,000 cfs. Water travel time on the Bighorn River from Boysen Dam to Bighorn, MT is approximately three days. Releases from Boysen will be reduced to prevent, insofar as possible, discharges at Bighorn, MT in excess of 25,000 cfs unless greater release is needed to meet another authorized purpose. Similar to the regulation described for local flood control, the regulation curves on Plate 7-3 will designate the release level to be maintained when the pool is in the exclusive flood control zone. However, such releases will be limited when physically feasible so as not to contribute to flows in excess of 30,000 at Bighorn, MT. Evacuation of the exclusive flood control storage space will be as described in the preceding subparagraph. Conditions during any particular flood event may require some modification from the above schedule.

In coordination with Yellowtail Dam, Boysen Reservoir will also be regulated to reduce crest flows on the Yellowstone River at Miles City, MT insofar as is practical and consistent with the regulation previously described; and when practicable prevent Miles City, MT flows from exceeding 70,000 cfs. The travel time to Miles City, MT is four to five days. For general floods resulting primarily from snowmelt, Boysen Reservoir will be used to reduce flows at Miles City, MT, but cannot be expected to prevent all flooding because of the large uncontrolled drainage area. The risk of increased Bighorn River flooding resulting from operating for Yellowstone flooding should be considered before operating for the Yellowstone River. With floods resulting from rainfall, Boysen may be unable to decrease the flood crest at Miles City, MT, due to the considerable travel time from Boysen Dam to Miles City, MT. During major Wind River flood events, storage limitations may prevent Boysen Reservoir from providing flood reduction benefits to Miles City, MT.

c. Integrated Regulation of All Flood Control Reservoirs In Missouri River Basin

Releases from Boysen Dam eventually flow into Garrison Reservoir of the Missouri River Mainstem Reservoirs. In the quotes below, the USACE Northwestern Division's Missouri River Basin Water Management is abbreviated MRBWM. As per the Missouri River Mainstem Reservoir System Master Water Control Manual (Master Manual), November, 2018, paragraph 7-04.25, "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." Additionally, as per Section 208.11 of 33 CFR Chapter II, "The water control plan is subject to temporary modification by the Corps of Engineers if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communication available. The action taken shall be confirmed in writing the same day to the project owner and shall include justification for the action." As a result of these requirements, during large floods affecting the Missouri River Mainstem Reservoirs, releases of flood storage in Boysen Reservoir may be adjusted in order to meet basin-wide flood control goals of the Missouri River System. In the case of Boysen Reservoir, requests for modification will be made to the Wyoming Area Office Resources Management Division, Bureau of Reclamation in Mills, WY, which is part of the Missouri Basin and Arkansas-Rio Grande-Texas Gulf Regions. Requests should be made via telephone call or email, and confirmed via an official reservoir regulation order the same day.

d. Regulation Curves

The regulation curves shown on Plate 7-3 have been developed as described in EM 1110-2-3600 as an aid for flood control regulation of Boysen Reservoir. Characteristics of the reservoir design flood (Plate 8-10) were utilized in their preparation. These curves relate suggested releases to the mean inflow for the preceding 12-hour period and the current reservoir elevation. Since these releases will generally assure fill of the joint use storage space, they should be considered the minimum, when the pool is in the joint use zone, unless they will contribute to downstream flooding. When the pool is in the exclusive flood control zone the indicated releases should also be considered the minimum allowable unless they will contribute to substantial downstream flooding, in which case the Corps will best balance the current risk of downstream flooding with risk of potentially higher releases in the future.

e. Evacuation and Refill of Joint Use Zone

Filling of the joint use zone in Boysen Reservoir prior to the end of the flood season is a prime requisite for regulation of the reservoir. The joint use zone is evacuated each year to a level that balances flood control and conservation. Monthly seasonal forecasts, as described in Appendix VII define the pool elevation of responsibility. Reclamation is required to maintain flood control capacity by keeping the pool elevation at or below the pool elevation of responsibility. If pool elevation of responsibility is exceeded before the end of the runoff season the Corps will notify Reclamation and Reclamation will increase releases to non-damaging levels and return the pool to the pool elevation of responsibility. Table 4 in Exhibit VII is an aid in establishing and maintaining the pool elevation of responsibility. See Plate 7-2 for a graphical depiction of the Corps and Reclamation release responsibility at various pool elevations.

7-06 RECREATION

The Corps does not have specific recreation responsibilities at Boysen Reservoir. See Section 2-06 for more information about public facilities around the Boysen Reservoir.

7-07 WATER QUALITY

The Corps does not have specific water quality responsibilities at Boysen Dam and Reservoir. Reclamation will continue its water quality monitoring program for the reservoir.

7-08 FISH AND WILDLIFE

The Corps does not have any specific fish and wildlife responsibilities at Boysen Dam and Reservoir. Reclamation will continue to coordinate fish and wildlife interests with state, local, and other interested parties.

7-09 WATER SUPPLY

The State Water Commission adjudicates water rights by setting minimum release rates from reservoirs or at diversion dams, especially during the irrigation season when water shortages occur.

Reclamation states the prime function of the project is to regulate the flow of the Bighorn River, and that irrigation and hydropower storage will not only provide a firm irrigation supply for new downstream irrigation, but will protect existing downstream water rights so that additional upstream diversion may be made. The releases for power generation will generally satisfy the irrigation and other downstream conservation requirements. See Sections 4-12.b and 4-12.c for more information on consumptive water uses in the Yellowstone basin.

According to Reclamation's Boysen Dam Standing Operating Procedure, "Wyoming Game and Fish recommends the preferred flow from October 1 – February 28 is 800 cfs and suggest flows greater than 1,100 cfs and below 600 cfs would be detrimental to the river fishery. To the extent possible, flow should not fall below 600 cfs or exceed 1,100 cfs" during this period.

7-10 HYDROELECTRIC POWER

Boysen power plant is a key component of the Boysen Project. All releases except during times of floods and maintenance are made through the power plant to maximize project output. See Section 2-03.f for detailed physical information regarding Boysen power plant.

7-11 NAVIGATION

Boysen Dam is not regulated for navigation.

7-12 DROUGHT CONTINGENCY PLANS

Regulation to assist in drought contingency planning will be conducted by Reclamation.

7-13 FLOOD EMERGENCY ACTION PLANS

Reclamation maintains an Emergency Action Plan that is distributed among state, county and local emergency officials. The Corps will maintain communications with the WYAO during flood control operations. If communications with the WYAO are lost, the Corps will communicate release decisions directly with the Boysen Dam Tender.

7-14 DEVIATION FROM NORMAL REGULATION

a. Emergencies

An emergency situation is defined as a circumstance where failure to act immediately could result in loss of life or significant property damage. Occasional non-flood emergencies can occur where deviation from the normal operating procedures would assist other interests in managing the emergency. Examples of these types of emergencies include dam safety emergencies, downstream chemical spills, drowning, and facility failures. The Emergency Action Plan for Boysen Dam was prepared by the WYAO. Copies of this plan are maintained at Reclamation offices and in the Omaha District's WCWQS. If the water control actions taken during an emergency are not covered in the Water Control Manual, the Omaha District must inform MRBWM as soon as practicable. Written confirmation of the deviation and a description of the cause must be furnished to MRBWM.

b. Unplanned Minor Deviations

In some instances, activities of other interests create the potential need for unplanned deviations from normal operations. These activities usually require temporary deviations, usually from a few hours to a few days. A typical example of activities that would create the potential for unplanned minor deviations would be modifications of bridge and utility crossings or maintenance and inspection of reservoir project facilities. Each request should be analyzed on its own merits to determine if it is covered by the Water Control Manual. If the proposed action is not covered by the Water Control Manual, a deviation will be required. An evaluation of the proposed action should be included in the deviation request, including consideration of upstream watershed conditions, potential flood threats, the amount of water in storage at Boysen Reservoir, and whether any alternative measures could be taken that would not require a deviation. Each deviation request will be evaluated to ensure that any potential adverse impacts to authorized project purposes are identified and considered prior to implementation. Approval for these minor deviations normally will be obtained from MRBWM by email. Post-deviation written documentation to MRBWM should contain an explanation of the deviation and its cause. In turn, a written response to the deviation request will be provided by MRBWM.

c. Planned Deviations

In accordance with NWDR 1110-2-6, the Chief, MRBWM at NWD is the responsible approving official for all deviation requests for Boysen Dam and Reservoir. All deviation requests involving controversial regional or nationally significant actions shall be coordinated with the Chief of MRBWM prior to approval. The Chief of MRBWM retains authority to approve or disapprove all deviation requests. Prior approval is required for deviations from this Water Control Manual that do not meet the requirements of Sections 7-15.a and 7-15.b. Pre-coordination of a potential deviation request should occur between the requesting office and the approving authority to ensure a deviation is necessary. Deviation requests should be submitted to the Chief, MRBWM as appropriate. MRBWM will coordinate with the appropriate district or districts for all division-originated deviation requests. All deviations shall be documented in order to respond to any public concerns raised by those deviations. Coordination with federal, state, tribal, local, and private interests should be undertaken as appropriate. At a minimum, deviation requests should discuss the need for coordination and present a plan for that coordination. Informal coordination prior to a deviation request may also be appropriate.

7-15 RATE OF RELEASE CHANGE

Downstream constituents should be notified if release changes of greater than 500 cfs per day are planned.

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CHAPTER 8—EFFECT OF WATER CONTROL PLAN

8-01 GENERAL

The following regulation objectives can be met at Boysen Dam and Reservoir by following the water control plan: a) provide desired river and reservoir regulation to maximize the power generation benefit at Boysen power plant; b) provide water for irrigation, municipal, and industrial use; c) provide desired river flow conditions to meet the needs of the downstream river fishery; d) provide desired conditions for fish, wildlife, and recreational use in the reservoir; and e) regulate river flow to mitigate downstream flood risk. Plates 8-1 through 8-8 show plots of elevation, inflow and outflow for the period of record.

8-02 FLOOD CONTROL

a. Probable Maximum Flood

The 1988 PMF as determined by Reclamation has a peak inflow of 864,967 cfs and a 15 day volume over 3,000,000 af. The event was a combination of rain on snow. The routing of the PMF assumes the pool begins at 4717.0 feet. 10,000 cfs is released until the pool enters the exclusive flood control pool where releases are increased as the pool rises to maintain 3 inches of freeboard on the spillway gates. Releases were held at 20,000 cfs until the pool exceeded 4752.0 feet, at which point the spillway gates were fully opened. It is expected Boysen's PMF would overtop the dam by 18 feet and cause dam failure. Plate 8-9 displays the PMF inflow hydrograph as produced by Reclamation.

b. Reservoir Design Flood

A design flood, in which the maximum observed snowmelt and rainfall floods were combined, has been computed for the Boysen drainage area. The inflow hydrograph has a crest of 44,000 cfs and a 47-day volume of 1,531,000 af (3.7 inches over the drainage area). The routing upon which the total flood control storage of the reservoir was based had a peak storage 1,024,000 af (currently 947,000 af due to sedimentation); peak elevation 4734.6 feet. However, the method of regulation assumed in this routing does not agree with that adopted in this manual. In this routing, it was assumed that initially, the joint-use pool was evacuated and downstream conditions were such that inflows would be released up to 15,000 cfs. Releases would be maintained at this level until the joint-use zone was filled after which releases would be the greater of 15,000 cfs or those indicated by the regulation curves on Plate 7-3, subject to a maximum release of 20,000 cfs. This resulted in a maximum release of 20,000 cfs and a crest pool of elevation 4734.0 feet, two feet above the top of the exclusive flood control zone. Plate 8-10 shows the latter flood routing.

c. Original Spillway Design Flood

Per the Boysen Standing Operating Procedure, "A memorandum dated December 19, 1946, included an inflow design flood with a peak discharge 160,000 cfs and a 15-day volume of 1,300,000 af. This flood would be a combination of rainstorm runoff and snowmelt. The rainstorm runoff was from a design storm of 3.2 inches of rain in a 12-

hour period. The design snowmelt flood was a 15-day volume of 801,000 af and a peak of 40,000 cfs. Plate 8-11 displays the original spillway design routing."

8-03 RECREATION

The Corps does not have specific recreation responsibilities at Boysen Dam and Reservoir. See Section 2-06 for more information about public facilities around the Boysen Reservoir.

8-04 WATER QUALITY

The Corps does not have specific water quality responsibilities at Boysen Dam and Reservoir. Reclamation will continue its water quality monitoring program for the reservoir.

8-05 FISH AND WILDLIFE

The Corps does not have any specific fish and wildlife responsibilities at Boysen Dam and Reservoir. Reclamation will continue to coordinate fish and wildlife interests with state, local and other interested parties.

8-06 WATER SUPPLY

See Section 7-06 for more information on water supply.

8-07 HYDROELECTRIC POWER

See Section 7-07 for hydropower details.

8-08 NAVIGATION

Boysen Dam is not regulated for navigation.

8-09 DROUGHT CONTINGENCY PLAN

See Section 7-09 for Drought Contingency details.

8-10 FLOOD EMERGENCY ACTION PLAN

See Section 7-10 for Emergency Action Plan details.

8-11 FREQUENCIES

An analysis of historic peak pool elevations at Boysen Dam is shown in Plate 8-12.

8-12 OTHER STUDIES

No studies affecting Boysen flood control regulation are currently underway.

As forecast methods are used, possible improvements will be studied. With increase in available data, changes will be made to make use of these data.

a. Examples of Regulation

Plates 4-2 through 4-8 show the regulation of several floods that occurred during Boysen's period of record. Exhibit VII provides an example of producing the May-July runoff forecast and setting the pool elevation of responsibility. These examples along with the regulation criteria specified in this manual will assist the water manager in making release decisions.

b. Channel and Floodway Improvement

Channel capacity has decreased in certain stretches of the Bighorn River. Flows approaching 20,000 cfs at Bighorn, MT and flows of 10,000 cfs near Thermopolis, WY will begin to cause damage.

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CHAPTER 9—WATER CONTROL MANAGEMENT

9-01 RESPONSIBILITIES AND ORGANIZATION

The organization for regulation of Boysen Dam and Reservoir is based on a division of regulating responsibilities between Reclamation and the Corps. In accordance with the Flood Control Act of 1944, the Corps is responsible for prescribing regulations for the use of storage allocated to flood control. All other regulatory functions are the responsibility of Reclamation.

a. Corps of Engineers

ER 1110-2-1400, September 1993, assigns the Corps' reservoir regulation responsibility in the Missouri River Basin to the NWD Engineer. The regulations permit delegation of certain reservoir regulation functions to the District Engineer in the project area. The responsibility for assembly and interpretation of data affecting current reservoir regulation and for carrying out flood control regulation of Boysen Dam and Reservoir, according to plans agreed on in advance, has been delegated to the Omaha District Engineer. The WCWQS of the Omaha District has been assigned this District responsibility. In addition, the NWD Engineer, through NWD's MRBWM, monitors and reviews the overall regulation procedures performed by the Omaha District. An organization chart for the Omaha District is shown on Plate 9-1

b. Bureau of Reclamation

Reclamation is the construction agency for Boysen Dam and Reservoir and is responsible for coordinating all matters pertaining to the operation and regulation of the project. Reclamation is solely responsible for regulation of the reservoir when the pool elevation is below 4717.0 feet (unless downstream flood targets are expected to be exceeded) or above 4732.0 feet. Between elevations 4717.0 feet and 4725.0 feet, the joint use storage zone, releases for flood control will be the responsibility of the Corps and releases for all other purposes will be the responsibility of Reclamation.

Reclamation's Resources Management Division, WYAO in Mills, WY is responsible for water regulation at Boysen Dam and Reservoir for all purposes except flood control. Within limits for the use of water and storage set by the Resources Management Division, power generation is scheduled by Western Area Power Administration in Montrose, CO. Operation and maintenance of the project are under the immediate supervision of the Boysen Facility Manager who resides at the project. The Facility Manager's duties for flood control operation are given in Exhibit III, Standing Instructions to Dam Tender. The Facility Manager will operate the outlet facilities and collect and report reservoir and hydrologic data. Exhibit III also lists Reclamation's Resources Management Division personnel. An organization chart for Reclamation is shown on Plate 9-2.

c. National Weather Service

The NWS works closely with the Corps and Reclamation in providing forecasts of reservoir inflows and flood warnings to the public. An organization chart for the NWS is shown on Plate 9-3.

9-02 INTERAGENCY COORDINATION

a. Local Press and Corps Bulletins

Reclamation is responsible for coordination with the press when Boysen is not in a flood control operation. When flood control operations are occurring, Reclamation will remain the leader in coordination and the Corps will assist as needed.

b. National Weather Service

The Corps and Reclamation each have working relationships with the National Weather Service and these existing lines of communication will be used during a flood event.

c. U.S. Geological Survey

The Corps and Reclamation each have working relationships with the U.S. Geological Survey and these existing lines of communication will be used during a flood event.

d. Power Marketing Agency

Reclamation routinely communicates with Western Area Power Administration. This existing line of communication will be used during a flood event.

e. Other Federal, State, or Local Agencies

Reclamation is responsible for coordination with other federal, state and local agencies when Boysen is not in a flood control operation. When flood control operations are occurring, Reclamation will remain the leader in coordination and the Corps will assist as needed.

9-03 INTERAGENCY AGREEMENTS

The Field Working Agreement between Reclamation and the Corps is located in Exhibit II.

9-04 COMMISIONS, RIVER AUTHORITIES, COMPACTS AND COMMITTEES

There are committees and interest groups who provide operation suggestions in the Bighorn Basin. The responses and studies required by these groups are generally the responsibility of Reclamation. Reclamation will involve the Corps if any impacts to flood risk reduction from Boysen Dam are possible.

9-05 NON-FEDERAL HYDROPOWER

There is minimal non-federal hydropower that affects the regulation of Boysen Dam.

9-06 REPORTS

The Omaha District WCWQS publishes an Annual Operating Report that describes operation and flood regulation for each project in the Omaha District. Reclamation's Resources Management Division of the WYAO also publishes an Annual Operations Report each year that describes the operation and flood regulation for Boysen.

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EXHIBIT I

33 CFR Chapter II Part 208, Flood Control Regulations, Section 208.11

This exhibit contains text and table from 33 CFR Chapter II, Part 208, Flood Control Regulations, Section 208.11, Regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to prescription of rules and regulations by the Secretary of the Army in the interest of flood control and navigation (7-1-12 Edition). In this document, the text of Section 208.11 has been reformatted (indented) for clarity, and the List of Projects table at the end of document has been shortened to only include reservoirs within the Missouri River basin. Section 208.11 should be reviewed on an annual basis to identify any changes and these changes should be included in an updated exhibit to this manual. Updated editions of Section 208.11 can be found at the following website: http://www.ecfr.gov.

Exhibit I

33 CFR Chapter II Part 208 Flood Control Regulations, Section 208.11 (7-1-12 Edition), Regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to prescription of rules and regulations by the Secretary of the Army in the interest of flood control and navigation.

(a) *Purpose.* This regulation prescribes the responsibilities and general procedures for regulating reservoir projects capable of regulation for flood control or navigation and the use of storage allocated for such purposes and provided on the basis of flood control and navigation, except projects owned and operated by the Corps of Engineers; the International Boundary and Water Commission, United States and Mexico; and those under the jurisdiction of the International Joint Commission, United States, and Canada, and the Columbia River Treaty. The intent of this regulation is to establish an understanding between project owners, operating agencies, and the Corps of Engineers.

(b) *Responsibilities.* The basic responsibilities of the Corps of Engineers regarding project operation are set out in the cited authority and described in the following paragraphs:

(1) Section 7 of the Flood Control Act of 1944 (58 Stat. 890, 33 U.S.C. 709) directs the Secretary of the Army to prescribe regulations for flood control and navigation in the following manner:

> Hereafter, it shall be the duty of the Secretary of War to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds provided on the basis of such purposes, and the operation of any such project shall be in accordance with such regulations: Provided, That this section shall not apply to the Tennessee Valley Authority, except that in case of danger from floods on the lower Ohio and Mississippi Rivers the Tennessee Valley Authority is directed to regulate the release of water from the Tennessee River into the Ohio River in accordance with such instructions as may be issued by the War Department

(2) Section 9 of Public Law 436–83d Congress (68 Stat. 303) provides for the development of the Coosa River, Alabama and Georgia, and directs the Secretary of the Army to prescribe rules and regulations for project operation in the interest of flood control and navigation as follows:

> The operation and maintenance of the dams shall be subject to reasonable rules and regulations of the Secretary of the Army in the interest of flood control and navigation. NOTE: This Regulation will also be applicable to dam and reservoir projects operated under provisions of future legislative acts wherein the Secretary of the Army is directed to prescribe rules and regulations in the interest of flood control and navigation. The Chief of Engineers, U.S. Army Corps of Engineers, is designated the duly authorized representative of the Secretary of the Army to exercise the authority set out in the Congressional Acts. This Regulation will normally be implemented by letters of understanding between the Corps of Engineers and project owner and will incorporate the provisions of such letters of understanding prior to the time construction renders the project capable of significant impoundment of water. A water control agreement signed by both parties will follow when deliberate impoundment first begins or at such time as the responsibilities of any Corps-owned projects may be transferred to another entity. Promulgation of this Regulation for a given project will occur at such time as the name of the project appears in the FEDERAL REGISTER in accordance with the requirements of paragraph 6k. When agreement on a water control plan cannot be reached between the Corps and the project owner after coordination with all interested parties, the project name will be entered in the FEDERAL REGISTER and the Corps of Engineers plan will be the official water control plan until such time as differences can be resolved.

(3) Federal Energy Regulatory Commission (FERC), formerly Federal Power Commission (FPC), Licenses.

(i) Responsibilities of the Secretary of the Army and/or the Chief of Engineers in FERC licensing actions are set forth in reference 3c above and pertinent sections are cited herein. The Commission may further stipulate as a licensing condition, that a licensee enter into an agreement with the Department of the Army providing for operation of the project during flood times, in accordance with rules and regulations prescribed by the Secretary of the Army.

(A) Section 4(e) of the Federal Power Act requires approval by the Chief of Engineers and the Secretary of the Army of plans of dams or other structures affecting the navigable capacity of any navigable waters of the United States, prior to issuance of a license by the Commission as follows:

> The Commission is hereby authorized and empowered to issue licenses to citizens * * * for the purpose of constructing, operating and maintaining dams, water conduits, reservoirs, powerhouses, transmission lines, or other project works necessary or convenient for the development and improvement of navigation and for the development, transmission, and utilization of power across, along, from or in any of the streams or other bodies of water over which Congress has jurisdiction * * * Provided further, That no license affecting the navigable capacity of any navigable waters of the United States shall be issued until the plans of the dam or other structures affecting navigation have been approved by the Chief of Engineers and the Secretary of the Army.

(B) Sections 10(a) and 10(c) of the Federal Power Act specify conditions of project licenses including the following:

(1) Section 10(a). ‘‘That the project adopted * * * shall be such as in the judgment of the Commission will be best adapted to a comprehensive plan for improving or developing a waterway or waterways for the use or benefit of interstate or foreign commerce, for the improvement and utilization of waterpower development, and for other beneficial public uses * * *.’’

(2) Section 10(c). ‘‘That the licensee shall * * * so maintain and operate said works as not to impair navigation, and shall conform to such rules and regulations as the Commission may from time to time prescribe for the protection of life, health, and property * * *.’’

(C) Section 18 of the Federal Power Act directs the operation of any navigation facilities built under the provision of that Act, be controlled by rules and regulations prescribed by the Secretary of the Army as follows:

> The operation of any navigation facilities which may be constructed as part of or in connection with any dam or diversion structure built under the provisions of this Act, whether at the expense of a licensee hereunder or of the United States, shall at all times be controlled by such reasonable rules and regulations in the interest of

> navigation; including the control of the pool caused by such dam or diversion structure as may be made from time to time by the Secretary of the Army, * * *.

(ii) Federal Power Commission Order No. 540 issued October 31, 1975, and published November 7, 1975 (40 FR 51998), amending § 2.9 of the Commission's General Policy and Interpretations prescribed Standardized Conditions (Forms) for Inclusion in Preliminary Permits and Licenses Issued Under part I of the Federal Power Act. As an example, Article 12 of Standard Form L–3, titled: ''Terms and Conditions of License for Constructed Major Projects Affecting Navigable Waters of the United States,'' sets forth the Commission's interpretation of appropriate sections of the Act, which deal with navigation aspects, and attendant responsibilities of the Secretary of the Army in licensing actions as follows:

> The United States specifically retains and safeguards the right to use water in such amount, to be determined by the Secretary of the Army, as may be necessary for the purposes of navigation on the navigable waterway affected; and the operations of the Licensee, so far as they affect the use, storage and discharge from storage of waters affected by the license, shall at all times be controlled by such reasonable rules and regulations as the Secretary of the Army may prescribe in the interest of navigation, and as the Commission may prescribe for the protection of life, health, and property, * * * and the Licensee shall release water from the project reservoir at such rate * * * as the Secretary of the Army may prescribe in the interest of navigation, or as the Commission may prescribe for the other purposes hereinbefore mentioned.

(c) *Scope and terminology.* This regulation applies to Federal authorized flood control and/or navigation storage projects, and to non-Federal projects which require the Secretary of the Army to prescribe regulations as a condition of the license, permit or legislation, during the planning, design and construction phases, and throughout the life of the project. In compliance with the authority cited above, this regulation defines certain activities and responsibilities concerning water control management throughout the Nation in the interest of flood control and navigation. In carrying out the conditions of this regulation, the owner and/or operating agency will comply with applicable provisions of Pub. L. 85–624, the Fish and Wildlife Coordination Act of 1958, and Pub. L. 92–500, the Federal Water Pollution Control Act Amendments of 1972. This regulation does not apply to local flood protection works governed by § 208.10, or to navigation facilities and associated structures which are otherwise covered by part 207 (Navigation Regulations) of title 33 of the code. Small reservoirs, containing less than 12,500 acre-feet of flood control or navigation storage, may be excluded from this regulation and covered under § 208.10, unless specifically required by law or conditions of the license or permit.

(1) The terms *reservoir* and *project* as used herein include all water resource impoundment projects constructed or modified, including natural lakes, that are subject to this regulation.

(2) The term *project owner* refers to the entity responsible for maintenance, physical operation, and safety of the project, and for carrying out the water control plan in the interest of flood control and/or navigation as prescribed by the Corps of Engineers. Special arrangements may be made by the project owner for ''operating agencies'' to perform these tasks.

(3) The term *letter of understanding* as used herein includes statements which consummate this regulation for any given project and define the general provisions or conditions of the local sponsor, or owner, cooperation agreed to in the authorizing legislative document, and the requirements for

compliance with section 7 of the 1944 Flood Control Act, the Federal Power Act or other special congressional act. This information will be specified in the water control plan and manual. The letter of understanding will be signed by a duly authorized representative of the Chief of Engineers and the project owner. A ‘‘field working agreement’’ may be substituted for a letter of understanding, provided that the specified minimum requirements of the latter, as stated above, are met.

(4) The term *water control agreement* refers to a compilation of water control criteria, guidelines, diagrams, release schedules, rule curves and specifications that basically govern the use of reservoir storage space allocated for flood control or navigation and/or release functions of a water control project for these purposes. In general, they indicate controlling or limiting rates of discharge and storage space required for flood control and/or navigation, based on the runoff potential during various seasons of the year.

(5) For the purpose of this regulation, the term *water control plan* is limited to the plan of regulation for a water resources project in the interest of flood control and/or navigation. The water control plan must conform with proposed allocations of storage capacity and downstream conditions or other requirements to meet all functional objectives of the particular project, acting separately or in combination with other projects in a system.

(6) The term *real-time* denotes the processing of current information or data in a sufficiently timely manner to influence a physical response in the system being monitored and controlled. As used herein the term connotes * * * the analyses for and execution of water control decisions for both minor and major flood events and for navigation, based on prevailing hydrometeorological and other conditions and constraints, to achieve efficient management of water resource systems.

(d) *Procedures*—

(1) *Conditions during project formulation.* During the planning and design phases, the project owner should consult with the Corps of Engineers regarding the quantity and value of space to reserve in the reservoir for flood control and/or navigation purposes, and for utilization of the space, and other requirements of the license, permit or conditions of the law. Relevant matters that bear upon flood control and navigation accomplishment include: Runoff potential, reservoir discharge capability, downstream channel characteristics, hydrometeorological data collection, flood hazard, flood damage characteristics, real estate acquisition for flowage requirements (fee and easement), and resources required to carry out the water control plan. Advice may also be sought on determination of and regulation for the probable maximum or other design flood under consideration by the project owner to establish the quantity of surcharge storage space, and freeboard elevation of top of dam or embankment for safety of the project.

(2) *Corps of Engineers involvement.* If the project owner is responsible for real-time implementation of the water control plan, consultation and assistance will be provided by the Corps of Engineers when appropriate and to the extent possible. During any emergency that affects flood control and/or navigation, the Corps of Engineers may temporarily prescribe regulation of flood control or navigation storage space on a day-to-day (real-time) basis without request of the project owner. Appropriate consideration will be given for other authorized project functions. Upon refusal of the project owner to comply with regulations prescribed by the Corps of Engineers, a letter will be sent to the project owner by the Chief of Engineers or his duly authorized representative describing the

reason for the regulations prescribed, events that have transpired, and notification that the project owner is in violation of the Code of Federal Regulations. Should an impasse arise, in that the project owner or the designated operating entity persists in noncompliance with regulations prescribed by the Corps of Engineers, measures may be taken to assure compliance.

(3) *Corps of Engineers implementation of real-time water control decisions.* The Corps of Engineers may prescribe the continuing regulation of flood control storage space for any project subject to this regulation on a day-to-day (real-time) basis. When this is the case, consultation and assistance from the project owner to the extent possible will be expected. Special requests by the project owner, or appropriate operating entity, are preferred before the Corps of Engineers offers advice on real-time regulation during surcharge storage utilization.

(4) *Water control plan and manual.* Prior to project completion, water control managers from the Corps of Engineers will visit the project and the area served by the project to become familiar with the water control facilities, and to insure sound formulation of the water control plan. The formal plan of regulation for flood control and/or navigation, referred to herein as the water control plan, will be developed and documented in a water control manual prepared by the Corps of Engineers. Development of the manual will be coordinated with the project owner to obtain the necessary pertinent information, and to insure compatibility with other project purposes and with surcharge regulation. Major topics in the manual will include: Authorization and description of the project, hydrometeorology, data collection and communication networks, hydrologic forecasting, the water control plan, and water resource management functions, including responsibilities and coordination for water control decision-making. Special instructions to the dam tender or reservoir manager on data collection, reporting to higher Federal authority, and on procedures to be followed in the event of a communication outage under emergency conditions, will be prepared as an exhibit in the manual. Other exhibits will include copies of this regulation, letters of understanding consummating this regulation, and the water control agreements. After approval by the Chief of Engineers or his duly authorized representative, the manual will be furnished the project owner.

(5) *Water control agreement.*

(i) A water control diagram (graphical) will be prepared by the Corps of Engineers for each project having variable space reservation for flood control and/or navigation during the year; e.g., variable seasonal storage, joint-use space, or other rule curve designation. Reservoir inflow parameters will be included on the diagrams when appropriate. Concise notes will be included on the diagrams prescribing the use of storage space in terms of release schedules, runoff, nondamaging or other controlling flow rates downstream of the damsite, and other major factors as appropriate. A water control release schedule will be prepared in tabular form for projects that do not have variable space reservation for flood control and/or navigation. The water control diagram or release schedule will be signed by a duly authorized representative of the Chief of Engineers, the project owner, and the designated operating agency, and will be used as the basis for carrying out this regulation. Each diagram or schedule will contain a reference to this regulation.

(ii) When deemed necessary by the Corps of Engineers, information given on the water control diagram or release schedule will be supplemented by appropriate text to assure mutual understanding on certain details or other important aspects of the water control plan not covered in this regulation, on the water control diagram or in the release schedule. This material will include clarification of any aspects that might otherwise result in unsatisfactory project performance in the interest of flood control and/or navigation. Supplementation of the agreement will be necessary for each project where the Corps of Engineers exercises the discretionary authority to prescribe the flood control regulation on a day-today (real-time) basis. The agreement will include delegation of the responsibility. The document should also cite, as appropriate, section 7 of the 1944 Flood Control Act, the Federal Power Act and/or other congressional legislation authorizing construction and/or directing operation of the project.

(iii) All flood control regulations published in the FEDERAL REGISTER under this section (part 208) of the code prior to the date of this publication which are listed in § 208.11(e) are hereby superseded.

(iv) Nothing in this regulation prohibits the promulgation of specific regulations for a project in compliance with the authorizing acts, when agreement on acceptable regulations cannot be reached between the Corps of Engineers and the owner.

(6) *Hydrometeorological instrumentation.* The project owner will provide instrumentation in the vicinity of the damsite and will provide communication equipment necessary to record and transmit hydrometeorological and reservoir data to all appropriate Federal authorities on a real-time basis unless there are extenuating circumstances or are otherwise provided for as a condition of the license or permit. For those projects where the owner retains responsibility for real-time implementation of the water control plan, the owner will also provide or arrange for the measurement and reporting of hydrometeorological parameters required within and adjacent to the watershed and downstream of the damsite, sufficient to regulate the project for flood control and/or navigation in an efficient manner. When data collection stations outside the immediate vicinity of the damsite are required, and funds for installation, observation, and maintenance are not available from other sources, the Corps of Engineers may agree to share the costs for such stations with the project owner. Availability of funds and urgency of data needs are factors which will be considered in reaching decisions on cost sharing.

(7) *Project safety.* The project owner is responsible for the safety of the dam and appurtenant facilities and for regulation of the project during surcharge storage utilization. Emphasis upon the safety of the dam is especially important in the event surcharge storage is utilized, which results when the total storage space reserved for flood control is exceeded. Any assistance provided by the Corps of Engineers concerning surcharge regulation is to be utilized at the discretion of the project owner, and does not relieve the owner of the responsibility for safety of the project.

(8) *Notification of the general public.* The Corps of Engineers and other interested Federal and State agencies, and the project owner will jointly sponsor public involvement activities, as appropriate, to fully apprise the general public of the water control plan. Public meetings or other effective means of notification and involvement will be held, with the initial meeting being conducted as early as practicable but not later than the time the project first becomes operational. Notice of the initial public meeting shall be published once a week for 3 consecutive weeks in one or more newspapers of general circulation published in each county covered by the water control plan. Such notice shall also be used when appropriate to inform the public of modifications in the water control plan. If no

newspaper is published in a county, the notice shall be published in one or more newspapers of general circulation within that county. For the purposes of this section a newspaper is one qualified to publish public notices under applicable State law. Notice shall be given in the event significant problems are anticipated or experienced that will prevent carrying out the approved water control plan or in the event that an extreme water condition is expected that could produce severe damage to property or loss of life. The means for conveying this information shall be commensurate with the urgency of the situation. The water control manual will be made available for examination by the general public upon request at the appropriate office of the Corps of Engineers, project owner or designated operating agency.

(9) *Other generalized requirements for flood control and navigation.*

(i) Storage space in the reservoirs allocated for flood control and navigation purposes shall be kept available for those purposes in accordance with the water control agreement, and the plan of regulation in the water control manual.

(ii) Any water impounded in the flood control space defined by the water control agreement shall be evacuated as rapidly as can be safely accomplished without causing downstream flows to exceed the controlling rates; i.e., releases from reservoirs shall be restricted insofar as practicable to quantities which, in conjunction with uncontrolled runoff downstream of the dam, will not cause water levels to exceed the controlling stages currently in force. Although conflicts may arise with other purposes, such as hydropower, the plan or regulation may require releases to be completely curtailed in the interest of flood control or safety of the project.

(iii) Nothing in the plan of regulation for flood control shall be construed to require or allow dangerously rapid changes in magnitudes of releases. Releases will be made in a manner consistent with requirements for protecting the dam and reservoir from major damage during passage of the maximum design flood for the project.

(iv) The project owner shall monitor current reservoir and hydro- meteorological conditions in and adjacent to the watershed and downstream of the damsite, as necessary. This and any other pertinent information shall be reported to the Corps of Engineers on a timely basis, in accordance with standing instructions to the damtender or other means requested by the Corps of Engineers.

(v) In all cases where the project owner retains responsibility for real-time implementation of the water control plan, he shall make current determinations of: Reservoir inflow, flood control storage utilized, and scheduled releases. He shall also determine storage space and releases required to comply with the water control plan prescribed by the Corps of Engineers. The owner shall report this information on a timely basis as requested by the Corps of Engineers.

(vi) The water control plan is subject to temporary modification by the Corps of Engineers if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communication available. The action taken shall be confirmed in writing the same day to the project owner and shall include justification for the action.

(vii) The project owner may temporarily deviate from the water control plan in the event an immediate short-term departure is deemed necessary for emergency reasons to protect the safety of the dam, or to avoid other serious hazards. Such actions shall be immediately reported by the fastest means of communication available. Actions shall be confirmed in writing the same day to the Corps of Engineers and shall include justification for the action. Continuation of the deviation will require the express approval of the Chief of Engineers, or his duly authorized representative.

(viii) Advance approval of the Chief of Engineers, or his duly authorized representative, is required prior to any deviation from the plan of regulation prescribed or approved by the Corps of Engineers in the interest of flood control and/or navigation, except in emergency situations provided for in paragraph (d)(9)(vii) of this section. When conditions appear to warrant a prolonged deviation from the approved plan, the project owner and the Corps of Engineers will jointly investigate and evaluate the proposed deviation to insure that the overall integrity of the plan would not be unduly compromised. Approval of prolonged deviations will not be granted unless such investigations and evaluations have been conducted to the extent deemed necessary by the Chief of Engineers, or his designated representatives, to fully substantiate the deviation.

(10) *Revisions.* The water control plan and all associated documents will be revised by the Corps of Engineers as necessary, to reflect changed conditions that come to bear upon flood control and navigation, e.g., reallocation of reservoir storage space due to sedimentation or transfer of storage space to a neighboring project. Revision of the water control plan, water control agreement, water control diagram, or release schedule requires approval of the Chief of Engineers or his duly authorized representative. Each such revision shall be effective upon the date specified in the approval. The original (signed document) water control agreement shall be kept on file in the respective Office the Division Engineer, Corps of Engineers, Department of the Army, located at division offices throughout the continental USA. Copies of these agreements may be obtained from the office of the project owner, or from the office of the appropriate Division Engineer, Corps of Engineers.

(11) *Federal Register.* The following information for each project subject to section 7 of the 1944 Flood Control Act and other applicable congressional acts shall be published in the FEDERAL REGISTER prior to the time the projects becomes operational and prior to any significant impoundment before project completion or * * * at such time as the responsibility for physical operation and maintenance of the Corps of Engineers owned projects is transferred to another entity:

(i) Reservoir, dam, and lake names,

(ii) Stream, county, and State corresponding to the damsite location,

(iii) The maximum current storage space in acre-feet to be reserved exclusively for flood control and/or navigation purposes, or any multiple-use space (intermingled) when flood control or navigation is one of the purposes, with corresponding elevations in feet above mean sea level, and area in acres, at the upper and lower limits of said space,

(iv) The name of the project owner, and (v) Congressional legislation authorizing the project for Federal participation.

(e) *List of projects.* The following tables, ‘‘Pertinent Project Data—Section 208.11 Regulation,’’ show the pertinent data for projects which are subject to this regulation. Note that the following tables show only those projects within the Missouri River basin, which includes the Omaha District and Kansas City District of the Northwestern Division, Corps of Engineers.

LIST OF PROJECTS
[Missouri River Basin Non-Corps projects with Corps Regulation Requirements]

Project name[1] (1)	State (2)	County (3)	Stream[1] (4)	Project purpose[2] (5)	Storage 1000 AF (6)	Elev limits feet M.S.L. Upper (7)	Elev limits feet M.S.L. Lower (8)	Area in acres Upper (9)	Area in acres Lower (10)	Authorizing legis.[3] (11)	Proj. owner[4] (12)
Omaha District Projects											
Boysen Dam & Res	WY	Fremont	Wild R	F FEIQ EIQ	150.4 146.1 403.8	4732.2 4725.0 4717.0	4725.0 4717.0 4685.0	22170 19560 16960	19560 16960 9280	PL 78–534	USBR.
Canyon Ferry Dam & Lk	MT	Lewis Clark	Missouri R	F FEI EI	99.5 795.1 711.5	3800.0 3797.0 3770.0	3797.0 3770.0 3728.0	33535 32800 24125	32800 24125 11480	PL 78–534	USBR.
Clark Canyon Dam & Res	MT	Beaverhead	Beaverhead R	F FI I	79.1 50.4 126.1	5560.4 5546.1 5535.7	5546.1 5535.7 5470.6	5900 5160 4495	5160 4495 220	PL 78–534	USBR.
Glendo Dam & Res	WY	Platte	N Platte R	F EIM	271.9 454.3	4653.0 4635.0	4635.0 4570.0	17990 12370	12370 3130	PL 78–534	USBR.
Heart Butte Dm & Lk Tschida	ND	Grant	Heart R	F IQ	147.9 69.0	2094.5 2064.5	2064.5 2030.0	6580 3400	3400 810	PL 78–534	USBR.
Jamestown Dam & Res	ND	Stutsman	James R	F IQ	185.4 28.1	1454.0 1429.8	1429.8 1400.0	13210 2090	2090 160	PL 78–534	USBR.
Keyhole Dam & Res	WY	Crook	Belle Fourche R	F IQ	140.5 185.8	4111.5 4099.3	4099.3 4051.0	13730 9410	9410 820	PL 78–534	USBR.
Pactola Dam & Res	SD	Pennington	Rapid Cr	F IM	43.1 55.0	4621.5 4580.2	4580.2 4456.1	1230 860	860 100	PL 78–534	USBR.
Shadehill Dam & Res	SD	Perkins	Grand R	F IQ	218.3 80.9	2302.0 2271.9	2271.9 2250.8	9900 4800	4800 2800	PL 78–534	USBR.
Tiber Dam & Res	MT	Libert Toole	Marias R	F FIQ IQ	400.9 268.0 121.7	3012.5 2993.0 2976.0	2993.0 2976.0 2966.4	23150 17890 13790	17890 13790 11710	PL 78–534	USBR.
Yellowtail Dam & Bighorn Lk	MT	Big Horn	Bighorn R	F FEIQ EIQ	258.3 240.3 336.1	3657.0 3640.0 3614.0	3640.0 3614.0 3547.0	17280 12600 6915	12600 6915 4150	PL 78–534	USBR PUD
Kansas City District Projects											
Bonny Dam & Res	CO	Yuma	S Fork Republic R	F ICR	128.2 39.2	3710.0 3672.0	3672.0 3638.0	5036 2042	2042 331	PL 78–534 PL 79–732	USBR.
Cedar Bluff Dam & Res	KS	Trego	Smoky Hill R	F IMCR	191.9 149.8	2166.0 2144.0	2144.0 2107.8	10790 6869	6869 2086	PL 78–534	USBR.
Enders Dam & Res	NE	Chase	Frenchman Cr	F ICR	30.0 34.5	3127.0 3112.3	3112.3 3082.4	2405 1707	1707 658	PL 78–534 PL 84–505	USBR.
Glen Elder Dam & Waconda Lk	KS	Mitchel	Solomon R	F IM	722.3 204.8	1488.3 1455.6	1455.6 1428.0	33682 12602	12602 3341	PL 78–534 PL 79–526	USBR.
Kirwin Dam & Res	KS	Phillips	N Fork Solomon R	F ICR	215.1 89.6	1757.3 1729.2	1729.3 1697.0	10640 5080	5080 1010	PL 78–534 PL 79–732; PL 79–526	USBR.
Lovewell Dam & Res	KS	Jewell	White Rock Cr	F ICR	50.5 24.9	1595.3 1582.6	1582.6 1571.7	5025 2986	2986 1704	PL 78–534 PL 79–732	USBR.
Medicine Cr Dam Harry Strunk Lk	NE	Frontier	Medicine Cr	F ICR	52.7 26.8	2386.2 2366.1	2366.1 2343.0	3483 1840	1840 701	PL 78–534 PL 84–505	USBR.
Norton Dam & Kieth Sebelius Lk	KS	Norton	Prairie Dog Cr	F IMRC	98.8 30.7	2331.4 2304.3	2304.3 2280.4	5316 2181	2181 587	PL 78–534 PL 79–526 PL 79–732	USBR.
Red Willow Dam Hugh Butler Lk	NE	Frontier	Red Willow Cr	F IRC	48.9 27.3	2604.9 2581.8	2581.8 2558.0	2682 1629	1629 787	PL 78–534 PL 85–783 PL 84–505	USBR.
Trenton Dam & Res	NB	Hitchcock	Republican R	F IRC	134.1 99.8	2773.0 2752.0	2752.0 2720.0	7940 4922	4922 1572	PL 78–534 PL 84–505	USBR.
Webster Dam & Res	KS	Rocks	S Fork Solomon R	F IRC	183.4 72.1	1923.7 1892.5	1892.5 1860.0	8480 3772	3772 906	PL 78–534 PL 79–526 PL 79–732	USBR

[1]Cr—Creek; CS—Control Structure; Div—Diversion; DS—Drainage Structure; FG—Floodgate; Fk—Fork; GIWW—Gulf Intercoastal Waterway; Lk—Lake; L&D—Lock & Dam; PS—Pump Station; R—River; Res—Reservoir

[2]F—Flood Control; N—Navigation; P—Corps Hydropower; E—Non Corps Hydropower; I—Irrigation; M—Municipal and/or Industrial Water Supply; C—Fish and Wildlife Conservation; A—Low Flow Augmentation or Pollution Abatement; R—Recreation; Q—Water Quality or Silt Control

[3]FCA—Flood Control Act; FERC—Federal Energy Regulatory Comm; HD—House Document; PL—Public Law; PW—Public Works; RHA—River & Harbor Act; SD—Senate Document; WSA—Water Supply Act

[4]Appl Pwr—Appalachian Power; Chln PUD—Chelan Cnty PUD 1; CLPC—CT Light & Power Co; Dgls PUD—Douglas Cnty PUD 1; DWR—Department of Water Resources; EB-MUD—East Bay Municipal Utility Dist; GRD—Grand River Dam Auth; Grnt PUD—Grant Cnty PUD 2; Hnbl—city of Hannibal; M&T Irr—Modesto & Turlock Irr; Mrcd Irr—Merced Irr; NEPC—New England Power Co; Pgnt P&L—Pugent Sound Power & Light; Ptmc Comm—Upper Potomac R Comm; Rclm B—Reclamation Board; Rkfd—city of Rockford; Sttl—city of Seattle; Tac—City of Tacoma; Vale USBR—50% Vale Irr 50% USBR; WF&CWID—City of Wichita Falls and Wichita Cnty Water Improvement District No. 2; WMEC—Western MA Electric Co; YCWA—Yuba City Water Auth; Yolo FC&W—Yolo Flood Control & Water Conserv Dist

(Sec. 7, Pub. L. 78–534, 58 Stat. 890 (33 U.S.C. 709); the Federal Power Act, 41 Stat. 1063 (16 U.S.C. 791(A)); and sec. 9, Pub. L. 83–436, 68 Stat. 303)

[43 FR 47184, Oct. 13, 1978, as amended at 46 FR 58075, Nov. 30, 1981; 55 FR 21508, May 24, 1990]

EXHIBIT II

FIELD WORKING AGREEMENT

BOYSEN DAM AND RESERVOIR

MEMORANDUM OF AGREEMENT
BETWEEN
U.S. ARMY CORPS OF ENGINEERS, OMAHA DISTRICT
AND
U.S. BUREAU OF RECLAMATION, MISSOURI BASIN AND ARKANSAS-RIO GRANDE-TEXAS GULF REGIONS

SUBJECT: Memorandum of Field Working Agreement for Boysen Dam and Reservoir

1. Flood Control Regulations governing the operating of Boysen Dam and Reservoir, Wind River, Wyoming, having been completed and published in the Federal Register at page 5834, Volume 32, issue of 12 April 1967, it is agreed that the dam and reservoir will be operated under the following rules, unless and until such rules shall be amended by mutual agreement:

a. Storage Capacity Allocations. The storage capacity allocations of Boysen Reservoir, exclusive of surcharge storage capacity above elevation 4732.0 feet, which is provided in combination with spillway capacity to ensure safety of the structure, are defined in the following subparagraphs:

(1) Exclusive Flood Control Storage. Exclusive flood control storage capacity allocation shall include the storage capacity between elevation 4725.0 feet and elevation 4732.0 feet, for which there have been constructed suitable outlet works to provide discharges as expressly indicated herein.

(2) Joint Use Storage. Joint use storage capacity allocation shall include the storage capacity between elevation 4717.0 feet and elevation 4725.0 feet. Joint use storage capacity shall normally be available as conservation storage, but will be vacated for seasonal flood control between February 1 and July 31 as provided hereinafter.

(3) Conservation Storage. Conservation storage capacity allocation shall include the storage capacity between elevation 4685.0 feet and elevation 4717.0 feet.

(4) Inactive Storage. Inactive storage capacity allocation shall include the storage capacity between elevation 4657.0 feet and elevation 4685.0 feet, which serves the purpose of maintaining head for the production of power.

(5) Dead Storage. Dead storage capacity allocation shall include the storage capacity between streambed elevation and elevation 4657.0 feet. This capacity is established by the elevation of the sill of the outlet works.

b. Storage Reallocations. Allocation of storage in sub-section a above will be reduced by the sediment deposition. The Regional Director shall at reasonable intervals make necessary field surveys and office studies to prepare estimates of the volume and location of sediment deposits in the reservoir. If the results of these studies show that the total storage available for exclusive and joint use flood control and conservation (including joint use), respectively, (initially amounting to 300,000 acre-feet for flood control and 560,000 acre-feet for conservation), is reduced by an amount exceeding 10 percent of the allocation for either purpose, the operating plan described herein with respect to the elevation limits of the storage allocations shall be reviewed with the view of equitably distributing for the loss of reservoir capacity between the primary reservoir uses. Any redistribution of storage capacity allocations is to be contingent on sub-section h.

c. Plan of Operation. The Regional Director shall operate the Boysen Dam and Reservoir in the interest of flood control in accordance with the Flood Control Regulations.

(1) Joint Use Operation. Responsibility for operation of storage in the joint use space between elevations 4717.0 feet and 4725.0 feet shall be established by the pool elevation of responsibility. Filling of the joint use zone in Boysen Reservoir prior to the end of the flood season is a prime requisite for regulation of the reservoir. The joint use zone is evacuated each year to a level that balances flood control and conservation. Monthly seasonal forecasts as described in Appendix VII define the pool elevation of responsibility. Reclamation is required to maintain flood control capacity by keeping the pool elevation at or below the pool elevation of responsibility. If pool elevation of responsibility is exceeded before the end of the runoff season the Corps will notify Reclamation, and Reclamation will increase releases to non-damaging levels and return the pool to the pool elevation of responsibility. Table 4 in Exhibit VII is an aid in establishing and maintaining the pool elevation of responsibility. During these periods whenever the reservoir is above the elevations so defined, operation of the reservoir shall be construed as a flood control operation, and releases shall be determined by the District Engineer, except for minimum releases needed for power, irrigation, and other downstream conservation requirements. Whenever the reservoir is below the elevation of responsibility and stages at downstream flood points are below target levels, releases will be determined by the Regional Director. The Regional Director and the District Engineer may, by mutual agreement, as changing circumstances or experience gained in the operation of the reservoir warrant, recommend change in the plan of operation set forth herein for consideration and approval by higher echelons of their respective organizations.

(2) Flood Targets. Regulation of storage of Boysen Reservoir will be made to prevent exceeding the values below, insofar as possible. Effectiveness of operation may be restricted by the limited volume of storage space available below the top of the spillway gates.

Bighorn River at Kane, WY	15,000 cfs
Bighorn River at Bighorn, WY	25,000 cfs
Yellowstone River at Miles City, MT	70,000 cfs

Similar to the regulation described for local flood control, the regulation curves on Plate 7-3 will designate the release level to be maintained when the pool is in the exclusive flood control zone. However, such releases will be limited when physically feasible so as not to contribute to flows above those listed below.

Bighorn River at Kane, WY	20,000 cfs
Bighorn River at Bighorn, WY	30,000 cfs
Yellowstone River at Miles City, MT	70,000 cfs

The above flood targets may be exceeded if large Boysen inflows are forecasted to force damaging releases later in the snowmelt runoff season. Conditions during any particular flood event may require some modification from the above schedule.

d. Integrated Regulation of All Flood Control Reservoirs in Missouri River Basin. Releases from Boysen Dam eventually flow into Garrison Reservoir of the Missouri River Mainstem Reservoirs. In the quotes below, the USACE Northwestern Division's Missouri River Basin Water Management is abbreviated MRBWM. As per the Missouri River Mainstem Reservoir System Master Water Control Manual (Master Manual), November, 2018, paragraph 7-04.25, "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." Additionally, as per Section 208.11 of 33 CFR Chapter II, "The water control plan is subject to temporary modification by the Corps of Engineers if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communication available. The action taken shall be confirmed in writing the same day to the project owner and shall include justification for the action." As a result of these requirements, during large floods affecting the Missouri River Mainstem Reservoirs, releases of flood storage in Boysen Reservoir may be adjusted in order to meet basin-wide flood control goals of the Missouri River System. In the case of Boysen Reservoir, requests for modification will be made to the Wyoming Area Office Resources Management Division, Bureau of Reclamation in Mills, WY, which is part of the Missouri Basin and Arkansas-Rio Grande-

Texas Gulf Regions. Requests should be made via telephone call or email, and confirmed via an official reservoir regulation order the same day.

e. During periods of ice cover. In reaches downstream from the dam, releases from the reservoir shall be held to a minimum consistent with other uses unless otherwise requested by the District Engineer in the interest of flood control. The District Engineer shall be notified at least 24 hours in advance of releases at any time in excess of 10,000 cfs, except when necessary to protect the dam and reservoir from major damage. When the reservoir level is above the exclusive flood control pool or below the joint use pool with no flood targets exceeded, the District Engineer may make recommendations to the Regional Director for operation in the interest of flood control, but such recommendations shall not be considered mandatory.

f. Instructions issued by the District Engineer. Flood control operations shall be issued to the Regional Director. The operating personnel at the dam shall act upon the order of the District Engineer after receipt of the order by the Regional Director. In the absence of communication between the operating personnel and the Regional Director, the District Engineer will issue flood control operations directly to the operating personnel.

g. Collection and assembly of Hydrologic Data and Reporting Arrangements. Available reports from precipitation and streamflow stations pertinent to the flood control operation of the Boysen Reservoir which are collected by either the Regional Director or District Engineer will be relayed to the other by the most expeditious means of communication, under such detailed arrangements as may be made from time to time.

h. Design Limitations. It is recognized that any changes in the discharge characteristics if the spillway structures resulting from reallocation of storage capacities, or for any other reason, which otherwise are mutually acceptable to the Corps of Engineers and the Bureau of Reclamation, must be approved by the Chief Engineer of the Bureau of Reclamation.

[redacted]

Colonel, Corps of Engineers
District Commander

16 OCT 2020
(Date)

[redacted]

Regional Director
Missouri Basin and Arkansas-Rio Grande-
Texas Gulf Regions

2021 July 13
(Date)

EXHIBIT III

STANDING INSTRUCTIONS TO DAM TENDER FOR FLOOD CONTROL OPERATIONS

BOYSEN DAM AND RESERVOIR

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

EXHIBIT IV

AREA-CAPACITY TABLES IN ONE-FOOT INCREMENTS

BOYSEN DAM AND RESERVOIR

Boysen Reservoir Capacity in Acre-Feet (2001 Survey)

Elevation, feet	Elevation Increment (in feet)								
	0	1	2	3	4	5	6	7	8	9
4620			0	1	3	6	14	30	54	85
4630	125	179	253	347	461	596	765	984	1252	1570
4640	1938	2418	3074	3907	4915	6101	7521	9235	11240	13550
4650	16140	18980	22020	25240	28660	32270	36080	40080	44290	48690
4660	53290	58080	63030	68150	73440	78900	84510	90260	96150	102200
4670	108300	114600	121100	127700	134400	141200	148200	155400	162800	170300
4680	178000	185800	193900	202100	210600	219200	228000	236900	246000	255200
4690	264700	274200	284000	293900	304000	314300	324700	335300	346100	357100
4700	368300	379600	391200	403000	415000	427300	439800	452600	465600	479000
4710	492700	506700	521000	535600	550500	565700	581300	597400	613900	630900
4720	648400	666200	684500	703200	722200	741600	761400	781500	802100	823000
4730	844200	865800	887800	910100	932700	955700	979000	1003000	1027000	1052000
4740	1077000	1103000	1129000	1155000	1182000	1209000	1237000	1265000	1293000	1323000
4750	1352000	1382000								

Boysen Reservoir Area in Acres (2001 Survey)

Elevation, feet	Elevation Increment (in feet)									
	0	1	2	3	4	5	6	7	8	9
4620						0	128	257	385	513
4630	641	770	898	1026	1155	1283	1411	1539	1668	1796
4640	1924	2053	2181	2309	2437	2566	2694	2822	2950	3079
4650	3207	3335	3464	3592	3720	3848	3977	4105	4269	4434
4660	4598	4763	4927	5092	5256	5420	5585	5749	5914	6078
4670	6243	6407	6571	6736	6900	7065	7229	7394	7558	7722
4680	7887	8051	8216	8380	8545	8709	8946	9184	9421	9658
4690	9896	10133	10370	10608	10845	11082	11319	11557	11794	12031
4700	12269	12506	12743	12981	13218	13455	13693	13930	14167	14405
4710	14642	14879	15116	15354	15591	15828	16066	16303	16703	17103
4720	17503	17903	18302	18702	19102	19502	19875	20249	20622	20995
4730	21369	21742	22115	22540	22978	23415	23853	24291	24728	25166
4740	25604	26042	26479	26917	27355	27792	28230	28668	29105	29543
4750	29981	30418	30856							

EXHIBIT V

AREA-CAPACITY TABLES IN 0.1 FOOT INCREMENTS

BOYSEN DAM AND RESERVOIR

BOYSEN RESERVOIR CAPACITY TABLE

Station ID: BOYR
Station description: BOYSEN RESERVOIR, THERMOPOLIS, WYOMING

Date: 30-AUG-2001

	.00	.10	.20	.30	.40	.50	.60	.70	.80	.90
4622.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
4623.00	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0
4624.00	3.0	3.0	3.0	4.0	4.0	4.0	5.0	5.0	5.0	6.0
4625.00	6.0	6.0	7.0	8.0	8.0	9.0	10.0	11.0	12.0	13.0
4626.00	14.0	15.0	17.0	18.0	19.0	21.0	23.0	24.0	26.0	28.0
4627.00	30.0	32.0	34.0	36.0	38.0	41.0	43.0	46.0	48.0	51.0
4628.00	54.0	56.0	59.0	62.0	65.0	69.0	72.0	75.0	78.0	82.0
4629.00	85.0	89.0	93.0	96.0	100.0	104.0	108.0	112.0	116.0	121.0
4630.00	125.0	129.0	134.0	139.0	144.0	149.0	155.0	160.0	166.0	172.0
4631.00	179.0	185.0	192.0	199.0	206.0	213.0	221.0	228.0	236.0	244.0
4632.00	253.0	261.0	270.0	279.0	288.0	297.0	307.0	316.0	326.0	336.0
4633.00	347.0	357.0	368.0	379.0	390.0	401.0	413.0	425.0	437.0	449.0
4634.00	461.0	474.0	486.0	499.0	513.0	526.0	540.0	553.0	567.0	581.0
4635.00	596.0	610.0	626.0	641.0	658.0	674.0	691.0	709.0	727.0	746.0
4636.00	765.0	785.0	805.0	826.0	847.0	868.0	891.0	913.0	936.0	960.0
4637.00	984.0	1009.0	1034.0	1059.0	1085.0	1112.0	1139.0	1167.0	1195.0	1223.0
4638.00	1252.0	1282.0	1312.0	1343.0	1374.0	1405.0	1437.0	1470.0	1503.0	1536.0
4639.00	1570.0	1605.0	1640.0	1675.0	1711.0	1748.0	1785.0	1822.0	1860.0	1899.0
4640.00	1938.0	1978.0	2020.0	2063.0	2108.0	2156.0	2204.0	2255.0	2307.0	2362.0
4641.00	2418.0	2475.0	2535.0	2596.0	2659.0	2724.0	2790.0	2859.0	2928.0	3000.0
4642.00	3074.0	3149.0	3227.0	3305.0	3386.0	3468.0	3552.0	3638.0	3726.0	3815.0
4643.00	3907.0	4000.0	4094.0	4191.0	4289.0	4389.0	4491.0	4594.0	4699.0	4806.0
4644.00	4915.0	5026.0	5139.0	5252.0	5368.0	5486.0	5605.0	5727.0	5849.0	5974.0
4645.00	6101.0	6229.0	6361.0	6495.0	6633.0	6774.0	6917.0	7064.0	7213.0	7365.0
4646.00	7521.0	7679.0	7840.0	8004.0	8171.0	8341.0	8514.0	8690.0	8868.0	9050.0
4647.00	9235.0	9423.0	9614.0	9806.0	10003.0	10202.0	10405.0	10610.0	10818.0	11029.0
4648.00	11243.0	11461.0	11681.0	11903.0	12129.0	12358.0	12590.0	12825.0	13061.0	13302.0
4649.00	13546.0	13792.0	14042.0	14293.0	14549.0	14807.0	15069.0	15333.0	15599.0	15869.0
4650.00	16142.0	16418.0	16695.0	16973.0	17255.0	17538.0	17823.0	18111.0	18398.0	18689.0
4651.00	18982.0	19277.0	19574.0	19871.0	20172.0	20475.0	20779.0	21086.0	21392.0	21703.0
4652.00	22015.0	22329.0	22645.0	22962.0	23282.0	23604.0	23928.0	24253.0	24580.0	24909.0
4653.00	25241.0	25574.0	25910.0	26245.0	26585.0	26926.0	27269.0	27614.0	27960.0	28309.0
4654.00	28659.0	29012.0	29367.0	29722.0	30081.0	30441.0	30804.0	31168.0	31533.0	31901.0
4655.00	32271.0	32643.0	33017.0	33392.0	33770.0	34150.0	34532.0	34916.0	35300.0	35688.0
4656.00	36078.0	36470.0	36864.0	37258.0	37656.0	38056.0	38458.0	38862.0	39266.0	39674.0
4657.00	40084.0	40496.0	40910.0	41324.0	41742.0	42162.0	42584.0	43007.0	43431.0	43859.0
4658.00	44289.0	44721.0	45154.0	45588.0	46026.0	46466.0	46907.0	47351.0	47795.0	48242.0
4659.00	48692.0	49144.0	49597.0	50051.0	50508.0	50968.0	51430.0	51893.0	52357.0	52824.0
4660.00	53294.0	53765.0	54238.0	54711.0	55187.0	55665.0	56145.0	56627.0	57108.0	57592.0
4661.00	58079.0	58567.0	59057.0	59546.0	60040.0	60535.0	61031.0	61530.0	62027.0	62529.0
4662.00	63033.0	63538.0	64044.0	64550.0	65061.0	65572.0	66086.0	66601.0	67115.0	67634.0
4663.00	68154.0	68676.0	69200.0	69723.0	70250.0	70778.0	71309.0	71841.0	72372.0	72907.0
4664.00	73444.0	73983.0	74524.0	75063.0	75607.0	76153.0	76700.0	77249.0	77797.0	78349.0
4665.00	78903.0	79458.0	80015.0	80571.0	81130.0	81691.0	82254.0	82817.0	83380.0	83946.0
4666.00	84514.0	85083.0	85654.0	86223.0	86797.0	87372.0	87948.0	88525.0	89101.0	89682.0
4667.00	90263.0	90847.0	91431.0	92014.0	92601.0	93190.0	93780.0	94371.0	94961.0	95555.0
4668.00	96151.0	96747.0	97346.0	97942.0	98543.0	99146.0	99750.0	100355.0	100958.0	101566.0
4669.00	102175.0	102786.0	103398.0	104009.0	104623.0	105240.0	105857.0	106476.0	107093.0	107715.0
4670.00	108338.0	108963.0	109589.0	110213.0	110841.0	111471.0	112103.0	112736.0	113367.0	114002.0
4671.00	114639.0	115277.0	115917.0	116555.0	117198.0	117841.0	118487.0	119133.0	119778.0	120428.0
4672.00	121078.0	121730.0	122384.0	123036.0	123692.0	124350.0	125009.0	125669.0	126328.0	126991.0
4673.00	127656.0	128322.0	128989.0	129655.0	130325.0	130996.0	131669.0	132344.0	133016.0	133693.0
4674.00	134372.0	135051.0	135733.0	136412.0	137096.0	137781.0	138468.0	139156.0	139843.0	140533.0
4675.00	141226.0	141920.0	142615.0	143309.0	144008.0	144709.0	145411.0	146115.0	146818.0	147525.0
4676.00	148234.0	148945.0	149658.0	150369.0	151085.0	151802.0	152522.0	153243.0	153962.0	154687.0
4677.00	155413.0	156141.0	156871.0	157598.0	158331.0	159066.0	159803.0	160541.0	161277.0	162019.0
4678.00	162762.0	163507.0	164254.0	164999.0	165749.0	166501.0	167254.0	168009.0	168763.0	169521.0
4679.00	170282.0	171044.0	171807.0	172569.0	173336.0	174105.0	174876.0	175648.0	176418.0	177194.0
4680.00	177971.0	178750.0	179531.0	180311.0	181095.0	181882.0	182671.0	183461.0	184249.0	185044.0
4681.00	185840.0	186637.0	187437.0	188235.0	189038.0	189844.0	190651.0	191460.0	192267.0	193080.0
4682.00	193895.0	194711.0	195530.0	196346.0	197168.0	197992.0	198818.0	199646.0	200472.0	201303.0
4683.00	202136.0	202972.0	203809.0	204644.0	205485.0	206327.0	207172.0	208019.0	208863.0	209713.0
4684.00	210565.0	211419.0	212275.0	213128.0	213988.0	214849.0	215713.0	216578.0	217441.0	218310.0
4685.00	219181.0	220053.0	220927.0	221798.0	222676.0	223554.0	224434.0	225316.0	226195.0	227080.0
4686.00	227966.0	228854.0	229744.0	230631.0	231523.0	232417.0	233313.0	234210.0	235105.0	236005.0
4687.00	236907.0	237810.0	238715.0	239617.0	240525.0	241435.0	242346.0	243258.0	244168.0	245084.0
4688.00	246001.0	246920.0	247840.0	248758.0	249681.0	250606.0	251533.0	252461.0	253386.0	254317.0
4689.00	255250.0	256184.0	257120.0	258053.0	258992.0	259932.0	260874.0	261818.0	262758.0	263705.0
4690.00	264653.0	265603.0	266555.0	267503.0	268459.0	269416.0	270374.0	271335.0	272292.0	273256.0
4691.00	274222.0	275189.0	276159.0	277125.0	278098.0	279073.0	280049.0	281027.0	282002.0	282984.0

BOYSEN RESERVOIR CAPACITY TABLE

Station ID: BOYR   Date: 30-AUG-2001
Station description: BOYSEN RESERVOIR, THERMOPOLIS, WYOMING

	.00	.10	.20	.30	.40	.50	.60	.70	.80	.90
4692.00	283967.0	284953.0	285940.0	286924.0	287914.0	288906.0	289900.0	290896.0	291889.0	292888.0
4693.00	293890.0	294893.0	295897.0	296899.0	297907.0	298917.0	299929.0	300942.0	301953.0	302970.0
4694.00	303989.0	305009.0	306032.0	307051.0	308077.0	309104.0	310134.0	311165.0	312193.0	313228.0
4695.00	314264.0	315303.0	316343.0	317379.0	318423.0	319468.0	320515.0	321564.0	322610.0	323662.0
4696.00	324716.0	325772.0	326829.0	327884.0	328945.0	330008.0	331072.0	332139.0	333201.0	334271.0
4697.00	335343.0	336416.0	337491.0	338563.0	339642.0	340722.0	341804.0	342888.0	343969.0	345056.0
4698.00	346145.0	347236.0	348329.0	349418.0	350514.0	351612.0	352712.0	353813.0	354911.0	356016.0
4699.00	357123.0	358231.0	359341.0	360448.0	361562.0	362677.0	363794.0	364913.0	366029.0	367151.0
4700.00	368275.0	369402.0	370530.0	371655.0	372788.0	373923.0	375061.0	376200.0	377337.0	378481.0
4701.00	379627.0	380775.0	381926.0	383074.0	384229.0	385386.0	386546.0	387708.0	388866.0	390033.0
4702.00	391201.0	392372.0	393545.0	394715.0	395892.0	397072.0	398254.0	399438.0	400619.0	401808.0
4703.00	402998.0	404192.0	405387.0	406579.0	407778.0	408980.0	410185.0	411391.0	412594.0	413805.0
4704.00	415018.0	416234.0	417451.0	418665.0	419887.0	421112.0	422338.0	423567.0	424792.0	426025.0
4705.00	427261.0	428499.0	429740.0	430978.0	432225.0	433474.0	434727.0	435983.0	437235.0	438497.0
4706.00	439761.0	441029.0	442299.0	443566.0	444842.0	446122.0	447404.0	448689.0	449970.0	451261.0
4707.00	452555.0	453852.0	455152.0	456448.0	457753.0	459062.0	460373.0	461688.0	462999.0	464319.0
4708.00	465642.0	466968.0	468297.0	469623.0	470958.0	472296.0	473636.0	474980.0	476320.0	477670.0
4709.00	479022.0	480378.0	481736.0	483091.0	484455.0	485822.0	487193.0	488566.0	489935.0	491314.0
4710.00	492696.0	494081.0	495469.0	496853.0	498247.0	499645.0	501045.0	502449.0	503849.0	505259.0
4711.00	506671.0	508088.0	509507.0	510922.0	512347.0	513776.0	515208.0	516642.0	518073.0	519514.0
4712.00	520958.0	522406.0	523856.0	525302.0	526759.0	528218.0	529681.0	531147.0	532609.0	534081.0
4713.00	535556.0	537035.0	538516.0	539994.0	541481.0	542972.0	544466.0	545963.0	547456.0	548959.0
4714.00	550466.0	551975.0	553488.0	554996.0	556515.0	558037.0	559562.0	561090.0	562614.0	564148.0
4715.00	565686.0	567227.0	568774.0	570317.0	571872.0	573432.0	574997.0	576566.0	578132.0	579711.0
4716.00	581294.0	582881.0	584474.0	586063.0	587665.0	589271.0	590882.0	592498.0	594110.0	595735.0
4717.00	597365.0	598999.0	600638.0	602273.0	603921.0	605574.0	607231.0	608893.0	610552.0	612223.0
4718.00	613899.0	615579.0	617265.0	618946.0	620641.0	622340.0	624043.0	625752.0	627456.0	629174.0
4719.00	630896.0	632623.0	634355.0	636082.0	637823.0	639569.0	641319.0	643074.0	644824.0	646588.0
4720.00	648357.0	650130.0	651907.0	653678.0	655463.0	657251.0	659043.0	660839.0	662630.0	664433.0
4721.00	666240.0	668052.0	669867.0	671676.0	673499.0	675325.0	677156.0	678990.0	680819.0	682660.0
4722.00	684506.0	686355.0	688208.0	690056.0	691917.0	693782.0	695650.0	697523.0	699390.0	701270.0
4723.00	703153.0	705041.0	706932.0	708818.0	710717.0	712620.0	714527.0	716438.0	718343.0	720261.0
4724.00	722183.0	724109.0	726038.0	727962.0	729900.0	731841.0	733786.0	735735.0	737678.0	739634.0
4725.00	741594.0	743558.0	745526.0	747488.0	749463.0	751442.0	753424.0	755410.0	757391.0	759384.0
4726.00	761381.0	763382.0	765387.0	767386.0	769398.0	771413.0	773433.0	775456.0	777473.0	779504.0
4727.00	781538.0	783576.0	785617.0	787653.0	789702.0	791755.0	793811.0	795871.0	797925.0	799992.0
4728.00	802064.0	804139.0	806217.0	808289.0	810375.0	812465.0	814558.0	816655.0	818746.0	820850.0
4729.00	822959.0	825071.0	827186.0	829295.0	831418.0	833545.0	835675.0	837809.0	839936.0	842078.0
4730.00	844223.0	846372.0	848524.0	850669.0	852827.0	854990.0	857155.0	859324.0	861486.0	863661.0
4731.00	865840.0	868023.0	870209.0	872387.0	874580.0	876775.0	878975.0	881177.0	883373.0	885582.0
4732.00	887795.0	890011.0	892230.0	894442.0	896668.0	898898.0	901131.0	903367.0	905596.0	907839.0
4733.00	910086.0	912335.0	914589.0	916834.0	919094.0	921357.0	923624.0	925894.0	928156.0	930433.0
4734.00	932713.0	934997.0	937284.0	939563.0	941857.0	944154.0	946454.0	948758.0	951054.0	953364.0
4735.00	955678.0	957996.0	960318.0	962634.0	964966.0	967303.0	969644.0	971990.0	974329.0	976684.0
4736.00	979043.0	981408.0	983777.0	986139.0	988517.0	990900.0	993288.0	995680.0	998065.0	1000467.0
4737.00	1002873.0	1005284.0	1007700.0	1010108.0	1012533.0	1014962.0	1017397.0	1019835.0	1022267.0	1024715.0
4738.00	1027168.0	1029625.0	1032087.0	1034542.0	1037013.0	1039489.0	1041970.0	1044455.0	1046933.0	1049428.0
4739.00	1051927.0	1054431.0	1056939.0	1059440.0	1061958.0	1064481.0	1067008.0	1069540.0	1072064.0	1074605.0
4740.00	1077151.0	1079701.0	1082254.0	1084799.0	1087361.0	1089926.0	1092495.0	1095068.0	1097632.0	1100212.0
4741.00	1102796.0	1105384.0	1107976.0	1110559.0	1113158.0	1115761.0	1118368.0	1120979.0	1123581.0	1126199.0
4742.00	1128821.0	1131447.0	1134077.0	1136698.0	1139335.0	1141976.0	1144621.0	1147270.0	1149909.0	1152566.0
4743.00	1155226.0	1157890.0	1160558.0	1163216.0	1165891.0	1168570.0	1171253.0	1173940.0	1176617.0	1179312.0
4744.00	1182010.0	1184712.0	1187417.0	1190114.0	1192827.0	1195544.0	1198265.0	1200990.0	1203705.0	1206437.0
4745.00	1209173.0	1211914.0	1214659.0	1217396.0	1220152.0	1222912.0	1225678.0	1228448.0	1231210.0	1233991.0
4746.00	1236776.0	1239567.0	1242362.0	1245149.0	1247955.0	1250766.0	1253581.0	1256402.0	1259214.0	1262044.0
4747.00	1264880.0	1267721.0	1270566.0	1273403.0	1276259.0	1279119.0	1281985.0	1284856.0	1287718.0	1290598.0
4748.00	1293484.0	1296375.0	1299271.0	1302157.0	1305063.0	1307974.0	1310890.0	1313810.0	1316722.0	1319653.0
4749.00	1322589.0	1325529.0	1328475.0	1331412.0	1334368.0	1337328.0	1340294.0	1343265.0	1346227.0	1349208.0
4750.00	1352193.0	1355184.0	1358180.0	1361167.0	1364173.0	1367184.0	1370200.0	1373221.0	1376232.0	1379263.0
4751.00	1382299.0	1385340.0	1388386.0	1391422.0	1394478.0	1397539.0	1400605.0	1403676.0	1406737.0	1409818.0
4752.00	1412905.0									

EXHIBIT VI

SEASONAL RUNOFF FORECAST PROCEDURE

BOYSEN DAM AND RESERVOIR

EXHIBIT VI
SEASONAL RUNOFF FORECAST PROCEDURE
BOSYEN DAM AND RESERVOIR

Table of Contents

Tables

Plates

1. General

Since the drainage area above Boysen Dam is mostly bounded by mountains, over half of its annual inflow normally occurs during the May-July period as a result of mountain snowmelt. In years when the snow accumulation is high it is necessary that joint use storage space be made available in advance of the anticipated runoff. To determine the amount of space needed to store and control this runoff, a seasonal volume forecast has been developed.

2. Development of forecast procedure

Multiple correlation studies were made which related independent variables (October and November antecedent runoff, antecedent yearly precipitation, 1st of the month or peak yearly snow-water content, and January through June precipitation) to the dependent variable (May through July runoff volume). Reliable reservoir data starts in 1952, but an adequate SNOTEL record did not become available until 1981, leading to the use of a 37-year record (1981-2017) for forecast development. The dependent variable, May through July runoff volume, and the independent variable, antecedent runoff, were obtained using inflow values from monthly reservoir operations records maintained at Boysen Reservoir by the Omaha District and Reclamation. Snowpack snow water equivalent (SWE) data was taken from SNOTEL automated measurements for Wyoming by the Natural Resources Conservation Service. Precipitation amounts were taken from climatological data compiled by the National Oceanic and Atmospheric Administration (NOAA). Plate VI-1 is a map of the Boysen Reservoir drainage basin showing the location of the snow and precipitation stations used in developing the forecast.

a. May through July runoff

For the analysis, the dependent variable (May through July runoff volume) was calculated from the actual historical inflow to Boysen Reservoir. The effects of evaporation were ignored in calculating inflow. Plate VI-2 shows historic monthly inflow to Boysen Reservoir for the period 1954 to 2017.

Average May-Jul inflow = 0.545 Million Acre Feet (MAF)
Maximum May-Jul inflow = 1.503 MAF (2017)
Minimum May-Jul inflow = 0.090 MAF (2001)
**Maximum May-Jul inflow from the POR = 1.26 MAF (1967)
Note: The Average May-Jul inflow is based on 1981-2017 period to align with runoff forecast analysis.

b. Antecedent runoff

Antecedent runoff was calculated from the actual historical inflow to Boysen for the months of October and November. The effects of evaporation were ignored in calculating the inflow.

Average Oct-Nov inflow = .112 Million Acre Feet (MAF)
Maximum Oct-Nov inflow = .217 MAF (1982)
Minimum Oct-Nov inflow = 0.04 MAF (2001)

c. Snow-water content

Analysis of the Boysen basin indicated accurate up-to-date snowpack water content could be provided by 12 different SNOTEL sites. Plate VI-1 shows a map of these stations. Plate 5-4 of the Boysen Water Control Manual lists these stations and their average first of the month and mid-month snow water content. Real-time and historical SNOTEL data for all 12 stations can be found at http://www.wcc.nrcs.usda.gov/snow/. Note that during the analysis, the Burroughs Creek data was not included. This station is within the basin, but a recent wildfire burnt the gaging area. To assure anomalies in the snow accumulation pattern do not distort the estimates, this gage will not be used in the computation until growth around the gaging area returns.

d. Spring and summer precipitation

Monthly precipitation data is available from the National Weather Service at 2 reliable reporting stations. Table 1 shows a listing of these stations and their elevations. Other reliable stations have current readings, but only stations with data back to 1981 were used.

Table 1. Spring and Summer Precipitation Stations

Precipitation Station	Elevation (feet)
Riverton Regional Airport	5443
Lander/Hunt Field	5587

3. Application of forecast equation

An average of the Snow Water Equivalent (SWE) at the SNOTEL sites (Plate VI-1) on the first of the month is used from February 1st through April 1st. For the forecast on May 1st, June 1st, and July 1st, the peak snowpack is used. Antecedent inflow (ANTQ) for October and November and the total antecedent precipitation (ANTPREC) from the previous year will remain constant for the entire forecast period. For the February 1st forecast the average precipitation that fell in January (P_J) is used, for the March 1st forecast the average precipitation from January plus February (P_{J+F}) is used and so on. Coefficients (C_{swe}, C_{antQ}, $C_{antprec}$, and $C_{intercept}$) are specific to the month of the forecast and should be updated as necessary to maximize the accuracy of inflow forecasting. A multiple linear regression analysis is applied to the historical dataset determining these coefficients. The forecasted total inflow volume to the reservoir (1,000,000 ac-ft) from May-July (Q) is the result.

May-July inflow volume forecast equations:

February 1st:
$Q=C_{swe}(SWE_{FEB}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_{p}(P_{J}) + C_{intercept}$

March 1st:
$Q=C_{swe}(SWE_{MAR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_{p}(P_{J+F}) + C_{intercept}$

April 1st:
$Q=C_{swe}(SWE_{APR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_{p}(P_{J+F+M}) + C_{intercept}$

May 1st:
$Q=C_{swe}(SWE_{APR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_{p}(P_{J+F+M+A}) + C_{intercept}$

June 1st:
$Q=C_{swe}(SWE_{APR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_{p}(P_{J+F+M+A+M}) + C_{intercept}$

July 1st:
$Q=C_{swe}(SWE_{APR}) + C_{antQ}(ANTQ) + C_{antprec}(ANTPREC) + C_{p}(P_{J+F+M+A+M+J}) + C_{intercept}$

NOTE: Coefficients (C) are specific to the month of the forecast and are updated yearly to include prior year's dataset.

The coefficients developed based on 1981-2017 data are show in Table 2. These coefficients should be updated as necessary to maximize the accuracy of inflow forecasting. Updating the coefficients is completed by collecting the model data (inflow, SWE and precipitation) since the coefficients were last updated and including them in the multiple linear regression analysis. The data shows a negative forecast improvement from June to July. This is due primarily to the unpredictability of July rainfall. For this reason the June forecasted inflow volume is often used over the July estimate for predicting operations in late-June or July.

Table 2. Linear Regression Coefficients

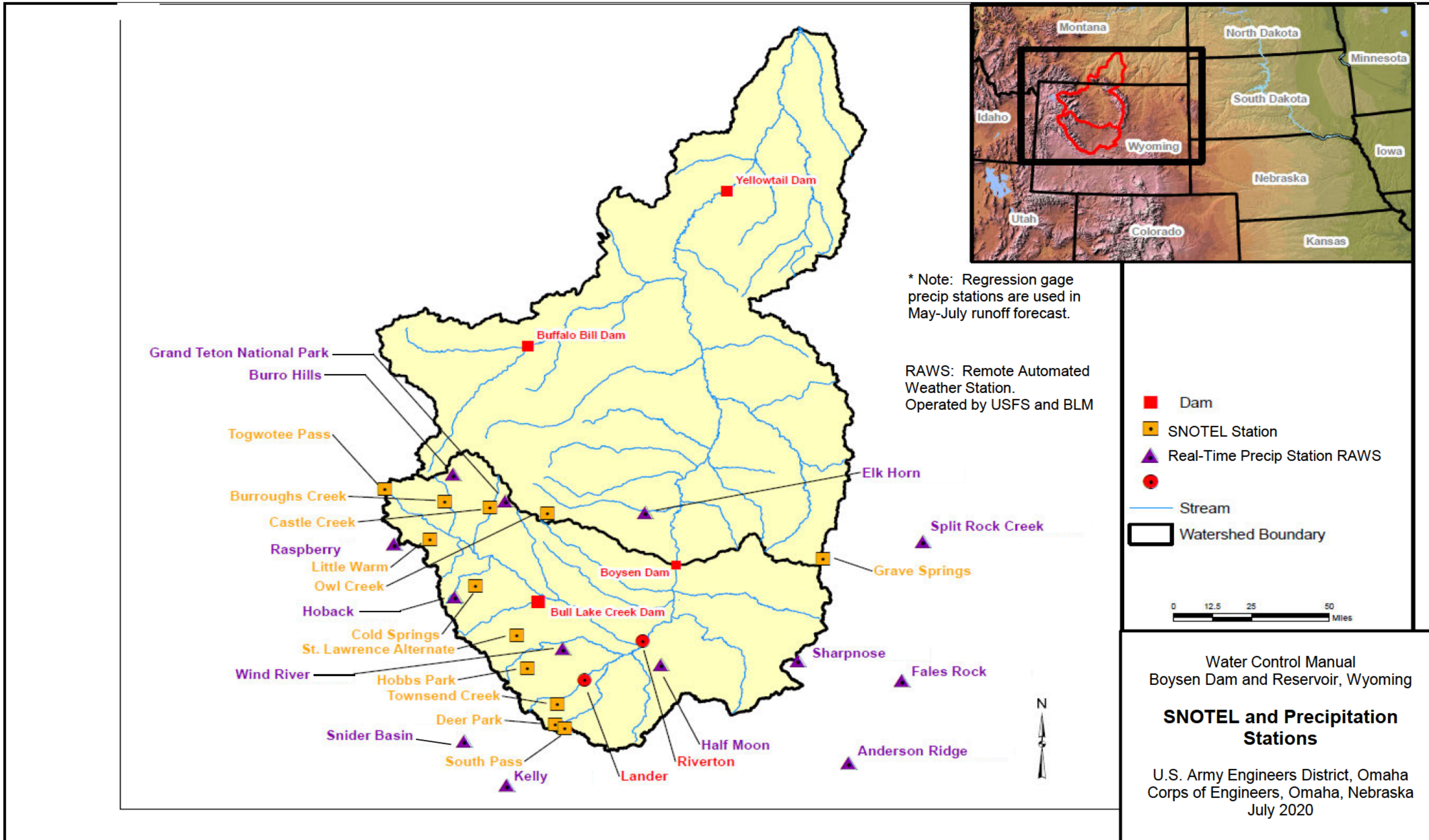
	February	March	April	May	June	July
Intercept	-0.4480	-0.6134	-0.7052	-0.6919	-0.8690	-0.8654
SWE - (SWE_{xxx})	0.0576	0.0633	0.0738	0.0715	0.0627	0.0619
ANT Flow - (ANTQ)	0.6366	1.1430	1.4488	0.0111	0.4868	0.5846
ANTPREC - (ANTPREC)	0.0470	0.0322	0.0159	0.0169	0.0157	0.0171

Year-to-Date Precip - (P_{xx})	-0.0136	0.0960	0.0119	0.0445	0.0745	0.0582

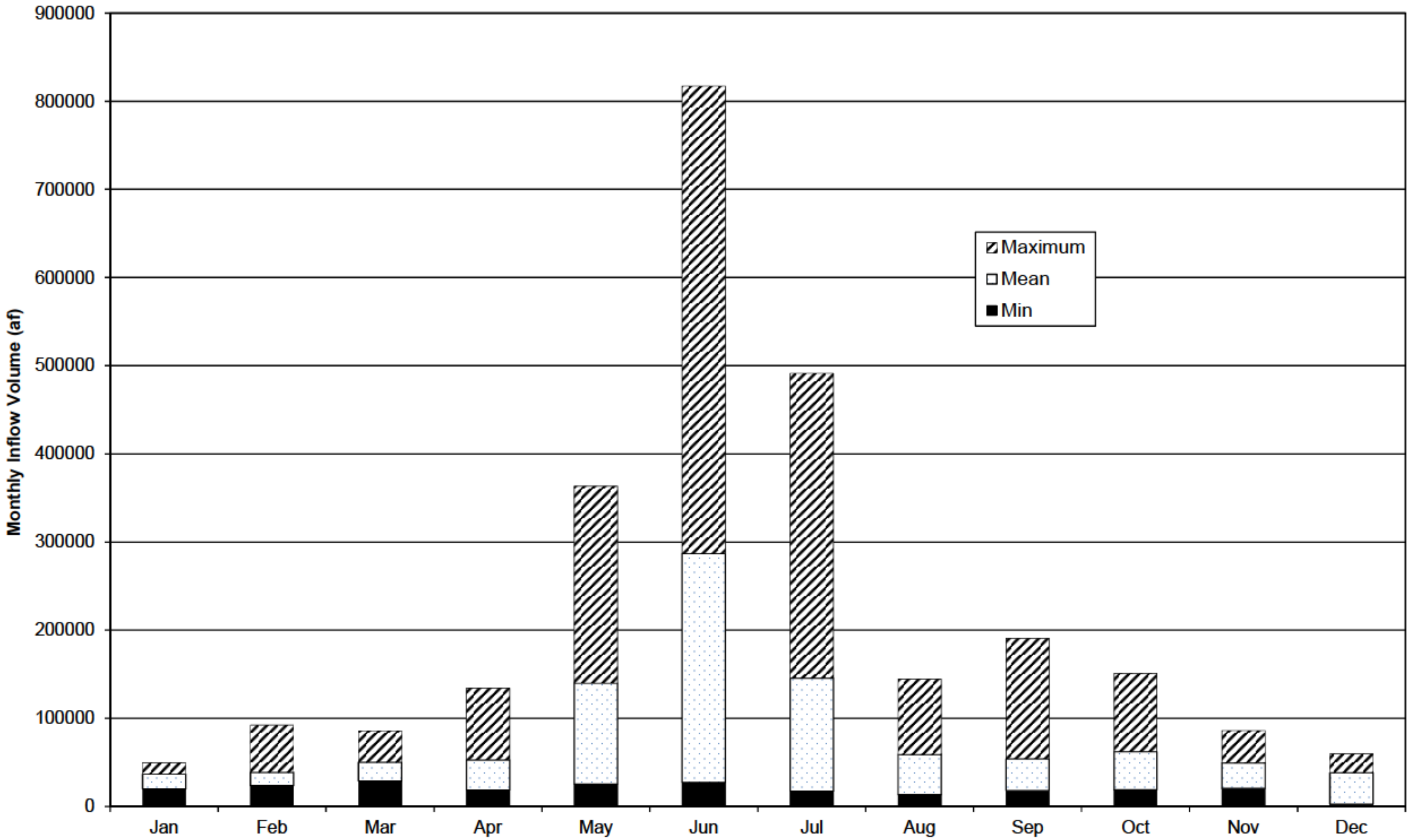
**Note: These coefficients are as of WY 2017. These coefficients should be updated as necessary to maximize the accuracy of inflow forecasting.

4. Pertinent data

Plates E-VI-3 and E-VI-4 present a more detailed summary of the independent variables. Plates E-VI-5 and E-VI-6 show the observed inflows and forecasted inflows. Plates E-VI-7 and E-VI-8 show the residual and squares of residuals of the forecasts.



Montana
North Dakota
Minnesota
South Dakota
Idaho
Wyoming
Iowa
Nebraska
Utah
Colorado
Kansas
Yellowtail Dam
Buffalo Bill Dam
Boysen Dam
Bull Lake Creek Dam
* Note: Regression gage precip stations are used in May-July runoff forecast.
RAWS: Remote Automated Weather Station. Operated by USFS and BLM
Grand Teton National Park
Burro Hills
Togwotee Pass
Burroughs Creek
Castle Creek
Raspberry
Little Warm
Owl Creek
Hoback
Cold Springs
St. Lawrence Alternate
Wind River
Hobbs Park
Townsend Creek
Deer Park
Snider Basin
South Pass
Kelly
Lander
Riverton
Half Moon
Elk Horn
Split Rock Creek
Grave Springs
Sharpnose
Fales Rock
Anderson Ridge
Dam
SNOTEL Station
Real-Time Precip Station RAWS
Stream
Watershed Boundary
0 12.5 25 50 Miles
N
Water Control Manual
Boysen Dam and Reservoir, Wyoming
SNOTEL and Precipitation Stations
U.S. Army Engineers District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Period Analyzed: 1952-2017
Total Average Annual Inflow = 1,014,000 af

Source: USBR HydroMet Database

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Historical Monthly Min, Max and Mean Inflow Volume

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

Years	Previous yrs OCT-NOV Inflow, maf	Average Snow Water Equivalent, inches Jan	Feb	Mar	Apr	May	Jun	Annual Max
1981	0.11	5.4	6.4	7.8	10.3	7.1	4.5	10.3
1982	0.09	7.8	11.4	13.0	15.9	15.9	9.1	15.9
1983	0.22	6.2	8.0	9.5	13.0	16.3	11.9	16.3
1984	0.16	6.7	7.7	8.8	11.1	14.3	4.0	14.3
1985	0.16	5.0	5.8	7.7	9.8	6.0	1.6	9.8
1986	0.11	8.0	9.9	17.4	18.4	19.0	9.0	19.0
1987	0.15	6.8	8.9	10.9	13.4	5.9	0.9	13.4
1988	0.08	5.0	6.9	8.5	11.5	7.7	1.8	11.5
1989	0.06	4.4	6.9	8.9	12.3	8.4	3.5	12.3
1990	0.10	4.5	7.4	8.5	10.7	9.0	3.2	10.7
1991	0.11	6.1	7.4	8.2	11.5	15.0	7.3	15.0
1992	0.10	5.9	6.6	7.3	9.5	4.2	0.0	9.5
1993	0.07	4.9	6.8	8.1	10.3	12.0	2.2	12.0
1994	0.10	3.9	5.5	8.2	10.5	8.3	0.3	10.5
1995	0.09	6.3	8.4	10.2	12.7	16.1	15.3	16.1
1996	0.12	7.6	10.7	12.6	15.4	15.7	8.5	15.7
1997	0.10	10.3	13.4	14.9	16.8	18.4	4.8	18.4
1998	0.17	5.3	8.6	10.0	13.3	14.0	3.4	14.0
1999	0.19	6.1	8.7	12.2	13.7	20.3	9.7	20.3
2000	0.13	2.7	5.6	8.0	10.3	7.8	1.0	10.3
2001	0.07	4.1	4.5	6.2	7.2	5.6	0.0	7.2
2002	0.04	4.3	6.1	7.0	9.8	8.7	1.8	9.8
2003	0.06	4.2	5.9	8.5	12.6	9.0	1.5	12.6
2004	0.07	5.7	7.1	9.6	9.2	10.0	2.1	10.0
2005	0.12	6.3	8.3	9.4	11.4	11.5	4.4	11.5
2006	0.09	5.4	7.6	9.2	11.1	8.1	1.5	11.1
2007	0.09	4.3	6.1	7.8	9.1	6.6	0.6	9.1
2008	0.07	5.0	7.6	9.5	12.6	12.0	7.5	12.6
2009	0.08	5.4	7.2	8.3	11.6	14.2	2.8	14.2
2010	0.11	4.8	6.1	7.1	10.1	11.4	8.9	11.4
2011	0.08	6.9	8.4	10.3	12.8	15.4	15.4	15.4
2012	0.11	5.0	7.1	9.7	8.7	5.0	1.4	8.7
2013	0.10	4.8	5.5	7.3	8.7	9.0	1.0	9.0
2014	0.15	5.3	7.0	10.4	13.6	11.9	3.2	13.6
2015	0.13	5.0	5.8	7.9	7.4	5.8	3.3	7.4
2016	0.08	3.65	4.75	6.49	11.19	11.4	4.67	11.4
2017	0.14	6.03	9.58	15.45	18.4	21.44	11.27	21.4
Ave	0.11	5.54	7.45	9.49	11.78	11.31	4.68	12.75
Max	0.22	10.31	13.41	17.40	18.44	21.44	15.35	21.44
Min	0.04	2.66	4.51	6.15	7.20	4.19	0.00	7.20

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Regression Analysis
Independent Variables

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

	Average Annual Precip	Average Cumulative Rainfall					
Years	inches	Jan	**Jan -** Feb	**Jan -** Mar	**Jan -** Apr	**Jan -** May	**Jan -** June
1980	9.63	0.61	1.00	1.84	2.94	6.67	6.9
1981	8.30	0.46	0.69	2.05	3.10	5.40	5.5
1982	10.58	0.30	0.39	0.75	1.23	2.51	3.9
1983	11.99	0.04	0.42	1.53	3.75	5.94	7.2
1984	9.97	0.71	1.38	1.89	4.35	4.57	6.0
1985	8.84	0.41	0.54	0.84	1.48	2.24	3.9
1986	9.36	0.20	1.21	1.59	2.98	4.22	4.4
1987	11.07	0.58	1.91	3.51	4.26	6.37	7.3
1988	5.69	0.03	0.33	1.14	1.87	3.08	3.4
1989	12.06	0.02	0.62	0.82	1.51	5.79	7.7
1990	8.64	0.01	0.09	1.14	2.73	3.14	3.6
1991	12.10	0.27	0.65	0.94	3.24	6.92	7.8
1992	10.74	0.26	0.42	2.00	2.13	4.64	6.0
1993	15.02	0.80	1.06	2.06	3.43	5.30	10.8
1994	9.45	0.70	0.89	1.61	2.64	2.76	3.0
1995	16.55	1.05	1.66	2.27	4.66	9.17	12.2
1996	9.80	0.82	1.28	2.54	3.01	5.08	5.5
1997	13.66	0.57	1.01	1.76	3.36	5.28	6.4
1998	15.46	0.15	0.64	3.83	4.76	5.72	8.8
1999	11.26	0.10	0.43	0.88	5.93	6.83	7.8
2000	7.56	0.09	0.47	1.02	2.37	4.11	4.7
2001	5.23	0.18	0.71	1.07	2.11	2.52	2.9
2002	7.82	0.21	0.36	0.91	2.20	3.55	4.0
2003	9.67	0.23	1.36	2.32	3.17	4.40	6.5
2004	11.86	0.10	1.54	1.55	4.69	5.22	6.5
2005	10.04	0.62	0.66	1.40	2.66	6.17	6.5
2006	6.25	0.24	0.89	1.42	2.55	2.70	2.8
2007	9.54	0.47	0.61	1.72	1.94	3.61	4.3
2008	11.88	0.20	0.75	1.18	1.82	7.22	7.9
2009	13.90	0.25	0.25	1.86	4.66	5.46	8.0
2010	12.68	0.30	0.90	2.33	4.42	8.67	10.5
2011	13.06	0.44	1.51	1.69	2.38	8.42	9.0
2012	5.29	0.32	0.94	1.16	1.87	3.38	3.4
2013	12.69	0.46	1.59	2.22	6.22	7.72	8.2
2014	9.18	0.62	0.79	1.62	2.13	3.42	4.5
2015	12.71	0.02	1.44	1.95	3.66	8.72	9.53
2016	18.54	0.32	1.11	1.79	2.89	6.07	7.03
2017	15.56	0.17	1.28	1.87	3.27	7.40	8.28
Ave	10.88	0.35	0.89	1.68	3.11	5.27	6.38
Max	18.54	1.05	1.91	3.83	6.22	9.17	12.25
Min	5.23	0.01	0.09	0.75	1.23	2.24	2.77

Note: Average Precipitations are comprised of the following stations:
Lander Hunt Field Airport
Riverton

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Boysen Dam and Reservoir, Wyoming

Regression Analysis
Independent Variables

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

	*Reported in maf		Deviation		
	Natural	Arithmetic	from	Deviation	
Years	Inflow	Mean	Mean	Squared	
1981	0.46	0.60	-0.14	0.02	
1982	0.68	0.60	0.08	0.01	
1983	1.00	0.60	0.41	0.17	
1984	0.68	0.60	0.09	0.01	
1985	0.29	0.60	-0.30	0.09	
1986	1.03	0.60	0.43	0.18	
1987	0.46	0.60	-0.14	0.02	
1988	0.18	0.60	-0.42	0.17	
1989	0.50	0.60	-0.09	0.01	
1990	0.29	0.60	-0.30	0.09	
1991	0.90	0.60	0.30	0.09	
1992	0.29	0.60	-0.31	0.09	
1993	0.68	0.60	0.08	0.01	
1994	0.16	0.60	-0.44	0.19	
1995	1.19	0.60	0.59	0.35	
1996	0.73	0.60	0.13	0.02	
1997	0.95	0.60	0.36	0.13	
1998	0.78	0.60	0.19	0.03	
1999	1.11	0.60	0.52	0.27	
2000	0.28	0.60	-0.32	0.10	
2001	0.08	0.60	-0.52	0.27	
2002	0.20	0.60	-0.40	0.16	
2003	0.28	0.60	-0.31	0.10	
2004	0.36	0.60	-0.24	0.06	
2005	0.59	0.60	0.00	0.00	
2006	0.21	0.60	-0.39	0.15	
2007	0.19	0.60	-0.40	0.16	
2008	0.58	0.60	-0.01	0.00	
2009	0.80	0.60	0.21	0.04	
2010	0.86	0.60	0.26	0.07	
2011	1.03	0.60	0.44	0.19	
2012	0.22	0.60	-0.37	0.14	
2013	0.25	0.60	-0.35	0.12	
2014	0.69	0.60	0.09	0.01	
2015	0.74	0.60	0.15	0.02	
2016	0.73	0.60	0.13	0.02	
2017	1.60	0.60	1.00	1.00	
Ave	0.60		SST	4.57	
Max	1.60	SST = Sum of the squares due to			
Min	0.08	total variability.			

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Regression Analysis
Observed Inflows

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

		Forecast Natural May-Jul Inflow						
	Natural	**maf**						
Years	Inflow	Jan	Feb	Mar	Apr	May	Jun	Jul
1981	0.46	0.540	0.505	0.442	0.446	0.396	0.435	0.370
1982	0.68	0.740	0.723	0.690	0.832	0.719	0.551	0.603
1983	1.00	0.771	0.800	0.695	0.817	0.927	0.947	0.962
1984	0.68	0.834	0.760	0.717	0.618	0.802	0.696	0.739
1985	0.29	0.563	0.564	0.506	0.476	0.312	0.188	0.287
1986	1.03	0.809	0.681	1.114	1.085	1.046	0.913	0.855
1987	0.46	0.739	0.712	0.831	0.777	0.696	0.744	0.724
1988	0.18	0.517	0.537	0.430	0.497	0.439	0.325	0.299
1989	0.50	0.205	0.282	0.310	0.451	0.415	0.520	0.546
1990	0.29	0.514	0.645	0.472	0.484	0.436	0.303	0.294
1991	0.90	0.586	0.531	0.443	0.518	0.748	0.858	0.811
1992	0.29	0.681	0.599	0.428	0.403	0.323	0.347	0.372
1993	0.68	0.480	0.484	0.454	0.390	0.539	0.527	0.790
1994	0.16	0.563	0.622	0.600	0.501	0.449	0.288	0.273
1995	1.19	0.607	0.569	0.662	0.608	0.894	1.104	1.154
1996	0.73	1.080	1.046	1.022	0.971	0.886	0.850	0.809
1997	0.95	1.104	0.919	0.941	0.955	1.019	0.958	0.947
1998	0.78	0.725	0.866	0.750	0.824	0.812	0.778	0.907
1999	1.11	0.915	0.977	0.959	0.880	1.372	1.320	1.294
2000	0.28	0.287	0.524	0.471	0.459	0.387	0.353	0.340
2001	0.08	0.255	0.233	0.204	0.085	0.077	-0.051	-0.059
2002	0.20	0.157	0.183	0.116	0.210	0.236	0.156	0.120
2003	0.28	0.279	0.319	0.429	0.535	0.535	0.458	0.521
2004	0.36	0.529	0.472	0.575	0.282	0.424	0.372	0.375
2005	0.59	0.752	0.739	0.638	0.588	0.507	0.618	0.559
2006	0.21	0.538	0.569	0.543	0.484	0.431	0.268	0.240
2007	0.19	0.257	0.323	0.315	0.274	0.209	0.166	0.165
2008	0.58	0.450	0.512	0.502	0.567	0.504	0.710	0.639
2009	0.80	0.601	0.598	0.449	0.541	0.779	0.711	0.790
2010	0.86	0.642	0.654	0.523	0.492	0.586	0.814	0.806
2011	1.03	0.796	0.693	0.723	0.634	0.779	1.029	0.936
2012	0.22	0.632	0.686	0.688	0.358	0.264	0.210	0.178
2013	0.25	0.283	0.252	0.358	0.237	0.375	0.476	0.395
2014	0.69	0.696	0.734	0.779	0.822	0.657	0.560	0.601
2015	0.74	0.495	0.437	0.537	0.233	0.201	0.513	0.450
2016	0.73	0.433	0.416	0.437	0.520	0.499	0.581	0.555
2017	1.60	0.995	0.882	1.297	1.266	1.367	1.452	1.403

Water Control Manual
Boysen Dam and Reservoir, Wyoming
Regression Analysis
Forecast Results

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

		Residuals (Natural Inflow - Forecasted)						
	Natural	**maf**						
Years	Inflow	Jan	Feb	Mar	Apr	May	Jun	Jul
1981	0.46	-0.08	-0.05	0.02	0.01	0.06	0.02	0.09
1982	0.68	-0.06	-0.05	-0.01	-0.16	-0.04	0.13	0.07
1983	1.00	0.23	0.20	0.31	0.19	0.08	0.06	0.04
1984	0.68	-0.15	-0.08	-0.04	0.06	-0.12	-0.01	-0.06
1985	0.29	-0.27	-0.27	-0.21	-0.18	-0.02	0.11	0.01
1986	1.03	0.22	0.34	-0.09	-0.06	-0.02	0.11	0.17
1987	0.46	-0.28	-0.26	-0.37	-0.32	-0.24	-0.29	-0.27
1988	0.18	-0.34	-0.36	-0.25	-0.32	-0.26	-0.14	-0.12
1989	0.50	0.30	0.22	0.19	0.05	0.09	-0.02	-0.04
1990	0.29	-0.22	-0.35	-0.18	-0.19	-0.14	-0.01	0.00
1991	0.90	0.31	0.36	0.45	0.38	0.15	0.04	0.08
1992	0.29	-0.39	-0.31	-0.14	-0.11	-0.03	-0.06	-0.08
1993	0.68	0.20	0.19	0.22	0.29	0.14	0.15	-0.11
1994	0.16	-0.41	-0.47	-0.44	-0.35	-0.29	-0.13	-0.12
1995	1.19	0.58	0.62	0.53	0.58	0.30	0.09	0.04
1996	0.73	-0.35	-0.32	-0.29	-0.24	-0.16	-0.12	-0.08
1997	0.95	-0.15	0.04	0.01	0.00	-0.06	0.00	0.01
1998	0.78	0.06	-0.08	0.03	-0.04	-0.03	0.01	-0.12
1999	1.11	0.20	0.13	0.15	0.23	-0.26	-0.21	-0.18
2000	0.28	-0.01	-0.25	-0.19	-0.18	-0.11	-0.07	-0.06
2001	0.08	-0.18	-0.15	-0.13	-0.01	0.00	0.13	0.14
2002	0.20	0.04	0.01	0.08	-0.01	-0.04	0.04	0.08
2003	0.28	0.01	-0.03	-0.14	-0.25	-0.25	-0.17	-0.24
2004	0.36	-0.17	-0.12	-0.22	0.07	-0.07	-0.02	-0.02
2005	0.59	-0.16	-0.15	-0.05	0.00	0.08	-0.03	0.03
2006	0.21	-0.33	-0.36	-0.34	-0.28	-0.23	-0.06	-0.03
2007	0.19	-0.07	-0.13	-0.12	-0.08	-0.02	0.03	0.03
2008	0.58	0.13	0.07	0.08	0.02	0.08	-0.13	-0.06
2009	0.80	0.20	0.20	0.35	0.26	0.02	0.09	0.01
2010	0.86	0.22	0.21	0.34	0.37	0.27	0.04	0.05
2011	1.03	0.24	0.34	0.31	0.40	0.26	0.00	0.10
2012	0.22	-0.41	-0.46	-0.47	-0.13	-0.04	0.01	0.04
2013	0.25	-0.04	0.00	-0.11	0.01	-0.13	-0.23	-0.15
2014	0.69	-0.01	-0.05	-0.09	-0.13	0.03	0.13	0.09
2015	0.74	0.25	0.31	0.21	0.51	0.54	0.23	0.29
2016	0.73	0.30	0.31	0.29	0.21	0.23	0.15	0.17
2017	1.60	0.60	0.72	0.30	0.33	0.23	0.14	0.19

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Regression Analysis
Forecast Residuals

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

	Square of Residuals						
Years	Jan	Feb	Mar	Apr	May	Jun	Jul
1981	0.01	0.00	0.00	0.00	0.00	0.00	0.01
1982	0.00	0.00	0.00	0.02	0.00	0.02	0.01
1983	0.05	0.04	0.10	0.04	0.01	0.00	0.00
1984	0.02	0.01	0.00	0.00	0.01	0.00	0.00
1985	0.07	0.07	0.04	0.03	0.00	0.01	0.00
1986	0.05	0.12	0.01	0.00	0.00	0.01	0.03
1987	0.08	0.07	0.14	0.10	0.06	0.08	0.07
1988	0.11	0.13	0.06	0.10	0.07	0.02	0.01
1989	0.09	0.05	0.04	0.00	0.01	0.00	0.00
1990	0.05	0.12	0.03	0.04	0.02	0.00	0.00
1991	0.10	0.13	0.21	0.14	0.02	0.00	0.01
1992	0.15	0.10	0.02	0.01	0.00	0.00	0.01
1993	0.04	0.04	0.05	0.08	0.02	0.02	0.01
1994	0.17	0.22	0.20	0.12	0.09	0.02	0.01
1995	0.34	0.39	0.28	0.34	0.09	0.01	0.00
1996	0.12	0.10	0.09	0.06	0.03	0.01	0.01
1997	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.01	0.00	0.00	0.00	0.00	0.02
1999	0.04	0.02	0.02	0.05	0.07	0.04	0.03
2000	0.00	0.06	0.04	0.03	0.01	0.01	0.00
2001	0.03	0.02	0.02	0.00	0.00	0.02	0.02
2002	0.00	0.00	0.01	0.00	0.00	0.00	0.01
2003	0.00	0.00	0.02	0.06	0.06	0.03	0.06
2004	0.03	0.01	0.05	0.01	0.00	0.00	0.00
2005	0.03	0.02	0.00	0.00	0.01	0.00	0.00
2006	0.11	0.13	0.11	0.08	0.05	0.00	0.00
2007	0.00	0.02	0.02	0.01	0.00	0.00	0.00
2008	0.02	0.01	0.01	0.00	0.01	0.02	0.00
2009	0.04	0.04	0.12	0.07	0.00	0.01	0.00
2010	0.05	0.04	0.11	0.13	0.07	0.00	0.00
2011	0.06	0.12	0.10	0.16	0.07	0.00	0.01
2012	0.17	0.21	0.22	0.02	0.00	0.00	0.00
2013	0.00	0.00	0.01	0.00	0.02	0.05	0.02
2014	0.00	0.00	0.01	0.02	0.00	0.02	0.01
2015	0.06	0.09	0.04	0.26	0.30	0.05	0.09
2016	0.09	0.10	0.08	0.04	0.05	0.02	0.03
2017	0.36	0.51	0.09	0.11	0.05	0.02	0.04
SSE	2.57	3.00	2.34	2.15	1.20	0.51	0.52
MSE	0.07	0.08	0.06	0.06	0.03	0.01	0.01
Std Err	0.27	0.29	0.25	0.24	0.18	0.12	0.12
R^2	0.47	0.45	0.41	0.51	0.79	0.79	0.89

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Regression Analysis
Squares of Residuals

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

EXHIBIT VII

DETERMINATION OF SEASONAL FLOOD CONTROL STORAGE REQUIREMENTS

BOYSEN DAM AND RESERVOIR

EXHIBIT VII
DETERMINATION OF SEASONAL FLOOD CONTROL STORAGE REQUIREMENTS BOYSEN DAM AND RESERVOIR

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DETERMINATION OF SEASONAL
FLOOD CONTROL STORAGE REQUIREMENTS
BOYSEN DAM AND RESERVOIR

1. General. Boysen Reservoir joint use storage space (a total of 144,229 acre-feet (af) between elevations 4717.0 and 4725.0 feet) will be vacated for flood control purposes, provided it can be reasonably assured of refill prior to the end of the snowmelt period while conservation release requirements are satisfied.

2. Forecast Accuracy. Long-term runoff forecasting is not an exact science. The May-July inflow volume forecast equations were developed based on historical data and are not wholly predictive into the future. Therefore, determining the amount of vacated space needed to minimize flooding in any given year also contains uncertainty. The May-July inflow volume forecast, outlined in Exhibit VI, is initially made on February 1 and then updated monthly with the most up-to-date information. The uncertainty, sometimes referred to as error allowance, in making this inflow volume forecast will, in some years, result in the observed May-July inflow being much greater or much less than the forecast May-July inflow volume.

3. Reasonable Assurance of Refill. The evacuation of joint use storage for flood control purposes is designed such that there is a reasonable assurance that refill of the joint use zone will occur. To balance the impact of the May-July inflow volume forecast uncertainty to non-flood control purposes, an assured inflow (85-90 percent exceedance) volume forecast is made. Reclamation determines and provides a Boysen release volume estimate for the same 3-month period. The assured inflow volume forecast combined with the estimated release are used to determine the required joint use zone evacuation.

4. Assured Inflow. The established criteria for reasonable assurance of filling the joint use storage is satisfied by using an assured forecast that will be exceeded during 85-90 percent of the years. The May-July assured inflow forecast is determined by applying a volume deviation factor (or forecast error allowance) to May-July inflow volume calculated in Exhibit VI. The volume deviation factors, which are different for each month, are sometimes referred to as the assured inflow factors. They were determined by analyzing the variation between historical May-July forecasted and observed inflow volumes. The monthly assured inflow factors are outlined in Table 1 and were mutually agreeable to the Corps and Reclamation. Plates E-VII-1 through E-VII-6 outline how the assured inflow factors were determined for February 1 through July 1, respectively.

Table 1 - Assured Inflow Factors
(Volume Deviation Factors)

February 1	352,000 af
March 1	270,000 af
April 1	250,000 af
May 1	240,000 af
June 1	150,000 af
July 1	150,000 af

As the runoff season advances the assured inflow factor becomes progressively smaller. This is because more observed data has become available and the forecasts become more accurate. These factors represent the volume to be subtracted from the most probable May-July inflow volume, as determined in Exhibit VI, to obtain the assured forecast volume.

5. Estimated Outflow. Shortly after the first of each month, from February 1 through July 1, Reclamation will furnish the Corps an estimate for May-July conservation release requirements based on power generation and irrigation requirements. The release estimate is provided in Reclamation's monthly water supply outlook and Boysen projected operations plan. The release estimate should be used as the conservation release whenever available and relevant. If the current month's data is not yet available, the previous month's conservation release estimate should be used. In the absence of recent Reclamation estimates, Table 2 shows estimated monthly conservation releases during the runoff period.

Table 2 - Monthly Conservation Releases (Volume and Rate)

May	61,500 af	1,000 cfs/day
June	59,500 af	1,000 cfs/day
July	61,500 af	1,000 cfs/day

6. Determining Storage Requirements. An example is provided to demonstrate how flood control storage requirement is determined. Refer to Exhibit VI for additional information about determining the May-July inflow volume forecast. Table 3 lists the monthly distribution percentages, based on 1981-2017 observed inflows, which are useful when determining the joint use storage evacuation.

Table 3 – Monthly Percentages of May-July Inflow Volume

Period	Percentage of Inflow		
	May	June	July
May – July	24	50	26
June – July		66	34
July			100

After the water manager has determined the most probable May-July inflow volume, the water manager should then use Table 4 to determine the necessary evacuation of the joint use zone. A detailed explanation of the joint use storage requirement calculations and a step-by-step look at Table 4 is detailed in an example. Table 4 is available in the Corps and Reclamation's electronic file systems. For some, the logic and methods used in these tables is better understood in the electronic version.

The following example is provided to demonstrate the regulation of the joint use storage zone. The example scenario details the regulation of the spring 2017 runoff season. Table 4 shows the example calculations in tabular form. Plate 7-2 helps graphically show how and when the joint use zone is used for flood control.

Conditions on 1 February:

Pool elevation: 4719.0 feet; 110,900 af of joint use space vacant (4717.0 feet to 4725.0 feet).

February 1 forecast: The most probable May-July inflow forecast from the methods in Exhibit VI is 953,000 af. After adjustment for the assured factor (352,000 af) the May-July assured inflow forecast was 601,000 af. May-July release in Reclamation's February Operation Plan was 583,000 af. Subtracting the 583,000 af planned release from the 601,000 af assured inflow forecast would show a joint use evacuation requirement of 18,000 af by May 1. As of February 1, 110,900 af of joint use storage was evacuated and the Reclamation Operation Plan expected to evacuate all of the joint-use storage. This operation met and exceeded the Corps' flood control requirement and no modification to Reclamation's operations were necessary.

March 1 forecast: Pool elevation was 4720.7 feet. The most probable May-July inflow forecast from methods in Exhibit VI was 1,195,000 af. After adjustment for the assured factor (240,000 af) the May-July assured inflow forecast was 925,000 af. May-July release in Reclamation's March Operation Plan was 776,000 af. Subtracting the 776,000 af release from the 925,000 af assured inflow forecast showed a joint use evacuation requirement of 149,000 af by May 1. The maximum join-use evacuation requirement is 144,229 af. Any drawdown larger than 144,229 af is Reclamation's decision and responsibility. The May 1 expected pool elevation of 4708.6 feet (268,000 af drawdown) in Reclamation's March Operation Plan exceeded the Corps' flood control requirement and no modification to Reclamation's operations were necessary.

April 1 forecast: Pool elevation was 4718.3 feet (123,300 af drawdown). The most probable May-July inflow forecast was 1,356,000 af. After adjustment for the assured factor (250,000 af) the May-July assured inflow forecast was

1,106,000 af. May-July release in Reclamation's April Operation Plan was 707,000 af. Subtracting the 707,000 af release from the 1,106,000 af assured inflow forecast showed a joint use evacuation requirement of 399,000 af by May 1. The maximum joint-use evacuation requirement is 144,229 af. Any drawdown larger than 144,229 af is Reclamation's decision and responsibility. The May 1 expected pool elevation of 4705.2 feet (312,200 af drawdown) in Reclamation's April Operation Plan exceeded the Corps' flood control requirement and no modification to Reclamation's operations were necessary.

May 1 forecast: Pool elevation was 4707.9 feet, 9.1 feet below the base of joint use zone. This pool level on May 1 met and exceeded the Corps' flood control requirement set in April. The most probable May-July inflow forecast was 1,517,000 af. After adjustment for the assured factor (240,000 af), the May 1 May-July assured inflow forecast was 1,277,000 af. May-July release in Reclamation's May Operation Plan was 1,097,000 af. Subtracting the planned release from the expected inflow (1,277,000 af – 1,097,000 af) created a joint use requirement of 180,000 af. Since this requirement is larger than the joint use storage zone, the entire joint use storage zone was to be evacuated as of May 1. The May 1 forecast provides a joint-use pool target for June 1. This is determined first by multiplying the assured May-July inflow forecast by the average June-July share of May-July runoff (76%) from Table 3 (1,277,000 af * 76% = 971,000 af). Lastly, subtracting the June-July release (765,000 af) from the 971,000 af assured June-July inflow forecast would show a joint use evacuation requirement of 205,000 af on June 1. The maximum joint-use evacuation requirement is 144,229 af. Any drawdown larger than 144,229 af is Reclamation's decision and responsibility. The June 1 expected pool elevation of 4709.2 feet (260,400 af drawdown) in Reclamation's May Operation Plan exceeded the Corps' flood control requirement and no modification to Reclamation's operations were necessary. It should be noted that if downstream flood targets at Kane, WY, Bighorn River at Bighorn, MT or Miles City, MT were threatened during the month of May releases from Boysen could be decreased and the joint-use zone and possibly the exclusive flood control zone should be filled to mitigate downstream flooding.

June 1 forecast: Pool elevation was 4709.3 feet. This pool level on June 1 met and exceeded the Corps' flood control requirement. The June 1 most probable natural May-July inflow was 1,517,000 af. After adjustment for the assured factor (150,000 af), the May 1 May-July assured inflow forecast was 1,367,000 af. 370,000 af of inflow was received in May, leaving a forecast of 997,000 af to come in June and July. June-July release in Reclamation's June Operation Plan was 499,000 af. Subtracting the planned release from the remaining inflow (997,000 af – 499,000 af) created a joint use requirement of 498,000 af. Since this requirement is larger than the joint use storage zone, the entire joint use storage zone was to be evacuated as of June 1. The June 1 forecast also provides Reclamation with a joint-use pool target for

July 1. This is determined first by multiplying the assured June-July inflow forecast by the average July share of June-July runoff (34%) from Table 3 (997,000 af * 0.34 = 339,000 af). Lastly subtracting the 150,000 af expected release by Reclamation from the 339,000 af assured July inflow forecast would show a joint use evacuation requirement of 189,000 af on July 1. This indicated the entire joint-use storage zone should remain vacant through July 1 and filled with the remaining runoff in July. However, the downstream flooding experienced in June required the joint-use storage and part of the exclusive flood control zone be filled to mitigate flooding along the Bighorn River in Wyoming.

July 1 forecast: Pool elevation was 4728.7 feet, 3.7 feet into the exclusive flood control zone. Water was stored above the joint-use zone requirements to mitigate flooding along the Bighorn River in Wyoming. Since the reservoir had already filled the joint-use zone and was in the exclusive flood control zone, a July 1 joint-use evacuation target was not needed. If the joint-use zone had not already been occupied, comparison of assured July inflow against Reclamation's planned July release volume would be performed to assure adequate volume is evacuated without entering the exclusive flood control zone.

7. Other Considerations.

a. Some factors involved in assured storage refill are as follows. By using an assured inflow forecast there exists an 85-90 percent chance that inflow will be greater than the forecast, thereby resulting in an 85-90 percent chance that releases will have to be increased above conservation requirements in order to maintain evacuated flood control storage space in the joint use zone. However, releases necessary for conservation purposes are generally much less than those which can be tolerated without contributing to flood damages. For example conservation requirements may be satisfied with a release of 1,000 cfs while releases up to 8,000 cfs may be made without contributing to downstream flooding. An increase of releases in the approximate range of 1,000 cfs to 8,000 cfs will be required during 85-90 percent of the years when it becomes apparent that increasing releases are necessary to maintain evacuated joint use storage space. As an example, suppose a negative forecast error occurs resulting in the inflow being 200,000 af more than the forecasted assured inflow. Then this amount (200,000 af) will have to be released during the May-July period, in addition to conservation release requirements, in order to keep the pool level within the joint use zone. Maintaining joint use evacuation requirements throughout the May-July period will tend to spread this volume, and the resultant releases, over the entire period. However, in the event that non-damaging stages below the dam cannot be maintained and still keep the pool in the joint use zone, the exclusive flood control zone will have to be utilized. When the joint use flood control pool becomes filled, Plate 7-3 will be used as a guide to avoid overtopping the dam.

b. Forecasts made prior to May 1 will determine joint use space requirements on May 1. Any evacuation of space needed to achieve this will be made by Reclamation in a gradual and orderly manner.

c. On or after May 1, if pool levels encroach into the evacuated space required for flood control as determined from the techniques shown in Table 4, the Corps will determine evacuation flood control releases. During May, the Corps shall schedule flood control releases, which may be sometimes described as excess conservation spill necessary to target the June 1 requirement, to occur uniformly throughout the month. After June 1, the Corps shall schedule flood control evacuation releases necessary to meet the July 1 requirement as rapidly as downstream conditions permit. The above scenario from prior to May 1 through July 1 assumes the flood targets outlined in this manual are not exceeded during that period. If the flood targets are exceeded while at any pool elevation releases from the project will be reduced to a level that minimizes downstream flooding without creating undue risk of higher discharges later in the runoff season. See regulation plate 7-3 for assistance in determining flood control releases.

Table 4

Boysen Joint Use Requirements Example

(Using 2017 Data and Forecasts)

Be sure to work down each column. Following the 1st of each month, data can be filled in for that month.

Boysen May-July Forecasts

	1-Feb	1-Mar	1-Apr	1-May	1-Jun	1-Jul
Most Probable Actual:	0.953	1.195	1.356	1.517	1.517	
Assured Factor:	0.352	0.27	0.25	0.24	0.15	0.15
Assured Actual:	0.601	0.925	1.106	1.277	1.367	n/a
Measured inflow after May 1					0.37	
Remaining May-Jul Assured	0.601	0.925	1.106	1.277	0.997	n/a
Assured Inflow May-July	0.601	0.925	1.106	1.277		
Conservation Requirements May-July	0.583	0.776	0.707	1.097		
1 May Requirement	0.018	0.149	0.399	0.180		
1 May Elevation Requirement	4724.00	4717.00	4717.00	4717.00		
Assured Inflow June-July				0.971	0.997	
Conservation Requirements June-July				0.765	0.499	
1 June Requirement				0.205	0.498	
1 June Elevation Requirement				4717.00	4717.00	
Assured Inflow July					0.339	n/a
Conservation Requirements July					0.15	
1 July Requirement					0.189	n/a
1 July Elevation Requirement					4717.00	n/a

Color Codes

- User Entered
- Static Data from WCM
- Calculated Value

Notes:

July forecast not produced in 2017, as the joint use storage was already full.

In the event the runoff pattern occurs significantly different than anticipated, additional (middle of the month) forecast of remaining runoff should be made to determine new space requirements to protect both the flood control and conservation (assurance of joint use fill) useage of the joint use zone.

Table 4 is generated from a Microsoft Excel spreadsheet and is used to calculate the drawdown requirement. This spreadsheet is maintained by the Omaha District and is available on request.

Years	Col 1 - Observed BOYN May-Jul Inflow Natural (maf)	Col 2- Forecast BOYN May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1981	0.46	0.49	0.14	**0.32**	Exceeded
1982	0.68	0.74	0.39	**0.29**	Exceeded
1983	1.00	0.70	0.34	**0.66**	Exceeded
1984	0.68	0.70	0.35	**0.33**	Exceeded
1985	0.29	0.49	0.14	**0.15**	Exceeded
1986	1.03	0.68	0.32	**0.70**	Exceeded
1987	0.46	0.66	0.30	**0.15**	Exceeded
1988	0.18	0.58	0.23	**-0.04**	**Not Exceeded**
1989	0.50	0.31	-0.04	**0.54**	Exceeded
1990	0.29	0.67	0.31	**-0.02**	**Not Exceeded**
1991	0.90	0.51	0.16	**0.74**	Exceeded
1992	0.29	0.61	0.26	**0.03**	Exceeded
1993	0.68	0.53	0.17	**0.50**	Exceeded
1994	0.16	0.66	0.31	**-0.15**	**Not Exceeded**
1995	1.19	0.58	0.23	**0.96**	Exceeded
1996	0.73	1.08	0.73	**0.00**	Exceeded
1997	0.95	0.94	0.58	**0.37**	Exceeded
1998	0.78	0.84	0.49	**0.29**	Exceeded
1999	1.11	0.95	0.59	**0.52**	Exceeded
2000	0.28	0.52	0.17	**0.11**	Exceeded
2001	0.08	0.25	-0.10	**0.18**	Exceeded
2002	0.20	0.23	-0.13	**0.32**	Exceeded
2003	0.28	0.35	0.00	**0.29**	Exceeded
2004	0.36	0.52	0.16	**0.19**	Exceeded
2005	0.59	0.72	0.37	**0.22**	Exceeded
2006	0.21	0.58	0.23	**-0.02**	**Not Exceeded**
2007	0.19	0.30	-0.05	**0.24**	Exceeded
2008	0.58	0.54	0.19	**0.39**	Exceeded
2009	0.80	0.63	0.28	**0.52**	Exceeded
2010	0.86	0.67	0.32	**0.54**	Exceeded
2011	1.03	0.74	0.39	**0.65**	Exceeded
2012	0.22	0.69	0.34	**-0.12**	**Not Exceeded**
2013	0.25	0.22	-0.13	**0.38**	Exceeded
2014	0.69	0.69	0.33	**0.35**	Exceeded
2015	0.74	0.40	0.04	**0.70**	Exceeded
2016	0.73	0.44	0.09	**0.64**	Exceeded
2017	1.60	0.86	0.51	**1.09**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.352 maf**
Years in Record:	37
Years Forecast Exceeded:	32
Exeedance Probability:	**86%**

Water Control Manual
Boysen Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Feb 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

Years	Col 1 - Observed BOYN Apr-Jul Inflow Natural (maf)	Col 2 - Forecast BOYN Apr-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1981	0.46	0.43	0.16	**0.29**	Exceeded
1982	0.68	0.70	0.43	**0.25**	Exceeded
1983	1.00	0.64	0.37	**0.63**	Exceeded
1984	0.68	0.69	0.42	**0.26**	Exceeded
1985	0.29	0.47	0.20	**0.09**	Exceeded
1986	1.03	1.13	0.86	**0.17**	Exceeded
1987	0.46	0.81	0.54	**-0.08**	**Not Exceeded**
1988	0.18	0.45	0.18	**0.00**	Exceeded
1989	0.50	0.32	0.05	**0.45**	Exceeded
1990	0.29	0.48	0.21	**0.08**	Exceeded
1991	0.90	0.43	0.16	**0.74**	Exceeded
1992	0.29	0.43	0.16	**0.13**	Exceeded
1993	0.68	0.48	0.21	**0.47**	Exceeded
1994	0.16	0.62	0.35	**-0.20**	**Not Exceeded**
1995	1.19	0.67	0.40	**0.79**	Exceeded
1996	0.73	1.05	0.78	**-0.05**	**Not Exceeded**
1997	0.95	0.95	0.68	**0.27**	Exceeded
1998	0.78	0.74	0.47	**0.31**	Exceeded
1999	1.11	0.95	0.68	**0.43**	Exceeded
2000	0.28	0.47	0.20	**0.08**	Exceeded
2001	0.08	0.21	-0.06	**0.14**	Exceeded
2002	0.20	0.13	-0.14	**0.34**	Exceeded
2003	0.28	0.44	0.17	**0.11**	Exceeded
2004	0.36	0.60	0.33	**0.03**	Exceeded
2005	0.59	0.63	0.36	**0.23**	Exceeded
2006	0.21	0.55	0.28	**-0.07**	**Not Exceeded**
2007	0.19	0.30	0.03	**0.16**	Exceeded
2008	0.58	0.52	0.25	**0.34**	Exceeded
2009	0.80	0.46	0.19	**0.61**	Exceeded
2010	0.86	0.53	0.26	**0.60**	Exceeded
2011	1.03	0.75	0.48	**0.56**	Exceeded
2012	0.22	0.70	0.43	**-0.20**	**Not Exceeded**
2013	0.25	0.34	0.07	**0.18**	Exceeded
2014	0.69	0.76	0.49	**0.20**	Exceeded
2015	0.74	0.52	0.25	**0.50**	Exceeded
2016	0.73	0.45	0.18	**0.55**	Exceeded
2017	1.60	1.26	0.99	**0.60**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.27 maf**
Years in Record:	37
Years Forecast Exceeded:	32
Exeedance Probability:	**86%**

Water Control Manual
Boysen Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Mar 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

Plate E-VIII-2

Years	Col 1 - Observed BOYN May-Jul Inflow Natural (maf)	Col 2 - Forecast BOYN May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1981	0.46	0.45	0.20	**0.26**	Exceeded
1982	0.68	0.83	0.58	**0.09**	Exceeded
1983	1.00	0.82	0.57	**0.44**	Exceeded
1984	0.68	0.62	0.37	**0.31**	Exceeded
1985	0.29	0.48	0.23	**0.07**	Exceeded
1986	1.03	1.09	0.84	**0.19**	Exceeded
1987	0.46	0.78	0.53	**-0.07**	**Not Exceeded**
1988	0.18	0.50	0.25	**-0.07**	**Not Exceeded**
1989	0.50	0.45	0.20	**0.30**	Exceeded
1990	0.29	0.48	0.23	**0.06**	Exceeded
1991	0.90	0.52	0.27	**0.63**	Exceeded
1992	0.29	0.40	0.15	**0.14**	Exceeded
1993	0.68	0.39	0.14	**0.54**	Exceeded
1994	0.16	0.50	0.25	**-0.10**	**Not Exceeded**
1995	1.19	0.61	0.36	**0.83**	Exceeded
1996	0.73	0.97	0.72	**0.01**	Exceeded
1997	0.95	0.95	0.70	**0.25**	Exceeded
1998	0.78	0.82	0.57	**0.21**	Exceeded
1999	1.11	0.88	0.63	**0.48**	Exceeded
2000	0.28	0.46	0.21	**0.07**	Exceeded
2001	0.08	0.09	-0.16	**0.24**	Exceeded
2002	0.20	0.21	-0.04	**0.24**	Exceeded
2003	0.28	0.53	0.28	**0.00**	**Not Exceeded**
2004	0.36	0.28	0.03	**0.32**	Exceeded
2005	0.59	0.59	0.34	**0.25**	Exceeded
2006	0.21	0.48	0.23	**-0.03**	**Not Exceeded**
2007	0.19	0.27	0.02	**0.17**	Exceeded
2008	0.58	0.57	0.32	**0.27**	Exceeded
2009	0.80	0.54	0.29	**0.51**	Exceeded
2010	0.86	0.49	0.24	**0.62**	Exceeded
2011	1.03	0.63	0.38	**0.65**	Exceeded
2012	0.22	0.36	0.11	**0.12**	Exceeded
2013	0.25	0.24	-0.01	**0.26**	Exceeded
2014	0.69	0.82	0.57	**0.12**	Exceeded
2015	0.74	0.23	-0.02	**0.76**	Exceeded
2016	0.73	0.52	0.27	**0.46**	Exceeded
2017	1.60	1.18	0.93	**0.67**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.25 maf**
Years in Record:	37
Years Forecast Exceeded:	32
Exeedance Probability:	**86%**

Water Control Manual
Boysen Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Apr 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

Years	Col 1 - Observed BOYN May-Jul Inflow Natural (maf)	Col 2 - Forecast BOYN May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1981	0.46	0.39	0.15	**0.31**	Exceeded
1982	0.68	0.72	0.48	**0.20**	Exceeded
1983	1.00	0.89	0.65	**0.35**	Exceeded
1984	0.68	0.79	0.55	**0.13**	Exceeded
1985	0.29	0.29	0.05	**0.25**	Exceeded
1986	1.03	1.05	0.81	**0.22**	Exceeded
1987	0.46	0.68	0.44	**0.02**	Exceeded
1988	0.18	0.45	0.21	**-0.03**	**Not Exceeded**
1989	0.50	0.42	0.18	**0.32**	Exceeded
1990	0.29	0.44	0.20	**0.10**	Exceeded
1991	0.90	0.74	0.50	**0.39**	Exceeded
1992	0.29	0.32	0.08	**0.21**	Exceeded
1993	0.68	0.55	0.31	**0.36**	Exceeded
1994	0.16	0.46	0.22	**-0.06**	**Not Exceeded**
1995	1.19	0.90	0.66	**0.53**	Exceeded
1996	0.73	0.89	0.65	**0.08**	Exceeded
1997	0.95	1.02	0.78	**0.17**	Exceeded
1998	0.78	0.81	0.57	**0.22**	Exceeded
1999	1.11	1.37	1.13	**-0.02**	**Not Exceeded**
2000	0.28	0.38	0.14	**0.14**	Exceeded
2001	0.08	0.08	-0.16	**0.24**	Exceeded
2002	0.20	0.25	0.01	**0.19**	Exceeded
2003	0.28	0.55	0.31	**-0.02**	**Not Exceeded**
2004	0.36	0.44	0.20	**0.16**	Exceeded
2005	0.59	0.50	0.26	**0.33**	Exceeded
2006	0.21	0.43	0.19	**0.01**	Exceeded
2007	0.19	0.20	-0.04	**0.23**	Exceeded
2008	0.58	0.51	0.27	**0.31**	Exceeded
2009	0.80	0.79	0.55	**0.25**	Exceeded
2010	0.86	0.59	0.35	**0.51**	Exceeded
2011	1.03	0.79	0.55	**0.48**	Exceeded
2012	0.22	0.26	0.02	**0.20**	Exceeded
2013	0.25	0.37	0.13	**0.11**	Exceeded
2014	0.69	0.64	0.40	**0.29**	Exceeded
2015	0.74	0.19	-0.05	**0.80**	Exceeded
2016	0.73	0.51	0.27	**0.46**	Exceeded
2017	1.60	1.37	1.13	**0.46**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured)	
Factor:	**0.201**
Years in Record:	37
Years Forecast Exceeded:	31
Exeedance Probability:	**84%**

Water Control Manual
Boysen Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (May 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

Years	Col 1 - Observed BOYN May-Jul Inflow Natural (maf)	Col 2 - Forecast BOYN May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1981	0.46	0.43	0.28	**0.18**	Exceeded
1982	0.68	0.55	0.40	**0.27**	Exceeded
1983	1.00	0.93	0.78	**0.23**	Exceeded
1984	0.68	0.69	0.54	**0.15**	Exceeded
1985	0.29	0.17	0.02	**0.27**	Exceeded
1986	1.03	0.92	0.77	**0.26**	Exceeded
1987	0.46	0.73	0.58	**-0.12**	**Not Exceeded**
1988	0.18	0.33	0.18	**0.00**	**Not Exceeded**
1989	0.50	0.53	0.38	**0.13**	Exceeded
1990	0.29	0.31	0.16	**0.14**	Exceeded
1991	0.90	0.86	0.71	**0.19**	Exceeded
1992	0.29	0.35	0.20	**0.09**	Exceeded
1993	0.68	0.54	0.39	**0.29**	Exceeded
1994	0.16	0.30	0.15	**0.01**	Exceeded
1995	1.19	1.11	0.96	**0.23**	Exceeded
1996	0.73	0.86	0.71	**0.02**	Exceeded
1997	0.95	0.96	0.81	**0.14**	Exceeded
1998	0.78	0.77	0.62	**0.16**	Exceeded
1999	1.11	1.32	1.17	**-0.06**	**Not Exceeded**
2000	0.28	0.35	0.20	**0.08**	Exceeded
2001	0.08	-0.05	-0.20	**0.28**	Exceeded
2002	0.20	0.16	0.01	**0.18**	Exceeded
2003	0.28	0.47	0.32	**-0.03**	**Not Exceeded**
2004	0.36	0.38	0.23	**0.13**	Exceeded
2005	0.59	0.61	0.46	**0.13**	Exceeded
2006	0.21	0.27	0.12	**0.09**	Exceeded
2007	0.19	0.16	0.01	**0.18**	Exceeded
2008	0.58	0.72	0.57	**0.02**	Exceeded
2009	0.80	0.72	0.57	**0.23**	Exceeded
2010	0.86	0.82	0.67	**0.19**	Exceeded
2011	1.03	1.04	0.89	**0.14**	Exceeded
2012	0.22	0.21	0.06	**0.16**	Exceeded
2013	0.25	0.47	0.32	**-0.07**	**Not Exceeded**
2014	0.69	0.55	0.40	**0.29**	Exceeded
2015	0.74	0.50	0.35	**0.39**	Exceeded
2016	0.73	0.59	0.44	**0.29**	Exceeded
2017	1.60	1.44	1.29	**0.31**	Exceeded

Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.15 maf**
Years in Record:	37
Years Forecast Exceeded:	32
Exeedance Probability:	**86%**

Water Control Manual
Boysen Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Jun 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

Years	Col 1 - Observed BOYN May-Jul Inflow Natural (maf)	Col 2 - Forecast BOYN May-Jul Inflow Natural (maf)	Col 3 Forecast - Assured (maf)	Col 4 Forecast - Assured - Obs (maf)	Col 5 Exceedance Occurrences
1981	0.46	0.43	0.28	**0.18**	Exceeded
1982	0.68	0.55	0.40	**0.27**	Exceeded
1983	1.00	0.93	0.78	**0.23**	Exceeded
1984	0.68	0.69	0.54	**0.15**	Exceeded
1985	0.29	0.17	0.02	**0.27**	Exceeded
1986	1.03	0.92	0.77	**0.26**	Exceeded
1987	0.46	0.73	0.58	**-0.12**	**Not Exceeded**
1988	0.18	0.33	0.18	**0.00**	**Not Exceeded**
1989	0.50	0.53	0.38	**0.13**	Exceeded
1990	0.29	0.31	0.16	**0.14**	Exceeded
1991	0.90	0.86	0.71	**0.19**	Exceeded
1992	0.29	0.35	0.20	**0.09**	Exceeded
1993	0.68	0.54	0.39	**0.29**	Exceeded
1994	0.16	0.30	0.15	**0.01**	Exceeded
1995	1.19	1.11	0.96	**0.23**	Exceeded
1996	0.73	0.86	0.71	**0.02**	Exceeded
1997	0.95	0.96	0.81	**0.14**	Exceeded
1998	0.78	0.77	0.62	**0.16**	Exceeded
1999	1.11	1.32	1.17	**-0.06**	**Not Exceeded**
2000	0.28	0.35	0.20	**0.08**	Exceeded
2001	0.08	-0.05	-0.20	**0.28**	Exceeded
2002	0.20	0.16	0.01	**0.18**	Exceeded
2003	0.28	0.47	0.32	**-0.03**	**Not Exceeded**
2004	0.36	0.38	0.23	**0.13**	Exceeded
2005	0.59	0.61	0.46	**0.13**	Exceeded
2006	0.21	0.27	0.12	**0.09**	Exceeded
2007	0.19	0.16	0.01	**0.18**	Exceeded
2008	0.58	0.72	0.57	**0.02**	Exceeded
2009	0.80	0.72	0.57	**0.23**	Exceeded
2010	0.86	0.82	0.67	**0.19**	Exceeded
2011	1.03	1.04	0.89	**0.14**	Exceeded
2012	0.22	0.21	0.06	**0.16**	Exceeded
2013	0.25	0.47	0.32	**-0.07**	**Not Exceeded**
2014	0.69	0.55	0.40	**0.29**	Exceeded
2015	0.74	0.50	0.35	**0.39**	Exceeded
2016	0.73	0.59	0.44	**0.29**	Exceeded
2017	1.60	1.44	1.29	**0.31**	Exceeded

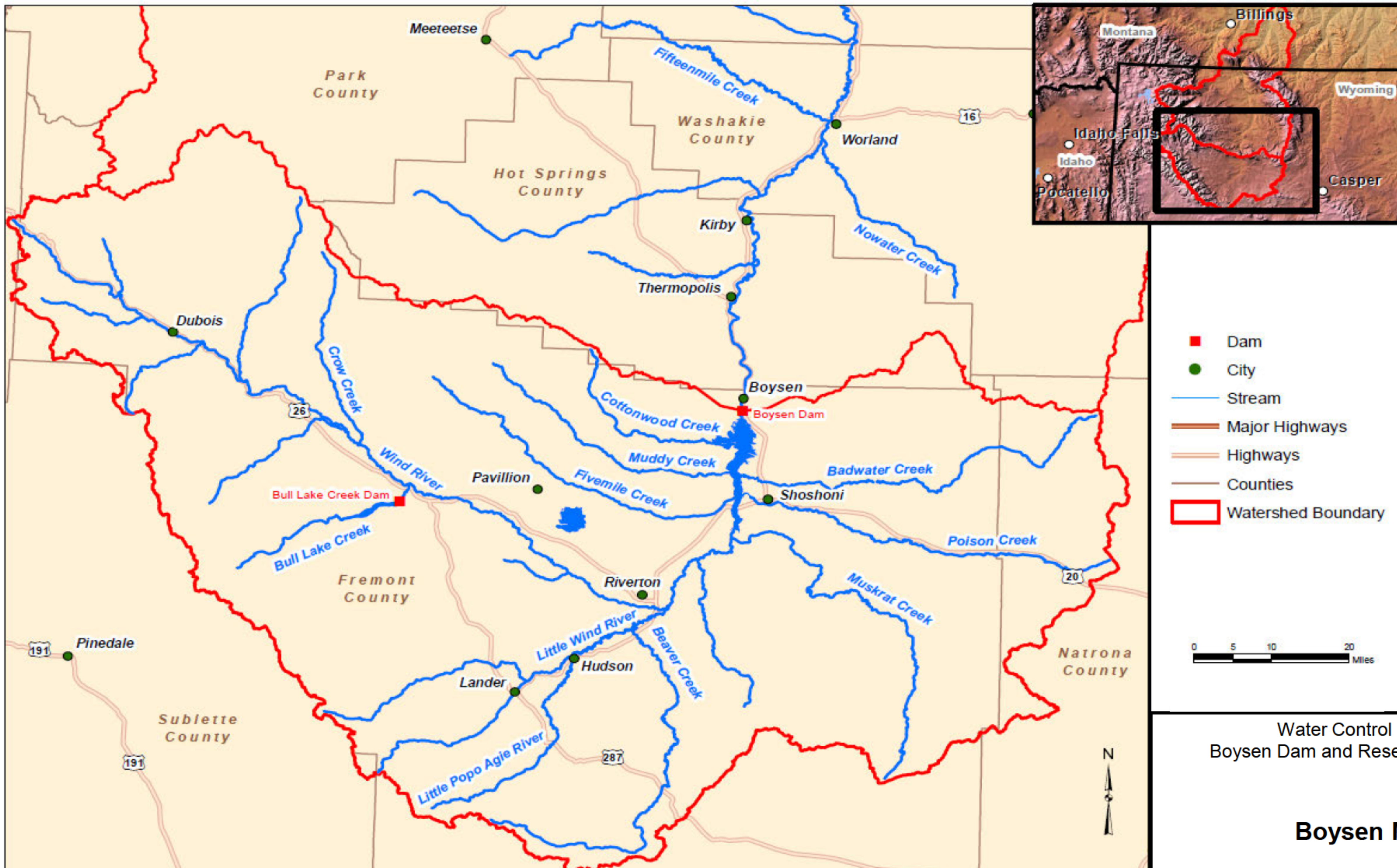
Note: A negative Forecast - Assured - Obs (Column 4) value indicates the observed runoff did not exceed the Forecasted Assured (factored) inflow (Column 3).

STATS	
Exeedance (assured) Factor:	**0.15 maf**
Years in Record:	37
Years Forecast Exceeded:	32
Exeedance Probability:	**86%**

Water Control Manual
Boysen Dam and Reservoir, Wyoming

May-July Inflow Forecast Assured Fill Analysis (Jul 1 Forecast)

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

Boysen Map

US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska

Plate 2-1

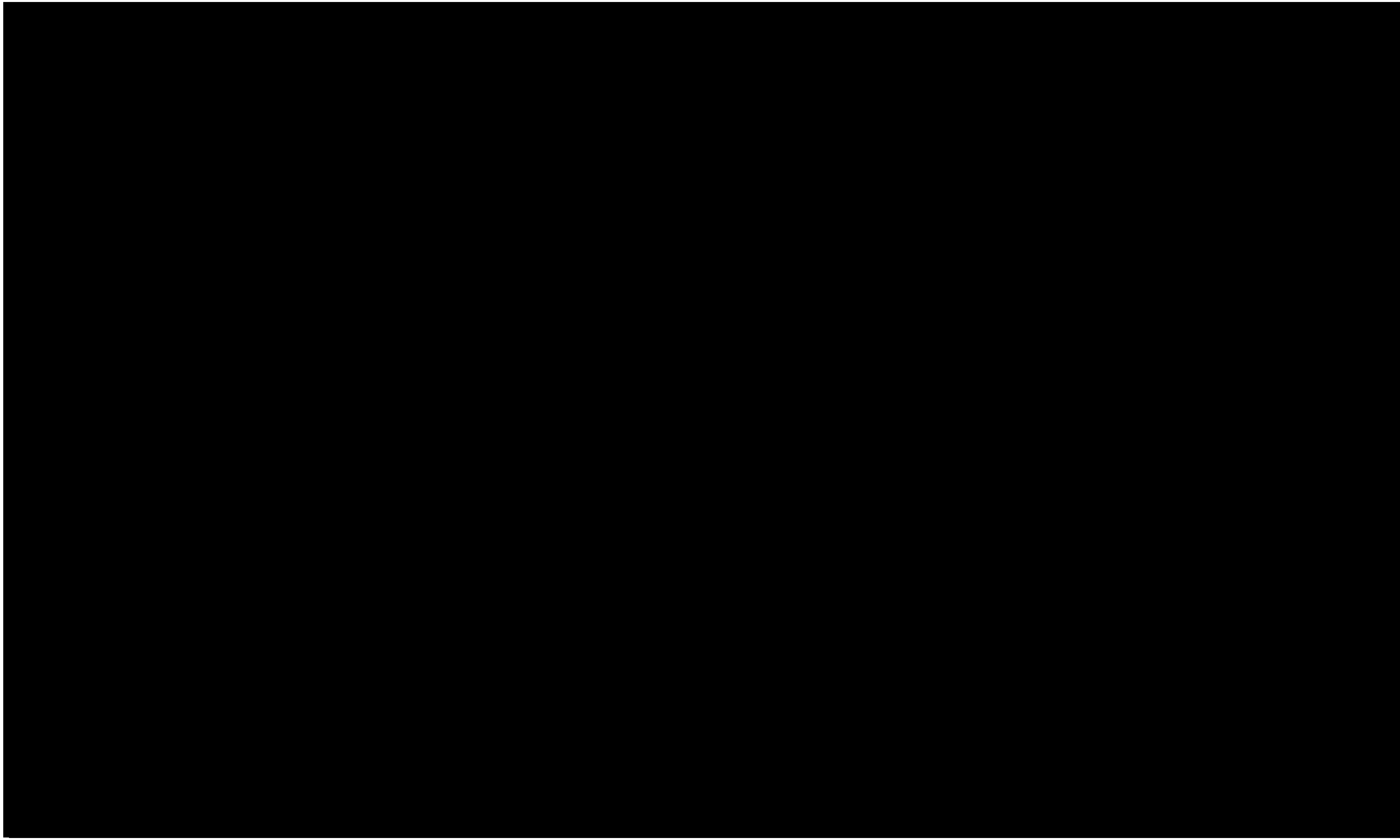


Plate 2-2

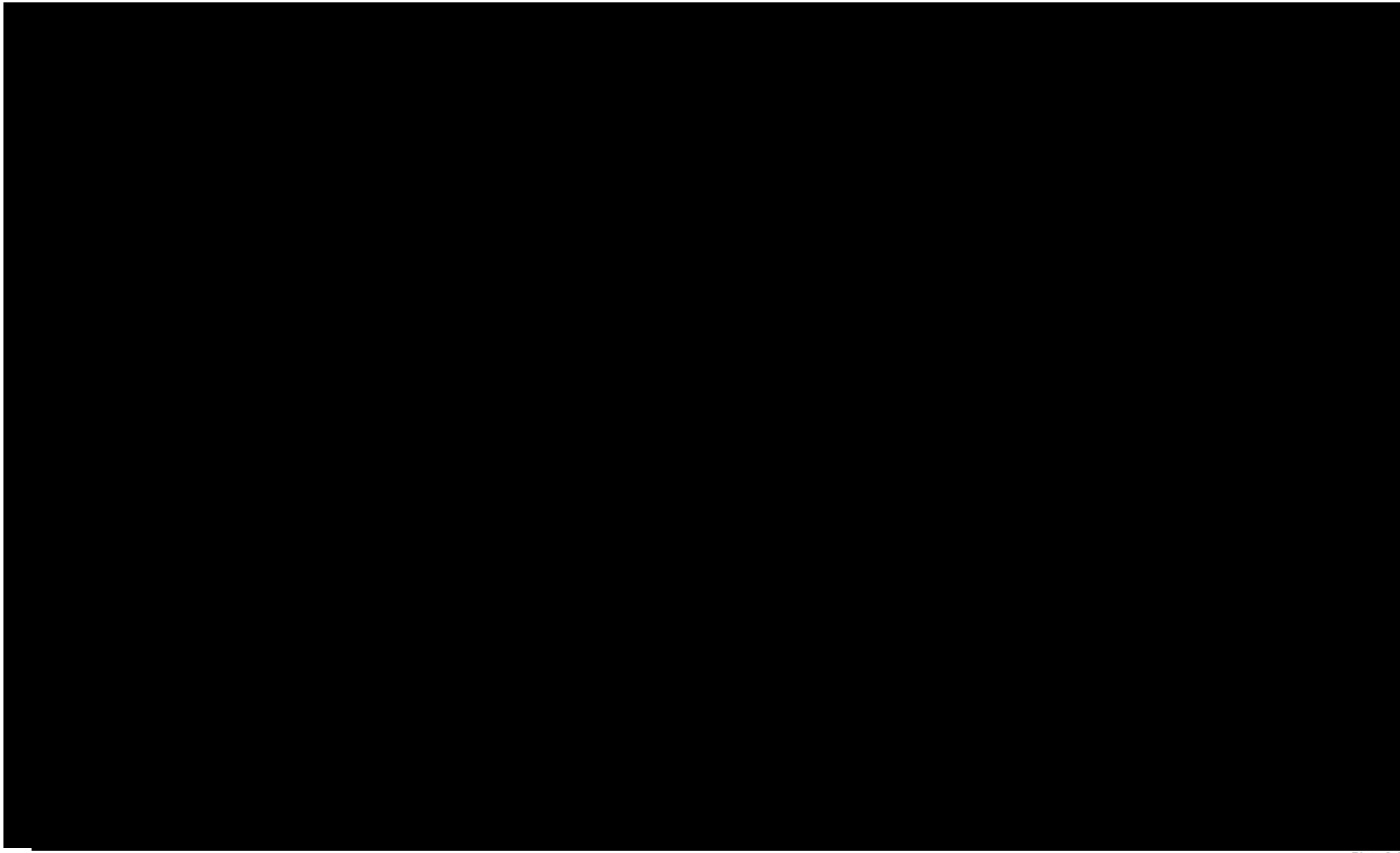


Plate 2-3

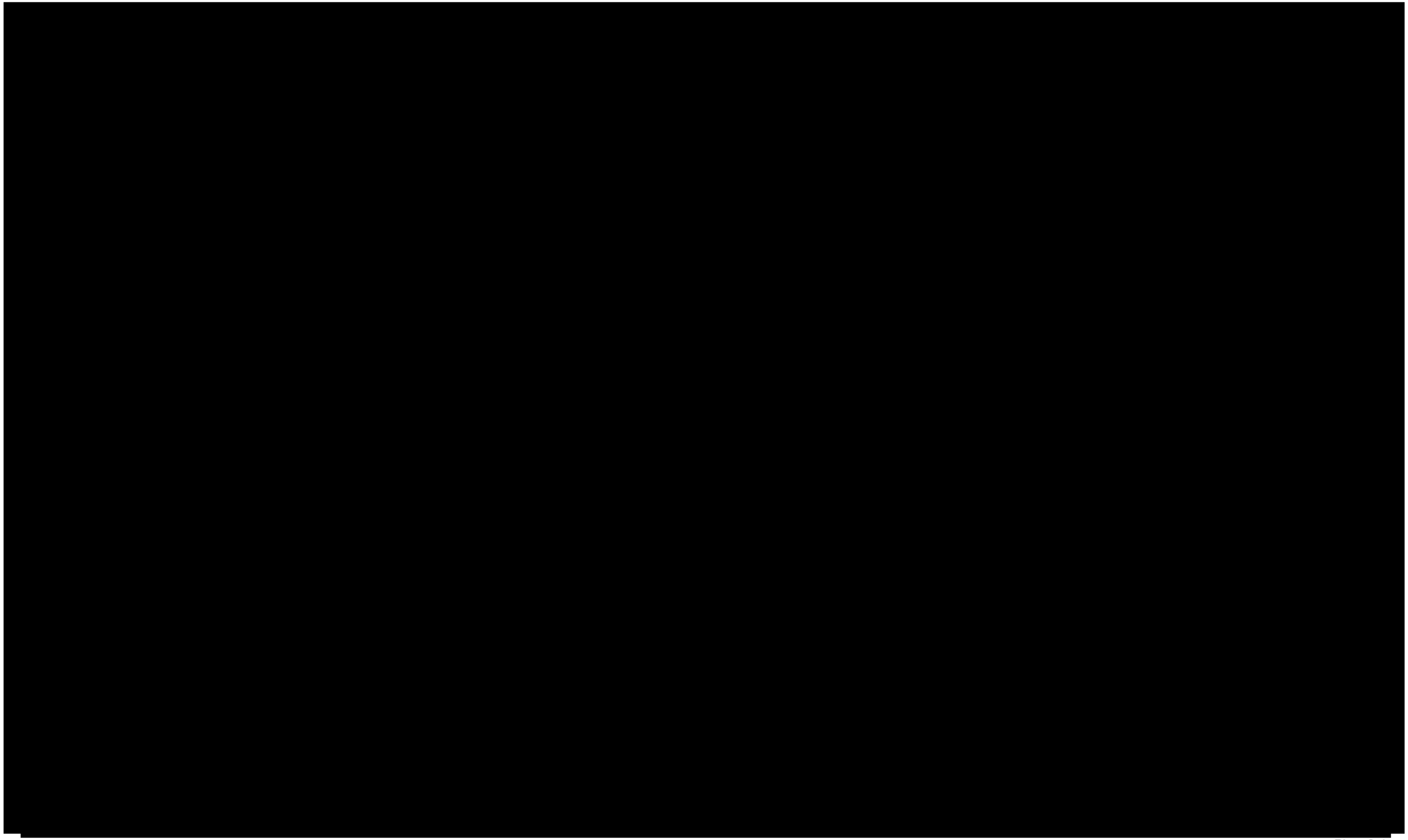


Plate 2-4

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Plate 2-5

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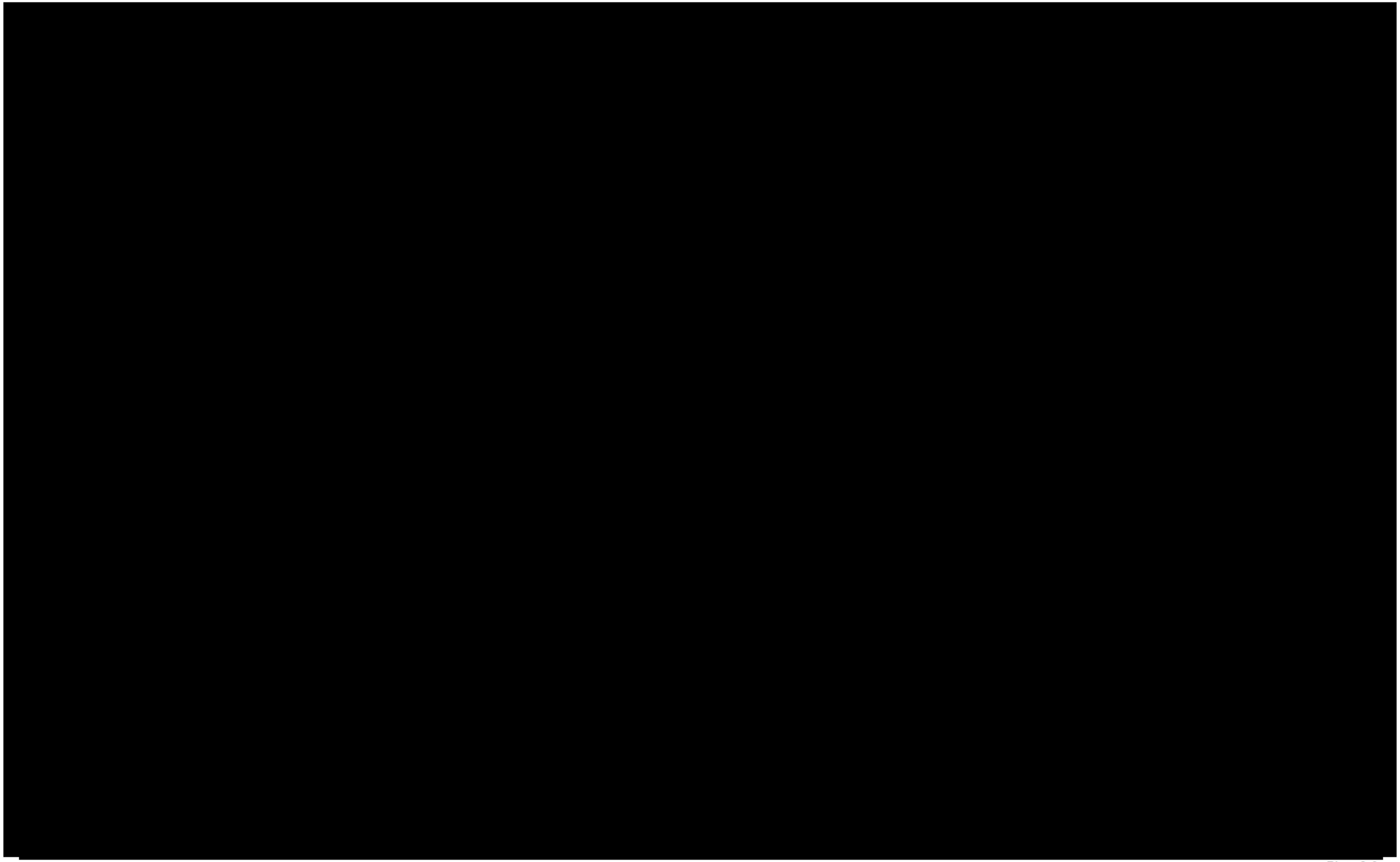
Plate 2-6

[redacted]

Plate 2-7



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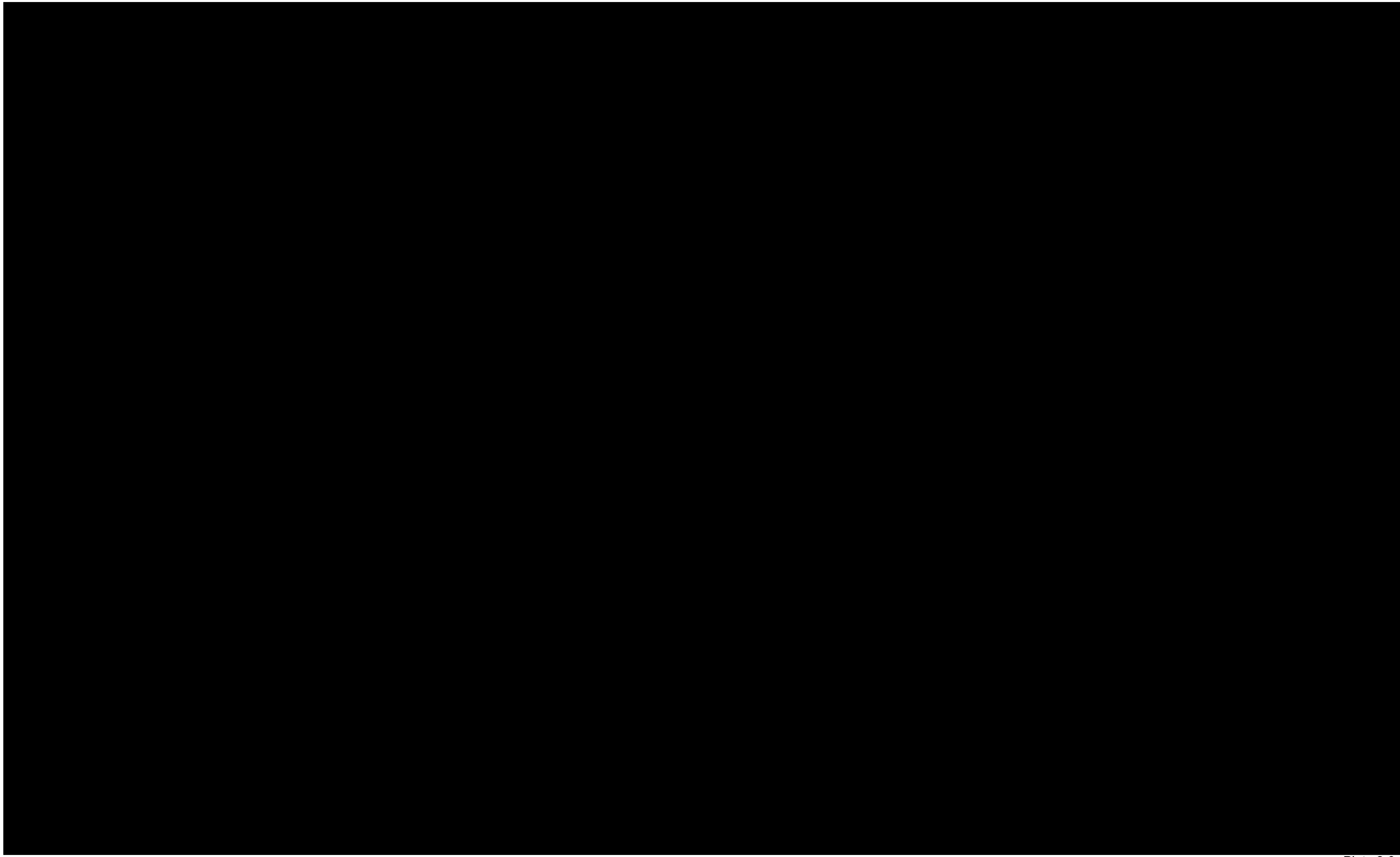

Plate 2-9

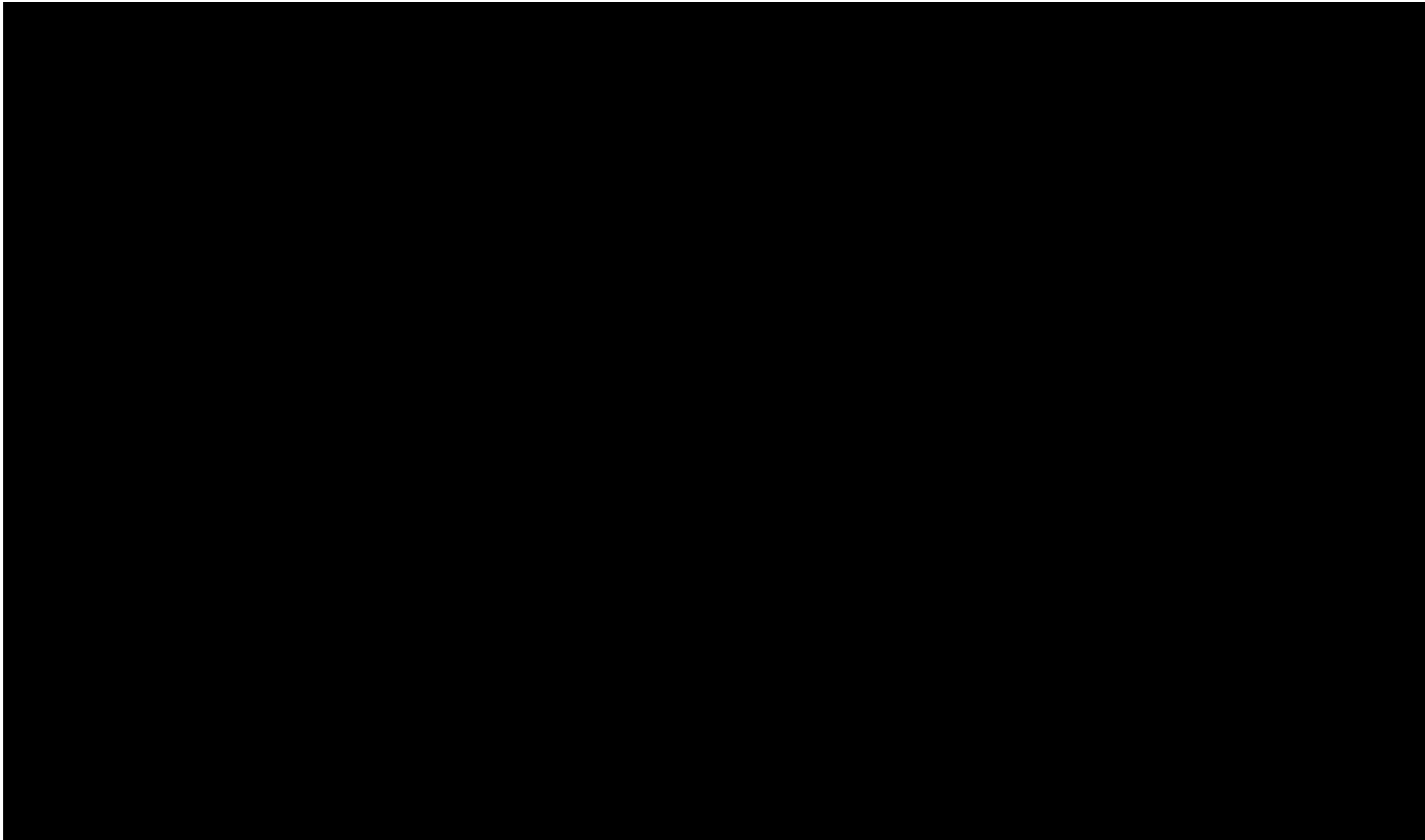

Plate 2-10

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Plate 2-11

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Plate 2-12

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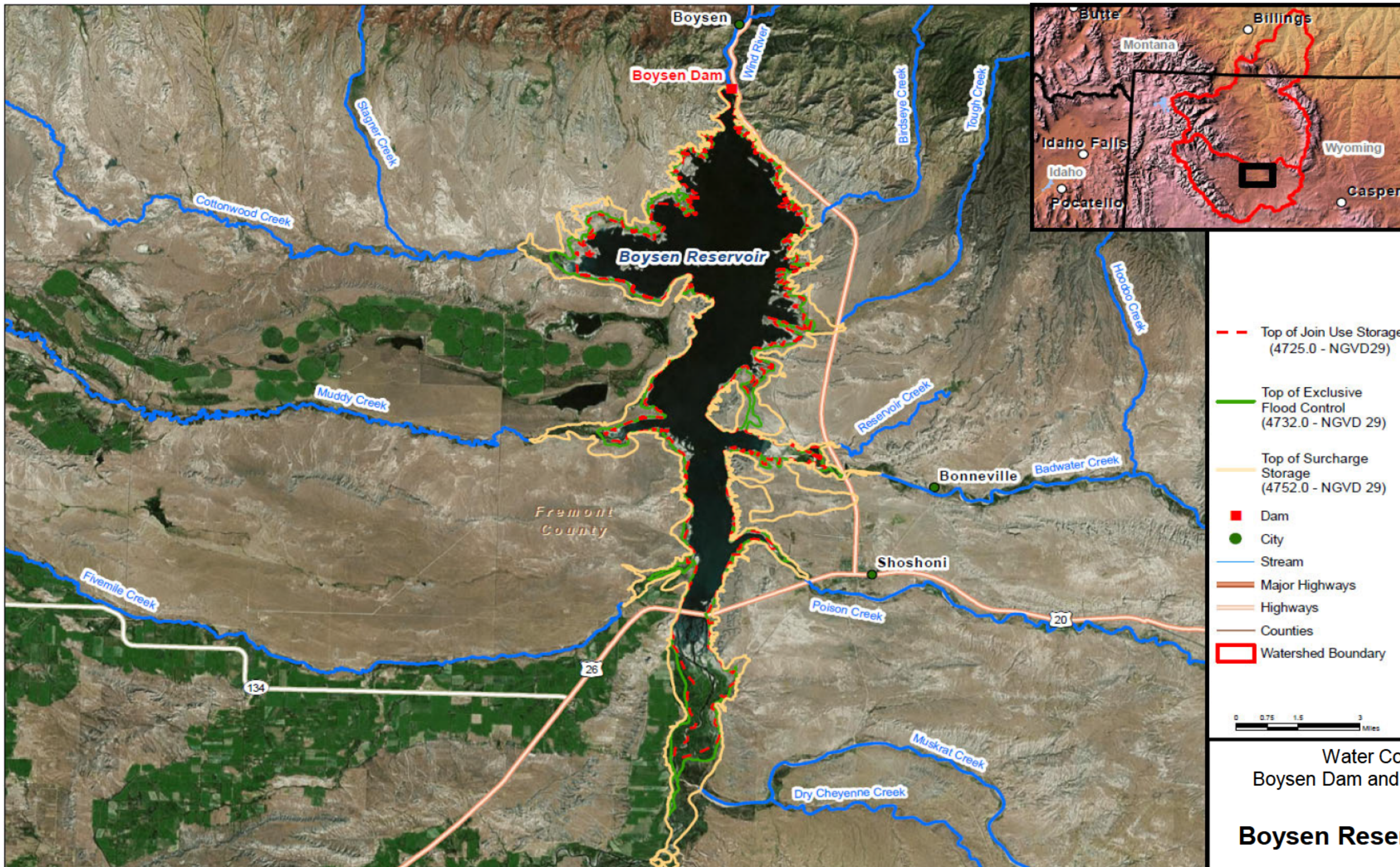
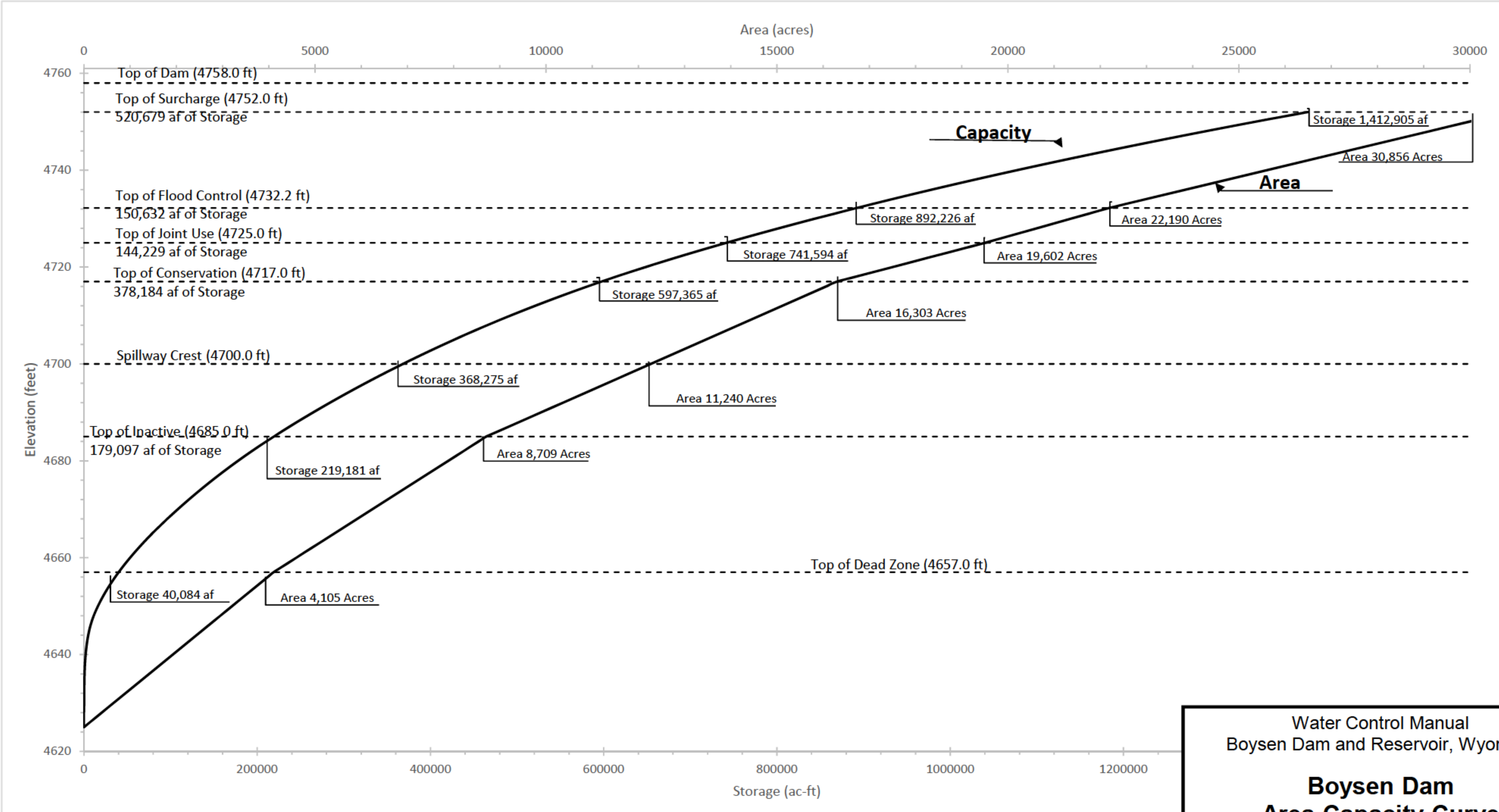
Plate 2-13



Water Control Manual
Boysen Dam and Reservoir, Wyoming

Boysen Reservoir Inundation

US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

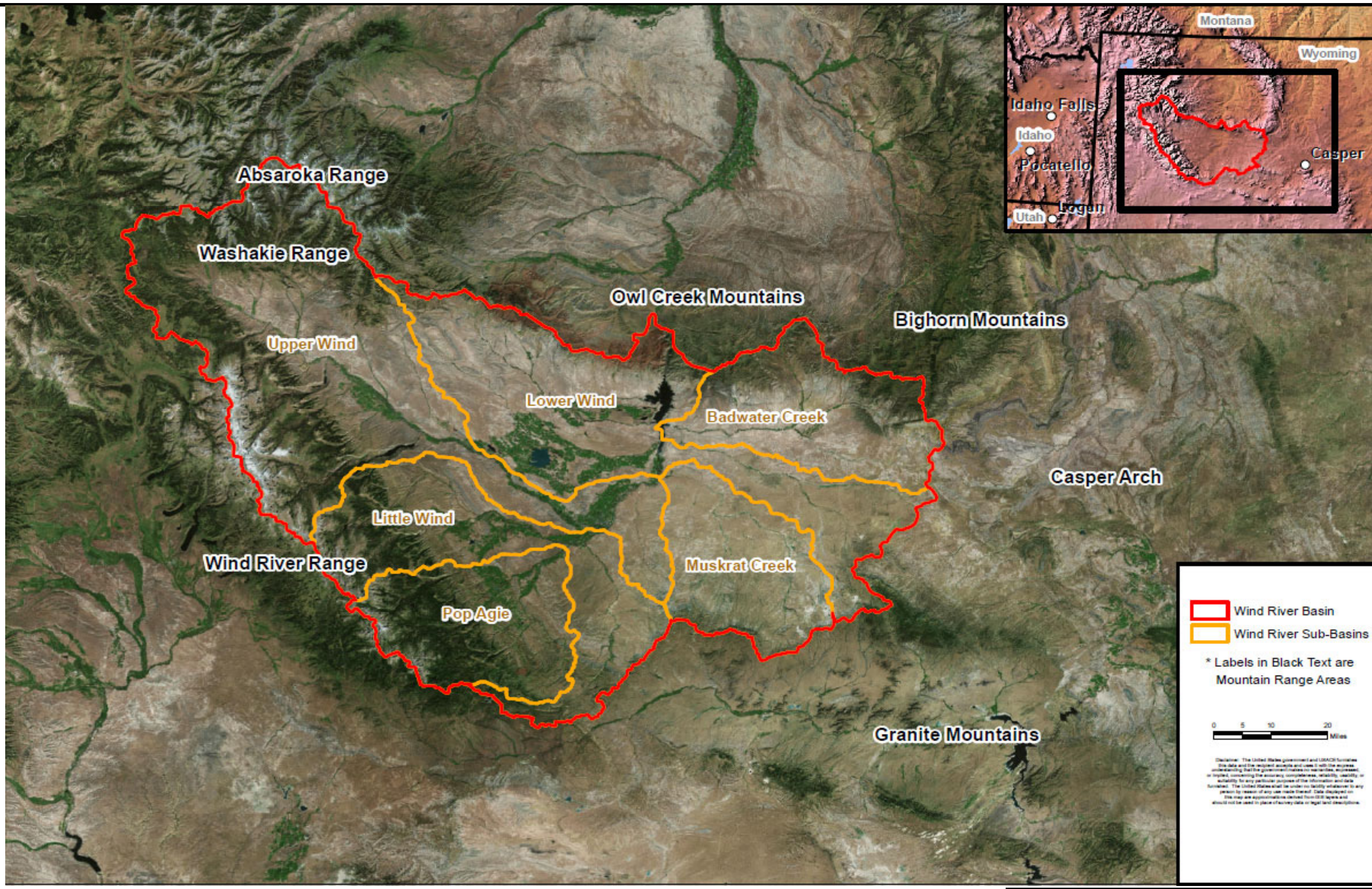


Per Reclamation survey, July 1994.

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Boysen Dam
Area-Capacity Curve

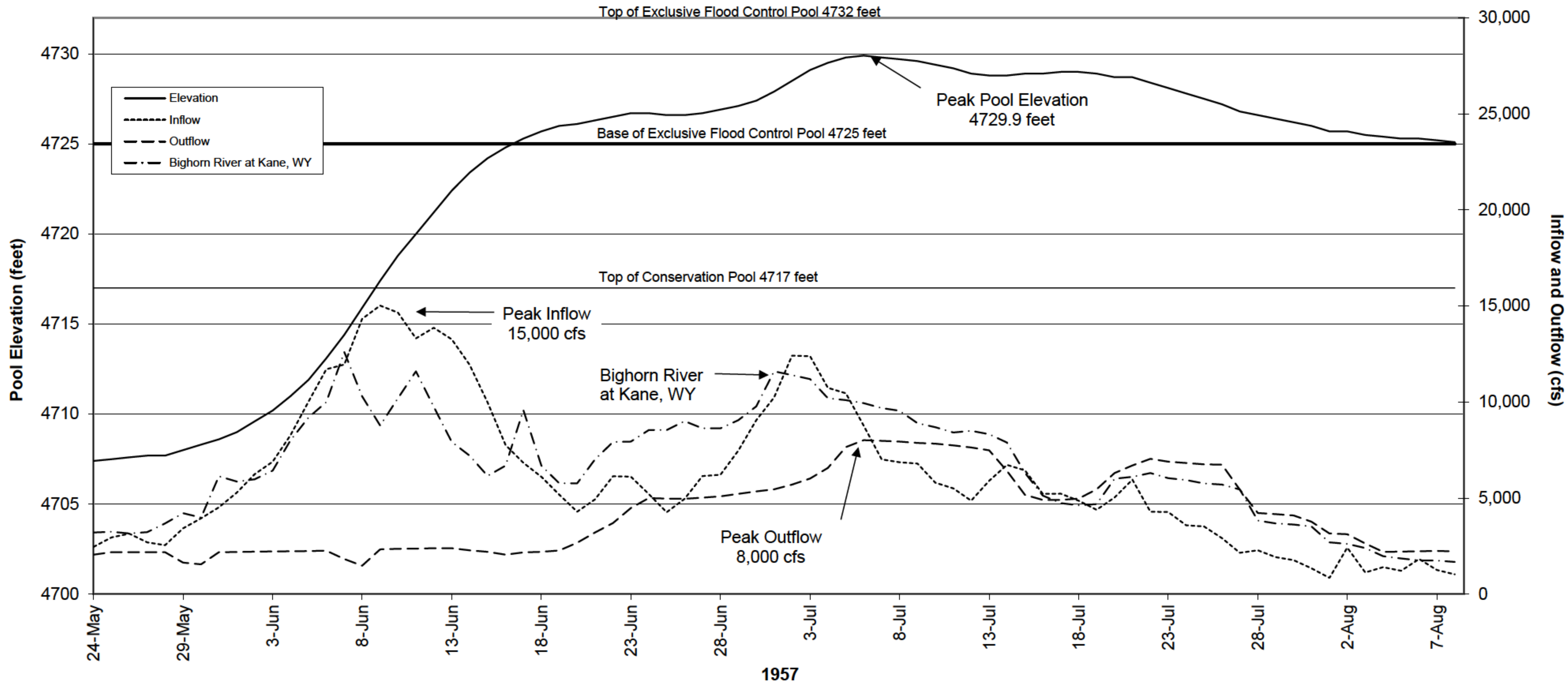
US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

Sub Basin Map

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020

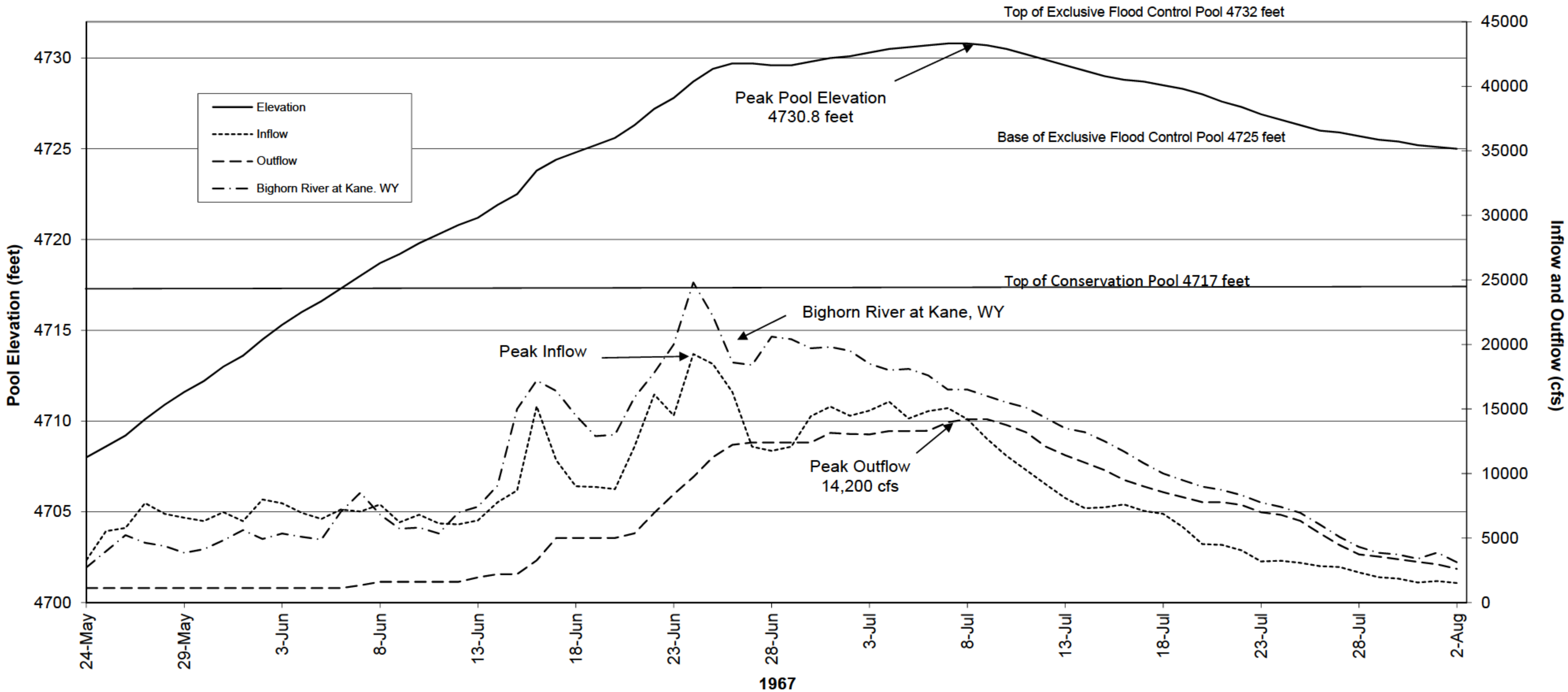


Source: USBR Hydromet Data, USGS gage data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

1957 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



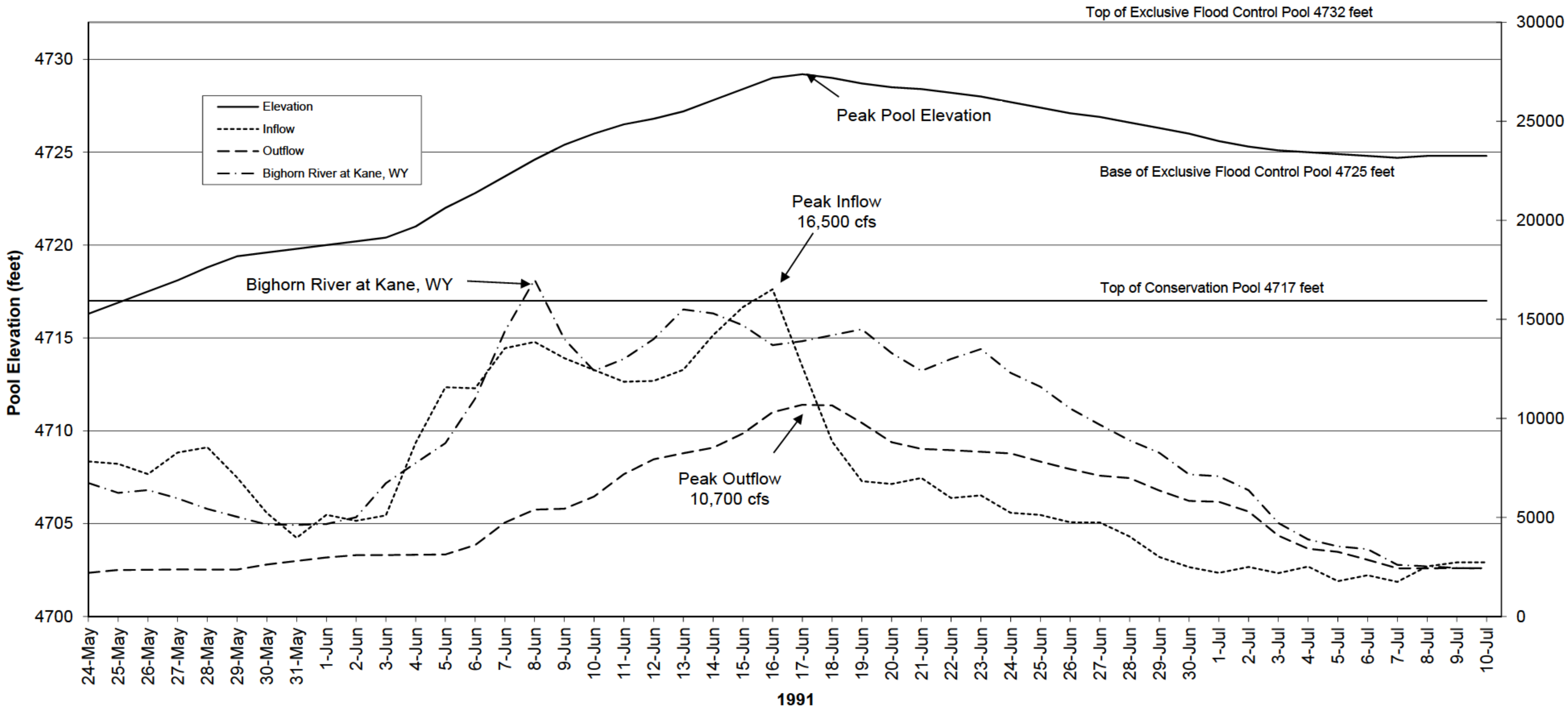
Source: USBR Hydromet Data, USGS gage data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

1967 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

Plate 4-3

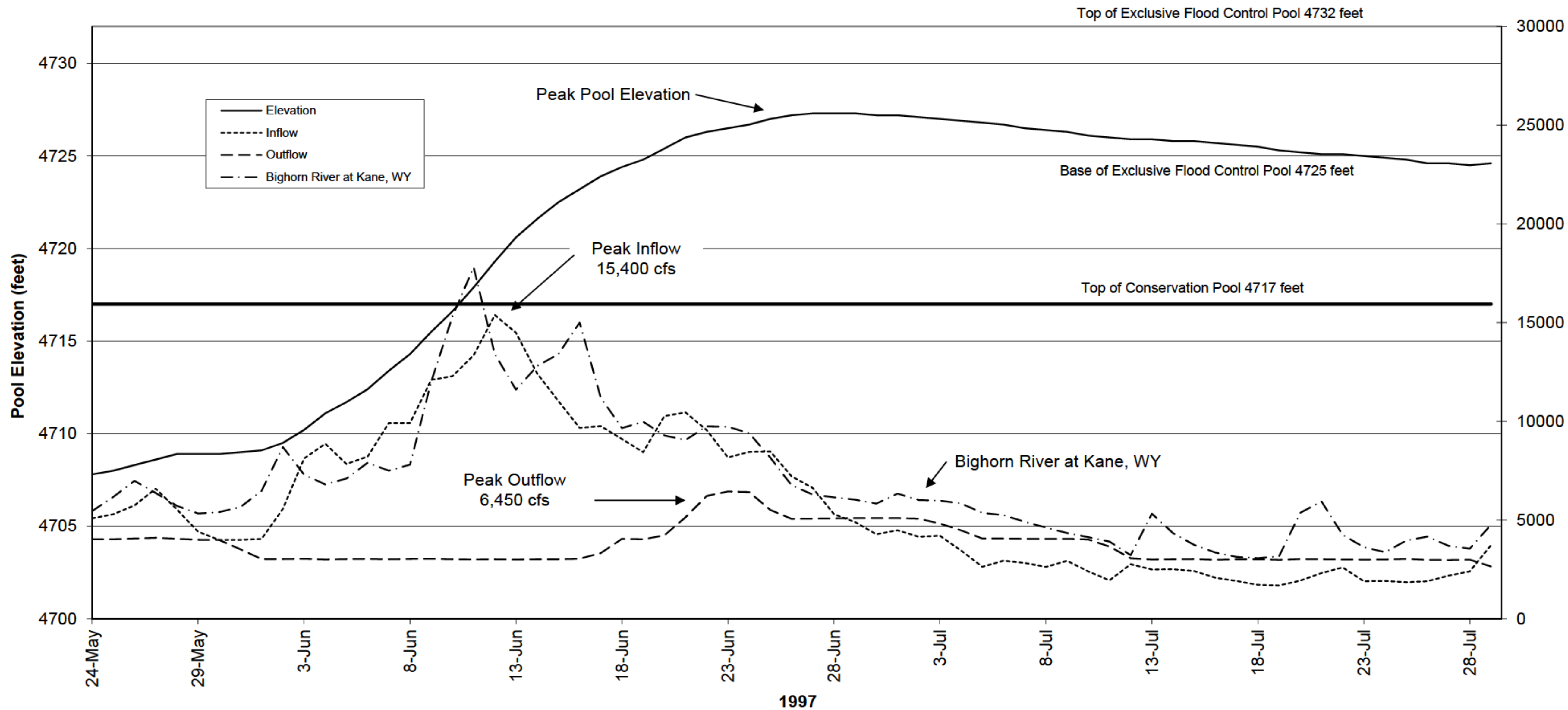


Source: USBR Hydromet Data, USGS gage data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

1991 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

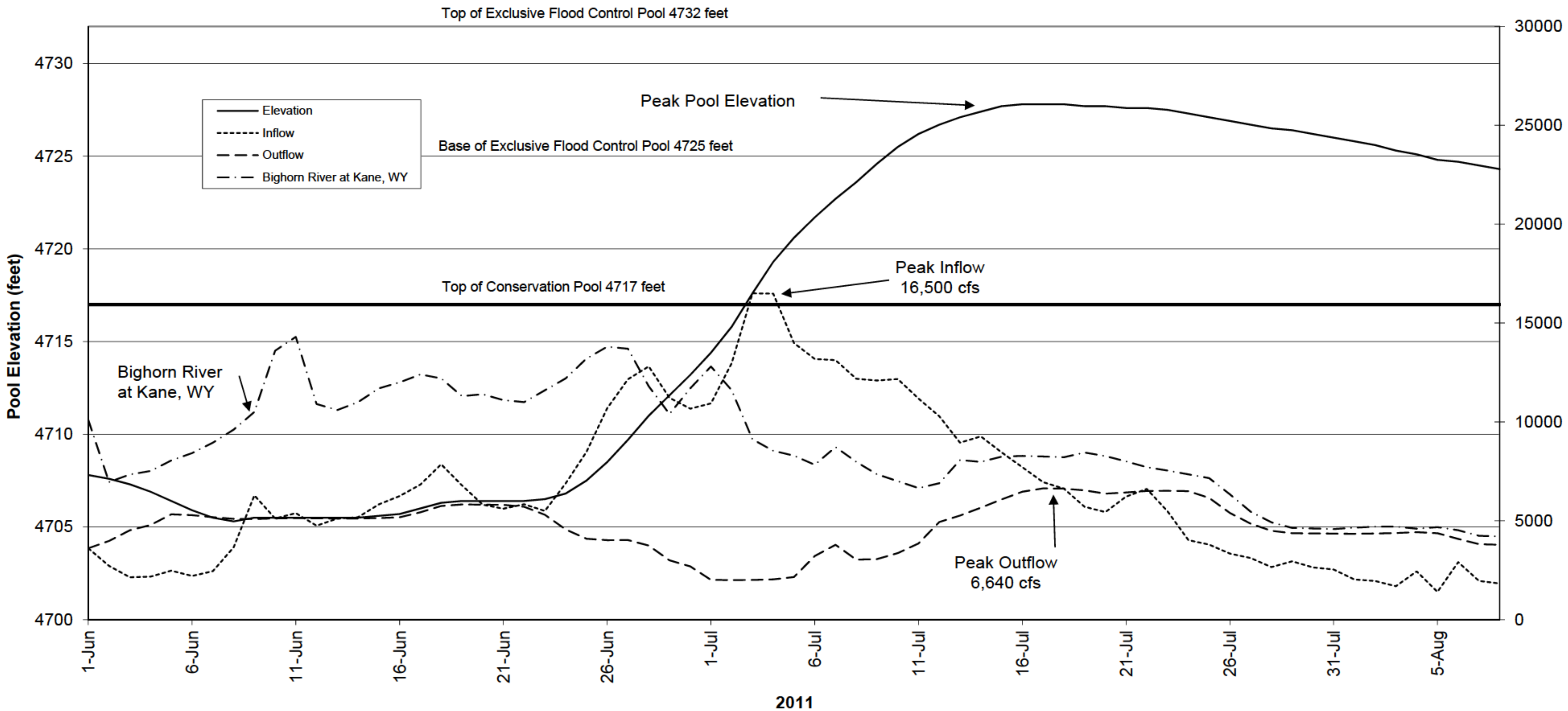


Source: USBR Hydromet Data, USGS gage data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

1997 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

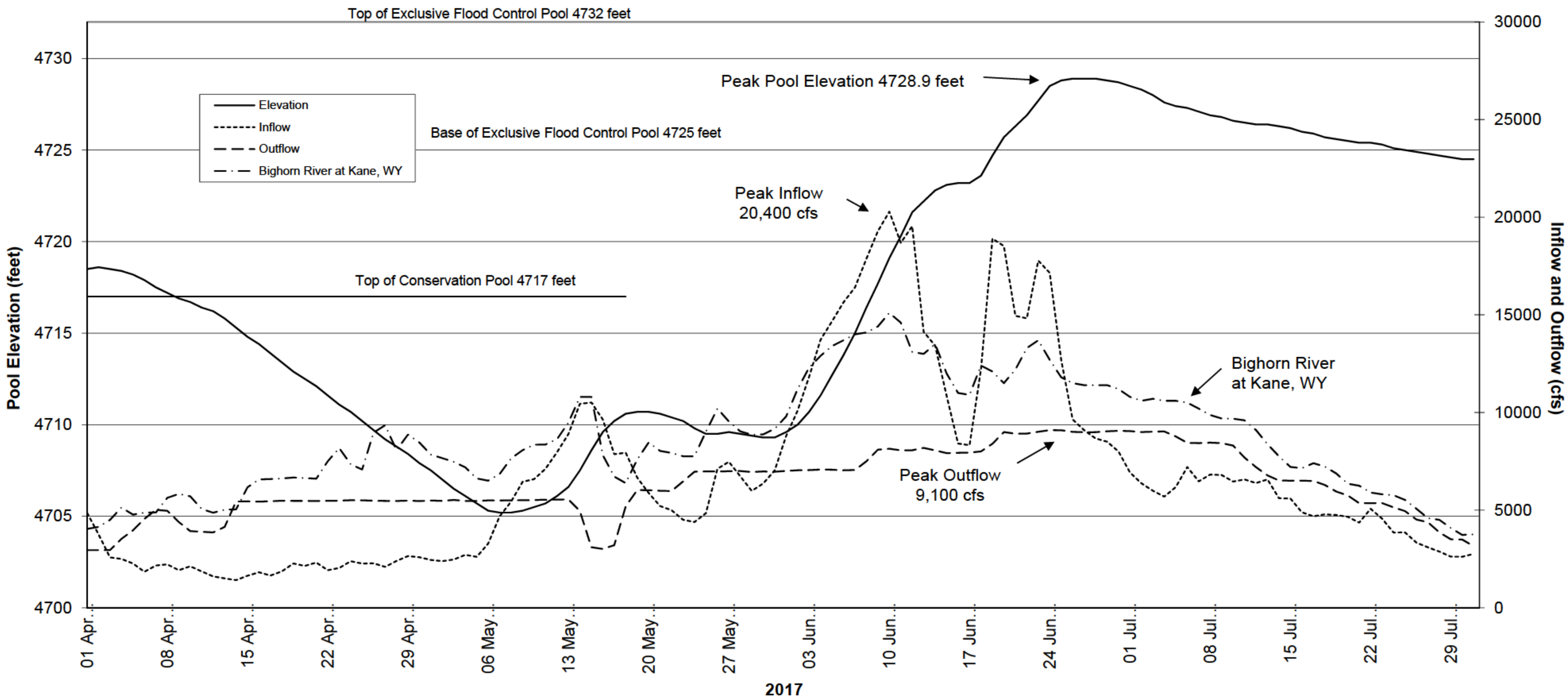


Source: USBR Hydromet Data, USGS gage data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

2011 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

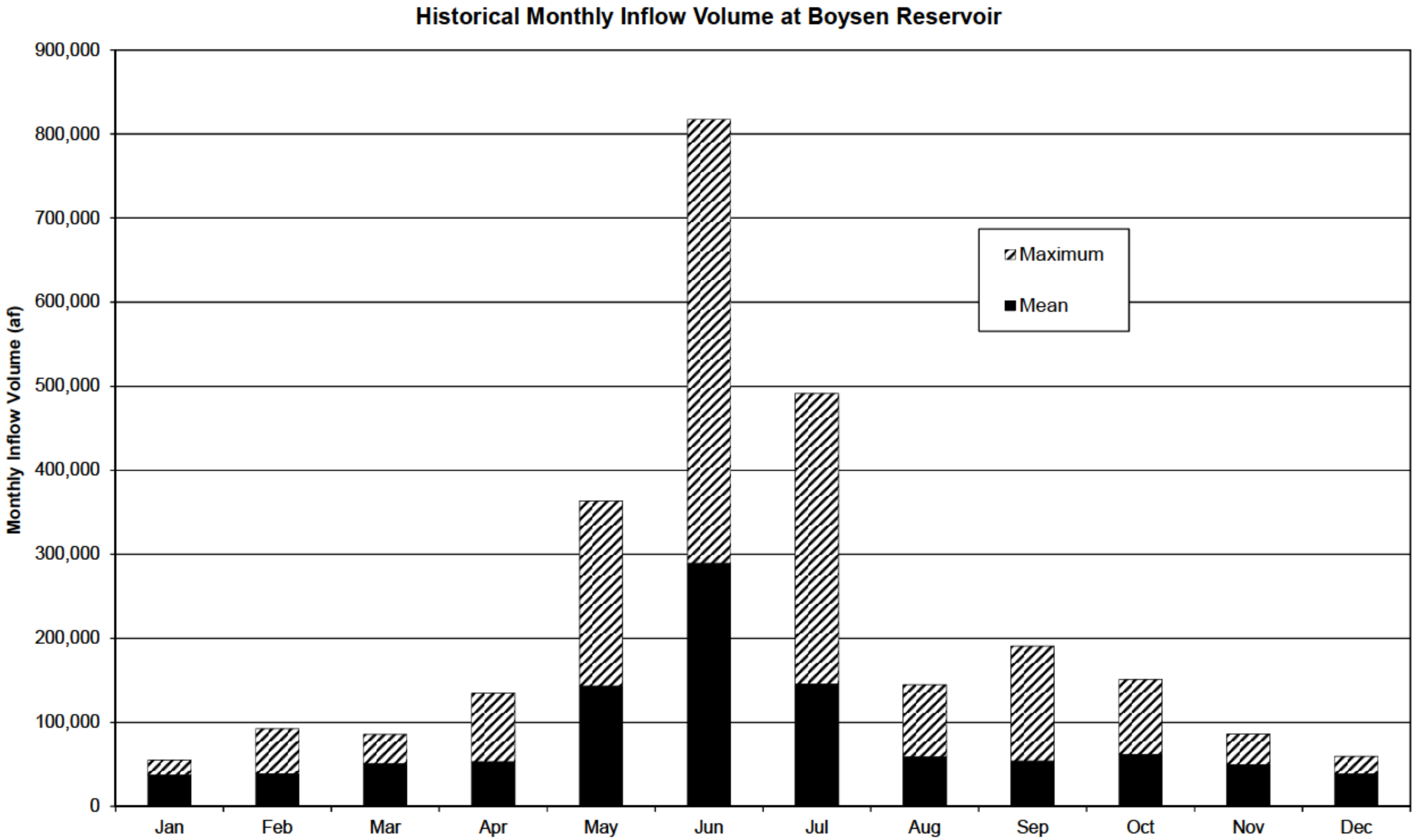


Source: USBR Hydromet Data, USGS gage data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

2017 Flood Routing

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Period Analyzed: 1952-Jul 2018
Total Average Annual Inflow = 1,014,000 af

Source: USBR HydroMet Database

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Historical Monthly Inflow Volume

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020

Boysen Reservoir
Historical Monthly Inflow Volumes (af)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1952			43,959	106,610	240,031	303,596	106,221	68,689	46,130	49,523	37,203	41,116
1953	47,626	38,256	38,346	44,909	70,486	284,557	74,024	51,915	32,720	48,992	49,039	40,158
1954	48,449	43,220	42,032	43,743	203,058	139,639	144,660	45,343	42,030	47,480	41,367	33,025
1955	34,833	23,558	28,949	41,205	73,476	151,100	63,588	31,976	30,195	46,696	33,137	45,534
1956	40,200	30,110	57,040	51,546	234,768	404,064	129,135	52,406	36,947	47,662	41,489	35,724
1957	33,047	36,069	38,985	52,737	195,869	526,737	328,056	77,857	66,800	98,826	58,044	49,875
1958	41,664	44,875	48,008	49,429	310,344	147,793	50,051	53,962	35,384	44,974	45,214	43,874
1959	37,621	36,950	57,552	43,210	57,767	227,870	59,048	45,729	33,104	59,950	46,408	39,095
1960	35,608	27,884	53,253	53,298	43,532	73,401	24,757	21,179	26,689	57,291	42,831	31,456
1961	25,966	29,399	29,270	19,142	90,124	207,930	34,598	29,785	41,749	61,219	47,101	31,486
1962	38,685	92,395	41,631	85,775	143,459	382,155	165,239	54,090	53,499	57,452	40,050	32,463
1963	27,502	39,411	41,319	44,486	97,412	438,461	118,844	54,675	80,398	53,861	37,050	28,391
1964	31,122	31,214	37,501	48,853	117,470	329,315	207,602	32,437	28,654	40,551	28,805	30,376
1965	40,339	34,335	35,645	76,336	110,145	539,779	392,243	122,801	84,479	97,437	63,676	46,765
1966	42,546	34,014	48,549	40,681	77,245	82,222	48,685	42,094	49,927	57,863	38,913	36,023
1967	37,111	41,344	53,145	42,597	173,782	629,719	452,132	60,974	53,433	73,746	59,312	47,375
1968	35,428	48,049	72,167	50,110	88,392	348,107	105,579	98,141	61,675	82,312	78,013	45,271
1969	42,828	38,227	57,579	70,552	158,221	290,177	109,605	48,873	44,481	56,995	42,089	34,656
1970	30,372	31,146	30,898	42,634	139,735	266,228	89,028	38,543	38,088	44,485	46,095	31,766
1971	33,477	33,559	39,937	51,227	198,290	627,555	232,823	78,275	82,829	91,878	61,603	52,897
1972	44,264	81,791	82,064	60,765	200,605	443,536	142,682	88,028	58,487	75,915	55,513	41,976
1973	40,164	32,325	50,247	113,889	251,913	174,041	136,023	59,915	190,780	104,652	75,713	50,382
1974	40,471	35,994	63,092	79,310	162,688	420,137	162,213	64,770	57,420	64,547	47,255	32,314
1975	32,119	31,104	54,681	41,120	119,350	274,091	394,774	78,727	53,996	64,139	49,490	47,015
1976	35,030	37,582	51,829	40,674	142,779	250,988	164,824	121,983	71,792	71,883	44,555	34,832
1977	24,215	32,335	37,097	63,401	55,647	30,116	37,339	28,235	24,287	49,199	39,921	36,624
1978	33,167	31,720	39,211	20,956	169,431	361,964	288,821	78,663	58,299	59,178	44,860	41,061
1979	33,226	34,156	74,269	56,784	189,171	130,253	73,426	90,542	55,676	53,579	39,142	35,325

Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir, Wyoming
Table of Historical Monthly Inflow Volumes

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020

Boysen Reservoir
Historical Monthly Inflow Volumes (af)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	31,715	34,568	44,644	47,332	242,190	322,661	175,724	52,956	49,663	62,559	50,636	51,182
1981	40,807	38,317	30,337	37,135	114,520	211,391	74,286	57,278	53,865	50,128	44,116	36,555
1982	32,582	33,831	35,515	25,959	66,738	251,358	265,843	116,499	122,244	151,188	65,562	43,253
1983	40,941	46,381	64,959	74,398	195,630	497,985	277,079	99,681	72,145	94,975	65,950	44,824
1984	45,841	44,981	66,685	62,199	223,245	229,817	187,253	110,777	88,287	92,939	65,575	40,880
1985	42,235	29,443	55,086	50,497	91,696	100,730	72,417	59,367	59,705	62,794	43,621	44,118
1986	41,491	59,751	56,566	72,386	148,698	566,432	214,818	78,076	73,115	85,858	63,669	39,573
1987	36,378	41,697	77,761	98,399	172,732	145,808	89,206	63,928	65,079	47,774	36,637	35,761
1988	30,143	36,225	54,833	53,374	89,747	62,336	32,510	20,306	23,091	24,496	33,407	28,644
1989	28,650	26,085	45,246	18,824	37,808	234,527	110,691	43,473	50,211	56,101	47,116	31,051
1990	37,919	33,181	49,107	62,476	49,525	126,006	79,539	52,946	56,473	54,940	54,661	32,561
1991	36,825	35,550	47,618	49,798	227,642	519,078	101,136	59,541	60,055	49,375	54,272	37,134
1992	32,888	43,115	52,073	35,863	51,635	101,726	94,945	33,526	33,456	28,359	38,824	36,654
1993	37,454	34,689	56,699	46,398	180,690	300,255	104,552	75,148	57,063	52,447	45,446	40,174
1994	37,700	35,341	55,518	55,604	91,966	50,394	22,119	21,614	22,755	44,291	42,032	34,673
1995	32,391	54,451	57,189	36,618	125,854	562,262	406,747	74,644	60,338	66,405	58,305	42,073
1996	40,061	47,619	59,956	49,676	107,950	387,966	180,307	53,664	50,656	48,015	56,708	47,299
1997	49,845	43,513	63,353	49,628	189,460	543,171	157,456	144,717	84,122	103,364	67,500	48,995
1998	49,607	49,008	85,811	82,350	136,209	282,398	314,079	101,513	77,648	108,185	76,962	43,773
1999	46,726	46,486	50,050	89,921	280,621	552,873	223,233	73,454	71,873	70,087	54,511	41,858
2000	38,452	41,098	42,284	35,076	101,485	101,960	39,802	25,392	33,120	30,704	36,686	35,569
2001	31,801	28,314	49,706	27,937	44,665	27,232	17,647	13,576	18,039	19,025	20,557	30,166
2002	28,386	25,905	37,847	29,383	25,650	71,276	33,289	26,102	36,180	33,897	29,921	31,254
2003	34,927	30,107	56,077	37,300	76,502	110,868	37,337	25,620	44,637	29,287	37,541	36,565
2004	32,780	33,151	50,903	44,240	69,641	101,265	105,658	39,621	47,960	66,906	54,691	41,354
2005	42,125	38,708	39,174	39,226	190,517	263,739	95,937	39,180	32,658	47,646	47,001	34,046
2006	38,484	31,466	41,680	36,392	70,704	64,339	28,769	22,925	37,288	52,338	40,488	24,846
2007	19,978	24,360	36,168	31,201	86,267	60,989	32,634	30,324	28,296	33,262	38,383	31,477

Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Table of Historical Monthly Inflow Volumes

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020

Boysen Reservoir
Historical Monthly Inflow Volumes (af)

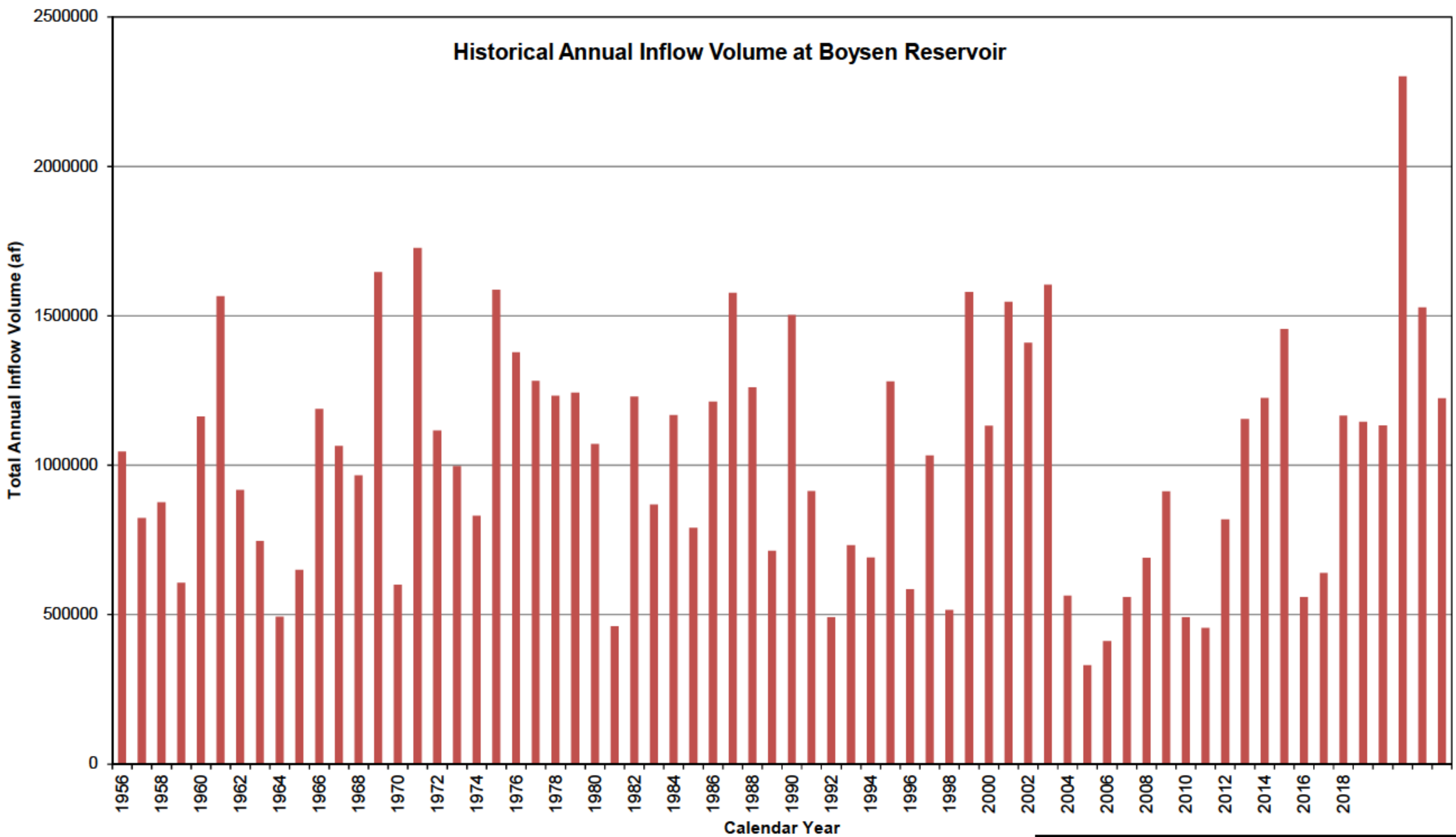
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	27,926	31,539	41,491	28,290	131,338	240,296	122,044	38,606	42,381	36,846	45,652	30,105
2009	34,434	32,819	42,916	52,439	125,702	405,388	218,350	55,590	38,389	63,688	50,833	31,690
2010	31,249	29,202	56,112	69,688	163,352	510,717	137,497	49,621	43,553	40,751	44,193	46,126
2011	40,393	32,915	48,496	37,762	96,209	392,531	491,358	86,343	54,764	68,376	57,530	2,753
2012	46,382	39,535	56,683	54,615	55,177	93,717	31,909	35,281	36,263	30,000	45,199	33,261
2013	30,391	30,018	39,964	36,137	82,519	73,153	44,282	35,958	67,236	96,724	62,763	42,270
2014	40,604	33,437	50,285	57,549	176,126	285,778	187,839	79,326	58,193	88,491	55,669	50,860
2015	46,467	48,024	55,232	47,175	187,591	439,767	98,068	42,678	42,038	46,868	49,028	40,653
2016	32,924	42,441	49,193	67,020	267,584	367,783	49,397	33,287	40,690	75,710	64,055	40,063
2017	42,215	79,975	80,651	134,602	363,595	817,486	322,116	102,148	93,371	116,925	86,094	59,820
2018	55,050	47,485	72,864	59,235	355,630	444,034	148,473	41,729	38,393	49,986	50,833	42,448
2019	41,003	37,375	58,863	65,099	151,310	442,873	163,823	58,348	59,919			

Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Table of Historical Monthly Inflow Volumes

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



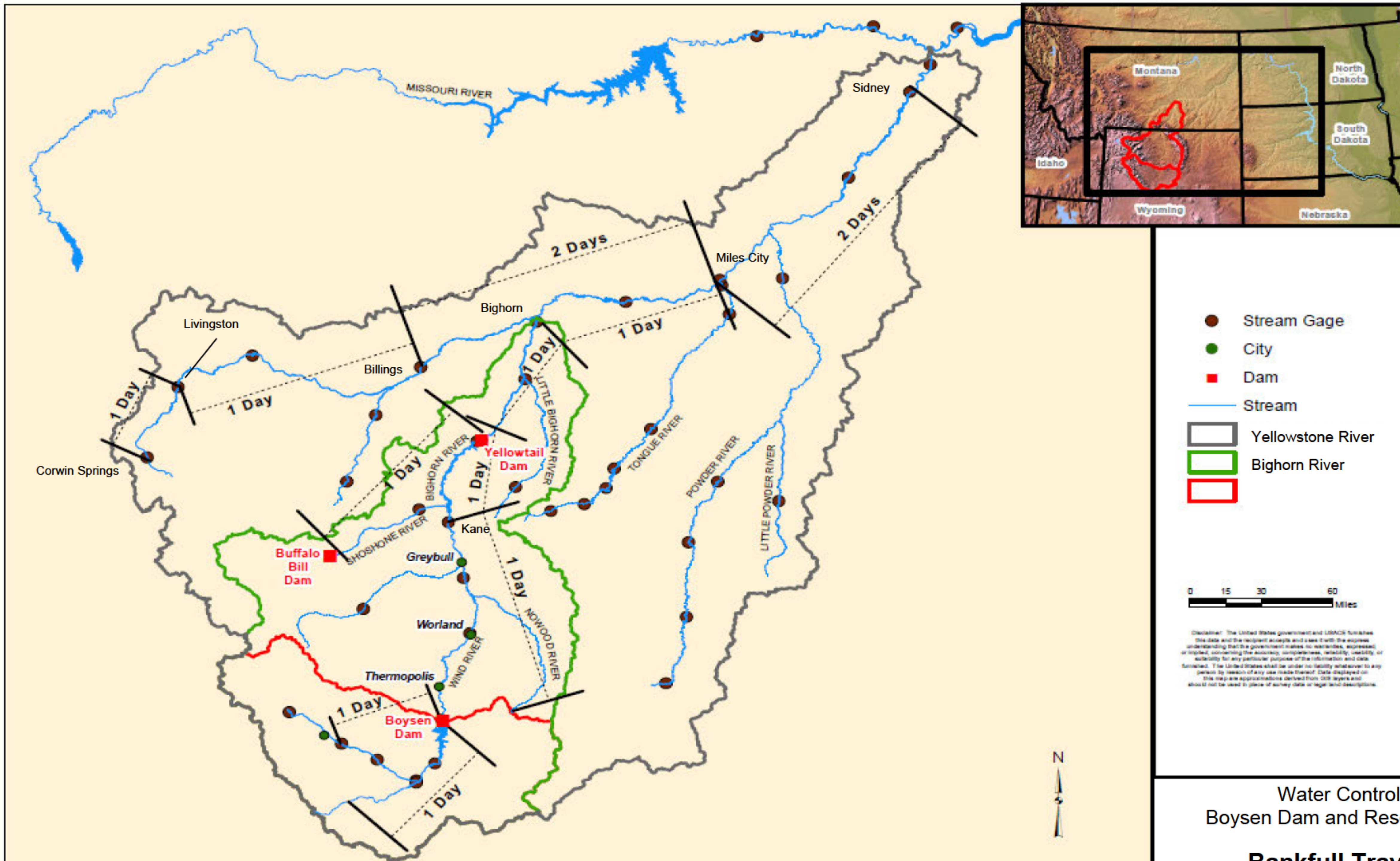
Annual Inflow Volume is an accumulation of daily average inflows over a calendar year.

Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Historical Annual Inflow Volume

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020

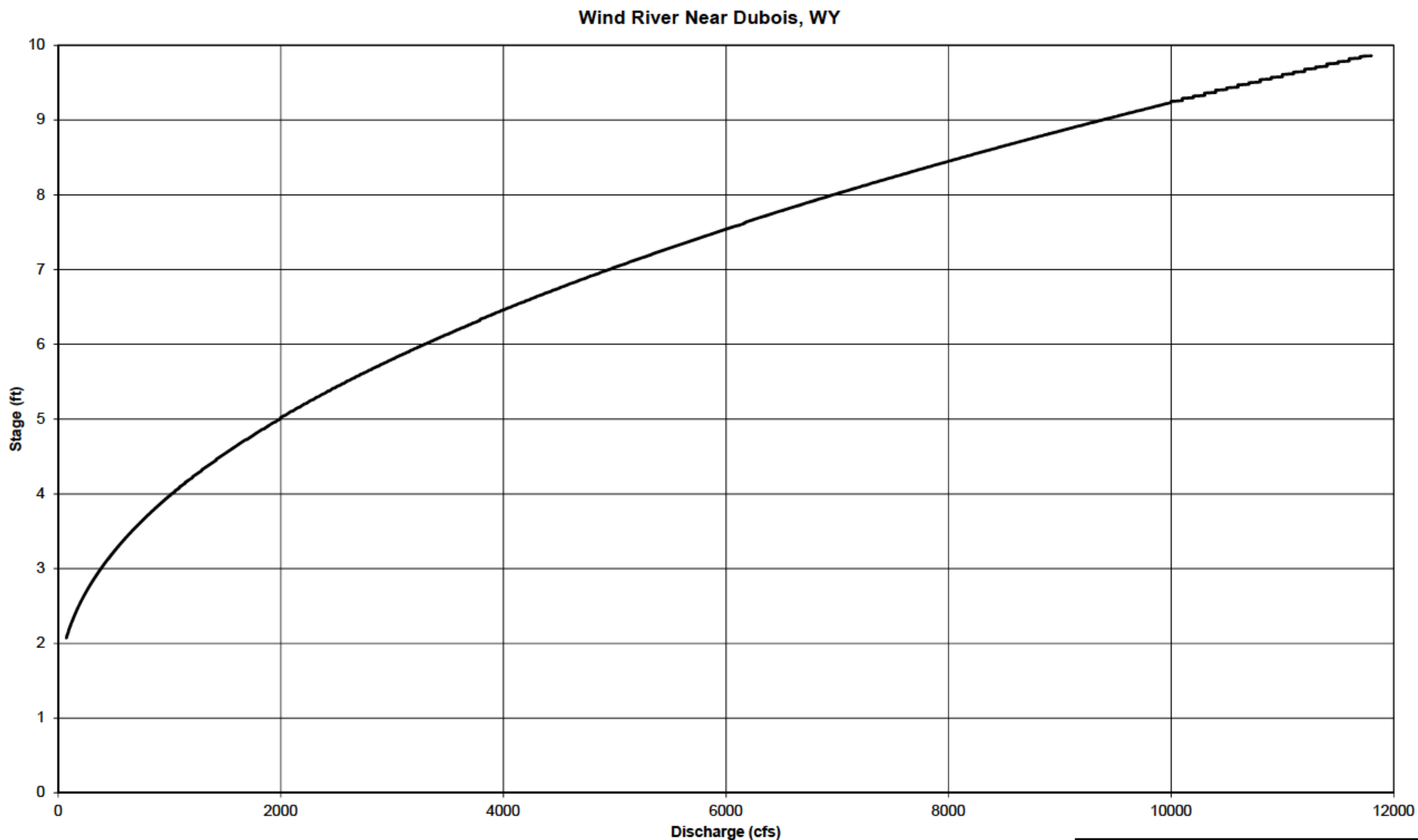


Water Control Manual
Boysen Dam and Reservoir, Wyoming

Bankfull Travel Times

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska

July 2020

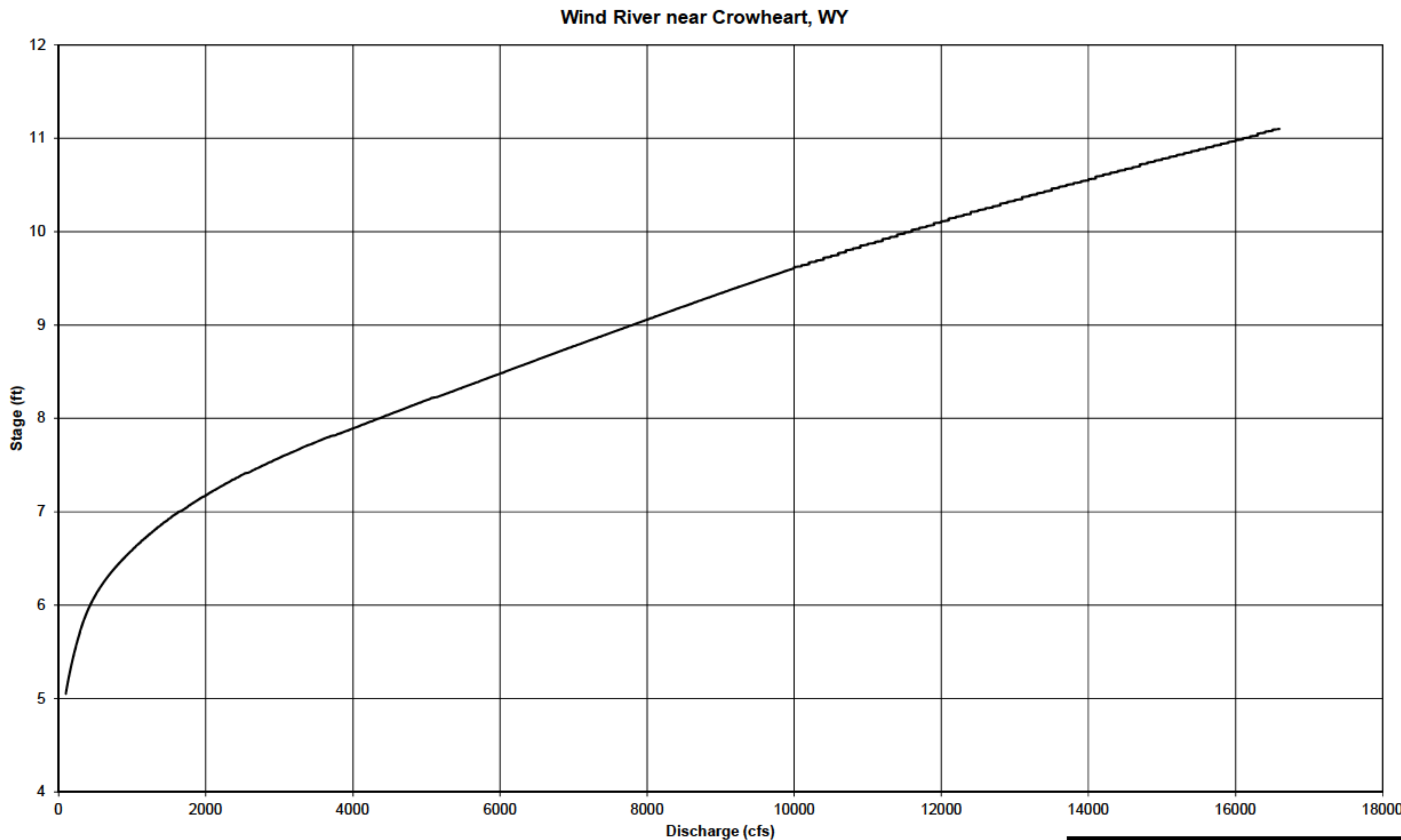


Source: USGS, Rating #8.1

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
for Wind River near Dubois

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

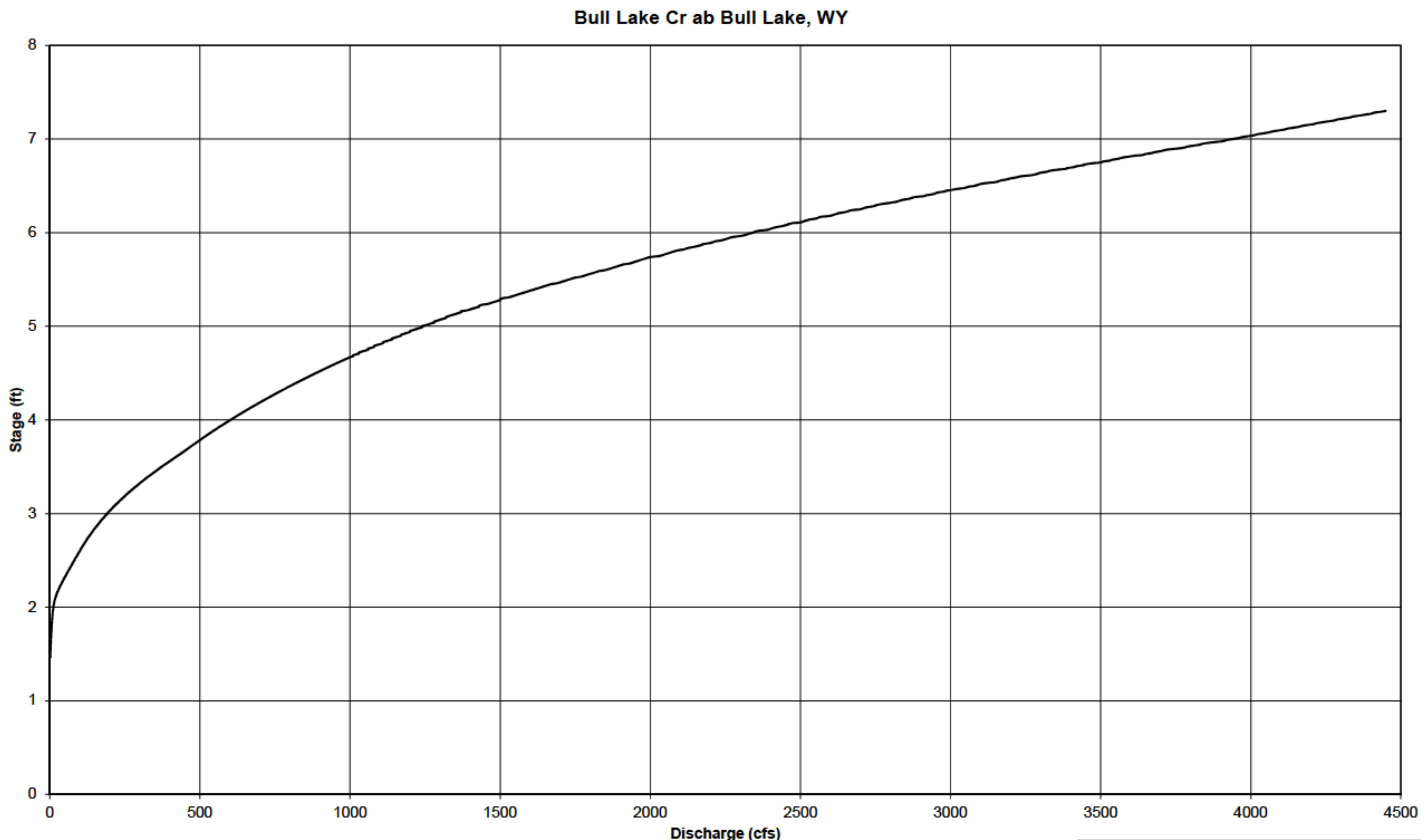


Source: USGS, Rating #24.0

Water Control Manual
Boysen Dam and Reservoir, WY

Rating Curve
for Wind River near Crowheart

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

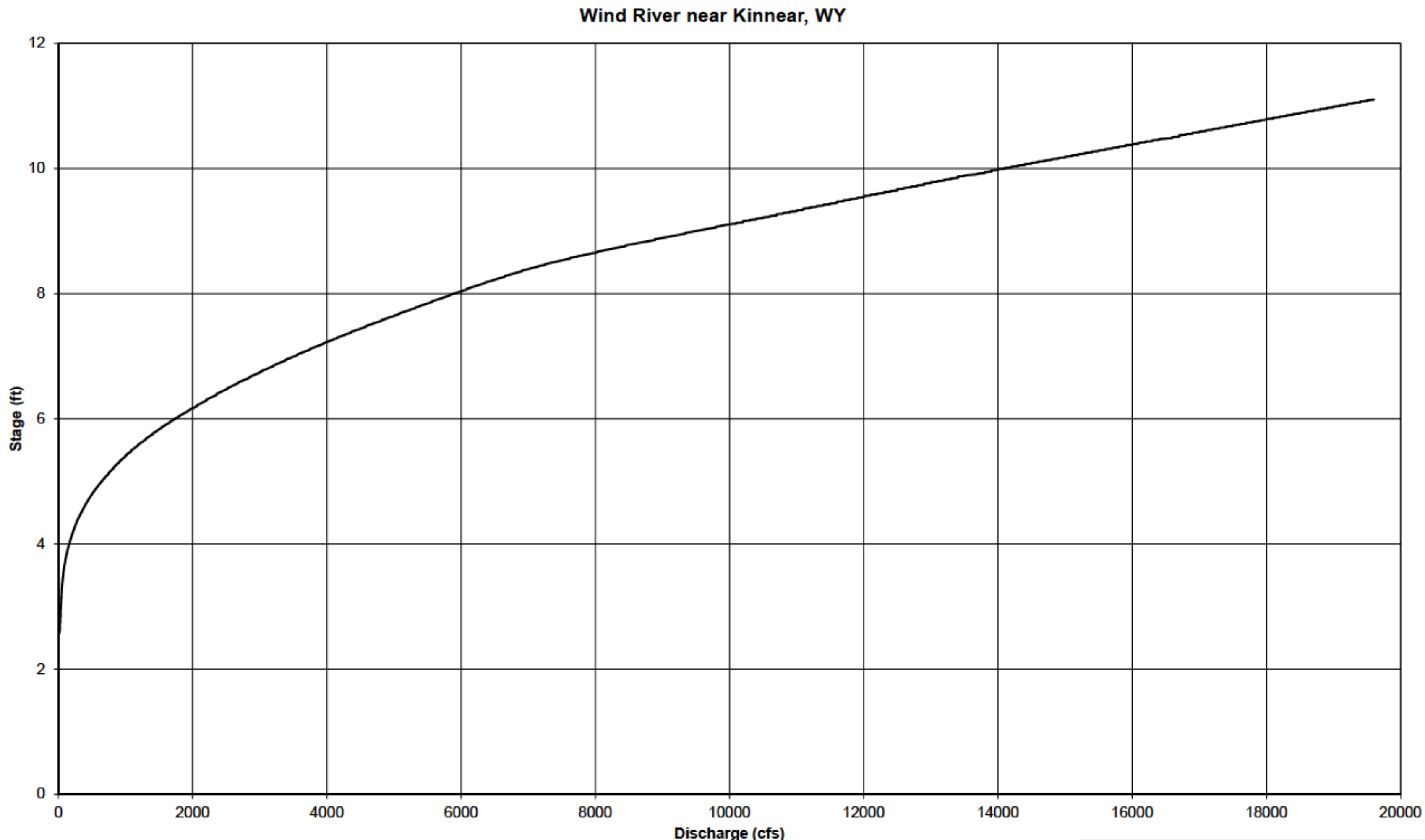


Source: USGS, Rating #15.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Bull Lake Creek ab Bull Lake, WY

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

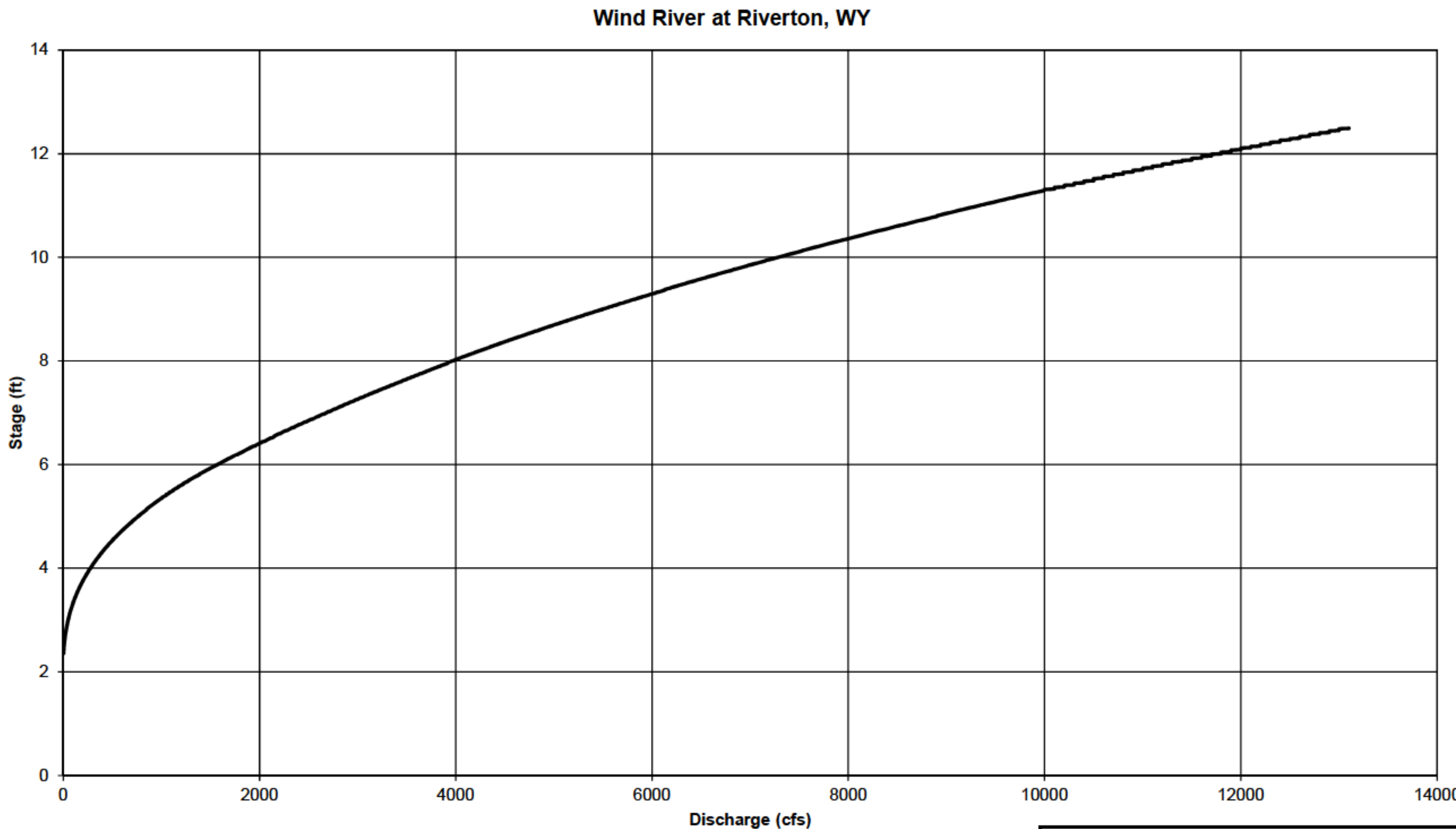


Source: USGS, Rating #15.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
for Wind River near Kinnear, WY

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

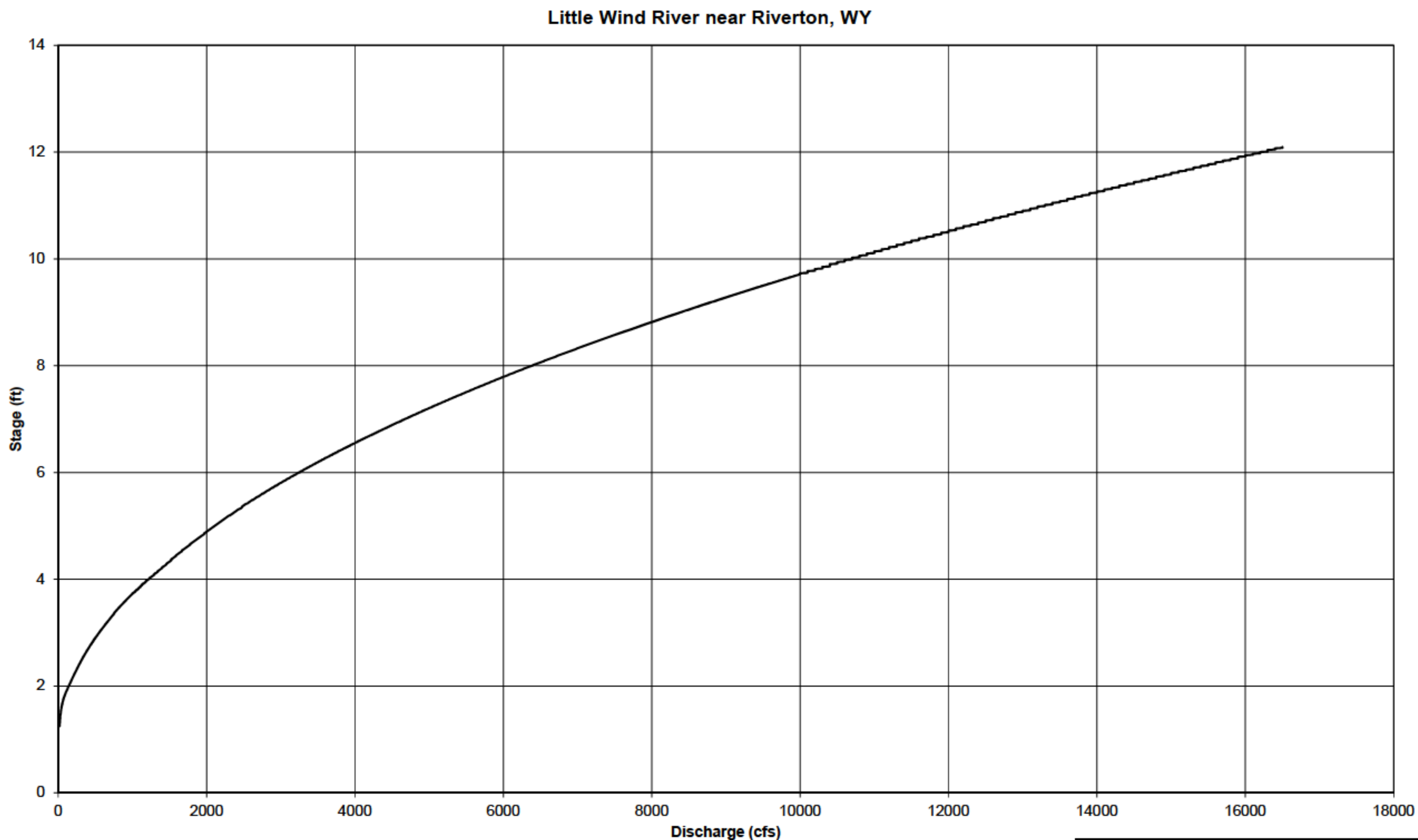


Source: USGS, Rating #30.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
for Wind R at Riverton, WY

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

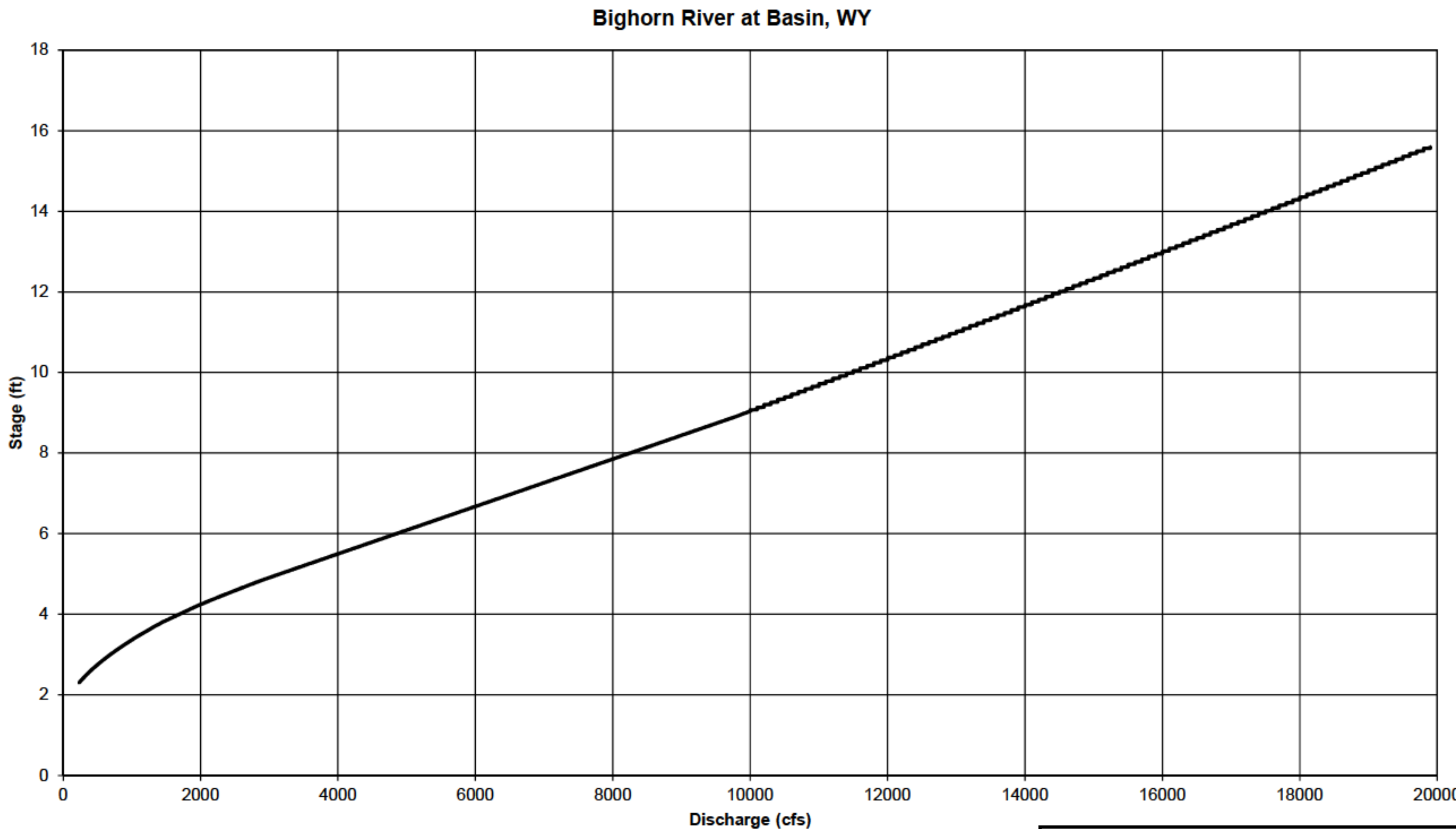


Source: USGS, Rating #25.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Little Wind River near Riverton, WY

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

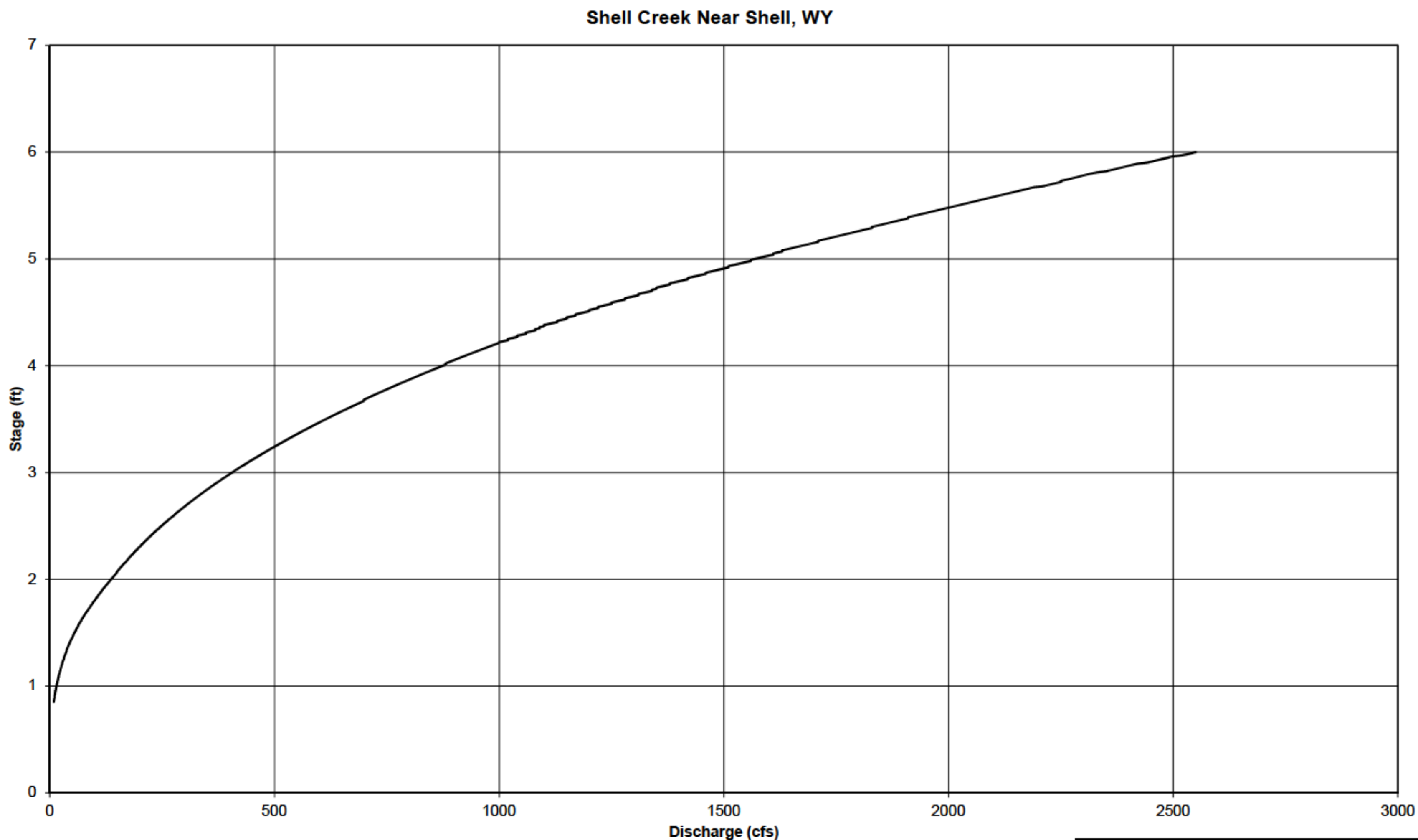


Source: USGS, Rating #9.0

Water Control Manual
Boysen Dam and Reservoir, WY

Rating Curve
Bighorn River at Basin, WY

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
Jul 2020

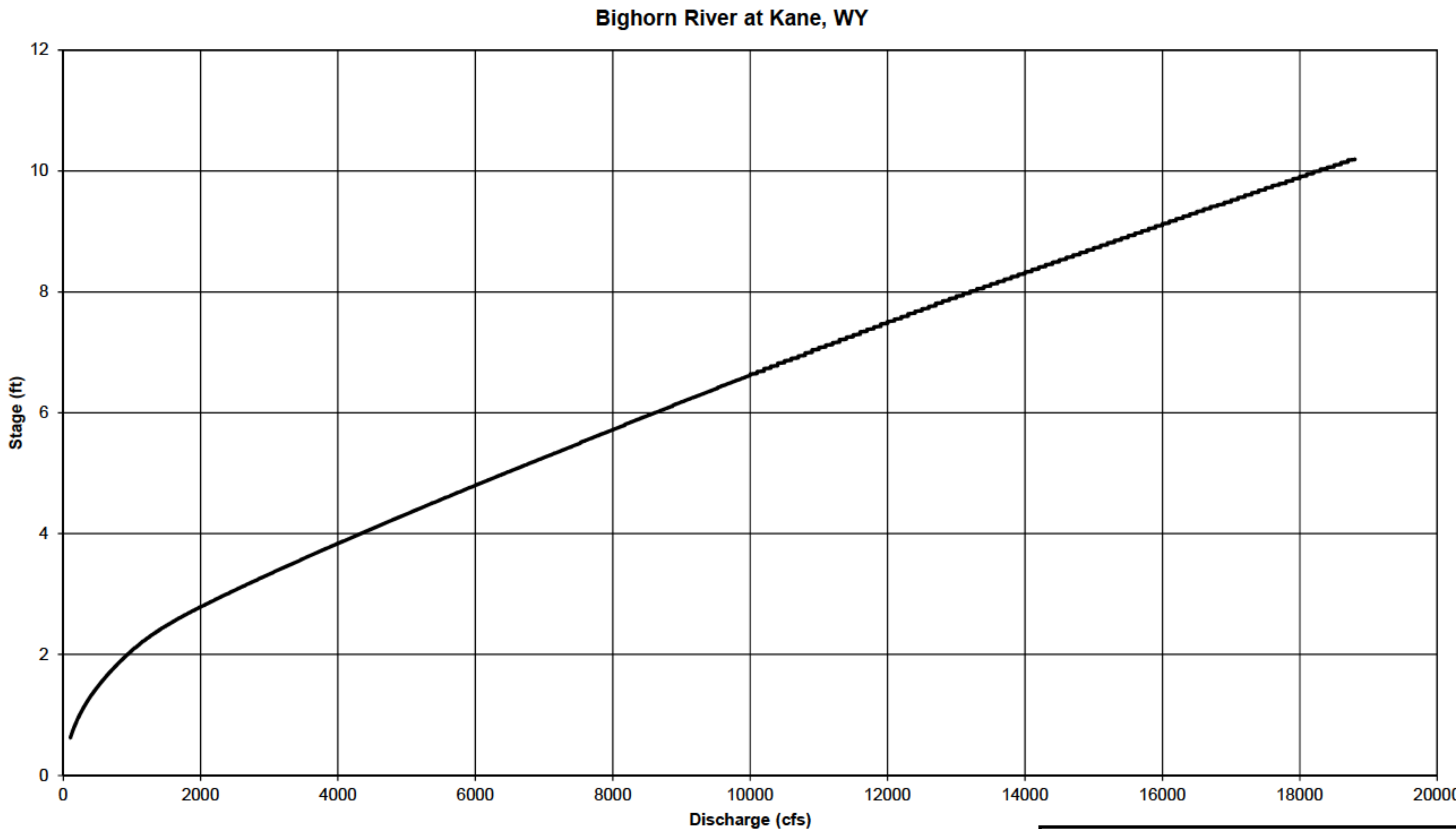


Source: USGS, Rating #23.1

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Shell Creek Near Shell, WY

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

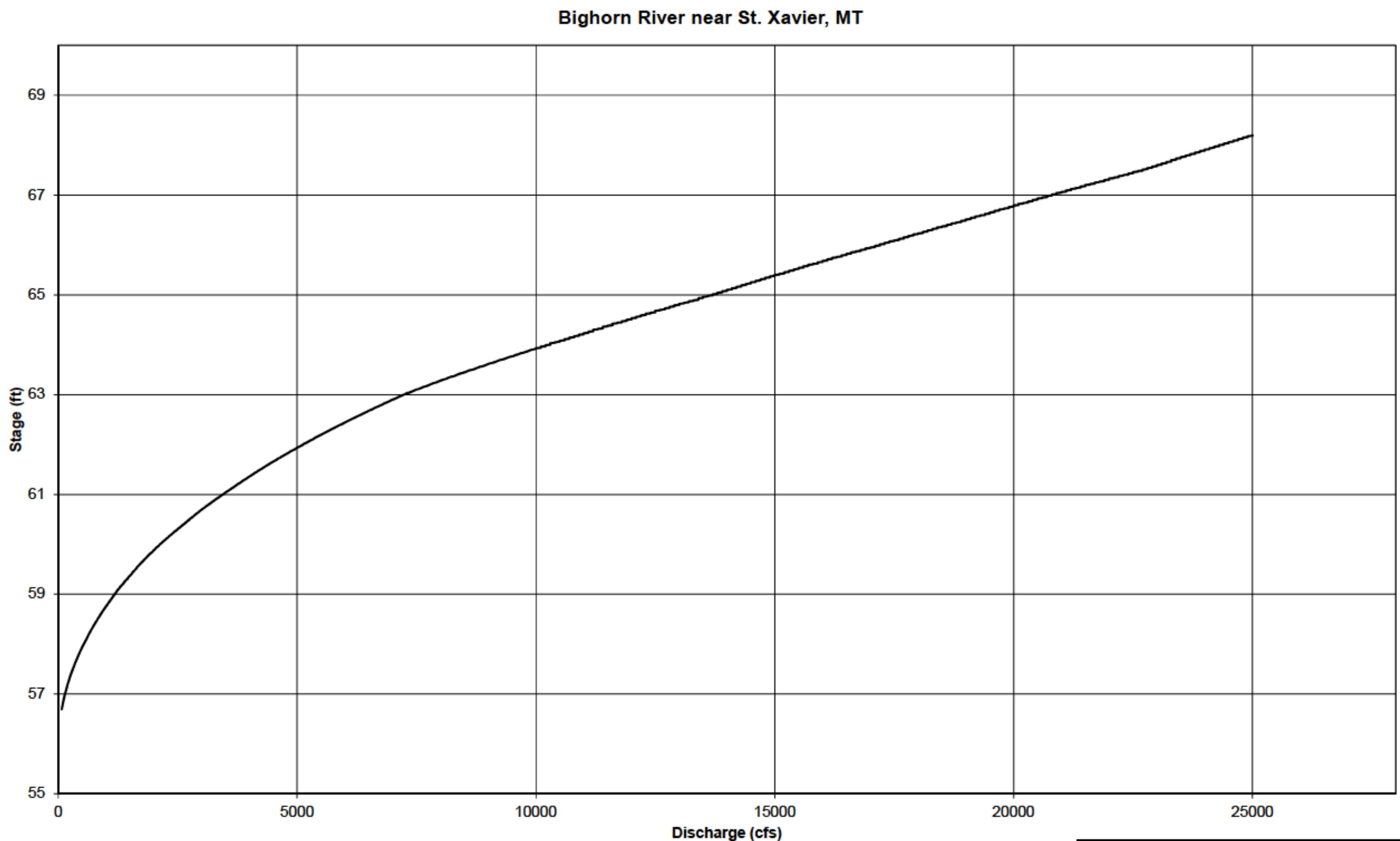


Source: USGS, Rating #14.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Bighorn River at Kane, WY

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

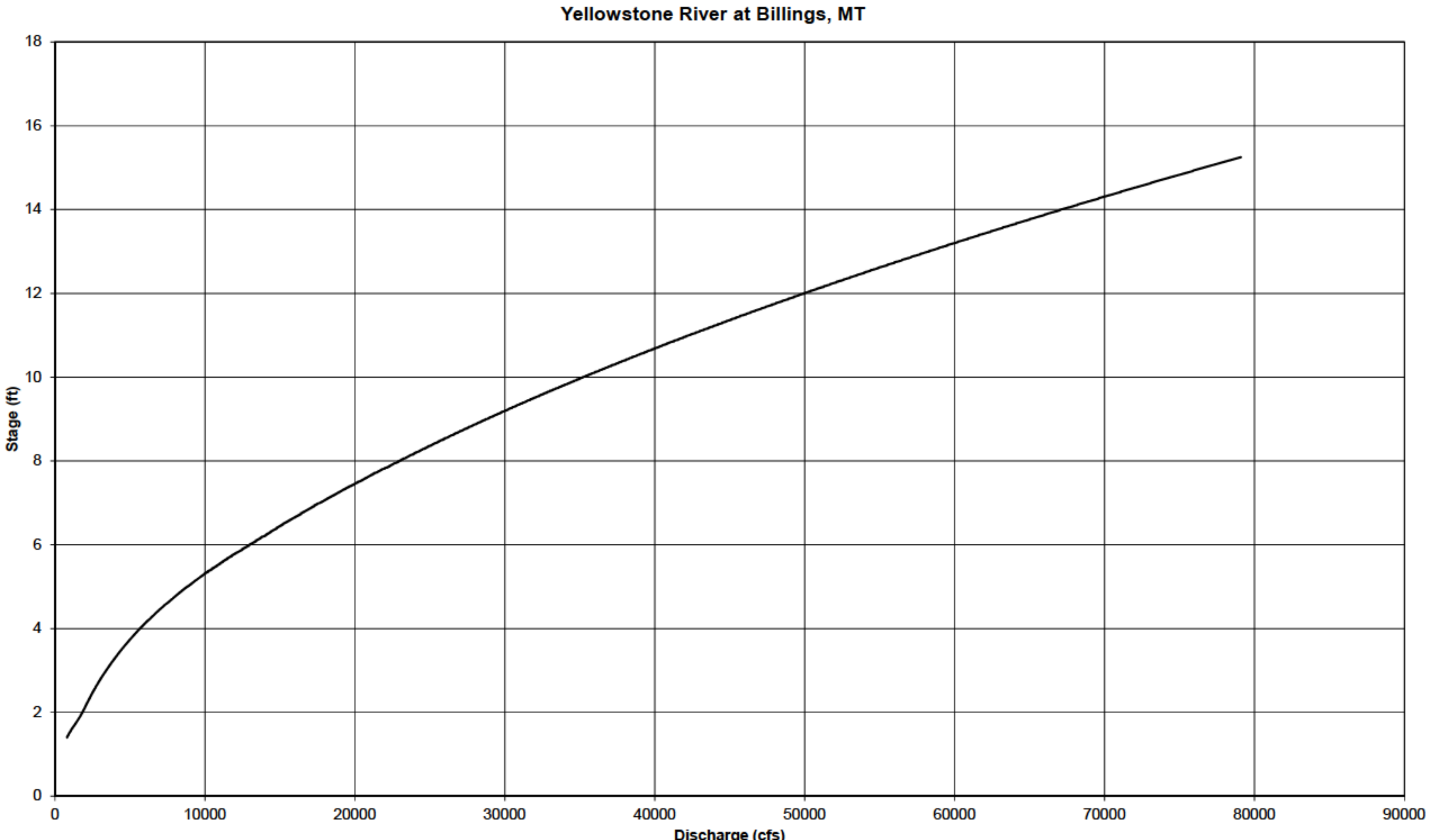


Source: USGS, Rating #7.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Bighorn River near St. Xavier, MT

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

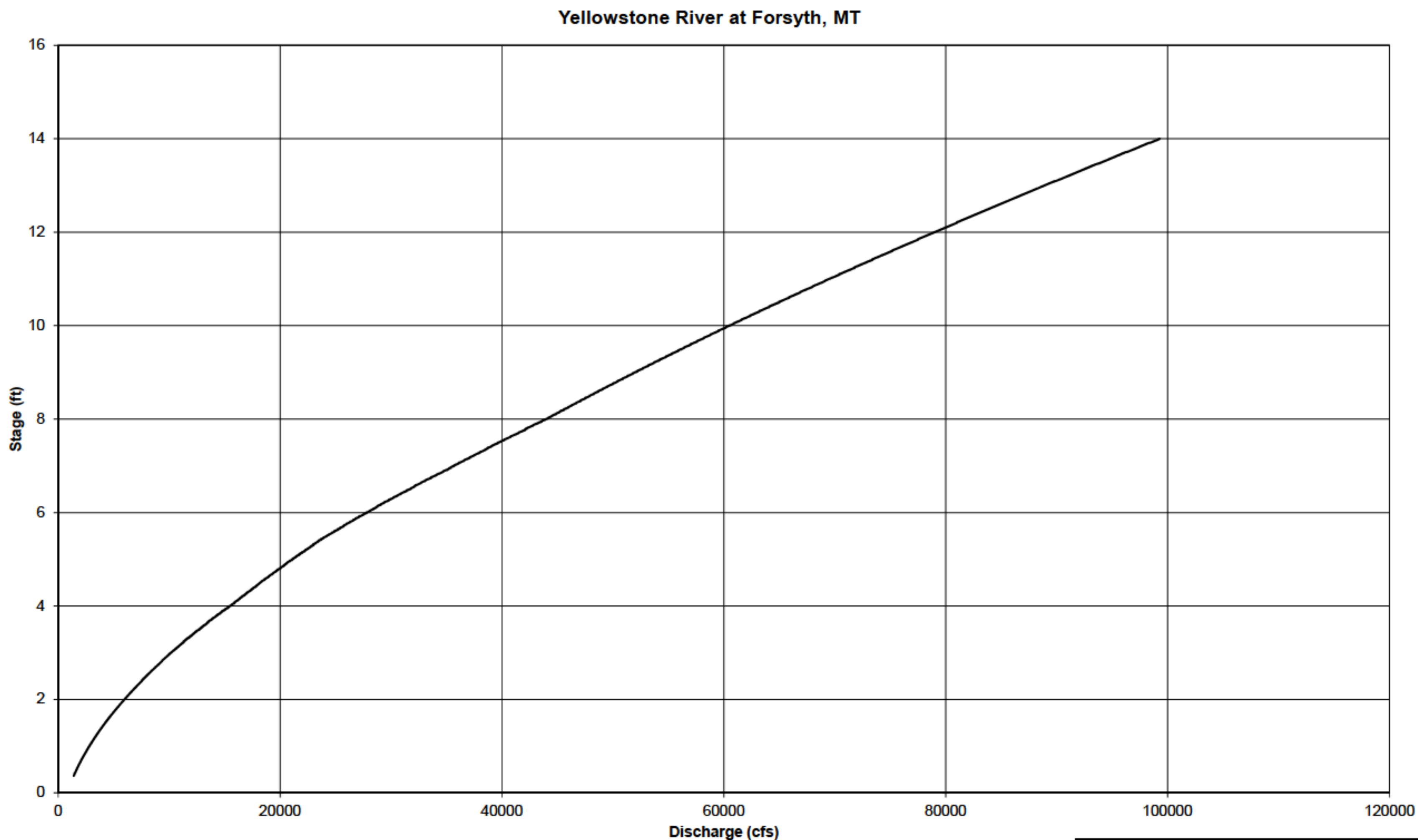


Source: USGS, Rating #20.1

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Yellowstone River at Billings, MT

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

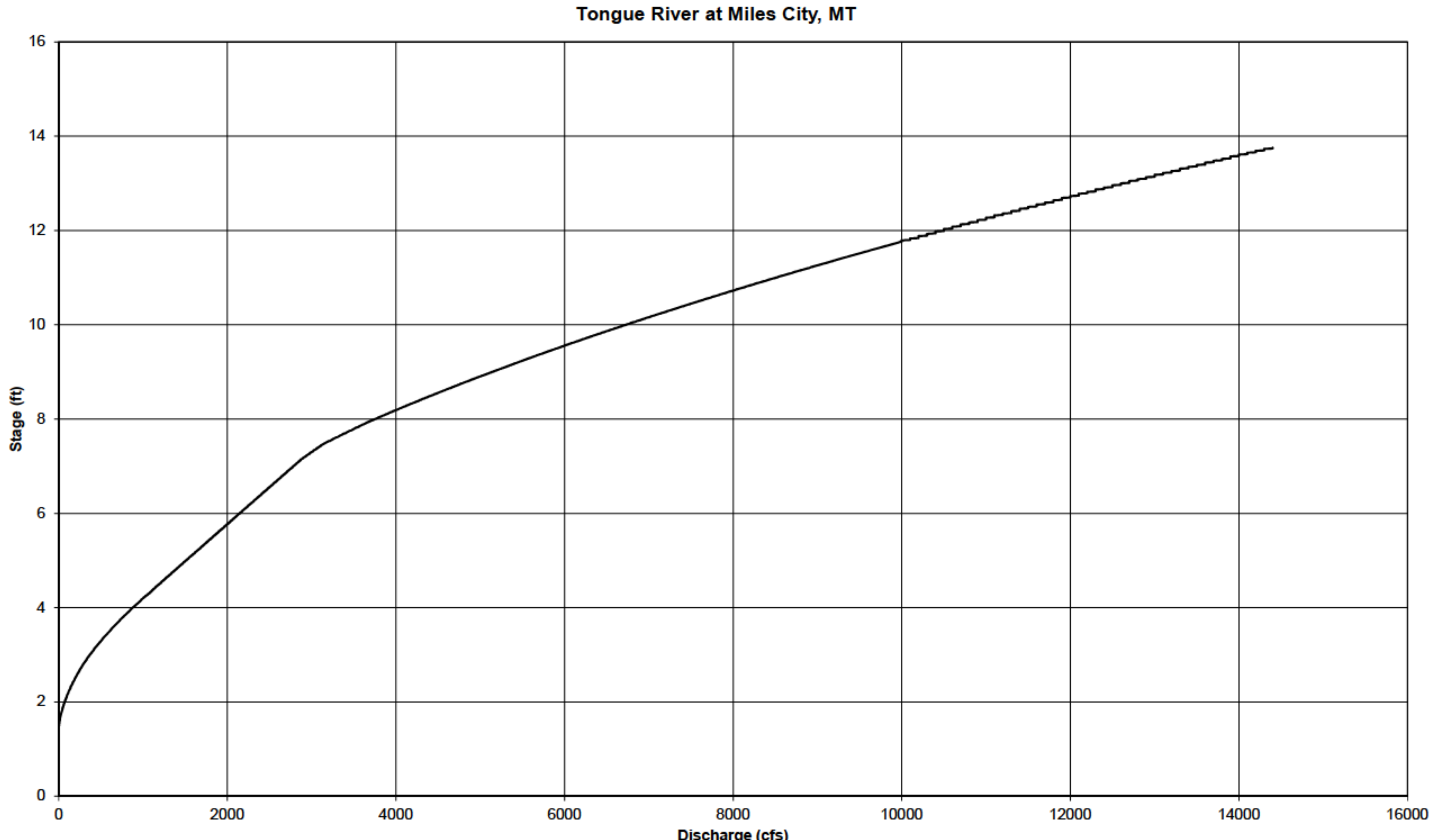


Source: USGS, Rating #7.2

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Yellowstone River at Forsyth, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
Jul 2020

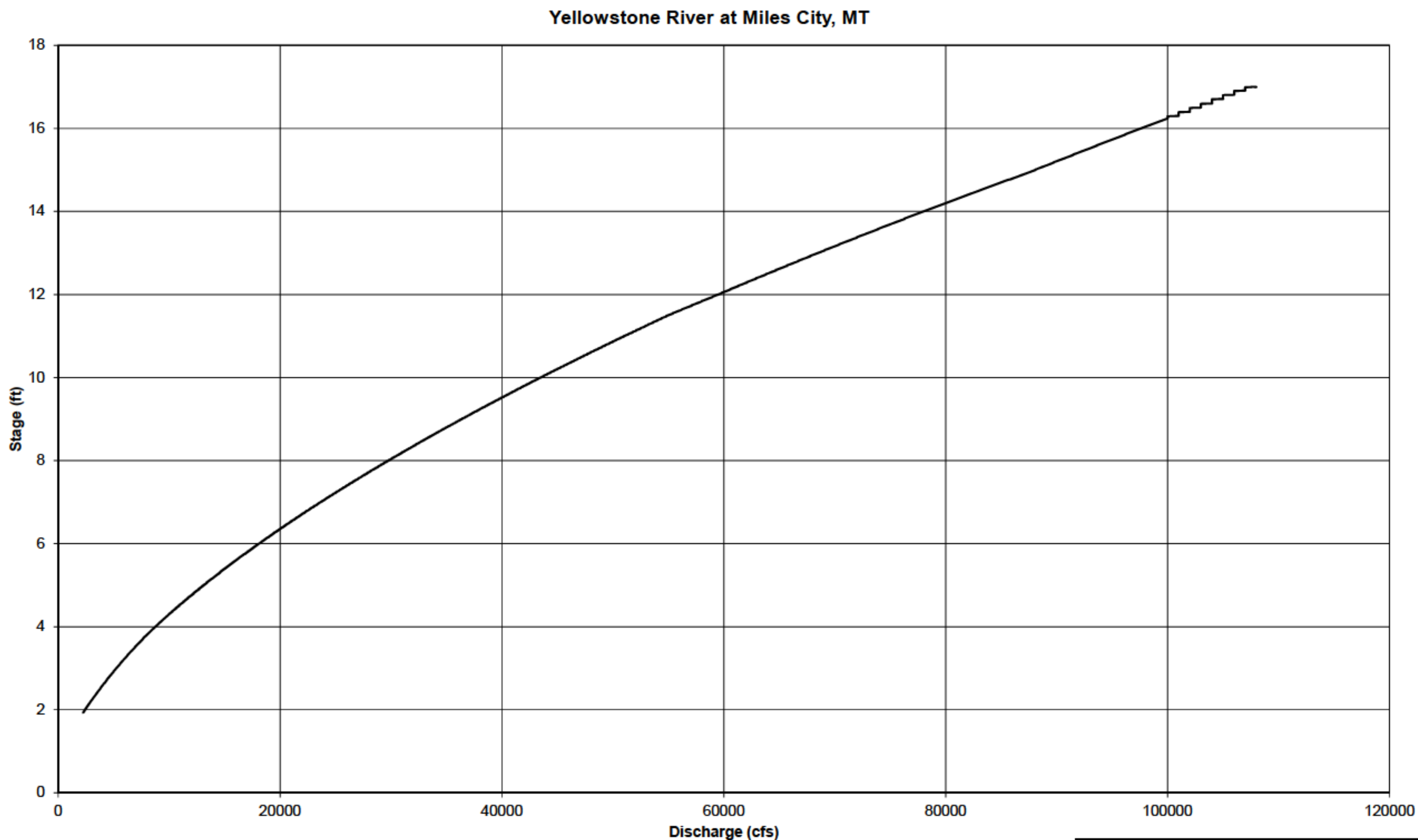


Source; USGS, Rating #19.0

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Tongue River at Miles City, MT

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
Jul 2020

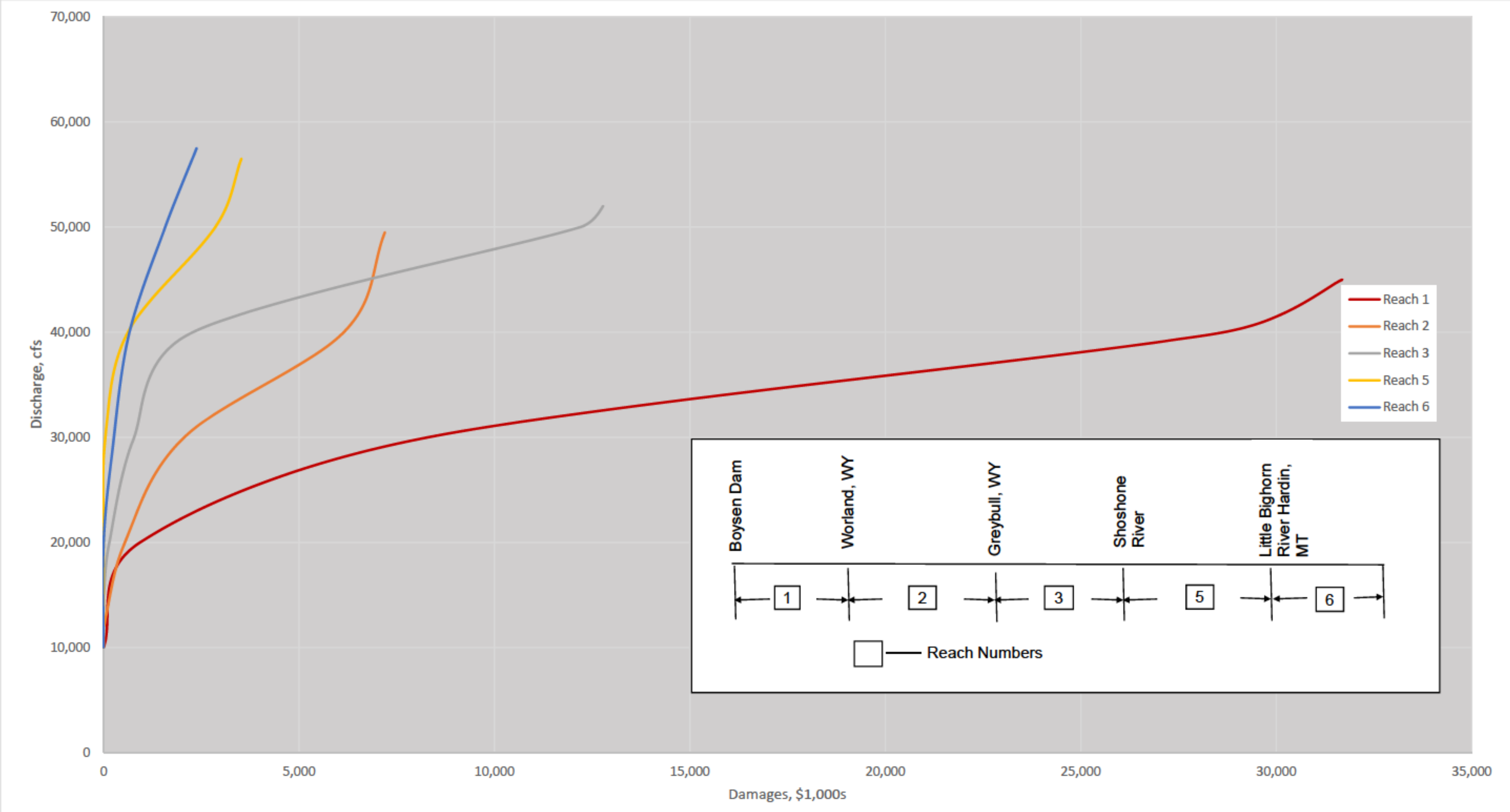


Source: USGS, Rating #12.2

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Rating Curve
Yellowstone River at Miles City, MT

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020



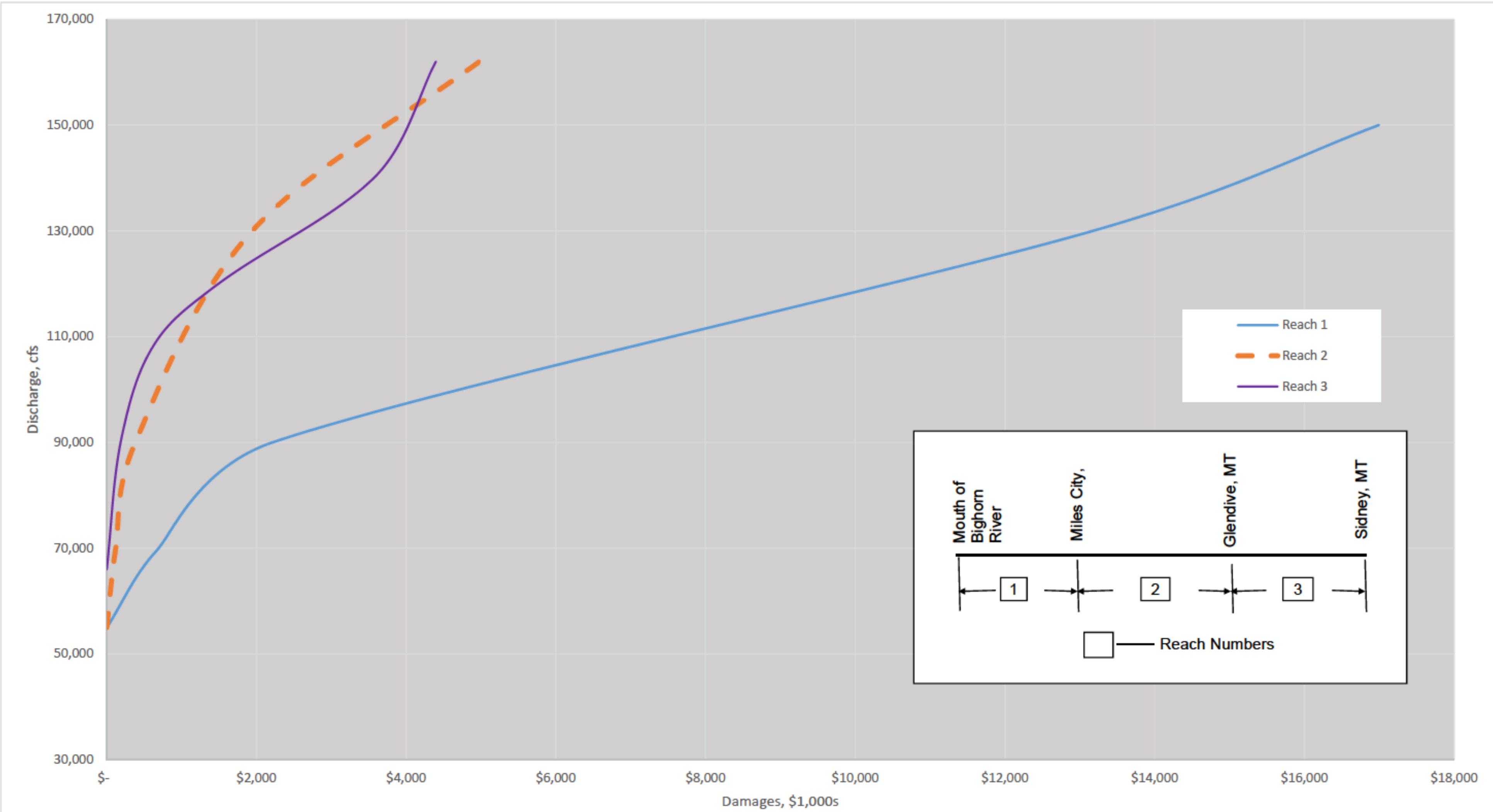
2015 Price Levels
Source: Environmental, Economics and Cultural Resource Section,
Project Management Branch, Corps of Engineers, Omaha District

Note: Reach 4 was inundated by Yellowtail Dam / Bighorn Lake and is no longer included as a damage reach.

Water Control Manual
Boysen Reservoir and Dam, Wyoming

Bighorn River Discharge-Damage Curves

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020



2015 Price Levels
Source; Environmental, Economics and Cultural Resource Section,
Project Management Branch, Corps of Engineers, Omaha District

Water Control Manual
Boysen Reservoir and Dam, Wyoming

Yellowstone River-Discharge Damage Curves

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
Jul 2020

	Unadjusted (x$1,000)			Adjusted to 2018 $ (x$1,000)		
Year	Local	Mainstem	Total	Local	Mainstem	Total
1952	20	0	20	292	0	292
1953	73	0	73	1,030	0	1,030
1954	0	0	0	0	0	0
1955	0	0	0	0	0	0
1956	142	0	142	1,759	0	1,759
1957	234	355	589	2,796	4,241	7,037
1958	0	0	0	0	0	0
1959	30	425	455	333	4,716	5,049
1960	0	0	0	0	0	0
1961	0	0	0	0	0	0
1962	700	263	963	7,340	2,758	10,097
1963	1,250	92	1,342	12,797	942	13,739
1964	0	138	138	0	1,371	1,371
1965	0	0	0	0	0	0
1966	0	348	348	0	3,256	3,256
1967	230	6,610	6,840	2,069	59,464	61,533
1968	0	270	270	0	2,277	2,277
1969	0	0	0	0	0	0
1970	10	246	256	73	1,789	1,862
1971	174	232	406	1,117	1,488	2,605
1972	143	1,550	1,692	827	8,993	9,820
1973	16	68	84	85	362	447
1974	578	1,192	1,770	2,917	6,016	8,933
1975	0	2,146	2,146	0	9,993	9,993
1976	0	678	678	0	2,893	2,893
1977	0	0	0	0	0	0
1978	303	393	696	1,114	1,445	2,559
1979	0	1	1	0	3	3
1980	0	110	110	0	345	345
1981	0	1,006	1,006	0	2,917	2,917
1982	0	1,169	1,169	0	3,183	3,183
1983	431	1,346	1,777	1,099	3,434	4,533
1984	88	2,234	2,322	221	5,621	5,842
1985	0	0	0	0	0	0

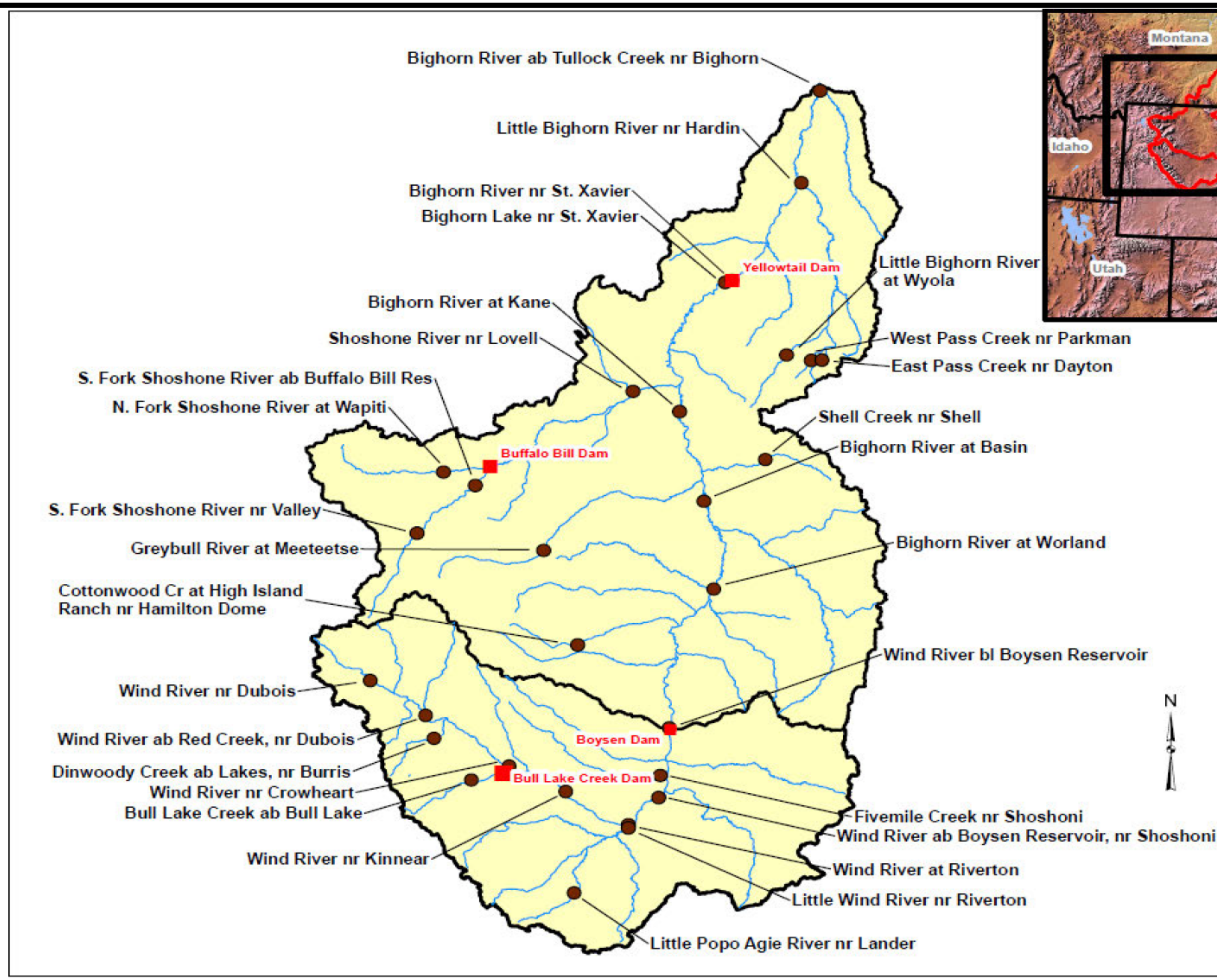
	Unadjusted (x$1,000)			Adjusted to 2018 $ (x$1,000)		
Year	Local	Mainstem	Total	Local	Mainstem	Total
1986	2,675	0	2,675	6,551	0	6,551
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	363	0	363	813	0	813
1991	1,036	3,236	4,272	2,255	7,049	9,304
1992	0	348	348	0	741	741
1993	26	9,127	9,153	52	18,446	18,498
1994	0	298	298	0	582	582
1995	1,003	134	1,136	1,954	260	2,214
1996	196	6,232	6,428	367	11,676	12,043
1997	1,434	18,044	19,478	2,576	32,418	34,994
1998	8	2,600	2,608	15	4,662	4,676
1999	727	3,049	3,776	1,262	5,292	6,554
2000	0	569	569	0	975	975
2001	0	0	0	0	0	0
2002	0	105	105	0	175	175
2003	0	4,781	4,781	0	7,822	7,822
2004	0	0	0	0	0	0
2005	0	6,968	6,968	0	9,991	9,991
2006	0	4	4	0	6	6
2007	0	69	69	0	93	93
2008	235	8,527	8,762	296	10,743	11,038
2009	35	1,870	1,905	44	2,387	2,432
2010	1,156	6,231	7,387	1,432	7,717	9,149
2011	1,534	463	1,997	1,830	552	2,382
2012	0	620	620	0	726	726
2013	0	185	185	0	213	213
2014	126	9,548	9,675	142	10,736	10,878
2015	279	2,890	3,169	306	3,172	3,478
2016	274	520	794	294	559	853
2017	2,830	11,095	13,926	2,931	11,489	14,420
2018	1,401	12,988	14,389	1,401	12,988	14,389
TOTAL	19,758	131,375	151,133	60,391	288,976	349,367

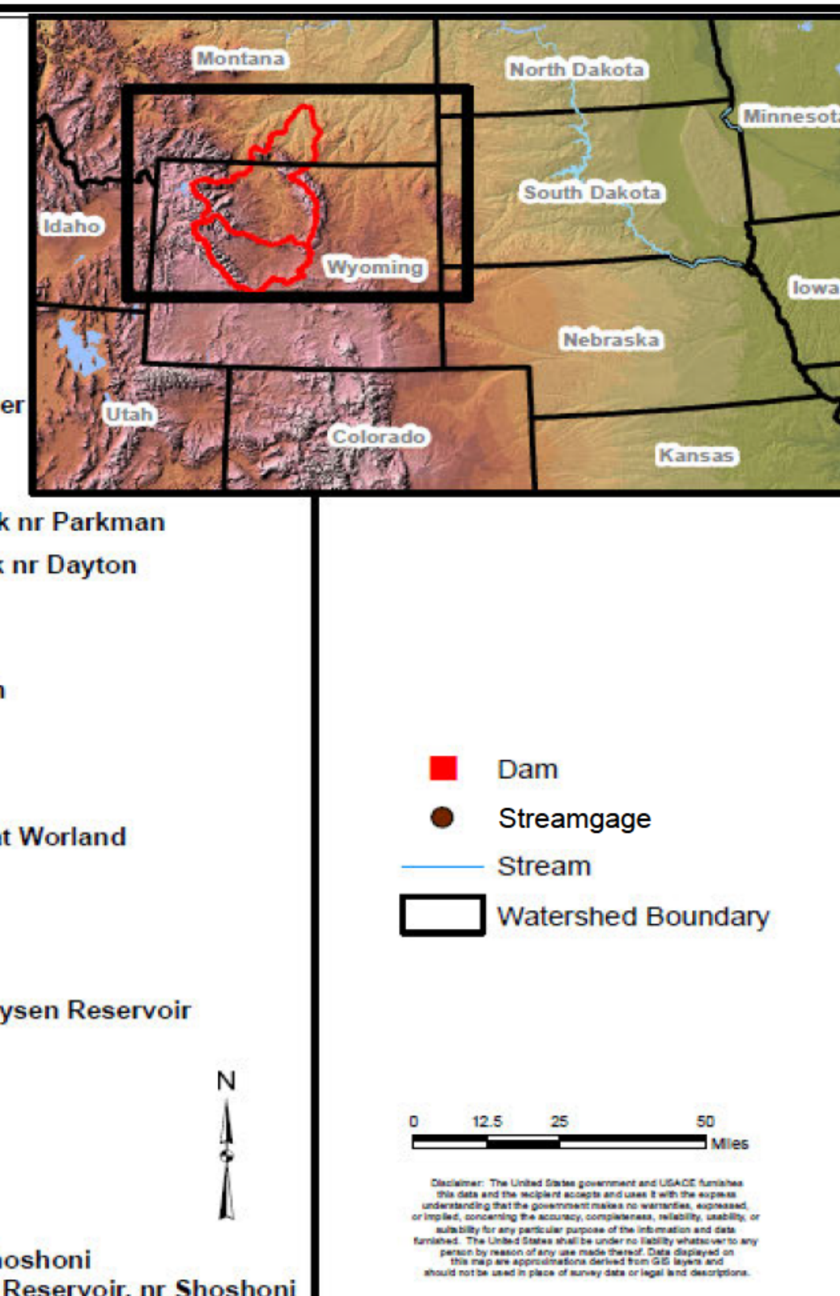
Source: USACE Omaha District, Environmental, Economics, and Cultural Resources Section

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Damages Prevented

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
March 2020





Water Control Manual
Boysen Dam and Reservoir, Wyoming

Streamgage Map

U. S. Army Engineer District, Omaha

July 2020

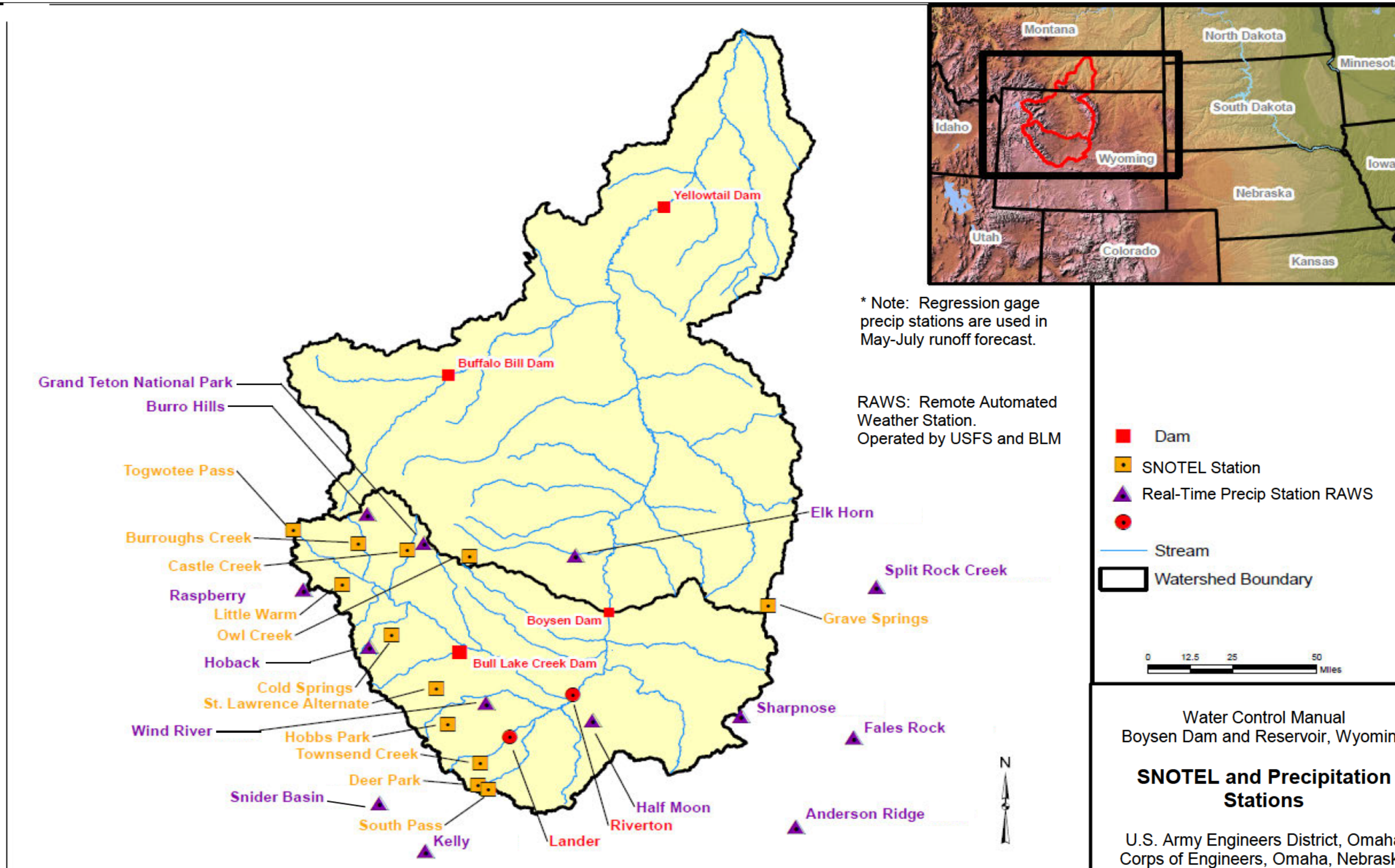
Plate 5-1

Gage	USGS Number	Corps Station ID in CWMS	NWS NESSID	USBR Hydromet ID	Drainage Area (sq. mi.)	Flood Stage (ft)	Annual Mean (cfs)	Records
Bighorn River ab Tullock Cr near Bighorn MT	06294500	BHMT	CE790122	BHMT	22419	Unknown	3756	1945-current
Bighorn River at Basin, WY	06274300	BHDY	DD5B4350	-	13223	10.5	1652	1984-current
Bighorn River at Bridge, at St. Xavier, MT	06287800	STMT	DF05E0C6	BHSX	-	Unknown	2827	1935-current
Bighorn River at Kane, WY	06279500	KAWY	DD3DA25E	-	15762	Unknown	2174	1929-current
Bighorn River at Two Leggins Bridge, near Hardin, MT	06288400	HBMT	DF0566D2	-	-	Unknown	2947	2012-current
Bighorn River at Worland, WY	06268600	BWWY	DE34156A	-	10810	Unknown	1948	1965-1970; 2015-2018
Bighorn River near St. Xavier, MT	06287000	SXMT	344727D2	-	19672	Unknown	3424	2012-current
Bull Lake Creek above Bull Lake, WY	06224000	BLAY	173524B6	BLAY	187	Unknown	289	1942-1953; 1967-current
Bull Lake Creek near Lenore, WY	06225000	BLCK	DD7AD526	BLR	213	Unknown	273	1918-1923; 1926-2017
Dinwoody Creek above lakes near Burris, WY	06221400	DCBY	DE08518C	DCBY	88.2	Unknown	144	1958-1979; 1989-current
Fivemile Creek near Shoshoni, WY	06253000	FMWY	17B037B8	FMSY	285	Unknown	165	1941-1942; 1948-1983; 1989-
Greybull River at Meeteetse, WY	06276500	MEWY	DDF8D76A	GRMY	681	7.5	440	1921-current
Little Bighorn River at State Line near Wyola, MT	06289000	WYMT	1734353A	LBSM	182	Unknown	151	1939-current
Little Popo Agie River near Lander, WY	06233000	LPWY	DDD38550	LPLY	125	Unknown	112	1946-current
Little Wind River near Riverton, WY	06235500	RILW	178BE408	LWRV	1904	8.0	568	1941-current
North Fork Shoshone River at Wapiti, WY	06279940	NFS	F231F5C8	NFS	699	8.0	880	1990-current
Shoshone River below Buffalo Bill Reservoir, WY	06282000	SRBB	347683A0	SRBB	1538	Unknown	1095	1921-2016
Shoshone River near Lovell, WY	06285100	SRLY	F0033016	SRLY	2350	11.0	909	1967-current
South Fork Shoshone River ab Buffalo Bill Res, WY	06281000	SFS	F2320242	SFS	585	9.5	446	1903-1908; 1921-1926; 1974-
South Fork Shoshone River near Valley, wy	06280300	VSWY	17AFD546	SFVY	297	8.00	419	1957-1958; 1960-
Wind River ab Boysen Reservoir, nr Shoshoni, WY	06236100	WRSY	1662058E	-	-	Unknown	1116	1990-2013
Wind River above Red Creek, near Dubois, WY	06220800	WRDY	DDF8F186	WRDY	1073	9.5	890	1991-2007; 2009-
Wind River at Riverton, WY	06228000	WRRY	17972714	WRRY	2309	9.0	774	1912-1917; 1919-1928; 1930-
Wind River below Boysen Reservoir	06259000	BYWY	34766052	WRBD	7701	Unknown	1471	1951-current
Wind River near Crowheart, WY	06225500	WRCH	DD7AC650	WRCH	1891	10.0	1192	1946-2017
Wind River near Dubois,WY	06218500	WDWY	DD5A7430	-	232	5.0	173	1946-1992; 2001-
Wind River near Kinnear, WY	06227600	WRKY	DD35D068	WRKY	2194	9.0	815	1974-1979; 1991-

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Table of Relevant Hydrologic Stations

US Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

SNOTEL and Precipitation Stations

U.S. Army Engineers District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

SNOTEL Site Name	NRCS SITE ID	Elevation (feet)	Basin Name	Average Snow Water Equivalent in Inches (1981-2010)																									
				1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec	1-Jan	15-Jan	1-Feb	15-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	Peak	Date
Burroughs Creek*	379	8750	Upper Wind	0.2	0.5	1.2	2.5	3.8	5.3	6.7	8.2	9.5	10.6	11.8	12.8	14.0	14.3	13.2	9.7	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	14.3	11-Apr
Castle Creek	1130	8400	Upper Wind	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cold Springs	405	9630	Upper Wind	0.1	0.3	0.9	1.6	2.4	3.0	3.6	4.3	4.8	5.3	6.0	6.6	7.2	5.7	4.1	2.6	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	7.2	1-Apr
Deer Park	923	9700	Popo Agie	0.1	0.9	2.3	3.6	4.5	5.8	7.4	8.8	10.2	11.7	12.9	14.2	16.0	17.1	17.7	15.1	6.9	3.0	0.0	0.0	0.0	0.0	0.0	0.1	18.1	25-Apr
Grave Springs	501	8550	near Badwater	0.1	0.5	1.1	1.7	2.3	2.9	3.8	4.6	5.3	6.2	7.0	7.8	9.1	9.6	9.1	5.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	10-Apr
Hobbs Park	525	10100	Popo Agie	0.3	1.1	2.3	3.6	4.8	5.9	6.9	8.0	8.8	9.8	10.9	12.4	14.3	15.5	16.4	14.6	8.3	3.7	0.5	0.0	0.0	0.0	0.0	0.1	16.5	27-Apr
Little Warm	585	9370	Upper Wind	0.2	0.5	1.2	2.2	3.2	4.1	5.0	6.0	6.9	7.7	8.6	9.6	10.7	10.9	9.4	6.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	11-Apr
Owl Creek	676	8975	Owl Creek	0.2	0.5	0.9	1.4	1.8	2.1	2.5	2.9	3.2	3.6	4.0	4.6	5.4	4.5	2.9	1.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.4	3-Apr
South Pass	775	9040	Popo Agie	0.1	0.5	1.6	2.9	4.4	6.0	7.5	8.9	10.2	11.6	12.9	14.5	16.0	16.3	15.5	10.8	4.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	16.5	9-Apr
St. Lawrence Alt	786	8620	Popo Agie	0.1	0.3	0.9	1.4	2.1	2.6	3.1	3.6	4.0	4.6	5.2	5.9	6.7	5.9	4.3	2.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	3-Apr
Togwotee Pass	822	9580	Upper Wind	0.3	1.3	2.7	4.9	7.2	9.2	11.5	13.8	15.8	17.7	19.4	21.2	23.3	24.7	25.6	24.3	18.1	10.8	2.2	0.0	0.0	0.0	0.0	0.0	25.6	2-May
Townsend Creek	826	8700	Popo Agie	0.1	0.5	1.2	1.9	2.7	3.4	4.2	4.8	5.4	6.2	6.9	7.8	9.2	9.1	7.5	4.3	1.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1	9.5	8-Apr
AVERAGE OF ALL STATIONS				0.2	0.6	1.5	2.5	3.5	4.6	5.6	6.7	7.6	8.6	9.6	10.7	12.0	12.1	11.4	8.8	4.1	1.7	0.2	0.0	0.0	0.0	0.0	0.0	12.8	12-Apr

Source - Natural Resources Conservation Service (NRCS) National Water and Climate Center

* Burroughs Creek site was affected by wildfires and the snow may not accumulate and melt as it had during the 1981-2010 period.

Water Control Manual
Boysen Reservoir and Dam, Wyoming

Table of Snow Water Equivalent for SNOTEL Stations in Upstream Basin

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020

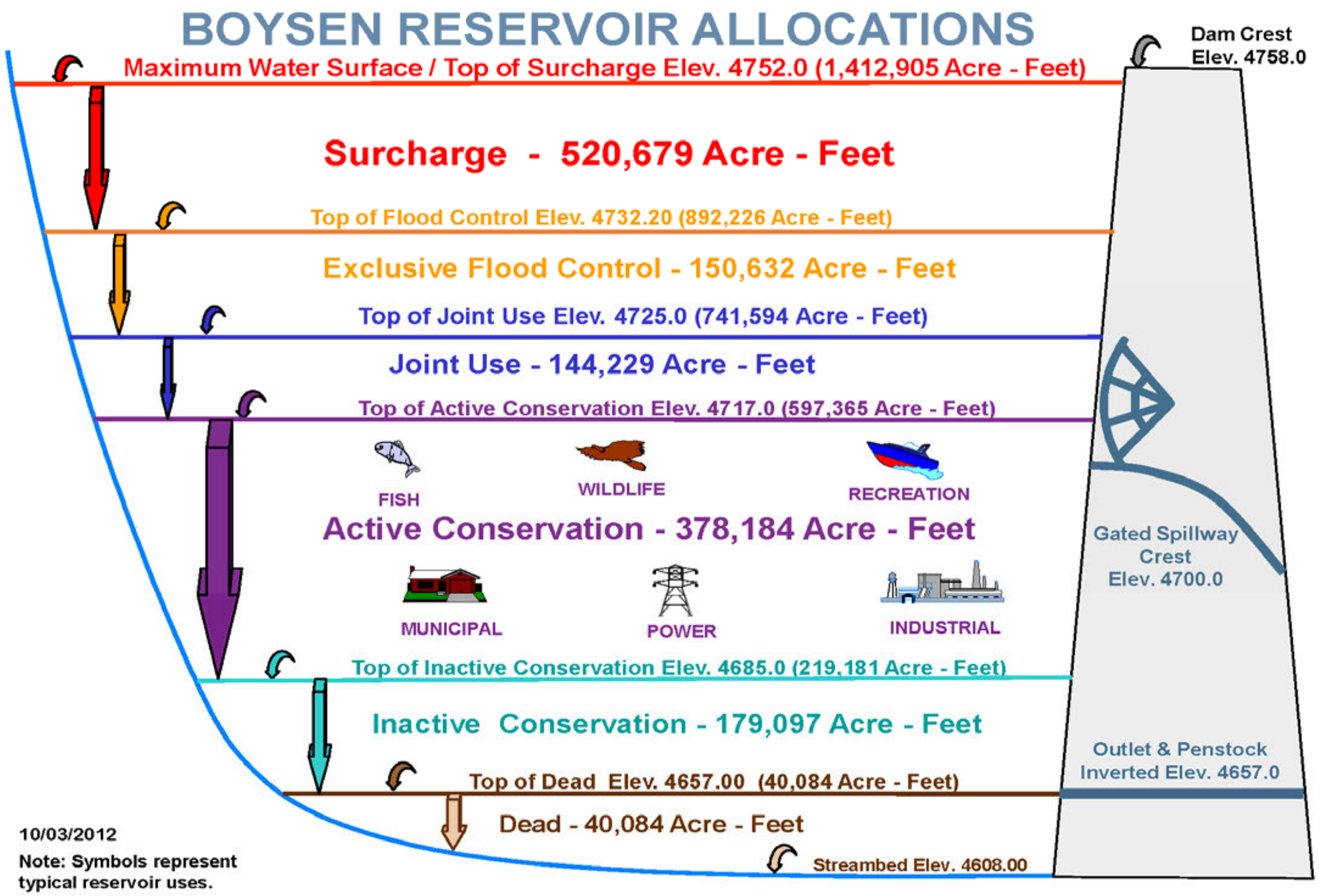
Station Name	Elevation feet	Period of Record	Average Precipitation (Inches)												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Crandall	6612	1993-2019	0.09	0.29	0.36	0.81	1.42	1.45	1.14	0.99	0.97	0.98	0.58	0.20	9.30
Eagle	7500	1999-2019	0.18	0.16	0.64	0.82	1.76158	1.59	0.83	1.11	1.26	1.23	0.34	0.33	10.25
Elkhorn	8325	1989-2019	0.08	0.14	0.26	0.85	1.59	1.33	0.92	0.76	1.12	1.66	0.28	0.07	9.08
False Rock	6380	1997-2019	0.02	0.13	0.38	0.97	1.57	0.99	0.75	0.66	0.84	0.58	0.10	0.18	7.16
Grass Creek Divide	7100	1991-2019	0.06	0.10	0.52	0.98	2.31	2.17	1.49	1.06	1.39	0.77	0.16	0.09	11.10
Lander	5587	1892-2019	0.41	0.58	1.16	1.87	2.20	1.27	0.78	0.61	1.05	1.29	0.86	0.58	12.66
Leigh Creek	8202	1999-2019	0.25	0.30	0.68	1.14	2.14	1.43	1.00	0.99	1.53	1.11	0.37	0.27	11.20
Pistol Draw	4520	2016-2019	0.03	0.10	1.06	2.16	1.24	0.31	0.16	0.25	1.63	1.00	0.63	0.15	8.71
Raspberry	10040	1985-2019	0.14	0.14	0.47	0.93	1.62	1.40	1.16	2.16	1.48	0.94	0.32	0.24	11.00
Rattlesnake Mtn	6800	1988-2019	0.11	0.23	0.64	1.76	2.71	2.03	1.37	1.18	1.31	1.08	0.33	0.11	12.86
Riverton	5443	1907-2019	0.24	0.27	0.55	1.30	1.72	1.28	0.89	0.57	0.90	0.89	0.50	0.32	9.43
Sharpnose	5555	2015-2019	0.04	0.14	1.41	1.96	3.24	0.68	0.10	0.49	0.70	0.63	0.26	0.08	9.72
Split Rock	6000	1988-2019	0.06	0.14	0.50	1.31	2.69	1.60	1.30	0.80	1.40	1.12	0.40	0.09	11.41
Wind River	9235	1991-2019	0.11	0.19	0.48	1.28	2.27	1.45	0.97	1.00	1.19	0.77	0.19	0.13	10.00

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Average Monthly Precipitation Table

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska

July 2020



Source: US Bureau of Reclamation

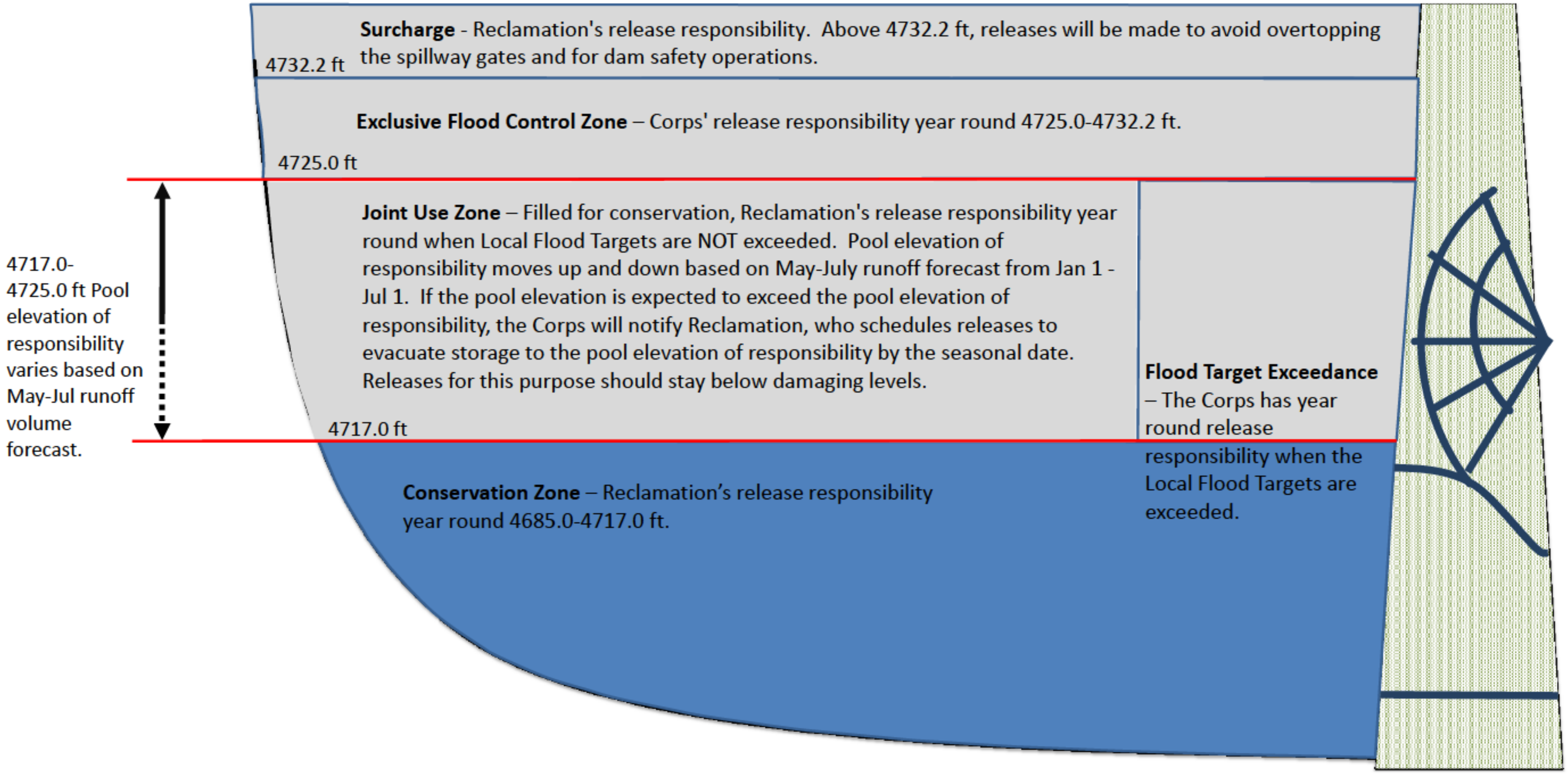
Water Control Manual
Boysen Dam and Reservoir, Wyoming

Reservoir Storage Allocations
Boysen Reservoir

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
Jul 2020

Release Responsibility Diagram

Note: Figure below denotes who is responsible for release decisions based on the time of year and pool elevation. All elevations are NGVD29.

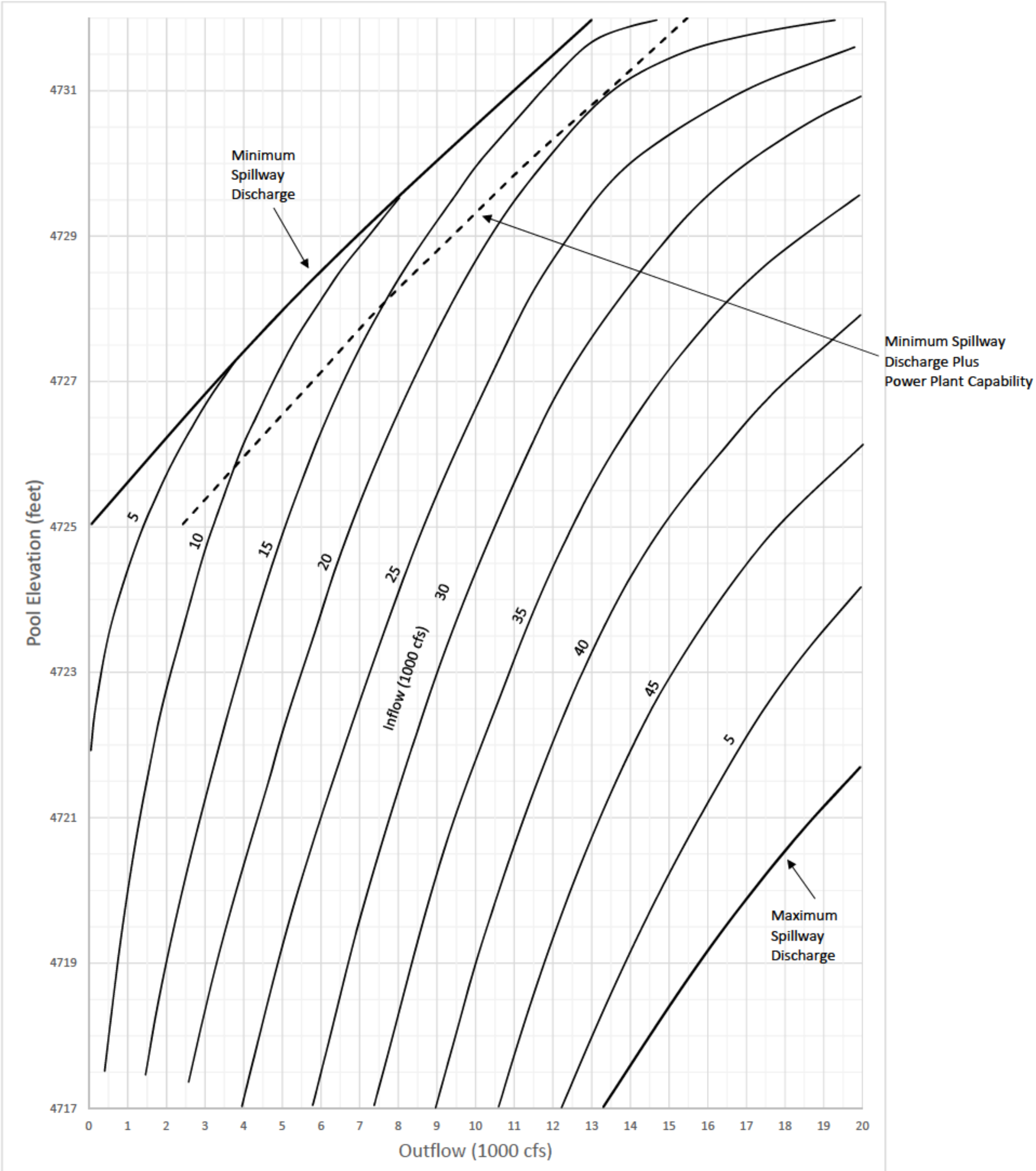


Note: Drawing not to scale

Water Control Manual
Boysen Dam and Reservoir, Wyoming

Release Responsibility Diagram

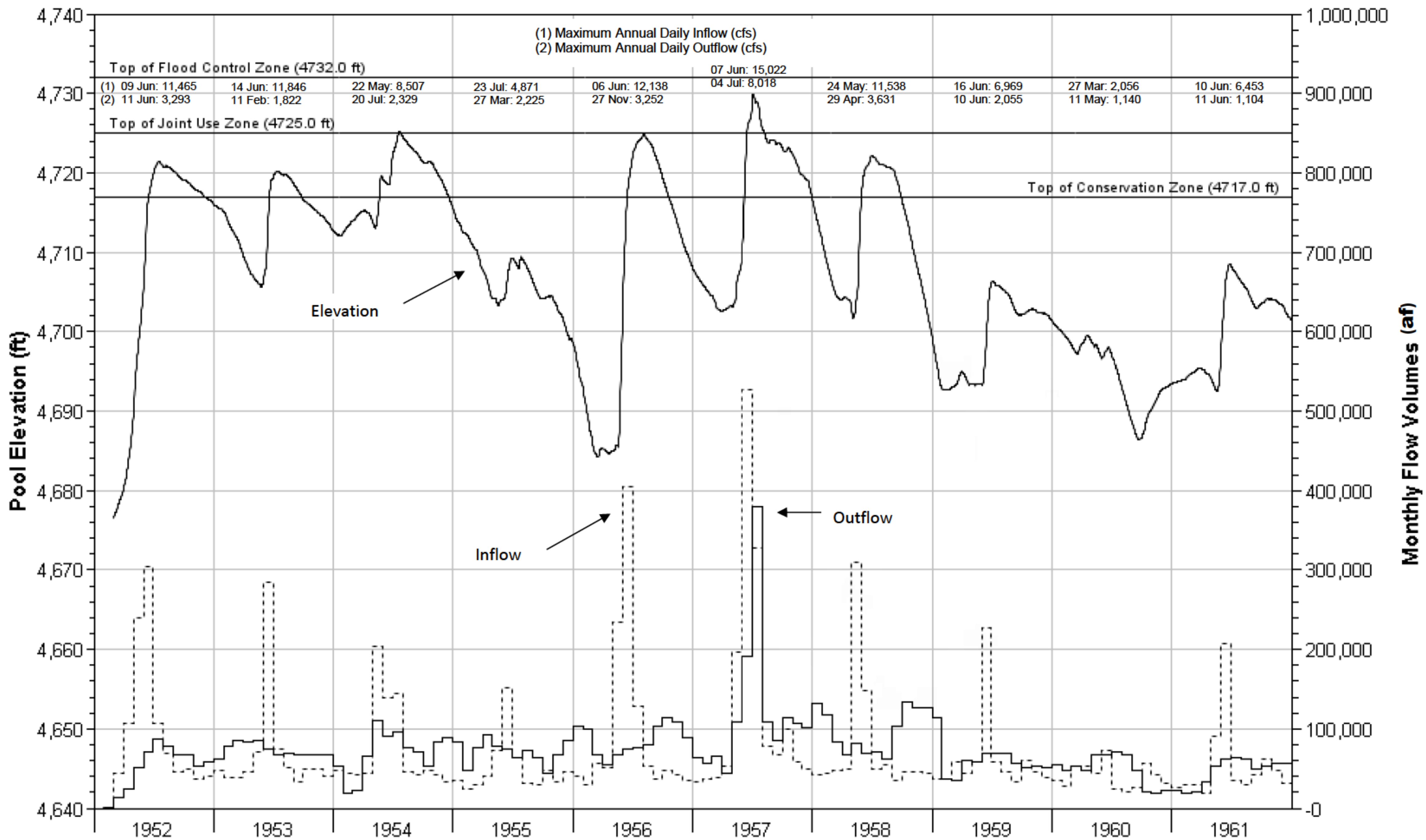
U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
Jul 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

Reservoir Regulation Curves
Spillway Discharge

U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

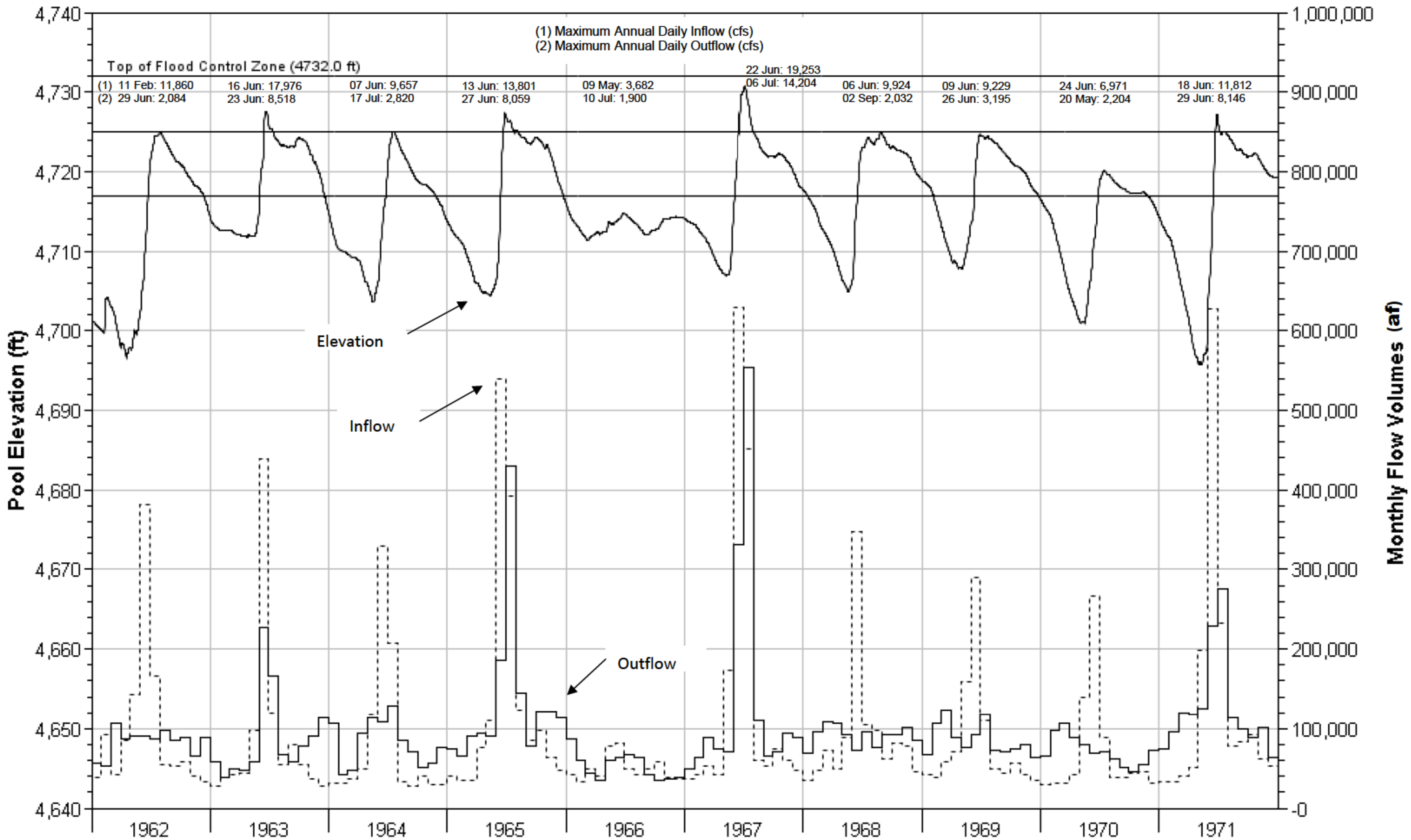
Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases

1952-1961

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

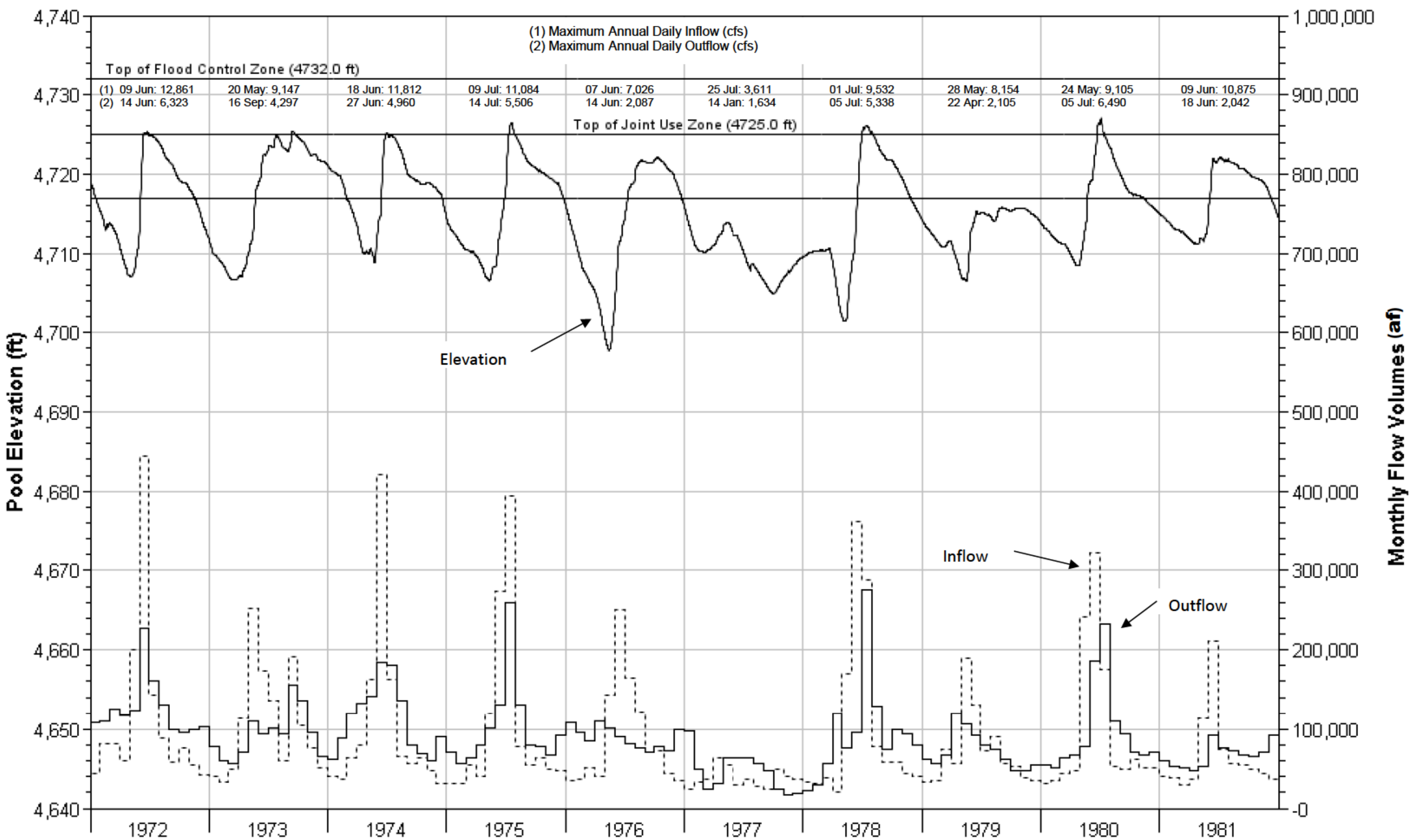
Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases

1962-1971

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

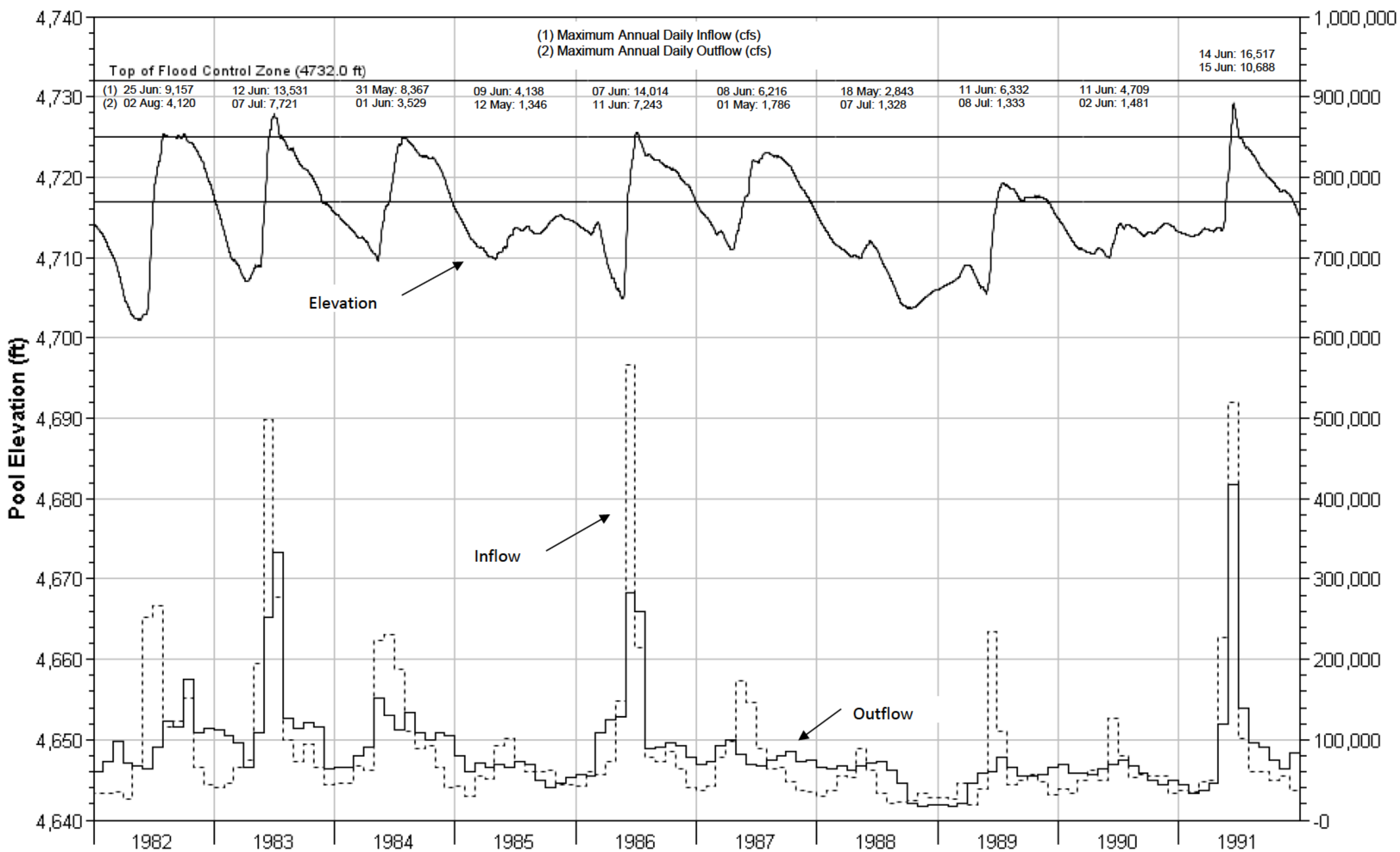
Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases

1972-1981

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

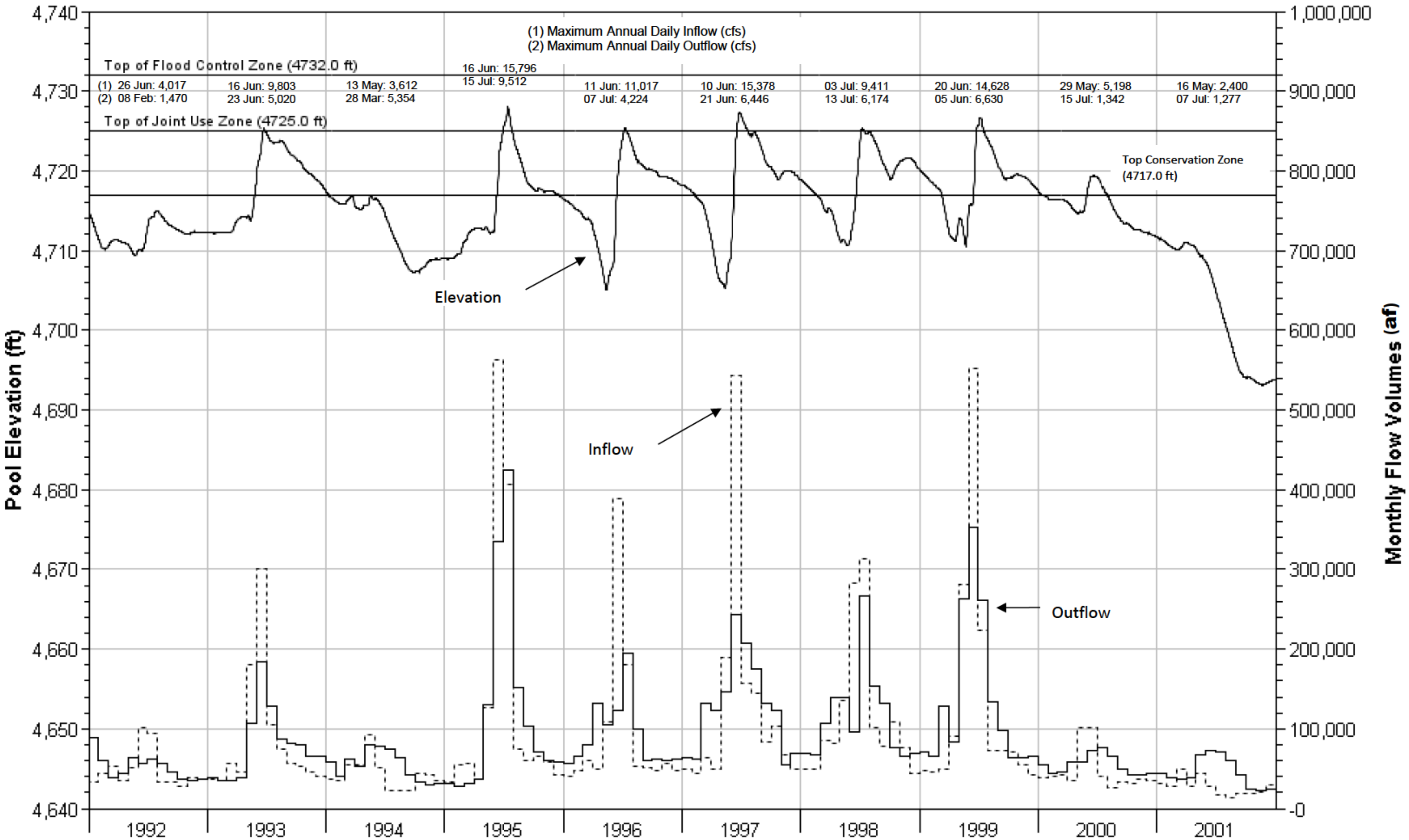
Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases

1982-1991

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



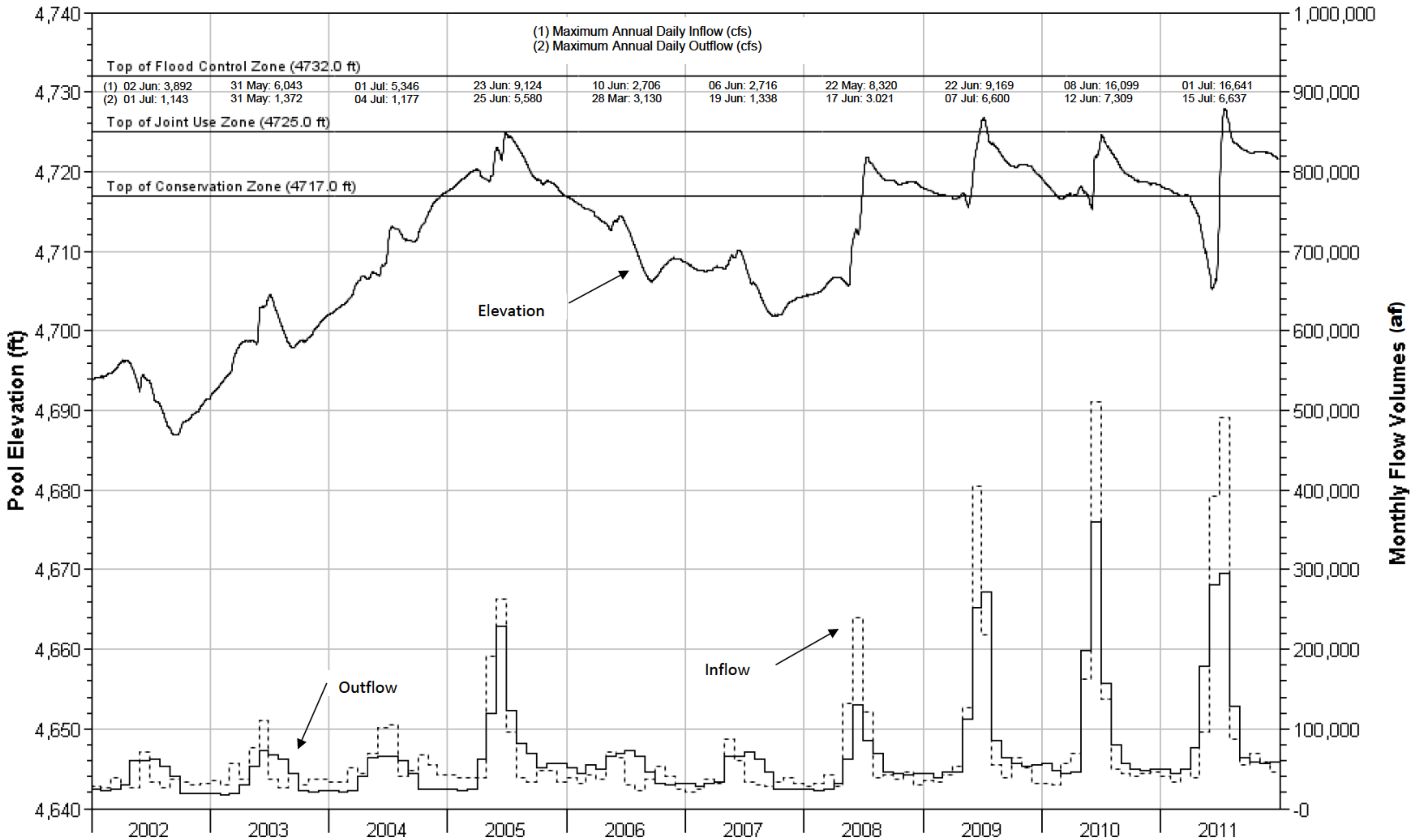
Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases
1992-2001

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



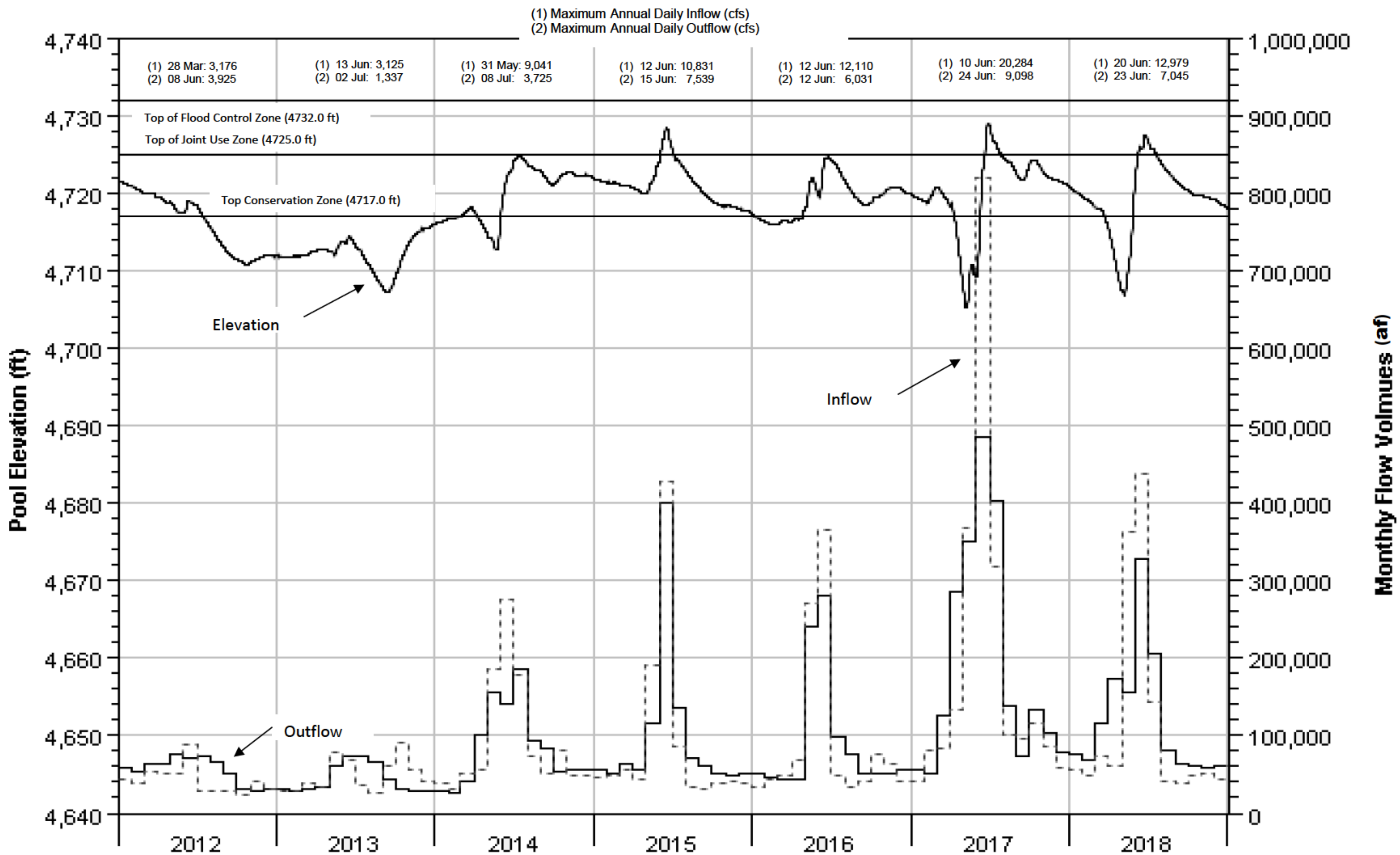
Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases
2002-2011

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



Pool Elevations are reported in NGVD29.
Flow Volumes are an accumulation of daily average flows in ac-ft.

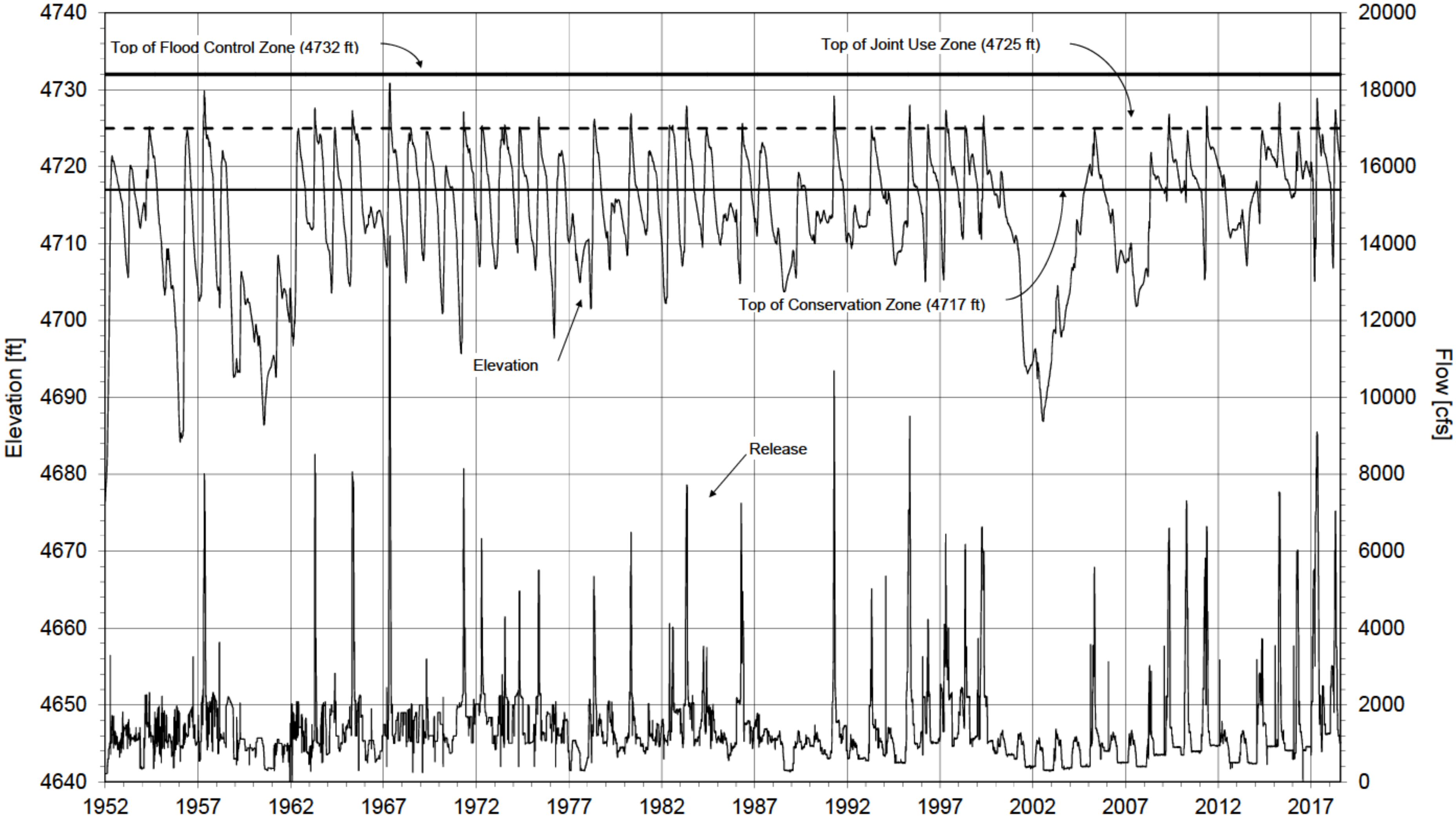
Source: USBR HydroMet Data

Water Control Manual
Boysen Dam and Reservoir

Historical Pool Elevation, Inflows, and Releases

2012-2018

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020

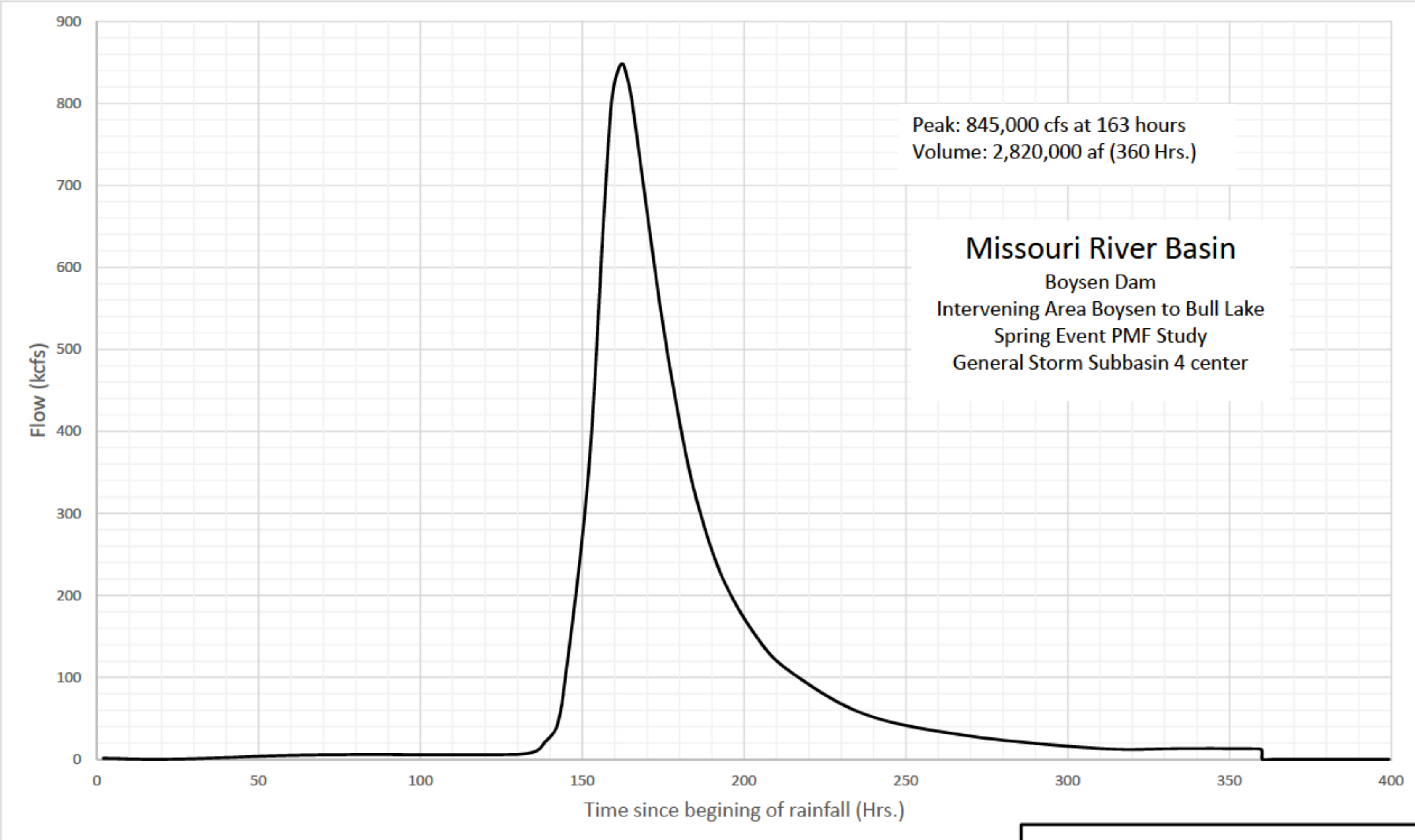


Source of data: USBR Hydromet-Hydrological database

Water Control Manual
Boysen Dam and Reservoir, Wyoming

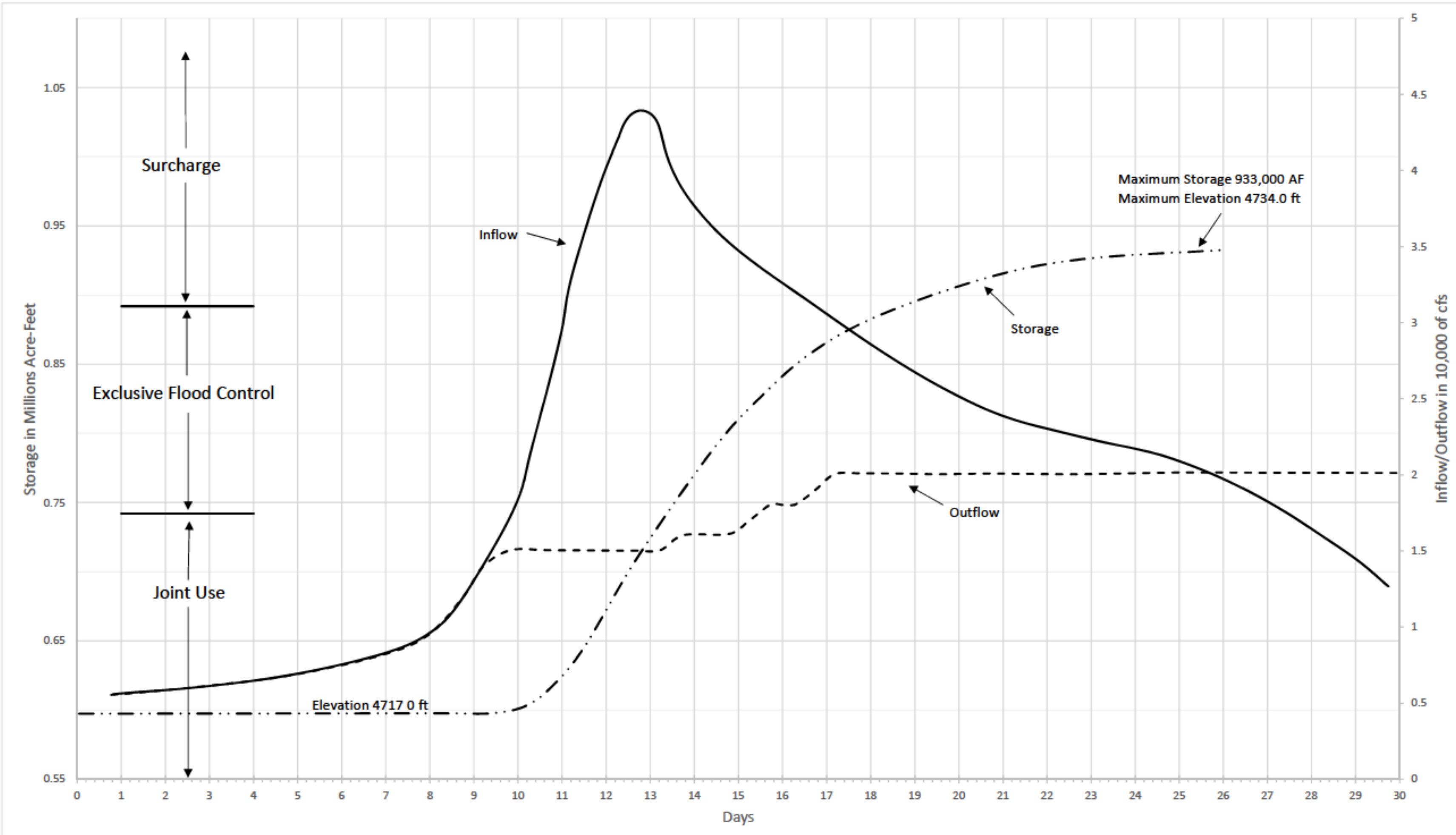
Period of Record
Pool Elevation and Releases

U.S. Army Engineer District
Corps of Engineers, Omaha, Nebraska
July 2020



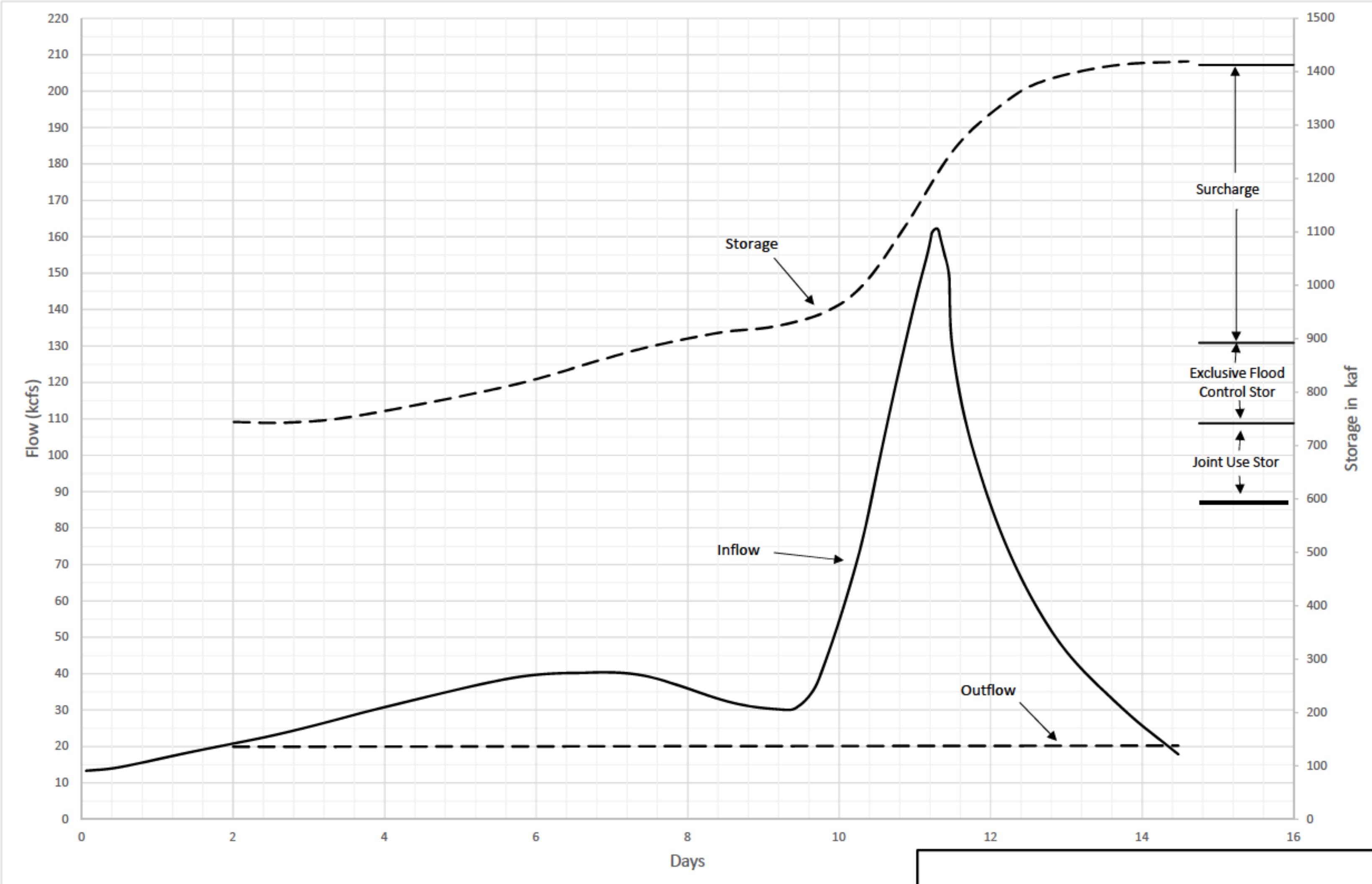
Source: Boysen Standing Operating Procedures

Water Control Manual
Boysen Dam and Reservoir, Wyoming
Probable Maximum Flood Hydrograph
U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



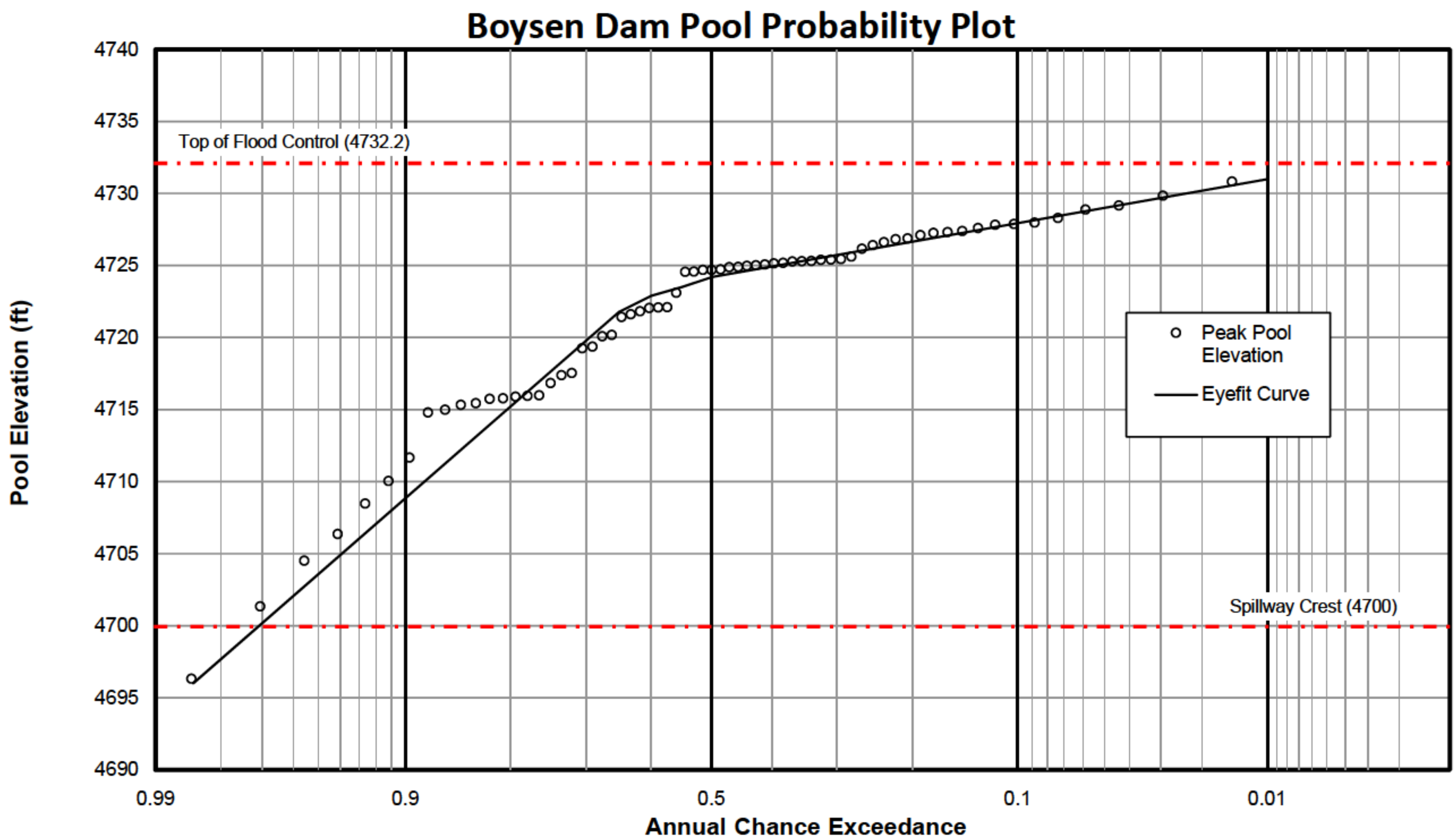
Source: Boysen Dam and Reservoir – Reservoir Regulation Manual – Flood Regulation Only, March 1963

Water Control Manual
Boysen Dam and Reservoir, Wyoming
Reservoir Design Flood Routing
U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Source: Boysen Standing Operating Procedure

Water Control Manual
Boysen Dam and Reservoir, Wyoming
Original Spillway Design Flood
U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



NOTE: Plot was created based on historical pool levels from 1952-2012; no modeling or routing was used to compute data points. The curve was plotted using the eyefit method.

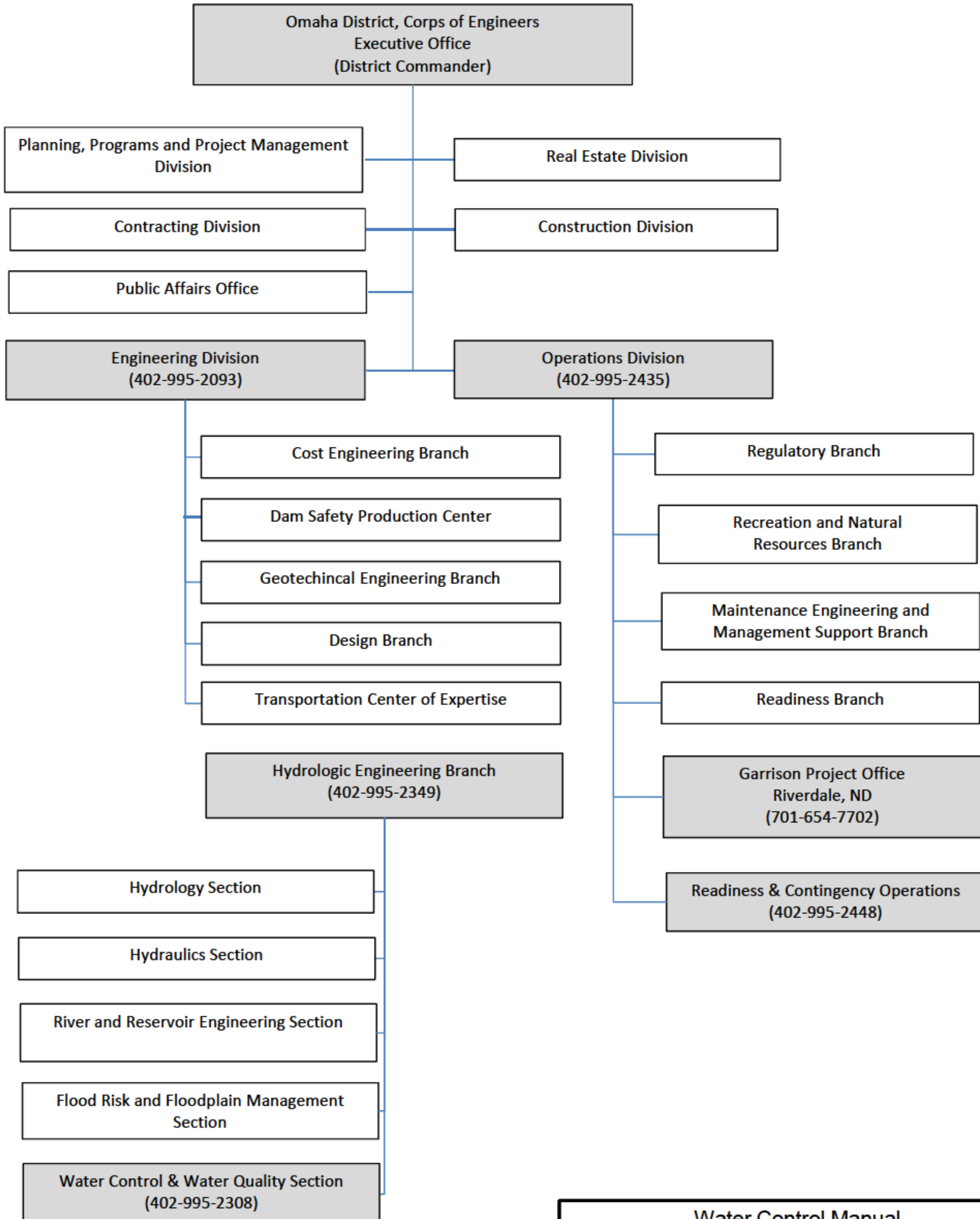
Top of Dam: 4758.0 ft

Water Control Manual
Boysen Dam and Reservoir

Pool Probability

Boysen Reservoir

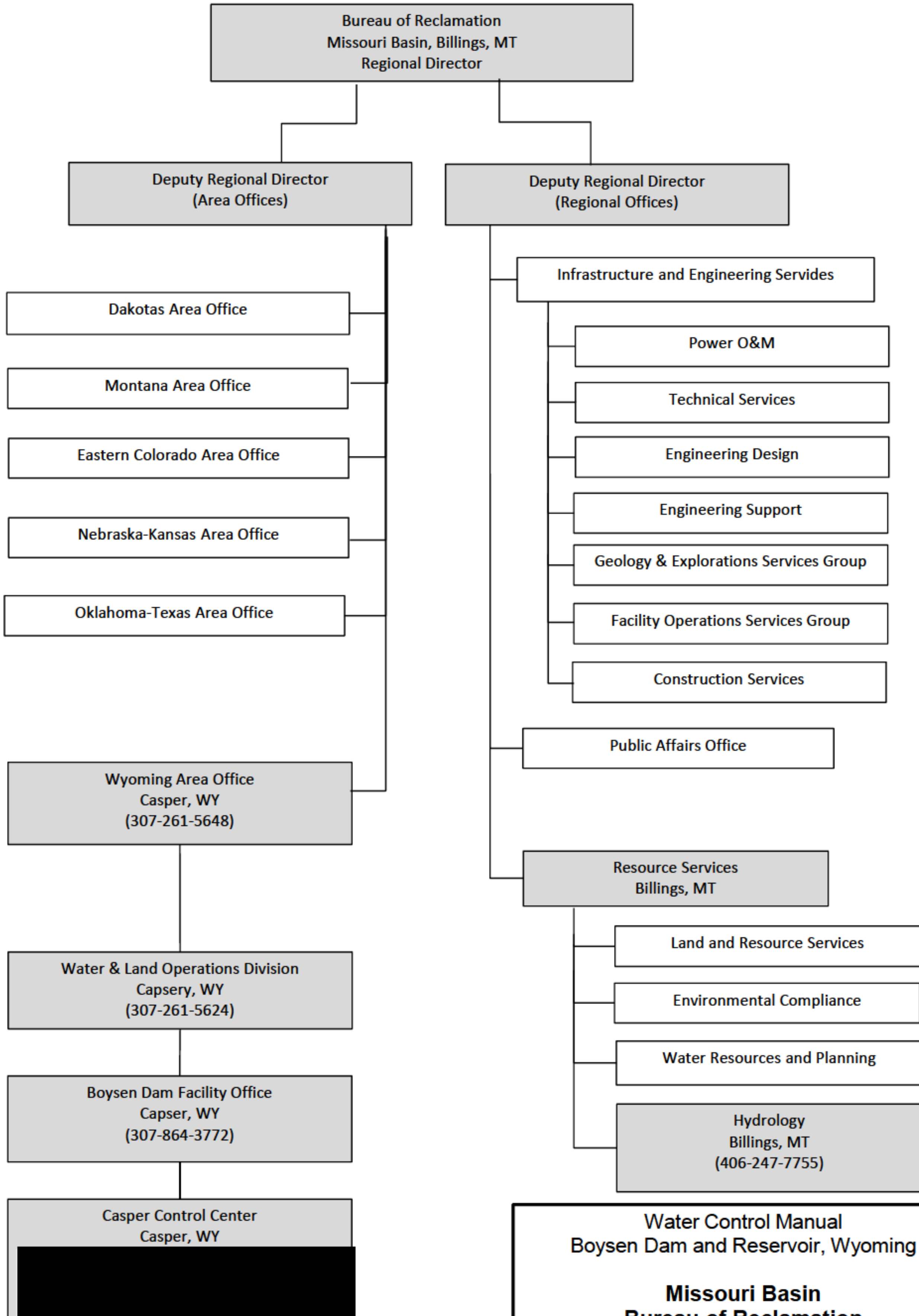
U.S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

Omaha District
Corps of Engineers
Organization Chart

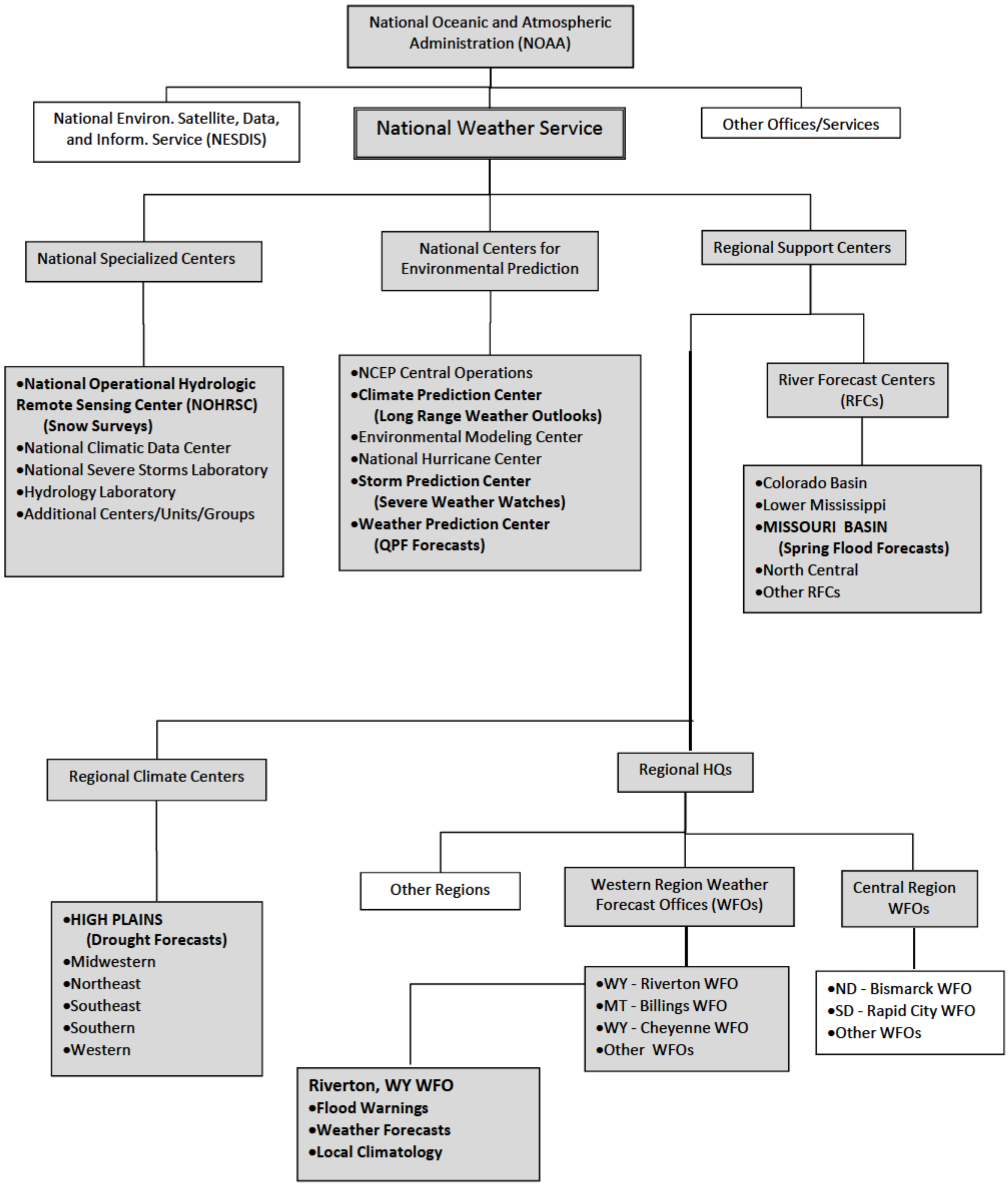
U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

Missouri Basin
Bureau of Reclamation
Organization Chart

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020



Water Control Manual
Boysen Dam and Reservoir, Wyoming

National Weather Service Organization Chart

U. S. Army Engineer District, Omaha
Corps of Engineers, Omaha, Nebraska
July 2020