MISSOURI RIVER
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL

GAVINS POINT MANUAL

U. S. ARMY ENGINEER DIVISION, MISSOURI RIVER
CORPS OF ENGINEERS
OMAHA, NEBRASKA
1978

Murphy
gh/4610

MROED-HC

Garvey

SUBJECT: Reservoir Regulation Manual, Gavins Point Dam - Lewis and Clark Lake, South Dakota

Horihan

Burnett

Project Manager, Lewis and Clark Lake

Inclosed for your information and retention are three copies of the above subject Reservoir Regulation Manual.

FOR THE DISTRICT ENGINEER:

1 Incl
as

R. G. BURNETT
Chief, Engineering Division

CF:
MROOP-H w/1 incl

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
P. O. BOX 103, DOWNTOWN STATION
OMAHA, NEBRASKA 68101

MRDED-R

15 March 1979

SUBJECT: Reservoir Regulation Manual, Gavins Point Reservoir, South Dakota

District Engineer, Omaha
ATTN: MROED-HC

Seven copies of the subject manual are inclosed for your information and retention. It was agreed in conversation between Messrs. Franklin, MRD, and Garvey, OD, that three of these manuals would be made available to the Lewis and Clark Lake Project.

FOR THE DIVISION ENGINEER:

Lloyd A. Duscha

1 Incl
as

LLOYD A. DUSCHA
Chief, Engineering Division

MISSOURI RIVER

MAIN STEM RESERVOIR SYSTEM

RESERVOIR REGULATION MANUAL

In 7 Volumes | Volume 7

GAVINS POINT RESERVOIR (LEWIS AND CLARK LAKE)

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

PREPARED BY
U.S. ARMY ENGINEER DIVISION, MISSOURI RIVER
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GAVINS POINT DAM AND RESERVOIR
MISSOURI RIVER

PERTINENT DATA

1. PURPOSE

Gavins Point Dam and Reservoir, in coordination with other projects in the Missouri River main stem system, is operated as a multiple- purpose reservoir for navigation, flood control, hydroelectric power, irrigation, water supply, water quality control, recreation, fish and wildlife and other conservation purposes.

2. AUTHORIZATION

Authorized by the Flood Control Act approved 22 December 1944 (Public Law 534, 78th Congress, 2nd Session) as part of the general comprehensive plan for flood control and other purposes in the Missouri River Basin.

3. LOCATION OF DAM

State	Nebraska and South Dakota
Counties	Cedar County, Nebraska and Yankton County, South Dakota
River	Missouri River, 811.05 above the mouth (1960 mileage)
Town	Approximately 4 miles west of Yankton, South Dakota

4. DRAINAGE AREAS

Total Missouri River Basin, sq. mi.	529,350
Above Gavins Point Dam, sq. mi.	279,480
Fort Randall Dam to Gavins Point Dam, sq. mi.	16,000
Gavins Point Dam to Sioux City, Iowa, sq. mi.	35,140
Sioux City to Rulo, Nebraska, sq. mi.	104,290

5. STREAM FLOW DATA

Observed Flow at Dam Site, c.f.s. (1898-1955)	
Maximum of Record (1952)	480,000
Minimum (1940)	2,700

Actual Regulated Flow at Dam Site, c.f.s. (1955-1977)	
Maximum (1975)	61,100
Minimum (1963 and 1964)	4,900
Average	25,200

Average Annual Runoff at Dam Site, (1898-1977) Acre-Feet	23,200,000
Average Annual Runoff at Sioux City (1989-1977) Acre-Feet	24,700,000

6. RESERVOIR DATA

Approximate Length of Reservoir, miles (Pool Level at Maximum Normal Operating Level and 1960 River Conditions)	25
Shoreline, miles at Elev. 1204.5	90

Storage Capacity (1975 Survey)	Elevation M.S.L.	Gross Storage Acre-Feet	Gross Area Acres
Maximum Operating Pool	1210	517,000	32,000
Maximum Normal Operating Pool	1208	455,000	30,000
Base of Flood Control Pool	1204.5	358,000	26,000
Exclusive Flood Control	1208-1210	62,000	
Seasonal Flood Control	1204.5-1208	97,000	
Inactive Storage	1160-1204.5	358,000	

7. DAM

Embankment Type - Rolled Earth Fill	
Abutment Formations - Niobrara Chalk and Carlisle Shale	
Top of Embankment, Elev. Ft. m.s.l.	1,234
Total Crest Length, Feet (excluding spillway)	8,700
Maximum Height, Feet	74
Damming Height (Low Water to Max. Oper. Pool)	45
Top Width, Feet	35
Maximum Base Width, Feet	850
Fill Quantity, Cubic Yards	7,000,000

8. SPILLWAY

Location	Right Bank
Type - Chute, Concrete Lined with Gated Overflow Weir	
Crest Elevation, Feet m.s.l.	1,180
Crest Length, Gross, Feet	664

Crest Length, Net, Feet	560
Gates - Tainter - No. & Size, Feet	14 - 40 x 30
Design Discharge Capacity, c.f.s.	584,000
Discharge Capacity at Maximum Operating Pool, (Elev. 1210) c.f.s.	345,000

9. POWERHOUSE AND INTAKE

Location	Right Abutment
Type - Concrete - Powerhouse and Intake Integrally Constructed	
Service Gates, Type	Vertical Lift Tractor
Service Gates, No. & Size in Feet	3 - 18 x 35 for Each Unit
Emergency Gates, Type	Bulkhead
Emergency Gates, No. & Size in Feet	3 - 17.67 x 36.75
Intake Inlet Elevation, Feet, m.s.l.	1,139.5
Present Tailwater Elevation, Feet, m.s.l.	1156-1162

10. POWER INSTALLATION

Average Gross Head Available, Feet	45
Number of Generating Units	3
Turbines, Type	Kaplan
Turbines, Speed, rpm	75
Discharge Capacity at Rated Head (48 feet) cfs	36,000
Generator Rating, KW	33,333

12. POWER AVAILABLE

Plant Capacity, KW	100,000
Dependable Capacity, KW (3)	67,000
Average Annual Energy, KWH (4)	651,000,000

NOTE: (1) Based on full loading of 2 of 3 units.
(2) Based on Operation Study 2-76-1975.

MISSOURI RIVER BASIN
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL
IN 7 VOLUMES - VOLUME NO. 7
GAVINS POINT DAM AND RESERVOIR

SECTION I - AUTHORIZATION AND SCOPE

1-1. Authorization. This manual has been prepared as directed in ER 1110-2-240 and in accordance with pertinent sections of EM 1110-2-3600, "Reservoir Regulation".

1-2. Scope. This manual is one of the 7 volumes being prepared for the main stem system of reservoirs as follows:

Volume	Project
1	Master Manual
2	Fort Peck
3	Garrison
4	Oahe
5	Big Bend
6	Fort Randall
7	Gavins Point

1-3. The system of reservoirs on the main stem of the Missouri River consists of six projects, Fort Peck (Fort Peck Lake), Garrison (Lake Sakakawea), Oahe (Lake Oahe), Big Bend (Lake Sharpe), Fort Randall (Lake Francis Case, and Gavins Point (Lewis and Clark Lake) constructed by the Corps of Engineers for the purpose of flood control and other multiple use purposes. In order to achieve the multipurpose benefits for which the main stem reservoirs were authorized and constructed, they must be regulated as a hydraulically and electrically integrated system. Therefore, the Master Manual presents the basic operational objectives and the plans for their optimum fulfillment, with supporting basic data. The Gavins Point Manual supplements the Master Manual by discussing the factors pertinent to the regulation of the Gavins Point Reservoir. The regulation of major tributary reservoirs located within the Missouri River Basin affecting the regulation of the Gavins Point project is detailed in separate manuals prepared for the individual tributary projects.

1-4. In an effort to reduce redundancy, frequent reference will be made in this, the Gavins Point project manual, to information contained in the Master Manual. This is particularly true with respect to details concerning organization, coordination with other projects and agencies, and other factors that are pertinent to operation of the system as a whole. This project manual should therefore be considered as a supplement to the Master Manual, presenting further information and expanding or emphasizing details that are of particular importance to the Gavins Point project.

1-5. Additionally, since the Gavins Point Reservoir is the most downstream of the six projects comprising the Missouri River main stem system of reservoirs, system releases and Gavins Point releases are identical. System release definition is discussed in detail within the Master Manual and these details are not repeated in this, the Gavins Point project manual. Reference is made to the Master Manual for release definition procedures during all times other than those when system procedures must be subordinated to those applicable to Gavins Point alone as a result of unusual circumstances.

SECTION II

DESCRIPTION OF MISSOURI RIVER AND DRAINAGE AREA

II-A Basin Geography

2-1. Areal Extent. The Missouri River Basin drainage area upstream from Gavins Point Dam includes all of Montana east of the continental divide, northern Wyoming, southwestern North Dakota, western South Dakota, a portion of northern Nebraska, and portions of the tributary Milk River drainage lying in southern Canada. The total area controlled by Gavins Point Dam is 279,480 square miles. This includes 57,500 square miles of drainage above Fort Peck Dam, 123,900 square miles between Fort Peck and Garrison Dams, 62,090 square miles between Garrison and Oahe Dams, 5,840 square miles between Oahe and Big Bend Dams, 14,150 square miles of incremental drainage area between Big Bend and Fort Randall Dams, and 16,000 square miles between Fort Randall and Gavins Point Dams. Those portions of the Missouri River drainage area lying upstream from Fort Randall Dam are described in the Fort Peck, Garrison, Oahe, Big Bend and Fort Randall Reservoir Regulation Manuals. The portion of the Missouri Basin described in this manual consists of the 16,000 square miles of incremental drainage area between Fort Randall Dam and Gavins Point Dam. The Missouri River and its drainage area below Gavins Point Dam is discussed in the Master Manual as being pertinent to system regulation, although some details concerning the area contributing immediately below Gavins Point Dam are included in the manual. Plate 1 is a general map of the Missouri River Basin while the incremental drainage area defined by the Fort Randall and Gavins Point Dams and described in this manual is shown in more detail on Plate 2.

2-2. Topography. The Missouri River drainage area between Fort Randall and Gavins Point Dams forms a portion of the Great Plains province of the United States. The area to the north and east of the Missouri River is within the Glaciated Missouri Plateau consisting of gently rolling topography in which stream dissection and drainage are not well established except in areas immediately adjacent to the Missouri River. Drainage in upland areas is largely into pot holes, small intermittent lakes and a few larger permanent lakes. Most of the incremental drainage area lies to the south and west of the Missouri River within the high plains region. These plains are characterized by rolling tablelands with hilly to rough broken areas along the sides of stream valleys. Stream dissection is well established with broad smooth divides between the larger drainages. Portions of the northern Nebraska sandhills are also contained within the Fort Randall-Gavins Point drainage. In these hills the sandy character of the soil allows a large portion of the annual precipitation to percolate into groundwater storage. Withdrawal from this storage maintains streamflow originating from the area at a relatively constant rate throughout the year.

2-3. The major portion of the Fort Randall-Gavins Point incremental drainage lying to the west of the Missouri River has a general west to east slope of about 10 feet to the mile. Elevations range from about 5,000 feet in the western extremity to less than 1200 feet on bottom lands adjacent to the Missouri River. Immediately below Gavins Point Dam, downstream to Sioux City, Iowa, the incremental drainage area lies almost entirely to the east of the Missouri River and is characterized by much flatter slopes than to the west, with maximum elevations in the 2,000 feet m.s.l. range.

2-4. Land Use. Agriculture represents the primary use of the land in this portion of the Missouri Basin, estimated to extend over 95 percent of the total area. The remainder is devoted to recreation, fish and wildlife, transportation and built-up areas. Pasture and range is the primary agricultural pursuit, utilizing about 75 percent of the total area. Cropland comprises about 18 percent of the total area to the west of the Missouri River, but increases to about 50 percent of the total area contributing between Gavins Point Dam and Sioux City. Forested lands, probably less than 5 percent of the total area, exist in western portions of the region and along stream bottoms throughout the incremental area. Due to the general lack of an assured water supply, irrigation is practiced on only a minor amount of land in the incremental drainage area, with irrigated lands less than one percent of total cropland. Water areas in this incremental drainage area make up about one percent of the total area, but the rivers, lakes, reservoirs, farm ponds and other bodies of water involved are extremely important to the region's economy.

2-5. Drainage Pattern. The drainage pattern of the Missouri River Basin is shown on Plate 1. Noteworthy in the drainage basin above Gavins Point Dam is the large area of the upper Missouri River Basin controlled by the Fort Peck, Garrison, Oahe, Big Bend and Fort Randall projects. These upstream main stem projects control about 94 percent of the total drainage contributing to the Gavins Point project, including all of the mountainous area contributing to the Missouri River above Gavins Point Dam.

2-6. The prominent feature of the incremental portion of the Missouri River Basin between Fort Randall and Gavins Point Dams is the single major tributary of this reach, the Niobrara River, a right bank tributary flowing in an easterly direction. This direction of flow is of particular importance from the standpoint of flow contribution from storms that typically move in an easterly direction. Additionally, it becomes important at the time of snowmelt and ice breakup in the spring since normal temperatures at that time in the tributary headwaters are significantly higher than at the tributary mouths, resulting in an aggravation to ice jamming near their mouths during the ice break-up period. The drainage pattern contributing from the area west of the Missouri River in this reach is generally well defined. However, to the east of the Missouri River the drainage pattern is much more immature. This is true of much of the area contributing to the Missouri River between Gavins Point Dam and Sioux City, Iowa where numerous low depressions restrict surface runoff.

2-7. The Niobrara River originates in extreme eastern Wyoming and flows across almost the entire northern portion of Nebraska before joining the Missouri River immediately above the headwaters of Gavins Point Reservoir and 32.5 river miles upstream from Gavins Point Dam. The drainage area of the Niobrara River, 12,000 square miles, is 75 percent of the total drainage between Fort Randall and Gavins Point Dams. Other minor tributaries to the Missouri River in this reach are Ponca Creek, a right bank tributary draining 827 square miles entering the Missouri River 5.5 miles upstream from the mouth of the Niobrara River, and Bazile Creek, a right bank tributary draining about 450 square miles. This latter stream flows into the extreme headwaters of Gavins Point Reservoir. Minor left bank tributaries entering this reach in descending order are Choteau Creek, Emanuel Creek and Sand Creek. The largest of these is Choteau Creek with a drainage area approximating less than 400 square miles.

2-8. The James River is the first major tributary entering the Missouri below Gavins Point Dam. It enters the Missouri River below Yankton, South Dakota, and drains an area of 22,000 square miles and is characterized as being extremely sluggish. As a consequence, flows experienced from this tributary, although usually not large, can be utilized to a great extent in scheduling Gavins Point releases to meet downstream flow targets. The same also applies, but to a lesser extent, to other major tributaries entering the Missouri River between Gavins Point Dam and Sioux City, Iowa, the first major navigation control point on the Missouri River below the main stem system.

2-9. Stream Slopes. The total fall of the Missouri River from Fort Randall Dam to Gavins Point Dam averages about one foot per river mile. Tributary stream slopes entering from the right bank are significantly steeper, generally averaging between 5 and 8 feet per mile. Slopes of the tributary streams progressively tend to flatten toward their mouths. Left bank tributaries entering the Missouri River between Gavins Point and Sioux City have much flatter slopes than the right bank tributaries discussed above. This is particularly true for the James River where slopes of less than a foot per mile prevail through much of its length, resulting in an extremely sluggish tributary stream.

II-B Climate

2-10. General. The incremental portion of the Missouri Basin discussed in this manual is located near the geographical center of the

North American continent. The region lies near the center of the belt of westerly winds; however, the Rocky Mountains to the west form a barrier to a Pacific moisture source. Consequently, the climate of the region is generally classified as continental semi-arid. Through the region there is a marked seasonal variation in all weather phenomena.

2-11. Annual Precipitation. Annual average precipitation over the Fort Randall-Gavins Point drainage area increases from west to east, ranging from about 14 inches in the headwaters of the tributary Niobrara River to almost 25 inches in the vicinity of Yankton, South Dakota. Average yearly precipitation also decreases in a north-south direction, reflecting decreasing distances from the main moisture source, the Gulf of Mexico. In the extreme headwaters of the tributary James River in central North Dakota annual precipitation averages about 17 inches. The pattern of average annual precipitation throughout the Missouri Basin, including the incremental drainage area emphasized in this manual, is presented on an appropriate plate in the Master Manual. Wide variations from the average amounts may be experienced in any year, with severe, extended drought periods as well as successive years of well above normal amounts of precipitation occasionally occurring.

2-12. Seasonal Precipitation. Precipitation over the incremental drainage area between the Fort Randall and Gavins Point dams usually occurs as snow during the months November through March and as rain during the remainder of the year. About three-fourths of the total yearly precipitation occurs during the rainfall season, with May, June and July normally being the wettest months. Most rainfall occurs in showers or thunderstorms; however, steady rains lasting for several hours or a day or two may occasionally occur. Excessive rainfall over a relatively large area is unusual; more common are intense thunderstorms resulting in large precipitation amounts in a short period of time over a very restricted area.

2-13. Precipitation occurring as snow usually is at a very slow rate. During the entire winter season about 20 inches of total snowfall can normally be expected through most of the incremental region. Snow does not usually progressively accumulate through the winter season, but is melted by intermittent thaws. However, there have been notable exceptions when plains area snow accumulations containing as much as 6 inches or more of water equivalent have blanketed large areas prior to a significant melt period. Snowfall is frequently accompanied by high winds resulting in much drifting.

2-14. Temperatures. Because of its mid-continent location, this region experiences temperatures noted for fluctuations and extremes. Temperatures each year usually range from a maximum of over 100 degrees Fahrenheit at some time during the summer months to a minimum of 20 degrees below zero or colder during the mid-winter period. Winters are long and cold; however, the cold temperatures are occasionally interrupted by short periods of milder weather. Moderate temperatures usually prevail during the non-winter season, although extended periods of high temperature can be expected during summer season, interrupted by outbreaks of cooler air from the north and west.

2-15. Evaporation. Annual evaporation from the surface of the Gavins Point Reservoir is normally slightly more than three feet. Studies made by the Reservoir Control Center conclude that the average net evaporation (evaporation adjusted for precipitation on the reservoir surface, runoff that would have occurred from land area now inundated by the reservoir and the channel surface area existing prior to development of the Gavins Point project) amounts to about 17 inches annually. Due to seasonal precipitation patterns, combined with seasonal variation in gross evaporation depths, a major share of the annual net evaporation from Gavins Point Reservoir can be expected to occur during the five month period July through November.

2-16. Storm Potentialities. The source of moisture for all major storms in the plains region of the Missouri Basin is the Gulf of Mexico. Based on available moisture alone, major storms would be most probable in late July or early August, since it is at this time that normal and maximum recorded air mass moisture is at its highest. However, major storms result almost exclusively from conditions accompanying frontal systems, and since frontal passages are more numerous and more severe in May and June than later in the year, major storms occur more frequently in late spring and early summer than at the time of maximum moisture charge. Major storms alone do not provide a complete index to the probability of large amounts of runoff within the region. A sequence of minor storms may saturate the soil and subsequently contribute much larger volumes to streamflow than would be the case if dry conditions prevailed prior to the runoff producing events. During winter months continued minor storms are the rule, occasionally producing significant snow accumulations over the drainage area. Usually the highest annual flows experienced in the region result from the melt of these snow accumulations. Severe flooding only occasionally will occur over portions of the basin due to an individual major storm event.

II-C Runoff

2-17. Streamflow Records. With the exception of a few stations, records of runoff from the incremental areas considered in this manual exist only from the early 1930's to date. As discussed in the Master Manual, planning of the main stem reservoir system made it desirable to extend Missouri River streamflow records to the extent practicable. From the studies carried on at the time, based on main stem stages and the discharge records available, records of monthly incremental flows between the Fort Randall and Gavins Point dam sites and between Gavins Point Dam and Sioux City were developed for an extended period. Supplemented by gaged flows, such records are now available to the period 1898 to date. Daily flows at many locations within the incremental areas are available for varying periods of time since 1930. Inasmuch as water use for all purposes has expanded significantly since settlement of the region began, it is necessary to adjust main stem incremental inflow records to a common level of water resource development in order that flow data are directly comparable from year to year. The total flows originating from these incremental reaches have been adjusted to the 1949 level of water resource development, with such adjustment being a continuing process as further data are accumulated. While any development level would have been satisfactory, the 1949 level, prior to recent accelerated resource development, was selected.

2-18. Sources of Runoff. The primary source of runoff from the region near the Gavins Point project is melt of the snow accumulated during the winter months. However, on occasion rainfall during May and June has resulted in substantial runoff amounts from the total incremental area between Fort Randall Dam and Sioux City. Runoff is extremely variable from year to year. Normal annual runoff from the general area ranges from less than one inch over most of the tributary James River Basin to almost three inches over areas of northeastern Nebraska and northwestern Iowa. Generalized estimates of mean annual runoff throughout the Missouri Basin are presented by a plate in the Master Manual, while normal contributions to annual runoff from tributary drainages which are important to the regulation of Gavins Point are given in Table 1.

TABLE 1

NORMAL ANNUAL RUNOFF, MISSOURI RIVER BASIN
BETWEEN FORT RANDALL DAM AND SIOUX CITY, IOWA

Contributing Area	Drainage Area Square Miles	Average Annual Runoff (1) 1,000 AF	Inches
Ponca Creek			
Verdel	812	54	1.25
Niobrara River			
Verdel	12,600	1,100	1.64
Keya Paha River (Niobrara tributary)			
Wewela	1,070	48	0.84
Bazile Creek			
Niobrara	440	62	2.64
James River			
Scotland	21,550	270	0.23
Vermillion River			
Wakonda	1,680	80	0.89
Big Sioux River			
Akron	9,030	603	1.25
Missouri River (2)			
Fort Randall Dam	263,480	21,698	1.54
Gavins Point Dam	279,480	23,162	1.55
Sioux City, Iowa	314,600	24,798	1.48
Fort Randall-Gavins Pt.			
Incr. Drainage	16,000	1,464	1.72
Local Drainage (3)	2,588	310	2.25
Gavins Pt.-Sioux City			
Incr. Drainage	65,120	1,636	0.47
Local Drainage (4)	32,860	683	0.39

(1) Based on available record at each location.
(2) Missouri River runoff at the 1949 level of water resource development.
(3) Incremental drainage area between Fort Randall and Gavins Point dams less Ponca Creek at Verdel and Niobrara River at Verdel.
(4) Incremental drainage area between Gavins Point Dam and Sioux City less James River at Scotland, Vermillion River at Wakonda and Big Sioux River at Akron.

2-19. Seasonal Runoff Pattern. Runoff from the Missouri River drainage basin between Fort Randall Dam and Sioux City usually follows a characteristic seasonal pattern as follows:

a. Winter is characterized by frozen streams and intermittent snowfall and thaws. The season usually ends with a "spotty" snow cover of relatively low water content and a considerable amount of water in ice storage in the stream channels. Runoff during this period, which usually extends from late November into March, is very low.

b. Early spring is marked by a rapid melting of snow and ice upon frozen ground, usually in March or April, as temperatures rise rapidly, accompanied usually by very little rainfall. This causes a characteristic early spring ice breakup and rise. Ice jams are frequently experienced on tributary streams during this period. The rapid release of water from melting snow and ice jams results in a flashy "March rise" in flow. Annual maximum peak stages and flows frequently occur at this time along tributary streams.

c. Late spring consists of the months of May and June. At this time extensive general rains may occasionally occur, sometimes accompanied by severe local rainstorms. Incremental area runoff is usually quite low unless these rains occur.

d. Summer and autumn in this portion of the Missouri Basin are generally characterized by a lack of general rainfall and frequent, widely scattered thundershowers that contribute little to runoff.

2-20. Total unregulated Missouri River runoff originating above the Gavins Point damsite usually follows a definite and characteristic annual pattern as illustrated on Plate 3. Normal monthly runoff from the total contributing area shows a general increase from January through June and then decreases through December. As illustrated on Plate 3, wide variations in total runoff have occurred during every month of the year. As would be expected, the variations are largest during the months comprising the March-July flood season, ranging from a maximum for this entire season of 26.5 million acre-feet in March-July 1975 to a minimum of 6.2 million acre-feet in 1961. The effect of project regulation upon these runoff patterns is discussed in Section X.

2-21. Plate 4 illustrates the average and maximum recorded values of monthly runoff originating from the incremental drainage areas between Fort Randall Dam and Gavins Point Dam and between Gavins Point Dam and Sioux City. Similar to the total basin above Gavins Point Dam illustrated on Plate 3, average runoff from these incremental areas is greatest during the March-July period with lesser amounts during the remainder of the year. However, the average runoff from the Fort Randall-Gavins Point reach is remarkably uniform through the year, illustrating the stabilizing effect that the sandhills drainage contributing to the Niobrara has upon seasonal flows. The maximum observed monthly flows shown on Plate 4 and the incremental inflow hydrographs shown on Plate 5 illustrate that the largest amounts of incremental monthly runoff have occurred as a result of the melt of a large plains snow accumulation. Minimum runoff from the incremental areas has been calculated to be negative in some years during nearly every month of the year, indicating that evaporation from the Missouri River channel (or other losses) may exceed the flow of tributaries entering the Missouri River in these reaches.

2-22. Floods. Regulation provided by Gavins Point Reservoir and upstream main stem projects, augmented by upstream tributary reservoir storage, has virtually eliminated flooding along the portion of the Missouri River extending below Gavins Point Dam downstream as far as the mouth of the Platte River in central Nebraska. The minor flooding that is now sometimes experienced represents the inundation of encroachments upon adjacent floodplain at elevations well below established flood stages. Many instances of above bank-full flows were experienced through this reach prior to construction of the main stem projects and would be continuing if the projects were not in operation. All floods recorded in this portion of the Missouri River prior to main stem reservoir operation occurred in the March-July flood season.

2-23. The Master Manual contains relatively detailed descriptions of several of the experienced Missouri River floods, including data that is pertinent to the incremental reaches described in this Gavins Point Manual. Since there is little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed further in this manual. Paragraphs that follow present descriptions of large flows that have originated in the Fort Randall to Gavins Point reach of the river. Gavins Point incremental drainage area inflow hydrographs for selected floods that have occurred since regulation of the project began in 1955 are shown on Plate 5. These hydrographs are based on elevation changes of Gavins Point Reservoir, Gavins Point releases, and the upstream Fort Randall releases coincident with the changes in Gavins Point elevation.

2-24. Flood of 1950. Monthly runoff originating between Fort Randall and Gavins Point Dams in April 1950 is near to the largest recorded monthly amount from this reach since records began in 1898. Heavy amounts of snow had accumulated over the plains regions of the Dakotas through the preceding winter season. Warm temperatures in early March over the incremental area resulted in ice break-up on the lower

Niobrara River and a crest mean daily discharge from this stream of 15,000 cfs. However, cold temperatures and continuing precipitation in the form of additional snow storms set in soon after this crest. Complete melt of the snow cover did not occur until late March and April, resulting in long-sustained, well-above-normal tributary flows for a long period of time. Substantial flows also occurred from the tributary streams entering the Missouri River immediately below Gavins Point Dam. James River crest flows were over 6,000 cfs near the mouth and high flows from this stream continued through a long period of time. Most unusual for this stream was the sustained flow of over 2,000 cfs prevailing for most of the time during the late March through early July period.

2-25. Flood of 1952. The most severe floods experienced along the Missouri River through the Dakotas extending downstream past Nebraska and Iowa since records began in 1898 occurred in 1952 as a result primarily of the melt of the winter's snow accumulation over the plains area of the Missouri. Monthly runoff during April 1952 from the Fort Randall to Gavins Point Dams incremental drainage area was the largest for any month since records began in 1898. However, flow originating on the major tributaries, Ponca Creek and the Niobrara River were not extremely large for this month, amounting to less than one-third of the total reach inflow. Most of the runoff originated from the ungaged area immediately adjacent to Gavins Point Reservoir.

2-26. Flood of 1960. Melt of the winter's snow accumulation over the Fort Randall-Gavins Point incremental drainage area in late March 1960 resulted in the greatest two-week volume of runoff from this incremental area since the Gavins Point project became operational. The incremental inflow volume of 400,000 acre-feet above a base flow rate of 5,000 cfs is the largest experienced from this reach. Respective crest flows of gaged tributaries entering this reach were as follows:

Ponca Creek	9,810 cfs
Niobrara River	23,400 cfs
Bazile Creek	7,810 cfs

Further discussion of this flood and the regulation performed by Gavins Point Reservoir is given in Section X of this manual.

2-27 Flood of 1962. Flood inflows from the Fort Randall to Gavins Point incremental drainage area during late March and early April 1962 were somewhat similar to those occurring in 1960, as described in the preceding paragraph. However, the total flood volume above the base flow rate of 5,000 cfs amounted to only 278,000 acre-feet. Crest flows observed on tributary streams entering this reach were as follows:

Ponca Creek	5,320 cfs
Niobrara River	10,000 cfs (mean daily)
Bazile Creek	6,600 cfs

The crest inflow to Gavins Point from the total incremental area approached 50,000 cfs. Further discussion of this flood and Gavins Point regulation of flood inflows is given in Section X. The maximum crest flow observed near the mouth of the Niobrara River during 1962 resulted from a later June rainstorm and amounted to almost 26,000 cfs. However, as is typical of many rainfall events, the computed mean daily crest inflow to Gavins Point Reservoir from the total incremental area was less than observed on this single tributary.

2-28. Basinwide Floods. Due to the relatively small amount of flood control storage provided in Gavins Point Reservoir, this project is not a major factor in the control of large floods originating over the total Missouri River drainage area contributing to the project. Essentially, all control of these floods is accomplished by upstream mainstem and tributary reservoirs. Storage in Gavins Point is utilized for reregulation of flood control releases from Fort Randall reservoir and for the control of flood flows originating between Fort Randall and Gavins Point Dams. Floods of the basinwide type are described in the Master Manual.

2-29. Effects of the Gavins Point Project on Flood Inflows. Studies conducted by the Reservoir Control Center indicate that operation of the Gavins Point project in conjunction with other upstream reservoir projects would virtually eliminate significant flood damages in the reach extending from Gavins Point Dam downstream to below Omaha, Nebraska, if any past floods of record were to recur. Further discussion of regulation effects on flood inflows is given in Section X of this manual.

2-30. Water Travel Time. The Master Manual contains a plate from which estimates of water travel time throughout the Missouri Basin can be obtained. Water travel times are particularly pertinent to Gavins Point release requirements and are discussed in the Master Manual as an important factor to be considered in scheduling system releases. The water travel time from gaging stations on tributaries entering the Fort Randall-Gavins Point reach of the Missouri River (namely Ponca Creek at Verdel, Niobrara River near Verdel and Bazile Creek near Niobrara) to the Gavins Point Reservoir is quite short. In all instances inflows to Gavins Point Reservoir will reflect the flows gaged at these locations in less than one day. Upstream gaging locations on the Niobrara River and Ponca Creek (Spencer and Anoka, respectively) are about one day's water travel time from Gavins Point Reservoir. Tributaries entering the Missouri River between Gavins Point Dam and Sioux City have gaging stations with travel time to the Missouri River related to the time of travel of Gavins Point releases to the tributary mouths as follow:

James R. at Scotland, 1 day prior to Gavins Point release
Vermillion R. at Wakonda, equal to Gavins Point release
Big Sioux R. at Akron, one-half day after Gavins Point release

2-31. Water Quality. The entire incremental drainage area between Fort Randall and Gavins Point Dam is rural in character with no large municipal or industrial pollution source. The major tributary, the Niobrara River, has an average concentration of dissolved solids of less than 250 milligrams per liter. Pollution through runoff from grazing and cultivated lands is not severe. In fact, the upper portion of the Niobrara River in Nebraska is designated as a trout stream. The quality of Missouri River water within the Gavins Point Reservoir is considered to be good due to the stabilizing effect provided by the upstream main stem reservoirs. Releases of good quality water from Gavins Point dilute downstream tributary inflows and result in good quality Missouri flows past Sioux City, Iowa and, in most cases, past Omaha, Nebraska. Short term taste and odor problems are occasionally observed in the municipal water supply at Omaha during the early spring breakup of ice from the Missouri River tributaries below Sioux City.

2-32. Sediment. Average-annual, long-term sediment inflow to Gavins Point Reservoir is estimated to be 2,500 acre-feet. Since the reservoir traps the inflowing sediment, Gavins Point releases are clear. Most sediment inflow to the project originates in the Niobrara Basin or from erosion of the Missouri River banks between Fort Randall Dam and the Gavins Point headwaters. Long-term contribution of sediment from the Niobrara River is estimated to be about three-fourths of the total sediment inflow to Gavins Point.

II-D. Missouri River Channel Below Gavins Point Dam.

2-33. Areal Extent. Gavins Point Dam is the most downstream of the main stem projects. The Missouri River channel remains largely in its natural state for a distance of about 60 river miles extending from Gavins Point Dam downstream to Ponca, Nebraska, some 20 miles about Sioux City, Iowa. Below Sioux City, control structures have been installed in connection with the Missouri River navigation and stream bank stabilization project. These structures extend through the 732 mile reach of the river from Sioux City to the mouth. The navigation and stabilization project is described in the Master Manual.

2-34. Channel Description. The Missouri River channel between Gavins Point Dam and Sioux City meanders through an alluvial flood plain. Between the dam and Yankton, South Dakota, a distance of about 5 miles, and for a distance of about 20 miles above Sioux City the channel is now fairly well confined by revetments in place. Additional bank protection to reduce active erosion through the Gavins Point-Sioux City reach is contemplated. This bank protection would not channelize the Missouri River for navigation, however. Photographs of the channel from Gavins Point Dam downstream to a point about 20 river miles above Sioux City are shown on Plates 6 through 14. Channel widths vary markedly through the reach from less than 1,000 feet where well confined to over 2,500 feet in some sections. Numerous sandbars occur throughout the reach, particuarly in the wider portions of the channel. At normal flow levels (Gavins Point releases in the 30,000 cfs range) water surface elevations in the channel are 10 feet or more below most of the surrounding floodplain area; however, some encroachment in lower lying areas adjacent to the channel is occurring, encouraged by the control afforded by the main-stem system of reservoirs.

2-35. Channel Capacity and Stage-Discharge Relationships. Flood stage at Yankton, South Dakota, immediately downstream from Gavins Point Dam, is 32 feet. Under open water conditions this represents a flow, or Gavins Point release, of about 200,000 cfs. Further downstream at Sioux City, Iowa, the flood stage is 36 feet, also representing an open water flow of about 200,000 cfs, based on discharge measurements made prior to closure of Fort Randall Dam in 1952. No discharges approaching flood stage in this reach have been experienced since that time. Rating curves for these two locations are shown on Plate 15. Stage-discharge-damage curves, as related to both Yankton and Sioux City are shown on a plate in the Master Manual. While substantial flows may be passed on the Missouri River without flood stage being exceeded, during 1975 Gavins Point releases of 61,000 cfs were being made with little additional inflow downstream to Sioux City. At that time a few cultivated fields in areas recently reclaimed from the low lying flood plain adjacent to the river channel were inundated to some degree. This is an example of encroachment encouraged by main-stem reservoir regulation that was discussed earlier.

2-36. River Ice. A virtually complete ice-cover can be expected to form on the Missouri River between Gavins Point Dam and Sioux City, Iowa, during every winter. During most winters, an ice cover will also form over some reaches of the channel downstream from Sioux City. This cover severely restricts the Missouri River channel capacity, particularly at times ice blocks form on the river below an extended reach of open water within which ice floe formation is occurring. With Gavins Point releases in the 17,000 cfs to 20,000 cfs range numerous instances have been recorded of downstream stages exceeding flood stage as a result of ice block formation. However, resulting damages have generally been minor due to the season of the year during which the ice blocks occurred. At Sioux City a stabilized ice cover can be expected to raise stages by three to four feet above the open water level associated with discharges usually prevailing during the winter season.

2-37. Prior to the time that the main-stem system of reservoirs was constructed, severe ice jams were expected at the time of the spring break-up of the winter's river ice cover. The reservoirs now act as a trap to upstream ice and severe jamming has essentially been eliminated on the Missouri River below Gavins Point Dam during the spring break-up period. However, a marked increase of Gavins Point releases into a solid downstream ice cover can cause this cover to break up. While severe jamming is not probable due to the generally small ice volume in the downstream reaches, the large and hard ice floes can result in damage to downstream river control and navigation structures.

SECTION III
WATER RESOURCE DEVELOPMENT

III-A General

3-1. History. Due to the lack of other transportation facilities, development of water resources in the portion of the Missouri Basin in the vicinity of Gavins Point Dam and Reservoir began soon after settlement by the white man in the early 1800's. Initial development was concerned with navigation as a means of transportation in the region. The economy of the region is primarily agricultural. This, combined with the semi-arid climate would have been expected to foster irrigation development. However, the lack of perennial tributary streams in the region discouraged such development except in headwaters area of the Niobrara River and in restricted areas immediately adjacent to the Missouri River. The most widespread development in relatively recent history has been construction of dams controlling small drainage areas to provide a water supply for the extensive livestock grazing practiced through this region. Control of floods became a major concern in the 1940's and in recent years municipal and industrial water supply, recreation, water quality enhancement, fish and wildlife and the environment have been oi increasing importance.

3-2. Legislation. Federal legislation pertinent to water resource development throughout the Missouri Basin is summarized in the Master Manual. As indicated in that publication, the Flood Control Act of 1944 is of primary importance through this portion of the basin. This act authorized the construction of Gavins Point Dam, as well as the other main stem projects and many tributary projects, and emphasized the multiple-purpose aspects of water resource development.

3-3. Reservoirs. One important means of water resource development in this section of the Missouri Basin is the construction of dams controlling sizeable drainage areas and development of the associated reservoirs. In addition to the Gavins Point project, a few tributary reservoir projects have been constructed in the incremental drainage area between Fort Randall Dam and Gavins Point Dam and along the James River, entering the Missouri River a short distance below Gavins Point Dam. While initially some of these tributary reservoirs may have been constructed for a single purpose, they all now serve several functions - although service to some functions may be incidental to a primary purpose. Most of the reservoir projects in this incremental drainage area of the Missouri Basin were developed by the Bureau of Reclamation for the primary purposes of irrigation and water supply. Flood control is also served by some of the projects. Recreation and fish and wildlife enhancement are served by all of the projects. Within the Fort Randall-Gavins Point drainage area there are only two reservoirs having a usable storage capacity of 5,000 acre-feet or more. These are the Merritt Reservoir near Valentine, Nebraska and the Box Butte Reservoir near Chadron, Nebraska, developed by the Bureau of Reclamation and having capabilities of 74,000 and 31,000 acre-feet respectively. Both projects are located in the headwaters area of the Niobrara River and control respective drainage areas of 640 and 1460 square miles. Existing reservoirs of over 5,000 acre-feet capacity in the Gavins Point-Sioux City drainage area are the Bureau's Jamestown and the Corps of Engineers' Pipestem reservoirs, both located in the James River basin near Jamestown, North Dakota. Respective capacities of these projects are 221,000 and 147,000 acre-feet.

3-4. The tributary reservoirs in this reach of the Missouri River have very little effect on regulation of Gavins Point and other mainstem reservoirs. They control only a small portion of the incremental drainage area and the portion controlled has large areas that are noncontributing to surface runoff. Reductions to the crest of Missouri River incremental inflows are usually very small, even during major flood occurrences and travel times to the Missouri River are very long. Consequently, these tributary projects are regulated to meet local area requirements rather than main-stem requirements.

III-B. Functional Water Resource Development

3-5. Flood Control. In addition to the flood control storage provided in the Gavins Point project, reservoir storage space allocated to this purpose has been provided only in the Pipestem and Jamestown projects on the James River, the major tributary entering the Missouri River immediately below Gavins Point Dam. Flood control storage space within these two projects totals 337,000 acre-feet and can be expected to store significant volumes of runoff during large plains snowmelt events such as occurred in 1950 and 1952, as well as in other years. However, floods originating above these projects seldom have any appreciable effect upon Missouri River flood crests below the mouth of the James River. Consequently, since tributary flood control space is essentially not effective for main stem flood control, the availability of tributary flood control storage space in this region has had little significant effect upon either storage requirements or upon regulation procedures of the Gavins Point project or other main stem reservoirs. There are no local flood protection projects that affect, or are affected by, Gavins Point operation, except those far downstream of the reservoir system, such as the Omaha and Kansas City levees, as described in the Master Manual.

3-6. Irrigation. Irrigation from surface water supplies is practiced in the headwaters area at the Niobrara River. Box Butte Reservoir supplies water for the U. S. Bureau of Reclamation Mirage Flats project while the Ainsworth irrigation unit is supplied from Merritt

Reservoir. Respective areas irrigated are 11,300 and 34,000 acres. Additional scattered private irrigators withdraw water directly from streams in the region. Extensive irrigation development is visualized in the eastern Dakotas in connection with the planned Garrison and Oahe diversions. These are described in the Garrison and Oahe regulation manuals. If these units are constructed, water will be diverted from the Missouri River into the James River basin. Increased James River flows can then be expected as a result of these irrigation return flows.

3-7. Navigation. Although navigation on the Missouri River through South Dakota opened up this region for initial Caucasion settlement, there is now no commercial navigation through the reach of the river occupied by Gavins Point Reservoir. The upstream terminus of the Missouri River navigation project is at Sioux City, Iowa, although at times consideration has been given to an upstream extension to Yankton, South Dakota. Storage space has been provided in Gavins Point Reservoir for multiple purposes, including Missouri River navigation; however, the space is so limited that it serves essentially only for reregulation of upstream reservoir releases. Gavins Point releases are essential for satisfactory operation of the navigation project and are geared to this function a majority of the time. A description of the Missouri River navigation project is contained in the Master Manual.

3-8. Hydroelectric Power. The Gavins Point power plant, with an installed capacity of 100,000 KW, is the main hydroelectric power generating facility located in the incremental Missouri River drainage area discussed in this manual. A small generating facility is located on the Niobrara River near Spencer, Nebraska. All power generated by Federal facilities in the Missouri Basin is marketed by the Wester Area Power Administration and Gavins Point power generation is integrated with generation from the other main stem projects, as well as with power generated from other Federal and private facilities throughout the power marketing area. Further details concerning hydropower generation and the WAPA's power marketing and transmission facilities are provided in the Master Manual.

3-9. Municipal and Industrial Water Supply. The Missouri River between Fort Randall and Gavins Point Dams is the source of water supply for the municipality of Springfield, South Dakota. The intake is located in the headwater's region of Gavins Point Reservoir and has experienced continuing difficulties resulting from aggradation in this area. Below Gavins Point Dam there are numerous water intakes supplying water from the Missouri River for both municipal and industrial purposes. The most immediate downstream intake serves the city of Yankton, South Dakota. Maintenance of adequate flows for continuing operation of the intakes is an important function of the Gavins Point project.

3-10. Land Treatment. In response to the program administered by the Department of Agriculture, land treatment measures designed to reduce erosion and local floods, and to increase the local surface water supply, are in operation throughout large portions of the incremental drainage area discussed in this manual. Associated with this program are many stock ponds or farm ponds that have been developed in recent years. While these ponds and other land treatment measures have a depleting effect on the overall water supply to the Missouri River, and provide a degree of local flood protection, their effect on major Missouri River flood flows is minimal.

3-11. Fish, Wildlife and Recreation. The effects of water resource development upon fish and wildlife is a major concern through the drainage area in the planning and operational processes. Recreation opportunities have generally been increased as a result of water resource developments. To the degree practical, fish and wildlife interests are consulted prior to operation of projects and the potential effects upon these functions become an important constraint upon operations. Recreational use of Gavins Point Reservoir continues to increase through the years and is a factor to be considered in actual regulation of the project.

3-12. Streambank Stabilization. Streambank erosion is a continuing process along the Missouri River and also along the tributaries in the region. Sediment inflow to Gavins Point Reservoir results largely from this erosion process along streams contained within the incremental drainage area. The Missouri River channel below Gavins Point Dam to a point about 20 mile above Sioux City is subject to continuing erosion with some claims that erosion has been accelerated by operation of the main stem reservoir projects. However, bank erosion has always occurred, extending back since the river first formed. Data available to the Corps of Engineers indicates that average erosion rates through the unstabilized portion of the channel since main stem projects began operation are essentially the same as during pre-project conditions. Further, bank protective measures, encompassing nearly all of the readily erodible banks within this reach of the Missouri River, were proposed in the recently completed "Umbrella Study."

III-C. Streamflow Depletions.

3-13. General. The major effect of the tributary water resource developments in the incremental drainage between Fort Randall and Gavins Point Dams on the regulation of Gavins Point Reservoir is a depletion in the available water supply. As resource development continues, a growth in depletions can be expected. While increasing depletions probably benefit the flood control function, it is evident that they may have adverse effects on other functions that are dependent on the availability of a continuing water supply.

3-14. Depletion Growth. Prior to 1865 streamflow throughout the Missouri Basin was largely unused, except for transportation. Settlers and homesteaders in the late 1800's and soon after the turn of the century started substantial irrigation and mining ventures in several regions of the upper Missouri Basin. However, in most of the drainage area contributing to the Missouri River reach discussed in this manual, the available water supply was very small and unreliable. Consequently, irrigation development occurred in only scattered areas, principally in the headwater's area of the Niobrara River. Major developments were the Mirage Flats project commencing in about 1945 and the Ainsworth unit in the mid-1960's. Private development has also occurred, mostly since 1949. During the years 1910 to 1949 it is estimated that average annual depletions from the Fort Randall-Gavins Point reach of the Missouri River increased by about 7,000 acre-feet while an increased depletion of about 9,000 acre-feet occurred in the Gavins Point to Sioux City reach of the river. Reflecting increased development occurring since 1949, average annual depletion growth between the years 1949-1970 amounted to 116,000 acre-feet and 107,000 acre-feet for the respective reaches.

3-15. A continuing increase in depletions is expected from this incremental drainage area. Estimates are that with a reasonable rate of water resource development, the increase in average annual stream flow depletion from the area extending from Fort Randall to Gavins Point Dams will approximate 535,000 acre-feet over the next 50 years. The growth in average annual depletions during this period between Gavins Point Dam and Sioux City is expected to be about 295,000 acre-feet.

3-16. By 1970, the average annual depletions for the total drainage area above Gavins Point Dam, including the areas controlled by the other upstream main stem reservoir projects had increased by about 3.1 million acre-feet above the 1949 "base level" selected for adjustment of streamflow records in the Missouri Basin. This amounts to about 13 percent of the total 1949 water supply available above Gavins Point Dam. Streamflow depletion projections made in connection with the Comprehensive Framework Study for the Missouri Basin indicate that by the year 2020 average annual depletions from the total area above Gavins Point Dam will increase to 11 million acre-feet above the 1949 level. Subsequent depletion estimates have lowered this earlier estimate by several million acre-feet.

3-17. Depleting Functions. The water resource development function resulting in most depletions in this region is irrigation. For example, the Missouri River Basin Framework Studies indicate that about 71 percent of the increase in average annual depletions between Fort Randall and Gavins Point Dams from 1949 to 1970 can be attributed to water losses resulting directly from irrigation. Land treatment measures, including stock ponds, resulted in a depletion increase amounting to 7 percent of the total. Depletion increases resulting from rural domestic, livestock, mining and municipal and industrial uses together amounts to only 1 percent of the total increase. An important depleting factor that cannot be assigned to any particular development function is evaporation from large multiple-purpose reservoirs. The 1949-1970 depletion increase in the Fort Randall-Gavins Point drainage area resulting from large reservoir evaporation amounted to about 21 percent of the total increase. Average annual evaporation losses occurring from large tributary reservoirs constructed during the 1949-1970 period, together with main stem reservoirs, above Gavins Point Dam total 1.9 million acre-feet or over 8 percent of the 1949 water supply above this location.

SECTION IV

HISTORY AND DESCRIPTION OF THE GAVINS POINT PROJECT

IV-A Project Development

4-1. General. The Gavins Point Reservoir project was planned and constructed by the Corps of Engineers' Omaha District under supervision of the Missouri River Division and the Chief of Engineers. Preparation of a Definite Project Report by the Omaha District was directed by the Chief of Engineers with the initial report published in November 1949. Supplements to this initial report during the following three years modified portions of the original design. Construction began in February 1952 with diversion of the Missouri River through the spillway accomplished in July 1955. The embankment was completed in 1956. Power generation began in September 1956 and by 1958 most major construction was completed.

4-2. Project Authorization. The 69th Congress, 1st Session, in House Document 308, authorized a survey by the Corps of Engineers of navigable streams in the United States with a view to the formulation of general plans for the most effective improvement of such streams. The purpose contemplated was navigation in combination with the most efficient development of the potential water power, the control of floods and the needs of irrigation. The resultant report submitted to Congress was printed as House Document No. 238, 73rd Congress, 2nd Session. This report, generally referred to as the "308 Report," contained the results of an examination of the possibilities of a dam about 7 miles west of Yankton, South Dakota. The conclusions reached were that a dam of medium height might be feasible from an engineering standpoint, however, better sites were available for the plan of development then considered. A subsequent Congressional resolution requested review of the report with a view of determining the advisability of constructing a lock and dam in the vicinity of Gavins Point for navigation and other purposes. Several other resolutions were adopted requesting review of the 308 report to determine the advisability of the improvement of this reach of the Missouri River for navigation, flood protection, bank erosion, power, irrigation pumping and for other purposes. Additional investigation of the feasibility of a dam was made as a result of these resolutions.

4-3. House Document 475 (78th Congress, 2d Session 1944) presented the Corps of Engineers' plan for the overall development of the main stem of the Missouri River and certain of its tributaries. This document proposed the Gavins Point Dam at a site about 4 miles upstream from Yankton. The Bureau of Reclamation, in Senate Document 191, 78th Congress, 2d Session, proposed several upstream Missouri River Dams, but did not include a project near the present Gavins Point site. The differences between the plans were adjusted in an inter-departmental conference and the coordinated plan, including the Gavins Point project, was presented to Congress in Senate Document 247, otherwise known as the "Pick-Sloan Plan."

4-4. The Gavins Point project was then authorized by the Flood Control Act approved 22 December 1944 (Public Law 534, 78th Congress, 2d Session) as follows:

> "Sec. 9 (a) The general comprehensive plans set forth in House Document 475 and Senate Document 191, 78th Congress, 2d Session, as revised and coordinated by Senate Document 247, 78th Congress, 2d Session, are hereby approved and the initial stages recommended are hereby authorized and shall be prosecuted by the War Department and the Department of the Interior as speedily as may be consistent with budgetary requirements."

By Public Law 710, 83rd Congress, approved 30 August 1954, the reservoir was named Lewis and Clark Lake.

4-5. Construction History. Construction of the Gavins Point project was initiated in February 1952, with awarding of the contract for the access road to the area. The first earthwork on the dam was begun in April 1952. Diversion and closure took place in July 1955. Partial flood control was available in March 1956. The first of three 33,333 KW power units started generating commercial energy in September 1956. The last of the three units was available for service in January 1957. The project was essentially complete in June 1958.

4-6. Relocations. Approximately 17 miles of county and local highways were relocated, raised or abandoned in the construction of the Gavins Point Project. No existing state or Federal highways or railroads were affected by reservoir development. Affected rural telephone lines totalled about 18 miles. Sewage systems of both Springfield, South Dakota and Niobrara, Nebraska required remedial action. Initially there was no relocation of towns or cities involved. However, in the years following closure of Fort Randall in 1952, aggradation at the mouth of the Niobrara River, just upstream of the headwaters area of Gavins Point Reservoir, resulted in increased ground water levels in the City of Niobrara, Nebraska and in adjacent agricultural areas. As a consequence, most of the Town of Niobrara has been relocated to adjacent higher elevations and flowage easements are being obtained on the affected agricultural areas.

4-7. Real Estate Acquisition. Approximately 34,474 acres in fee and 212 acres in easements were acquired for the Gavins Point Dam and Reservoir. No Public Domain land was involved in this project. There are seven maps located in the Omaha District Real Estate Division which show the land acquired for this project. The guide taking line for land purchased for the main body of the reservoir was to elevation 1210 feet m.s.l., plus allowances for wave heights, erosion, bank caving, set-up and wave run-up. Provision was also made for raising the elevation of the taking line in the upper reaches of the reservoir to allow for sedimentation and backwater.

4-8. Operational History. Closure of Gavins Point Dam and the first impoundment of water in the associated reservoir was in July 1955. Deliberate storage within the reservoir began in June 1956 when the minimum operating pool (elevation 1195 feet m.s.l. at the time) was filled and maintained. The flood control and multiple use zone (base at elevation 1204.5 feet m.s.l.) was first utilized during the next month. Exclusive flood control storage space (base of zone at elevation 1208 feet m.s.l.) was first used in 1958 while surcharge storage space (above elevation 1210 feet m.s.l.) has been utilized only once, in March-April 1960. The majority of releases have been through the powerplant since the first power unit became operational in September 1956, although due to the limited release capacity of the power plant some supplementary releases have been necessary during most years. Minimum mean daily and mean monthly releases respectively of 4,900 cfs (March 1963 and March 1964) and 5,500 cfs (February 1963) have been recorded. Respective daily and monthly maximum releases were 61,100 and 61,000 cfs, both occurring in the fall months of 1975. Further information concerning historical operation is contained in Section X of this manual. Detailed descriptions of each year's project operations are in the Annual Operating Plan reports published every August.

IV-B. Description of the Gavins Point Project

4-9. Location. Gavins Point Dam is located at Mile 811 (1960 mileage) on the Missouri River in Cedar County, Nebraska and Yankton County, South Dakota, about 4 miles west of the city of Yankton. Four sites, extending from Yankton to a point upstream from the mouth of the Niobrara River, were examined in detail prior to final site selection. Gavins Point Reservoir extends 25 miles in a westerly direction from the dam along the Nebraska-South Dakota border, terminating near the town of Niobrara, Nebraska and the mouth of the Niobrara River.

4-10. Embankment. Gavins Point Dam is a rolled earthfill structure 8,700 feet in length extending from the left bank of the Missouri River valley to the spillway and powerhouse structures located on the right bank of the valley. The embankment contains about 7 million cubic yards of fill consisting largely of compacted and uncompacted chalk obtained from the excavations for the spillway, powerhouse and downstream channels. A core and a blanket extending 300 feet upstream from the core were constructed from impervious material. The crest of the embankment is at elevation 1234 feet m.s.l., representing a maximum height above streambed of 74 feet and an average height above the valley floor of about 60 feet. Between elevations 1203 and 1217 feet m.s.l. the upstream face of the dam has a slope of 1 on 15. The uncompacted chalk forming the gradual slope through this range of elevation, where the level of the reservoir can be expected most of the time, provides protection for wave action on the embankment. The plan and section of the embankment are shown on Plate 16.

4-11. Embankment freeboard was based on a Gavins Point Reservoir level of elevation 1221.4 feet msl, the maximum level attained during routing of the spillway design flood. A set-up allowance of 3.1 feet and wave height plus ride-up allowance of 8.8 feet was developed in design studies. An additional safety factor of 0.7 foot resulted in a total freeboard allowance of 12.6 feet, establishing the embankment crest at elevation 1234 feet m.s.l.

4-12. Spillway. The Gavins Point spillway is located on the right bank between the embankment and the power house. Since no outlet works were constructed at this project, all releases in excess of power plant discharge capabilities must be made through the spillway structure. The spillway is a chute type consisting of a short approach channel, a gated ogee crest structure, a concrete paved chute, a stilling basin and discharge channel. The approach channel from the reservoir is relatively short with a bottom elevation of 1155 feet m.s.l. The flood plain directly upstream has a surface elevation of approximately 1176. The riverward or north approach wall, a semi-gravity type structure 184 feet in length, is an extension of the reinforced concrete north abutment. The south wall of the concrete anchored type converges toward the south abutment from a point approximately 100 feet upstream of the crest of the spillway. A floating boom consisting of steel floats 20 feet long by 30 inches is located across the upper portion of the approach channel protecting both the spillway and the powerhouse. Plan and profile of the spillway is shown on Plate 16 and spillway rating curves are on Plate 17.

4-13. The spillway crest structure consists of 560 linear feet of mass concrete weir and thirteen 8-foot reinforced concrete piers, resulting in a total structure length of 664 feet. The weir has an ogee crest of elevation 1180 feet msl, 25 feet above the approach channel floor. Flow over the crest is controlled by 14 tainter gates, each 40 feet long and 30 feet high.

4-14. A paved chute, 664 feet in width and 216 feet in length, connects the weir and the stilling basin. The upstream end of the chute is at elevation 1155.0 feet m.s.l. The downstream end terminates at the stilling basin floor elevation, 1123.0. The chute walls are relatively short sloping downward from the spillway to the elevation of the stilling basin walls.

4-15. The reinforced concrete slab stilling basin has a length of 220 feet from the spillway chute to the downstream face of the end sill. The floor is at elevation 1123 feet m.s.l. and has a width of 638 feet. The walls are sloped 4 on 1 from the floor to elevation 1175 then vertical to the top of the wall at elevation 1180. There are two rows of baffles each 12 feet wide and 8 feet high. A stepped end sill provides a transition between the floor of the stilling basin and the upstream end of the discharge channel.

4-16. The unpaved spillway discharge channel begins at the stilling basin sill. From elevation 1132 feet m.s.l. at the end sill the channel bottom slopes upward to a uniform elevation of 1140. The stilling basin wall on the riverward side extends approximately 127 feet downstream. The landward side wall terminates at the stilling basin. A training dike on the riverward side restricts the flow to its present channel below the dam. The powerhouse tailrace channel joins the spillway discharge channel at an angle of approximately 20 degrees.

4-17. Power Plant and Switchyard. The flow of water from the reservoir to the powerhouse intake is guided by a relatively short approach channel located at the right end of the dam. It is curved in plan along a circular arc of 220-foot radius, and has a bottom elevation of 1155.0 feet m.s.l. The bottom width of the channel is 240 feet and the side slopes are 1 on 1, giving a sectional area of 15,529 square feet when the reservoir is at pool elevation 1208.0. Velocity of flow in the approach channel with a plant discharge of 33,000 c.f.s. is approximately 2.0 fps. About 102 feet upstream from the powerhouse intake the bottom of the channel slopes downward on a 1 on 4 slope to elevation 1139.3 to provide sufficient entrance area at the intake. The sides of the approach channel at the intake to the powerhouse are closed off by the concrete abutment walls. The flow entering the powerhouse is confined to rectangular passages formed by the concrete floor, roof and piers of the intake structure.

4-18. The intake structure contains three separate intakes for each of the three turbines. Each unit intake is subdivided into three gate passages by intermediate piers 6.5 feet in width. The water passages are 34.75 feet in height and have a horizontal floor at elevation 1139.5. Five removable trash rack sections of welded steel construction are provided at each intake opening. Each passage contains two sets of gate slots. Nine tractor type, vertical lift service gates operate in the downstream gate slots. One slide, vertical-lift type gate is provided to operate in any one of the upstream (bulkhead) gate slots. The service gates are designed to close against flow in the event that the wicket gates of the turbine fail to close completely. The velocity of the flow at the service gate slot, 41.75 feet upstream from the centerline of the units, is approximately 6.0 fps with a 11,000 cfs turbine discharge.

4-19. The powerhouse consisting of two elements, the main structure and the service bay, is constructed integrally with the intake. The main structure provides housing for the power units, service and storage rooms, and personnel facilities. The service bay located along the downstream side contains the control room, various service rooms, office and public facilities. The generator bay substructure of mass concrete is divided into three separate monoliths each 80 feet wide, founded on shale strata underlying the site. The erection bay is located at the south end of the powerhouse and has a substructure of heavy reinforced concrete. The superstructure of the generator room and erection bay is constructed of massive reinforced concrete up to the elevation of the crane rails and of light reinforced concrete walls above. An access road to the powerhouse leads from the vicinity of Yankton along the right bank of the river. A service road provides access to the spillway, dam, and switchyard.

4-20. Three hydraulic turbines of the vertical shaft, single runner, adjustable-blade propeller, Kaplan type, with governor controlled runner blades, concrete semi-spiral cases and concrete elbow type draft tubes are installed in the powerhouse. Each turbine is rated 54,000 hp at 48 feet net head and operating at normal speed of 75 rpm. Each turbine is provided with a cabinet actuator oil-pressure type governor.

4-21. The Gavins Point power plant has three hydraulic turbine-driven, vertical-shaft generators each rated 35,100 kva at 95 percent power factor, generating power at 13,800 volts. Each generator is connected to a 3-phase step-up transformer delivering power to a 115 kv switchyard. The generator neutrals are grounded through a neutral air circuit breaker and a current limiting reactor. Power for station requirements is supplied from the first two generators through 13.8 kv air circuit breakers and dry-type transformers stepping down the generated voltage to 460 volts. To permit supply of station service power from the system when the generators are not in operation, 13.8 kv air circuit breakers are provided for these two units in the generator switchgear.

4-22. A straight tailrace channel conveys the flow from the draft tube outlets to the spillway discharge channel which it joins at an angle of approximately 20 degrees. A concrete apron slab extending 99 feet downstream from the draft tube outlet is built on a 1 on 4 slope to match the inclined draft tube floor. At the end of the apron the inclined tailrace bottom meets the horizontal bottom of the tailrace channel at elevation 1134.0. The vertical retaining wall along the south side of the tailrace channel is parallel to the flow and flush with the inside face of the draft tube end pier. It extends 99 feet from the end of the draft tube to the end of the inclined apron slab. At that point a vertical cut-off wall at right angle to the flow extends to the abutment. Downstream from that point the channel side is sloped 1 on 1. The north bank of the tailrace is sloped 1 on 1 along its entire length. The portion extending 99 feet from the draft tube is lined with concrete.

4-23. The transformer yard is separated from the switchyard and located adjacent to the erection bay at the same elevation as the erection bay floor. The transformers can be moved on tracks into the erection bay for servicing. The yard accommodates the three main step-up transformers, the cable riser structures for the 13.8 kv cable termination, and the take-off structure for the 115 kv overhead aerial conductors to the switchyard.

4-24. The switchyard is located at a higher elevation, approximately 40 feet above the transformer yard grade, and south of the transformer yard so that the bays in both yards are in line for straight overhead high-voltage connections. Initial installation provided for three transformer switching bays, one bus tie bay, and four outgoing line bays. All bays are 32 feet wide. Transformers and lines connect through oil circuit breakers of 3,500 mva interrupting capacity to the 115 kv main bus. An underground duct provides for cable runs between the powerhouse and the switchyard.

4-25. A more detailed description of power facilities, as well as other structures at the dam site, is contained in the Gavins Point Operation and Maintenance Manual. Plan and section of the powerhouse are shown on Plate 16. Power plant tailwater rating curves and power plant characteristic curves are shown on Plates 18 and 19.

4-26. Gavins Point Reservoir. The reservoir formed by Gavins Point Dam (known as Lewis and Clark Lake) extends westward forming the border between the states of Nebraska and South Dakota through its length. At normal operating level of 1208 feet m.s.l. the reservoir has a length of 25 miles, a shoreline of 90 miles, a surface area of 30,000 acres and a maximum depth of 50 feet. Gavins Point Reservoir is long and relatively narrow, confined almost entirely to the Missouri River valley since no major tributaries enter the river within the reach occupied by the reservoir. The reservoir area is shown on Plate 20.

4-27. Allocation of storage in Gavins Point reservoir was based on local main-stem system requirements as described in Section V of the Master Manual. Types of storage space, with associated elevations and storage quantities for each type, are given in Table 2. In addition to this allocated space, the reservoir level during the spillway design flood would crest at elevation 1221.5, representing a surcharge of about 418,000 acre-feet of storage above the top of the exclusive flood control storage zone. Area-capacity tables for Gavins Point Reservoir are on Plate 21.

TABLE 2

Gavins Point Reservoir Storage Space Allocations

Storage Designation	Elevation MSL From	Elevation MSL To	Storage Space Acre-Feet
Exclusive Flood Control	1208.0	1210.0	62,000
Flood Control & Multiple Use	1204.5	1208.0	97,000
Inactive	1160.0	1204.5	358,000
Total Storage			517,000

NOTE: Storage volumes are based on January 1976 capacity tables.

4-28. In addition to the above listed storage zones, the Gavins Point Reservoir originally contained a carryover multiple use zone between elevations 1195 and 1204.5 feet m.s.l. However, this zone was deleted and the top of the inactive storage zone raised from 1195 to 1204.5 after many years of operational experience, and numerous long range regulation studies demonstrated the undesirability of drawing the reservoir below elevation 1204.5 except on infrequent occasions when local snow conditions indicate large runoff volumes are imminent. The reservoir is held near elevation 1204.5 during the March-July flood season, after which it is raised to near 1208, the top of the annual flood control and multiple use zone. Therefore, normal re-regulation of upstream reservoir releases will frequently result in deliberate minor encroachments of a temporary nature into the Gavins Point exclusive flood control zone during seasons of low runoff potential from the incremental drainage area.

4-29. Boat Ramps and Recreation Facilities. Fluctuating levels have a major effect on recreational use of reservoirs. However, the annual fluctuation in water level of Gavins Point Reservoir is normally less than on any of the other main stem reservoirs other than the Big Bend project. Usually the level of Gavins Point Reservoir will be maintained between elevations 1205 and 1210 feet m.s.l. Numerous public-use areas have been established around the shoreline. A common development of most of these areas is a boat ramp providing access to the lake. Boat ramp elevations are given in Table 3. Boat ramps have also been constructed for access to the Missouri River below the dam. These downstream ramps generally continue operable through the normal range of releases from the Gavins Point project. While some of the facilities within the reservoir area or in the immediate vicinity of Gavins Point Dam are considered to be a portion of the Gavins Point project, many others have been constructed along the Missouri River below Gavins Point Dam by private interests or as a part of other Federal, State and private recreational developments.

Table 3

GAVINS POINT RESERVOIR BOAT RAMPS

Recreation Area	Ramp Type	Ramp Width	Elevation Top	Elevation Bottom	Date of Constr.
Bloomfield	Concrete	1-lane			
Deepwater	Concrete Plank	12 ft.	1209.7	1200	1962
Gavins Point Area	Concrete	2-lane			
Midway Bay	Concrete	1-lane			
Miller Creek	Gravel	18 ft.	1216.6	1204	1960
Niobrara	Gravel	2-lane			
Santee	Concrete	1-lane			
South Shore	Concrete	1-lane			
Springfield	Concrete	3-lane			
Tabor	Concrete	1-lane			
Tailrace Right Bank	Concrete	2-lane	1174	1154	1973
Training Dike	Concrete	2-lane	1170.5	1155	1973
Weigand	Concrete	2-lane			
Yankton	Concrete	6-lane			
Yankton	Gravel	5-lane			

4-30. Leasing of Project Lands. As indicated previously, essentially all lands surrounding the Gavins Point Reservoir below elevation 1210 has been acquired for project purposes. Blocking out procedures and other allowances at the time of real estate acquisition also resulted in the purchase of some land above elevation 1210 feet m.s.l. Unless unusual conditions occur, inundation of lands lying above elevation 1210 feet m.s.l. would not be expected during any given year. Consequently, on an annual basis, the Corps of Engineers makes some tracts of land available for lease, generally for agricultural purposes, as a part of their land management program. A major portion of the revenue from this leasing program is returned to the counties within which the leased land lies. During fiscal year 1977 the revenues returned to local government (amounting to 75 percent of total revenues) from the Gavins Point land leasing program amounted to about $700 as a result of 8 leases involving a total of 185 acres of land. All such leases are subject to possible flooding of lands if needed for operational purposes and do not serve as an overriding constraint upon regulation of the project for authorized purposes.

4-31. Reservoir Aggradation and Backwater. The long term sediment deposition rate in the Gavins Point Reservoir is estimated to be 2,500 acre-feet per year, most of which will be contributed by the Niobrara River into the headwater's area of the reservoir. The density of these deposits is about 75 pounds per cubic foot, dry weight, and its composition will average about 70 percent sand and the remainder silt and clay. Since the predominant portion of the sediment is of sand size, the major portion of the deposition is occurring immediately below the mouth of the Niobrara River and in the upper reaches of the reservoir above Springfield, South Dakota.

4-32. Tailwater Degradation. Since the Gavins Point Reservoir acts as a trap to inflowing sediment, releases from the project are sediment free. Releases immediately act upon the downstream channel areas, scouring the sand from the banks and the channel bottom. As a result, a gradual lowering of the channel and associated water surface profile occurs. During the period 1955 through 1975 tailwater elevations corresponding to normal Gavins Point releases have lowered by over 7 feet. The continuing degradation process is illustrated by the family of tailwater rating curves shown on Plate 18.

SECTION V

ORGANIZATION FOR RESERVOIR REGULATION

5-1. Normal Regulation. Gavins Point reservoir is regulated as a component of the six project main stem reservoir system. As such, regulation must be fully coordinated with regulation of the other five projects. Therefore, regulation of all main stem reservoirs is as directed by the Missouri River Division Reservoir Control Center. Full details relating to organizational responsibilities, coordination, and communications pertinent to the system's regulation process are contained in Section VI of the Master Manual. Consequently, only a brief summarization is presented in this project manual and reference must be made to the Master Manual for a complete understanding of these factors.

5-2. Orders to project personnel for release from the Gavins Point project control the regulation process. These are issued by the Reservoir Control Center and are based on detailed analysis of current and expected hydrologic conditions throughout the Missouri Basin and functional needs of the Gavins Point project as well as the system as a whole. The coordination with other Corps of Engineers offices, outside agencies, and special interest groups is a responsibility of the Reservoir Control Center, as described in the Master Manual.

5-3. Gavins Point project personnel are expected to continually furnish the Reservoir Control Center all information they may receive that is pertinent to the regulation process. This includes observations made by personnel as well as complaints or suggestions from those affected by project regulation. In addition, project personnel are responsible for informing the public in the local area of current and probable near-future regulation activities. It is the responsibility of the Reservoir Control Center to keep project personnel informed of such activities. Any requests for information that are complex, long-term in nature, or that involve policy are referred to the Reservoir Control Center.

5-4. The Omaha District is responsible for project maintenance, including maintenance of those facilities required to support the regulation process. They also collect data pertinent to Gavins Point regulation and are responsible for analysis of runoff events, particularly over tributary drainage areas. The District is responsible for flood fighting activities, for regulation of Corps of Engineers tributary reservoirs located in the incremental drainage area, and for flood control regulation of the USBR reservoir projects located in the incremental drainage area. Information available to the Omaha District considered pertinent to regulation of the Gavins Point Project or other main stem reservoirs is immediately furnished the Reservoir Control Center.

5-5. Emergency Regulation. If emergency conditions develop at the Gavins Point project, project personnel are expected to take appropriate action, depending on the nature of the emergency. When there is an immediate threat to serious injury or loss of life at the project, or the probability that serious damage may occur or has occurred to project facilities, prompt action is required and project personnel are expected to take tne actions deemed necessary. Prompt notification of the Omaha District and Reservoir Control Center of the circumstances and actions initiated is then accomplished. Subsequent modification or continuance of regulation of project facilities would then be based on evaluation of conditions and effects by all offices concerned, and be directed by the Reservoir Control Center.

5-6. Loss of communication between the Reservoir Control Center and Gavins Point project personnel is an emergency of a different type for which plans can be made in advance. Exhibit A of this manual provides instructions for project personnel in case of such an event. These instructions are designed to continue operations for the functions for which the project was constructed through the period of communications failure. As indicated by Exhibit A, continuing efforts will be made by project personnel to re-establish communications with either the Reservoir Control Center or Omaha District Reservoir Regulation Section (or responsible personnel of those offices) in an effort to terminate the emergency.

SECTION VI

HYDROLOGIC DATA

6-1. General. Section VII of the Master Manual outlines the basic hydrologic data required for regulation of the Missouri River Main Stem Reservoir System, including the Gavins Point project, and gives agency responsibilities, communications methods and other details relevant to the data collection process. Reference is made to the Master Manual for this information. Succeeding paragraphs provide further details of particular interest to the regulation of the Gavins Point Reservoir.

6-2. Gavins Point Project Data. Daily reports from the Gavins Point project to the Reservoir Control Center and to the Omaha District include hourly releases and pool elevations, as well as periodic reports of tailwater elevations and wind conditions, and daily reports of maximum and minimum air temperatures, precipitation, pan evaporation and tailwater temperatures. Reservoir elevations and tailwater elevations and temperatures are obtained from recorders located in the powerhouse. Air temperature, precipitation, wind and evaporation data are obtained from a site located near the Gavins Point power plant.

6-3. Throughout the year project personnel investigate requests and complaints that occur as a result of Gavins Point regulation and report their recommendations and findings to the Reservoir Control Center. The effects of significant changes in release rates through the downstream reach are also investigated. Project personnel are also responsible for informing immediate downstream interests of any major change in the general level of release rates that may be scheduled, or in significant variations in pool level that may be expected to prevail over an extended period of time.

6-4. Precipitation and Temperatures. Whenever significant amounts of precipitation occur, reports from many more locations than shown in the basic network presented in the Master Manual are received by the Reservoir Control Center. The National Weather Service has established reporting criteria for these stations, with transmission to the Reservoir Control Center over the RAWARC teletype network. Plate 22 presents locations of precipitation reporting stations established by the National Weather Service in the incremental drainage area between Fort Randall and Sioux City. These stations are also shown and listed in monthly summaries published and furnished the Reservoir Control Center by the National Weather Service. Temperature data obtained from first order National Weather Service Stations and available daily to the Control Center are adequate for regulation purposes.

6-5. Snow. During the winter season reports of snowfall and accumulated snow depths are received from many of the National Weather Service stations shown on Plate 22. These reports are supplemented by weekly snow and water content reports from first order Weather Service stations and plains snow surveys conducted by Corps of Engineers personnel, as described in the Master Manual.

6-6. Stages and Discharges. Stage information reported to the Reservoir Control Center as indicated by the basic network in the Master Manual are supplemented by reports from many tributary locations, particularly during the March-July flood season or at other times of the year if unusual stages are occurring. Plate 23 indicates locations within the incremental drainage area where stage and discharges are available. Most stage reports are transmitted over the National Weather Service RAWARC Teletype. Most of the principal tributary locations have been rated by the Geological Survey and from available rating curves or tables an estimate of flows corresponding to reported stages is available along the principal streams at all times. During those periods when significant inflows are occurring to tributary reservoirs, or when flood storage is accumulated or being evacuated from these projects, daily reports of elevation and releases are furnished the Reservoir Control Center from the tributary reservoirs located in the James River portion of the Gavins Point to Sioux City drainage area. Tributary reservoirs in the Niobrara River drainage have such a minor effect upon Missouri River flows that current operational reports are not necessary.

SECTION VII

ANALYSES PERTINENT TO REGULATION OF GAVINS POINT RESERVOIR

7-1. General. Regulation of the Gavins Point project as a component of the main stem reservoir system requires continuing analyses of available hydrologic information and, to the degree practicable, forecasts of future events. These are considered, in conjunction with the anticipated demands imposed, in serving the various project purposes. These considerations may be of a long-term nature or may be based on anticipated inflows and demands for a relatively short period in the future. Operational planning studies are discussed in the Master Manual. Also discussed in the Master Manual are analyses, forecasts, and studies which, while important for the regulation of the Gavins Point Reservoir, have essentially the same degree of importance for all of the other main stem projects. Analyses considered to be unique, or particularly important, to Gavins Point regulation are presented in the following paragraphs.

7-2. Precipitation and Temperature Forecasts. As discussed in the Master Manual, Weather Service forecasts of all meteorological elements are utilized by the Reservoir Control Center to the degree practicable in the regulation process. Weather Service forecasts are supplemented by forecasts developed by the Reservoir Control Center staff meteorologist and tailored to particular regulation requirements. Particularly pertinent to regulation of the Gavins Point project are the forecasts for northeastern Nebraska and southeastern South Dakota, including the areas contributing to the Niobrara River and Ponca Creek, major contributors of inflow to the project. Forecasts are also important in scheduling Gavins Point releases; however, since releases from this project are identical to the system releases discussed in the Master Manual, reference is made to that publication for a discussion of this subject.

7-3. Precipitation-Runoff Relationships. Infiltration of rainfall over the Missouri River basin between the Fort Randall Dam and Yankton, South Dakota, ranges from 0.50 to 1.00 inch for the initial loss and from 0.10 to 0.30 inch per hour infiltration loss. Losses from the downstream Missouri River contributing areas are somewhat higher. These values are based on relatively few rainfall events because of the rarity of heavy rainfall centers in the area. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values shown for rainfall. In actual practice, estimating the rainfall or snowmelt runoff is very imprecise. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snow cover available for melt, errors in estimating the snowmelt rate, as well as marked departures from the average infiltration or loss rates given above.

7-4. Unit Hydrograph Analyses. A conventional means of forecasting flows from a particular drainage area is by the use of unit hydrographs. However, unit hydrograph development and subsequent use of the developed hydrographs as a forecasting tool has been found to be impractical for the drainage area under consideration in this manual. Reasons for this include the relatively large size of the drainage area, requiring the division of the area into many subareas, the lack of rainfall and subsequent runoff events for unit-hydrograph definition, the sparsity of rainfall reporting stations needed for both analysis and forecasting purposes, and the fact that by far the greatest amount of runoff that occurs from this drainage area does not result from particular rainfall events but results from progressive snowmelt, making runoff definition during a selected time period very imprecise. However, additional hydrometeorologic data are being collected and runoff studies continued in an attempt to improve inflow forecasting. Currently, this forecasting is based on routing of gaged flows rather than precipitation-runoff relations. Unit-hydrograph procedures will continue to receive consideration as a means of possibly improving the regulation process.

7-5. Plains Area Snowmelt Volume. In many years a major portion of the annual runoff from the plains contributing area between the Fort Randall and Gavins Point Dams and from the area immediately below Gavins Point Dam is a result of melting the snow cover accumulated during the winter months. This melt usually occurs during late March or April and often results in the annual maximum peak flow from these drainage areas. Basic data pertinent to plains area snowmelt volume analyses are precipitation during the late fall and winter months, winter season temperatures, water content of the accumulated snow cover prior to the melt period and soil conditions. However, even with these data, forecasts of the plains snowmelt runoff volume are usually quite imprecise.

7-6. Plains area snow surveys are made during any year that a substantial snow accumulation exists over the drainage area. One method of obtaining quantitative estimates of the expected runoff volume is to compare water content of the current survey with surveys made in preceding years. This comparison will indicate which of the past years is most analogous to the current year for each portion of the total drainage basin between Fort Randall and Gavins Point Dams and downstream to Sioux City. Forecasts are developed by assuming that the volume of snowmelt runoff from each portion of the basin should be similar to that observed in the most analogous year. These estimates are tempered by available ground condition data, which could either increase or decrease the losses as the time of runoff. If analogous data are not available for a particular portion of the basin, it is necessary to estimate the runoff volume by noting runoff depths during previous years from other areas where snow cover conditions appear similar to this year's snow cover over the areas in question.

7-7. Improvements in the techniques of forecasting the runoff resulting from plains snowmelt are being investigated as a technical study by personnel of the Reservoir Control Center and hopefully more precise and objective methods will be developed. In addition, the National Weather Service is investigating this matter and has initiated forecasts of plains snowmelt runoff volumes. These forecasts are made just prior to the melt season. As experience is gained it appears probable that more valid estimates will be available than in the past.

7-8. <u>Monthly Reach Inflow Forecasts</u>. Soon after the first of each month throughout the year, a forecast of incremental inflows originating between Fort Randall and Gavins Point Dam, as well as between Gavins Point Dam and Sioux City, is prepared by the Reservoir Control Center, with the forecast period extending from the time the forecast is made through the succeeding March. Since precipitation forecasts through such an extended period are not feasible, the forecasts are essentially based on three factors. These are monthly normal runoff, antecedent runoff, and accumulated snow over the incremental drainage area. In this reach, snow contributions to runoff are important only during the early spring, March-April, period of plains snowmelt runoff. Consequently, long range forecasts for periods other than this early spring period consist primarily of subjectively modifying the long term normal runoff volume by experienced antecedent conditions. These forecasts are utilized to develop system regulation studies, as described in the Master Manual. Details and techniques currently applicable for forecast development are contained in the MRD RCC Technical Report MH-73, "Missouri River Main Stem Reservoirs, Long Range Inflow Forecasting Procedures."

7-9. <u>Short Range Forecasts of Daily Inflow</u>. Experience has indicated that a satisfactory method of anticipating Gavins Point inflows for periods of up to a week beyond the current date consists of combining anticipated daily releases from the upstream Fort Randall project with anticipated daily flows from the Niobrara River, together with an allowance for local runoff. A simple translation of the current day's Fort Randall releases plus the current day's flow of the Niobrara River at Spencer, Nebraska, as equivalent to the succeeding day's inflow to Gavins Point Reservoir, is a satisfactory method of forecasting inflows for a majority of the time when substantial runoff is not occurring from the drainage area adjacent to the reservoir. In this connection, the Omaha District makes Niobrara River forecasts for several days in the future and furnishes these forecasts to the Reservoir Control Center daily for operational purposes. During significant flood events, Ponca Creek and Bazile Creek flows should be considered in addition to Niobrara flows. However, most of the time when only moderate runoff originates between Fort Randall and Gavins Point Dams, the Gavins Point inflow can be considered in total, with forecasts largely an extrapolation of past total runoff, modified as necessary to consider current hydrologic conditions. Typical inflow hydrographs from the total incremental area are discussed in Section II.

7-10. Stage-discharge relationships are maintained in the Reservoir Control Center for all important streamflow stations in the incremental drainage area. These are kept current on the basis of discharge measurements made by the United States Geological Survey. Plate 24 indicates the present relationships at locations that are most important for developing short range inflow forecasts pertinent to Gavins Point regulation.

7-11. Flow Forecasts at Downstream Locations. Flows through the reach from Gavins Point Dam to Sioux City usually are made up mostly of Gavins Point releases. However at times the three major tributaries entering this reach, the James, Vermillion and Big Sioux Rivers, will have substantial flows. Forecasts of flows originating in this reach are very pertinent to the definition of system releases, and are discussed in the Master Manual. Details of the forecast procedures are contained in MRD-RCC Technical Report F-62, "Forecast Procedures for Definition of System Releases."

7-12. Downstream Stage Forecasts. Stage forecasts at Yankton can be made on the basis of anticipated Gavins Point releases and the Yankton rating curve shown on Plate 15. Since the rating curve has shifted considerably since Gavins Point Reservoir first began operation, and the maximum release from Gavins Point was 61,000 cfs in 1975, confirmation of the stage-discharge relationship above this discharge level is lacking. If higher releases are made, appropriate adjustments to the curve, based on experienced stages, may be necessary for valid forecasts. Stage forecasts for downstream locations on the Missouri River may be derived from current rating curves, together with the flow forecasts discussed in the Master Manual.

7-13. Routing Procedures. For purposes of anticipating inflows to Gavins Point Reservoir, a simple translation of observed or anticipated upstream flows by the approximate travel time from the upstream location is an adequate routing procedure for a large majority of the time. On rare occasions it may be desirable to more accurately define the portions of Gavins Point inflow originating from below Fort Randall Dam. In such cases a lag-average approach to routing Fort Randall releases into Gavins Point Reservoir is utilized. Experience has indicated that, if the Missouri River channel between the projects is free of ice, hourly releases from Fort Randall can be converted to hourly Gavins Point inflow increments by averaging 5 consecutive hourly releases and lagging these averages by 16 hours from the last hour of releases comprising the average. With an ice cover in the channel, the travel time and the attenuation in Fort Randall release fluctuations will be increased and modifications of the routing coefficients may be necessary.

7-14. Gavins Point Reservoir Evaporation Estimates. Due to the relatively large surface area, evaporation is an important component of the overall water budget of Gavins Point Reservoir. An estimate of the daily evaporation volume is required for developing daily inflow estimates, as well as for more precisely estimating the effects of reservoir regulation upon the available water supply. While one means of estimating daily evaporation depths is application of the common 0.7 factor to adjacent pan evaporation, this is not considered reliable for Gavins Point due to the difference between the lake surface temperature and pan temperature. MRD-RCC Technical Report JE-73, "Evaporation Estimates," addresses this problem in detail and recommends the use of a variable pan-to-lake factor. This factor for Gavins Point varies from as little as 0.53 during periods when lake surface temperatures are less than air temperatures to as high as 1.59 when lake surface temperatures materially exceed air temperatures. During those portions of the year when pan data are not available, normal evaporation depths for the season of the year appears to offer the most practical means of developing evaporation estimates for day-to-day regulation activities. Reference is made to the cited Technical Report for further details pertinent to the development of evaporation estimates for this project. This report also recommends procedures for the adjustment of initial estimates at the time detailed analyses of the effects of the project upon streamflow are made.

7-15. In addition to evaporation considerations, development of the effects of the Gavins Point Reservoir upon streamflow must consider precipitation upon the reservoir surface and must also make allowances for the channel area in existence prior to the impoundment of water in the reservoir. Also, allowance must be made for that portion of the rainfall now falling on the reservoir surface which prior to the reservoir would have contributed to direct runoff from the area now inundated. Precise calculations of these factors are entirely impractical. In practice, it is assumed that 75% of the precipitation that falls on the reservoir is effective in offsetting gross evaporation (this assumes that 10% would have fallen on original channel area and that 15% would have appeared as direct runoff from the former ground surface now inundated by the reservoir).

7-16. Wind Effects on Water Surface Elevations. The general orientation of the Gavins Point Reservoir is to the west of the damsite where the pool level recorder is located. Winds with a component from this direction result in set-up at the dam while a wind component from the opposite direction results in set-down. Plate 25 is a wind correction table for the pool level recorder at the dam. An annemometer is located adjacent to the dam; however, it should be recognized that only approximations of the wind effect on the reported pool level can be obtained with data from this instrument. The time required for set-up to be fully established, variations in wind velocity and direction over the reservoir surface and the unrepresentativeness of the observations at the dam will all result in deviations from calculated values. Synoptic surface weather maps may also be used for qualitative wind estimates or to determine the probable representativeness of the annemometer.

7-17. Daily Inflow Estimates. Estimates of inflow to the Gavins Point Reservoir are made each day for operational purposes. The steps involved consist of the following:

a. A plot of hourly pool elevations as given by the pool level recorder is maintained.

b. Utilizing reported winds, the set-up or set-down effects are estimated and average lake levels, adjusted for wind, throughout the past 24-hour period are determined.

c. Storage change equivalent to the estimated 24-hour elevation change is determined. Combining this with reported releases and estimated evaporation, an equivalent inflow is computed.

d. Fort Randall releases and gaged tributary flows are routed to the Gavins Point Reservoir. These are combined with estimates of ungaged flow and precipitation on the reservoir surface to obtain an additional estimate of reservoir inflow.

e. Difference in inflow estimates as determined by c. and d. are reconciled by judgement.

f. At times it will be necessary to adjust data for previous days on the basis of continuing trends in the lake level which were not evident during those days.

7-18. Unregulated Flows. Construction of Gavins Point Dam, together with the other main stem and tributary projects in the basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows augmented by reservoir regulation. A quantitative estimate of the effects of regulation upon flows at the damsite and important locations immediately downstream is frequently required. This represents a continuing effort by the Reservoir Control Center, involving such factors as reservoir evaporation, precipitation on the Gavins Point Reservoir, variations in travel time resulting from reservoir development, channel area inundated by the reservoir, runoff that could have been expected from previous overbank areas now inundated by the reservoir, inflows, outflows, and Gavins Point storage changes. Details of the required analysis are contained in the RCC Technical Study S-73, "Upper Missouri River, Unregulated Flow Development," and, rather than repeating in this manual, reference is made to that publication.

7-19. In addition to unregulated flows, development of flows at the 1949 level of basin development (prior to construction of Gavins Point Dam and most of the other water resource developments in the Missouri Basin) represents a continuing effort of the Reservoir Control Center. Gavins Point Dam represents a location where an analysis of such development is made. Reference is made to Section VIII of the Master Manual for further details of these analyses.

7-20. Evaluation of Regulation Effects. In the evaluation of the effects of regulation upon downstream flows, and consequent flood damage reduction estimates, the Gavins Point project is considered to be a component of the main stem reservoir system. Damage reductions attributable to regulation of this individual project are not differentiated from those resulting from the 6-project system as a whole. Details of the evaluation process are given in Section VIII of the Master Manual and in other references cited in that publication.

SECTION VIII

MULTIPLE-PURPOSE REGULATION OF GAVINS POINT RESERVOIR

8-1. General. Aspects of multi-purpose regulation that are pertinent to the Missouri River main stem reservoir system as a whole are discussed in Section IX of the Master Manual. Since continuing development of system operating plans requires coordination of plans for all main stem projects, this subject has been explored thoroughly in the Master Manual and will not be repeated in this, the Gavins Point project manual. Rather, the following paragraphs will be concerned with amplifying the operational objectives and requirements given in the Master Manual as they are pertinent to regulation of the Gavins Point project for the functions of irrigation, navigation, water supply, power, fish and wildlife, water quality and recreation. Regulation of the Gavins Point project for flood control is discussed in Section IX.

8-2. Basis for Service. As an introduction to regulation of the project, the need to conform to certain storage provisions and basic regulation criteria should be recognized. The bottom inactive storage zone of the Gavins Point Reservoir, or that zone lying below elevation 1204.5 feet m.s.l., is normally filled with water. This insures maintenance of a minimum power head, a minimum level for the design of irrigation diversion and water supply facilities, and a minimum pool for recreation, fish and wildlife purposes. The only exception to this would occur on a very temporary basis immediately prior to an anticipated much-above-average runoff from the Fort Randall-Gavins Point incremental drainage area. At such a time the reservoir could be partially lowered toward the previously established minimum operating pool level of elevation 1195 feet m.s.l. The top storage zones in the lake, extending above elevation 1208 feet m.s.l., are provided for the handling of the largest floods and to insure safety of the project structures. With the exception of temporary fluctuations of the reservoir level above elevation 1208 feet m.s.l. resulting from reregulation of upstream reservoir releases, these upper storage zones are reserved exclusively for this purpose. Storage space intermediate to these zones, extending from elevations 1204.5 to 1208 feet m.s.l., provides for the multiple-purposes enumerated in Paragraph 8-1 as well as for the control of moderate floods, and together with the upper zones, allows a degree of control of major floods including those approaching the maximum possible that can occur from the incremental area below Fort Randall.

8-3. The following general approach is observed during regulation of the Gavins Point project:

a. Regulation of Gavins Point Reservoir as an individual project must be subordinate to regulation of the entire main stem system as a whole.

b. Flood control will be provided for by evacuating the storage space in the reservoir above elevation 1204.5 feet m.s.l. prior to March of each year and maintaining some reserve for this purpose throughout the year, insofar as practicable.

c. All irrigation and other upstream water requirements for beneficial consumptive purposes will be served.

d. At all times when a reserve of vacant flood control storage is available in the Gavins Point Reservoir, flood control releases will be scheduled on the basis of flood control considerations of the entire main stem reservoir system.

e. Releases required to support Missouri River navigation will be maintained in accordance with system regulation criteria outlined in the Master Manual.

f. Downstream water supply and water quality flows will be at all times supported by appropriate releases.

g. By adjustment of releases within the criteria designated above, the efficient generation of power to meet the area's needs as consistent with other uses and market conditions will be provided for.

h. Insofar as possible without serious interference with the foregoing, the Gavins Point Reservoir will be regulated for maximum benefit to recreation, fish and wildlife.

8-4. Flood Control. Regulation of the Gavins Point project for flood control purposes is discussed in Section IX of this manual and therefore not presented in detail in this Section. However, it is evident that the storage of water during periods of high inflow for flood control purposes is compatible with regulation for other uses.

8-5. Irrigation. There are no Federally financed irrigation projects in existence or proposed that are directly affected by regulation of Gavins Point Reservoir. However, upstream irrigation has a depleting effect upon inflows and power revenues derived from the project help finance irrigation in the Missouri River basin. Maintenance of the Gavins Point Reservoir elevation in a relatively narrow range between elevations 1204.5 and 1208 feet m.s.l., most of the time provides almost ideal conditions for setting and operation of irrigation intakes withdrawing water from the reservoir. As yet such withdrawals by private interests have been minor, but can be expected to increase in the future. Considerable withdrawals for irrigation purposes occur along the Missouri River below Gavins Point Dam. Maintenance of flows for navigation and other purposes also provides an adequate supply for irrigation, although at times access to the available water may be a problem.

8-6. Water Supply and Quality Control. Some water supply withdrawals from Gavins Point Reservoir are occurring and more will probably develop as time progresses. The City of Springfield, South Dakota, withdraws water from the upstream end of the reservoir and has experienced problems associated with sedimentation of their intake. The city modified their original intake by placing a "piggy-back" pipe above their original intake line and raising the original intake invert level by two feet, to 1202 feet m.s.l. The Corps of Engineers, in issuing the permit for construction, again called attention to the sedimentation problems that could be expected and suggested that the new installation may be no more permanent than the original installation which functioned for only seven years. However, except for such sedimentation problems, the relatively narrow range within which Gavins Point Reservoir is regulated makes the project a good water source.

8-7. As discussed in the Master Manual, certain minimum flows are required at major pollution sources along the Missouri River below Gavins Point Dam. These minimums now range from 1,350 cfs during the spring and fall months at Sioux City, Iowa, to 9,000 cfs at Kansas City, Missouri, during the summer months. Gavins Point releases for other purposes will usually result in downstream flows well above these requirements. An exception can occur during a prolonged drought period, comparable to that experienced over the Missouri Basin in the 1930's, when system releases are markedly reduced and water quality flow requirements become controlling.

8-8. There are numerous water supply intakes throughout the length of the Missouri River below Gavins Point Dam serving municipal and industrial sources. The closest to the dam is the Yankton, South Dakota, municipal intake. Many other intakes are in the reach from Sioux City, Iowa to the mouth of the river, including intakes supplying cooling water to major fossil fueled and nuclear power facilities. Minimum daily flow requirements established for water quality purposes would create operational problems at many of the intakes with problems resulting primarily from high intake elevations or access to the supply rather than the rate of Missouri River flows. As a consequence, minimum daily releases of 6,000 cfs should be maintained insofar as possible, and if releases at a level of less than 10,000 cfs should be necessary, continuing surveillance of downstream intakes will be required in order to assure proper action by affected interests to obtain adequate supplies.

8-9. Navigation. Since Gavins Point Reservoir is the most downstream of the main stem reservoirs, the Missouri River navigation project is directly served by releases from the reservoir. Navigation releases are scheduled on the basis of criteria presented in the Master Manual. The relatively small amount of storage space in Gavins Point Reservoir between elevations 1204.5 and 1208 feet m.s.l. is most important for reregulating upstream reservoir navigation releases even though it is not a source of storage to sustain navigation except for extremely short time intervals. The availability of this space in Gavins Point does allow daily fluctuations in the upstream Fort Randall release that, if uncontrolled, would be inconsistent with providing steady flows for Missouri River navigation.

8-10. Power Production. Hydroelectric power generated by the Gavins Point project is integrated with the power generated by the other main stem projects and many other public and private generation facilities in the Missouri Basin and surrounding areas. To the extent practical all releases from Gavins Point Reservoir are made through the power plant; however, the maximum discharge capacity of the installed power units is about 35,000 cfs. In some drought years daily navigation requirements will exceed the power plant capacity. Also, evacuation of flood control storage from the system often requires releases in excess of power plant capacity. Considering both factors, releases in excess of power plant capacity can be expected in about half the years. These excess releases are made entirely during the non-winter period.

8-11. While hourly loadings of the Gavins Point power plant are scheduled by the Western Area Power Administration's system power dispatcher in Watertown, South Dakota, these loadings must be within limits prescribed by the Reservoir Control Center of the Corps of Engineers. These limits are developed on the basis of daily as well as hourly releases required to serve functions other than power. Due to the fact that the maximum discharge capacity of the Gavins Point power plant approximates the normal full-service releases required for navigation, there is little opportunity to schedule significant power peaking operations while navigation is in progress. However, minor hourly fluctuations can sometimes be accomplished while maintaining mean daily discharges at the level required for navigation. Experience has indicated that moderate variations in discharges through the day do not result in objectionable surges through upstream portions of the navigation project near Sioux City, Iowa. In the winter months when the power plant discharge capacity exceeds normal winter release rates by a large amount, there is more opportunity for peaking. However, power plant maintenance is normally accomplished during these months and a single inoperative unit restricts peaking considerably. Additionally, the water intake immediately downstream from the dam serving Yankton, South Dakota, requires instantaneous flows of about 6,000 cfs to remain operable.

8-12. As indicated above, there is a seasonal variation in the general level of power releases from Gavins Point Reservoir reflecting services being provided other functions. During the open-water season, relatively large releases are required from the reservoir for navigation. Additionally, during years of above normal water supply, the major portion of required system storage evacuation must be accomplished during the open water season. These large releases generate substantial amounts of power. During the winter months when navigation is not possible, releases are usually restricted to less than one-half their navigation season level, due to the reduced capacity of the ice-covered Missouri River channel below Gavins Point Dam.

8-13. Fish and Wildlife. Regulation of main stem reservoirs for fishery purposes largely involves pool level manipulations which will provide a suitable environment for the spawning and initial growth of game and forage fish. Stationary or rising reservoir elevations through the late March to early July period are desirable for this purpose. Additionally, some species such as the northern pike require the inundation of terrestrial vegetation during the late March and April period for a suitable spawning habitat. The provision of such conditions in Gavins Point Reservoir has been found to be impractical without serious consequences to the other purposes for which the project was designed. Maintenance of the full flood control capability of the project during the spring and early summer months is considered essential; therefore, a continuing rise in pool elevations during this period cannot be permitted within the flood control range of elevations. Reregulation of upstream releases and incremental inflows causes fluctuations in the reservoir level that are pronounced due to the relatively large change in level that accompanies moderate storage changes. Minimizing these changes would require fluctuating releases often in excess of downstream requirements. Consequently, no effort is made to manipulate Gavins Point pool levels to enhance spawning activities.

8-14. Another effect of the relatively small amount of storage space in Gavins Point Reservoir, when related to discharges from the project, is the rapid exchange rate of the reservoir contents, generally averaging about one week. Fisheries interests claim that the rapid rate is detrimental to the fish population in the reservoir. However, the exchange rate is mostly dependent only upon runoff from the total upstream drainage area and the physical dimensions of the reservoir. Neither can be changed by modified regulation procedures.

8-15. Recreation. Water based recreation upon the Gavins Point Reservoir is dependent to a considerable degree on the constructed access facilities. Boat ramps constructed around the perimeter of the project have top elevations of about 1210 feet m.s.l. and bottom elevations near

1200 feet m.s.l., as described in Section IV of this manual. Regulation criteria for other purposes result in pool levels within this range at nearly all times, insuring access to the reservoir. Recreational use of the project exceeds that of any other main stem reservoir project in spite of the fact that the Gavins Point Reservoir surface area is much less than any of the other projects. This higher level of use is due largely to its closer proximity to large population centers. As a means of enhancing recreation by increasing the area of the lake and also improving the shoreline conditions, the reservoir level is often raised to near elevation 1206 feet m.s.l. by early July and to near elevation 1208 feet m.s.l. by the end of that month. The 1208 elevation is maintained during the remainder of the year. This increase in elevation in July above the elevation 1204.5 feet m.s.l., base of annual flood control, is made only when the Fort Randall-Gavins Point incremental drainage area flood potential is low.

8-16. Release Scheduling. As discussed in the Master Manual, scheduling of the general release level from the Gavins Point project, as well as all other main stem reservoir projects, is normally based on continuing studies by the Reservoir Control Center in which all functional requirements, including flood control, are considered. These studies are made at maximum intervals of one month and incorporate current conditions with the most recent estimates of future runoff as expressed in terms of forecast inflow to the individual reservoir projects. Service to all authorized functions receives consideration, including current projections of power demands and navigation requirements. The frequency of these studies, which often result in modifications of the current and projected Gavins Point general release level, is increased when previously unanticipated inflows occur that may have a substantial effect upon system regulation. An examole of these studies is included in the Annual Operating Plan, published each year as described in the Master Manual.

8-17. Reservoir regulation orders, furnished by the Reservoir Control Center to operating personnel at the Gavins Point project, are the basis for scheduling mean daily releases from this project. Definition of daily release rates, as opposed to the general level of releases discussed in the preceding paragraph, during the late-March to late-November navigation season is usually based on maintaining selected target flows at downstream locations on the Missouri River. During periods navigation is not being served, daily release rates are based on water supply, water quality, and power production requirements as well as storage excavation needs. Allowable variations in Gavins Point release rates from those specified in the order are always very small. Hourly patterning of the Gavins Point mean daily release rate within limits prescribed by the Reservoir Control Center is accomplished by the Western Area Power Administration scheduling of daily power production. Patterning is seldom extreme.

8-18. Scheduling of Gavins Point releases during periods when a failure in communications between the Reservoir Control Center and Gavins Point project personnel occurs is discussed in Section IV of this manual. Specific instructions to project personnel are designed to continue an acceptable level of service to multiple-purpose functions, consistent with circumstances then occurring. These instructions are given in Exhibit A.

SECTION IX

FLOOD CONTROL REGULATION OF GAVINS POINT RESERVOIR

9-1. Objectives of Flood Control Regulation. The flood control regulation objectives of the Gavins Point Reservoir are: (1) to coordinate regulation of Gavins Point with the regulation of the other main stem reservoirs on the Missouri River to prevent runoff from the drainage basin above Gavins Point Dam from contributing to damaging flows through the lower reaches of the Missouri River; (2) to utilize available storage space in the best possible manner to control flood runoff originating in the Fort Randall-Gavins Point incremental area flood runoff. The first objective given is the primary flood control objective for the main stem system as a whole. As a consequence, it is discussed in the Master Manual. The concerns of this manual are to amplify system regulation procedures as they apply particularly to the Gavins Point Project and to discuss regulation geared to reduce floods originating in the incremental drainage area.

9-2. Method of Flood Control Regulation. In general, the developed method of regulation of the Gavins Point Reservoir may be classified as Method C, as defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available storage space in the reservoir during each flood event, with regulation procedures based on the control of floods of approximate project design magnitude.

9-3. Storage Space Available for Flood Control Regulation. During any specific flood event all available space in the Gavins Point Reservoir will be utilized to the maximum extent practicable for flood control purposes. The control of floods will be combined with regulation for other beneficial water uses. Storage space allocated for flood control in the Gavins Point Reservoir totals 155,000 acre-feet, less than the amount contained in any of the other main stem reservoirs. Of this total space, 60,000 acre-feet is exclusive flood control storage space, to be utilized only during unusually large flood season inflows. The remainder is annual flood control and multiple-use storage space that will be kept available during the season of maximum flood potential for flood control purposes and, after this season, filled in the interest of other beneficial uses. Surcharge storage space has also been provided in Gavins Point Reservoir to insure the safety of the Gavins Point project during extreme floods. Utilization of surcharge storage will usually provide some downstream flood reductions during these extreme floods events. Storage space provided in tributary reservoirs within the incremental drainage area discussed in this manual has little effect upon regulation of Gavins Point or other main stem reservoir projects.

9-4. Flow Regulation Devices. Releases from the Gavins Point Project may be made through the power plant and the spillway. Normally, discharge through the power plant will be used to the fullest extent possible in order to achieve the maximum economic return from the project. The discharge capacity of the Gavins Point power plant ranges up to 35,000 cfs. When it is necessary to release at rates greater than the power plant is capable of maintaining, the spillway, capable of passing almost 600,000 cfs, will be used. Since the power plant is essentially capable of releasing only normal navigation requirements, it is evident that flood control releases, or releases in excess of full-service navigation demands, will usually require spillway operation.

9-5. General Plan of Flood Regulation. Flood control regulation of the Gavins Point Reservoir to meet the stated objectives is based on consideration of the following factors.

a. Coordination of flood control regulation of Gavins Point with the regulation of the other main stem reservoirs and upstream tributary reservoirs is as described in Section X of the Master Manual.

b. Deliberate storage of water in Gavins Point Reservoir for flood control purposes will be undertaken only to control runoff originating downstream from Fort Randall Dam. Effort will be made at all times to maintain the reservoir level near the selected seasonal target.

c. The primary means of maintaining Gavins Point Reservoir at selected levels is by adjustment of the upstream Fort Randall release.

d. At all times a reserve of vacant flood control storage space is expected to remain available in Gavins Point Reservoir, releases from the project will be governed by system release criteria as given in the Master Manual.

e. Releases will be increased above those defined by system release criteria given in the Master Manual if it appears that such will be necessary to prevent the Gavins Point Reservoir from rising significantly above elevation 1210 feet m.s.l., the top of the exclusive flood control storage zone.

f. Definition of releases in excess of system release requirements will be based on anticipated future inflows, the channel capacity downstream, and a qualitative estimate of probable adverse effect of any further increase in the Gavins Point Reservoir elevation.

9-6. The general plan of regulation applicable to most of the main stem reservoirs, including Gavins Point Reservoir, is to have the flood control storage space evacuated prior to the beginning of the March-July flood season. Gavins Point Reservoir levels are reduced to the appropriate level, elevation 1204.5 feet m.s.l., as late in February as this can be accomplished without adverse effects on the power function. Maintaining high pool levels through the winter season has a beneficial effect upon the power function as a result of increased head. If an exceptionally large amount of runoff is expected to originate from the Fort Randall-Gavins Point incremental drainage area, a drawdown below elevation 1204.5 feet m.s.l. is scheduled. Such an operation was accomplished prior to the 1962 early spring flood. However, any drawdown below elevation 1204.5 feet m.s.l. must carefully consider any harmful effects upon water supply facilities and other developments in the reservoir area through continuing contact between personnel of the project and the Reservoir Control Center. Refill of the reservoir to elevation 1204.5 feet m.s.l. is accomplished with flood inflows.

9-7. Deliberate long-term storage in the annual flood control and multiple use zone to satisfy future multiple-use requirements, as is done in the major upstream main stem reservoirs, is not scheduled in the Gavins Point project. Rather, this deliberate storage when made is largely to improve recreational use, although the power function also receives some benefit due to the increased head that is developed. Raising the Gavins Point pool above the base of flood control is dependent upon a reduced flood potential from the Fort Randall-Gavins Point incremental drainage area. Normally a significant increase is not made until the end of June. By the end of July the flood potential normally decreases to such an extent that the entire annual flood control and multiple use zone (up to elevation 1208 feet m.s.l.) may be filled. If there is a marked increase in the flood potential of the incremental drainage area during such time water is stored in the annual flood control and multiple use zone, evacuation of this zone to the extent deemed necessary will be accomplished by appropriate short-term adjustments in the Fort Randall release rate.

9-8. Coordinated System Flood Control Regulation. The main stem system of reservoirs, of which Gavins Point Reservoir is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the system. Release scheduling from the Gavins Point project to accomplish this objective is based on studies performed by the Reservoir Control Center. The longer range studies extend from the current date through the succeeding months up to a 1 March date when the start of the following flood season occurs. All factors listed in paragraph 9-5 are considered to the extent possible in these studies. Such studies are made at a maximum interval of one month as new estimates of future inflows are developed and, if conditions change materially from those anticipated in previous monthly studies, additional within-month studies are made. The published Annual Operating Plan, discussed in the Master Manual, is based on one of these studies, with deviations from the published plan based on the results of subsequent monthly (or more frequent) studies. Details of flood control regulation procedures applicable to the system of rese-voirs are given in Section X of the Master Manual.

9-9. Exclusive Flood Control Regulation Techniques. The Gavins Point Reservoir will usually be operated at an elevation of 1208 feet m.s.l. or less. However, occasionally flood inflows will be of such magnitude that encroachment into the exclusive flood control zone above elevation 1208 feet m.s.l. will occur. Consequential action is to reduce Fort Randall releases to the extent necessary to lower the Gavins Point pool to 1208 as soon as practicable. No release whatsoever from Fort Randall for a day or two may be necessary at times. Such an action occurred in 1962 and would be quite probable in future periods of large incremental area runoff. Encroachment into the surcharge storage zone (above elevation 1210 feet m.s.l.) should be avoided. If anticipated incremental inflows are of such magnitude that significant encroachment would be expected in spite of Fort Randall release reductions, the system release level based on downstream target flows, as described in the Master Manual, should be appropriately increased to keep the encroachment at an acceptable level.

9-10. Surcharge Regulation Techniques. During exceptionally large flood inflows, all available flood control storage space may be utilized and the Gavins Point Reservoir may rise into the surcharge zone above elevation 1210 feet m.s.l. Since the primary reason for providing surcharge space is to insure the safety of Gavins Point Dam and also since real estate surrounding the lake has in general not been acquired much above elevation 1210 feet m.s.l., significant surcharge encroachment should be allowed only when necessary to prevent extensive downstream damage or if unprecedented flood inflows were to occur. When unprecedented flood inflows occur and reservoir levels exceed elevation 1210, the regulation procedures given with the emergency instructions, Exhibit A, should be used as a guide for release scheduling. In part, these procedures relate reservoir level and inflow to suggested release, with the suggested release based on typical recession curves, by the method outlined in EM 1110-2-3600.

9-11. Responsibility for Application of Flood Control Regulation Techniques. As described in Section VI of the Master Manual, the Missouri River Division Reservoir Control Center is responsible for and directs all regulation, including flood control regulation, of Gavins Point and the other main stem reservoirs. Instructions to assure continuation of Gavins Point regulation during periods of communication failure between the project and the Reservoir Control Center are given in succeeding paragraphs and in Exhibit A of this manual.

9-12. Emergency Regulation. Rapid communication is usually available between the Reservoir Control Center and operating personnel of the Gavins Point project. When communications are interrupted for any extended period of time, project personnel will be required to continue regulation, as discussed in Section V. Exhibit A of this manual outlines the emergency procedures to be followed. In general, these procedures are such that they will continue service to multiple-use functions through the period of communications failure at the approximate level prevailing prior to the communications outage, if Gavins Point inflows continue in the range of those previously anticipated. The emergency procedures also allow for increased inflows, up to those occurring during maximum possible floods, as developed for spillway design purposes.

9-13. Emergency regulation curves included with Exhibit A were developed by the method described in EM 1110-2-3600. A T_s value of 1.5 days was selected in curve development with this value based on inflow hydrographs of design floods developed during reservoir design studies. This value is somewhat less than most of the T_s values for incremental inflow hydrographs shown on Plate 5; however, use of a near minimum T_s value is encouraged by the referenced engineering manual and provides more assurance that available storage space will be filled prior to making large releases. These curves were also constructed to allow the accumulation of two feet of storage in the surcharge space prior to making releases at full spillway capacity. Routings indicated that such an accumulation had no significant effect upon maximum reservoir levels or releases during the spillway design flood and in addition provided better control over the smaller floods much more likely to occur.

9-14. Gavins Point releases under emergency conditions are related to inflows, subject to the following:

a. The minimum release of all times will be that specified on the most recent available regulation order. This assures continuation of service to navigation, power and downstream water supply requirements.

b. Releases in excess of 100,000 cfs, the approximate downstream channel capacity prior to occurrence of significant damages, will not be made unless the reservoir is at or above the base of exclusive flood control storage space, elevation 1208 feet m.s.l.

c. With a falling reservoir level between elevations 1208 and 1213 feet m.s.l., release will be limited to a maximum of 100,000 cfs.

d. Full spillway capacity will be utilized to maintain the reservoir level at or below elevation 1213 feet m.s.l. or to lower it to this elevation. A transitional zone between elevations 1212 and 1213 feet m.s.l. is provided for adjusting releases between the 100,000 cfs rate and full spillway capacity.

SECTION X

EXAMPLES OF GAVINS POINT REGULATION

X-A Historical Regulation

10-1. Gavins Point Reservoir Elevations. Closure of Gavins Point Dam was made at the end of July 1955, beginning the accumulation of storage in the reservoir. Deliberate storage for operational purposes took place in 1956 when the reservoir was first raised to the base of the annual flood control and multiple-use zone, elevation 1204.5 ft msl. Since that time the project has been regulated within its normal operating range except for short excursions below 1205.4 and above 1210 in the interest of flood control. Exclusive flood control storage space (elevations 1208 to 1210 feet m.s.l.) has been used several times, generally in the late summer and fall when the flood potential was very low and the storage space was used temporarily to retain inflows in excess of downstream needs. On occasion this space has also been used to control flood inflows originating from the Fort Randall-Gavins Point incremental area. In one year, 1960, storage was allowed to accumulate in the Gavins Point surcharge zone (above elevation 1210 feet m.s.l.) in the process of controlling extremely large plains snowmelt inflows from the incremental drainage area. In 1962 and 1969, the reservoir was drawn down several feet below the base of flood control in anticipation of high inflows from plains snowmelt.

10-2. Plates 26 and 27 show the levels of the Gavins Point Reservoir since initial fill occurred in 1956 and illustrate the past annual variations in reservoir levels. A distinct seasonal pattern in pool level variations is evident, particularly during the more recent years. Minimum levels usually occur in the early spring, prior to the March-July Missouri River flood season. During the late spring and early summer months the average reservoir level is allowed to rise through the annual flood control and multiple-use zone up to the base of exclusive flood control. The reservoir is then maintained near the base of exclusive flood control, elevation 1208 ft msl, through the late summer, fall and winter period Until drawdown to provide storage space for control of flood season inflows is made. Of interest is the extreme amount of drawdown made in 1962 and 1969 illustrated on Plate 26. Regulation during these periods of drawdown was in anticipation of large runoff amounts originating from the Fort Randall-Gavins Point incremental drainage area at the time of the plains area snowmelt.

10-3. Gavins Point Releases. Experienced mean monthly releases from the Gavins Point Project are also shown on Plate 26 and 27. A typical pattern of higher releases during the Missouri River navigation season than during the winter months is evident. During early years of operation, prior to 1967, initial fill of the entire main stem reservoir system was taking place. Combined with this were several successive years of subnormal runoff from the drainage area above the reservoirs. As a consequence, Gavins Point releases during these years were well below the normal levels that can be expected. Navigation seasons of less than 8 months duration, accompanied by releases near the minimum that would sustain downstream requirements, were the rule and regulation during this period is illustrative of what can be expected during a future protracted drought period. Beginning in 1969, several years occurred where the evacuation of excess flood inflows from the main stem reservoirs was a prime consideration, accompanied by much higher winter releases than during early years of operation and navigation season releases well in excess of those necessary to supply the downstream full-service navigation flows. In general, any extended Gavins Point release exceeding 35,000 cfs may be assumed to be necessary to evacuate flood storage space rather than for the support of navigation. Except during transition periods from winter season to navigation season flows, or the reverse, mean daily Gavins Point releases have not usually differed substantially from the mean monthly flows illustrated on these plates. The greatest variations occur during the spring and early summer months when sharp mean daily release reductions are frequently made to compensate for rainfall runoff originating downstream from Gavins Point Dam. Many months have been recorded where mean daily release through the month varied less than 2,000 cfs from the monthly mean.

10-4. Regulation Effects. The historical effects of regulation provided by the Gavins Point Reservoir, combined with regulation of upstream reservoir projects, upon mean monthly flows at the Gavins Point damsite are also illustrated on Plates 26 and 27. Mean monthly unregulated flows shown on these plates are the computed estimates of flows at the damsite if none of the upstream projects, including Gavins Point, had been in operation. Mean daily maximum and minimum flows for each year of the 1956-1976 period for regulated (observed) and unregulated conditions are given in Table 4. From this table it is evident that regulation has resulted in substantial reductions to all annual crest flows that would have been experienced at the Gavins Point damsite. Minimum regulated flows are usually greater than would have been experienced without upstream regulation and the much greater consistency of flows from year to year resulting from regulation is evident. Further discussion of the regulation provided at the Gavins Point damsite during particular years is contained in succeeding paragraphs and in the discussion of system regulation given in the Master Manual.

TABLE 4

ANNUAL EXTREME MEAN DAILY FLOWS
MISSOURI RIVER AT GAVINS POINT DAM

	Mean Daily Flow, 1,000 cfs			
	Regulated		Unregulated	
Year	Maximum	Minimum	Maximum	Minimum
1956	35.1	7.2	111	3
1957	30.5	6.7	118	4
1958	29.5	7.3	77	2
1959	31.5	8.0	124	5
1960	31.9	7.8	210	5
1961	28.5	5.9	61	2
1962	33.0	5.0	136	2
1963	30.8	4.9	131	6
1964	31.5	4.9	217	5
1965	32.0	7.8	145	10
1966	33.5	9.9	130	6
1967	34.5	6.5	213	5
1968	37.5	7.8	123	5
1969	53.1	6.0	151	8
1970	44.1	15.0	133	3
1971	52.0	16.0	123	9
1972	48.5	16.0	233	10
1973	33.0	16.8	70	7
1974	36.0	16.8	144	6
1975	61.1	16.8	176	6
1976	40.0	19.9	114	5
1977	35.2	10.0	53	1
1978	52.0	10.0	261	8

10-5. 1960 Regulation. Very large amounts of snow accumulated over the Fort Randall-Gavins Point incremental drainage area during the 1959-1960 winter period, prior to initial fill of the main-stem reservoir system. Efforts at that time were continuing to accomplish this initial fill to the maximum extent practicable. In addition, regulation criteria applicable to the Gavins Point project at that time had not evolved to those presently in force in that reservoir levels up to elevation 1208 feet m.s.l. were permissible until the rainfall runoff season began in May. Consequently, the regulation provided by the reservoir was not entirely indicative of that provided by current criteria. However, it does illustrate the control that can be provided over large volumes of runoff originating from the incremental contributing area. Reservoir levels, inflows and outflows for this flood event are shown on Plate 28. Of particular interest is the low level of Fort Randall releases, in the range of 1,000 cfs or less, for several days duration, thereby adding but little to the incremental inflows shown. As illustrated on this plate, Gavins Point Reservoir levels were in the surcharge storage zone for about a week, with a maximum encroachment of 0.7 foot. During this time, the spillway gates remained closed with spill over the top of gates reaching a maximum of 1,600 cfs.

10-6. 1961 Regulation. Runoff originating from the total Missouri River drainage area above Gavins Point dam during 1961 totalled about 11.3 million acre-feet, less than one-half of the long term average. Since runoff records first became available in 1898, there have been only two years with less runoff from this drainage area, these being in the early 1930's when runoff totalled less than 11 million acre-feet. Additionally, during 1961 the total storage within the main stem reservoir system was at extremely low levels. Therefore, the Gavins Point releases (regulated flows) shown on Plate 29 are illustrative of the general release level from this project that would occur during periods of extremely deficient water supply. Comparison of regulated and unregulated flows on this plate indicates the marked supplementation of flows during low water periods, resulting from operation of upstream reservoirs. Development of water resources in the basin above Gavins Point Dam has continued since 1961 and, if 1961 hydrologic conditions should be repeated, the supplementation would be more marked. While similar regulated flows could be expected, the increased depletion occasioned by further water resource development would have the effect of resulting in an extended period of negative unregulated flows, indicating that the current resource development is served only by withdrawal from storage during such drought periods.

10-7. 1962 Regulation. During the 1961-1962 winter season, snow progressively accumulated over the plains area of southeastern South Dakota and northern Nebraska to such an extent that substantial runoff amounts were anticipated when the melt of this cover took place. This was also at a time that initial fill of the main-stem reservoir system was taking place and, as a consequence, major emphasis was being placed on retaining as much water as possible within the system. In anticipation of larger runoff amounts from the Fort Randall-Gavins Point incremental drainage area, the level of Gavins Point Reservoir was drawn below the base of flood control, elevation 1204.5 feet m.s.l., in the latter part of March to a minimum level of 1201.9. Inflow, outflow and pool elevation hydrographs pertaining to Gavins Point Reservoir through the flood period are shown on Plate 30. Inflows to Gavins Point Reservoir during this flood period were minimized by operation of the upstream Fort Randall project. During the 11-day period extending from March 25 through April 4, mean daily Fort Randall releases were in the 1,000 cfs range or less and were eliminated entirely during a period of almost three days duration. Minimum Gavins Point releases of 5,000 cfs were synchronized with downstream flood inflows into the Missouri River while low releases from the project through the flood period enabled retention of storage within the reservoir system. The emphasis on system storage retention at the time precluded a rapid evacuation of flood control storage space. If the system had been near normal storage levels, larger Gavins Point releases following the crests of downstream tributary inflows would have probably been scheduled in an effort to make evacuated space available sooner.

10-8. <u>1967 Regulation</u>. Total Missouri Basin runoff above Gavins Point Dam during the June-July period of 1967 was among the largest of record for this period of the year, ver 70 percent greater than the long-term average. Combined with this runoff above Gavins Point Dam were severe flood flows originating in the Missouri River drainage areas below the main stem system of reservoirs. Damages prevented by the regulation of Gavins Point and the other main stem reservoirs during this flood period approached 250 million dollars. As illustrated on Plate 31, unregulated flows in excess of 150,000 cfs would have continued for a 25-day period without upstream regulation. Throughout this same period Gavins Point releases were maintained in the 25,000 to 30,000 cfs range. Prior to 1967 initial fill of the main stem reservoir system had not been completed; consequently, Gavins Point releases greater than required to sustain downstream navigation were not necessary during the open-water season. Regulation of the system, including Gavins Point releases, during this year is illustrative of flood control provided by fill of the system carry-over storage space. If this space had been filled prior to the 1967 season, Gavins Point releases somewhat similar to those experienced during 1975 (as described later) would have been probable.

10-9. <u>1975 Regulation</u>. Runoff originating above Gavins Point Dam during the 4-month April-July period of 1975 was the greatest for any similar period that had been experienced since runoff records began in 1898, exceeding the previous maximum, occurring in 1927, by over 2 million acre-feet. While the crest unregulated flow of 176,000 cfs at the Gavins Point damsite was relatively small in relation to the flood season volume, the unusual aspect was the sustained large unregulated flows extending from late April through July, as illustrated on Plate 32. Also unusual was that most of the well above normal precipitation contributing to the record high runoff occurred after early April and extended through July. As a consequence, Gavins Point releases during the early portions of the year were continued at near normal levels. Downstream constraints prohibited significant release increases during May and June and it was not until July that outflows were increased to levels that significantly exceeded those necessary to maintain full-service navigation flows through the lower Missouri River. Releases during the period extending from near the end of July through November were maintained at a uniformly high level, reflecting the absence of any significant runoff below Gavins Point

Dam during the period. These releases in the 60,000 cfs range maintained downstream Missouri River stages close to flood stage at several locations. Further information relating to this flood and regulation afforded by all reservoirs in the main stem system is given in the Master Manual and in the special Reservoir Control Center "Summary Report on Regulation of the Missouri River Main Stem Reservoir System to Control the 1975 Inflows."

10-10. Summary of Historical Regulation. Historical regulation of the Gavins Point project has proceeded for only a relatively short period of time, and a substantial portion of this historic period was during the initial fill of the main stem reservoir system. However, annual upstream runoff during this period has ranged from near the minimum to the maximum recorded since 1898. Therefore, regulation during these years is believed to be quite representative of conditions that are likely to prevail through the life of the project. Based on this experience, supplemented by analyses of the entire period of hydrologic record, it is believed that the regulation criteria developed for the Gavins Point project, and for the system as a whole (presented in the Master Manual) as it affects Gavins Point regulation are reasonable and represent a near-optimum utilization and control of the water supply that may be available. Of course, studies will continue through the life of the project in an effort to improve criteria. In general, it may be stated that unless very unusual conditions occur, a characteristic seasonal variation of Gavins Point Reservoir elevations will occur, irrespective of the amount of upstream runoff from year to year. Unless it is necessary to evacuate flood control storage space within upstream main stem reservoirs, Gavins Point releases will be almost entirely through the powerplant. However, in many years maintenance of full-service navigation flows in the downstream river will require some minor supplementary releases, particularly during early portions of the navigation season when the characteristically lower Gavins Point elevations reduce the power plant release capability below the maximum rate of about 35,000 cfs with a level at elevation 1208 ft msl. Since power peaking operations at Gavins Point are minimal, relatively uniform release rates enhance recreational use of the Missouri River below the project.

X-B Long-Term Regulation Analyses.

10-11. Long-Term Studies. Simulated regulation of the Gavins Point Reservoir, as a component of the main stem reservoir system, through the entire period of available hydrologic record is a technique utilized by the Reservoir Control Center for the development and modification of regulation criteria. Current regulation criteria are the result of many involved and detailed studies, augmented by actual regulation experience. Accomplishment of the long-term studies is described in Chapters V and IX of the Master Manual and in the detailed reports that have been published describing specific studies. From the long-term studies that incorporate current regulation criteria, as well as any anticipated level of water-resource development in the Missouri Basin, long-term examples of Gavins Point regulation are available. From the examples incorporating the present level of water resources development, as well as actual regulating experience to date, conclusions relative to regulation of the Gavins Point project can be established as described in succeeding paragraphs.

10-12. Gavins Point Reservoir Elevations. All long-term regulation studies assume that Gavins Point Reservoir will be regulated at a constant reservoir level. Due to the relatively small amount of storage space involved in pool level variations that actually occur, such a simplification in criteria has little effect upon the overall system analyses. Therefore, the actual historical record serves as the basis for elevation analyses. Since relatively normal operation of the Gavins Point pool began in 1957 through 1977, the reservoir level has varied from a low at elevation 1199.8 ft msl in March 1969 to a high at elevation 1210.7 ft msl in 1960, a variance of almost eleven feet. However, the usual annual variation between minimum and maximum levels has been about 4.5 feet. On the basis of actual operating experience the reservoir level duration curve shown on Plate 33 was developed. This indicates that a level at or above elevation 1204.5 feet msl, the base of the annual flood control and multiple-use zone has been maintained about 97 percent of the time. Drawdown below this level is only in anticipation of large amounts of runoff from the Fort Randall to Gavins Point incremental area. An elevation of 1606.5 ft msl has been exceeded about one-half of the time while elevation 1208 ft msl, the base of the exclusive flood control zone, is exceeded about 15 percent of the time.

10-13. A frequency curve of Gavins Point Reservoir elevations has not been developed. However, from recent operating experience it appears probable that a level somewhat above elevation 1208 ft msl could be expected each year. MRD-RCC Technical Report B-76 on "100 Year Maximum Releases and Pool Elevations" concerns frequencies and concludes that the 100-year Gavins Point Reservoir level is about elevation 1213 feet m.s.l. Plate 34 presents average operating levels of the reservoir on a month-by-month basis, as determined by recent operating experience. There is about a 3.5 ft variation in the average levels, ranging from a low in mid-March to high levels extending through the August-January period.

10-14. Gavins Point Releases. Long-term regulation studies indicate that Gavins Point releases in excess of power plant capacity (ranging up to 35,000 cfs) are not uncommon, as confirmed by actual regulation of the project to date. However, the supplementary releases in excess of the power plant capacity over a long term period are only a small percentage of the releases made through the power plant. Duration curves of mean monthly releases shown on Plate 33 indicate that outflows in excess of the full power plant capacity will be necessary about 20 percent of the time. A median mean-monthly outflow of 27,000 cfs is indicated. The frequency curve of annual maximum releases shown on Plate 35 was developed from long-term regulation study results, augmented by data experienced during actual regulation. The horizontal portion of this curve at 35,000 cfs reflects instantaneous releases at full power plant capacity during all years to supply peak generation requirements. Further particulars regarding development of these frequency curves are given in the above referenced MRD-RCC Technical Report B-76. Average monthly releases based on long-term studies are shown on Plate 34. The seasonal release pattern illustrated by this plate reflects the restricted releases during the winter months and higher releases needed to support Missouri River navigation and evacuate system flood control storage space during much of the remainder of the year.

X-C. Emergency Regulation.

10-15. Spillway Design Flood. The flood developed for the purpose of designing the Gavins Point spillway is of the late spring type and combines runoff resulting from design mountain snowmelt and rainfall in the Missouri River drainage area above Fort Randall Dam with runoff from a maximum possible rainstorm centered between Fort Randall and Gavins Point Dam. Releases from Fort Randall Dam entering Gavins Point Reservoir have a long flat crest in the 200,000 cfs range prior to the incremental area rainstorm. As a result of the rainstorm the total inflows to Gavins Point crest sharply at 647,000 cfs. In the spillway design studies the Gavins Point pool was maintained at elevation 1210 ft msl until inflows exceeded the spillway capacity of about 350,000 cfs at this elevation. Subsequent free outflow over the spillway resulted in a crest reservoir level at elevation 1221.4 ft msl and a maximum discharge over the spillway of 584,000 cfs. The power plant was assumed to be inoperable at the time inflows exceeded the spillway capacity.

10-16. Routing of the spillway design flood by the developed emergency procedures entailed maintaining Gavins Point Reservoir at elevation 1212 feet m.s.l. by gradually opening the gates to release inflows until inflows exceeded the spillway capacity of about 380,000 cfs at this elevation. Again the power plant was assumed to be inoperable and the spillway gates were fully opened as the reservoir level rose above elevation 1212. The resulting crest reservoir level was slightly above elevation 1421.4, and a crest outflow of 585,000 cfs was computed. This was essentially identical to the outflow hydrograph and crest reservoir level of the design studies. Since the emergency regulation outflow hydrograph and crest reservoir elevation are so similar to the design conditions, hydrographs have not been included with this manual.

10-17. Reservoir Design Flood. The flood used for developing the flood control storage allocations in the Gavins Point Reservoir was of the rainfall type of an approximate 100-year frequency. Runoff from the rainstorm centered between Fort Randall and Gavins Point Dams was combined with assumed releases from Fort Randall to provide the total Gavins Point inflow. Routing procedures in design studies consisted of releasing inflows up to 50,000 cfs, then maintaining a 50,000 cfs release rate through the peak inflows and extending until flood control storage space had been completely evacuated. Design regulation assumed an initial pool at elevation 1204.5 feet m.s.l., the base of flood control. With this regulation, the reservoir crested at elevation 1210 feet m.s.l., the selected top of exclusive flood control storage space. The crest inflow of about 145,000 cfs was reduced to the maximum release rate of 50,000 cfs.

10-18. Hydrographs pertaining to routing of this reservoir design flood by the developed emergency procedures are shown on Plate 36. In this routing it was assumed that the initial reservoir would be at elevation 1205.5, a level that is considered more likely to occur than elevation 1204.5, the base of the annual flood control and multiple use space. The 30,000 cfs release rate assumed prior to the flood was continued until the combination of inflows and reservoir levels were such that an increase in release rate was indicated by the emergency regulation curves included with Exhibit A. Continuing use of these curves resulted in a crest outflow of 75,000 cfs some 8 to 14 hours after the crest inflow occurred, after which outflows were reduced to 65,000 cfs. The reservoir crested at elevation 1210.2 about 30 hours after the crest inflow occurred. Since the release rate at the time of the reservoir crest was 65,000 cfs, this rate was maintained until the exclusive flood control storage space was entirely evacuated, after which the release rate of 30,000 cfs prevailing prior to the flood was resumed.

10-19. Although the emergency procedures resulted in higher crest outflows and reservoir levels than the design studies, it is not believed that the assumptions made in the design studies are entirely realistic for actual operation of the project. The emergency crest outflow of 75,000 cfs is within the downstream channel capacity prior to significant damage while the crest elevation does not significantly encroach on the surcharge storage zone of the project. If emergency loss-of-communications conditions were not occurring and flooding was present below Gavins Point Dam, it is quite possible that inflows of the magnitude assumed for the reservoir design flood would result in use of a greater amount of induced surcharge storage space than shown on Plate 36. If outflows had been limited to 50,000 cfs following crest inflows, as assumed in the design studies, the reservoir would have peaked at elevation 1211.4 feet m.s.l.

As evidenced by the above discussion of the spillway design flood routing, where an elevation of 1212 feet m.s.l. was maintained prior to crest inflows, such an operation would not compromise the integrity of the project.

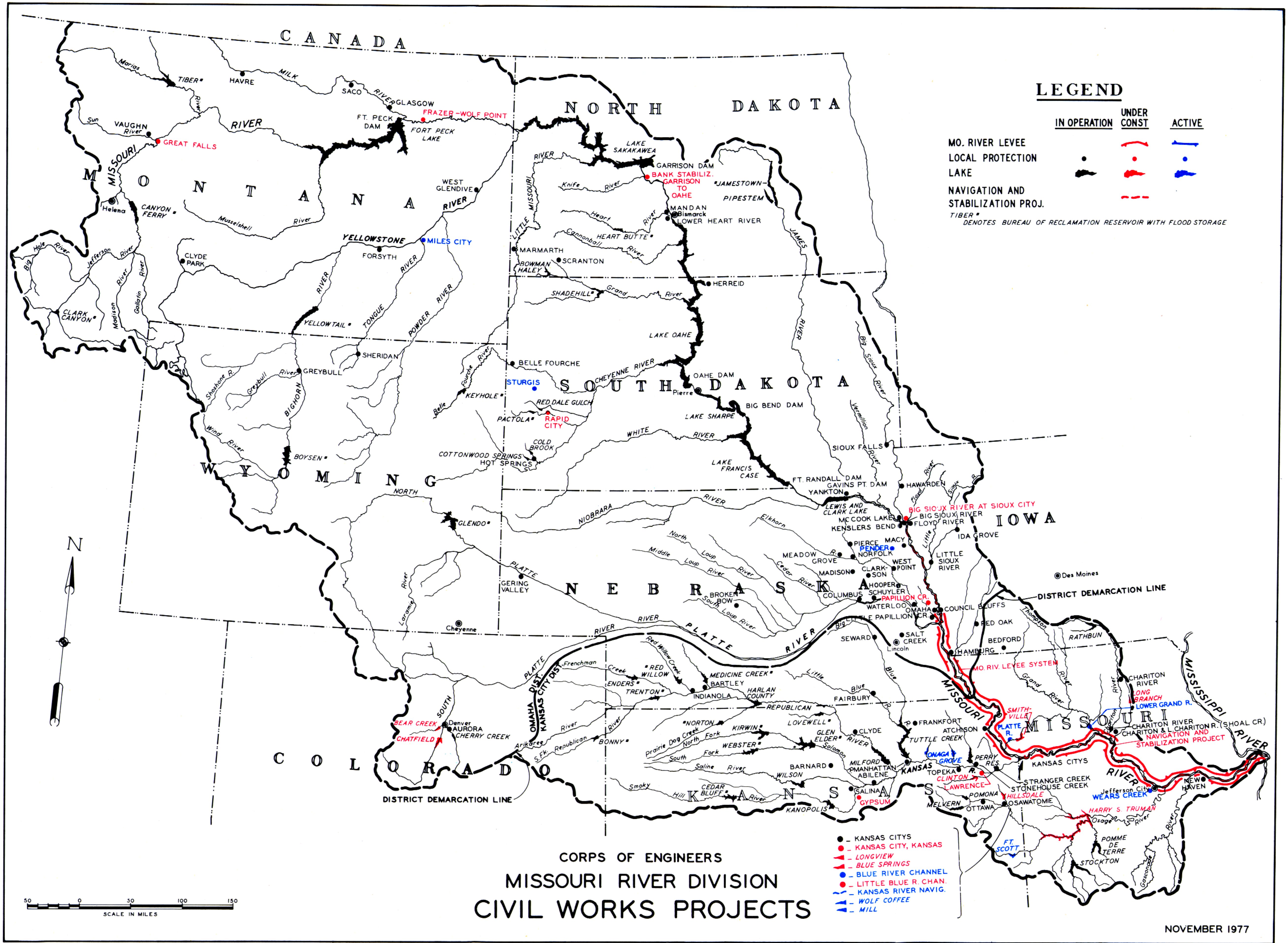
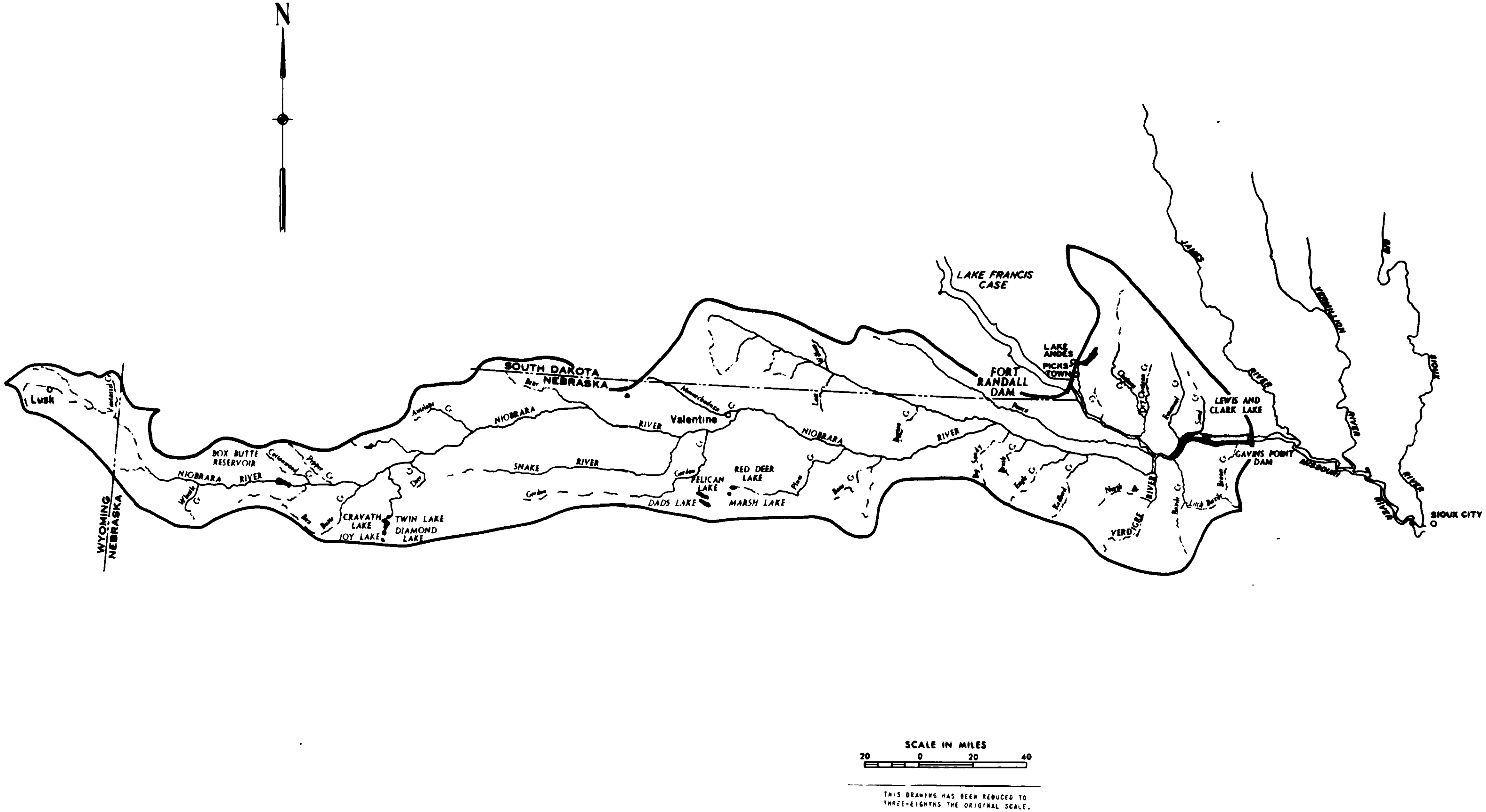
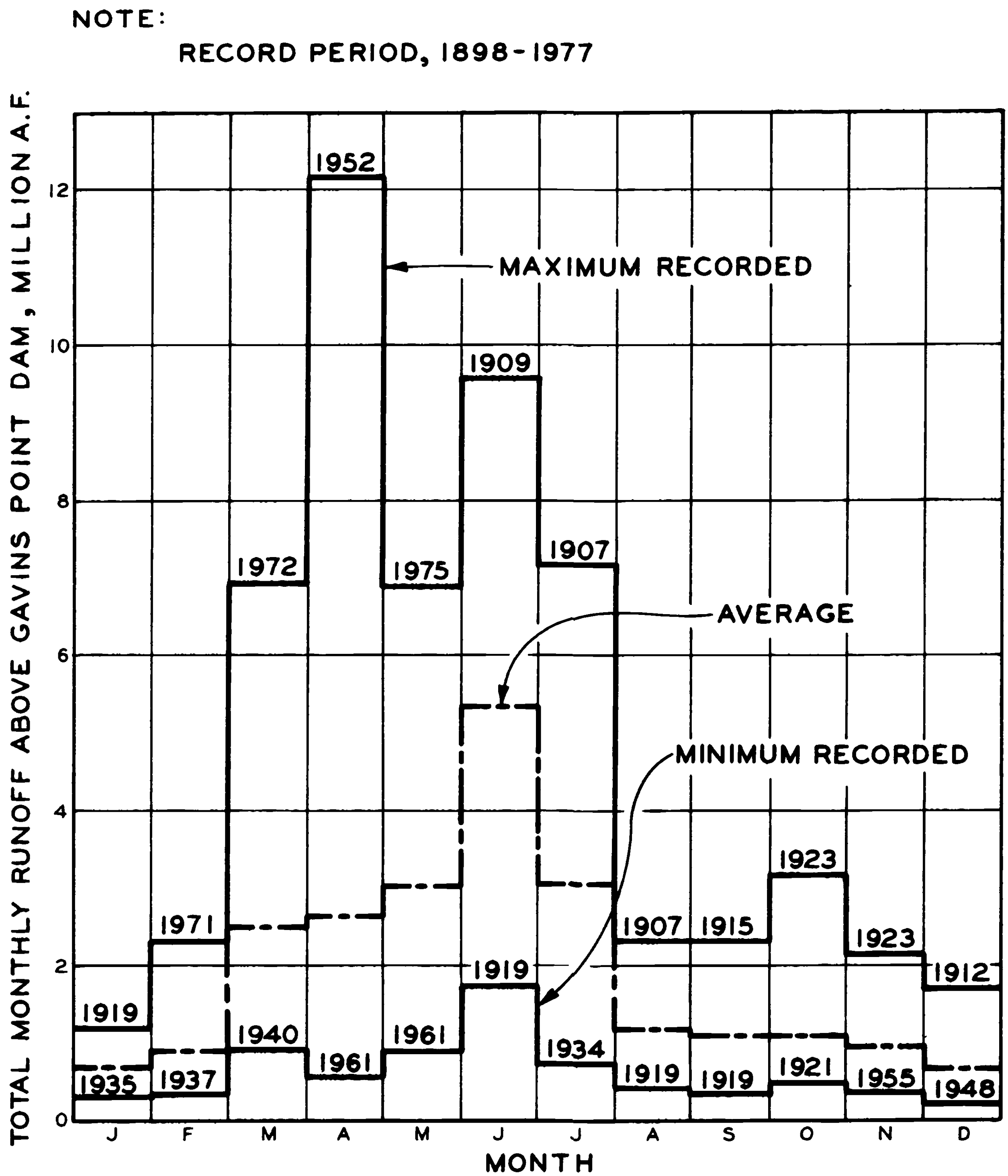

CORPS OF ENGINEERS
MISSOURI RIVER DIVISION
CIVIL WORKS PROJECTS
NOVEMBER 1977
LEGEND
IN OPERATION
UNDER CONST
ACTIVE
MO. RIVER LEVEE
LOCAL PROTECTION
LAKE
NAVIGATION AND STABILIZATION PROJ.
TIBER* DENOTES BUREAU OF RECLAMATION RESERVOIR WITH FLOOD STORAGE
CANADA
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
IOWA
COLORADO
KANSAS
MISSOURI
DISTRICT DEMARCATION LINE
OMAHA DIST.
KANSAS CITY DIST.
MISSISSIPPI RIVER
MISSOURI RIVER
YELLOWSTONE RIVER
PLATTE RIVER
GREAT FALLS
FRAZER - WOLF POINT
FT. PECK DAM
FORT PECK LAKE
MILES CITY
GARRISON DAM
LAKE SAKAKAWEA
BANK STABILIZ. GARRISON TO OAHE
LAKE OAHE
OAHE DAM
BIG BEND DAM
LAKE SHARPE
LAKE FRANCIS CASE
FT. RANDALL DAM
GAVINS PT. DAM
LEWIS AND CLARK LAKE
BIG SIOUX RIVER AT SIOUX CITY
STURGIS
RAPID CITY
PENDER
PAPILLION CR.
MO. RIV. LEVEE SYSTEM
SMITHVILLE
PLATTE R.
LONG BRANCH
LOWER GRAND R.
CHARITON & L. CHARITON R. (SHOAL CR.)
NAVIGATION AND STABILIZATION PROJECT
HARRY S. TRUMAN
WEARS CREEK
ONAGA GROVE
CLINTON
LAWRENCE
HILLSDALE
FT. SCOTT
GYPSUM
BEAR CREEK
CHATFIELD
KANSAS CITYS
KANSAS CITY, KANSAS
LONGVIEW
BLUE SPRINGS
BLUE RIVER CHANNEL
LITTLE BLUE R. CHAN.
KANSAS RIVER NAVIG.
WOLF COFFEE
MILL
SCALE IN MILES
50 0 50 100 150

PLATE 1



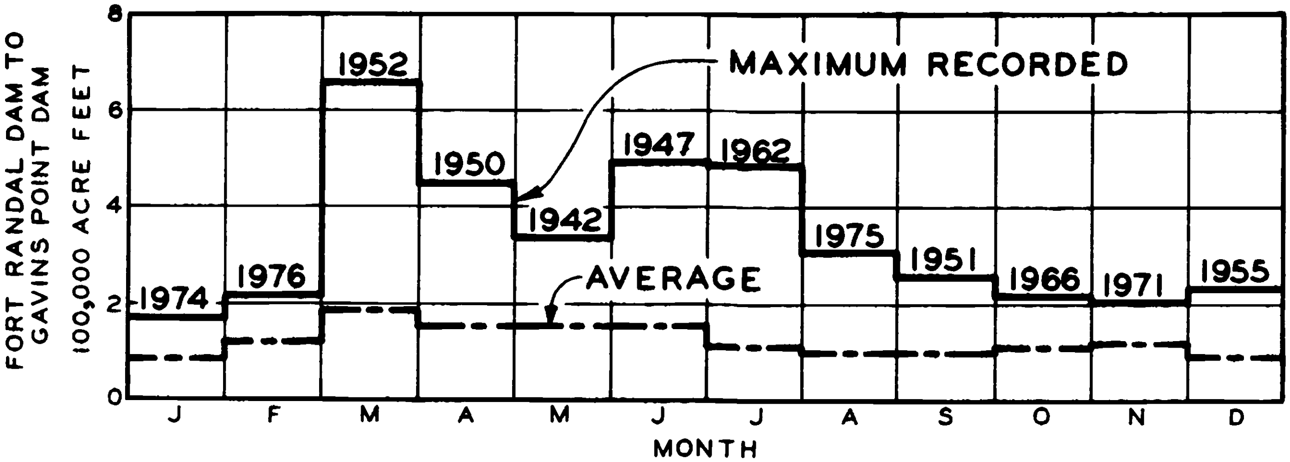
INCREMENTAL DRAINAGE AREA BETWEEN FORT RANDALL DAM AND GAVINS POINT DAM

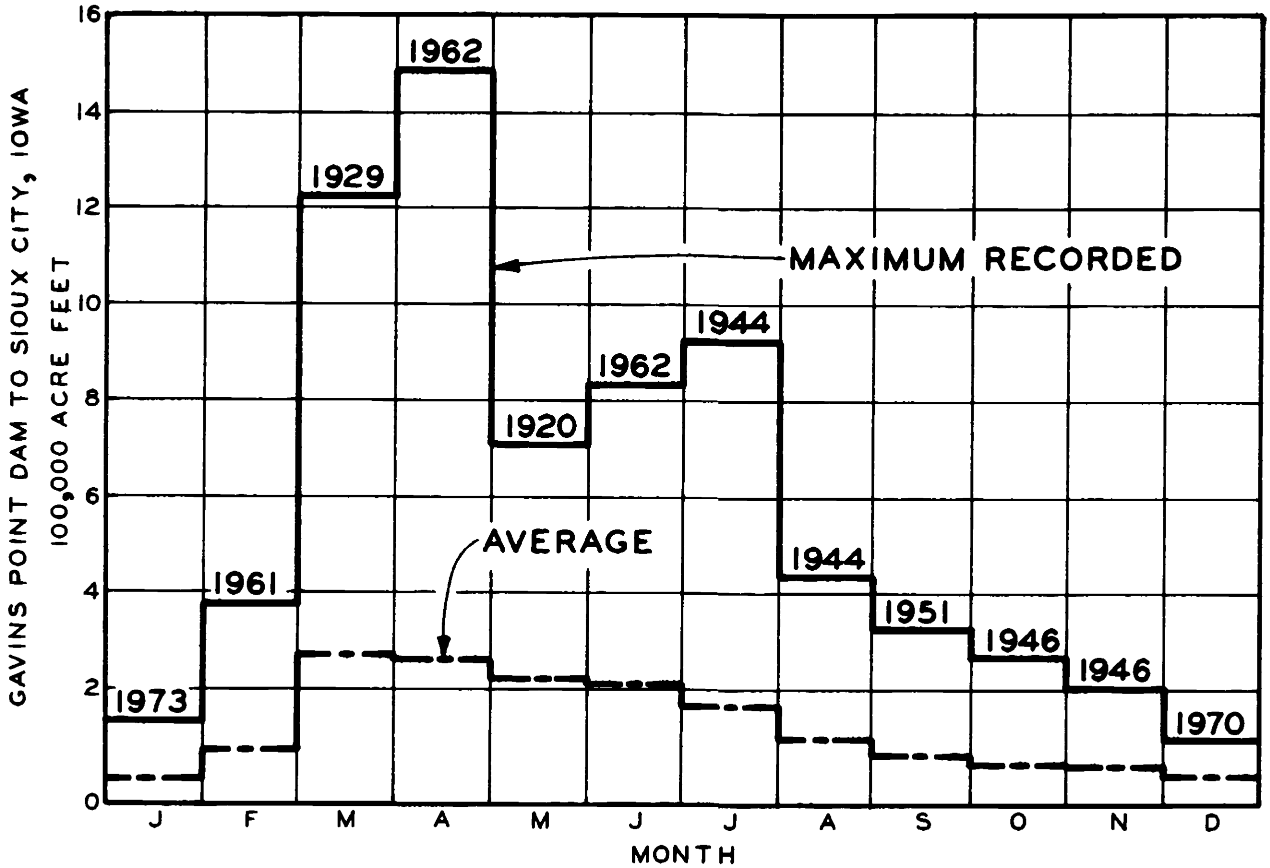
PLATE 2



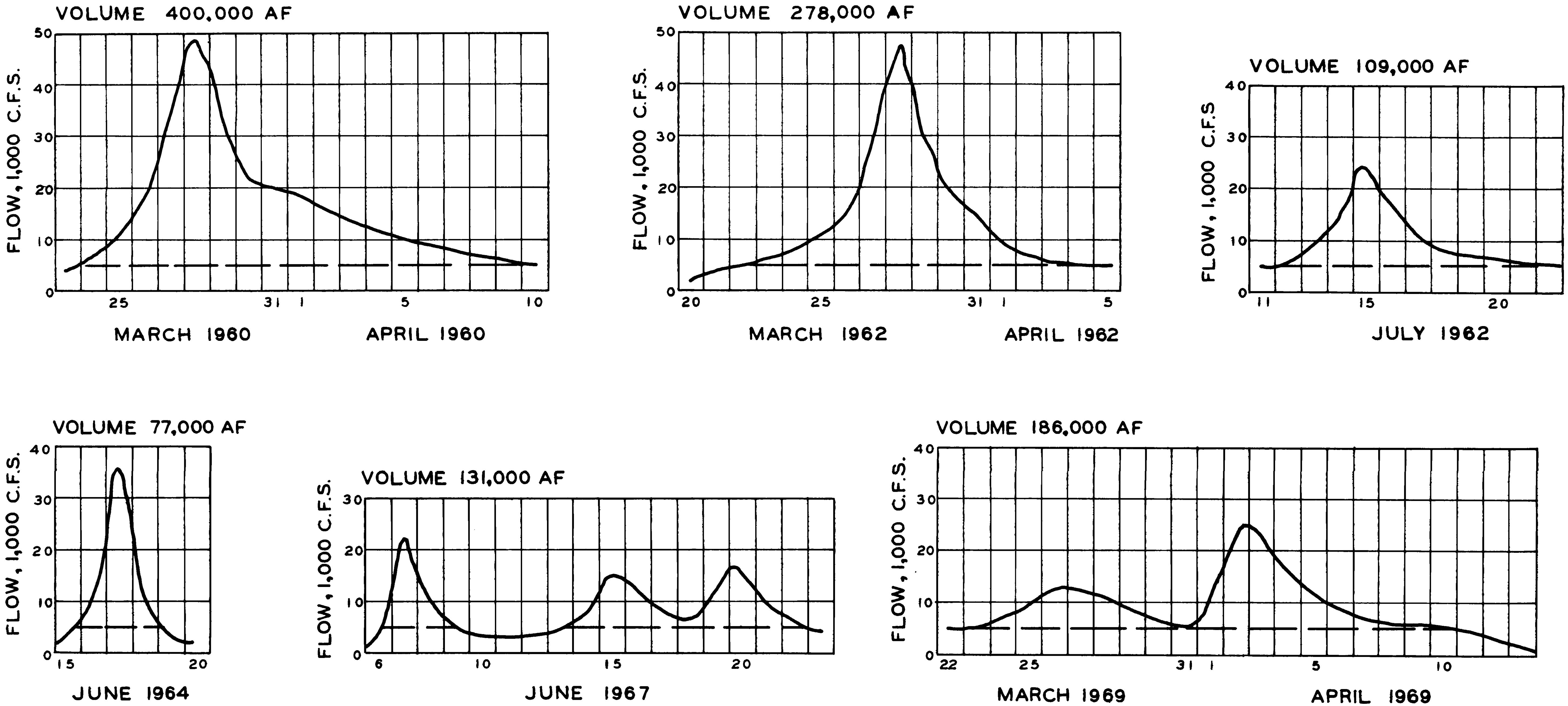
UNREGULATED
MONTHLY RUNOFF DISTRIBUTION
MISSOURI RIVER
ABOVE GAVINS POINT DAM

PLATE 3





MONTHLY RUNOFF DISTRIBUTION
INCREMENTAL DRAINAGE AREAS
MISSOURI RIVER
FORT RANDALL DAM TO GAVINS POINT DAM
AND
GAVINS POINT DAM TO SIOUX CITY, IOWA

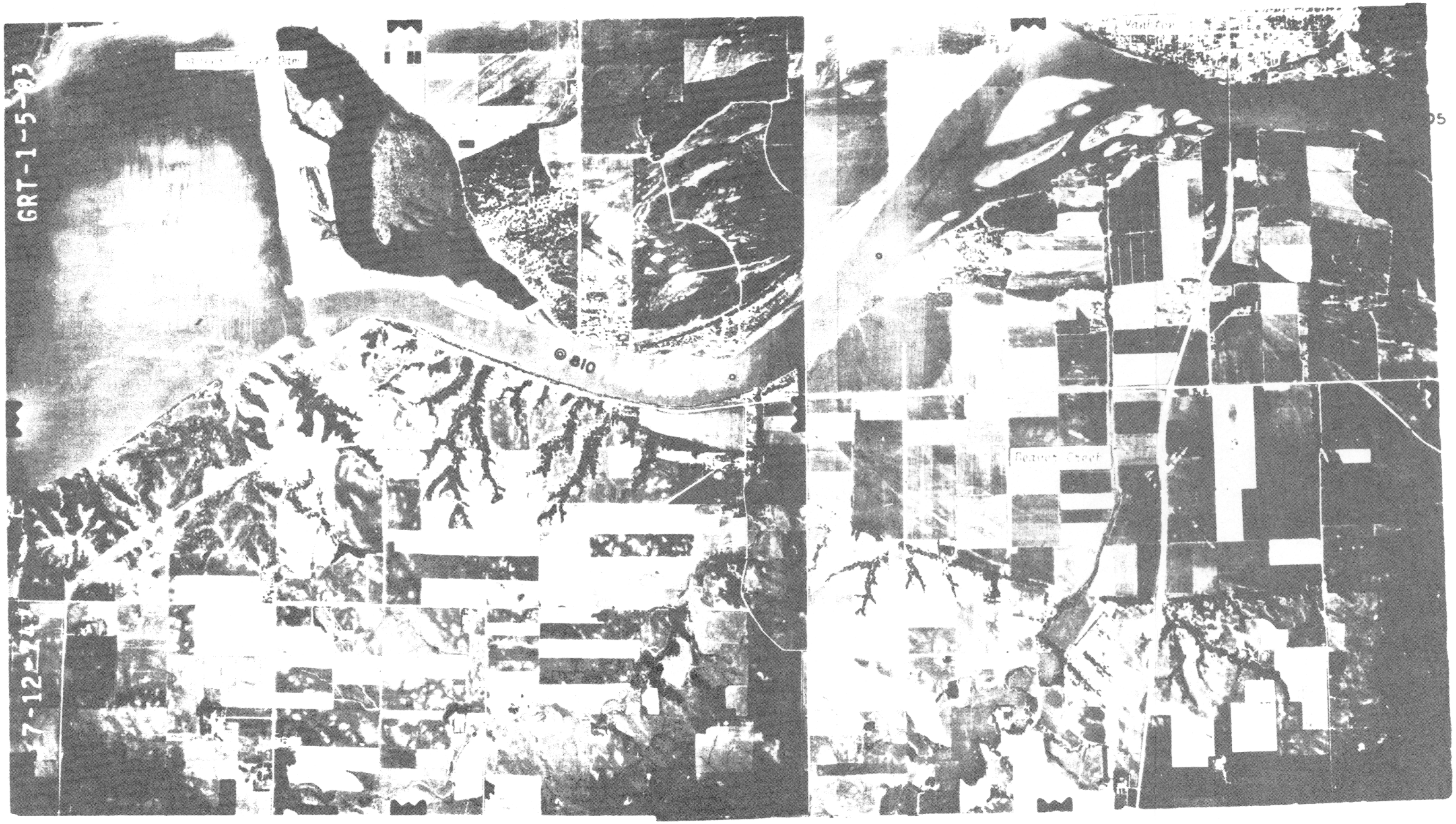


INCREMENTAL INFLOWS
FORT RANDALL DAM TO
GAVINS POINT DAM

PLATE 5

NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.



AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 805 TO 811

PLATE 6

NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.

N

SCALE: 1 INCH = 2000 FEET

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 799 TO 805

NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 795 TO 799

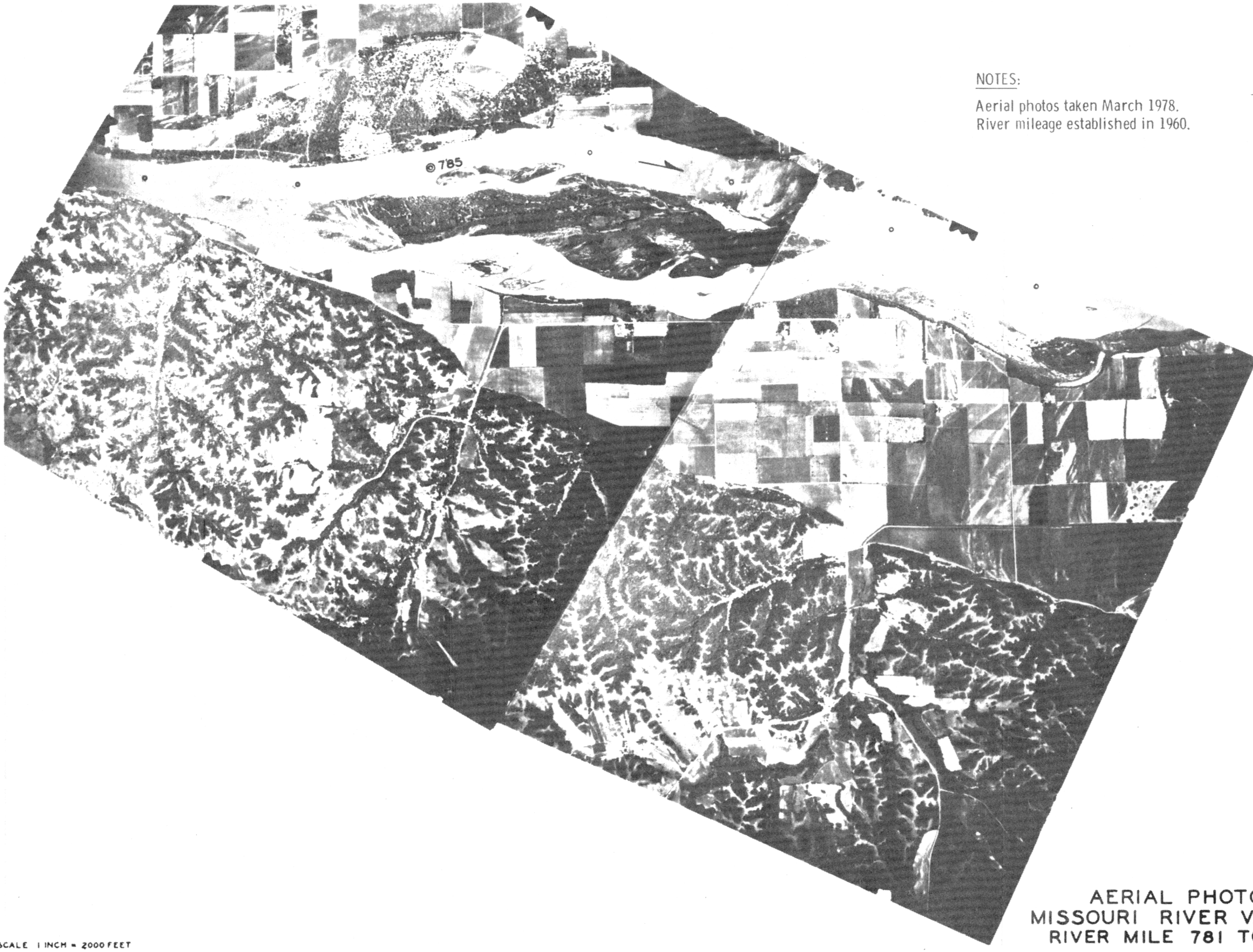
N

NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 787 TO 794

PLATE 9



N

NOTES:

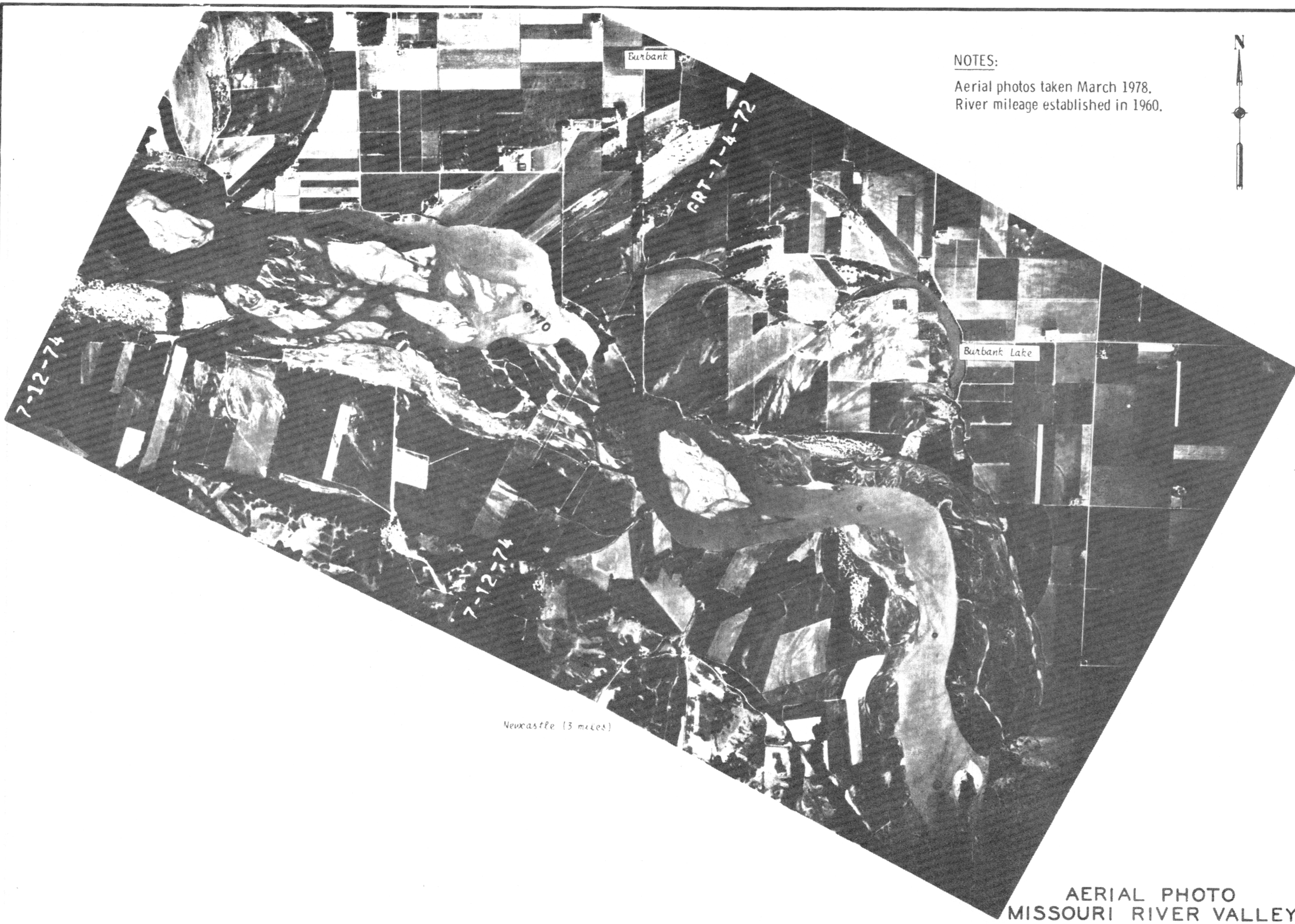
Aerial photos taken March 1978.
River mileage established in 1960.

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 781 TO 787

SCALE 1 INCH = 2000 FEET

PLATE 10

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 772 TO 781



Newcastle (3 miles)

N

NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.

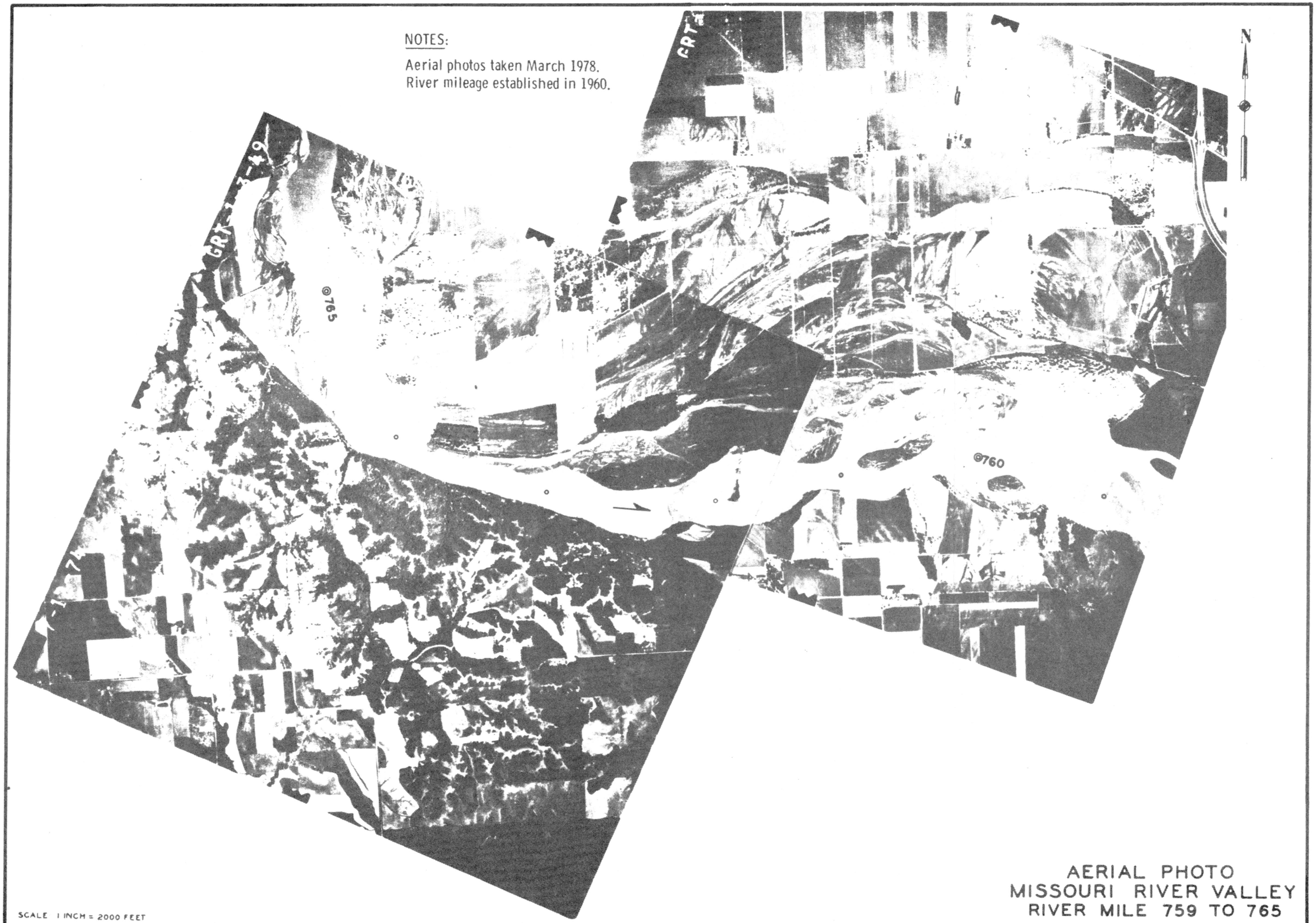
AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 765 TO 772

SCALE: 1 INCH = 2000 FEET

PLATE 12

NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.



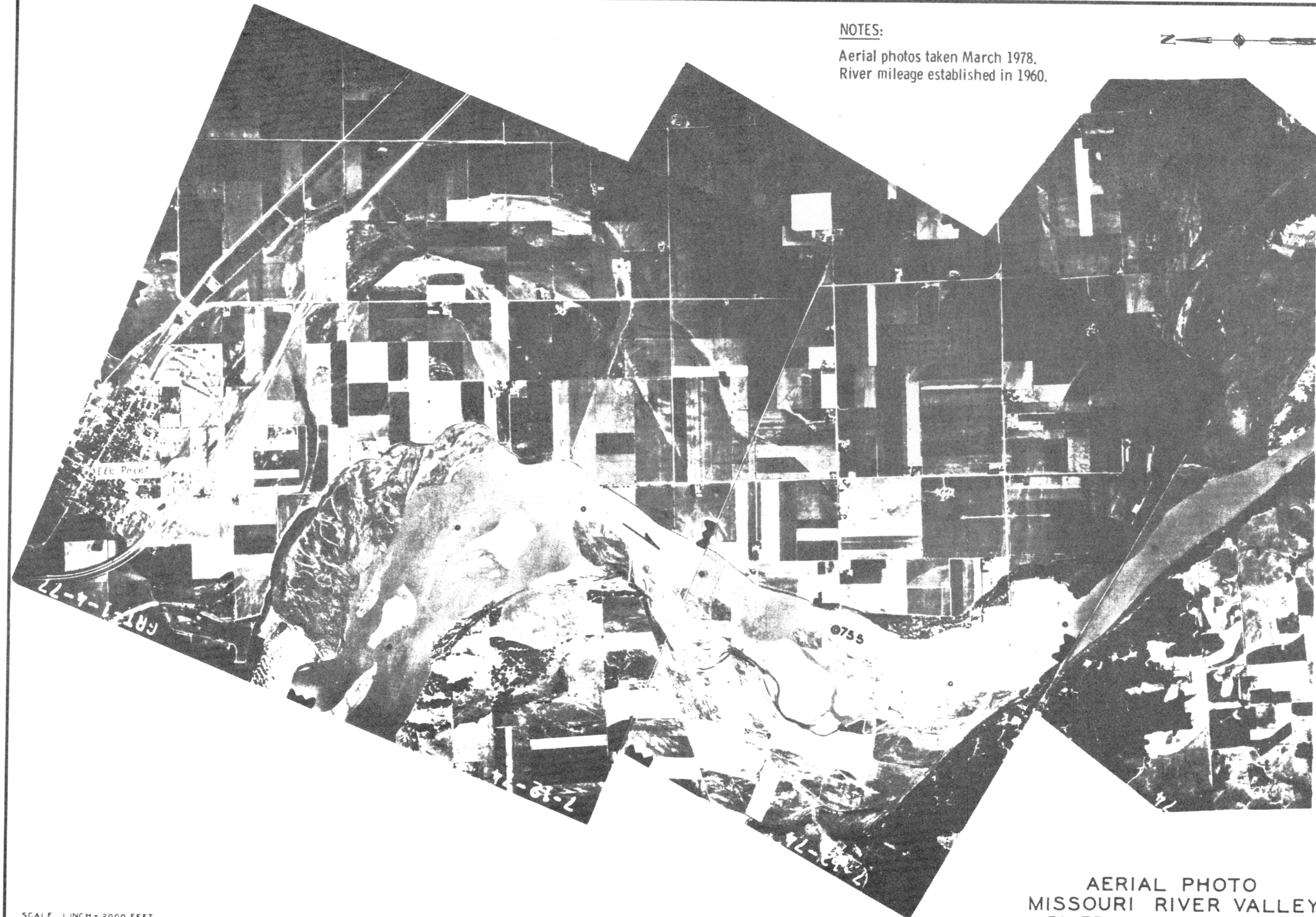
SCALE 1 INCH = 2000 FEET

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 759 TO 765

PLATE 13

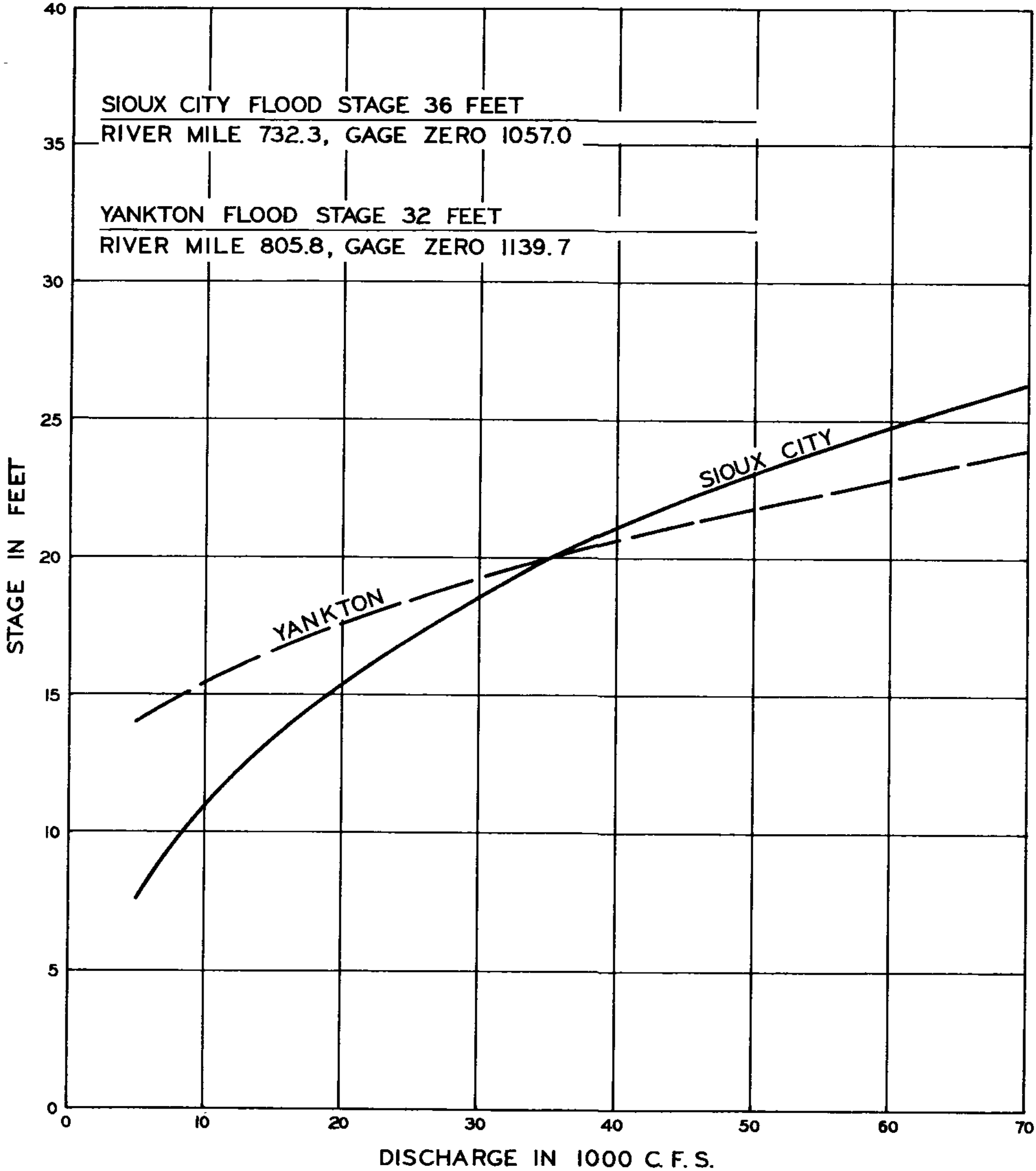
NOTES:

Aerial photos taken March 1978.
River mileage established in 1960.



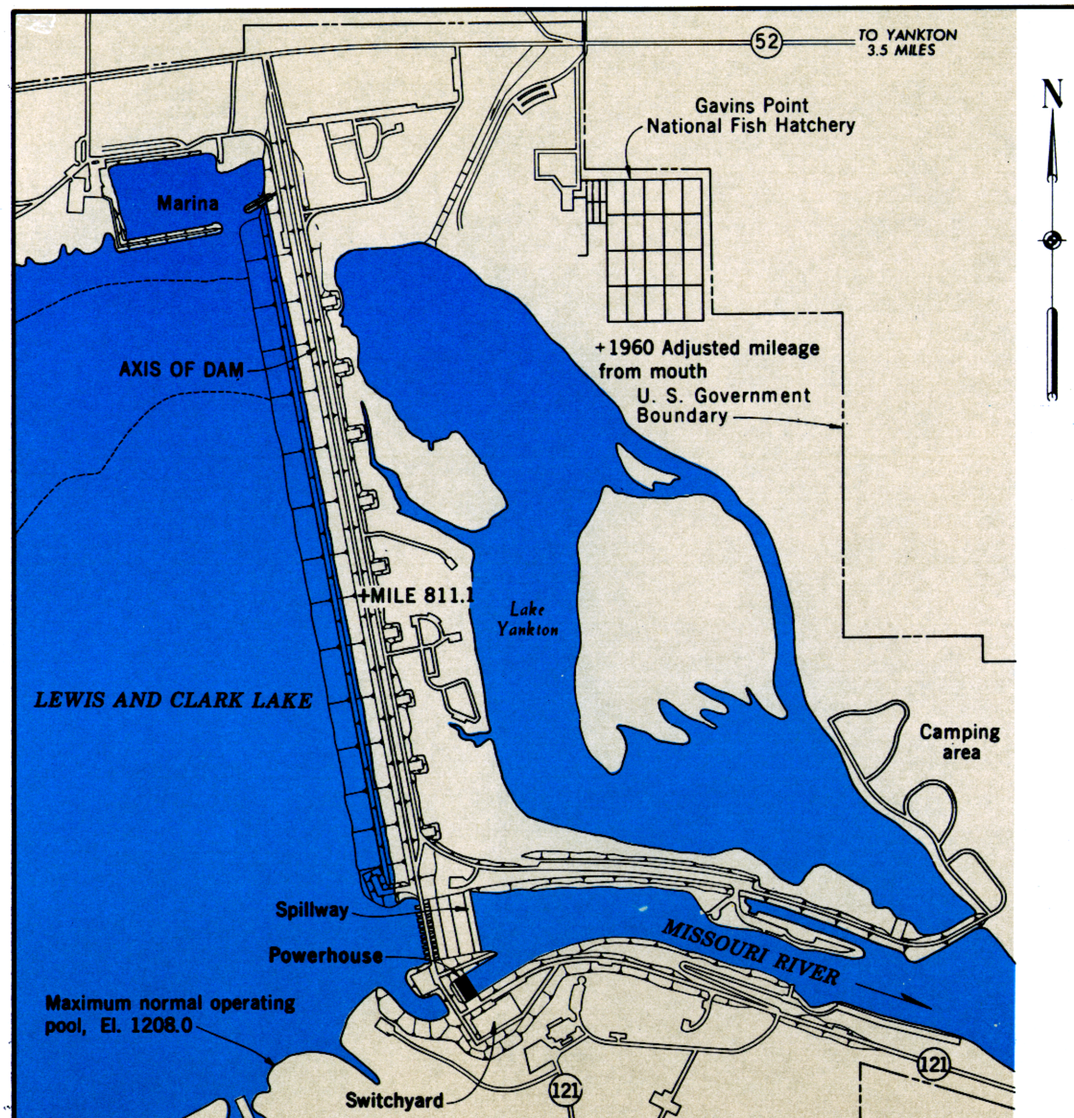
SCALE 1 INCH = 2000 FEET

AERIAL PHOTO
MISSOURI RIVER VALLEY
RIVER MILE 752 TO 759

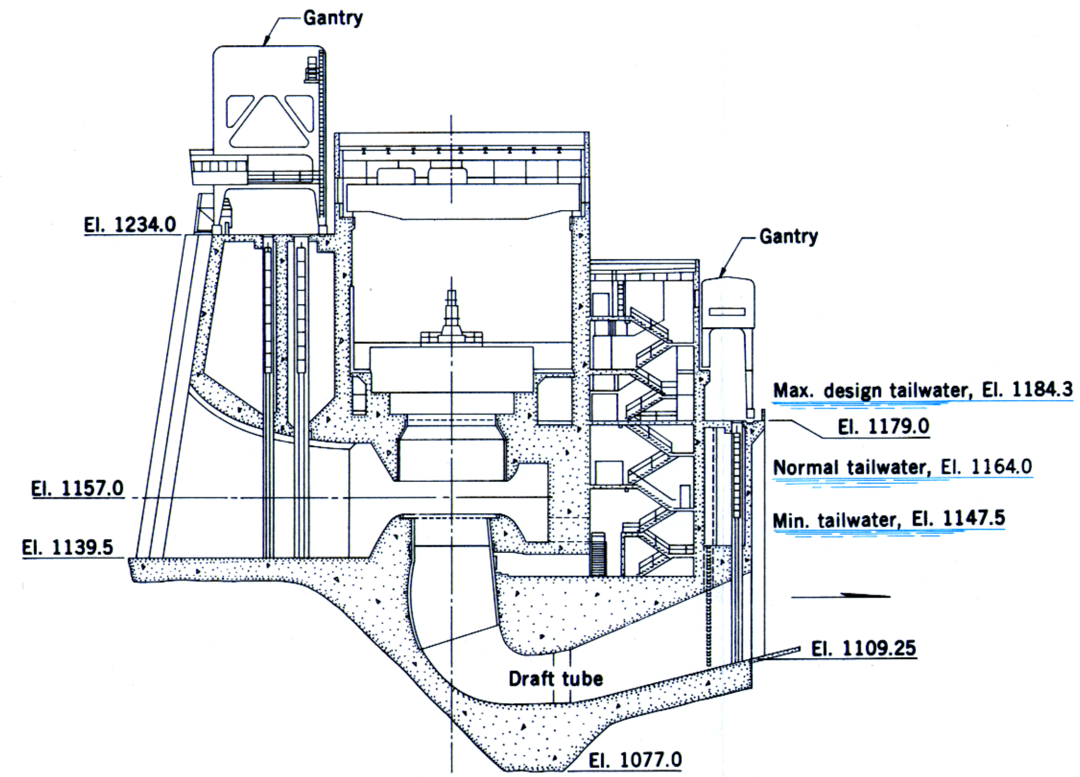


STAGE – DISCHARGE RELATIONS
MISSOURI RIVER
AT YANKTON, SOUTH DAKOTA
AND AT SIOUX CITY, IOWA

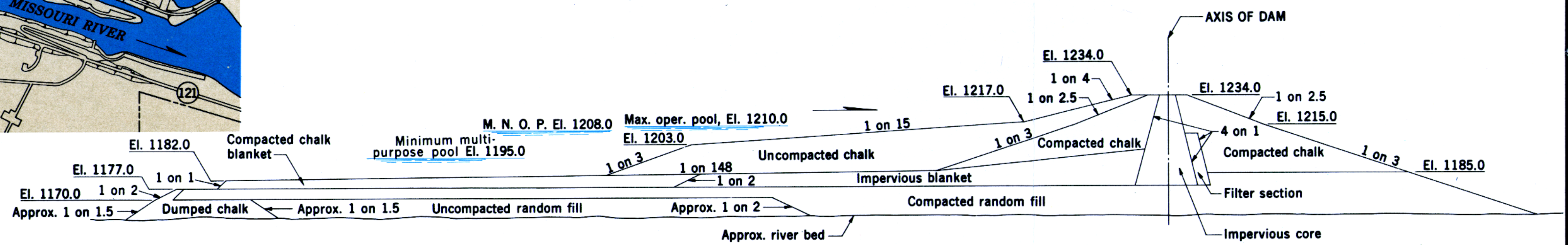
PLATE 15



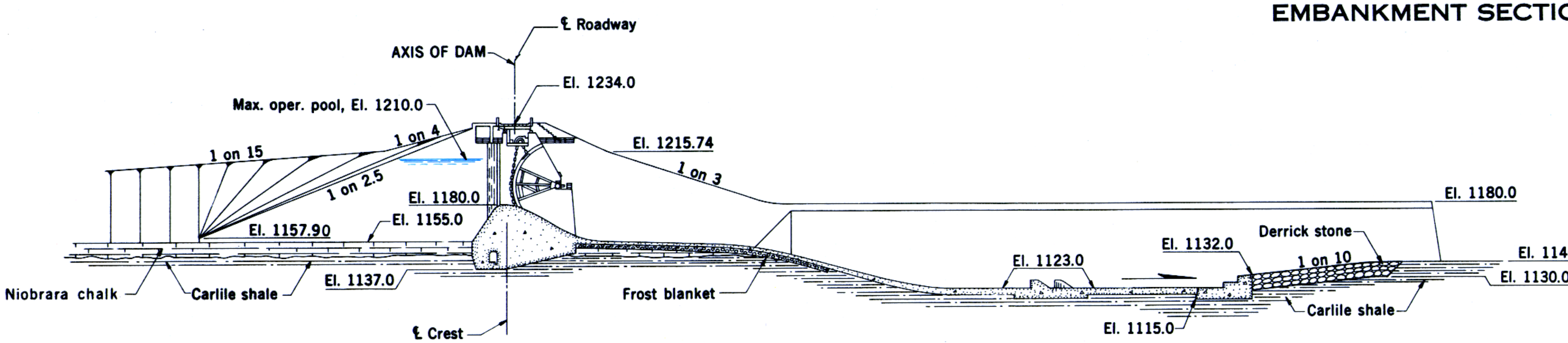
PLAN



POWERHOUSE SECTION

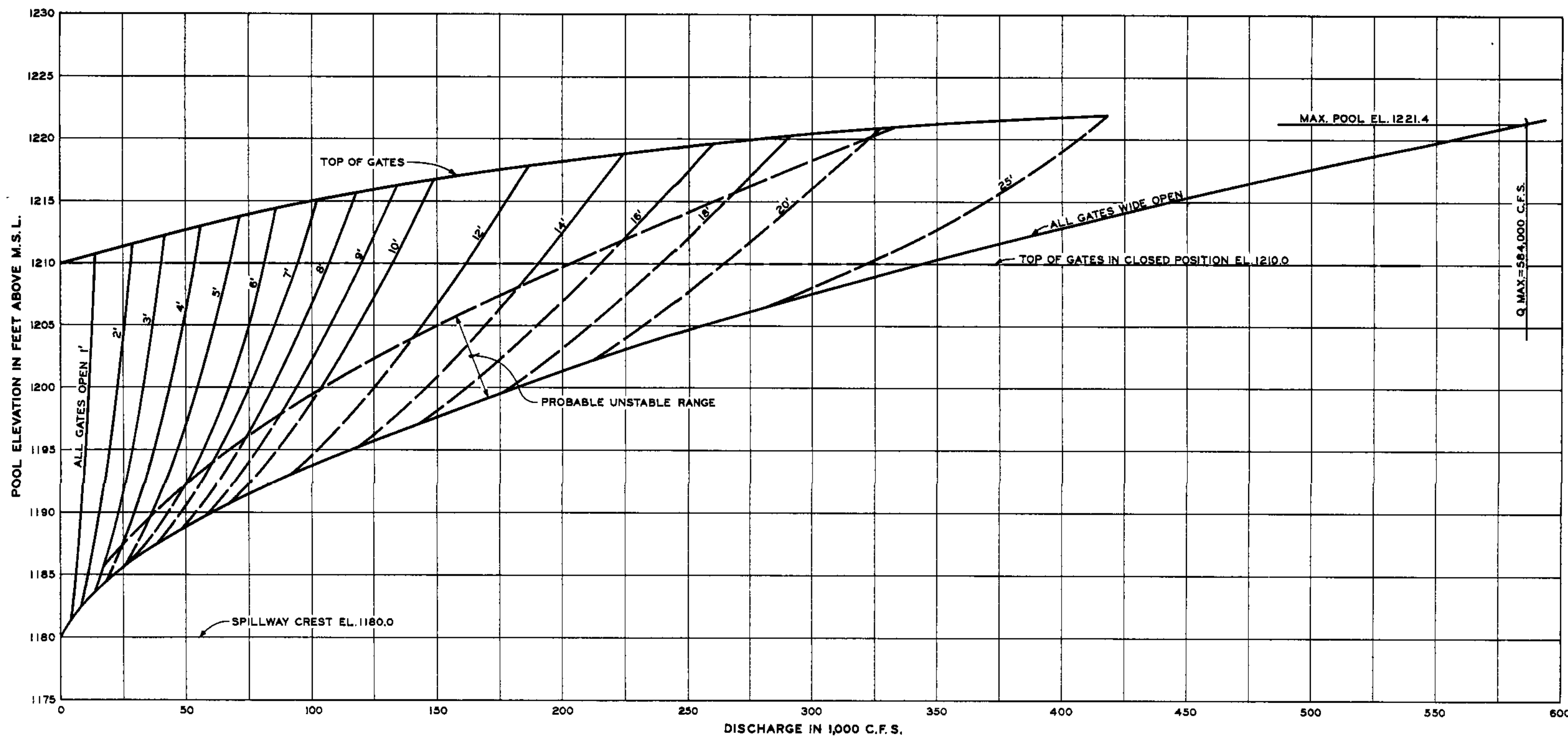


EMBANKMENT SECTION



SPILLWAY PROFILE

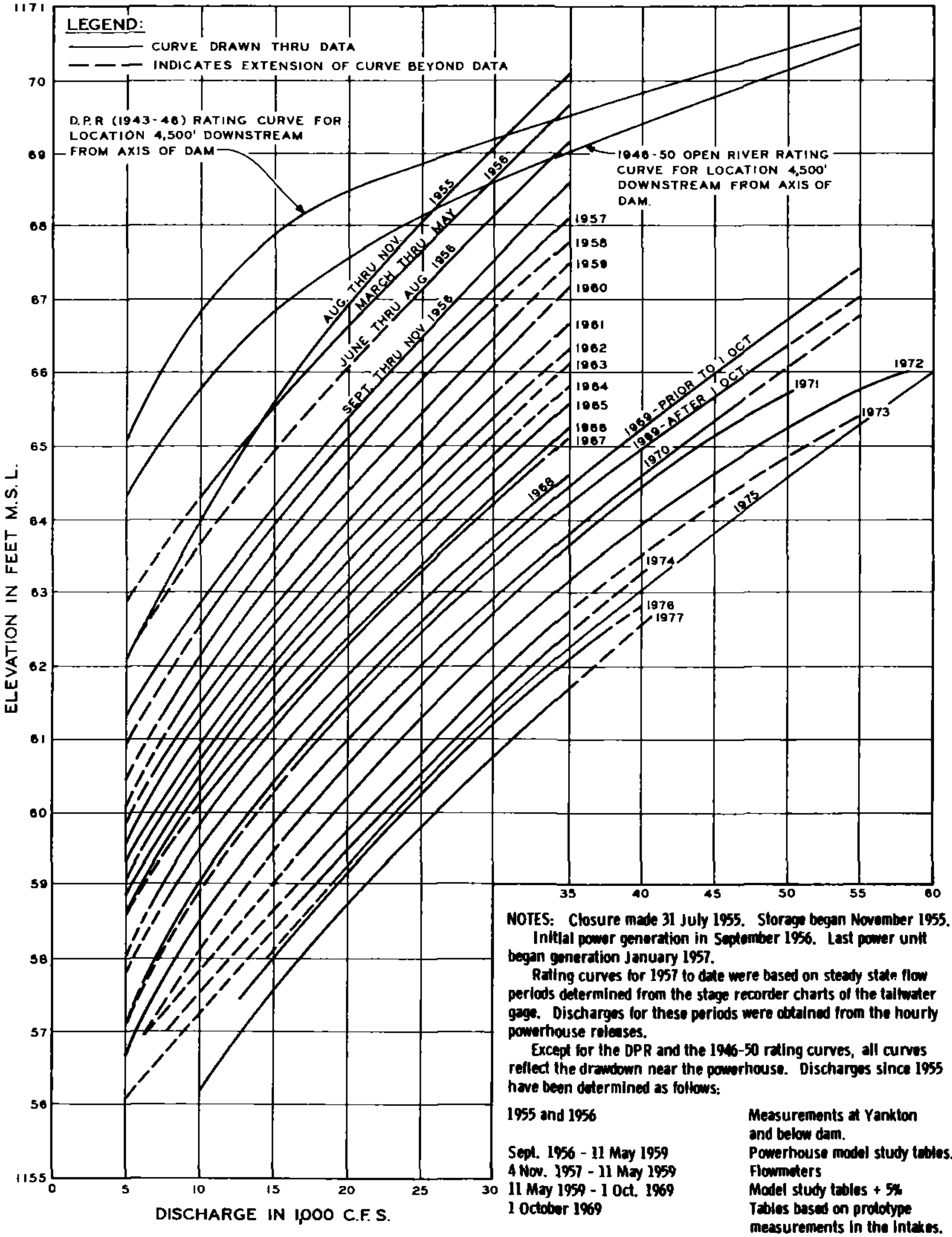
FLOOD CONTROL PROJECT
GAVINS POINT DAM
LEWIS AND CLARK LAKE
MISSOURI RIVER BASIN
NEBRASKA AND SOUTH DAKOTA
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
30 SEPT 1977



NOTES:

1. GATE OPENING DIAL INDICATES THE GATE TRAVEL IN FEET ALONG CIRCULAR ARC.
2. 14 GATES SYMMETRICALLY OPEN.

SPILLWAY RATING CURVES
GAVINS POINT PROJECT



NOTES: Closure made 31 July 1955. Storage began November 1955.
Initial power generation in September 1956. Last power unit began generation January 1957.

Rating curves for 1957 to date were based on steady state flow periods determined from the stage recorder charts of the tailwater gage. Discharges for these periods were obtained from the hourly powerhouse releases.

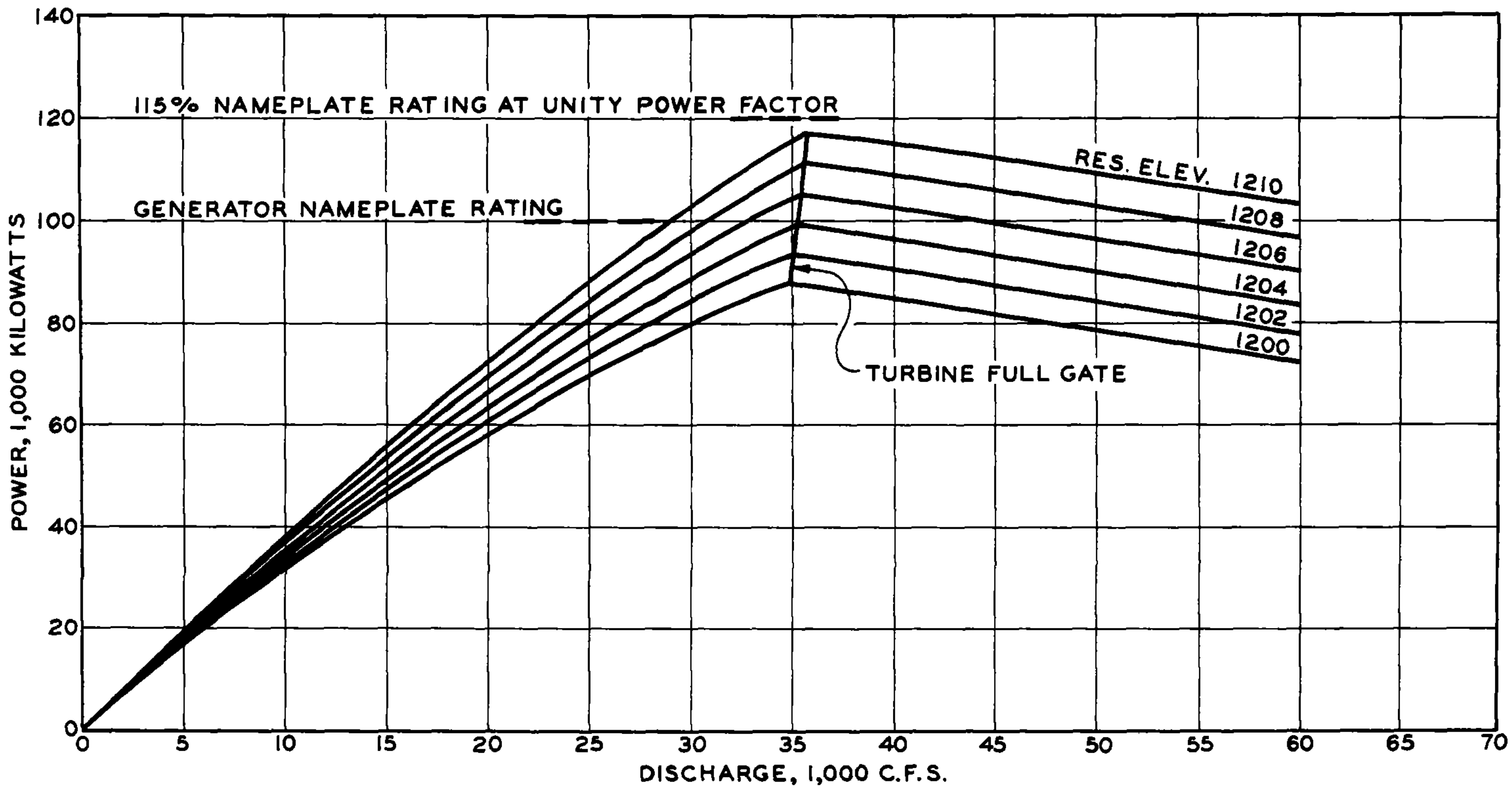
Except for the DPR and the 1946-50 rating curves, all curves reflect the drawdown near the powerhouse. Discharges since 1955 have been determined as follows:

1955 and 1956	Measurements at Yankton and below dam.
Sept. 1956 - 11 May 1959	Powerhouse model study tables.
4 Nov. 1957 - 11 May 1959	Flowmeters
11 May 1959 - 1 Oct. 1969	Model study tables + 5%
1 October 1969	Tables based on prototype measurements in the intakes.

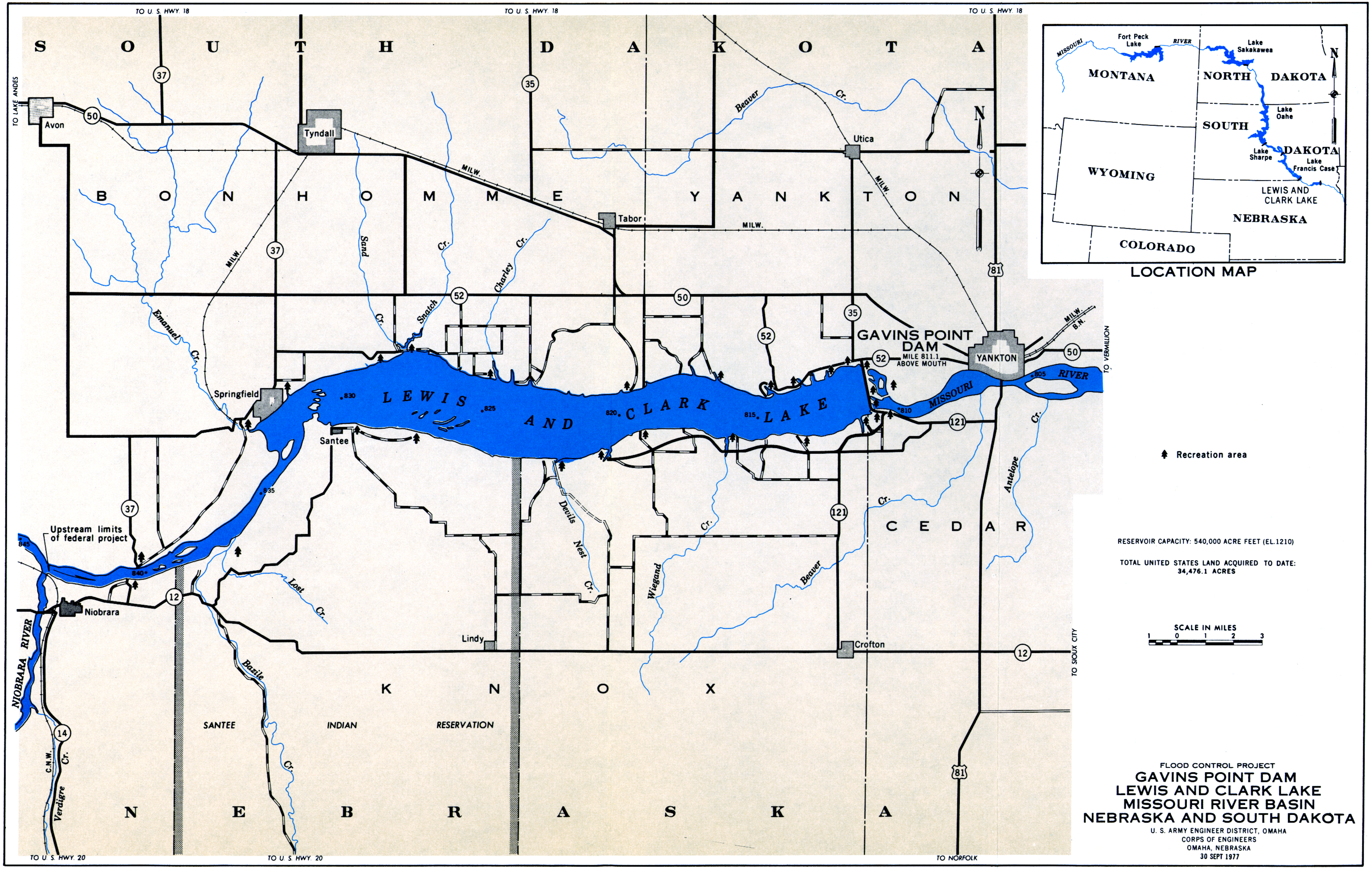
Tailwater gage installed July 1955 over conventional well in the right bank side of powerhouse with 2 intakes throught the downstream side of powerhouse.

Unless otherwise noted, these curves reflect open river conditions for the indicated calendar year.

TAILWATER RATING CURVES
GAVINS POINT PROJECT



POWER PLANT CHARACTERISTICS
GAVINS POINT PROJECT


FLOOD CONTROL PROJECT
GAVINS POINT DAM
LEWIS AND CLARK LAKE
MISSOURI RIVER BASIN
NEBRASKA AND SOUTH DAKOTA
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
30 SEPT 1977
LOCATION MAP
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
COLORADO
Fort Peck Lake
Lake Sakakawea
Lake Oahe
Lake Sharpe
Lake Francis Case
LEWIS AND CLARK LAKE
MISSOURI RIVER
Recreation area
RESERVOIR CAPACITY: 540,000 ACRE FEET (EL.1210)
TOTAL UNITED STATES LAND ACQUIRED TO DATE: 34,476.1 ACRES
SCALE IN MILES
1 0 1 2 3
SOUTH DAKOTA
BON HOMME
YANKTON
CEDAR
KNOX
NEBRASKA
SANTEE INDIAN RESERVATION
LEWIS AND CLARK LAKE
GAVINS POINT DAM
MILE 811.1 ABOVE MOUTH
MISSOURI RIVER
NIOBRARA RIVER
Upstream limits of federal project
Avon
Tyndall
Tabor
Utica
YANKTON
Springfield
Santee
Niobrara
Lindy
Crofton
TO U. S. HWY. 18
TO U. S. HWY. 20
TO LAKE ANDES
TO VERMILLION
TO SIOUX CITY
TO NORFOLK
Emanuel Cr.
Sand Cr.
Snatch Cr.
Charley Cr.
Beaver Cr.
Lost Cr.
Bazile Cr.
Devils Nest Cr.
Wiegand Cr.
Antelope Cr.
Verdigre Cr.
MILW.
B.N.
C.N.W.

GAVINS POINT PROJECT

AREA IN ACRES

(1979 SURVEY)

EFFECTIVE 1 MAY 1981

ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	133	260	297	290	329	426	581
1170	727	813	939	1182	1540	1930	2253	2578	2987	3479
1180	3976	4406	4866	5434	6126	6827	7447	8093	8868	9772
1190	10727	11626	12592	13417	14370	15321	16240	17176	18176	19230
1200	20313	21348	22391	23490	24645	25797	26898	28029	29254	30575
1210	31961	33333	34647	35907	37114	38302	39516	40736	41931	43102
1220	44257	45419	46593	47774	48964	50158	51349	52537	53726	54914
1230	56103									

GAVINS POINT PROJECT

CAPACITY IN ACRE-FEET

(1979 SURVEY)

EFFECTIVE 1 MAY 1981

ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	56	266	576	861	1156	1520	2009
1170	2683	3463	4310	5342	6674	8423	10534	12929	15691	18903
1180	22650	26858	31463	36587	42341	48839	55995	63733	72182	81470
1190	91726	102924	114978	127928	141612	156668	172455	189146	206808	225500
1200	245285	266126	287982	310908	334962	360149	386556	413996	442614	472505
1210	503764	536427	570431	605721	642245	679949	718849	758961	800321	842844
1220	886525	931359	977363	1024545	1072912	1122473	1173228	1225171	1278303	1332623
1230	1388132									

GAVINS POINT
AREA AND CAPACITY DATA

Effective 1 Jan 1978

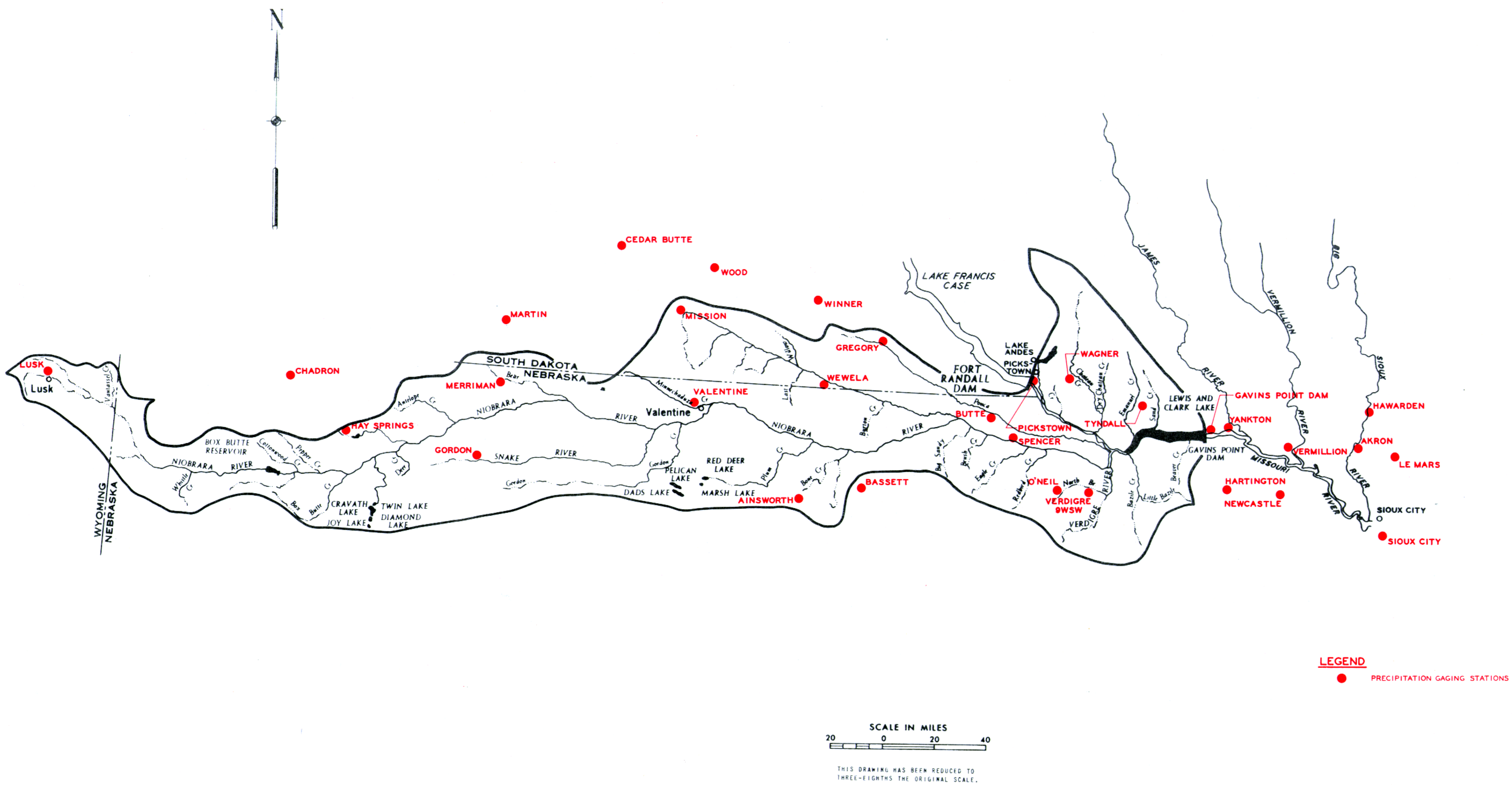
GAVINS POINT PROJECT
AREA IN ACRES
(1975 SURVEY)

ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	74	148	221	295	350	384	448	571	754
1170	933	1059	1216	1472	1828	2207	2524	2850	3260	3753
1180	4252	4686	5147	5717	6396	7091	7712	8353	9110	9982
1190	10889	11737	12578	13485	14457	15429	16346	17290	18334	19478
1200	20666	21817	22942	24079	25229	26367	27482	28620	29815	31066
1210	32356	33638	34885	36101	37285	38458	39646	40838	42015	43177
1220	44331	45488	46652	47822	48996	50172	51347	52520	53692	54866
1230	56040									

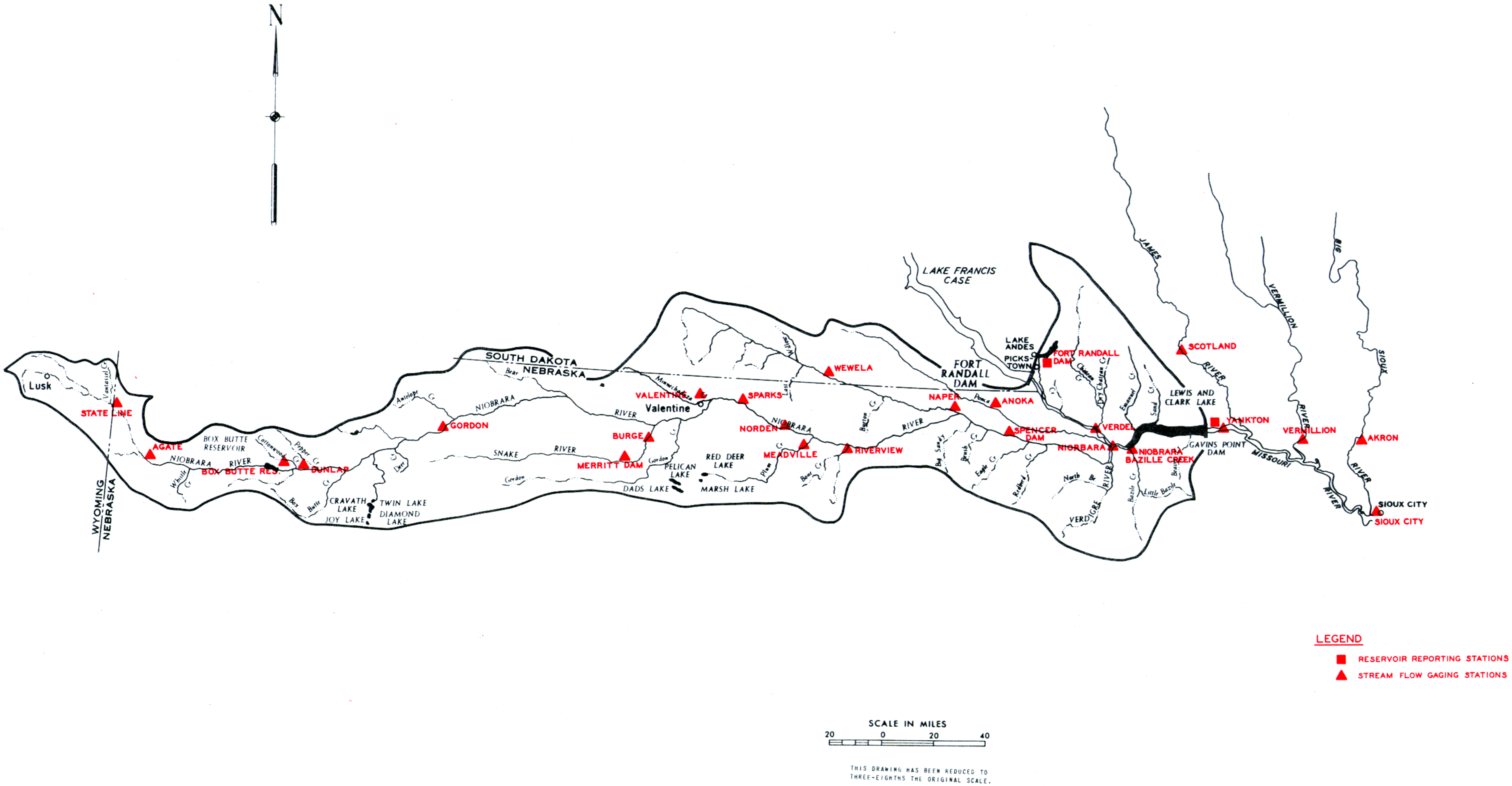
Effective 1 Jan 1978

GAVINS POINT PROJECT
CAPACITY IN ACRE-FEET
(1975 SURVEY)

ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	37	148	333	591	924	1291	1692	2187	2835
1170	3695	4701	5814	7133	8758	10790	13173	15839	18874	22359
1180	26380	30863	35753	41158	47188	53951	61371	69375	78077	87595
1190	98041	109373	121515	134530	148485	163445	179343	196137	213924	232806
1200	252880	274139	296515	320023	344674	370482	397409	425446	454650	485077
1210	516783	549790	584060	619561	656262	694131	733178	773424	814854	857454
1220	901209	946117	992186	1039422	1087830	1137414	1188174	1240108	1293214	1347493
1230	1402946									



KEY PRECIPITATION STATIONS
INCREMENTAL DRAINAGE AREA BETWEEN
FORT RANDALL DAM AND GAVINS POINT DAM



KEY STREAM GAGING STATIONS

INCREMENTAL DRAINAGE AREA BETWEEN
FORT RANDALL DAM AND GAVINS POINT DAM

STAGE-DISCHARGE TABLE FOR SELECTED GAGING STATIONS

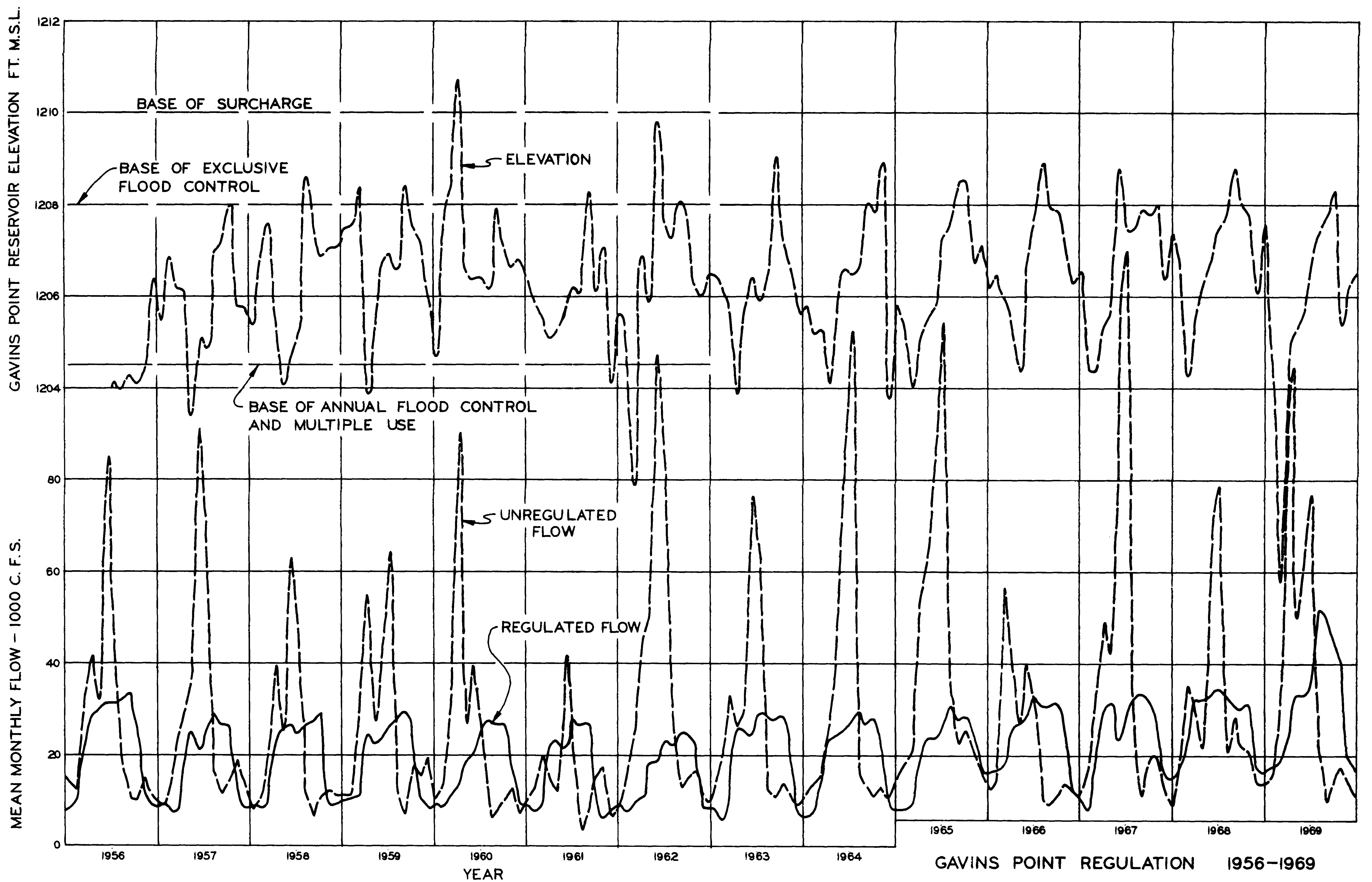
BETWEEN FORT RANDALL DAM AND GAVINS POINT DAM

Gage Height (feet)	Ponca Creek at Verdel, NB Gage Datum 1232.9 msl (cfs)	Niobrara R. near Norden, NB. Gage Datum 2109.93 msl (cfs)	Niobrara R. near Verdel, NB Gage Datum 1473.67 msl (cfs)	Bazile Creek near Niobrara, NB Gage Datum 1210.81 msl (cfs)
0				
1	4.8	685		
2	114	1390		
3	429	2350	360	
4	910	3390	1550	
5	1470	4630	3810	
6	2180		6460	
7	3040		9400	
8	4000		12400	
9	5040		15800	
10	6200		19800	
11	7400		23800	3.5
12	8800		27800	135
13	10600		31800	810
14	12600		35800	1650
15	15400		39800	2810
16				4500
17				7450
18				12700

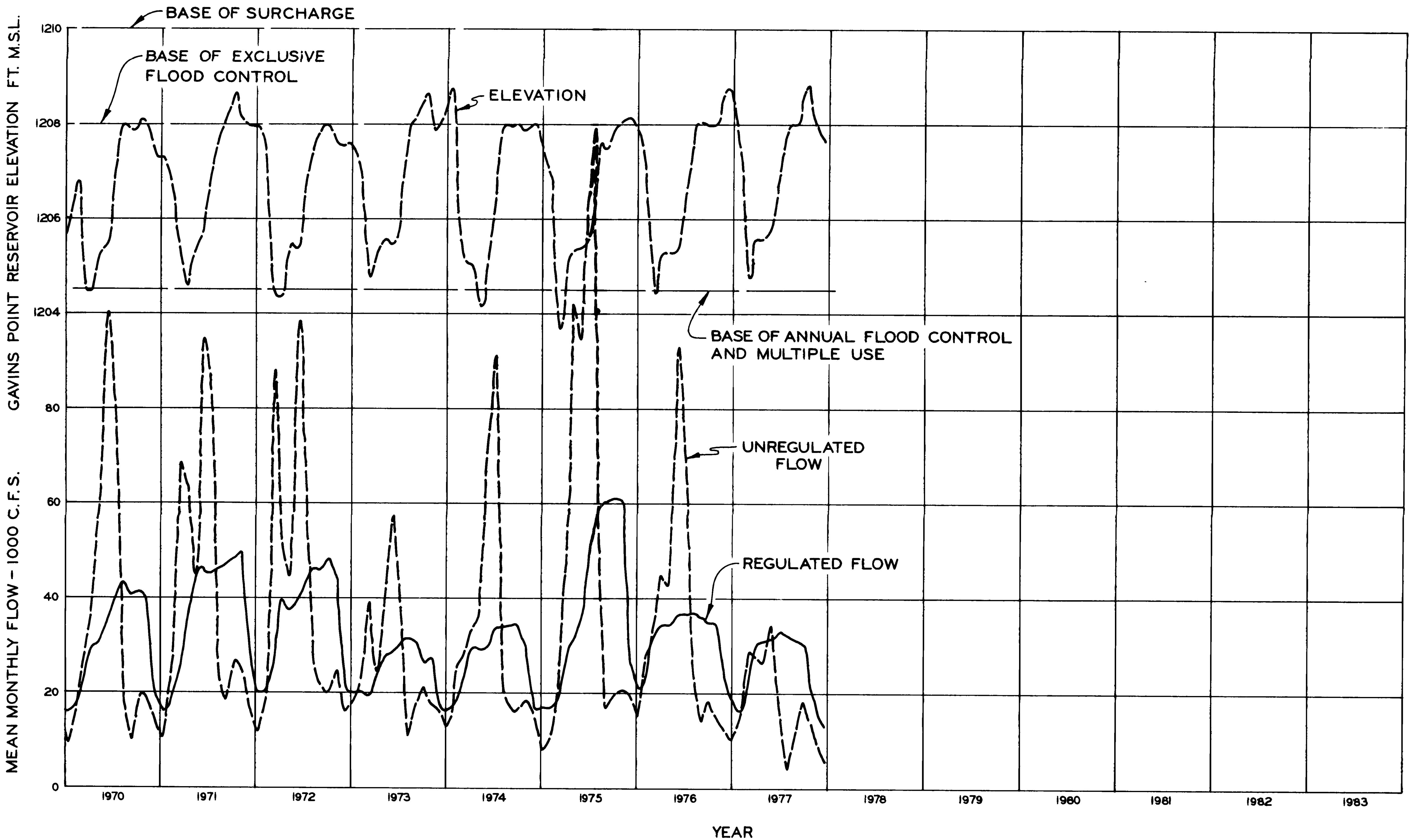
RESERVOIR ELEVATION CORRECTIONS AT THE GAVINS POINT DAM
TO ALLOW FOR WIND TIDE EFFECTS

ELEVATION 1205 M.S.L.
(TRUE ELEVATION = REPORTED POOL ELEVATION + CORRECTION)
WIND SPEED - MILES PER HOUR

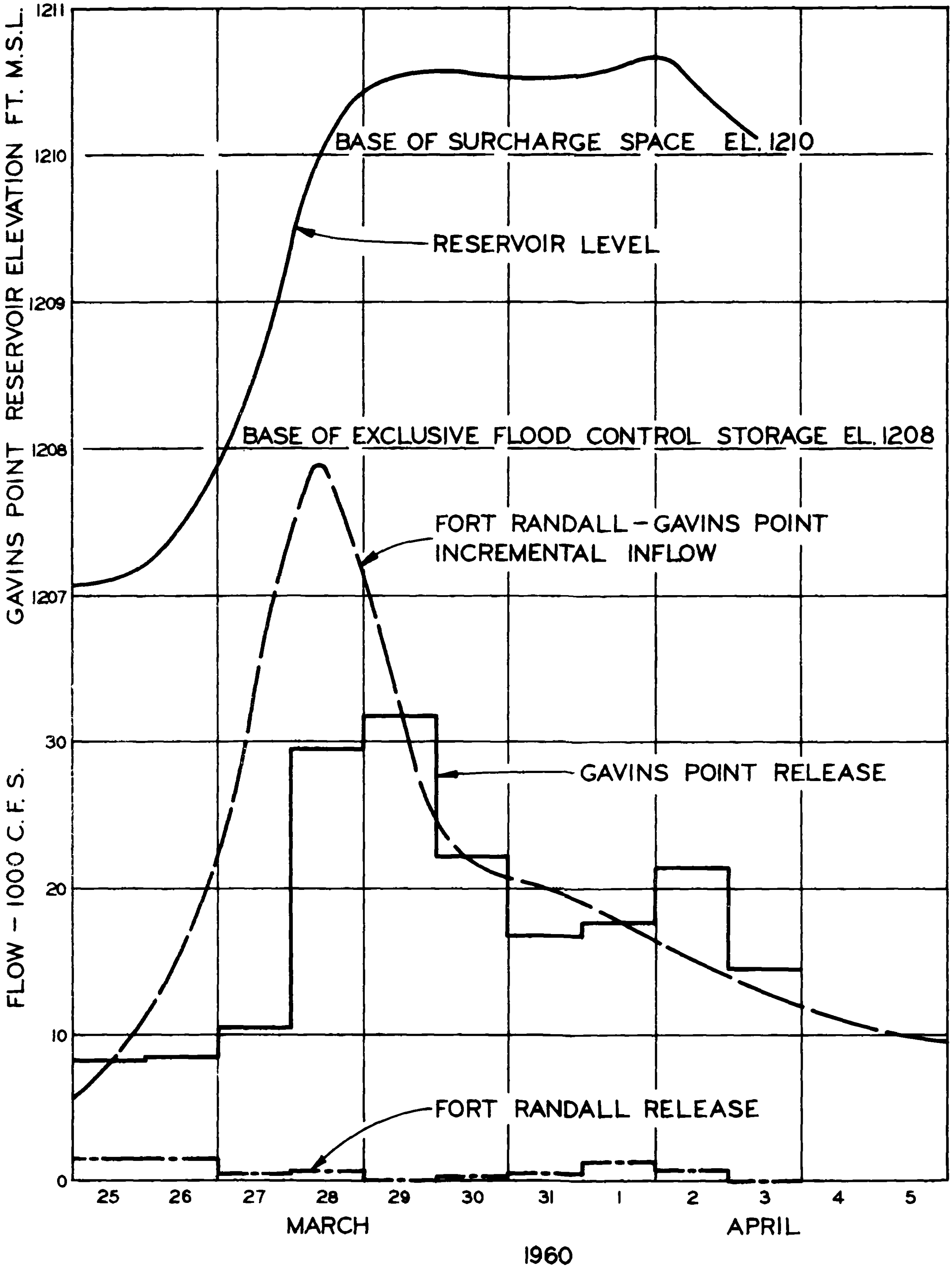
WIND DIR.	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
10	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.0	+1.2	+1.4	+1.6
20	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.2	+1.5	+1.7	+2.0	+2.3
30	+0.0	+0.0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



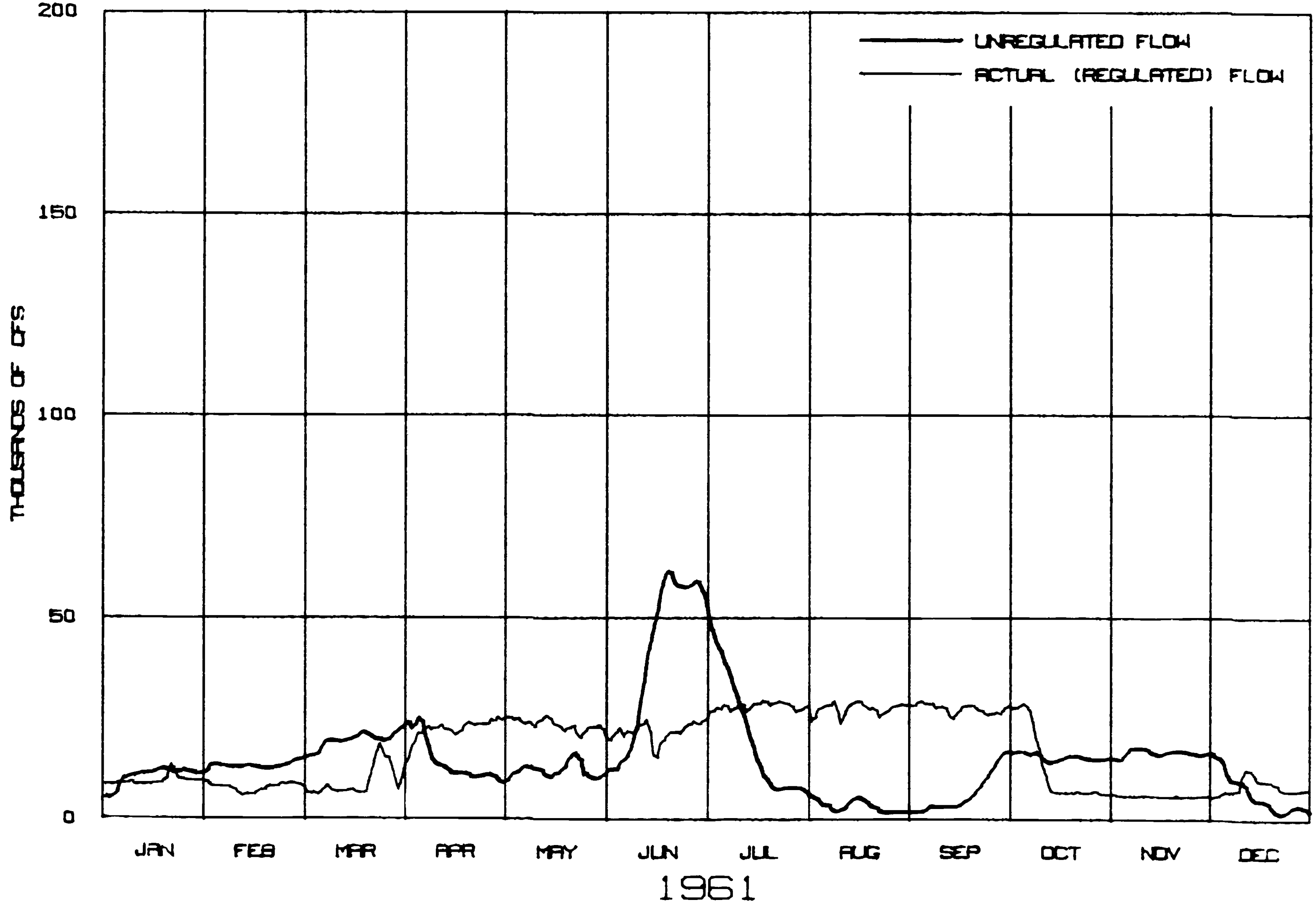
GAVINS POINT REGULATION 1956–1969



GAVINS POINT REGULATION 1970-1977

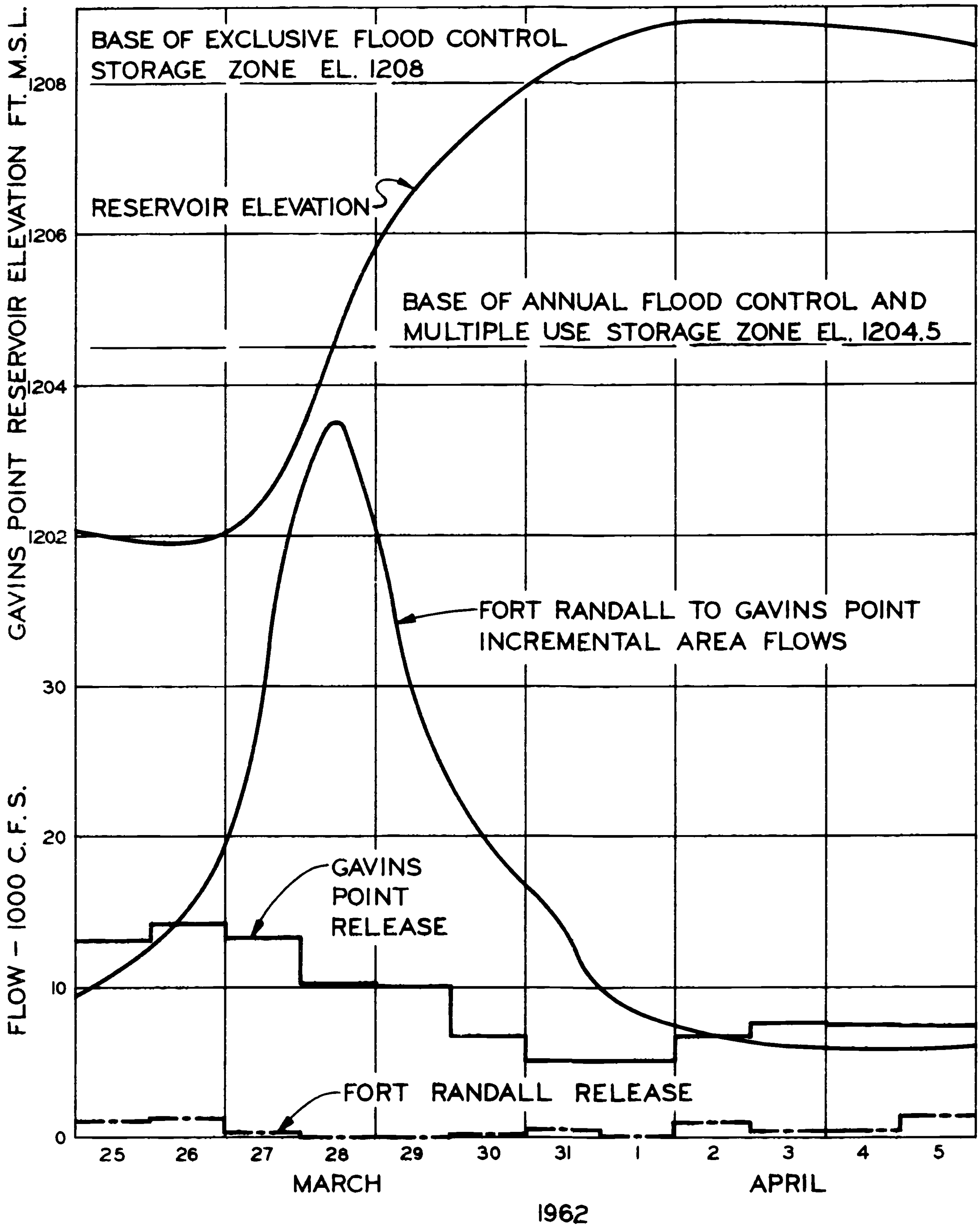


EXAMPLE OF REGULATION
1960 FLOOD

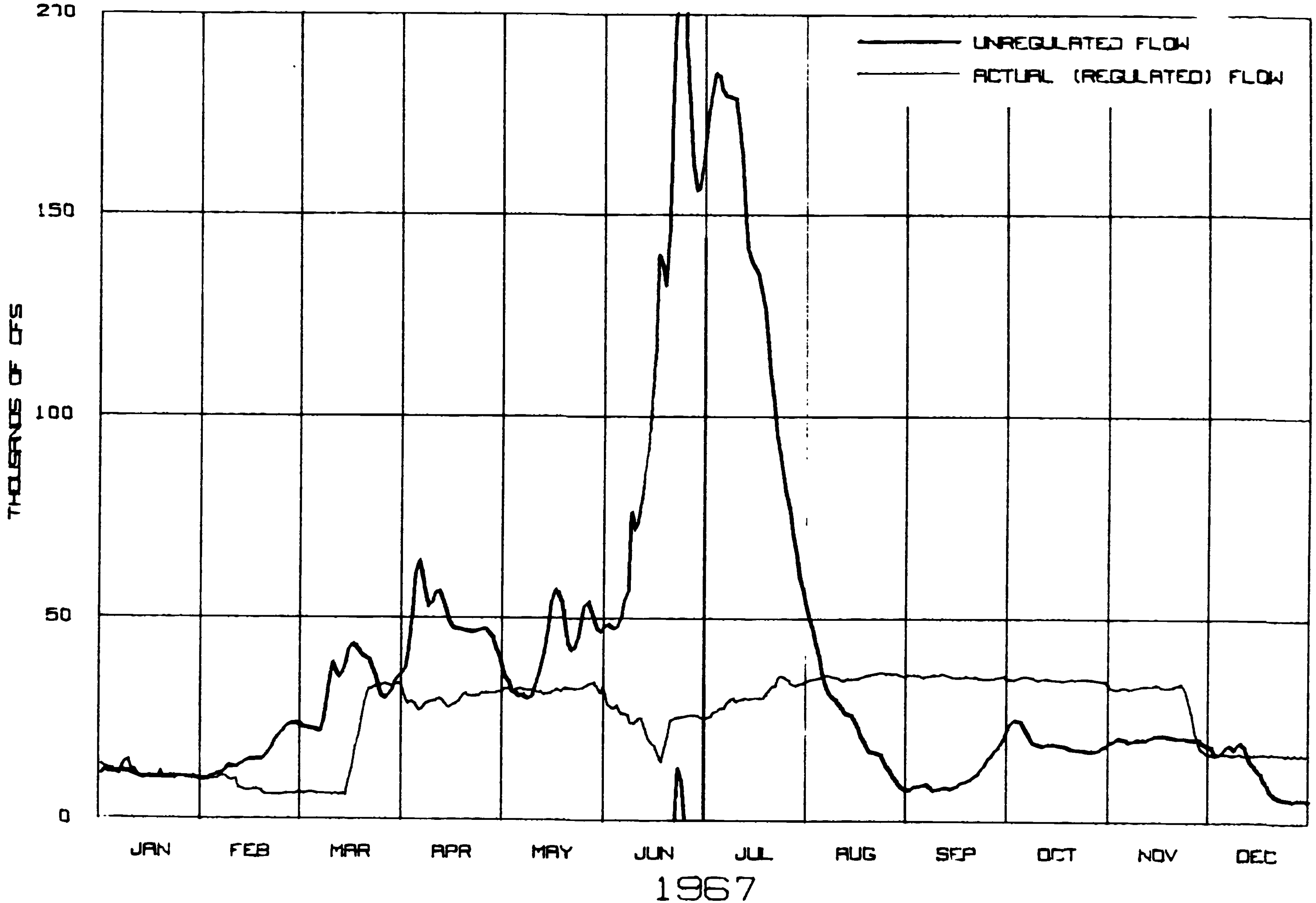


ACTUAL AND UNREGULATED FLOWS

MISSOURI RIVER AT GAVINS POINT DAM

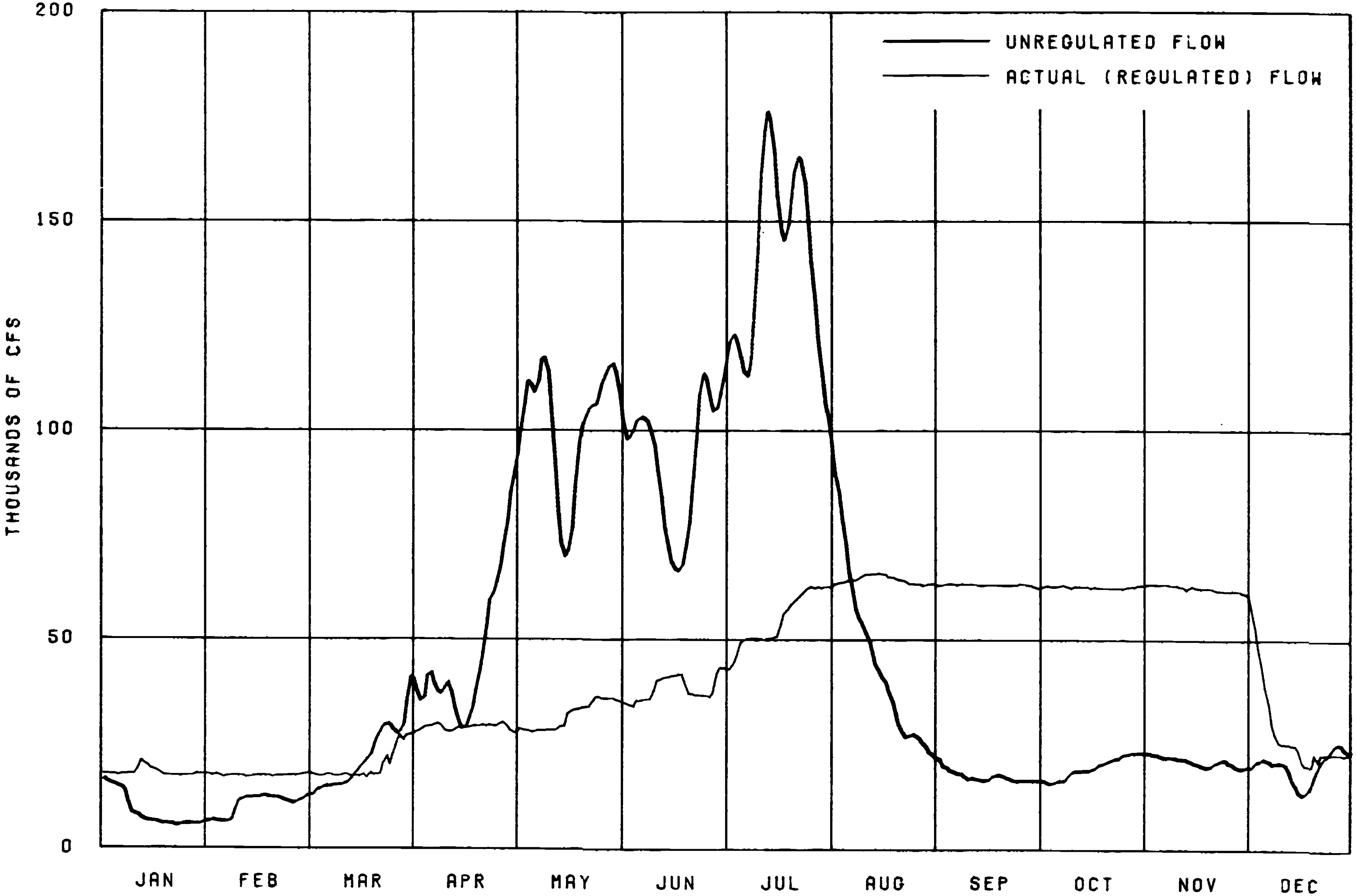


EXAMPLE OF REGULATION
1962 FLOOD



ACTUAL AND UNREGULATED FLOWS
MISSOURI RIVER AT GAVINS POINT DAM

PLATE 31

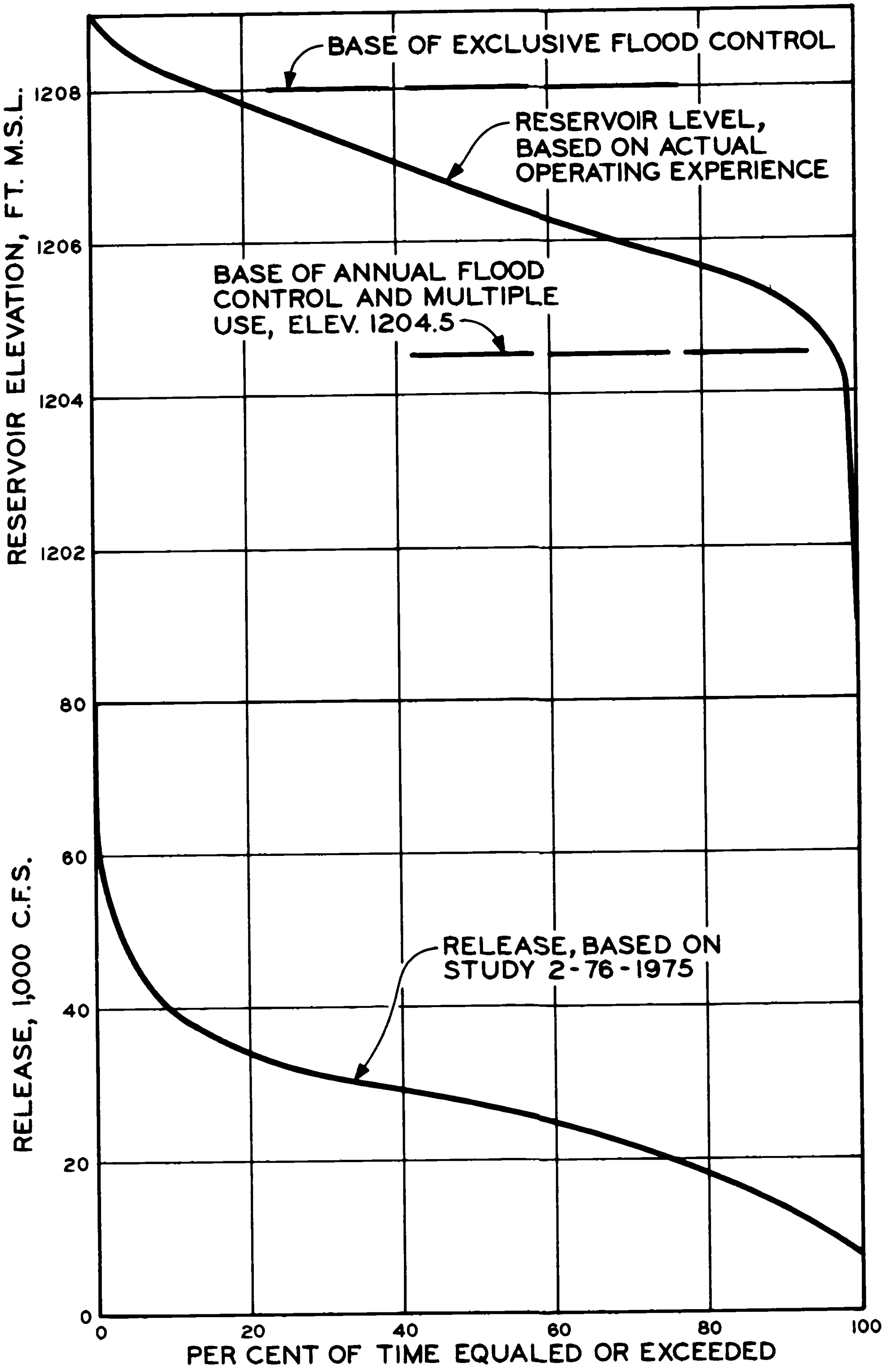


1975

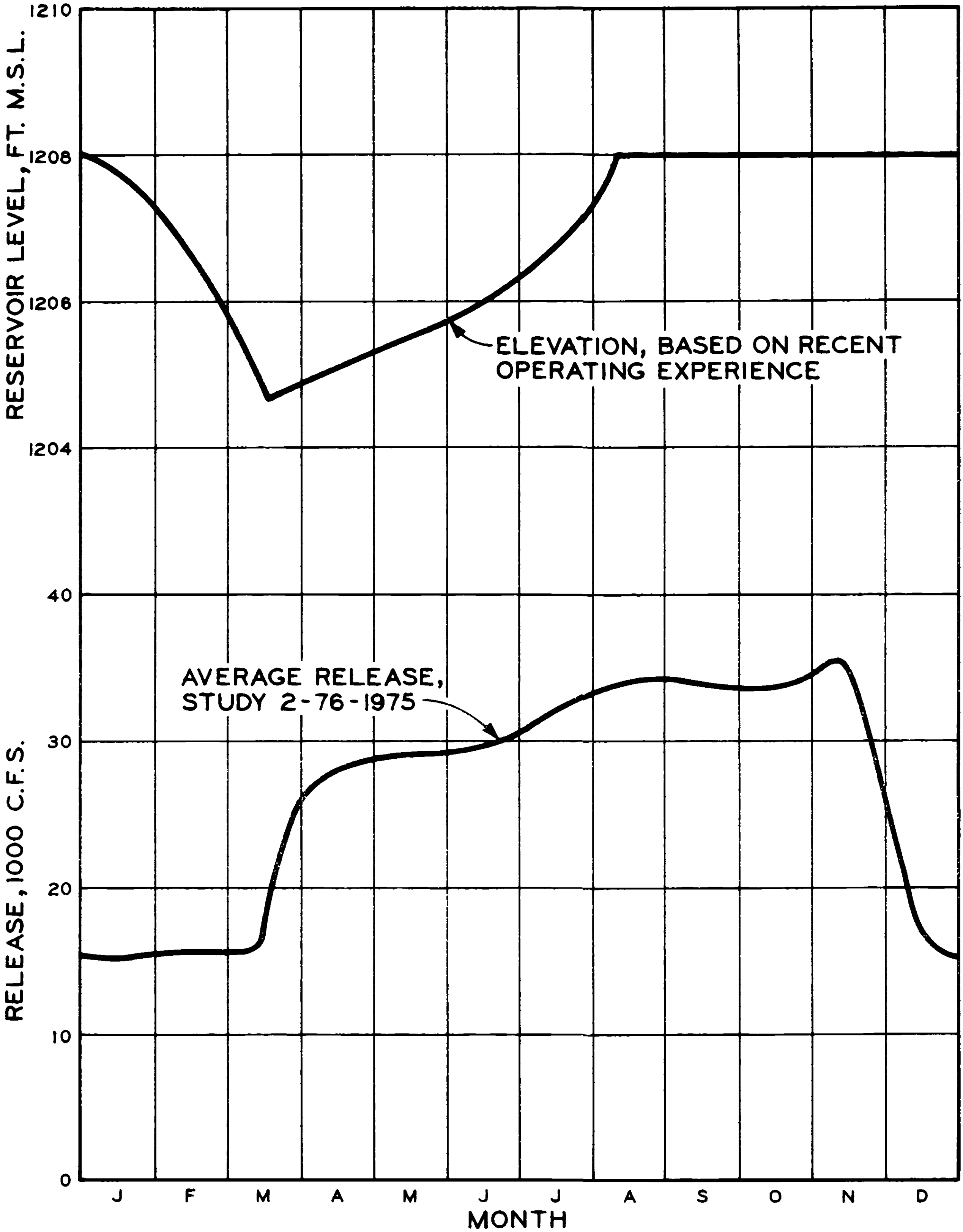
ACTUAL AND UNREGULATED FLOWS

MISSOURI RIVER AT GAVINS POINT DAM

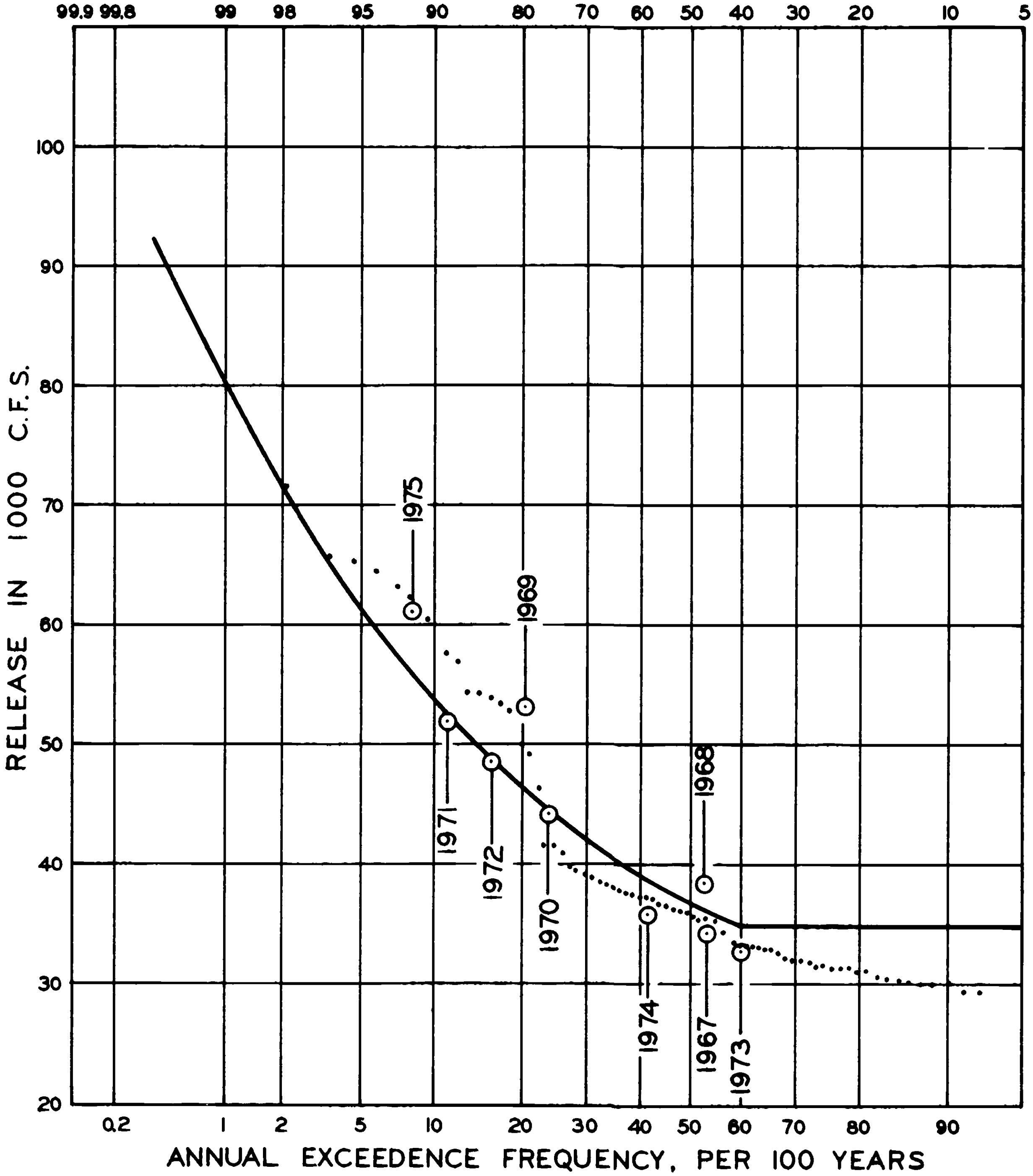
PLATE 32



DURATION CURVES FOR POOL LEVELS AND RELEASES GAVINS POINT PROJECT



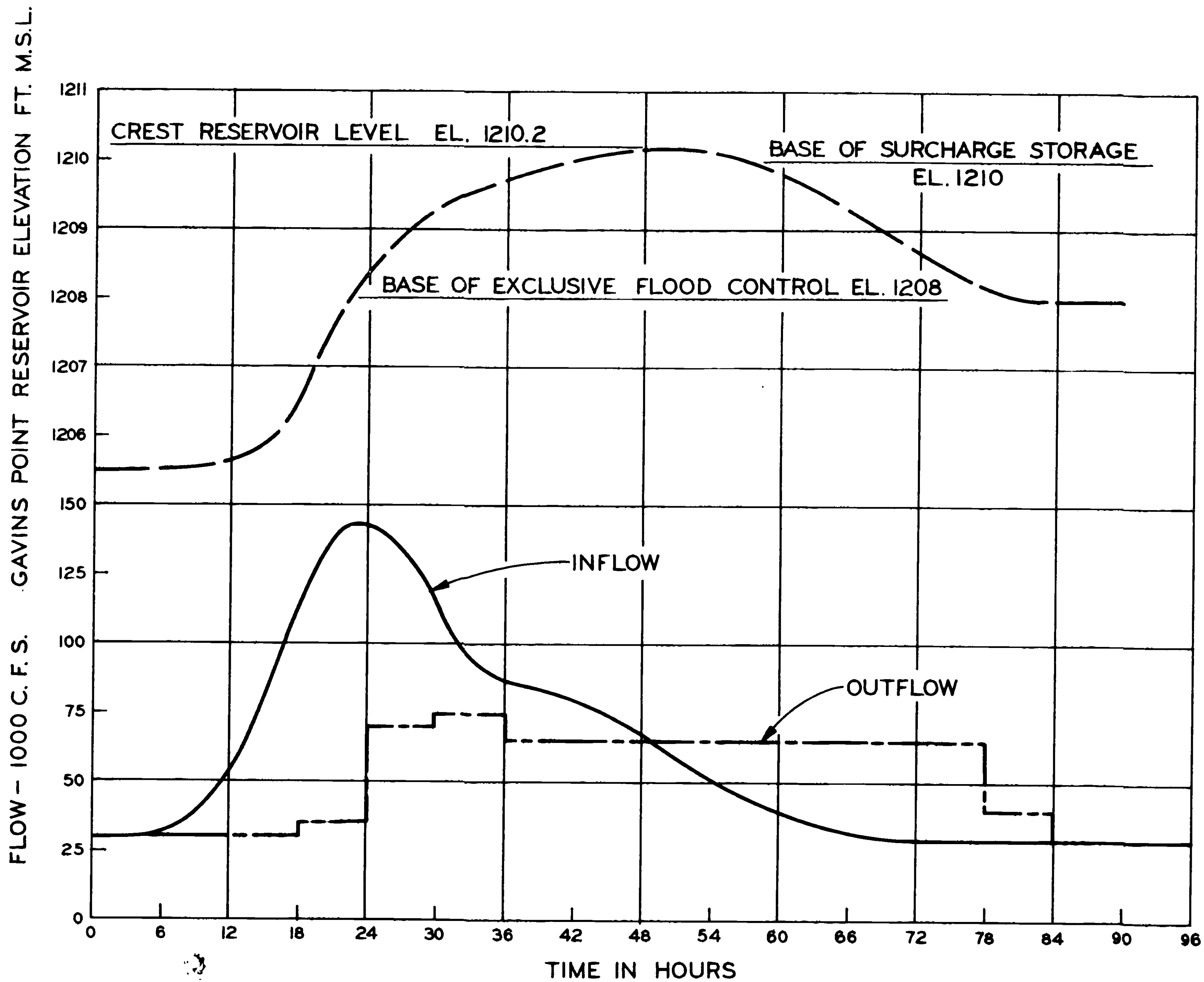
AVERAGE REGULATION
GAVINS POINT PROJECT



NOTES:

1. SMALL POINTS ARE BASED ON RESERVOIR REGULATION STUDY 2-76-1975, USING MEAN MONTHLY RELEASES AND END OF MONTH ELEVATIONS.
2. LARGE CIRCLES ARE BASED ON ACTUAL DAILY DATA FOR LISTED YEAR.

ANNUAL EXCEEDENCE FREQUENCY CURVE
FOR RELEASES
GAVINS POINT PROJECT



EMERGENCY REGULATION OF GAVINS POINT FOR RESERVOIR DESIGN FLOOD

PLATE 36

EXHIBIT A

EMERGENCY REGULATION PROCEDURES

FOR

GAVINS POINT RESERVOIR

MRDED-R

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Gavins Point Reservoir

TO: Power Plant Superintendent
Gavins Point Power Plant

FROM: Missouri River Division
Reservoir Control Center

1. Procedures applicable to the regulation of the Gavins Point Reservoir during any period that communication with the Missouri River Division Reservoir Control Center or the Omaha District Reservoir Regulation Section is not possible are outlined in the following paragraphs. These instructions supersede all previously furnished emergency reservoir regulation criteria.

2. Normally, reservoir regulation orders specifying project releases and power production will be furnished your office by the Reservoir Control Center and your office will report at least once daily to the Reservoir Control Center and the Omaha District pertinent data relating to regulation of the Gavins Point Reservoir. With a rapid rise in Gavins Point Reservoir elevations, amounting to a foot or more since the latest report, a special report giving data should be furnished. These data will include reservoir elevations, releases, power generation and related hydrologic data. The MRD teletype network will normally be used for transmission of orders and reports. However, if this network is inoperative, alternate means of communication are to be utilized. These include direct telephone, the MRD radio network, relay of data by other main stem project offices and utilization of Western Area Power Administration (WAPA) communication facilities.

3. When communication, as outlined in paragraph 2 above, cannot be established, the following will apply:

a. Every reasonable effort will be made by the Power Plant Superintendent to re-establish communications with the Reservoir Control Center or the Omaha District Reservoir Regulation Section, including use of any Federal, commercial or private means of communication.

b. Following a communication failure, the provision of the latest regulation order will be extended. Hourly power plant loading will follow the WAPA loading schedule, if available. If the hourly schedule has not been received from the WAPA, releases will be made at a uniform rate to provide the daily release schedule specified in the order. If requested by the WAPA Power Systems Operations Office and if power emergency conditions have been declared, energy generation may be increased to the maximum allowable limit shown on the latest regulation order. These procedures will continue to be utilized until communications are re-established as long as the Gavins Point pool level remains below elevation 1205 ft msl.

c. If the Gavins Point pool level is above elevation 1205, and the elevation is remaining relatively stable (levels changing at a rate of one foot or less per day), procedures given in paragraph b will be applicable during the first day of communication failure, after which conditions will be reviewed to determine if the release level should be changed. With a rapid increase in reservoir elevations, this review should be initiated after six hours of the communications failure have elapsed.

d. Release definition based on review of existing conditions is as follows:

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

(2) The mean inflow for the preceding 6 hours will be estimated by computing the storage change during the 6-hour period on the basis of pool elevations observed at the damsite. Normally, the pool elevation will follow a relatively smooth curve. Therefore, any sudden fluctuations in the pool level recorder trace from a smooth curve (probably due to wind effects on the reservoir gage) should be disregarded and the storage change based on an extrapolation of the smoothed pool level curve through the 6-hour period. The approximate mean inflow in cfs is equivalent to the mean outflow in cfs plus twice the storage change in acre-feet during the 6-hour period. Six-hour inflow may also be approximated by the equation:

Inflow = Outflow + (60,000 X Elevation change in feet)

(3) With a rising reservoir level between elevation 1205 and elevation 1212 feet m.s.l.

(a) Utilizing the mean inflow for the past 6 hours as developed above and the current pool elevation (as indicated by the smoothed pool level curve), determine the rule curve release by use of the emergency curves shown on the attached Inclosure 1.

(b) If the rule curve release developed by (3)(a) is greater than the release given by (1), make release specified by the rule curve.

(4) With a reservoir level between elevations 1212 and 1213 ft msl, release inflows up to a maximum of full spillway capacity in order to prevent any further increase in the reservoir level. The minimum release in this range of elevations will be 100,000 cfs.

(5) With a reservoir level above elevation 1213 ft msl, release the full capacity of the Gavins Point spillway.

(6) With a reservoir level between elevations 1208 and 1212 ft msl and falling, continue the release rate occurring at the time the reservoir level crested, subject to a maximum release rate of 100,000 cfs.

(7) With a falling reservoir level below elevation 1208, release as specified in the most recent available regulation order.

e. The analyses and release adjustments made necessary by these instructions during periods of communications failure should be made at intervals of six hours until such time communication with the MRD Reservoir Control Center is re-established.

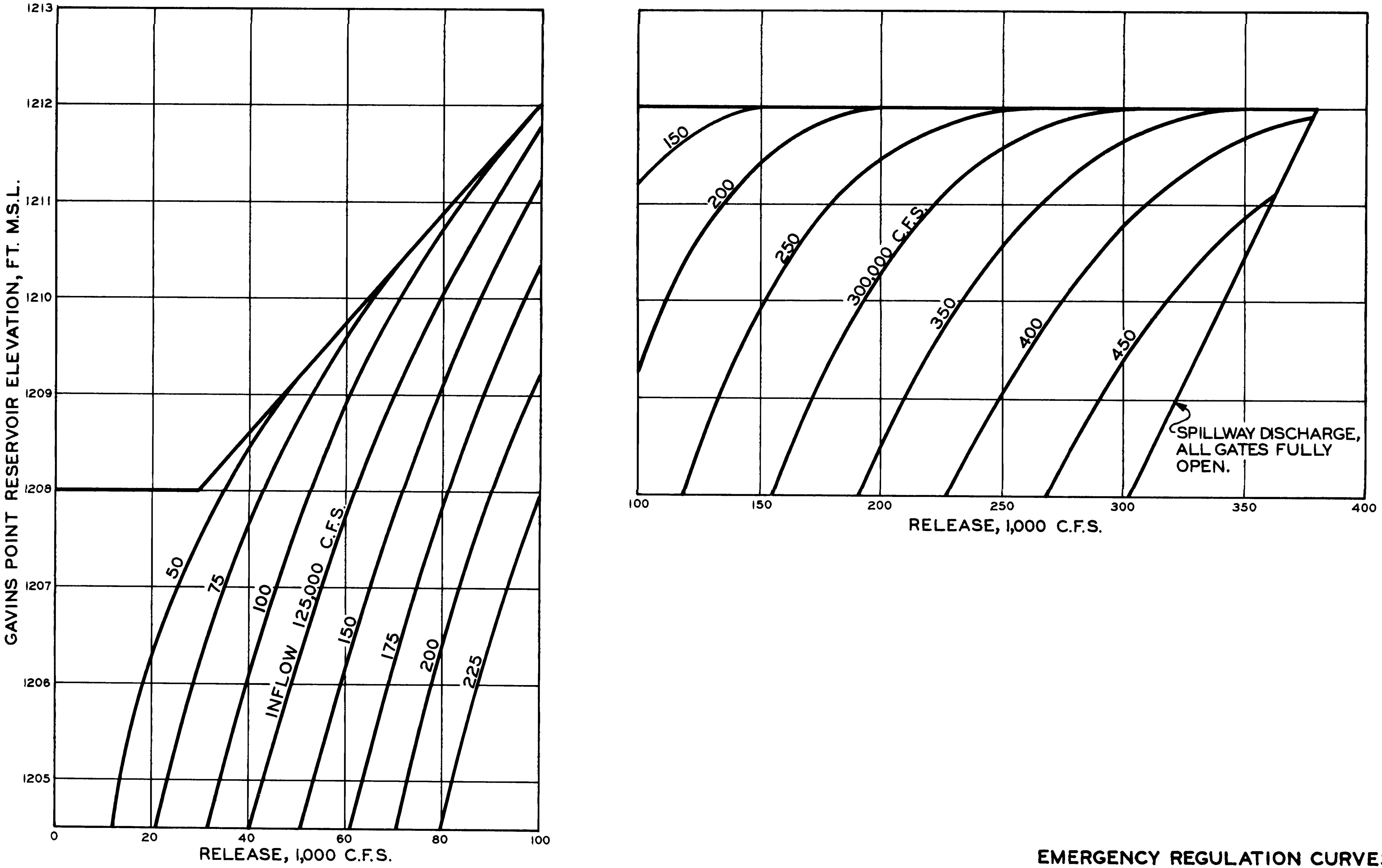
f. If release is less than full power plant capability, power plant loading will be patterned similar to recent experience or as prescribed by the WAPA, if communication with their Systems Operations Office is possible.

4. In the event of downstream flooding, as reported to or anticipated by the Power Plant Superintendent, releases will be reduced as deemed necessary to alleviate these conditions. However, with Gavins Point Reservoir above elevation 1208, releases will not be reduced below those levels defined by the emergency procedures in paragraph 3d above.

5. The foregoing procedures are not intended to relieve the Power Plant Superintendent of taking such additional measures believed necessary to assure the safety of the project.

1 Incl
Rule Curve

ELMO W. McCLENDON
Chief, Reservoir Control Center



EMERGENCY REGULATION CURVES
GAVINS POINT RESERVOIR

EXHIBIT A - INCLOSURE 1