MISSOURI RIVER
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL

FORT PECK MANUAL

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
1966
REVISED — 1976

MISSOURI RIVER

MAIN STEM RESERVOIR SYSTEM

RESERVOIR REGULATION MANUAL

In 7 Volumes

Volume 2

FORT PECK LAKE

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

PREPARED BY
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FORT PECK LAKE
MISSOURI RIVER
MONTANA

PERTINENT DATA

1. PURPOSE.

Originally authorized for navigation, incidental flood control and power. The 1944 Flood Control Act modified authorization to provide for operation for flood control, power, irrigation, navigation and other purposes.

2. AUTHORIZATION.

a. Recommended to Congress by House Document No. 238 dated 30 September 1933 (73d Congress, 2d Session).

b. Approved by the President of the United States by Executive Order on 14 October 1933.

c. River and Harbor Act approved 30 August 1935 (P.L. No. 409-74th Congress).

d. Fort Peck Power Act approved 18 May 1938 (P.L. No. 529-75th Congress, 3d Session).

e. Flood Control Act of 1944 (P.L. No. 534-78th Congress, 2d Session).

3. LOCATION OF DAM.

State	Montana
Counties	McCone and Valley
River	Missouri River, 1771.5 above the mouth (1960 mileage) 17 miles southeast of Glasgow, Montana, and 9 miles south of Nashua, Montana

4. DRAINAGE AREAS.

Total Missouri River Basin, Sq. Mi.	529,350
Above Fort Peck Dam, Sq. Mi.	57,500

5. STREAMFLOW DATA

Natural Flow at Damsite, c.f.s.	
Maximum (Estimated - 1908)	154,000 (1)
Maximum of Record (1953)	137,000 (1)
Minimum (1936)	1,120 (1)
Average	10,000 (1)
Actual Regulated Flow at Damsite, c.f.s.	
Maximum (1975)	35,400 (2)
Minimum (1940, 1943 & 1944)	0 (2)
Average	9,000 (2)
Average Annual Runoff at Damsite (1898-1974) Acre-Feet Adjusted to 1949 Level of Depletion	7,256,000

Note (1) For period 1898-1975, incl.
Note (2) Average daily release during period 1938-1975 incl.

6. RESERVOIR DATA

Approximate Length of Reservoir, miles (Pool Level at Maximum Normal Operating Level and 1960 River Conditions)	134
Shoreline, miles at Elev. 2234	1,520

Storage Capacity	Elevation M.S.L.	Gross Storage Acre-Ft.	Gross Area Acres
Maximum Operating Pool	2250	18,900,000	249,000
Maximum Normal Operating Pool	2246	17,900,000	240,000
Base of Flood Control Pool	2234	15,200,000	212,000
Minimum Operating Pool	2160	4,300,000	92,000
Exclusive Flood Control	2250-2246	1,000,000	
Flood Control and Multiple Use	2246-2234	2,700,000	
Carryover Multiple Use	2234-2160	10,900,000	
Inactive Storage	2160-2030	4,300,000	

7. DAM.

Embankment Type - Hydraulic and Rolled Earth Fill	
Abutment Formations - Bearpaw Shale and Glacial Till	
Top of Embankment, Elev. Ft. m.s.l.	2280.5
Total Crest Length, Feet	21,026
Maximum Height, Feet	250.5
Damming Height (Low Water to Max. Oper. Pool)	220
Top Width, Feet	50
Maximum Base Width, Feet	4,900
Fill Quantity, Cubic Yards	125,628,000

8. SPILLWAY.

Location	Right Bank - Remote
Type - Chute, Concrete Lined with Gated Overflow Weir	
Crest Elevation, Feet m.s.l.	2225
Crest Length, Gross, Feet	820
Crest Length, Net, Feet	640
Gates - Stoney Vertical Lift - No. & Size, Feet	16 - 40 x 25
Design Discharge Capacity, c.f.s.	250,000
Discharge Capacity at Maximum Operating Pool, (Elev. 2250) c.f.s.	230,000
Discharge Capacity at 3.5 Feet Surcharge Above Maximum Pool (Elev. 2253.5) c.f.s.	275,000

9. OUTLET WORKS.

Location	Right Bank
Type - Concrete Lined Tunnels	
Tunnels, No. and Dia. in Feet	2 - 24.67
Tunnels, Length, Feet	6,615 & 7,240
Main Control Gates, Type	Cylinder
Main Control Gate Size, Feet	12 x 28 Dia.
Emergency Gates, Type	Vertical Lift Tractor
Emergency Gates, No. and Size, Feet (Each Tunnel)	2 - 11.5 x 22
Discharge Capacity per Tunnel, c.f.s. (Reservoir Water Surface at Elev. 2250)	22,500
Present Tailwater Elevation, Feet m.s.l.	2033-2037
Intake Inlet Elevation, Feet m.s.l.	2095
Intake Invert Elevation, Feet m.s.l.	2030

10. POWER STRUCTURES

Location	Right Bank
Powerhouse, Type	Indoor Reinforced Concrete
Tunnels - Concrete Lined with Steel	
Tunnels - No. and Dia. in Feet	1 - 24.67 & 1- 22.33
Tunnels Length, Feet	5,653 & 6,355
Gates, Type	Vertical Lift Tractor
Gates per Tunnel, No. and Size in Feet	2 - 11.5 x 22
Surge Tanks, No. and Dia. in Feet PH #1	3 - 40
PH #2	2 - 65

11. POWER INSTALLATION.

Average Gross Head Available, Feet	193
Number of Generating Units	5
Turbines, Type	Francis
Turbines, Speed, rpm PH #1	2 - 128.5, 1 - 164
PH #2	2 - 128.6
Discharge Capacity at Rated Head, c.f.s. PH #1	7,800
PH #2	7,200
Generator Rating, KW	2 - 35,000 1 - 15,000 2 - 40,000

12. POWER AVAILABLE.

Plant Capacity, KW	165,000
Dependable Capacity, KW (3)	173,000
Average Annual Energy, KWH (4)	1,019,000,000

Note (3) Based on 4th year of drought drawdown. (From 1970 Level Study 1-74-1970)

Note (4) Based on study 1-74-1970

MISSOURI RIVER BASIN
MAIN STEM RESERVOIR SYSTEM
RESERVOIR REGULATION MANUAL

IN 7 VOLUMES - VOLUME NO. 2

FORT PECK MANUAL

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. The Missouri Main Stem System of reservoirs consists of six reservoirs, 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 operated as a hydraulically and electrically integrated system. Therefore, the Master Manual presents the basic objectives and the plans for their optimum fulfillment, with supporting basic data. The Fort Peck Manual serves as a supplement to the Master Manual and covers in detail the factors pertinent to the regulation of the Fort Peck Lake including hydrology, hydrologic networks, forecasting and methods of regulation for multipurpose and flood control. The flood control regulation of tributary reservoirs located within the Missouri River Basin which will affect the regulation of Fort Peck Lake is detailed in separate manuals prepared for each of the individual projects.

1-3. This manual is one of the 7 volumes being prepared for the main stem reservoirs as follows:

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

SECTION II - BASIN AND RIVER DESCRIPTION

II-A. Basin Geography

2-1. Location. The portion of the Missouri River Basin discussed in this manual includes the drainage basin above Fort Peck Dam and the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River, including the Milk River Basin. The Yellowstone River Basin since it is the major contributor of inflows to Lake Sakakawea is described in the Garrison Manual (Volume 3). The Missouri River drainage area above the mouth of the Yellowstone River totals 92,520 square miles of which 82,750 square miles lie within the United States and 9,770 square miles in Canada. The western boundary is formed by the continental divide; the southern and eastern boundaries are formed by the northerly divide of the Yellowstone River Basin; and the northern boundary by the Hudson Bay divide in Canada. Over one-half of the state of Montana and a very small portion of the states of Wyoming and North Dakota lie within this area. An area of 57,500 square miles, extending from Fort Peck Dam west to the continental divide, is controlled by Fort Peck Lake. The Fort Peck drainage is bounded on the north by the Milk River and on the south by the Yellowstone River. Plate 1 is a general map of the entire Missouri River Basin. The drainage basin above Fort Peck Dam and the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River are shown in detail on Plate 2.

2-2. Topography. The terrain of the upper Missouri River Basin ranges from mountainous in the upper reaches on the eastern slope of the Rocky Mountains to the relatively flat or rolling Great Plains which commence as broad piedmont slopes and extend across the eastern two-thirds of the state of Montana. The Great Plains are broken by isolated areas of mountainous uplift such as the Bear Paw, Little Rocky, Highwood, Judith, and Big Snowy Mountains. The relative levelness of the plains is further modified by streams flowing through broad valleys paralleled by terraces and high bluffs. The area to the south of the Missouri River ranges from local badlands to moderately sloping land. Extremes of elevations are the 1847 feet m.s.l. streambed elevation of the Missouri River near the mouth of the Yellowstone River to mountain peaks of over 10,000 feet m.s.l. in the western part of the basin. Mountain drainage areas above elevation 6000 feet m.s.l. in the Missouri River Basin above Fort Peck Dam total approximately 13,200 square miles.

2-3. Drainage Pattern. The Missouri River is formed by the confluence of the Gallatin, Madison, and Jefferson Rivers near the town of Three Forks in southwestern Montana. Above Three Forks, the Gallatin, Madison and Jefferson Rivers spread in a fan-like manner to their sources in the principal and secondary ranges of the Rocky Mountains. From Three Forks, the Missouri River flows northerly to the vicinity of the town of Wolf Creek and then northeasterly through the city of Great Falls to the town of Virgelle. From Virgelle the Missouri River flows in an easterly direction through Fort Peck Lake to its confluence with the Yellowstone River near Williston, North Dakota. Most of the tributaries originate in the mountain areas. Principal tributaries above the mouth of the Yellowstone River are shown in Table 1. Minor tributaries include the Dearborn River, Arrow Creek, Belt Creek above Fort Peck Dam, Little Porcupine Creek and Wolf Creek between Fort Peck Dam and the mouth of the Yellowstone River and numerous smaller streams.

2-4. The Milk River, with a drainage area of about 23,200 square miles, is the only major tributary which materially affects the flow of the Missouri River between Fort Peck Dam and the mouth of the Yellowstone River. The headwaters of the Milk River rise in Glacier County, Montana on the eastern slope of the Rocky Mountains at an elevation of about 7,000 feet m.s.l. where numerous small spring-fed and lake-fed streams flow down through steep, narrow coulees to join and form the South Fork of the Milk River. Farther north in Glacier County, the North Fork rises at an elevation of about 5,200 feet m.s.l. The two forks flow northeasterly through narrow valleys into Canada, joining to form the Milk River about 14 miles west of Milk River, Alberta. About 460 miles above the mouth, the Milk River again crosses the international boundary, re-entering the United States at Eastern Crossing near Goldstone, Montana. From this point to Malta, Montana, the river follows a circuitous course through the wide valley marked with bench lands which once was the course of the preglacial Missouri River. Below the mouth of the Big Sandy Creek near Havre, Montana, the Milk River is a sluggish meandering stream with many oxbow lakes along its course. The flood plain is generally quite flat, but frequent sloughs, representing former channels give the arable land an irregular outline. As far east as Malta the Milk River valley widens to about 3 miles in width. Below Malta, the Milk River leaves the early course of the Missouri to flow through a narrow valley in the northern uplands known as the Big Bend Country. At Hinsdale, the river re-enters the wide preglacial Missouri valley which it follows to its confluence with the present Missouri River below Fort Peck Dam. Numerous small lakes, both natural and artificial, which tend to decrease the runoff from storms, are found in the basin. The drainage pattern of the Missouri River above the mouth of the Yellowstone River is shown on Plate 2.

2-5. <u>Stream Slopes</u>. The total fall of the Missouri River from its headwaters at the confluence of the Jefferson, Madison and Gallatin Rivers to Fort Peck Dam is approximately 2,000 feet and averages 3.7 feet per mile. Slopes range from 4.8 feet per mile for the reach from Three Forks (head of the river) to Cascade, Montana, 0.5 foot per mile for the reach from Cascade to above the falls at Great Falls, 40 feet per mile from above the falls through five reservoirs to below the falls at Morony Dam, 5.7 feet per mile from Morony Dam to Fort Benton, to 2.2 feet per mile from Fort Benton to the head of Fort Peck Lake. The total fall of the Missouri River between Fort Peck Dam and the mouth of the Yellowstone River is approximately 183 feet and averages 0.9 foot per mile. The length of the Milk

TABLE 1

Principal Missouri River Tributaries Above the Mouth of the Yellowstone River

Stream	Bank of Missouri River	1960 Missouri River Mileage at Mouth	Drainage Area (Sq. Mi.)	Total Fall (Ft. MSL)	Length (Miles)	Average Slope (Ft. Per Mile)
Jefferson River	--	2316.40	9,661	4,400	245	18.0
Madison River	--	2316.40	2,531	4,400	164	27.0
Gallatin River	--	2315.14	1,826	4,800	100	48.0
Smith River	Right	2146.40	2,021	4,200	126	33.3
Sun River	Left	2120.79	1,991	3,900	123	31.7
Marias River	Left	2051.18	(1) 9,147	4,150	261	15.9
Teton River	--	(2) --	1,989	4,650	204	22.8
Judith River	Right	1984.25	2,750	4,600	130	35.4
Musselshell River	Right	1867.34	9,040	5,250	281	18.7
Milk River	Left	1761.50	23,159	4,780	705	6.8
Redwater Creek	Right	1681.31	2,113	740	115	6.4
Poplar River	Left	1678.56	3,340	940	126	7.5
Big Muddy Creek	Left	1630.36	2,693	860	106	8.1

(1) Includes drainage area of the Teton River.

(2) Teton River is a major tributary of the Marias River.

River from the confluence of the north and south forks and its mouth is approximately 625 miles, and it has an average slope of about 2.6 feet per mile. The average slope of the Milk River varies from 0.4 foot per mile between its mouth and Nashua, Montana, 1.0 foot per mile between Nashua and Malta, Montana, 1.3 foot per mile between Malta and Havre, Montana, and 5.0 feet per mile between Havre, Montana, and the confluence of the north and south forks. The north fork of the Milk River has an average slope of about 21 feet per mile and the South Fork a slope of about 26 feet per mile. The total fall and average slope of the principal tributaries of the Missouri River in the Fort Peck drainage basin are shown in Table 1. Profiles of the Missouri River and its principal tributaries in the upper Missouri River basin are shown on Plate 3.

2-6. Geology. The Missouri River headwaters is in an area underlain by Miocene rocks. Beneath the Miocene rocks and exposed at higher elevations in the adjacent mountains are rock of various Paleozoic systems. Downstream at a point southeast of Helena, the Missouri River enters a broad area of pre-Cambrian granites and other igneous rocks. The valley has cut into these rocks to the bend of the river near Craig, in Lewis and Clark County. From this point eastward to the Fort Peck Lake the Missouri River flows in a valley cut in Cretaceous rocks. These Cretaceous rocks are represented by the Colorado shale, Eagle, Claggett, Judith River and Bearpaw formations and consist of marine deposits of shale and sandstones, and some lignite and coal. Tertiary intrusions of igneous dikes and sills occur in the general area south of the Bearpaw mountains. The Bearpaw mountains lie approximately 20 to 25 miles north of the Missouri River Valley and were formed during the Tertiary period. Deposits of Pleistone glacial drift covers most of the upland plains area, with the exception of the area south of the Bearpaw mountains and adjacent Little Rockies. These mountains formed a barrier which blocked the advancing ice sheets, diverting the flow of ice to the east and west sides of the mountains. Prior to glaciation in this area, the Missouri River flowed in a general northeasterly direction from Fort Benton around the north side of the Bearpaw mountains and east in the valley now occupied by the Milk River. This preglacial drainage of the Missouri River was blocked by the advancing ice sheet, ultimately diverting the river in an easterly direction south of the Bearpaw mountains to its present course.

2-7. The basin of the Milk River is situated east of the Rocky Mountain uplift, formed in a large area of almost horizontal beds and surfaced by erosion, weathering and glaciation. Bedrock may be found from 75 to 125 feet below the surface with a dip to the east. Far below the surface rock extends a syncline of the limestones, sandstones, and shale of the older formations dipping to the west. Outcroppings throughout the basin reveal a succession of formation ranging in ages from the Lower Paleozoic to Tertiary. Two anticlines, the Milk River and the South Fork, occur in the upper basin.

2-8. <u>Soils</u>. Due to variance of precipitation, temperatures, vegetation and topography the major soil groups change with decreasing elevation from the Podzol, Brown Podzolic and Gray Wooded soils developed under forest cover, to the Chernozem, Chestnut and Brown soils developed under grasses in the lower valleys. In the mountainous regions of the western and southwestern portions of the basin the soil cover consists mainly of partially decomposed rock which may be residual at the site of decomposition, may be slowly moving down the slope under the influence of erosion and gravity, or may have accumulated in the valley bottoms. Many of the mountain soils are thin and poorly developed since the soil material often is eroded from the slopes and deposited in the valleys. In most of the eastern portion of the basin the soil cover has matured under the climatic regime of cold winters, warm summers and low precipitation, and a vegetation consisting of grasses. Low topographic relief reduces the possibility of soil movement. This relative stability of the soil has permitted accumulation of humus from the natural grass cover of the plains, being quite similar over large areas regardless of the kind of rock from which they have developed. These soils have dark surface layers and are underlain by deposits of lime. Extensive areas of alluvial soils occur along the Missouri River and its tributaries in the upper Missouri basin. Soils in the Milk River basin have been derived from alluvial deposits, from glacial drift and from disintegration of geological formations. Most of the arable soils of the upper Missouri River basin are inherently fertile and are suitable for continued profitable cultivation when supplied with adequate and properly distributed moisture. Soils in the stream valleys and bottoms and on the first terraces or benches are, in general, the most productive. Most of these soils are of medium texture and have good natural drainage. Areas of the Missouri River are in glacial tills, while south and east of the river many of the soils have their origin in shales and sandstones.

2-9. <u>Vegetative Cover</u>. Natural vegetative cover includes the dense growths of coniferous trees on the high mountain slopes of western and southwestern Montana, the thin stands and isolated patches of trees along the streams in eastern Montana, and the grazing land in the mountain and plains areas. The margin of the forests lies above elevation 6,000 feet. The better grazing land is in the high valleys and mountain peak areas. Natural vegetation in the low areas and prairies consists principally of grass and sagebrush except for the thin stands of timber along the streams. Irrigation is practiced where water supplies can be easily obtained from the lowest altitude to the high mountain valleys. Although most of the irrigated acreage is located in the southwestern portion of the basin and along the Milk River there is some irrigation along the Missouri River and its other principal tributaries throughout the basin. Dry land farming is practiced in the prairies in eastern Montana. Approximately 73 percent of the land in the drainage basin above Fort Peck Dam is in farms and ranches and 18 percent in forests. In the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River, exclusive of the Milk River basin, approximately 89 percent of the land is in farms and ranches and only 0.25 percent in forests. In the Milk River basin approximately 75 percent of the land is in farms and ranches and 3 percent in forests. The balance of the land in these areas includes water surfaces, land used by highways, railroads, industries and other miscellaneous uses.

2-10. Population and Industry. The upper Missouri River basin is sparsely populated. The portion of the basin within the United States had a population of approximately 305,000 persons in 1960, which gives a density of 3.6 persons per square mile. The majority of the urban and rural population is located in areas bordering the major streams. The larger cities include Helena and Great Falls on the Missouri River, Bozeman on the Gallatin River and Havre on the Milk River. The upland areas and mountain regions of the basin are sparsely populated with most of the population living in small towns and villages. Agriculture is the principal industry of the basin and the majority of the population is supported directly, or indirectly, by farming or cattle raising. Other industries important to the basin include oil and gas production and refining, railroad and highway transportation, mining and manufacturing.

II-B. Climatology.

2-11. General. The climate of the upper Missouri River drainage basin varies from semi-arid in the eastern portion and the lower elevations in the central portion to subhumid in the mountainous areas along the continental divide. The climate of the basin is influenced by the barrier effect of the mountain ranges in the west and southwest, the differences in elevations, the interior location on the American continent, the latitude, and the movement of air masses and storms. These factors result in large variations in annual and daily temperatures and relatively low amounts of precipitation within the basin.

2-12. Annual Precipitation. Principal moisture-bearing air masses approach the upper Missouri River drainage basin from the Pacific Coast, however, a large portion of their moisture is lost as precipitation in crossing the more western mountain ranges of the continent. Crossing the main range of the Northern Rockies results in further uplift of the air masses and precipitation over the western part of Montana. These losses together with the warming and drying of the air during its descent over the eastern slope of the mountains largely account for the small amount of precipitation in the areas of lower elevation of the upper Missouri drainage basin. In the mountainous regions of the basin the amount of precipitation tends to increase with elevation. Average annual precipitation varies widely throughout the basin, from less than 12 inches in northeastern Montana and other areas of lower elevations to over 30 inches along the continental divide, with an average over the basin of about 14 inches. Total normal annual precipitation is shown on plate 4.

2-13. Seasonal Precipitation. Approximately 70 percent of the yearly total precipitation occurs during the months of April through September. Most spring and summer rainfall occurs in showers or thundershowers, however, steady rains may occasionally occur. Excessive rainfall is unusual. May and June are normally the wettest months of the year. Winter precipitation generally is very light and almost invaribly falls as snow. Measurable precipitation normally occurs on about 90 days per year over the basin. Average monthly and annual precipitation data for representative stations are shown on Plate 5.

2-14. Snow. The snow season in the upper Missouri River drainage basin generally extends from late October through April, however, snowfall may be expected during any month of the year in the higher elevations of the mountainous regions of the basin. The average annual snowfall over the basin varies from 20 inches in the plains area of eastern Montana to an excess of 100 inches at some high elevation stations. Nearly all stations have recorded heavy snowstorms with a foot or more of snowfall in one day. Blizzard conditions occur less frequently in the western sheltered valleys than over the exposed plains to the east. With the exception of the eastern portion of the drainage area, snow cover over the plains area and lower valleys is rarely continuous through the winter due to drifting caused by high winds and melting caused by the warming effect of downslope "Chinook" winds.

2-15. Temperatures. Extreme seasonal temperatures are experienced in the upper Missouri River drainage basin with long and cold winters and relatively short and hot summers. Maximum temperatures in excess of 100° F. have been reported at most of the meteorological stations in the basin while winter temperatures of 20° F. below zero are quite common. The warmest months of the year are July and August with average temperatures generally in the upper 60's. The coldest month in the year is January with the average temperature usually in the upper teens. The mountains give the western portion of the basin some protection from cold waves which sweep out of the interior of Canada on an average of six to twelve times a winter resulting in snow and subzero temperatures. A few of the cold waves at times cover the entire basin. Often the cold waves are modified by the downslope Chinook winds resulting in the adiabatic heating of the east flow of air as it descends to lower elevations in crossing the mountains and results in abrupt ending of the intense cold followed by extended periods of mild weather. The so-called "Chinook Belt" extends from the Browning-Shelby area to the Yellowstone Valley above Billings. The transition from winter to summer is usually fairly rapid; however, cold weather may extend into May. During the summer the days are normally warm with cool nights and low humidity. The autumns are normally mild with occasional short periods of cold temperatures. Average monthly and annual temperatures for representative stations in the basin are shown on Plate 6.

2-16. Storm Potentialities. Major storms throughout the basin result almost exclusively from conditions accompanying frontal systems. During winter months major storms and minor storms in the upper part of the basin often result in sufficient accumulation of snow to cause the greatest flows of the year at the time the accumulation of snow melts and appears as streamflow. Since frontal passages are more numerous in May and June, major storms occur more frequently in late spring and early summer than in late summer. A sequence of minor storms which exceed the infiltration capacity in the basin may also result in severe flooding due to the additional moisture from the later storms contributing much larger volumes to the streamflow than if the soil was relatively dry prior to the later storms.

II-C. Runoff of the Upper Missouri River.

2-17. Runoff Records. Records of runoff at gaging stations on the Missouri River and its tributaries in the drainage basin above Fort Peck Dam are recent in origin with the exception of a few stations. The longest continuous period of record in the basin is at Fort Benton where reliable records date back to October 1890. A few of the tributary stations have records starting around 1890 but there are long periods of time when no records are available. The more important gaging stations which are pertinent to the regulation of Fort Peck Lake are Fort Benton, Virgelle and Landusky on the Missouri River above the reservoir and Wolf Point on the Missouri River and Nashua on the Milk River below the reservoir where records date back to October 1890, February 1935, February 1934, September 1928, and October 1939, respectively. Daily discharges at these locations are published in appropriate U. S. Geological Survey Surface Water Records. The Corps of Engineers also maintains records of runoff originating above Fort Peck from which the inflow to the lake shown on Plate 14 were developed.

2-18. Source of Runoff. The mountain area in the western portion of the basin will normally contribute the greatest share of the total water year runoff into Fort Peck Lake with the largest volume occurring during the "late spring" or "June Rise" period. The plains area of the basin is occasionally a major source of runoff with large contributions occurring during the "early spring" or "March Rise" period. High intensity rainstorms throughout the basin during the spring and summer months often cause locally high runoff volumes of short duration. Average annual runoff for the Missouri River and its tributaries above the mouth of the Yellowstone River are shown in Table 2. Plate 7 shows the annual and seasonal runoff probabilities for the drainage basin above Fort Peck Dam.

2-19. Seasonal Runoff Pattern. Since very little mountainous area drains into the Milk River, runoff appearing as streamflow in its lower reaches results largely from the melt of the winters accumulation of plains snow cover and rains during the spring and early summer period. Plate 8 illustrates the monthly distribution of flow volumes and seasonal peak discharges of this river. Runoff from the Missouri River drainage basin above Fort Peck Dam follows a characteristic seasonal hydrologic pattern as illustrated by the monthly distribution of flow volumes and seasonal peak discharges shown on Plate 9 . This pattern is generally as follows:

a. Winter is characterized by frozen streams; progressive accumulation of snow in the mountain areas; and intermittent snowfall and thaws in the plains area where the season usually ends with a "spotty" snow cover of

TABLE 2

Average Annual Runoff on the Missouri River
and Principal Tributaries Above the Mouth of the Yellowstone River

Stream	Station	Drainage Area Sq. Mi.	Period of Record	No. of Years	Avg. Annual Discharge c.f.s.
Jefferson R.	Near Twin Bridges	7,632	1940-1943 1957-1972	18	2,014
Madison R.	McAllister	2,186	1938-*	36	1,744
Gallatin R.	Logan	1,795	1893-1905 1928-*	58	1,036
Missouri R.	Toston	14,669	1910-1916 1941-*	39	5,307
Missouri R.	Below Holter Dam	17,149	1945-*	29	5,461
Dearborn R.	Craig	325	1945-1969	24	218
Smith R.	Eden	1,594	1951-1969	18	328
Missouri R.	Ulm	20,941	1957-*	17	6,564
Sun R.	Vaughn	1,854	1934-*	40	724
Missouri R.	Great Falls	23,292	1956-*	18	7,687
Missouri R.	Fort Benton	24,749	1890-*	84	7,691
Marias R.	Shelby	(1) 3,242	1902-1906 1911-*	66	949
Marias R.	Near Loma	(1) 6,995	1959-1972	13	977
Teton R.	Dutton	(2) 1,307	1954-*	20	157
Missouri R.	Virgelle	34,379	1935-*	39	8,391
Missouri R.	Near Landusky	40,987	1934-*	40	9,100
Musselshell R.	Mosby	7,846	1930-1932 1934-*	42	247
Missouri R.	Ft. Peck Dam	57,500	1898-*	76	10,022
Milk R.	Nashua	22,332	1939-*	35	693
Missouri R.	Wolf Point	82,290	1928-1939 1943-*	11 31	(3) 7,219 (4)10,150
Poplar R.	Poplar	3,174	1908-1924 1947-1969	38	133
Missouri R.	Culbertson	91,557	1943-1951 1958-*	24	10,250

(1) 518 sq. mi. probably non-contributing
(2) Teton R. major tributary of the Marias R.
(3) Prior to Fort Peck Res. reaching operational level
(4) After Fort Peck Res. reached operational level
* To date

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 quite low.

b. Early Spring is marked by a rapid melting of snow and ice, usually in March or April, in the plains area as temperatures rise rapidly, accompanied usually by very little rainfall. Due to the tendency of temperatures to rise above freezing first to the south and west, and the northerly drainage pattern of the upper basin, severe ice jams are frequently experienced on the upper Missouri River and its tributaries. The rapid release of water from melting snow results in a flashy "March rise" on the Missouri River. Snowmelt in the mountains also usually begins in this period but contributes little to runoff until later in the year.

c. Late Spring, consisting generally of the months of May, June and early July, is characterized by occasional extensive general rains sometimes accompanied by severe local rainstorms, and the most rapid melting of snow in the mountains. The peak runoff from these conditions usually occurs in late May, June or the early part of July. This results in a characteristic "June rise" with peak discharges usually less and volumes of runoff greater than the Early Spring rise. A short interlude of moderately low discharges usually is experienced between the Early Spring and Late Spring rises.

d. Summer and Autumn are generally characterized by diminishing general rainfall, fairly frequent widely scattered intense local rainstorms, and occasional severe storms. Flow in the rivers usually decreases rapidly from the June flows, and thereafter decreases generally, with infrequent interruptions, to the low flows which prevail in winter.

II-D. Missouri River Open-River Channel Capacities.

2-20. General. The Missouri River is essentially a mountain stream flowing in a deep canyon through a very rugged mountain region to above the town of Cascade. Between Great Falls and Virgelle, Montana, the river flows progressively through steep, narrow canyon sections, characterized by sheer falls and numerous rapids, into a narrow valley bordered by hills that slope steeply to the water's edge in many reaches and finally assumes the traits of an alluvial stream as the valley widens in the vicinity of Virgelle. In the reach between Fort Peck Dam and the mouth of the Yellowstone River, the Missouri River has the characteristics of a typical, alluvial stream flowing in a meandering pattern within a valley varying from one to three miles in width. The alluvial nature of the river results in caving banks and shifting sandbars becoming more pronounced in this reach. The maximum flow which may be passed without damage will vary in the upper Missouri River basin, and is dependent upon channel characteristics, the degree of economic encroachment upon the flood plain and upon improvements such as levees and channel modifications. Capacities will vary from season to season with a decrease in capacity during the winter and early spring when an ice cover is formed. A discussion on the effect of ice is contained in paragraph 2-25.

2-21. Channel Capacities. The average open water channel capacity increases in a downstream direction approximately in proportion to the average flow of the tributaries as shown in Table 3. During the winter ice cover those open water capacities are markedly reduced, as will be discussed in subsequent paragraphs.

2-22. Flood Damages. Damages begin with open water flows at 30,000 c.f.s. in the reach between Fort Peck to the mouth of the Yellowstone River, however, with flows ranging from 50,000 c.f.s. in the upper portion of the reach to 70,000 c.f.s. in the lower portion, damages are relatively minor and limited largely to pasture and wasteland. Rating and damage curves, relating stage at particular locations with open-river discharge and damages through an adjacent reach along the upper Missouri River are shown on Plate 10. These curves were developed from presently available data and are considered applicable to present conditions. For further discussion on this subject reference should be made to the Master Manual.

II-E. Ice Formation.

2-23. Ice Cover Season. The upper Missouri River and its tributaries are at least partially ice covered for several months of the year with this period usually extending from late November to late March. Ice thickness on streams in the basin will range up to 2 to 3 feet with the greatest thickness of ice on the slower flowing streams. A tabulation of the record of ice cover in Fort Peck Lake is shown in Table 4. From this it may be noted that reservoir ice cover has formed as early as 29 November with ice breakup occurring as late as 9 May. The reservoir ice cover will normally lag that on the streams by about one month.

2-24. Effect on Streamflow. During the freeze-up of the Missouri River and its tributaries above Fort Peck a very noticeable drop in reservoir inflow occurs due to a large volume of water going into ice storage. On the other hand, there is a corresponding marked increase in reservoir inflow during the ice breakup in the spring.

2-25. Effects on Channel Capacities. Formation of ice cover greatly decreases the channel capacities of any given stage of the stream. This reduction varies considerably from location to location, season to season, and at a specific location during a single winter period. Observation of flows in the reach between Fort Peck Dam and the mouth of the Yellowstone River indicates that, with minor tributary inflows, Fort Peck releases of 10,000 c.f.s. or less at the time an ice cover initially forms and ranging up to 15,000 c.f.s. after the downstream ice cover has stabilized will not contribute to material damages in this reach.

TABLE 3

Estimated Open Water Channel Capacities
of the Missouri River, Headwaters to Mouth of Yellowstone River

Reach or Town	Approximate Channel Capacity in c.f.s.	Corresponding Stage Ft. M.S.L.
Three Forks to 2 Miles below Townsend:	15,000	
- Trident	30,000	
- Townsend	30,000	
Canyon Ferry to Holter Dam	30,000	
Holter Dam to Mouth of Sun River:	20,000	
- Craig	40,000	
- Ulm	50,000	3324
Mouth of Sun River to Mouth of Marias River:		
- Great Falls	50,000	
- Fort Benton	80,000	2628
Mouth of Marias to Fort Peck Lake	80,000	
Below Fort Peck Dam	50,000	2030
Wolf Point	60,000	1971
Culbertson	70,000	1898

TABLE 4

Record of Ice Formation in Fort Peck Lake

Year	Reservoir Frozen Over	Ice Breakup
1941-42	26 Dec	15 April
1942-43	7 Dec	10 April
1943-44	9 Feb	13 April
1944-45	2 Jan	31 March
1945-46	23 Dec	29 March
1946-47	29 Dec	17 April
1947-48	16 Jan	22 April
1948-49	28 Dec	20 April
1949-50	31 Dec	9 May
1950-51	4 Jan	1 May
1951-52	21 Dec	29 April
1952-53	15 Jan	6 April
1953-54	16 Jan	15 April
1954-55	25 Jan	15 April
1955-56	29 Nov	21 April
1956-57	10 Jan	23 April
1957-58	2 Feb	10 April
1958-59	5 Jan	17 April
1959-60	6 Jan	13 April
1960-61	29 Jan	25 March
1961-62	19 Dec	20 April
1962-63	21 Jan	3 April
1963-64	13 Jan	16 April
1964-65	24 Dec	4 May
1965-66	20 Jan	16 April
1966-67	18 Jan	19 April
1967-68	3 Jan	30 March
1968-69	2 Jan	23 April
1969-70	9 Jan	30 April
1970-71	6 Jan	19 April
1971-72	29 Dec	17 April
1972-73	5 Jan	27 March
1973-74	8 Jan	14 April
1974-75	28 Jan	26 April

2-26. Ice Blocks and Jams. The breakup of the ice cover often causes ice jams which have a marked effect upon streamflow during such periods. Downstream flow and accompanying stages may be reduced at the beginning of the ice jam while stages just upstream may rise at restricted points and cause some overbank flooding. The volume of ice in any particular reach of the river which may contribute to jamming is a function of the thickness of the ice, the width of the river and the length of the reach. With low stages the river width, and consequently the ice volume within the reach, is reduced from that of higher stages. Fort Peck Lake traps the flowing ice from the upstream portion of the river and thereby reduces the probability of severe ice jams in the reach of the Missouri River from Fort Peck Dam to the mouth of the Yellowstone River.

II-F. Floods.

2-27. General. Floods in the upper Missouri River drainage basin are of three types: floods caused by mountain snowmelt frequently augmented by rainfall in the foothills and plains areas; floods caused by plains area snowmelt accompanied by ice jamming; and floods caused by intense rains which are usually of the thunderstorm type. Usually the floods in the basin will occur either in the early spring flood period of March or April, or in the late spring period of late May, June or early July. The flood of 1881 was an early spring flood of considerable magnitude which occurred prior to the establishment of the gage at Fort Benton, Montana. The records of the U. S. Geological Survey indicate that the largest known flood on the Missouri River above Fort Peck Dam was that of June 1908. Although later floods were controlled to a varying extent by reservoirs both on the main stem and tributaries, the flood of June 1948 was the second greatest in the upper part of the basin and the flood of 1953 the second largest in the lower reaches in central Montana. The flood of 1964 was caused by a combination of snowmelt and heavy rainfall, including one of the largest and most intense major rainstorms which has occurred in northwestern Montana. Brief description of these floods are given in the following paragraphs.

2-28. Flood of 1881. The flood of March-April 1881 was one of the greater early spring floods occurring on the Missouri River above Fort Peck Dam for which information is available. Following a wet year in 1880, the winter of 1880-81 was marked by below-normal temperatures and heavy snows, resulting in heavy snowfall in the mountainous headwaters region and the heaviest known snow blanket on the plains area by spring. Unusually warm weather in Montana resulted in spring thaws and ice breakup accompanied by spring rains in the upper part of the basin beginning in late February and early March while the lower part of the river was still frozen. This caused heavy flooding in March in the Fort Peck drainage basin and severe flooding downstream from Fort Peck. Discharge records of the Missouri River in the Fort Peck drainage basin were not available prior to 16 June 1881; however, hydrographic comparisons with gage heights at Bismarck, North Dakota, adjusted to agree with available precipitation records, indicates that the flow at the Fort Peck damsite reached a peak of about 85,000 c.f.s. on 26 March during the 1881 flood. The 1881 early spring flood was followed by a late spring and summer flood with an appreciable volume of flow characterized by moderate sized peaks.

2-29. Flood of 1908. U. S. Geological Survey records indicate the 1908 flood was probably the greatest flood to date in the reach of the Missouri River between Helena, Montana, and the Yellowstone River. This was also the greatest known flood on many of the tributaries in the Fort Peck drainage basin. This flood was caused by heavy rainfall in the latter part of May and early days of June followed by the occurrence of a severe rainstorm on 3-6 June. This rain accompanied by the mountain snowmelt caused basin-wide flooding and considerable damage. The amount of damage in the reach from Fort Peck to the mouth of the Yellowstone River with a flow of 154,000 c.f.s., the estimated crest discharge, would be about $1,500,000 using present day costs. Insufficient data are available to estimate the damages which would result in other reaches. Available gage and discharge information in the Fort Peck basin for this flood is shown in Table 5.

2-30. Flood of 1948. In the period from 20 May to 19 June 1948 damaging floods occurred in the basin above Fort Peck. A sudden rise in temperature during May caused an above normal snow pack in the mountain areas to melt rapidly and the resultant runoff coupled with runoff from heavy rainfall which occurred over the area caused flooding on the main stem of the Missouri River and a majority of its tributaries from the headwaters to the Fort Peck Lake. Records of the National Weather Service indicate that June 1948 was the 3rd wettest June since records began in 1895. Precipitation recorded for the period 30 May 1948 to 15 June 1948 was 2.97 inches at Belgrade, Montana, 2.36 inches at Helena, Montana, and 3.04 inches at Great Falls, Montana. Approximately 51,220 acres were flooded in the basin upstream from Fort Peck during this period. Total damages were estimated to be $1,465,943. Operation of Fort Peck Lake during this period prevented flooding in the reach from Fort Peck Dam to the Yellowstone River. The maximum average daily inflow into the lake during this period was about 81,900 c.f.s., while releases were limited to 25,000 c.f.s. Pertinent stages and discharges in the Missouri River Basin above Fort Peck Dam for this flood are shown in Table 5.

2-31. Flood of 1953. This flood is second to the flood of June 1908 in general magnitude and extent in the central Montana area of the Fort Peck drainage basin. Snowmelt from the normal winter's accumulation of snow combined with runoff from the storm sequence of late May and early June resulted in high flows. Although high altitude snow surveys on 1 April and 1 May indicated normal snowpack, subnormal spring temperatures allowed more of the snow to remain on the ground through April and most of May up to the time of the runoff producing storms. The storm period extended from 24 May through 3 June. Three distinct storms with accompanying precipitation moved through the region during this period. The first storm on 24 and 25 May left snow in the uplands and rain in the lowlands. Similar storms on 29 May and 2 and 3 June, each more severe than the preceding one, occurred. Flood-producing runoff started with the second storm and was increased by the third storm. This condition caused flooding on the main stem and a greater portion of the tributaries of the Missouri River from the eastern slopes of the continental divide in central Montana to Fort Peck Lake. Records of the National Weather Service indicate the month of May to be one of the wettest recorded, exceeded only three times since 1895. The stations in the area of heavy rainfall reported the highest recorded for June. Precipitation amounts recorded for the period from 23 May to 4 June 1953 were 8.69 inches at Choteau, Montana, 9.43 inches at Great Falls, Montana, 12.92 inches at Highwood, Montana, and 19.90 inches at Shonkin, Montana, with 6.52 inches occurring in a 24-hour period. In the higher areas to the west, snowmelt was added to the runoff from rainfall. General flooding of rural areas occurred along the main stem and most of the tributaries of the Missouri River upstream from the Fort Peck Lake and resulted in the inundation of approximately 54,800 acres of land and total damages estimated to be $5,756,890. Municipal flooding occurred at Sun River and Great Falls, Montana, on the Sun River; Belt and Highwood, Montana, on the Belt and Highwood Creeks; and Lewistown, Montana on Big Spring Creek causing total estimated damages of $1,004,450. The Fort Peck Lake Project prevented floods in the area downstream from the dam. The inflow to Fort Peck Lake during the flood period reached a peak of about 120,000 c.f.s. daily average flow, whereas releases from the lake averaged about 3,000 c.f.s. Stage reductions effected by the Fort Peck Lake ranged from about seven feet at Bismarck, North Dakota, and Omaha, Nebraska, to about 3.5 feet at Waverly, Missouri. As a result, it is estimated that flood control operations of the lake during this period prevented the downstream flooding of valley land and reduced flood damages by approximately $13,634,000. Pertinent stages and discharges in the Fort Peck basin for this flood are shown in Table 5.

2-32. Flood of 1964. The direct cause of the June 1964 flood in Montana was heavy rainfall creating a large volume of runoff into stream channels that were already carrying heavy runoff from mountain snowmelt. Snow surveys made on 1 May 1964, indicated that the snowpack in the mountains was generally 150 to 200 percent of normal. Precipitation during the month of May in the area was well above normal and conditions were favorable for runoff at elevations below the snowpack. During early June, tributary irrigation reservoirs in the area were filled or rapidly filling, mountain snowmelt was in progress, and streams were high--but not flooding. Then on 7 and 8 June 1964, a major rainstorm, one of the largest and most intense of record, occurred over the northwestern portion of Montana. The storm extended generally from Lewistown, Montana, northwestward into Canada and across the continental divide. It covered all of the mountain region west and northwest of Great Falls and extended over the plains area northeast and southeast of Great Falls. The heaviest amounts of rainfall were reported along the eastern slope of the continental divide. Rainfall amounts reported for the period were 14.5 inches in the Two

Medicine Lake area; 13.0 inches, 27 miles west and northwest of Choteau; 12.8 inches, 13 miles southwest of Augusta and 11.0 inches at Heart Butte. The heavy rainfall coupled with high snowmelt runoff caused unprecedented flooding in the Sun and Marias River Basins.

2-33. The Missouri River drainage area most seriously affected by this flood was the portion of the basin lying between Canyon Ferry Dam and the mouth of the Marias River. Severe flooding was experienced throughout the Sun River Basin. Urban areas of Augusta, Sun River, Vaughn and Great Falls sustained extensive damage from stages that exceeded any experienced in the past. Flooding in the Marias River Basin was equally widespread and severe. Flooding was experienced along the entire length of the Teton River, a major tributary, of the Marias River. Floodwaters from the Teton River and a tributary, Spring Creek, combined to flood practically the entire town of Choteau. Flooding on the Marias River was limited to the basin above Tiber Dam. Pondera Coulee, which flows into the Marias River below Tiber Dam, and all of the headwater stream of the Marias River experienced flooding. Damages in the basin were compounded by failure of two irrigation dams, Swift Dam on Birch Creek and Lower Two Medicine Dam on Two Medicine Creek. Swift Dam released in excess of 30,000 acre-feet of stored water and Lower Two Medicine Dam added over 20,000 acre-feet of stored water to the flood when they failed. Other contiguous and outlying basin areas sustaining flood damage from the 1964 June floods include the Milk and St. Mary Rivers which flow into Canada, the Judith River, Musselshell River, Dearborn River, Jefferson River, Belt Creek and Highwood Creek Basins, the main stem of the Missouri River from Canyon Ferry Dam to Fort Benton, and other minor tributary drainage basins of the Missouri River from its headwaters to Fort Peck Lake.

2-34. Urban flooding occurred at Great Falls, Montana, on the Missouri and Sun Rivers; Vaughn, Sun River and Augusta, Montana, on the Sun River; Choteau, Montana, on the Teton River; Shelby, Dupuyer, East Glacier Park and Browning, Montana, in the Marias River Basin; St. Mary, Montana, on Divide Creek, a small tributary of the St. Mary River; Lewistown, Montana, on the Judith River; Raynesfor, Montana, in the Belt Creek Basin, and in the vicinity of Fort Benton on the Missouri River, causing total estimated damages of $6,451,000. Rural damage to crops, farmsteads, fences, irrigation works and lands in the drainage basin above Fort Peck Dam total in excess of $13,000,000. Damage to transportation facilities are estimated at nearly $12,150,000. Flood damages prevented by Tiber Dam and Reservoir downstream from Tiber Dam on the Marias River and on the main stem of the Missouri River are estimated to be $600,000. Canyon Ferry Dam and Lake is credited with prevention of $60,000 in flood damages in Montana. The inflow into Fort Peck Lake during this flood period reached a peak of about 90,000 c.f.s. daily average flow, whereas the maximum release from the lake was approximately 9,000 c.f.s. During this period Fort Peck Lake was regulated to prevent flooding in the reach between Fort Peck Dam and the mouth of the Yellowstone River and as part of the Missouri River main stem reservoir system to reduce downstream flood stages. Stage reductions of the 1964 June flood which were affected by the Missouri River main stem reservoir system ranged from 15.7 feet at Omaha, Nebraska, to 4.5 feet at Herman, Missouri. Flood damages prevented by the Missouri River main stem reservoir system during the flood of June 1964 are estimated to be $41,673,000. Pertinent stages and discharges in the Fort Peck Basin for this flood are shown in Table 5.

2-35. Flood of 1975. The March-July flood season runoff originating above the main stem reservoir system was the largest since records first became available in 1898, exceeding the previous maximum by approximately one million acre-feet. The greatest runoff excess occurred in the drainage area above Fort Peck Lake where the flood season runoff was over twice that usually occurring and almost two million acre-feet greater than occurred in any comparable period for which there is record.

2-36. During January and February of 1975 the runoff outlook for the main stem system was less than the long term average. With increasing mountain snow accumulations and a heavy snowfall occurring on the plains of North and South Dakota the runoff outlook increased to the long term normal during March. In April, with precipitation in Montana and western North Dakota being extremely heavy (some precipitation amounts were four times greater than the normal) the runoff prospects increased to approximately greater than the long term normal. Early in the month of June the outlook was for approximately 9 million acre-feet of runoff greater than the long term normal but a major storm occurred on 18-19 of June. The center of the storm was located east of the Continental Divide in Montana with a rainfall center of over 14 inches with average depths of 10 inches covering 2,500 square miles, while a 10,000 square mile area had an average rainfall exceeding 6 inches. As a result of this storm many maximum stages and flows were recorded. The following is a list of some of the stations recording maximum discharges

STREAM OR RIVER	LOCATION (MONT.)	1975 DISCHARGE	PREVIOUS HIGH DISCHARGE
Musselshell	at Harlowton	20 June-7300 cfs	4500 cfs in 1938
So. Fork Musselshell	above Martinsdale	19 June-4300 cfs	1330 cfs in 1967
Boulder River	near Boulder	19 June-3500 cfs	3490 cfs in 1964
Judith River	near Ithaca	20 June-1750 cfs	1120 cfs in 1927
Boulder Creek	near Maxwell	19 June-1300 cfs	764 cfs in 1953
Prickly Pear Creek	near Clancy	19 June-1070 cfs	700 cfs in 1927
Tenmile Creek	near Rimini	19 June- 990 cfs	718 cfs in 1917

2-37. This storm resulted in serious flooding in Montana with most of the urban flooding occurring in Great Falls, Montana. Flood damages along the main stem of the Missouri River during the January-July period are estimated to be 18 million dollars. Canyon Ferry Dam and Lake is credited with prevention of $6,944,000 in flood damages. Tiber Dam and Reservoir and Clark Canyon Dam and Reservoir are credited with the prevention of $19,919,000 and $1,392,000 in flood damages respectively. The main stem system is credited with preventing an additional $87,000,000 worth of flood damage. Pertinent stages and discharges in the Fort Peck Basin for this flood are shown in Table 5.

TABLE 5a

MISSOURI RIVER AND TRIBUTARIES ABOVE FORT PECK RESERVOIR

CREST STAGES AND DISCHARGES FOR MAJOR FLOODS

		1908 Flood			1948 Flood			1953 Flood		
Stream	Station	Date	Peak Gage Height	Discharge C.F.S.	Date	Peak Gage Height	Discharge C.F.S.	Date	Peak Gage Height	Discharge C.F.S.
Red Rock River	Lima	7 June	-	882						
Beaverhead River	Barretts	20 June	6.1	3,720	5 June	4.2	2,150	4 June	3.6	1,710
Jefferson River	Sappington	-	-	-	6 June	11.0	19,900 1/	16 June	9.0	12,200
Madison River	Below Ennis L.	-	-	-	4 June	6.0	5,420	13 June	6.0	5,380
Gallatin River	Logan	-	-	-	5 June	8.4	7,870 1/	14 June	7.3	5,930
Missouri River	Toston	-	-	-	6 June	11.8	32,000 1/	16 June	10.0	22,000
Missouri River	Below Holter Dam	-	-	-	8 June	11.7	34,800 1/	19 June	6.1	13,500
Dearborn River	Clemons	2 June	-	4,000	4 June	6.0	3,420	4 June	6.2	3,200
Dearborn River	Craig	-	-	-	5 June	7.9	4,400	4 June	9.6	7,960
Missouri River	Cascade	5 June	16.7	54,250	-	-	-	-	-	-
Smith River	Eden	-	-	-	-	-	-	4 June	10.5	12,300 1/
Missouri River	Ulm	-	-	-	-	-	-	-	-	-
N. Fk. Sun River	Augusta	7 June	-	20,000	3 June	7.0	4,320	3 June	6.4	3,990
Willow Creek	Augusta	5 June	-	900	-	-	-	-	-	-
Smith Creek	Augusta	4 June	5.5	1,500	5 June	5.7	1,830	-	-	-
Ford Creek	Augusta	4 June	-	1,030	-	-	-	-	-	-
S. Fk. Sun River	Augusta	2 June	6.8	4,300	-	-	-	-	-	-
Sun River	Sun River	7 June	13.4	27,200	-	-	-	-	-	-
Muddy Creek	Vaughn	June	24.0	-	17 June	10.2	1,470	4 June	17.7	7,600
Sun River	Vaughn	-	-	-	6 June	13.5	14,300	4 June	16.4	17,900
Missouri River	Great Falls	-	-	-	-	-	-	-	-	-
Missouri River	Fort Benton	6 June	18.5	140,000	7 June	10.9	52,800	5 June	13.6	78,700
Dupuyer Creek	Dupuyer	5 June	4.8	1,080	-	-	-	-	-	-
Cutbank Creek	Cutbank	5 June	11.0	10,400	-	-	-	8 June	8.5	5,640
Marias River	Shelby	-	-	-	18 June	17.8	40,000 1/	5 June	12.8	21,000
Marias River	Brinkman	19 June	24.0	70,000	19 June	21.0	50,700 1/	5 June	16.3	28,100
Marias River	Loma	-	-	-	-	-	-	-	-	-
Teton River	Strabone	10 June	-	2,300	-	-	-	-	-	-
Teton River	Dutton	-	-	-	-	-	-	-	-	-
Missouri River	Loma	-	-	-	20 June	17.6	92,000	5 June	21.0	121,000 1/
Missouri River	Near Landusky	-	-	-	21 June	18.2	93,200	6 June	22.2	137,000 1/

1/ Maximum discharge of record (does not include flood of 1908)

TABLE 5b

MISSOURI RIVER AND TRIBUTARIES ABOVE FORT PECK RESERVOIR

CREST STAGES AND DISCHARGES FOR MAJOR FLOODS

Stream	Station	1964 Flood Date	1964 Flood Peak Gage Height	1964 Flood Discharge C.F.S.	1975 Flood Date	1975 Flood Peak Gage Height	1975 Flood Discharge C.F.S.
Red Rock River	Lima	28 May to 8 June	2.2	504			
Beaverhead River	Barretts	19 June	3.7	1,910	20 June	3.59	1,680
Jefferson River	Sappington	12 June	10.2	16,000			
Madison River	Below Ennis L.	28 June	6.2	5,660	26 June	6.14	5,250
Gallatin River	Logan	8 June	7.4	6,290	4 July	8.44	7,770
Missouri River	Toston	12 June	10.0	22,000	26 June	10.52	25,000
Missouri River	Below Holter Dam	19 June	10.0	27,100	23 June	8.10	19,300
Dearborn River	Clemons	-	-	-			
Dearborn River	Craig	9 June	13.5	15,400			
Missouri River	Cascade	-	-	-			
Smith River	Eden	10 June	5.5	3,860			
Missouri River	Ulm	22 June	14.4	27,500	22 June	14.64	27,200
N. Fk. Sun River	Augusta	8 June	15.8	51,100			
Willow Creek	Augusta	-	-	-			
Smith Creek	Augusta	-	-	-			
Ford Creek	Augusta	-	-	-			
S. Fk. Sun River	Augusta	-	-	-			
Sun River	Sun River	-	-	-			
Muddy Creek	Vaughn	9 June	12.2	3,720			
Sun River	Vaughn	9 June	23.4	53,500 1/	22 June	22.28	29,000
Missouri River	Great Falls	10 June	-	72,000	21 June	N.A.	60,180
Missouri River	Fort Benton	10 June	13.4	77,400	21 June	11.87	62,000
Dupuyer Creek	Dupuyer	-	-	-			
Cutbank Creek	Cutbank	9 June	13.9	16,600			
Marias River	Shelby	9 June	23.6	241,000 2/	20 June	18.2	76,000
Marias River	Brinkman	-	-	-			
Marias River	Loma	16 June	8.7	10,800			
Teton River	Strabone	-	-	-			
Teton River	Dutton	9 June	18.9	71,300	20 June	14.8	15,500
Missouri River	Loma	-	-	-			
Missouri River	Near Landusky	11 June	19.7	114,700	23 June	29.07	77,000

1 Maximum discharge of record (does not include Flood of 1908)

2 Largely due to failure of Swift Dam

2-38. Other Floods. Other floods of significance in the Fort Peck drainage basin include those of the years of 1886, 1887, 1892, 1894, 1916, 1917, 1927, 1943, 1947, and 1952. The 1886 and 1887 floods were June rises and apparently had very similar characteristics of a fairly high peak in a relatively short period of time. The peak discharge at the Fort Peck damsite was estimated to have been about 70,000 c.f.s. on 18 June during the 1886 flood and about 73,000 c.f.s. on 17 June during the 1887 flood. The 1892 and 1894 floods were also June rises, the 1892 flood cresting with a peak discharge of about 93,000 c.f.s. on 15 June at the Fort Peck damsite and the 1894 flood cresting at about 78,000 c.f.s. on 9 June. The 1916 flood was characterized by a relatively sharp discharge peak of about 73,000 c.f.s. occurring at the Fort Peck damsite on 27 June followed by another sharp peak of approximately 95,000 c.f.s. on 2 July. The 1917 and 1927 floods had very large volumes of runoffs. During the 1917 flood the flow at Fort Peck damsite was estimated to have been above 50,000 c.f.s. from 16 May to 4 July with a peak discharge of approximately 75,000 c.f.s. occurring on 28 May. In 1927 the flow at the Fort Peck damsite was estimated to have been in excess of 50,000 c.f.s. from 28 May to 27 June with peak discharges of 75,000 c.f.s. and 78,000 c.f.s. occurring at Fort Peck on 3 June and 15 June, respectively. The flood of 1943 was characterized by a high peak discharge of relatively short duration followed by a secondary peak after a short period of time. Peak flows recorded during this flood were 38,500 c.f.s. on 16 June at Fort Benton, 55,800 c.f.s. on 17 June at Loma, and 63,800 c.f.s. on 20 June near Landusky, Montana. The 1947 flood was an early spring flood resulting from snowmelt combined with the break-up of the river ice cover. This caused damaging floods upstream from the Fort Peck Lake and from Fort Peck downstream to the mouth of the Yellowstone River. During the 1947 flood, inflows to Fort Peck Lake exceeded 15,000 c.f.s. from 17 March to 28 March and reached a peak of 93,000 c.f.s. on 22 March. In 1952 extended periods of thawing temperatures in the lower reaches caused major flooding during late March and early April. Snowmelt runoff caused major flooding on minor tributaries on the Missouri River above Fort Peck. During this period there was also sporadic ice jam flooding on the Missouri River above Fort Peck. The peak flow near Landusky due to ice jamming was 55,000 c.f.s. on 29 March and inflow to Ft. Peck on 31 March was 86,400 c.f.s. The estimated damages for the area above Fort Peck was $355,100.

II-G. Sedimentation.

2-39. General. The sediments contributing to the delta formations within Fort Peck Lake are derived from two general sources; (1) the alluvial material forming the banks and bed of the Missouri River and its tributaries within their entrenched valleys, and (2) sheet erosion of the weathered surface of the uplands terrain. In general, their origin is limited to the drainage area downstream from Cascade, Montana since several small powerplant reservoirs located upstream entrap most of the headwater contribution. In the vicinity of Virgelle, where the Missouri River assumes the traits of an alluvial stream, channel meanderings develop with shifting sandbar formations, and bank erosion becomes more pronounced. Upstream from this alluvial transition point the streambed and banks are essentially stable due to the abundance of rock and gravel. The channel erosion below Virgelle can be severe during periods of high flows and particularly where the channel has cut into the Bearpaw shale formation. Sheet erosion of the weathered uplands surface is accomplished by runoff from either rainstorms or snowmelt. Although the amount of precipitation occurring over this plains area is relatively low, the gross erosion potential is increased by wind erosion during dry periods which causes surface soils to accumulate in drainage courses, or coulees, where it is available for transport by surface runoff into tributary streams. The Bearpaw shale formation is particularly susceptible to such erosion. Sediment carried in suspension at the Powerplant Ferry sampling station above Fort Peck Lake generally consists of 35 percent sand, 25 percent silt, and 40 percent clay. Prior to the closure of Fort Peck Dam, the Missouri River probably transported an average of 15 to 20 million tons of sediment past the damsite each year.

2-40. Downstream from Fort Peck Dam, the bed of the Missouri River is composed essentially of medium to fine sand with occasional segments of gravel and cobbles and outcrops of clay and shale. The channel, averaging 800 to 1,200 feet in width depending upon sandbar or island configurations, flows between vertical banks varying up to 15 feet in height. The bank materials consist predominately of a mixture of fine sand and silts interspersed with lenses or pockets of dense, resistant clay formations.

II-H. Miscellaneous Data.

2-41. Travel Time. Travel time for the Missouri River and its tributaries in the drainage basin above Fort Peck Dam and the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River is shown on Plate 11. The travel time as shown is for average travel time of moderate rises at or near bankfull levels.

2-42. Frost Penetration. Frost penetration in the upper Missouri River basin normally begins in November with the incidence of below freezing mean temperature. The ground remains frozen until March or April. Depth of maximum frost penetration varies from 6 to 8 feet throughout most of the drainage basin above the mouth of the Yellowstone River except in the extreme northwest portion near the Canadian border where depths of 10 feet have been experienced. The major factors which influence the depths of the frost layer are snow cover, vegetation and temperature.

2-43. Reservoir Evaporation. The Fort Peck Lake is located in a region characterized by moderate-to-strong winds, low humidities, light precipitation and hot summers. For these reasons substantial evaporation occurs from Fort Peck Lake, particularly during the summer months. Low temperatures and higher humidities during the cold winter months result in greatly reduced evaporation during this season. Daily pan evaporation observations during the open water season have been made at the Fort Peck weather station since September 1934. No observations were made during the winter season when freezing temperatures occur. These observations plus winter estimates indicate that the average annual lake evaporation was approximately 47 inches for the excessively dry and hot period from 1935 through 1945 and 39 inches from 1946 through 1955. Based on the averal annual lake evaporation of 39 inches for the period 1946-55 and the mean annual precipitation rate of 13 inches for the Fort Peck area, the average net evaporation (average annual evaporation minus precipitation) would be about 26 inches for this period.

SECTION III - WATER RESOURCE DEVELOPMENT

III-A. History

3-1. Early Development (1804-1902). The first Federal exploration and survey of the Missouri River Basin was made by the Lewis and Clark Expedition of 1804-06 following the Louisiana Purchase in 1803. Information available indicates that it was probably in the late spring of 1805 when Lewis and Clark and their party reached the vicinity of Fort Peck. The removal of snags in the Missouri River by the Federal Government to improve navigation was begun as early as 1838. Water was diverted from the Missouri River for irrigation purposes by the early settlers in the 1850's.

3-2. In 1862 the Homestead Act was passed which led to increased immigration and settlement. This increase in travel, a large part of which was by river transport, led to further improvement of the river channel for navigation. The first work on the Missouri River above Sioux City was performed under the River and Harbor Act of 14 August 1876. The project provided for the removal of boulders and construction of the channel through the shoals in the "Rocky River" section of the Missouri River which extends from Ft. Benton for a distance of 150 miles downstream. Dredging was later added. Other early improvements included further channel rectification below Ft. Benton and in the reach from the crest of the falls at Great Falls to Cascade, Montana, and a small amount of open-river work in the steeper stretch of the river above Cascade. Projects below Ft. Benton were suspended due to cessation of navigation in 1889. No appropriation for improvement of navigation above Ft. Benton was made after 1896.

3-3. Later Development (1902-1944). In 1902 Congress passed the Reclamation Act for assistance in developing the western regions of the United States. This Act established the Reclamation Service (Bureau of Reclamation) and provided for Federal assistance in the development of irrigation projects which accelerated their development. Several hydroelectric power projects were developed during this period by the Montana Power Company on the Missouri River between Ft. Benton and Great Falls and on the upper reaches of the Missouri River and its tributaries in the mountainous region.

3-4. The 1927 River and Harbor Act authorized a multipurpose basin-wide series of investigations. The reports of these investigations are contained in the "308" report and includes the investigation of the Upper Missouri River and its tributaries. The first project undertaken as a result of the "308" report on the Missouri River Basin was the Fort Peck Project in Montana.

III-B. The Comprehensive Plan.

3-5. Conception. In 1943-44 the Corps of Engineers and the Bureau of Reclamation working separately, completed investigations and presented to Congress their separate reports on the development of the Missouri River Basin water resources. These reports were published as House Document

No. 475, 78th Congress, 2d Session and Senate Document No. 191, 78th Congress, 2nd Session. As a result of extensive congressional hearings the two plans were revised and coordinated by the two agencies. The coordinated plan, commonly known as the Pick-Sloan Plan was published as Senate Document No. 247, 78th Congress, 2d Session and was approved by Congress in the Flood Control Act of 1944.

3-6. Flood Control Act of 1944. Congress, in Section 9 of the 1944 Flood Control Act, approved the coordinated general comprehensive plan for water resource development in the Missouri River Basin and authorized the agencies to proceed. The program adopted was a long-range flexible plan for the development of water resources of the Missouri Basin for multiple-purpose uses. The general comprehensive plan provides for the construction of reservoirs for flood control, irrigation, navigation, and generation of hydroelectric power; the conservation, control and use of the water resources for related multiple-purpose such as municipal water supply, stream sanitation, recreation and wildlife preservation; local flood protection projects, projects for the irrigation of lands, together with provision for integrated conservation and improvement of the basin agricultural and forest lands. This plan is described in the Main Stem Master Manual.

3-7. Future Development. The comprehensive framework studies of the Missouri River drainage area above the mouth of the Yellowstone River drainage area visualize an intensive and increased economic efficiency of the agricultural base and the preservation, development, and management of its environmental attributes for the development of an economically viable recreation industry. Irrigation, coupled with land treatment measures, development of farm ponds, improved agricultural practices, erosion control, drainage, and flood control factilities offer opportunities for economic growth and higher land use efficiency. The developed framework plan includes the addition of over three million acre-feet of storage space by the year 2020, an addition of almost 500,000 acres of irrigated land, and land conservation measures applied to almost four million acres of federally owned land in the drainage basin.

III-C. Reservoirs.

3-8. General. A number of reservoirs have been constructed in the Missouri River Basin above the mouth of the Yellowstone River by Federal, state and private agencies. Several have been constructed by the Montana Power Company for hydroelectric power production. The Montana State Water Conservation Board, Irrigation Districts and the Bureau of Indian Affairs have numerous reservoirs in the basin that were constructed for irrigation purposes. There are also a number of reservoirs in the basin constructed by private organizations for irrigation purposes. Reservoirs in the drainage basin having a usable storage capacity of 5,000 acre-feet or more are shown in Table 6. In addition, many reservoirs with a storage capacity of less than 5,000 acre-feet used for irrigation and other conservation purposes, and numerous small stock ponds, have been constructed in the arid regions of the basin.

TABLE 6

RESERVOIRS IN THE MISSOURI RIVER BASIN
ABOVE THE MOUTH OF THE YELLOWSTONE RIVER
(Over 5,000 Acre-Feet Storage Capacity)

Reservoir	Basin	Useable Storage (1) Acre-Feet	Date Completed	Operated By (2)
Lima	Jefferson	84,050	1934	Private
Clark Canyon	Jefferson	328,900	1964	BR
Ruby	Jefferson	38,850	1938	MWCB
Delmoe Lake	Jefferson	6,600	1913	Private
Willow Creek	Jefferson	17,731	1938	MWCB
Hebgen Lake	Madison	377,500	1915	MPC
Earthquake Lake	Madison	35,000 (3)	(4)	----
Ennis Lake	Madison	34,210	1900	MPC
Middle Creek	Gallatin	8,030	1951	MWCB
Canyon Ferry	Missouri	1,615,000	1953	BR
Hauser Lake	Missouri	51,420	1907	MPC
Lake Helena	Missouri	10,450	1945	MPC
Holter Lake	Missouri	65,260	1918	MPC
Smith River	Smith	10,650	1936	MWCB
Gibson	Sun	105,000	1940	BR
Pishkun	Sun	32,050	1940	BR
Willow Creek	Sun	32,230	1941	BR
Nilan	Sun	10,090	1951	MWCB
Morony	Missouri	7,800	1930	MPC
Bynum	Teton	74,500	1926	Private
Lower Two Medicine Lake	Marias	16,620	1913	BIA
Four Horns	Marias	19,250	1932	BIA
Swift	Marias	29,980	1967	Private
Lake Frances	Marias	112,000	1913	Private
Tiber	Marias	1,313,000	1956	BR
Ackley Lake	Judith	5,820	1938	MWCB
Durand	Musselshell	7,000	1939	MWCB
Martinsdale	Musselshell	23,110	1939	MWCB
Deadman's Basin	Musselshell	72,220	1958	MWCB
War Horse Lake	Musselshell	23,800	1938	Private
Petroleum	Musselshell	9,190	1951	MWCB
Fort Peck	Missouri	14,800,000	1940	CE
Fresno	Milk	127,200	1939	BR
Nelson	Milk	66,800	1922	BR
Frenchman	Milk	7,010	1952	MWCB

(1) Storage available for release.
(2) MWCB - Montana State Water Conservation Board
CE - Corps of Engineers BIA - Bureau of Indian Affairs
BR - Bureau of Reclamation MPC - Montana Power Company
(3) Total Storage
(4) Formed by earthquake in 1959

3-9. Future reservoir development in this portion of the Missouri River Basin will be dependent on a satisfactory compromise to conflicts between such types of development and environmentally oriented desires to maintain the river and streams in their natural state. However, it is recognized that there is a need for further development in order to develop the irrigation potential of the region, provide flood protection to metropolitan and agricultural areas, sustain low water flows, provide lake based recreation opportunities and develop the hydroelectric power potential of the region. Recent comprehensive framework studies indicate that, from a purely developmental standpoint, additional reservoirs having a total storage capacity of slightly more than 12 million acre-feet would be required. However, with emphasis upon environmental objection, the total storage capacity would be reduced to 2.4 million acre-feet.

3-10. The framework plan as presented, features an additional storage capacity of about 3 million acre-feet developed by the year 2020 most of which would be included in 91 multiple purpose reservoirs. Fifteen multiple purpose projects would have an individual capacity in excess of 25,000 acre-feet and a total capacity of 2.3 million acre-feet while 76 multiple purpose projects with individual capacities or less than 25,000 acre-feet would have a collective capacity near 0.7 million acre-feet. Of the total multiple purpose storage space about 0.8 million would be for sediment or other inactive uses, 1.6 million acre-feet for conservation storage for joint beneficial uses and the remainder would be for exclusive flood control or regulation of high flows. The major storage projects visualized by the framework plan are on the lower Big Hole River (531,000 acre-feet) and on the Missouri River upstream from Fort Benton, Montana (921,000 acre-feet).

3-11. Effects on Fort Peck Lake Regulation. The upstream and tributary reservoirs affect the regulation of Fort Peck Lake by usually reducing the natural crest flows provided significant runoff contributing to the crest flows originates above these reservoirs. In certain instances a reservoir may increase the size of the crest below the project over that which would be observed naturally either by the speed-up of travel time through the length of the reservoir or by delaying a portion of the runoff from a sub-area and thereby contributing to a major crest on the main stream. However, with the storage space provided and the large number of reservoirs tributary to the main stem, the possibility of their aggregate effect increasing the main stem flows is remote.

3-12. Flood Control. Fort Peck Lake, as a multiple-purpose reservoir, is regulated to prevent or reduce flooding in the reach from Fort Peck Dam to the headwaters of Lake Sakakawea and as a component of the Missouri River main stem system of reservoirs to lower flood heights in the lower Missouri River valley. Many of the tributary reservoirs previously discussed may have incidental effects on flood flows; however, with the exception of Fort

Peck, only four reservoirs in this area of the Missouri Basin have been constructed and actively regulated for flood control as a stated purpose. These are Tiber on the Marias River, Clark Canyon on the Beaverhead River, Canyon Ferry on the headwaters of the Missouri and Fresno on the Milk River, all Bureau of Reclamation projects. Regulation of Fresno Reservoir for flood control consists only of having 40,500 acre-feet of space evacuated prior to the plains snowmelt in early March with the refill of this space and subsequent regulation based on multi-purpose needs.

3-13. Tiber Reservoir was initially designed with an allocation of 362,000 acre-feet for irrigation and 400,000 acre-feet for flood control; however, irrigation projects did not develop and the total allocation for flood control was temporarily increased to 690,000 acre-feet. Following the large 1964 flood, it was noted that failure of the spillway foundation was progressing and retention of significant storage for flood control purposes has been terminated. Since that time the spillway has been isolated from the reservoir and an emergency structure constructed. However, incidental flood control benefits do accrue and the Bureau of Reclamation has been willing to store up to their current seasonal rule curve under informal arrangements with the Corps of Engineers.

3-14. Agreement between the Corps of Engineers and the Bureau of Reclamation provides for exclusive flood control, replacement-joint use and local flood control-joint use storage zones in the Canyon Ferry Reservoir. Storage allocations include 104,276 acre-feet of exclusive flood space, 449,335 acre-feet of replacement-joint use space and 349,789 acre-feet of local flood control-joint use space. Exclusive flood control space is utilized only for control of large flood inflows and is evacuated as soon as local flood control objectives in the downstream reaches permit. Joint use space will be evacuated for flood control purposes prior to the flood season on the basis of forecasts of future inflows. During the flood season this joint use space will be filled while performing its flood control function. The storage so accumulated will be available for conservation purposes during the remainder of the year. Replacement storage space defines storage space in tributary reservoirs upstream from the main stem system of reservoirs which, if regulated in conjunction with the regulation of the main stem reservoirs, can replace a portion of the annual flood control and multiple use storage space in the main stem system. Replacement of annual flood control space in the main stem reservoirs allows an increase of carry over storage in the system while still providing the same degree of flood protection to the reaches below the system. Replacement and joint use space in tributary reservoirs is regulated by Corps of Engineers directives in such a manner to provide reasonable assurance of refill, provided sufficient runoff above minimum multi-purpose needs occurs, at the end of the mountain snowmelt season. It is available for conservation purposes from that time until its evacuation prior to the succeeding year's flood season is necessary.

3-15. Agreement between the Corps of Engineers and the Bureau of Reclamation also provides for exclusive-local flood control, replacement-local flood control and joint use storage zones in Clark Canyon Reservoir. Storage allocation includes 22,615 acre-feet of exclusive-local flood control space, 56,475 acre-feet of replacement-local flood control space and joint use space of 50,436 acre-feet. Joint use space is normally available for conservation usage except when needed for local flood control and replacement storage between 1 February and 30 June. Replacement storage space is similar to that described for Canyon Ferry above.

III-D. Local Flood Protection.

3-16. General. Levee projects have been constructed at Havre, Saco, and Glasgow on the Milk River and at Musselshell on the Musselshell River. A project is authorized at Great Falls on the Missouri River above Fort Peck. These projects have essentially no effect upon the regulation of Fort Peck Lake. Through the reach of the Missouri River below Fort Peck Dam to the mouth of the Yellowstone River there has been no projects constructed. Therefore, the operation and maintenance of local protection projects is not a factor in the regulation of Fort Peck Lake.

III-E. Water Rights.

3-17. General. The Montana State water rights laws apply to the waters of the Fort Peck Basin. These laws are known as the Doctrine of Prior Appropriation. The statutes provide that the unappropriated water of any river, stream, ravine, coulee, spring, lake or other natural source of supply may be appropriated, and that an appropriator may impound flood, seepage and waste waters in a reservoir and thereby appropriate the same. These statutes basically provide that the use of water may be acquired by both riparian and non-riparian landowners; that the value of the right is determined by the priority of the appropriation; that the right is limited to the use of water for beneficial purposes; that a right to use of the water is considered as real property only in the sense that it may be bought or sold and that its owner may not be deprived of it except by due process of law. The Montana State Legislature has provided procedures for the acquisition, determination of priority and administration of the water rights.

III-F. Irrigation.

3-18. Existing Irrigation Above Fort Peck Dam. Irrigation development in the Fort Peck drainage basin consists of numerous community or privately owned developments; the Lower Marias, the Sun River, Helena Valley, and Crow Creek projects developed by the Bureau of Reclamation, the Broadwater-Missouri, Middle Creek, Willow Creek and Ruby River projects developed by the Montana State Water Conservation Board and the irrigation system constructed by the Bureau of Indian Affairs on the Blackfoot Indian Reservation.

In the basin above Fort Peck Dam 980,400 acres were under irrigation in 1970. Of this total 103,000 acres were in the Musselshell River basin, 100,000 acres in the Marias River basin, 10,000 acres in the Judith River basin. There are a number of small irrigators along the Missouri River between Morony and Fort Peck Lake. Approximately 750,400 acres are under irrigation above Morony Dam. Irrigation from Fort Peck Lake is limited to a few isolated pumping units. Development of the utilization of water from Fort Peck Lake in this area in general is impracticable due to the high pumping heads required to reach the surrounding tablelands upstream from the dam. Acres irrigated above Fort Peck from 1890 through 1970 are summarized as follows:

Year		Acres	Year	Acres
1890	1/	313,200	1944	933,700
1900	1/	571,600	1950	847,400
1910		1,027,600	1954	869,900
1920		803,000	1959	856,900
1930		734,500	1965	960,000
1940		853,300	1970	980,400

1/ Indian lands not included. The above figures are as reported by Crop Census and other reports.

3-19. Existing Irrigation from Fort Peck Dam to Yellowstone River. Irrigation development which affects the flow of the Missouri River between Fort Peck Dam and the mouth of the Yellowstone River consists of the Milk River Project and the Buford-Trenton Project developed by the Bureau of Reclamation; the Little Porcupine Creek Unit, the Poplar River Unit, the Big Muddy Creek Unit, the Wiota and Frazer Pumping Plant Units developed by the Bureau of Indian Affairs in the Fort Peck Indian Reservation; land developed on the Missouri River bottom lands; and a few private projects in Daniels and Sheridan Counties in the northeastern part of Montana. The Milk River basin has a total of 140,000 acres of irrigated land. In the Fort Peck Indian Reservation a total of 17,400 acres are irrigated with water supplied from the Poplar River and the Little Porcupine and Big Muddy Creeks. On the Missouri River the Wiota and Frazer pumping plants of the Bureau of Indian Affairs supply water for 5,000 and 11,400 acres respectively and small private pumps supply 3,800 acres. Private irrigation outside the Reservation includes 2,900 acres in Daniels and Sheridan Counties and 12,700 acres of bottom land supplied by small pumps along the Missouri River. The Buford-Trenton Project contains 11,000 acres of irrigated land in North Dakota supplied with water from the Missouri River by a pumping unit of 240 c.f.s. capacity located on the left bank about 2½ miles upstream from the mouth of the Yellowstone River. These existing developments include irrigated land totaling 193,200 acres in Montana and 11,000 acres in North Dakota.

3-20. Future Irrigation Development. In the Missouri River Basin above the mouth of the Yellowstone River there are approximately 7,188,000 acres of land having some kind of irrigation potential. About one-fourth of this, or 1,673,000 acres, is irrigable under present conditions. About 527,000 acres is land with conditions suitable for irrigation, but located in a position where water supply under current technology is not available at a cost favoring private or public developments, but may be in the foreseeable future. About 4,988,000 acres is land suitable for irrigation, but located in a position where water supply is not available or is only available at a cost exceeding criteria for potentially irrigable land. In the Big Hole Basin where only storage and regulation can provide a dependable water supply, future irrigation development would have to include the proposed Reichle and Milligan Reservoirs. In the Sun and Teton River basins irrigation developments have been hampered by lack of storage facilities both for existing and proposed new irrigation works. The existing Sun River Project has approximately 18,000 acres undeveloped for lack of reliable conservation storage capacity and approximately 30,000 acres adjacent to the project in the Teton River Basin could be irrigated if proper reservoir storage could be provided on the upper Sun River. In the Madison River Basin development proposals provide for irrigation of about 33,000 acres by direct diversion from the river.

3-21. Existing and Future Depletions. Detailed description of depletions caused by irrigation is contained in Section III of the Master Manual. Based on the recent comprehensive framework study depletions increased by 216,200 acre-feet, excluding evaporation from Fort Peck Lake, on an average annual basis during the period from 1910 to 1949. The framework study also estimates that they have increased by another 465,400 acre-feet on an average annual basis to 1970 reaching a total of 681,600 acre-feet. The increase in depletions during the period from 1910 to 1949 and during the period from 1949 to 1970, by sub-basins and for selected locations along the main stem of the Missouri River above Fort Peck are summarized in Table 7. Increased depletions during the period are broken down by geographical locations only. The estimated increase of 465,400 acre-feet in average annual depletions between 1949 and 1970 is due to the following activities:

Activity	Acre-Feet
Irrigation	277,300
Large Reservoir Evaporation	151,800
Forestry Practices	- 16,900
Watershed Treatment and Ponds	53,200

The framework study estimates increases in depletions above Fort Peck for the periods of 1970 to 1980, 1980 to 2000 and 2000 to 2020 as 280,000 acre-feet, 424,000 acre-feet and 46,000 acre-feet respectively. This results in a total expected depletion of 1,431,600 acre-feet by 2020.

TABLE 7
SUMMARY OF ESTIMATED AVERAGE ANNUAL DEPLETIONS
ABOVE FORT PECK DAM

General Area Description	Depletion in 1000 Acre-Feet Total	1910 to 1949	1949 to 1970	Average Annual Flow After 1970 1,000 A.F.
Beaverhead River Basin	91.2	14.0	77.2	200
Ruby River Basin	40.6	40.9	-0.3	130
Bighole River Basin	-7.3		-7.3	790
Jefferson River Valley Area	4.7		4.7	
Madison River Basin	-1.6		-1.6	1,170
Gallatin River Basin	24.1		24.1	650
Missouri Valley Area above Toston	70.1	45.0	25.1	
Smith & Dearborn Rivers Area	9.4	-25.0	34.4	
Sun River Basin	112.1	96.3	15.8	490
Marias-Teton River Basins	135.6	34.0	101.7	
Arrow-Judith River Basins	11.3		11.3	
Musselshell River Basins	46.1	20.0	26.1	130
Missouri Valley Area to Fort Peck	145.2	-9.0	154.2	
Evaporation from Fort Peck	441.0	441.0		
Total above Fort Peck Dam	1122.5	657.2	465.4	

Note: Above data from Missouri River Basin Comprehensive Framework Study

III-G. Water Supply and Pollution Control.

3-22. Municipal Water Supply. A number of towns and cities obtain their water supply from the streams and reservoirs in the basin above Fort Peck Reservoir and from the Missouri River below Fort Peck Dam. Above Fort Peck Lake, Great Falls and Helena have the only large municipal water systems using Missouri River water. Other municipal requirements above Fort Peck Lake are supplied by smaller tributaries or wells. The City of Butte obtains its municipal water supply from the Bighole River. Below Fort Peck Dam, the towns of Nashua, Culbertson and Williston obtain their municipal water supply from the Missouri River. The Glasgow Air Force Base has installed a water intake directly below Fort Peck Dam and also obtains its water supply from the Missouri River. The present usage of the water supply for municipal purposes is far below the available supply, and it is not anticipated that demands in the near future will exceed the supply.

3-23. Stream Pollution. Pollution of streams has not developed into a serious problem in this area as urban areas are small and there are only a small number of industries. Since the Montana State Government, by education as well as laws, is inducing cities and industries to treat wastes before they reach flowing streams, it seems unlikely that any future problem will develop. Contemplated minimum releases from Fort Peck Lake are far more than adequate for all present requirements in the directly affected reach for municipal purposes and pollution abatement. This water supply is sufficient for all future anticipated demands, and should be a decided influence in the growth of cities and industrial development along the reach of the Missouri River between Fort Peck Dam and Lake Sakakawea.

III-H. Navigation.

3-24. General. The Missouri River main stem reservoir system is designed with storage reserves ample to support navigation in the reach of the river below Sioux City, Iowa. The coordinated regulation of Fort Peck Lake, as a component unit of the Missouri River main stem reservoir system, assists in providing stabilized flows. The original design for the Corps of Engineers 9-foot navigation channel was based on a full 8-month navigation season at Sioux City with a minimum flow of 30,000 c.f.s. for 90 percent of the time and as low as 20,000 c.f.s. for the remaining 10 percent of the time. This original plan was based on utilization of reservoir storage from Fort Peck Lake alone, and did not contemplate either the new main stem reservoirs or the new large upstream depletions, which will be largely compensating in their effects. The presently authorized project is described in detail in Section III of the Master Manual. When completed the Missouri River 9-foot navigation channel will be comparable to and will form an important link with the remainder of the 7,000 mile Mississippi River waterway system.

III-I. Hydroelectric Power Production and Distribution.

3-25. History. Montana's first hydroelectric powerplant of importance was built at Black Eagle Falls on the Missouri River near the City of Great Falls in 1891. It had a capacity of 8,000 horsepower and supplied electricity to the Great Falls area. In 1908, hydroelectric powerplants were built at Canyon Ferry on the Missouri River, 17 miles from Helena (this Montana Power Company plant was removed with the construction of the U.S.B.R. Canyon Ferry Project), and on the Bighole River, 21 miles from Butte. These three early plants formed the nucleus of the Montana Power Company's system. These were soon followed by other hydroelectric powerplants constructed by the Montana Power Company at Madison Dam on the Madison River, at Rainbow Falls and Ryan Dam on the Missouri River below the City of Great Falls and at Holter, Hauser and Hebgen Dams above Great Falls. Additional hydroelectric powerplants were constructed by the Montana Power Company on the Missouri River at Morony Dam in 1930 and at Cochrane Dam in 1958.

3-26. At the present time there are eleven hydroelectric powerplants in operation in the upper Missouri River Basin having a total installed capacity of 472,850 kw. These include the two Fort Peck powerplants at Fort Peck Dam constructed by the Corps of Engineers, Canyon Ferry on the Missouri River constructed and operated by the Bureau of Reclamation and nine plants constructed and operated by the Montana Power Company. The ultimate planned power capacity of 165,000 kilowatts has been developed at the Fort Peck Project. Based on a 100 year economic life, the average capacity is estimated to be 166,000 kw for the first 50 year period and 150,000 kw for the second 50 year period. The average annual energy is estimated to be 979 million kwh for the first 50 year period and 940 million kwh for the second 50 year period. Revenue from power sales will repay all costs of the Fort Peck Project allocated to electric power, including interest and amortization. Excess revenue from power sales will be used to assist repayment of costs for irrigation projects developed by the Bureau of Reclamation in the Missouri River Basin. Descriptions of the existing hydroelectric generating facilities above Fort Peck Lake are shown in Table 8.

3-27. Distribution and Marketing. The Bureau of Reclamation is the agency responsible for the distribution and marketing of all Federal power produced in the basin. To accomplish this purpose they have constructed a transmission grid to interconnect Federal hydroelectric plants with private and non-Federal public hydroelectric and thermal plants. This subject is discussed in more detail in the Main Stem Master Manual.

III-J. Department of Agriculture Program.

3-28. Watershed Program. The Department of Agriculture, in administration of Public Law 566, as amended, deals directly with management, conservation

TABLE 8

Hydroelectric Generating Facilities on Missouri River above Fort Peck Dam

Facility	Hebgen (1)	Madison (1)	Canyon Ferry	Hauser	Holter	Black Eagle	Rainbow	Cochrane	Ryan	Morony
Total Storage (acre-feet)	384,840	42,060	2,051,000	108,680(3)	240,420	1,700	1,000	4,500	2,800	7,900
Usable Storage (acre-feet)	377,500	34,210	1,615,000	61,870(3)	65,260	1,700	1,000	2,700	2,400	7,800
Dead Storage (acre-feet)	7,340	7,850	434,500(2)	46,810	175,160(2)	0	0	1,800	0	100
Maximum Operating Pool elev.	6,534.9	4,841.5	3,800.0	3,635.0	3,564.0	3,290	3,224	3,115	3,039	2,888
Normal T.W. elev.	-	4,722.0	3,650.0	3,568.0	3,454.0	3,238	3,112	3,039	2,888	2,805
Gross head (Max)	-	119.5	150	67	110	52	112	76	151	83
Installed kw.	50	9,000	50,000	17,000	38,400	16,800	35,600	48,000	48,000	45,000
Avg. annual gen. (million kw-hrs)	(station use)	62.7	320.1	115.3	234.3	121.0	236.8	269.3	398.0	262.4
Owner	MPC	MPC	USBR*	MPC	MPC	MPC	MPC	MPC	MPC	MPC
Max. drawdown (ft)	Complete	14.5	72	18	21	11	10	25	19	27
Type dam	Earth with concrete core	Timber Crib	Concrete	Concrete	Concrete	Concrete	Rock Filled Timber Crib	Concrete	Concrete	Concrete
Crest length (ft)	-	-	1,000	732	1,364	831	1,146	814	1,250	872

*Montana Power Company has the right to store 47,500 acre-feet in Canyon Ferry Reservoir to compensate for Lake Sewell storage inundated.

(1) On Madison River above Three Forks, Montana
(2) Inactive and dead storage
(3) Includes 10,450 acre-feet usable storage in Lake Helena.

and multiple use of water on small watershed projects. The small watershed protection program under this law is a water resources development program initiated, planned, constructed, operated and maintained by locally organized and legally authorized districts under State laws, with technical and financial assistance of the Federal Department of Agriculture, and other Federal, state and local agencies. The objectives and purposes of this program are those of reducing flooding, sediment damages, and soil erosion; and the application of water management practices and structure installations designed for multiple use of water for agriculture, domestic and municipal water supply, recreational and wildlife improvements.

3-29. The Watershed Protection Program is steadily advancing as local communities recognize their need for better management, conservation and use of their water resources. The Box Elder watershed project on the Big Muddy Creek in northeastern Montana provides approximately 3,675 acre-feet of storage for flood detention and 1,025 acre-feet of storage for fish development and sediment deposit. The State Soil Conservation Committee has approved application for the Boulder Creek Project in Jefferson County and the Medicine Lodge Creek Project in Beaverhead County for construction under Public Law 566. While the overall effect of the land treatment program is not appreciable upon large flood inflows to Fort Peck Lake, it does stabilize runoff and reduce sediment flows from the area directly controlled. This program also results in depletion to streamflow, estimated by framework studies to amount to 53,000 acre-feet annually above Fort Peck at the 1970 level of basin development.

3-30. Forestry Program. The Department of Agriculture Forestry Program activities related to water resources, watershed protection, flood prevention, and erosion and sediment control include the administration of National Forests, state and private forestry cooperation, and forest, range and watershed research. There are approximately 15 million acres of forest in Montana east of the Continental Divide. This includes about 7,800,000 acres of land in National Forests. Most of Montana's forests lie in the mountainous regions.

3-31. The U.S.D.A. Forestry Program in this area includes the cutting of salable timber in a manner which will thin out the very dense stands of timber to allow space for reproduction, but maintain partial cover; thinning of even-aged stands of young timber; planting trees in bare cut-over areas for timber production and erosion prevention; forest management for increased snow catch and water yield; intensification of fire and disease prevention; and construction of improvements incidental to the foregoing. The Montana Forest Tree Nursery, established in 1927, is part of the Forest and Conservation Experiment Station, operated by the School of Forestry, Montana State University in Missoula, in cooperation with the U. S. Forest Service. Trees are made available to farmers and forest landowners at a nominal price under the provisions of the Clarke-McNary Act of 7 June 1924. In addition to this nursery, the U. S. Forest Service maintains the Savenac Nursery at Haugen, Montana, which produces stock for planting in National Forests. In the great plains area, the Department of Agriculture proposes to extend the development and expansion of farm wood lots, shelter breaks and wind breaks to the maximum degree practicable. This would serve to protect the soil by reducing wind erosion in this area.

3-32. The effects of the Forestry Program in the basin above Fort Peck Dam upon the water supply has been to increase the runoff from forested areas. Framework studies estimate that the increase from 1949 to 1970 has amounted to about 17,000 acre-feet annually. By the year 2020, it is estimated that the program will result in an additional 70,000 acre-feet of annual runoff.

III-K. Miscellaneous Resource Development.

3-33. Fish and Wildlife. The Upper Missouri River Basin provides a great variety and abundance of wildlife. Big game include deer, elk, antelope, bear, bighorn sheep and mountain goat. Game birds include grouse, ptarmigan, pheasant, partridge, geese, duck and wild turkey. Fish include rainbow, golden brown and cutthroat trout, whitefish, grayling, pike, perch, bass, drum and ling. Water development programs in the Upper Missouri River Basin are assisting in maintaining these resources by providing for fish and wildlife interests in the planning, construction and operation of the projects and coordination with the Bureau of Sport Fisheries and Wildlife and the Montana State Fish and Game Commission as provided by legislation enacted by Congress in 1946. Comprehensive State and Federal wildlife management programs in the basin have been instigated in response to the growing concern over the depletion of these resources.

3-34. The Montana State Fish and Game Commission maintains game ranges, wildlife development areas, game preserves, game bird farms, fish hatcheries and spawning stations. These are widely distributed throughout the Missouri River Basin above the mouth of the Yellowstone River and include 7 game ranges, 6 waterfowl development areas, 21 game preserves, state fish hatcheries near Great Falls and Lewistown and three state spawning stations near the town of West Yellowstone. A game bird farm is operated by the state near the Fort Peck Project.

3-35. There are a total of 11 Federal game preserves in the Upper Missouri River Basin above the mouth of the Yellowstone River. Included in these is the Charles M. Russell National Wildlife Range, presently under management of the Bureau of Sport Fisheries and Wildlife in cooperation with the Bureau of Land Management. The Lake Bowdoin Migratory Waterfowl Refuge in Phillips County, the Pishkun Bird Reserve in Teton County, and the Willow Creek Bird Refuge in Lewis and Clark County are managed by the Bureau of Sport Fisheries and Wildlife in cooperation with the Bureau of Reclamation. The other Federal refuges are operated by the Bureau of Sport Fisheries and Wildlife.

3-36. Recreation. Outdoor recreation is of major importance in the development of water resources in the Upper Missouri River Basin. Recreation in this area includes big game hunting, fishing in mountain streams and reservoirs, camping, swimming, boating, riding, hiking, mountain climbing, prospecting, rock and fossil hunting and sightseeing. Much of Montana's magnificant scenery and recreational areas are administered by the Federal Government at National Parks, Monuments, Forests and Wilderness areas. Existing reservoirs provide opportunities for boating, swimming, fishing, water skiing, camping and picnicking.

3-37. Federal law and policy define recreational development at water control projects as primarily a State and local responsibility. However, Federal construction agencies, in cooperation with the Bureau of Outdoor Recreation, the National Park Service, State and local interests actively promote the development of recreational facilities at water control projects and the preservation and conservation of existing recreational measures.

3-38. Fort Peck Lake and its shorelands is a principal recreation attraction in eastern Montana. The reservoir (at elevation 2250) with its 140 mile length, 1,600 miles of shoreline and 249,000 acres of water surface is rapidly increasing in recreational use. It affords opportunity for all water sports on a grand scale. Recreational facilities for the public have been established along the shores of the reservoir and below the dam. The Charles M. Russell National Wildlife Range (formerly Fort Peck Game Range) is an important wildlife recreational area in the breaks of the Missouri River along the shores of Fort Peck Lake. Most of the game range is rugged, scenic, colorful badlands with considerable scrub pine, juniper, browse and grass cover, which provides habitat for deer, antelope, elk and upland game birds. Plate 12 indicates the location of available recreational facilities on Fort Peck Lake.

SECTION IV - HISTORY AND DESCRIPTION OF FORT PECK PROJECT

IV-A. Project History.

4-1. General. The preliminary investigations, studies and design of the Fort Peck project were accomplished by the Kansas City District under the supervision of the Missouri River Division and the Chief of Engineers. The major portion of the construction of the Fort Peck project was supervised by the Fort Peck District which was organized at the inception of construction of the project. On 1 July 1956 the Fort Peck District was abolished and the office became an Area Office under the Garrison District. On 1 April 1960, the Garrison District was reduced to an Area Office under the Omaha District and Fort Peck became a Project Office under the Garrison Area Office. Fort Peck was established as an Area Office under the Omaha District on 1 July 1961 and maintains this status at the present time. Construction of the project was initiated in 1933, closure of the dam was made in 1937, and the project was placed in operation for navigation and flood control in 1938. In 1943, the first unit of the power installation was placed on the line. With the completion of the second powerplant in 1961, the project is now operating 5 units with a total capacity of 165,000 kilowatts. Since 1954 the Fort Peck project has been operating as an integral unit of the Missouri River main stem reservoir system. The reservoir formed by the dam has been designated Fort Peck Lake.

4-2. Project Authorization.

a. Construction of Fort Peck Dam and Lake primarily for navigation and future power generation was recommended by the Chief of Engineers in report to Congress on the general plan for improvement of the Missouri River dated 30 September 1933 (House Document No. 238, 73d Congress, 2d Session).

b. Construction of Fort Peck Dam and Lake was approved by the President of the United States by Executive Order dated 14 October 1933, as part of the public works program to provide employment and to stimulate economic recovery from the depression of the 1930's.

c. Construction of the project for navigation with secondary purposes of flood control, hydroelectric power and irrigation was authorized by the River and Harbor Act approved 30 August 1935. (Public Law No. 409, 74th Congress).

d. Construction of the hydroelectric powerplant was authorized by the River and Harbor Act approved 18 May 1938 (Public Law No. 529, 75th Congress, 3d Session). Under the provisions of this Act the Corps of Engineers was authorized to construct and operate the powerplant and the Bureau of Reclamation was authorized to distribute and sell electrical power not required for the operation of the project.

e. The 1944 Flood Control Act (Public Law No. 534, 78th Congress, 2d Session) modified the original authorizations to provide for the operation of the project as a multiple-purpose reservoir, and as an integral unit of the main stem system, for flood control, irrigation, navigation, generation of hydroelectric power, and other conservation uses, including municipal water supply, stream sanitation, recreation and wildlife preservation. The 1944 Flood Control Act also authorized construction, maintenance and operation of recreational facilities for public use in the reservoir area.

4-3. Project Planning. Development of the Upper Missouri Basin was considered by the U. S. Army Engineers as early as 1890 when the Chief of Engineers ordered that a topographic survey, made under the direction of the Missouri River Commission, be published. Subsequent studies and reconnaissances were actuated by the Flood Control Act of 15 May 1928, which provided for a detailed study and report of the potentialities of streams in the Missouri River Basin. A program of field surveys and reconnaissances, together with studies of records and reports of other Federal Agencies, was immediately commenced. On 27 June 1933, an allotment of $80,000 was made by the Chief of Engineers for a more extensive preliminary investigation, including underground exploration of the Fort Peck damsite by core borings and test pits, a report by a competent geologist as to geological feasibility of constructing a dam, an accurate topographic survey of the reservoir for determining its capacity, and laboratory tests of soils to determine their suitability for use in the construction of an earth fill dam.

4-4. The report on the Missouri River and Tributaries compiled by the Chief of Engineers dated 30 September 1933 was transmitted to the Speaker of the House of Representatives by the Secretary of War on 3 October 1933 (House Document No. 238, 73d Congress, 2d Session). The report recommended that " - - - the reservoir at the site of Fort Peck be built to the maximum practicable capacity; and be operated primarily for navigation, with such arrangements for future installation of power as will permit the maximum production of hydroelectric power consistent with the primary demands of navigation - - - -." The general plan for improvement of the Missouri River contained in the report of the Chief of Engineers dated 30 September 1933 included the development of a reservoir having a gross storage capacity of 17,000,000 acre-feet by construction of a dam at the Fort Peck damsite to provide a minimum flow of 30,000 c.f.s. at Yankton, South Dakota during the navigation season. The principal features as outlined in the general plan included the dam with a height of approximately 231 feet above the streambed and normal water surface elevation at Elev. 2242 (m.s.l.); a spillway with capacity of 200,000 c.f.s.; four 28-foot diameter tunnels and an ultimate power development of 400,000 kw.

4-5. Extensive investigations, studies and design of the Fort Peck project were commenced in June 1933. A Board of Consultants was appointed to advise on the design and construction of the major features of the project. Studies and design of the major features were not complete at the time of commencement of initial construction. This necessitated the design to be accomplished concurrently with construction. A definite project report was not prepared for the major features of the Fort Peck Dam and Lake project because such reports were not a requirement at the time construction was initiated, and none is contemplated in view of the advanced stage of project completion, except for the definite project report for the second powerplant which has been prepared. Details of design studies made by the Corps of Engineers and the Board of Consultants are contained in the compilation of design memoranda located in the Fort Peck Lake Area Office.

4-6. The following is a description of the basis of the preliminary design for the major features of the Fort Peck project. Later design changes are discussed in paragraph 4-7.

a. Spillway. The following combination of hydrometeorological factors was assumed for spillway design purposes:

(1) Abnormal precipitation in September just prior to the advent of freezing temperatures.

(2) A severe winter of continued cold weather accompanied by sharp thawing periods and abnormal heavy snowfall.

(3) A late spring accompanied by sharp periods of thaw and a normal amount of precipitation of sufficient quantity to consolidate and saturate the snow blanket, followed by a long sustained period of high temperature.

(4) A rainstorm of high intensity, falling in such a manner as to synchronize with the period of high-runoff from melting snow.

This study indicated a maximum peak discharge of 360,000 c.f.s. at the Fort Peck damsite under natural conditions would result from the combination of circumstances assumed in computing the hypothetical flood. As a result of these studies a spillway with a discharge capacity of 207,000 c.f.s. with reservoir stage at Elev. 2250 and a discharge capacity of 255,000 c.f.s. with reservoir stage at Elev. 2253.5 was adopted for design purposes. This spillway was considered to be of adequate capacity to meet the conditions of the adopted hypothetical flood. Further studies indicated that for a Bearpaw shale formation, vertical lift gates would be preferable as pressure could be better distributed. Sixteen vertical lift gates, 25 feet high by 40 feet wide were found to be necessary.

b. Outlet Works. The preliminary design of the outlet works of the Fort Peck project provided for a submerged intake, four diversion tunnels, emergency gate shafts, main control shafts, outlet portals with emergency gates provided for each of the four tunnels and main control gates for the flood control tunnels. The original design for the diversion tunnels contemplated an inside finished diameter of 28 feet with each tunnel having a discharge capacity of 30,000 c.f.s. The tentative final design for the diversion tunnels as approved by the Board of Consultants on 24 August 1934 provided for a minimum excavated diameter of 32 feet 2 inches and a 21-inch concrete lining, an inner lining of 1-inch steel plate backed by 6-inches of grout and a 9-inch thickness of concrete inside the steel plate with a finished inside diameter of 26 feet. Elevations of the inverts of the tunnels were established at Elev. 2030 at the intake and at Elev. 2028 at the outlet portal. The elevation of the top of the submerged intake structure was established at Elev. 2095.

c. Dam. The design of the earthfill dam was not complete at the inception of construction of the dam. The design cross section of the dam approved in March 1934 provided for a crest width of 100 feet at Elev. 2270 with a parapet on the upstream side to be constructed to Elev. 2284; a puddled fill core and steel sheet pile outoff wall extending above the bottom of the core to firm shale; gravel toes at the upstream and downstream toes of the slope; riprap on the entire upstream face of the dam; and slopes of 1 on 4 above Elev. 2112 and 1 on 5 below Elev. 2112 on the upstream slope of the dam and 1 on 8.5 on the downstream slope.

d. Freeboard. In the study for freeboard requirements for the dam two factors were considered, i.e. (a) the amount of water in the lake that would be setup due to wind and (b) the height which waves are likely to run up the water slope. The setup was based on a wind velocity of 80 miles per hour, a fetch of 40 miles, depth of water of 160 feet and angle of wind and fetch of 30 degrees. A wind setup of 2 feet, a wave height from trough to crest of 14.0 feet and a height of 7.0 feet run-up of the waves was obtained from the study. The total effect for a pool elevation of 2250 is summarized as follows:

	Feet	Elev. in Feet (M.S.L.)
Maximum Pool Level	-	2250
Rise due to flood	3.5	2253.5
Rise due to wind setup	2.0	2255.5
Rise due to waves	7.0	2262.5
Rise due to wave run-up on slope of dam	7.0	2269.5

e. Powerplant No. 1.

(1) General. Following authorization of the Fort Peck Powerplant, by the Act approved 18 May 1938, preliminary studies were initiated to determine the general design features and the method by which design and construction would be accomplished. On the basis of the preliminary studies it was determined that the design of the powerplant would provide for an ultimate hydroelectric generating capacity of three 35,000-kw units.

(2) Initial Design. An Architect-Engineer contract was awarded to the Harza Engineering Company of Chicago, Illinois in 1938, for preparation of plans and specifications for the powerplant. The general plans for powerplant No. 1 were essentially completed by 1939, detailed plans for the substructure were complete in early 1940 and remaining plans were completed in 1941.

(3) Revised Design. The major expansion of World War II industries and military installations in the northwestern part of the United States resulted in an immediate need for additional electric power. Consequently it was decided in April 1942 that powerplant No. 1 should be completed sufficiently to permit the installation and operation of one 35,000 kw generator. The proposed plan of construction included the deferral of construction of the surge tanks and other features that were not absolutely essential and reduction in the amount of required critical materials by omissions, substitutions and changes in design wherever possible. An Architect-Engineer contract was negotiated with the Harza Engineering Company on 6 May 1942 for the required redesign of Powerplant No. 1 as modified. Additionally, as a result of the war emergency, a 15,000 kw power unit originally destined for Shasta Dam was diverted to Fort Peck Dam and installed in place of one of the 35,000 kw units. Following the war, approval was received to remove the temporary wartime construction features.

f. Powerplant No. 2.

(1) Preliminary Design. An Architect-Engineer contract was awarded to Erick Floor and Associates, Inc. of Chicago, Illinois in October 1952, for the studies and preliminary design of additional power facilities at Fort Peck Dam. As a result of these studies it was agreed that the design of the second powerplant would provide for the installation of two hydroelectric generating units each having a rating of 40,000-kw. Description of the studies, design drawings and proposed procurement and construction schedules are included in the report entitled Preliminary Design Report for Fort Peck Dam Powerplant Additional Power Facilities submitted by Erick Floor and Associates, Inc. in August 1953.

(2) Final Design. The Architect-Engineer contract for the final design preparation of contract drawings and specifications was awarded to Erick Floor and Assocaites, Inc. of Chicago, Illinois in December 1953. The Report on the Analysis of Design of Fort Peck Dam Second Powerplant presents a review of the design of the Fort Peck Second Powerplant and provides the basic criteria and other data pertinent to the development of the design.

4-7. Major Departures from the Preliminary Design Studies.

a. Diversion Tunnels. In order to permit earlier completion of the tunnels and corresponding diversion of the river, the inside finished diameter of the diversion tunnels was changed from 26 feet to 24 feet 8 inches, the tunnel lining changed to monolithic concrete and the steel plate lining eliminated in all tunnels, except that portion of Tunnel No. 1 from the main control shaft to the outlet portal. The plate liner was installed in Tunnel No. 1 as this tunnel was planned to be used for a power tunnel. A steel plate liner was also installed from the main control shaft to the outlet in Tunnel No. 2 when the second powerplant was constructed.

b. Sheet Pile Cut-off Wall. In the maximum valley section, steel sheet piling was driven to the then unprecedented depth of 163 feet. Two different weights of steel sheet piling were used, the bottom tier of alternating 70-ft. and 80-ft. lengths of 3/8-inch web, 23 pounds per foot, and the top tier of 1/2-inch web, 28 pounds per foot. Driving to the required depths demanded much experimentation and the principal items of equipment developed on the job were the 196-ft. high traveling gantry crane and the hydraulic spade jet. Design called for grouting into the interlocks of the steel sheet piling and along the sides of the piling. It was decided to abandon grouting entirely as no practical way could be developed to get grout into the interlocks and it was believed unnecessary to grout alongside of the piling since these spaces were filled with material washed down from above by jetting of subsequent piling.

c. Earth-Fill Dam. During construction of the dam numerous studies and tests were made to determine the stability of the dam as designed. A slide that occurred on the right bank of the closure section just before diversion in June 1937 initiated an investigation and a report was prepared by the District Engineer on subsidence, compaction, settlement and other movements of the dam. Additional stability studies and investigations were made which indicated the necessity of an upstream berm. Plans for the upstream berm were approved by the Chief of Engineers in August 1937. Report and Recommendations of the Board of Consulting Engineers regarding the slide of a portion of the upstream face of the dam which occurred in September 1938 and the proposed reconstruction plans were made to the

District Engineer in a report dated 2 March 1939. Redesigned cross-sections of the dam after the slide of September 1938 included revisions to the downstream slope above elevation 2183. The original slope of 1 on 7.7 was revised at that elevation to continue with a slope of 1 on 11 to elevation 2227 where, after a 30-foot berm, it was to continue with a slope of 1 on 4 to the top of the dam, elevation 2275.5. The original design for protection of the upstream face of the Fort Peck Dam provided for an 18-inch blanket of gravel upon which was placed a layer of field boulders up to elevation 2150 and a layer of quarry stone from elevation 2150 to the crest of the dam. The addition of the berm to the upstream face of the dam in 1938 made it necessary to salvage a portion of the rock and gravel facing between station 30 and station 70, and later the slide of 1938 and subsequent redesign of the upstream face of the dam necessitated the removal and salvage of all gravel, field stone, and quarry rock below elevation 2162. In the final design of the dam, the rock facing and gravel was omitted below elevation 2162 as the upstream berm tied into the main fill at this elevation and slopes upstream at 1 on 50 for approximately 450 feet and then changed to a slope of 1 on 7 continued to the flood plain. No protection was considered necessary on the flat slope below the minimum pool level of elevation 2162. The final design of the dam provided for riprap with a gravel filter blanket above elevation 2162, a crest width of 50 feet and crest elevation of 2280.5. A roadway and roadway lighting were constructed on the crest of the dam. The final design of the maximum cross-section of the dam as constructed is shown on Plate 13.

d. Intake Structure. As a result of the slide which occurred in a portion of the upstream face of the dam on 22 September 1938, an earth pressure was created, that according to calculations, would have collapsed the walls of the outlet tunnels intake structure if it had been unwatered under certain conditions. To compensate for the increased pressure, the original structure was modified by constructing a 15-foot thick reinforced concrete wall external to the original front wall, raising both front and back walls an additional ten feet, raising the end walls to the ultimate height of the structure with reinforced walls and a gable top, installing 15-foot thick concrete diaphragms in the intake between tunnels, strengthening the floor with an additional 5 feet of reinforced concrete, and constructing a removable A-frame trash rack on top of the intake structure. The intake structure for the outlet tunnels is shown on Plate 13.

e. Pressure Relief Wells. During construction of the dam, piezometer pipes were placed in the dam at various foundation depths and were checked to determine the hydrostatic pressure developed in the foundation strata. When the reservoir reached elevation 2174 in the summer of 1942 (the highest to that date), the piezometer readings indicated that hydrostatic pressures were relatively high in the porous strata below the impervious surface materials along the downstream toe of the dam. In order to reduce these pressures a system of twenty-one temporary pressure relief wells was installed downstream from the downstream toe of the dam. In 1946, the twenty-one temporary relief wells were replaced by seventeen permanent pressure relief wells.

4-8. Construction History.

a. General. Principal construction features of the Fort Peck project consisted of preliminary construction; the diversion tunnels and outlet works; the spillway; the earthfill dams; the first powerplant and switchyard; and the second powerplant and switchyard. Sources of information for the resume of construction history of the principal features contained in subsequent paragraphs of this manual include a report in draft form entitled "General History of the Fort Peck Dam" available in files in the Fort Peck Lake Area Office, a report entitled "Fort Peck Dam" revised in 1947, available in the Omaha District library and other miscellaneous documents pertaining to the project.

b. Preliminary Construction. Construction of the Fort Peck Dam was started on 23 October 1933 when initial clearing operations were commenced. Clearing operations included clearing the valley upstream and downstream of the dam so dredges could have access to suitable fill material as well as the area required for the base of the dam and the general construction area. Access road and railroad facilities including a bridge across the Missouri River and trackage and trestles for access to the diversion tunnel and spillway work areas, for placing the upstream and downstream gravel and rock toes of the dam and the riprap on the upstream face of the dam were provided. A sand and aggregate plant erected near the damsite was capable of producing 500 tons of finished product per hour. Field boulders required for facing the upstream slope of the dam were gathered and stockpiled. Four dredges and attendant floating plant equipment were built at the site by Government forces. A 287-mile 161-kv electrical transmission line was built from the Rainbow Falls plant of the Montana Power Company, near Great Falls, Montana, to be damsite to supply electrical energy. Numerous contracts were awarded for the construction of the town of Fort Peck. The buildings in the townsite were ready for occupancy in the fall of 1934.

c. Dam. Stripping of overburden from the base of the dam, involving excavation of 4,153,500 cubic yards was accomplished by contract during the summer and fall of 1934. In December 1935, construction of a cut-off wall of steel sheet piling within the limits of the core of the dam was completed by contract. Upstream and downstream toes for the dam were constructed with more than 3,000,000 cubic yards of gravel ranging from 1/2-inch to 6 inches in size. Dredge placement of the fill on the dam was started by Government forces on 13 October 1934 by dredges located upstream of the dam. The dredges were transferred downstream in June 1937 just prior to the closure which was effected on 24 June 1937. All four dredges immediately started filling the closure section to the height of the fill on each side of the river channel. The total fill in place at the end of the 1937 dredging season was over 82,000,000 cubic yards. On 22 September 1938 a slide occurred and a portion of the upstream shell of the dam moved out into the reservoir in a swing similar to that of a gate hinged at the right abutment. About 5,000,000 cubic yards of fill were displaced in the slide. Reconstruction was started immediately and the cross section of the dam redesigned for greater stability. This necessitated constructing a berm along the upstream toe. After the slide it was decided that the construction of the dam above elevation 2250 would be by rolled-fill methods. On 5 November 1939 the last hydraulic fill was placed and the dredges shut down and dismantled. Total hydraulic fill was 122,178,000 cubic yards. Topping out by rolled-fill methods and completing the upstream slope protection was accomplished in 1940. By 1946 experience records indicated that settlement of the dam had decreased to such a rate that the final topping out to a new design elevation of 2280.5 was accomplished and a paved road constructed across the dam. Gross grades were computed so that the entire crest of the dam would be at elevation 2280.5 m.s.l. in the year 2000 if the settlement continued at the indicated rate. The paved roadway and lighting across the top of the dam were completed in 1948.

d. Spillway. Initial spillway channel excavation was started on 20 October 1934. By 5 December 1935 all excavation was complete except for the protective cover of shale which could not be removed until just prior to placing concrete. Initial concrete was placed on the spillway approach slab in July 1935. Work also started on the pile holes and cutoff trench under the gate structure in late 1935. During 1936 the spillway approach slab, and the training walls were completed; the approach channel sidewall lining and the channel floor slab essentially completed; and concrete placement commenced on all gate piers. Excavation for the cutoff structure at the downstream end of the paved discharge channel was started and one concrete monolith placed during 1936. Spillway channel sidewall lining was started late in the 1936 construction season. During 1937 the spillway gate structure including completion of gate piers, highway bridge, service bridge, bridge abutments, roadway retaining walls, installation of spillway gates and machinery, spillway sidewall channel lining to the cutoff structure, and cutoff structure trench excavation were completed and concrete placed in the trenches and floor slab of the cutoff structure and the first lift of the channel sidewalls above the cutoff structure. The channel sidewalls at the cutoff structure were completed, roads paved, structural steel painted, construction buildings removed, area cleaned up and the spillway gate structure accepted as complete on 7 September 1938 and the spillway channel accepted as complete on 1 September 1938.

e. Diversion Tunnels, Main Control Gates and Shafts and Emergency Control Gates and Shafts. Work commenced under contract for the completion of the diversion tunnels, the excavation of the emergency gate shafts and the excavation of the main control shafts in May 1934. Due to change in design of the tunnels to permit closure of the dam in July 1937, the Government took over this work on 15 January 1936 and completed the work with Government forces. The Government hired labor forces completed with excavation of the emergency gate shafts in July 1936, the excavation of the main control shafts in November 1936, the outlet structure in May 1937, the tunnels in June 1937 and the intake structure as originally designed in June 1937. Government forces also installed the steel lining in tunnel No. 1 which extended from the main control shaft to the outlet portal. Following a slide at the east abutment, the intake structure was reconstructed. Work commenced on the reconstruction in August 1939 and was completed in March 1940. Concrete work in the gate shafts and foundations; furnishing and installing the emergency gates, main control gates and associated mechanical and electrical equipment; construction of the gate shaft control buildings and installation of the shaft substation equipment were accomplished by contract. This work was commenced in June 1936 and completed in March 1941. A diesel-electric standby generator was purchased by the Government and installed in the shaft control building by Government forces. Stop logs for the intake and outlet portals, stop log lifting beam and intake stop log carrier were fabricated and assembled by Government hired labor.

f. Powerplants. In September 1941 bids were invited for construction of Powerplant No. 1. However, the war emergency necessitated concellation of the plans for construction of the powerplant at that time. When need for additional power became apparent, the War Production Board, in May 1942, authorized the use of materials to install the 35,000-kw unit without the surge tank and the construction of that part of the superstructure necessary to house the equipment essential to operation of the generator. This work was completed by contract and the generator placed in service in July 1943. Following the war, approval was received of plans to complete Powerplant No. 1 and to complete the installation of Unit No. 1 (35,000-kw) and to install Unit No. 2 (15,000-kw). Work started under contract in 1946 and was completed in 1949. In March 1950 a contract was awarded for the installation of Unit No. 3 (35,000-kw) with completion scheduled for late 1951. With the demand for electric power increasing a second powerplant was planned to be constructed at the downstream end of tunnel No. 2. This required lining tunnel No. 2 with steel downstream from the main control shaft as accomplished in tunnel No. 1 during the original construction, removal of the two main control gates from tunnel No. 2, and modification of tunnel No. 2 at the main control shaft to use the shaft as a supplemental surge tank. Contracts were awarded in the spring of 1957 for the construction of the second powerplant and its related appurtenant equipment. Two generators were installed with each having a capacity of 40,000 kw. Construction of Powerplant No. 2 was essentially completed in 1961.

4-9. Operational History.

a. General. Impoundment of water in Fort Peck Lake began late in 1937 and the reservoir was regulated primarily for navigation during the initial years of the project operation. Power generation was begun in July 1943 with the completion of the installation of Unit No. 1. Power Unit No. 2 was completed and placed in service in June 1948; Unit No. 3 in December 1951 and Units Nos. 4 and 5 in June 1961 respectively. Flood control became an important consideration after closure. In 1946 and the spring and early summer of 1947 filling of the large carry-over zone of the reservoir was accomplished. Floods and excess flows during each year's high water season were stored and the impounded water later released for navigation on the lower reaches of the river, for generation of hydroelectric power and for other incidental purposes. A drawdown to Elevation 2225 by early November of each year was required to insure adequate storage capacity for the control of floods which might occur during the ensuing year. In general during this period requirements were a minimum of 30,000 c.f.s. at Sioux City, Iowa, for navigation during the open water season and an average minimum release of about 3,000 c.f.s. at the dam subsequent to the installation of the second hydroelectric power unit in June 1948. Since 1952 regulation of the main stem reservoirs on the Missouri River has broadened from a single reservoir to a multiple-reservoir basis. Initial filling of Fort Randall was started during FY 1953 in coordinated operation with Fort Peck Lake. During 1956 water was released from storage in Fort Peck Lake to assist in filling inactive storage zones in Garrison and Gavins Point projects while maintaining adequate flows for downstream purposes. Filling of the Oahe reservoir to power operating level was accomplished in the early spring of 1962. The closure at Big Bend was made in August 1963 and the Big Bend pool brought up to the spillway crest level in February 1964. Fort Peck Lake is now being operated as an integral unit of the six main stem Missouri River reservoir system.

b. Pool Elevation of Fort Peck Lake. Records of pool elevation of Fort Peck reservoir began with closure in June 1937. The pool was maintained below elevation 2100 until construction activities progressed to the point that the project was available for flood control and navigation purposes in July 1940. The pool gradually rose during the following years during the filling of the carry-over multiple use zone between elevations 2160 and 2234. A maximum elevation of 2244.8 was reached in 1948. The pool was then regulated between elevation 2240 and 2214 until 1953. The pool was drawndown during the next two years to assist in the filling of Fort Randall and Garrison projects. A minimum elevation of 2167.4 was reached in January 1956. During the following years to 1965 the carryover multiple use storage was refilled. In May 1965 the reservoir rose above elevation 2234, the top of carry-over multiple use zone. Since that time the reservoir has been regulated to be between that elevation and maximum operating pool elevation, the normal range of operating levels. The pool has been above maximum normal operating elevation of 2246 in 1969,1970 and in 1975 when a record maximum elevation of 2251.6 was reached.

c. Inflows to Fort Peck Lake. During the period of operation of the Fort Peck project from the calendar year 1938 through the calendar year 1971 the total yearly inflow varied from a minimum of 3,781,000 acre-feet in 1940 to a maximum of 13,516,000 acre-feet in 1975. The mean daily inflow varied from a minimum of 190 c.f.s. in November 1955 to a maximum of 119,700 c.f.s. in June 1953.

d. Releases from Fort Peck Lake. During the period of operation of the Fort Peck project from 1938 through the year 1975, inclusive, the total yearly release varied from a minimum of 2,812,000 acre-feet in 1941 to a maximum of 11,389,000 acre-feet in 1975. The minimum mean daily releases during this period varied from 0 in 1940, 1943 and 1944 to a maximum of 35,400 c.f.s. on 16 July 1975. The release hydrograph is shown on Plate 14.

e. Flood Control. Storage of high inflows in Fort Peck reservoir in the spring and summer months during 1938 and from 1942 through 1953, inclusive, resulted in substantial downstream stage reductions on the Missouri River during the high water season. The flood control effects of Fort Peck Lake were particularly noteworthy in March 1947, in March-April 1952, and in June 1953. Description of the major floods occurring in the Upper Missouri River basin above Fort Peck Dam during this period are contained in Sections II and X of this manual. The hydrographs on Plate 14 reflect the high inflows experienced during these flood events and the corresponding regulated releases from the reservoir.

f. Navigation. During the period from the calendar year 1940 through 1954, inclusive, only Fort Peck Lake was available to make releases to provide navigation on the Missouri River during the open water season downstream from Sioux City, dependent upon the water supply available. Subsequent to 1954 navigation on the Missouri River has been provided from Sioux City to the mouth of the Missouri River during the open water season by the Missouri River main stem reservoir system.

g. Power. Hydroelectric power generation commenced at the Fort Peck project with the installation of Unit No. 1, a 35,000-kw unit, was completed and placed in operation in June 1948. Unit No. 3, a 35,000-kw unit was completed and placed in operation in December 1951. Units Nos. 4 and 5, each a 40,000-kw unit were completed and placed in operation in June 1961. Gross energy generated at the Fort Peck project during the period from FY 1944 through FY 1972, inclusive, varied from a minimum of 84,334,630-kwh in FY 1945 with one unit in service to a maximum of 1,630,340,000-kwh in FY 1971 with five units in service. Plate 14 illustrates the gross monthly hydroelectric power generated at the Fort Peck project.

IV-B. Description of Dam.

4-10. Location. Fort Peck Dam is located at mile 1771.55 (1960 mileage) on the Missouri River in Valley and McCone Counties, Montana about 10 miles above the mouth of the Milk River.

4-11. Embankment. The dam consists of an earthfill embankment with an impervious core approximately four miles in length including the 2-mile dike section. The embankment has a maximum height of 250.5 feet and a maximum width of 4,900 feet. The crest elevation of the dam is at elevation 2280.5 feet (m.s.l.) with crest widths of 50 feet on the main dam section and on the dike section. The dam is a hydraulic fill type except for the final topping out and a section at the end of the dike which is rolled fill. The upstream face of the dam is protected from wave action by riprap placed above elevation 2162 feet (m.s.l.) Gravel placed in the downstream toe of the dam stabilizes the slopes and facilities drainage at the downstream toe. Seepage control is provided by a continuous sheet steel piling cutoff wall located 37.5 feet upstream from the axis of the dam. A system of relief wells is installed along the downstream toe to facilitate drainage of seepage water and reduce hydrostatic pressures in the foundation material downstream from the cutoff wall. Detailed description of the embankment is contained in the Operation and Maintenance Manual for the Fort Peck Dam Embankment. The plan and maximum section of the Embankment are shown on Plate 13.

IV-C. Description of Spillway.

4-12. General. The spillway, located in a natural saddle of the reservoir rim, about three miles east of the dam, consists of a partially lined approach channel, the gate control structure including the training wall section, the lined discharge channel and the unlined earth discharge channel which enters the Missouri River approximately 9 miles below the dam. The concrete gate structure is surmounted by a highway bridge, a service bridge, equipment platform, and service walkways. Plan, profile and section of the spillway are shown on Plate 13. Spillway discharge rating curves are shown on Plates 15 and 16.

4-13. Approach Channel.

a. Base Slab and Riprap. The concrete base slab and riprap extend upstream of the gate structure to protect the structures from erosion and to provide a constant cross section immediately upstream of the gate control structure. The concrete base slab extends 220 feet upstream from the gate control structure and a 2-foot layer of riprap is provided for another 100 feet upstream of the concrete base slab. The approach channel concrete consists of monoliths, 20 feet by 40 feet except where irregular shapes are necessary to fit the structure. The slabs are 3 feet thick with four-by-four collars extending entirely across the channel underneath each transverse construction joint.

b. Concrete Walls. The approach channel side slopes are concrete lined for a distance of about 360 feet. The walls vary from a slope of 1 on 2 to a vertical wall adjacent to the gate structure. The upstream 196 feet of side wall was constructed against sloping shale cut and the slope changed from 1 on

1 slope to a vertical wall at a point approximately 70 feet upstream from the point where it joins the gate structure abutment. A cutoff trench 10 feet deep by 8 feet wide was provided as the upstream end of the wall and intermediate cutoff walls three feet deep by four feet wide were provided at 20-foot centers or beneath each construction joint.

c. Unlined Approach Channel. From the upstream end of the lined channel the approach channel is excavated in glacial till and shale. The channel is trapezoidal in section and has a bottom width of 820 feet. The slope of the side walls is 1 on 1 for shale and 1 on 3 for glacial till. The unlined approach channel is about 1,600 feet in length.

4-14. Spillway Gate Structure.

a. Foundation Piling. A total of 467 concrete piles, each 5 feet in diameter and from 30 to 40 feet deep, provide stability and sliding resistance for the structure. The reinforced concrete piles are spaced on 18.33-foot center longitudinally and on 13-foot centers transversely with intermediate piles located at the center of each group of four piles.

b. Cutoff Wall. A reinforced concrete cutoff wall, 10 feet wide by 30 feet deep, was installed beneath the upstream edge of the gate pier foundation. This wall extends across the channel under the slab and up the side slopes to elevation 2260 in the form of a 4-foot by 12-foot reinforced concrete collar.

c. Foundation Slab and Gate Piers. The pier foundation slab monoliths are approximately 75 feet long, 57 feet wide, and 12 feet thick and were placed on a foundation of Bearpaw shale, the concrete foundation piling and the concrete cutoff wall. The 17 gate piers are set in a curved line and uniformly spaced at 52-foot centers on the crest line of the gate structure. Piers No. 1 and No. 17 are considered to be part of the abutment structures. Each of the other piers has a maximum height of 77 feet, a width of 12 feet and a length of 75 feet. The piers serve to support and provide mountings for the 16 vertical lift spillway gates and support the steel service bridge, the reinforced concrete highway bridge and piers, the machinery platforms and service walkways.

d. Training Walls. The training walls downstream of the gate structure can be considered 187-foot extensions of the gate piers and were provided to eliminate turbulence during high spillway discharges. The training walls vary in thickness from about 11 feet at the gate pier to 1-1/2 feet at the downstream end. The height varies from 24-1/2 feet to 22 feet. The base slabs beneath the training walls are four feet thick and 20 feet wide. The intermediate slabs between the training walls are three feet thick and vary from 25 to 30 feet in width. A system of transverse collars was provided beneath each construction joint.

e. Gate Structure Abutments. The cellular abutments on the right and left ends of the gate structure are about 123 feet long by 75 feet wide and consist of a thick base slab supported by 46 concrete piles, a relatively thick back slope slab, a number of 4-foot thick crosswalls, two piers, and a section of channel wall which in effect is a modified pier with a curved nose section on the channel side containing the gate slots and castings. A cutoff collar 4 feet wide by 12 feet deep was constructed along the upstream edge of the abutment structure up to elevation 2262.

f. Bridge Abutments. The bridge abutments retain the highway and railroad approach fill and support the highway bridge, service bridge, and control house. The abutments consist of a group of independent but adjoining counterforted retaining wall structures on slab footings at different elevations and form a continuous wall around three sides of the approach fill for the highway and railroad bridges, (railroad bridge for stop log car). Each abutment is about 171 feet long, 75 feet long, 75 feet wide, and 45 feet high except for the left abutment which has the control structure built into it. The base of each abutment adjoins the upper portion of the gate substructure abutment at elevation 2262 which is about eight feet below the top of the access road.

g. Spillway Gates. The 16 vertical lift spillway gates are each 25 feet high by 40 feet wide. The gates are electrically operated and can be individually controlled from the service bridge. Selective operation of all gates is accomplished from the control house at the west end of the gate structure. Spillway Rating Curves are shown on Plates 15 and 16.

4-15. Lined Discharge Channel.

a. Channel Slab. The concrete-lined channel is about 4,800 feet long varying in width from about 700 feet at the end of the training wall section to 120 feet at the downstream end of the cutoff structure. The floor slab of the concrete lined discharge channel varies from 2.33 feet to 4.0 feet thick. The floor slab monoliths are 20-feet wide in the longitudinal direction of the channel and generally 30 or 40 feet wide in the transverse direction. Collars with a bottom width of 4 feet and 1 on 1 side slopes varying in depth from 5.33 feet to 7.33 feet from the top of the channel floor slab were provided at each joint. Drain tile was provided below the collars under transverse joints connecting to the main longitudinal drain installed in a trench along the center line at a depth of 10 feet below the top of the floor slab.

b. Lined Channel Walls. The slab-channel walls are about 4,700 feet long and extend from the cellular wall at the gate structure to the cutoff structure at the downstream end. The walls consist of a cantilever base, a sloping slab wall and an 8-foot vertical section. A parapet wall, four feet high by two feet thick surmounts the walls. The cantilever slab varies from 2.33 feet to 7 feet in thickness. The sloping slab walls are on a 1 on 1 slope and vary from three to six feet in thickness with cutoff collars varying in depth from 2 to 3.5 feet below the slab and apaced every 20 feet. The vertical section of wall is about eight feet high and seven feet wide at the top.

c. Cutoff Structure. A cellular reinforced concrete cutoff structure is provided at the downstream end of the lined discharge channel. The cutoff structure extends approximately 70 feet below the channel floor and has wide wing walls to prevent scour on the sides of the channel. The reinforced concrete walls of the cellular structure are 8 feet thick and the natural shale left in place between the walls. The main part of the cutoff structure which spans the channel is 95 feet in width parallel to the channel and 229 feet normal to the channel. Each wingwall branches off at a 45-degree angle and is 260 feet long by 71 feet wide.

4-16. Stilling Basin. Immediately downstream of the cutoff structure the channel has been enlarged and deepened by erosion and this area now serves as a natural stilling basin to dissipate the energy created by the high velocity spillway discharges. The initial deepening of the channel appears to have stabilized at a depth of about 25 feet below the end of the lined channel. This deep scour area slopes upward and intersects the original excavation line about 450 feet downstream from the end of the lined discharge channel. The sections immediately downstream of the lined channel indicate the deepest scour is in the center of the channel and it slopes upward to each side at a slope of about 1 on 6 or flatter.

4-17. Unlined Discharge Channel.

a. Excavated Portion. Downstream of the cutoff structure the spillway channel was excavated through the shale bluffs to the river flood plain. The unlined channel was trapezoidal in cross section with 1 on 2 side slopes, a bottom width of 130 feet and a flat grade at elevation 2010 m.s.l. Since operation of the spillway, erosion and deposition have altered the original shape and grade of this unlined portion of the spillway.

b. Unexcavated Portion. The unlined channel originally terminated at the flood plain. Just prior to the operation of the Fort Peck spillway a pilot channel about 10 feet in width was excavated to the river. The initial controlled releases from the spillway soon enlarged the channel until it could accommodate the maximum required releases.

4-18. Spillway Movement. Movement observations covering a period of over 25 years indicates there has been substantial movement of the spillway structure. The movements which are of serious concern in the Fort Peck spillway are differential movements taking place in localized areas. The record of movement to date indicates the differential movement in localized areas will continue in the future. This type of movement has caused only slight apparent structural damage to date, however, continued movement will eventually result in structural damage and possibly complete destruction of sections of the spillway. Movement observations indicate that the entire gate structure of the spillway had risen about 0.2 foot prior to 1944 with some additional rebound since that date; appreciable differential movement has occurred in the gate structure area; consolidation of the fill in the spillway bridge abutments has caused the intermediate wall at both abutments to settle and shift laterally; movement of the spillway channel paving and sidewalls and roadway retaining wall has occurred; and there has been considerable erosion at the downstream end of the lined discharge channel. Detailed description of the results of movement observations are included in reports entitled "Report on Fort Peck Spillway Movement Survey" dated 1 July 1947 and "Report on Spillway Movement Observations, Fort Peck Dam" dated September 1962.

4-19. Repairs to the Fort Peck Spillway made to date include the replacement of the intermediate walls of the spillway bridge abutments in 1949 and 1950 with walls supported by piling; provision of an expansion joint to allow independent movement of the approach slab and the gate pier structure, and repair of the construction joint between gate structure and training wall slabs. Detailed description of these joint repairs are contained in the "History of Reconstruction of Concrete Pier Base and Approach Slabs at Fort Peck Spillway - Fort Peck, Montana" and in Design Memorandum No. MFP-106 entitled "Spillway Gate Structure Downstream Joint Repair" dated February 1964.

4-20. Studies and investigations to determine factors causing the differential movement include geological and foundation surveys, laboratory analysis of shale samples, time movement studies, significant crack surveys, plastic flow analysis, slab replacement study, drainage system study and experimental grading plans. Detailed descriptions of these studies and investigations are contained in Design Memorandum No. MFP-109 entitled "Spillway Rehabilitation" dated June 1965.

IV-D. Description of Outlet Works and Powerplants.

4-21. Tunnels. The Fort Peck Dam outlet release system consists of four tunnels, the intake structure, the emergency control shafts, the main control shafts and the outlet structure. The tunnels are spaced 125 feet center to center at the intake and the control shafts and fan out to 195 feet center to center at the outlet. The tunnels vary in length; the length of tunnels Nos. 1, 2, 3 and 4 are 5653 feet, 6355 feet, 6615 feet and 7240 feet respectively and bypass the dam through the right abutment. Tunnels 1 and 2 are used to supply water to the power units and tunnels No. 3 and 4 are used for flood control purposes and to supplement downstream flows. The four tunnels are reinforced concrete lined, with steel liners installed downstream from the control shafts in tunnels Nos. 1 and 2. The finished inside diameters of tunnels No. 1, 3 and 4 are 24 feet 8 inches. Tunnels No. 2 has an inside finished diameter of 24 feet 8 inches upstream from the control shafts and 22 feet 4 inches inside diameter downstream from the main control shaft. The plan and section of the tunnel system are shown on Plate 13. The discharge rating curve for the outlet tunnels is shown on Plate 17.

4-22. Intake Structure. The intake is a submerged type reinforced concrete structure located at the upstream end of the flood control and power tunnels. The intake structure has a length of 517.5 feet, a width of 57 feet and a height of 65 feet. The structure is divided into four individual water intake chambers by three cross walls each 15 feet thick. Each chamber is equipped with removable steel trash racks. The inlet of the intake and the base of the trash racks are at elevation 2095.0. The intake floor at the tunnel portals is at elevation 2030.0. Slots and guides are provided for installing stop logs to permit unwatering the tunnels.

4-23. Emergency and Main Control Shafts. The control gates for the tunnels are located near the axis of the dam and are housed in reinforced concrete shafts which extend upward to ground level where a reinforced concrete structure houses the gate operating machinery. In each tunnel there are both an emergency shaft and a main control shaft. The emergency control shafts are 71 feet 9 inches upstream from the main control shafts and consist of a reinforced concrete shaft and building, emergency gates, and hoisting equipment. The emergency control shafts are rectangular, approximately 34 feet by 17 feet in outside dimensions, are divided into two gate passages with inside dimensions of 7 feet by 12 feet 1 inch. Each tunnel has two 48-ton vertical lift tractor type emergency gates which are 11 feet 6 inches wide and 22 feet high. The main control shafts are located just upstream from the axis of the dam and consist of a transition section, a reinforced concrete shaft, control building, control gates and gate hoist machinery installed in tunnels Nos. 3 and 4, overhead crane and miscellaneous operators' facilities. The main control shaft consists of a circular waterway 50 feet in diameter with an inner tower having an inside diameter of 28 feet 1 inch and an orifice having an inside diameter of 24 feet 8 inches. Tunnels Nos. 3 and 4 have 2 cylindrical main control gates installed in each of the main control shafts. The upper main control gates are installed at elevation 2165 and the lower main control gates at elevation 2085. Each of the main control gates has a diameter of approximately 28 feet and height of 12 feet. Tunnels Nos. 1 and 2 which are used as power tunnels are controlled at the powerhouse and the main control shafts in these tunnels serve as auxiliary surge tanks.

4-24. Outlet Structure. The tunnels discharge into a stilling pool which is downstream from the dam embankment and is adjacent to the downstream riverbed. The stilling pool is protected by reinforced concrete retaining walls, training walls, outlet portals, base slab and baffle piers. The retaining walls extend along the right and left sides of the outlet channel and between the outlet portals. The right retaining wall is approximately 900 feet long, the left retaining wall 660 feet long and the retaining wall between portals is 305.4 feet long. The retaining walls vary in height from 33.17 feet to 43.17 feet. The outlet portals connect tunnels Nos. 3 and 4 to the outlet channel and consist of a barrel section, portal transition, portal wall and stop log guide slots. Powerplants Nos. 1 and 2 are located downstream from the portals of tunnels Nos. 1 and 2 respectively. The penstocks for the powerplants are connected to tunnels Nos. 1 and 2 at the portals. Training walls extend out about 100 feet into the outlet channel from the south side of each portal (except No. 1). The discharge channel is about 1200 feet in length with a maximum width of 550 feet. Paving in the discharge channel consists of a 3-foot thick reinforced concrete slab with a 10-foot wide and 37-foot deep cutoff wall at the downstream end of the paving. Downstream from the cutoff wall cast concrete blocks, approximately 6 feet by 6 feet 3 inches, have been placed for a distance of about 25 feet in lieu of paving. The discharge channel slab is at elevation 2026.83 which is approximately 6 feet below the low range of tailwater elevations. Forty baffle piers have been placed at the downstream end of the lined discharge channel to reduce kinetic energy and to direct the outflow toward the left bank. The baffle piers are made of reinforced concrete and are 12 feet long with the widths varying from 7.08 feet to 9.42 feet and the heights from 10 to 12 feet. Complete detailed descriptions of the various features of the outlet works are contained in the Operation and Maintenance Manual for the Fort Peck Outlet Works. The plan, profile and section of the Outlet Works are shown on Plate 13.

4-25. Powerplant No. 1.

a. General Features. Powerplant No. 1 is on the left bank of the discharge channel with the center line of units approximately 263 feet downstream from the portal of Tunnel No. 1. Principal features of the powerplant include three penstocks extending from a wye branch at the outlet end of tunnel No. 1 to the surge tanks; an enclosed surge tank section that houses three interconnected surge tanks; a generator section that houses the generators, turbines, control room and related equipment; the three draft tubes that carry turbine outflows to the tailrace; and the outdoor substation and switchyard. The generating facilities include one 15,000-kw and two 35,000-kw turbine-driven generators and associated control and switching equipment. Detailed description of Powerplant No. 1 is contained in the Operation and Maintenance Manual for Fort Peck Powerplant No. 1. Plans and Sections of Powerplant No. 1 are shown on Plate 18. Powerplant tailwater rating curves and Powerplant characteristic curves are shown on Plates 19 and 20 respectively.

b. Penstocks and Surge Tanks. Water is supplied to Powerplant No. 1 by a 24-foot 8-inch I.D. steel penstock connected to the steel liner in tunnel No. 1 at the portal. Approximately 50 feet downstream from the portal of tunnel No. 1 a wye branch divides the flow into two 14-foot I.D. penstocks supplying Units Nos. 1 and 3 and an 11-foot I.D. penstock supplying Unit No. 2. Each of the penstocks is provided with a butterfly valve and surge tank. The three surge tanks are enclosed in a structure 94.5 feet by 144 feet by 271 feet high. The surge tank for each unit is approximately 40 feet in diameter with the low point of the hemispherical bottom at approximately elevation 2120 (m.s.l.) and the top at elevation 2288 (m.s.l.). Penstocks for Units

Nos. 1 and 3 have risers approximately 11 feet in diameter and Unit No. 2 has an approximate 8-foot diameter riser connecting to the surge tanks. The three surge tanks are interconnected by a total of six 5-foot I.D. equalizing pipes at elevation 2162 and 2180 (m.s.l.).

c. Powerhouse. The powerhouse consists of three generator bays and an erection bay, and also contains office space, control room, public reception lobby, observation balcony, machine shop, and all necessary water treatment, sewage treatment, heating and ventilating facilities. The substructure has an overall length of 186 feet 6 inches and the transverse width exclusive of the surge tank base is 76 feet. The substructure of the powerhouse and surge tank structure are constructed as a single monolith in order to eliminate the possibility of differential settlement. The height of the substructure is 42 feet above the low point of the draft tubes. The control room, cubicles, offices, machine shop and station service facilities are located in the surge tank base immediately adjacent to the upstream side of the powerhouse. The powerhouse superstructure is of reinforced concrete and structural steel construction and has a length of 186 feet 6 inches and a transverse width of 61 feet. The height of the superstructure is approximately 62 feet above the turbine room floor.

d. Turbines. Three hydraulic turbines of the vertical shaft, single-runner, Francis type, with plate-steel scroll cases are installed in the powerhouse. Unit No. 1 and Unit No. 3 turbines are rated 50,000 hp at 170 feet net head and operate at 128.5 r.p.m. Unit No. 2 turbine is rated 20,000 hp at 140 feet net head and operates at 164 r.p.m. Governors are of the isochronous, oil hydraulic-conventional type capable of full-opening or full-closing time of 6 seconds.

e. Generators. The generators installed in powerplant No. 1 include one 15,000-kw and two 35,000-kw, 3-phase, 60-cycle, 13.8-kv, wye-connected, class B insulation for normal temperature rise of 60 degrees C. and rated at 0.90 power factor. Speeds of Units No. 1 and 3 are 128.5 rpm and speed of Unit No. 2 is 164 rpm. The generating units are enclosed, forced air cooled, with waste heat used to heat the generator room and surge tank enclosures. Each generator has a direct-connected exciter permanently connected to the generator field, a pilot exciter, and a high speed voltage regulator. Main generator protective system includes a neutral reactor and circuit breaker, surge protective equipment, differential relays, ground detector, resistance temperature detector and overspeed protection for each unit.

f. Tailrace. The tailrace for Powerplant No. 1 is paved reinforced concrete for a distance of 100 feet downstream from the powerhouse, and slopes upward to join the concrete paving of the discharge channel for the outlet works. The surface of the tailrace paving is level at Elevation 2010.62 at the ends of the draft tubes and slopes upward to Elevation 2026.83 where it joins the discharge channel paving. The width of the tailrace floor slab varies from 130 feet at the upstream edge of the ends of the draft tubes to 146 feet at the downstream edge, the width increasing on the left side. Slope paving connects the tailrace floor slab to the retaining walls on the sides of the tailrace at Elevation 2026.83.

4-26. Powerplant No. 2.

a. General Features. The powerhouse is located to the right of the tailrace for Powerplant No. 1, with the center line of units approximately 350 feet downstream from the portal of tunnel No. 2. Principal features of the powerplant include two penstocks extending from a wye branch at the outlet end of tunnel No. 2 to the surge tanks; and enclosed surge tank structure that houses two interconnected surge tanks; a generator section that houses the generators, turbines, erection bay, switchgear, oil storage and purification facilities and other equipment; two draft tubes that carry turbine discharge to the tailrace; and the outdoor substation and switchyard. The generating facilities include two 40,000-kw turbine-driven generators and associated control and switching equipment. Detailed description of Powerplant No. 2 is contained in the Operation and Maintenance Manual for Fort Peck Powerplant No. 2. Plans and Sections of Powerplant No. 2 are shown on Plate 18. Powerplant tailwater rating curve and Powerplant characteristic curves are shown on Plates 19 and 20 respectively.

b. Penstocks and Surge Tanks. Water is supplied to Powerplant No. 2 by a 22-foot 4-inch I.D. Steel penstock connected to the steel liner in tunnel No. 2. Approximately 95 feet downstream from the portal of tunnel No. 2 a wye branch divides the flow into two 15-foot 11-5/8 inch I.D. penstocks supplying Units Nos. 4 and 5. Each of the penstocks is provided with a butterfly valve and surge tank. The two surge tanks are enclosed in a structure 73 feet 3 inches by 155 feet 4 inches by 190 feet high. The surge tank for each unit is approximately 65 feet in diameter, with the low point of the hemispherical bottom at Elevation 2107.5 (m.s.l.) and with the top at Elevation 2237 (m.s.l.). Each penstock has a 13-foot I.D. riser connection to its surge tank. The two surge tanks are interconnected by two 8-foot I.D. equalizing pipes with center lines at Elevations 2158 and 2230 (m.s.l.).

c. Powerhouse. The powerhouse consists of two generator bays and an erection bay. The generating units are on 56-foot centers and the erection bay is 52 feet and 3 inches wide. The overall length of the substructure is 186 feet and 6 inches, and the transverse width, excluding the base of the surge tank structure is 83 feet. The substructure of the powerhouse and surge tank base are constructed as a single monolith in order to eliminate the possibility of differential settlement. Equipment rooms, the carbon dioxide fire protection system, heating system and ventilating systems are located in the base of the surge tank structure. The height of the substructure above the low point of the draft tubes is approximately 48 feet.

The superstructure is of reinforced concrete and structural steel construction and has a length of 185 feet and 6 inches and a transverse width of 68 feet and 8 inches. The height of the superstructure is approximately 62.5 feet above the turbine room floor.

d. Turbines. Two hydraulic turbines of the vertical shaft, single runner, Francis type, with plate steel scroll case are installed in Powerplant No. 2. The turbines are rated 55,000 hp (at best gate) at 170 feet net head and operate at 128.6 rpm. Governors are of the isochronous, oil hydraulic conventional type capable of full-opening or full-closing time of 5 seconds.

e. Generators. The generators are 40,000-kw, 3-phase, 60 cycles, 13.8-kv, wye-connected 128.6 rpm, class B insulation for normal temperature rise of 60 degrees C and rated at 0.95 power factor. Provision is made for alternative control of the two generating units from the control room in Powerplant No. 1 or from the turbine room in Powerplant No. 2. The generating units are enclosed, forced air cooled, with waste heat used to heat the generator room and the surge tank enclosures. Each generator has a direct-connected exciter permanently connected to the generator field, a pilot exciter, and a high speed voltage regulator. Main generator protective system includes a neutral reactor and circuit breaker, differential relays, ground detector, resistance temperature detectors and over speed protection for each unit.

f. Tailrace. The tailrace for Powerplant No. 2 is 120 feet wide and is paved reinforced concrete for a distance of 120 feet downstream from the powerhouse. The surface of the tailrace paving is level at the ends of the draft tubes and slopes upward to where it joins the concrete paving of the discharge channel for the outlet works. A training wall is located on the left side of the tailrace in order to maintain minimum tailwater at Elevation 2032 with one unit operating. The right training wall is an extension of the training wall located on the left side of the portal of Tunnel No. 3. Slope paving connects the tailrace floor slab to the training wall on the right side of the tailrace.

4-27. Switchyard No. 1. The switchyard for Powerplant No. 1 is an outdoor type and is located southwest of the first powerhouse and to the left of the tailrace. Installations located in switchyard No. 1 include the 13.8-kv bus structure, a 50,000-kva 161-kv substation; a 25,000-kva 69-kv substation and switchyard; a 15,000-kva 115-kv substation, a 50,000-kva 115-kv substation and a 115-kv switchyard; a 1,500-kva 33-kv substation and a 4,160 volt project substation. Power transformers are 13.8-kv delta connected on the low side and grounded wye on the high side.

4-28. Switchyard No. 2. The switchyard for Powerplant No. 2 is an outdoor type and is located to the right and adjacent to the second powerhouse. Equipment in Switchyard No. 2 includes the main power transformers for Units Nos. 4 and 5, a system interconnecting autotransformer, high voltage busses, circuit breakers, disconnects, coupling capacitor, lightning arresters and instrument transformers. The generating voltage of Powerplant No. 2 is stepped up to 230-kv by two 3-phase 36/48 mva main power transformers located in Switchyard No. 2. The switchyard provides for one initial 230-kv overhead line (Fort Peck-Dawson County Transmission Line), a future 230-kv overhead line, and also, a 3-phase 230/115-13.8-kv system interconnecting autotransformer, rated 40/53.3/66.7 kva with a tie line to Switchyard No. 1 to provide means for interchanging power between Powerplant No. 2 and Powerplant No. 1. Power transformers and autotransformers are 13.8-kv delta connected on the low side and grounded wye on the high side.

IV-E. Description of Reservoir.

4-29. General. The reservoir formed by the Fort Peck Dam provides a maximum storage of 18,900,000 acre-feet at elevation 2250 with a normal operating maximum storage of 17,900,000 acre-feet at elevation 2246 and a minimum storage of 543,000 acre-feet at elevation 2095, the elevation of the inlet to the tunnel intake structure. The reservoir at elevation 2250 has an approximate length of 134 miles, a maximum width of 16 miles, a shoreline of 1,600 miles, a surface area of 247,000 acres and a maximum depth of 220 feet.

4-30. Area Capacity Data. Area and Capacity Curves and Tables for the Fort Peck Reservoir are shown on Plate No. 21.

4-31. Storage Allocations. The storage allocation in the Fort Peck Lake is based on interim allocations pending completion of the comprehensive allocation studies of the total system storage as described in Section V of the Master Manual. The allocation of storage in the Fort Peck Lake with corresponding elevations and storage zones is shown as follows:

	Elevations M.S.L.	Storage Acre-Feet
Exclusive Flood Control	2246-2250	1,000,000
Flood Control & Multiple Use	2234-2246	2,700,000
Carry Over Multiple Use	2160-2234	10,900,000
Inactive	2030-2160	4,300,000
Total Storage		18,900,000

4-32. Aggradation. Accumulation of sediment within Fort Peck Reservoir is evidenced by progressive delta growths at the confluence of the prevailing reservoir pool levels and each contributing stream. The growth of individual delta formations is variable depending upon the pool elevation and the sediment production from each contributing stream. The 1972 resurvey indicates an annual sediment depletion rate of 18,600 acre-feet with an average density of 60 pounds per cubic foot for the period 1937-1972. A limited redistribution of the deposited material may occur in each delta area dur to local channel slope adjustment and scour whenever the reservoir reaches lower operating levels for significant periods of time. The location of the aggradation ranges are s hown on Plate 22.

4-33. Degradation. Since Fort Peck Dam entraps all upstream contributed sediment, the downstream river remains relatively free of suspended sediment until the Milk River and other tributaries introduce their individual load contributions into the main stem flow. As the finer sand particles in the streambed are gradually entrained into suspension from between the larger sand or gravel particles and transported downstream, a gradual lowering or degradation of the channel occurs. This degradation will continue at a diminishing rate until the bed surface becomes sufficiently covered, or armored, with particles whose size, shape and position resit further movement by prevailing maximum flow conditions. After this time the degradation trend will remain relatively static until higher flow conditions sufficiently rearrange or disturb the armored bed surface to induce further particle losses or such a disturbance is artificially introduced to accelerate degradation. At the present time, several natural clay and shale outcrops cause local controls which augment this armoring process to further curtail the rate of degradation. The degradation rate for a flow of 10,000 c.f.s. during the period 1938-1963 at the USGS 7 mile gage, located at River Mile 1766.0 (1960 mileage), has averaged 0.21 feet per year. The powerhouse tailwater rating curves have remained relatively constant for the past several years because of the control exerted by the concrete tailrace apron and baffles. The location of the degradation ranges are shown on Plate 23.

4-34. Land Acquisition. The land acquired for the construction of the Fort Peck Dam and Reservoir include a total of 590,084.29 acres which was acquired prior to 1 January 1943. The total land acquired is summarized as follows:

167,704.62 acres, fee
422,068.97 acres, transferred from the U. S. Department of the Interior (Public Domain)
310.70 acres, easement
590,084.29 acres, total area acquired prior to 1 January 1943

Land within the reservoir was acquired to elevation 2250 (m.s.l.) from Fort Peck Dam to River Mile 1863 (1960 mileage) which is approximately 3 miles below the mouth of the Musselshell River in Section 13, Township 20 North, Range 30 East. Land was acquired to elevation 2270 (m.s.l.) from River Mile 1863 (1960 mileage) to River Mile 1931.8 (1960 mileage). The upstream limit of the land acquired is in Sections 5 and 6, Township 22 North, Range 23 East. Land was acquired to elevation 2270 above River Mile 1863 due to the flatness of the terrain within the area and the effect of high backwater from flooding which may be caused by ice jams on the Musselshell and Missouri River where these streams flow into the reservoir. Land acquired was taken to the nearest practicable land subdivision above the criteria elevations of 2250 and 2270 and is shown on Drawings FP 31-1 to FP 31-4, incl (4 sheets). These drawings are available in the Fort Peck Lake Area Office.

4-35. Reservoir Development.

a. Master Plan. The original Master Plan for Reservoir Development at the Fort Peck project was approved on 28 April 1947 and has served as a guide for development since that date. Design Memorandum MFP-105C updated in August 1965 is the Master Plan for comprehensive reservoir development at the Fort Peck project prepared by the Omaha District in accordance with instructions contained in EM-1130-2-302. The objective of the updated Master Plan is to present a description of the existing public and semi-public facilities and a comprehensive program for additional public use facilities to meet anticipated needs in the foreseeable future.

b. Fish and Wildlife Resources. The Charles M. Russell National Wildlife Range (formerly the Fort Peck Game Range), which consists of approximately 1,000,000 acres, surrounding the reservoir, was created in 1936 by Executive Order. The game range lands are reserved for the development of natural wildlife resources and for the protection and improvement of public grazing lands and natural forage resources. The lands were withdrawn from settlement, sale or entry, however, they may be used subject to specific approval for mineral, oil and gas exploration, hunting and fishing. The Fish and Wildlife agencies together with the Bureau of Land Management recognized the need for public use developments due to the lack of such facilities in the vicinity, and have cooperated in the development program. The reservoir area supports abundant wildlife and various species of fish.

c. Access Roads. The recreation areas on the north shore near the vicinity of the Fort Peck townsite and the dam are served by State Highways 24 and 249 leading in from east and west and Federal Highway 2 running through Glasgow, Nashua and Wolf Point. Recreation areas along the east shore of the Big Dry Creek Arm of the reservoir are served by State Highway 24. Areas along the south shore of the main reservoir are served by county gravel and dirt roads leading in from the town of Jordan and State Highway 200. U. S. Highway 191 running north and south between Malta and Lewistown crosses the reservoir approximately 5-1/2 miles southeast of the western terminus of the reservoir area.

d. Recreational Facilities. Fort Peck Lake presently provides an outstanding public use resource in the State of Montana. It is the largest expanse of water in the state. Its rugged badland background offers an unusual scenic attraction. The climate and topography combined with the fish and wildlife in the area are favorable factors for providing outdoor public use facilities for boating, water skiing, swimming, fishing, winter sports, picnicking, camping and sightseeing. Facilities already constructed are located at Fort Peck, Hell Creek, James Kipp Park, Rock Creek, The Pines, Turkey Joe, the recreational areas below the dam, and at the Bear Creek and Devils Creek fishing camps. The state has leased and maintains Hell Creek, James Kipp Park and Rick Creek recreation areas. Significant drawdown of the reservoir affects the physical use of the recreation areas and results in adverse public reaction. Boat ramps have been constructed at eight recreation areas around the reservoir. The top and bottom elevations of these boat ramps are listed below:

LAKE FORT PECK BOAT RAMP ELEVATIONS

Recreation Area	Elevation, Ft. M.S.L. Top	Botton
Fort Peck		
#1	2249.1	2240.9
#2	2249.3	2239.4
Hell Creek	2250.9	2237.5
James Kipp	2267.6	2253.2
Rock Creek	2251.1	2240.6
The Pines	2252.0	2239.0
Turkey Joe	2245.5	2239.2
Downstream Areas		
Downstream	2036.0	2032.1
Dredge Cuts	2049.7	2035.8

Detailed description of the existing developments and planned improvements for the public use areas are contained in the updated Master Plan, Design Memorandum No. MFP-105C. Location of these areas are shown on Plate 12.

e. Cooperating Agencies. The Fort Peck Inter-Agency Council was organized in 1959 to coordinate the various Government agencies and organizations interested in the development of the reservoir area. Agencies represented at the semi-annual meetings include the Corps of Engineers, National Park Service, Bureau of Land Management, Charles M. Russell National Wildlife Range, Fish and Wildlife Service, Montana Highway Commission State Parks Division, Montana Fish and Game Commission, Montana State Board of Health and Counties surrounding the reservoir. In addition, the Coast Guard, Glasgow Senior and Junior Chambers of Commerce and the Fort Peck Businessmens' Association attend the meetings to offer suggestions and recommendations for consideration.

4-36. Reservoir Management.

a. General. The Fort Peck project, including the reservoir, is operated and managed by the Corps of Engineers; power is distributed and sold by the Bureau of Reclamation; the surrounding Federal Game Range is managed jointly by the Bureau of Land Management and the Fish and Wildlife Service; and State agencies cooperate in the management of the recreational areas. The Corps of Engineers has the overall responsibility for reservoir management of the Fort Peck project. This responsibility includes the direction, planning and review of all functions incident to operation and maintenance of the recreational facilities and other reservoir developments.

b. Administration. The Reservoir Manager and personnel of his staff, under direction of the Area Engineer is responsible for the administration of the reservoir management program at the Fort Peck project. Reservoir facilities which are under the supervision of the Reservoir Manager and his staff include the dam and reservoir, the project area, the townsite area, public use areas, leased areas, other land areas and all water areas. The reservoir management program is administered in accordance with the provisions described in detail in the Reservoir Management Manual dated March 1964 which has been prepared by the Omaha District for use at all of the main stem reservoirs.

c. Corps Floating Plant Area. The harbor area for Corps of Engineers floating plant equipment is determined by the Area Engineer as pool elevations require. During periods of normal operating levels, the floating plant is harbored in a protected bay within the Fort Peck Recreation Area upstream from the damsite on the left bank. This plant area is served by a circulation road within the recreation area. Other Corps water craft for emergency and rescue purposes are placed on trailers under roof at locations designated by the Area Engineer.

d. Management by Other Agencies. The land and water areas at the Fort Peck area are administered and managed so as to obtain maximum sustained public benefits from conservation and use of their natural resources. Other Federal, State and local agencies have and will continue to be encouraged to assume responsibility for administration and development for public uses and wildlife management lands where feasible and it is determined that they have the resources to properly develop and utilize the area for the use intended. The Corps of Engineers reviews plans and recommendations of the State and Federal agencies in order to interpret and translate their effects and their relationship to the aspects of the project and assure compliance with the requirements of the overall operational plan.

SECTION V - ORGANIZATION FOR RESERVOIR REGULATION

5-1. Coordination. Prior to 1943 the principal purpose of Fort Peck was to supplement low water flows for navigation and consequently operation planning was largely accomplished by the Corps of Engineers. In 1943 when power generation began at the Fort Peck project, a Memorandum of Understanding between the Bureau of Reclamation and the Corps of Engineers was agreed upon to coordinate the generation of Fort Peck power with power transmission and marketing by the Bureau of Reclamation. These procedures continued until 1952 after which time additional reservoirs became part of the Missouri River main stem system. The regulation of Fort Peck Lake as a part of the main stem system requires the coordination with various Federal and state agencies interested in flood control, navigation, power production, irrigation, sanitation, water supply, recreation, fish and wildlife and other related matters. Details of this coordination are presented in Section VI of the Master Manual.

5-2. Regulation Responsibilities. Section VI of the Master Manual presents details relating to normal and emergency organization, regulation responsibilities, transmission of regulation orders and communication facilities. Plates are included in the Master Manual showing organization charts and routing channels for water and power scheduling.

5-3. ER 1110-2-1400 delegates primary responsibility for general management of reservoir regulation activities in the Missouri Basin to the Division Engineer. This overall management includes: preparation, coordination, and approval of reservoir regulation plans and manuals and subsequent scheduling of operations in accordance therewith; review of survey reports, design memos and other publications dealing with reservoirs; conducting or managing technical studies relating to reservoir regulation; training of personnel; review of data collection programs and forecasting services; and making reservoir-related information available to the public. The Reservoir Control Center, a branch of the Engineering Division, is responsible for these functions insofar as they apply to the main stem reservoir system including Fort Peck Lake.

5-4. The Omaha District has been delegated responsibility for the assembly and interpolation of data affecting current main stem reservoir operations, development of the descriptive portions of the main stem reservoir regulation manuals and for carrying out regulation of tributary reservoirs in accordance with approved plans. The Reservoir Regulation Section of the Hydrologic Engineering Branch, Engineering Division, is the Omaha District's office most immediately concerned with Fort Peck Lake regulation.

The Montana Area Engineer and his staff are responsible for the execution of specified release and power schedules, for the collection of Hydrologic and power data and furnishing these data to the District, Division and Bureau of Reclamation offices, and for the management and maintenance of the project land and water area for use by the public.

SECTION VI - COLLECTION AND DISTRIBUTION OF BASIC HYDROLOGICAL DATA

6-1. General. Regulation of Fort Peck Lake as part of the Missouri River main stem reservoir system requires the collection and distribution of information regarding existing and anticipated hydrologic conditions within the basin, both upstream and downstream of the project. Due to the seasonal variations and areal range of hydrologic events within the Fort Peck basin, it is necessary to assemble and integrate large quantities of basic data pertaining to precipitation, snowfall and snow water content, streamflow and available reservoir storage in order to achieve the optimum objectives in the operation of the Fort Peck Lake as part of the main stem system.

6-2. Responsibilities. The Omaha District Office is responsible for the collection of adequate hydrologic data required for the regulation of Fort Peck Lake, for regulation of U.S.B.R. tributary reservoirs in the Fort Peck basin when pools are within the limits of the flood zone, and for the determination of existing or potential flood situations. Pertinent data collected by the Omaha District Office is immediately forwarded to the Reservoir Control Center of the Missouri River Division Office.

6-3. Cooperative Programs. The cooperative program for the collection and distribution of hydrologic and meteorological data in the Fort Peck area includes various Federal, state, municipal and private organizations. Federal agencies in the cooperative program include the Corps of Engineers, U. S. Geological Survey, Bureau of Reclamation, Bureau of Indian Affairs, National Park Service, U.S. Forest Service, Soil Conservation Service, National Weather Service and the U. S. Department of State. State organizations include the Montana State Engineer, Montana State Water Conservation Board, Montana State Highway Commission and the Montana Fish and Game Commission. Other organizations aiding in the collection of data include the Montana Power Company, the Lewis and Clark Generating and Transmission Cooperative, and the Cities of Helena and East Helena. In the Milk River basin adjacent to the international boundary certain gaging stations are maintained by the United States (or Canada) under agreement with Canada (or the United States) and the records for these stations obtained and compiled in a manner equally acceptable in both countries. These stations are designated as "International Gaging Stations."

6-4. The cooperative program with the National Weather Service includes hydrometeorological investigations, river stage and rainfall reporting networks and hydroclimatic networks. The work of the hydrometeorological section of the National Weather Service accomplished for and in cooperation with the Corps of Engineers consists of general coverage of all phases of the subject and specific investigations of Corps of Engineers problems.

River and rainfall reporting networks are maintained by the National Weather Service in cooperation with the Corps of Engineers and supplement the standard National Weather Service stations. The hydroclimatic network has been maintained by the National Weather Service in cooperation with the Corps of Engineers since 1940.

6-5. Rainfall data are collected from a total of approximately 200 precipitation stations in the Upper Missouri River basin above the mouth of the Yellowstone River through the cooperative program. These data are published in the monthly publication entitled "Climatological Data" prepared by the National Weather Service and is also reported for stations included in the Fort Peck Hydrometeorological Network as described in paragraph 6-9. In addition to data furnished by reporting networks and in publications, the National Weather Service Office in Kansas City furnishes the Missouri River Division and the Omaha District data from selected precipitation stations for each month of the year immediately after these data become available.

6-6. The cooperative stream gaging program of the Corps of Engineers with the U. S. Geological Survey provides for the maintenance and operation of certain gaging stations in which the Corps of Engineers has an interest by the U. S. Geological Survey personnel. The Corps of Engineers furnishes a proportionate share of the funds required for the maintenance and operation of these gages. U. S. Geological Survey personnel stationed at the Fort Peck project facilitate collection and reporting of hydrologic data pertinent to the regulation of Fort Peck Lake.

6-7. Stage and streamflow discharge data include approximately 130 gaging stations at which the U. S. Geological Survey collects, computes and publishes discharge data, and a few National Weather Service gaging stations. The data collected from the U. S. Geological Survey gages are published in Surface Water Records prepared annually by the U. S. Geological Survey. Selected U. S. Geological Survey and National Weather Service gaging stations are reported as described in paragraph 6-11. During flood periods additional gage readings are taken and data reported as requested by the Missouri River Division and Omaha District.

6-8. The location of the stream gaging stations, precipitation stations, reservoir gaging stations, mountain snow courses and meteorological stations included in the cooperative programs are shown on the hydrologic river basin maps prepared by the Inter-Agency Committee on Water Resources under the supervision of the National Weather Service.

6-9. Meteorological Data. Reports of precipitation, temperature and other current meteorologic data, as well as forecasts developed by the National Weather Service, for the portion of the Missouri River basin pertinent to Fort Peck regulations are received by the Missouri River Division Reservoir Control Center and the Omaha District Reservoir Regulation Section. Transmission of these data and forecasts may be by the Corps of Engineers teletype circuit, the National Weather Service Circuit C, public service and RAWARC teletype circuits, and by bulletins prepared by other agencies. Details of these data collections are presented in Section VII of the Master Manual.

6-10. Special precipitation reports from the special reporting network are made by the observers on the basis of a specified minimum precipitation in a given time interval, i.e., one inch in 24 hours or less, or three inches in 4 hours or less. The precipitation gages included in the reporting network in the Missouri River basin above the mouth of the Yellowstone River are shown on plate 24. A listing of the precipitation stations in the climatological network of the National Weather Service is tabulated on Plate 25.

6-11. Streamflow Reporting Network. Reports of river stages at key stream gaging stations in the Missouri basin above Fort Peck Dam and in the incremental drainage area below the dam to the mouth of the Yellowstone River are obtained by the National Weather Service by telephone calls from observers and by calls to telemetering stations. These reports are relayed to the Missouri River Division Section by transmission on the Corps of Engineers teletype circuit, and the National Weather Service Circuit C and RAWARC teletype circuits. Inflow and releases from all the reservoirs included in the streamflow reporting network above the mouth of the Yellowstone except Clark Canyon and Tiber are also reported and relayed by teletype. Daily reports of releases from Clark Canyon Reservoirs are reported by postcards mailed weekly to the Omaha District Reservoir Regulation Section or by telephone as requested. Arrangements are made with the Bureau of Reclamation to obtain direct daily reports when Clark Canyon and Tiber Reservoirs are in the flood pool. The hydrologic network is divided into three station categories as follows:

a. Stations reporting the daily stream stage at a specific time.

b. Stations reporting only when the stream exceeds a specified minimum stage.

c. Stations reporting reservoir inflow and releases.

The key stream gages included in the streamflow reporting network in the Missouri River basin above the mouth of the Yellowstone River are shown on Plate 26. A listing of the principal stream gaging station is tabulated on Plate 27.

6-12. Mountain Snow Surveys. The Soil Conservation Service and the states of Montana and Wyoming in cooperation with other Federal, state and private organizations survey a total of 56 mountain snow courses in the Missouri River basin above Fort Peck Dam. A current list of the snow courses and results of the surveys are contained in the "Water Supply Outlook" and the "Summary of Snow Survey and Soil Moisture Measurements for Montana" prepared by the Soil Conservation Service and the Montana Agricultural Experiment Station at Bozeman, Montana. Observations at the snow courses in this network are normally made monthly during the period from 1 January to about 1 May. The snow courses particularly pertinent to forecast studies included in the Mountain Snow Survey Network are shown on Plate 28.

6-13. Plains and Valley Snow Surveys. A network of thirty-five snow courses has been established by the Corps of Engineers on the plains and in the valleys of the Missouri River basin above the mouth of the Yellowstone River. Observations at the snow courses in this network are made when directed by the Omaha District Office and are dependent upon the amount of snow. Samples are taken throughout the area covered by a snowpack having about one inch or more of water equivalent in the snow. Soil moisture and frost data are also obtained. Results are forwarded by teletype or mail to the District Office for analysis and interpretation. The snow courses included in the Plains and Valley Snow Survey Network are shown on Plate 28.

6-14. Soil Moisture. The Soil Conservation Service and the State of Montana in cooperation with other Federal and state agencies make soil moisture surveys at monthly intervals at a total of eight stations in the Missouri River basin above Fort Peck Dam. A list of these stations is shown in Table 9. Results of these surveys are contained in the "Water Supply Outlook" published monthly and the "Summary of Snow Survey and Soil Moisture Measurements for Montana" prepared by the Soil Conservation Service and the Montana Agricultural Experiment Station at Bozeman, Montana.

TABLE 9

Soil Moisture Stations, Missouri River Basin above Fort Peck Dam
Surveyed by the Soil Conservation Service and the
State of Montana in Cooperation with Other Agencies

Station Name	River Basin	Elev. Ft. msl
Lakeview	Beaverhead	6700
Gibbons Pass	Bighole	7100
Red Bluff	Madison	4800
College Site	Gallatin	4856
Twenty-One Mile	Gallatin	7150
Stemple Pass	Mo. R. Main Stem	6350
Kings Hill	Mo. R. Main Stem	7420
Marias Pass	Marias	5250

6-15. Soil Temperatures, Evaporation and Wind. Measurements of soil temperatures, evaporation and wind are made in the Fort Peck Lake Area at the following stations on a regularly scheduled basis by various agencies and included in the monthly publication entitled "Climatological Data" prepared by the National Weather Service.

Soil Temperatures
Bozeman Agricultural College

Evaporation and Wind Observations
Babb 6 NE
Bozeman Agricultural College
Canyon Ferry PH
Dillon WMCE
Fort Assinniboine
Fort Peck Powerplant
Malta
Moccasin Experiment Station
Sidney
Terry
Tiber Dam
Valier

6-16. Reservoir Data. Pertinent reservoir data essential for the regulation of Fort Peck Lake are observed and collected at Fort Peck, Canyon Ferry and Morony Dam Reservoirs on the Missouri River, Clark Canyon Reservoir on the Beaverhead River and Tiber Reservoir on the Marias River. Reports of reservoir data pertaining to Fort Peck Reservoir regulation are furnished the Missouri River Division Reservoir Control Center and the Omaha District Reservoir Regulation Section as shown on Plate 29. Fort Peck data are accumulated and disseminated by means of daily and monthly reports as detailed in the Master Manual.

SECTION VII - ANALYSES AND FORECASTS PERTINENT TO RESERVOIR REGULATION

7-1. General. Analyses and forecasts pertinent to the regulation of Fort Peck Lake include weather forecasts, snowmelt forecasts, long and short range streamflow forecasts, reservoir inflow and pool elevation forecasts and the development of flow routing procedures. These forecasts and analyses provide a means for arriving at estimates of seasonal and annual water yields and short range forecasting of volume of runoff expected to result from storms originating over the drainage basin upstream of Fort Peck Dam and over the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River including the Milk River basin. Analyses of the forecasts are used as a guide for determining releases and storage required for Fort Peck Lake to provide for minimum releases for navigation, water supply and sanitation purposes; flood control for preventing or reducing flood damage in the reach of the Missouri River between Fort Peck Dam and the mouth of the Yellowstone River and for reducing flood stages in the lower reaches of the Missouri River; and for optimum utilization of water for power production, irrigation and other conservation uses.

7-2. Meteorology Forecasts - Corps of Engineers. The meteorological forecasts and analyses received from the National Weather Service are supplemented by further analyses and detailed specialized forecasts by the Missouri River Division Reservoir Control Center and the Omaha District Hydrology and Meteorology Section and Reservoir Regulation Section as required for reservoir regulation. For flood situations involving personnel and property of the Corps of Engineers detailed forecasts are made at District level using basic weather data received from National Weather Service teletype data and facsimile maps. National Weather Service analyses and forecasts are also used as a guide for short range forecasting of inflows and releases for the regulation of Fort Peck Lake.

7-3. Inflow Forecasts. The Reservoir Control Center develops forecasts of future inflows to Fort Peck Lake and the other associated main stem reservoirs at frequent intervals. Each week inflow forecasts extending three weeks into the future are developed. At the first of each month inflow forecasts extending through the remainder of the calendar year up to 1 March of the succeeding year are prepared. These are supplemented by additional inflow forecasts as conditions warrant. Inflow forecast procedures applicable for the drainage area above Fort Peck Dam are summarized in the paragraphs that follow. Additional details are presented in MRD-RCC Technical Study MH-73, on file in the Reservoir Control Center.

7-4. Mountain Snowmelt Forecasts. Forecasts of seasonal inflow into Fort Peck Lake are made by the Omaha District Reservoir Regulation Section for the period April through July on 1 January, 1 February, 1 March and 1 April. Omaha District forecasts are made by the use of empirical formulas developed from multiple correlation studies which related antecedent runoff, precipitation and snow cover water content with seasonal runoff, as summarized in Exhibit A.

7-5. Plains and Valley Snowmelt Forecasts. The basis for all plains and valley snowmelt runoff forecasts is a plains snow survey of the water equivalent of the snowpack coupled with information on soil moisture conditions and frost depth. An isochion map showing water equivalent of the snowpack is constructed in the District Office. The volume of the water equivalent of the snowpack is determined for each basin or sub-basin covered with snow. The area with hard, deep frost and/or ice layer on the ground is also indicated on the map. From the data so developed an analogous year is selected from past records on snowpack and runoff, giving due consideration to frost depths and quality and to ice layers. The percentage of water equivalent which appeared as runoff in the most closely analogous year is applied to the water equivalent in the current forecast year, yielding a volume of runoff to be expected during the early spring plains snowmelt season. Peak flow estimates are also made. These are based on the volume of snowmelt water available; assumptions or forecasts of temperatures to be expected and of solar radiation; and on the quality (density) of the snowpack as the season progresses. This latter element is obtained from additional snow surveys at about two week intervals. These elements are combined to determine a daily melt rate and runoff rate providing the assumed conditions do actually occur. Results are checked against peak inflows from analogous years. Unexpected cloud cover, cold temperatures which reduce or stop melting, and the action of frost leaving the ground are all vaiables which can cause appreciable error in the estimates.

7-6. An example of estimating the volume and peak discharge using the most analogous year method is presented below. The Grand River Basin above Haley, North Dakota, was selected for use in this illustration as data are not really available for the area above Fort Peck Dam. This basin is located in southwestern North Dakota and has runoff characteristics that are very similar to the plains and valley streams above Fort Peck. The forecasting procedure for the area above Fort Peck would be the same as that illustrated. In this example an estimate was made of the snowmelt volume and peak discharge that would occur in the North Fork of the Grand River Basin due to a 4.0 inch water equivalent snowpack in April 1952.

7-7. The most analogous year to the April 1952 snowpack condition in the North Fork of the Grand River Basin was the snowpack prior to the April 1950 snowmelt season. The Corps of Engineers conducted a snow survey on 29 March 1950, and it was determined that the snowpack in the basin contained an average of 3.3 inches of water equivalent. The total runoff from this event was 71,000 acre-feet over an 18-day period. One inch of runoff over the 509 square mile area is 27,140 acre-feet, so the 71,000 acre-feet volume is equivalent to about 2.6 inches of runoff. The percent runoff was equal to 2.6/3.3 or about 79 percent. The peak discharge from this event was 11,300 c.f.s., so the peak rate would be 11,300 c.f.s./3.3 inches of available water or about 3,420 c.f.s. per inch of water equivalent.

7-8. On 20 March 1952 a snow survey was conducted and a water equivalent map prepared from the survey data. From this map, the average water equivalent over the North Fork Basin was found to be about 4.0 inches of water equivalent times 79 percent times 27,140 acre-feet per inch which equals 85,800 acre-feet of runoff. This is compared with the actual snowmelt runoff of 95,000 acre-feet. The estimated runoff volume is within 10 percent of the actual runoff volume. The error is probably due to the lack of precision in the snow survey data and variable frost that affects losses. On 4 April the snowpack had ripened and there was a flow of about 1,400 c.f.s. in the channel. Weather forecasts made on 4 April 1952 indicated a warming trend for the next few days which was similar to the temperatures experienced during the 1950 runoff period. Using the runoff rates computed from the 1950 event, the estimated peak discharge in April 1952 would be 4.0 inches times 3,420 c.f.s. per inch of water equivalent which equals 13,680 c.f.s. This estimated peak compares favorably with the recorded peak of 14,100 c.f.s.

7-9. Other Long Range Streamflow Forecasts. The above forecasts are used by the Missouri River Division Reservoir Control Center as a guide for making estimates of annual and seasonal water yields and for scheduling of releases for the regulation of Fort Peck Lake. Forecasts of water supply and extended period runoff for the upper Missouri River Basin above Fort Peck Dam issued by other agencies are as follows:

a. Federal-State Cooperative Snow Survey and Water Supply Forecasts. Data are collected and report entitled "Snow Survey and Water Supply Forecasts" is published by the Soil Conservation Service as of 1 February, 1 March, 1 April and 1 May. These publications contain anticipated volumes of future runoff and data pertaining to mountain snow accumulation.

b. Water Supply Forecasts for the Western United States published by the National Weather Service. These forecasts are published on the first of the month, January through May, and cover the period of a water year (October through September) and the residual portion of the water year remaining after the forecast date.

c. Water Supply and Utilization published by the Bureau of Reclamation. These forecasts are long range volume forecasts largely for the operation of their tributary reservoirs in the upper basin and are published on the first of each month, February through October.

7-10. Infiltration Indices. Infiltration losses in the Missouri River basin above the mouth of the Yellowstone River are estimated to be 0.75 inch for the initial loss and 0.15 inch per hour infiltration loss. These values are based on relatively few rainfall events because of the rarity of heavy rainfall centers in the area as well as the wide spacing between rain gages. Snowmelt infiltration would range from 0 inches per hour for frozen ground, or ice under snow, to approximately the values shown for rainfall.

7-11. Rainfall-Runoff Relationship. Rainfall-runoff envelope curves developed for the Missouri River drainage basin above Fort Peck Dam are shown on Plate 30. These curves have been developed from limited information available from records of a few of the rainstorms which have occurred in this area, and are the best estimate of rainfall-runoff relationship available at the present time. The curves were drawn to envelope the values obtained from observed data and extrapolated above the actual value of 4 inches of rain with 1.32 inch of runoff to the 6 inch rainfall amount. Revisions to the curves may be necessary in the future as additional data are accumulated. In using the rainfall-runoff relationship curves, it is contemplated that cognizance will be taken of the season of the year, effect of antecedent rainfall, duration of rainfall and that runoff forecasts will be adjusted and modified to conform to actual observations of runoff during the progress of floods.

7-12. Basin Sub-Areas. The Missouri River Basin between Canyon Ferry Dam and Fort Peck Dam and between Fort Peck Dam and the mouth of the Yellowstone River has been divided into sub-areas for use in preparing runoff forecasts. These sub-areas are shown on Plate 31 and pertinent data for the sub-areas are shown in Table 10.

7-13. Unit Hydrographs. Unit hydrographs were developed for each of the sub-areas shown on Plate 31 by analyzing available records of floods on tributary streams located within the respective basins. Tabular data for these unit hydrographs are shown on Plates 32 and 33.

7-14. Stage-Discharge Relationship. Stream gages are operated in the Missouri River Basin above Fort Peck Dam and in the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River by the U. S. Geological Survey, the National Weather Service and the Corps of Engineers as described in Section VI of this manual. Discharge rating curves for gaging stations operated by the U. S. Geological Survey are kept current by annual revisions to the discharge rating curves and by measurements reported by the U. S. Geological Survey by post cards and teletype. Measurements for gaging stations in the cooperative program are usually reported every two weeks. Open water stage-discharge relations for key streamflow gaging stations pertinent to the regulation of Fort Peck Lake are shown on Plate 34.

TABLE 10

BASIN SUB-AREAS - PERTINENT DATA

Sub-Area	Basin	Contributing Drainage Area (Sq.Mi.)	Volume 1-Inch Runoff A.F.
FP-1	Ft. Peck Reservoir Area	350	18,700
FP-2	Ft. Peck Reservoir Local	5,525	294,500
FP-3	Mo. R. - Judith R. to Ft. Peck Reservoir	2,410	128,500
FP-4	Big Dry Creek at Van Norman	2,554	136,100
FP-5	Musselshell R. at Mosby	7,846	418,200
FP-6	Mo. R. - Marias R. to Judith R.	956	51,000
FP-7	Judith River	2,750	146,600
FP-8	Arrow River	1,286	68,500
FP-9	Marias R. - Tiber Dam to Mouth	2,235	119,100
FP-10	Teton River	1,989	106,000
FP-11	Mo. R. - Great Falls to Marias R.	914	48,700
FP-12	Belt Creek	812	43,300
FP-13	Sun River	1,991	106,100
FP-14	Mo. R. - Canyon Ferry to Great Falls	3,376	179,900
FP-15	Smith River	2,021	107,700
FP-16	Marias R. - Above Tiber Dam	4,405	234,800
FP-17	Mo. R. - Above Canyon Ferry Dam	15,904	847,700
G-6	Mo. R. - Yellowstone R. to Poplar R.	3,540	188,700
G-7	Poplar River	3,340	178,000
G-8	Redwater Creek	2,113	112,600
G-9	Mo. R. - Milk R. to Poplar R.	2,105	112,200
M-1	Milk R. at Nashua	22,332	1,190,300

7-15. Flow Forecast Procedures. Three procedures are used for estimating in advance the inflow to Fort Peck Lake or flows at other downstream control points. The procedure to be used at any given time depends upon the hydrologic situation. In each case the procedure has been simplified to its essentials for ease and rapidity of handling the data. The long routing reaches above Fort Peck and the large storage capacity provided by Fort Peck Lake allow this to be done at no loss in flood control protection or regulation efficiency. Studies for modernizing the routing procedures are continuing. The procedures are described below in paragraphs 7-16 through 7-19.

7-16. When the daily changes in flow are minor it is not necessary to utilize a formal routing method. This condition exists 60 to 80 percent of the time in the subject reach. Channel storage effects are negligible. This analysis requires converting stage reports from key gaging stations to discharges, translating or lagging them with no changes to the next station downstream and obtaining in the process an incremental inflow discharge for the intervening drainage area. This process is repeated at as many locations both on the main stem and tributaries as considered most practical with respect to efforts, time limitations and accuracy.

7-17. At the onset of rainfall, snowmelt or a combination of both, the translation of discharges as described above lacks the accuracy and flexibility necessary for inflow forecasting. To provide the estimates, before the reporting stream gage readings define a significant portion of the hydrograph, unit graphs presented on Plates 32 and 33 are used for analyses. The isohyetal pattern of the storm is plotted from the data received from the precipitation reporting network described in Section VI of this manual. From this pattern the average rainfall over specific sub-areas listed in Table 10 is determined. The runoff for the sub-areas is then computed by applying the estimates of initial loss and rate of infiltration as described in paragraph 7-10 or using the rainfall-runoff relationship curves described in paragraph 7-11. The runoff in inches for each sub-area is then applied to the respective unit hydrographs. The sub-area hydrographs are combined with release schedules from the upstream reservoirs and lagged to the Fort Peck Lake or other downstream control points. Unit hydrographs of 12 hour duration were developed for this period. This duration is representative of most runoff producing rains reported in the sub-areas. Also, 12 hour units of average discharge are convenient for routing inflow into the reservoir. The 12 hour units in tabular form can be converted to 24 hour units by simply averaging two units to combine with daily routed discharges when it is desirable to use two flow routing procedures. These 12 hour unit hydrograph tabulations have been compiled into a table with each hydrograph lagged the approximate travel time from the unit graph site to Fort Peck Lake. The velocity of the flood wave from each site has been assumed to be the normal maximum, attained when flows are near bankfull. During runoff periods, the tabular 12 hour average discharges for each unit graph should be multiplied by the rainfall excess for the individual area. This computation provides an easy way to obtain reservoir inflow forecasts prior to the high flow period. Similar tabulations of 12 hour unit hydrographs have been developed for the sub-areas of the incremental drainage area downstream from Fort Peck Lake to the mouth of the Yellowstone River. Plates 32 and 33 respectively, contain the tabulations of the 12 hour unit hydrographs for the sub-areas above and below Fort Peck Dam.

7-18. The size of the drainage basin above Fort Peck Lake places economic limitations upon the establishment of sufficient precipitation stations desirable for collection of basic hydrologic data and therefore restricts the accuracy of forecasting by the unit hydrograph method. Economic considerations also limit the development of initial loss and infiltration rate curves for the many sub-basins above Fort Peck Lake required for more accurate forecasting by the unit hydrograph method. Due to these limitations, forecasting by the use of unit hydrographs will require extensive testing and comparison with results during future storms.

7-19. A progressive lag-average routing procedure has been developed from numerous observations of acutal flood flows in the reach under study. It is a simple method of transposing flood hydrographs. The method is described in paragraph 5-03 of EM 1110-2-1408. There is some loss in accuracy due to the long reaches used and the simplification of procedure, but for the purpose of Fort Peck inflow estimates the method is sufficiently precise. The ease in making adjustments and modifications to the routing during actual flood periods is advantageous. The method consists of lagging the mean average of a certain number of mean flow values by what is considered to be the approximate travel time through the reach under consideration. The nearest odd integer to from one-half to three-fourths of the selected travel time (not necessary actual) determine the number of periods to be averaged with the exception that if the integer is one, a three period average is used. Normally, daily average discharges are used for this method. Periods of 12 hours can be used for short reaches but for long reaches it would defeat the principal advantage of the speed with which this method can be used. The routing criteria developed for the daily average outflow of the sub-areas above Fort Peck to the reservoir are shown on Table 11. During many periods, forecasts for day-to-day regulation can be obtained by using the flows at the terminal points of the Missouri River at Great Falls, the mouth of the Marias and the mouth of the Judith River which locations are sub-areas FP-14, FP-11 and FP-6 respectively. A one day lag time between the terminal points makes the method flexible to adjust to the desired routing for each individual flood event. Table 12 contains an example of routing the 1964 flood on the Missouri River at Great Falls to Fort Peck Lake. For this particular routing, criteria for sub-area FP-14 are applicable. Average travel velocities utilized in this method are approximately 96 miles per day or 4 miles per hour. This average rate is usually observed between medium and overbank flows.

TABLE 11

TABULATION OF ROUTING DATA

Region		Routing Criteria to Fort Peck Lake Number of days Averaged	 Approximate (1) Number of days Mean Value Lagged
FP-1	Ft. Peck Res. Area	1	0
FP-2	Ft. Peck Res. Local	1	0
FP-3	Mo. R. - Judith R. to Res.	1	0
FP-4	Big Dry Cr. at Van Norman	3	1
FP-5	Musselshell R. at Mosby	3	1
FP-6	Mo. R. - Marias R. to Judith R.	3	1
FP-7	Judith River	3	1
FP-8	Arrow Cr.	3	1
FP-9	Marias R. below Tiber	3	2
FP-10	Teton R.	3	2
FP-11	Mo. R. - Great Falls to Marias	3	2
FP-12	Belt Cr.	3	3
FP-13	Sun R.	3	3
FP-14	Mo. R. - Canyon Ferry to G.F.	3	3
FP-15	Smith R.	3	4
FP-16	Tiber Releases	3	3
FP-17	Canyon Ferry Releases	3	5

(1) From Middle Day of Those Averaged

TABLE 12

EXAMPLE OF PROGRESSIVE AVERAGE-LAG ROUTING
MISSOURI RIVER AT GREAT FALLS TO FORT PECK LAKE

Date June 1964	Avg. Daily c.f.s.	3 Day Avg. Daily Total	3 Day (1) Avg. Lagged 3 Days
5	21,400		
6	20,200	60,800	
7	19,200	62,100	
8	22,700	74,200	
9	32,300	118,400	20,300
10	63,400	150,000	20,700
11	54,300	156,000	24,700
12	38,300	124,000	39,500
13	31,400	100,500	50,000
14	30,800	93,800	52,000
15	31,600	92,200	41,300
16	29,800	90,400	33,500
17	29,000	88,100	31,300
18	29,300	88,700	30,700
19	30,400	91,400	30,100
20	31,700	94,700	29,400
21	32,600	97,400	29,600
22	33,100		30,500
23			31,600
24			32,500

(1) From mean day of those averaged

7-20. Short Range Streamflow Forecasts. Short range streamflow forecasts for the drainage basin above Fort Peck Dam and for the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River are based on upstream reservoir releases, observed and anticipated precipitation and temperature, temperature-snowmelt relationships, rainfall-runoff relationships, observed streamflow in the main stem and tributaries, antecedent precipitation, and other factors which often may be subject only to qualitative analysis.

7-21. The National Weather Services, the Federal agency responsible for the preparation and issuance of river forecasts for public dissemination, prepares forecasts for many locations within the Missouri River Basin as described in Section VIII of the Master Manual. The National Weather Service river forecasting services are utilized to the maximum extent practicable for the regulation of Fort Peck Lake. These services are particularly useful at time when flood conditions are occurring, or are imminent, within the basin. During such flood periods the National Weather Service District Offices at Helena, Montana, and Bismarck, North Dakota, the River Forecast Center at Kansas City, and the Corps of Engineers District Office at Omaha and the Missouri River Division Reservoir Control Center interchange all available data upon which the most reliable forecasts and subsequent reservoir regulation procedures for Fort Peck Lake may be based.

7-22. River stage and discharge forecasts made by the Corps of Engineers are strictly for flood control operations and reservoir regulation purposes. Any forecasts released by the Corps of Engineers will be those issued or approved by the National Weather Service.

7-23. Reservoir Regulation Forecasts. The Reservoir Control Center makes numerous studies through the year on a continuing basis which serves to indicate anticipated pool elevations, releases and hydro-power generation which may be expected at Fort Peck Project as well as the other five reservoirs of the main stem system. Details are presented in the Master Manual and summarized data from these studies are routinely furnished the projects for their information on Friday of each week. Special requests for further information are referred to the Reservoir Control Center.

7-24. Wind Effects on Reservoir Gage. The general orientation of the major axis of Fort Peck Lake is from west-southwest to east-northeast although the major Dry Creek Arm has a south to north orientation. The pool elevation gage, which forms the basis for estimates of storage, storage change and inflows, is located at the damsite. Due to the orientation of the reservoir, winds from a direction having a southwesterly component can be expected to result in a pool elevation reading at a higher level than the true mean pool surface elevation while a lower than mean pool surface elevation would occur with winds having a northeasterly component. Based on observations and theoretical considerations, the wind correction table shown on Plate 35 has been developed. Its use requires an estimate of the average gradient winds over the reservoir surface and assumes that the wind effects to be fully established. These winds may be established from current surface weather maps and reported winds in the region including the winds reported by the Fort Peck anemometer mounted on a tower above the roof of the surge tanks. When the reservoir is ice covered the winds have minor effects on reservoir pool readings.

7-25. Reservoir Evaporation. Since normal annual evaporation from the main stem system is approximately three million acre-feet, evaporation determination is an important consideration in reservoir regulation. Daily estimates of evaporation can be determined by obtaining the daily evaporation and multiplying by the proper coefficient. The coefficients for the main stem projects including Fort Peck Lake are available in a report entitled MRD-CC TECHNICAL REPORT IE-73 prepared by the Missouri River Division, Reservoir Control Center of the Corps of Engineers in Omaha, Nebraska in June 1973. The coefficients contained in this technical report may have to be modified from time to time by the Reservoir Control Center as additional hydrologic data becomes available.

7-26. Net Evaporation. While the gross reservoir evaporation, as described in the preceding paragraph, is an estimate of the total evaporation from the reservoir and consequently is used to develop inflows, it is not satisfactory for developing reservoir regulation effects. Net evaporation is the term applied to the summation of the effects upon streamflow of evaporation upon the reservoir surface, original channel area now inundated by the reservoir, and runoff from the original surface areas now inundated by the reservoir. Based on examination of characteristics of the reservoir area, net evaporation development assumes that the original channel area is ten percent of the reservoir area and also assumes that about 15 percent of the precipitation that falls over the area now inundated by the reservoir but not part of the original Missouri River channel would have appeared as direct runoff prior to the existence of the Fort Peck Project.

7-27. Cooperation With Other Agencies. Forecasts made of seasonal runoff and anticipated reservoir elevations are furnished the Fish and Wildlife Service, the Montana State Fish and Game Commission and others interested in reservoir stages at the Fort Peck Project. Daily forecasts of anticipated operation are given local distribution and furnished local newspaper and radio stations for public information.

SECTION VIII - MULTIPLE-PURPOSE REGULATION

8-1. General. This section of the manual presents the operational objectives and requirements of the project, together with descriptions of multi-purpose operation plans when regulated as an integral part of the main stem reservoir system for functions other than flood control. These include irrigation, navigation, downstream water supply and stream sanitation, power, recreation, fish and wildlife preservation and other purposes. Objectives, requirements and procedures for specific flood control functions of the Fort Peck project are included in Section IX.

8-2. Regulation Objectives and Requirements. The conservation regulation objectives and requirements for the Fort Peck Reservoir are as follows:

a. To support the long range objectives for maintaining the main stem reservoir system near the normal operating pool level by storing excess runoff during the spring and summer flood periods for downstream flood control, while maintaining the downstream releases required for conservation purposes.

b. To vacate the seasonal flood control and multiple-use storage by the beginning of each flood season (on or about 1 March) in such a manner that downstream flood conditions will not be aggravated and optimum conservation benefits will be achieved.

c. As an integral part of the main stem reservoir system, to coordinate releases with other main stem projects to provide for optimum overall service consistent with the available or anticipated water supply for the production of hydroelectric power, downstream irrigation, navigation, municipal water supply and stream sanitation, recreation, and preservation of fish and wildlife.

8-3. Irrigation. The effects of irrigation and depletions in streamflow due to irrigation are considered in the regulation planning for the main stem reservoir system as described in the Master Manual. Maintenance of adequate downstream flows is the only active regulation required of Fort Peck for this function since there are no significant acreages irrigated by pumping from the reservoir. Releases of sufficient quantity to meet irrigation diversion requirements along the Missouri River below the dam are made at all times, but supplemental releases to provide desirable river levels for satisfactory intake operation are made only to the degree that available water supply and equitable regulation for other project purposes will permit. In general a minimum release of 1,000 c.f.s. is sufficient to satisfy present flow requirements during the irrigation season for irrigation from the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea. However, with releases this low, numerous problems relating to access to the available water supply can be expected. Therefore, to minimize these problems average releases during the irrigation season are maintained at the highest level consistent with other functions. A relatively steady mean daily release pattern from Fort Peck Lake during the irrigation season helps to minimize problems that irrigators have experienced in raising and lowering of pumps and intakes due to variations in streamflow and changes in sandbars.

8-4. The Bureau of Indian Affairs has two pumping plants on the left bank downstream from Fort Peck Dam as discussed in Section III-F of this manual. The Wiota Pumping Plant, 20.2 miles downstream from Fort Peck, has a pumping capacity of 120 c.f.s. Past experience indicates the pumps will operate with flows as low as 1,000 c.f.s. High river levels in the winter resulting from ice conditions have resulted in flooding the plant floor. Minor electrical damages resulted from high river levels the first winter after the plant began operation in 1964. Since that time prior to freeze up electrical equipment has been removed from the lower portion of the control cabinets to prevent damages if river stages rise above the floor level. No further damages from ice have been reported since that initial time. Permanent modifications to the project to alleviate potential ice damage in the winter have been deferred since they would possibly hinder the operation of the plant during periods of low flows. Pending these modifications it is necessary to carefully schedule Fort Peck releases during the winter period when active ice formation is occurring in this reach of the Missouri River.

8-5. The other Bureau of Indian Affairs unit, the Frazer-Wolf Point Pumping Plant, 34.5 miles downstream from Fort Peck, has a pumping capacity of 285 c.f.s. Erosion along the left bank about one mile upstream from the irrigation intake has modified the flow characteristics of the river. The changing channel has moved the main flow section away from the pumping plant intake. The resulting restricted channel to the intake is unable to carry sufficient water to simultaneously serve all pumps during periods of low releases from Fort Peck Dam. Authorized channel rectification structures should improve flow conditions so that the pumping plant can operate during periods of low flows. Pending installation of these structures, it is necessary to schedule Fort Peck releases to maintain mean daily flows of 7,000 to 8,000 c.f.s. adjacent to this pumping unit, if the pumps are to be operative. During drought periods Fort Peck average-monthly releases as low as 3,000 c.f.s. during the irrigation season are considered necessary for optimum system regulation. Under such conditions, special corrective measures may be necessary to permit the plant to stay in operation.

8-6. Municipal Water Supply and Water Quality Control. Fort Peck is regulated to provide sufficient streamflow in the reach between Fort Peck Dam and the headwaters of Lake Sakakawea for municipal water supply and stream sanitation purposes. Operating experience has demonstrated that a minimum daily average release of 3,000 c.f.s. from Fort Peck Lake is normally adequate for all municipal and water quality requirements as well as providing sufficient flow for existing irrigation requirements. However, at times of low tributary inflow it may be necessary to temporarily increase releases above 3,000 c.f.s.

to provide sufficient stage for satisfactory operation of water supply intakes. No difficulty is anticipated in meeting municipal water supply and water quality requirements in the foreseeable future.

8-7. <u>Navigation</u>. The Fort Peck project is operated as a unit of the main stem reservoir system for Missouri River navigation below Sioux City. Normally, when adequate multiple use storage space is available in the project, releases from Fort Peck Lake are reduced during the spring and summer seasons and increased during the winter to obtain optimum power benefits while transferring storage to downstream main stem reservoirs which will eventually be released from the system to support navigation.

8-8. <u>Power Production</u>. Power production at the Fort Peck project is dependent upon the pool elevations of Fort Peck and other main stem reservoirs water supply, water release requirements for downstream purposes, downstream channel capacity during ice cover season, capability of the powerplants at Fort Peck and the power demands of the system. The water requirements for the generation of hydroelectric power are not consumptive. However, the realization of the maximum power potential provided by water passing through the reservoir system requires the regulation of Fort Peck Lake to be carefully integrated with the overall regulation of the main stem system as described in the Master Manual. During the winter period of peak power demand, releases can normally be expected to average about 50 percent greater than during the remaining months.

8-9. Advanced planning for the regulation of Fort Peck Lake, including advanced planning for power production as an intergrated part of the main stem system, is described in the Master Manual. Day-by-day regulation of Fort Peck Lake for power purposes is closely coordinated with the Bureau of Reclamation (the marketing agency for Federally generated power in the basin) and with the regulation of the system for non-power purposes. Combined reservoir regulation and power production orders are issued by the Reservoir Control Center to the Fort Peck Powerplant. The orders include scheduled daily generation along the maximum and minimum loading limits of the two powerplants. The actual loadings of the Fort Peck Powerplants are controlled by the Bureau of Reclamation, subject to the limitations imposed by load limits in the power production order and discharge limitations stipulated in concurrent reservoir regulation orders. Hourly patterning of the daily releases is of major importance in realizing the full power potential of the Fort Peck Powerplants. An illustration of hourly regulation and power production during the navigation season is shown on Plate 36. A similar illustration during the non-navigation season is shown on Plate 37. The patterns illustrated are for fairly representative weeks, however, main stem system requirement and hydrologic conditions vary the schedules considerably during either season.

8-10. Fluctuations in discharge resulting from power peaking operations are dampened relatively rapidly in the channel below Fort Peck Dam. The large dredge pools below the dam aid in this damping. In the past daily releases have varied from zero in portions of the day to full powerplant capacity (15,000 c.f.s.) with tailwater levels varying up to 8 feet. Through the first 10 miles of channel below the dam these fluctuations in water level can be expected to be reduced to about 5 feet. At 60 river miles below the dam a diurnal fluctuation of about one foot will occur. While these fluctuations could be responsible for some bank erosion and do aggravate problems associated with access to water at irrigation intakes, the only restrictions on peaking currently in effect occur during the irrigation season. When irrigation pumping is occurring minimum generation and releases for 4 to 7 hour periods are often specified.

8-11. Recreation. Recreational use of the Fort Peck Lake is enhanced by near full pool levels and will be adversely affected during those periods of low inflows when a loss of storage becomes necessary to sustain downstream multipurpose demands. In addition to reducing the water surface area available for recreation, continued drawdown results in the exposure of increasing areas of mud flats which are unpleasant in appearance. As a consequence, when a loss of system storage below the essentially full condition occurs, it is distributed insofar as practical amongst the major reservoirs in the system, including Fort Peck, so that no one project bears the brunt of these adverse circumstances. Additionally, with a loss in system storage, the service to downstream project purposes is reduced. With this reduction in service the effects of drought periods upon recreation and related functions are ameliorated to some extent.

8-12. A significant drawdown of Fort Peck Lake can also affect recreation by limiting access to the reservoir. Boat ramps at the reservoir public use areas as described in Section IV of this manual have top elevations varying from 2267.6 to 2245.5 and bottom elevations from 2253.2 to 2237.5. If extended drought conditions were to occur it would be necessary to extend these boat ramps to a lower elevation.

8-13. Fish and Wildlife. Project land in this vicinity of Fort Peck Lake provides excellent habitat for several species of wildlife, as discussed in section III-K. Wildlife management is not an important factor in reservoir regulation; however, higher than normal pool levels do have the effect of decreasing river bottom habitat in the reservoir headwater region.

8-14. The reservoir is also an important fishery resource in the State of Montana. Perhaps the most important aspect of reservoir regulation relating to the fishery resource is the enhancement of spawning activities; particularly of the northern pike species. To assist in the initial fill of the downstream main stem reservoirs, the Fort Peck pool level was drawn down toward its minimum operating pool level. During the years 1956 through 1965 the reservoir refilled to the normal operating range. Following this refill a marked increase of northern pike in the reservoir was noted. This increased pike

pike reproduction resulted from the establishment of terrestial vegetation along the shoreline during the period that the pool level was low and subsequent shallow inundation of vegetation during the rising pool levels, providing ideal northern pike spawning habitat.

8-15. With the reservoir at normal operating levels, enhancement of northern pike spawning requires deliberate regulation. First it is necessary to establish the terrestial vegetation which provides the spawning habitat. At least one growing season with an exposed shoreline appears necessary for this purpose. This established terrestial vegetation must then be inundated during the northern pike spawning period, which at Fort Peck appears to occur in April or early May. Following spawning the inundation of the vegetation must continue until after the eggs hatch and the fish develop sufficiently to follow falling pool levels. Due to the character of inflows to Fort Peck Lake, regulation to enhance northern pike spawning can be accomplished only by serious disruption to power production at that project when normal inflows and pool levels are occurring. Additionally, there is no guarantee that successful spawning will occur even if the terrestial vegetation is present with ideal pool elevations since spawning is affected by numerous other conditions. Consequently, to this time, it has been considered impractical to regulate Fort Peck for this purpose unless antecedent and coincident hydrologic conditions are such that serious adverse effects will not result to the other functions the reservoir is designed to serve.

8-16. Regulation Studies. The Annual Operating Plan, described in Section IX of the Master Manual, is a multipurpose regulation study for the main stem reservoir system which is prepared and published during August-September of each year. The AOP analyzes regulation of each reservoir in the system under various forecast and assumed runoff conditions for the remainder of the current year and through the ensuing year. The AOP also presents somewhat more limited information on possible system operations during the 5-year period beyond the close of the ensuing year. While the annual operating plan provides a general framework for regulation of the system for all purposes except flood control during the succeeding year, additional studies are also made frequently through the year to more definitely define the anticipated regulation. Each week a forecast of regulation of Fort Peck and the other main stem projects is made for a period extending for three weeks into the future. Additionally, as the need arises, studies extending up to several months into the future are made and coordinated with the Bureau of Reclamation to determine the most effective regulation of Fort Peck, in combination with the other reservoirs of the system, for the power function. All these studies are based on the latest available inflow forecasts for each of the projects and provide the information necessary for the day-by-day scheduling of releases from Fort Peck and other reservoirs in the system.

8-17. Fort Peck Regulation Guide Curves. The regulation guide curves shown on Plate 39 illustrate the relationship of possible reservoir inflow, reservoir storage, and release rates for various periods of the year for use as an aid in determining project regulation as a unit of the main stem reservoir system to achieve flood control, water conservation, and power production. They can serve as an aid in defining project releases; however, many other factors must also be considered, as described in the Master Manual. The curves reflect the following basic conditions and assumptions:

a. Reservoir storage capacities are based on the 1961 aggradation survey.

b. Streamflow depletions are based on 1970 level of basin development.

c. Inflows are based on the hydrologic period extending from 1898, adjusted to the 1950 level of basin development.

d. Reservoir evaporation losses are average annual losses.

8-18. The regulation guide curves show the release rates necessary for evacuation of reservoir storage through the following periods of the year:

a. The major runoff season. This period usually extends from March through July. About two-thirds of the annual volume of inflow usually occurs during these months. The largest volume of flow and the widest variation in inflow occurs during this time. The regulation guide curves for the period indicate the volume of storage required to store various percentages of the average inflow in conjunction with specified releases. The curves also indicate that about 1.150 million acre-feet of storage would be used to store the average flows with releases of 9,500 c.f.s. during the entire March-November period and resilt in no overall reservoir storage gain or draft. A large part of the runoff during the period comes from snowmelt and may be forecast with reasonable accuracy.

b. The late summer and fall. The period extends from August through November. Inflows to the reservoir are relatively low during these months and draft on reservoir storage is usually required in support of system multipurpose operation. The curves for the reservoir drawdown period show that, with average flows during this period, about 1.8 million acre-feet of storage could be evacuated by releases averaging 12,500 c.f.s. With 15,000 c.f.s. release, which approximates the maximum discharge capability of the power installation, the reservoir would be drawn down about 2.4 million acre-feet during the period. The curves indicate that storage equivalent to the total allocated seasonal and exclusive flood control could usually be evacuated by the end of November by releasing 25,000 c.f.s. beginning in late August.

c. The winter months with ice condition. The channel capacity of the river with ice is less than for open water conditions and consequently regulation is somewhat restricted with ice conditions. The regulation guide curves show the storage needed at the end of November to maintain the specified release rates to the end of February which is the target date for adjusting reservoir storage in preparation for the major runoff season. The curves also show the effect on storage if the winter release rates are continued into or through March. The curves indicate that 1.125 million acre-feet of storage would be required in combination with average inflow to release 12,500 c.f.s. These guide curves do not reflect regulation afforded by tributary reservoirs upstream from Fort Peck that have been constructed since 1950. Consequently, conclusions derived from these curves must be tempered by anticipated tributary reservoir regulation including replacement storage operations.

SECTION IX - FLOOD CONTROL REGULATION

9-1. Objectives of Flood Control Regulation. The flood control regulation objectives of the Fort Peck Lake are: (1) to utilize available storage space to the best possible advantage to prevent or reduce flooding in the reach from Fort Peck Dam to Lake Sakakawea; (2) to coordinate flood control regulations of Fort Peck Lake with the regulation of the other main stem reservoirs on the Missouri River to prevent flows from the drainage basin above Fort Peck Dam from contributing to damaging flows through the lower reaches of the Missouri River valley. In most cases, regulations to reduce floods on the Missouri River also serve to reduce floods on the Mississippi River.

9-2. Method of Flood Control Regulation. In general, the developed method of regulation of Fort Peck Lake may be classified as Method C defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available storage space in Fort Peck Lake during each flood event with regulation procedures based on the control of floods of approximate project design magnitude. Procedures for the accomplishment of flood regulation of Fort Peck Lake are outlined in succeeding paragraphs and examples of this regulation are shown in Section X.

9-3. General Plan of Flood Regulation. Regulation of the Fort Peck Lake for flood control to meet the stated objectives is based on consideration of the following factors:

a. Coordination of flood control regulation of Fort Peck Lake with the regulation of the downstream main stem reservoirs as described in Section X of the Master Manual.

b. Channel capacity through the reach of the Missouri River between Fort Peck Dam and the mouth of the Yellowstone River.

c. Observed and anticipated inflows in the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River.

d. Observed and anticipated inflows to the Fort Peck Reservoir.

e. Space currently available within Fort Peck Lake for storage of future floods.

f. Flood producing potential of the drainage basin above Fort Peck Dam and the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River.

g. Release requirements from Fort Peck Lake for purposes other than flood control.

h. Flood storage space available in tributary reservoirs upstream from Fort Peck Dam.

9-4. Flow Regulation Devices. Releases from the Fort Peck Lake may be made through the two powerplants, outlet works and the spillway. Normally discharge through the powerplants will be used to the fullest extent possible in order to achieve the maximum economic return from the project. When releases in excess of that required for power generation or larger than the powerplant capacity demand are necessary, the outlet tunnels and/or the spillway will be used.

9-5. Fort Peck Flood Control Storage Space. The flood control storage allocations for Peck Lake, and associated reservoir elevations based on the 1972 Aggradation Survey, are described in Section IV of this manual. Flood control storage space includes 2,700,000 acre-feet for seasonal flood control and multiple-use and 1,000,000 acre-feet for exclusive flood control. These allocations are based on system as well as project requirements and assume no significant tributary storage development. Surcharge space is provided above these specific flood storage allocations primarily to insure safety of the project during maximum probable flood conditions.

9-6. Coordinated System Flood Control Regulation. The main stem system of reservoirs, of which Fort Peck Lake is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the system. Integrated regulation techniques to accomplish this objective are described in Section X of the Master Manual. The general plan of regulation applicable to most of the main stem reservoirs including Fort Peck is to have the flood control storage space evacuated prior to the beginning of the March-July flood season. During the flood season inflows that are in excess of the current multiple-use requirements are deliberately impounded in annual flood control and multiple-use storage space until such time there is reasonable assurance that adequate reserves are stored to satisfy multiple-use requirements to the beginning of the next flood season without drawdown into the carry-over zone of system storage. This deliberate storage for future multiple-use also serves the flood control function. Following the time that adequate supplies of multiple-use storage are reasonably assured, releases in excess of current multiple-use requirements are made as a storage evacuation measure when such releases are not anticipated to contribute to downstream flooding. Normally, system releases in excess of multiple-use requirements are scheduled at a relatively uniform rate, to the degree practicable, in order that maximum multiple-use benefits may be achieved. Of course, modifications from these uniform rates are made when required for flood control purposes.

9-7. Replacement Flood Control Space. Tributary flood control storage provided in Canyon Ferry and Clark Canyon Reservoirs upstream from Fort Peck is regulated in a manner that effectively replaces a portion of the allocated annual flood control and multiple-use space in the main stem system, as described in Section III of this manual. Since Fort Peck is the immediate downstream main stem project below these tributary reservoirs, replaced main stem flood control storage space equivalent to that provided in Clark Canyon and Canyon Ferry would normally be in the Fort Peck Lake. This would allow Fort Peck to be maintained at a higher elevation at the start of the flood season than indicated by storage allocations previously described. However, the nature of system design floods is such that the transfer of space (or storage) from one of the major upstream main stem projects to another during the progress of a flood can be accomplished with relative ease. Therefore, at times the encroachment into the allocated flood control and multiple purpose permitted by existence of this upstream space may be in the Garrison or Oahe Reservoirs rather than Fort Peck.

9-8. Regulation of the tributary reservoirs with a replacement flood control function is described in appropriate tributary reservoir regulation manuals. Insofar as Fort Peck (or other main stem reservoirs) is concerned, regulation is based on the tributary replacement space being essentially considered as a portion of the main stem annual flood control and multiple-use space. Therefore, evacuation of the tributary space allows retention of water in main stem (Fort Peck) space.

9-9. Coordinated Flood Regulation Techniques. Regulation of Fort Peck Lake as one of the major components of the main stem reservoir system will generally parallel that described above for the system as a whole. However, some variations are allowed as described below:

a. Evacuation of storage space to the base of the annual flood control and multiple-use zone is a recognized objective; however, to the extent that this evacuated tributary storage space can replace annual flood control and multiple-use storage space in Fort Peck, an encroachment into the Fort Peck flood control storage zone is allowed.

b. Due to the relatively large channel capacity between the major main stem reservoirs (Fort Peck, Garrison, Oahe and Fort Randall) some imbalance of evacuated storage space prior to the beginning of the flood season is allowed if this imbalance results in surplus water in Fort Peck Lake balanced by surplus space in a downstream project. However, it should be recognized that when such an imbalance occurs, the probability of future flood events requiring releases from Fort Peck in excess of powerplant capacity, even though well within the limits imposed by flood control considerations, is increased.

c. While the pattern of system regulation generally is as described in paragraphs 9-6 and 9-7, during a particular year the pattern of Fort Peck may differ materially from other downstream projects. Dependent upon inflows, a major portion of the annual flood control and multiple-use space may be filled in Fort Peck Lake with only a minor portion filled in downstream projects. However, prior to significant encroachment into the Fort Peck exclusive flood control zone, complete fill of the annual flood control and multiple-use zones of all other main projects is scheduled. Criteria specific to the Fort Peck project upon its encroachment into the exclusive flood control zone is discussed in a later paragraph.

9-10. Release scheduling from Fort Peck Lake, as well as from all of the other main stem projects, is normally done on the basis of studies performed by the Reservoir Control Center which 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 9-3 are considered to the extent possible in these studies. Such studies are made at a maximum interval of each month as new estimates of future inflows are developed and, if conditions change materially from those anticipated in the monthly studies, additional 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.

9-11. Local Flood Control Regulation. Procedures described in the preceding paragraphs are designed for regulation of Fort Peck Lake as a significant part of the main stem reservoir system. This project is also designed to provide flood protection through the reach extending from Fort Peck Dam to the headwaters of Lake Sakakawea and at times regulation is based on conditions in this reach. The Milk and Yellowstone Rivers are major tributaries entering this reach. Other minor tributaries can also contribute large inflows for short periods of time. Immediately below the mouth of the Milk River the Missouri River has an open water channel capacity of about 30,000 c.f.s.; therefore, Milk River flows are monitored accordingly. At times Milk River discharges exceed this rate and it is necessary to reduce Fort Peck releases to minimum mean daily rates of 3,000 c.f.s. or less. With an ice cover the channel capacity below the mouth of the Milk River is reduced and regulation is based on maintaining Wolf Point stages at 11 feet or less. Fortunately, the Milk River is a slow cresting stream and flows at Nashua, the most downstream gaging station on the Milk River are approximately coincidental (with respect to downstream travel time) with Fort Peck releases. Regulation to achieve the above objective is not difficult.

9-12. Due to the rapid cresting time of minor tributaries below Fort Peck Dam and the lack of stream data from these tributaries, regulation of Fort Peck for desyncronization with crest tributary rainfall runoff becomes impracticable. Sharp tributary rainfall crests will enter the Missouri

River prior to the time that Fort Peck release reductions based on rainfall reports can be effective. However, unless high flows are also occurring from the Milk River as a result of runoff which occurred some time previously, there will usually be adequate channel capacity with Fort Peck releases at or below the powerplant capacity. Crest flows from these tributaries attenuate rapidly when entering the Missouri River. At times when a significant plains snowmelt runoff appears imminent from these minor tributary streams, it is practical to reduce Fort Peck releases. During the winter ice cover period Fort Peck regulation is based on maintaining a Culbertson, Montana, stage of 13 feet or less. This requires consideration of possible snowmelt runoff from the tributary area.

9-13. The Yellowstone River is capable of producing flows which exceed the Missouri River channel capacity below the confluence of the two streams. However, nearly all of the flood plain below the Yellowstone River to Garrison Dam has been acquired by the government in connection with the Garrison project. Therefore, release scheduling from Fort Peck to project areas below the Yellowstone River is seldom required. There have been complaints from the Missouri River flood plain area immediately above the Yellowstone River as a result of backwater effects from high Yellowstone River flows. However, in general it appears that these complaints originate from low lying areas that have been developed since control has been provided by Fort Peck Lake. There is little regulation action that can be taken to alleviate this problem.

9-14. Regulation During Missouri River Ice Formation. Winter ice cover forms each year on the reach of the Missouri River extending from Fort Peck Dam to the headwaters of Lake Sakakawea. Usually this occurs in late November and December with the initial cover forming near the headwaters of Lake Sakakawea. The head of the ice cover then progresses upstream toward Fort Peck Dam with the rate of progress and total extent of cover dependent largely on temperatures experienced at the time. As the ice cover forms at a particular point, a sudden sharp increase in stage is experienced due to the associated friction effects. With the passage of time after the cover has formed the frictional effects are reduced; however, the channel capacity remains well below the open-river capacity.

9-15. On the basis of actual experience, Fort Peck releases are limited to 10,000 c.f.s. during the period of initial active ice formation in the reach extending from the headwaters of Lake Sakakawea up to Wolf Point, Montana. If this initial freeze continues rapidly upstream from Wolf Point, maximum releases continue to be limited to 10,000 c.f.s. However, after the Missouri River has frozen to above Wolf Point and the ice cover from Wolf Point downstream has stabilized, satisfactory regulation occurs if Fort Peck releases are limited to 12,000 c.f.s. during further periods of active ice formation in the reach immediately below the dam. After a stabilized ice cover has formed from the mouth of the Milk River downstream, releases can be increased to the full powerplant capacity of 15,000 c.f.s. provided significant inflows are not occurring from the incremental drainage area extending from Fort Peck to the mouth of the Yellowstone River. The head of the ice cover will move downstream during warm periods which often occur during the winter months. Continued powerplant capacity releases during the time the ice cover is diminishing create no problems; however, if a substantial amount of ice cover is lost as a result of warm temperatures, conditions revert to those described for initial freeze-up when cold temperatures recur.

9-16. Studies are continuing to more closely define the relationships between release temperature, release volume, air temperature and downstream ice formation. As yet only qualitative conclusions are available. These indicate that minimum temperatures well below zero and a mean daily temperature of near zero are required for the initial ice cover to form rapidly through this reach when releases are in the 10,000 to 15,000 c.f.s. range. While release temperatures apparently have little effect on ice formation through the lower portion of the reach, high release temperatures do retard formation closer to the dam. Regulation during the winter ice season must consider these factors as occurring or forecast.

9-17. Regulation Guide Curves. Regulation guide curves shown on Plate 39 have been developed for use as an aid for regulation of Fort Peck Lake. Detailed description of the development of these curves and the use thereof are described in Section VII of this manual.

9-18. Exclusive Flood Control Regulation Techniques. The procedures described in paragraph 9-10 will result in the Fort Peck pool being below the base of exclusive flood control most of the time. However, occasionally flood inflows will be of such magnitude that encroachment into the exclusive flood control zone will occur and supplementary actions may be necessary. These actions will be dependent upon conditions existing or anticipated in the other reservoirs in the main stem system. If exclusive flood control space is being utilized in all main stem reservoirs, action will be on the basis of the studies described in the preceding paragraphs with system releases and the balance of exclusive storage scheduled in each reservoir of the system as defined by procedures discussed in the Master Manual.

9-19. At times encroachment into the Fort Peck exclusive flood control space will occur or will be anticipated when ample annual flood control storage space remains vacant in the downstream Garrison, Oahe and Fort Randall projects. Normally when this occurs Fort Peck releases will be maintained at full powerplant capacity in an effort to transfer the excess storage downstream while at the same time developing the maximum practical revenue for the government. However, significant encroachment into the exclusive flood control space will require releases in excess of the powerplant capacity in order that a storage space reserve can be maintained for unanticipated flood inflows. Regulation curves shown on Plate 40 serve as a guide for defining minimum releases at such times. These curves relate pool elevation and current inflows to minimum releases. To the extent that short range inflow forecasts are available, analysis of forecast pool elevation with possible release rates will be used in conjunction with these curves. The early spring plains snowmelt and rainfall curves recognize the relatively sharp peaking hydrographs resulting therefrom, as compared to the generally long and flat crests during the late spring mountain snowmelt season. Two late spring curves are given, the first applicable prior to 1 July. Substantial mountain snowmelt often continues to that date while after 1 July the recession from this runoff source has begun. The May - June curve results in somewhat higher releases for corresponding inflows than the July curves. Since floods resulting primarily from intense rainfall have characteristics similar to early spring floods, the early spring curves should be used following the mountain snowmelt season or when reports indicate that a sharp increase in inflows is due largely to a rainstorm over the contributing area. When the inflow-pool level relationship falls beyond the limits of these curves, the emergency regulation curves, described later, should be consulted.

9-20. Surcharge and Emergency Flood Regulation Techniques. Previously described procedures assume that reservoir inflows will not be extremely high and that rapid communication is available between the Reservoir Control Center and operating personnel at the Fort Peck Powerplant. When such assumptions are no longer valid it may be necessary for operating personnel of the dam to modify operations on the basis of information available to them. Additionally, with extremely large inflows, integrity of the dam and associated facilities becomes an important consideration.

9-21. Regulation techniques pertinent to extreme floods and emergency conditions are presented in Exhibit B. These techniques require data which, in general, may be obtained directly at the powerplant and for this reason are applicable under emergency conditions when rapid communication to the site from the Reservoir Control Center is not available. Due to marked differences in characteristics between the early spring and late spring floods originating in the upper part of the Missouri basin, separate curves have been developed for Fort Peck Lake for each flood type. Reservoir release rates are dependent upon pool elevations and rate of inflow. The schedules have been developed in accordance with the method described in Engineering Manual 1110-2-3600 and change 1 dated 10 October 1961, change 2 dated 26 September 1962, and change 3 dated 26 December 1962. The T_s values adopted are 3.5 days for the early spring regulation curve and a variable from 6 to 10 days for the late spring and summer regulation curve. The adequacies of the emergency regulation curves have been checked by test routings of historic floods.

9-22. The presented techniques are such that indicated release rates will insure the safety of the project by maintaining adequate freeboard even in the case of the extreme spillway design or comparable floods. The maximum release rate during the progress of such a flood will not materially exceed the maximum river discharge which would have occurred if the project had not been in operation. In most cases releases will be increased in such a manner so as not to result in an extremely abrupt flood wave downstream from the project. For these reasons they may be used as a guide to system operations during any exceptionally large flood. In addition, the developed techniques are of such a nature that if during a large flood the storage balance between the main stem projects is not achieved, they may be used as a guide to obtain a restoration of this balance.

9-23. Responsibility for Application of Regulation Techniques. As described in Section VI of the Master Manual, the Missouri River Division Control Center is responsible for and directs all regulation, including flood control regulation, of Fort Peck and the other main stem reservoirs. Instructions to assure continuation of Fort Peck regulation during periods of communication failure between the project and the Reservoir Control Center are given in Exhibit B of this, the Fort Peck Manual.

9-24. Reports of Flood Control Regulation. Reports of regulation of Fort Peck Lake are made as described in Section X of the Master Manual.

SECTION X - EXAMPLES OF REGULATION

X-A. Scope.

10-1. In this section of the Manual observed regulation since construction of the Fort Peck Project, use of replacement storage and examples of emergency regulation are described and illustrated. The examples of emergency regulation include major observed floods representative of the early spring flood period of March and April and of the late spring and summer flood period of May, June and July and synthetic floods comparable to the spillway design flood, the standard project flood and the maximum probable flood. These examples illustrate flood control regulation under emergency conditions by means of emergency flood control rule curves and serve as a guide in the event of the recurrence of similar floods. Examples and description of coordinated regulation for the Missouri River main stem reservoir system are contained in Section XI of the Master Manual.

X-B. Observed Regulation.

10-2. General. Illustration of actual regulation of Fort Peck Lake from 1938 to 1974 is shown on Plate 14. During the years from late 1937 to 1952, Fort Peck Reservoir was regulated primarily for flood control and navigation, usually scheduled to support downstream navigation during the open water season, except that a minimum of 1,000 c.f.s. was scheduled during the irrigation season. Flood control regulation consisted largely of storing water during the high water season to be released during late summer or fall. Releases were controlled to provide flood protection in the reach immediately below the Fort Peck project, with benefits further downstream only incidental to such regulation and to regulation for navigation. To the extent practical, releases were scheduled through the available power generating facilities. Initial filling of the reservoir was also in progress during the first half of this period. From 1938 to 1943, minimum daily inflows to Fort Peck Lake during each month varied from 540 c.f.s. in August 1941 to 24,520 c.f.s. in June 1943; maximum daily inflows from 4,810 c.f.s. in September 1940 to 98,070 c.f.s. in June 1943 and mean monthly inflows from 2,830 c.f.s. in August 1940 to 48,540 c.f.s. in June 1943. Mean monthly releases varied from 510 c.f.s. in April 1943 to 19,270 c.f.s. in September 1943.

10-3. In 1943, when hydroelectric power generation was commenced at Fort Peck Lake, minimum releases were governed by power demands as well as flow requirements for downstream navigation, irrigation and other conservation purposes. Fort Peck Lake was filled to normal operating level in 1945. In 1946, and again in the spring and summer of 1947, the large seasonal carryover zone was filled. Subsequent to the installation of Generating Unit No. 2 in 1948, Fort Peck Reservoir was regulated to provide a flow of 30,000 c.f.s. at Sioux City for navigation and a minimum of 3,000 for other conservation purposes when the available water supply was adequate to support such releases. Regulation for flood control became an important consideration after the reservoir was filled to normal operating levels. During the period from 1944 to 1952, minimum daily inflows during each month varied from 490 c.f.s. in November 1946 to 38,210 c.f.s. in June 1948; maximum daily inflow from 3,860 c.f.s. in August 1949 to 93,580 c.f.s. in March 1947 and mean monthly inflows from 2,847 c.f.s. in August 1945 to 54,670 c.f.s. in June 1948. Mean monthly releases from 1944 to 1952 varied from 700 c.f.s. in June 1944 to 28,170 c.f.s. in October 1948. Observed floods of significance during the period from 1938 to 1952 include the floods of 1943, 1944, 1947, 1948 and 1952.

10-4. Since 1952 the regulation of Fort Peck Lake has broadened from a single reservoir to regulation as a unit of the main stem reservoir system. The principal floods which have occurred above the Fort Peck Project from 1952 to the present time include the 1953 and 1964 floods. This period of record illustrates the actual regulation of Fort Peck Lake in coordination with other main stem projects, during which the 1953-1967 period is unique in that the main stem reservoirs were in the process of being filled to normal operating levels. Since 1967 the reservoirs have been regulated as an essentially full system.

10-5. Numerous studies have been made of regulation of the main stem system under current and anticipated levels of water resource development. One of the latest long range studies (6-69 Series) were published early in 1970 and encompassed the entire available hydrologic record to that time. Plate 38 presents duration curves of Fort Peck pool elevation and releases from these studies for the 1970 basin development level and anticipated 1980, 2000 and 2020 levels.

10-6. Regulation of the 1947 Flood. The 1947 flood was an early spring flood resulting from snowmelt combined with the breakup of the river ice cover which resulted in extreme ice jam flooding. Above Fort Peck Lake, the abnormally thick ice cover produced by a prolonged period of cold weather, broke up during the March 1947 thaw. Flood waters from melting snow carried block ice down the river where it gorged and spread over lowlands. Damaging floods occurred in the reach extending upstream from Fort Peck Lake to Loma, Montana and from Fort Peck downstream to the mouth of the Yellowstone River due to ice jam flooding. During the flood period from 17 March to 28 March 1947, inflows to Fort Peck Lake exceeded 15,000 c.f.s. and reached a peak of 93,600 c.f.s. on 22 March. The total volume of inflow to Fort Peck Reservoir during this period was approximately 936,000 acre-feet. Releases from Fort Peck Lake during the flood period were nominal as the seasonal flood control zone was in the process of being filled. The reservoir pool level was at elevation 2228.5 at the beginning of the flood period and rose to an elevation of 2232.9 on 28 March. The peak flow immediately below Fort Peck Dam was reduced by about 92,000 c.f.s. A stage reduction of about 13.5 feet and a maximum flow reduction of about 76,000 c.f.s. were effected at the gaging station near Wolf Point, Montana by Fort Peck Lake during this flood.

10-7. Regulation of the 1948 Flood. The 1948 flood was a late spring and summer flood resulting from the rapid melting of a above normal snowpack in the mountain area combined with heavy rainfall in the drainage basin above Fort Peck Lake. Description of this flood is contained in Section II of this Manual. Inflows into Fort Peck Lake during this flood period varied from 20,000 c.f.s. on 20 May 1948 to peaks of 70,000 c.f.s. on 4 June, 60,800 c.f.s. on 9 June and 81,900 c.f.s. on 21 June. The inflow receded to 20,000 c.f.s. by 9 July with an additional small peak of 43,000 c.f.s. occurring on 13 July. The total volume of inflow to Fort Peck Lake from 20 May to 15 July was approximately 4,922,000 acre-feet. Releases from Fort Peck Lake were increased from 1,870 c.f.s. to 10,470 c.f.s. on 17 June and increased to peaks of 23,950 c.f.s. on 6 July and 23,740 c.f.s. on 13 July. The reservoir pool level rose from elevation 2228.8 on 20 May to elevation 2244.8 on 15 July. The peak flow immediately below Fort Peck Dam was reduced by about 67,000 c.f.s. and releases kept below channel capacity. A stage reduction of about 8.0 feet and a maximum flow reduction of about 58,000 c.f.s. were effected at the gaging station near Wolf Point by Fort Peck Lake during the 1948 flood.

10-8. Regulation of the 1952 Flood. The 1952 flood in this area was an early spring flood resulting from snowmelt and ice jams on the Missouri River above Fort Peck Lake and a record flow from the Milk River below Fort Peck Dam. These conditions were caused by above normal snow cover below elevation 8,000 feet m.s.l. in the mountain region in northern Montana east of the Continental Divide. The plains snow cover in northern Montana east of the Continental Divide during late March varied from 5 inches to 13 inches with a water equivalent of from 1 inch to slightly over 3 inches. The ground was frozen to a depth of one foot or more with a layer of ice 1-inch thick. Frozen streams were caused by prolonged low winter temperatures. Thawing temperatures occurred throughout the drainage basin above Fort Peck Dam and in the incremental drainage area between Fort Peck Dam and the mouth of the Yellowstone River during late March and early April. The runoff from snowmelt and ice breakup occurred in the Fort Peck area in late March and early April 1952. Overbank flooding by open water predominated on the Milk River, the Poplar River, Big Muddy Creek and ice jam flooding on the Missouri River above Fort Peck Lake. With the advent of thawing temperatures in March 1952, snowmelt runoff caused ice to rise, break up, move downstream and in some cases to jam. An ice jam flood on the main stem of the Missouri River in Fergus County upstream from Fort Peck Lake occurred on 31 March. The coincident timing and accumulated of high flows from mountain snowmelt on the many tributaries throughout the Milk River basin caused the greatest flood of record on the Milk River and the month-long flood caused unanticipated and unprecedented damage throughout the Milk River basin. Peak flows of the Milk River at Nashua reached 30,800 c.f.s. on 8 April and 44,200 c.f.s. on 18 April with high flows occurring throughout the period from early April to early May. During the flood period, inflows to Fort Peck Lake reached a peak of 86,400 c.f.s. on 31 March. The total volume of inflow to Fort Peck Lake during this period was approximately 1,251,000 acre-feet.

10-9. Total volume of inflow during the flood period from 27 March to 30 April was approximately 1,975,000 acre-feet. Releases during the flood period were normal as the reservoir was well below the base of the annual flood control zone during most of the flood period. The reservoir pool level rose from elevation 2218.0 on 27 March to elevation 2226.7 on 30 April. The maximum peak flow immediately below Fort Peck Dam was reduced by about 81,000 c.f.s. during this flood. A stage reduction of 10.5 feet and a flow reduction of 74,000 c.f.s. were effected by the regulation of Fort Peck Lake during this flood at the gage near Wolf Point, Montana.

10-10. Regulation of the 1953 Flood. The 1953 flood was a late spring and summer flood resulting from snowmelt from a normal winter's accumulation of snow combined with runoff from three distinct storms with accompanying precipitation in the drainage basin above Fort Peck Lake. Description of this flood is contained in Section II of this Manual. Inflows into Fort Peck Lake during this flood period varied from 20,000 c.f.s. on 24 May 1953, peaks of 85,000 c.f.s. on 29 May; 76,000 c.f.s. on 3 June, 119,700 c.f.s. on 7 June and 73,000 c.f.s. on 13 June. The inflow to Fort Peck Lake receded to below 20,000 c.f.s. on 25 June. The total volume of inflow to Fort Peck Lake from 24 May to 25 June was approximately 3,572,000 acre-feet. Releases from Fort Peck Lake during the flood period averaged about 3,000 c.f.s. The reservoir water level increased from elevation 2221.7 on 20 May to elevation 2238.0 on 26 June. The maximum peak flow immediately below Fort Peck Dam was reduced by about 117,000 c.f.s. A stage reduction of about 14 feet and a flow reduction of about 113,000 c.f.s. at the streamflow gage near Wolf Point, Montana was effected by the regulation of Fort Peck Lake.

10-11. Regulation of the 1964 Flood. The 1964 flood was a late spring and summer flood resulting from heavy rainfall which caused a large volume of runoff to flow into streams already carrying heavy runoff from mountain snowmelt, as described in Section II of this Manual. Inflows into Fort Peck Lake during this period varied from an averaging of about 21,000 c.f.s. in May to flows of about 90,000 c.f.s. on 12 June and 18 June. Average inflows for June 1964 were about 47,000 c.f.s. and gradually decreased to less than 10,000 c.f.s. by 18 July. The total volume of inflows to Fort Peck Lake from 3 May to 18 July was approximately 4,931,000 acre-feet. Releases were nominal during the flood period as the water level of Fort Peck Lake was well below the base of the seasonal flood control zone during May and most of June. Releases averaged about 6,000 c.f.s. during May and about 4,400 c.f.s. in June and July. The reservoir level increased from elevation 2214.4 in early May to elevation 2234.5 by 18 July. The maximum peak flow was reduced by about 87,000 c.f.s. during the flood period. At the Wolf Point gage, a stage reduction of about 14.0 feet and a maximum flow reduction of about 78,000 c.f.s. was effected by Fort Peck Lake.

10-12. Regulation of the 1975 Flood. The 1975 flood had the largest volume of runoff (for the March-July period) of record. The monthly precipitation amounts during the March through May period were above normal and an intense rainstorm on 18 and 19 June resulted in heavy runoff which in combination with mountain snowmelt caused severe flooding in Montana. Several maximum discharges of record occurred and are indicated in Section II of this manual. Mean monthly inflows into Fort Peck during April, May, June, and July were; 18,500 c.f.s., 36,800 c.f.s., 43,600 c.f.s., and 36,600 c.f.s. respectively with a peak mean daily inflow of 80,000 c.f.s. occurring on 23 June. The mean daily outflow from Fort Peck varied from a low of 4,300 c.f.s. on 24 April to a maximum of 35,400 c.f.s. on 7 July. This was the highest maximum mean-daily release since the project has been operating but was considerably less than the unregulated discharge of 120,000 c.f.s. which would have occurred without the project. During the March through July period inflow into Fort Peck Lake totaled 8,911,000 acre-feet (not including tributary reservoir holdouts). Fort Peck Lake pool elevation rose from 2236.1 feet m.s.l. on 15 March to elevation 2251.6 feet m.s.l. on 16 July (this was the maximum pool elevation of record). The stages at Wolf Point and Culbertson were reduced 8.3 feet and 8.6 feet respectively.

X-C. Replacement Regulation.

10-13. General. Replacement storage regulation, as discussed in Section IX of this Manual, is necessary only during those years when it appears that a major amount of the annual flood control storage space in downstream main stem reservoirs may be used in storing flood inflows. In years when main stem pool levels do not, or are not expected to encroach substantially into the annual flood control zone, distinct power head benefits are realized by passing inflows directly through the tributary reservoirs into the main stem projects. Normally, any water deliberately stored in the replacement storage zone will be released following the flood season after it becomes apparent that sufficient evacuated space will remain available in main stem projects to provide downstream flood protection. From the standpoint of increased power heads in the main stem system, evacuation of the storage accumulated in the replacement zone of tributary reservoirs as soon as permissible by main stem flood control considerations is desirable.

10-14. Regulation of Fort Peck as a component of the main stem system and associated tributary replacemement space can be illustrated by the actual regulation which was performed during the late summer and fall of 1968, extending into the flood season of 1969. Main stem system storage peaked at 63,621,000 acre-feet in mid-July 1968, leaving 6.8 million acre-feet of the annual flood control and multiple-use vacant. Canyon Ferry and Clark Canyon Reservoirs are the only upstream tributary projects which contained significant amounts of replacement storage space. This space in Canyon Ferry, amounting to 450,000 acre-feet was completely filled at the time of the system peak. While the complete fill of the Canyon Ferry space was not required for replacement storage purposes, it provided local flood control as well as storage to be utilized for future hydro-power generation at the Canyon Ferry powerplant. A portion of the 76,000 acre-feet of replacement space in Clark Canyon had been filled earlier in the year; however, as the runoff pattern into the main stem system developed, it became evident that this space would not be required to prevent the main stem storage from exceeding its annual flood control level and it was therefore evacuated. Evacuation of the replacement storage accumulated in Canyon Ferry was made at the full capacity of its powerplant through the succeeding summer and fall months, while the main stem storage was also evacuated to be at its base of flood control prior to the 1969 flood season. Since winter releases are restricted, evacuation of the main stem system in excess of downstream multiple-use requirements must be largely completed prior to the winter season, or prior to 1 December. Fort Peck storage peaked at a level about 2 million acre-feet in the flood control pool, with most of this storage scheduled to be evacuated prior to the winter season.

10-15. Based on anticipated inflows during the winter months, evacuation of Fort Peck storage to a level of about 16,600,000 acre-feet and system storage to about 59,750,000 acre-feet on 1 December would have been indicated if there had been no upstream replacement storage designed to assist the main stem system in its flood control function. Estimates prior to 1 December were that about 200,000 acre-feet of replacement space would be vacant on the 1 December date; therefore evacuation of the main stem system was scheduled only to the 59,950,000 acre-feet level and Fort Peck to 16,800,000 acre-feet. If all of the replacement storage space had been evacuated by 1 December, a main stem storage level of near 60,300,000 and a Fort Peck level of 17,150,000 acre-feet would have been selected for that date.

10-16. Evacuation of the storage accumulated in the replacement storage zone of Canyon Ferry continued through the winter and early spring months at maximum powerplant capacity, while that in Clark Canyon was completely evacuated by March 1969. In the meantime, snow survey information as well as main stem storage conditions indicated that runoff above the main stem system could result in filling all of the annual flood control space in the system. Storage in the replacement zones of the upstream reservoirs was definitely indicated. However, both of these tributary reservoirs also have a local flood control function, and as expressed in a preceding paragraph, power head conditions are improved with increased storage in the main stem system, so fill of the tributary replacement storage space was purposely delayed and when started, limited to those levels from which reasonably assured fill could be achieved prior to cresting of the main stem storage. At Canyon Ferry this meant substantial bypass of its powerplant while at Clark Canyon releases far in excess of downstream multiple-use requirements were made.

10-17. As the flood season progressed and the 1969 plains snowmelt runoff entered the main stem system, subnormal precipitation in the mountain drainage area of the basin together with actual water in storage resulted in decreasing forecasts of peak reservoir storage in the main stem system. Accordingly, soon after the 1 May data were available, the need for complete fill of the replacement zones of the tributary reservoirs no longer appeared necessary. The decision was made to pass Clark Canyon Reservoir inflows instead of filling the replacement zone. This preserved storage space for later local flood control use, if needed. Since Canyon Ferry has a powerplant, distinct advantage to the government is realized by passing as much of the release as possible through its generators. Accordingly, releases from this project were scheduled at full powerplant capacity plus release of inflows in excess of those required to fill the replacement space. Releases from both of the tributary projects were limited to downstream channel capacity.

10-18. This coordinated replacement regulation of main stem and upstream tributary reservoirs allowed the retention of about one-half million acre-feet of water in Fort Peck Lake and the main stem system. This water was essentially all in excess of multi-purpose needs during the normal 1968 evacuation season, and was available for use during later years. This was accomplished while still providing the same degree of downstream flood protection designed for the main stem system.

X-D. Regulation for Extreme Floods and Under Emergency Conditions.

10-19. General. Regulation procedures described in Section IX and regulation curves contained in Exhibit B of this Manual have been developed as guides to regulation when inflow and storage conditions are such that available flood control storage space may be completely filled during the progress of a flood. They also serve as criteria for regulation by project personnel at times communication facilities between the project and the Reservoir Control Center are inoperative. Examples contained in subsequent paragraphs illustrate this type of regulation for historical floods as well as floods of design and maximum probable magnitude.

10-20. The criteria used in the examples are as follows:

a. Storage level of Fort Peck Lake assumed to be at the base of the annual flood control and multiple-use zone (Elev. 2234 m.s.l.) prior to early spring plains snowmelt floods, or at the base of the exclusive flood control zone (Elev. 2246 m.s.l.) prior to the late spring mountain snowmelt and rainfall floods.

b. Regulation would be by use of the applicable emergency rule curves included in Exhibit B.

c. Evaporation from the reservoir surface was neglected as well as the effect of direct rainfall on the surface of the reservoir.

d. Storage allocations were based on the allocations in use at the present time.

e. Inflows used for the 1948 and 1952 floods were the averaged daily computed inflows obtained from project operation records which reflect actual releases and changes in reservoir storage at the time of the particular flood.

10-21. Emergency Regulation of the 1948 Flood. The 1948 flood was the largest late spring and summer flood experienced since the closure of Fort Peck Dam. Description of this flood is contained in Section II and in paragraph 10-7 of this Manual. Regulation of Fort Peck Lake during the 1948 flood using the Emergency Rule Curve for a Late Spring and Summer Flood is shown on Plate 41. This regulation provides for releases of 10,000 c.f.s. from 20 April to 8 June. Release rates not over 25,000 c.f.s. were maintained for the balance of the flood period. Regulation as illustrated resulting in the Fort Peck Lake reaching a maximum elevation of 2249.7 by 14 July, reduced the natural flow below Fort Peck Dam from a maximum peak of 81,900 c.f.s. to 25,000 c.f.s. Regulation of Fort Peck Lake as shown on Plate 41 would have prevented major flood damages as the channel capacity of the Missouri River below Fort Peck Dam is about 30,000 c.f.s. during open water season.

10-22. Emergency Regulation of the 1952 Flood. The 1952 flood was the largest early spring flood experienced since the closure of Fort Peck Dam. Description of this flood is contained in Section II and paragraphs 10-8 and 10-9 inclusive of this Manual. Regulation of Fort Peck Reservoir during the 1952 flood by means of the Emergency Rule Curve for an Early Spring Flood is shown on Plate 42. Regulation was based on the assumption that the reservoir elevation was at the base of the seasonal flood control and multiple-use zone on 15 March and provides for a constant release of 10,000 c.f.s. Under these conditions the Fort Peck Lake would have reached an elevation of 2245.9 by 20 June and would have reduced the peak flow under natural conditions below Fort Peck Dam by approximately 76,400 c.f.s. Releases during this flood were well within downstream channel capacity.

10-23. Emergency Regulation of an Early Spring Flood of Spillway Design Magnitude. An early spring flood corresponding to the present day concept of a spillway design flood has not been developed for the Fort Peck Project. The example used in illustrating the emergency regulation of an early spring flood of design magnitude was the maximum probable (or spillway design) early spring flood shown in the Master Manual. This flood was developed by increasing the observed 1947 March rise by five times. The developed flood has a crest flow of 469,000 c.f.s. which appears to be a reasonable size for a flood of this type when compared to spillway design floods developed for other main stem projects. Regulation of this flood by means of the Emergency Rule Curve for an Early Spring Flood is shown on Plate 43 and is based on the assumption that the reservoir elevation was at the base of the seasonal flood control and multiple-use zone on 16 March. Inflows to Fort Peck Lake during this flood varied from a base flow of about 10,000 c.f.s. on 16 March to a peak flow of 469,000 c.f.s. on 22 March, receding to about 20,000 c.f.s. by 30 March. The total volume of inflow to Fort Peck Lake during the period from 16 March to 30 March was approximately 4,641,000 acre-feet. Releases were maintained at 10,000 c.f.s. to 21 March then increased to 78,100 c.f.s. on 24 March. Releases were decreased to about 35,000 c.f.s. by 30 March. During the flood period the water level of Fort Peck Lake rose from an elevation of 2234 on 16 March to a maximum elevation of 2250.2 on 28 March.

10-24. Emergency Regulation of the Spillway Design Flood. Description of the basis for the development of the spillway design flood used in the actual design of the project is contained in paragraph 4-6, Section IV of this Manual. Plate 44 illustrates the regulation of Fort Peck Lake during the spillway design flood by use of the late Spring and Summer Flood Emergency Rule Curve shown in Exhibit B. The maximum runoff for 16 days during the spillway design flood totaled about 7,000,000 acre-feet with the daily average inflow varying from 52,000 c.f.s. to a maximum of 360,000 c.f.s. In the illustration the reservoir was assumed to be at the base of the exclusive flood control zone (elevation 2246 m.s.l.) at the beginning of the flood. Regulation by this method resulted in the reservoir reaching a maximum elevation of 2256.1 with a maximum average daily release of 263,700 c.f.s.

10-25. Emergency Regulation of the Standard Project Flood. The standard project flood based on the latest criteria was developed for the Fort Peck Lake by the Omaha District using procedures outlined in EM 1110-2-1411, subject: "Standard Project Flood Determinations." The standard project storm used in developing the standard project flood was centered over the lower portion of the Missouri River drainage basin between the mouth of the Marias River and the Fort Peck Dam using a typical isohyetal pattern. This storm pattern resulted in an average of 2.43 inches of rainfall in a 24-hour period over the 23,677 square mile contributing drainage area. Runoff from this rainfall was applied to unit hydrographs determined for pertinent subarea basins lying above the Fort Peck Lake. The resulting flood hydrographs from the subareas were then lagged to the Fort Peck Lake to obtain the Standard Project Flood hydrograph shown on Plate 45. The initial loss and infiltration index used in the computation of runoff for the standard project flood was 0.4 inch and 0.1 inch per hour respectively. The base flow of 60,000 c.f.s. used for this flood was estimated from the base flow experienced in the 1953 flood. The standard project flood hydrograph as developed has a 10-day volume of 2,261,300 acre-feet, a 30-day volume or 4,540,000 acre-feet, and a peak flow of 224,000 c.f.s. Plate 45 illustrates the regulation of Fort Peck Lake during the standard project flood as developed by use of the Late Spring and Summer Flood Emergency Rule Curve shown in Exhibit B. The reservoir was assumed to be at the base of the exclusive flood control zone (elevation 2246 m.s.l.) at the beginning of the flood. Regulation by this method resulted in the reservoir reaching a maximum elevation of 2252.1 and a peak release of 132,000 c.f.s.

10-26. Emergency Regulation of the Maximum Probable Flood. The maximum probable flood (based on the latest criteria) for the Fort Peck Lake determined by the Omaha District resulted from a maximum probable mid-June rainfall event centered over the lower portion of the drainage basin between the mouth of the Marias River and Fort Peck Lake preceded by a maximum snowmelt event over the upper portion of the basin centered over the area above Canyon Ferry Dam. In developing the maximum probable flood all available maximum probable rainfall data applicable to the area was examined, including extrapolation of values from National Weather Service Technical Paper 38. After examination of these data, the rainfall criteria used for computing the maximum probable flood for the Fort Peck Reservoir was based on data prepared by the National Weather Service Hydrometeorological Section for the area above Garrison Dam, as presented in a report entitled "An Estimate of Maximum Possible Flood-Producing Meteorological Conditions in the Missouri River Basin above Garrison Damsite," dated 1 November 1945. This study contains the only data available on maximum rainfall criteria over large areas in this region. Although it is recognized that this study was made for an area immediately east of the area above Fort Peck Lake, an approximate storm transposition study indicated little change in precipitation values would be involved in transposing the storm to the area above Fort Peck Lake and it was considered that the use of precipitation data from the Hydromet Report (without modification) in the area farther west represented a conservative extrapolation of the data. Copies of the two plates from the Hydromet Report which were utilized in these studies are shown on Plate 46 of this Manual. The maximum probable precipitation based on these curves for the months of June and July for the area above Fort Peck Dam are also shown on Plate 46. These curves were used in computing the rainfall-runoff component of the maximum probable inflow hydrograph for Fort Peck Lake.

10-27. The maximum probable storm pattern as determined from a typical isohyetal pattern resulted in an average rainfall of 4.48 inches in a 24-hour period over the 23,677 square mile contributing drainage area. Principles utilized in determining the maximum probable snow accumulation are also those presented in the Garrison Hydromet Report. From examination of the region's topography it was estimated that the contributing mountain area would amount to about 8,000 square miles above Canyon Ferry Reservoir, 550 square miles above Tiber Reservoir and 1,450 square miles between these reservoirs and the Fort Peck Lake, totaling about 10,000 square miles. The normal annual precipitation of these mountain areas was estimated to be 23 inches and it was assumed that snowfall would accumulate to about 1 May. From figures contained in the Garrison Hydromet Report, the water equivalent of the mountain snow accumulation would amount to 16.1 inches over the 10,000 square mile contributing area. From this accumulation estimated evaporation and irrigation losses were subtracted. Accumulated losses in the amount of 6.1 inches were subtracted leaving 10.0 inches of snow water content available for snowmelt runoff. This represents a snowmelt runoff volume of about 5,350,000 acre-feet above the Fort Peck Lake. This runoff was distributed through an assumed 60-day melt period and on the basis of observed occurrence of this type of runoff from the drainage area involved. The maximum probable flood hydrograph for the Fort Peck Reservoir shown on Plate 47 was determined by adding the hydrograph resulting from the maximum probable mid-June rainfall event over the lower basin (between the mouth of the Marias River and Fort Peck Lake) to the hydrograph of the maximum snowmelt event centered over the area above Canyon Ferry Reservoir. The rainfall portion of the maximum probable flood hydrograph was obtained by applying runoff from the maximum probable storm to unit hydrographs for the subarea basins lying above the Fort Peck Lake. The subarea flood hydrographs were then lagged to the Fort Peck Lake to obtain the rainfall portion of the maximum probable flood hydrograph shown on Plate 47. The initial loss and infiltration index used in computation of the runoff for the maximum probable flood was 0.4 inch and 0.1 inch respectively. The maximum probable flood hydrograph as developed has a 10-day volume of 4,058,000 acre-feet, a 30-day volume of 6,597,000 acre-feet and a peak flow of 486,000 c.f.s. Plate 47 illustrates the regulation of Fort Peck Lake during the maximum probable flood as developed by use of the Late Spring and Summer Rule Curve shown in Exhibit B. The reservoir was assumed to be at the base of the exclusive flood control zone (elevation 2246 m.s.l.) at the beginning of the flood. Regulation by this method resulted in the reservoir reaching a maximum elevation of 2255.0 and a peak release of 265,900 c.f.s. Approximately 8 days were required to evacuate the surcharge storage to the top of the exclusive flood control zone at elevation 2250.

EXHIBIT A

PROCEDURE FOR FORECASTING SEASONAL
INFLOW INTO FORT PECK RESERVOIR

The equation for the natural inflows into Fort Peck Reservoir for the period April through July is:

$$X_1 = -56 + 1.54\ X_5$$

Where X_1 = natural inflow to Fort Peck Reservoir in 1,000,000 AF. for April through July and X_5 = sum of the forecasted April-July natural inflow to Canyon Ferry Reservoir (Missouri River), Tiber Reservoir (Marias River) and at Vaughn (Sun River) in 1,000,000 AF.

In forecasting, the value of X_5 will be obtained by solving the forecast equations for the 3 rivers. These equations and the explanation of each are shown as follows:

Canyon Ferry Natural Inflow Forecasts

1 January Forecast for April through July.

$$X_2 = -0.22 + 1.635\ X_{83} + 0.0518\ X_{89} + 0.02375\ X_{88}$$

X_2 = natural April through July runoff in 1,000,000 AF.

X_{83} = antecedent runoff in 1,000,000 AF and consists of the average September through November natural runoff at Canyon Ferry for the 1st and 2nd preceding years.
X_{89} = the sum of the 1 January snow water content at Chessman Reservoir, Upper, Middle and Lower Rimini snow courses.
X_{88} = the sum of April through July average precipitation at Helena and Bozeman Agricultural College Precipitation stations.

1 February Forecast for April through July.

$$X_2 = -0.78 + 0.976\ X_{83} + 0.0516\ X_{90} + 0.0643\ X_{88}$$

X_2, X_{83} and X_{88} are the same as for 1 Jan.
X_{90} = the sum of the 1 Feb. snow water content at Chessman Reservoir, Upper Middle and Lower Rimini snow courses.

1 March Forecast for April through July.

$$X_2 = -1.69 + 1.468\ X_{83} + 0.0742\ X_{91} + 0.0733\ X_{88}$$

X_2, X_{83} and X_{88} are the same as for 1 Jan.
X_{91} = 1/3 the sum of the 1 March snow water content at Upper, Middle and Lower Rimini, Devil's slide, Hood Meadow and Gibbons Pass snow courses.

1 April Forecast for April through July.

$$X_2 = -1.40 + 1.915\ X_{83} + 0.0333\ X_{92} + 0.0491\ X_{88}$$

X_2, X_{83} and X_{88} are the same as for 1 Jan.
X_{92} = the sum of 1 April snow water content at Upper, Middle and lower Rimini and Storm Lake #2 snow courses.

Tiber Dam & Reservoir Natural Inflow Forecasts

1 February Forecast for April through July

$Y = -433.7 + 32.5\ X_2 + 74.7\ X_3$

Y = The natural April through July runoff forecast in 1,000 A.F.

X_2 = The sum of the 1 Feb. Marias Pass snow water content and the normal increase in water content from 1 Feb. to 1 April of 6.1".

X_3 = The average April through June precipitation of the following stations averaged equally: Conrad, Valier, Browning and Cut Bank. Average precipitation April through June = 6.0". (1960 mean)

1 March Forecast for April through July

$Y = -433.7 + 32.5\ X_2 + 74.7\ X_3$

Y = the same as 1 Feb.

X_2 = The sum of the 1 March Marias Pass snow water content and the normal snow water content increase from 1 March to 1 April of 2.7" averaged with the sum of the 1 March Goat Mt. snow water content and the normal increase in snow water content from 1 March to 1 April of 1.7".

X_3 = The same as 1 Feb.

1 April Forecast for April through July

$Y = -433.7 + 32.5\ X_2 + 74.7\ X_3$

Y = The same as 1 March and 1 Feb.

X_2 = The mean of the 1 April snow water content of the Marias Pass and Goat Mountain snow courses.

X_3 = The same as 1 March and 1 Feb.

Vaughn, Montana (Sun River) Natural Flow Forecasts

1 February Forecast for April through July

$Y = -349.98 + 45.33\ X_2 + 12.20\ X_3$

Y = The April through July natural flow at Vaughn in 1,000 A.F.

X_2 = Mean of the sum of the average April through July precipitation at Augusta, Gibson Dam and Fairfield.

X_3 = Value computed by multiplying 1 Feb. snow water content of Marias Pass X 2.08 + normal snow water content increase to 1 April.

1 March Forecast for April through July

$Y = -349.98 + 45.33\ X_2 + 12.20\ X_3$

Y = Same as 1 Feb.

X_2 = Same as 1 Feb.

X_3 = Sum of the 1 March snow water content of Stemple Pass, Goat Mt. and Marias Pass snow courses plus normal March-April snow water content increase.

1 April Forecast for April through July

$Y = -349.98 + 45.33\ X_2 + 12.20\ X_3$

Y = Same as 1 Feb. and 1 March.

X_2 = Same as 1 Feb. and 1 March.

X_3 = Sum of the 1 April snow water content of Stemple Pass, Goad Mt. and Marias Pass snow courses.

EXHIBIT B

EMERGENCY REGULATION PROCEDURE

FOR

FORT PECK LAKE PROJECT

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

MRDED-R 20 December 1972

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Fort Peck Lake Project

TO: Powerplant Superintendent
Fort Peck Powerplant

FROM: Missouri River Division
Reservoir Control Center

1. Procedures applicable to the regulation of Fort Peck 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 daily to the Reservoir Control Center and the Omaha District pertinent data relating to regulation of Fort Peck Reservoir. 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 USBR communication facilities.

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

a. Every reasonable effort will be made by the Powerplant 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 powerplant loading will follow the USBR loading schedule, if available. If the hourly schedule has not been received from the USBR, powerplant releases will be made to provide the daily energy schedule specified in the order and will be patterned similar to recent experience. If requested by the USBR 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 reservoir level remains below elevation 2234.0.

c. If the reservoir level is above elevation 2234, 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. Procedures are as follows:

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

(2) The mean inflow for the preceding 24 hours will be estimated by computing the storage change during the 24-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 24-hour period. The approximate mean inflow in c.f.s. is equivalent to the mean outflow in c.f.s. for the 24-hour period plus one-half the storage change in acre-feet.

(3) Utilizing the inflow 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 or 2, as appropriate for the season.

(4) If the rule curve release developed by (3) is greater than that given by (1), make release specified by the rule curve. However, releases will not be increased to a rate which is greater than twice the average rate for the preceding 24 hours.

(5) With a pool level below elevation 2246, any release adjustments made necessary by use of the rule curve in accordance with (4) should be made once daily. With a pool above elevation 2246, the analysis and necessary adjustments should be at intervals of 12 hours or less.

(6) If rule curve release is less than full powerplant capability, powerplant loading will be patterned similar to recent experience or as prescribed by the USBR if communication with their Systems Operations Office is possible.

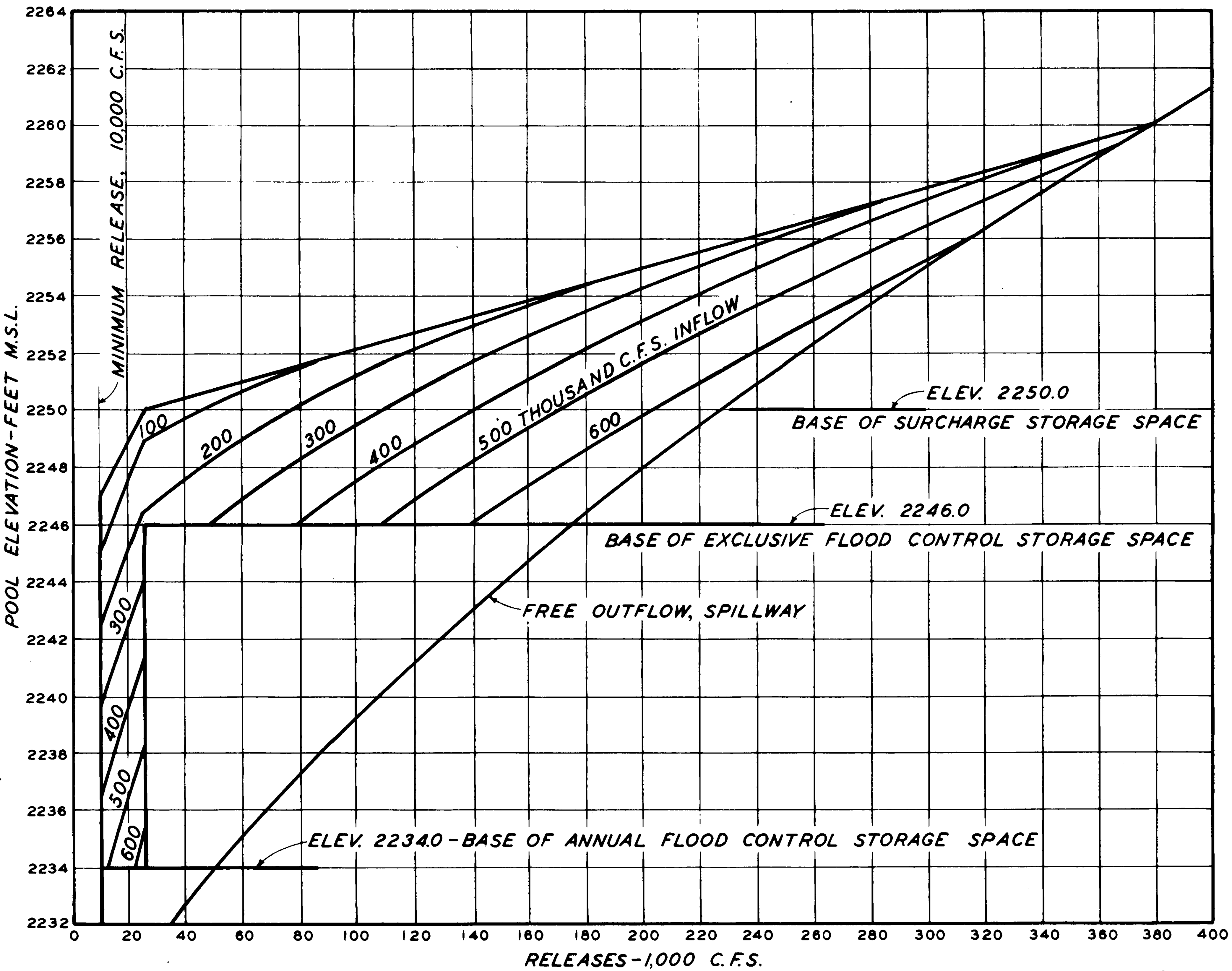
(7) Releases from the project shall be made through the powerhouses to the degree feasible.

4. In the event of downstream flooding, as reported to or anticipated by the Powerplant Superintendent, releases will be reduced as deemed necessary to alleviate these conditions. However, with a pool above elevation 2234 releases will not be reduced below those levels defined by the emergency curves, Inclosures 1 and 2.

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

Elmo W. McClendon
ELMO W. McCLENDON
Chief, Reservoir Control Center

2 Incl
1. Rule curve (Spring)
2. Rule curve (Summer)

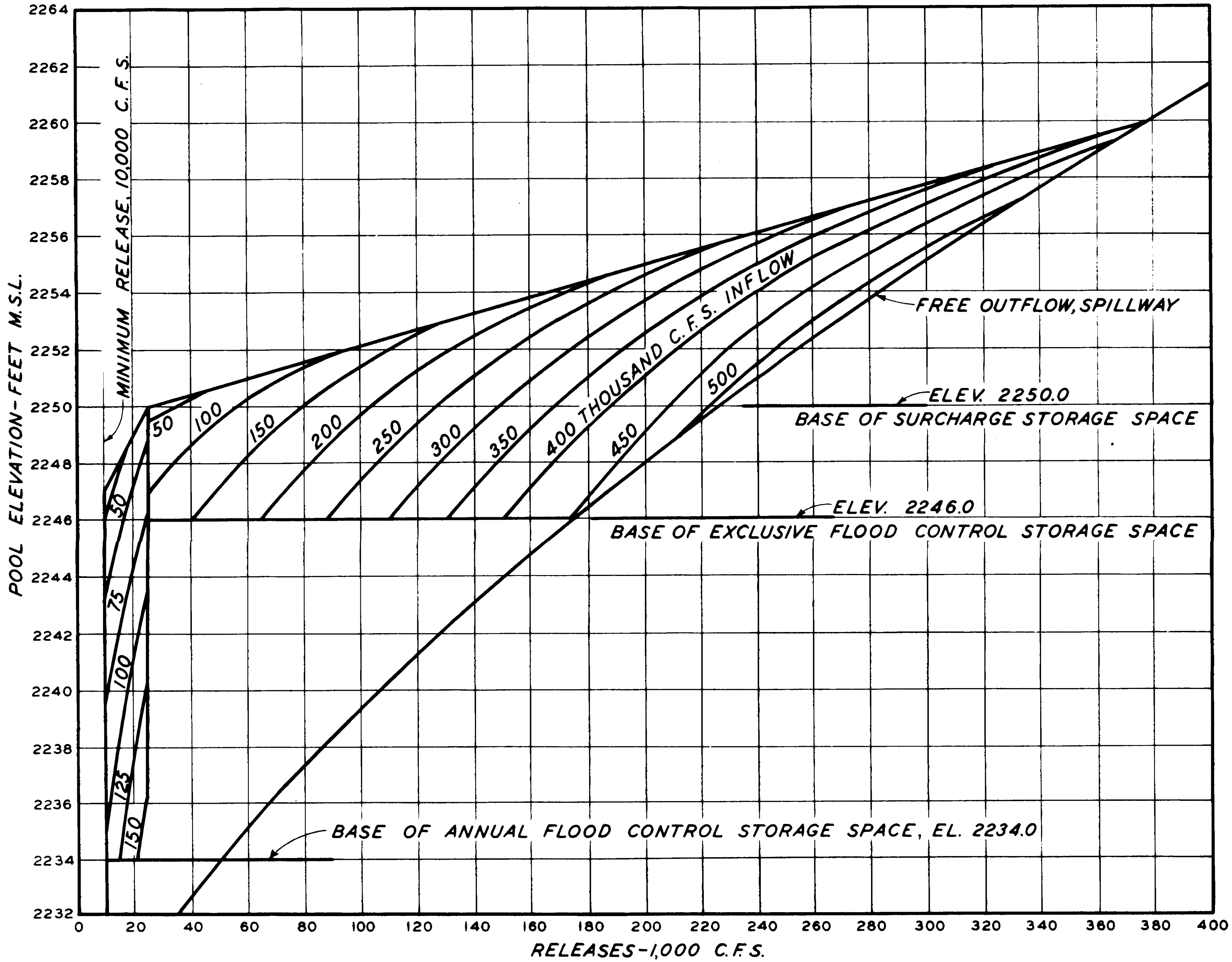


NOTES:

1. Curves are applicable for period 16 November to 30 April.
2. Numbered curves represent inflow in thousand C.F.S.
3. Emergency procedure will consist of:
   a. Enter curves with current pool elevation.
   b. Proceed to curve which equals inflow as determined for preceding 24-hours.
   c. Maintain release as indicated by point of intersection.
   d. No release shall exceed a rate greater than twice the average release rate for the preceding 24-hours.

FORT PECK RESERVOIR

EMERGENCY REGULATION CURVES
EARLY SPRING FLOOD SEASON

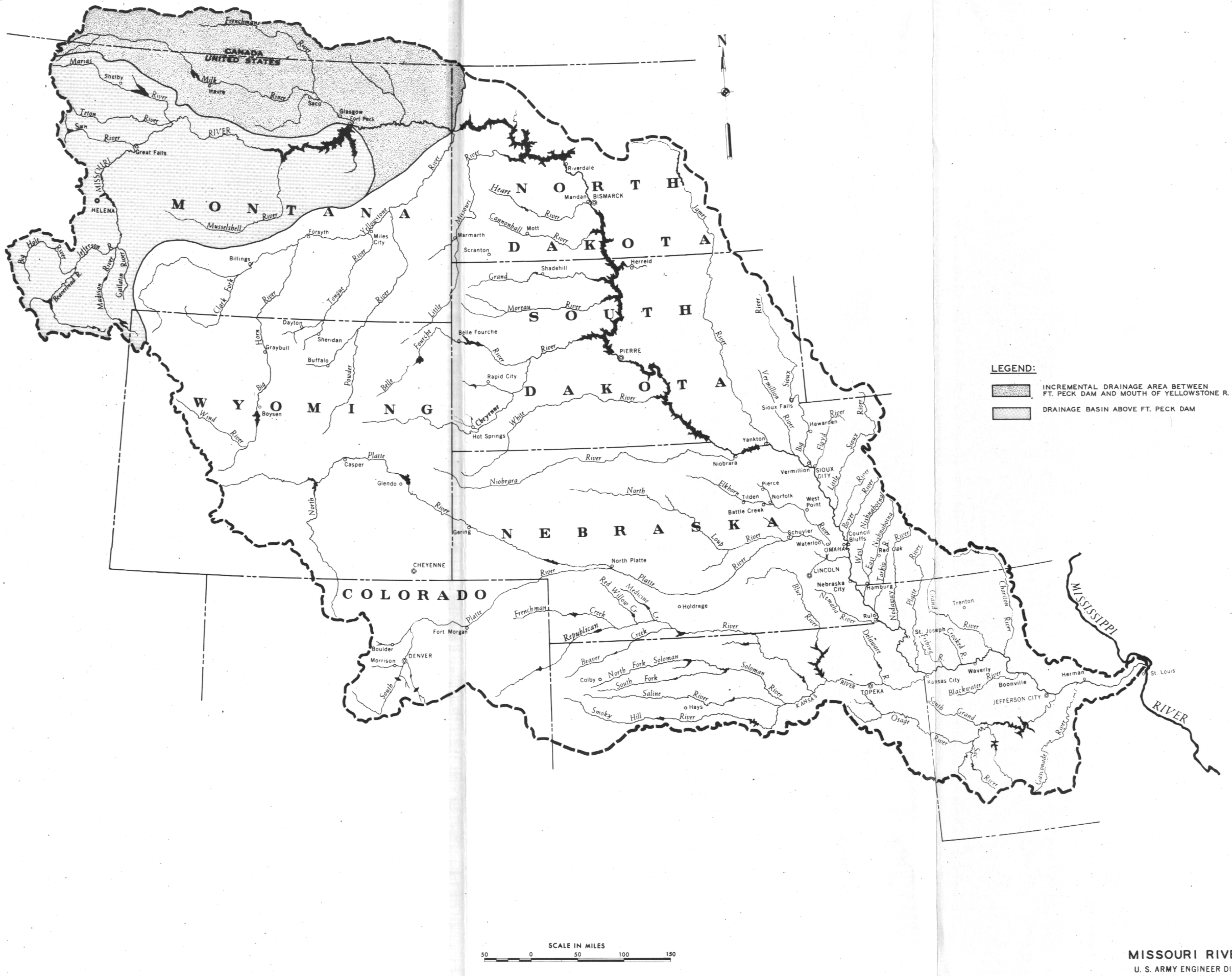


NOTES:

1. Curves are applicable for period 1 May to 15 November.
2. Numbered curves represent inflow in thousand C.F.S.
3. Emergency procedure will consist of:
   a. Enter curves with current pool elevation.
   b. Proceed to curve which equals inflow as determined for preceding 24-hours.
   c. Maintain release as indicated by point of intersection.
   d. No release shall exceed a rate greater than twice the average release rate for the preceding 24-hours.

FORT PECK RESERVOIR

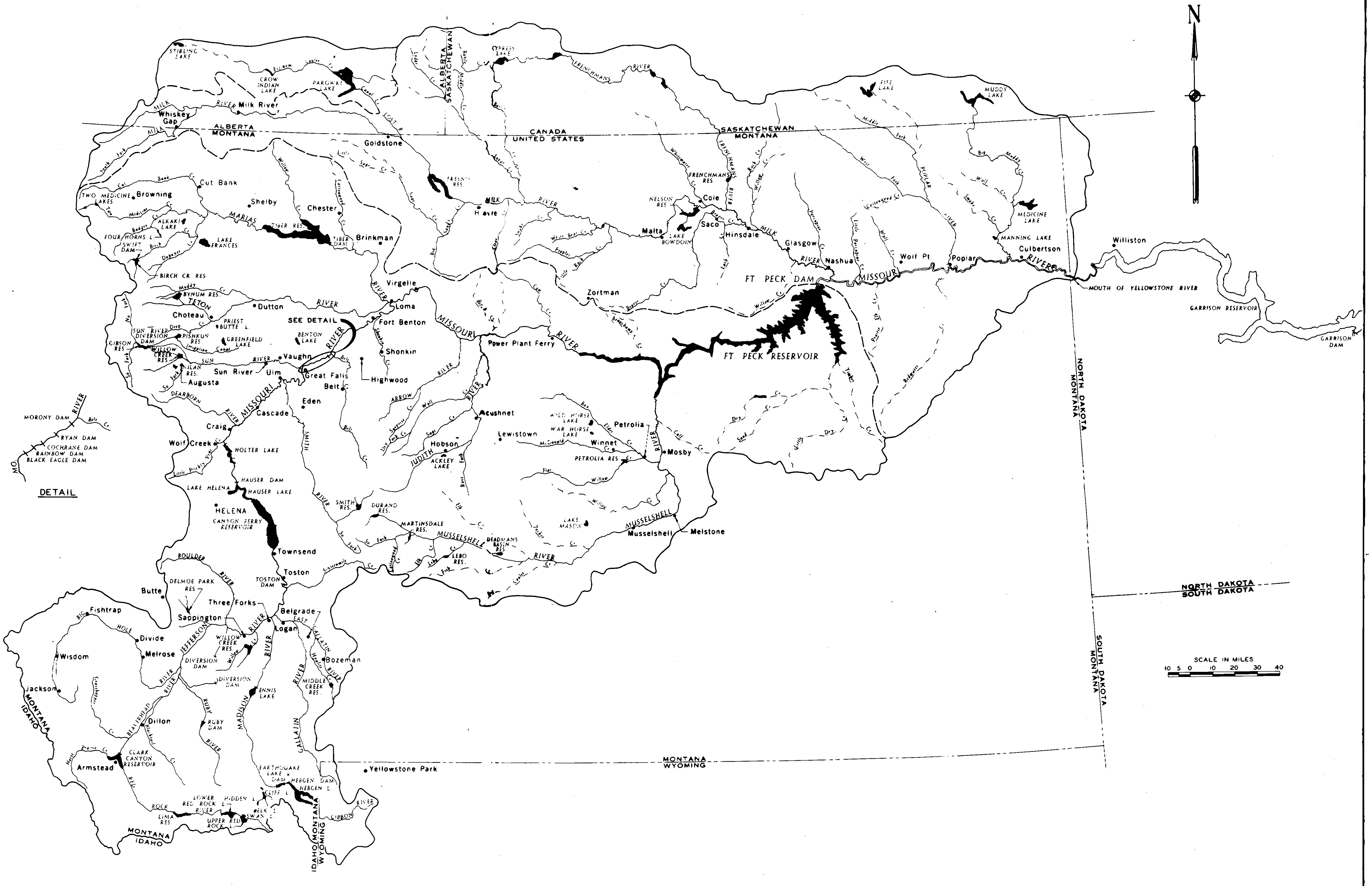
EMERGENCY REGULATION CURVES
LATE SPRING FLOOD SEASON



THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

MISSOURI RIVER BASIN

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

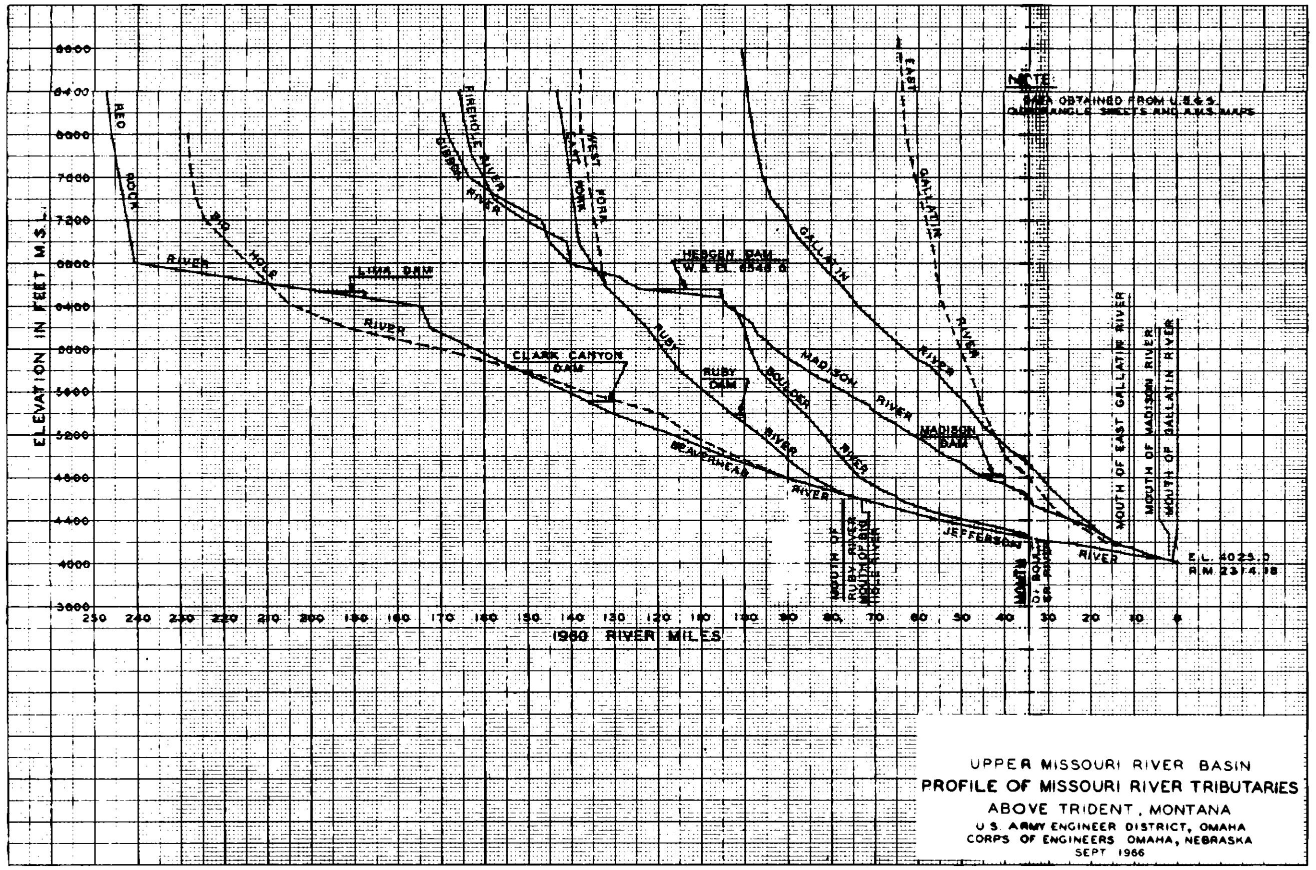


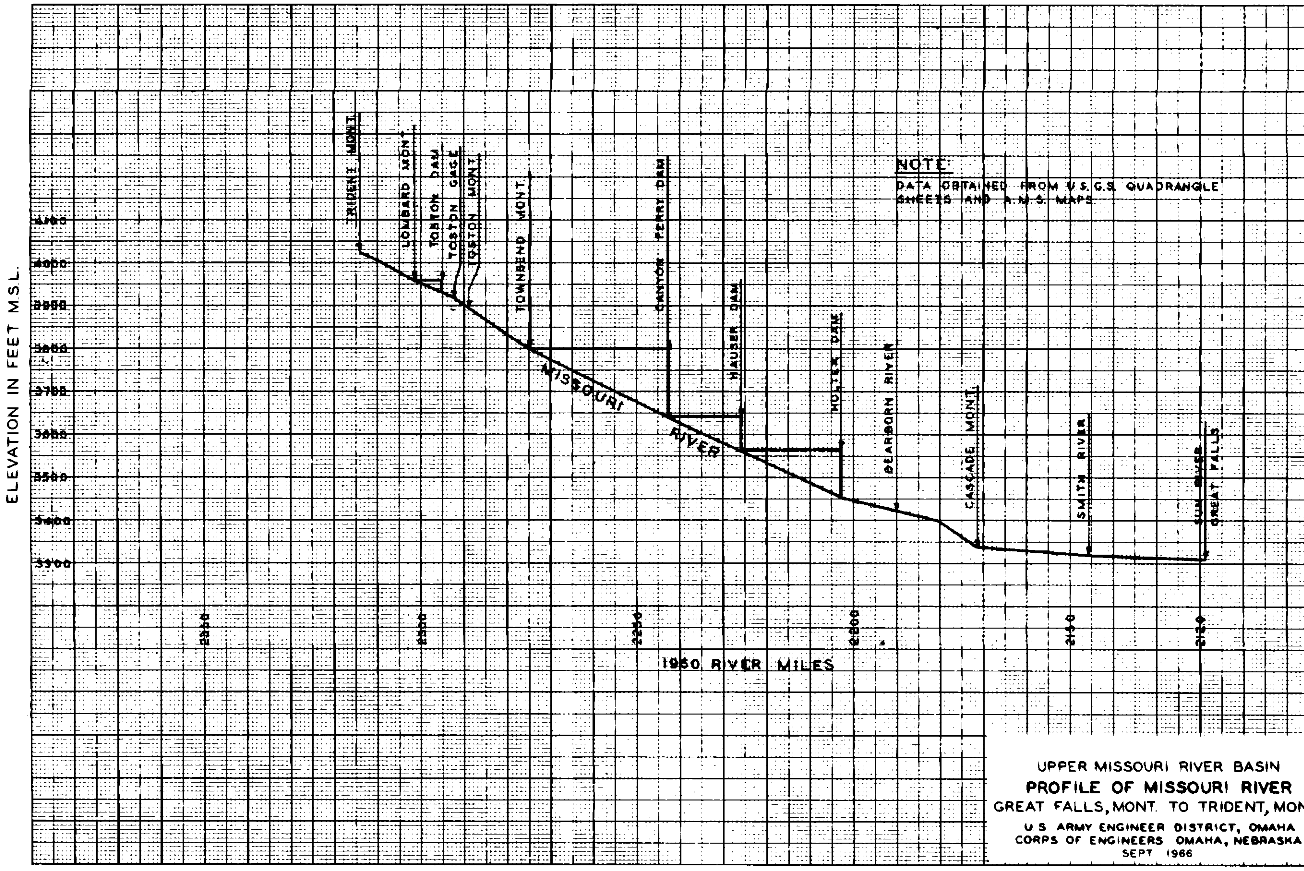
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

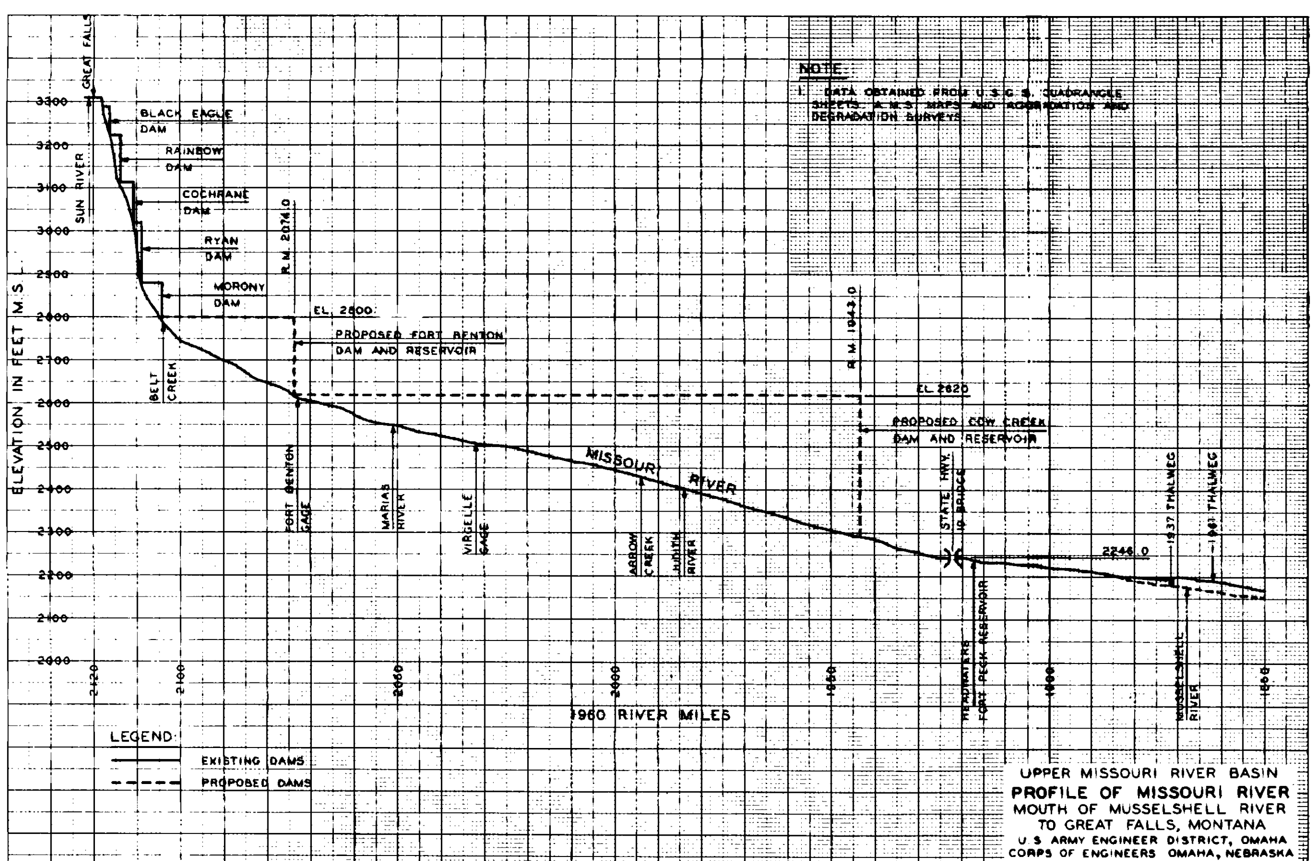
UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER

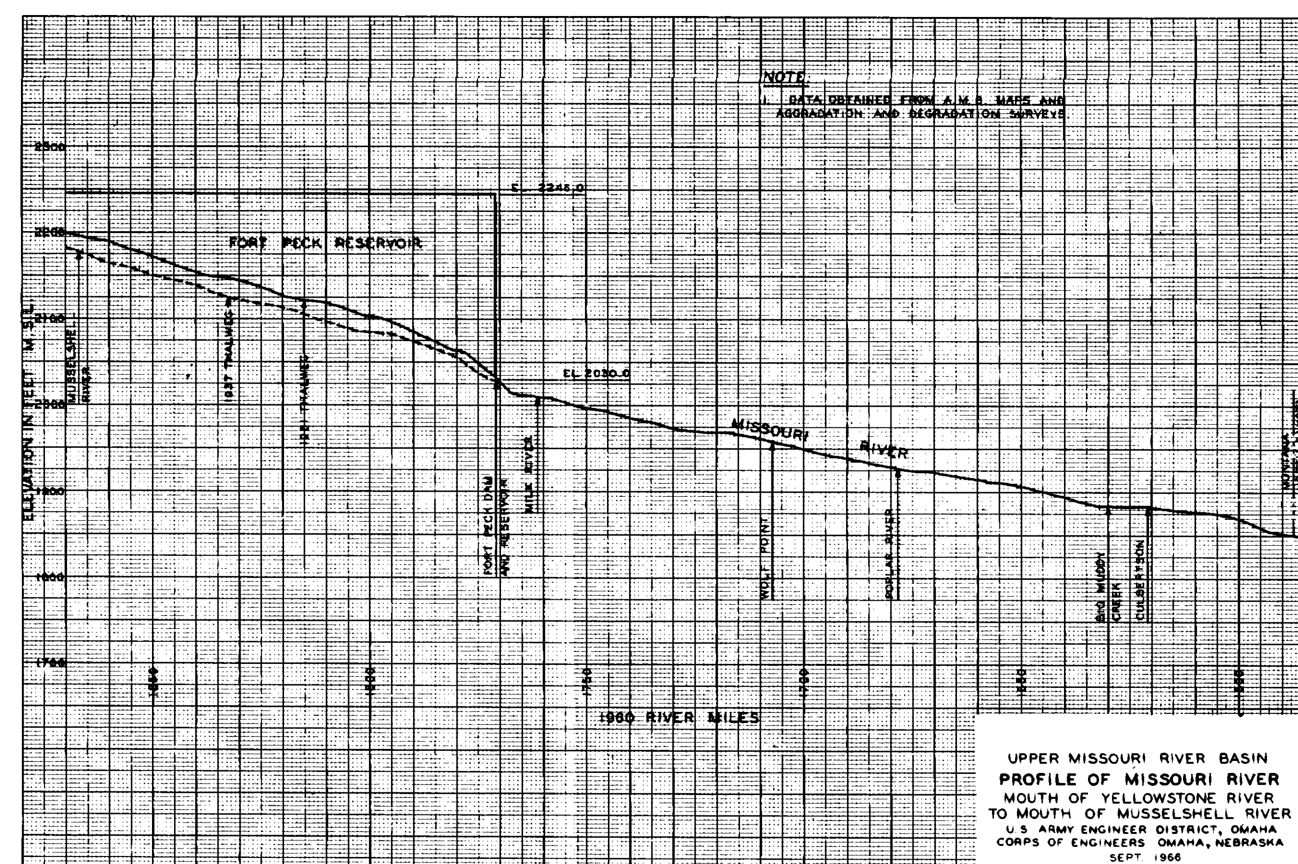
GENERAL MAP

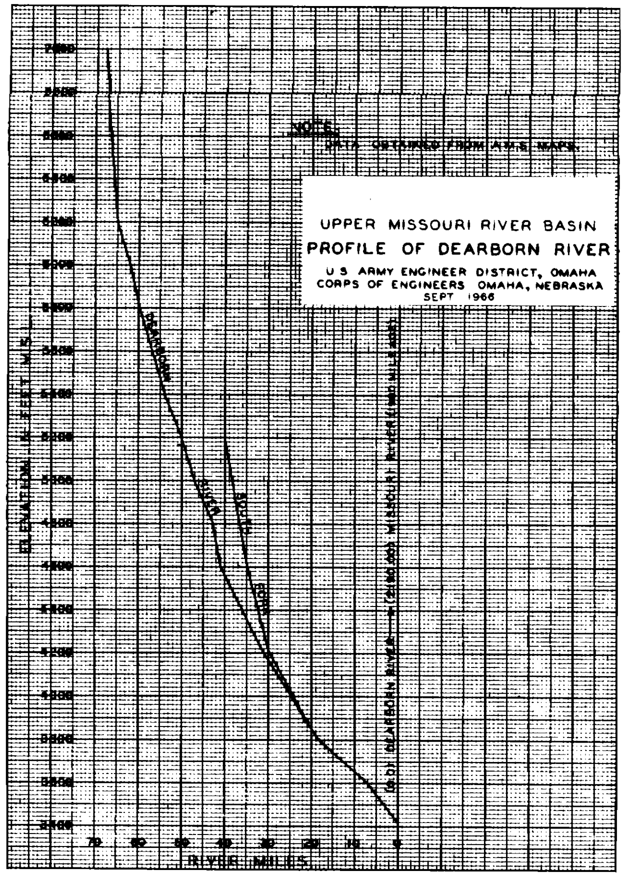
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

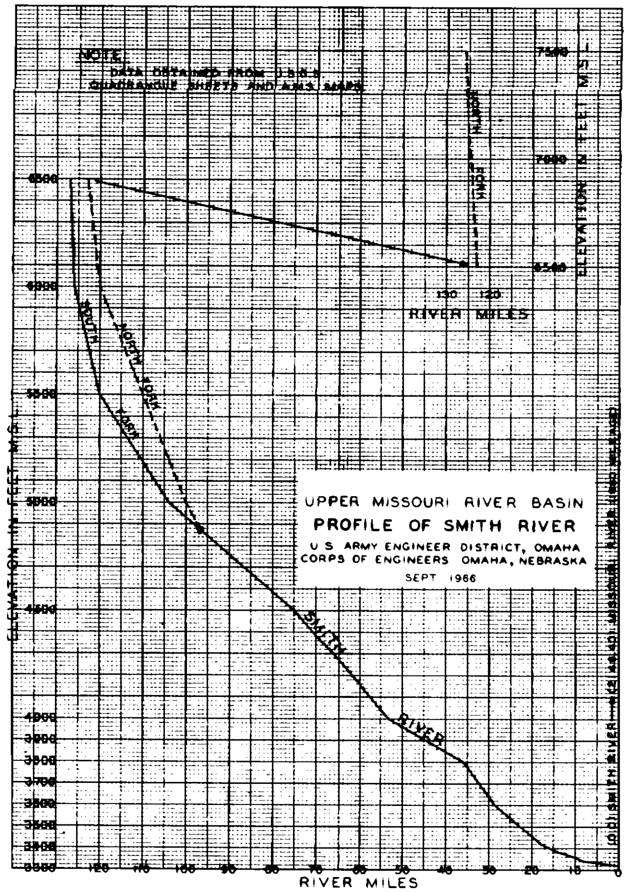

NOTE:
DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS
ELEVATION IN FEET M.S.L.
1960 RIVER MILES
RED ROCK RIVER
BIG HOLE RIVER
LIMA DAM
CLARK CANYON DAM
BEAVERHEAD RIVER
RUBY RIVER
RUBY DAM
BOULDER RIVER
MADISON RIVER
MADISON DAM
HEBGEN DAM
GALLATIN RIVER
JEFFERSON RIVER
EL. 4025.0
R.M. 2314.38
MOUTH OF EAST GALLATIN RIVER
MOUTH OF MADISON RIVER
MOUTH OF GALLATIN RIVER
UPPER MISSOURI RIVER BASIN
PROFILE OF MISSOURI RIVER TRIBUTARIES
ABOVE TRIDENT, MONTANA
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966

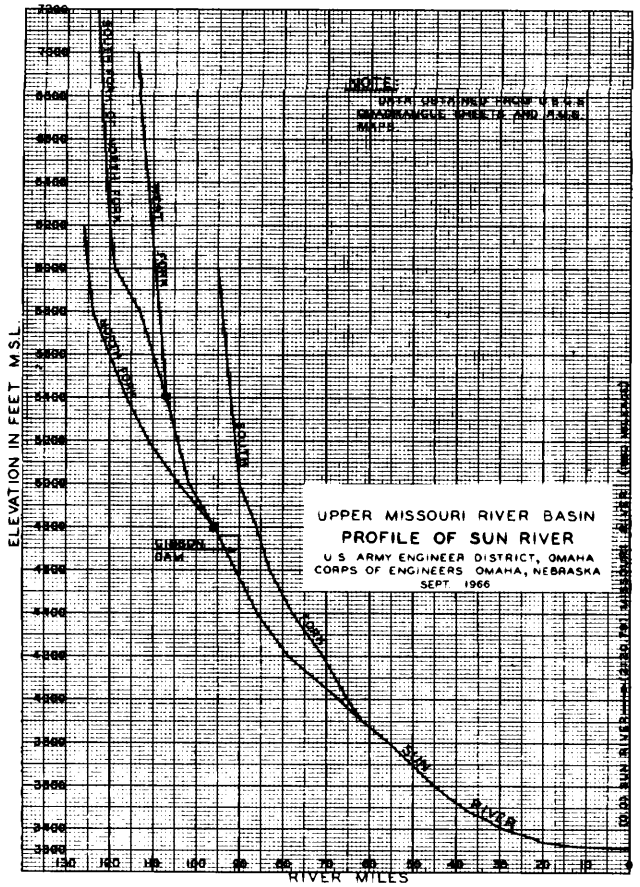

NOTE:
DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS
ELEVATION IN FEET M.S.L.
1960 RIVER MILES
TRIDENT, MONT.
LOMBARD, MONT.
TOSTON DAM
TOSTON GAGE
TOSTON, MONT.
TOWNSEND, MONT.
CANYON FERRY DAM
HAUSER DAM
HOLTER DAM
DEARBORN RIVER
CASCADE, MONT.
SMITH RIVER
SUN RIVER
GREAT FALLS
MISSOURI RIVER
UPPER MISSOURI RIVER BASIN
PROFILE OF MISSOURI RIVER
GREAT FALLS, MONT. TO TRIDENT, MONT.
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966

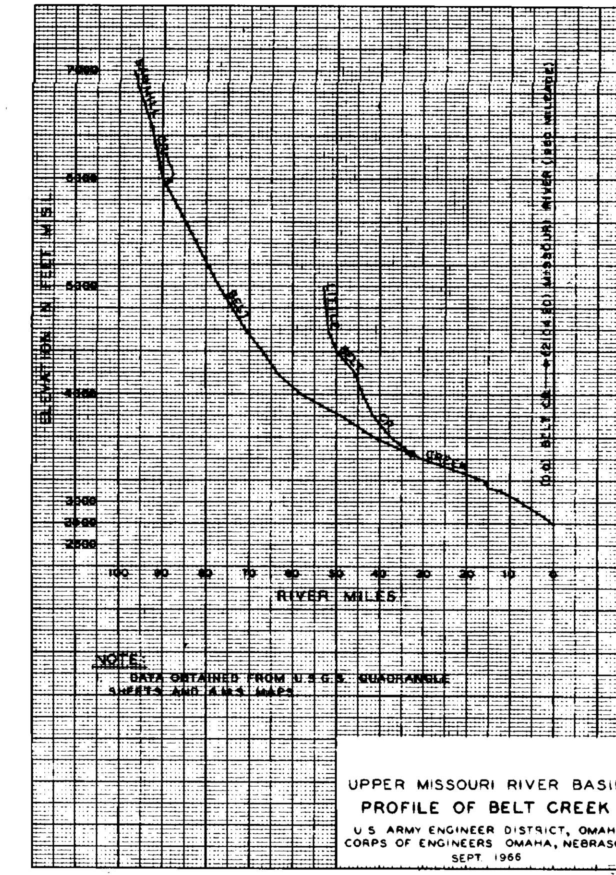

NOTE:
1. DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS, A.M.S. MAPS AND AGGRADATION AND DEGRADATION SURVEYS
ELEVATION IN FEET M.S.L.
1960 RIVER MILES
GREAT FALLS
SUN RIVER
BLACK EAGLE DAM
RAINBOW DAM
COCHRANE DAM
RYAN DAM
MORONY DAM
R.M. 2074.0
EL. 2600
PROPOSED FORT BENTON DAM AND RESERVOIR
BELT CREEK
FORT BENTON GAGE
MARIAS RIVER
VIRGELLE GAGE
ARROW CREEK
JUDITH RIVER
MISSOURI RIVER
R.M. 1943.0
EL. 2620
PROPOSED COW CREEK DAM AND RESERVOIR
STATE HWY. 19 BRIDGE
HEADWATERS FORT PECK RESERVOIR
2246.0
1937 THALWEG
1961 THALWEG
MUSSELSHELL RIVER
LEGEND:
EXISTING DAMS
PROPOSED DAMS
UPPER MISSOURI RIVER BASIN
PROFILE OF MISSOURI RIVER
MOUTH OF MUSSELSHELL RIVER
TO GREAT FALLS, MONTANA
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966

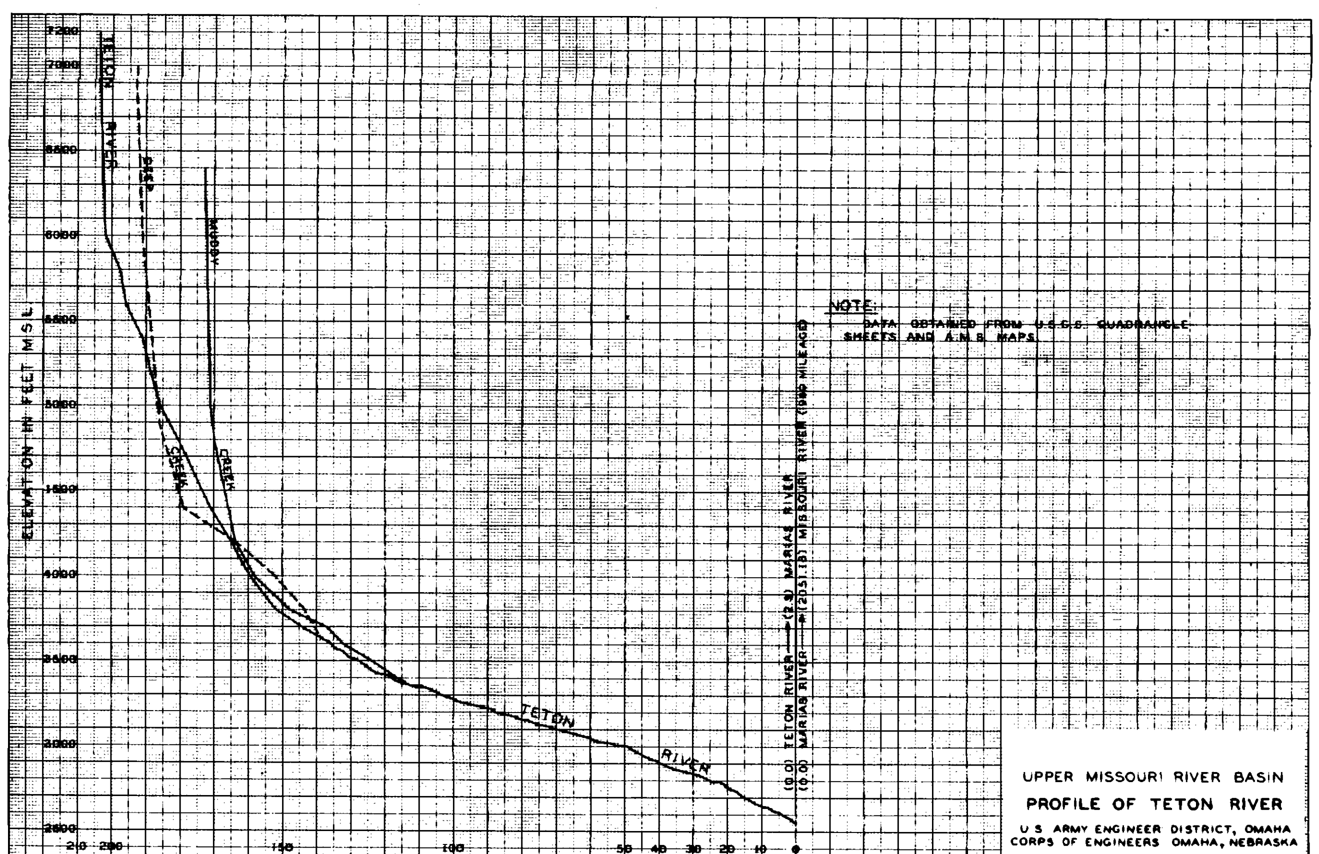

NOTE:
1. DATA OBTAINED FROM A.M.S. MAPS AND AGGRADATION AND DEGRADATION SURVEYS
ELEVATION IN FEET M.S.L.
1960 RIVER MILES
EL. 2246.0
FORT PECK RESERVOIR
MUSSELSHELL RIVER
1937 THALWEG
1961 THALWEG
EL. 2030.0
FORT PECK DAM AND RESERVOIR
MILK RIVER
MISSOURI RIVER
WOLF POINT
POPLAR RIVER
BIG MUDDY CREEK
CULBERTSON
MONTANA NORTH DAKOTA
YELLOWSTONE RIVER
UPPER MISSOURI RIVER BASIN
PROFILE OF MISSOURI RIVER
MOUTH OF YELLOWSTONE RIVER
TO MOUTH OF MUSSELSHELL RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966

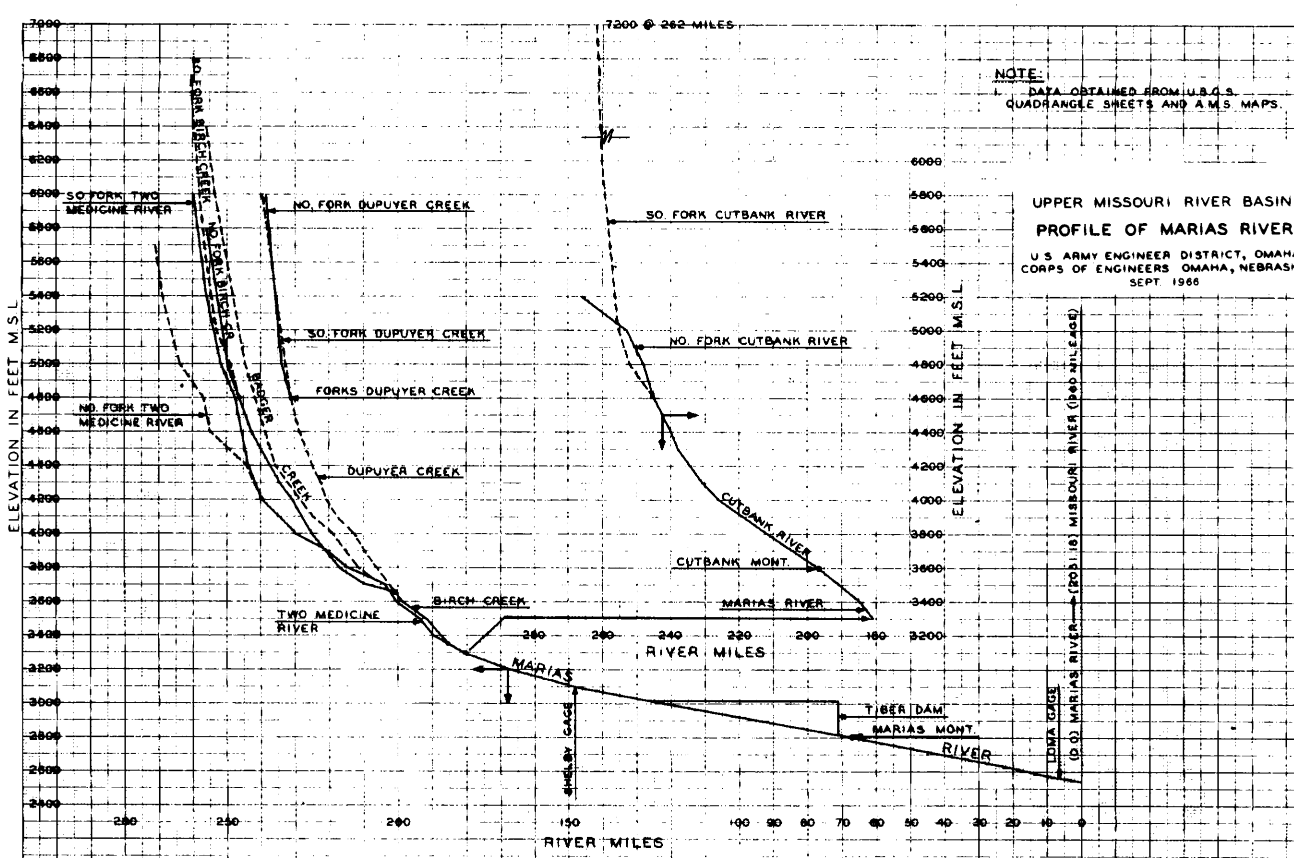

NOTE:
DATA OBTAINED FROM A.M.S. MAPS.
UPPER MISSOURI RIVER BASIN
PROFILE OF DEARBORN RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966
ELEVATION IN FEET M.S.L.
RIVER MILES

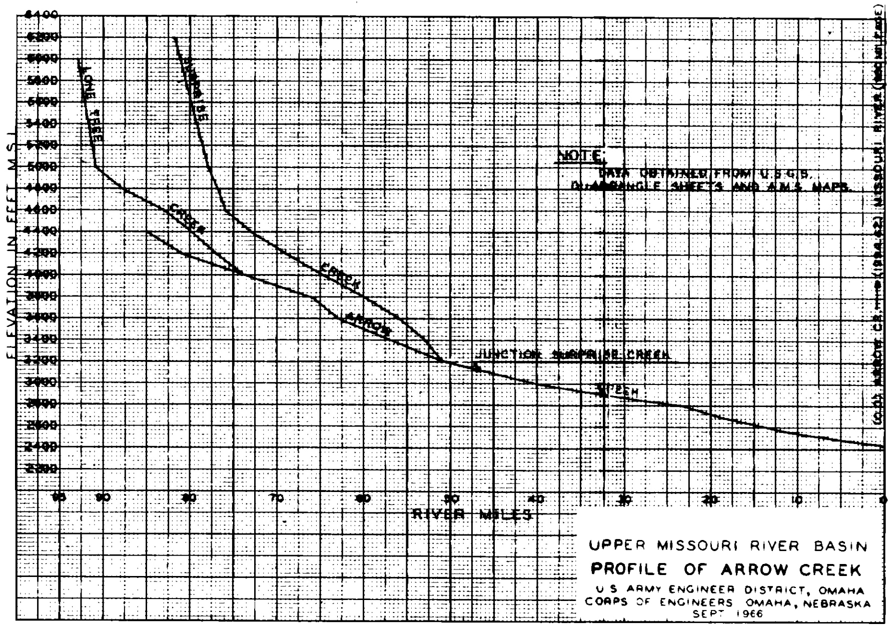

NOTE:
DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS
RIVER MILES
ELEVATION IN FEET M.S.L.
UPPER MISSOURI RIVER BASIN
PROFILE OF SMITH RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966
SMITH
RIVER
RIVER MILES


NOTE:
DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS
ELEVATION IN FEET M.S.L.
GIBSON DAM
UPPER MISSOURI RIVER BASIN
PROFILE OF SUN RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966
SUN
RIVER
RIVER MILES

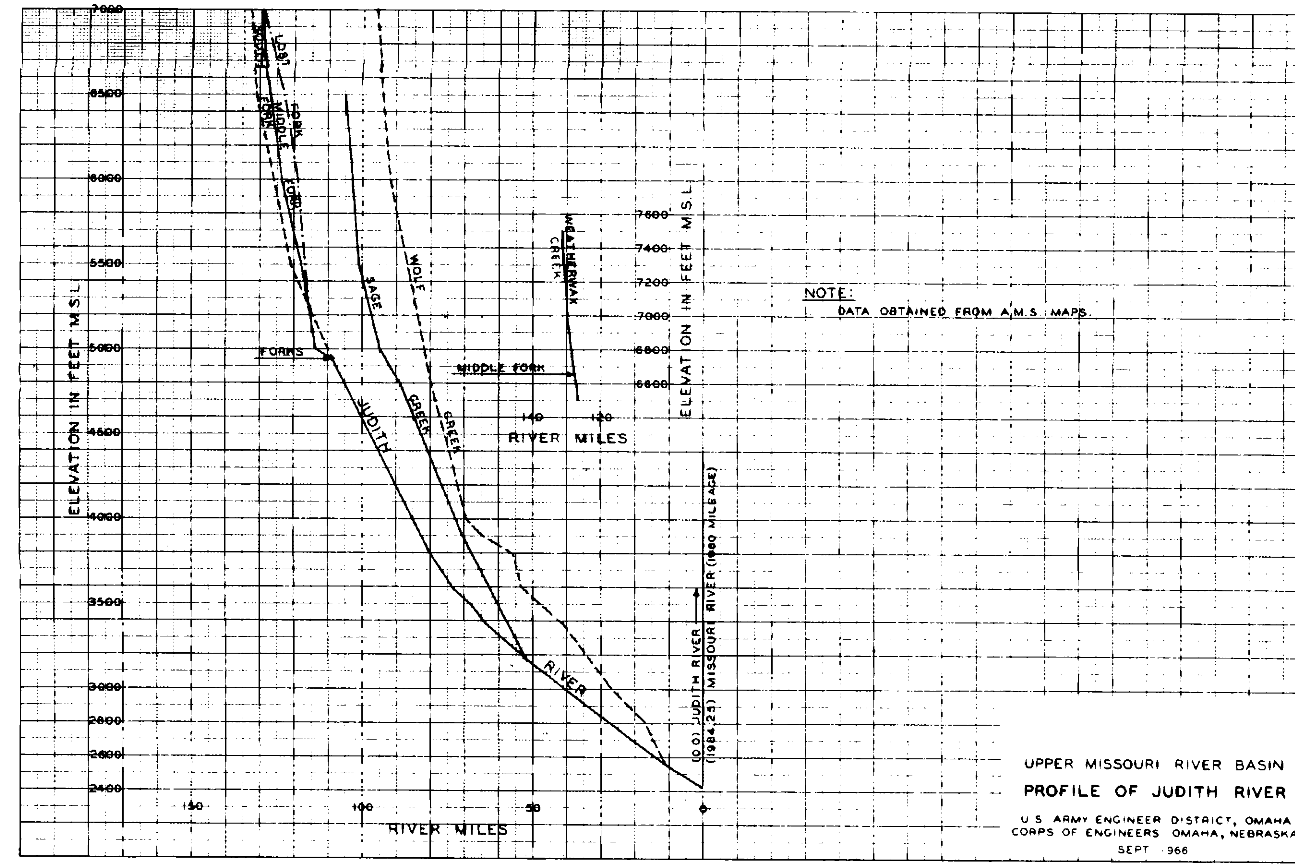

ELEVATION IN FEET M.S.L.
RIVER MILES
NOTE:
DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS
UPPER MISSOURI RIVER BASIN
PROFILE OF BELT CREEK
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966


TETON RIVER
ELEVATION IN FEET M.S.L.
NOTE:
DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS
TETON
RIVER
RIVER MILES
UPPER MISSOURI RIVER BASIN
PROFILE OF TETON RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966

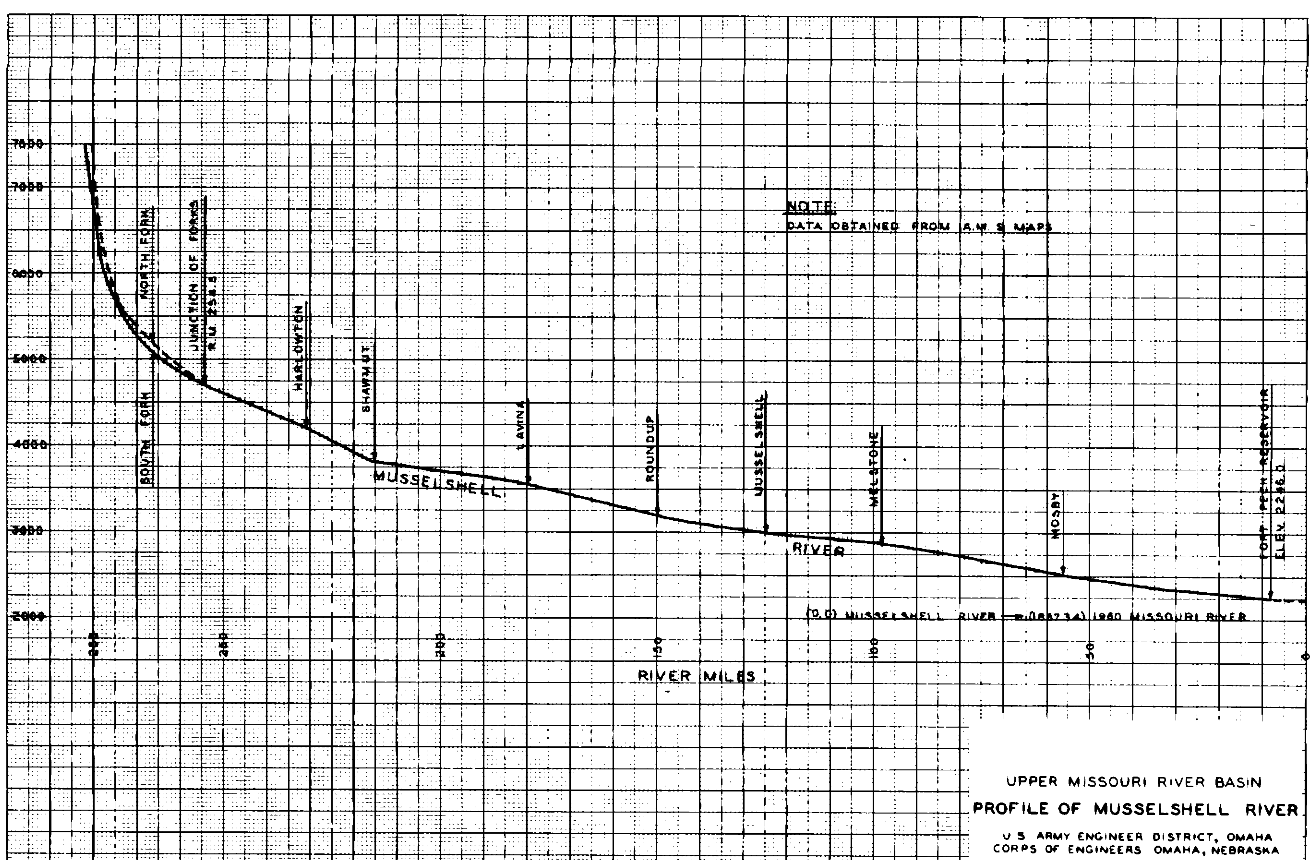

7200 @ 262 MILES
NOTE:
1. DATA OBTAINED FROM U.S.G.S. QUADRANGLE SHEETS AND A.M.S. MAPS.
UPPER MISSOURI RIVER BASIN
PROFILE OF MARIAS RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966
SO. FORK TWO MEDICINE RIVER
NO. FORK DUPUYER CREEK
SO. FORK CUTBANK RIVER
SO. FORK DUPUYER CREEK
NO. FORK CUTBANK RIVER
FORKS DUPUYER CREEK
NO. FORK TWO MEDICINE RIVER
DUPUYER CREEK
CUTBANK RIVER
CUTBANK MONT.
MARIAS RIVER
BIRCH CREEK
TWO MEDICINE RIVER
MARIAS
TIBER DAM
MARIAS MONT.
RIVER
SHELBY GAGE
LOMA GAGE
ELEVATION IN FEET M.S.L.
RIVER MILES



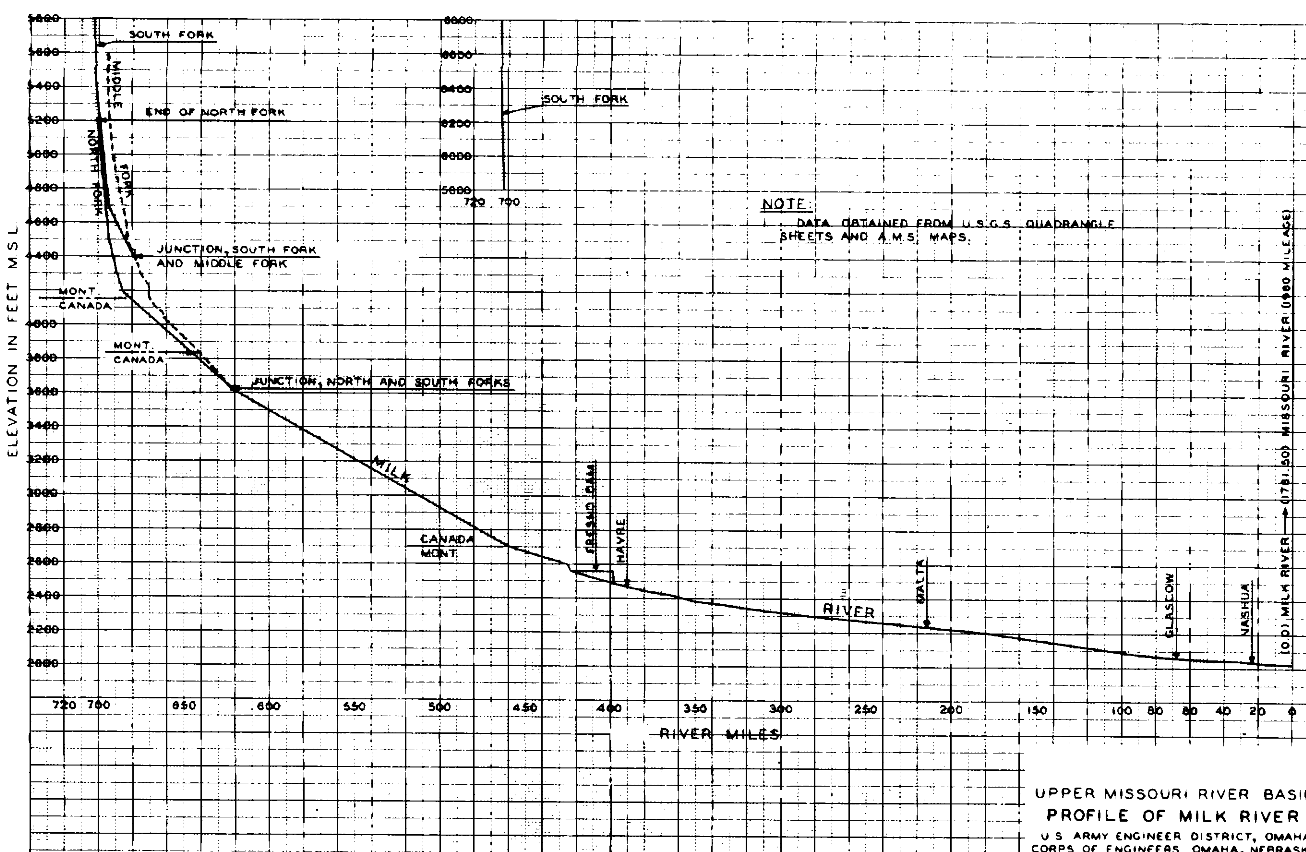
UPPER MISSOURI RIVER BASIN
PROFILE OF ARROW CREEK
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966



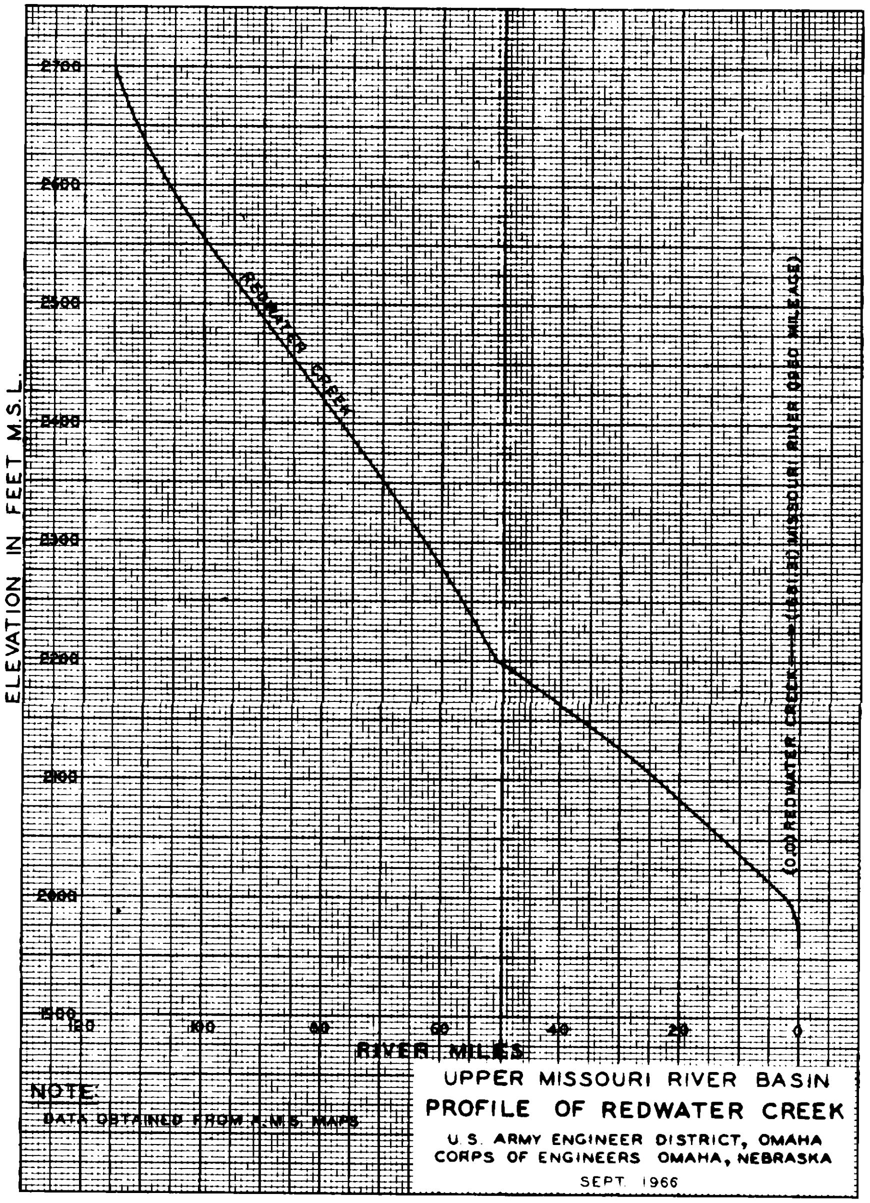
UPPER MISSOURI RIVER BASIN
PROFILE OF JUDITH RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966



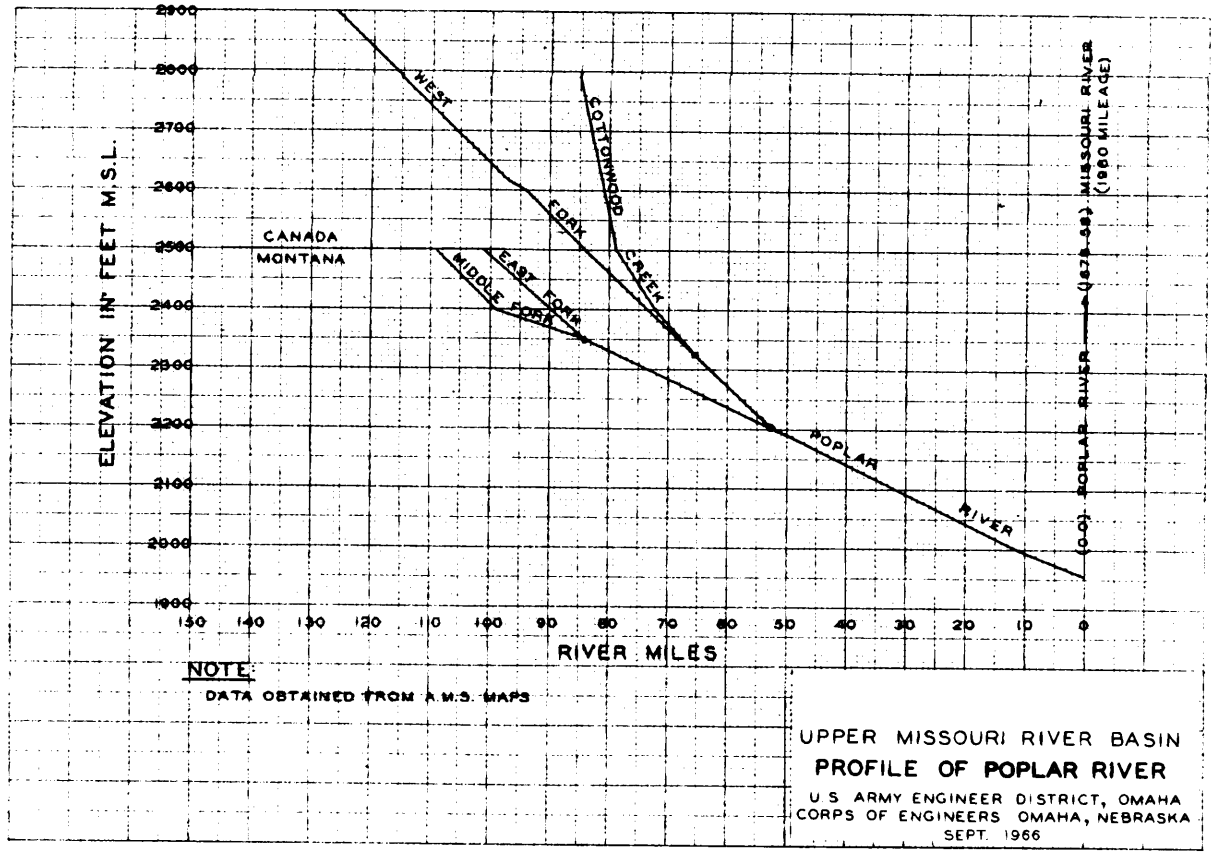
UPPER MISSOURI RIVER BASIN
PROFILE OF MUSSELSHELL RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966



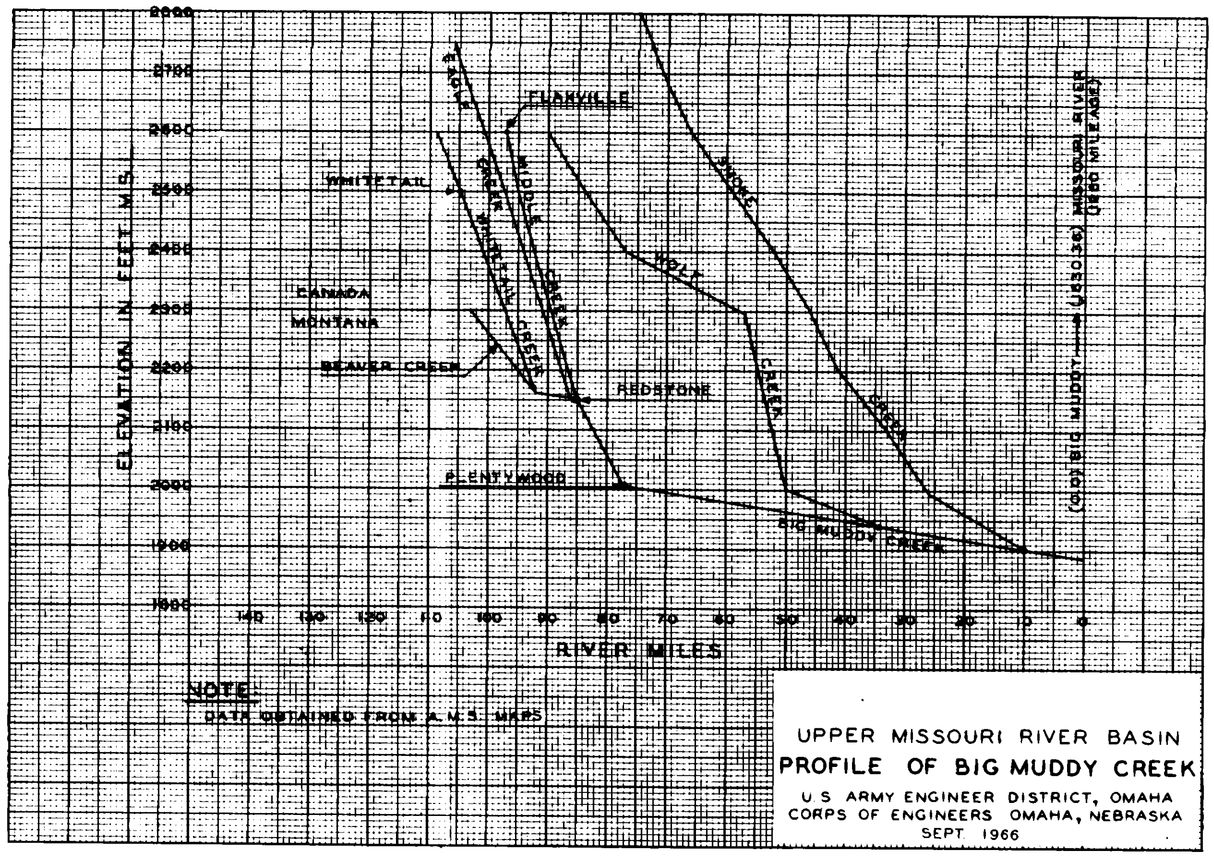
UPPER MISSOURI RIVER BASIN
PROFILE OF MILK RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966



UPPER MISSOURI RIVER BASIN
PROFILE OF REDWATER CREEK
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966



UPPER MISSOURI RIVER BASIN
PROFILE OF POPLAR RIVER
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966



UPPER MISSOURI RIVER BASIN
PROFILE OF BIG MUDDY CREEK
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966

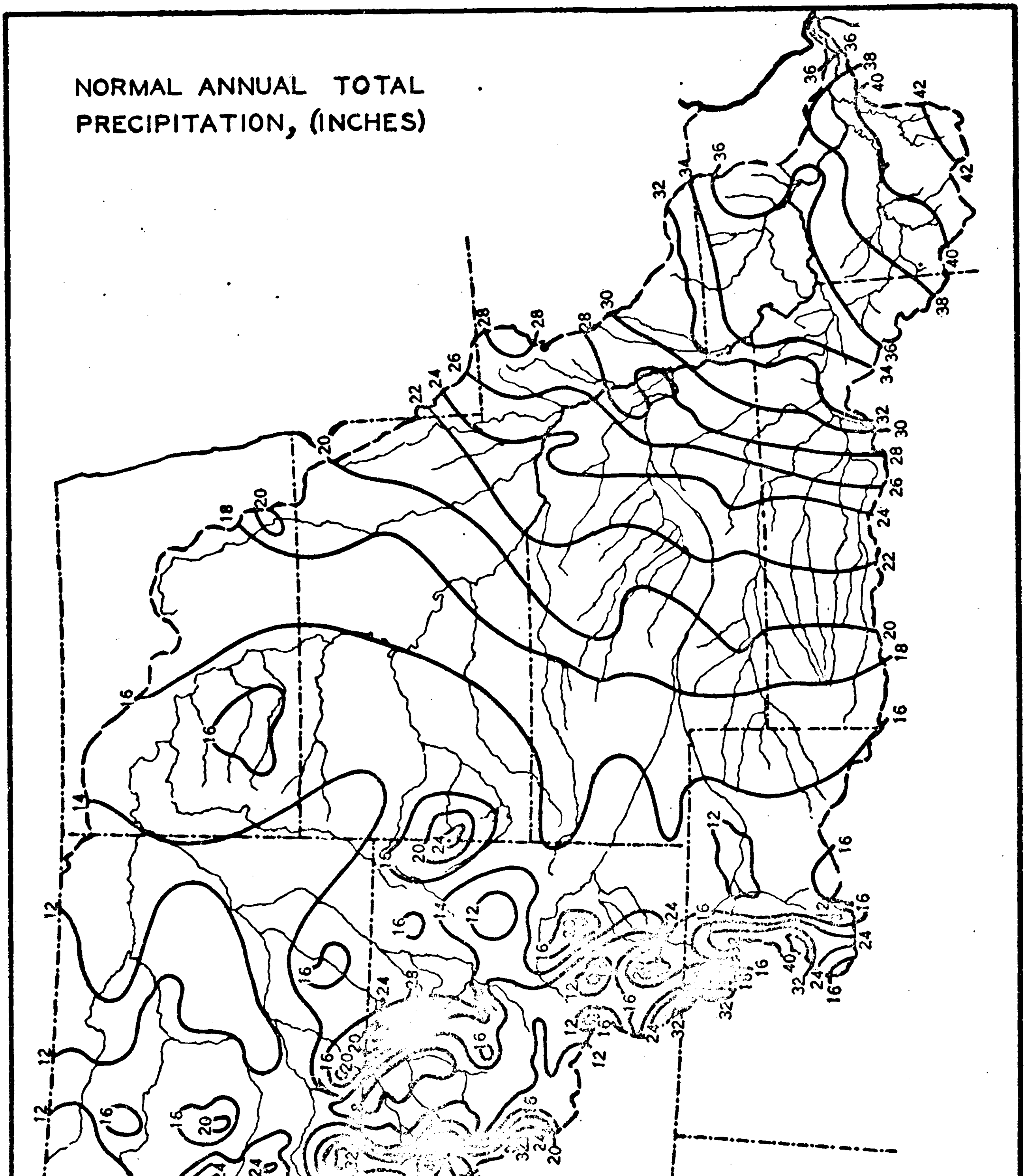
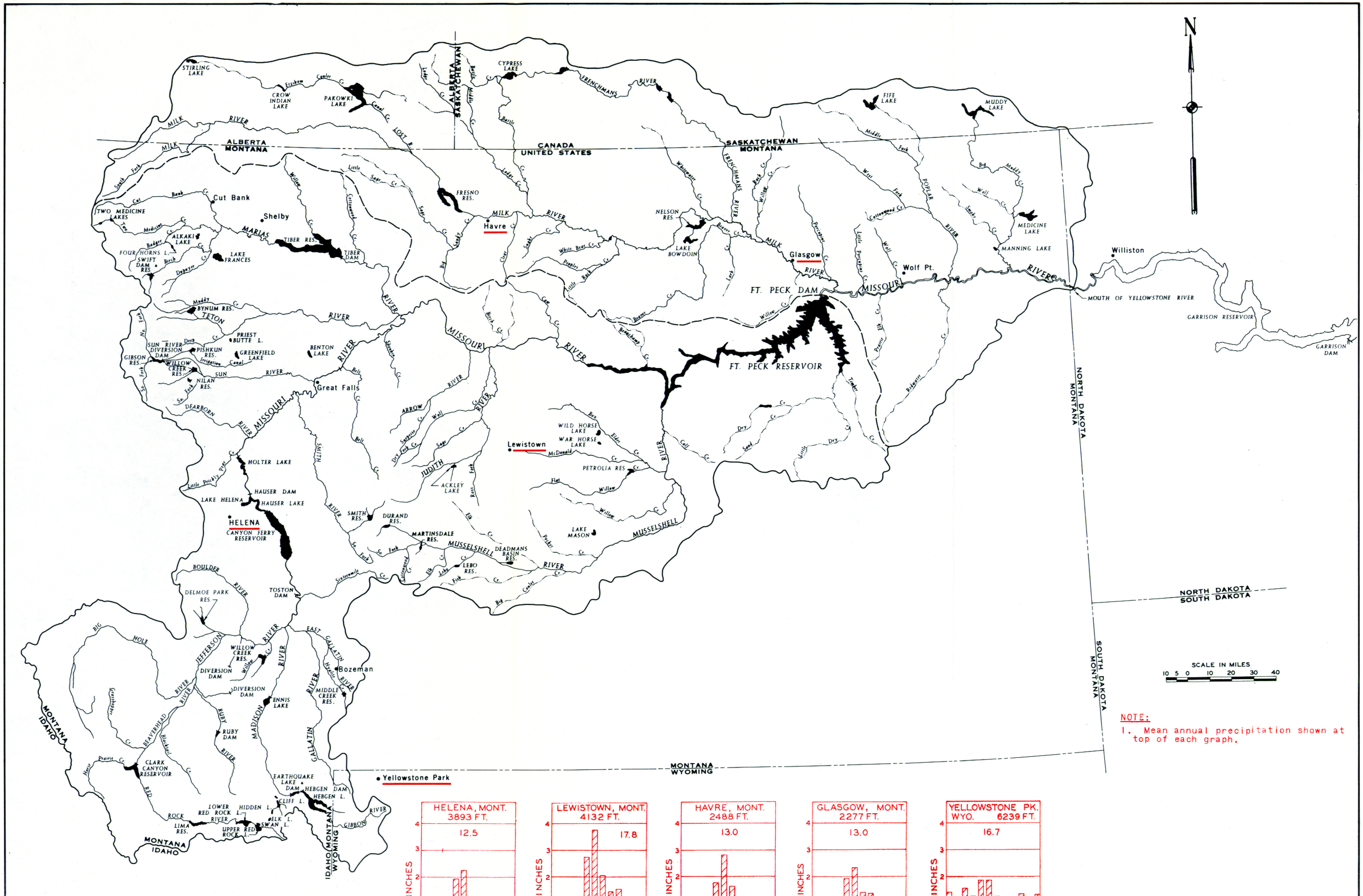

NORMAL ANNUAL TOTAL
PRECIPITATION, (INCHES)
DATA BASED ON PERIOD 1931—1960

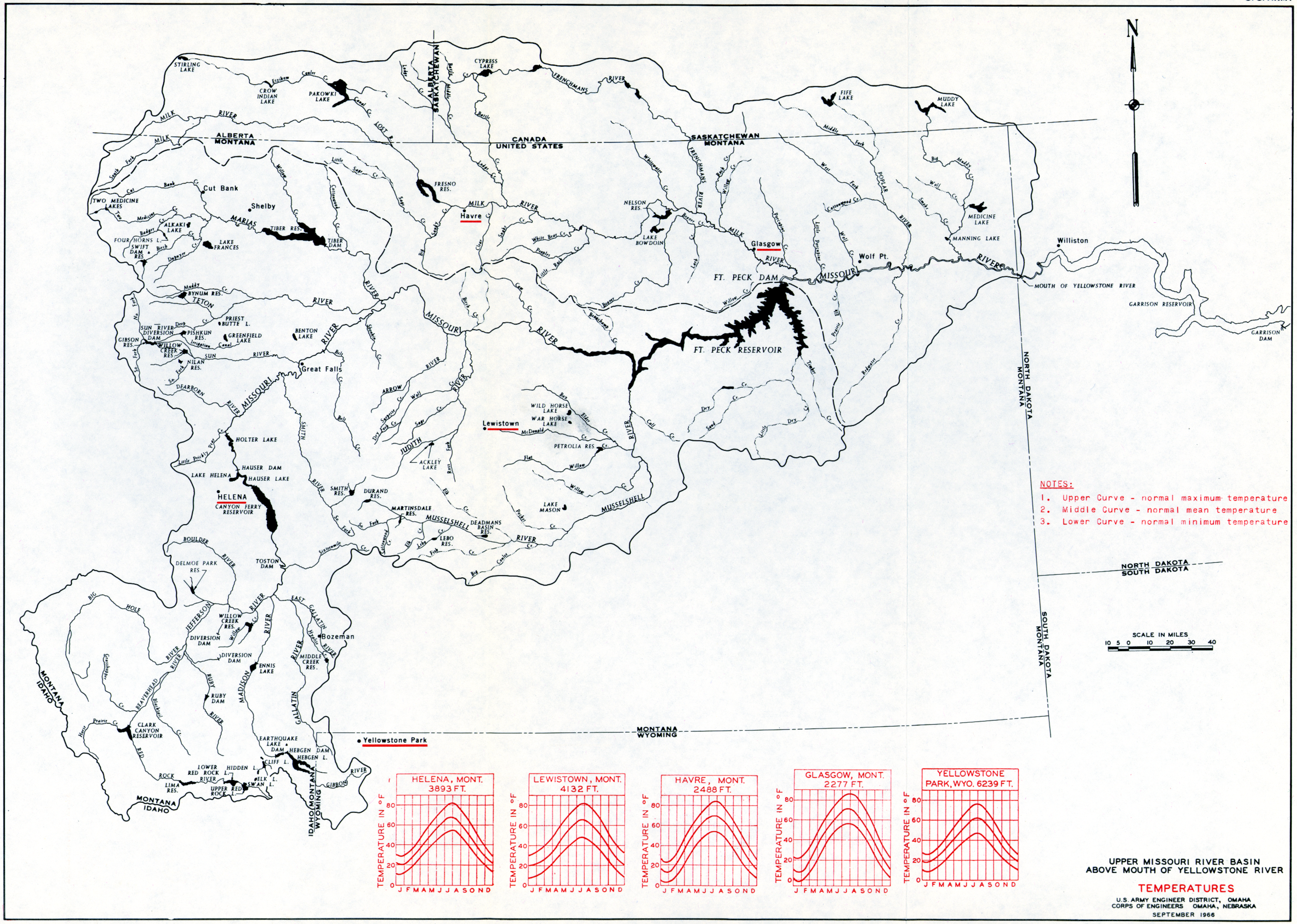
PLATE 4



UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER

MEAN MONTHLY PRECIPITATION

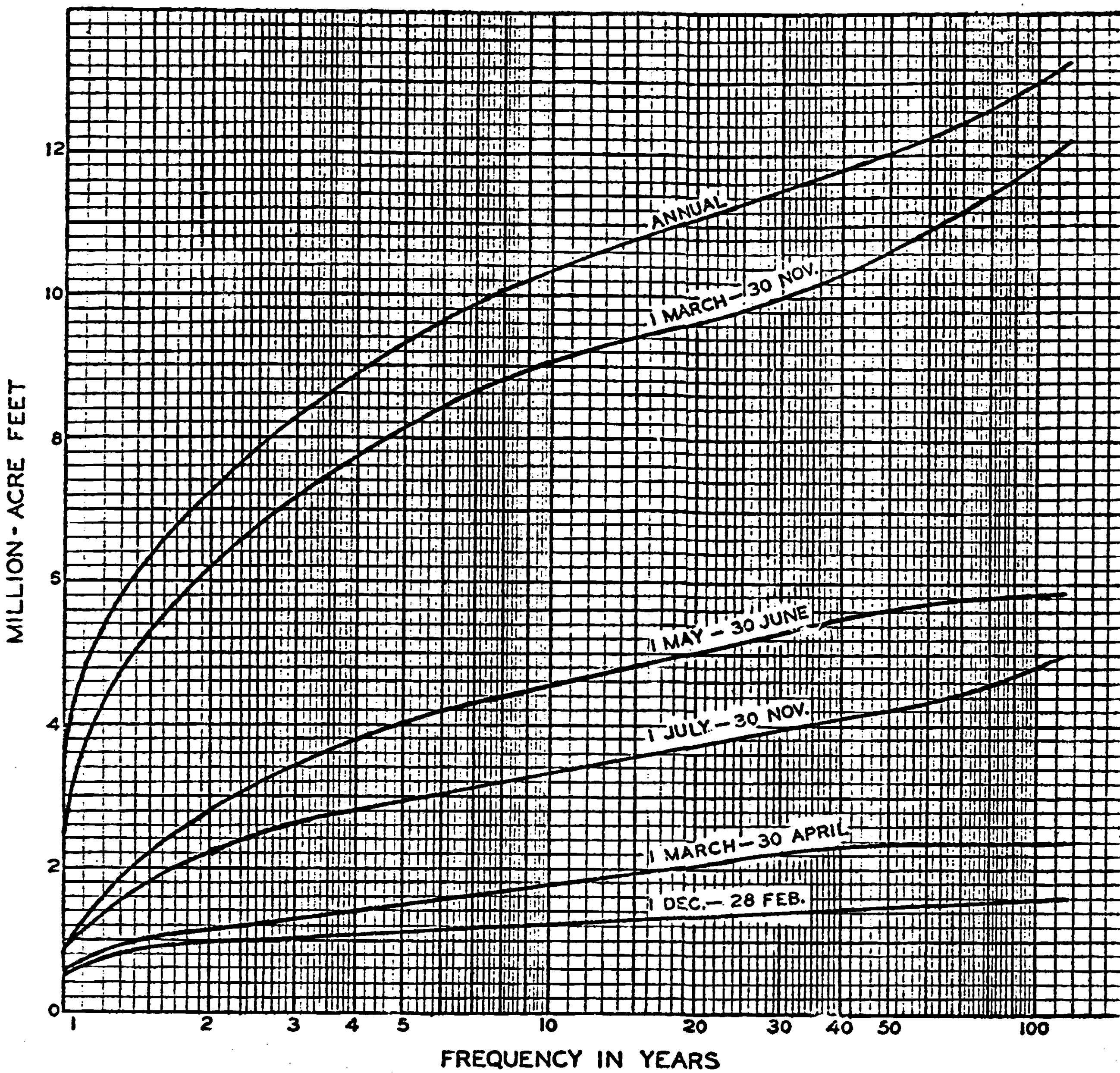
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966



UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER

TEMPERATURES

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966



NOTE:

ADJUSTED TO 1949 LEVEL OF DEPLETION DEVELOPMENT

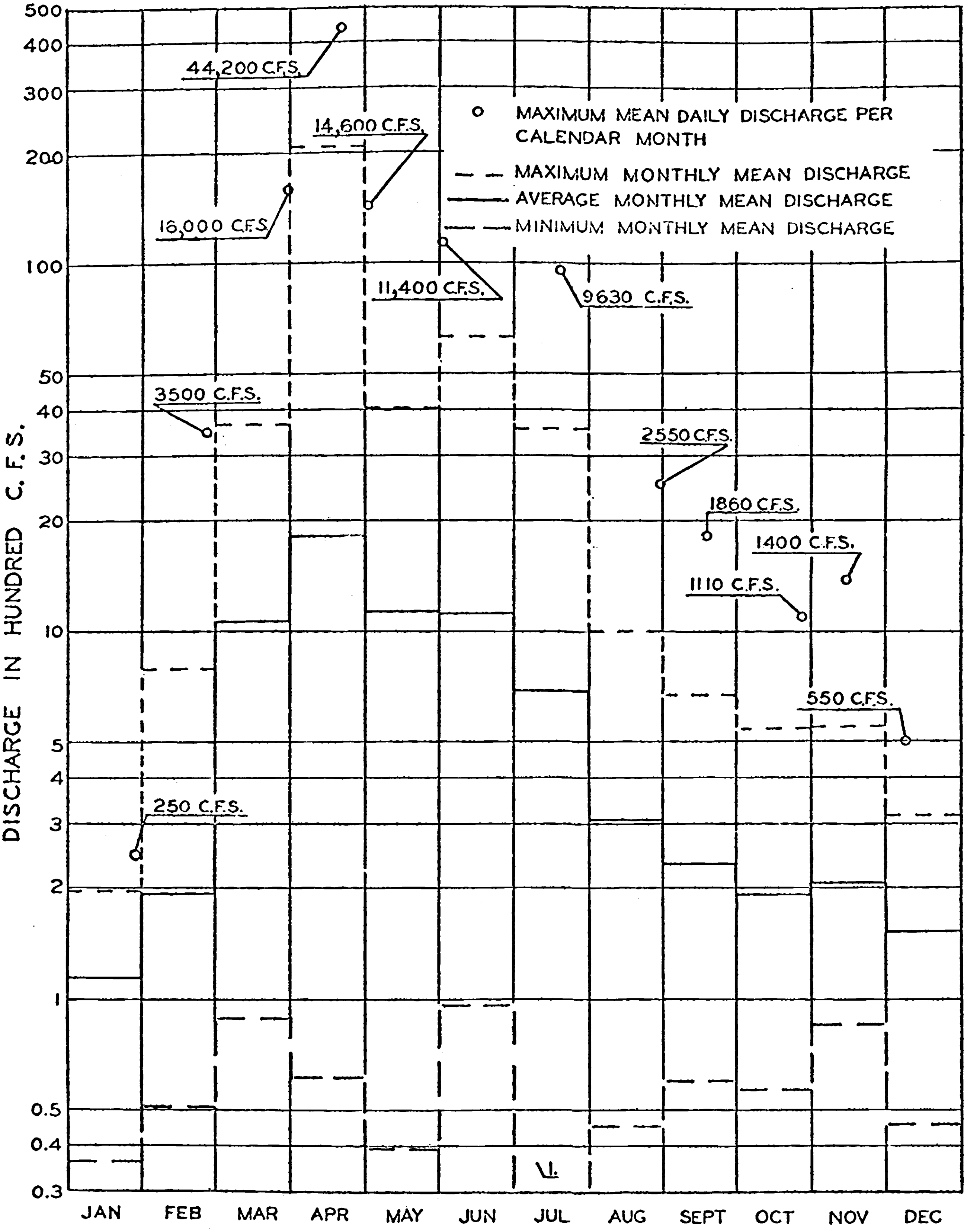
MISSOURI RIVER

FORT PECK LAKE

ANNUAL AND SEASONAL INFLOW PROBABILITY

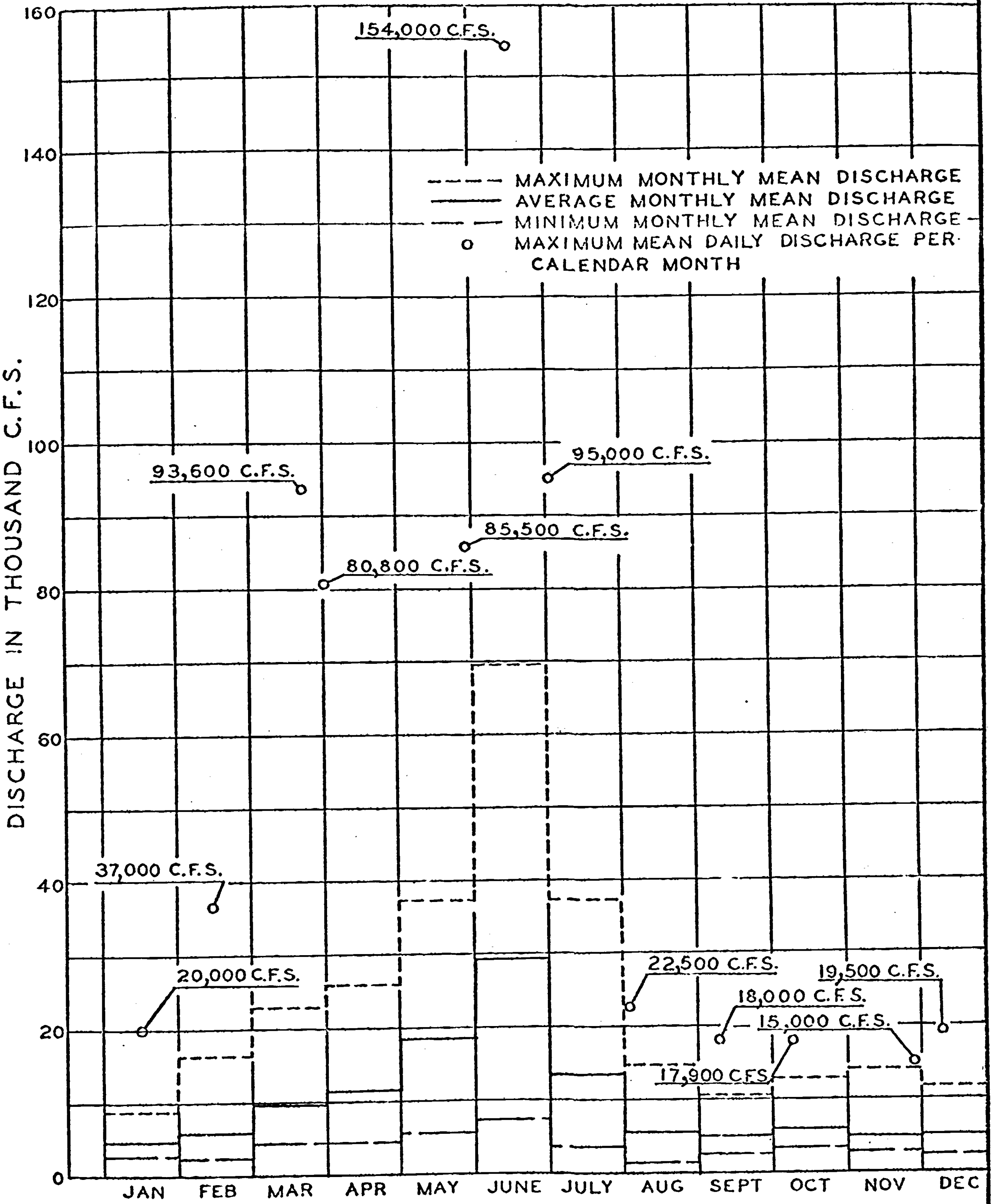
1898 – 1975

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



NOTE:
1. MINIMUM MONTHLY DISCHARGE FOR JULY IS 15 C.F.S.

MILK RIVER
NASHUA, MONTANA
MONTHLY STREAM FLOW DISTRIBUTION
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



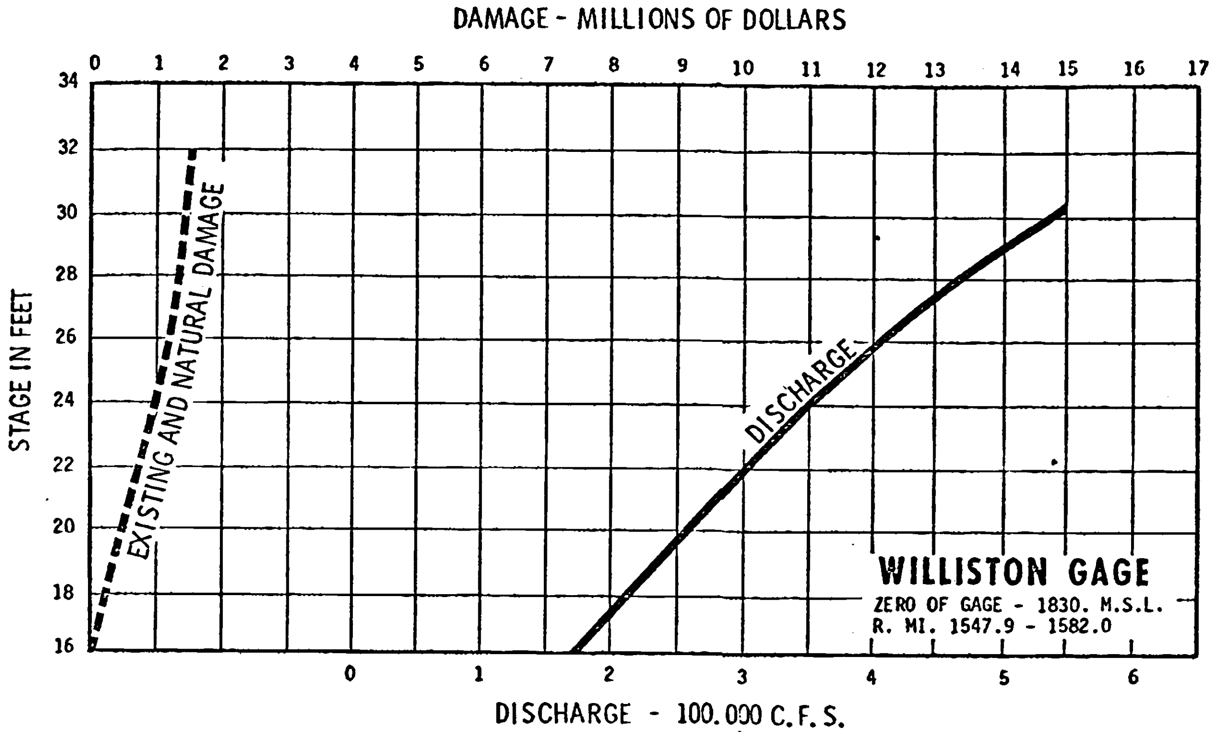
NOTE:
DISCHARGES ARE BASED ON RECORDED AND ESTIMATED INFLOWS, ADJUSTED TO 1950 LEVEL OF DEPLETION

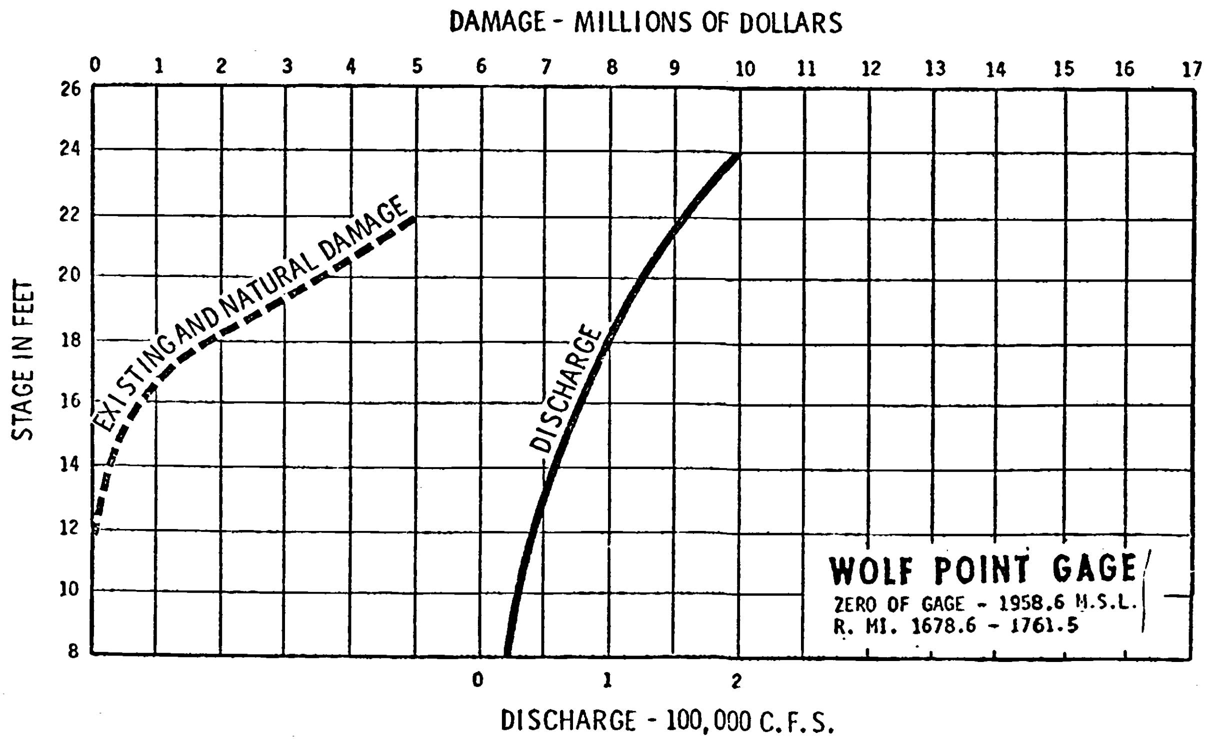
MISSOURI RIVER

FORT PECK LAKE, MONTANA

MONTHLY STREAM FLOW DISTRIBUTION

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA





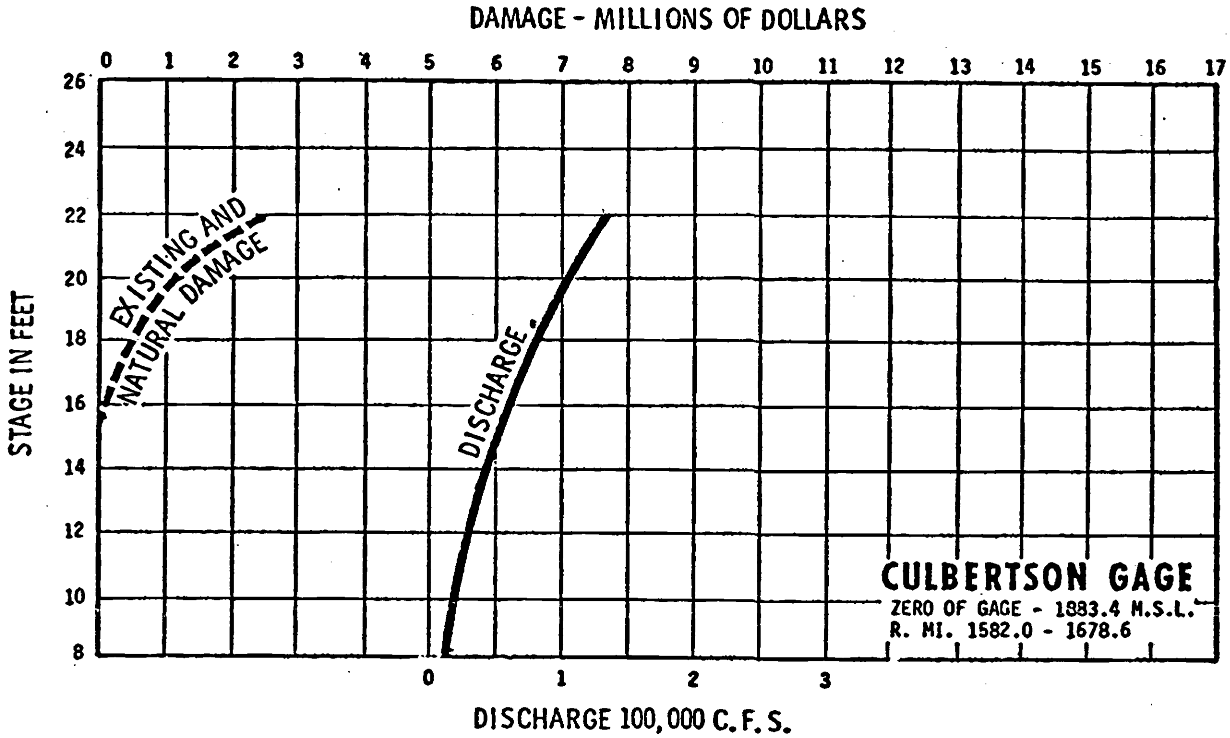
NOTE: DAMAGE CURVES ARE BASED ON ESTIMATED 1975 AVERAGE ANNUAL DAMAGES PER CROP YEAR.

MISSOURI RIVER

STAGE - DISCHARGE - DAMAGE CURVES

RURAL AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



NOTE: DAMAGE CURVES ARE BASED ON ESTIMATED 1975 AVERAGE ANNUAL DAMAGES PER CROP YEAR.

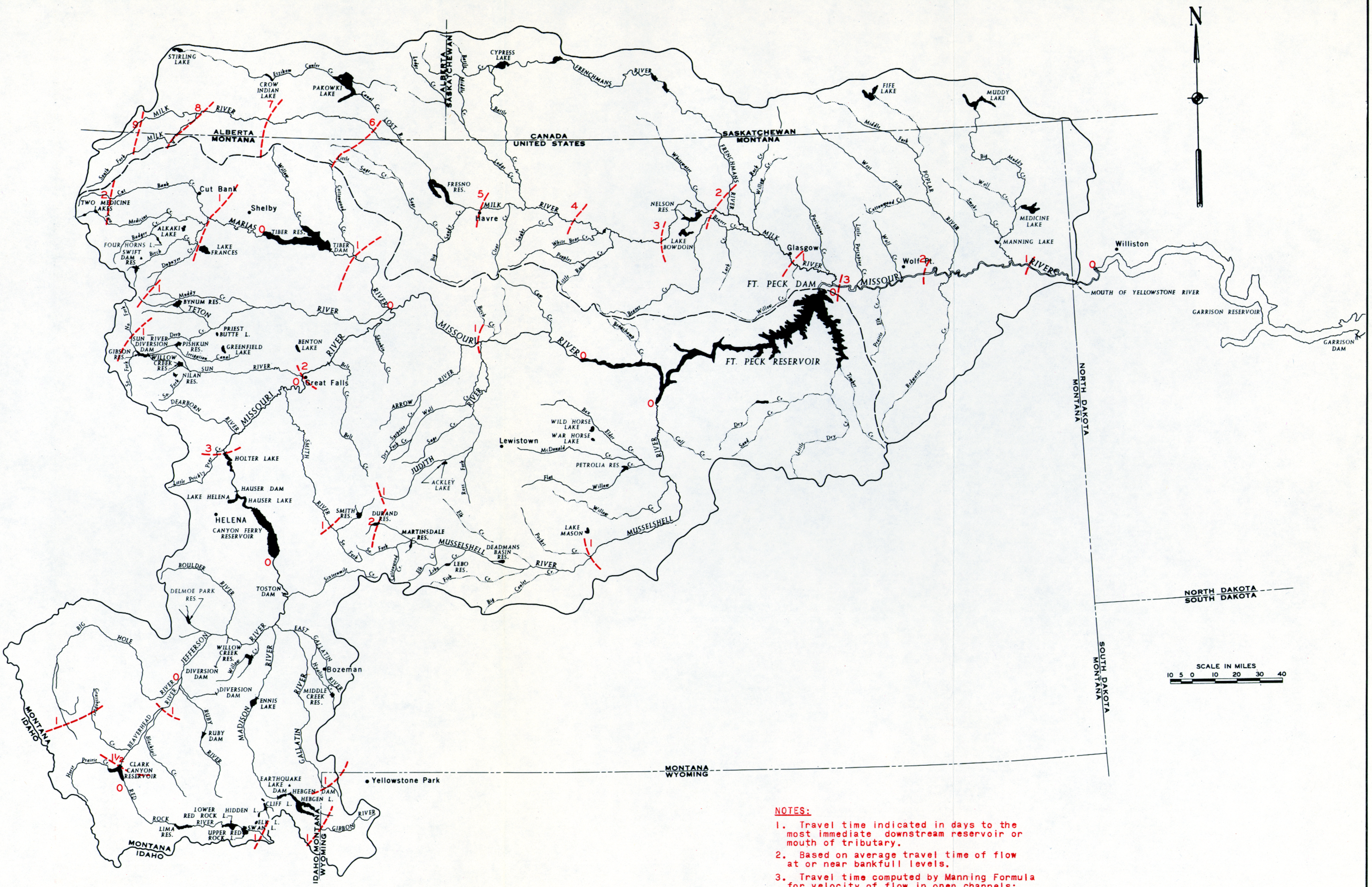
MISSOURI RIVER

STAGE — DISCHARGE — DAMAGE CURVES

RURAL AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 10B



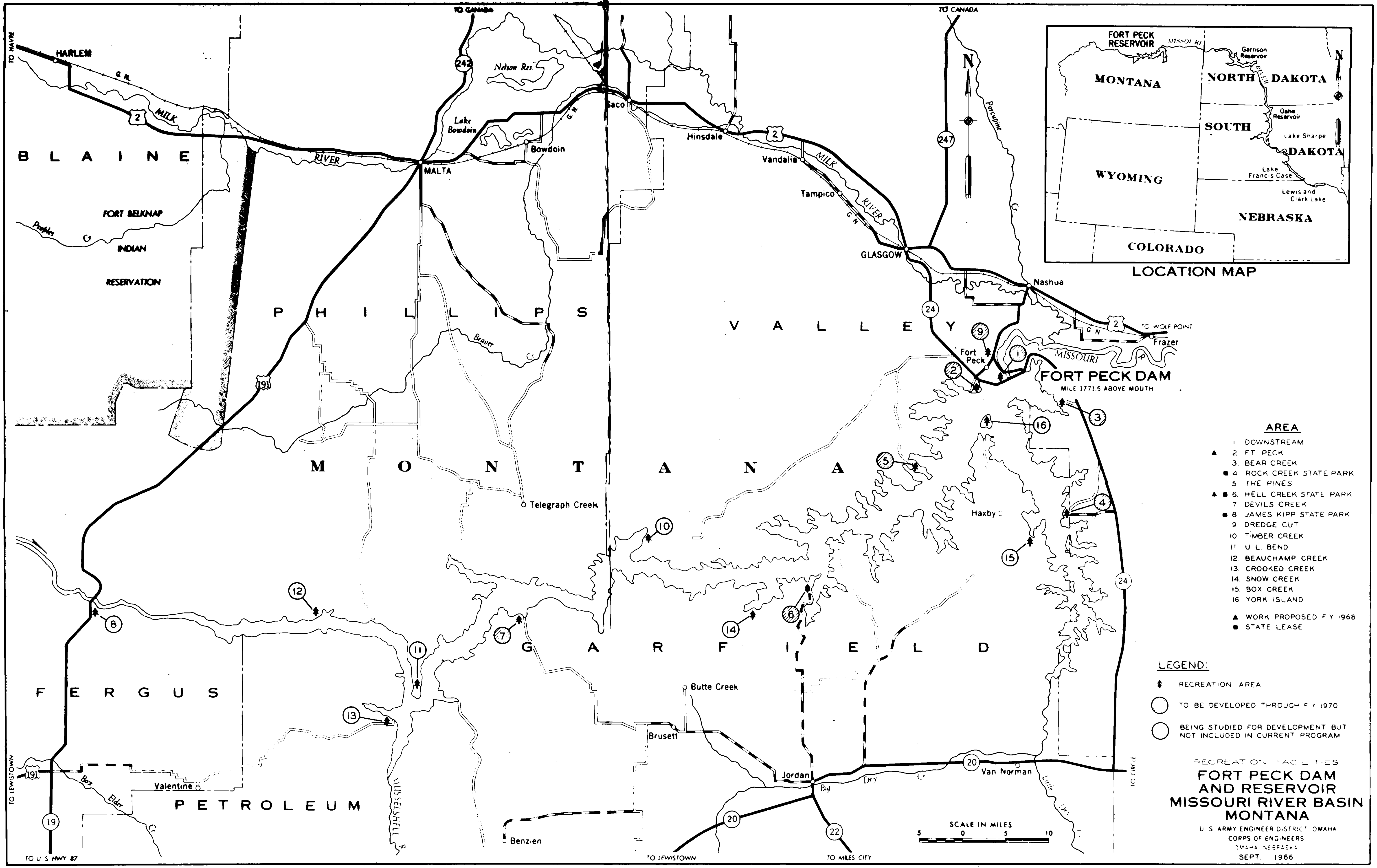
NOTES:

1. Travel time indicated in days to the most immediate downstream reservoir or mouth of tributary.
2. Based on average travel time of flow at or near bankfull levels.
3. Travel time computed by Manning Formula for velocity of flow in open channels:
$$V = \frac{1.486}{n} R^{0.67} S^{0.5}$$
Missouri River and Tributaries n = .025
Milk River n = .035

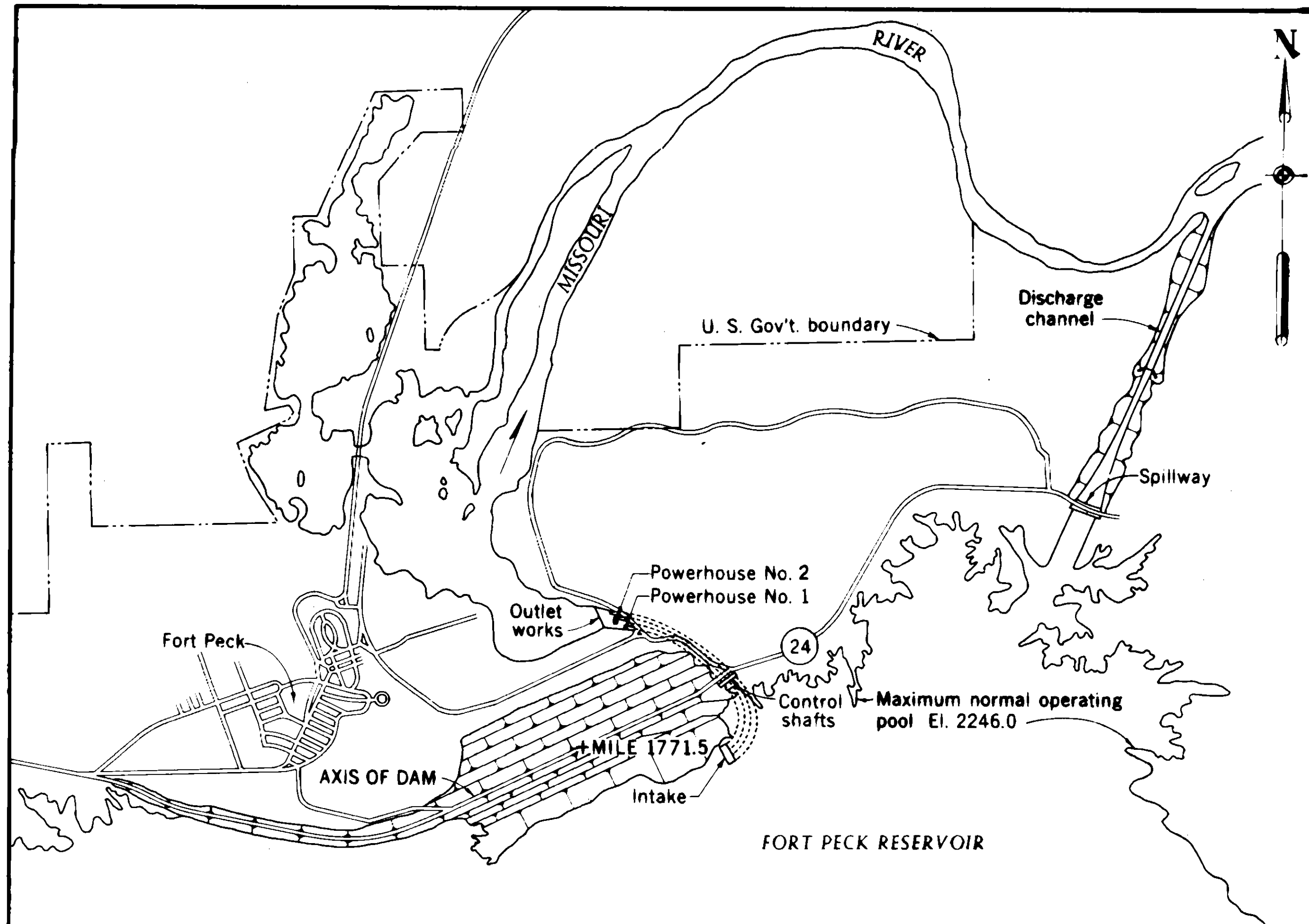
UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER

WATER TRAVEL TIME

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

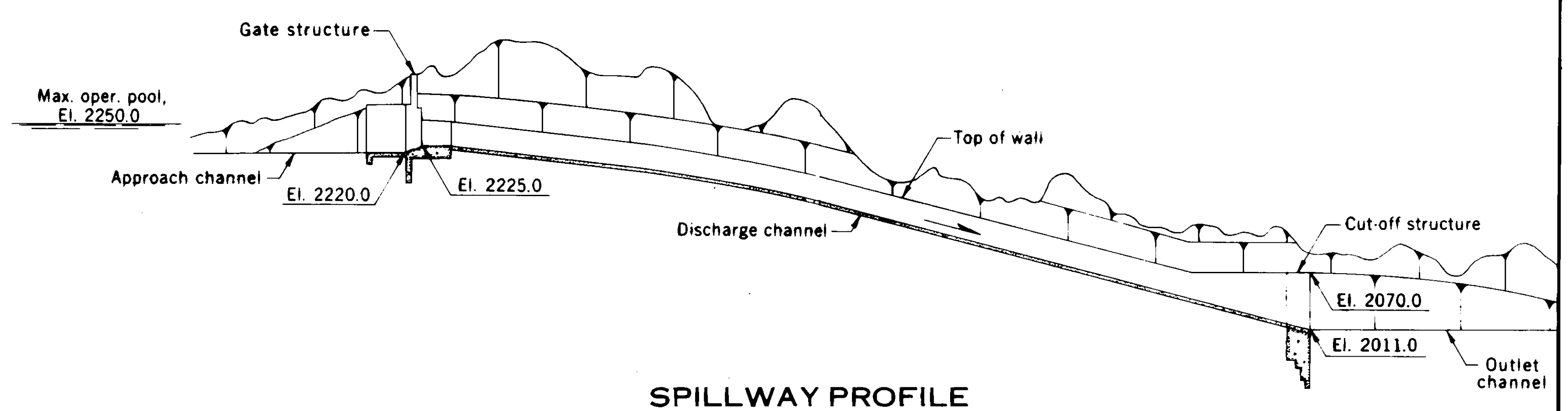


TO CANADA
TO CANADA
TO HAVRE
HARLEM
G. N.
MILK
RIVER
Nelson Res
Lake Bowdoin
Bowdoin
MALTA
Saco
Hinsdale
Vandalia
Tampico
GLASGOW
Nashua
Frazer
TO WOLF POINT
MISSOURI
Fort Peck
FORT PECK DAM
MILE 1771.5 ABOVE MOUTH
Porcupine Cr.
B L A I N E
FORT BELKNAP INDIAN RESERVATION
Peoples Cr.
P H I L L I P S
Beaver Cr.
V A L L E Y
M O N T A N A
Telegraph Creek
Haxby
G A R F I E L D
F E R G U S
P E T R O L E U M
Butte Creek
Brusett
Jordan
Big Dry Cr.
Van Norman
Little Dry
Valentine
Box Elder Cr.
MUSSELSHELL R.
Benzien
TO LEWISTOWN
TO U S HWY 87
TO LEWISTOWN
TO MILES CITY
TO CIRCLE
2
191
242
247
24
20
22
19
FORT PECK RESERVOIR
MISSOURI
Garrison Reservoir
MONTANA
NORTH DAKOTA
Oahe Reservoir
SOUTH DAKOTA
Lake Sharpe
Lake Francis Case
Lewis and Clark Lake
WYOMING
NEBRASKA
COLORADO
LOCATION MAP
AREA
1 DOWNSTREAM
2 FT PECK
3 BEAR CREEK
4 ROCK CREEK STATE PARK
5 THE PINES
6 HELL CREEK STATE PARK
7 DEVILS CREEK
8 JAMES KIPP STATE PARK
9 DREDGE CUT
10 TIMBER CREEK
11 U L BEND
12 BEAUCHAMP CREEK
13 CROOKED CREEK
14 SNOW CREEK
15 BOX CREEK
16 YORK ISLAND
WORK PROPOSED F Y 1968
STATE LEASE
LEGEND:
RECREATION AREA
TO BE DEVELOPED THROUGH F Y 1970
BEING STUDIED FOR DEVELOPMENT BUT NOT INCLUDED IN CURRENT PROGRAM
SCALE IN MILES
5 0 5 10
RECREATION FACILITIES
FORT PECK DAM AND RESERVOIR
MISSOURI RIVER BASIN
MONTANA
U S ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS
OMAHA NEBRASKA
SEPT. 1966

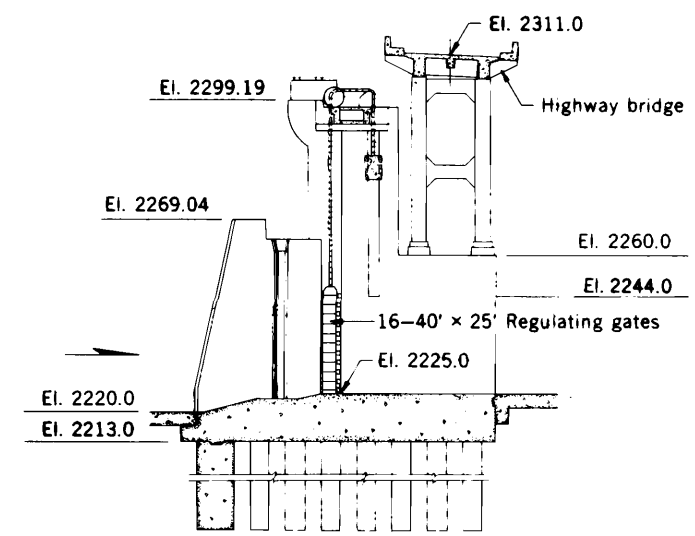


+ 1960 Adjusted mileage above mouth

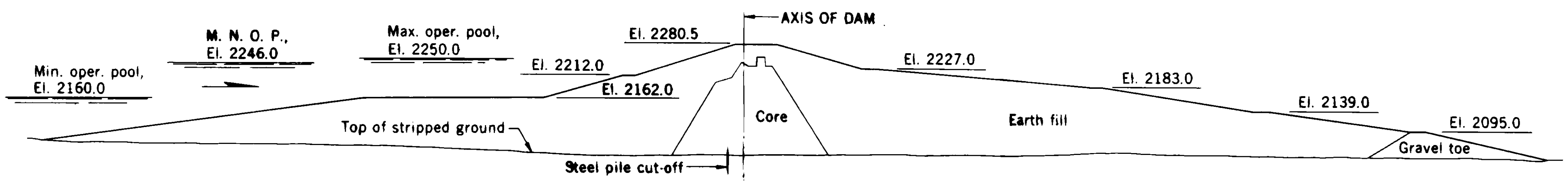
PLAN



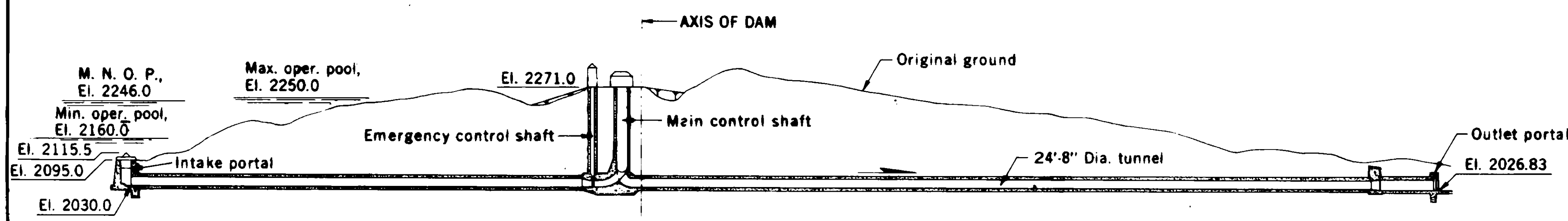
SPILLWAY PROFILE



SPILLWAY GATE STRUCTURE



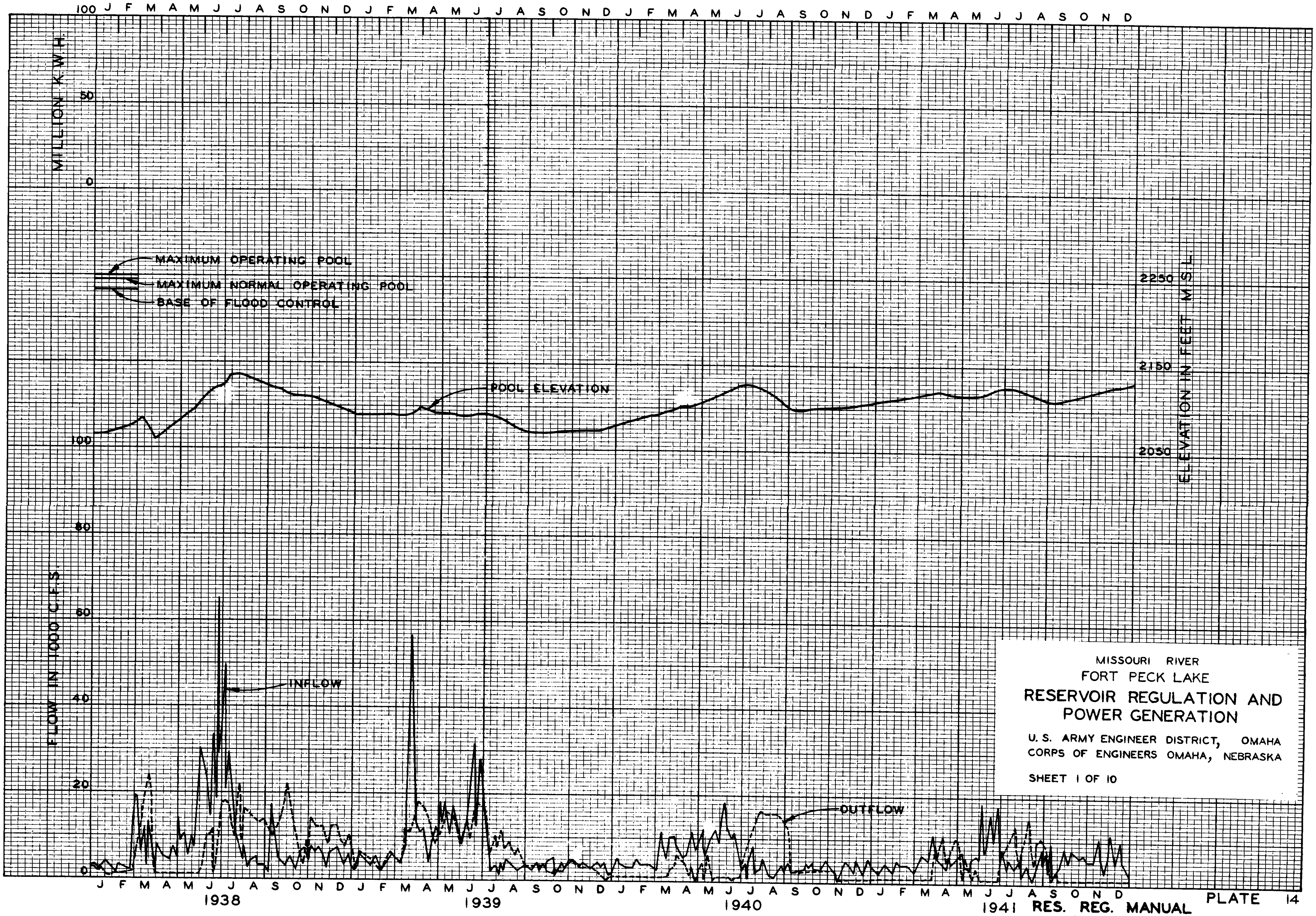
MAXIMUM EMBANKMENT SECTION

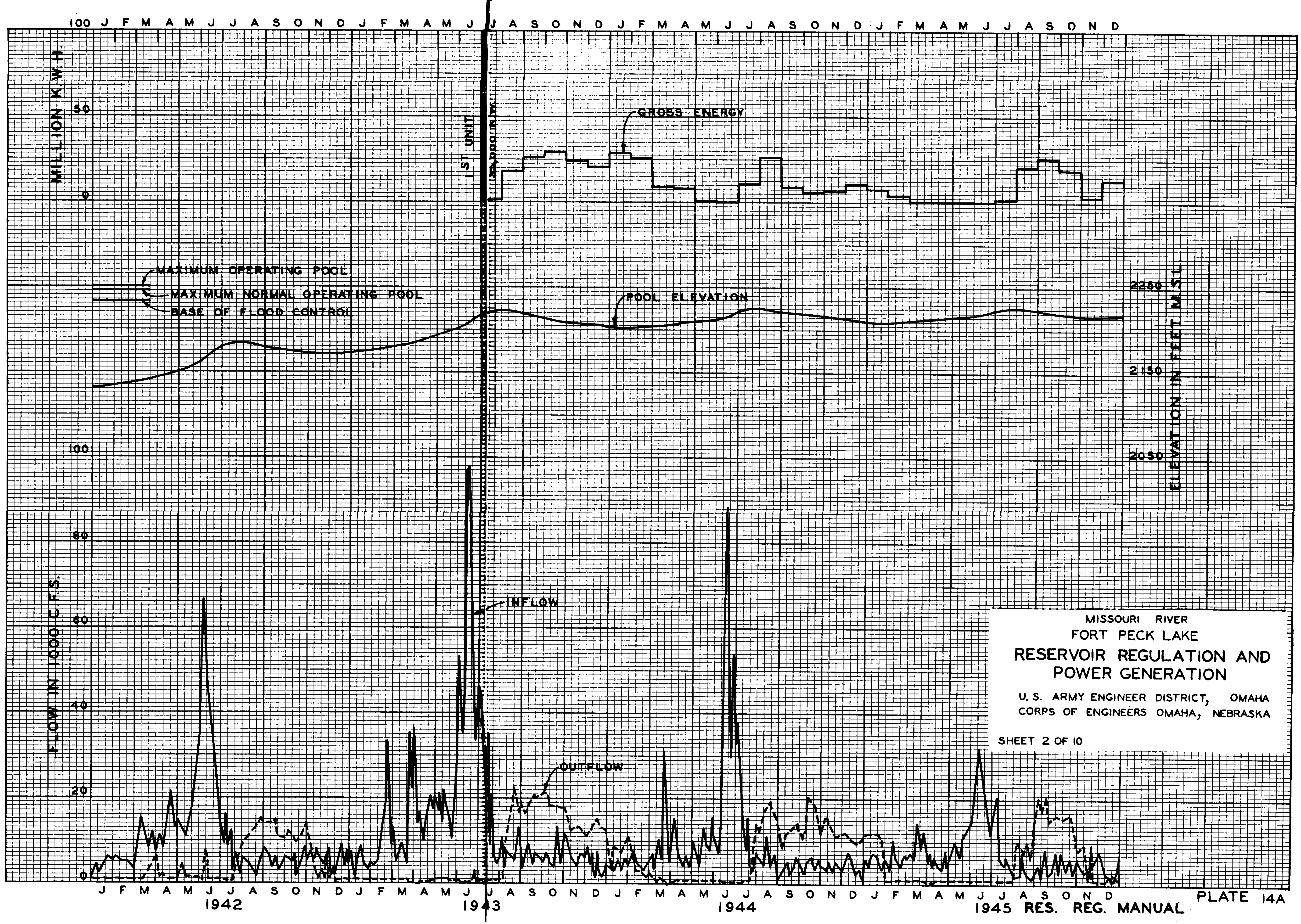


OUTLET WORKS PROFILE

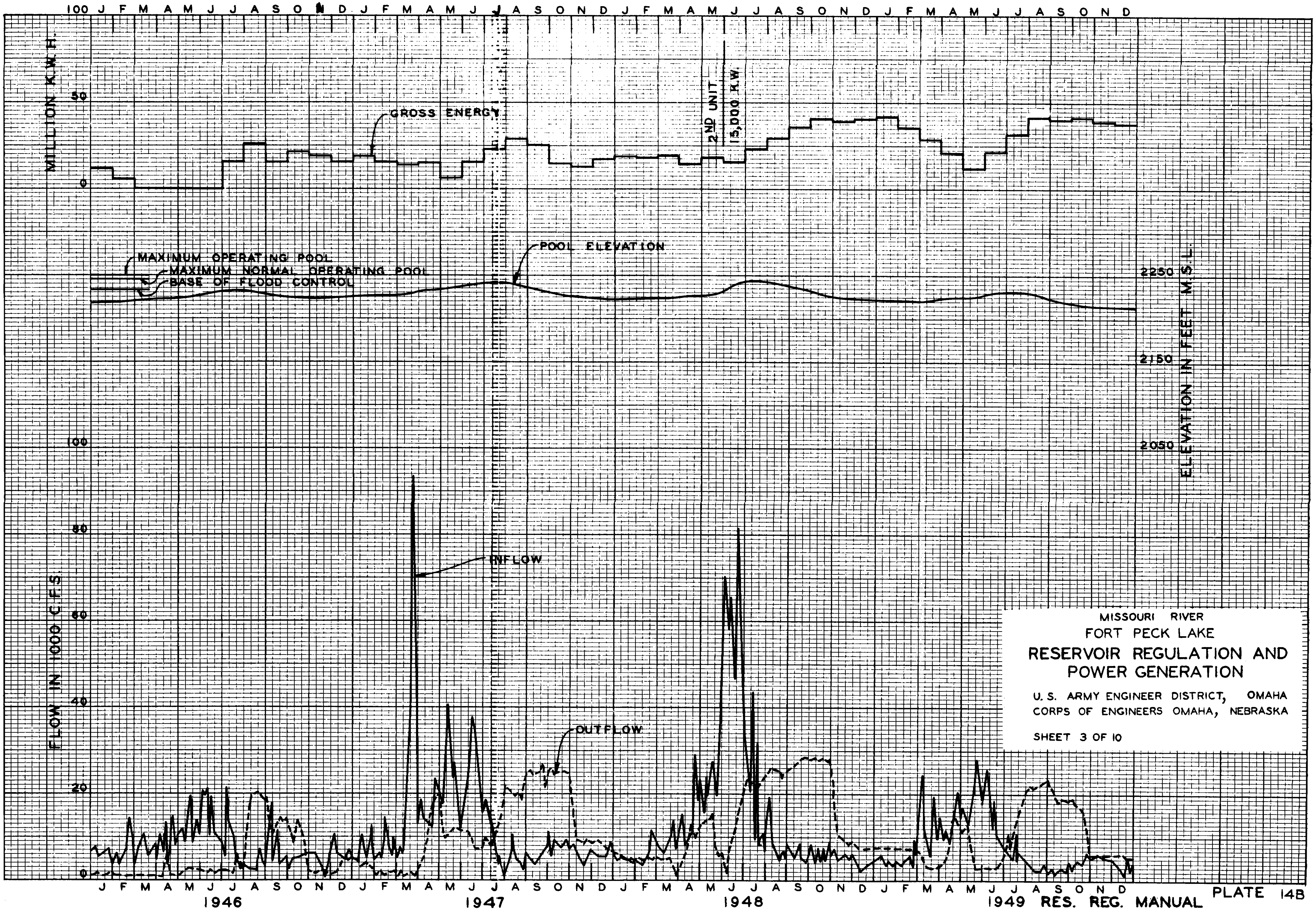
FORT PECK DAM
SPILLWAY AND OUTLET WORKS
MISSOURI RIVER BASIN
MONTANA

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

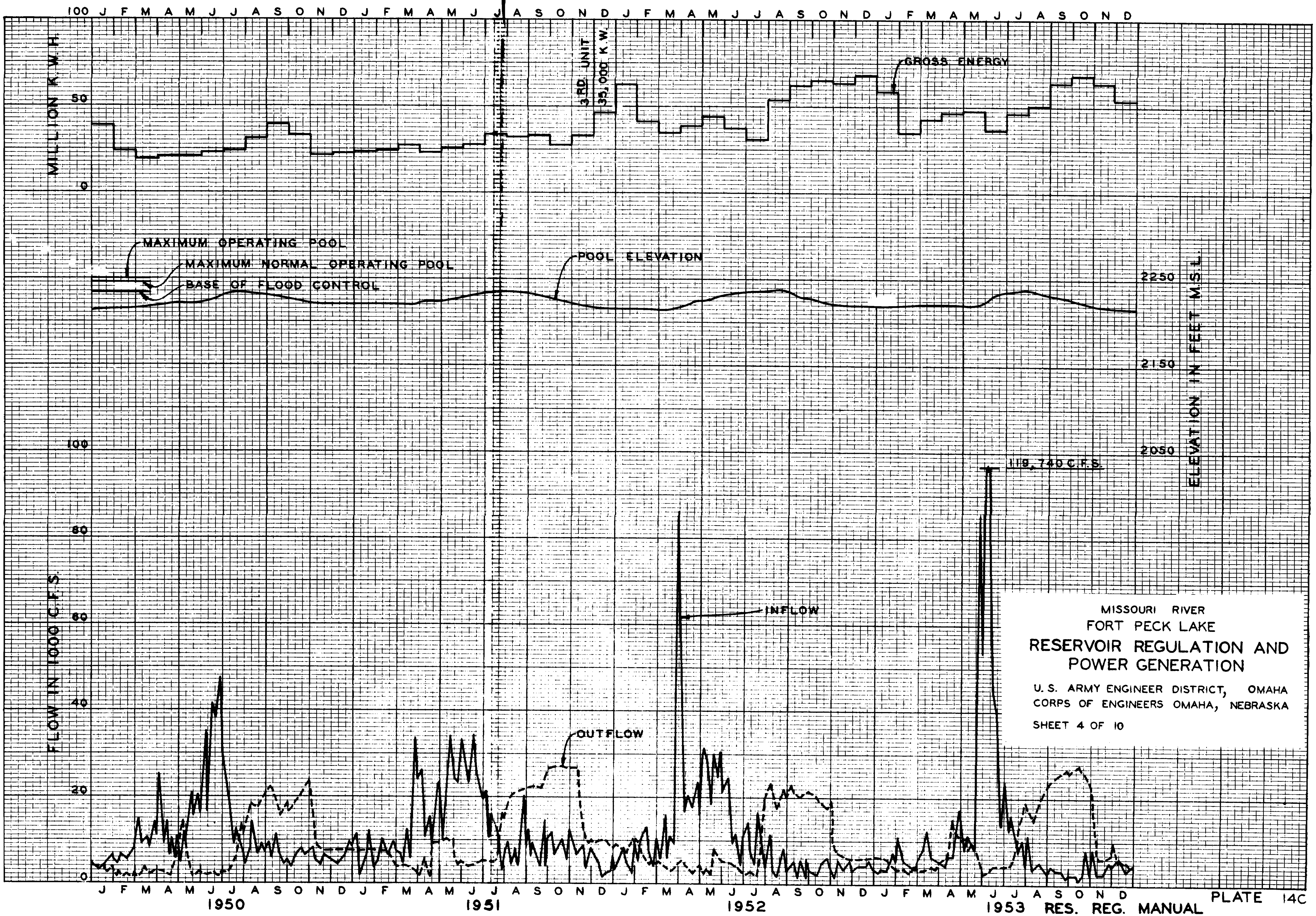

MILLION K.W.H.
ELEVATION IN FEET M.S.L.
FLOW IN 1000 C.F.S.
MAXIMUM OPERATING POOL
MAXIMUM NORMAL OPERATING POOL
BASE OF FLOOD CONTROL
POOL ELEVATION
INFLOW
OUTFLOW
1938
1939
1940
1941
MISSOURI RIVER
FORT PECK LAKE
RESERVOIR REGULATION AND POWER GENERATION
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SHEET 1 OF 10



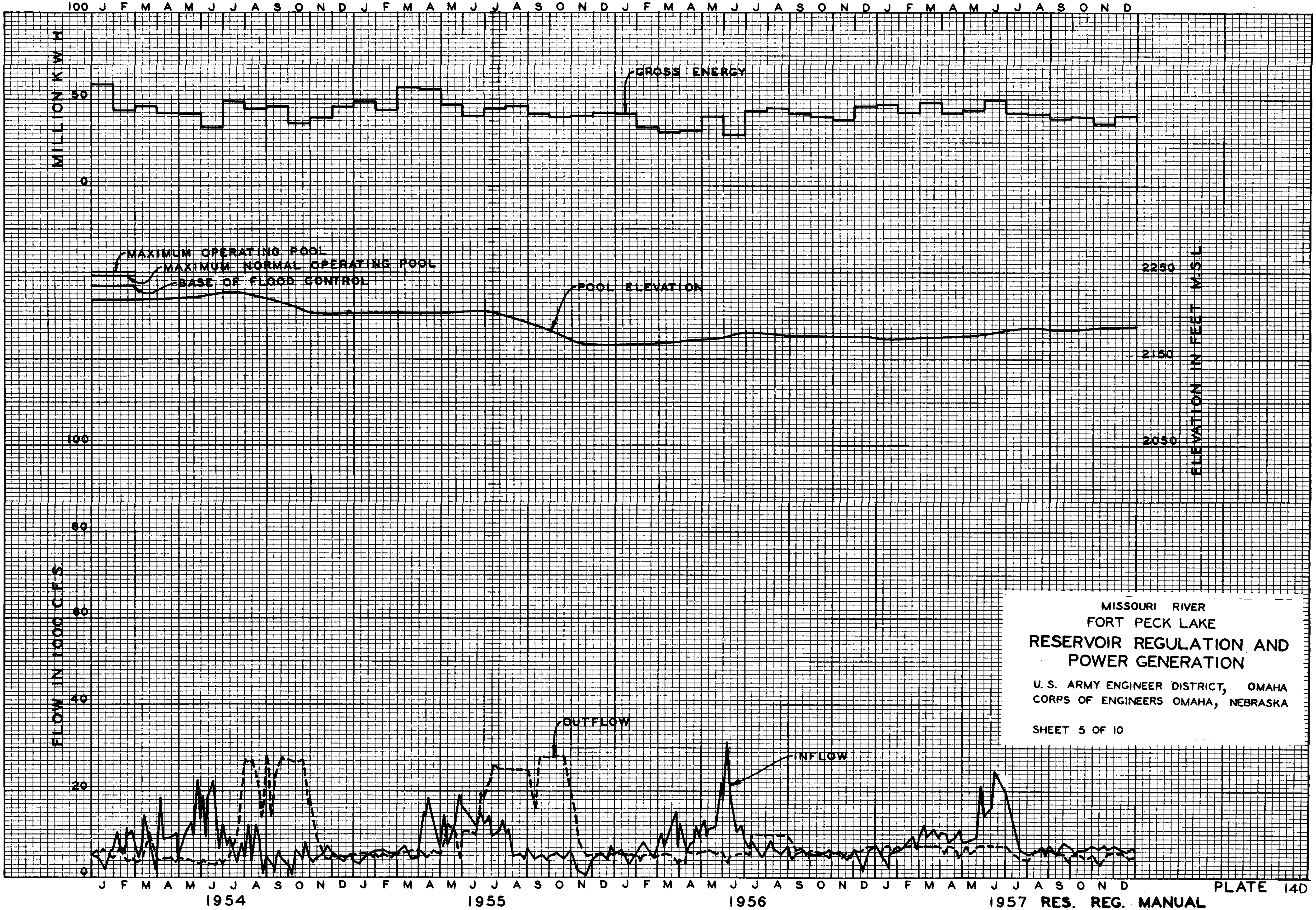
RES. REG. MANUAL PLATE 14A



MISSOURI RIVER
FORT PECK LAKE
RESERVOIR REGULATION AND POWER GENERATION
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SHEET 3 OF 10



MISSOURI RIVER
FORT PECK LAKE
RESERVOIR REGULATION AND POWER GENERATION
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SHEET 4 OF 10



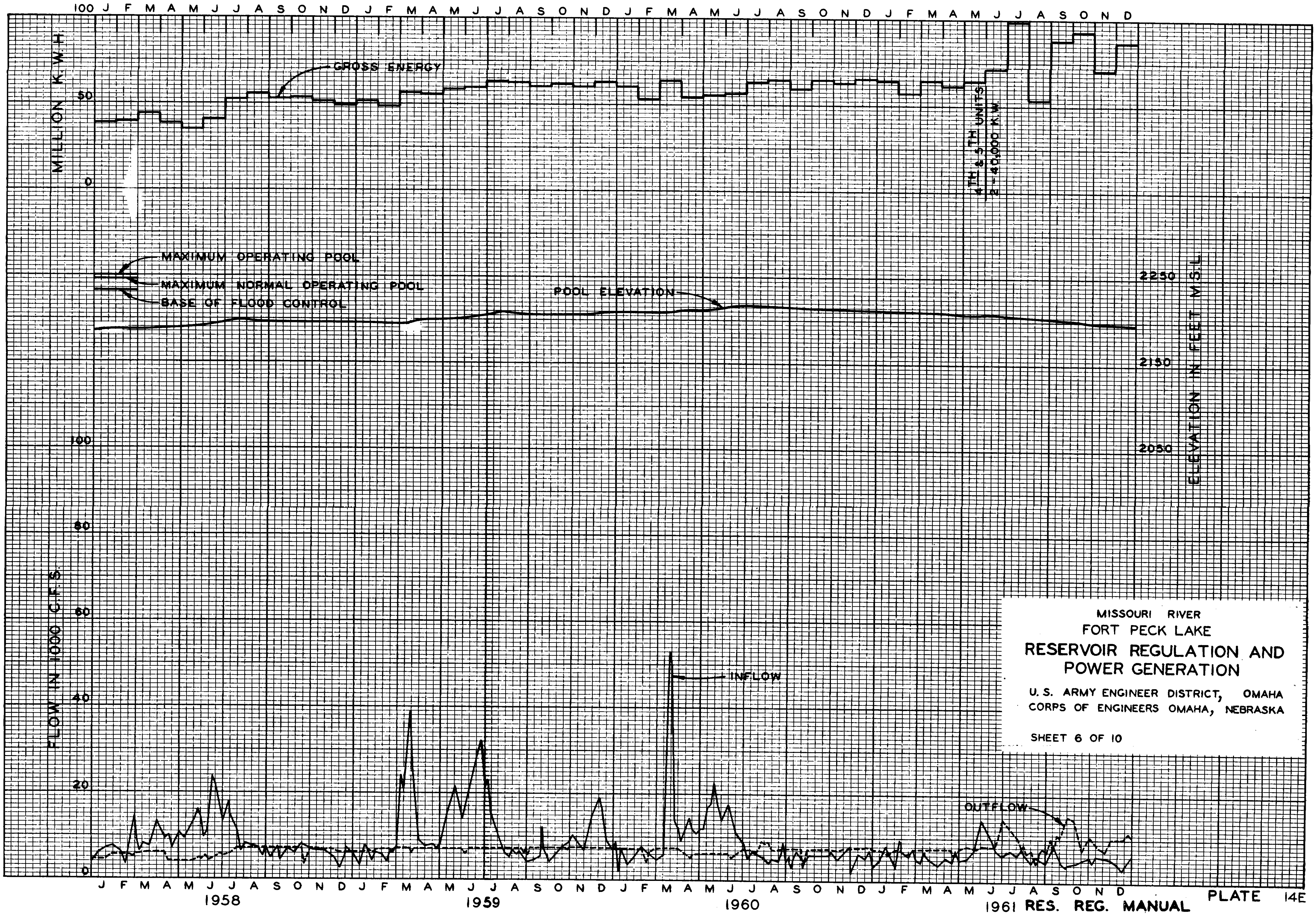
MISSOURI RIVER

FORT PECK LAKE

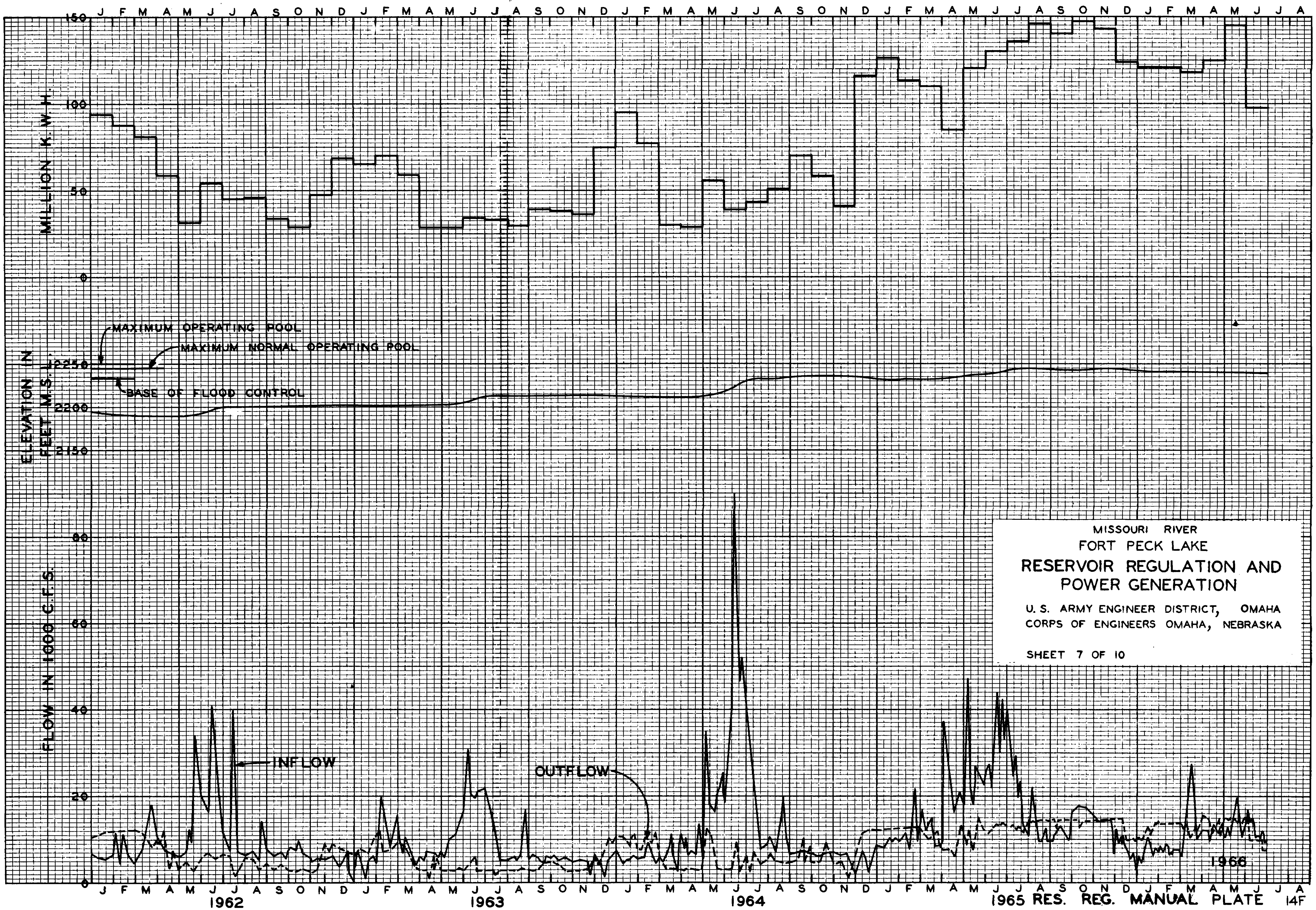
RESERVOIR REGULATION AND POWER GENERATION

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

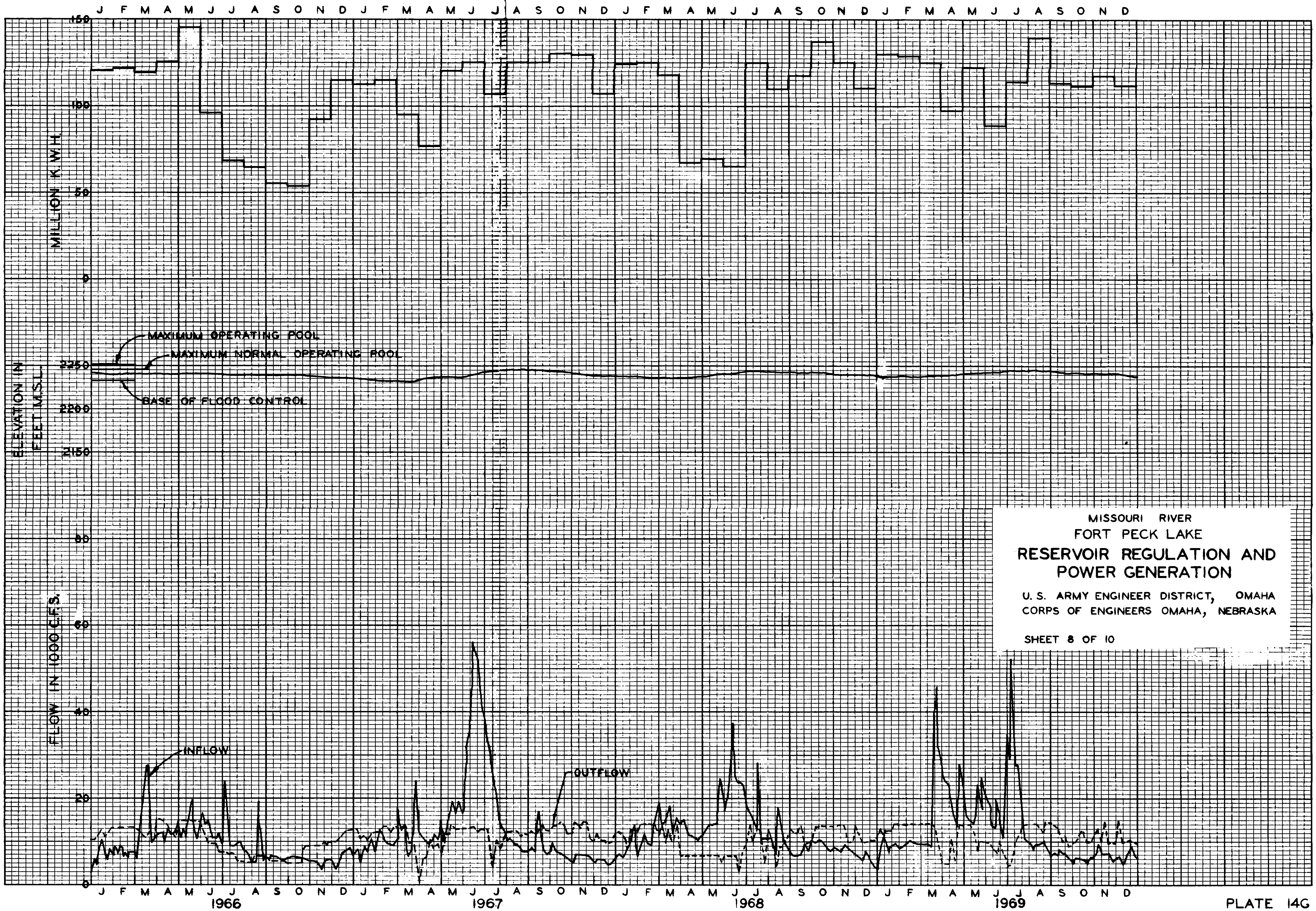
SHEET 5 OF 10



MILLION K.W.H.
GROSS ENERGY
4 TH & 5 TH UNITS
2 - 40,000 K.W.
MAXIMUM OPERATING POOL
MAXIMUM NORMAL OPERATING POOL
BASE OF FLOOD CONTROL
POOL ELEVATION
ELEVATION IN FEET M.S.L.
FLOW IN 1000 C.F.S.
INFLOW
OUTFLOW
1958
1959
1960
1961
MISSOURI RIVER
FORT PECK LAKE
RESERVOIR REGULATION AND POWER GENERATION
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SHEET 6 OF 10



RES. REG. MANUAL PLATE 14F



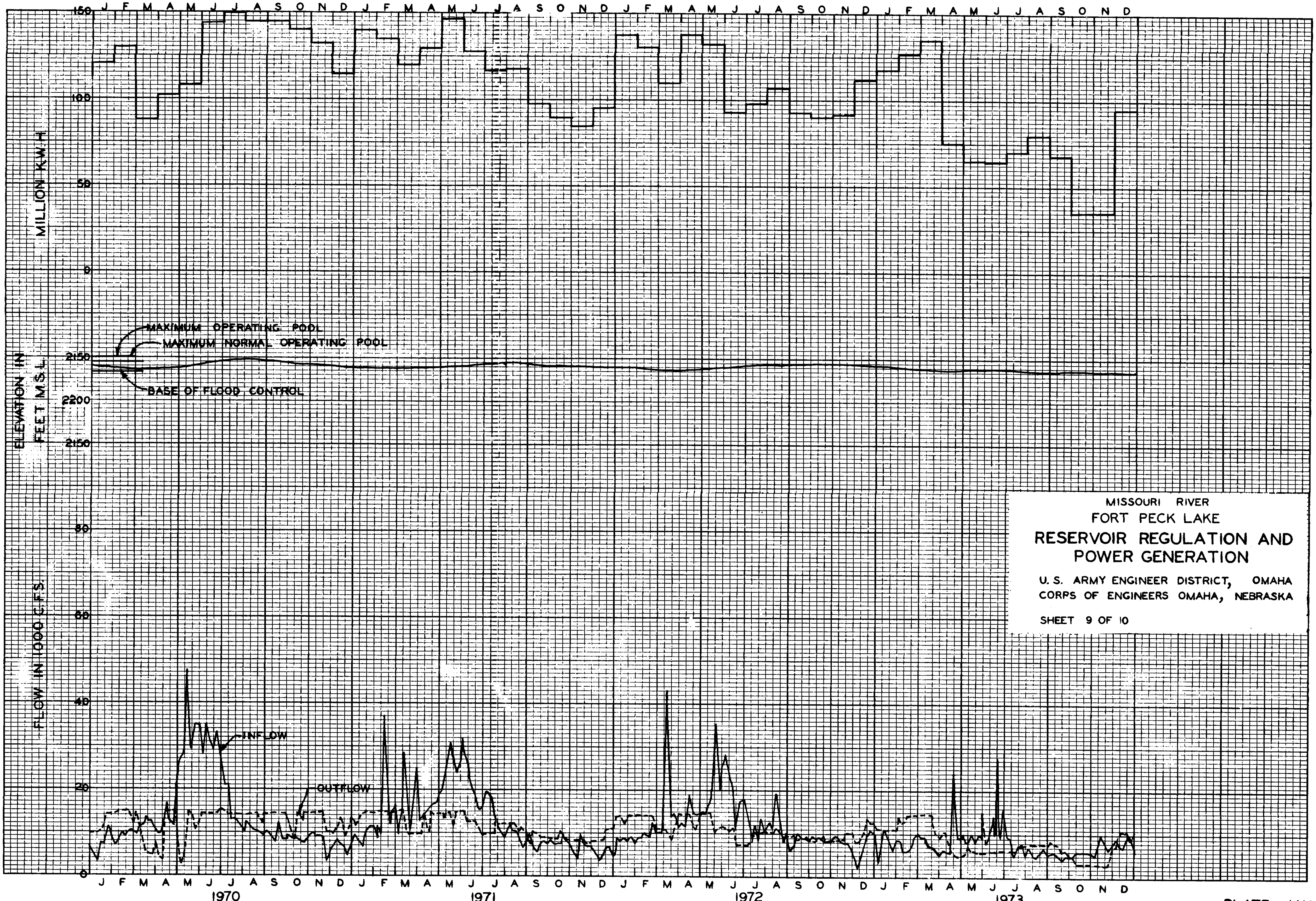
MISSOURI RIVER

FORT PECK LAKE

RESERVOIR REGULATION AND POWER GENERATION

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

SHEET 8 OF 10



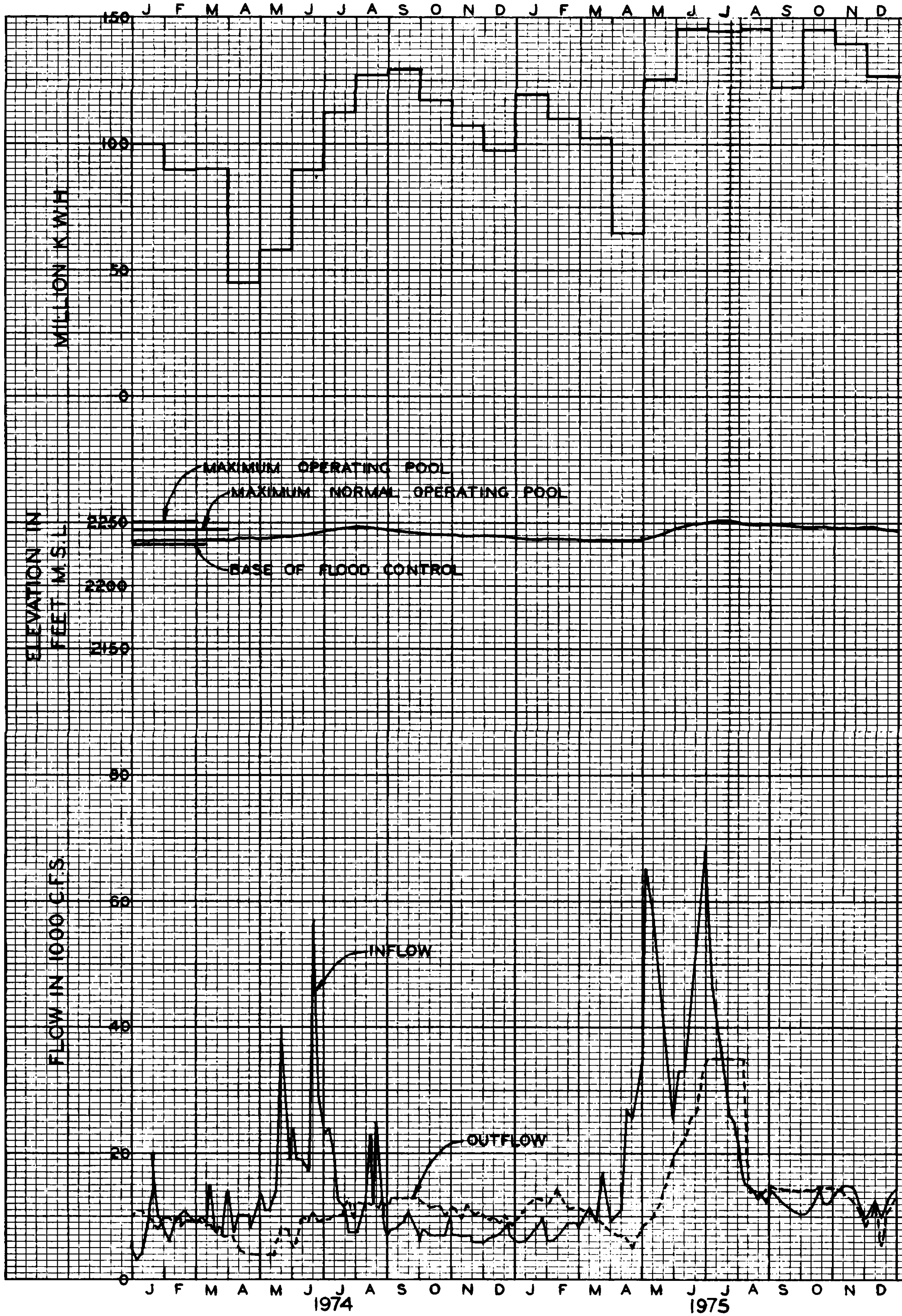
MISSOURI RIVER
FORT PECK LAKE

RESERVOIR REGULATION AND POWER GENERATION

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

SHEET 9 OF 10

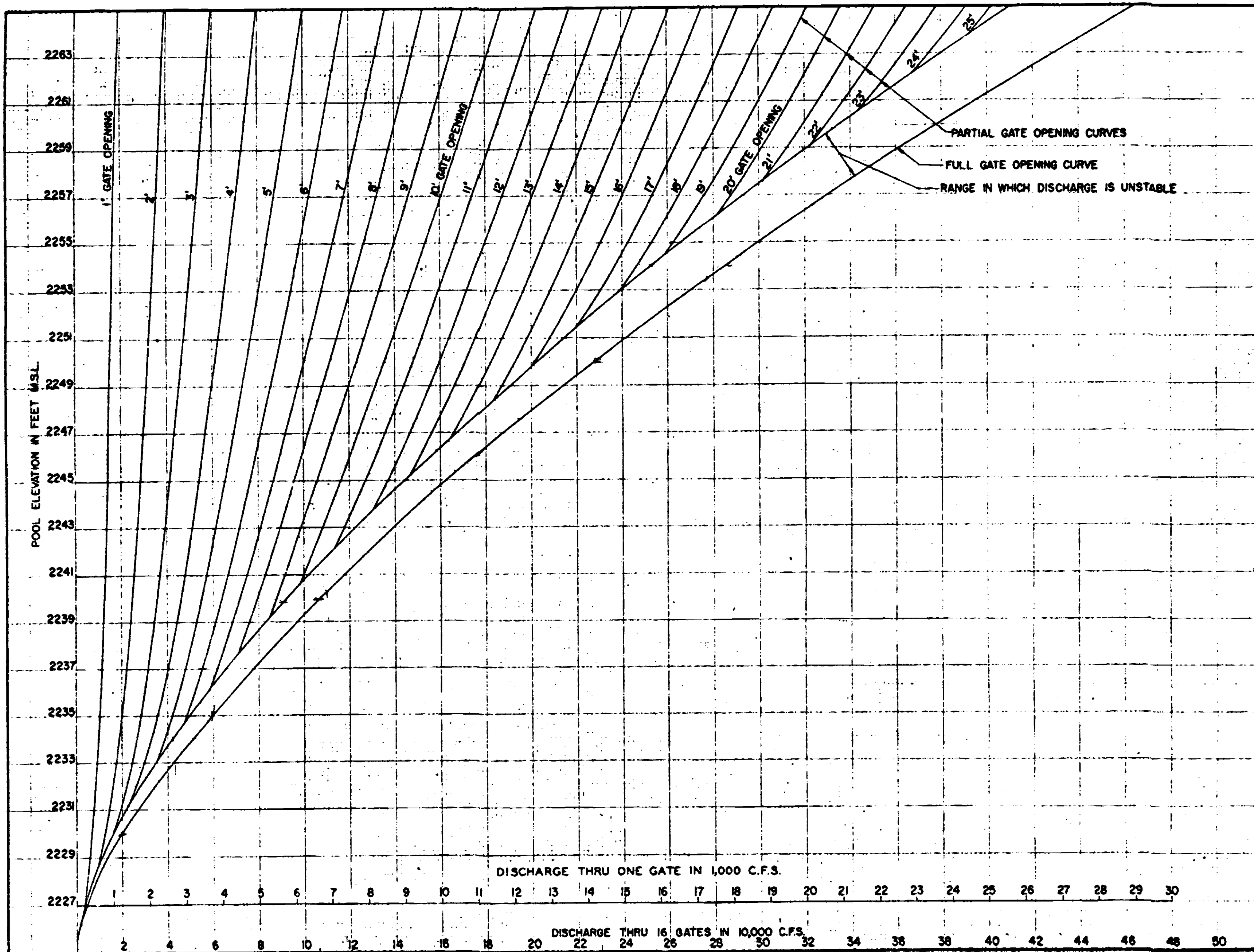
PLATE 14H



MISSOURI RIVER
FORT PECK LAKE
RESERVOIR REGULATION AND POWER GENERATION
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SHEET 10 OF 10

PLATE 141

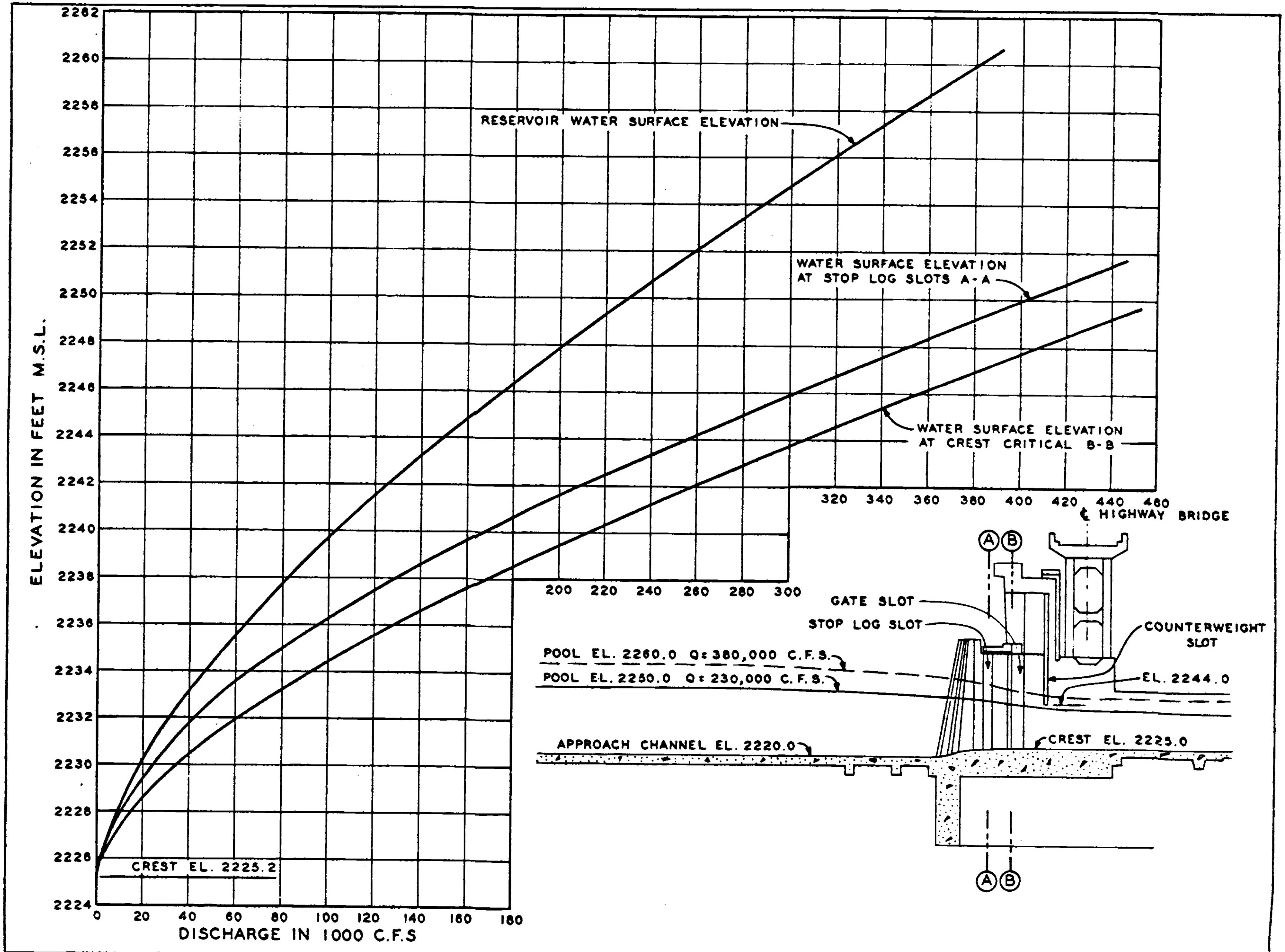
NOTE:
THESE CURVES HAVE BEEN EXTRAPOLATED FROM CURVES PREPARED BY MRD, OMAHA, NEB., DATED JAN. 1949



MISSOURI RIVER
FORT PECK LAKE
SPILLWAY DISCHARGE
RATING CURVES
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

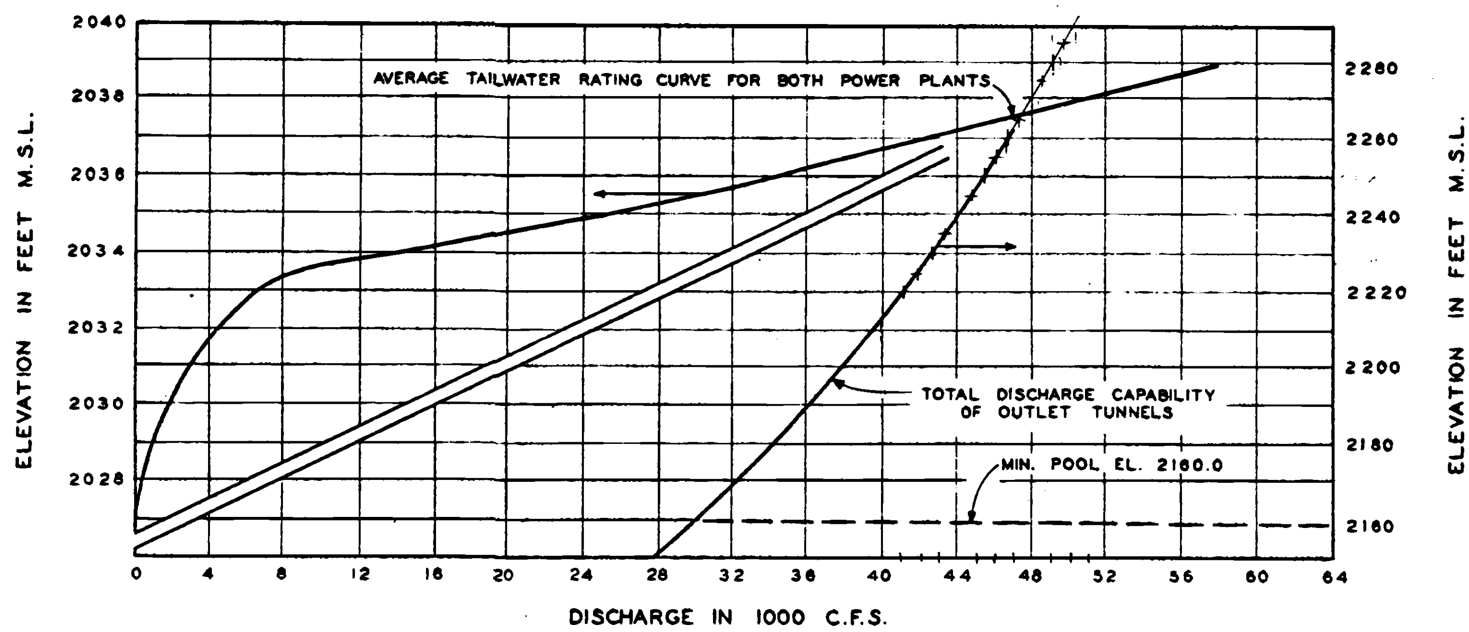
PLATE 15

NOTES:
DISCHARGE AND DRAWDOWN WITH 16 GATES WIDE OPEN.
BOTTOM OF SPILLWAY GATE AT MAXIMUM POSSIBLE GATE OPENING IS EL. 2250.45.



MISSOURI RIVER
FORT PECK LAKE
DISCHARGE RATING CURVE
AND DRAWDOWN
AT SPILLWAY GATES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

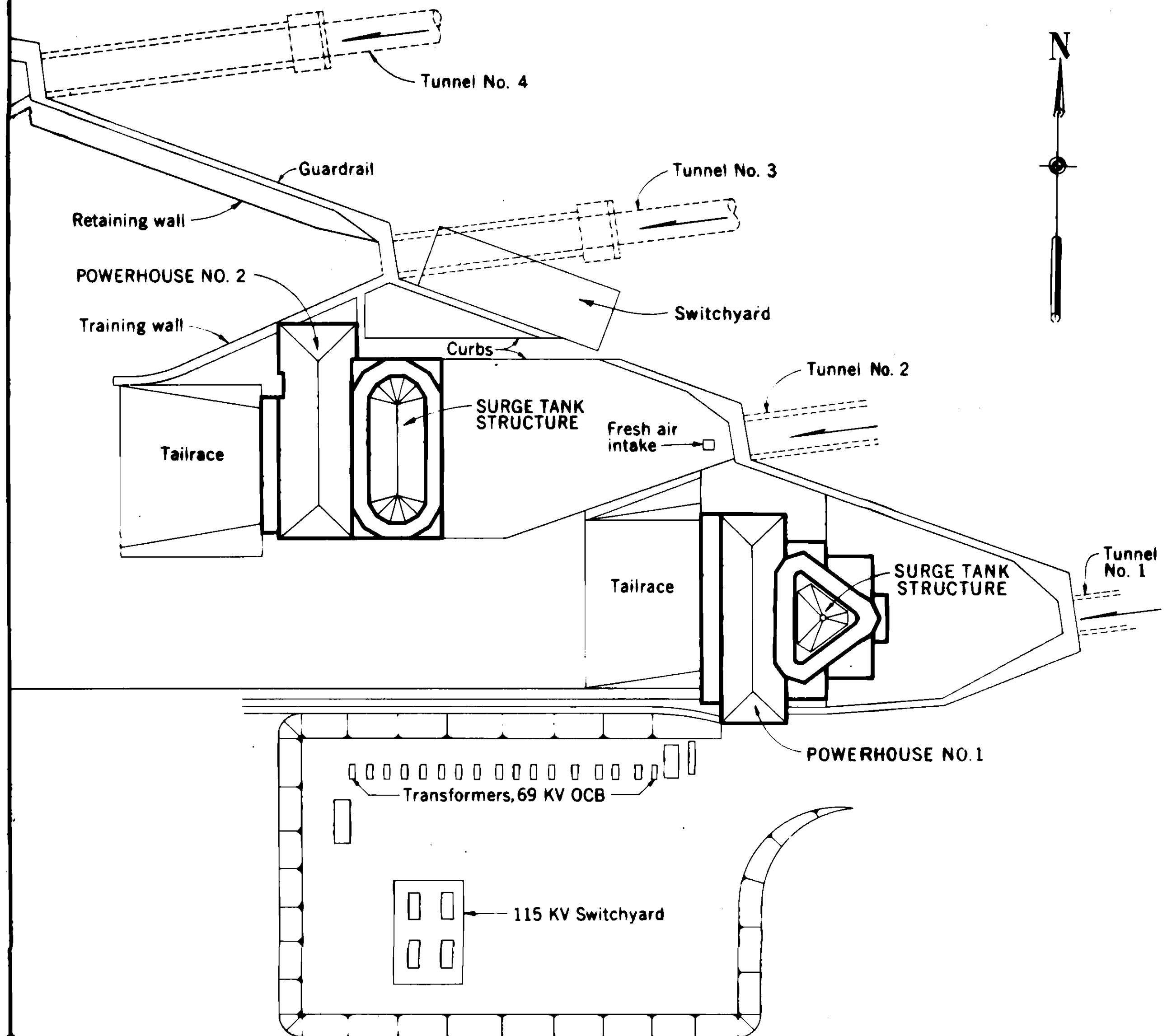
PLATE 16



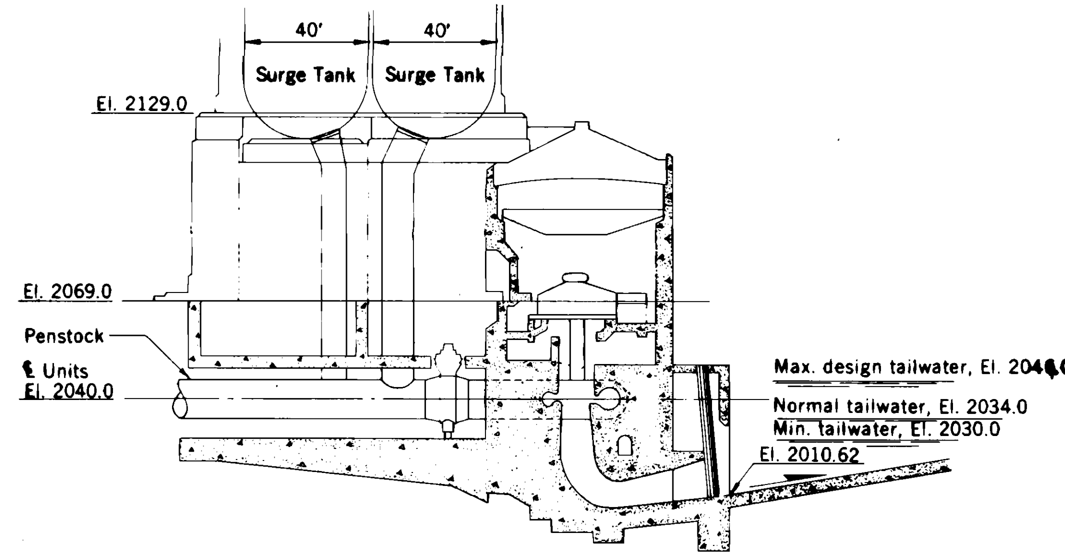
MISSOURI RIVER
FORT PECK LAKE
POWER PLANT, TAILWATER
RATING CURVE AND
DISCHARGE CAPABILITY OF
OUTLET TUNNELS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

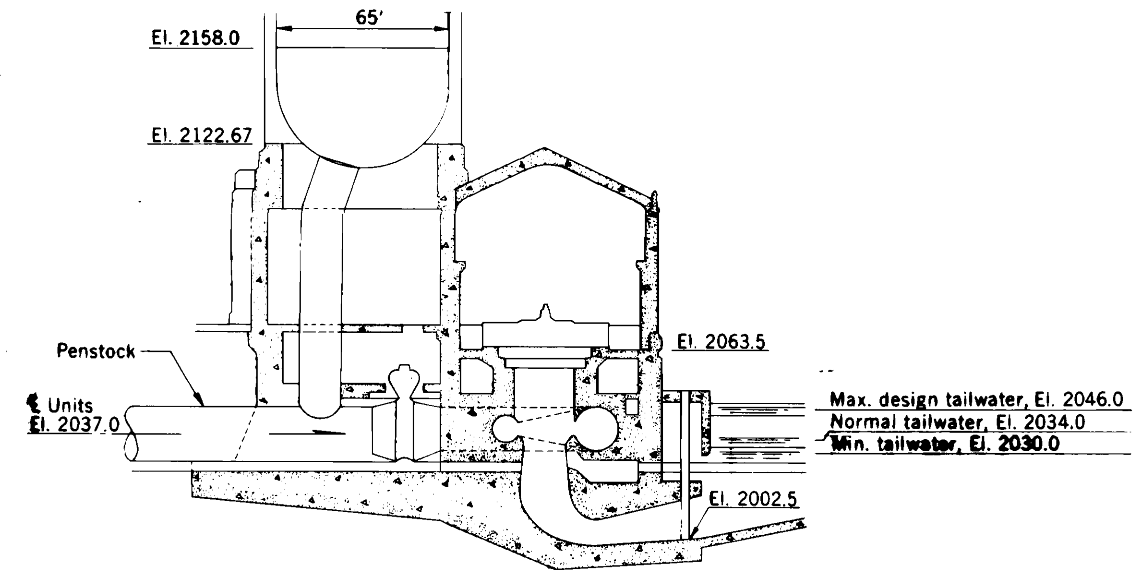
PLATE 17



PLAN



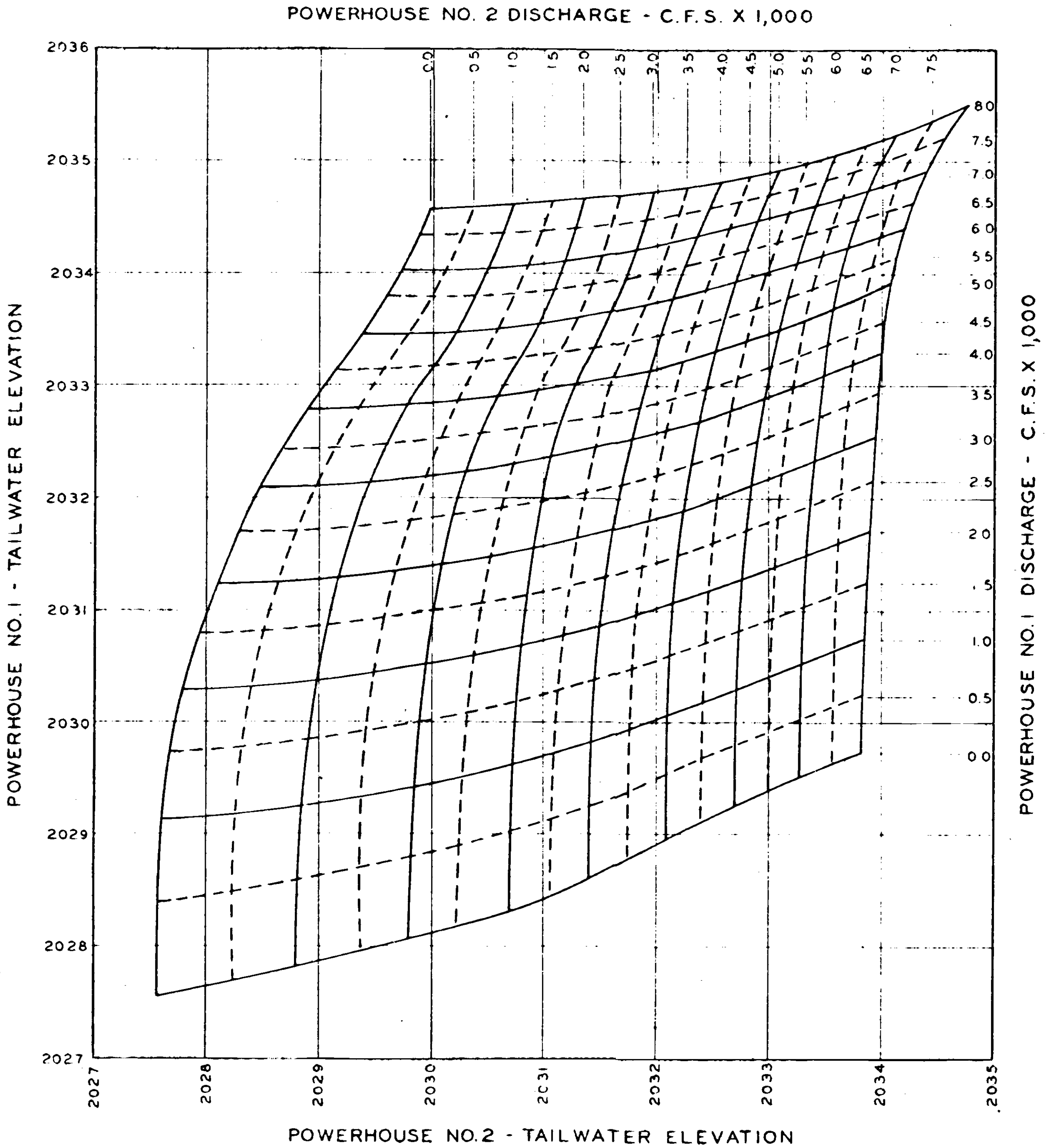
POWERHOUSE SECTION
FIRST POWER PLANT



POWERHOUSE SECTION
SECOND POWER PLANT

FORT PECK DAM
POWER PLANTS
MISSOURI RIVER BASIN
MONTANA

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA



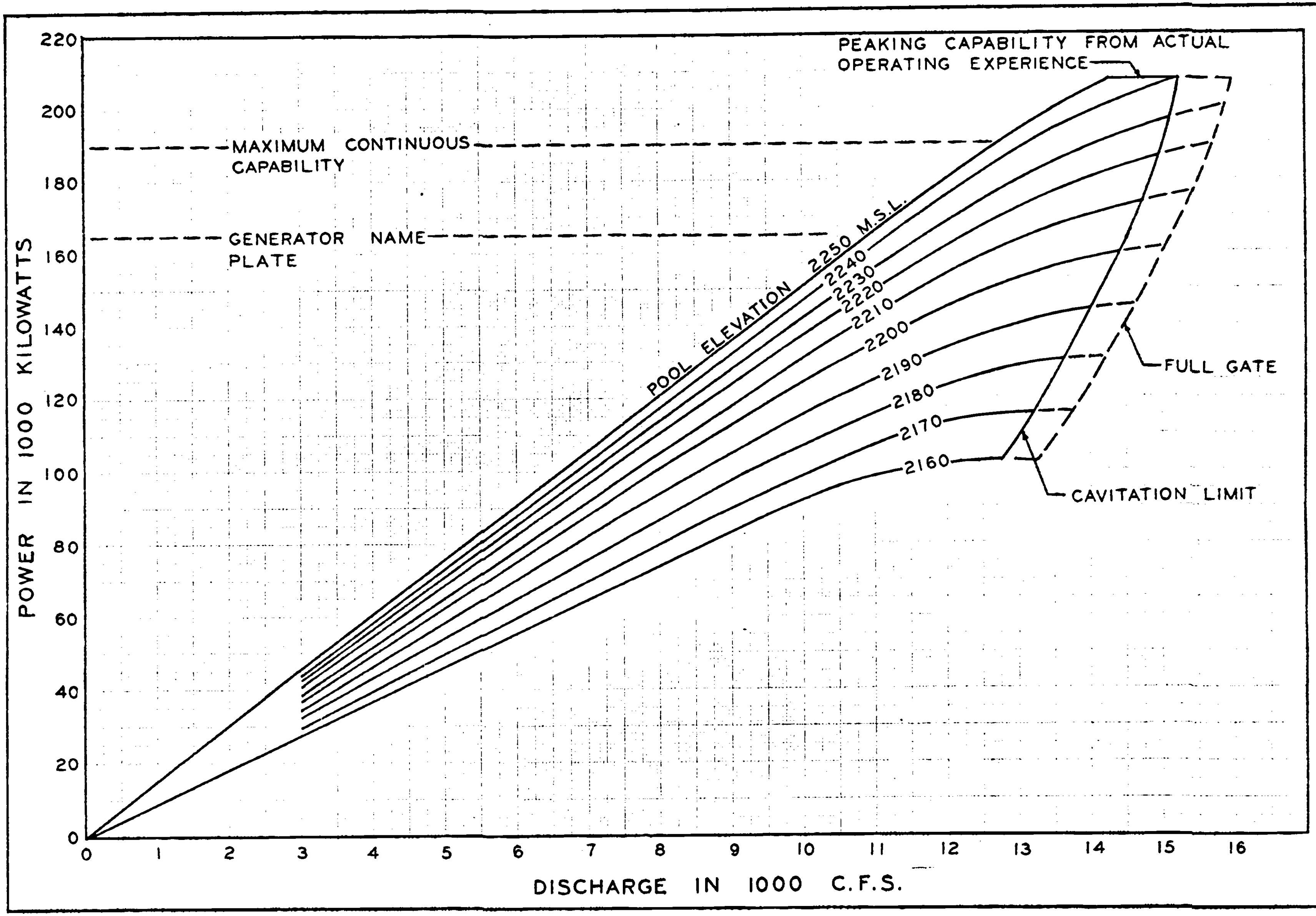
DIRECTIONS:

Tailwater elevation can be determined by following the Powerhouse No. 1 discharge curve to the left until the correct Powerhouse No. 2 discharge is reached. From this point read directly to the left for Powerhouse No. 1 tailwater elevation and straight down for Powerhouse No. 2 tailwater elevation.

NOTES: These curves are only good when steady state flow conditions exist at both powerhouses.

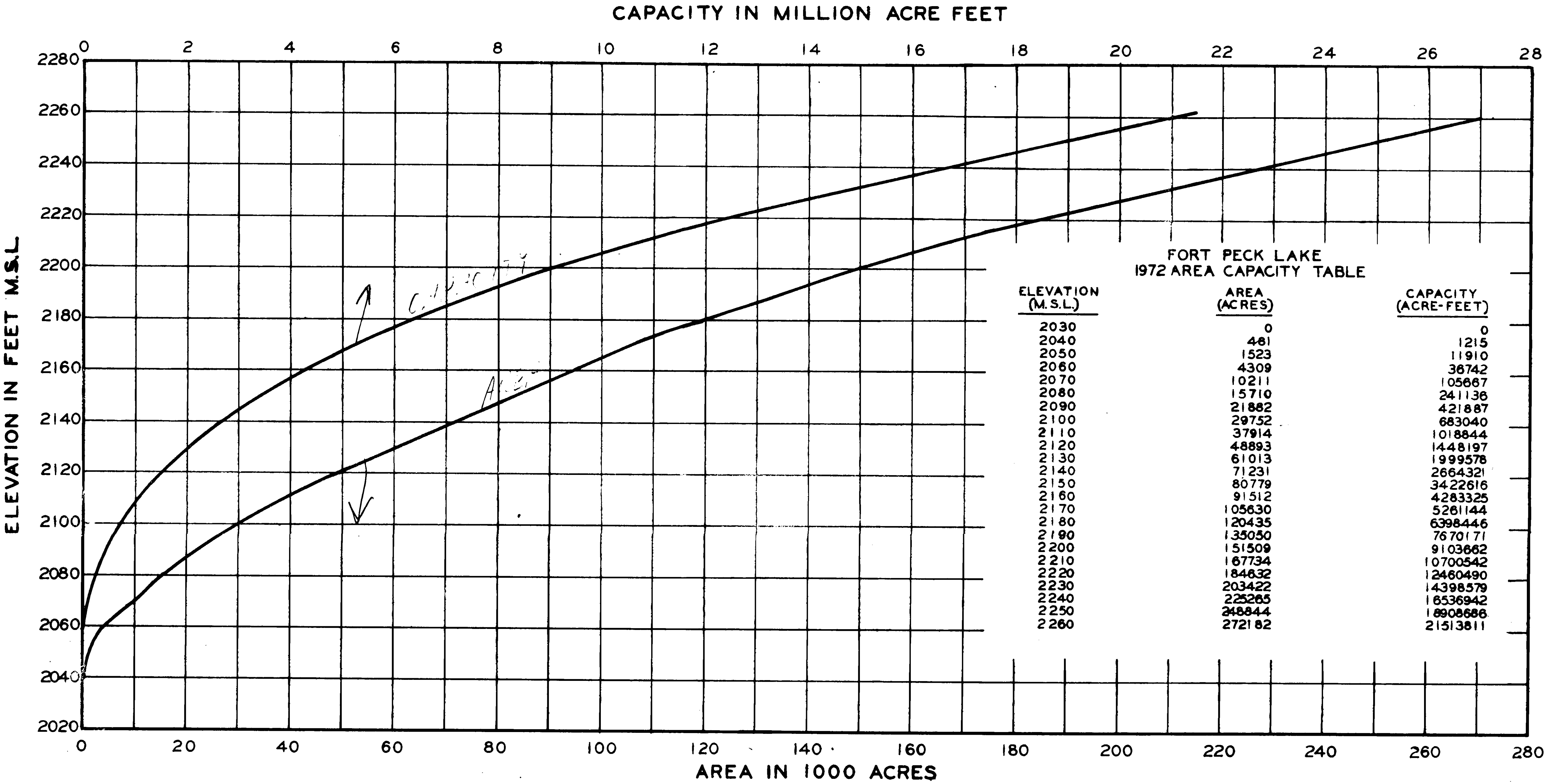
The curves are based on steady state flow periods determined from the 1963 through 1965 stage recorder charts of both powerhouses. Discharges for these periods were obtained from the hourly powerhouse releases.

FORT PECK LAKE
TAILWATER RATING CURVES
POWER PLANT NO. 1 AND
POWER PLANT NO. 2
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS, OMAHA NEBRASKA



MISSOURI RIVER
FORT PECK LAKE
POWER PLANT CHARACTERISTICS
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA NEBRASKA

PLATE 20



FORT PECK LAKE
1972 AREA CAPACITY TABLE

ELEVATION (M.S.L.)	AREA (ACRES)	CAPACITY (ACRE-FEET)
2030	0	0
2040	481	1215
2050	1523	11910
2060	4309	36742
2070	10211	105667
2080	15710	241136
2090	21882	421887
2100	29752	683040
2110	37914	1018844
2120	48893	1448197
2130	61013	1999578
2140	71231	2664321
2150	80779	3422616
2160	91512	4283325
2170	105630	5261144
2180	120435	6398446
2190	135050	7670171
2200	151509	9103662
2210	167734	10700542
2220	184632	12460490
2230	203422	14398579
2240	225265	16536942
2250	248844	18908686
2260	272182	21513811

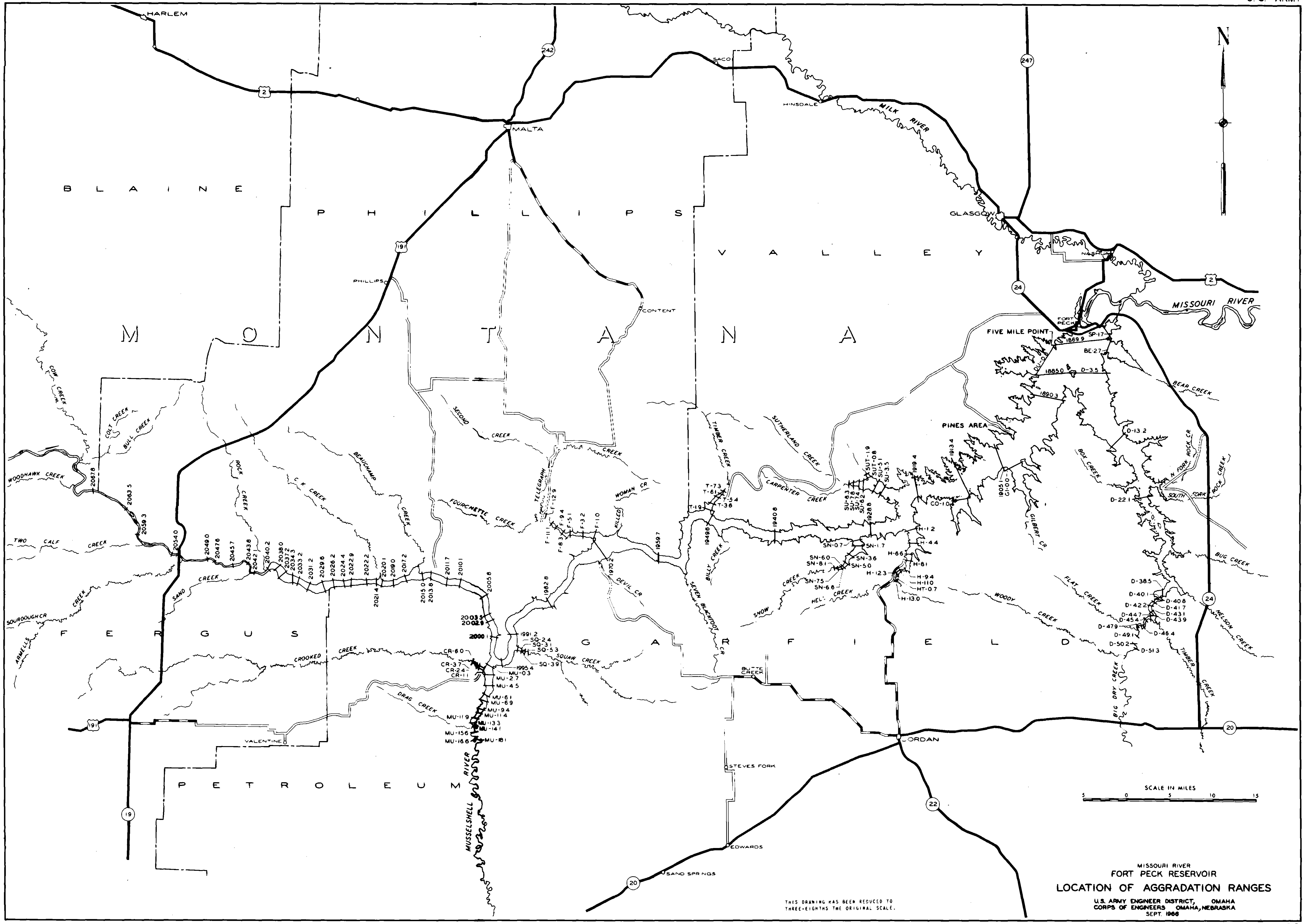
NOTE:

1. BASED ON 1972 AGGRADATION SURVEY.

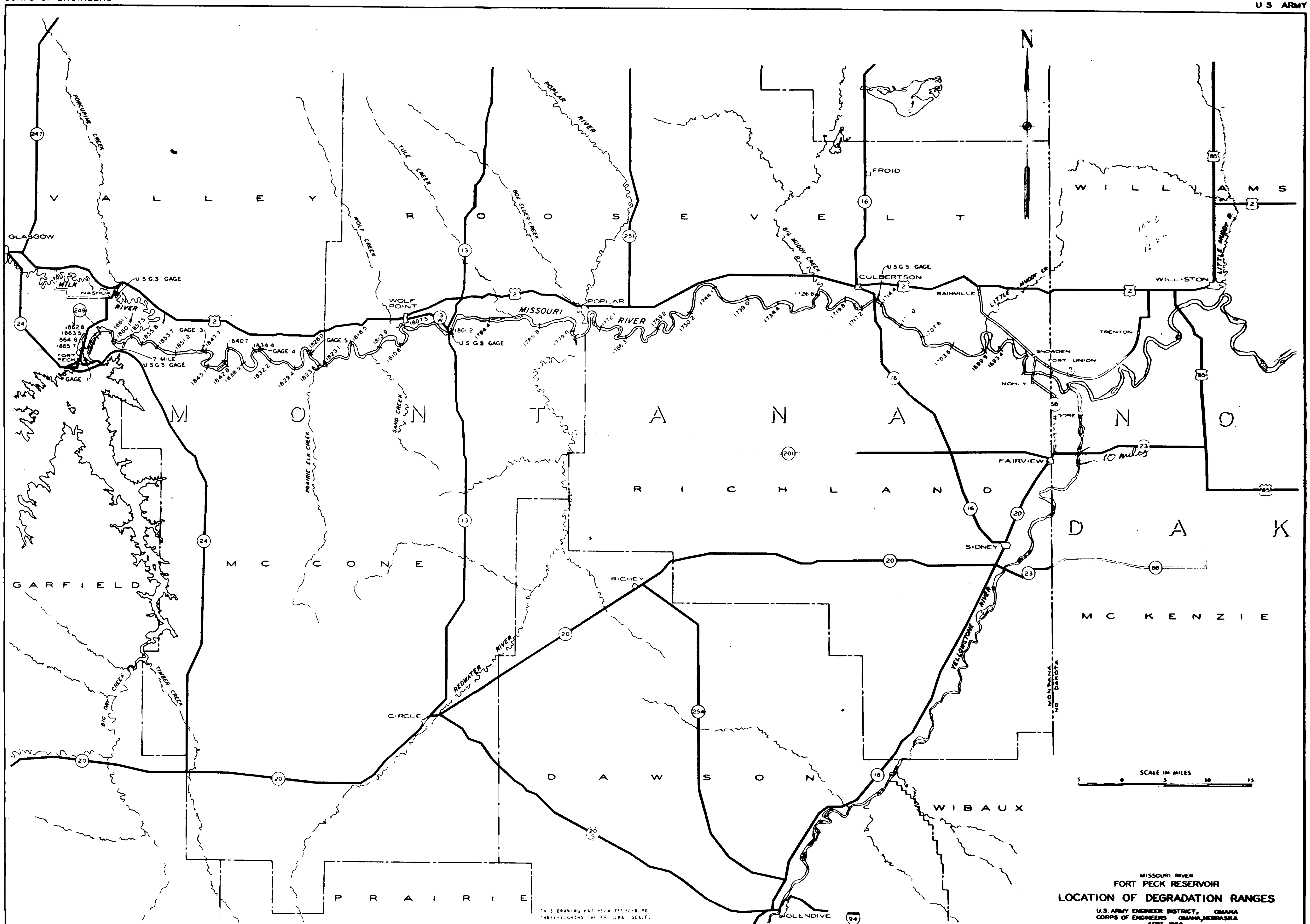
MISSOURI RIVER

FORT PECK LAKE
AREA-CAPACITY CURVES AND TABLE

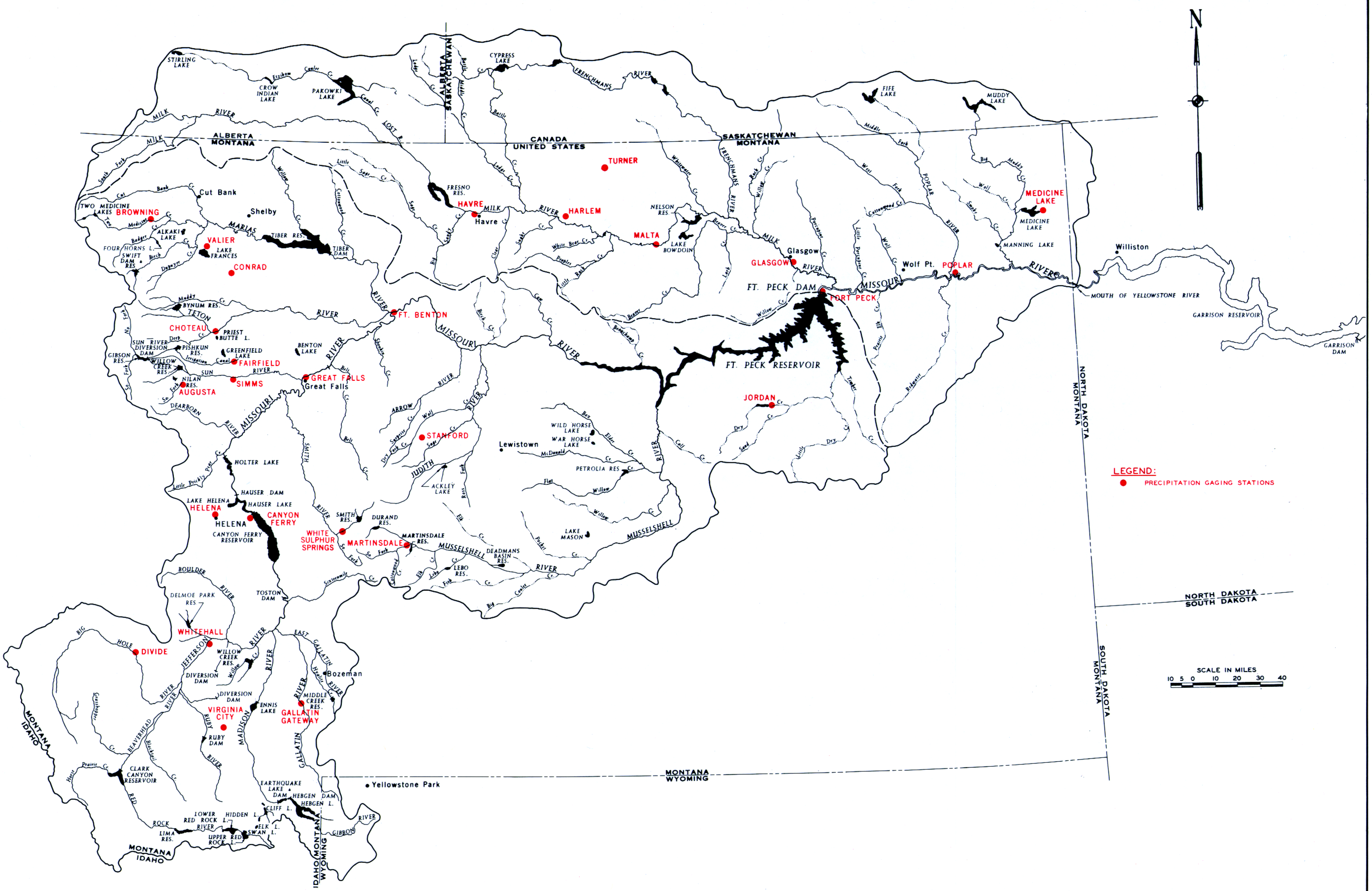
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



MISSOURI RIVER
FORT PECK RESERVOIR
LOCATION OF AGGRADATION RANGES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966



MISSOURI RIVER
FORT PECK RESERVOIR
LOCATION OF DEGRADATION RANGES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966



UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER

PRECIPITATION REPORTING NETWORK

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

PRECIPITATION STATIONS
NATIONAL WEATHER SERVICE
MISSOURI BASIN ABOVE CULBERTSON, MONTANA

DRY BASIN
Brusett 5NW
Cohagen
Haxly 18SW
Jordan
Jordan 22E

GALLATIN BASIN
Anceny
Belgrade
Bozeman Univ.
Bozeman 6W
Bozeman 12NE
G. Gateway 9SSW
G. Gateway 26SSW
Logan
Manhattan
Menard 3NE

JUDITH BASIN
Denton 1NNE
Hilger
Lewiston 10S
Lewiston 2SW
Lewistown APT
Stanford 1WNW
Utica 11WSW

JEFFERSON BASIN
Alder
Alder 17S
Apex 2NW
Basin 3W
Basin 16WSW
Boulder
Boulder 15S
Clark Canyon
Dillon APT
Dillon WMCE
Dillon 9SSE
Divide 2NW
Elkhorn Hot Spgs.
Glen 4N
Grant
Jackson
Lakeview
Lima
Monida
Monida 17NE
Monida 13NNE
Silver Star
Twin Bridges
Virginia City
Virginia City 22SSE
Whitehall
Willow Creek
Wisdom
Wise River 3WNW

MADISON BASIN
Cameron
Ennis
Hebgen Dam
Norris 3ENE
Pony
West Yellowstone

MARIAS BASIN
Brady AZNOE
Browning
Chester
Conrad
Conrad 9ESE
Conrad 29ENE
Cut Bank
Dunkirk
DuPuyer
DuPuyer 7WNW
East Glacier
Fort Benton 20NW
Galatia 16SSW
Shelby
Summit
Swift Dam
Tiber Dam
Valier

MILK BASIN
Baylor
Big Sandy
Chester 26NNW
Chinook
Cleveland 5ENE
Content
Del Bonita
Dodson
Dodson 11N
Ethridge
Forks 4NNE
Fort Assiniboine
Gildford
Glasgow 15NW
Glasgow APT
Goldbutte 7NW
Harb
Harlem
Havre
Hingham
Hinsdale 4SW
Hinsdale 23N
Hogeland 7WSW
Joplin 1N
Kremlin
Loring 10N
Malta
Phillips 1S
Rocky Boy
Rudyard 30N
Saco 1NNW
Santa Rita 17N
Simpson
Sunburst 8E
Sweetgrass
Turner
Whitewater

MISSOURI BASIN
Austin 1W
Canyon Cr.
Canyon Ferry
Cascade 5S
Culbertson
Deepcreek Pass
Fort Benton
Fort Peck
Geraldine
Great Falls
Helena APT
Helena 6N
Highwood
Highwood 7NE
Hobson
Holter Dam
Iliad
Loma 1WNW
Lonesome Lake
Malta 35S
Moccasin Sta.
Neihart 8NNW
Nohly 4NW
Raynesford 2NNW
Rogers Pass 6NE
Roy 24NE
Shonkin 7S
Telegraph Cr.
Terry 21 NNW
Toston 3SW
Townsend
Townsend 12ENE
Trident
Westby
Winifred
Wolf Point 4ESE
Zortman

MUDDY BASIN
Froid 4NE
Medecine Lake 3SE
Plenty Wood
Raymond Sta.
Redstone
Reserve 14W

MUSSELSHELL BASIN
Barber
Delphia
Dovetail
Flatwillow 4ENE
Gradd Range
Harlowtown
Judith Gap
Judith Gap 13E
Lavina
Lennep 6WSW
Martinsdale 3NNW
Melstone
Mosby 2ENE
Mosby 18N
Ryegate 18NNW
Winnett 5NNE
Winnett 11ESE

POPLAR BASIN
Bredette
Four Buttes
Lustre 4NNW
Opheim 10N
Opheim 12SSE
Poplar
Scoby

REDWATER BASIN
Brockway 3WSW
Circle
Vida

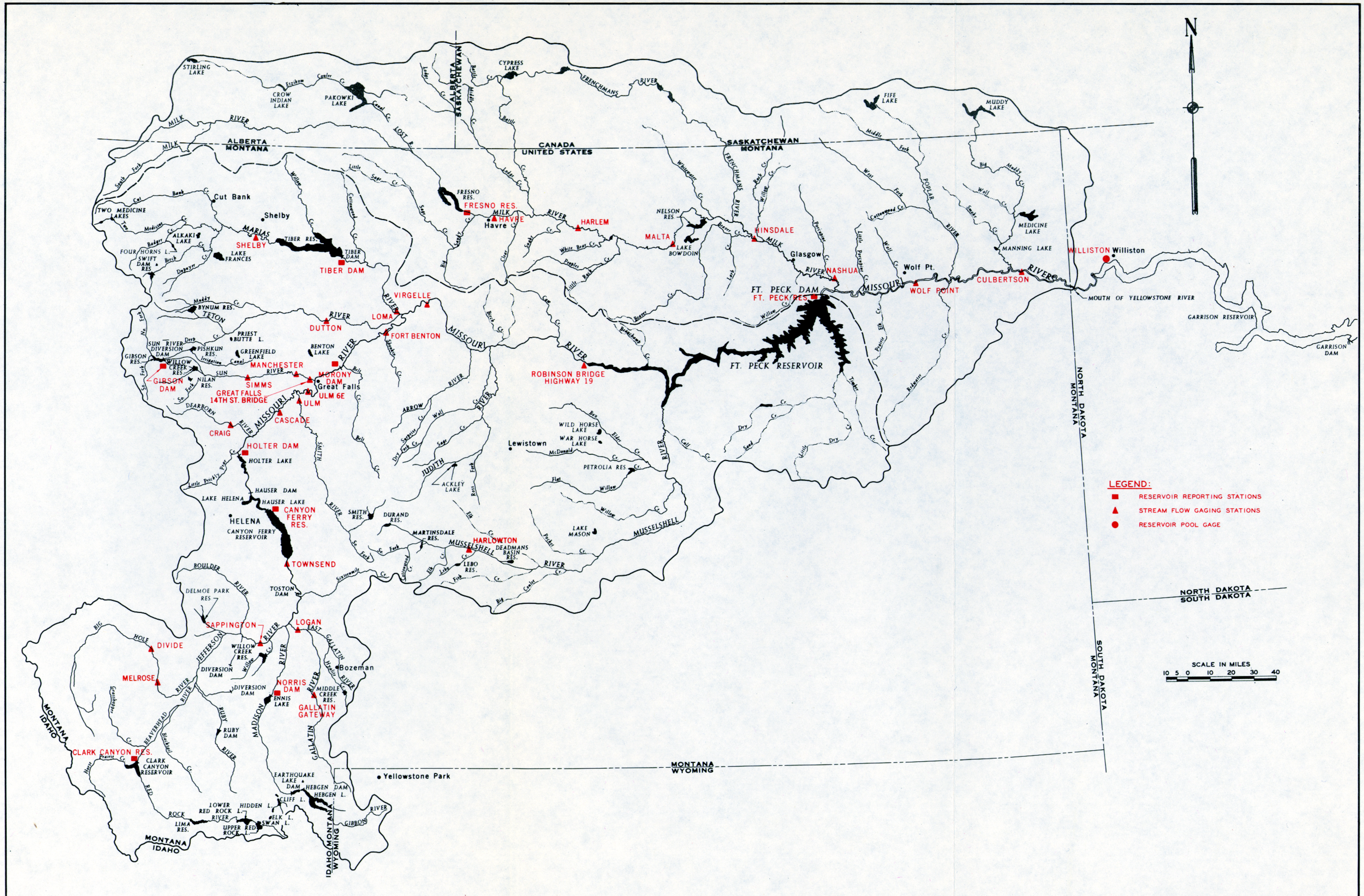
SMITH BASIN
Cascade 20SSE
Fort Logan 3ESE
Kings Hill
Milligan
W. Sulphur Spgs.
W. Sulphur Spgs. 10N
W. Sulphur Spgs. 24NW

SUN BASIN
Augusta
Bench Mark
Fairfield
Gibson Dam
Power 6E
Simms
Sun River 5SW
Wrong Creek

TETON BASIN
Black Leaf
Bynum 4SSE
Choteau
Dutton 6E
Pendroy 2NNW

MISSOURI RIVER BASIN
FORT PECK LAKE
PRECIPITATION STATIONS
NATIONAL WEATHER SERVICE
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 25



UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER
STREAM FLOW REPORTING NETWORK
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

MISSOURI RIVER BASIN
FORT PECK LAKE
STREAM GAGING STATIONS
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

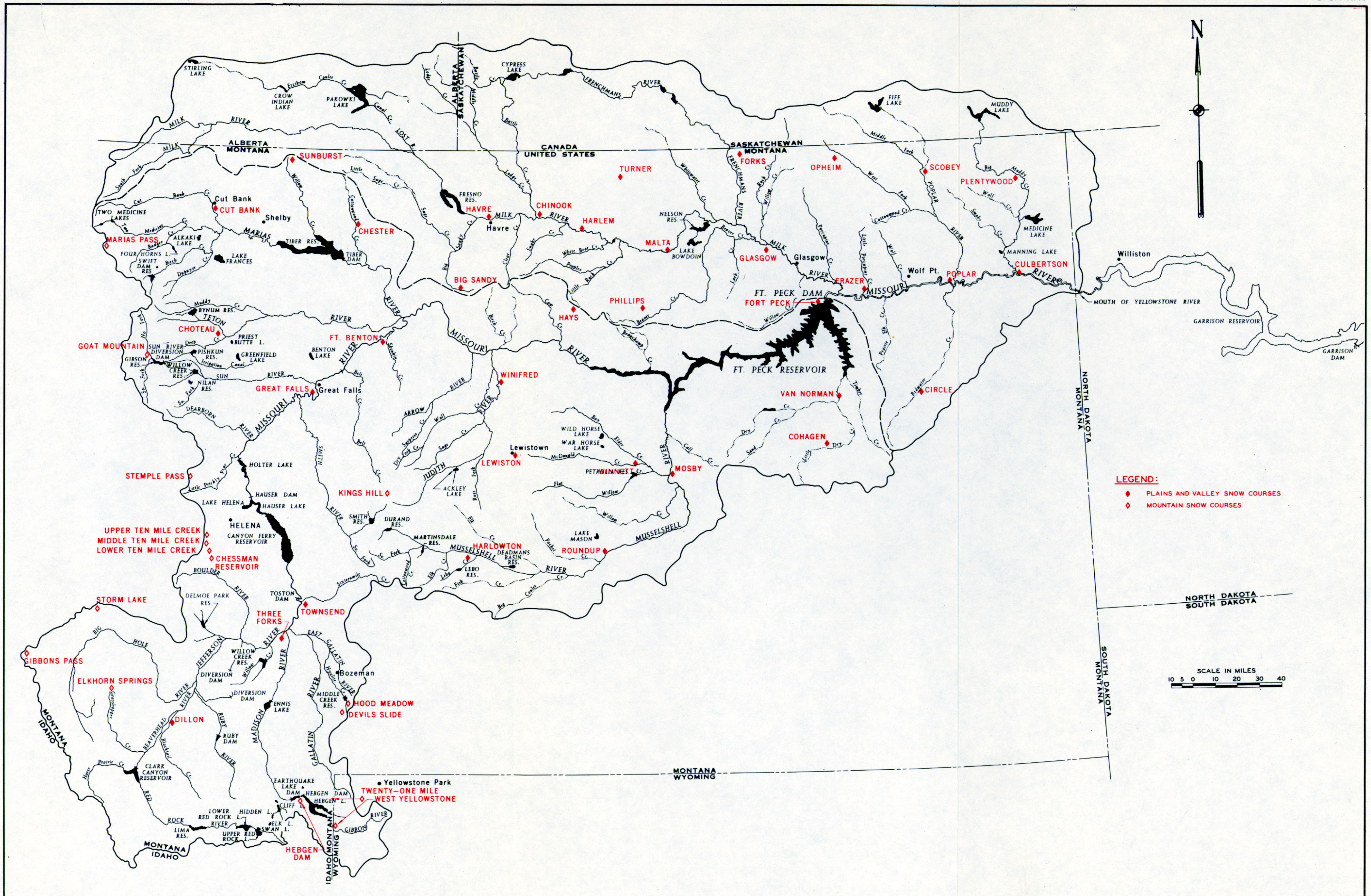
PLATE 27

PRINCIPAL STREAM GAGING STATIONS MISSOURI RIVER BASIN ABOVE CULBERTSON, MONTANA

RIVER		STATION
Red Rock		Nr. Dell
Beaverhead		Nr. Grant
Beaverhead		At Barretts
Beaverhead		At Dillon
Beaverhead		Nr. Dillon
Beaverhead		Nr. Blaine
Beaverhead		Nr. Twin Bridges
Big Hole	*	Nr. Divide
Big Hole	*	Nr. Melrose
Jefferson		Nr. Twin Bridges
Jefferson	*	Nr. Sappington
Madison		Nr. West Yellowstone
Madison		Nr. Grayling
Madison		Nr. McAllister
Gallatin	*	At Gallatin Gateway
Gallatin	*	At Logan
Missouri	*	At Toston
Crow Cr		Nr. Radersburg
Missouri		Nr. Townsend
Missouri		Nr. Helena
Prickley Pear Cr		Nr. Clancy
Ten Mile Cr		Nr. Romini
Missouri	*	Nr. Wolf Point
L. Prickley Pear Cr		At Wolf Creek
Dearborn	*	Nr. Craig
Missouri	*	At Cascade
Smith		Nr. Eden
Smith	*	Nr. Ulm
Missouri	*	Nr. Ulm
N. Fk. Sun		Nr. Augusta
Sun	*	At Simms
Sun		At Manchester
Sun	*	At Great Falls
Missouri		Nr. Great Falls
Belt Cr		Nr. Monarch
Missouri	*	At Fort Benton

RIVER		STATION
Cutbanks Cr		Nr. Cutbank
Marias	*	Nr. Shelby
Marias		Nr. Chester
Marias		Nr. Loma
Teton	*	Nr. Dutton
Missouri	*	At Virgelle
Judith		Nr. Utica
Missouri	*	Nr. Robinson
Missouri		Nr. Landusky
Musselshell	*	At Harlowton
Musselshell		Nr. Rygate
Musselshell		Nr. Round Up
Musselshell		At Musselshell
Box Elder Cr		Nr. Winnett
Musselshell	*	At Mosby
Big Dry Cr	*	Nr. Van Norman
Missouri		Blw Fort Peck
Missouri		Blw Fort Peck
Milk	*	At Eastern Crossing
Milk	*	At Havre
Milk	*	Nr. Harlem
Milk	*	At Malta
Frenchmans Can		At Saco
Milk	*	Nr. Hindsdale
Milk	*	At Vandalia
Milk		At Glasgow
Willow Cr		Nr. Glasgow
Milk	*	At Nashua
Missouri		Nr. Frazer (No. 3)
Missouri		Nr. Fraser (No. 4)
Missouri		Nr. Oswego (No. 5)
Missouri	*	Nr. Wolf Point
Red Water Cr		At Circle
Poplar		Nr. Poplar
Big Muddy Cr		At Daleview
Missouri	*	Nr. Culbertson

* Reports by observer or telemeter



UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER

SNOW SURVEY NETWORK

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

Reporting Schedule for Reservoirs
Upper Missouri River Basin
Above Mouth of Yellowstone River

Reservoir	River	Operating Agency	Type of Report	Data Reported
Fort Peck	Missouri	C.E.	See Plate 29A	See Plate 29A
Canyon Ferry	Missouri	U.S.B.R.	N.W.S. RAWARC and Main Stem Daily Teletype Reports	Pool and tailwater elevation at midnight. Average inflow and outflow for previous day. High and low temperature and precipitation for previous day.
Morony	Missouri	Montana Power Co.	N.W.S. RAWARC and Main Stem Daily Teletype Reports	Pool elevation at midnight. Average inflow, outflow, and precipitation for previous day.
Clark Canyon	Beaverhead	U.S.B.R.	N.W.S. RAWARC, Weekly Postcard Report and by telephone as requested	Daily pool elevation, storage, inflow, outflow, and precipitation.
Gibson	Sun	U.S.B.R. and Greenfield Irrigation Dist.	N.W.S. RAWARC, Service C Teletype, and Weekly Postcard	Daily pool elevation, storage, inflow and discharge.
Tiber	Marias	U.S.B.R.	Main Stem Daily Teletype Report, Weekly Postcard Report, and by telephone as requested.	Daily pool elevation, storage, discharge, precipitation, and pan evaporation.
Fresno	Milk	U.S.B.R.	N.W.S. RAWARC, Service C Teletype, and Weekly Postcard	Daily pool elevation and discharge.

REPORTS OF RESERVOIR DATA PERTAINING TO FORT PECK RESERVOIR REGULATION

DAILY MORNING TELETYPE REPORT

#MPM
TO STAS A B C FROM STA P
21 APR 76 0750 MST

TIME	GEN	DISCH	ELEV
0100	199	14496	2243.51
0200	202	14796	.54
0300	204	14880	.52
0400	204	14904	.54
0500	202	14664	.55
0600	202	14688	2243.56
0600	TW 2034.52		

WIND 290 DEG 18 MPH

END/TD
#

DAILY AFTERNOON TELETYPE REPORT

#MPM
TO STAS A B C FROM STA P
21 APR 76 1452 MST

TIME	GEN	DISCH	ELEV
0700	204	14904	2243.56
0800	206	14928	.58
0900	204	14880	.58
1000	206	14928	.58
1100	204	14904	.57
1200	204	14832	.57
1300	206	14880	.59
1400	206	14928	.60
1400	TW 2034.61		

WIND 300 DEG 38 MPH

TIBER DAM ELEV 2965.67 STOR 569,120 DISC 1409

END/TD

DAILY AFTER MIDNIGHT TELETYPE REPORT

#MABC
STA P TO STA A B C
DATA FOR 21 APR 1976

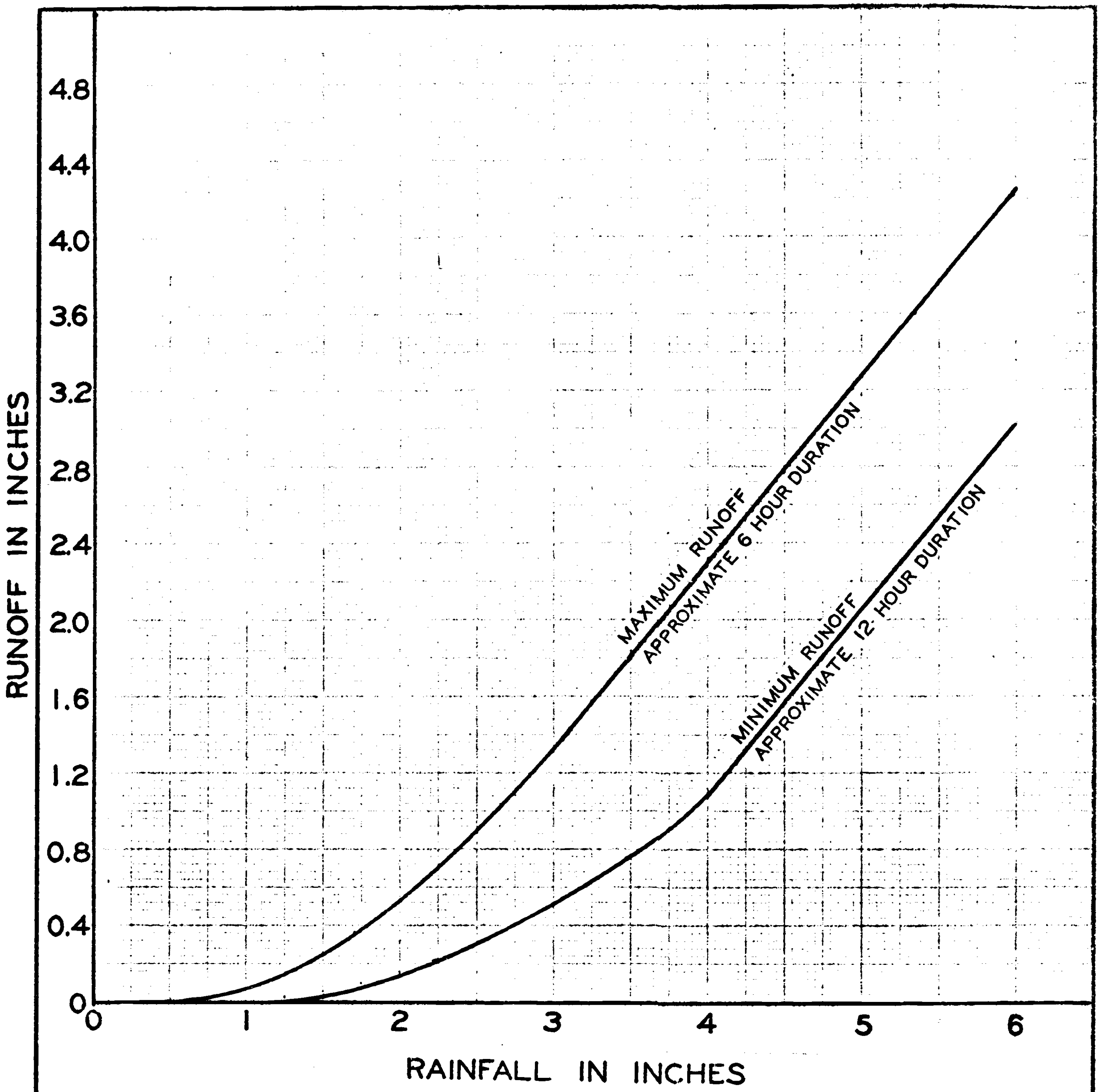
	ELEV	TW ELEV	INFLOW	OUTFLOW	H	L	PCPN
FT PECK	2243.51	2033.20		14800	57	38	TR
C FERRY	3783.56	3650.33	10330	13040	53	32	0
MORONY	23.40		16590	16610	53	38	0

FT PECK 6 PM TEMP 50 WEATHER COND CLEAR PAN WINDS 98
PENSTOCK WATER TEMP 44 PAN TEMP H 58 L 40 EVAP .15

TIME	GEN	DISCH	ELEV	
1500	207	15024	2243.60	
1600	205	14928	.59	
1700	205	14928	.60	
1800	205	14904	.60	WIND 300 DEG 35 MPH
1900	204	14976	.60	
2000	206	14856	.56	
2100	205	14928	.56	
2200	206	14880	.54	
2300	205	15000	.52	
2400	193	13944	.51	WIND 250 DEG 20 MPH
TOTAL	4894	355920		
AVG	203.916	14800		

END EAW
#

NOTE: Tributary reservoir data, river stages, precipitation and evaporation data and discharge measurements which are available at time of transmission are included in the above reports.

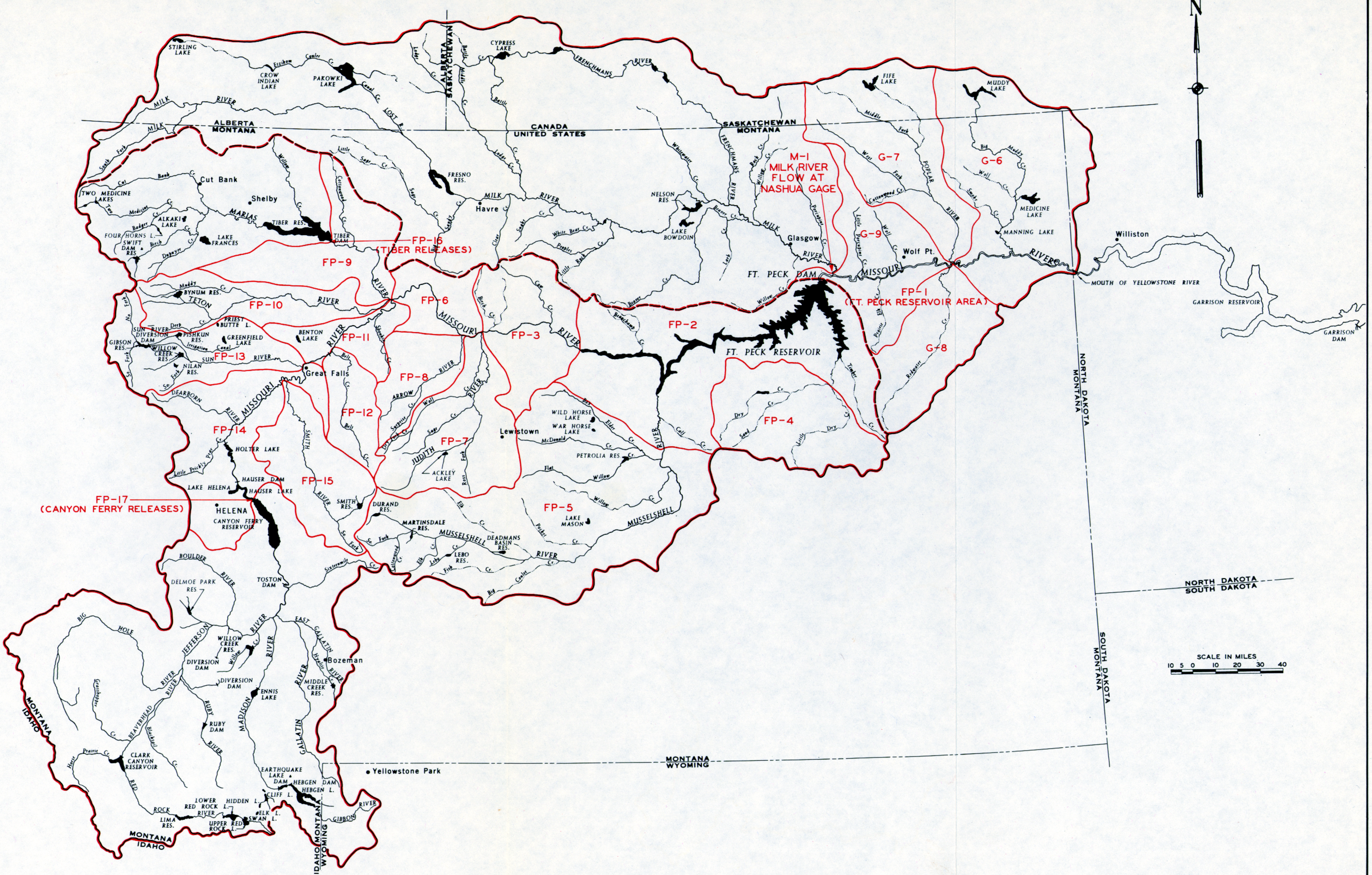


MISSOURI RIVER BASIN

ABOVE FORT PECK LAKE

RAINFALL – RUNOFF RELATIONSHIP

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



UPPER MISSOURI RIVER BASIN
ABOVE MOUTH OF YELLOWSTONE RIVER
BASIN SUB-AREAS ABOVE
MOUTH OF YELLOWSTONE RIVER

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPTEMBER 1966

COMPOSITE UNIT HYDROGRAPH LAGGED TO FORT PECK RESERVOIR
For Total Area between Canyon Ferry Dam, Tiber Dam and Fort Peck Dam - 36,673 Sq. Mi.

Time (Days)	FP-17 Canyon Ferry Res. Releases 84HrLag	FP-15 Smith River 48HrLag	FP-13 Sun River 48HrLag	FP-14 Mo. R. Canyon Ferry to Gt. Falls 48HrLag	Mo. R. Gt. Falls Total 48HrLag	FP-12 Belt Creek 48HrLg	FP-10 Teton River 36HrLag	FP-16 Tiber Reservoir Releases 60HrLag	FP-9 Marias R. Tiber Dam to Mouth 30HrLag	FP-11 Mo. R. Gt. Falls to Marias R. 36HrLag	Mo. R. below Marias R. Total 36HrLag	FP-8 Arrow River 24HrLag	FP-7 Judith River 24HrLg	FP-6 Mo. R. Marias R. to Judith R. 24HrLag	Mo. R. below Judith R. Total 24HrLag	FP-5 Mussel-shell River at Mosby 12HrLag	FP-4 Big Dry Creek at Van Norman 12HrLag	FP-3 Mo. R. Judith R. to Ft. Peck 0 Lag	FP-2 Fort Peck Reservoir Local 0 Lag	FP-1 Ft. Peck Reservoir Area 0 Lag	Fort Peck Total
																		0	0	0	0
																0	0	8,200	36,800	18,800	63,800
1												0	0	0	0	10,000	7,400	16,200	77,000	0	110,600
							0		0	0	0	4,900	4,400	3,400	12,700	19,900	14,700	24,100	73,000		144,400
2		0	0	0	0	0	2,100		4,100	3,000	9,200	9,800	8,900	7,000	34,900	30,000	21,900	27,100	50,000		163,900
		3,700	3,600	5,200	12,500	2,700	4,200	0	8,400	6,100	33,900	14,700	13,300	10,500	72,400	40,000	29,000	19,600	27,300		188,300
3		7,400	7,400	10,300	25,100	5,300	6,300		12,400	9,400	58,500	14,400	17,900	10,800	101,600	50,000	21,800	11,700	15,100		200,200
	0	11,200	11,000	15,500	37,700	8,000	8,500		16,600	10,400	81,200	9,500	22,400	7,200	120,300	61,000	14,600	8,000	10,600		214,500
4		14,900	14,800	20,600	50,300	9,300	10,700		20,700	7,400	98,400	5,700	20,900	4,100	129,100	51,100	9,200	6,200	5,900		201,500
		18,700	18,400	25,700	62,800	6,600	12,800		16,600	4,400	103,200	4,400	16,500	3,400	127,500	40,800	7,400	4,500	1,300		181,500
5		14,900	14,800	25,800	55,500	4,100	13,200		12,400	3,400	88,600	3,100	12,000	2,500	106,200	30,600	5,500	2,800	0		145,100
		11,200	11,100	20,600	42,900	3,000	11,000		8,300	2,500	67,700	1,900	7,900	1,600	79,100	20,400	3,800	1,200			104,500
6		7,600	7,400	15,500	30,500	2,200	8,800		6,200	1,700	49,400	600	6,700	900	57,600	13,700	1,900	0			73,200
		6,300	6,200	10,600	23,100	1,500	6,700		5,000	900	37,200	0	5,600	0	42,800	12,100	0				54,900
7		5,000	4,900	9,100	19,000	900	5,700		3,900	0	29,500		4,500		34,000	10,600					44,600
		3,800	3,700	7,500	15,000	0	4,900		2,800		22,700		3,400		26,100	9,000					35,100
8		2,500	2,500	6,000	11,000		4,100		1,700		16,800		2,300		19,100	7,600					26,700
		1,300	1,200	4,500	7,000		3,200		900		11,100		1,100		12,200	6,000					18,200
9		100	0	3,000	3,100		2,300		0		5,400		0		5,400	4,500					9,900
		0		1,500	1,500		1,600				3,100				3,100	2,900					6,000
10				0	0		700				700				700	1,400					2,100
							0				0				0	0					0
11																					
		108,600	107,000	181,400	397,000	43,600	106,800		120,000	49,200	716,600	69,000	147,800	51,400	984,800	421,600	137,200	129,600	297,000	18,800	1,989,000

Note: All values in cubic feet per second.

COMPOSITE UNIT HYDROGRAPHS FOR INCREMENTAL DRAINAGE AREA
BETWEEN FORT PECK DAM AND MOUTH OF YELLOWSTONE RIVER

Time (Days)	Fort Peck Reservoir Releases	M-1 Milk R. Flow at Nashua Gage	G-8 Redwater Creek	G-7 Poplar River	G-9 Mo. R. Milk R. to Poplar R.	Mo. R. Poplar R. Total	G-6 Mo. R. Poplar R. to Nohly	Mo. R. Total
	72 Hr Lag	72 Hr Lag	36 Hr Lag	36 Hr Lag	36 Hr Lag	36 Hr Lag	0 Hr Lag	0 Hr Lag
0							0	0
							14,800	14,800
1							25,100	25,100
			0	0	0	0	32,200	32,200
2			19,900	7,700	11,600	39,200	36,300	75,500
			36,300	28,000	30,200	94,500	29,200	123,700
3	0	0	23,800	37,200	35,200	96,200	20,400	116,600
			13,400	31,800	21,100	66,300	13,300	79,600
4			8,400	24,200	8,500	41,100	8,700	49,800
			5,500	17,500	4,000	27,000	5,100	32,100
5			3,500	12,600	1,500	17,600	3,100	20,700
			2,000	8,800	800	11,600	1,500	13,100
6			800	5,500	300	6,600	500	7,100
			0	3,300	0	3,300	0	3,300
7				1,600		1,600		1,600
				900		900		900
8				300		300		300
				0		0		0
Total			113,600	179,400	113,200	406,200	190,200	596,400

Note: All values in cubic feet per second.

UPPER MISSOURI RIVER BASIN
STAGE DISCHARGE TABLE
KEY GAGING STATIONS ABOVE MOUTH
OF YELLOWSTONE RIVER

Gage Height (Feet)	Jefferson River at Sappington, Montana Gage Datum Approx 4170 Ft. M.S.L. (CFS)	Gallatin River at Logan, Montana Gage Datum 4086.42 Ft. M.S.L. (CFS)	Missouri River at Toston Montana Gage Datum Appr. 3920 Ft. M.S.L. (CFS)	Missouri River Below Holter Dam Gage Datum 3464.11 Ft. M.S.L. (CFS)	Missouri River Near Ulm, Montana Gage Datum Approx 3310 Ft. M.S.L. (CFS)	Sun River Near Vaughn, Montana Gage Datum 3317.12 Ft. M.S.L. (CFS)	Missouri River at Ft. Benton, Montana Gage Datum 2614.05 Ft. M.S.L. (CFS)	Marias River at Loma, Montana Gage Datum Approx. 2570 Ft. M.S.L. (CFS)	Teton River Near Dutton, Montana Gage Datum Approx 3235 Ft. M.S.L. (CFS)	Missouri River at Virgelle, Montana Gage Datum 2507.50 Ft. M.S.L. (CFS)	Missouri River at Power Plant Ferry Zortman, Montana Gage Datum 2273.02 Ft. M.S.L. (CFS)	Musselshell River at Mosby, Montana Gage Datum Approx. 2550 Ft. M.S.L. (CFS)	Milk River at Nashua, Montana Gage Datum 2027.75 Ft. M.S.L. (CFS)	Missouri River Near Wolf Point, Montana Gage Datum 1958.57 Ft. M.S.L. (CFS)	Missouri River Near Culbertson, Montana Gage Datum 1883.4 Ft. M.S.L. (CFS)
0	0		0	200	900	0	0	0		0	0	0		0	0
2	350	0	400	3,070	2,460	870	4,380	270	0	2,800	1,000	20	0	4,000	1,500
4	1,930	1,310	3,020	7,370	5,000	2,270	10,600	1,900	400	7,000	4,500	480	1,030	8,250	3,900
6	4,900	3,830	7,200	13,200	8,200	4,000	20,000	4,760	1,450	13,500	12,300	1,300	1,830	13,600	7,500
8	9,270	7,300	13,700	20,300	12,200	6,200	31,500	8,780	3,200	22,000	21,400	2,450	2,600	20,800	12,700
10	15,400		22,000	28,000	16,400	8,200	45,500	17,000	5,000	31,000	34,000	3,700	3,400	30,800	19,400
12	22,500		36,000	35,800	21,100	10,200	63,500		7,000	41,000	49,000	5,300	4,300	43,000	30,100
14					26,000	12,000	84,000		-	53,000	65,000		5,300		56,100
16						15,800	109,000		-	67,000	81,500		6,500		
18						21,600	134,000		-	81,500	98,000		7,900		
20						29,000	160,000		72,000	95,400	115,500		9,400		
22										112,000	133,500		11,000		
24										127,000			12,600		
26													14,400		
28													20,000		
30													35,000		

NOTE :

1. Stage-Discharge Relations are based on data obtained from the U.S.G.S. Water Resources Division.

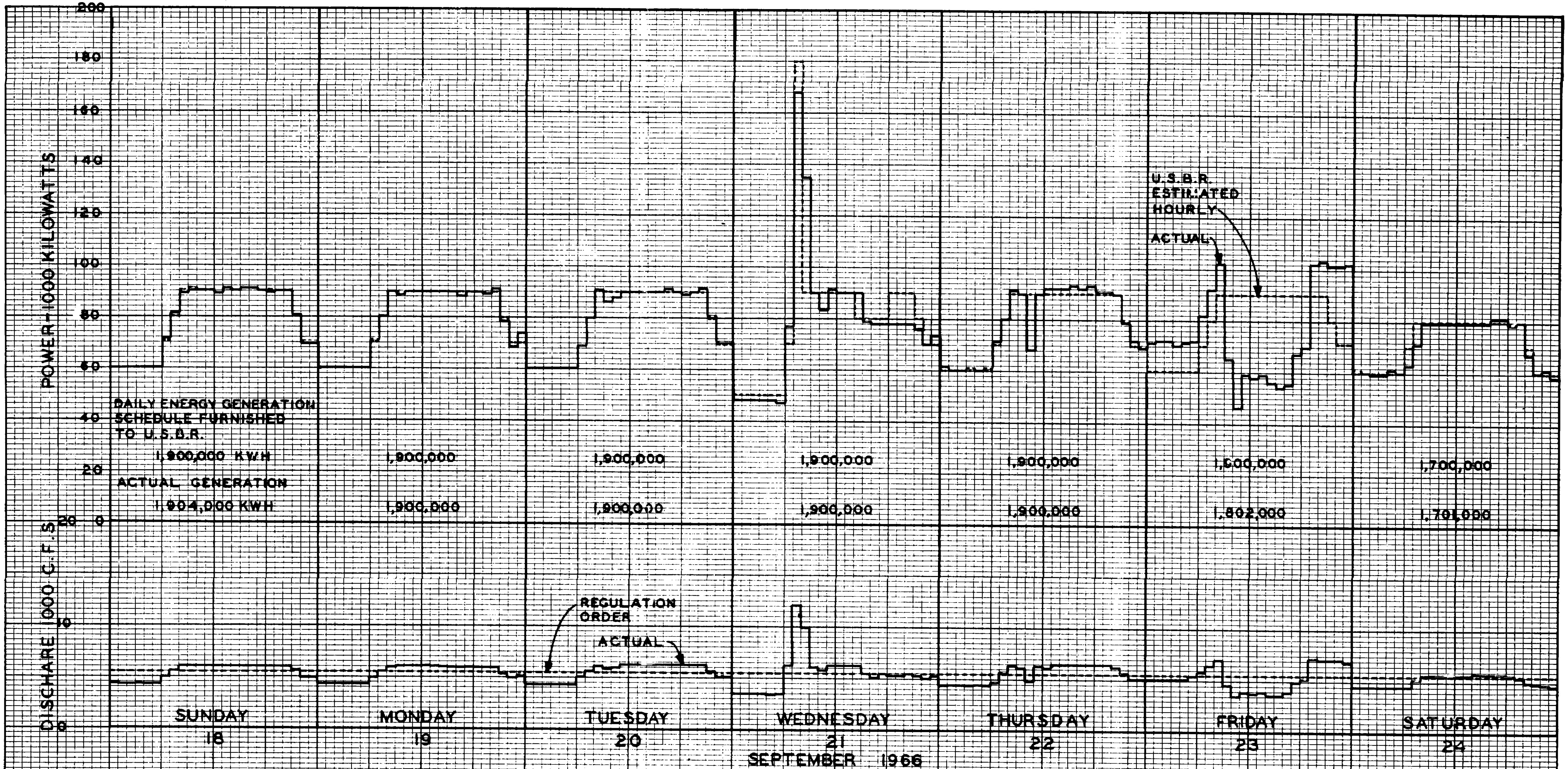
RESERVOIR ELEVATION CORRECTIONS FOR WIND EFFECTS

FORT PECK LAKE

(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	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.2	+1.4	+1.7	+1.9
10	+0.0	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.6	+0.8	+1.0	+1.2	+1.5	+1.8	+2.1	+2.5
20	+0.0	+0.0	+0.0	+0.1	+0.1	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.5	+3.0
30	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.0	+2.5	+2.9	+3.3
40	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.2	+1.5	+1.8	+2.3	+2.7	+3.1	+3.6
50	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.2	+1.6	+1.9	+2.3	+2.8	+3.3	+3.8
60	+0.0	+0.0	+0.0	+0.1	+0.3	+0.4	+0.7	+0.9	+1.2	+1.6	+2.0	+2.4	+2.8	+3.3	+3.9
70	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.2	+1.6	+1.9	+2.3	+2.8	+3.3	+3.8
80	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.2	+1.5	+1.8	+2.3	+2.7	+3.1	+3.6
90	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.0	+2.5	+2.9	+3.3
100	+0.0	+0.0	+0.0	+0.1	+0.1	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.5	+3.0
110	+0.0	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.6	+0.8	+1.0	+1.2	+1.5	+1.8	+2.1	+2.5
120	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.2	+1.4	+1.7	+1.9
130	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.1	+0.3	+0.4	+0.5	+0.7	+0.8	+0.9	+1.1	+1.3
140	+0.0	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.1	+0.2	+0.3	+0.4	+0.4	+0.5	+0.7
150	-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
160	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2
170	-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	-0.4	-0.5
180	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.4	-0.6	-0.7	-0.9
190	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-1.0	-1.3
200	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-1.1	-1.5	-1.7
210	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-0.9	-1.3	-1.7	-2.1
220	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.4	-0.6	-0.7	-1.2	-1.5	-2.0	-2.4
230	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.3	-0.4	-0.5	-0.7	-0.9	-1.2	-1.6	-2.0	-2.5
240	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.3	-0.4	-0.5	-0.7	-0.9	-1.2	-1.7	-2.1	-2.6
250	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.3	-0.4	-0.5	-0.7	-0.9	-1.2	-1.6	-2.0	-2.5
260	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.4	-0.6	-0.7	-1.2	-1.5	-2.0	-2.4
270	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-0.9	-1.3	-1.7	-2.1
280	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-1.1	-1.5	-1.7
290	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-1.0	-1.3
300	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.4	-0.6	-0.7	-0.9
310	-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	-0.4	-0.5
320	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2
330	-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
340	+0.0	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.1	+0.2	+0.3	+0.4	+0.4	+0.5	+0.7
350	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.1	+0.3	+0.4	+0.5	+0.7	+0.8	+0.9	+1.1	+1.3

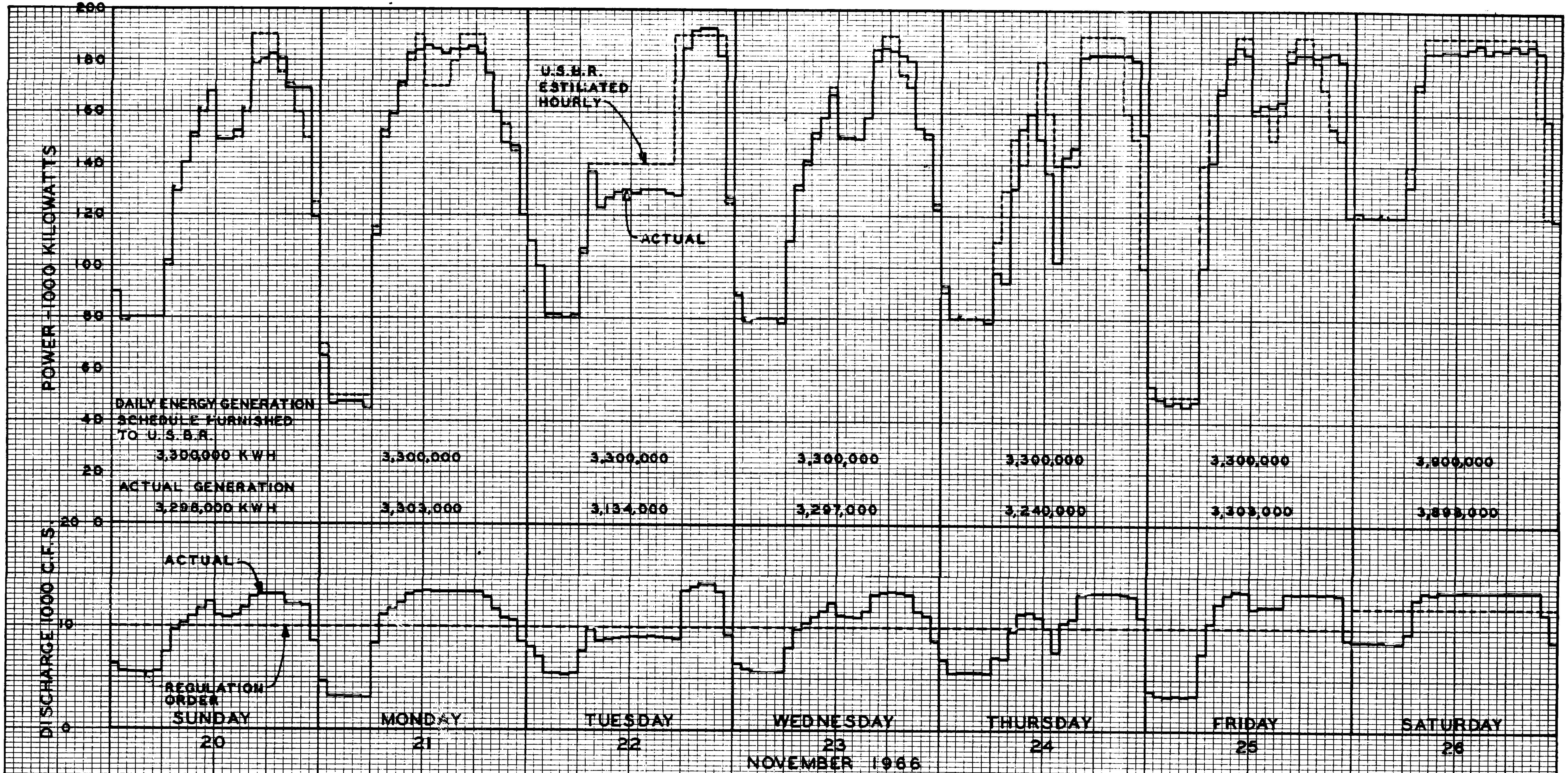


FORT PECK COMBINED RESERVOIR REGULATION AND POWER PRODUCTION ORDERS: (MRD Reservoir Control Center to Fort Peck Powerplant)

Order Number	Effective Time	Daily Average Release Schedule	Daily Generation Schedule Maximum	Daily Generation Schedule Scheduled	Hourly Power Limitations
56,1966	17-23 Sep	5,500 c.f.s. *	As required	1,900 MWH	Max. 205 MW
57,1966	24-30 Sep	5,000 c.f.s. *	As required	1,700 MWH	Max. 205 MW

* Provisions of Order No. 4, 1964 apply. (Re: Supplementary releases only to maintain daily average discharge of 3,000 c.f.s.)

MISSOURI RIVER
FORT PECK LAKE PROJECT
ILLUSTRATION OF HOURLY REGULATION & POWER PRODUCTION DURING NAVIGATION SEASON
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
DEC. 1972

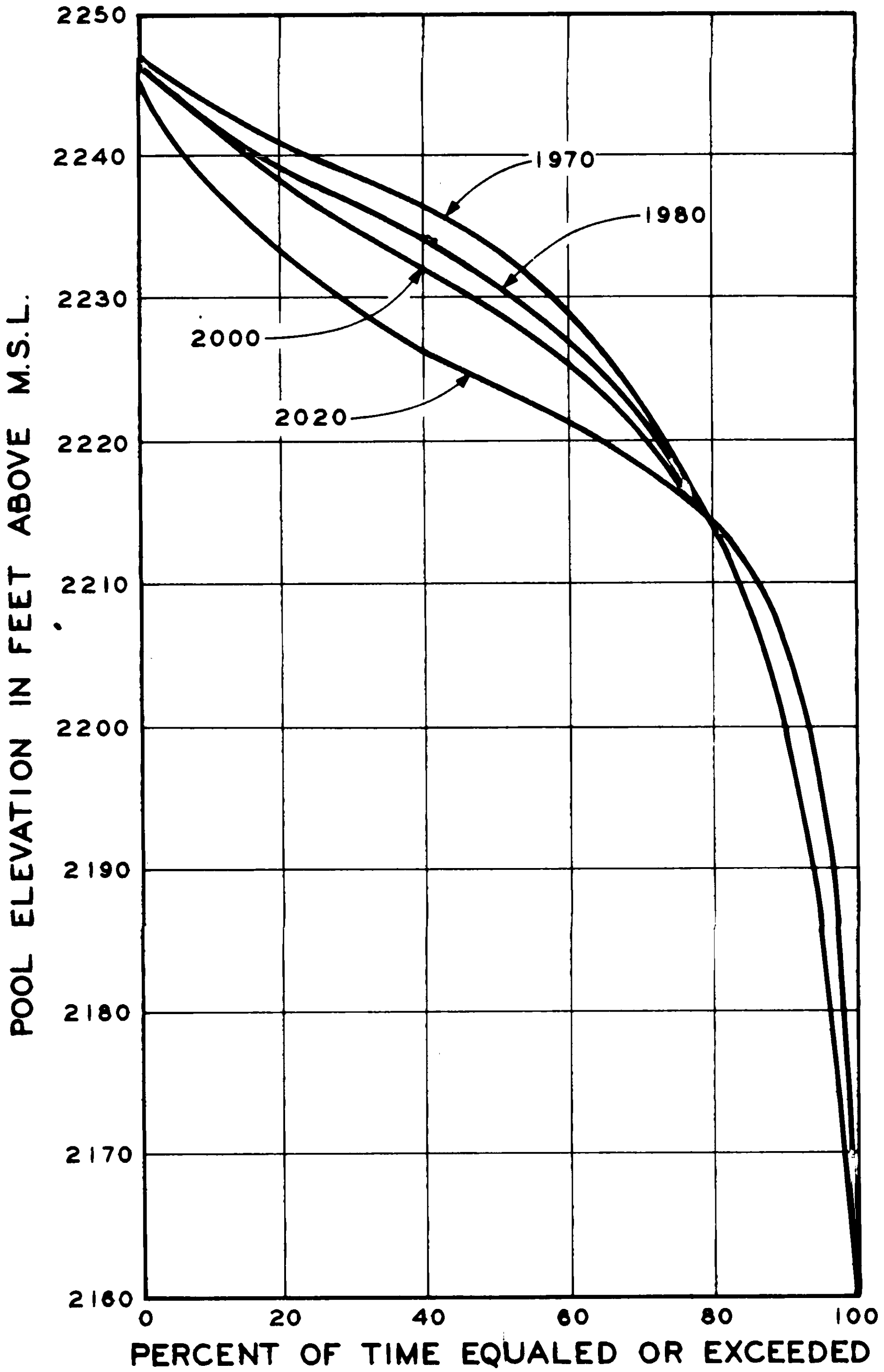


FORT PECK COMBINED RESERVOIR REGULATION AND POWER PRODUCTION ORDERS: (MRD Reservoir Control Center to Fort Peck Powerplant)

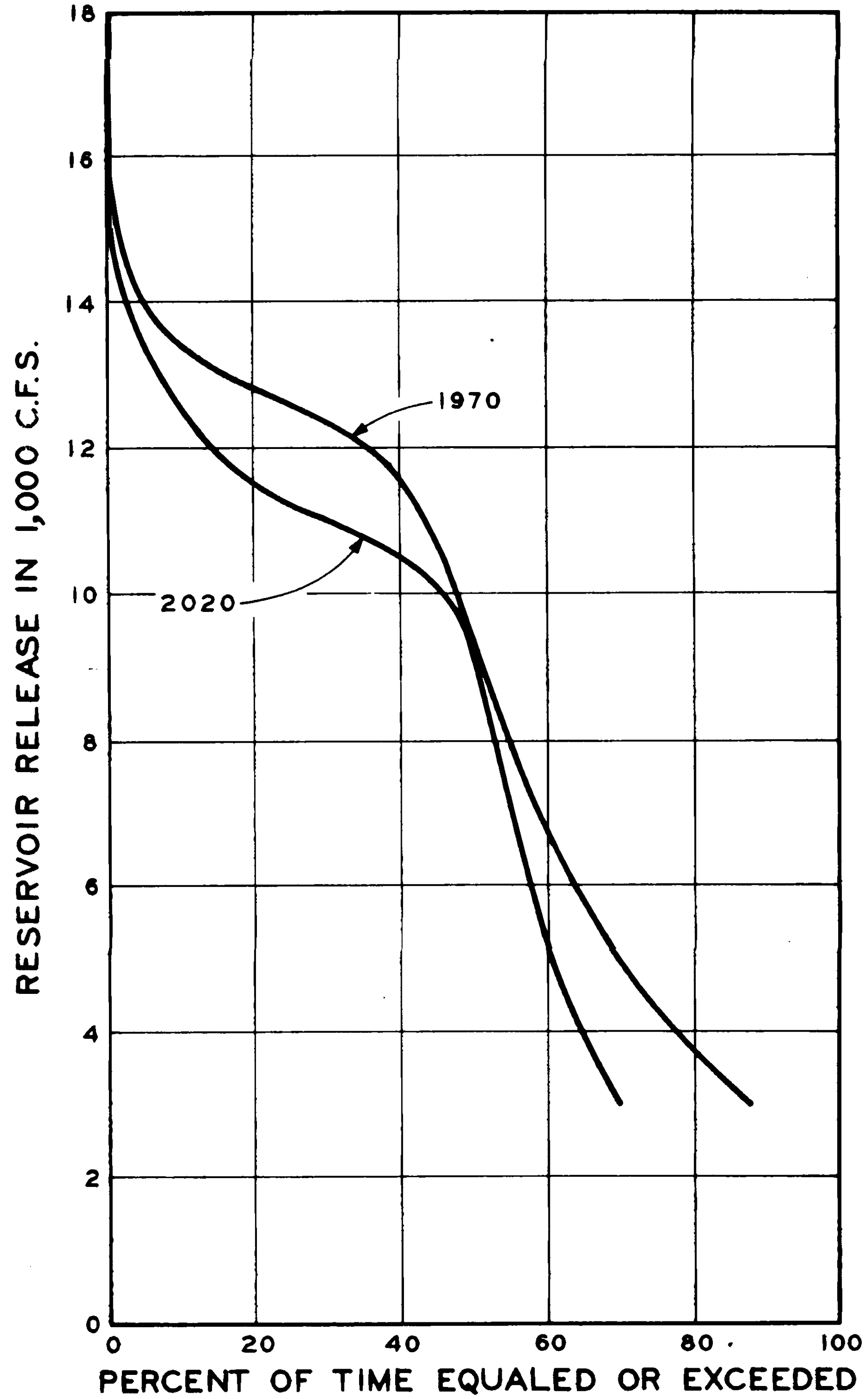
Order Number	Effective Time	Daily Average Release Schedule	Daily Generation Schedule: Maximum	Daily Generation Schedule: Scheduled	Hourly Power Limitations
66,1966	18-25 Nov	10,000 c.f.s. *	As required	3,300 MWH	Max. 205 MW
67,1966	26 Nov	12,000 c.f.s. *	As required	3,900 MWH	Max. 205 MW
	27 Nov	10,000 c.f.s. *		3,300 MWH	
	28 Nov-2 Dec	12,000 c.f.s. *		3,900 MWH	

* Provisions of Order No. 4, 1964 apply. (Re: Supplementary releases only to maintain daily average discharge of 3,000 c.f.s.)

MISSOURI RIVER
FORT PECK LAKE PROJECT
ILLUSTRATION OF HOURLY REGULATION & POWER PRODUCTION DURING NON-NAVIGATION SEASON
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
DEC. 1972



POOL ELEVATION DURATION

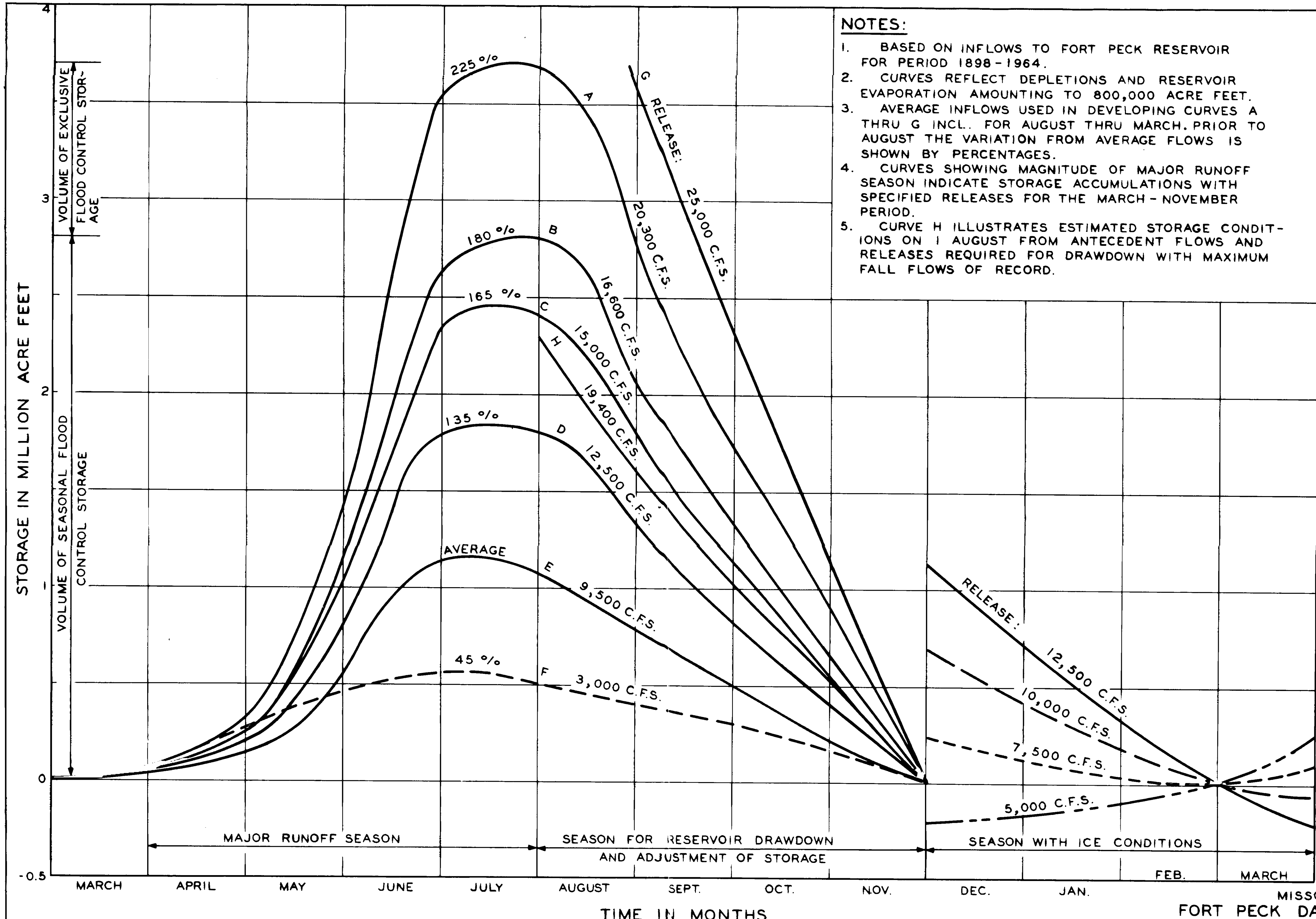


RELEASE DURATION

MISSOURI RIVER
FORT PECK LAKE, MONTANA

POOL ELEVATION AND RELEASE DURATION CURVES

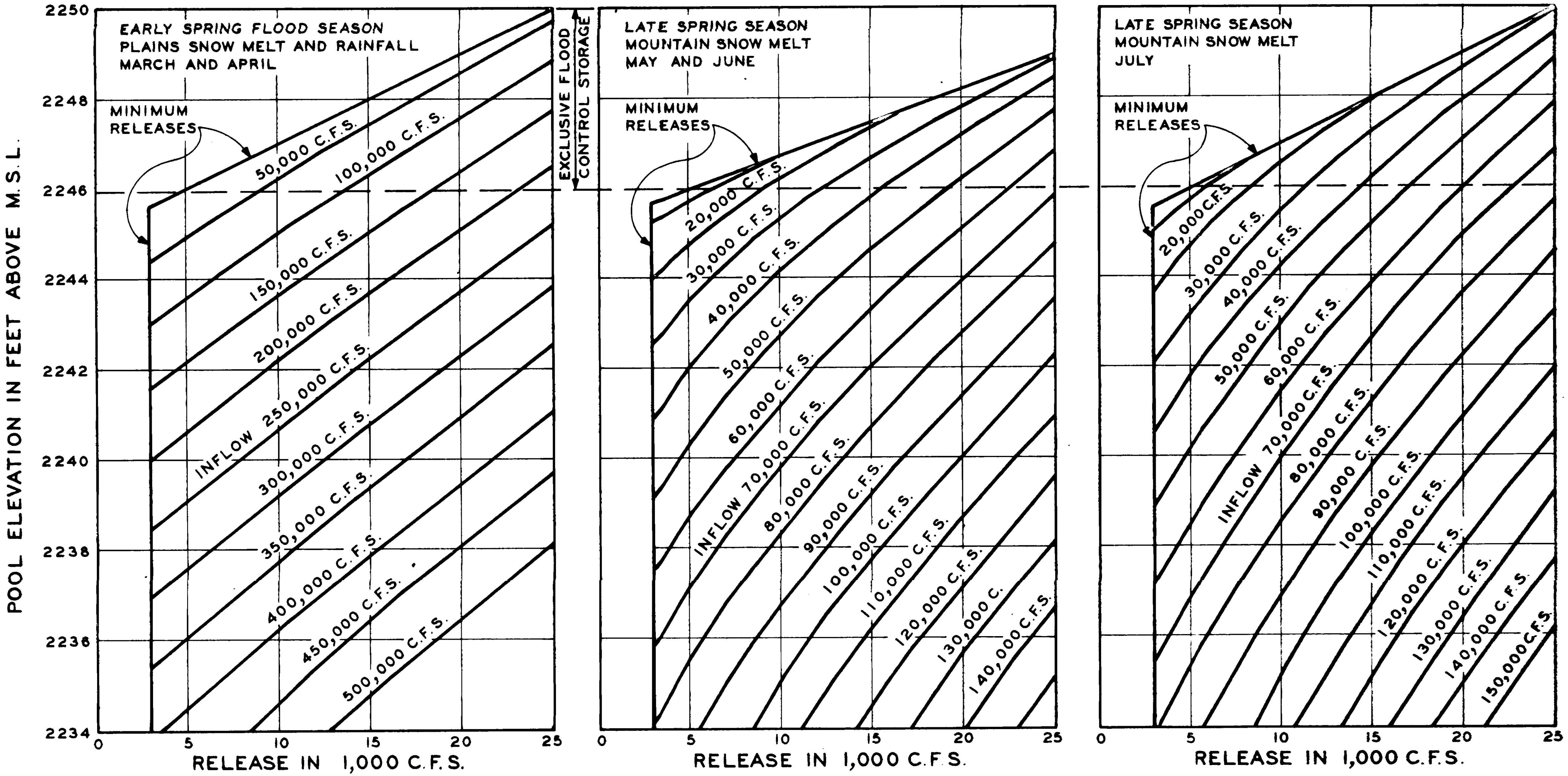
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCT. 1972



NOTES:

1. BASED ON INFLOWS TO FORT PECK RESERVOIR FOR PERIOD 1898-1964.
2. CURVES REFLECT DEPLETIONS AND RESERVOIR EVAPORATION AMOUNTING TO 800,000 ACRE FEET.
3. AVERAGE INFLOWS USED IN DEVELOPING CURVES A THRU G INCL. FOR AUGUST THRU MARCH. PRIOR TO AUGUST THE VARIATION FROM AVERAGE FLOWS IS SHOWN BY PERCENTAGES.
4. CURVES SHOWING MAGNITUDE OF MAJOR RUNOFF SEASON INDICATE STORAGE ACCUMULATIONS WITH SPECIFIED RELEASES FOR THE MARCH - NOVEMBER PERIOD.
5. CURVE H ILLUSTRATES ESTIMATED STORAGE CONDITIONS ON 1 AUGUST FROM ANTECEDENT FLOWS AND RELEASES REQUIRED FOR DRAWDOWN WITH MAXIMUM FALL FLOWS OF RECORD.

MISSOURI RIVER
FORT PECK DAM AND RESERVOIR
REGULATION GUIDE CURVES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966



NOTES:

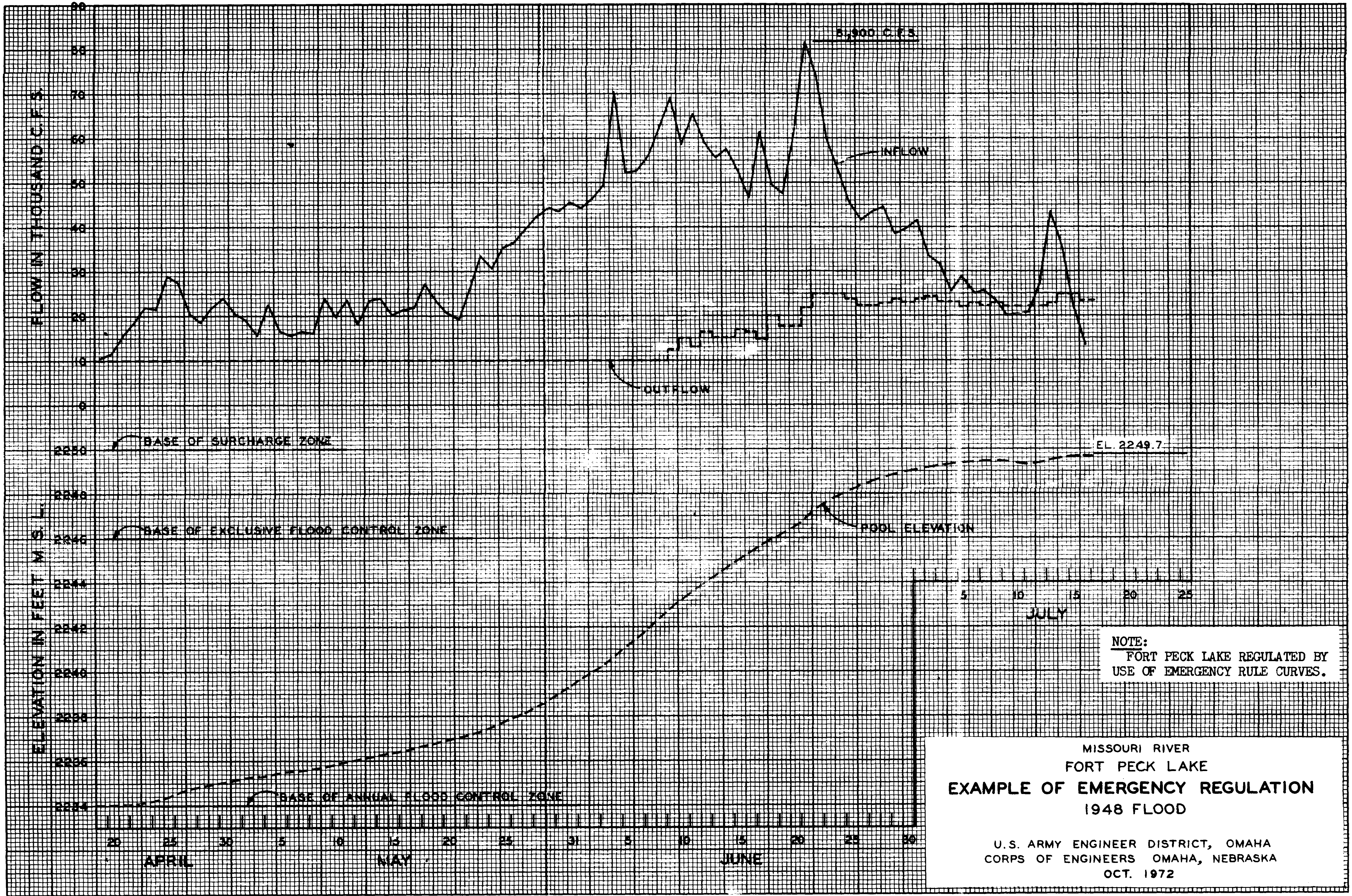
1. RELEASES ARE DETERMINED FROM CURRENT POOL ELEVATION AND MEAN INFLOW FOR THE PRECEDING 24 HOURS.

2. CURVES ARE APPLICABLE FOR THE REGULATION OF MODERATE FLOODS. FOR LARGE FLOODS, THE RULE CURVES INCLUDED IN THE EMERGENCY REGULATION PROCEDURES MAY BE USED AS REGULATION GUIDES.

MISSOURI RIVER
FORT PECK LAKE PROJECT

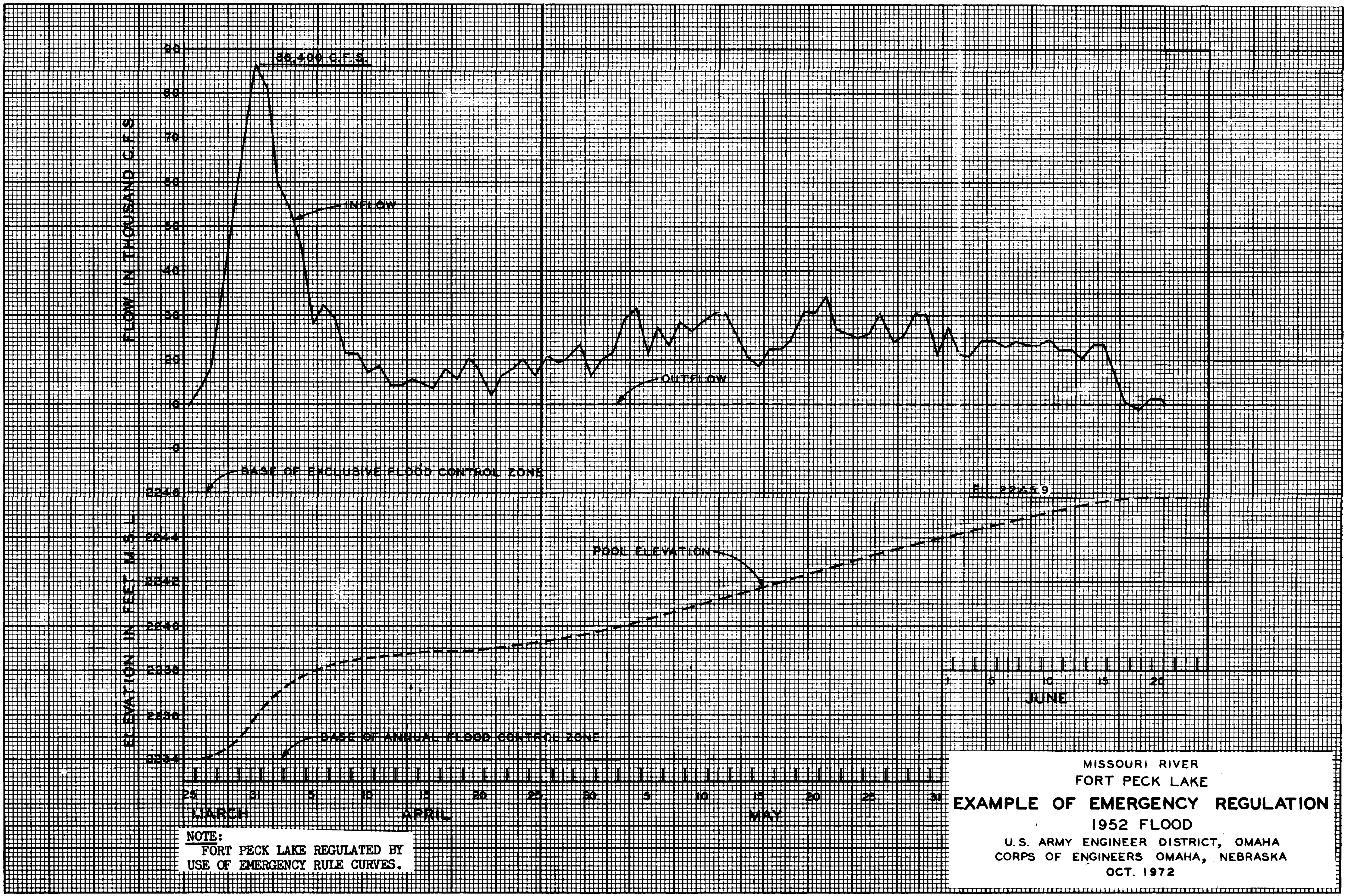
EXCLUSIVE FLOOD CONTROL REGULATION CURVES

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCT. 1972



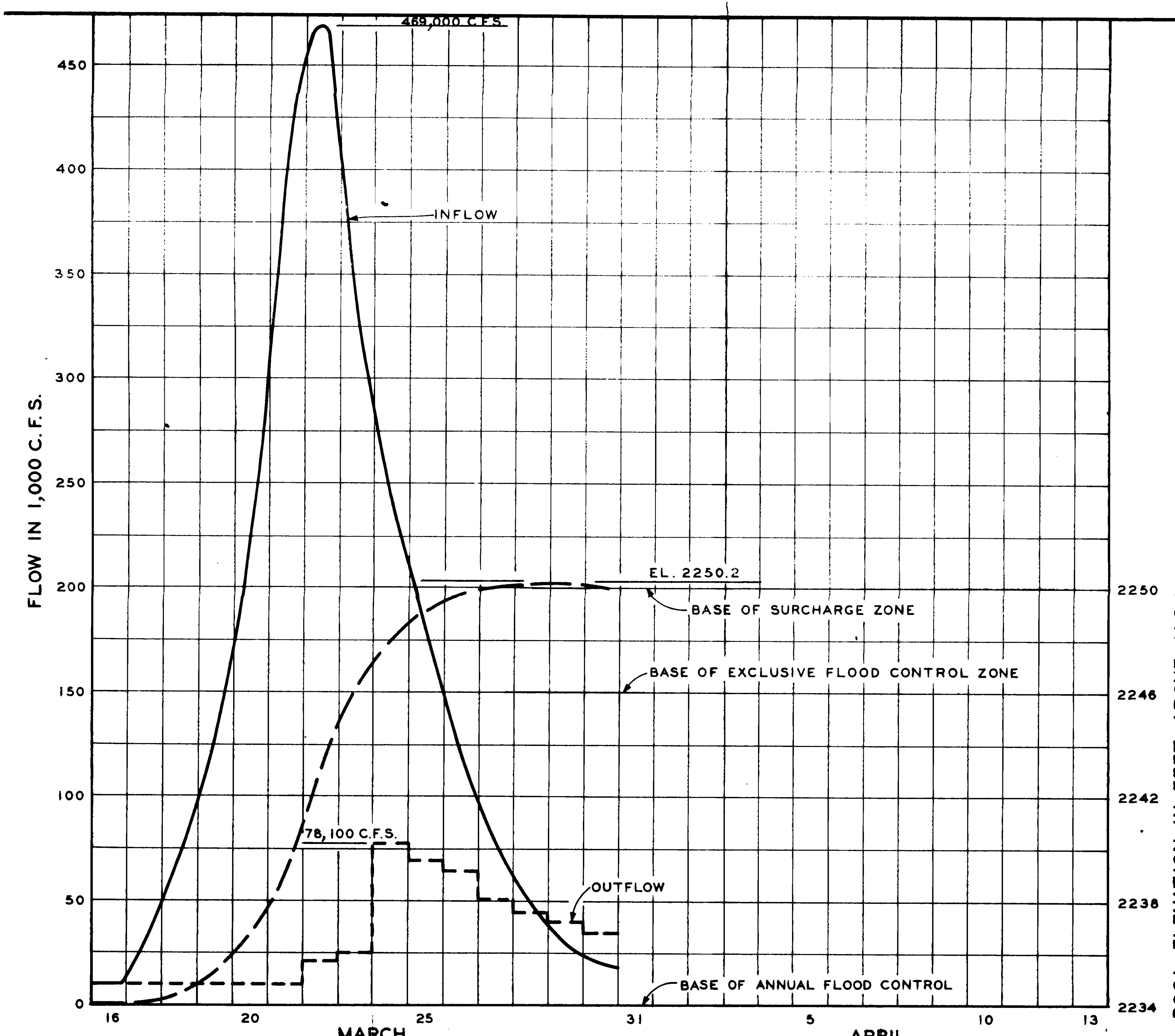
MISSOURI RIVER
FORT PECK LAKE
EXAMPLE OF EMERGENCY REGULATION
1948 FLOOD

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCT. 1972



NOTE:
FORT PECK LAKE REGULATED BY USE OF EMERGENCY RULE CURVES.

MISSOURI RIVER
FORT PECK LAKE
EXAMPLE OF EMERGENCY REGULATION
1952 FLOOD
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCT. 1972



NOTES:

1. INFLOW EQUALS 500 % OF 1947 SPRING FLOOD.
2. FORT PECK PROJECT REGULATED BY EMERGENCY REGULATION.

MISSOURI RIVER

FORT PECK LAKE, MONTANA

EXAMPLE OF EMERGENCY REGULATION

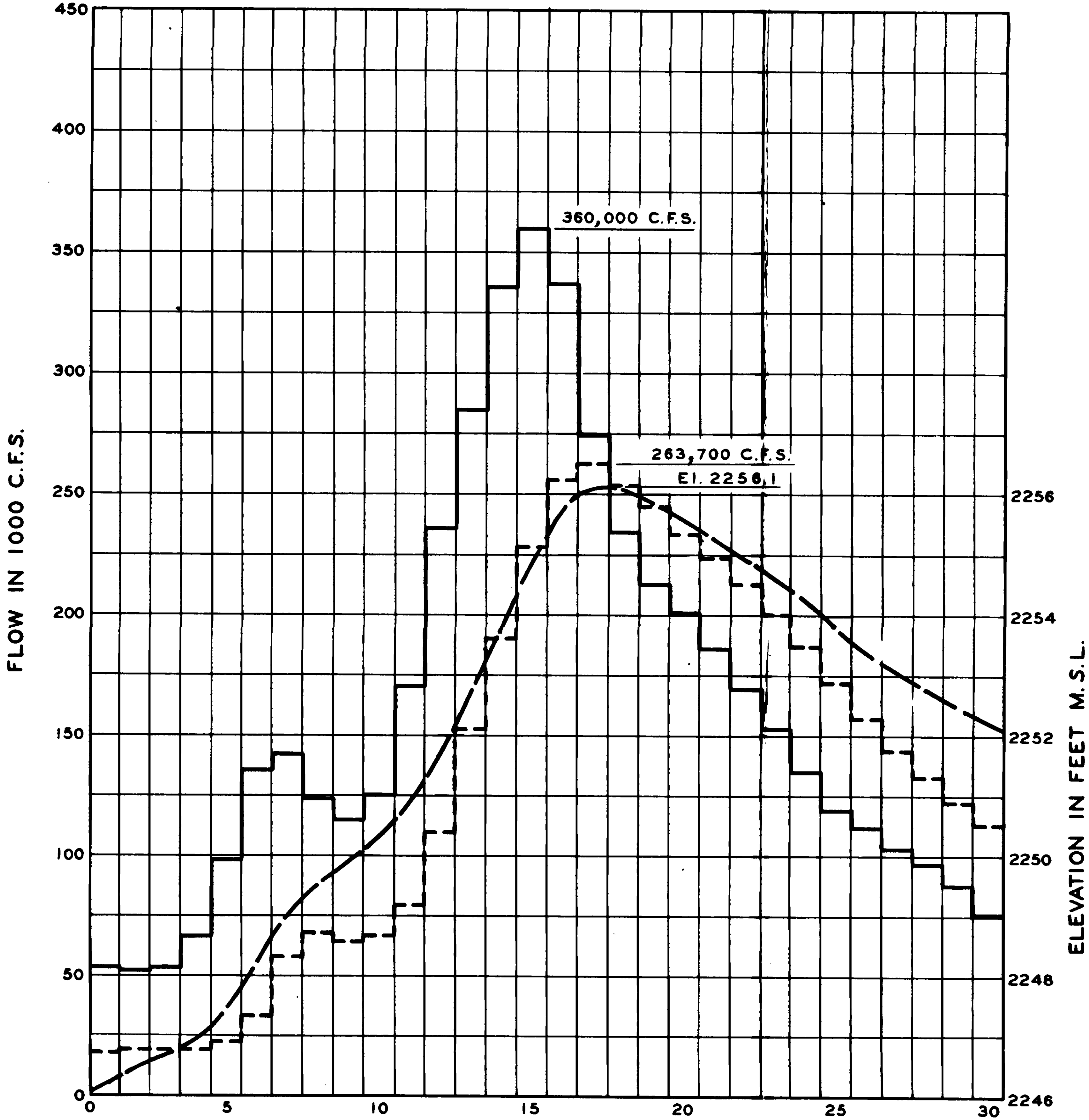
EARLY SPRING FLOOD OF

SPILLWAY DESIGN MAGNITUDE

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS OMAHA, NEBRASKA

OCT 1972



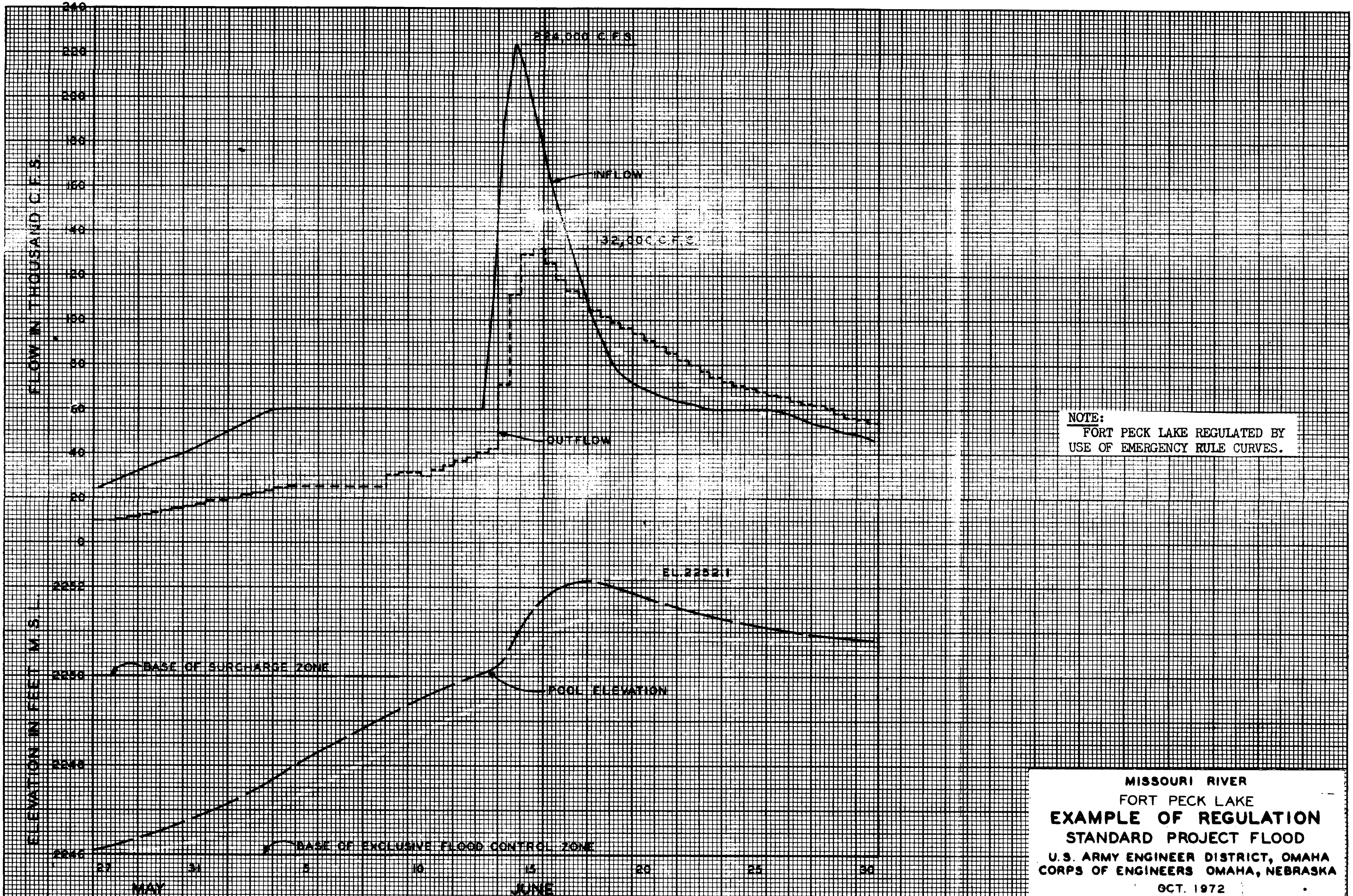
NOTES:

1. BASED ON 1934 ESTIMATE OF SPILLWAY DESIGN FLOOD (SUMMER).
2. FORT PECK RESERVOIR REGULATED BY USE OF EMERGENCY RULE CURVES.

LEGEND:

INFLOW
OUTFLOW
POOL ELEVATION

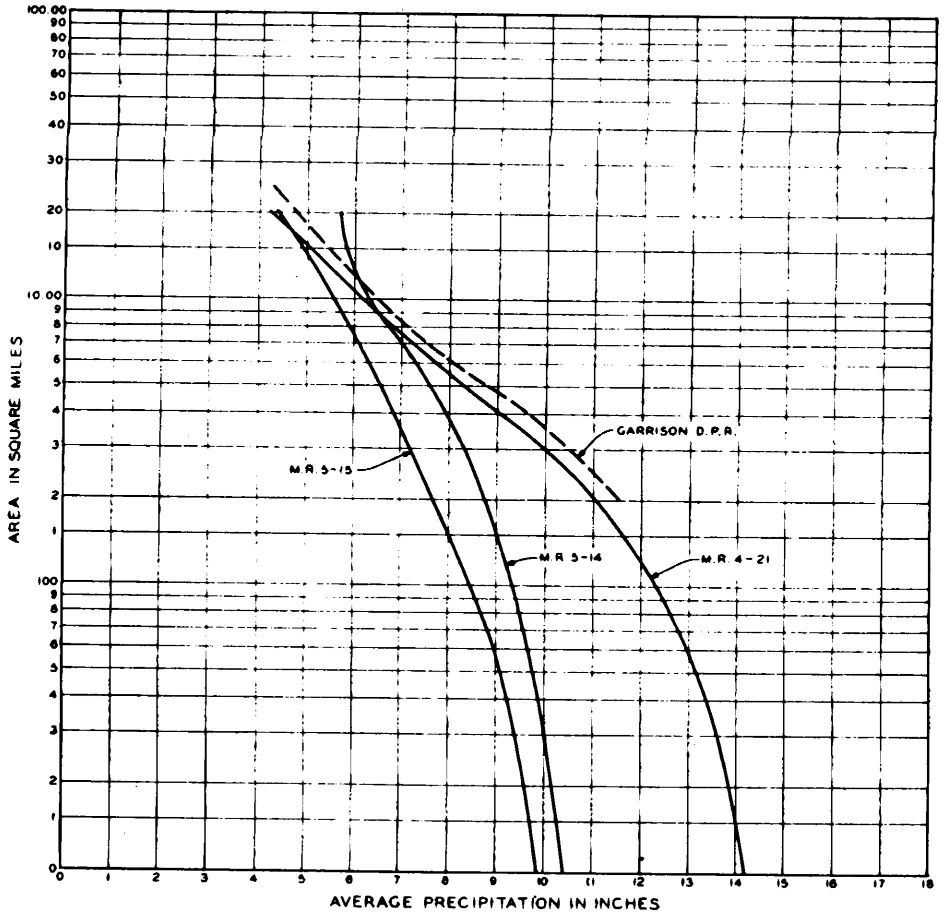
MISSOURI RIVER
FORT PECK LAKE
EXAMPLE OF EMERGENCY REGULATION
SPILLWAY DESIGN FLOOD
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA


FLOW IN THOUSAND C.F.S.
ELEVATION IN FEET M.S.L.
224,000 C.F.S.
INFLOW
132,000 C.F.S.
OUTFLOW
EL. 2252.1
BASE OF SURCHARGE ZONE
POOL ELEVATION
BASE OF EXCLUSIVE FLOOD CONTROL ZONE
240
220
200
180
160
140
120
100
80
60
40
20
0
2252
2250
2248
2246
27
31
5
10
15
20
25
30
MAY
JUNE
NOTE:
FORT PECK LAKE REGULATED BY USE OF EMERGENCY RULE CURVES.
MISSOURI RIVER
FORT PECK LAKE
EXAMPLE OF REGULATION
STANDARD PROJECT FLOOD
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCT. 1972

TRANSPOSITION FACTORS

M.R. 5-14	21-23 JUNE 1907, 400 SE. CHOTEAU MONTANA	196%
M.R. 5-15	3-6 JUNE 1908, 510 E.SE EVANS MONTANA	150%
M.R. 4-21	17-21 JUNE 1921, 500 E.SE. SPRINGBROOK, MONT.	109%

GARRISON D.P.R. - MAX. POSSIBLE MID-MAY STORM FOR LOWER YELLOWSTONE (EXCLUDING BIG HORN), BETWEEN BILLINGS AND SIDNEY - 100 % ADJ. TO MID-JUNE 124 %



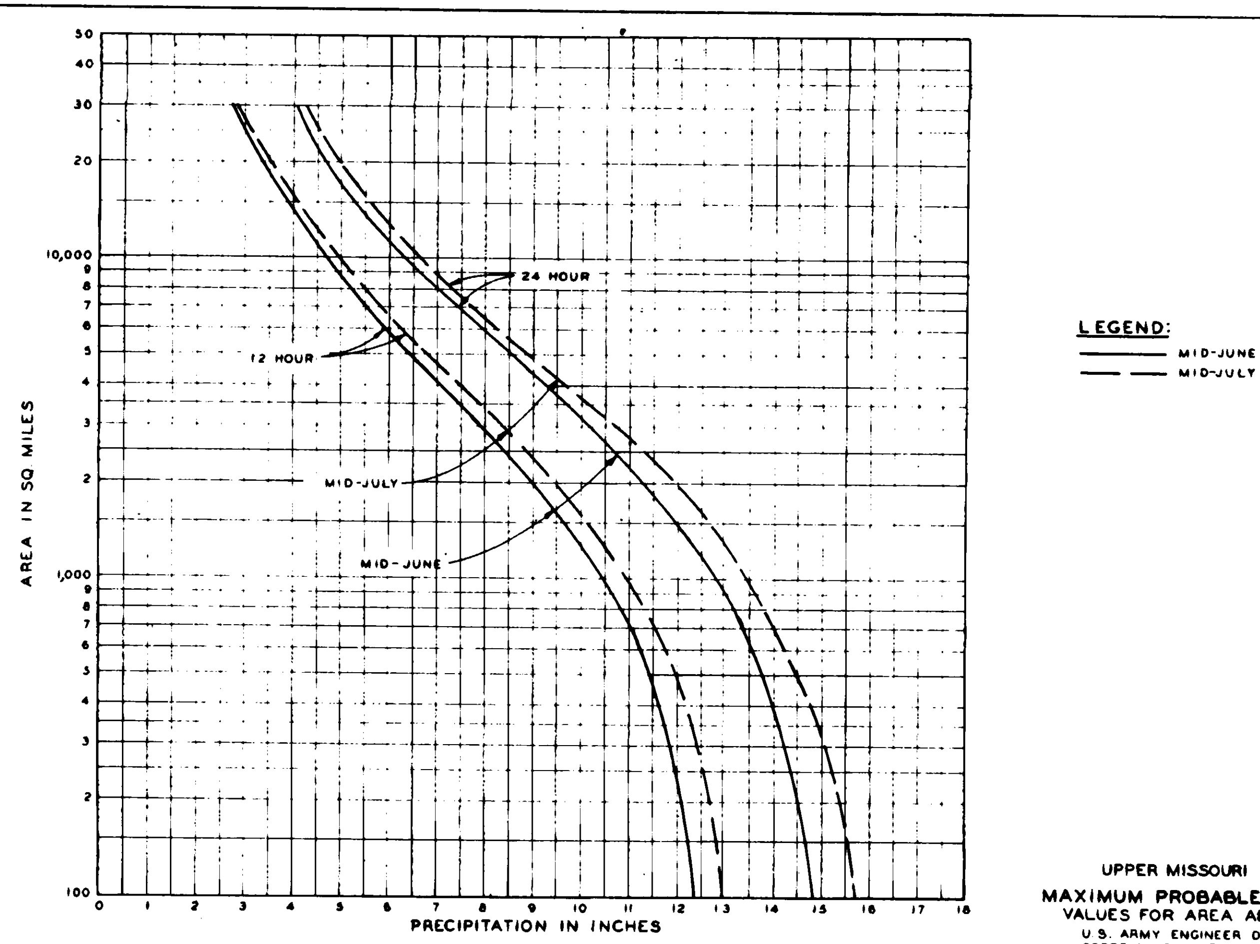
NOTE: THESE CURVES ARE FOR STORMS TRANSPOSED TO VICINITY GREAT FALLS, MONTANA AS A JUNE OCCURRENCE.

UPPER MISSOURI RIVER BASIN

24-HOUR DEPTH-AREA CURVES

STORMS TRANSPOSED TO AREA ABOVE FORT PECK

U.S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
1 SEPT 1966

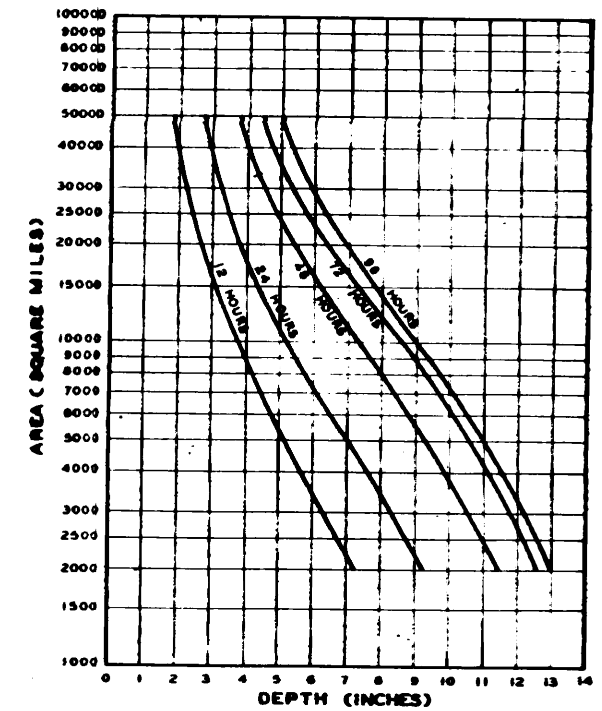


UPPER MISSOURI RIVER BASIN

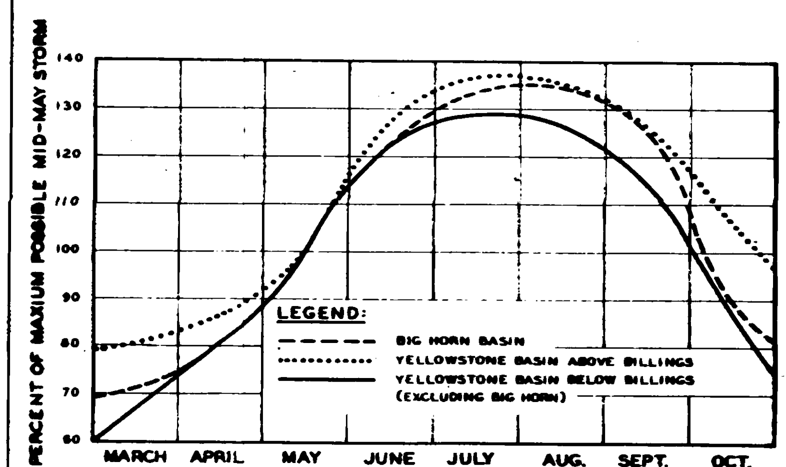
MAXIMUM PROBABLE PRECIPITATION

VALUES FOR AREA ABOVE FORT PECK

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT 1966



MAXIMUM PROBABLE DEPTH-AREA CURVES
MID-MAY STORM OVER YELLOWSTONE BASIN
(BELOW BILLINGS - EXCLUDING BIG HORN BASIN)



SEASONAL VARIATION OF MAXIMUM PROBABLE STORM
MARCH THROUGH OCTOBER

UPPER MISSOURI RIVER BASIN
MAXIMUM PROBABLE RAINFALL CURVES
FROM GARRISON D.P.R. REPORT

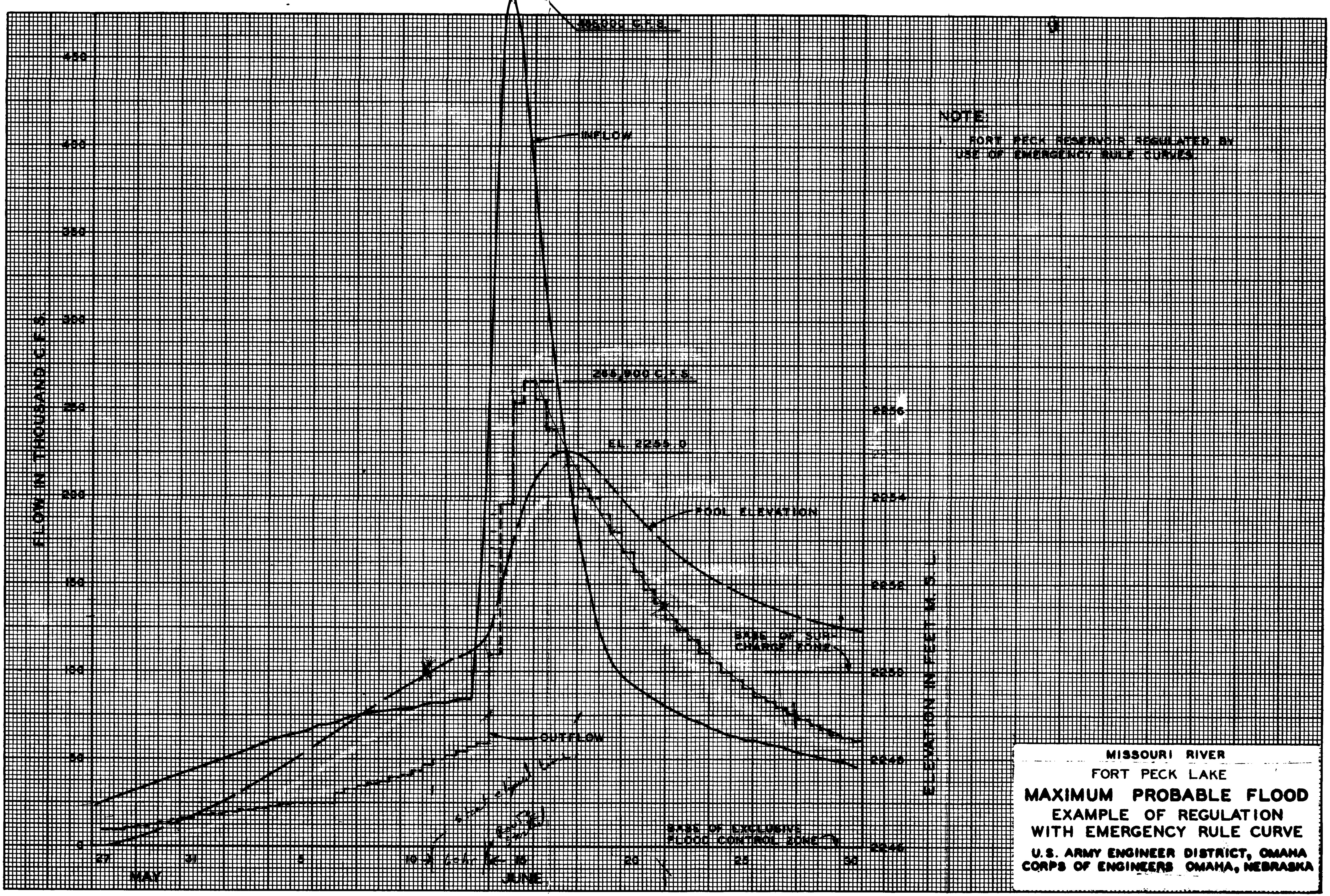
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966

MISSOURI RIVER

FORT PECK LAKE

MAXIMUM PROBABLE PRECIPITATION AND DEPTH AREA CURVES

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEPT. 1966



MISSOURI RIVER
FORT PECK LAKE
MAXIMUM PROBABLE FLOOD
EXAMPLE OF REGULATION WITH EMERGENCY RULE CURVE
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA