

WATER CONTROL MANUAL FOR FLOOD CONTROL

HOOVER DAM
AND LAKE MEAD
COLORADO RIVER

DECEMBER 1982



U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

**HOOVER DAM AND LAKE MEAD
COLORADO RIVER
PERTINENT DATA**

COLORADO RIVER DRAINAGE AREAS

Location	Drainage Areas (sq mi) ¹	
	Total	Incremental
Glen Canyon Dam	107,740	
Lee Ferry ²	108,040	300
Hoover Dam	167,740	59,700
Davis Dam	169,340	1,600
Parker Dam	178,740	9,400
Imperial Dam	184,540	5,800
Southerly International Boundary	242,740	58,200

Notes:

- USGS Water Resources Data less 3,959 square miles in Great Divide Basin.
- Compact Point

**REPRESENTATIVE STREAMFLOWS AND VOLUMES
AT HOOVER DAM**

Mean Annual Natural Runoff (1906-80)	15,135,000 ac-ft
Maximum Mean Daily Recorded Inflow ¹	220,000 cfs
Standard Project Rain Flood	
Maximum Mean Daily Inflow	112,000 cfs
Total Volume	1,079,000 ac-ft
Probable Maximum Rain Flood	
Maximum Mean Daily Inflow	194,800 cfs
Total Volume	2,760,000 ac-ft
Probable Maximum Snowmelt Flood	
Maximum Month	14,800,000 ac-ft
Total Volume, Jan-Aug	25,900,000 ac-ft

NOTES:

¹Colorado River near Grand Canyon, June 19, 1921.

DESCRIPTIVE DATA

DAM

Type	Concrete Gravity - Arch
Crest Elevation	1232 ft
Parapet Elevation	1236 ft
Structural Height	726.4 ft
Crest Length	1244 ft
Crest Width	45 ft
Freeboard Above Maximum Design Flood Pool	3 ft

SPILLWAY

Description	Two side-channel, gated spillways discharging through 50-ft dia. concrete lined tunnel through abutments, one on each side.
Total Crest Length	800 ft
Gates	
Description	Four floating drum gates on each spillway activated by filling float chambers.
Length, Each	100 ft
Maximum Height	16 ft

POWERPLANT

Operating Head	440 to 590 ft
Number of Units	19
Capacity (1980 Configuration)	1345 MW
Penstocks ¹	Two 30-ft dia. steel conduit through concrete lined tunnels each abutment.

OUTLETS AND POWER PENSTOCKS

Intakes	
Description	Four towers, two near each abutment, one each for river outlets and power penstocks.
Sill Elevations	lower 895 ft upper 1045 ft
Gates	Two 32-ft dia. gates in each tower

RIVER OUTLETS

Conduits	Two 30-ft dia. steel conduits in concrete lined tunnels, one on each side ¹ .
Valves	Four 72-inch dia. needle valves on each conduit, each with an emergency ring-follower type gate immediately upstream.
Centerline Elevation of Valves (Nevada)	653.88 ft
(Arizona)	652.92 ft

CANYON WALL OUTLETS

Conduit	Two 30-ft dia. steel conduits in 37-ft dia. concrete lined tunnels, one through each abutment ¹ .
Valves	Two 84-inch diameter needle valves on each penstock, each w/an emergency ring-follower type gate immediately upstream.
Centerline Elevation of Valves	820.0 ft

NOTES:

¹30-ft dia. conduits used for both power penstocks and river and canyon-wall releases.

AREA, STORAGE AND DISCHARGES AT CRITICAL POOL ELEVATIONS

Point	Elevation (ft)	Area (1000 ac)	Storages (1000 ac-ft)			Maximum Discharge (cfs)				
			Total ² Active	Incremental Active	Below Maximum Design Pool	Maximum Power Plant ³	Canyon Wall Outlets ⁴	River Outlets ⁴	Spillway Gates Up	Gates Down
Top of Dam	1232	—	—	—	—	—	—	—	—	—
Maximum Design Flood Pool	1229	162.7	27377	340	0	—	16000	28500	65000 ⁵	335000
Spillway Discharge @ 40,000 cfs Channel Capacity	1226.9	162±	27037	878	340	33500	16000	28400	40000	292000
Top of Raised Spillway Gates	1221.4	157.9	26159	282	1218	34000	16000	28100	0	184000
Minimum Required Flood Control Pool	1219.6	157±	25877	2169	1500	34100	16000	28300	—	154000
Permanent Spillway Crest	1205.4	148±	23708	1681	3669	35200	15900	27900	—	0
Maximum Required Flood Control Pool	1193.8	140±	22027	12003	5350	35700	15800	27500	—	—
Minimum Power Pool	1083	83±	10024	10024	17353	38000	14300	24500	—	—
Dead Storage	895	29±	2378	—	27377	—	0	0	—	—

Notes:

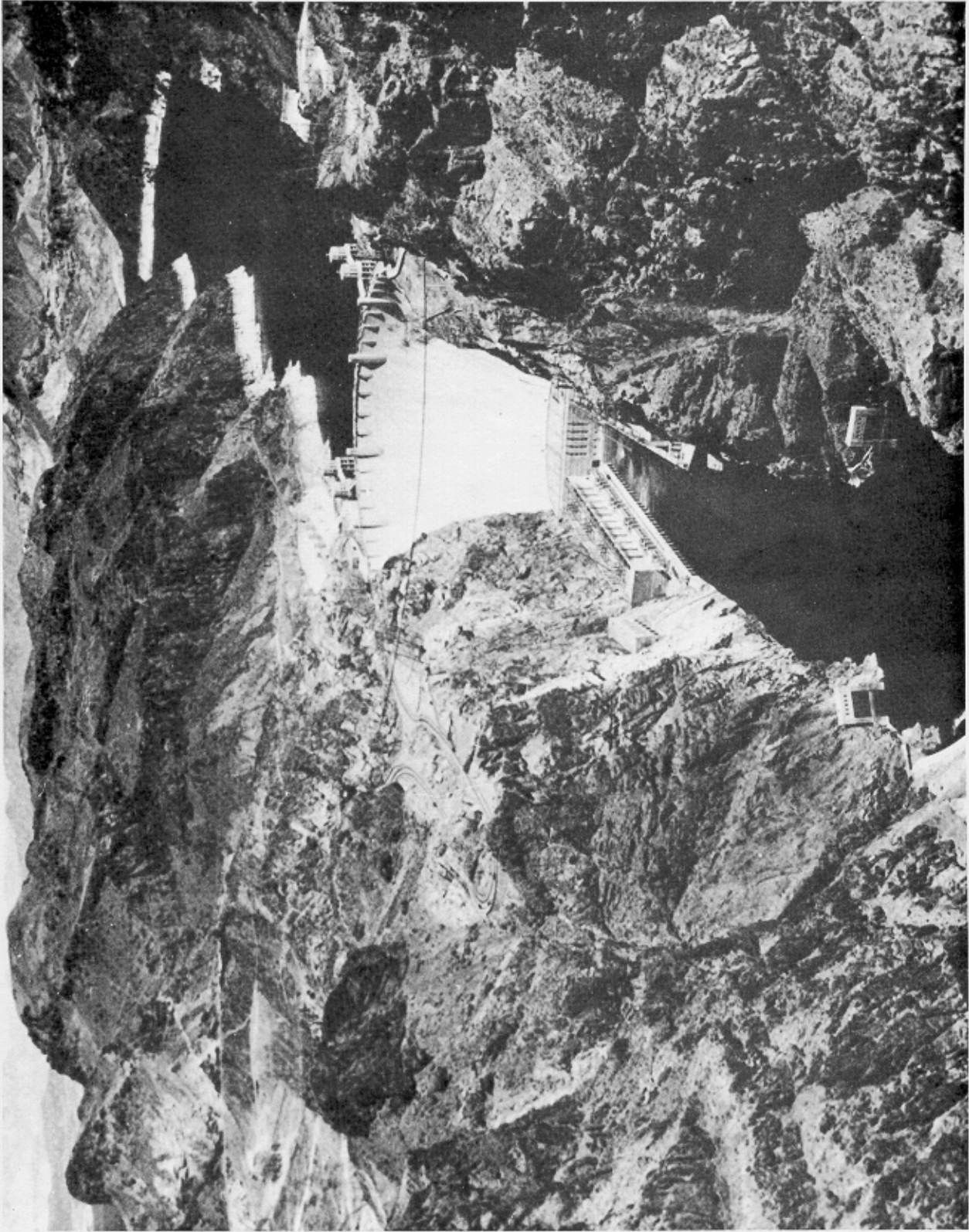
- Elevations refer to mean sea level datum.
- Exclusive of dead storage except as indicated.
- 1980 configuration.
- With all turbines operating.
- Gates designed to release inflow to 400,000 cfs.

WATER CONTROL MANUAL
FOR FLOOD CONTROL
HOOVER DAM AND LAKE MEAD
COLORADO RIVER, NEVADA AND ARIZONA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

DECEMBER 1982

Prepared
by
U.S. Army Corps of Engineers
Sacramento District
Reservoir Control Section



HOOVER DAM — LAKE MEAD

NOTICE TO USERS OF THIS MANUAL

a. Regulations specify that this Water Control Manual be published in looseleaf form, and only those sections, or parts thereof, requiring changes will be revised and printed. Therefore, this copy should be preserved in good condition so that inserts can be made to keep the manual current.

b. Nothing in this report is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994, 59 Stat. 1219), the decree entered by the Supreme Court of the United States in *Arizona v. California, et al.* (376 U.S. 340), the Boulder Canyon Project Act (45 Stat. -11-0-57), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620), or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501).

c. A portion of the material used in preparation of this report, including photos and some of the plates showing features of the project, were furnished by the U.S. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

d. This manual supersedes all prior revisions.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise, contact can be made by telephone to the Reservoir Regulation Unit, Los Angeles District Office (FTS 798-4756 or 213-688-4756).

**WATER CONTROL MANUAL
FOR FLOOD CONTROL**

**HOOVER DAM AND LAKE MEAD
COLORADO RIVER, NEVADA AND ARIZONA
TABLE OF CONTENTS**

	Page
PERTINENT DATA	Inside Front Cover
TITLE PAGE	i
PHOTOGRAPH	ii
NOTICE TO USERS OF THIS MANUAL	iii
TABLE OF CONTENTS.....	a
ABBREVIATIONS USED	f

TEXT OF MANUAL

Paragraph	Subject	Page
I - INTRODUCTION		
1-01	Authorization	I-1
1-02	Purpose and Scope	I-1
1-03	Related Manuals and Reports	I-1
1-04	Project Owner... ..	I-1
1-05	Operating Agencies	I-1
1-06	Regulating Agencies.....	I-2
II - DESCRIPTION OF PROJECT		
2-01	Location.....	II-1
2-02	Purpose	II-1
2-03	Physical Components	II-1
2-04	Related Control Facilities	II-7
2-05	Real Estate.....	II-8
2-06	Public Facilities.	II-8
III - HISTORY OF PROJECT		
3-01	Authorization	III-1
3-02	Planning and Design	III-4
3-03	Construction.....	III-4
3-04	Related Projects.....	III-6
3-05	Modifications to Regulations.....	III-15
3-06	Principal Regulation Problems	III-19

TABLE OF CONTENTS (Cont'd)

Paragraph	Subject	Page
IV - WATERSHED CHARACTERISTICS		
4-01	General Characteristics	IV-1
4-02	Topography	IV-1
4-03	Geology and Soils	IV-4
4-04	Sediment	IV-5
4-05	Climate	IV-6
4-06	Storms and Floods	IV-10
4-07	Runoff Characteristics	IV-13
4-08	Water Quality	IV-13
4-09	Channel and Floodway Characteristics	IV-14
4-10	Economic Data	IV-21
V - DATA COLLECTION AND COMMUNICATION NETWORKS		
5-01	Hydrometeorological Networks	V-1
5-02	Water Quality Stations	V-2
5-03	Sediment Stations	V-2
5-04	Recording Hydrologic Data	V-3
5-05	Communication Network	V-3
5-06	Communication with Project	V-4
5-07	Project Reporting Instructions	V-4
5-08	Warnings	V-5
VI - HYDROLOGIC FORECASTS		
6-01	General	VI-1
6-02	Flood Condition Forecasts	VI-1
6-03	Conservation Purpose Forecasts	VI-3
6-04	Long Range Forecasts	VI-4
VII - WATER CONTROL PLAN		
7-01	General Objectives	VII-1
7-02	Major Constraints	VII-1
7-03	Overall Plan for Water Control	VII-2
7-04	Standing Instructions to Damtender	VII-2
7-05	Flood Control	VII-3
7-06	Recreation	VII-6
7-07	Water Quality	VII-6
7-08	Fish and Wildlife	VII-6
7-09	Water Supply	VII-6
7-10	Hydroelectric Power	VII-7

TABLE OF CONTENTS (Cont'd)

Paragraph	Subject	Page
VII - WATER CONTROL PLAN (Cont'd)		
7-11	Navigation	VII-8
7-12	Deviation from Normal Regulation	VII-8
7-13	Rate of Release Change	VII-9
VIII - EFFECT OF WATER CONTROL PLAN		
8-01	General	VIII-1
8-02	Flood Control	VIII-2
8-03	Recreation	VIII-3
8-04	Water Quality	VIII-3
8-05	Fish and Wildlife	VIII-4
8-06	Water Supply	VIII-5
8-07	Hydroelectric Power	VIII-6
8-08	Navigation	VIII-6
8-09	Frequencies	VIII-7
8-10	Other Studies	VIII-7
IX - WATER CONTROL MANAGEMENT		
9-01	Responsibilities and Organization	IX-1
9-02	Interagency Coordination	IX-2
9-03	Interagency Agreements	IX-3
9-04	Commissions, River Authorities, Compacts, and Committees	IX-3
9-05	Other Related Reports	IX-3

LIST OF FIGURES

Figure No.	Subject	Page
1	Colorado River Reservoir System Storage	III-18
2	Principal Physiographic Features of the Colorado River Basin	IV-2
3	Mean Monthly Flows on the Colorado River below Hoover Dam	VIII-1

LIST OF TABLES

Table No.	Subject	Page
1	Related Manuals and Reports	I-2
2	Minimum Flood Control Space Required Under Historic Flood Operation Plans	III-15
3	Average Monthly Meteorological Variables for Selected Stations	IV-7
4	Selected Large Rain Floods, Colorado River Near Grand Canyon, Arizona	IV-12

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES (Cont'd)

Table No.	Subject	Page
5	Net Average Monthly Diversions From the Lower Colorado River	IV-14
6	Flow-Damage Values, Lower Colorado River	IV-15
7	Lower Colorado River Annual Consumptive Uses, 1971-75	VIII-5
8	Major Acreages Irrigated, Colorado River Below Hoover Dam	VIII-6
9	Maximum Monthly Discharge in Selected Reaches.....	VIII-7
10	List of Reports on Channel and Floodway Improvements by the US Bureau of Reclamation	VIII-8

LIST OF PLATES

Plate No.	Subject
1	Colorado River Basin Location Map
2	Lake Mead Area Map
3	Hoover Dam Plans, Profiles, and Sections
4	Lake Mead Area and Capacity Curves
5	Lake Mead Area and Capacity Tables
6	Pictorial of Outlet Works, Spillways, and Turbines
7	Outlets and Powerplant Discharge Rating Curves
8	Spillway Discharge Rating Curves
9	Characteristics of Major Storage Projects Colorado River Basin
10	Topography and Stream Gaging Stations Map
11	Colorado River and Major Tributaries Streambed Profiles
12	Colorado River Delta Map and Cross-Sections
13	Normal Annual Precipitation and Key Precipitation and Snow Survey Stations Map
14	Historic Monthly Estimated Natural Flows, Colorado River at Lees Ferry
15	Regulated Monthly Lake Mead Historic Inflows Adjusted to 1980 Conditions
16	Volume-Frequency Curves, Colorado River at Lees Ferry Natural Flows
17	Historic Annual Peak Inflows to Lake Mead
18	Upper Colorado River System Diagram
19	Lower Colorado River System Map and Diagram
20	Diagram of Channels and Diversion Works, Imperial Dam to Moreles Dam
21	Colorado River Delta Tidal Sand Bar
22	Important Telephone Numbers
23	Sample Snowmelt Runoff Forecast Bulletin
24	Routings of Hypothetical Rain Floods
25	Routings of Historical and Hypothetical Snowmelt Floods
26	Volume-Frequency Curves, Colorado River Downstream from Hoover Dam

TABLE OF CONTENTS (Cont'd)

LIST OF PLATES (Cont'd)

Plate No.	Subject
27	Lake Mead and Lake Powell Plots of Historical Operation
28	Hoover Dam Typical Power Generation Patterns

LIST OF EXHIBITS

Exhibit No.	Subject
A	Flood Control Regulations
B	Code of Federal Regulations Title 33, Par. 208.11
C	Summary of Colorado River Water Law
D	Pertinent Data, Glen Canyon Dam and Lake Powell

ABBREVIATIONS USED

ac-ft, a-f	acre-feet
cfs	cubic feet per second
COE	Corps of Engineers
DWP	Los Angeles Department of Water and Power
FWS	Fish and Wildlife Service
IBWC	International Boundary and Water Commission
LAD	Los Angeles District, Corps of Engineers
MWD	The Metropolitan Water District
NPS	National Park Service
NWS	National Weather Service
CBRFC	Colorado Basin River Forecasting Center, National Weather Service
SCS	Soil Conservation Service
USGS	US Geological Survey
USBR	US Bureau of Reclamation
WAPA	Western Area Power Administration
P/M	Parts per million
MAF	Million acre-feet

I - INTRODUCTION

1-01. AUTHORIZATION

The Hoover Dam and Lake Mead Water Control Manual was prepared in compliance with the following directives: EC 1110-2-208, ER 1110-2-241, EM 1110-2-3600, and ETL 1110-2-251.

1-02. PURPOSE AND SCOPE

The water control manual is prepared pursuant to requirements set forth in the Code of Federal Regulations, Title 33, Part 208.11, subparagraph d-4, entitled "Water Control Plan and Manual." These regulations are reprinted in Exhibit B. This manual provides a detailed plan for regulation of Hoover Dam and Lake Mead on the Colorado River for flood control. Hoover Dam is located about 28 miles southeast of Las Vegas, Nevada. The flood control regulations contained in this manual are based on a review study conducted jointly by the Lower Colorado Region, U.S. Bureau of Reclamation (USBR) and the Los Angeles District Corps of Engineers (COE) during the period 1977 through 1982. The results of study and selection process for the current flood control regulation are presented in the report entitled "Colorado River Basin, Hoover Dam, Review of Flood Control Regulations by the COE." These regulations are part of a coordinated comprehensive plan for regulation of all water resources projects in the Colorado River Basin. Physical characteristics and hydrologic analyses of the Colorado River Basin above the dam are described. Hoover Dam and appurtenant structures are detailed.

Broader emergency operations in flooding situations pertaining to Hoover Dam, such as those related to failure, partial failure, or malfunction of upstream storage structures, fall within the responsibilities of the Secretary of the Interior and as such are not evaluated within the scope of this Water Control Manual.

1-03. RELATED MANUALS AND REPORTS

Manuals and reports with data relevant to the regulations in this manual are listed in Table 1.

1-04. PROJECT OWNER

Hoover Dam and Lake Mead are under the jurisdiction of the U. S. Bureau of Reclamation (USBR). The Lake Mead National Recreation Area is administered by the National Park Service.

1-05. OPERATING AGENCIES

a. USBR is responsible for the operation and maintenance of the dam, reservoir (excluding recreational facilities), intake and outlet works, and powerplant (except power generating units).

b. The recreational features of Lake Mead and adjacent land - part of the Lake Mead National Recreation Area are managed by the National Park Service.

TABLE 1 RELATED MANUALS AND REPORTS

1. U.S. Army Engineer District, Los Angeles Corps of Engineers, "Reservoir Regulation Manual For Flood Control Storage at Hoover Dam and Reservoir (Lake Mead), Colorado River Basin," revised date June 1957.
2. U.S. Army Engineer District, Los Angeles Corps of Engineers, "Report on Reservoir Regulation For Flood Control Storage at Hoover Dam and Lake Mead," revised date November 1968.
3. U.S. Army Corps of Engineers, Los Angeles District - Lower Colorado Region, U.S. Bureau of Reclamation, "Colorado River Basin, Hoover Dam, Review of Flood Control," 1982,
4. U.S. Army Engineer District, Los Angeles Corps of Engineers, "Reservoir Regulation Manual For Painted Rock Reservoir," June 1962.
5. U.S. Army Engineer District, Los Angeles Corps of Engineers, "Reservoir Regulation Manual For Alamo Lake," revised date April 1973.
6. US. Bureau of Reclamation Region 3, "Definite Plan Report, Colorado River Front Work and Levee System, Imperial Dam Division, Senator Wash Unit, California," December 1963.
7. U.S. Bureau of Reclamation Region 3, "Flood Plain Information, Colorado River, Davis Dam to Topock," March 1969.
8. U.S. Bureau of Reclamation Region 3 Status Report, "The Laguna Settling Basin," February 1971.
9. U.S. Bureau of Reclamation Region 3 Status Report, "Lower Colorado River Management and Phreatophyte Programs," March 1971.
10. U.S. Bureau of Reclamation Region 3, "Flood Plain Information, Colorado River, Parker Dam to Headgate Rock Dam," July 1971.
11. U.S. Bureau of Reclamation Region 3, "Flood Plain Information, Colorado River, Imperial Dam to San Luis," August 1973.
12. U.S. Bureau of Reclamation Status Report, "Colorado River Water Quality Improvement Program," January 1974.
13. U.S. Bureau of Reclamation, "Flood Plain Information, Colorado River, Palo Verde Dam to Imperial Dam," October 1974.
14. U.S. Bureau of Reclamation, "Report On: River Control Work and Investigations, Lower Colorado River Basin, 1974-1975," December 1976.
15. U.S. Bureau of Reclamation Status Report, "Colorado River Basin Salinity Control Project, Title I Division Desalting Complex Unit, Arizona," April 1977.
16. U.S. Department of Interior Progress Report No. 10, "Quality of Water Colorado River Basin," January 1981.
17. U.S. Bureau of Reclamation, "Annual Report, Operation of Colorado River Basin and Projected Operations," yearly.

c. The Southern California Edison Company and the City of Los Angeles Department of Water and Power operate and maintain the power generating units in conformance with monthly reservoir release objectives established by USBR and the power requirements of energy contractors. Starting in 1987, the Federal Government proposes to consolidate powerplant operations for Hoover, Davis and Parker Dams.

1-06. REGULATING AGENCIES

a. USBR plans and regulates the comprehensive operation of Hoover Dam and Lake Mead, the cornerstone of the Lower Colorado River reservoir system.

b. The Corps of Engineers (COE) is responsible for developing the flood control operation plan for Hoover Dam and Lake Mead. The plan is the result of a coordinated effort by COE and USBR, but COE is responsible for providing the flood control regulations (operating criteria) and has authority for final approval. Any deviation from the flood control operating instructions must be authorized by COE.

c. The National Park Service is responsible for regulating and administering recreation programs and facilities at Lake Mead.

II - DESCRIPTION OF PROJECT

2-01. LOCATION

Hoover Dam is situated on the Colorado River about 350 miles upstream from the Mexican border and 28 miles southeast of Las Vegas, Nevada. Spanning Black Canyon, it has one abutment in Mohave County, Arizona, and the other in Clark County, Nevada. The location of Hoover Dam and Lake Mead is shown on Plates 1 and 2. Hoover Dam can be reached from Las Vegas by using U.S. Highway 93 which crosses over the dam.

2-02. PURPOSE

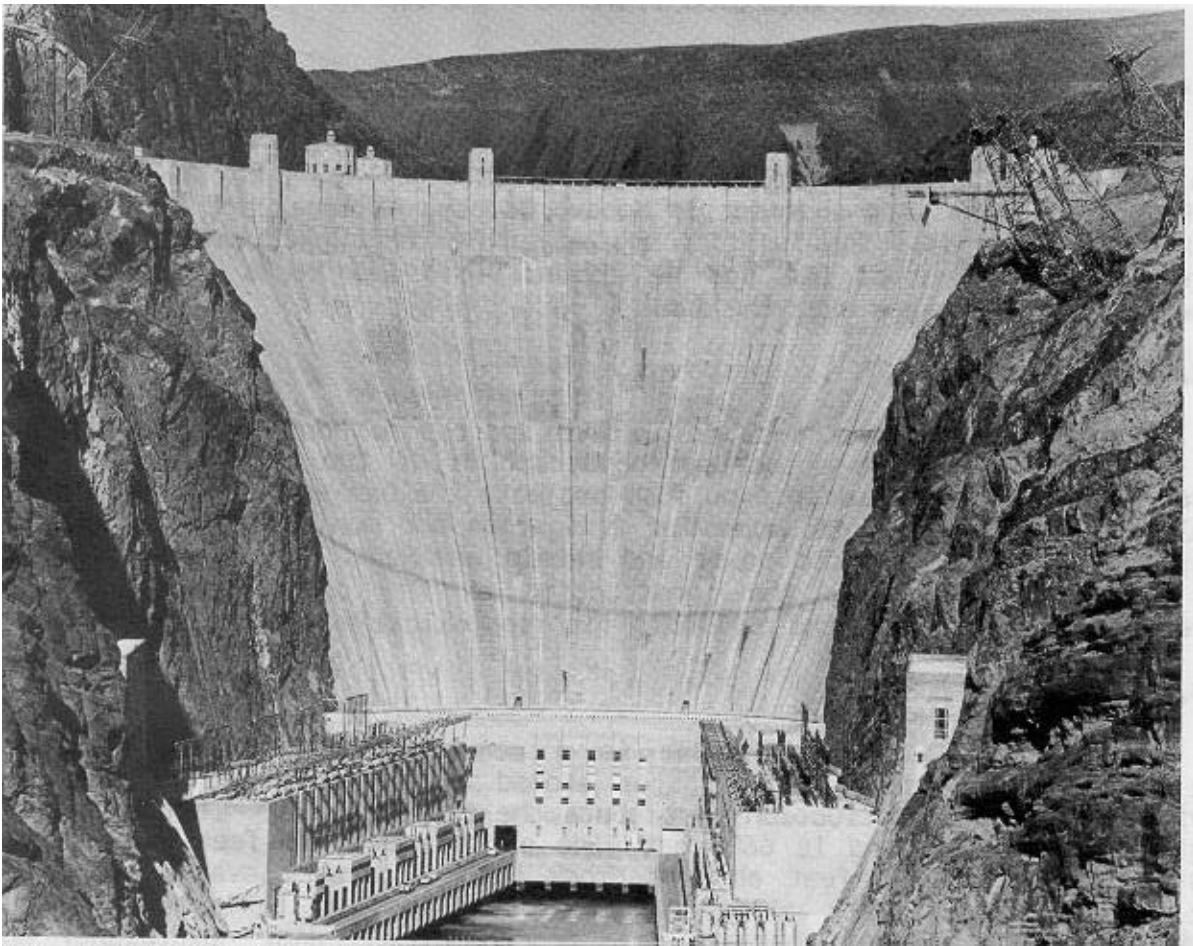
Hoover Dam and Lake Mead were authorized by the Boulder Canyon Project Act of 1928, which also authorized construction of the All American Canal System. Designed as a multiple purpose project, the Dam and Lake controls and regulate flood flows; store water for irrigation and municipal and industrial uses; generate hydroelectric power and retain sediment. Incidental purposes that have developed from the construction of the dam include providing recreation opportunities; and enhancing fish and wildlife habitat.

2-03. PHYSICAL COMPONENTS

a. Hoover Dam. Hoover Dam is a concrete, gravity-arch structure that counters the force of the water stored behind it with the force of gravity and arched construction that abuts the canyon walls, It has a crest length of 1,244 feet and is 660 feet wide at the base, 45 feet wide at the crest, -and rises 726.4 feet above bedrock with a crest elevation of 1,232 feet. It is the highest concrete dam in the western hemisphere. About 4,400,000 cubic yards of concrete were placed in the dam, powerplant, and appurtenant structures - the dam alone required about 3,250,000 cubic yards. Plans, elevations, and sections are shown on Plate 3. See Plate 2 for a general map of Hoover Dam and Lake Mead.

b. Lake Mead. Lake Mead is the largest manmade reservoir in the United States. At the top of the flood control pool (elevation 1,229 feet), it has a gross capacity, including dead storage, of 29,755,000 acre-feet, extends along the Colorado River for about 115 miles and along the Virgin River from its submerged mouth for about 35 miles, has a surface area of about 162,700 acres or 254 square miles, and has a maximum depth of 507.6 feet. The lake varies in width from several hundred feet in canyon areas to about 8 miles in its lower reaches and has a shoreline of about 825 miles. Adjacent topography is a contrast between steep, high-walled canyons and open, lakeside land that transitions to rugged, rolling hills. Area-capacity curves for Lake Mead are shown on Plate 4. Areas and capacities for specific elevations at one foot increments are tabulated on Plate 5.

c. Project Features. The four major features of Hoover Dam are the dam itself, the powerplant, the outlet works, and the spillway. The powerplant houses the generators (turbines) which produce electric power concurrently with regular lake releases for flood control and water supply purposes. The outlet works can function independently from the powerplant operations. Therefore, releases of Lake Mead water can be made for flood control and water supply purposes without generating power. However, it is not expected that the powerplant will ever have to be completely shut

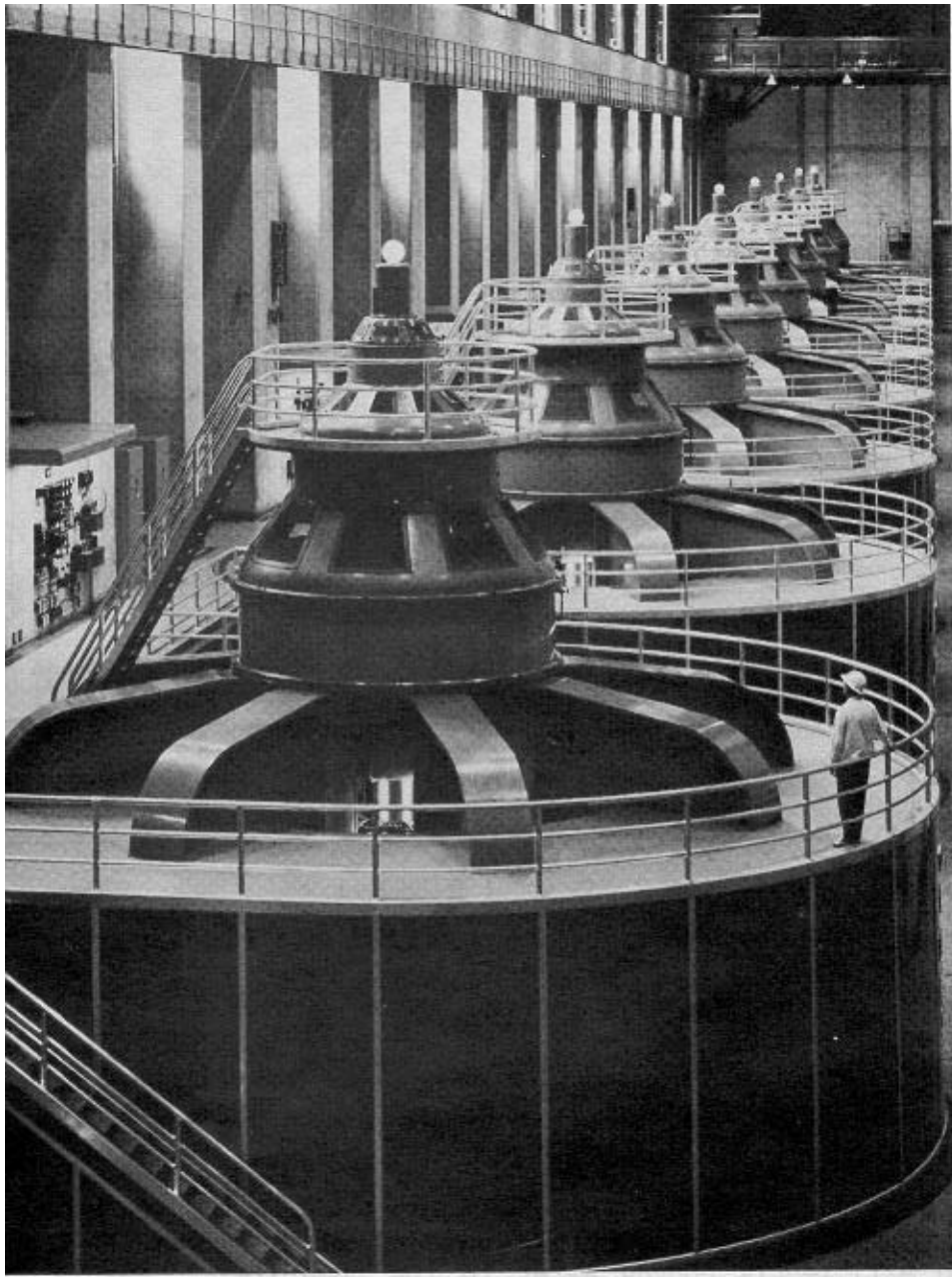


Hoover Dam

Downstream Face Showing Powerplant

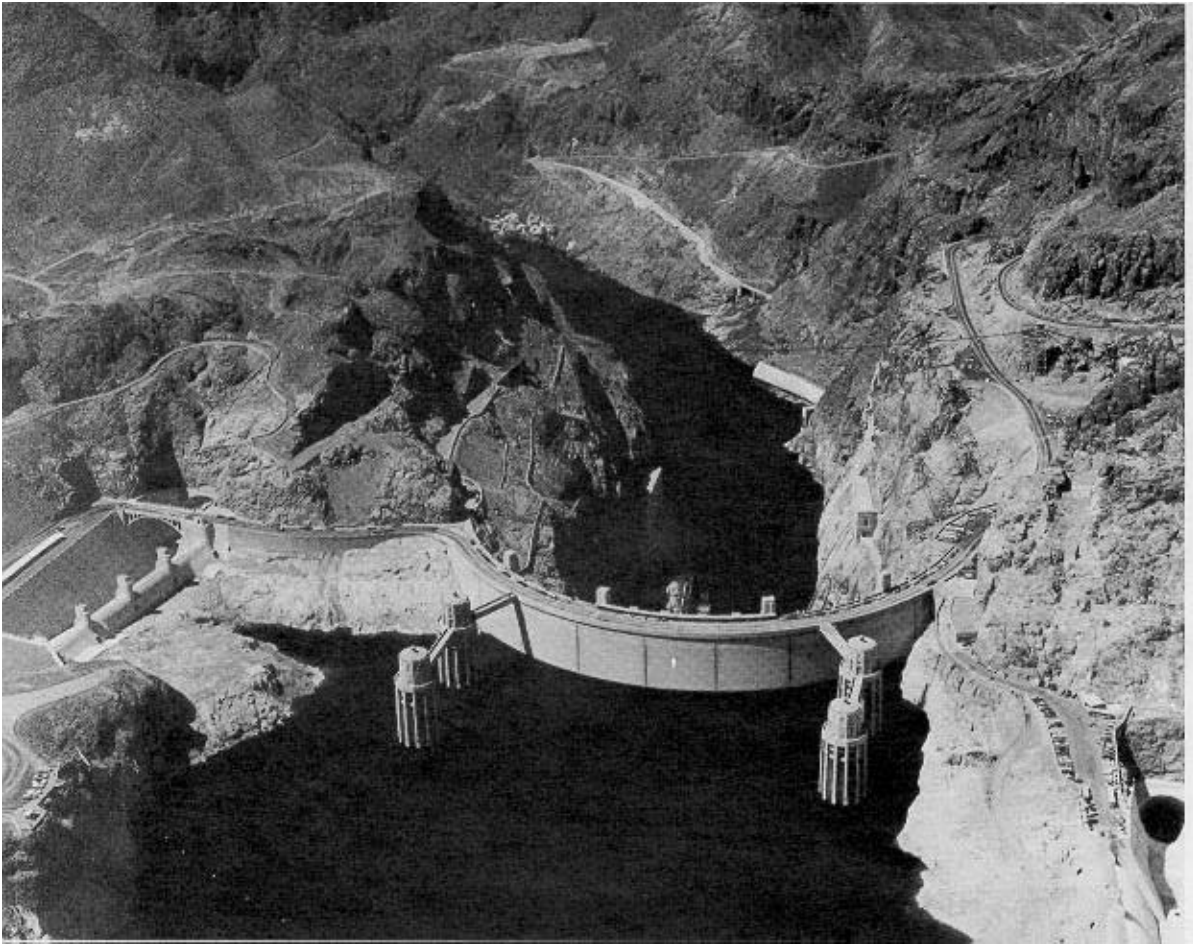
down. The spillways have the capability to release flows up to the maximum expected inflows in order to prevent overtopping of the dam if maximum inflows occur when the lake is full. An illustration of these features is shown on Plate 6.

(1) The powerplant is a "U" shaped building located at the toe of Hoover Dam and is one of the largest hydroelectric producers in the world. It houses 17 main units (turbines) that have a combined rated capacity of 1,850,000 horsepower and 1,340,000 kilowatts. Additionally, there are 2 station-service units, each rated at 3,500 horsepower and 2,400 kilowatts, thus increasing the total horsepower and kilowatts to 1,857,000 and 1,344,800, respectively. Nine of the main units are located in the Arizona wing and eight main units are in the Nevada wing, as shown on Plates 3 and 6. Water is delivered to the units through sixteen 13-foot diameter steel power-penstocks, eight for each wing. Four 30-foot diameter steel conduits, each originating at one of the intake towers, transfer water to the penstocks. Each 30-foot conduit services either four or five 13-foot penstocks. (See illustration on Plate 6). A rating curve for the powerplant is presented on Plate 7.



Generators

(2) The outlet works begin at the four reinforced concrete intake towers which are located immediately upstream from the dam. Two towers are near each abutment and are about 165 feet apart and parallel to the river. Each tower is 395 feet high, 82 feet in diameter at the base tapering to 63 feet 3 inches at the hoist house floor. Two cylindrical gates 32 feet in diameter and 11 feet high are located in each tower to control inflow. One gate is at elevation 895 feet near the bottom and the other is at elevation 1,045 feet near the middle. Each gate inlet is protected by a trashrack.

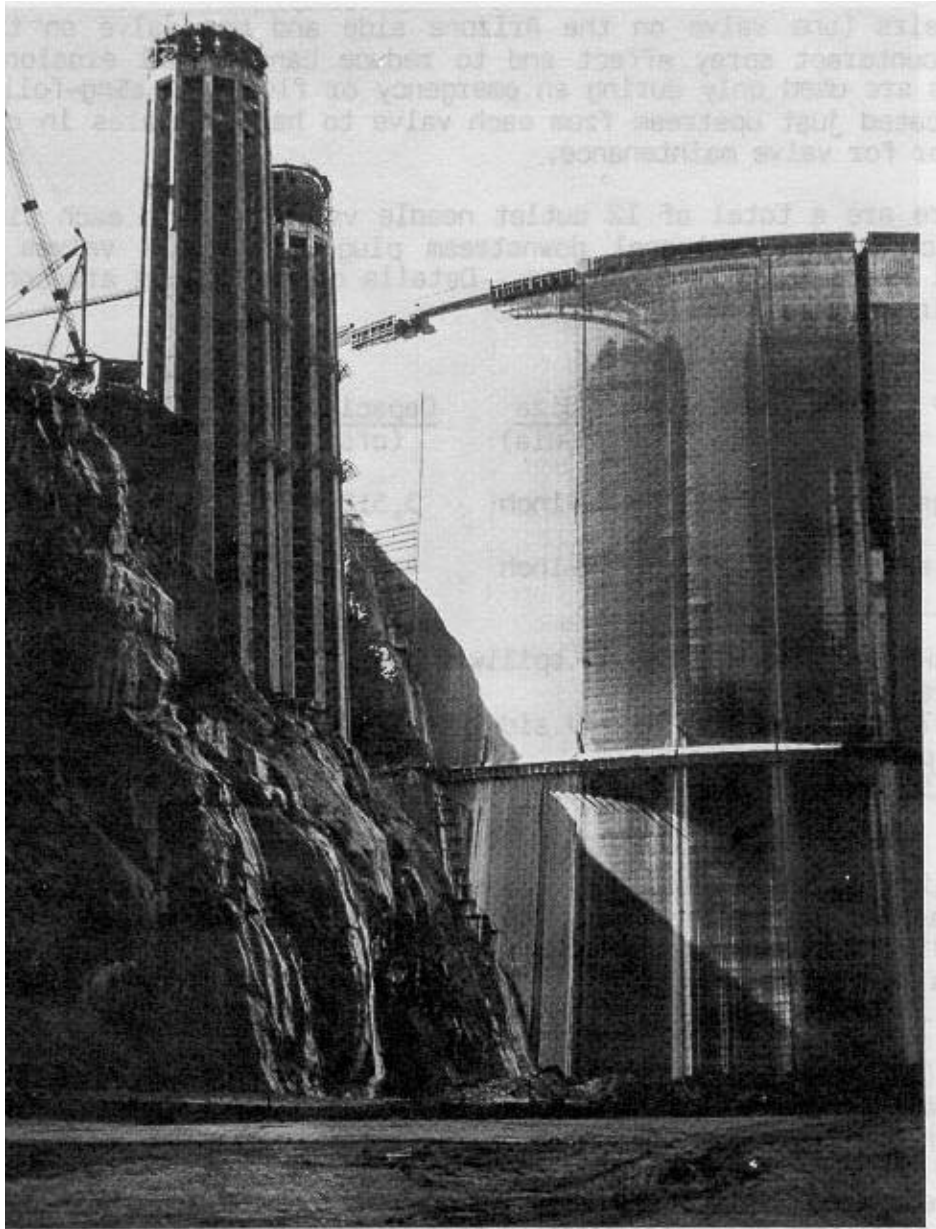


Hoover Dam

Upstream Site Showing
Spillways and Intake Towers

Plates 3 and 6 illustrate the project's complex outlet-conduit and valve system. Steel lined conduits installed within concrete lined tunnels are used to efficiently convey water to the powerplant. Needle valves are available to bypass the powerplant. Tunnels extend nearly a half mile from intake towers to exit portals. Thirty-foot diameter conduits (within 37-foot diameter tunnels) lead from each of four intake towers to separate penstock manifolds. The power penstocks are 13-foot diameter conduits inclosed in 18-foot diameter tunnels.

The inner two of the four 50-foot diameter tunnels, originally used to divert riverflow during construction, supply two of the manifolds. Each of these diversion tunnels contain two concrete plugs. The upstream plugs seal the original diversion route and are located just upstream of the juncture of the 37- and 50-foot diameter tunnels. The downstream plugs which each house four 72-inch needle valves are midway between the penstocks and the river outlet portal. These tunnel valves are operated in pairs to maintain hydraulic symmetry minimizing tunnel erosion. Each unlined diversion tunnel



Hoover Dam

Upstream Face Showing Intake Towers

extends downstream from the plug-valve assembly to a rectangular stoney gate that is 50-feet wide by 35-feet high. The stoney gates can be closed to prevent backwater from entering the tunnel during maintenance.

The two intake towers closest to the dam direct flow to the two remaining penstock manifolds and to the canyon wall outlets. The canyon wall outlets include 8-1/2-foot diameter conduits inclosed in 11-foot diameter tunnels leading to 84-inch needle valves. The canyon wall valves operate in

opposing pairs (one valve on the Arizona side and one valve on the Nevada side) to counteract spray effect and to reduce canyon wall erosion. Canyon wall valves are used only during an emergency or flood. A ring-follower type gate is located just upstream from each valve to halt releases in case of an emergency or for valve maintenance.

There are a total of 12 outlet needle valves - 6 on each side of the river. Each diversion tunnel downstream plug contains 4 valves and each canyon wall valve house has 2 valves. Details of the valves are contained in the following tabulation.

<u>Valve Location</u>	<u>Quantity</u>	<u>Size (dia)</u>	<u>Capacity 1/ (cfs)</u>	<u>Elevation 2/ (ft, MSL)</u>
Tunnel Plugs <u>3/</u>	8	72-inch	3,512.5	653.88 (Nevada Side) 652.92 (Arizona Side)
Canyon Walls <u>4/</u>	4	84-inch	4,000.0	820 ft

1/ With lake elevation at top of spillway gate.

2/ At centerline of valve.

3/ About 470 (AZ side) and 41 (NV side) feet upstream from inner diversion tunnel portal.

4/ About 150 feet above streambed.

Originally there were 23 valves, but 11 were removed because their capacity was no longer required. Two 72-inch diameter valves were removed from each diversion tunnel downstream plug, four 84-inch diameter valves from the Arizona canyon wall, and three 84-inch diameter valves from the Nevada canyon wall. Rating curves for the outlets are presented on Plate 7.

(3) There are two spillways - one on each side of the river. Spillway rating curves are shown on Plate 8. The spillways begin with concrete-lined, two-sided channels with the river side formed into an ogee-shaped crest. The channels are about 650 feet long, 150 feet wide, and 170 feet deep, with walls 1-1/2 feet thick and floors 2 feet thick. Water is discharged from the channels into 50-foot diameter, 600-foot long inclined tunnels that connect with the 50-foot diameter outer diversion tunnels that extend to the river. The diversion tunnels previously used to divert riverflow during construction now contain concrete plugs just upstream from where they intersect with the inclined tunnels.

The fixed spillway crest elevation is 1,205.4 feet. Each spillway crest has 4 drum gates, 100 feet long and 16 feet high, which operate semi-automatically to control discharge. The gates are hollow and watertight and float in a sealed gate chamber. The chamber is connected with Lake Mead: the level of water in the chamber is controlled by the level of Lake Mead, and the rate of inflow of water to the chamber is controlled by a valve. The gates are lowered by closing the intake valve and opening the valve on the gate chamber draining system.

With the gates lowered and the lake at an elevation equivalent to the top of the gates in the raised position (about elevation 1221.4 feet), total discharge capacity of the spillways is

184,000 cfs. With the lake at the maximum design elevation 1,229 feet and the gates in the lowered position, up to 400,000 cfs can be discharged.



Hoover Dam

View From the Arizona Side

2-04. RELATED CONTROL FACILITIES

Parker Dam, the Colorado River Aqueduct, the All American Canal and Imperial Dam were all constructed in conjunction with Hoover Dam to develop an effective water supply system. These and other related projects are further described in Section 3-04.

Operations of the powerplants at Davis and Parker Dams, 67 and 155 miles, respectively, downstream from Hoover Dam, are integrated with the powerplant operations at Hoover Dam. A consolidated power transmission system extends from the dams into various communities in Arizona, California and Nevada. Electrical marketing and transmission responsibilities for these projects were transferred to the U.S. Department of Energy, Western Area

Power Administration. Combined administration of the dam's power is under the jurisdiction of the Department of Interior's Lower Colorado Dams Project Office.

2-05. REAL ESTATE ACQUISITION

Hoover Dam and Lake Mead Project Lands comprise 182,700 acres (285 square miles).

2-06. PUBLIC FACILITIES

The authorizing document for Hoover Dam (the Boulder Canyon Project Act) did not include recreation as a project purpose; thus there is no designated recreation pool for Lake Mead. However, under a 1936 agreement between the Bureau of Reclamation and the National Park Service, a recreation area was formed. This agreement was amplified by the Congress October 8, 1964, in Public Law 88-639 which gave the National Park Service the direct administration of the area for recreational purposes. The Lake Mead National Recreation Area includes Lake Mead, which extends 115 miles upstream from Hoover Dam into the lower end of Grand Canyon; Lake Mohave, which extends from the tailrace of Hoover Dam 67 miles downstream to Davis Dam; a short stretch of the Colorado River below Davis Dam and adjacent lands surrounding Lakes Mead and Mohave. Plate 2 shows the locations of major recreation facilities and boundaries of the Lake Mead National Recreation Area.

Recreation opportunities, some on a year-round basis, are available at various locations in the Lake Mead National Recreation Area. Included in the comprehensive recreation plan are marinas, boat launching ramps, camp sites, access roads, parking areas, beaches, and picnic areas. Some of the more popular recreation activities are swimming, water skiing, boating, and fishing.

Following a 1959 Memorandum of Understanding among the USBR, the National Park Service, and the Fish and Wildlife Service, a trout fish hatchery was constructed at Willow Beach, Arizona, about 15 miles below Hoover Dam. The installation covers almost 48 acres and provides trout stock for the entire lower Colorado River.

The Nevada Department of Fish and Game began operating its Lake Mead fish hatchery in 1973. The facility is located on the Nevada shore of Boulder Basin near Saddle Island and stocks Lake Mead with trout.

Guided tours of Hoover Dam and its powerplant are conducted daily by USBR personnel. Also open to the public is an exhibit building.

III - HISTORY OF PROJECT

3-01. AUTHORIZATION

a. History Of Problems. Early explorers recognized the possibilities of using water from the lower Colorado River to irrigate the rich and fertile lands in Southern California's Imperial Valley, but development did not begin until the 1890's. In 1896, the California Development Company, a privately owned enterprise, began construction of irrigation canals. In 1901, the first Colorado River water reached Imperial Valley fields, flowing through a canal which looped through Mexico for about 60 miles and followed the course of the Alamo River, one of the Colorado River's old overflow channels.

The early irrigation development encountered enormous difficulties due to the prominent characteristics of the natural flow of the lower Colorado: extreme variability of flows, inopportune timing of high flows, and high rates of sediment deposition.

In the late spring, the melting snows frequently caused the river to overflow its banks and inundate large areas of the surrounding flat terrain. During fall and winter, the predominating low flows were punctuated by flash rain floods on the lower Colorado and its tributaries. The irregularities of flows forced expensive adaptive measures by the irrigators. For high flows, the irrigators built expensive headworks and protective levees which themselves could be destroyed during the highest flows. Low flows required special diversion measures and limited the area of land that could be irrigated.

The immense quantity of sediment carried by the river during floods was deposited in irrigation canals where it created serious problems for water delivery and maintenance.

In 1905, a combination of sedimentation, off-season flash floods, and the normal seasonal spring high water caused the Colorado to overflow into the Imperial Valley's Salton Sink, creating the Salton Sea as it is known today. The overflow persisted for about 16 months and created havoc in the Imperial Valley. Finally, the Southern Pacific Railroad, which was forced to move its tracks to higher ground, helped with its resources and engineering skill and made the final closures which re-directed the river into its normal channels to the Gulf of California. However, problems continued because the Colorado's natural regimen through the delta had been upset during the time it was flooding Imperial Valley, and the river threatened to overflow into the Imperial Valley again. Controlling the river required more and more effort, levees and expense without complete success.

b. Development of a Solution. Several sites in the Colorado Basin were initially considered by Bureau of Reclamation engineers in solving the flood and water supply problems, but it was readily apparent that the most desirable dam sites were those with as much storage as possible as close to the problem area as possible in order to store and control the maximum quantities of basin runoff. Two excellent lower basin sites were found -Boulder Canyon and Black Canyon (also known as Lower Boulder Canyon). Each offered potential reservoir capacity of over 30,000,000 acre-feet, although both sites posed some unprecedented engineering problems.

In 1918 the United States Department of the Interior and the Imperial Irrigation District, successor to the California Development Company in the Imperial Valley, entered into an agreement providing for investigations, surveys, and cost estimates on the construction of a canal extending from the Colorado River to the Imperial Valley and lying wholly within the boundaries of this country. The surveys were to follow a general plan agreed upon by a joint board consisting of one representative each of the Government, the District, and the University of California.

The All-American Canal Board, appointed under this agreement, submitted its report during the summer of 1919. On the basis of its findings it recommended construction of an all-American canal and provision of large storage reservoirs on the Colorado River by the United States Government.

The first All-American Canal bill -- often spoken of as the first Kettner bill -- was introduced in Congress about the time the All-American Canal Board submitted its report, but the bill never came to a vote as the Congress was not satisfied with available data.

The Kinkaid Act authorizing and directing the Secretary of the Interior to make an examination and report on the condition and possible irrigation development of the Imperial Valley was passed in May 1920. Approximately one-half of the cost of this examination and investigation was paid by the United States and the other half by local interests.

In 1921 Arthur P. Davis, then director of Reclamation, reported to Secretary of the Interior Albert B. Fall on the results of the Colorado River investigations. Shortly thereafter in February 1922 the "Fall-Davis Report," recommending that the Government undertake construction of the All American Canal and a high dam at or near Boulder Canyon on the Colorado, was transmitted to the United States Senate.

Intensified investigations, including geologic and topographic surveys started in 1919, revealed the superiority of Black Canyon over Boulder Canyon in several respects. The depth to bedrock was less in Black Canyon, the geologic structure was better, and a dam of lesser height would give the same reservoir capacity.

From 1920 through 1923, workers drilled and tested the properties of the rock formations of Black Canyon to assure the suitability to support a dam.

In 1924 Reclamation's chief engineer, F. E. Weymouth, submitted eight volumes of precise data to the Secretary of Interior. This "Weymouth Report," which represented 2 additional years' work under the Kinkaid Act, emphasized the feasibility of a dam at either the Boulder or Black Canyon site in the lower basin.

Then the Senate Committee on Irrigation and Reclamation, in its report of March 1928, agreed that "The overwhelming weight of opinion favors the Boulder or Black Canyon site. These two sites are close together and are frequently termed the upper and lower Boulder Canyon sites. A dam at either site will inundate practically the same territory. Natural conditions at this site are extremely favorable for the construction of a great dam at a minimum cost." A board of consulting engineers also reviewed the feasibilities of these two sites and agreed with the Bureau of Reclamation that Black Canyon was the better choice.

Several legislative problems had to be solved. The most difficult legislative aspect had to do with equitable division of the water of the Colorado, for the people who lived in the basin were dependent on this water.

In 1920 a meeting of representatives of the governors of the Basin states had endorsed the proposal for an interstate compact. The Wyoming Legislature authorized the appointment of a compact commissioner in February 1921. Arizona followed, and before the middle of the year all of the states had provided for such appointments. Following authorization by an act of Congress, President Harding on December 17, 1921, appointed a Federal representative to the commission -- Herbert Hoover, then Secretary of Commerce. A little over a month later, on January 26, 1922, the Colorado River Commission held its first meeting in Washington, D.C., and elected Mr. Hoover as its presiding officer.

The first idea was to devise a compact that would divide the water among the individual states, but agreement on this proposition was impossible. Then Herbert Hoover proposed a big forward step that did clear the way to agreement. Known as the Hoover Compromise, it provided that the water would be apportioned to two groups, the upper and the lower basin states; and the division of water between the individual states would be left to future agreement.

The compact was signed by the members of the Commission on November 24, 1922, at Santa Fe, New Mexico, and is often referred to as the Santa Fe Compact. Ratification by the legislatures of the basin states and the United States followed over a period of years. The basic provisions of this agreement are described in Exhibit C.

c. Final Authorization. A bill authorizing the construction of Hoover Dam was first introduced in Congress in 1922 by Senator Hiram W. Johnson of California and Congressman Philip D. Swing of California in 1922. The project was finally authorized with the fourth Swing-Johnson Bill (the Boulder Canyon Project Act) which became law on December 21, 1928, when it was signed by President Coolidge. As passed, the Boulder Canyon Project Act:

Approved the Colorado River Compact and provided that in the event only six states should ratify, the compact should become effective as a six-state compact, provided that California should agree to limit its use of water for the benefit of the other six states;

Authorized the construction of a dam at Black Canyon or Boulder Canyon;

Authorized construction of an All-American Canal system connecting the Imperial and Coachella Valleys with the Colorado River; and

Authorized \$165 million for construction of the entire project.

Authorization of the project listed the following purposes: flood control; improvement of navigation and regulation of the flow of the Colorado River; storage and delivery of stored waters of the Colorado River for reclamation of public lands and other beneficial uses exclusively within the United States; and generation of electrical energy.

The act established a special fund -- the "Colorado River Dam Fund" -- for financing construction and authorized the transfer to it from the Treasury of \$165 million. A condition

precedent to the construction of the dam was that the Secretary of the Interior should provide for revenues adequate to ensure operation, maintenance, and amortization. These revenues were to repay, within 50 years, all advances for construction of Hoover Dam and powerplant with interest, except for \$25 million allocated to flood control, repayment of which -- without interest -could be deferred until after the interest-bearing portion of the debt was paid, subject to congressional direction. Revenues were to come mainly from the sale of electrical energy generated at the dam. Contracts for the sale of the electrical energy were negotiated soon thereafter.

3-02. PLANNING AND DESIGN

The design and related drawings and specifications of Hoover Dam and appurtenant structures were prepared by the Bureau of Reclamation's design office in Denver, Colorado. In order to create employment in the face of the ongoing depression, the central government in Washington, D.C. ordered an expedited design and specification schedule so that construction could begin as soon as possible. The specifications were completed 6 months ahead of schedule.

3-03. CONSTRUCTION

The labor contract for construction of Hoover Dam was awarded by the Secretary of the Interior in March, 1931, to Six Companies, Incorporated, of San Francisco, California. The bid of \$48,890,995.50 was the largest labor contract awarded by the U. S. Government up to that time.

Six Companies was a joint venture of several major Western Contracting firms: Pacific Bridge Co.; Henry J. Kaiser and W. A. Bechtel; MacDonald and Kahn Co.; Morrison-Knudsen Co.; and J. F. Shea Co. A joint venture of these large companies was necessary for sharing risks and dealing with the enormous problems involved in construction on such a large scale.

a. Preliminary construction. Before work on the dam and related structures could begin, several major problems had to be solved. For one, the site was in a desolate region without adequate transportation connections to sources of materials and equipment. Highway and railroad facilities had to be extended from Las Vegas.

Another problem was providing a labor force -- none existed near the damsite. A complete town -- Boulder City, Nevada -- was developed 7 miles southwest of the damsite to house the labor force. The workers were recruited from all over the country.

The canyon was initially spanned by temporary bridges and aerial cables. A large gravel-screening plant and two large concrete-mixing plants were designed and constructed. An air-compressor plant was built near the site. Electric power was brought in 222 miles across the desert from San Bernardino, California. All logistics problems required careful planning in order to finish the project in time.

b. Construction of Dam. Construction of Hoover Dam required construction of 2 diversion tunnels through the canyon walls on each side, and temporary cofferdams upstream and downstream to isolate the foundation from the river. (The tunnels driven were later

used for spillway discharge and for power penstocks.) The tunnels were started in June, 1931, and completed in November, 1933. Each of the circular tunnels was holed out to a diameter of 56 feet and lined with 3 feet of concrete. The combined length of the tunnels was about 3 miles.

Once the diversion was completed, the foundation was excavated to bedrock on a 24-hour per day schedule. At the same time, loose and unsound rock formations were scaled from the canyon walls at and near the dam abutments. The 3-inch-thick plate steel pipe required for the penstock systems could not be transported to the damsite by rail -- the sections were too large for average railroad tunnels and too heavy for standard railroad cars. For the solution, the contractor -- Babcock and Wilcox -- erected a plant to fabricate the pipe about a mile and a half from the damsite. Flat plates of steel were shipped to the plant, and the penstock sections were fabricated there.

The main job of concrete placement began in June, 1933, when the first bucket of concrete was placed. By February, 1935, construction of the dam, intake towers and outlet works were sufficiently advanced that the upstream portions of the two inner diversion tunnels were plugged with concrete, one of the outer diversion tunnels was blocked with a steel bulkhead gate, and the water began to rise behind the dam for the first time.

Because of the enormous mass of the dam, heat released by the curing of the concrete and shrinkage occurring during curing presented problems. Left alone, the dam would have taken more than a century to lose the heat released during curing. Furthermore, it would have shrunk as it cured, causing cracking throughout the structure. The problems were solved by building the dam in blocks; pipes were embedded in the blocks and cold water was pumped through the pipes. As the blocks cooled and shrank, grout was pumped into the planned gaps between the blocks.

By summer, 1935, all concrete was in place, and President Roosevelt dedicated the project in September. The construction contract had allowed seven years for the job; it was finished in five.

The original power units were installed a few at a time from 1936 through 1961. Since then, several of the generators have been rewound, and new, stainless steel turbine runners installed, and similar modification to other units are planned and in progress.

There is a curious sidelight to the matter of the name of the dam, one that perhaps explains the uncertainty surrounding it over the years: as plans for the dam progressed, the Black Canyon site became more familiarly known as "Boulder Dam," derived from the Boulder Canyon Project Act name. This name would stick, in spite of the fact that in 1930, the dam was named -- by Act of Congress -- "Hoover Dam." Herbert Hoover had been Secretary of Commerce during the planning years of the dam, and it is largely to his credit that the negotiations that preceded the signing of the Colorado River Compact were successful. It is for this reason--not because Hoover was President of the United States at the time of the 1930 act--that the dam was named for him.

When President Roosevelt dedicated the dam in 1935, it has been said that Secretary of State Harold L. Ickes, irked that the then unpopular Hoover was being honored, struck the ex-president's name from the dedication speech and substituted "Boulder." This was the name

that persisted until President Truman in 1947 asked the 80th Congress to find out just what the name of the dam really was. It was found that the legal name was--and always had been--Hoover Dam. This continues to be the official name of the dam, although one name is probably as prevalent as the other in popular usage.

3-04. RELATED PROJECTS

a. Colorado River Storage Project. The Colorado River Storage Project (CRSP) provides for the comprehensive development of the upper Colorado River Basin.^{1/} The project furnishes the long-term storage capacity - about 34 million acre feet total - needed to allow the states in the upper Colorado basin to meet their streamflow delivery obligations at Lee Ferry, as defined in the Colorado River Compact, and still utilize their apportioned share of water.

A portion of the water stored by the project is directly used in the upper basin. In addition, the various project features control sedimentation and flooding, facilitate recreation development, and aid in fish and wildlife conservation. A significant amount of electrical energy is generated to meet the needs of the upper basin and adjacent area. A power transmission system is part of the project.

During periods of low stream flow, water is released from project storage to meet basin needs and compact obligations at Lee Ferry. Diversions from upstream areas may be exchanged for releases from project storage facilities nearer to the lower Colorado basin to meet compact obligations.

The Colorado River Storage Project reservoirs are Flaming Gorge Dam and Reservoir on the Green River in Utah and Wyoming; the Wayne N. Aspinall Unit on the Gunnison River in Colorado, consisting of Blue Mesa, Morrow Point and Crystal Dams and Reservoirs; Navajo Dam and Reservoir on the San Juan River in New Mexico, and Glen Canyon Dam and Lake Powell on the Colorado River in Arizona and Utah. Basic data on these projects are presented in Plate 9, and more detailed data on Glen Canyon Dam and Lake Powell are presented in Exhibit D.

b. Southern Nevada Water Project. The purpose of the Southern Nevada Water Project is to deliver municipal and industrial water from Lake Mead to one of the fastest growing areas in the nation. This area is made up of the Las Vegas Valley Water District, North Las Vegas, Henderson, Boulder City, and Nellis Air Force Base. The first stage of the project has been operational since 1971. Construction of the project's second stage began in June 1977 and went into partial operation in August 1982. The two stages will be capable of delivering annually up to 299,000 acre-feet of Colorado River water, essentially all of Nevada's apportionment. The project is being constructed jointly by the USBR and the State of Nevada.

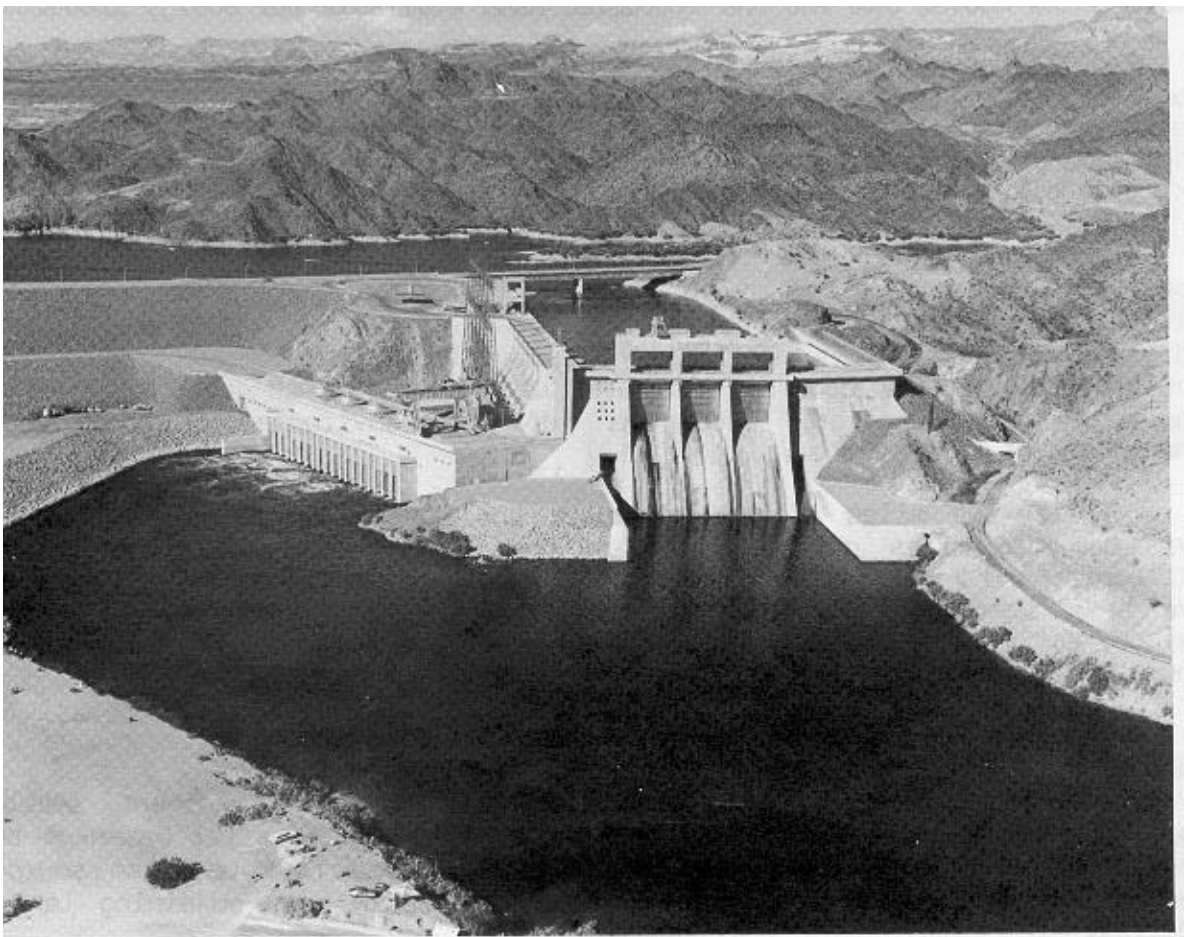
^{1/} The Colorado River Compact provides principally for a division of the available water of the Colorado River system between the "Upper Basin" and the "Lower Basin" at Lee Ferry, which is defined as a point on the Colorado River 1 mile below the mouth of Paria River. The nearest stream gage to this point on the Colorado River is at Lees Ferry, which is above the mouth of the Paria River. Lee Ferry, a few miles below the Arizona-Utah boundary, is a natural point of demarcation.

First stage works consist of the Lake Mead intake facilities, a 3-mile main aqueduct, a 4-mile tunnel through the River Mountains, 8 pumping plants and over 31 miles of pipeline laterals. The intake is at elevation 1,047.

The second stage will enlarge the first stage by expanding some of the existing facilities and by adding five new pumping plants, the second barrel to the main aqueduct, and about 30 miles of new pipeline laterals.

As part of the first stage, the Colorado River Commission of Nevada constructed the Alfred Merritt Smith Water Treatment Facility near Lake Mead. Capacity of this treatment plant is being doubled to 400 million gallons per day to accommodate the additional water through the second stage.

c. Davis Dam Project. The Davis Project was authorized in April 1941. Construction was initiated by the Bureau of Reclamation of 1942, suspended because of World War II, resumed in 1946, and completed in 1953. The Mexican Water Treaty of 1944 required the United States to construct Davis Dam and reservoir. The treaty states that a part of the capacity shall be used to make possible the regulation at the boundary of the waters to be delivered to Mexico. The Davis Dam reservoir (Lake Mohave) is being used for that purpose through integrated operations



Davis Dam

of Hoover and Davis Powerplants. Davis Dam also captures and delays the discharge of flash floods from side washes below Hoover Dam and assists downstream irrigators by partially reregulating river discharges from Hoover. Of the 1,818,000 acre-feet of storage capacity of Lake Mohave, the top 17 feet containing 451,000 acre-feet of storage are normally used for river regulation. In addition, the project generates electric power for Arizona, southern California, and southern Nevada and contributes to reduction of silt pollution, recreation, and waterfowl protection.

Davis Dam is located in Pyramid Canyon 67 river miles below Hoover Dam. The dam is a zoned earthfill structure with a height of 200 feet and a crest length of 1,600 feet. The spillway is a concrete, ogee weir, surmounted by 3 fixed-wheel regulating gates each 50 by 50 feet, with a discharge capacity of 214,000 cfs.

The semioutdoor-type powerplant is located on the Arizona side of the river, immediately downstream from the dam embankment. The forebay is formed by the spillway and intake structures. The powerplant has an installed capacity of 240,000 kilowatts provided by five generators.

Fluctuation in the water level at Lake Mojave influences tailwater levels below Hoover Dam and the hydraulic head available for energy production.

d. Colorado River Front Work and Levee System. The Colorado River Front Work and Levee System (CRFW&LS), authorized in 1925, is designed to control the Colorado River from Lee Ferry, Arizona (division point between the upper and lower basins) to the southernmost international boundary with Mexico, a distance of about 700 miles.

Since 1949, USBR has carried out an extensive river management program along the Colorado River below Davis Dam. The primary goals of this multipurpose program are: flood control, sediment control, water savings, fish and wildlife preservation, recreation, recreational development, navigational improvement, salinity control, drainage improvement on adjacent agricultural lands, river regulation, protection of the environment, and economic enhancement of land values.

Thirty-two miles of the river in the Mohave Valley downstream from Davis Dam, 16 miles of the river in the Cibola Valley south of Blythe, California, and 5 miles of the river in the North Gila Valley below Laguna Dam have been improved. Construction has changed the river from a shallow, braided actively meandering stream to a deeper and more narrow channel having a more uniform gradient and an improved channel alignment.

Portions of the river in the Parker and Palo Verde Valleys have been stabilized. The completed work consists primarily of jetties and river-training and bankline-protective structures. Two sediment settling basins-one above Topock, Arizona, and the other below Imperial Dam-have been created to trap large quantities of sediment eroded from upstream sources. Dredges pump and remove the sediment from each basin onto adjoining land as required.

e. Parker Dam Project. Parker Dam and Powerplant, 155 miles below Hoover Dam, provides a forebay and desilting basin for the 242-mile Colorado River Aqueduct of



Parker Dam

The Metropolitan Water District of Southern California (MWD). Water is pumped into the Colorado River Aqueduct from Lake Havasu, formed by Parker Dam. Lake Havasu, with a total capacity of 648,000 acre-feet, backs up behind the dam 45 miles, covering 20,390 acres. The dam, a concrete, variable radius arch structure, superimposed by five 50- by 50 foot Stoney gates for river control, was designed and constructed by the Bureau of Reclamation with funds advanced by The MWD and was completed in September 1938. Four hydroelectric generating units, each with a capacity of 30,000 kilowatts, give the powerplant an installed capacity of 120,000 kilowatts. Costs of powerplant construction were shared equally by the United States and The Metropolitan Water District. The United States retains one-half of the power privileges and responsibility for the operation of the plant, as well as control of all water passing the dam. Ownership of the dam, powerplant, and appurtenant works is vested in the United States, and the portion of costs chargeable to the Government is being repaid by power revenues.

Parker Dam assists Hoover and Davis Dams in controlling floods along the river and reregulates the river's flow for the benefit of downstream irrigation. Only the top 10 feet containing 180,000 acre-feet of storage are reserved for river regulation and flood control.

f. Central Arizona Project. Authorized in 1968 and now under construction, the Central Arizona Project will provide a new supplemental water supply to central Arizona, averaging 1.2 million acre-feet of Colorado River water, each year, based on long-term projections. This water will be used by municipalities, industries, Indian communities, and agriculture.

Colorado River water will be pumped from a point in Lake Havasu a short distance above Parker Dam, into the 190-mile-long Granite Reef Aqueduct and will be delivered to various users along the aqueduct route. Water in the aqueduct will flow to the south side of the Salt River some 20 miles east of Phoenix. At this point, the remaining water will be pumped into the Salt-Gila Aqueduct and flow 58 miles to a location near the Picacho Mountains. From there water will be pumped into the Tucson Aqueduct for delivery to the Tucson metropolitan area.

These aqueducts will consist of a series of canals, tunnels, river crossing siphons, and pumping plants. The water that is delivered in Tucson will have been lifted through an elevation change of about 2,000 feet from the elevation at Lake Havasu. The pumping plants will receive power from the 24.3 percent Federal share of the output of the Navajo Generating Station at Page, Arizona.

g. Colorado River Aqueduct. The Colorado River Aqueduct was built by The Metropolitan Water District (MWD). The MWD was organized specifically for delivering water to Southern California cities from the Colorado River. Parker Dam was constructed for The MWD by the USBR to provide a diversion facility.

Diversions began in 1941, but the system was not completed to its present capacity of 1,212,000 acre feet annually until 1957.

h. Headgate Rock Dam. Headgate Rock Dam, constructed by the Bureau of Indian Affairs, was completed in 1941 to provide diversion facilities for about 100,000 acres of land on the Colorado River Indian Reservation. It is an earthfill structure rising 77 feet above the lowest points of its foundation and about 38 feet above the streambed. The spillway is a reinforced concrete structure with 10 radial gates which hold the water surface behind the dam to a normal level of 364 feet. The diversion pool behind the dam has no active capacity.

i. Palo Verde Dam and Diversion Project. Palo Verde Diversion Dam was completed in 1957. The 1,300-foot-long, 50-foot-high, earth- and rock-fill dam spans the Colorado River 214 miles downstream from Hoover Dam, 59 miles from Parker Dam. It diverts water into the Palo Verde Irrigation District's canal system, serving 92,000 acres in California's Palo Verde Valley. The dam provides farmers in the Palo Verde Valley with their first assured means of obtaining water by gravity diversion.

A drain 21 miles long and a levee 30 miles long on the Arizona side upstream from the dam are features of the project. These works protect lands on the Colorado River Indian Reservation against floods and also intercept drainage water.

j. Senator Wash Dam and Regulating Reservoir. Senator Wash Dam and Regulating Reservoir is a small off-stream pumping-generating development on the California side

of the Colorado River, 2 miles upstream from Imperial Dam. This 94-foot-high earthfill embankment structure and its reservoir are designed to save water and improve deliveries to water users in the United States and Mexico.

Water in excess of deliveries is lifted from the river behind Imperial Dam into the Senator Wash Reservoir by six dual-purpose pump generators. With a usable capacity of 12,250 acre-feet, the reservoir saves up to 170,000 acre-feet of water a year.

As releases are made back to the river, hydroelectric energy is generated and fed into the Western Area Power Administration's transmission system. The pump generators have a rated generating capacity of 1,200 kilowatts each for a total of 7,200 kilowatts. The sale of this power helps offset the cost for pumping. The facility, built under the Colorado River Front Work and Levee System Program, also provides recreation and fish and wildlife opportunities.

k. Imperial Dam and Desilting Works. Imperial Dam, 300 miles below Hoover, diverts water from the Colorado River on the California side into the All-American Canal and on the Arizona side into the Gila Gravity Main Canal.



Imperial Dam

The All-American Canal delivers water to the Imperial and Coachella Valleys of Southern California and to the Yuma Project in southwestern Arizona and southeastern California via the Yuma Main Canal. The Gila Gravity Main Canal carries water to the Gila and Yuma Auxiliary Projects in Arizona. Below the headworks on the California side is the All-American Canal desilting works, consisting of three desilting basins, each 540 feet wide and 770 feet long.

Imperial Dam, a concrete-slab and buttress overflow structure 3,475 feet long, raises the river level 23 feet at the dam. Construction of the dam and desilting works began in 1936 and was completed in 1938. The desilting works prevent vast quantities of riverbed sediment from entering the canals and creating operation and maintenance difficulties.

1. All-American Canal System. The All-American Canal System including Imperial Dam and Desilting Works on the Colorado River, the All-American Canal and its major branch, the Coachella Main Canal - was authorized under the Boulder Canyon Project Act of 1928.

The All-American Canal proper can serve about 530,000 irrigable acres of land on the Imperial Division, while the Coachella Main Canal can deliver water to some 78,000 acres on the Coachella Division, both in southern California. The All-American Canal also furnishes water to 68,000 acres on the Yuma Project in California and Arizona. The All-American Canal has a capacity of 15,155 cubic feet per second below the desilting works.

Started in 1934, the All-American Canal delivered its first water to Imperial Valley in 1941. One of the world's largest canals, it extends westward 80 miles to the Imperial Valley. The Coachella Main Canal branches from the All-American Canal 20 miles west of Yuma and runs northwesterly 123 miles to the Coachella Valley. The branch canal was completed in 1948, and its underground lateral system in 1954.

Hydroelectric energy is generated at plants constructed by the Imperial Irrigation District on the All-American Canal at Drops Nos. 2, 3, and 4, and at Pilot Knob Check and Wasteway.

Imperial Valley crops include alfalfa hay and seed, cotton, sugar beets, barley, flax, cantaloupes, sorghum, and fresh vegetables for the Nation during the winter months. The Coachella Valley produces winter vegetables, dates, table grapes, citrus fruit, and cotton.

m. Laguna Dam and Yuma Project. The Yuma Project is the oldest Reclamation development on the Colorado River, authorized in 1904. About 53,000 of the project's 68,000 irrigable acres lie in Arizona and the remainder in California.

Laguna Dam, 13 miles north of Yuma on the Colorado River was the project's original diversion structure. Construction started in and was completed in 1909. First water deliveries began in 1910. The last major diversions were taken in 1948.

Water for the project is now diverted into the All-American Canal at Imperial Dam, 5 miles upstream from Laguna. The project's 1,600 kilowatt Siphon Drop Powerplant generated the first hydroelectric energy on the Colorado River in 1926. The obsolete plant was shut down in 1972 and studies to rehabilitate or replace it are now underway.

Yuma Valley produces alfalfa hay and seed, winter vegetables, cantaloupes and watermelons, cotton, sorghum and small grains, pasture crops, and some citrus. Feed crops provide for the seasonal feeding and pasturing of livestock.

n. Yuma Auxiliary Project. Containing 3,406 acres devoted to growing grapefruit, oranges, and lemons, this project lies on the Yuma Mesa in Arizona about halfway between Yuma and Mexico. As authorized in 1917, the project comprised 45,000 acres, of which only a limited area could be served through constructed works. Legislation passed in 1949 reduced the project's boundaries to include the present area because the remaining arable land could be better served through the Yuma Mesa Division of the Gila Project. Colorado River water for the project is diverted at Imperial Dam through the Gila Project's canal system.

o. Gila Project. The Gila Project's 105,000 acres of irrigable valley and mesa lands lie along the Colorado and Gila Rivers in southwestern Arizona.

Project water is diverted at Imperial Dam for delivery to the Yuma Mesa and Wellton-Mohawk Divisions of the Gila Project. The Gila Gravity Main Canal with a capacity of 2,200 cubic feet per second conveys this water from the dam 21 miles southeast to the Yuma Mesa Pumping Plant, where it is lifted 52 feet to the head of the Yuma Mesa distribution system. The Wellton-Mohawk Canal, diverting from the Gila Gravity Main Canal 15 miles below Imperial Dam, extends along the Gila River eastward for 18.5 miles, then branches into the smaller Wellton and Mohawk Canals.

The Gila Project system delivered its first water to the Yuma Mesa Division in 1943, and to the Wellton-Mohawk Division in 1952.

The Wellton-Mohawk Division's 65,000 acres of irrigable lands are along the Gila River and on the bordering Wellton Mesa. Three large pumping plants along the Wellton-Mohawk Canal lift water a total of 170 feet. Two small plants lift water an additional 69 feet to higher lands adjacent to the Mohawk Canal. Smaller lift pumps are scattered throughout the Division.

The Yuma Mesa Division is authorized for 40,000 acres of irrigable land, 25,000 on the Yuma Mesa and the remainder in the north and south Gila Valleys.

The Yuma Mesa grows citrus, alfalfa hay and seed, grapes, and grains. Alfalfa, cotton, flax, cantaloupes, winter vegetables, small grains, and Bermuda grass seed are grown on the Wellton-Mohawk Division. Sheep are brought from summer ranges into the area and are wintered on irrigated pastures of the project before being shipped to feed lots and markets. Cattle feed lots of various sizes operate in the area.

p. Colorado River Basin Salinity Control Project. Authorized by the Congress in 1974, the Colorado River Basin Salinity Control Project's purpose is control the salinity of water delivered to users in the United States and Mexico. The program's Title I deals with salinity control measures below Imperial Dam near the International Boundary, and Title II deals with salinity control measures above Imperial Dam.

Title I features will maintain the quality of Colorado River water delivered to Mexican farmlands under the 1944 water treaty as required by Minute 242 of the International Boundary and Water Commission. The major feature for accomplishing this is the 96-million-gallon-per-day membrane Yuma Desalting Plant, scheduled to go into operation in 1986. The plant will treat saline drainage water from the Welton-Mohawk Irrigation and Drainage District in southwestern Arizona and put most of it back into the river above Morelos Dam for delivery to Mexico. The plant, to be the world's largest, will make it possible to salvage the Welton-Mohawk drainage water and meet salinity standards at Morelos Dam as required by Minute 242. The specified salinity limits are now being attained by bypassing Welton-Mohawk drainage waters to the Santa Clara Slough in Mexico and replacing with stored water from upstream reservoirs.

Other major Title I features include replacement of the first 49 miles of the unlined Coachella Canal with a concrete-lined reach to salvage about 132,000 acre-feet of water annually now lost to seepage, and a protective and regulatory ground-water pumping unit located on the South Yuma Mesa along the Mexican border. The purpose of this well field is to recover ground water for use in the United States and for meeting Treaty obligations.

Also included in the project is an intense effort by the USBR to improve irrigation efficiencies in the Welton-Mohawk Valley. This will result in a reduction in the amount of drainage water to be treated by the Yuma Desalting Plant.

The Title II program provides for expedited investigations of 12 salinity control units throughout the Colorado River Basin and authorizes four for construction. The Title II program is expected to remove about one-fifth of an average of 10 million tons of salt each year from the Colorado River system. This would prevent the salinity at Imperial Dam from increasing approximately 155 milligrams per liter. Salinity at the dam now averages about 820 mg/L.

q. Alamo Dam and Lake. Alamo Dam is located on the Bill Williams River about 39 miles upstream from the River's mouth at Lake Havasu. Project purposes are flood control, water conservation, recreation, and public access. Basic data on the project are presented in Plate 9.

r. Salt River Project. The Salt River Project is located in central Arizona on the Salt and Verde rivers. This project consist of storage facilities, powerplants, and diversion and distribution facilities. The purpose of the project is to provide water for irrigation and a municipal and industrial supply as well as electrical service in the area. The principal storage feature of the project are Theodore Roosevelt Dam and Lake, Horse Mesa Dam and Apache Lake, Morman Flat Dam and Canyon Lake, and Stewart Mountain Dam and Saguaro Lake on the Salt River: and Bartlett and Horseshoe Dam and Reservoir on the Verde River. Data on these projects are presented in Plate 9.

s. San Carlos Irrigation Project. The San Carlos Irrigation Project in located on the Gila River in central Arizona, southeast of Phoenix near the town of Florence. The Project stores and distributes water for local agriculture, and generates power. The principal feature of the project are Coolidge Dam and San Carlos Lake, the Coolidge Powerplant, the Ashurst-Hayden

Diversion Dam and, the canals and laterals comprising the irrigation system. Basic data on Coolidge Dam and San Carlos Lake are presented in Plate 9.

t. Painted Rock Dam and Lake. Painted Rock Dam is located in southwestern Arizona on the Gila River, about 125 miles upstream from the River's confluence with the Colorado River near Yuma, Arizona. The dam was constructed by the Corps of Engineers to control flooding on the Gila and Colorado Rivers. Basic data concerning the facility are included in Plate 9.

u. Morelos Dam and Irrigation System Morelos Dam is a diversion structure located on the Colorado River about a mile below the Northerly International Boundary. The dam, which was completed in 1950, diverts water into the old Alamo Canal for use on lands in the Mexicali Valley in Baja California, under the provisions of the Water Treaty on the Colorado River entered into by the United States and Mexico in 1944 and ratified in 1945. Morelos Dam and the main canal system in Baja is owned and operated by the Mexican Government. Maximum diversion capacity is about 6,000 cfs [170 m³/s].

3-05. MODIFICATIONS TO REGULATIONS

a. Flood Control.

(1) 1935-1957. From the time of its completion to 1957, Hoover Dam was operated according to the plan developed by E. B. Debler and described in his report "Hydrology of the Boulder Canyon Reservoir," dated 31 January 1930.

Operation under Debler's plan involved attaining certain maximum, fixed storage objectives, depending on the time of the year, making flood control releases, if necessary. Beginning 1 October, releases were adjusted so that 9,500,000 acre-feet of storage space below elevation 1229 feet (maximum design pool) would be available by 1 April to control spring snowmelt floods. A flood storage space reservation of 2,500,000 acre-feet below elevation 1,229 was maintained during August and September for the control of rain floods. Table 2 shows Debler's flood storage space requirements by month.

**TABLE 2
MINIMUM FLOOD CONTROL SPACE REQUIRED
UNDER HISTORIC FLOOD OPERATION PLANS**

DATE	MINIMUM FLOOD STORAGE SPACE REQUIRED BELOW ELEVATION 1,229 (Acre-Feet)			
	1930 (DEBLER PLAN)	1957 PLAN	1968 PLAN	1982 PLAN
1 August	2,500,000	2,500,000	1,500,000	1,500,000
1 September	2,500,000	2,500,000	1,500,000	2,270,000
1 October	2,500,000	2,500,000	1,500,000	3,040,000
1 November	3,175,000	2,675,000	2,675,000	3,810,000
1 December	4,463,000	3,963,000	3,963,000	4,580,000
1 January	5,850,000	5,350,000	5,350,000	5,350,000
1 February	7,260,000	*	*	*
1 March	8,445,000	*	*	*
1 April	9,500,000	*	*	*

*None required; resulting storage is a function of releases made in response to forecasted seasonal runoff.

The Debler plan was based primarily on controlling the estimated flows -- adjusted for intervening changes in hydrologic conditions -- which occurred during the spring snowmelt flood of 1884, the largest historical flood known to have occurred in the Colorado River Basin.

Overall, the maximum release objective under Debler's plan was 40,000 cfs, the maximum non-damaging flow on the lower Colorado, but control of the 1884 flood under the plan would have required a maximum release of 75,000 cfs.

Debler's design operation plan recognized the possibilities of using inflow forecasts for operation, and made a general provision for use of such forecasts in connection with its prescribed, fixed maximum storage objectives, but specific applications of inflow forecasts were not integrated into the plan.

(2) 1957-1968. The 1957 plan maintained the minimum flood control storage requirements given in the design operation plan (Debler's plan) for the period 1 August to 1 January with the exception that refined techniques made it possible to reduce the flood control storage by 500,000 acre-feet during the period 1 November to 1 January (see Table 2). The plan further included the development of the application of inflow forecasts. Inflow forecasts formed the basis for operation during the period 1 January to 1 August for the new plan. Minimum releases from Hoover Dam were made to attain the 1 August flood control space of 2,500,000 acre-feet as determined for various conditions of available flood control storage space and maximum forecasted inflow.

All inflow forecasts for Lake Mead, as measured at the Grand Canyon, Arizona, gaging station were prepared by the United States Bureau of Reclamation, Boulder City, Nevada. The methods used were based upon intensive studies involving statistical correlations. Forecasts were prepared the first day of each month, or as otherwise needed, during the period 1 January through 1 August. The forecasts were derived from historic flows at Grand Canyon, Arizona, plus transmountain diversions for the period April through July. The final forecast was obtained by subtracting the estimated depletion during the April-July period by transmountain diversions and upstream reservoirs constructed during the preceding 20 years.

The maximum forecast, which was used in determining flood-control releases, was selected by the Bureau of Reclamation. The maximum forecast was defined as the estimated inflow volume in acre-feet that, on the average, will not be exceeded 19 times out of 20. The maximum forecast was calculated by adding to the mean forecast the so-called 1-in-10 error, as determined by the Bureau of Reclamation.

This plan was described in the 1957 "Reservoir Regulation Manual for Flood Control Storage at Hoover Dam and Reservoir (Lake Mead), Colorado River Basin," by the Los Angeles District, Corps of Engineers.

(3) 1968-1982. By 1968, the development of improved snowmelt flood forecasts and the construction of additional upstream reservoirs made it possible to reduce the flood storage space required at Lake Mead; and an increasing need for a future water supply made revision of the flood control operating plan necessary.

The revised plan was described in the 1968 revision of the "Report on Reservoir Regulation for Flood-Control Storage at Hoover Dam and Lake Mead," by the Los Angeles District, Corps of Engineers. The minimum required flood control space at Hoover Dam could be reduced to 1,500,000 acre-feet provided that any additional required space is available in upstream reservoirs: Flaming Gorge, Blue Mesa, Navajo, and Lake Powell (see section 3-04 and Plate 9 for descriptions of these reservoirs). For the period 1 August through 1 October, a minimum of 1,500,000 acre-feet would be held available at Lake Mead to control rain floods. This reduction in requirements from the original (Debler) plan was based on a study of the effect of Lake Powell and other upstream reservoirs on the design rain flood. With the pool level up to the top of the raised spillway gates (1,218,000 acre-feet of available storage) at the start of the same flood, the expected maximum release would be 40,000 cfs.

The fixed minimum flood control space requirements under the 1968 plan are shown in Table 2 for comparison with requirements of previous and present plans.

The flood control operation during January through July was based on the forecasted inflow volume through July, with releases made as needed to attain the required 1 August flood control storage space without exceeding the downstream channel capacity of 40,000 cfs to the extent possible. Where larger releases were required, they would be deferred as much as possible to the end of the period when forecasts are most accurate.

Inflow forecasts for Lake Mead were prepared by the Bureau of Reclamation, Boulder City, Nevada. They were based on correlations of natural runoff with accumulated precipitation, snow water content, and antecedent runoff. The computed "most probable" inflow was adjusted by the 1-in-10 error to obtain a "maximum" of the forecast to provide for underestimation of expected runoff. The 1-in-10 error for forecasts made in 1968 are given in the following tabulation:

Date	Forecast method	1-in-10 error Million acre-feet
1 January	Accumulated precipitation	4.0
1 February	do.	3.4
1 March	do	3.2
1 April	Water equivalent of snow, plus accumulated precipitation, plus antecedent runoff	2.5
1 May	do.	1.5
1 June	do.	1.0
1 July	30 June mean daily flow	.3

Tables of required minimum releases were developed corresponding to the forecast and the current storage.

(4) Present (1982) Plan. From the late 1950's through the late 1970's flows on the Colorado River below Hoover Dam were limited to water user requirements plus downstream tributary inflows. The resultant absence of high flows, together with extensive growth of water-based recreation, and lack of effective land use controls encouraged encroachment of

permanent and semi-permanent development into portions of the floodways. In addition, altered patterns of erosion and sediment deposition due to entrapment of sediments into upstream reservoirs changed the patterns of flooding along the river. (Aspects of these problems are discussed more fully in the following Section 3-06 and in Sections VII and VIII.)

At the time the older operating plans were developed, a flow of 40,000 cfs would have caused only minimal damage downstream. By 1982, however, extensive property damage would occur from a 40,000-cfs release because of encroachment in the floodway. Meanwhile, upstream reservoirs had very nearly filled to the maximum 1 January flood control storage, as shown in Figure 1, making inflows to Lake Mead higher, and thereby increasing the likelihood of flood control releases from Hoover Dam.

Therefore, beginning in 1977, a new operating plan was developed jointly by the Corps of Engineers and the Bureau of Reclamation. This plan is described in detail in Sections VII and VIII. The 1982 flood control regulations are presented in Exhibit A. The development of the 1982 plan and analysis of alternatives is fully described in the report entitled "Colorado River Basin, Hoover Dam, Review of Flood Control Regulation," dated 1982, by the Los Angeles District.

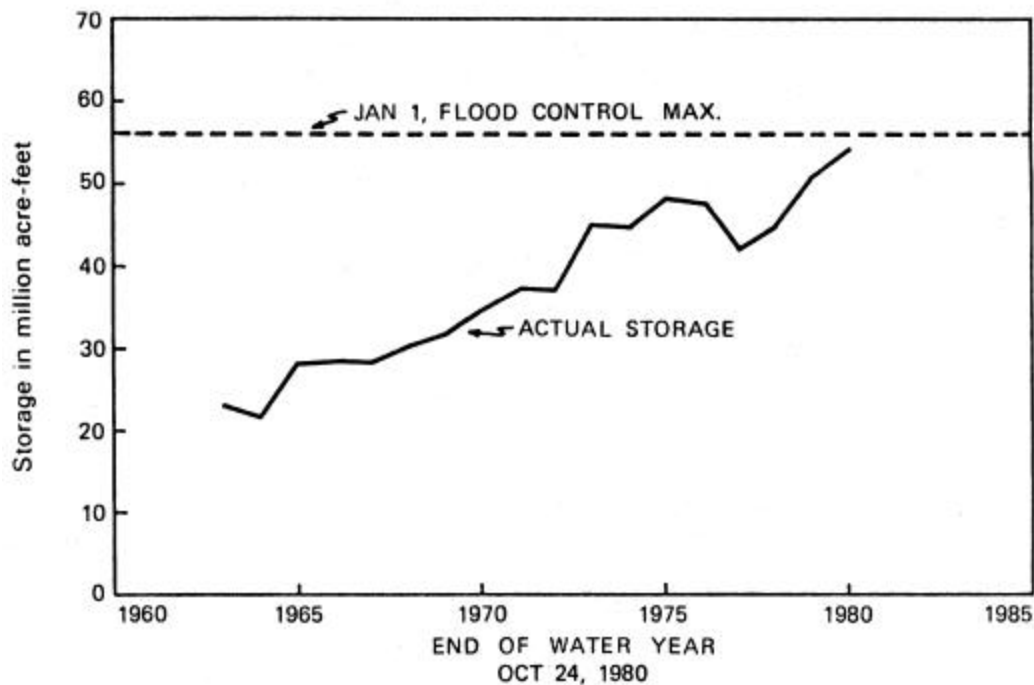


Figure 1 Colorado River Reservoir Storage System

b. Water Supply Operation Plans. Operating plans for water supply have essentially evolved as necessary to meet the limits and obligations for the apportionment and delivery of water among the seven states in the Basin and Mexico, as defined by the basic Colorado River Compact (1922), and further defined by the Boulder Canyon Project Act (1928), the Boulder Canyon Project Adjustment Act (1940), the Mexican Water Treaty of 1944 (ratified in 1945), the Upper Colorado Basin Compact (1948), the Colorado River Storage Project Act (1956), the Supreme Court Decision in *Arizona v. California* (1964), and various subordinate

laws, contracts and agreements. See Exhibit C for brief descriptions of these legal constraints.

In general, operating plans had been declared annually based on projected requirements, existing storage, and probable inflows. The Colorado River Basin Act of 1968 (Public Law 90-537) formally required the Secretary of the Interior to establish operational criteria and make annual reports to Congress and the Colorado River Basin states describing the actual operation for the preceeding year and the plan of projected operation for the forthcoming year. The plan must be consistent with all pertinent laws, contracts, compacts and treaties with respect to flood control, power production, water quality and other uses as well as water supply requirements. The existing operational criteria -- "Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs" -- was published in the Federal Register on 10 June 1970. The annual reports have been developed since January, 1972.

3-06. PRINCIPAL REGULATION PROBLEMS

As explained in section 3-05a, a release from Hoover Dam at the target maximum of 40,000 cfs would now result in significant damages due to encroachment into the flood plain. The main conditions that have contributed to this encroachment are (1) lack of large flood releases from Hoover Dam; (2) extensive growth in water-based recreation along the river; and (3) lack of effective land-use controls. In addition, erosion and deposition of sediment have altered channel flow characteristics in a number of areas.

Most water deliveries are for irrigation. Deliveries are made several days in advance to allow for travel time. Sudden rains on irrigated farm lands occasionally result in farmers rejecting deliveries at the point of diversion on the Colorado River. The resultant excess flow can cause downstream flooding and extra deliveries to Mexico. Senator Wash Dam, as described in paragraph 3-04, provides limited storage to reduce the effects of rejected water orders. Parker Dam, located about 3 days travel time above Imperial Dam (the last main point for United States diversion) provides the furthest downstream point of major storage to deal with significant rejections. Lake Havasu is operated such that adequate vacant storage space is available when water orders are high or when storms are likely to occur reducing irrigation demands or creating tributary inflow. Other action such as local flood damage or earthquake damage to diversion systems can also lead to sudden rejections of water orders. A discussion of flood flow damage relationships is presented in Section 4-09.

IV - WATERSHED CHARACTERISTICS

4-01. GENERAL CHARACTERISTICS

In the United States, the Colorado River drains about 250,000 square miles from portions of seven states - Wyoming, Colorado, Utah, New Mexico, Nevada, Arizona and California. Over 170,000 square miles of the watershed are above Hoover Dam.

The Colorado basin lies approximately between latitudes 31° N and 43° N and longitudes 106° W and 115° W. The watershed is about 870 miles long in the north-south direction, and is about 520 miles wide in the east-west direction. A general map of the basin is presented on Plate 1.

The headwaters of the Colorado River are located in central Colorado, about 1,440 river miles upstream from its mouth and 1,000 river miles upstream from Hoover Dam. The principal tributaries of the Colorado above Hoover Dam are the Green River System, including the Yampa, White, Uinta, Duchesne, Price, and San Rafael Rivers; Muddy, Fremont, Escalante, Gunnison, and Dolores Rivers; the San Juan River system; and the Paria, Little Colorado, and Virgin Rivers. Below Hoover Dam the principal tributaries are the Bill Williams and the Gila Rivers. These streams are shown in plan on Plate 1.

Basin elevations range from about 14,000 feet at the headwaters in the upper basin to sea level at the mouth. Streambed slopes range from about 250 feet per mile in the headwaters to about 1 foot per mile on the lower reaches. Streambed profiles of major streams are presented on Plate 11.

4-02. TOPOGRAPHY

The topography of the watershed is complex and varied; it is characterized by high mountains, plateaus, mesas, deep canyons and gorges, and flat to shallow rolling basins of many sizes. A topographic map of the Colorado River Basin is presented on Plate 10. Basically, the watershed comprises five broad physiographic provinces. The watershed above Hoover Dam consists of the broad Colorado Plateau Province in the center bounded on the west by the Middle Rocky Mountains Province, on the north by the Wyoming Basin, and on the east by the Southern Rocky Mountains. The area drained below Hoover Dam - is dominated by the Basin and Range Province. These basins are described generally below and shown in Figure 2.

Several other topographic features are important, including the mountain belt separating the Basin and Range Province from the Colorado Plateau, and the Salton Basin and Colorado River Delta region. These are also shown in Figure 2 and described below.

a. Middle Rocky Mountains Provinces. A segment of the Middle Rocky Mountains Province constitutes the northwestern part of the watershed. This segment is composed of a north-trending belt of parallel ranges in Wyoming referred to as the Wyoming Range and the east-trending Uinta Mountains in northeastern Utah. Crests of the Wyoming Range are 9,000 to 10,000 feet in altitude, and the intervening valley bottoms range from 6,500 to about 7,500 feet in altitude. The Uinta Mountains are a broad archlike structure, the high part of which has many crests more than 12,000 feet in altitude. Part of the range is eroded deeply into cirque basins which drain through steep-sided valleys into the Wyoming Basin to the north and the Uinta Basin to the south.

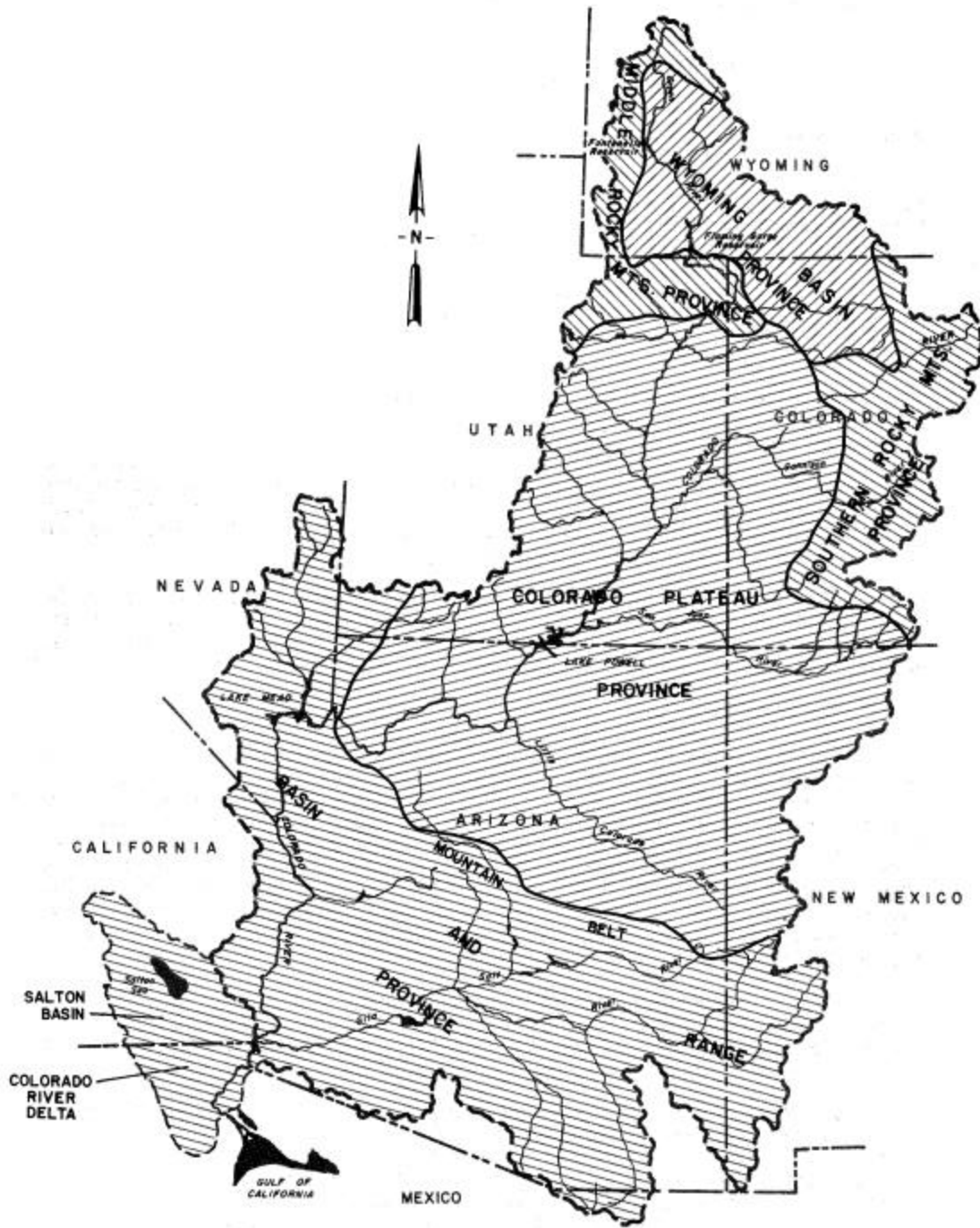


Figure 2 Principal Physiographic Features

b. Southern Rocky Mountains Province. Part of the Southern Rocky Mountains Province constitutes the eastern topographic boundary of the watershed. It is marked by a series of broad elevated ranges. The western border of the province is irregular and merges gradationally with the Colorado Plateau to the west. The mountains form subparallel ranges and subcircular mountain groups that are separated by steep-sided valleys and broad basins. Summits vary from 10,000 to 14,000 feet in altitude. Mountains are deeply eroded. The valley bottoms extend downward from about 10,000 feet to about 7,500 feet in altitude in their lower reaches.

c. Wyoming Basin. Between the Middle and Southern Rocky Mountain Provinces is part of a broad plateau-like feature known as the Wyoming Basin. It has a surface of fairly low relief that varies from 6,500 to 7,500 feet in altitude and is marked by buttes, rounded hills, and open plains. It merges imperceptibly with the Uinta Basin of the Colorado Plateaus province in the gap between the Uinta Mountains and the White River Plateau.

d. Colorado Plateau. The Colorado Plateaus province is a broad elevated surface which consists of a series of plateaus that range from 5,000 to more than 11,000 feet in altitude. The plateaus are notable for their steep rims and deeply incised canyons, created by differential resistances to erosion. Ledges, cliffs and benches are formed of resistant beds of sandstone and limestone separated by slopes, valleys and badlands carved on a weaker intervening shaly strata. The entire province is characterized by similar rock formations which are slightly inclined. In areas adjacent to the major basin streams, vast, extensive canyons have developed, the most notable one being the Grand Canyon.

In the northern half of the Colorado Plateau Province, the rock terrace and plateaus develop a high relief: 5,000 feet to 10,000 feet. To the south, the relief is subdued, and broad slopes and low mesa-like structures predominate.

e. Basin and Range Province. The Basin and Range province occupies the southern one-third of the Colorado River Watershed. It is characterized by isolated mountain ranges separated by broad, alluvial-floored basins. Toward the northeastern portion, up to the Mogollon Rim, the mountains predominate, and river channels are deeply incised in narrow canyons. In the southwestern part, the buttes and ranges are of smaller extent and height, often being buried in alluvium, and are isolated by the broad flat alluvial valleys. Ancient volcanic cones and reddish-black lava flows are interspersed throughout the region.

f. Mountain Belt. The mountain belt area is roughly 50 miles wide and extends southeast from Lake Mead, physically separating the Colorado Plateau and the Basin and Range Provinces. Elevations reach to over 12,000 feet. The Mogollon Rim is a major feature.

g. The Salton Basin and the Colorado River Delta. The Salton Basin, also known as the Colorado Desert, is a large, enclosed basin adjacent to the Colorado River watershed near the river's mouth. The basin comprises about 7,500 square miles, of which about 1,000 square miles are in Baja California, Mexico. The Salton Basin is bounded by mountain ranges to 10,000 feet in elevation to the west, north, and east, and the Colorado River Delta to the south. Much of the Salton Basin is below sea level, the lowest point is at elevation minus 277.7 feet.

A map and cross-section of the Salton Basin and the Colorado River Delta area are presented on Plate 12. During relatively recent geologic times, the Colorado River has periodically spilled into the Salton Basin. The last major spill occurred during 1905-07 when a combination of high water on the Colorado and problems with man-made diversions caused the entire flow of the Colorado to be diverted during that period. The Salton Sea was formed as a result.

4-03. GEOLOGY AND SOILS

The geology of the Colorado River Basin is diverse and complex, encompassing a broad spectrum of types and origins. The derivative soils of the Basin are even more complex and diverse owing to production by, interactions of wind and water erosion and chemical weathering processes.

a. Geology.

(1) Middle Rocky Mountains Province (Wyoming Range and Uinta Mountains). Rock formations in the Wyoming Range consist of a sequence of sedimentary beds, several thousand feet thick that have been thrust faulted and trend eastward where they dip and flatten under the Wyoming Basin. In the Uinta Mountains, a sequence of sedimentary beds several thousand feet thick flank a core of metasediments and metamorphic rock. These beds flatten north and south to dip under the Wyoming and Uinta Basins.

(2) Southern Rocky Mountain Province (Park, Sawatch, San Juan, Elk, and West Elk Ranges). Cores of the Park, Sawatch, and San Juan Ranges are composed mostly of metamorphic rock that has been uplifted into anticlinal and domal structures. The Elk Range is composed of tightly folded and thrust faulted sedimentary rock. The West Elk Range consists of several domal structures formed by sub-surface, igneous intrusions. Thrust and normal faults bound the southern end of the Park Range and both flanks of the Sawatch Range. Volcanic rock has modified the domal structure of all but the southern part of the San Juan Mountains.

(3) Wyoming Basin Province. A thick, varying age sedimentary sequence rock formation underlies this basin. The generally flat-lying formation also is warped into large, general basins that are structural and sedimentary features as well as geographic basins. The central core portions are 25 to 30 thousand feet thick.

(4) Colorado Plateau Province. Underlying the Green River portion of this province is a sedimentary rock formation that contains vast deposits of coal, oil, and oil shale. The remainder of the province contains severely eroded sedimentary strata -- 1,000 to 10,000 feet thick -- overlaying igneous and metamorphic rocks. The strata have local faulting and folding and there are occasional surface intrusions by granite and volcanic formations.

(5) Basin and Range Province. Large-scale faulting created an alternating mountain-valley trend in this province. Volcanic rock caps many of the mountains. Several stages of differing alluvial fill--up to 3,000 feet thick--underlie the valleys. Lava and alluvium are occasionally interbedded by volcanic intrusion.

(6) Mountain Belt. The underlying structures in this area generally transition between those in the Basin and Range Province and in the Colorado Plateau Province. The change is abrupt in some locations.

(7) Salton Basin and Colorado River Delta. This region was once an inland sea and then an upthrust created the mountain ranges to the east and west and elevated the entire area. A gradual settling of the central area caused a meandering Colorado River and the deposition of enormous quantities of silt in the delta and basin, eventually leading to the formation of the closed Salton Basin. The depth of silt in the basin is not known but in the delta it ranges up to 12,000 feet.

b. Soils.

(1) On steep mountain slopes throughout the watershed soils are shallow to moderately deep. Surface layers are generally loamy with sand and gravel mixtures and are moderately permeable. Rock outcroppings are common and there are many rocky areas with no soil cover. Subsoils are mainly sandy, gravelly, and clayey. Sediment yield is low to moderate and erosion is moderate to severe depending of the amount of precipitation. Vegetation consists mainly of oakbrush, aspen, and conifers.

(2) On the more gentle slopes of the foothills, valleys, mesas, plateaus, and high basins, soils range from shallow to deep and are fairly permeable. Surfaces are loamy; have varying amounts of organic matter; and contain gravel, sand, and silt. Subsoils consist principally of clay, sand, gravel, and lime. Sediment yield is generally low and erosion from water and wind is slight to moderate. Native grasses, sagebrush, and desert shrub are the main types of vegetation.

(3) In the lower elevations of the Salton Basin and the Colorado River Delta, soils are very deep and consist mainly of silt eroded from the entire Colorado River Basin. Sediment yield and erosion are slight.

4-04. SEDIMENT.

For thousands of years, the Colorado River transported large quantities of soil and fragmented rock, mainly from the basin above the Hoover Dam site, to the lower reaches. As a result, portions of the Colorado River Delta are 12,000 feet thick. The Colorado River and its tributaries meander in enormous canyons carved from the highly erodable rock and soil in the upper Basin. The areas with the highest sediment yield per acre are the southern portion of the Colorado Plateau Province, especially the Little Colorado River Basin, and the portion of the Basin and Range Province adjacent to the Mountain Belt region. These regions have yielded from 0.5 to more than 3.0 acre-feet per square mile per year. Although other large areas are similar to the high yield areas in topography, rocks and soils, the controlling factor is the amount of annual precipitation, since runoff is the driving force.

Human activities have altered the natural erosion and sedimentation patterns in two principal ways. First, mining, grazing, agricultural, and forestry activities have generally induced somewhat greater erosion rates. However, the present trend is toward lower sediment yields because of the efforts of watershed management in addition to reduced flow rates.

Secondly, and more important for the lower Colorado River, the development of the reservoir system has created problems by altering the sedimentation patterns of the river: channel instability has not been eliminated, but its characteristics have been changed. In each reservoir, sediments brought in with inflows settle out, and the water released from the reservoir is relatively free of sediments. Downstream, the clear releases pick up sediment deposited in earlier floods. The sediment picked up in this fashion is moved downstream to be deposited at the head of the next reservoir. Specifically, reaches of the Colorado River below Hoover Dam have been scoured and deepened, and reaches such as Topock Gorge and the reach above Imperial Dam have been raised by extensive sediment deposition. The effects of the raised streambed in Topock Gorge extend north to the City of Needles, where a portion of the city was inundated during high river flows. This emergency situation at Needles led to new legislation designed to deal with river problems along the entire lower river below Hoover Dam. Earlier authority under the Colorado River Front Work and Levee System Act was expanded in 1946 to permit the Bureau of Reclamation to initiate an active Lower Colorado River management program. The initial goal of the work was to prevent flooding and destruction of lands resulting from the meander of the river and deposition of sediment in the river channel. Sediment, sedimentation, and erosion are continuing major problems in the Colorado River below Hoover Dam, and are therefore factors of concern in operation of the project. In addition, sediment entrapment has decreased the capacity of Lakes Mead and Powell, however, this condition is of minor consideration in current operation plans. Section 3-04 describes in more detail the related activities along lower Colorado River.

4-05. CLIMATE

The climate of the Colorado River Basin may be classified as semi-arid to arid, but wide variations in climatic variables exist throughout. The wide variations of temperature, precipitation, evaporation and wind movement are due primarily to the Basin's topography, including elevation differences and the distribution and orientation of mountain ranges, and secondarily to the large differences in latitude. The high mountains are wet and cool, while the lower mountains and plateaus are drier with highly variable temperatures. The lower valleys and basins are dry and hot.

The basin climate is also influenced by Pacific Ocean air masses which move inland from the west, carrying most of the regions precipitation. Seasonal effects include dry, polar air from the north in the winter, and moist tropical cyclones from the Gulf of California in the summertime, but these events rarely affect the entire basin. Movement of all types of air masses is obstructed and deflected by the mountain ranges in and surrounding the basin. In the upper Basin, the surrounding ranges cause more erratic interactions and effects within the Basin than are usually found in many other parts of the United States.

Statistics for temperature, precipitation, snowfall and snow water content, and evaporation are presented for selected stations in Table 3. The characteristics of the variables are discussed on the following pages.

**TABLE 3
AVERAGE MONTHLY METEOROLOGICAL
VARIABLES FOR SELECTED STATIONS**

**SELECTED TEMPERATURE DATA
COLORADO RIVER BASIN
(In Degrees Fahrenheit)**

STATION	ELEV FT MSL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	MIN	MAX
Boulder City, Nev	2525	46.4	51.0	56.3	64.9	73.6	82.1	88.8	86.9	81.0	69.1	55.6	47.7	67.0	11	117
Yuma WSO, Ariz	194	55.4	59.4	63.9	71.2	78.7	85.8	93.7	92.8	87.1	75.9	63.5	56.3	73.7	27	116
Phoenix WSO, Ariz	1117	51.2	55.1	59.7	67.7	76.3	84.6	91.2	89.1	83.8	72.2	59.8	52.5	70.3	20	116
Flagstaff WSO, Ariz	7006	27.9	30.5	34.2	42.1	50.1	58.2	65.6	63.6	57.5	47.0	36.4	29.8	45.3	-20	96
Vernal Airport, Utah	5280	16.1	23.3	34.1	45.5	54.9	62.2	69.6	67.6	58.9	47.4	33.1	21.2	44.5	-38	102
Farmington 4 NE, NM	5395	28.6	35.0	40.6	49.7	59.5	67.9	75.0	72.6	64.6	52.9	39.2	30.1	51.3	-20	103
Durango, Colo	6550	25.9	30.8	36.6	45.1	52.9	60.2	67.5	66.0	58.6	48.8	36.9	28.0	46.4	-30	97
Grand Junction, WSO, Colo	4855	26.6	33.6	41.2	51.7	62.2	71.3	78.7	75.4	67.2	54.9	39.8	29.5	52.7	-13	103
Rock Springs, Wyo	6741	19.2	23.4	28.9	40.1	50.4	58.9	68.2	66.1	56.4	44.7	30.7	22.6	42.5	-37	98

1. Monthly Annual Averages 1941-70.

**SELECTED RAINFALL DATA
COLORADO RIVER BASIN
(In Inches)**

STATION	ELEV FT MSL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	MIN	MAX
Boulder City, Nev	2525	0.63	0.44	0.50	0.42	0.16	0.09	0.44	0.74	0.33	0.40	0.50	0.50	5.15	0.00	3.45
Yuma WSO, Ariz	194	0.38	0.27	0.21	0.11	0.03	0.00	0.18	0.44	0.22	0.27	0.22	0.34	2.67	0.00	2.68
Phoenix WSO, Ariz	1117	0.71	0.60	0.76	0.32	0.14	0.12	0.75	1.22	0.69	0.46	0.46	0.82	7.05	0.00	5.56
Flagstaff WSO, Ariz	7006	1.89	1.47	1.83	1.33	0.56	0.57	2.48	2.65	1.68	1.37	1.33	2.15	19.31	T	7.30
Vernal Airport, Utah	5280	0.54	0.42	0.52	0.73	0.62	0.96	0.45	0.76	0.66	0.90	0.55	0.71	7.82	0.00	3.29
Farmington 4 NE, NM	5395	0.54	0.46	0.52	0.60	0.47	0.46	0.78	1.18	0.85	1.08	0.47	0.66	8.07	0.00	3.71
Durango, Colo	6550	1.70	1.14	1.47	1.36	1.12	0.88	1.85	2.43	1.59	1.94	1.11	2.00	18.59	0.00	7.14
Grand Junction, WSO, Colo	4855	0.64	0.61	0.75	0.79	0.63	0.55	0.46	1.05	0.84	0.93	0.61	0.55	8.41	0.00	3.48
Rock Springs, Wyo	6741	0.46	0.54	0.68	1.02	1.11	1.14	0.49	0.74	0.72	0.87	0.53	0.49	8.79	0.02	3.26

1. Monthly Annual Averages 1941-70.

**TABLE 3 (CONTINUED)
AVERAGE MONTHLY METEOROLOGICAL
VARIABLES FOR SELECTED STATIONS**

**SELECTED SNOW ACCUMULATION DATA
COLORADO RIVER BASIN
(In Inches)**

STATION	ELEV.	DRAINAGE	NORMAL SNOW ACCUMULATION DEPTH AND WATER CONTENT									
			JAN		FEB		MAR		APR		MAY	
			DEPTH	W.C.	DEPTH	W.C.	DEPTH	W.C.	DEPTH	W.C.	DEPTH	W.C.
Lake Irene	10,600	Colorado R.	—	—	49	13.2	60	17.8	66	21.3	64	23.3
Berthoud Summit	11,320	Colorado R.	32	7.6	45	11.7	56	15.4	62	19.2	64	21.6
Independence Pass	10,600	Colorado R.	—	—	40	9.8	49	13.7	55	17.6	45	16.7
McClure Pass	9,500	Crystal & N.F. Gunnison R.	20	4.2	40	11.1	48	14.7	47	15.7	26	10.0
Lizzard Head	10,200	Dolores R.	39	9.7	39	10.0	46	13.1	54	17.3	37	14.5
Mineral Creek	10,300	San Juan R.	28	6.7	38	9.7	47	12.7	50	15.1	32	11.8
Lake City	10,200	Gunnison R.	—	—	26	5.7	29	7.0	30	7.8	13	4.0
Burro Mountain	9,000	White R.	—	—	43	10.9	51	14.7	54	18.1	39	15.2
Dry Lake	9,000	Yampa R.	33	7.9	47	12.1	57	17.0	58	20.0	38	16.5
Spirit Lake	10,300	Green R.	21.3	4.9	30.6	7.0	38.3	9.8	44.4	12.4	48.8	15.3
Strawberry Divide	8,000	Duchesne R.	33.7	7.9	46.3	12.7	55.8	17.2	57.7	20.0	39.1	17.9
Webster Flat	9,200	Virgin R.	22.7	5.8	39.2	10.8	47.7	14.7	51.0	17.9	30.9	13.7

**SELECTED EVAPORATION DATA
COLORADO RIVER BASIN
(In Feet)**

RESERVOIR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Flaming Gorge *	.046	.057	.112	.189	.267	.334	.355	.269	.233	.130	.061	.046	2.099
Blue Mesa *	.023	.028	.056	.094	.133	.167	.176	.134	.117	.065	.030	.023	1.046
Navajo *	.039	.048	.095	.164	.229	.286	.305	.231	.200	.111	.052	.040	1.800
Lake Powell *	.198	.186	.233	.265	.359	.411	.466	.478	.415	.375	.312	.261	3.959
Lake Mead **	.36	.33	.37	.46	.53	.64	.80	.85	.70	.51	.51	.44	6.50
Lake Havasu **	.34	.41	.48	.59	.70	.81	.90	.89	.81	.65	.46	.35	7.39

*Net evaporation on reservoir (gross evaporation minus precipitation).

**Gross evaporation on reservoir.

a. Temperature. Temperatures in the Colorado watershed are highly variable, depending on elevation, latitude, seasonal effects, and diurnal fluctuations. In the watershed above Hoover Dam, temperature extremes vary from -23°F to 105°F at Grand Junction, Colorado to 2°F to 115°F at Lees Ferry, Arizona. In the watershed below the Dam, temperature extremes vary from -30°F to 97°F at Flagstaff, Arizona to 22°F to 123°F at Yuma, Arizona. For most locations, the highest mean monthly temperature occurs in July and the lowest in January. The seasonal difference is typically about 50°F. Average annual temperatures vary from below freezing above 10,000 foot elevations to about 50°F for the lower mountains and plateaus and to 70°F for desert regions. Diurnal fluctuations are large - exceeding 40°F in the desert - due to clear skies, which facilitate intense surface heating during the day and active radiation cooling during the night, and the characteristic atmospheric dryness. The diurnal fluctuations are highest in the summer and lowest in the winter.

b. Precipitation. An average of about 13.75 inches (179,000,000 acre-feet) of precipitation falls on the Colorado River Basin each year. The normal annual precipitation amount for specific location varies from less than 5 inches in desert regions to more than 50 inches in the highest mountain elevations. Plate 13 presents a map of normal annual precipitation isohyets for the entire Basin.

The two major factors determining precipitation are the supply of moisture and the topography. The Pacific Ocean and the Gulf of California provide most of the moisture. These two sources result in different amounts and patterns of precipitation at different times of the year.

In the winter and early spring moist air masses moving in from the Pacific Ocean dominate the pattern and amounts of precipitation. These air masses lose much of their moisture because of the orographic effect of several intervening mountain ranges. As a result, precipitation from these storms is usually limited except in the mountains. For most of the upper watershed, precipitation from Pacific storms from October through April accounts for the greatest part of the normal annual amount. Precipitation from these air masses generally results in snow in the upper basin plateau and especially in the mountains. Warm air masses can also result in widespread rain. Intensities vary widely, but seldom exceed more than 4.0 inches of precipitation in 24 hours. These winter storms are usually of several days duration and their precipitation is widespread.

During the period from May through September, warm, cyclonic air masses from the Gulf of California and the South Pacific predominate in the lower Basin. These storms enter the Basin from the southwest. Both widespread, general storms and local thunderstorms are associated with these systems. The most active periods for summer storms are July through September. In the mountains, scattered afternoon thundershowers associated with the warm air masses occur almost daily. Summer storms account for the greatest portion of normal annual precipitation for most of the southern Colorado watershed. However, summer precipitation is highly variable, and in any year may not exceed the winter rainfall. General summer storms are often accompanied by heavy rainfall over large areas for periods of up to 24 hours, but may continue for as long as 3 days.

Local thunderstorms can occur at any time of the year, either during general storms or as isolated phenomena. They are most commonly associated with moist, unstable air systems from the Gulf of California. These storms cover relatively small areas and are characterized by high intensity precipitation of short duration.

c. Snow. Precipitation during October through April from the Mountain Belt in Arizona northward usually occurs as snow, especially at higher elevations. Annual average snowfall ranges from 200 to 300 inches in the high mountains down to 5 inches in lower valley and plateau areas. Maximum snow accumulation occasionally exceeds 100 inches in the higher areas and does not completely melt until late summer. The photograph on page IV-11 shows a typical pattern of late winter cover.

d. Evaporation. The combination of moderate wind movement, high temperatures, clear skies, and low humidity results in high rates of evaporation throughout the Basin. In the Basin above Hoover Dam, annual evaporation ranges from 30 inches at high elevations to about 60 inches in the lower valleys. Below Hoover, annual evaporation ranges from about 50 inches at higher elevations to over 80 inches along the Colorado River.

e. Wind. A wide range of surface wind conditions occurs in various portions of the Colorado River Basin. Winds due to air masses tracking east to west are strongly affected by topography. Average wind velocities are high in mountains and ridges with westerly exposure. Winds in protected valleys have lower average velocities with directions determined by surrounding ridges.

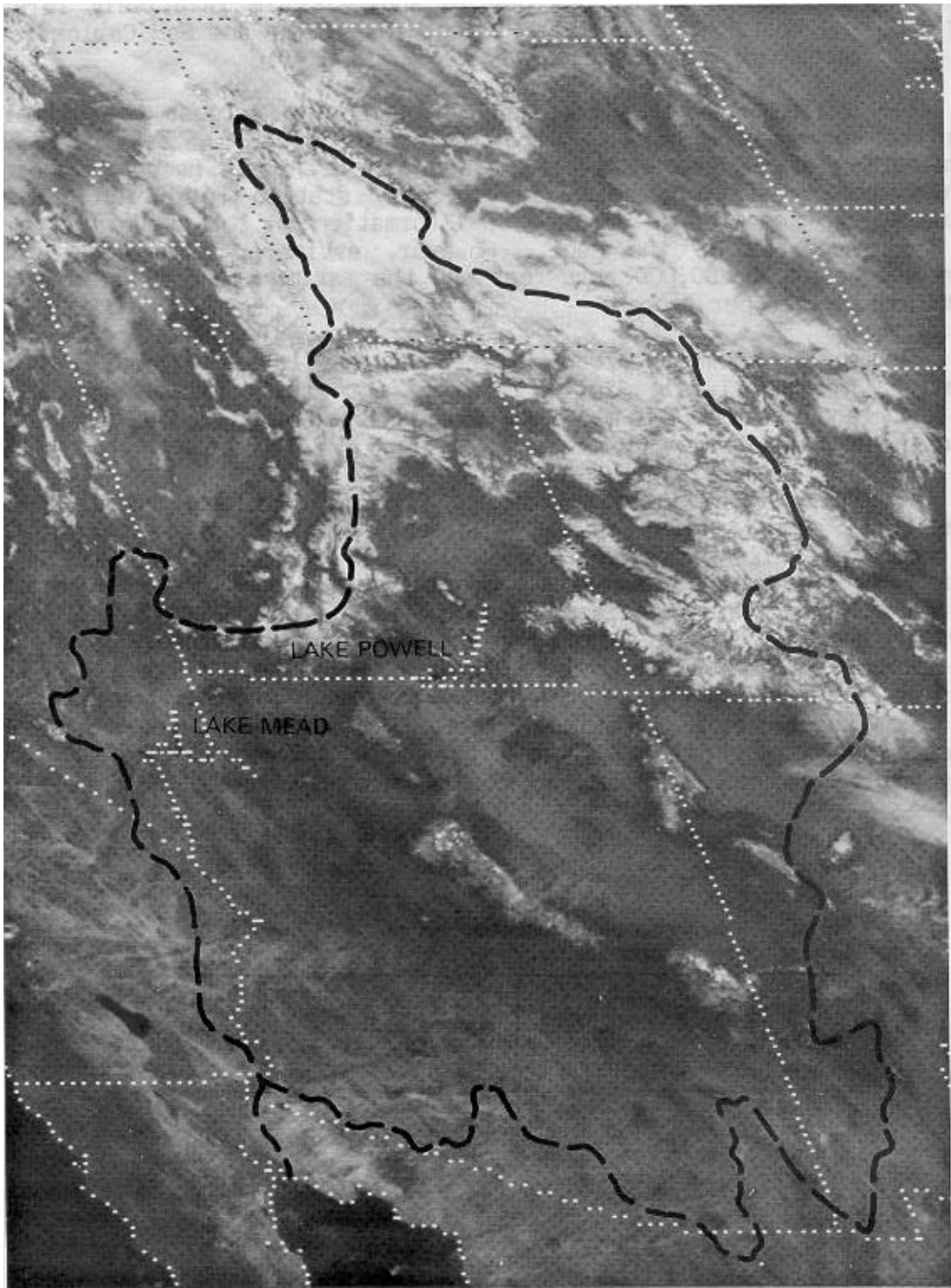
During much of the year stagnant, high-pressure systems and fair weather conditions dominate, and resulting winds are generally light. Typically, local surface winds blow up valley slopes during the day and down the slopes at night. These conditions often prevail for considerable periods. At points of convergence near canyons and upland slopes, this pattern results in consistently high average wind movement.

In the desert and southern plateau regions, the strongest winds are experienced during thunderstorms; peak gusts up to 100 miles per hour have been observed. The direction of these extreme winds is generally random. In the northern-most regions and in the mountains wind movement is greatest during winter and spring.

4-06. STORMS AND FLOODS

Floods in the Colorado River Basin result from both snowmelt and direct runoff of precipitation.

a. Snowmelt Floods. Floods resulting from snowmelt constitute about 70 percent of the annual runoff of the Colorado River at Lake Mead. Accumulation of snow begins around 1 October, and melting starts about 1 April. The resulting floods occur throughout the months of April through July with peak runoff usually reaching Lake Powell in June. Flood volumes range from about 2,000,000 acre-feet to 17,000,000 acre-feet, averaging approximately 8,800,000 acre-feet. These floods are characterized by gradual rise and recession and a moderate peak discharge.



SATELLITE PHOTO

Snow Cover on 25 February 1980

IV-11

Snowmelt floods originate mainly in the mountains of the upper Colorado Basin. Inflows below Hoover Dam due to snowmelt are relatively rare. They occur when the upstream Salt River Project reservoirs and San Carlos reservoir spill from large volumes of snowmelt.

The spring snowmelt flood of 1884 was the largest historical flood known to have occurred in the Colorado River watershed. Accurate determination of discharge for this flood is difficult because records from the Yuma gaging station, which is the only station for which records are available, are complicated by lack of information on the amount of scour and fill that occurred at the gage. However, estimates place the April-July inflow volume at 30,200,000 acre-feet and the maximum mean daily discharge at 300,000 cubic feet per second.

The spring snowmelt flood of 1917 was the largest flood with complete records. The April-July inflow volume for this flood was 16,900,000 acre-feet, and the maximum mean daily discharge was 160,000 cubic feet per second, near Grand Canyon, Arizona.

b. Rain Floods. While snowmelt floods contribute the largest share of the total runoff volume on the Colorado River, floods from rainfall with high peaks are also important. Several types of rain floods occur on the Colorado River and its tributaries. General rain floods of up to several days duration occurring both upstream and downstream from Hoover Dam are the most important because they result in high peaks and moderately high volumes. Large general rain floods above the Dam are more likely to occur in the late summer or early fall on the Virgin, Little Colorado, and San Juan River basins. Peaks from these events sometimes exceed 100,000 cubic feet per second and volumes sometimes approach 2,000,000 acre-feet. Examples of peak flows and 15-day volumes for several historic floods are presented in Table 4, below.

TABLE 4
SELECTED LARGE RAIN FLOODS
COLORADO RIVER NEAR GRAND CANYON, ARIZONA

WATER YEAR	MAXIMUM 15-DAY VOLUME MILLION ACRE-FEET	MAXIMUM MEAN DAILY DISCHARGE CUBIC FEET PER SECOND	DATE OF MAXIMUM DISCHARGE
1923	.91	98,500	19 Sep
1927	1.61	114,000	15 Sep
1929	1.48	60,900	13 Aug
1929	.87	48,100	25 Sep
1930	1.03	54,800	12 Aug
1932	.64	49,800	30 Aug
1941	1.16	82,000	16 Oct
1947	.83	49,500	25 Aug
1948	.63	45,800	15 Oct
1957	.74	47,700	2 Sep

Large general rain flood events below Hoover Dam can occur in summer or winter, mainly on the Gila and Bill Williams Rivers. Winter rain storms are occasionally augmented by melting snow.

4-07. RUNOFF CHARACTERISTICS

Changes in runoff reaching Hoover Dam can be rapid in response to intense local rainstorms or moderate in response to spring snowmelt. Winter base flow runoff is generally stable with rates reflecting the previous years precipitation amounts.

Tabulations of monthly inflows to Hoover Dam under natural and 1980 regulated conditions are presented in Plates 14 and 15, respectively. Plate 16 is an inflow volume frequency curve of natural flows at Lee Ferry. The average annual natural inflow volume is about 15.1 million acre-feet; the average annual regulated inflow under 1980 conditions is about 10.4 million acre-feet. Plate 17 is a tabulation of observed historic peak flows to Lake Mead.

Plate 18 presents a schematic diagram of the Colorado River system indicating major reservoirs, major tributary inflow points and drainage areas, and incremental drainage areas and flood-wave travel times. As indicated by the streambed profiles (Plate 11) slopes of the headwaters in the mountain region are steep and travel times are relatively rapid. Slopes in the plateau and desert regions are generally moderate, and flood-wave travel times are accordingly longer.

4-08. WATER QUALITY

Colorado River water quality is of critical importance because of its extensive use for water supply. The quality of the Colorado River shows little degradation from domestic and industrial wastes because no large metropolitan centers are located along the river. Instead, dissolved mineral salts are the foremost water quality problem. Salinity is introduced into the river in all reaches from various sources and generally has increased with increased development on the river until 1970.

Recently, the short-term salinity trend has been downward; however, the long-term salinity trend is expected to increase as depletions increase. As part of the Colorado River Water Quality Improvement Program (CRWQIP), the Bureau of Reclamation is currently authorized under Public Law 93-320 to implement the following measures for controlling salinity in the Lower Colorado River System: Point source control; Irrigation source control; and Diffuse source control.

Recent average annual salinity of the Colorado River at its headwaters is about 50 mg/l (milligrams per litre); at Imperial Dam, the concentration is about 825 mg/l.

Salinity is affected by two mechanisms-salt loading and salt concentration. Salt loading is the addition of salts to the stream by the dissolution of solvable salts in the soil and substrata. Salt concentration is the increase of salinity levels by the removal of lower salinity, high quality water through evaporation, transpiration, or diversion.

Studies show that about half the salinity at Hoover Dam is derived from natural sources and half from manmade operations. In order of importance, individual sources of salinity are: natural sources, irrigation, reservoir evaporation, out-of-basin export of water, and municipal and industrial uses.

4-09. CHANNEL AND FLOODWAY CHARACTERISTICS

Plate 19 presents a schematic of the Colorado River below Hoover Dam, levee design flows, locations of levees, travel times between key points, incremental drainage areas, major tributaries, and reaches and points susceptible to flood damages. Table 5 shows average monthly diversions. Table 6 presents a concise tabulation of flows and corresponding potential damages for the principal damage centers. Specific values of nondamaging channel capacity are not useful because of progressive nature of encroachment. Instead, discharge-damage values represented in Table 6 are better indicators of channel capacity. The subsections below describe in further detail the channel and floodway characteristics of the Colorado River below Hoover Dam by reaches. Potential damage values are provided in 1978 dollars.

Table 5
Net Average Monthly
Diversions
From the Lower Colorado River

Month	Net diversions by reach (units of 1000 acre-feet)					Monthly Total
	Hoover Dam to Parker Dam	Parker Dam (Metropolitan Water Dist. Div.)	Parker Dam to Palo Verde Dam	Palo Verde Dam to Yuma	Yuma to Morelos Dam	
Oct	14	52	38	225	96	425
Nov	10	48	29	174	157	313
Dec	21	47	30	180	116	394
Jan	28	51	38	225	88	430
Feb	35	57	41	244	154	531
Mar	56	80	76	450	205	867
Apr	53	86	81	479	264	963
May	46	86	83	495	144	854
Jun	49	74	88	523	132	866
Jul	32	80	91	540	234	977
Aug	24	77	83	495	157	836
Sep	24	62	66	392	100	644
Total Annual	392	800	744	4,422	1,742	8,100

NOTE: Includes evaporation, bank storage, diversions, and return flows for average 1980 conditions.

a. Hoover Dam to Davis Dam. Prior to the construction of Davis Dam, the Colorado flowed through a narrow canyon for 67 miles downstream from Hoover Dam. Now, the reach is almost totally inundated by Lake Mohave.

b. Davis Dam to Big Bend. For about the first six miles below Davis Dam, the Colorado flows through a relatively stable channel which is confined by cobble mesas. The clear water released from Davis has washed out finer natural sediments, leaving a generally armoured and stable river bed, although some small isolated erosion sites exist. The levee-design channel capacity in this reach is 50,000 cfs. Channel improvements in this reach are limited to small, local bank stabilization and bank protection works.

**TABLE 6
FLOW - DAMAGE VALUES*
LOWER COLORADO RIVER
(1980 Conditions)**

Use	Damage in thousands of dollars				
	At 30,000 (cfs)	At 40,000 (cfs)	At 50,000 (cfs)	At 78,000 (cfs)	At 100,000 (cfs)
Needles					
Commercial	0	0	0	38	50
Public	0	0	0	29	35
Residential	0	10	41	1,009	10,612
Mobile homes	0	0	0	47	72
Agriculture	<u>0</u>	<u>0</u>	<u>1,719</u>	<u>3,712</u>	<u>23,696</u>
Total	0	10	1,760	4,835	34,465
Parker Strip					
Commercial	1	11	26	154	280
Public	0	41	120	360	614
Residential	111	208	343	1,156	2,374
Mobile homes	28	77	311	2,876	9,414
Agriculture	0	0	526	526	4,299
Recreation facilities	<u>22</u>	<u>55</u>	<u>105</u>	<u>191</u>	<u>235</u>
Total	162	392	1,431	5,263	17,216
Blythe					
Commercial		0	0	0	0
Public		0	0	0	0
Residential		0	110	840	1,664
Mobile homes		0	19	44	75
Agriculture		<u>0</u>	<u>0</u>	<u>8,159</u>	<u>18,148</u>
Total		0	129	9,043	19,887
Yuma					
Commercial	0	0	0	0	0
Residential	18	41	68	522	1,462
Mobile homes	1	3	37	130	130
Agriculture	<u>57</u>	<u>158</u>	<u>158</u>	<u>1,878</u>	<u>5,180</u>
Total	76	202	263	2,530	6,772

Applicable to a Snowmelt Flood when 1-2 weeks warning is available. All values are in 197 dollars.

c. Big Bend to Topock. Below Big Bend (near Bullhead City, Arizona), the Colorado enters the Mohave Valley, an ancient, alluvial flood plain. This reach is about 32 miles long. In its natural state, the river meandered from one side to the other of the valley, which is five miles wide at its widest. After Parker and Hoover Dams were constructed, a problem of severe aggradation in the portion of the reach below Needles developed. The clear water

released from Hoover picked up sediments from upstream of Needles, while the backwater created by Parker Dam caused deposition in the lower reach. Prior to 1946, aggradation in the channel in the lower reach caused a rise in water levels until serious flooding occurred near Needles. Since then, dredging, channelization and related works - together with construction of Davis Dam - resulted in a stabilized channel and reasonable control of the aggradation problem.

The present levees and channel works which have confined and stabilized the river on the west side of the valley were constructed between 1957 and 1960 under the Colorado River Front Works Program. The levee design capacities of the system are 50,000 cfs from Big Bend to Piute Wash (a point between Big Bend and Needles) and 70,000 cfs from Piute Wash to Topock. However, since sediment deposition continues to be a maintenance problem in the lower reach, the USBR is not confident it can maintain a channel capacity of more than 40,000 cfs during flood stages, which could be of several months' duration. Furthermore, some minor damages begin to occur at Needles for flows exceeding 30,000 cfs, primarily to residential property on the east bank. A flow of 40,000 cfs could cause an estimated \$10,000 in damages. Damages would increase rapidly for flows in excess of 40,000 cfs: a flow of 50,000 cfs would cause an estimated \$41,000 in damage to residential property and over \$1.7 million to agricultural development.

d. Topock to Parker Dam. Below Topock, the Colorado enters the rugged and narrow Topock Gorge and flows about 17 miles to Lake Havasu.

Prior to the development of channel improvements, large amounts of sediment were deposited throughout Topock Gorge and in the upper reaches of Lake Havasu. In 1957, a four-mile segment of the river above Topock Bridge (upstream of the gorge) was over-excavated for use as a settling basin, and the segment has been intermittently dredged since then. As a result, the upper reach of Topock Gorge has been predominantly scoured, with the sediment moving to the lower gorge and into the upper reaches of Lake Havasu. Environmental concerns have made channel dredging in Topock Gorge unacceptable. The levee design flow from Topock to Lake Havasu is 70,000 cfs.

e. Parker Dam to Headgate Rock Dam. Below Parker Dam the Colorado flows about 14 miles generally through a canyon to Headgate Rock Diversion Dam. The downstream end of this reach is unique in that the Headgate Rock Dam spillway gates automatically maintains a constant pool elevation of 364.4 feet at the dam for flows up to 100,000 cfs and thus forms Lake Moovalya.

The levee-design flood is 50,000 cfs, but although the reach is predominantly confined in a canyon, substantial damages result in the reach beginning at a flow of 28,000 cfs because of the extensive water-oriented recreation in the reach. This reach known as the Parker Strip, is one of the most heavily used reaches of the river. The nearly stable pool which exists upstream from Headgate Rock Dam is attractive for boating, water skiing, and other water-oriented recreation. Much of the recreation development is located immediately above the normal water level established by the 22,600 cfs maximum powerplant release from Parker Dam.

Damages in the Parker Strip begin to occur with flows as low as 20,000 cfs. A flow of 30,000 cfs would result in about \$150,000 damage to property valued at about \$800,000. At 50,000 cfs, about \$1.4 million in damages would result to property valued at over

\$4.7 million. The type of property subject to damage include fixed residential, mobile homes, commercial, apartments and condominiums, recreational facilities, public property, and agricultural land.

Due to the absence of a sediment load in releases below Parker Dam and the relatively steep slopes, scour predominates throughout the reach.

f. Headgate Rock Dam to Imperial Dam. In the reach from Headgate Rock Dam to Imperial Dam, the Colorado flows about 100 miles through a rich agricultural valley. In the upper 60 miles of the reach, the river has been free to meander over the alluvial valley. Nearer to Imperial Dam, however, the river is confined to a relatively narrow and inaccessible gorge.

Sedimentation patterns in this reach appear unstable. Prior to the mid-1960's, the river meandered across the alluvial flood plain, and sediment deposition behind Imperial Dam and the reach just above it was heavy. Bank protection, training structures and channelization projects constructed since then have altered those patterns, but new ones have not been clearly established, although heavy deposition in the lower end has ceased.

The levee-design flood from Headgate Rock Dam to Palo Verde Dam is 50,000 cfs; from Palo Verde Dam to Taylor Ferry, 75,000 cfs; and from Taylor Ferry to Adobe Ruins, 80,000 cfs.

The major damage center in this reach is the portion in and around Blythe, California. No flood protection structures have been constructed in this portion; however, extensive channel improvements by the USBR - mainly earthfill training structures and bank protection - and an extensive irrigation and drainage network influence any flooding in the area. In particular, irrigation canals, which are typically 5 feet above grade, would serve as effective barriers to overland flood flows. Backwater analysis of the Blythe reach indicate that the river channel would contain a 28,000 cfs flow. A flow of 38,000 cfs would overtop river training structures in some places, but would not damage any agricultural land or structures. Above 38,000 cfs, damages would begin to occur. Damages from a flow of 50,000 cfs are estimated at \$110,000 to residential property and \$19,000 to mobile homes.

g. Imperial Dam to the Southern International Boundary. A diagram of the channels, diversions and canals in this reach is shown on Plate 20. The area between Imperial Dam and Laguna Dam was originally part of the diversion pool formed by Laguna Dam. However, this pool quickly filled with sediment and the river created a well-defined channel between new banks formed by natural processes. When Imperial Dam was completed in 1938, this channel was used to convey all river releases until 1963 when a new channel was dredged-from the California Sluice Gates at Imperial Dam directly south to Laguna Dam. A settling basin was constructed in this new channel and the sediment deposited in the basin is now dredged out periodically and placed on adjacent areas. The old channel is no longer used for flows in the normal operating range but will be used when floodflows in excess of 5,000 cfs are required to be conveyed to Laguna Dam. Below Laguna Dam, the Colorado River spreads into its broad, fertile delta extensively crossed with irrigation canals. Most of the Colorado Rivers' flow in that area is diverted at Imperial Dam: water destined for normal delivery to Mexico returns through the Pilot Knob Power Plant just above Morelos Dam. Under ordinary conditions, the Colorado River through the Yuma area

acts primarily as a drain for the surrounding irrigation lands. Flow in the Gila River, which enters the Colorado River at Yuma, ordinarily is also irrigation drainage.

From about a mile upstream of Morelos Dam southward of about 20 miles, the Colorado forms the boundary between the United States and Mexico. The International Boundary and Water Commission is responsible for maintenance in this reach, often referred to as the limitrophe section of the river.

Another major diversion occurs at Morelos Dam. Downstream from Morelos, flows are predominately irrigation drainage and wastage and seldom exceed a few hundred cfs.

Since most of the river's normal flow in this reach is diverted at Imperial Dam, downstream rates of scour and deposition are low, with deposition predominating. However, during high flows, resulting from flood runoff in both the Colorado and the Gila Rivers, considerable scour occurs.

The Colorado River is confined by flood control levees through much of the Yuma area. Many of the levees were originally constructed in the early 1900s. Upgrading and additions to the levee system were completed in the early 1960s to pass levee design flows of 103,500 cfs from Imperial Dam to the mouth of the Gila River, (36,500 cfs within the lower Gila River Channel), and 140,000 cfs below the mouth of the Gila River.

The existing levees at Yuma are capable of containing flows up to their design flood. However, existing development located between the levees is vulnerable to damage from smaller flows. Some low-lying agricultural fields would be flooded at a flow of about 16,000 cfs. A flow of 40,000 cfs would cause approximately \$200,000 in damage to about half a dozen farm structures between the Yuma levees. A flow of 71,000 cfs would flood all development between the Yuma levees, including about 54 structures, some of which are houses; irrigation canals; and extensive cultivated fields would be damaged.

h. Southern International Boundary to Mouth. The topographic divide in the Colorado River Delta is about on a line between Yuma and Cerro Prieto Mountain. The natural drainage of lands north of this line runs into the United States; the natural drainage of those south into the Gulf of California. This peculiar characteristic of the Delta is shown on Plate 12.

The significance of this fact, in evaluating the threat of overflow to the United States, is that river overflows that might occur south of this line would not pose a threat to the United States. Conversely, if river overflows were to occur north of this line, the greatest threat would be to the United States. It was in this northern portion of the Mexicali Valley that levees were built, repaired, and rebuilt by predecessors to the Imperial Irrigation District between 1907 and 1937, to protect against overflows from the Colorado River in Mexico turning back into the United States.

The first line of levees on the west bank of the river (Ockerson levee) is still intact. Most of the secondary levees built have been obliterated. But Mexico's leveed irrigation canals would serve as effective secondary barriers to any westward flows.

The Ockerson Levee is a 25-mile-long project that was built in 1911, and later reconstructed and repaired numerous times. The existing Ockerson Levee is well constructed. Its top provides the base of a 2-lane paved highway; and in many areas, its slopes are heavily protected by rock. A 9-mile section of this levee extending from the Southerly International Boundary northward stands today as the primary barrier against overflow of the Colorado River to the west. In the unlikely event that the river broke through the Ockerson Levee, Mexico's leveed canal and drain system stands as secondary lines of defense, protecting against possible overflow into the United States.

The fact that there have been no Colorado River overflows from Mexico into the United States since 1907--even though extremely high floodflows have occurred, ranging from 150,000 cfs to the maximum recorded flow of 250,000 cfs in 1916 at Yuma --demonstrates the effectiveness of the levee and levee canal system from a flood control standpoint.

In October 1979, the Mexican Ministry of Agriculture and Hydraulic Resources furnished updated river profiles, cross-sections, and other hydraulic data. Using these data, the IBWC, U.S. Section, evaluated levee heights in relation to expected flows. Mexico considered flows up to 28,000 cfs. For purpose of analysis, the U.S. Section added to the Mexican profiles a preliminary water surface profile for a flow of about 70,000 cfs.

The analysis shows the following: From Morelos Dam south to San Luis, Mexico, the river is flanked on the United States side (east side) by the Yuma Levee, and on the Mexican side (west side) by the Ockerson Levee. The U.S. Bureau of Reclamation constructed the Yuma Levee in 1952 to carry a flow of 140,000 cfs with 2 feet of freeboard. Based on the Mexican water surface profiles the system in this reach can carry a flow of 28,000 cfs with a levee freeboard of more than 7 feet on the Mexican side. This reach also can carry a flow of 70,000 cfs with a levee freeboard of more than 4 feet on the Mexican side.

From San Luis south to river kilometer 50 (31 miles below Morelos Dam), the channel is entirely in Mexico and has a capacity of 28,000 cfs with a levee freeboard of more than 9 feet on the west side (Rodriquez Levee) and more than 3 feet on the east side (De Piedra Levee). A flow of 70,000 cfs in this reach would rise to within 6 feet of the top of the levee on the west side. On the east side up to river kilometer 48 (mile 30), there would be at least 1.5 feet of freeboard above a flow of 70,000 cfs.

Thus, it can be concluded that the levee system on the west bank of the Colorado River from the Northerly International Boundary to a point 35 river miles below Morelos Dam can contain a flow of 70,000 cfs. The probability of a flow of this magnitude is very remote.

In the last 30 years, the high degree of reservoir control on the river has permitted few large flows to flush the river channel. As a result, sediment has built up and vegetation has encroached, reducing the main channel capacity. To offset this, however, overbank areas beyond the low flow channel but between the levees have been cleared for agricultural purposes, thereby removing obstructions to the passage of floodflows. The net effect probably is an increased capacity to carry large floodflows without return to the United States.

A tidal sandbar has developed in the main channel of the Colorado River near its mouth where it empties into the Gulf of California. The sandbar is about 14 miles upstream from Montague Island, about 78 river miles south of the Southerly International Boundary. A cross-section of the tidal sandbars shown on Plate 21.

According to a 1979 river profile prepared by the Ministry of Agriculture and Hydraulic Resources of Mexico, the tidal sandbar is about 18 miles long, with about 5 miles of its top above the water surface. At its highest point, the sandbar is about 6 feet above the normal river channel bottom. The sandbar has been there at least since 1972, when its presence was noted on a satellite photo.

The tidal sandbar blocks the present mouth of the river, restricting free flow of water into the Gulf. The sandbar has in effect acted as a dam, raising stages in the Colorado River a few miles upstream. As a result, flooding has been aggravated along the lowermost reach of the river. The river, unable to follow its normal course, seeks paths to the Gulf on either side of the sandbar. Left to its own means, the river could, if high flows continue, reestablish a channel through the sandbar or claim as its main course one or both of the side routes. Mexico reports some flow through the sandbar following the 1979-1980 anticipatory releases but no evidence that the flow is cutting a substantial new channel through the bar.

The tidal sandbar can in no way affect the movement of water northward to create a threat of overflow to United States. The main reason is that the elevations on the side of the sandbar range from sea level to 10 feet above sea level and that is significantly lower than the topographic divide to the north, which is about 35 feet above sea level. Also the leveed canals would block northward flow in any case.

i. Natural Environments. The effect of Hoover Dam releases on the natural environment along the Lower Colorado River are mixed. Sustained flows up to 20,000 cfs are predominantly beneficial to terrestrial and aquatic habitats from Davis Dam to Imperial Dam. As flows increase above 20,000 cfs, potential for damage to terrestrial and aquatic habitats increases, especially through Topock Gorge, from Agnes Wilson Road to Palo Verde Dam, and from Adobe Ruins to Imperial Dam. Flows above 30,000 cfs would have some detrimental effects over the entire Davis Dam to Imperial Dam reach.

Below Imperial Dam, sustained flows up to 10,000 cfs are predominantly beneficial to terrestrial and aquatic habitats. As flows increase above 10,000 cfs, the potential for damages to terrestrial and aquatic habitats increases along this reach. Because of the current channel conditions, the historically established low flow regime, and proximity of vegetation to the river, the potential is high for some long-term loss of terrestrial habitats below Imperial Dam.

The time of the year any large releases from Hoover Dam occur is probably more important than the size of the release. Large releases in the spring and summer would be the most detrimental because they would disrupt the nesting and breeding of most wildlife species and would cause inundation of plant communities during the growing season.

Rare and endangered wildlife that might be disturbed by Hoover Dam releases are limited to a few bird and fish species. The Yuma clapper rail is the only rare or endangered

bird resident in the flood plain. Peregrine and prairie falcons are transient visitors to the Lower Colorado River Basin, and the bald eagle may visit there on rare occasions. The Colorado River squawfish and the woundfin, once native to the waters of the study area, are no longer found below Hoover Dam. The bony tail chub and the humpback sucker, designated as rare in California by the Department of Fish and Game, are occasionally found in the Lower Colorado River Basin.

4-10. ECONOMIC DATA

Economic development in the upper Colorado Basin is dominated by mineral development, agriculture, forestry, tourism and recreation. These developments are dispersed among many locations within the Basin. Much of this development has nationwide economic importance. In addition, water supplies and power are exported to adjacent basins where they also are important to economic development.

In general, economic development oriented to the Lower Colorado River falls within four main categories: agriculture, recreation, tourism, and retirement. These are present in various combinations, with some aspects of each present in all reaches. The predominant centers of agriculture are on the Indian reservations, in the Palo Verde Valley (Blythe), and in the flood plain area of Yuma. The Parker Strip (between Parker and Headgate Rock Dams) is the most intensively developed recreational area. Many, if not most, of the residences along this area are either retirement or vacation homes. Blythe and Needles both benefit greatly from the tourist traffic along Interstate Highways 10 and 40, respectively. Of the two towns, Needles is the most dependent on tourist traffic.

In addition, the Lower Colorado River is an important source of municipal and industrial water for many communities in Nevada, Arizona, and California. The Metropolitan Water District of Southern California, serving metropolitan Los Angeles, is one of the larger customers of Lower Colorado River water and power for municipal and industrial purposes.

Because the River and reservoirs provide an exceptionally large surface area of protected waters within a warm and relatively rain free desert climate, the lower Colorado River offers unique and highly popular recreation opportunities. Supporting industries providing services and supplies from population centers as far away as Phoenix and Los Angeles represent an important element in the regional economy.

a. Population Data. The upper Colorado River watershed above Hoover Dam is sparsely populated, with an average of 6 persons per square mile. The largest communities and their respective populations (in 1980) are: Grand Junction, Colorado, 28,144; Farmington, New Mexico, 31,181; Durango, Colorado, 11,426; Rock Springs, Wyoming 19,458; and Las Vegas, Nevada 350,511.

The population of the watershed below Hoover Dam is one of the fastest growing in the United States, increasing from 1970 to 1980 by more than 50 percent. About 40 percent of the population resides in the two major metropolitan areas of Phoenix (764,911) and Tucson (330,537), Arizona.

b. Agriculture. Agricultural activities in the upper watershed are dominated by livestock and feed production. Vegetables and fruits are grown in small, isolated areas where

climate, soil and water supply conditions are suitable.

Livestock and feed activities are also prevalent throughout much of the lower Basin, but in terms of value of production, vegetables, citrus fruit, nuts and dates are far more significant; in fact, they are of national importance. Water from the lower Colorado River supports millions of irrigated acres in Nevada, Arizona, and California. Some of the most productive agricultural areas in the nation are located in the Lower Colorado River Basin. The major centers of crop production are the Imperial and Coachella Valleys in the Salton Basin, the Colorado Delta and the lower Gila River region in the vicinity of Yuma, Arizona, and areas near Phoenix, Arizona, Blythe, California, and Parker, Arizona. The production by this vast agricultural complex, worth billions of dollars each year, is almost totally dependent on Colorado River water.

c. Industry. Mineral development is a predominant industry throughout the Colorado Basin. The production of many of the materials mined is a large percentage of the total national product (for example, copper, uranium, molybdenum, vanadium, lead, zinc, and coal). Copper and uranium are important in the lower basin, and all but copper are important in the upper basin. Development of oil resources is also becoming important to the region.

Forestry and forestry products are another major industry throughout the Colorado basin in higher elevations areas with timber resources.

Recreation and tourism are important industries throughout the Colorado Basin. Major ski and mountain resorts are located in the mountains of Colorado and Utah. Unique scenic and esthetic settings are the basis for tourism throughout the Basin: several national parks, recreation areas and monuments are located there. Water-oriented recreation is important, especially in Arizona and Southern California. Entertainment is the specialty of Las Vegas, Nevada.

Manufacturing operations are predominantly located in central Arizona. They include: chemical processing; manufacturing of stone, clay and glass products; printing and publishing; metal fabrication; primary metals processing; textiles and apparels; leather and leather goods; and especially manufacture and assembly of electrical and electronics goods.

d. Flood Damages. Table 6 in Section 4-09 shows dollar value damages expected for different flows at major damage centers downstream from Hoover Dam. These damages would be associated with long duration releases on the Lower Colorado River during operations for snowmelt floods under current and reasonably foreseeable conditions. Flash flooding would usually result only in negligible local damages.

The primary cause of damage during flooding would be due to inundation. Damages to residential structures would comprise most of the total damages. Contents of all structures were not considered in the estimation of damages because large releases would be preceded by about a weeks' warning. A large number of mobile homes could be moved within the period of warning; therefore, the flood damages for the mobile homes would be limited -to the cost of moving them. Secondary damages from flood operation would include: impacts on operation and maintenance activities on the lower river, largely because of scour and deposition; and possible loss of hydropower generation.

V - DATA COLLECTION AND COMMUNICATIONS NETWORK

5-01. HYDROMETEOROLOGICAL NETWORKS

Several distinct hydrometeorological networks are involved in the operation of Hoover Dam.

a. USBR Operations Network. The Water Scheduling Branch of the Lower Colorado River Region of USBR utilizes a real-time, computerized network to monitor instantaneous flows and reservoir storage at key points on the Colorado River below Lake Powell for immediate use in day-to-day operations and control of the Lower Colorado River system. The network is described below, and locations and summaries of gage characteristics are presented on Plate 19.

The operations network consists of reservoir gages on Lakes Mead, Mohave and Havasu, and streamflow gages at key points from Lees Ferry to the Northerly International boundary with Mexico. Instruments at the stations measure the water surface elevations (except for the acoustic flow meters on the penstocks at Hoover Dam). Applying the latest functional relationships, this stage data is used to estimate storages and discharges.

Most of the gages are automatically interrogated hourly by radio. The Colorado River gages at Lees Ferry and the Grand Canyon report at three hour intervals via the U.S. Geological Survey's, (USGS) satellite reporting system using the Phoenix down link. Many of the gages can also be interrogated by alternate means should the automatic radio system be inoperative. The river gages at Taylor Ferry, below Cibola Valley, below the Yuma Canal Wasteway, and the Northern International Boundary are accessible by means of a back-up telemark system. The Imperial Irrigation District continues to use the telemark system and can be contacted by radio or by telephone for these data. The river gages below Davis Dam, below Cibola Valley and below the Yuma Canal wasteway also report over the USGS satellite system. Gages located near operation facilities can be visually observed by operations personnel who can report in by radio or telephone.

Most of the gages in the USBR operations network are owned and maintained on a cooperative basis with other agencies, principally the USGS.

b. Related Operations Networks. The Los Angeles District of the Corps of Engineers (COE) maintains a hydrometeorologic network for operation of Alamo and Painted Rock Dams. Data is obtained on an "as needed" basis. This radio reporting network has proven to be unreliable and is expected to be improved in the future. The COE also obtains data from upstream reservoirs on the Gila River via telephone. Data from the COE is currently available by telephone. In the future, these data may be available by means of computer-telephone links.

c. Flood Forecasting Networks. The flood control regulations require that necessary runoff forecasts be provided by the Colorado River Forecast Service (CRFS) located at the National Weather Service Colorado Basin River Forecasting Center (CBRFC) in Salt Lake City, Utah. The CBRFC utilizes an extensive network of meteorological stations, snowpack monitoring stations, and streamflow gages in its role in forecasting flood flows throughout the Colorado River Basin. Section VI provides a description of forecasting procedures.

The hydrometeorological stations utilized by the CBRFC are owned, maintained and operated by several public agencies and a few private organizations. Many individual cooperators also measure and report daily precipitation. The public agencies most significantly involved are the USBR, the Soil Conservation Service, the NWS, the Corps of Engineers the USGS and the Basin states.

d. Publication of Data. Most of the data pertinent to the operation of Hoover Dam is published by the USGS, the NWS, and the SCS. Neither the USBR nor the COE publish reservoir data. Streamflow, reservoir, sediment, and water quality data are published in USGS water supply papers. The USGS also maintains much of its data with the computer file entitled National Water Data Storage and Retrieval System (WATSTORE). Precipitation, temperature, evaporation, and wind movement data are published by the NWS. Snowcourse data are published by SCS.

5-02. WATER QUALITY STATIONS

Because the Colorado River plays a vital role in water supply, water quality is an important concern. It is monitored by means of an extensive network of sampling stations, with many of these stations monitoring a comprehensive set of parameters. Key stations in the lower Basin are located at:

(1) Colorado River below Hoover Dam, Arizona-Nevada (National streamquality accounting network station); (2) Colorado River below Davis Dam, Arizona-Nevada; (3) Colorado River near Topock, Arizona; (4) Colorado River below Parker Dam, Arizona-California; (5) Colorado River at Taylor Ferry, near Blythe, California; (6) Colorado River below Cibola Valley, Arizona; (7) Colorado River above Imperial Dam, Arizona-California (National streamquality accounting network, pesticide, radiochemical, and tritium network station); (8) Colorado River below Laguna Dam, Arizona-California; (9) Colorado River at Northerly International Boundary above Morelos Dam, near Andrade, California (National stream-quality accounting network and pesticide station); and (10) Colorado River at Southerly International Boundary, near San Luis, Arizona.

The USGS manages and publishes data for the largest number of stations. Data is also obtained by the USBR, The Metropolitan Water District of Southern California, and various local irrigation districts. The USBR collects water samples between the Hoover intake towers monthly for analysis by The Metropolitan Water District of California. The District provides the Bureau and the U.S. Geological Survey with the results of their testing.

5-03. SEDIMENT STATIONS

Sediment movement in the Colorado Basin is monitored by means of periodic sediment sampling in the rivers and surveys of degradation and sedimentation ranges in both rivers and impoundments.

The USGS measures, analyzes, and publishes daily data on suspended sediment for selected stations on the Colorado River and its tributaries.

The USBR samples suspended sediments generally once or twice per month at several stations on the Lower Colorado (below Hoover Dam). The USBR also periodically surveys

lakebeds and river channel geometry at about 220 locations in order to evaluate rates of scour and deposition. Certain river cross-sections are surveyed annually. River sections below Laguna Dam are surveyed for the USBR by the International Boundary Commission. Lake Mead was last surveyed in 1964. Since then Lake Powell has trapped most of the sediment inflow. None of the other lower Colorado reservoirs are routinely surveyed, although Lake Havasu was surveyed in 1956.

5-04. RECORDING HYDROLOGIC DATA

Records of water quality and daily discharge, elevation, and storage at Lake Mead are maintained by the Lower Colorado Dams Project office of the USBR. They are furnished to the USGS for publication. The USGS maintains daily records of discharge, elevation, and flow for all other stations involved in the operation of Parker and Davis Dams. The USBR maintains records of suspended sediment and sedimentation survey measurements and publishes summary reports at intervals of a year or more.

5-05. COMMUNICATION NETWORK

The operations of Hoover Dam are normally accomplished by four entities. The USBR's Water Scheduling Branch determines the releases required to accomplish Project purposes and obligations. The actual operation of the non-power outlet works is accomplished by the USBR Lower Colorado Dam Project Office Maintenance Branch. Releases through the turbines are controlled by the Los Angeles Department of Water and Power and Southern California Edison Company. Offices of each of the four organizations are located in Boulder City. Communications are accomplished by phone, messenger, radio or mail depending on urgency.

Operation of Davis and Parker Dams is similar to that of Hoover Dam in that a separate organization controls ordinary power releases. The Western Area Power Administration (WAPA) of the Department of Energy operates the powerplants at Parker and Davis by micro-wave radio remote control from Phoenix, Arizona. Maintenance personnel from the USBR are available to operate the spillway gates as necessary. Communications between the Operations Office at Boulder City and the facilities at the dam are primarily accomplished by radio; telephones are used as a backup. The WAPA office at Phoenix also communicates with the dams by radio with a telephone back-up. Communications between USBR Boulder City and WAPA Phoenix are usually by telephone.

Water control of the Lower Colorado River reservoirs involve the Corps of Engineers in two aspects. One is the Corps responsibility for directing operation of Hoover Dam for flood control. The other is in coordination with the Corps' operation of Alamo and Painted Rock Dams. The primary means of communications between the Water Scheduling Branch in Boulder City and the Reservoir Regulation Unit in the Los Angeles District are by telephone and mail. Telephone numbers of key personnel in USBR Lower Colorado Region and the Los Angeles District of the Corps of Engineers are presented on Plate 22.

The National Weather Service's Colorado Basin River Forecast Center (CBRFC) makes forecasts of flood flows for both the USBR and the Corps of Engineers. For rainfloods, where rapid communications are essential, the Weather Service Office in Phoenix will notify USBR personnel by telephone and the CBRFC can be reached by telephone and by computer

access to the CBRFC's Automatic Data Collection System (DATACOL). For snowmelt volume forecasts, communications are primarily by mail; but the telephone is also often used for updates and preliminary forecasts. The forecasting communication system is described in more detail in Section 6-02.

5-06. COMMUNICATION WITH PROJECT

Ordinary communications between the USBR's Water Scheduling Branch and Maintenance Branch personnel who maintain and physically operate the spillway gates and other non-power outlets at Hoover, Davis, and Parker Dams are accomplished by courier, telephone, radio, and direct conversation.

Under ordinary circumstances communications concerning releases from Hoover are made with personnel of the City of Los Angeles and Southern California Edison Company who schedule and operate Hoover powerplant. Communications concerning releases from Davis and Parker Dams are made with Department of Energy personnel in Phoenix where the "SCADA" (Supervisory Control and Data Acquisition) computer system is located. Some of the communications for Davis and Parker Dams are accomplished directly with USBR personnel at the dams concerning maintenance activities and other problems.

Communications from the Water Scheduling Branch to the Los Angeles Department of Water and Power and Southern California Edison (which operate the power turbines at Hoover) and the Department of Energy in Phoenix routinely consist of periodic revisions and updates (on a monthly or weekly basis) to the energy generation schedule which was mutually agreed upon at an annual integration meeting. Usually, the hourly and sometimes daily scheduling of Hoover Dam discharges is left to the discretion of the operating agents. This enables the operators to respond to the peaks in electrical demand on a short-term basis while still conforming to the overall objectives of the monthly and annual schedules.

If conditions warrant, the Secretary of Interior's representative (usually USBR's Regional Director of the Lower Colorado Region) may make a written request for the operating agents to adhere to a specific energy schedule. The operating agents have three days from receipt to comply with such a request. If either shall fail to comply as determined by the Secretary's representative, under the provisions of the Boulder Canyon Project Act and the related power contracts, he has authority to take charge of such operations of the powerplant facilities as he deems necessary.

Operators of large diversion facilities, including The Metropolitan Water District, and the Imperial Irrigation District, report daily to the Water Scheduling Branch on quantities diverted to their respective facilities and as needed to give advance notification of short-term changes.

5-07. PROJECT REPORTING INSTRUCTIONS

The Boulder Canyon Project Manager is responsible for operation and maintenance of Hoover Dam and Powerplant and related appurtenances. Personnel at the project office are responsible for operating the canyon wall and tunnel outlet works. The Water Scheduling Branch of the Regional Office is responsible for scheduling releases from Hoover Dam as required by operating plans and water contracts obligations. Through the utilization of a real-time

computerized network, the Water Scheduling Branch continuously monitors storage and flow as well as other pertinent conditions, such as precipitation and snow cover, as required to meet its responsibilities.

Water orders are received by the Water Scheduling Branch each Wednesday for anticipated daily water requirements for the following week from the agencies in the United States contracting for the delivery of water from Imperial Dam and for requirements under the Mexican Water Treaty from the Yuma Office of the International Boundary and Water Commission. The USBR prepares weekly master schedules of Lower Colorado River flows and diversions, and these schedules are distributed each Friday by the Lower Colorado Region at Boulder City, Nevada. The schedules are based on irrigation requirements in the United States, requests for delivery of water under the Mexican Water Treaty, and requirement for river regulation. They are coordinated with flood control and power operations to obtain the optimum overall efficiency from the available riverflow.

Normally, releases at Hoover Dam are based on daily electrical energy requirements of the Hoover allottees, which are furnished by the Operating Agents (Los Angeles Department of Water and Power and Southern California Edison Company). The Water Scheduling Branch receives their daily generating schedules by telephone. In the case of necessity for flood control releases from Lake Mead, the Water Scheduling Branch will arrange with the Hoover Operating Agents for such increases in powerplant releases as can be made. Should bypass of water through the outlets be necessary, the order for bypass will be transmitted to the Project Manager. During extended periods of flooding, consultation and assistance will be provided by Los Angeles District Corps of Engineers, when appropriate and to the extent possible.

5-08. WARNINGS

a. Snowmelt floods. The ability to forecast and control snowmelt runoff allows flood warnings to be given several weeks in advance. When unusual snowmelt flood control releases are scheduled, the Water Scheduling Branch of the Lower Colorado River Regional office notifies local Government agencies - sheriffs, public works, public safety and local press media giving specific times and flows planned. The USBR is also responsible for notifying the District Engineer, Los Angeles District Corps of Engineers, of planned flood control releases and associated hydrologic conditions.

b. Rain floods. Rain floods, especially from thunderstorms, can develop within a few hours, often without reliable forecasting. Warnings of such potential flood conditions are made by the National Weather Service and disseminated mainly by local press media. Warnings of rain flood control releases from Hoover Dam are issued by USBR as described in the previous Section, 5-08a.

VI - HYDROLOGIC FORECASTS

6-01. GENERAL

Hydrologic forecasts are made in conjunction with the operation of Hoover Dam for essentially two purposes: control of flooding, and water supply operations planning.

Hydrologic forecasts of runoff from key watersheds are made by the Colorado Basin River Forecast Center (CBRFC) of the National Weather Service (NWS) in Salt Lake City, Utah. The NWS has been designated as the nationally responsible agency in forecasting, but relies extensively on the cooperation of several agencies for funding, acquisition of data, and manpower assistance in developing forecasting procedures.

The Corps, USBR, Geological Survey (USGS) and the Soil Conservation Service (SCS) are among the organizations which supply basic data. The Corps owns radio-reporting precipitation stations which are used in short-term runoff forecasts. The USGS and the USBR provide flow and storage data which are incorporated in the forecasts, The SCS provides snow depth, extent of areal coverage, and water-content data from its extensive snow-measurement network.

6-02. FLOOD CONDITION FORECASTS

The CBRFC makes forecasts for both long-term, snowmelt based floods, and short-term runoff from rainfall. The specific objectives, requirements, and methods differ widely, as discussed below.

a. Snowmelt floods.

(1) Objectives and requirements. Snowmelt floods involve large volumes, several months durations, and low to moderate peak inflows. The magnitudes of snowmelt floods may be accurately and reliably forecast well in advance of the actual event because of the relatively long time required for the snow to melt and form runoff, the relative ease and reliability in measuring basic data, and the reliability of the methodology used.

Snowmelt forecasts estimate the total runoff volume from the date of the forecast through the end of July at various key points in the Colorado River watershed, including: Flaming Gorge Dam, Blue Mesa Dam, Navajo Dam, Glen Canyon Dam, and Hoover Dam. Forecasts are issued for the first day of each month from January through July. The forecasts include adjustments for depletions such as trans-basin diversions, net water use (in-basin diversions minus return flows) and evaporation from reservoirs, but not for reservoir storage changes. The USBR adjusts the forecast to account for effective upstream storage space as provided in the flood control plan to estimate inflow into Lakes Mead and Powell (see example Exhibit A).

The forecasts include minimum, mean, and maximum possible expected volumes. "Minimum" is defined as having a 95 percent chance of being exceeded and "maximum" has only a 5 percent chance of being exceeded. The maximum is used to determine the required flood control space in Lake Mead as provided in the flood control plan. The mean is used to estimate the effective upstream storage space. The minimum is used as a reference in assessing effective upstream storage.

Forecasts are issued regularly, once a month (January through July) by the CBRFC. Preliminary forecasts are provided to the USBR and the Corps by telephone on or about the first working day of the month; the official forecast is not distributed until about the sixth of the month because of the time required to check and print the official forecast (A sample printed forecast bulletin is shown on Plate 23). Additional updates are available via telephone whenever conditions change significantly due to the passage of large storms. The most current forecast is also available from the AFOS and DATACOL computer systems.

Forecasts of runoff distribution by month based on historic patterns of runoff are also available from the CBRFC.

(2) Methods. Snowmelt forecasts are based on modeling hydrologic factors of the Basin using historical runoff volumes with concurrent observations of physically related variables. These mainly include seasonal precipitation minus runoff and depth of snow, together with the precipitation expected during the remainder of the season.

Measurements of snow depth, density and water content are calculated daily using the NWS RFC model. The occurrence of storms make manual field measurements prior to 1 April impractical. Consequently, forecasts made in January, February and March are based on conceptual parameters as well as the accumulated seasonal precipitation and normal expected precipitation to the end of the season.

Precipitation measurements are made by a large network of NWS field offices, cooperating observers, and cooperating agencies dispersed throughout the watershed. NWS station observations are available by telephone or by accessing NWS computer networks. Cooperators generally report daily precipitation once a month by mail.

SCS snow surveys report measurements of snow depth at all stations and snow water content and density at selected stations. Much of the data is measured manually by field crews from one to several times during the season. Automatic radio-reporting SNOTEL stations are also used extensively to measure and report snowpack parameters more frequently.

The two major sources of uncertainty in the snowmelt forecasts are procedural error and variability in the precipitation for the remaining season. Procedural errors include data inaccuracy, inadequacy of data coverage, and inadequate computation techniques. Of the two components of error, the procedure relating runoff to snowpack measurements is the more certain. The largest uncertainty is due to the unpredictability of the remaining seasonal precipitation. As a result, the least certain forecast is the one made on 1 January. By 1 April most precipitation has occurred, and the snowpack is well defined resulting in a reduction in forecast error. The degree of uncertainty continues to decrease after 1 April.

The snowmelt forecasting procedures developed by the CBRFC are largely computerized. They incorporate observations from about 200 precipitation stations and about 100 snowpack stations. The locations of many of the stations are shown on Plate 13. The particular stations used are occasionally changed, and the associated statistical relationships are continually re-evaluated. The names, locations, and characteristics of the stations and procedures being

used at any given time may be obtained from the River Forecast Center (RFC).

b. Rain Floods.

(1) Objectives and Requirements. Rain floods arise from two distinct types of events. General rain storms produce widespread flooding of one to several days' duration. Volumes are relatively low when compared with snowmelt flood volumes, but peak flows are often much higher. Local floods from thunderstorms are characterized by extremely high peaks and short durations and small volumes. Local floods generally dissipate within a relatively short distance from their origin (see Section 4-06 for a more complete discussion of these events).

Of the two rain flood events, general rainfloods are both more predictable and more likely to cause widespread damage. Thunderstorms, on the other hand, occur erratically whenever atmospheric conditions are "ripe". Thus, such local floods are very difficult to predict.

Forecasts of Colorado River rainfloods into Lake Mead and for downstream tributaries allow for implementation of flood warnings, reservoir outflow adjustments, and flood fighting measures.

(2) Methods. General rain flood forecasts are essentially based on anticipated and measured precipitation and established relationships between runoff and precipitation. These data are supplemented by information from automatic, radio-reporting stream gaging stations at key locations in the watershed. Locations of several of the precipitation stations are shown on Plate 13. The specific stations used at any time are subject to change as new ones are added and old ones are re-evaluated or replaced. Stream gaging stations, however, remain relatively fixed. Some of the key stream gaging stations are shown on Plate 10.

Rain flood forecasting procedures are extensively computerized: the Antecedent Precipitation Index (API) rain flood model is used principally in Arizona, and the NWS RFC model is used elsewhere in the Basin.

Forecasts of rain floods are normally made only when a large event is anticipated. Forecasts are issued by telephone and are also available on the AFOS and DATACOL computer networks of the NWS.

6-03. CONSERVATION PURPOSE FORECASTS

a. Objectives and Requirements. The Colorado Basin River Forecast Center of the National Weather Service in Salt Lake City makes snowmelt runoff forecasts for Hoover Dam and other key points in the Colorado River watershed. Forecasts are issued for the first day of each month from January through May. Forecasts of conservation releases from Lake Mead are scheduled to meet the total downstream requirements (irrigation and water supply requirements in the United States, requests for delivery of water under the Mexican Water Treaty, and requirements for river regulation) during each year of operation. The monthly releases schedule is adjusted to fit nearly as possible the monthly energy schedules desired by the Hoover power allottees. Because of the distance the water must travel, water users normally must schedule orders 3 days in advance of the need. The scheduling of water releases from Lake

Mead is the responsibility of the USBR Lower Colorado Region's Water Scheduling Branch.

b. Methods. The forecasts made by the Colorado Basin River Forecasts Center are based upon measurement of snow depth and water content at selected stations and antecedent fall precipitation and normal or forecasted spring precipitation. The precasts include adjustments for depletions such as trans-basin diversions, net water use, and evaporation from reservations, but not reservoir storage changes. The USBR adjusts the forecast to account for available space in upstream storage.

User demands are developed by the respective agencies based on their individual needs. Each Wednesday, the Lower Colorado Region's Water Scheduling Branch receives the anticipated daily water requirements for the following week from the respective agencies. The USBR prepares a weekly master schedule of Lower Colorado River flows and diversions and distributes them each Friday. Planned releases from Hoover Dam take into account depletions, evaporation, and bank storage. Releases of water from Hoover, Davis, and Parker Dams are made pursuant to the total orders from the individual water users, but changes in weather conditions may cause water supply and irrigation needs to vary significantly between time of release and the scheduled time of diversion downstream.

6-04. LONG RANGE FORECASTS

a. Objectives and Requirements. Operation of Hoover Dam must be projected annually as required by law and described in Section 7-09. Projected operations are developed after taking into consideration probable runoff, depletions, and consumptive uses along with other relevant factors that affect the operation of the system. The annual operating plans are developed for each water year and revised at least monthly as forecasts of runoff become available from the CBRFC. Monthly reports, commonly referred to as the 2-year study, are issued by USBR showing projected reservoir conditions throughout the Colorado River Basin. Projected Lake Mead withdrawal by the Southern Nevada Water Project is reported annually by the USBR.

b. Methods. Projections of depletions and consumptive uses are based on average historical data modified for anticipated changes and estimated schedules. Projections of runoff are initially based on averages of historical data and then adjusted according to forecasts by the CBRFC.

VII - WATER CONTROL PLAN

7-01. GENERAL OBJECTIVES

Hoover Dam and Lake Mead is a multipurpose development with primary objectives of flood control; improvement of navigation and regulation of the flow of the Colorado River; storage and delivery of Colorado River water for reclamation of public lands and other beneficial uses exclusively within the United States; and generation of electrical energy. Recreation, downstream fishery enhancement, release of water to Mexico, and salinity control benefits are also provided by the project.

7-02. MAJOR CONSTRAINTS

a. Institutional. Since the construction of Hoover Dam, the institutionalization of the Colorado River has grown steadily. Use of its water is now governed by two interstate compacts, water laws of seven states, a treaty with Mexico, numerous Federal statutes, court decrees, and water and power contracts. Some of the more important documents affecting the use of Colorado River waters are:

Colorado River Compact - November 24, 1922

Boulder Canyon Project Act December 21, 1928

Seven-Party Water Agreement August 18, 1931

Boulder Canyon Project Water Contracts - April 24, 1930 through the present

Boulder Canyon Power Contracts - April 26, 1930 through the present

Boulder Canyon Project Adjustment Act - July 19, 1940

Mexican Water Treaty - February 8, 1944

Upper Colorado River Basin Compact - October 11, 1948

Colorado River Storage Project Act - April 11, 1956

General Principles to Govern, and Operating Criteria, for Glen Canyon Reservoir and Lake Mead During the Lake Powell Filling Period April 2, 1962

Colorado River Storage Project, General Power Marketing Criteria 1962

U.S. Supreme Court Decree in Arizona v. California - March 9, 1964

Lake Mead Flood Control Regulations - February 18, 1954, revised July 29, 1968

Colorado River Basin Project Act (Public Law 90-537, 90th Congress, approved September 30, 1968)

Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs - June 10, 1970

State Water Laws

Contracts for sale of water from Colorado River Storage Projects Reservoirs

Federal Water Pollution Control Act Amendments - 1972

Minute 242, Mexican Water Treaty - August 30, 1973

Colorado River Basin Salinity Control Act - 1974

b. Encroachment. Since the closure of Glen Canyon Dam in 1963, flows in the Colorado River below Hoover Dam were limited to water user and river regulation requirements until May 1979, by which time near-fall reservoir conditions were attained. The resultant lack of high flows has encouraged encroachment of permanent and semi-permanent development into portions of the floodway that at one time served for conveyance of floodflows. The initial 1935 flood control operation plan was devised to control flooding to the greatest extent possible with outflows from Hoover Dam limited to nondamaging flows of 40,000 cfs. Under today's conditions, extensive property damage would occur from a 40,000 cfs release from Hoover Dam because of the encroachments.

7-03. OVERALL PLAN FOR WATER CONTROL

In a multipurpose operation of a reservoir system, such as is in the Colorado River Basin, all purposes cannot concurrently achieve individual optimization. While it is desirable to keep reservoirs as full as possible to insure that an adequate water supply will be available for future demands on the system, it is also desirable to maintain a certain amount of storage space to minimize the possibility of being forced to make excessive releases during higher runoff years. These two objectives obviously conflict and some balance must be achieved between the two. The approach taken in the planned operation of Lake Mead is to determine optimum public benefits for the combined objectives of flood control, conservation, hydropower, etc.

Because it is the principal water resource in the Colorado River Basin the Colorado River is of major importance to each of the seven states of the Colorado River Basin, and to the Republic of Mexico. Each state has attempted to secure maximum rights to the use of Colorado River water, and out of those attempts has arisen a body of interstate compacts, Federal legislation, water contracts, state legislation, a treaty and other agreements with Mexico, a 1964 United States Supreme Court decree and a 1979 supplemental decree, and Federal administrative actions that define apportionments in Colorado River Basin. Collectively, these documents are generally referred to as "The Law of the River". The most significant documents are summarized in Exhibit C.

7-04. STANDING INSTRUCTIONS TO DAMTENDER

Normal project operation procedures are prescribed in the USBR report "Hoover Dam Standing Operating Procedures." The Project Manager of Boulder Canyon Project, whose offices are located at the dam itself, is responsible for its operation.

Instructions for discharge in accordance with the flood control criteria presented in paragraph 7-05 and Exhibit A of this manual will be issued by the Water Scheduling Branch of the Lower Colorado River Regional Office in Boulder City (located seven miles from the Dam). If releases are to bypass the powerplant, the Project Manager is notified. In the event communications with Boulder City are somehow disrupted, the reservoir will be regulated by personnel at the Dam in accordance with the following:

a. Continue release in accordance with the last instructions from Water Scheduling Branch in Boulder City, and make every attempt to re-establish communication.

b. If communication cannot be re-established and the reservoir is above elevation 1219.61 make releases in accordance with the criteria on Table 1 of the flood control regulations (see Exhibit A, page A-11).

7-05. FLOOD CONTROL

a. **General.** The flood control regulations presented in Exhibit A were established to deal with two distinct types of flooding: rain floods and snowmelt floods.

b. **Rain Floods.** Lake Mead's uppermost 1.5 million acre-feet of storage, between elevations 1219.6 and 1229.0 is allocated exclusively to control rain floods. Within this allocation 1.218 million acre-feet is above elevation 1221.4, top of the raised spillway gates. Table 1 in the regulations specifies minimum flood control releases. During rising reservoir stages, releases are made in progressive steps of 28,000, 40,000 and 65,000 cfs, each determined as a function of pool elevation. Outflow is regulated to equal inflow up to each step release value when the pool reaches specified elevations. At the maximum allowable reservoir elevation of 1229.0 all usable storage is filled and minimum flow over the raised spillway gates is 65,000 cfs. Outflow is then regulated to equal inflow when inflow exceeds 65,000 cfs. Under such conditions, inflow will be determined from frequent reports of reservoir storage change, upstream river gages, and releases from Glen Canyon Dam.

The regulations specify that once rain flood releases exceed 40,000 cfs, they shall be maintained at the highest rate achieved until the reservoir drops to elevation 1221.4, top of the raised spillway gates. Releases may then be gradually reduced to 40,000 cfs and no less until prescribed seasonal storage space is available (described in paragraph 7-05c).

The regulations also permit higher rainflood releases when based on forecasted inflow and within the objective of reducing the projected peak outflow.

c. **Snowmelt Floods.** The regulations set forth two primary criteria to deal with snowmelt floods: preparatory reservoir space requirements, and application of runoff forecasts to determine releases.

In preparation for the coming year's season of snow accumulation and melt, progressive expansion of reservoir space is required during the later half of each year. Minimum available flood control space shall increase linearly from 1.5 million acre-feet on 1 August to 5.35 million acre-feet on 1 January. Required space can be in either Lake Mead or specified

upstream projects: Lake Powell and Navajo, Blue Mesa, Flaming Gorge and Fontenelle Reservoirs. Minimum Lake Mead space required for exclusive flood control is 1.5 million acre-feet. Required system space is tabulated below.

<u>Date</u>	<u>Minimum Required Flood Control Storage Space (acre-feet)</u>
1 August.....	1,500,000
1 September.....	2,270,000
1 October.....	3,040,000
1 November.....	3,810,000
1 December.....	4,580,000
1 January.....	5,350,000

Normal space building releases from Lake Mead to meet the required 1 August-1 January flood control space are limited to 28,000 cfs, the approximate nondamaging, downstream channel capacity. However, with enactment of the rainflood criteria space building releases could reach 40,000 cfs.

Maximum creditable space for each upstream reservoir, except Lake Powell was derived by subtracting normal releases from inflow components to a January-July Lake Mead inflow forecast of 20 million acre-feet (the minimum forecast requiring flood releases under the 1968 regulations). The maximum space for each project was further established as follows:

Lake Powell. All of the snowmelt runoff to Lake Mead, except the minor contribution from the intervening drainage area, flows through Lake Powell. Consequently the January System space requirement of 5.35 million acre-feet minus Lake Mead's 1.5 million acre-feet minimum space requirement can be satisfied in Lake Powell. This difference, 3.85 million acre-feet, is the maximum creditable space at Lake Powell.

Navajo Reservoir. The Navajo Reservoir maximum creditable space is the total active space, 1,035,900 acre-feet.

Blue Mesa Reservoir. The Blue Mesa Reservoir maximum creditable space is the total active space, 748,500 acre-feet.

Flaming Gorge and Fontenelle Reservoirs. The combined Flaming Gorge-Fontenelle Reservoir space was determined by deducting from the January-July forecast inflow of 2,180,000 acre-feet (a component of the 20 million acre-feet Lake Mead forecast), the expected January-July outflow of 672,800 acre-feet resulting in a 1,507,200 acre-feet maximum creditable space. The 1982 regulations allow space in the upstream Fontenelle Reservoir to be treated as if it were in Flaming Gorge Reservoir because the two projects are operated as a system.

Maximum 1 August-1 January creditable upstream storage is tabulated on the next page.

<u>Reservoir</u>	<u>Creditable Storage Space (Acre-Feet)</u>
Lake Powell	3,850,000
Navajo	1,035,900
Blue Mesa	748,500
Flaming Gorge plus Fontenelle	1,507,200

Between 1 January and 31 July, flood releases, based on forecasted inflow, are required to prevent filling of Lake Mead beyond its 15 million acre-feet minimum space. Starting on 1 January the Colorado River Forecasting Service (CRFS) issues runoff forecasts on the first day of each month for the period extending through 31 July. The regulations are concurrently applied to determine minimum Lake Mead releases for each month, in a progressive manner.

The release schedule contained in the regulations is based on increasing releases in six steps. The lowest step, zero cfs, corresponds to times to when the regulations do not require flood control releases, which is the preponderance of the time. Hoover Dam releases are then predicated on water and power objectives, but may also be for more conservative flood control objectives as determined appropriate by the USBR. However, releases shall not exceed 28,000 cfs passing the gaging station, Colorado River below Davis Dam, unless required to by the regulations. The second step, 19,000 cfs, is based on the power plant capacity of Parker Dam. Releases in excess of 19,000 cfs for periods beyond the limited modulating capacity of Lake Mohave and Lake Havasu would waste energy by bypassing the Parker powerplant. The next step, 28,000 cfs is the approximate maximum release at Hoover Dam that will not cause damage through the Parker Strip. Also, the powerplant capacity at Davis is 28,000cfs. The present power plant capacity at Hoover Dam is 35,000 cfs, to which the fourth step corresponds. At the time Hoover Dam was completed, 40,000 cfs was the approximate maximum nondamaging flow downstream from the dam. Prior flood control plans regulated outflow to 40,000 cfs, which forms the fifth step. Releases of 40,000 cfs and greater would result from unusually large floods. The sixth and last step in the series, 73,000 cfs is the maximum controlled release from Hoover Dam without spillway flow.

The regulations require that forecasted inflow to Lake Mead account for all upstream depletions including transbasin diversions, net water use (diversion minus return flow) and evaporation from all upstream reservoirs, excluding Lake Powell. The regulations permit the maximum of the forecast (not exceeded 19 out of 20 times) to be reduced for effective upstream storage space, except in Lake Powell. Effective storage space in each upstream reservoir is the lesser of actual space available or usable space. Usable space is the difference between the mean forecasted inflow and projected release for each reservoir. The CRFS provides forecasts for Navajo, Blue Mesa, and Flaming Gorge Reservoirs. Fontenelle and Flaming Gorge are treated as one unit where actual space available is the sum for both reservoirs, but, usable space is the difference between forecasted inflow and projected releases at Flaming Gorge only. The USBR provides projections of releases in its 2 year study report, issued monthly. Effective upstream storage space is not limited to creditable maximums previously cited for the 1 August-1 January period.

Because of their relatively close proximity within the watershed, available space at Lakes Powell and Mead are added and considered as a single unit available to impound the adjusted maximum forecasted inflow. Flood control releases are required when the forecasted inflow exceeds the available Lakes Mead and Powell storage space including projected bank storage and evaporation losses at both lakes plus net withdrawal from Lake Mead by the Southern Nevada Water Project. The regulations set forth a procedure to release the volume of flow that cannot be impounded.

Average monthly releases are determined early in each month and apply only to the current month. The releases are progressively revised each subsequent month throughout the 1 January - 31 July runoff period in response to updated runoff forecasts and changing reservoir storage levels. Average releases for each current month are required to be equal to or less than an average theoretical release at one of the prescribed step values occurring during the remaining months (second month through 31 July). Additionally, the total volume of release through 1 August must equal the forecasted volume of inflow exceeding impoundment space at Lakes Mead and Powell. However, the current month's release cannot be less than one step below the assigned theoretical step (applied for the remaining months). The regulations present an algorithm that is applied in successive trials to determine the current month's release. A sample calculation is presented in Exhibit A.

7-06. RECREATION

No formal Hoover Dam water control objectives exist for recreation.

7-07. WATER QUALITY

Hoover Dam is not operated to meet specific water quality objectives, however, the project provides incidental salinity control by diluting summer low flows previously high in dissolved solids.

7-08. FISH AND WILDLIFE

The Willow Beach National Fish Hatchery located about 12 miles downstream from Hoover Dam on Lake Mohave went into production in 1963. The water supply for the hatchery is pumped from near the bottom of Lake Mohave. The production of the hatchery is sensitive to the temperature of the water. Selective withdrawal from Lake Mead is conducted whenever possible to maintain a release water temperature of 56° F.

A minimum flow objective of about 2,000 cfs, although not required by law, is maintained whenever possible on the river below Davis Dam in order to provide a suitable fish habitat, especially during the spawning season.

7-09. WATER SUPPLY

The Colorado River Basin Project Act, enacted in 1968, provides guidelines for system water supply operations. Major features of the Act are:

(1) In the event of a water shortage, the California apportionment of 4,400,000 acre-feet per year has priority over that of the Central Arizona Project.

(2) Authorization of the Central Arizona Project and several Upper Basin water projects.

(3) The United States assumes the responsibility for meeting the entire Mexican Water Treaty obligation when water supply in the River below Lee Ferry is augmented 1/ by at least 2,500,000 acre-feet per year.

(4) Authorization of a major water study by the Secretary of the Interior to determine water supply needs and a plan to meet future water requirements in the eleven western states.

(5) The Secretary of the Interior was directed to establish coordinated long-range operating criteria for the major Colorado River reservoirs based upon priorities listed in the Act.

The Coordinated Long-Range Operating Criteria for Colorado River reservoirs required to be established by this Act were issued by the Secretary of the Interior in June 1970. They have as an objective the release of a minimum of 8,250,000 acre-feet per year to Lee Ferry and provide that a reservoir operating plan be developed by the Secretary each year after consultation with the seven Basin states. The Criteria provide for a determination by the secretary of the amount of water to be retained in Upper Basin reservoirs in order to meet obligations to the Lower Basin without impairment of the Upper Basin's consumptive uses. When the Upper Basin storage is greater than the amount determined above, releases above the minimum will be made in order to maintain, as nearly as practicable, active storage at Lake Mead equal to active storage in Lake Powell. The Criteria also provide that the reasonable consumptive use requirements of all mainstream users in the Lower Basin will be met without cutback until such time as commence from the Central Arizona Project.

7-10. HYDROELECTRIC POWER

Southern California Edison and Los Angeles Department of Water and Power operate the Hoover Dam power plant as agents for the United States. Power is supplied to allottees in Arizona, California, and Nevada. The present total capacity is 1,344,800 kilowatts but because of the relatively limited amount of water, the Hoover powerplant normally operates at approximately 32-percent of capacity. The principal contractors and allocation to each for the firm energy generated is given in the tabulation on the next page.

Power is generated from the releases required for water supply and flood control purposes; no releases are made for the specific purpose of power generation. However, efforts are made to maximize useful power generation when flexibility is available.

1/ "Augment" means to increase the supply of the Colorado River or its tributaries by the introduction of water into the Colorado River system, which is in addition to the natural supply of the system.

<u>CONTRACTOR</u>	<u>ALLOCATION OF FIRM ENERGY (%)</u>
State of Arizona	17.6
State of Nevada	17.6
The Metropolitan Water District of Southern California	35.3
City of Burbank	0.6
City of Glendale	1.8
City of Pasadena	1.6
City of Los Angeles	17.6
Southern California Edison Co.	<u>7.9</u>
TOTAL	100.0

Normally, the Water Scheduling Branch of the USBR provides monthly generation total objectives to the two Hoover Powerplant operating agents who conform their daily and hourly power demand schedules to the monthly totals.

7-11. NAVIGATION

Navigation is a project purpose of Hoover Dam, and Lake Mead. Although releases are not made explicitly for navigation, the construction of Hoover Dam has resulted in the improvement of navigation on sections of the Colorado River. Technically, the Colorado River is considered a navigable stream. Actually, under natural conditions of unregulated streamflow, navigation of the River itself was extremely hazardous and impractical. Now, however, craft ranging in size from small boats to cabin cruisers do navigate Lakes Mead, Havasu, and Mohave.

7-12. DEVIATION FROM NORMAL REGULATION

The Lower Colorado Region of the Bureau of Reclamation may be requested to deviate from the established flood control plan. Prior approval of deviations with regards to flood control is required from District Engineer, Los Angeles District, Corps of Engineers, except for emergencies and deviations as discussed in subparagraphs a and b, below.

a. Emergencies. Some emergencies that can be expected are: drownings and other accidents, and failure of operation facilities bridges or levees. In some cases, necessary actions required by the operating plan could create equal or worse conditions. The District Engineer, Los Angeles District, Corps of Engineers, is to be informed of any deviations as soon as practical.

b. Unplanned Minor Deviations. There are unplanned instances that create a temporary need for minor deviations from the normal regulation of the reservoir although they are not

considered emergencies. Construction activities account for the major portion of such incidents and often include utility stream crossings, facility maintenance, bridge work, bank protection work, and channel maintenance and major construction contracts. Changes in releases are sometimes necessary for maintenance and inspection. Requests for changes of release rates are generally for a few hours to a few days. Each request is analyzed on its own merits. Consideration is given to upstream watershed conditions, potential flood threat, conditions of reservoirs, and possible alternative measures. In the interest of maintaining good public relations, the requests are usually complied with providing there are no foreseen adverse effects on the overall operation of the project for the authorized purposes. Approval for these minor deviations will normally be obtained from the District Engineer, Los Angeles District, Corps of Engineers, by telephone. A written confirmation explaining the deviation will be furnished by the Lower Colorado Region USBR.

c. Planned Deviations. Each condition is to be analyzed on its own merits. Sufficient data on flood potential, reservoir and watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other projects and useful purposes will be presented by letter or telephone to District Engineer, Los Angeles District, Corps of Engineers, along with recommendations for concerning approval.

d. Low Flow Contingency Plan. The flood control regulations described in this manual are not in conflict with any drought contingency plans developed by the USBR.

7-13. RATE OF RELEASE CHANGE

The rate of change of release from Hoover Dam is not an important consideration since Lake Mohave and Davis Dam substantially re-regulates and "smoothes" any short-term fluctuations which are normally due to power releases from Hoover Dam. Large fluctuations are felt in Black Canyon just below Hoover Dam, however, this canyon is closed to boating and no development that could be damaged exists there.

VIII - EFFECT OF WATER CONTROL PLAN

8-01. GENERAL

Management of releases and storage available at Hoover Dam and Lake Mead in accordance with past and present operation plans continues to provide a reliable water supply for the majority of the population in the Lower Colorado River Basin and to reduce the magnitude of flooding along the Lower Colorado River.

Operations for water supply and flood control have resulted in a stabilization of the flow regime on the Lower Colorado River in comparison with that occurring prior to construction of Hoover Dam as illustrated in Figure 3. The stabilization of flows has continuing positive effects on recreation, water quality, and fish and wildlife.

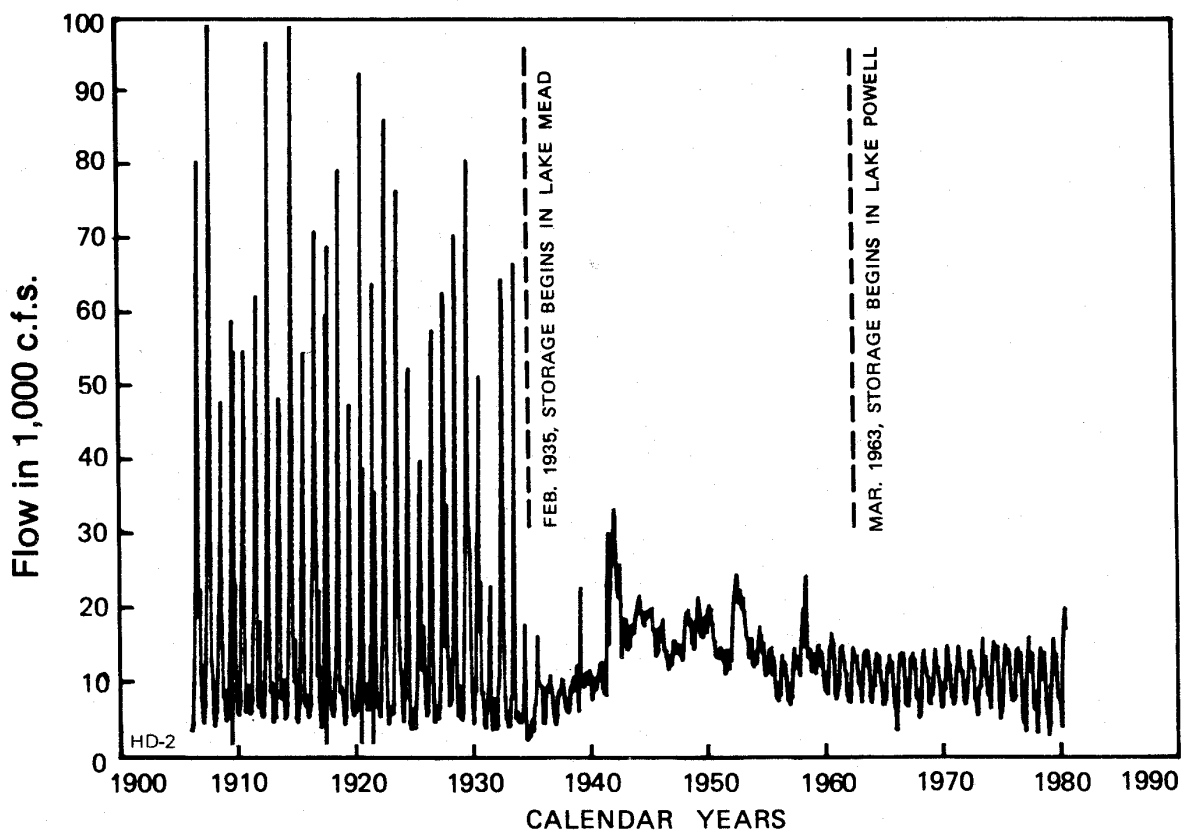


Figure 3 Mean monthly flows on the Colorado River below Hoover Dam.

The fulfillment of other project objectives besides water supply and flood control have also been achieved. The hydraulic energy available at Hoover Dam is converted into a significant electrical power supply for the Southwest. Also, Lake Mead and Lake Powell effectively trap the major portion of their sediment inflows.

8-02. FLOOD CONTROL

The operation of Hoover Dam under past and present flood control plans has achieved a high degree of protection from flooding along the Lower Colorado River.

a. Spillway Design Flood.

(1) Spillway. The spillway is capable of passing up to 400,000 cfs - about 1/3 greater than the estimated instantaneous peak occurring during the flood of 1884, the largest known historical flood; more than twice the peak daily inflow of the probable maximum rainflood; and about 40 per cent greater than the peak daily inflow of the probable maximum snowmelt flood. Refer to Plate 8 for spillway discharge rating curves.

(2) Probable Maximum Rain Flood. A probable maximum rain flood was developed by the USBR based on theoretical maximum precipitation amounts arranged in a critical sequence. The precipitation amounts were provided by the U.S. Weather Bureau's Hydrometeorological Section. The inflow hydrograph to Lake Powell had a peak of 417,000 cfs and a 48-hour volume of 1,238,300 acre-feet. Lake Powell was assumed full to normal water surface (elevation 3,700 feet) at the start of the flood. Maximum daily release from Glen Canyon Dam would be 86,500 cfs following spillway operation criteria. These releases combined with downstream tributary runoff were routed to develop an inflow hydrograph to Lake Mead.

Following the current flood control plan the COE routed the hydrograph through Lake Mead. The reservoir was assumed full to the top of the raised spillway gates at elevation 1221.4 leaving 1.218 million acre-feet of flood control space available at the start of the flood. The inflow volume to Lake Mead would be about 2.8 million for the first 12 days, with a maximum mean daily inflow of 193,600 cfs (a daily volume of 384,400 acre-feet). The maximum outflow from Hoover Dam would be 92,900 cfs, utilizing the entire 1.5 million acre-feet of flood control space (a maximum pool elevation of 1229.0 feet, 7.6 feet above than the initial elevation). A hydrograph of the probable maximum rain flood routing is shown on Plate 24.

(3) Probable Maximum Snowmelt Flood. A probable maximum snowmelt flood was developed by the USBR and routed through Lakes Powell and Mead under the current operating plan by the USBR. The routing took into account actual or anticipated forecast errors, evaporation, bank storage, and depletion losses, and an assumed 5,350,000 acre-feet of storage availability in upstream reservoirs including Lake Powell.

The total inflow volume at Lake Mead for the 7-month event would be about 25.9 million acre-feet. The maximum mean daily inflow would be about 247,000 cfs, and the maximum mean daily outflow would be about 73,000 cfs. 1.5 million acre-feet of remaining flood control space would remain at the end of the event as required by the flood control operating plan. Hydrographs of the probable maximum snowmelt flood routing are presented on Plate 25.

b. Standard Project Rain Flood. A standard project rain flood was developed by the USBR based on the three largest rain events recorded in the area - the floods of: September 15-19, 1923, September 3-7, 1939 and September 8-13, 1939. Inflow hydrographs to Lake Mead

for the portion of runoff occurring between Glen Canyon and Hoover Dams were established. By matching maximum daily inflows, the hydrographs for the periods of September 14-26, 1923 and September 4-16, 1939 were combined. The daily flow values were then rearranged in a critical manner and added to a steady release of 23,000 cfs (maximum powerplant capacity) from Glen Canyon Dam to develop the standard project flood hydrograph.

Following the current flood control plan the COE routed the hydrograph through Lake Mead. The initial pool elevation at Lake Mead was 1219.6 feet, leaving 1.5 million acre-feet of exclusive flood control space as required by the flood control operation plan. The total inflow to Lake Mead would be about 1.1 million acre-feet, with a maximum mean daily inflow of 112,000 cfs. The maximum outflow from Hoover Dam would be 40,000 cfs. About 413,000 acre-feet of storage would be utilized. The maximum pool elevation would be about 1222.2 feet, about 2.6 feet above the initial elevation. Hydrographs of the standard project rain flood routing are presented on Plate 24.

c. Other Floods. The large snowmelt floods of 1884 and 1917 were routed through Lakes Powell and Mead by the USBR in accordance with the current flood control operation criteria. The maximum release for these floods would be 73,000 cfs and 40,000 cfs, respectively. Hydrographs of these flood routings are presented on Plate 25.

The largest inflows to Lake Mead since the project's construction occurred in 1941, 1952, and 1957. Flood releases were made during the 1941 and 1952 events. In 1941, the maximum mean daily inflow of 119,200 cfs was reduced to a maximum mean daily outflow of 35,500 cfs. In 1952, the maximum mean daily inflow of 122,000 cfs was reduced to a maximum mean daily outflow of 30,900 cfs. In 1957, the maximum mean daily inflow of 124,000 cfs was reduced to a maximum mean daily outflow of 18,400 cfs. Each of these floods would have caused damages of several million or more dollars without the moderating effect of Hoover Dam and the operating plan. Plate 26 is a volume- frequency curve of reservoir outflow. Plate 27 provides a historical plot of Lake Mead and Lake Powell contents and outflow.

8-03. RECREATION

The relatively stable pools in Lakes Mead, Mohave, and Havasu and the stabilized flows along the Lower Colorado River together with the natural attractions of the Southwest have made Lake Mead National Recreation Area and various other sites and parks along the Lower Colorado River important recreation resources. The significance of these resources is indicated by the 1974 attendance of about 6,000,000 visitors to the Lake Mead National Recreation Area. When large floods are forecasted spring space building releases may cause adverse drawdown effects to Lake Mead marinas. Conversely recreation facilities adjacent to the downstream channel may experience highwater and flooding. During flood release periods Lakes Havasu and Mojave are also drawn down with negative recreation impacts to allow operational flexibility to deal with downstream storms or emergencies.

8-04. WATER QUALITY

The storage of water in Lake Mead and the operation of Hoover Dam affect water quality. The two water quality parameters of most critical consideration are salinity and temperature.

Evaporation from Lake Mead concentrates the dissolved solids in the lake to a small degree. Entrapment of sediments probably reduces the leaching of salts from the sediments from what would occur without the lake. During periods of dry climatic conditions and resulting reduced natural flows in the watershed, releases from Hoover Dam significantly dilute the more concentrated, low volumes from unregulated tributaries.

Because Lake Mead is large, deep, and turns over fairly slowly (its volume is large in relation to its inflows and outflows), the lake develops a thermal stratification throughout most of the year, with a warm layer (epilimnion) on top of a much colder layer (hypolimnion). The stratification creates conditions favorable for both cold and warm water fishes in the lake. Furthermore, since releases are made from the hypolimnion, the river downstream from Hoover Dam and the upper reaches of Lake Mohave are sufficiently cold to benefit the trout fishery that exists there.

Although the project affects other water quality parameters as well, whatever other changes take place cause no significant problems and some may be beneficial to other aspects of the aquatic system.

8-05. FISH AND WILDLIFE

Lake Mead supports an abundance of striped bass, black bass, bluegill, crappie, trout, and catfish as well as several non-game species. The State of Nevada's Department of Fish and Game operates a hatchery on Lake Mead which stocks the lake with trout.

Cold waters released during normal operation from the depths of Lake Mead have created favorable conditions for rainbow trout below the dam. A trout hatchery located at Willow Beach and owned by the USBR, NPS, and FWS raises trout for the Lower Colorado River.

During periods of dry climatic conditions and low natural flows in the watershed, maintenance releases from Hoover Dam help sustain the fish in the Lower Colorado River.

Lake Mead along with other Lower Colorado River projects support habitats for terrestrial and aquatic birds and other terrestrial animals. Four National Wildlife Refuges have been established along the Lower Colorado: Havasu, Cibola, Imperial, and Mittry. Other special locations, such as Topcock Marsh, also support significant wildlife populations. The lower Colorado River provides a high degree of flood protection as well as water and a source of food to these areas. Lake Mead attracts a large number of desert bighorn sheep to the Lake Mead National Recreation Area.

Waterfowl which visit or inhabit the Lower Colorado River include pintails, mallards, Canadian geese, and snow geese. Wading birds include egrets, great blue herons, and sandpipers. Lake Havasu is a favorite of migratory waterfowl.

Terrestrial birds are also diverse and abundant along the river and around the reservoirs. The endangered Yuma Clapper Rail inhabits areas along the lower Colorado River during the summer phase of its migratory cycle.

8-06. WATER SUPPLY

The Colorado River provides a major portion of the water supply in its watershed. In general, the coordinated operation of Colorado River reservoirs under current operating plans is sufficient to meet the full allocation of Colorado River waters as provided in the respective laws discussed in Section VII and Exhibit C. The exception would occur during conditions of a prolonged, general drought when reservoirs would be depleted.

The following account and table of deliveries to major water users during a typical, recent year indicates the magnitude of the water supply provided by Lake Mead. Table 7 provides a summary of annual consumptive use in the lower Colorado River.

During water year 1978, releases of 6,718,000 acre-feet of water from Lake Havasu were made to meet the requirements for water deliveries at Imperial Dam, as well as those of the Colorado River Indian Reservation near Parker, Arizona, the Palo Verde Irrigation District near Blythe, California, other miscellaneous users along the river, and transit losses between Parker Dam and Imperial Dam.

Deliveries to Mexico consisted of river water delivered to Imperial Dam and drainage return flows from return users below Imperial Dam.

The major water diversion above Parker Dam was by Metropolitan Water District (MWD) of southern California. MWD pumped 896,700 acre-feet from Lake Havasu during water year 1978, which included 7,674 acre-feet for delivery to the city of Tijuana, pursuant to a contract for temporary emergency delivery of a portion of Mexico's Treaty entitlement. During water year 1978, releases of 7,997,000 acre-feet were made from Lake Mohave to provide for releases at Parker Dam; to supply diversion requirements of the MWD, miscellaneous contractors, and other users; to offset evaporation and other transit losses between Davis and Parker Dams; and to maintain the scheduled levels of Lake Havasu.*

TABLE 7
LOWER COLORADO RIVER
ANNUAL CONSUMPTIVE USES
1971-75*
(in 1,000 Acre-Feet)

YEAR	LOWER BASIN TOTAL	WATER PASSING TO MEXICO
1971	11,554	1,562
1972	12,055	1,600
1973	12,033	1,594
1974	12,785	1,721
1975	12,175	1,656

*Secretary of Interior's "Annual Report, Operations of the Colorado River Basin, 1978, Projected Operations, 1979, 11 January 1979, USBR.

Additional insight into the significance of the water supply developed at Lake Mead is provided by the tabulation of major acreages under irrigation shown in Table 8.

TABLE 8
MAJOR ACREAGES IRRIGATED
COLORADO RIVER BELOW HOOVER DAM

AGRICULTURE USER	ACREAGE	ANNUAL PRODUCTION VALUE
Colorado River Indian Reservation	62,000 ¹	Unknown
Palo Verde Irrigation District	97,000 ¹	103,000,000 ²
Imperial Irrigation District	500,000 ¹	500,000,000 ²
Coachella Valley County Water District	67,300 ¹	128,000,000 ²
Gila Project	105,000 ³	Unknown
Yuma Project	68,000 ³	Unknown

1. "California's Stake in the Colorado River," Colorado River Board of California, August 1979.

2. Source in ¹, Table 8, 1978 values, includes livestock.

3. "Lower Colorado River Reclamation," (pamphlet) USBR, 1979.

Finally, the water supply developed at Hoover Dam is very important as a source of domestic, municipal, and industrial water for the nearly 11 million residents of California's southern coastal region. In 1978, The Metropolitan Water District, which markets the water from the Colorado River, obtained about 25 percent of its requirements from the Colorado River.

8-07. HYDROELECTRIC POWER

The average annual hydroelectric energy generated at Hoover Dam is about 3.9 billion kilowatt-hours, varying between about 2.6 and 6.5 billion. While this output is not large relative to the total demand and output of fossil-fuel plants in the region, the power generated at Hoover Dam has additional, unique values as a power source. First, power generated at Hoover Dam is non-polluting. Secondly, it is available practically instantaneously and therefore serves as a dependable standby and peaking source to follow the fluctuations in demand typical of large power networks. In contrast, the output of conventional, fossil-fuel plants cannot be varied as readily.

The dependability and stability of releases from Hoover Dam also enables a significant, firm power production at Davis and Parker Dams. Plate 28 shows typical power generation patterns for Hoover Dam.

8-08. NAVIGATION

Navigation is no longer an essential function of Hoover Dam, although the impoundments created by the project and downstream projects are continually navigated by all sizes of private pleasure craft.

8-09. FREQUENCIES

Peak Outflow. Frequency curves of average sustained peak outflows for 1, 6 and 12 month periods below Hoover Dam are shown on Plate 26. A tabulation of maximum monthly discharge for several frequencies at key locations on the lower Colorado River is listed on Table 9 below.

**TABLE 9
MAXIMUM MONTHLY DISCHARGE*
IN SELECTED REACHES
LOWER COLORADO RIVER
(1000 cfs)**

Reach	Return Period in Years									
	2	5	10	25	50	100	200	333	500	1,000
Hoover Dam to Parker Dam	18,700	27,100	28,000	31,000	35,000	35,000	40,000	40,000	53,000	62,000
Parker Dam to Headgate Rock Dam	15,700	24,400	26,300	29,000	32,000	32,100	37,700	39,000	52,300	61,800
Headgate Rock Dam to Imperial Dam	14,500	23,800	25,000	28,500	31,400	31,500	36,500	37,500	50,800	60,300
Imperial Dam to Morelos Dam	11,000	20,000	20,500	27,600	27,700	27,800	32,800	32,800	42,000	51,500
Immediately downstream from Morelos Dam	9,500	18,500	19,500	26,500	26,500	26,500	31,400	31,400	39,800	47,800

*Does not include downstream tributary flooding.

8-10. OTHER STUDIES

Since the water resources of the Lower Colorado River Basin are a paramount concern to the region, they are extensively studied, especially by the USBR. Many of these studies relate, in varying degrees, to the water control plan for Hoover Dam and Lake Mead. Reports of studies of particular interest are listed in Section 1-03 (Table 1).

a. Review of Flood Control Regulation. The flood control plan and regulation presented in this manual are based on a review study conducted jointly by the Lower Colorado Region, USBR, and the Los Angeles District COE during the period 1977 through 1982.

The study was motivated by changing conditions in the Colorado River watershed, mainly: the completion of filling of upstream reservoirs constructed during the 1960s, and the subsequent increased probability of flood releases; and a greater susceptibility to flooding on the Lower Colorado River due to development, including encroachment into the flood plain.

The study considered several alternative operation schemes and their different economic effects on flooding, water supply, hydropower, salinity, and operation and maintenance as well as other economic and non-economic criteria. The Colorado River Storage Project (CRSP) computer simulation model developed by the USBR was used extensively to assess the effects of the alternatives.

The selection of the most favorable alternative involved public meetings and coordination with all concerned government agencies.

The results of the study and the selection process for the current flood control regulation are presented in the report entitled "Colorado River Basin, Hoover Dam, Review of Flood Control Regulation" by the COE.

b. Central Arizona Project. The Central Arizona Project (CAP) will divert water from the Colorado River at Lake Havasu and convey it to storage facilities in central Arizona where the water will be a major supply source. Although portions of the project have been constructed, the project is not expected to begin diverting until at least 1985. The current operating plan does not include the effect of CAP. Because the CAP is expected to divert sufficient water to reduce the probability of flood releases, the current plan should again be reviewed when CAP diversions and operating plans are definite.

c. Channel and Floodway Improvements. The USBR has studied and published reports on hydraulic conditions in the critical reaches of the lower Colorado River under both flood insurance programs and the Colorado River Front Work and Levee System. These reports are listed below in Table 10.

**TABLE 10
LIST OF REPORTS ON CHANNEL
AND FLOODWAY IMPROVEMENTS
BY THE U.S. BUREAU OF RECLAMATION**

TITLE OF REPORT	DATE
Report on River Control Work and Investigations, Lower Colorado River Basin 1974-1975	December 1976
Lower Colorado River Maps	December 1976
Flood Plain Information, Colorado River, Davis Dam to Topock	March 1969
Flood Plain Information, Colorado River, Parker Dam to Headgate Rock Dam	July 1971
Flood Plain Information, Colorado River, Palo Verde Dam to Imperial Dam	October 1974
Flood Plain Information, Colorado River, Imperial Dam to San Luis	August 1973

Additional hydraulic studies were made by the Corps of Engineers for the report cited in 8.10-a.

IX - WATER CONTROL MANAGEMENT

9-01. RESPONSIBILITIES AND ORGANIZATION

a. Corps of Engineers. The role of the Corps of Engineers in the operation of Hoover Dam is based on Section 7 of the Flood Control Act of 1944, which reads in part:

Hereinafter it shall be the duty of the Secretary of War to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds provided on the basis of such purposes, and the operation of any such project shall be in accordance with such regulations * * *.

Rules and regulations published in "The Federal Register," Vol. 43, No. 199, Friday, 13 October 1978, under Title 33, Chapter 11, Part 208, provide for the revision of water control plans " * * * to reflect changed conditions that come to bear upon flood control and navigation * * *" These regulations are reprinted in Exhibit B.

In practice, the Corps' role has mainly consisted of developing flood control operating criteria and regulations and monitoring flood conditions and compliance with flood control regulations. The Corps is available for consultation on flood-related operations; deviations from the flood control plan require Corps approval.

The regulations for flood control operation of Hoover Dam are contained in the agreement presented in Exhibit A. The Corps chain of command and related telephone numbers are shown in Plate 22.

b. Bureau of Reclamation. The Bureau of Reclamation owns, operates and maintains Hoover Dam and related project features as well as Davis and Parker Dams except as described below.

The Lower Colorado River Region of the USBR is directly responsible for operation, maintenance, and construction. The offices of the Lower Colorado Region are located in Boulder City, Nevada.

Two basic elements of the Lower Colorado River Region have responsibilities in the operation of Hoover Dam. The chain of command of key Lower Colorado Region personnel and their phone numbers are shown on Plate 22; their specific responsibilities and functions are explained below.

The Boulder Canyon Project Manager is specifically responsible for operation, maintenance, and construction of Hoover Dam and Powerplant and related appurtenances. Personnel from the project office are designated for operating the canyon wall and tunnel plug outlet valves. The Boulder Canyon Project Office is located on the 7th floor of the central section of the powerplant, along the downstream toe of Hoover Dam.

The Water Scheduling Branch of the Regional office is responsible for scheduling releases from Hoover Dam as required by operating plans and water contract obligations.

The Water Scheduling Branch is located in the Lower Colorado Region's Offices in Boulder City, Nevada.

9-02. INTERAGENCY COORDINATION

a. Local Press Bulletins. The Lower Colorado Region of the USBR coordinates with the local press regarding floods and other aspects of project operation.

b. National Weather Service. Congress has given the National Weather Service national responsibility for making flood warnings for the public.

The River Forecast Center of the NWS at Salt Lake City, Utah, is responsible for forecasting streamflows, runoff, and precipitation throughout the Colorado River watershed as explained in Section VI.

The NWS' responsibilities also include operation and maintenance of their computerized hydrologic and climatic information networks accessible to user agencies.

c. US Geological Survey. The US Geological Survey cooperates with several agencies in the Lower Colorado River Basin in the operation of stream gaging stations. The USGS maintains and services many of the stations under contract. Data from many of the gages are published by the USGS in its Water Supply Papers. (See Section V for more information.)

d. Power Marketing. Electrical marketing and transmission are the responsibility of the U.S. Department of Energy's Western Area Power Administration. The generators at Hoover Dam are operated by the City of Los Angeles Department of Water and Power (DWP) and the Southern California Edison Company. The DWP generates for itself, other municipalities, the States of Arizona and Nevada, and The Metropolitan Water District of Southern California (MWD). The Southern California Edison Company generates for itself.

The States of Arizona and Nevada, the DWP, the Southern California Edison Company, The MWD, and the cities of Glendale, Burbank, and Pasadena, California, are the principal energy contractors.

e. Soil Conservation Service. The Department of Agriculture's Soil Conservation Service (SCS) collects and publishes snow survey data, including maintenance and operations of automatic (SNOTEL) stations, as part of the overall basin water supply and flood forecasting efforts.

f. International Boundary and Water Commission. The International Boundary and Water Commission (IBWC) facilitates the exchange of information on flood, channel, and meteorological conditions between the United States and Mexico. Water control for Mexico is limited to criteria defined by treaty. However, the United States will consider all requests made by Mexico through the IBWC.

Under Article 13 of the 1944 Mexican Water Treaty, the IBWC is specifically responsible for flood control on the Colorado River from the Northerly International Boundary to the Gulf of California.

g. Other. Several of the irrigation districts on the Lower Colorado either cooperate in streamflow station networks or else furnish their own local data for other agencies use.

9-03. INTERAGENCY AGREEMENTS

a. Bureau of Reclamation. A Field Working Agreement exists between Department of the Interior, Bureau of Reclamation and Department of the Army, Corps of Engineers for Flood Control Operation Hoover Dam and Lake Mead. A copy of the agreement is contained in Exhibit A.

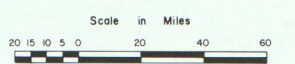
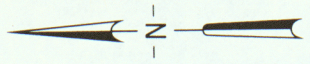
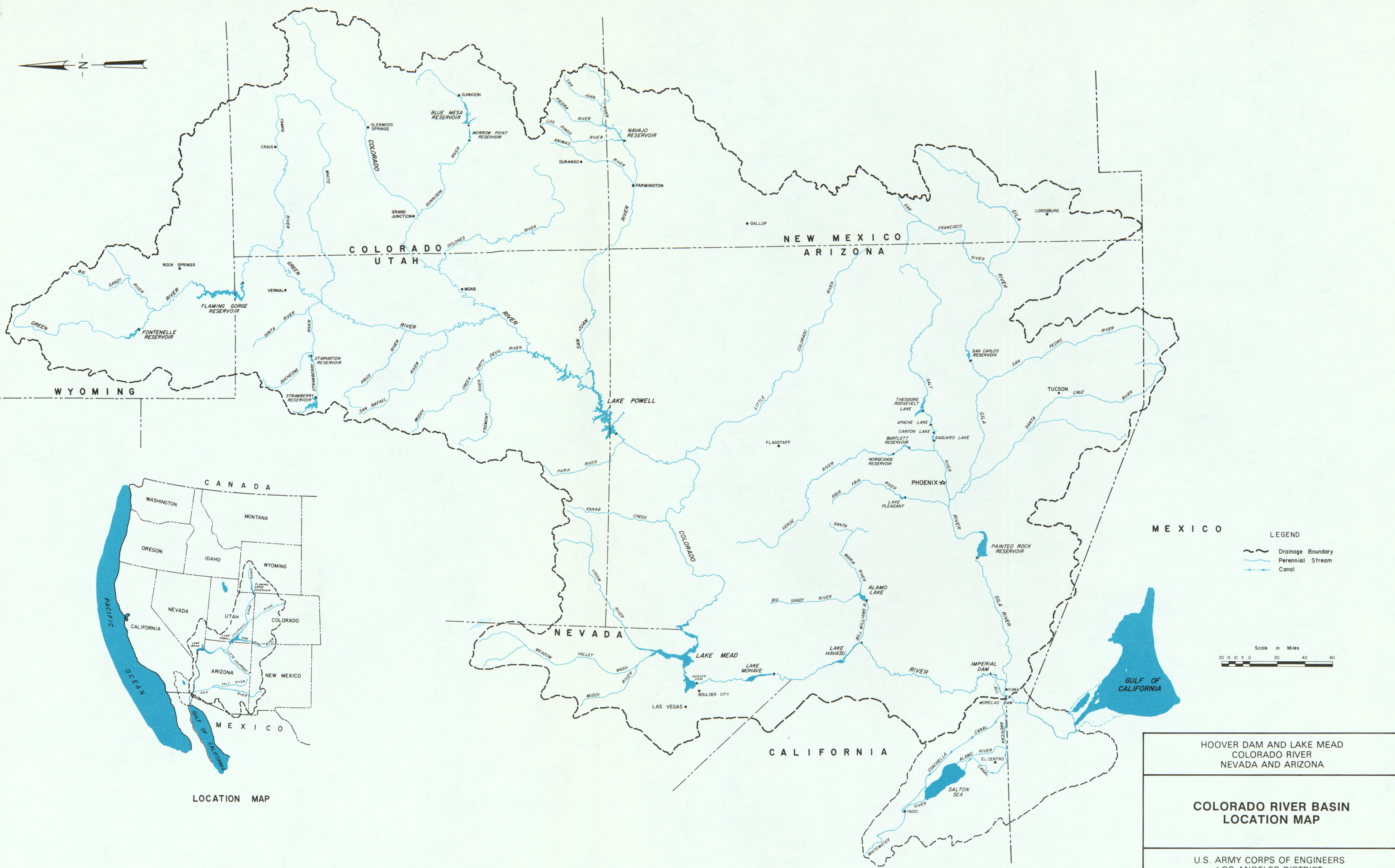
b. Colorado River Forecasting Service. The Colorado River Forecasting Service (CRFS) is a cooperative, interagency effort to pool agency resources in the development of improved streamflow forecasting techniques and data collection and dissemination networks for the Colorado River Basin. The CRFS is composed of representatives from the USBR, USGS, COE, NWS, SCS, and WAPA. By a Memorandum of Understanding dated November 1, 1979, these agencies agreed to participate in the CRFS. All development and operational activities of the CRFS are carried out at the National Weather Service River Forecast Center (Colorado Basin River Forecasting Center - CBRFC) in Salt Lake City, Utah. The program will embrace full utilization of advanced techniques for river forecasting, including application of computers, hydrologic computer models, telemetry of hydrometeorologic data from remote stations, and use of remote sensing techniques such as radar, satellites, and other sensors of hydrologic information, together with inputs of reservoir regulation schedules and other information required for forecasting streamflow and managing the Colorado River System.

9-04. COMMISSIONS, RIVER AUTHORITIES, COMPACTS, AND COMMITTEES

Management of the resources of the Colorado River involves many committees on various aspects of the River's different resources. Typically, these committees are composed of representatives from the various States and Federal agencies with differing interests, economic stakes and designated responsibilities. Related information is shown in Exhibit C - "Summary of Colorado River Law."

9-05. OTHER RELATED REPORTS

A sample seasonal snowmelt forecast is shown on Plate 23.



- LEGEND
- Drainage Boundary
 - Perennial Stream
 - Canal

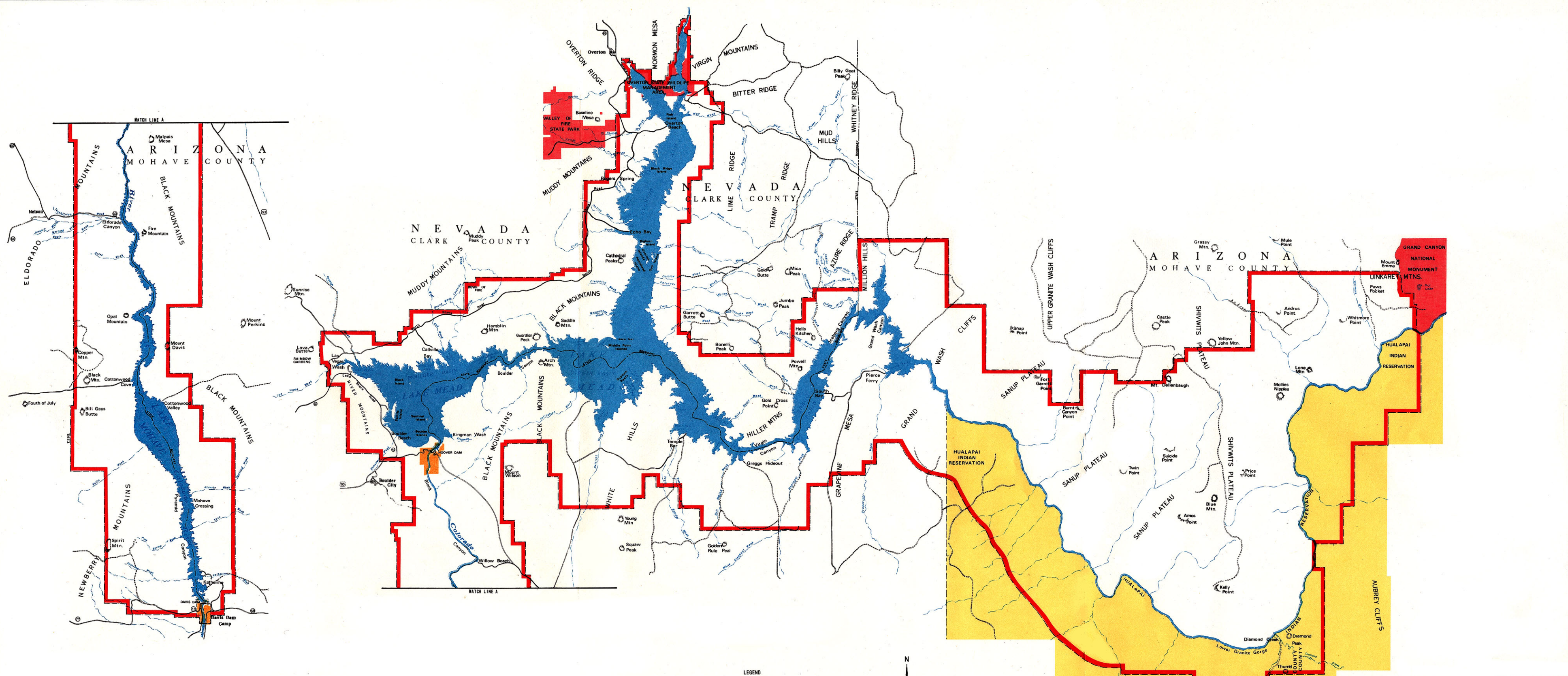


LOCATION MAP

HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

**COLORADO RIVER BASIN
 LOCATION MAP**

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT



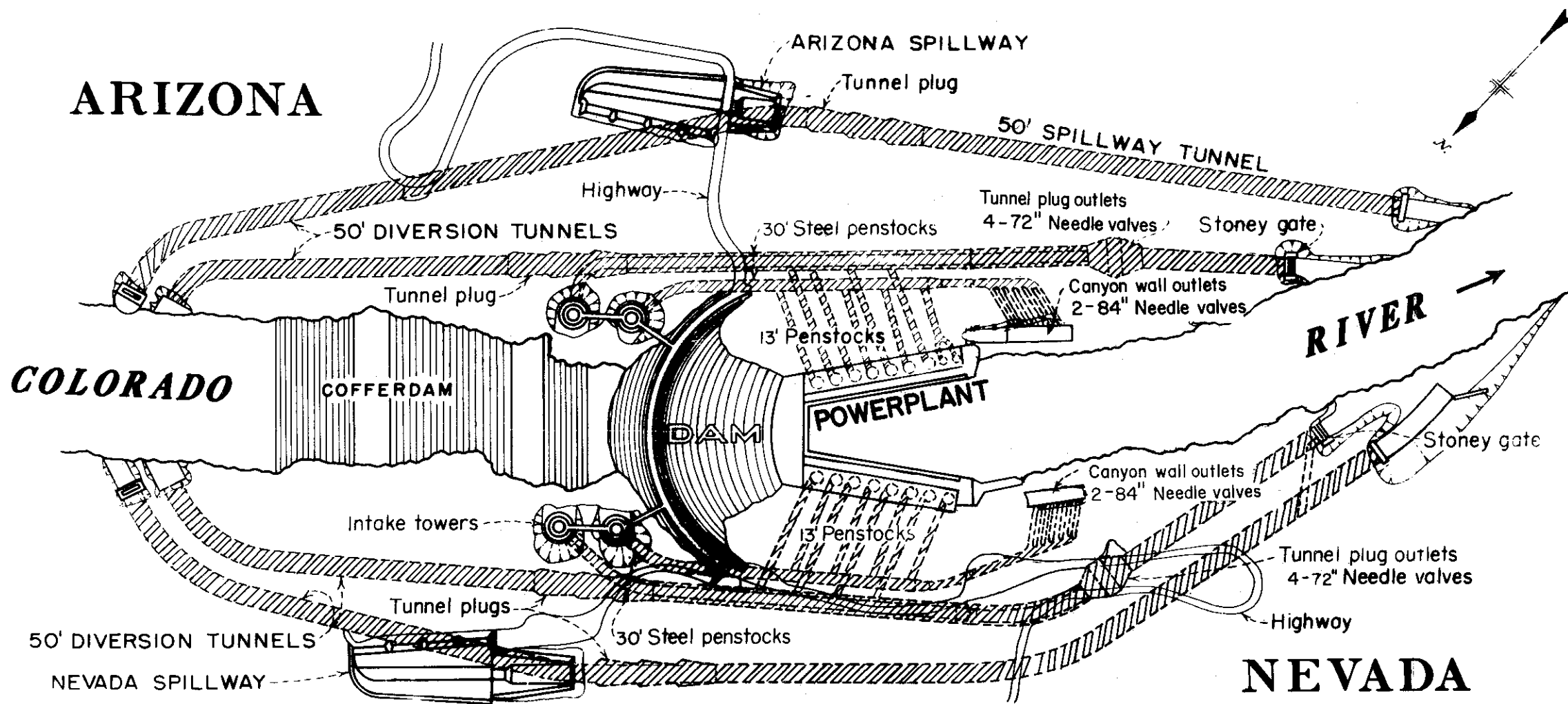
- LEGEND
- Lake Mead National Recreation Area Boundary
 - Primary Roads
 - Secondary Dirt Roads
 - Landing Strip



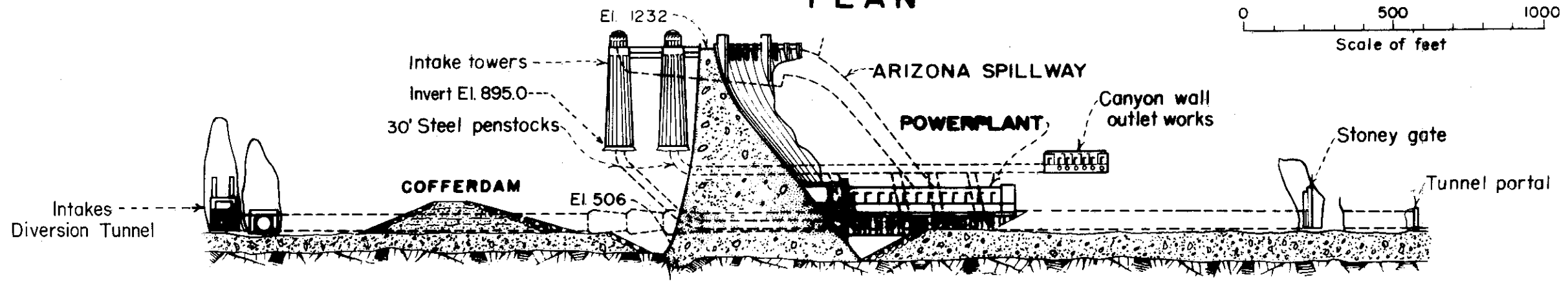
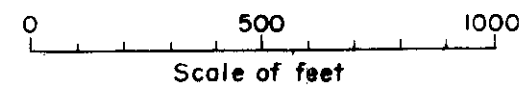
**HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA**

**LAKE MEAD
AREA MAP**

**U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT**

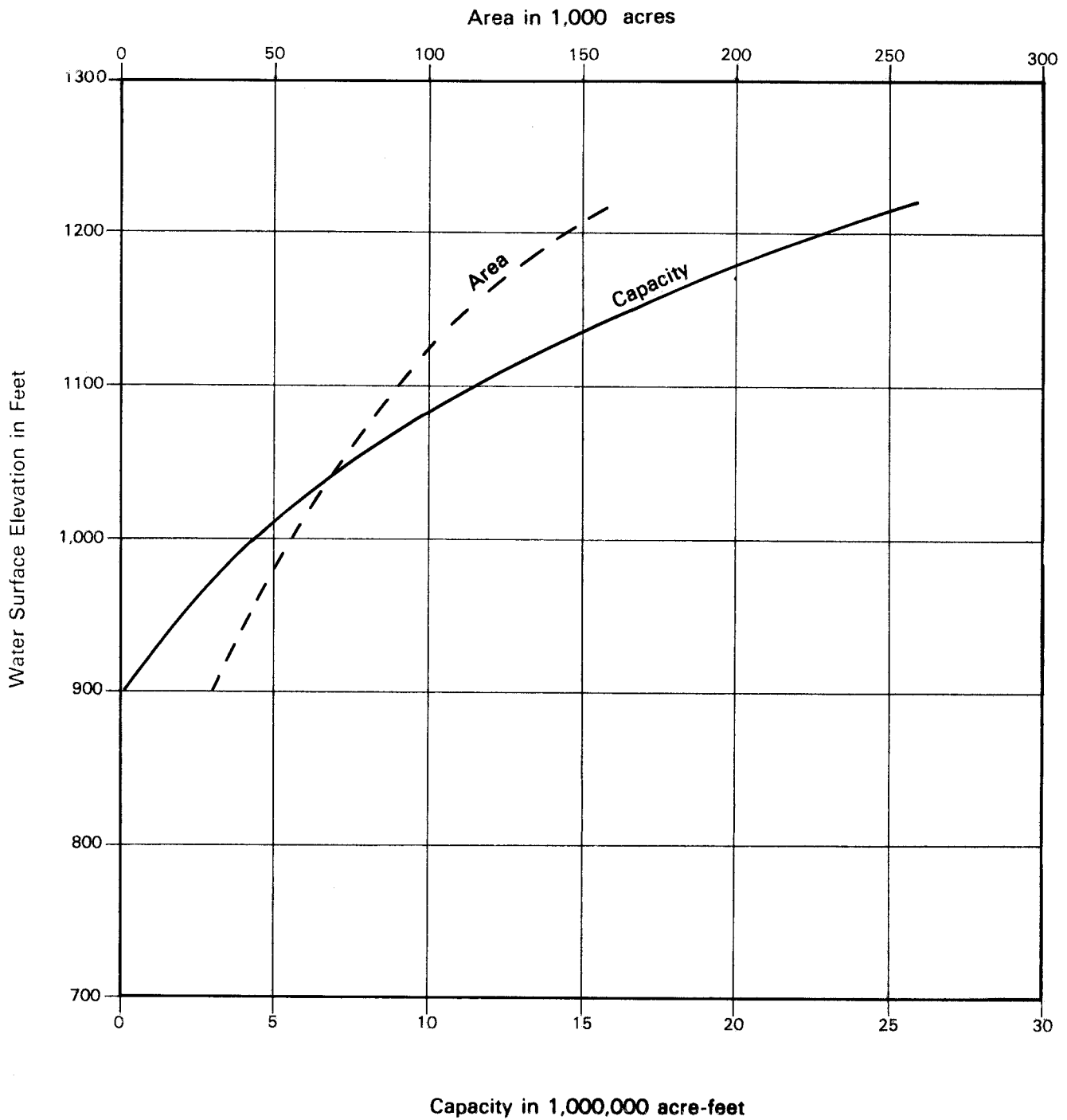


PLAN



LONGITUDINAL SECTION

HOOVER DAM AND LAKE MEAD COLORADO RIVER NEVADA AND ARIZONA
HOOVER DAM PLANS, PROFILES, AND SECTIONS
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT



NOTES:

1. Data based on survey of 1967.
2. Storage capacity is exclusive of 2,378,000 acre-feet dead storage below elevation 895.0 feet.

HOOVER DAM AND LAKE MEAD COLORADO RIVER NEVADA AND ARIZONA
LAKE MEAD AREA AND CAPACITY CURVES
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT

LAKE MEAD
ELEVATION — AREA
 (Area in 100 Acres at 1.0 Foot Elevation)

Elevation Feet	0	1	2	3	4	5	6	7	8	9
890						289	291	293	295	297
900	299	302	304	307	309	312	314	317	319	321
910	324	326	328	331	333	335	337	340	342	344
920	346	346	351	353	355	358	360	362	365	367
930	369	371	374	376	378	380	382	385	387	389
940	391	394	396	398	401	403	406	408	411	413
950	416	418	421	423	426	429	431	434	436	439
960	442	444	447	449	452	454	457	459	462	464
970	467	469	472	474	477	479	481	484	486	489
980	491	494	496	498	501	503	506	508	511	514
990	516	519	522	525	529	532	535	538	542	545
1,000	548	551	555	558	561	565	568	571	575	578
1,010	581	584	587	590	593	596	599	602	606	609
1,020	612	615	618	621	624	627	630	633	636	640
1,030	643	646	649	652	655	658	661	665	668	671
1,040	675	678	682	685	689	693	696	700	704	708
1,050	712	716	720	724	728	732	736	740	743	747
1,060	751	755	758	762	766	769	772	776	779	783
1,070	786	790	793	797	801	804	808	812	815	819
1,080	822	826	829	833	836	839	843	846	850	853
1,090	857	860	864	868	871	875	879	883	887	891
1,100	895	899	903	907	911	915	919	923	927	931
1,110	935	938	942	946	950	953	957	961	965	969
1,120	973	977	982	986	991	995	1,000	1,004	1,009	1,013
1,130	1,018	1,022	1,026	1,030	1,034	1,038	1,042	1,046	1,050	1,055
1,140	1,059	1,064	1,069	1,074	1,081	1,085	1,091	1,097	1,103	1,109
1,150	1,116	1,122	1,129	1,136	1,143	1,151	1,158	1,165	1,173	1,180
1,160	1,187	1,194	1,201	1,208	1,215	1,222	1,229	1,236	1,243	1,250
1,170	1,256	1,263	1,270	1,277	1,283	1,290	1,296	1,303	1,310	1,316
1,180	1,323	1,329	1,336	1,343	1,349	1,356	1,363	1,369	1,376	1,382
1,190	1,389	1,395	1,401	1,407	1,413	1,419	1,425	1,431	1,437	1,443
1,200	1,449	1,455	1,462	1,468	1,474	1,481	1,487	1,493	1,500	1,506
1,210	1,512	1,518	1,524	1,530	1,536	1,542	1,547	1,553	1,559	1,565
1,220	1,571	1,577	1,583	1,589	1,595	1,601	1,608	1,614	1,620	1,627

NOTE:

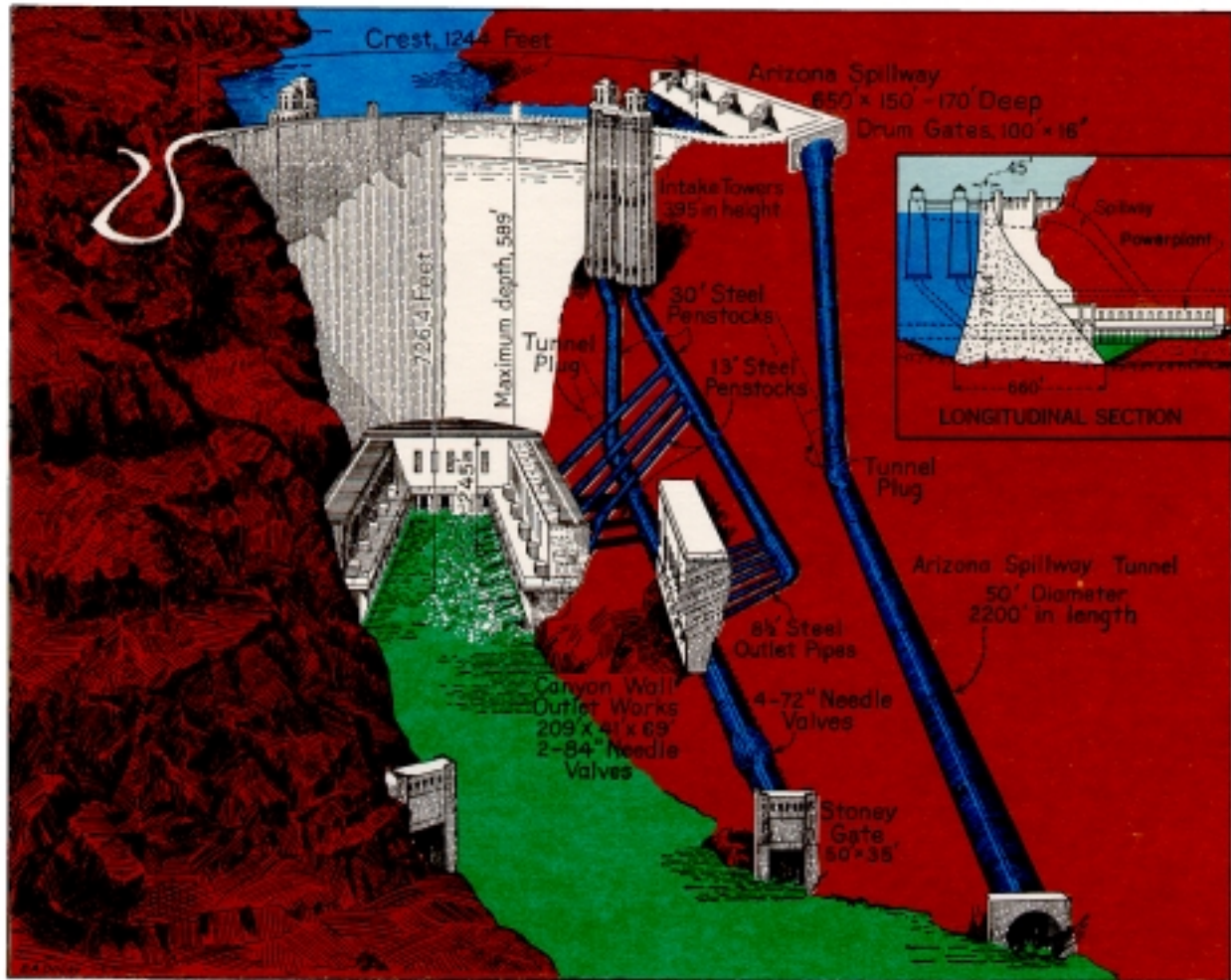
The USBR publication "LAKE MEAD AREA AND CAPACITY TABLES" dated April 1967 provides area values corresponding to 0.10 foot elevation increments.

**LAKE MEAD
ELEVATION — CAPACITY
(Active Storage in 1000 acre-feet)**

Elevation Feet	0	1	2	3	4	5	6	7	8	9
890							29	58	88	117
900	147	177	207	238	269	300	331	362	394	426
910	459	491	524	557	590	623	657	691	725	759
920	794	828	863	899	934	970	1,005	1,042	1,078	1,114
930	1,151	1,188	1,226	1,263	1,301	1,339	1,377	1,415	1,454	1,492
940	1,531	1,571	1,610	1,650	1,690	1,730	1,771	1,811	1,852	1,893
950	1,935	1,976	2,018	2,061	2,103	2,146	2,189	2,232	2,276	2,319
960	2,363	2,408	2,452	2,497	2,542	2,587	2,633	2,679	2,725	2,771
970	2,818	2,865	2,912	2,959	3,006	3,054	3,102	3,150	3,199	3,248
980	3,297	3,346	3,395	3,445	3,495	3,545	3,596	3,646	3,697	3,749
990	3,800	3,852	3,904	3,956	4,009	4,062	4,116	4,169	4,223	4,277
1,000	4,332	4,387	4,442	4,498	4,554	4,610	4,667	4,724	4,781	4,839
1,010	4,897	4,955	5,014	5,073	5,123	5,191	5,251	5,311	5,372	5,432
1,020	5,493	5,555	5,616	5,678	5,740	5,803	5,866	5,929	5,992	6,056
1,030	6,120	6,185	6,249	6,314	6,380	6,445	6,511	6,578	6,644	6,711
1,040	6,779	6,846	6,914	6,983	7,051	7,120	7,190	7,260	7,330	7,400
1,050	7,471	7,543	7,615	7,687	7,759	7,832	7,906	7,979	8,053	8,128
1,060	8,203	8,278	8,354	8,430	8,506	8,583	8,660	8,738	8,815	8,893
1,070	8,972	9,051	9,130	9,209	9,289	9,370	9,450	9,531	9,612	9,694
1,080	9,776	9,859	9,941	10,024	10,108	10,192	10,276	10,360	10,445	10,530
1,090	10,616	10,701	10,788	10,874	10,961	11,048	11,136	11,224	11,313	11,402
1,100	11,491	11,581	11,671	11,761	11,852	11,943	12,035	12,127	12,219	12,312
1,110	12,406	12,499	12,593	12,688	12,782	12,878	12,973	13,069	13,165	13,262
1,120	13,359	13,456	13,554	13,653	13,752	13,851	13,951	14,051	14,152	14,253
1,130	14,354	14,456	14,559	14,661	14,765	14,868	14,972	15,077	15,181	15,287
1,140	15,392	15,499	15,605	15,712	15,820	15,928	16,037	16,147	16,257	16,367
1,150	16,478	16,590	16,703	16,816	16,930	17,045	17,160	17,276	17,393	17,511
1,160	17,629	17,748	17,868	17,989	18,110	18,232	18,354	18,478	18,602	18,726
1,170	18,851	18,977	19,104	19,231	19,359	19,488	19,617	19,747	19,878	20,009
1,180	20,141	20,274	20,407	20,541	20,676	20,811	20,947	21,083	21,221	21,359
1,190	21,497	21,636	21,776	21,917	22,058	22,199	22,341	22,484	22,628	22,772
1,200	22,916	23,061	23,207	23,354	23,501	23,648	23,797	23,946	24,096	24,246
1,210	24,397	24,548	24,700	24,853	25,006	25,160	25,315	25,470	25,625	25,781
1,220	25,938	26,096	26,254	26,412	26,571	26,731	26,892	27,053	27,215	27,377

NOTE:

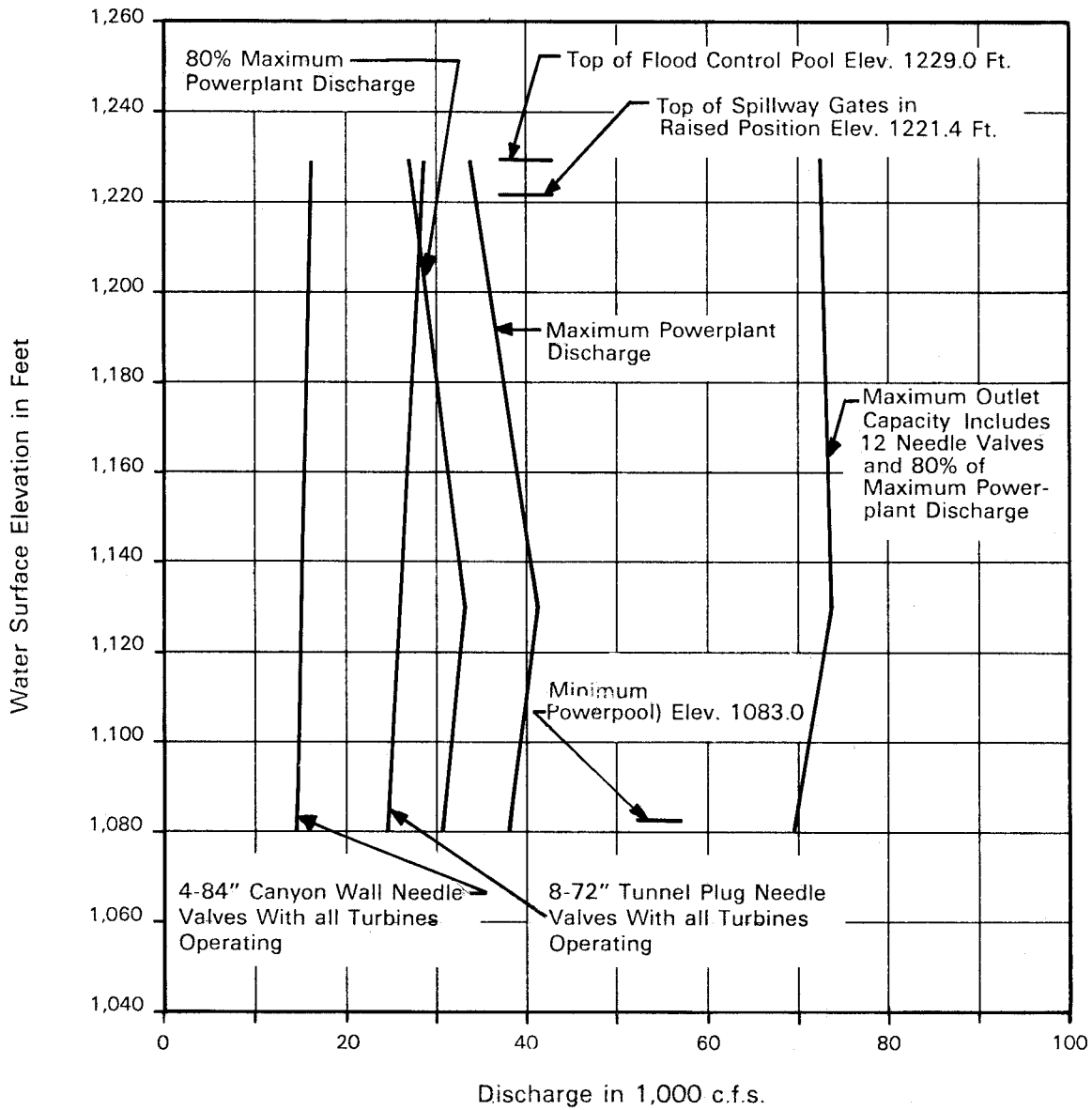
The USBR publication "LAKE MEAD AREA AND CAPACITY TABLES" dated April 1967 provides capacity values corresponding to 0.01 foot elevation increments.



HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA

**PICTORIAL OF
OUTLET WORKS
SPILLWAYS AND TURBINES**

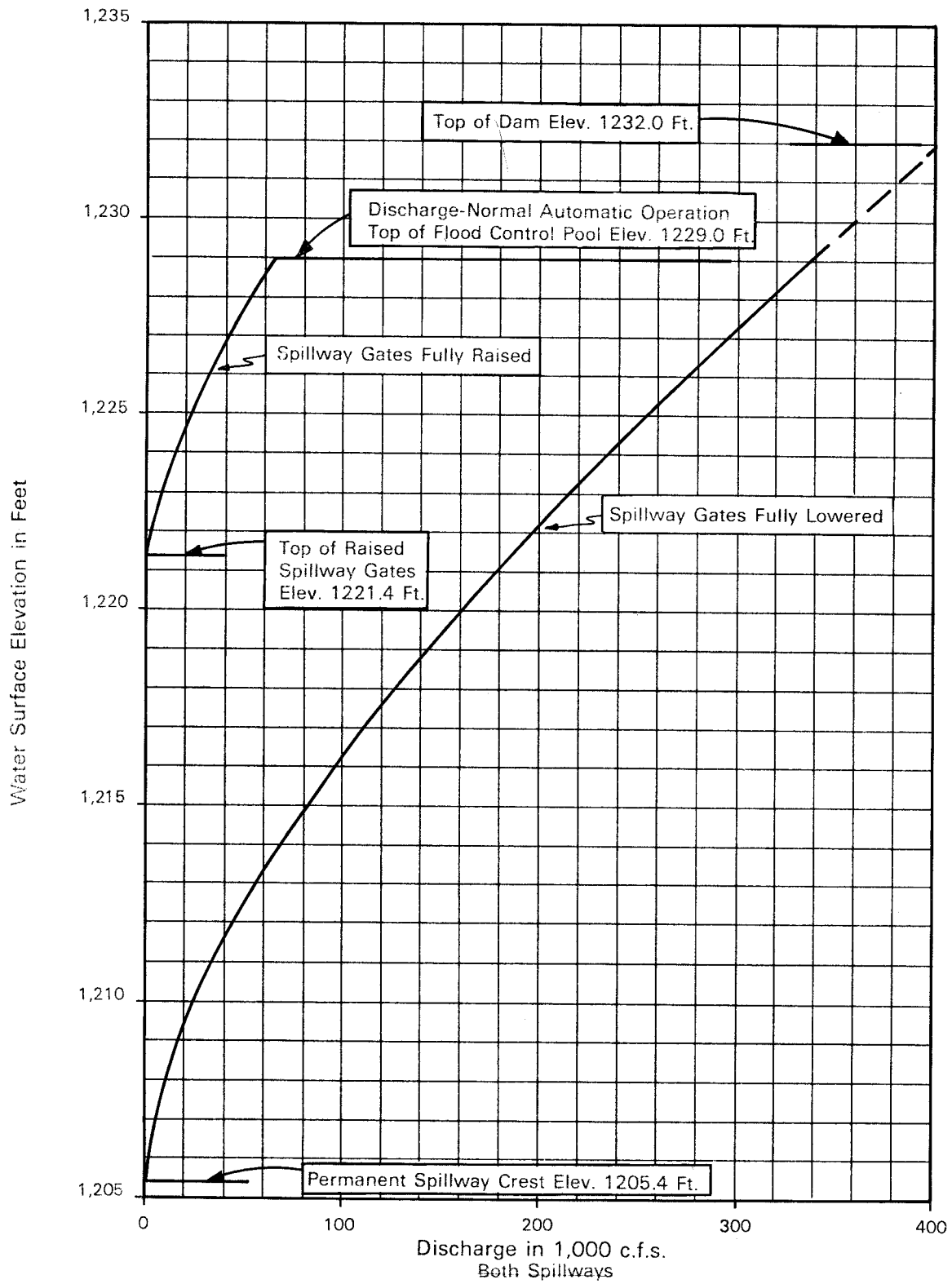
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

**OUTLETS AND POWERPLANT
 DISCHARGE RATING CURVES**

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT



HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

**SPILLWAY DISCHARGE
 RATING CURVES**

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT

**TABLE
CHARACTERISTICS OF MAJOR STORAGE PROJECTS
COLORADO RIVER BASIN**

Project					Dam				Spillway				Reservoir						Outlets		Power Plant		
Name of Dam	Name of Impoundment	State Located	Stream	Drainage Area (sq. mi)	Type	Crest Elevation (feet msl)	Height Above Streambed (feet)	Length (feet)	Type	Location	Crest Elevation (feet msl)	Design Capacity (1000 cfs)	Primary Purpose(s)	Owner	Year Storage Began	Elevations in feet, msl		Storage in 1,000 acre-feet		Number of Main Conduits	Design Capacity (1000 cfs)	Number of Units	Total Capacity (MW)
																Normal Full Pool	Maximum Design Pool	Normal Active	Design Surchage				
Fontenelle	(Reservoir)	Wyoming	Green R.	4,280	E	6519	100	5421	U	A	6506	20	P, WS	USBR	1964	6506	6512.9	344.8	58	2	18.7	1	10
Flaming Gorge	(Reservoir)	Utah-Wyoming	Green R.	15,390 ²	CA	6047	455	1180	G	A	6006	29	P, WS	USBR	1962	6040	6045	3749	214	2	4	3	108
Blue Mesa	(Reservoir)	Colorado	Gunnison R.	3,426	E, R	7528	342	785	G	A	7487.9	33.7	P, WS, FC	USBR	1965	7519.4	7519.4	748.5	0	2	5	2	60
Morrow Point	(Reservoir)	Colorado	Gunnison R.	3,637	CA	7165	418	720	G	D	7123	41	P, WS	USBR	1968	7160	7165	117	4.1	1	1.5	2	120
Navajo	(Reservoir)	New Mexico	San Juan R.	3,230 ³	E, R	6108	388	3648	U	A	6085	33.9	WS, FC	USBR	1962	6085	6101.6	1035.9	277.6	1	3.5	—	—
Glen Canyon	Lake Powell	Arizona-Utah	Colorado R.	107,740 ²	CA	3715	583	1560	G	A	3648	278	P, WS	USBR	1963	3700	3711	25002	1821	4	15	8	900
Soldier Creek	Strawberry Reservoir	Utah	Strawberry R.	213	E	7612	251	1198	—	—	—	—	WS	USBR	1974	7602.4	7603.6	1105.9	20.7	2	2.8	—	—
Starvation	(Reservoir)	Utah	Strawberry R.	1,040	E	5725	155	2920	U	A	5712	16.6	WS, FC	USBR	1969	5712	5718.3	152.3	21.7	2	2.3	—	—
Hoover	Lake Mead	Arizona-Nevada	Colorado R.	167,740	C, G, A	1232	592	1244	G	A	1205.4	335	P, WS, FC	USBR	1935	1229	1232	27377	482	4	35	19	1345
Davis	Lake Mohave	Arizona-Nevada	Colorado R.	169,340 ²	E	655	140	1600	G	A	597	214	P, WS, FC	USBR	1950	647	647	1810	0	2	43.4	5	240
Alamo	(Lake)	Arizona	Bill Williams R.	4,770 ³	E	1265	283	975	U	R	1235	39.7	FC, WS	COE	1968	1235	1259.6	1045.3	365.5	1	8.7	—	—
Parker	Lake Havasu	Arizona-California	Colorado R.	178,740 ²	CA	455	75	856	G	D	400	400	P, WS	USBR	1938	450	450	619	0	—	—	4	120
Roosevelt	(Lake)	Arizona	Salt R.	5,830 ⁴	MA	2142	234	723	G	A	2120.3	150	P, WS	SRP	1910	2136	2136	1382	0	5	2.6	1	36
Horse Mesa	Apache Lake	Arizona	Salt R.	4	CA	1915	266	660	G	A	1891	150	P, WS	SRP	1927	1914	1914	245.1	0	3	2	3(1)	33(93)
Mormon Flat	Canyon Lake	Arizona	Salt R.	4	CA	1666	142	380	G	A	1610.5	150	P, WS	SRP	1926	1660.5	1660.5	57.9	0	2	2.4	1(1)	10(44)
Stewart Mountain	Saguaro Lake	Arizona	Salt R.	4	CA	1530	116	1260	G	A	1506	150	P, WS	SRP	1930	1529	1529	69.8	0	3	3	1	13
Coolidge	San Carlos Reservoir	Arizona	Gila R.	12,886	CA (multi)	2535	152	920	U	A	2512	120	P, WS	BIA	1928	2519	2519	1073	0	2	4	2	10
Horseshoe	(Reservoir)	Arizona	Verde R.	5	E, R	2040	142	1140	G	A	2000	250	WS	SRP	1945	2026	2026	139.2	0	1	2.2	—	—
Bartlett	(Reservoir)	Arizona	Verde R.	6,185 ⁵	CA (multi)	1799.5	188	800	G	A	1748	175	WS	SRP	1939	1798	1798	178.5	0	5	4.0	—	—
Waddell	Lake Pleasant	Arizona	Agua Fria R.	1,459	CA (multi)	1606.9	—	1975	G	R	1577.9	140	WS	MCWCD	1927	1601.2	1601.2	157.6	0	1	.8	—	—
Painted Rock	(Lake)	Arizona	Gila R.	50,800	E	705	181	4780	U	R	661	401.7	FC	COE	1960	661	696.3	2492	2342.9	1	30.5	—	—

Impoundment Names

Designations of impoundments with same name as dam shown in parentheses.

Drainage Areas

1. Drainage areas are total at dam according to the USGS water supply papers except as indicated.
2. Excludes 3959 square miles in Great Divide Basin which is probably non-contributing.
3. Drainage area by COE.
4. Total drainage area for the four SRP reservoirs on the Salt River is given at Stewart Mountain Dam, which is furthest downstream.
5. Total drainage area for the two SRP reservoirs on the Verde River is given at Bartlett Dam which is furthest downstream.

Project Purposes

- FC — Flood Control
- P — Power
- WS — Water Supply

Owner

- USBR — US Bureau of Reclamation
- COE — Corps of Engineers
- SRP — Salt River Project
- BIA — Bureau of Indian Affairs
- MCWCD — Maricopa County Water Conservation District No. One

Power Plant

Numbers in parentheses are for pump storage units.

Dam Types

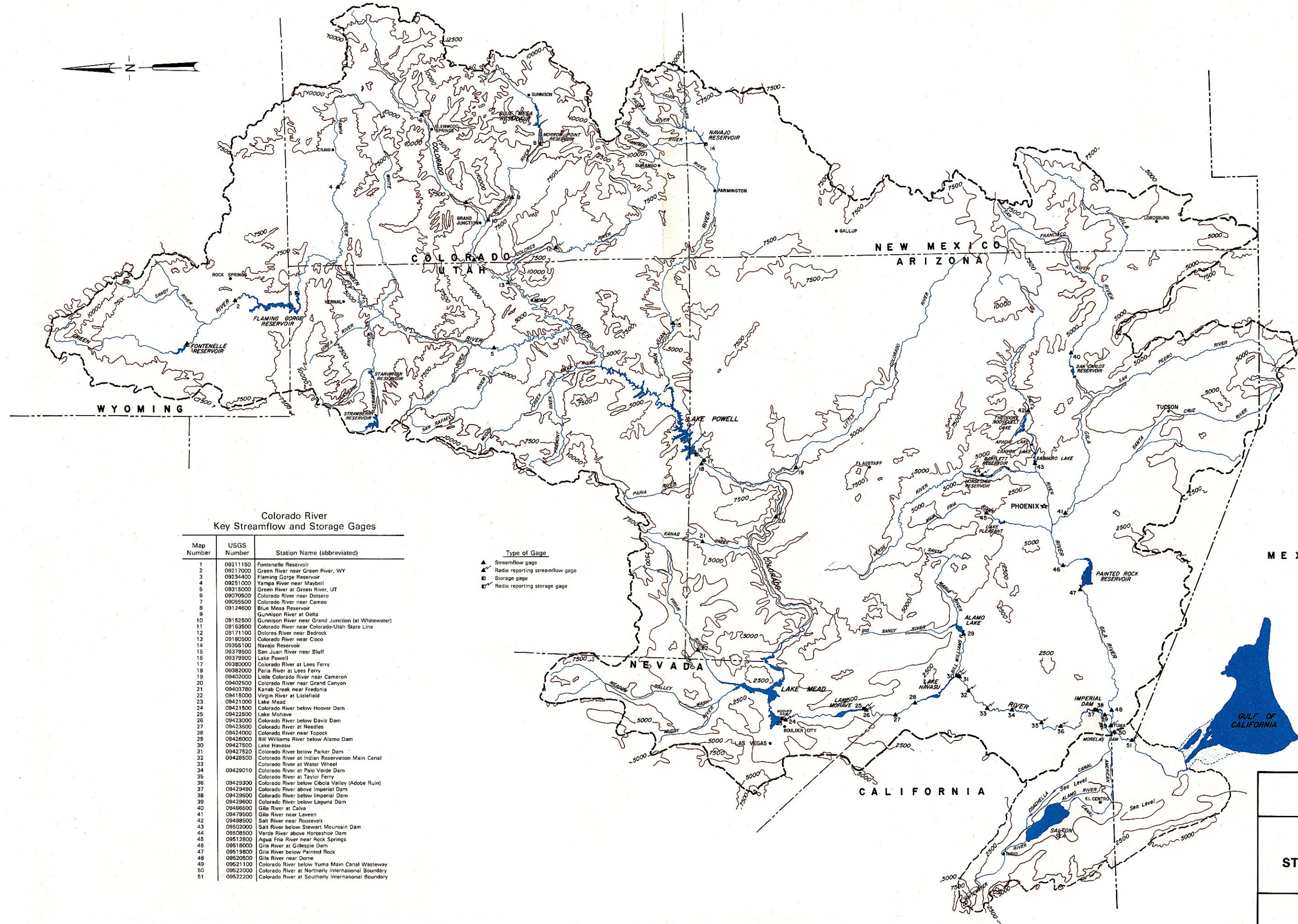
- | | |
|---------------|-------------|
| Material | Structure |
| E — Earthfill | A — Arch |
| R — Rockfill | G — Gravity |
| C — Concrete | |
| M — Masonry | |

Spillway Types

- U — Ungated
- G — Gated

Spillway Locations

- D — In dam
- A — At or near abutment
- R — Remote



Colorado River
Key Streamflow and Storage Gages

Map Number	USGS Number	Station Name (abbreviated)
1	09211500	Fontenelle Reservoir
2	09217000	Green River near Green River, WY
3	09234400	Flaming Gorge Reservoir
4	09251000	Yampa River near Maybell
5	09315000	Green River at Green River, UT
6	09070500	Colorado River near Dotsero
7	09095500	Colorado River near Cameo
8	09124600	Blue Mesa Reservoir
9		
10	09152500	Gunnison River at Delta
11	09163500	Colorado River near Colorado-Utah State Line
12	09171100	Dolores River near Bedrock
13	09180500	Colorado River near Cisco
14	09355100	Navajo Reservoir
15	09379500	San Juan River near Bluff
16	09379900	Lake Powell
17	09380000	Colorado River at Lees Ferry
18	09382000	Paria River at Lees Ferry
19	09402000	Little Colorado River near Cameron
20	09402500	Colorado River near Grand Canyon
21	09403780	Kanab Creek near Fredonia
22	09415000	Virgin River at Littlefield
23	09421000	Lake Mead
24	09421500	Colorado River below Hoover Dam
25	09422500	Lake Mohave
26	09423000	Colorado River below Davis Dam
27	09423500	Colorado River at Needles
28	09424000	Colorado River near Topock
29	09426000	Bill Williams River below Alamo Dam
30	09427500	Lake Havasu
31	09427520	Colorado River below Parker Dam
32	09428500	Colorado River at Indian Reservation Main Canal
33		Colorado River at Water Wheel
34	09429010	Colorado River at Palo Verde Dam
35		Colorado River at Taylor Ferry
36	09429300	Colorado River below Cibola Valley (Adobe Ruin)
37	09429450	Colorado River above Imperial Dam
38	09429500	Colorado River below Imperial Dam
39	09429600	Colorado River below Laguna Dam
40	09466500	Gila River at Calva
41	09479500	Gila River near Laveen
42	09498500	Salt River near Roosevelt
43	09502000	Salt River below Stewart Mountain Dam
44	09508500	Verde River above Horseshoe Dam
45	09512800	Agua Fria River near Rock Springs
46	09518000	Gila River at Gillespie Dam
47	09519500	Gila River below Painted Rock
48	09520500	Gila River near Dome
49	09521100	Colorado River below Yuma Main Canal Wasteway
50	09522000	Colorado River at Northerly International Boundary
51	09522200	Colorado River at Southerly International Boundary

Type of Gage
 ▲ Streamflow gage
 ● Radio reporting streamflow gage
 ■ Storage gage
 □ Radio reporting storage gage

MEXICO

LEGEND

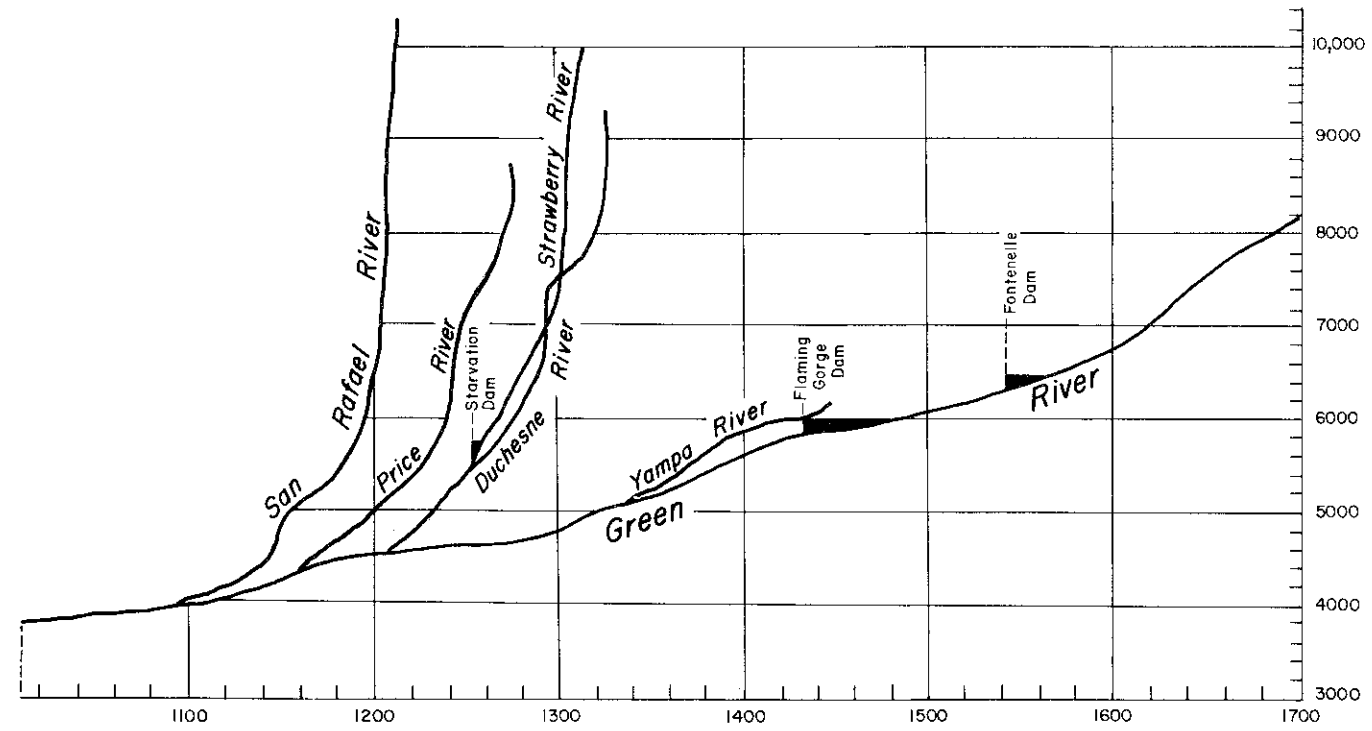
- Drainage Boundary
- Perennial Stream
- Canal
- 5000 Contour

Scale in Miles
 0 5 10 15 20 25 30 40 50

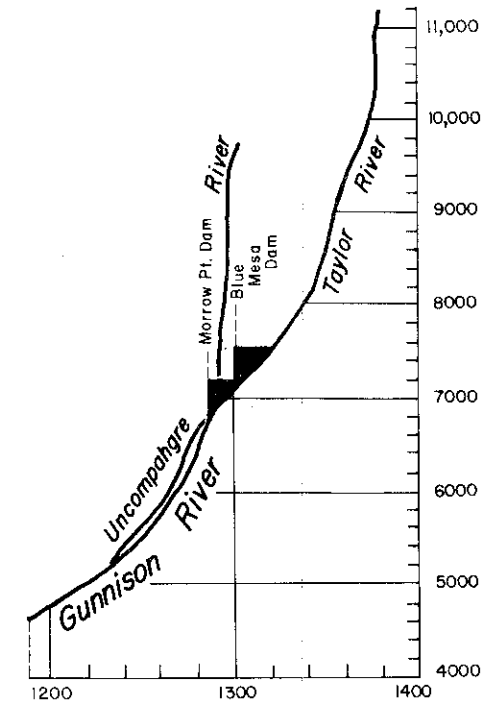
HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

**TOPOGRAPHY AND
 STREAM GAGING STATIONS MAP**

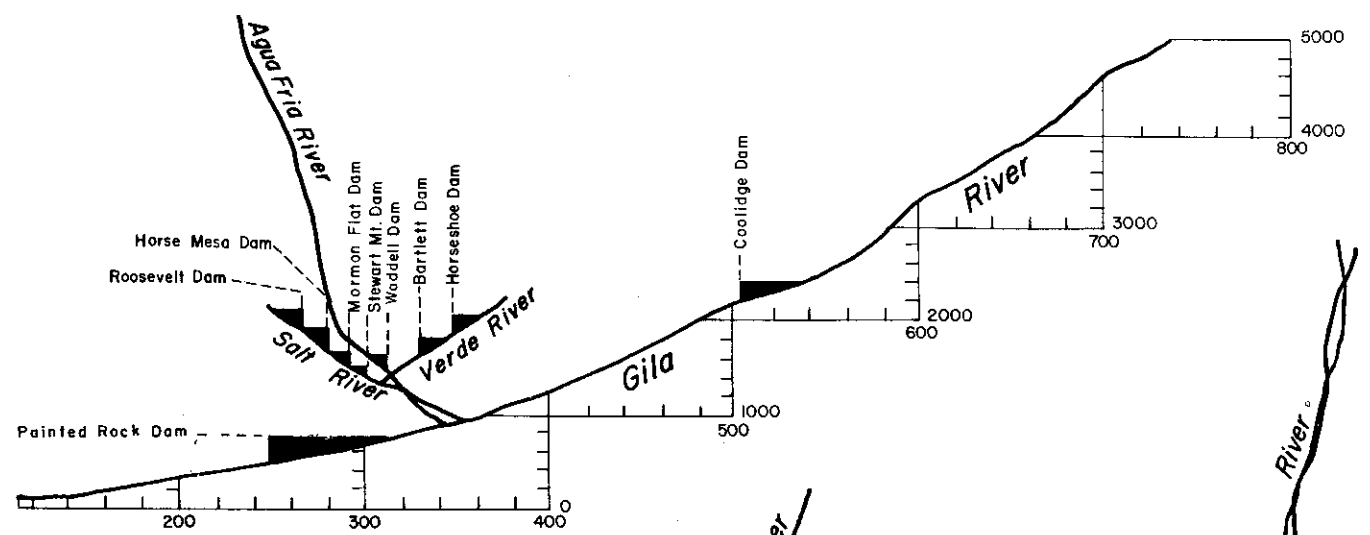
U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT



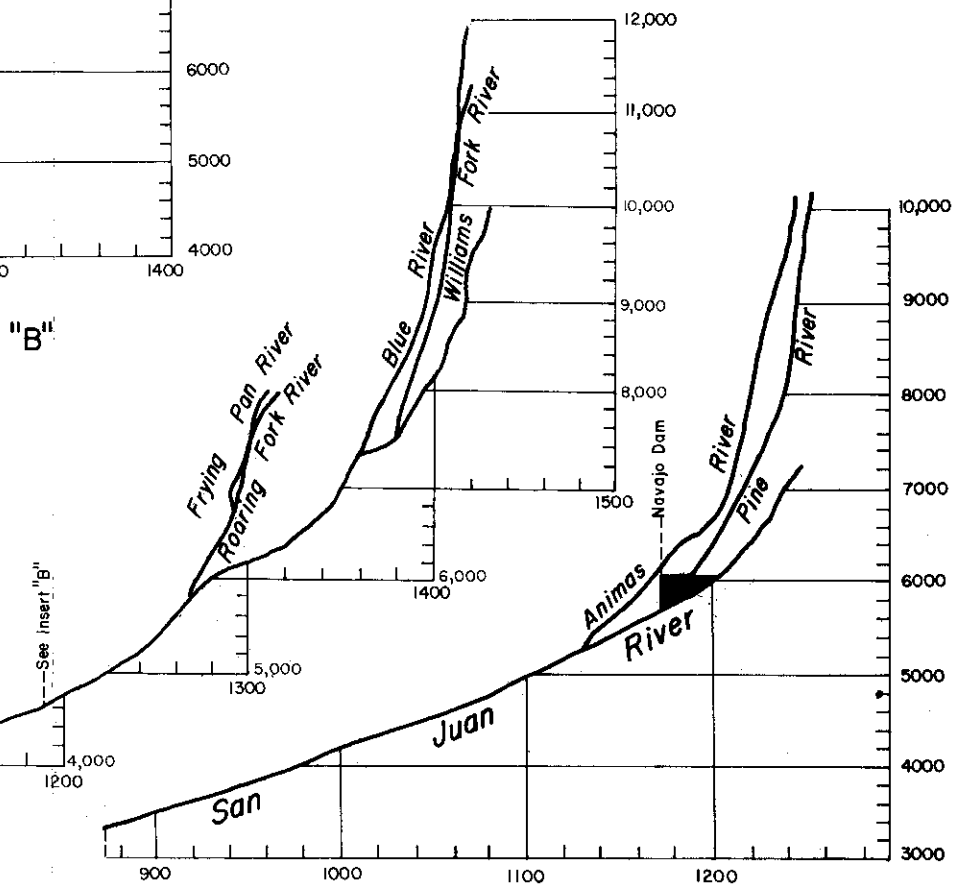
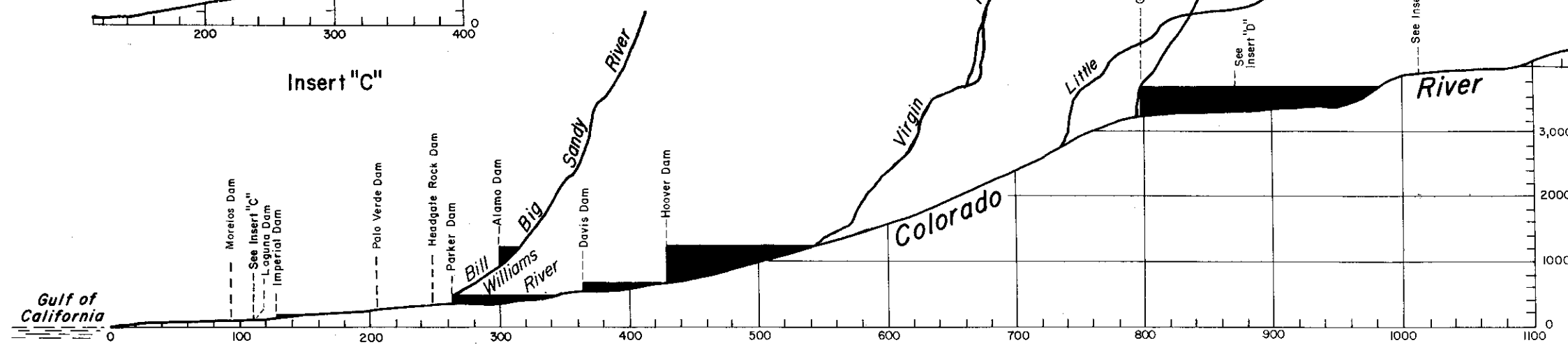
Insert "A"



Insert "B"



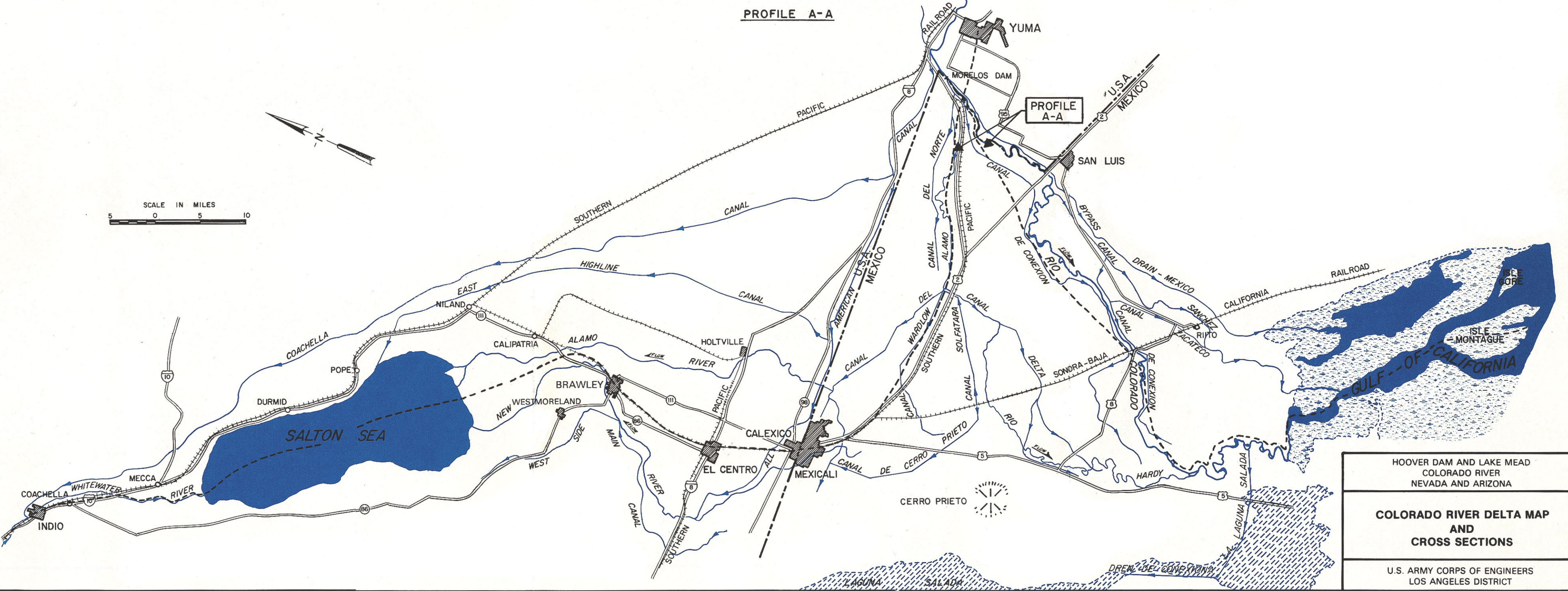
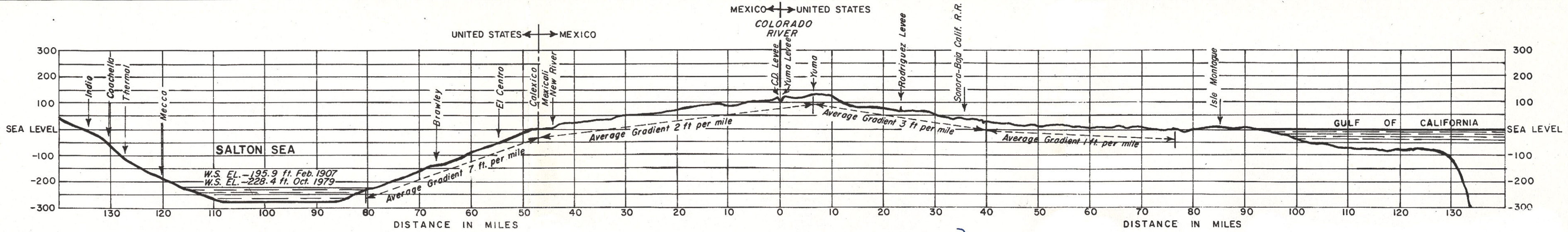
Insert "C"



Insert "D"

NOTES:
 1. Vertical scales indicate feet above mean sea level.
 2. Horizontal scales indicate miles from the Gulf of California.

HOOVER DAM AND LAKE MEAD COLORADO RIVER NEVADA AND ARIZONA
COLORADO RIVER AND MAJOR TRIBUTARIES STREAMBED PROFILES
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT



**Historic Monthly
Estimated Natural Flows
Colorado River at Lees Ferry
(1,000 Acre-Feet)**

Year	Flow Per Month												Water Year Total	Apr-July Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep		
1906	458	382	245	227	245	618	1,263	3,960	5,083	2,758	1,410	1,430	18,077	13,064
1907	730	477	351	289	387	788	1,621	3,155	6,119	4,747	1,883	903	21,450	15,642
1908	678	364	267	319	357	669	1,142	1,750	3,132	1,851	1,171	583	12,287	7,880
1909	558	375	308	375	309	720	1,192	3,716	7,375	3,843	1,775	1,451	21,997	16,127
1910	737	492	371	361	423	1,391	1,863	3,582	3,055	1,307	679	574	14,835	9,808
1911	620	427	368	378	438	917	1,002	3,016	4,097	2,244	911	564	14,982	10,358
1912	1,133	442	353	346	327	538	909	3,749	6,159	3,155	1,275	639	19,025	13,972
1913	628	533	305	354	314	524	1,851	3,310	3,150	1,931	791	699	14,389	10,241
1914	657	538	330	370	401	876	1,605	4,737	6,293	3,051	1,308	779	20,944	15,685
1915	955	525	334	304	397	527	1,502	2,493	3,663	2,049	748	546	14,044	9,707
1916	535	411	343	394	424	1,395	1,813	3,817	4,756	2,558	1,826	799	19,072	12,944
1917	1,396	496	369	260	352	507	1,544	3,804	7,791	4,882	1,525	811	23,737	18,021
1918	483	447	403	356	374	656	900	2,806	5,373	2,244	882	700	15,622	11,323
1919	551	496	410	287	317	653	1,427	3,293	2,593	1,448	843	535	12,854	8,761
1920	368	405	394	407	602	685	981	5,961	6,980	3,086	1,293	619	21,782	17,007
1921	528	596	405	414	457	948	935	4,241	8,477	2,779	1,888	938	22,607	16,433
1922	463	416	453	351	439	907	1,185	4,757	5,733	2,096	1,054	641	18,516	13,790
1923	311	401	400	375	340	449	1,318	3,895	5,104	2,969	1,672	1,013	18,249	13,287
1924	737	646	424	313	507	509	1,669	3,347	3,776	1,589	631	397	14,544	10,381
1925	370	392	275	262	403	609	1,402	2,562	2,845	1,954	1,005	1,186	13,267	8,763
1926	1,010	609	447	360	354	644	1,640	3,627	4,065	1,891	864	460	15,970	11,223
1927	443	334	379	337	389	606	1,279	4,208	4,054	3,029	1,202	2,124	18,385	12,570
1928	959	738	444	470	463	756	1,051	4,690	4,316	2,191	955	560	17,593	12,249
1929	622	576	344	332	346	924	1,721	4,398	5,481	2,710	2,276	1,778	21,509	14,311
1930	950	568	437	299	485	576	1,838	2,291	3,772	1,595	1,804	707	15,322	9,495
1931	571	428	289	264	367	431	627	1,509	2,059	1,009	613	444	8,611	5,205
1932	531	359	253	273	557	675	1,703	4,411	4,248	2,638	1,255	691	17,594	13,000
1933	355	382	273	273	256	502	534	1,710	4,723	1,825	735	577	12,145	8,792
1934	417	303	334	308	303	365	610	1,555	973	626	479	301	6,573	3,763
1935	188	183	229	255	274	341	708	1,676	4,760	2,145	907	613	12,278	9,289
1936	377	323	266	264	318	464	1,452	4,143	3,407	1,579	1,220	731	14,547	10,582
1937	369	448	317	200	414	702	1,588	3,965	3,004	1,844	773	617	14,241	10,401
1938	490	389	391	326	355	795	1,690	3,707	5,366	2,412	882	1,082	17,882	13,175
1939	605	485	411	348	300	811	1,289	3,005	2,304	960	532	698	11,749	7,558
1940	343	318	286	262	302	452	786	2,552	2,212	893	482	551	9,438	6,443
1941	720	415	366	356	430	676	1,147	5,394	4,620	2,375	1,133	711	18,343	13,536
1942	1,810	913	577	404	396	661	2,928	3,620	4,891	2,003	812	432	19,448	13,442
1943	346	378	369	345	345	539	1,673	2,580	3,361	2,020	1,143	625	13,723	9,633
1944	380	451	379	285	344	515	1,073	3,714	4,819	2,490	783	361	15,594	12,095
1945	356	383	308	330	359	430	811	3,257	3,433	2,424	1,395	516	14,004	9,925
1946	528	435	320	348	314	516	1,175	2,117	2,802	1,270	790	474	11,086	7,362
1947	430	479	424	265	353	667	884	3,685	3,834	2,614	1,522	790	15,948	11,018
1948	820	582	441	377	432	625	1,753	4,129	3,951	1,587	828	387	15,912	11,420
1949	347	404	350	328	351	695	1,408	3,583	5,157	2,720	895	437	16,673	12,868
1950	535	482	364	348	395	641	1,312	2,390	3,818	1,929	709	428	13,352	9,450
1951	390	358	424	308	357	423	601	2,152	3,724	2,070	1,085	520	12,410	8,547
1952	421	451	340	491	386	436	2,344	5,655	6,222	2,261	1,170	699	20,875	16,482
1953	348	376	374	402	365	466	572	1,381	3,923	1,598	956	398	11,160	7,474
1954	304	426	343	318	342	394	735	1,850	1,385	1,143	594	508	8,342	5,113
1955	562	361	290	255	253	591	716	2,053	2,367	1,115	851	354	9,766	6,250
1956	197	275	335	380	280	524	1,036	2,935	3,533	1,058	634	301	11,488	8,562
1957	162	304	258	295	331	510	876	2,858	6,724	4,834	1,951	1,018	20,124	15,293
1958	756	838	503	392	537	689	1,614	4,686	4,577	1,219	620	452	16,882	12,095
1959	306	359	368	306	314	351	492	1,489	2,804	1,323	695	332	9,138	6,107
1960	545	517	351	290	315	755	1,785	2,095	3,230	1,235	522	328	11,968	8,345

**Historic Monthly
Estimated Natural Flows
Colorado River at Lees Ferry
(1,000 Acre-Feet)**

Year	Flow Per Month												Water Year Total	Apr-July Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep		
1961	344	349	265	244	319	373	674	1,738	2,519	853	670	888	9,235	5,784
1962	827	547	371	334	775	548	2,586	4,240	3,886	2,411	792	412	17,729	13,123
1963	526	446	343	202	371	584	816	1,906	1,822	835	629	749	9,227	5,378
1964	278	338	266	268	263	344	659	2,467	3,006	1,591	873	365	10,716	7,723
1965	258	325	363	380	369	444	1,421	3,470	5,635	3,719	1,528	898	18,810	14,245
1966	836	568	552	455	395	982	1,363	2,628	1,933	951	515	357	11,537	6,876
1967	303	349	371	289	307	590	646	1,791	3,659	2,072	827	507	11,712	8,168
1968	312	328	239	313	338	524	661	2,216	5,064	1,625	1,429	417	13,464	9,566
1969	411	386	321	392	353	572	2,022	3,962	3,044	1,942	799	616	14,819	10,970
1970	664	514	369	371	347	436	609	3,709	4,182	1,944	845	1,142	15,132	10,445
1971	647	514	395	419	448	600	1,394	2,570	4,592	2,101	811	531	15,020	10,657
1972	588	518	418	434	441	863	855	2,138	3,835	1,108	538	469	12,206	7,936
1973	1,099	607	386	449	415	894	1,388	4,752	4,992	2,675	924	597	19,179	13,807
1974	390	452	380	385	378	814	977	3,674	3,422	1,420	604	285	13,182	9,494
MIN	162	183	229	200	245	341	492	1,381	973	626	479	285	6,573	3,763
MAX	1,810	913	577	491	775	1,395	2,928	5,961	8,477	4,882	2,276	2,124	23,737	18,021
MEAN	563	451	358	334	377	632	1,256	3,221	4,161	2,093	1,021	667	15,135	10,731

Note: Corresponds to U.S. Geological Survey station number 938000. Data as developed by Upper Colorado River Region, USBR, on 13 April 1977.

**Regulated Monthly Lake Mead
Historic Inflows Adjusted
to 1980 Conditions
(1,000 Acre-Feet)**

Water Year	Month												Water Year Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	
1906	1,581	1,546	1,619	1,643	625	582	751	966	1,270	1,707	1,058	1,005	14,353
1907	1,787	1,550	1,623	1,646	696	998	1,203	1,472	1,572	2,501	1,987	767	17,802
1908	1,687	1,550	1,624	1,623	527	510	518	551	585	1,045	1,012	350	11,582
1909	568	560	944	1,647	527	768	967	1,212	1,550	2,260	1,545	1,710	14,258
1910	1,894	1,550	1,623	1,646	527	510	518	551	585	1,045	1,012	350	11,811
1911	568	719	1,624	1,647	527	510	518	551	585	1,045	1,012	350	9,656
1912	1,585	1,547	1,618	1,642	527	738	903	1,109	1,422	1,829	1,042	511	14,473
1913	1,756	1,550	1,622	1,647	527	510	518	551	585	1,045	1,012	350	11,673
1914	568	1,114	1,619	1,647	586	865	1,059	1,306	1,611	2,088	1,012	450	13,925
1915	1,581	1,546	1,618	1,643	527	510	518	551	585	1,045	1,012	350	11,486
1916	568	610	1,620	1,647	527	554	740	949	1,206	1,489	1,454	575	11,939
1917	2,487	1,550	1,623	1,647	842	1,158	1,362	1,648	1,564	3,122	1,038	587	18,628
1918	1,571	1,550	1,624	1,647	527	510	518	551	585	1,045	1,012	350	11,490
1919	707	1,550	1,623	1,646	527	510	518	551	585	1,045	1,012	350	10,624
1920	568	560	856	1,649	609	923	1,124	1,376	2,641	1,788	1,012	350	13,456
1921	1,472	1,550	1,623	1,647	695	995	1,202	1,443	2,420	1,743	1,489	639	16,918
1922	1,538	1,546	1,603	1,647	527	655	828	1,033	1,970	1,046	1,012	350	13,755
1923	1,087	1,550	1,624	1,647	527	510	579	781	1,065	1,446	1,244	737	12,797
1924	1,780	1,550	1,622	1,646	527	510	518	551	585	1,045	1,012	350	11,696
1925	568	560	1,588	1,559	527	510	518	551	585	1,045	1,012	350	9,373
1926	568	606	1,587	1,648	527	510	518	551	585	1,045	1,012	350	9,507
1927	568	1,471	1,559	1,648	527	510	518	573	850	1,206	1,012	1,655	12,097
1928	1,995	1,550	1,622	1,646	527	510	590	761	1,222	1,166	1,012	350	12,951
1929	1,251	1,550	1,623	1,647	527	646	823	1,051	1,702	1,548	1,706	1,504	15,578
1930	1,967	1,551	1,623	1,647	527	510	518	551	585	1,045	1,012	350	11,886
1931	568	1,019	1,597	1,569	527	510	518	551	585	1,045	1,012	350	9,851
1932	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1933	568	742	1,456	1,645	527	510	518	551	585	1,045	1,012	350	9,509
1934	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1935	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1936	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1937	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1938	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1939	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1940	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1941	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1942	568	560	1,625	1,647	527	510	518	583	2,097	1,045	1,012	350	11,042
1943	593	1,527	1,534	1,648	527	510	518	551	585	1,045	1,012	350	10,400
1944	568	560	856	1,497	527	510	518	551	585	1,045	1,012	350	8,579
1945	568	1,332	1,509	1,648	527	510	518	551	585	1,045	1,012	350	10,155
1946	568	560	1,460	1,648	527	510	518	551	585	1,045	1,012	350	9,334
1947	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1948	568	560	1,625	1,648	527	510	518	551	585	1,045	1,012	350	9,499
1949	568	1,262	1,525	1,648	527	510	518	551	659	1,597	1,012	350	10,727
1950	1,074	1,551	1,583	1,648	527	510	518	551	585	1,045	1,012	350	10,954
1951	568	560	856	1,348	527	510	518	551	585	1,045	1,012	350	8,430
1952	568	560	856	1,291	527	510	644	926	2,680	1,131	1,012	350	11,055
1953	1,364	1,548	1,550	1,648	527	510	518	551	585	1,045	1,012	350	11,208
1954	568	560	856	958	527	510	518	551	585	1,045	1,012	540	8,230
1955	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1956	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1957	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1958	568	560	856	889	527	510	518	551	964	1,045	1,012	350	8,350
1959	568	795	1,542	1,648	527	510	518	551	585	1,045	1,012	350	9,651
1960	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230

**Regulated Monthly Lake Mead
Historic Inflows Adjusted
to 1980 Conditions
(1,000 Acre-Feet)**

Water Year	Month												Water Year Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	
1961	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1962	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1963	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1964	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1965	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1966	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1967	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1968	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1969	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1970	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230
1971	568	560	856	1,649	527	510	518	551	974	1,045	1,012	350	9,120
1972	568	560	1,526	1,648	527	510	518	551	585	1,045	1,012	350	9,400
1973	568	560	856	1,414	527	510	527	749	2,449	1,741	1,012	350	11,263
1974	1,092	1,551	1,624	1,648	527	510	518	551	585	1,045	1,012	350	11,013
1975	568	560	1,405	1,649	527	510	518	551	585	1,045	1,012	350	9,280
1976	866	1,548	1,625	1,648	527	510	518	551	585	1,045	1,012	350	10,785
1977	568	560	856	889	527	510	518	551	585	1,045	1,012	609	8,230

Notes:

- 1 Reservoir initially full to minimum flood control level.
- 2 1980 depletion level.
- 3 Lake Powell releases based on 1980 operating criteria.

Exceedence frequency per hundred years

99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 .5 .2 .1 .05 .02-01

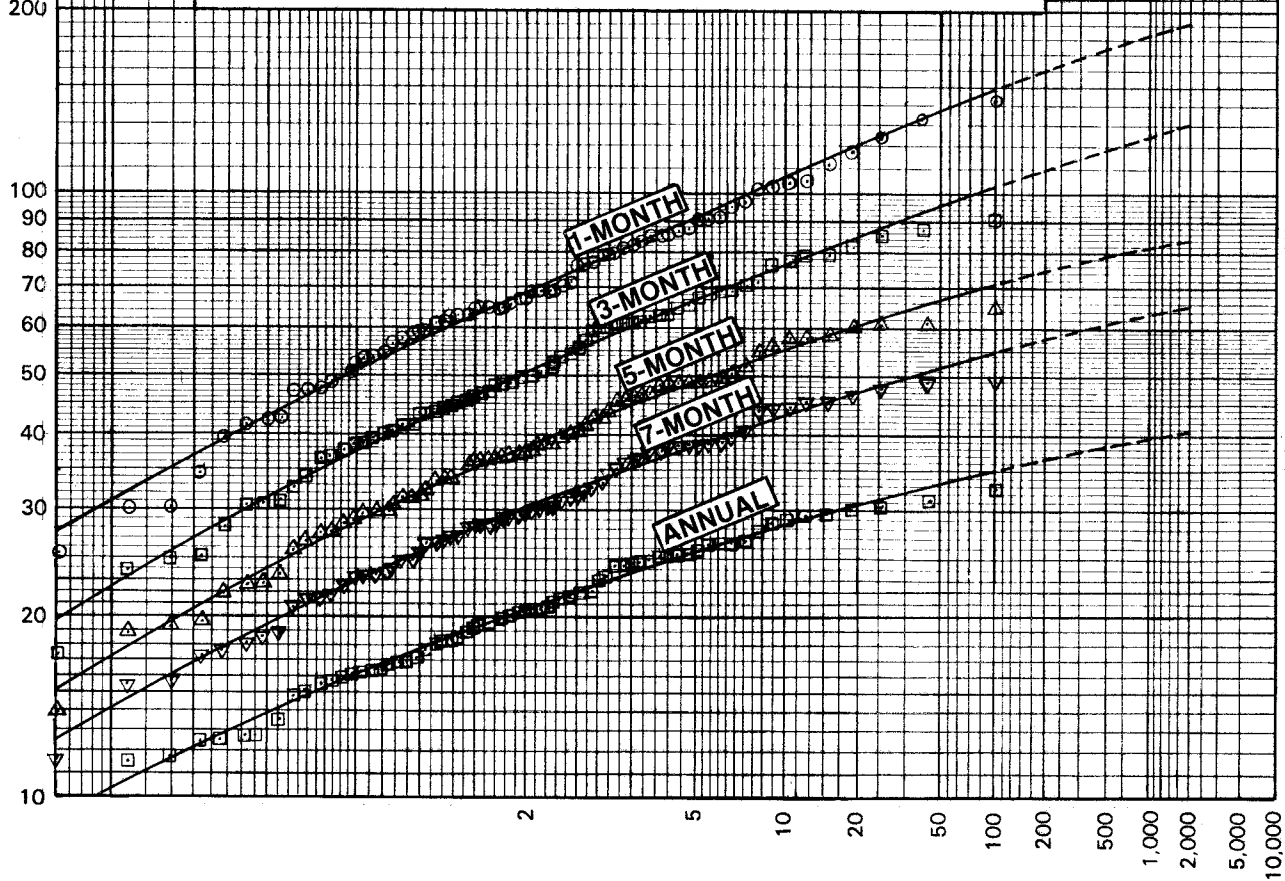
**MEDIAN PLOTTING POSITIONS FOR
N = 69 YEARS**

	1 MONTH	3 MONTH	5 MONTH	7 MONTH	ANNUAL
M =	4.830	4.570	4.570	4.468	4.304
S =	0.152	0.148	0.140	0.134	0.120
G _s =	-0.412	-0.596	-0.596	-0.527	-0.481
G _a =	-0.200	-0.500	-0.500	-0.500	-0.500

STATISTICS
FOR
ANALYTICAL
CURVES

M = MEAN OF LOGS
S = STANDARD DEVIATION OF LOGS
G_s = SKEW OF LOGS
G_a = ADOPTED SKEW

Flow in 1,000 c.f.s.



Exceedence interval in years

HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA

**VOLUME — FREQUENCY CURVES
COLORADO RIVER AT LEES FERRY
NATURAL FLOWS**

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

HISTORIC ANNUAL PEAK INFLOWS TO LAKE MEAD
(Colorado River Near Grand Canyon, Arizona)

Water Year	Date	Peak Discharge (CFS)	Water Year	Date	Peak Discharge (CFS)
1884	07/08/84	300,000 ¹	1950	06/06/50	58,400
1921	06/19/21	220,000	1951	06/01/51	63,700
1922	06/01/22	115,000 ¹	1952	06/12/52	122,000
1923	09/19/23	112,000	1953	06/17/53	68,500
1924	06/18/24	74,000	1954	05/27/54	32,800
1925	06/03/25	53,700	1955	06/14/55	40,400
1926	05/29/26	85,600	1956	06/06/56	67,200
1927	07/02/27	127,000	1957	06/13/57	125,000
1928	06/03/28	115,000	1958	06/02/58	107,700
1929	05/29/29	111,000	1959	06/19/59	38,300
1930	06/04/30	71,000	1960	06/10/60	46,300
1931	05/22/31	34,600	1961	06/06/61	39,800
1932	05/26/32	102,000	1962	05/17/62	85,600
1933	06/05/33	81,500	1963	10/22/63	20,700 ²
1934	05/17/34	25,500	1964	04/29/64	19,700 ²
1935	06/19/35	105,000	1965	06/15/65	58,400 ²
1936	05/24/36	76,300	1966	05/04/66	21,300 ²
1937	05/21/37	85,300	1967	09/09/67	23,900 ²
1938	06/08/38	100,000	1968	07/20/68	26,800 ²
1939	05/26/39	49,000	1969	09/12/69	30,800 ²
1940	05/18/40	46,800	1970	08/27/70	27,600 ²
1941	05/17/41	120,000	1971	08/24/71	33,400 ²
1942	05/31/42	91,800	1972	05/26/72	29,500 ²
1943	06/06/43	66,800	1973	04/19/73	38,300 ²
1944	05/20/44	93,400	1974	08/21/74	28,200 ²
1945	05/17/45	63,300	1975	07/30/75	28,900 ²
1946	06/14/46	50,100	1976	05/20/76	27,700 ²
1947	05/14/47	80,100	1977	08/19/77	32,100 ²
1948	05/26/48	89,800	1978	09/09/78	29,500 ²
1949	06/22/49	112,000			

¹Estimated.

²Affected by Lake Powell.

NOTES:

1. Drainage areas by USGS; 3,959 square miles non-contributing area in Wyoming Basin excluded.

2. Travel time by Clark equation:

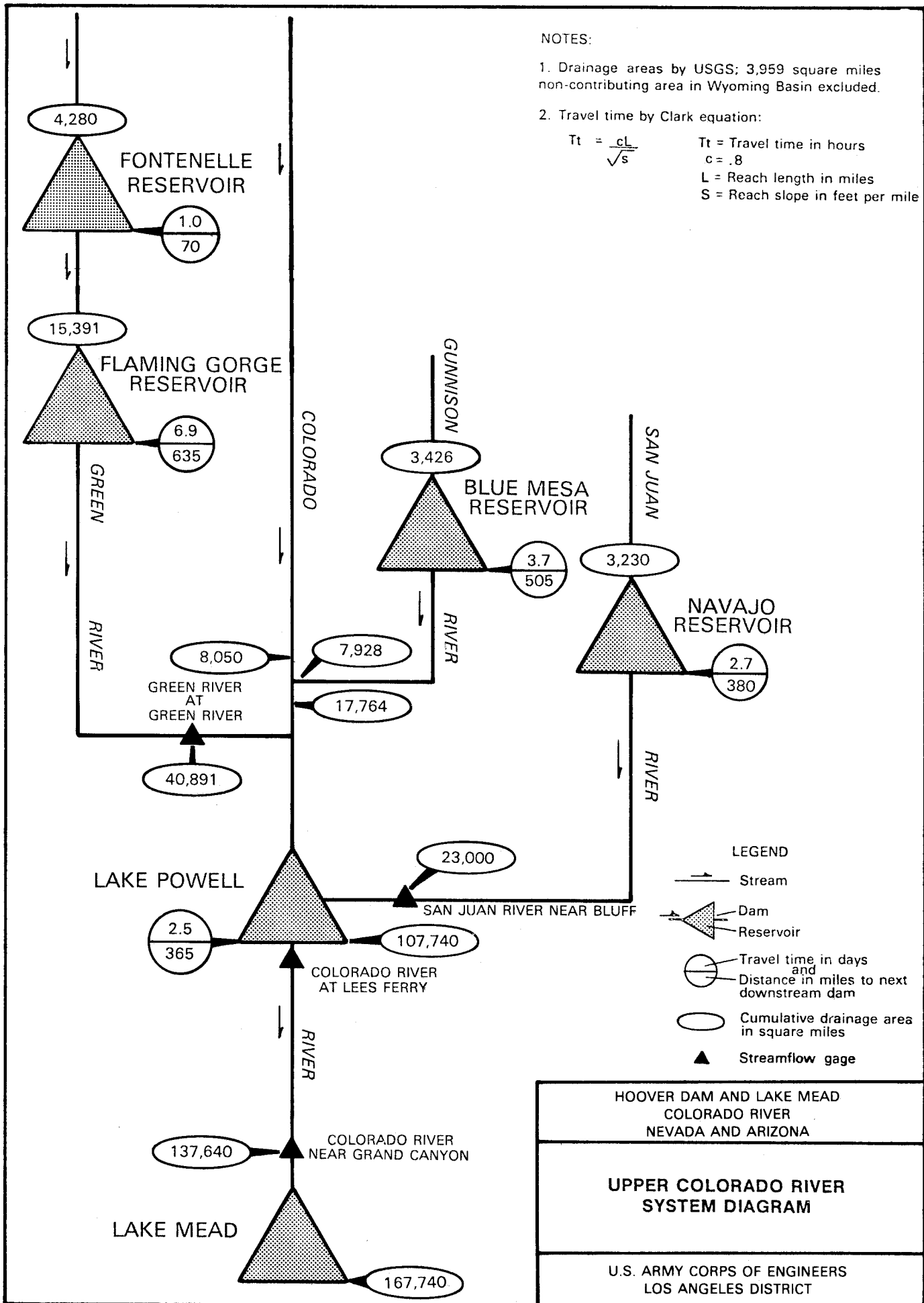
$$T_t = \frac{cL}{\sqrt{S}}$$

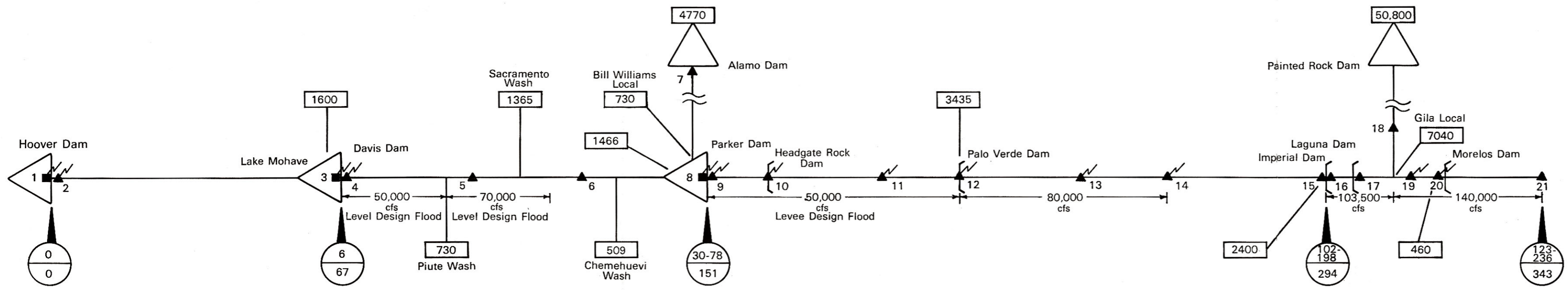
Tt = Travel time in hours

c = .8

L = Reach length in miles

S = Reach slope in feet per mile





SCHMATIC DIAGRAM

- LEGEND — SCHEMATIC DIAGRAM**
- Stream
 - Diversion Dam
 - Dam
 - Reservoir
 - Cumulative Travel Time, hrs./min.-max.
 - Cumulative Distance, miles
 - Incremental drainage area in square miles; unlabeled area is shown at downstream end of reach.
 - Streamflow Gage
 - Storage Gage
 - Radio Reporting Gages

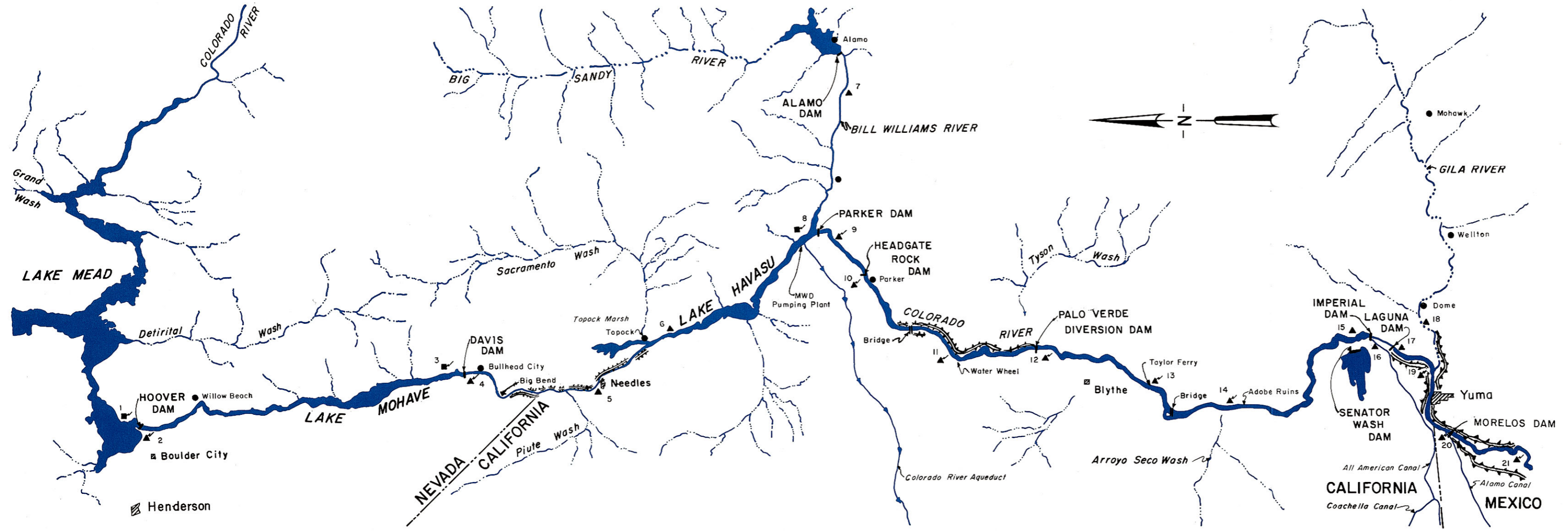
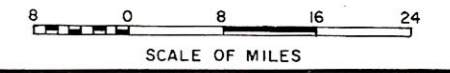
LEGEND — MAP

Levee

**Lower Colorado River
Key Streamflow and Storage Gages**

Map Number	USGS Number	Station Name (abbreviated)
1	09421000	Lake Mead
2	09421500	Colorado River below Hoover Dam
3	09422500	Lake Mohave
4	09423000	Colorado River below Davis Dam
5	09423500	Colorado River at Needles
6	09424000	Colorado River near Topock
7	09426000	Bill Williams River below Alamo Dam
8	09427500	Lake Havasu
9	09427520	Colorado River below Parker Dam
10	09428500	Colorado River at Indian Reservation Main Canal
11		Colorado River at Water Wheel
12	09429010	Colorado River at Palo Verde Dam
13		Colorado River at Taylor Ferry
14	09429300	Colorado River below Cibola Valley (Adobe Ruin)
15	09429490	Colorado River above Imperial Dam
16	09429500	Colorado River below Imperial Dam
17	09429600	Colorado River below Laguna Dam
18	09520500	Gila River near Dome
19	09521100	Colorado River below Yuma Main Canal Wasteway
20	09522000	Colorado River at Northernly International Boundary
21	09522200	Colorado River at Southernly International Boundary

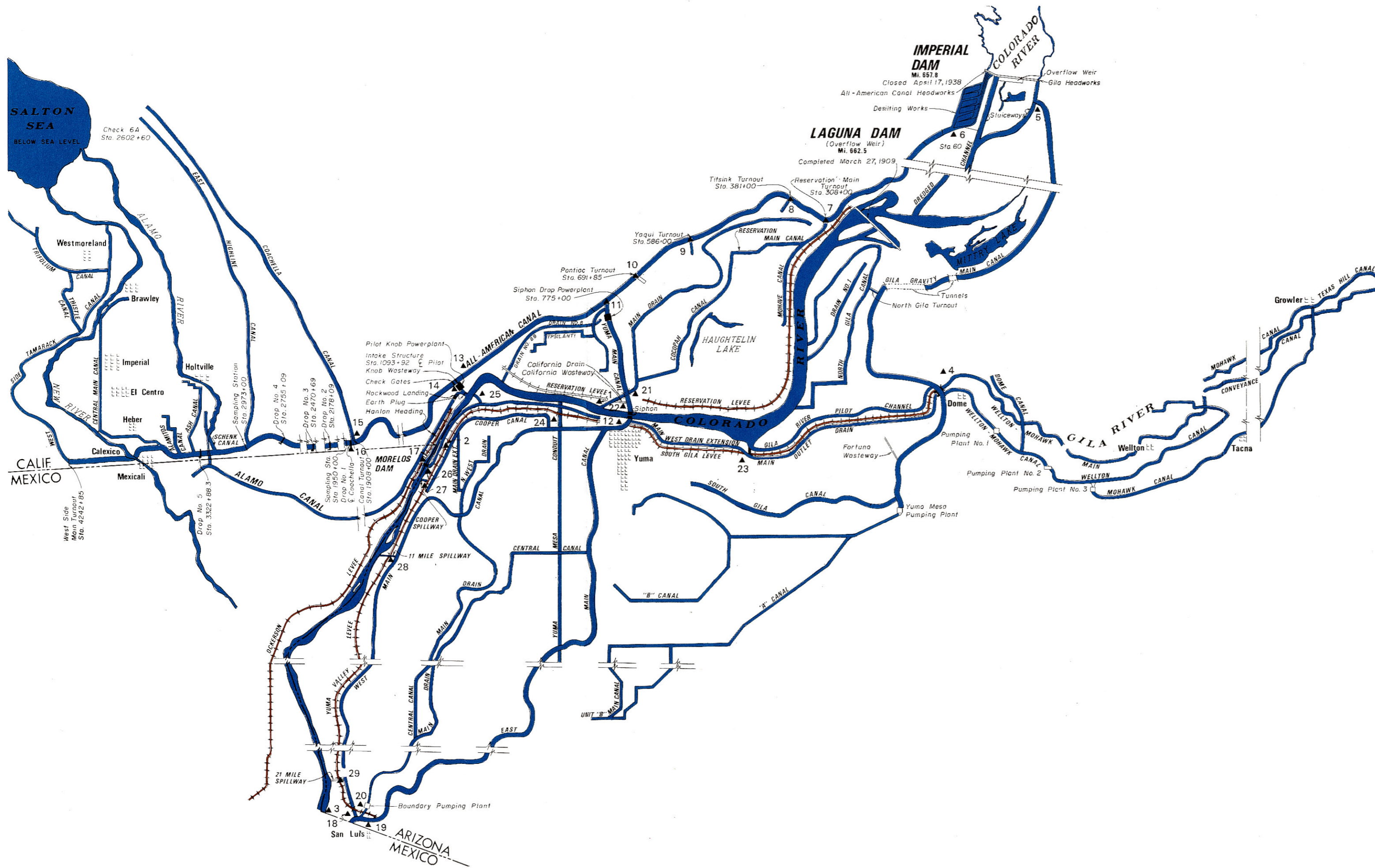
NOTE:
See Table 6 in chapter 4
for the discharge-damage
values for various releases.



HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA

**LOWER COLORADO RIVER
SYSTEM MAP
AND
DIAGRAM**

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



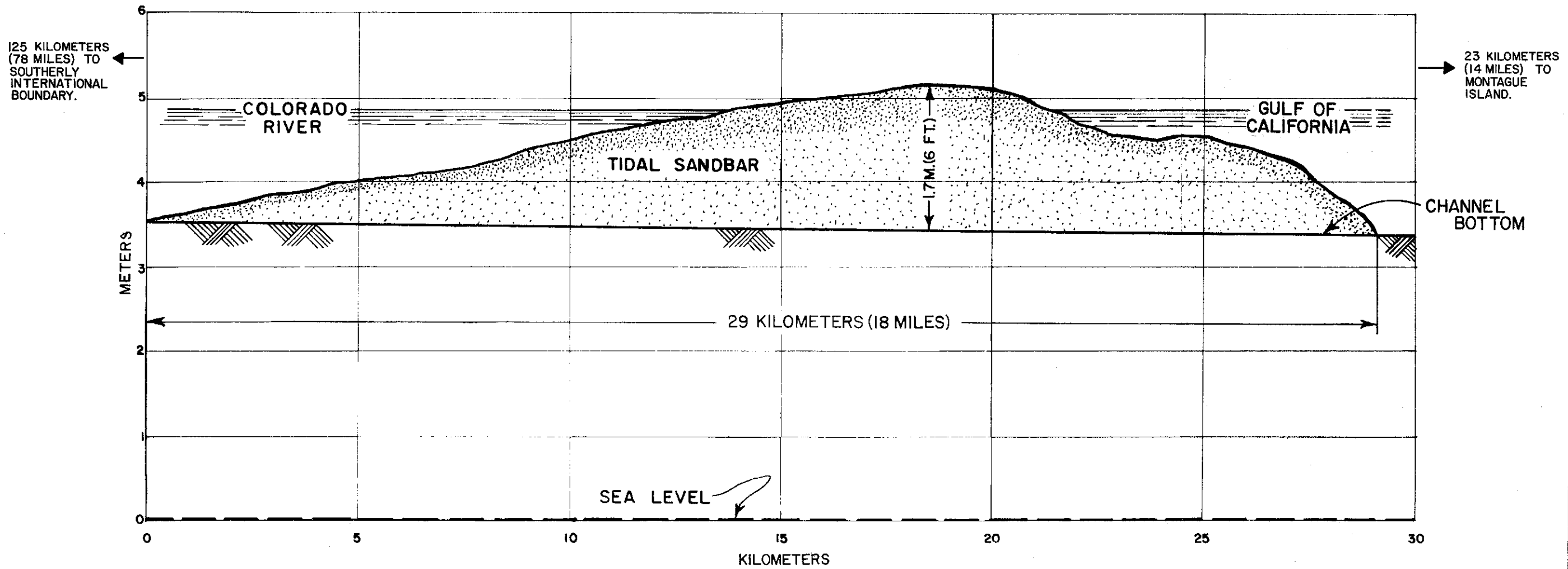
GAGING STATIONS (Designated thus ▲ on Operational Diagram)			
NO	DESIGNATION	TYPE OF MEASUREMENT	RESPONSIBLE AGENCY
Colorado River Main Stem			
1	Yuma Gage	Rated Section	U.S.G.S.
2	Colorado R. at Northerly International Boundary	Rated Section	I.B.W.C.
3	Colorado R. at Southerly International Boundary	Rated Section	I.B.W.C.
Gila River			
4	Near Dome	Rated Section	U.S.G.S.
5	Gila Gravity Main Canal Sta. 30 + 00	Rated Section	U.S.G.S.
All-American Canal			
6	Station 60, Near Imperial Dam	Rated Section	I.I.D.
7	Reservation Main Turnout A.A.C. Sta. 308 + 00	Calibrated Gate	U.S.B.R.
8	Titsink Turnout A.A.C. Sta. 381 + 00	Parshall Flume	U.S.B.R.
9	Yaqui Turnout A.A.C. Sta. 586 + 00	Parshall Flume	U.S.B.R.
10	Pontiac Turnout A.A.C. Sta. 691 + 85	Parshall Flume	U.S.B.R.
11	Yuma Main Canal at Siphon Drop Turnout	Rated Turbine Gate	U.S.G.S. & U.S.B.R.
12	Yuma Main Canal below Colorado River Siphon	Rated Siphon	U.S.G.S.
13	Above Pilot Knob Wasteway	Slope Section	I.I.D. & U.S.G.S.
14	Pilot Knob Wasteway A.A.C. Sta. 1093 + 92	Calibrated Gate	I.I.D.
15	Coachella Turnout	Calibrated Gate	I.I.D. & U.S.B.R.
16	Drop No. 1 A.A.C. Sta. 1908 + 00	Calibrated Gate	I.I.D. & U.S.B.R.
Diversion to Mexico			
17	Morelos Dam	Metering Section	I.B.W.C.
18	West Main Canal	Rated Section & Recorder	I.B.W.C.
19	East Main Canal	Rated Section & Recorder	I.B.W.C.
20	Main Drain	Rated Pumps	Y.C.W.U.A.
Return Flows to Colorado River (Yuma Area)			
21	Drainage Return Reservation Diversion	Rated Section	U.S.B.R.
22	Regulatory Waste Return to River	Computed	U.S.G.S.
23	M.O.D.E. No. 1	Calibrated Gate	U.S.G.S.
24	Yuma Mesa Conduit	Venturi Flowmeter	U.S.G.S.
25	M.O.D.E. No. 2	Parshall Flume & Recorder	U.S.G.S.
26	M.O.D.E. No. 3	Parshall Flume & Recorder	I.B.W.C.
27	Cooper Lateral Spillway	Weir & Recorder	I.B.W.C.
28	11 Mile Spillway	Rated Gate & Recorder	I.B.W.C.
29	21 Mile Spillway	Rated Flume & Recorder	I.B.W.C.

A.A.C. — All American Canal
 I.B.W.C. — International Boundary and Water Commission
 I.I.D. — Imperial Irrigation District
 M.O.D.E. — Main Outlet Drain Extension
 U.S.B.R. — United States Bureau of Reclamation
 U.S.G.S. — United States Geological Survey
 Y.C.W.U.A. — Yuma County Water Users Association

HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

**DIAGRAM OF
 CHANNELS AND DIVERSION WORKS
 IMPERIAL DAM TO MORELOS DAM**

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT



HOOVER DAM AND LAKE MEAD COLORADO RIVER NEVADA AND ARIZONA
COLORADO RIVER DELTA TIDAL SAND BAR
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT

CHAIN OF COMMAND FOR RESERVOIR OPERATIONS DECISIONS

Corps of Engineers
Los Angeles District

<u>Title</u>	<u>Office Phone Number</u>
District Engineer	(213) 688-5300 FTS 798-5300
Chief, Engineering Division	(213) 688-5470 FTS 798-5470
Chief, Hydrology & Hydraulic Branch	(213) 688-5520 FTS 798-5520
Chief, Hydrologic Engineering Section	(213) 688-4753 FTS 798-4753
Chief, Reservoir Regulation Unit	(213) 688-4756 FTS 798-4756

U.S. Bureau of Reclamation
Lower Colorado Region

Regional Director	(702) 293-8411 FTS 598-7411
Assistant Regional Director	(702) 293-8411 FTS 598-7411
Regional Supervisor of Water and Land Operations	(702) 293-8414 FTS 598-7414
Chief, Water Scheduling Branch	(702) 293-8677 FTS 598-7677
Project Manager	(702) 293-8302 (702) 293-8305 FTS 598-7302 FTS 598-7305

HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA

IMPORTANT TELEPHONE NUMBERS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

**SAMPLE
SNOWMELT RUNOFF
FORECAST BULLETIN**

Date _____
Issued by _____

- Final
- Preliminary

**COLORADO RIVER FORECASTS
FOR
FLOOD CONTROL OPERATION AT HOOVER DAM**

Forecast Period: _____ to 1 August

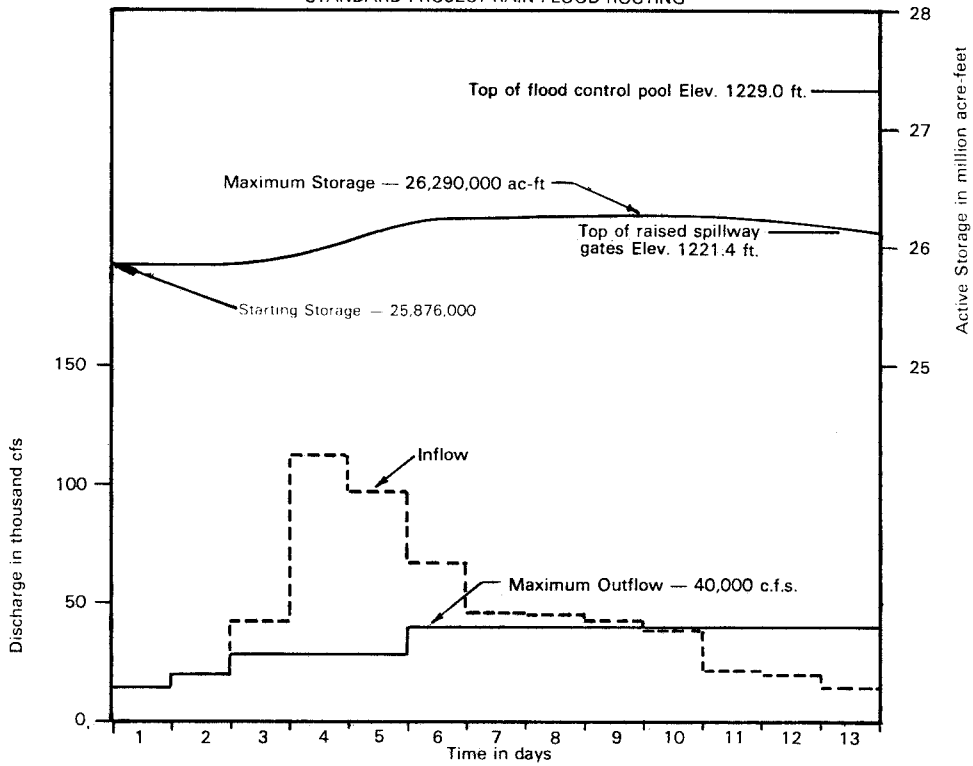
Reservoir	Forecast in Million Acre-Feet*		
	Maximum	Mean	Minimum
Lake Mead			
Lake Powell			
Navajo			
Blue Mesa			
Flaming Gorge			

**MONTHLY DISTRIBUTION OF MEAN FORECAST*
INTO LAKE POWELL
IN MILLION ACRE-FEET**

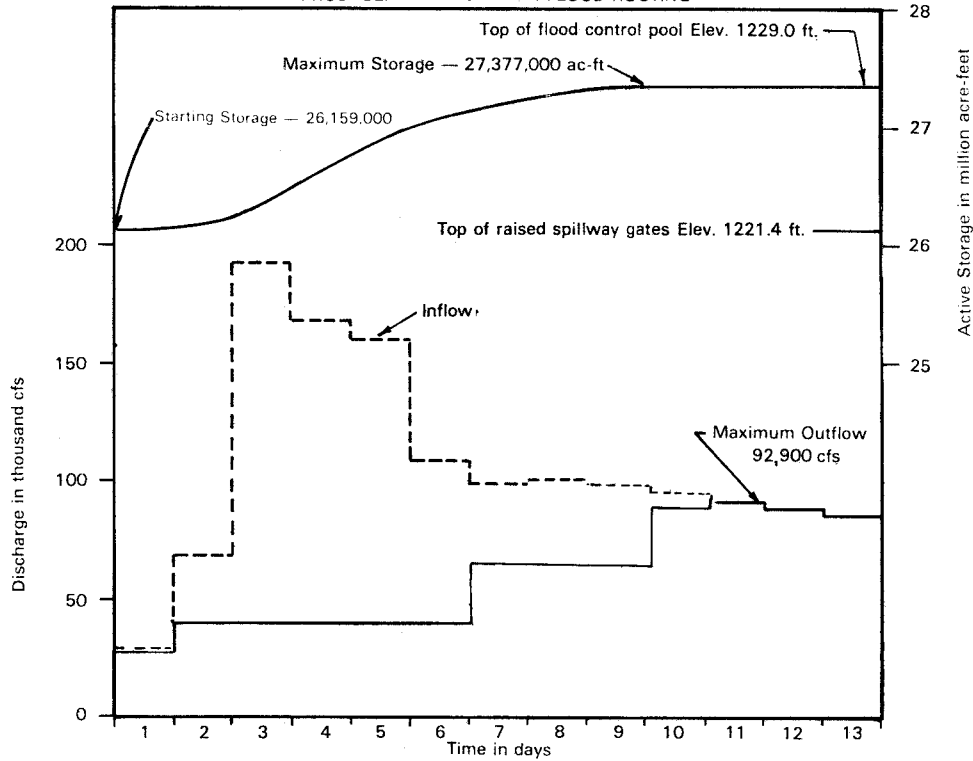
Month	April	May	June	July
Forecast				

*Virgin flows minus depletions.

STANDARD PROJECT RAIN FLOOD ROUTING



PROBABLE MAXIMUM RAIN FLOOD ROUTING

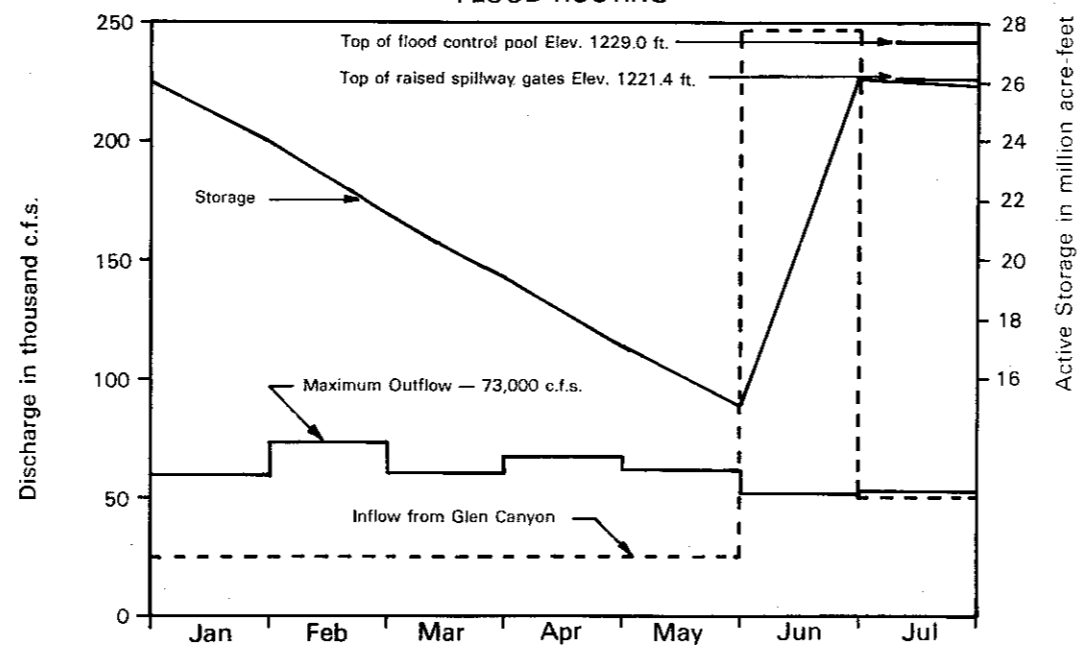


HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

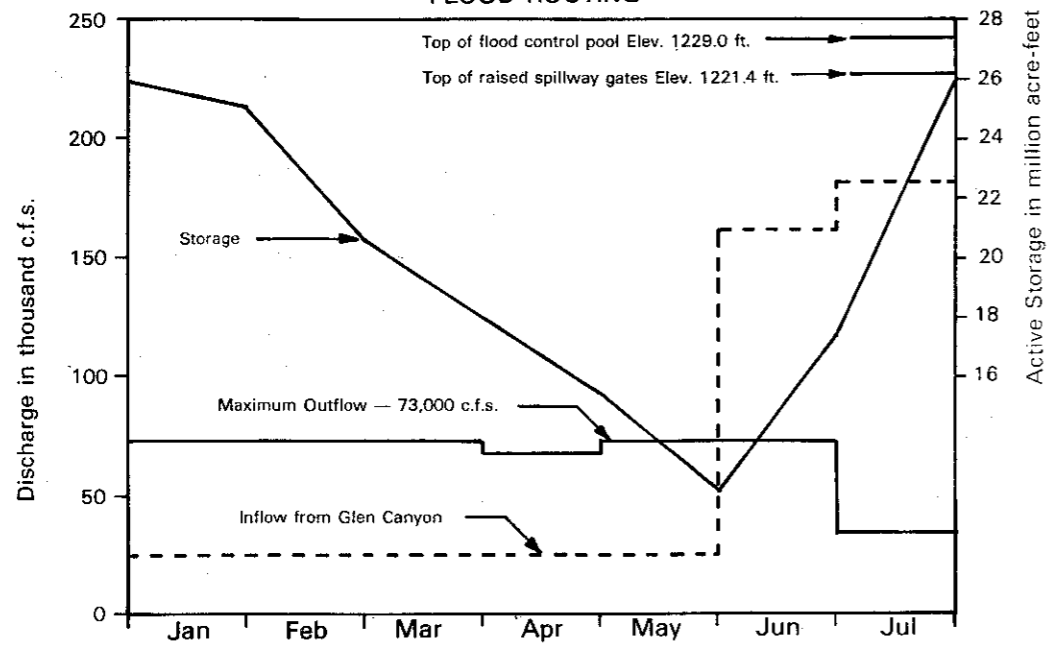
ROUTINGS OF HYPOTHETICAL
 RAIN FLOODS

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT

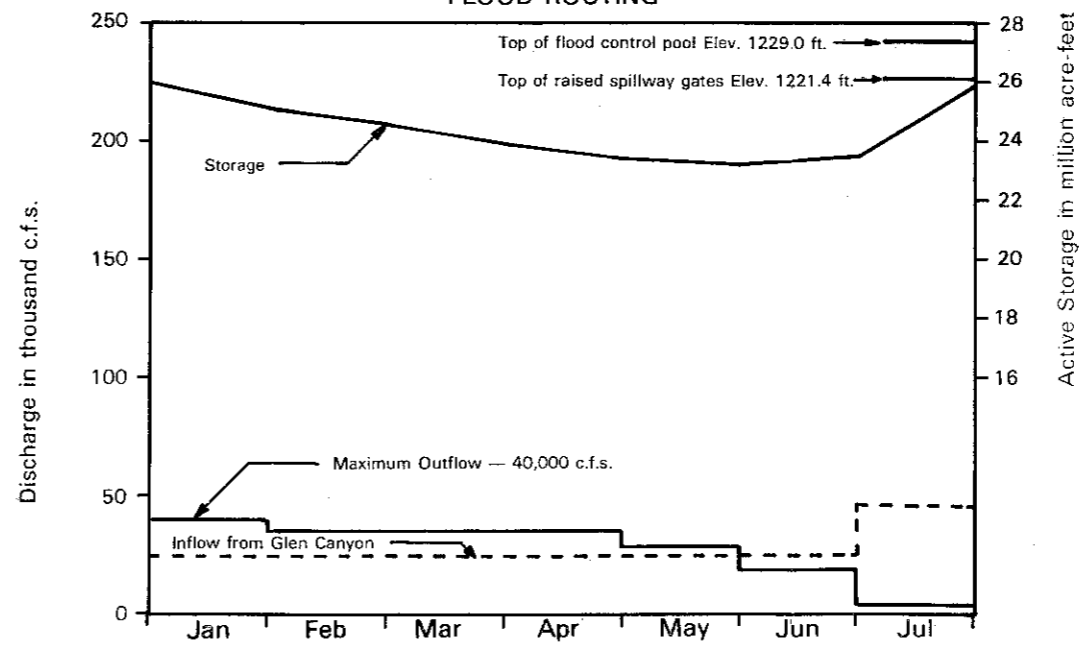
**PROBABLE MAXIMUM SNOWMELT
FLOOD ROUTING**



**1884 SNOWMELT
FLOOD ROUTING**



**1917 SNOWMELT
FLOOD ROUTING**

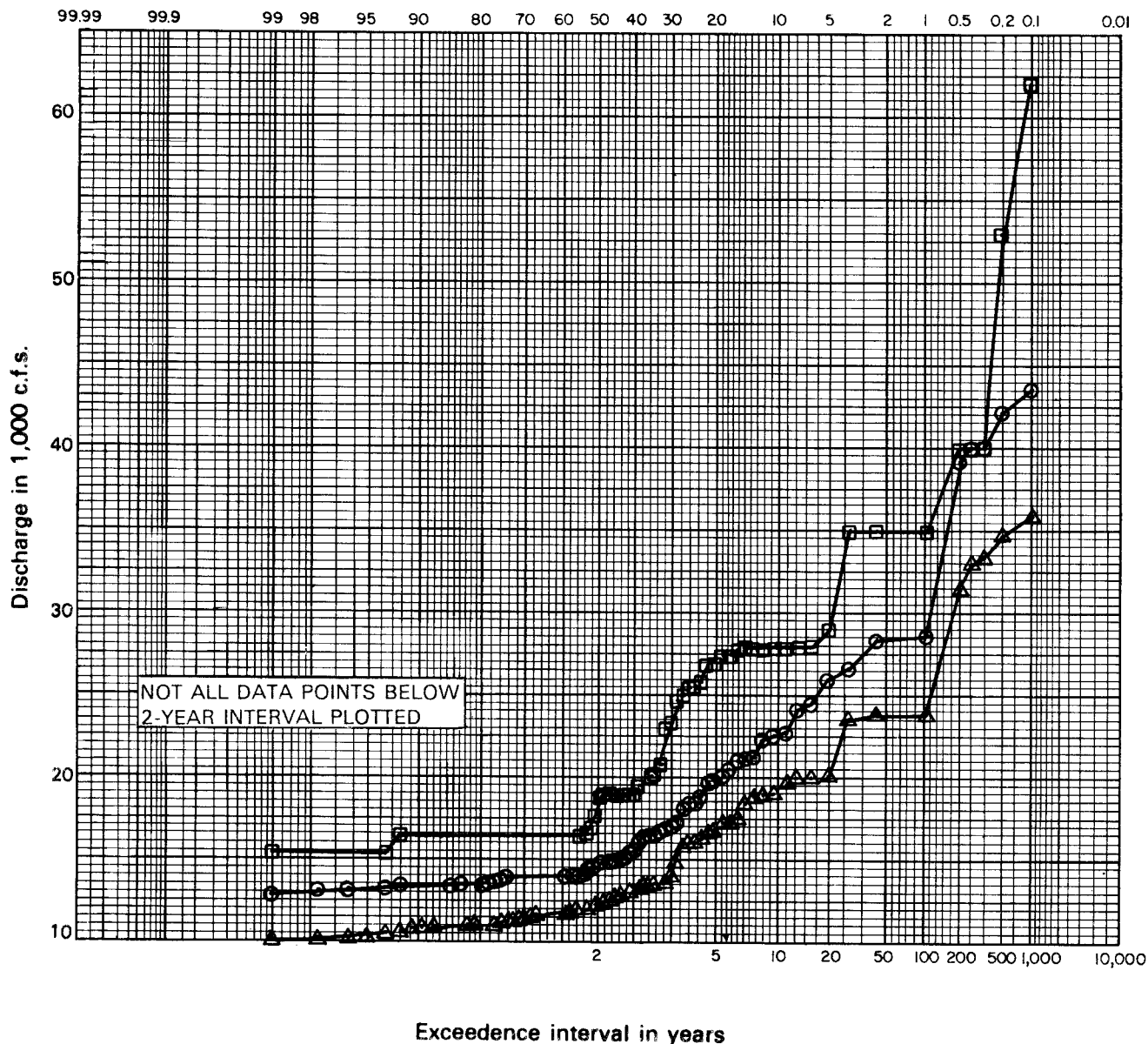


HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA

**ROUTINGS OF
HISTORICAL AND HYPOTHETICAL
SNOWMELT FLOODS**

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Exceedence frequency per hundred years



GRAPHICAL CURVES

Median Plotting Positions for 72 Years of Record

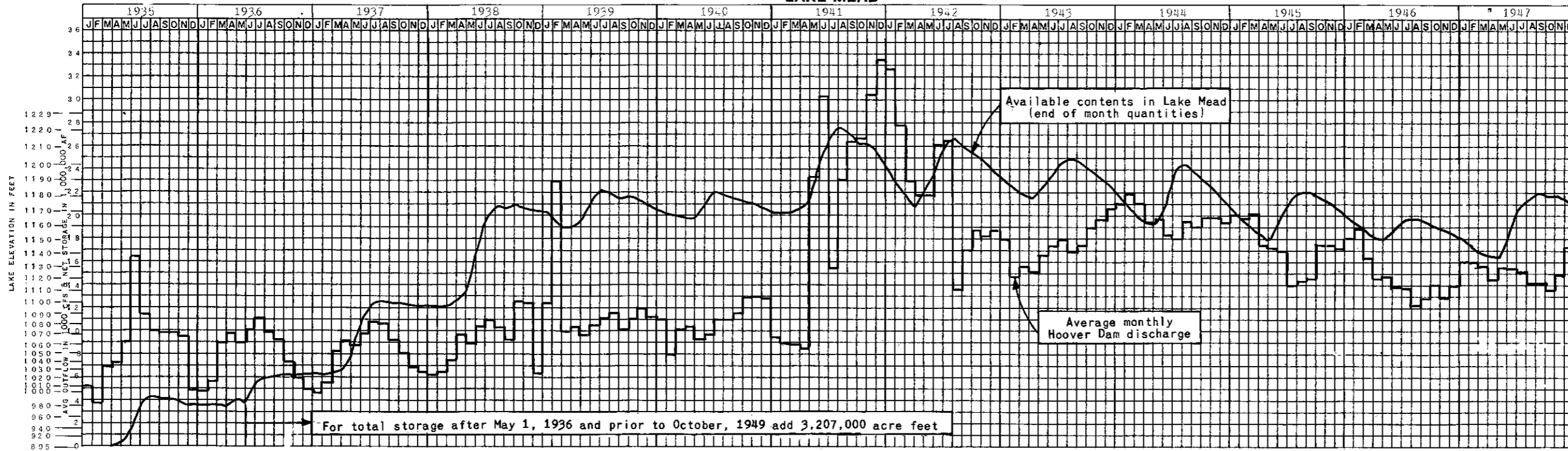
- 1 Month Ave.
- 6 Month Ave.
- △— 12 Month Ave.

HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

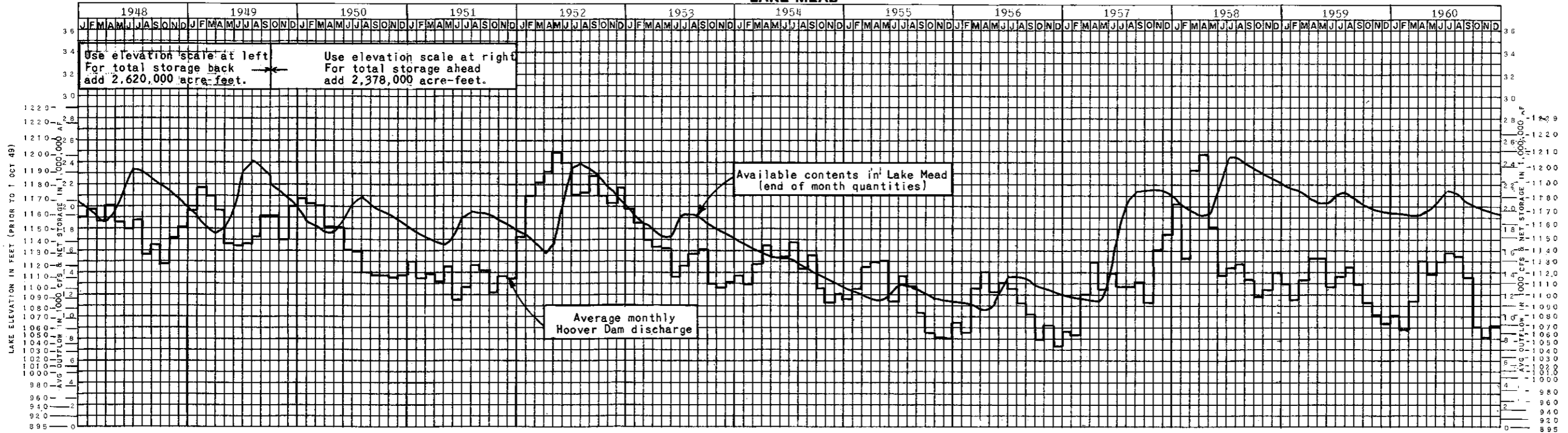
**VOLUME — FREQUENCY CURVES
 COLORADO RIVER DOWNSTREAM
 FROM HOOVER DAM**

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT

LAKE MEAD



LAKE MEAD



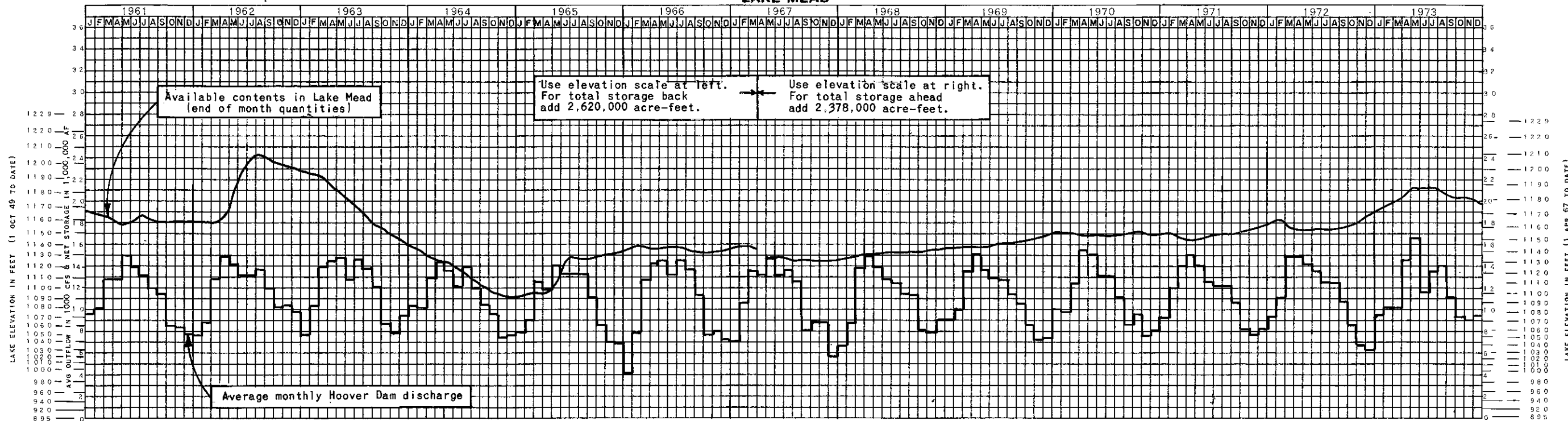
NOTES:
 New capacity table based on sediment surveys of 1948-49 put into use October 1, 1949. For total storage between May 1, 1936 and October 1949 add 3,207,000 A.F. to available contents. For total contents after October 1949 add 2,620,000 A.F.

HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

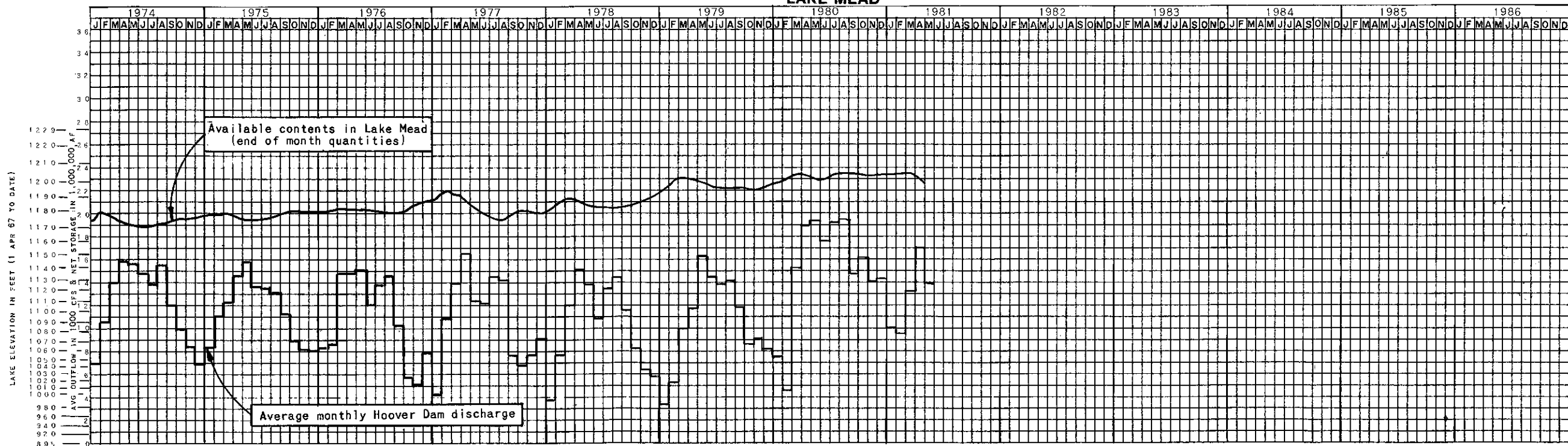
LAKE MEAD AND LAKE POWELL
 PLOTS OF HISTORIC OPERATIONS

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT

LAKE MEAD



LAKE MEAD



NOTES:

Data shown hereon were obtained from water supply papers published by the Geological Survey for the period prior to October, 1968.

Data since that time were obtained from provisional records of the Geological Survey and are subject to revision.

New capacity table based on sediment surveys of 1948-49 and 1963-64 were put into use October 1, 1949 and April 1, 1967 respectively.

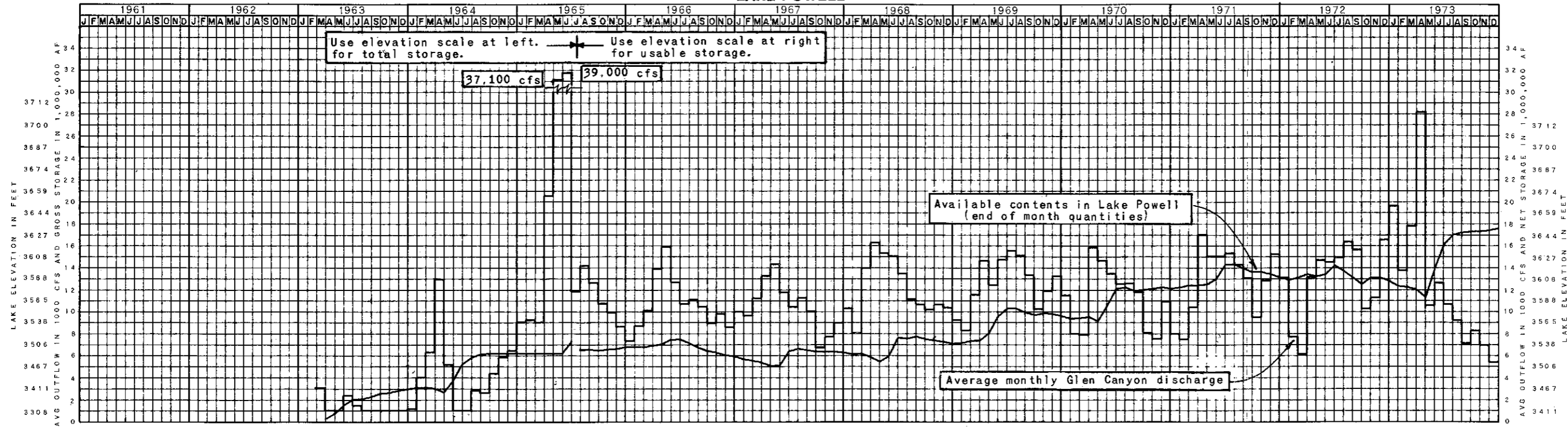
For total storage from May 1, 1936 through September 30, 1949 add 3,207,000 A.F., from October 1, 1949 through March 31, 1967 add 2,620,000 A.F. and from April 1, 1967 add 2,378,000 A.F. to available contents.

HOOVER DAM AND LAKE MEAD
COLORADO RIVER
NEVADA AND ARIZONA

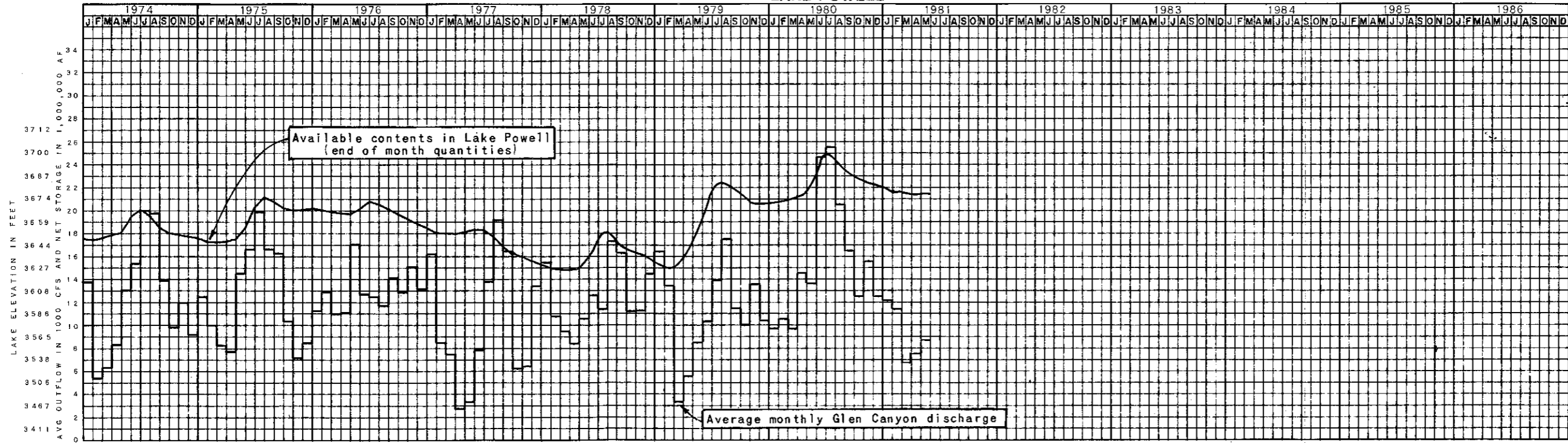
**LAKE MEAD AND LAKE POWELL
PLOTS OF HISTORIC OPERATIONS**

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT*

LAKE POWELL



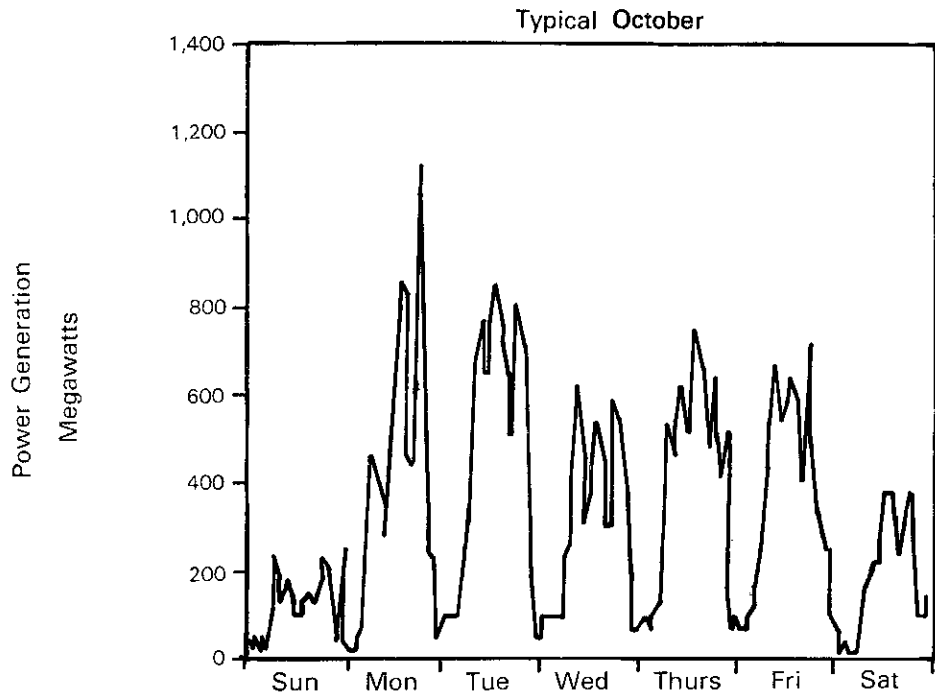
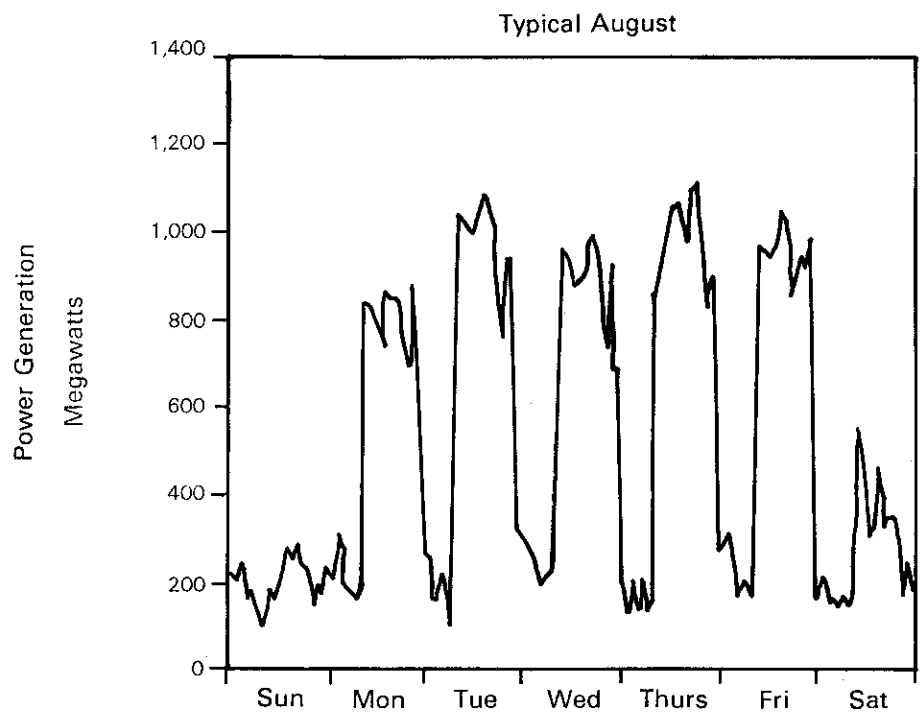
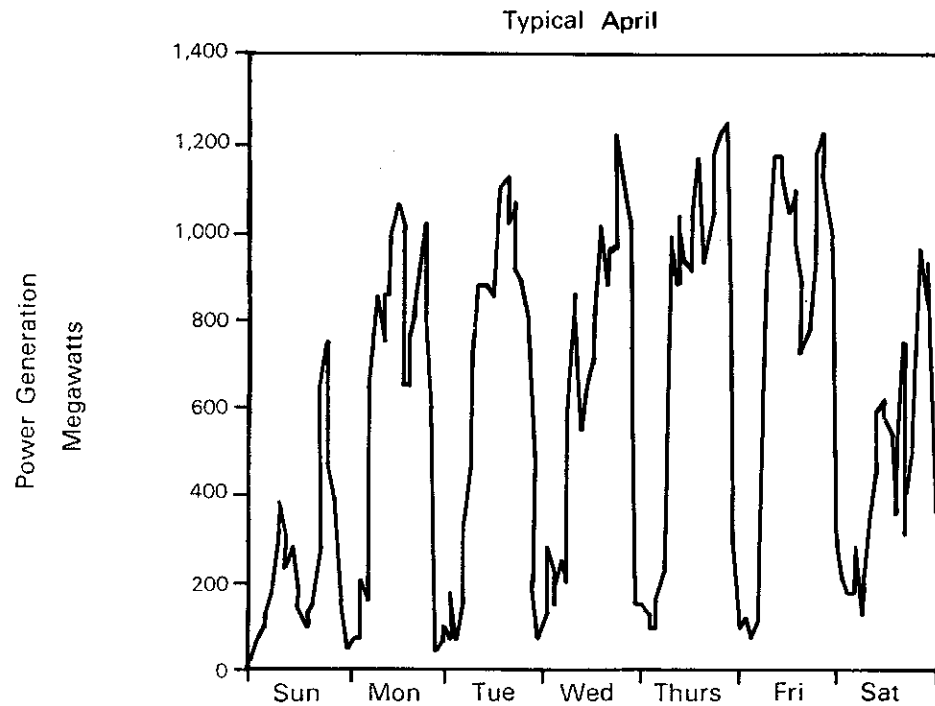
LAKE POWELL



HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

LAKE MEAD AND LAKE POWELL
 PLOTS OF HISTORIC OPERATIONS

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT



HOOVER DAM AND LAKE MEAD
 COLORADO RIVER
 NEVADA AND ARIZONA

**Hoover Dam
 Typical Power
 Generation Patterns**

U.S. ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT

WATER CONTROL MANUAL
FOR FLOOD CONTROL
HOOVER DAM AND LAKE MEAD
COLORADO RIVER, NEVADA AND ARIZONA

DECEMBER 1982

EXHIBIT A
FLOOD CONTROL REGULATIONS

EXHIBIT A
FLOOD CONTROL REGULATIONS

CONTENTS

Item		Page
1	Field Working Agreement Between Department of the Interior, Bureau of Reclamation and Department of the Army, Corps of Engineers for Flood Control Operation of Hoover Dam and Lake Mead, Colorado River, Nevada-Arizona	A-1
2	Sample Flood Control Release Calculation	A-28

FIELD WORKING AGREEMENT
BETWEEN
DEPARTMENT OF THE INTERIOR) BUREAU OF RECLAMATION
AND
DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS
FOR
FLOOD CONTROL OPERATION
OF
HOOVER DAM AND LAKE MEAD, COLORADO RIVER, NEVADA - ARIZONA

This field working agreement, made and entered into this ___day of _____1982, between the Lower Colorado Region, Bureau of Reclamation and the South Pacific Division, Corps of Engineers,

WITNESSETH THAT:

WHEREAS, Hoover Dam and Lake Mead, Colorado River, Clark County, Nevada and Mohave County, Arizona, was authorized as part of the Boulder Canyon Project Act (Public Law 70-642). The Boulder Canyon Project Act states that Boulder Dam (Public Law 43 changed the name of the structure from Boulder Dam to Hoover Dam) and the reservoir that it creates shall be used: first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses; and third, for power.

WHEREAS, the Department of the Interior, acting through the Bureau of Reclamation, represented by the appropriate Regional Director, hereinafter referred to as the Regional Director, has constructed Hoover Dam and

Reservoir, and is responsible for the safety of the structure and for normal operations of the Lower Colorado River, of which said dam and reservoir are a part.

WHEREAS, the Department of the Army, acting through the Corps of Engineers, represented by its appropriate District and Division Engineers, is responsible for the flood control operation of Hoover Dam and Lake Mead in accordance with Section 7 of the 1944 Flood Control Act (Section 7, Public Law 78-534, 58 Stat. 890, 33 U.S.C. 709), which directs the Army to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds, and as promulgated in the Code of Federal Regulations, Title 33, Part 208.11, 13 October 1978.

WHEREAS, there is a need for a working agreement to insure a clear understanding of flood control regulations and information exchange required for the operation of Hoover Dam and Lake Mead.

NOW, THEREFORE, it is mutually understood and agreed by and between the parties hereto that this field working agreement shall consummate the provisions of the 1944 Flood Control Act for Hoover Dam and Lake Mead. In addition to the responsibilities of the project owner and the Corps of Engineers spelled out in paragraph 208.11 , 33 CFR, it is agreed that Hoover Dam and Lake Mead will be operated in the interest of flood control in accordance with the following water control plan.

(a) In order to provide storage space for control of floods, releases from Lake Mead shall be scheduled so that available storage space for flood control will not be less than that indicated in the following table for the dates shown. Flood control storage space shall be the available storage space below elevation 1,229 feet.

<u>Date</u>	Available flood control storage space <hr style="width: 50%; margin: 0 auto;"/> (acre-feet)
1 August	1,500,000
1 September	2,270,000
1 October	3,040,000
1 November	3,810,000
1 December	4,580,000
1 January	5,350,000

Pertinent information on permissible changes in available flood control storage space in Lake Mead is given in subparagraphs (1), (2), and (3) of this paragraph.

(1) The available flood control storage space in Lake Mead during the period 1 August to 1 January may be reduced to a minimum of 1,500,000 acre-feet, provided the additional space prescribed under paragraph (a) above is available in active storage space in upstream reservoirs. The maximum storage space in upstream reservoirs that can be credited to the 1 September, 1 October, 1 November, 1 December, or 1 January storage space requirement in Lake Mead is given in the following table:

<u>Reservoir</u>	<u>Creditable storage space</u> (Acre-feet)
Lake Powell	3,850,100
Navajo	1,035,900
Blue Mesa	748,500
Flaming Gorge plus Fontenelle	1,507,200

2) Space building releases from Lake Mead during the period 1 August to 1 January shall not exceed 28,000 cubic feet per second.

Space building releases are herein defined as releases for the purpose of attaining the available flood control storage space given in paragraph (a) above.

(3) If, however, available flood control storage space diminishes at any time to less than 1,500,000 acre-feet then the minimum flood control releases are described in paragraph (b) below.

(b) At any time during the year, if available storage space in Lake Mead should become less than 1,500,000 acre-feet, then minimum releases from Lake Mead for flood control shall be determined daily from table 1 (Minimum Flood Control releases from Hoover Dam throughout the year) using available flood control storage space in Lake Mead. Pertinent information on permissible changes in the releases as indicated in table 1 is given in subparagraphs (1), (2), and (3) of this paragraph.

(1) During 1 August to 1 January minimum releases from Lake Mead as given in table 1 , if 40, 000 cubic feet per second or less, shall not be reduced when once initiated until the storage space prescribed in paragraph (a) above becomes available. During the remainder of the year, releases as given in table 1 if 40,000 cubic feet per second or less are maintained until 1,500,000 acre-feet of storage is available at Lake Mead.

(2) Minimum releases from Lake Mead as given in table 1, if greater than 40,000 cubic feet per second, shall not be reduced, when once initiated, until Lake Mead water surface has receded to elevation 1,221.4 (top of spillway gates raised position). During 1 August to 1 January, releases may then be gradually reduced to 40,000 cubic feet per second and shall be maintained at not less than that rate until the storage space prescribed in paragraph (a) above becomes available. During the remainder of the year releases may also be reduced to 40,000 cubic feet per second upon reaching elevation 1,221.4 in Lake Mead, and shall be maintained at not less than that rate until 1,500,000 acre-feet of storage space is available at Lake Mead.

(3) The releases required in table 1 are minimum releases. Based on forecasted inflow, releases when the Lake Mead water surface elevation is between 1219.61 feet and 1229.00 may be higher during the early stages of a flood so as to achieve a greater reduction in ultimate peak outflow.

(c) Releases from Lake Mead shall be restricted to quantities that will not cause a flow in excess of 40,000 cubic feet per second at the gaging station, Colorado River below Davis Dam, insofar as possible.

However, with the reservoir water surface at the top of the flood control pool, a discharge of about 65,000 cubic feet per second will be passing over the Hoover Dam spillways with the gates in the raised position.

(d) For the period 1 January through 31 July, minimum releases from Lake Mead to attain the 1 August flood control space prescribed in paragraph (a) above shall be determined by use of the Flood Control Algorithm described in Exhibit 1 and Water Loss Equations for Lakes Mead and Powell described in Exhibit 2. Pertinent information on inflow forecasts and on permissible changes in the prescribed releases is given in subparagraphs (1), (2), (3), (4), (5), and (6) of this paragraph.

(1) All inflow forecasts used in carrying out the provisions of these regulations shall be prepared by the Colorado River Forecasting Service located in the National Weather Service River Forecast Center in Salt Lake City, Utah and shall be for the flow of the Colorado River into Lake Mead including the runoff contribution from the tributary drainage area between Lake Powell and Lake Mead.

(2) Lake Mead inflow forecasts as provided by the Colorado River Forecast Service shall be determined from depleted flow. Depletion of natural (virgin) flow shall include transbasin diversions, net water use (diversion minus return flow), and evaporation from reservoirs upstream of Lake Powell. Adjustments to the forecast provided by the Colorado River Forecast Service shall be made for effective storage space in upstream reservoirs as specified in subparagraph (3) of this paragraph. The

maximum forecast for any specified runoff period is defined as the estimated inflow volume (acre-feet) that, on the average, will not be exceeded 19 times out of 20.

(3) Effective storage space in Navajo, Blue Mesa, and Flaming Gorge plus Fontenelle reservoirs is the lesser of the actual space available, or the usable space available. The usable space is the difference between the mean forecasted inflow volume (acre-feet) for any specified runoff period and projected mean reservoir releases. In computing effective storage space for Flaming Gorge plus Fontenelle, the actual space is the sum of the actual available space in both reservoirs; while mean forecasted inflow volume and projected mean reservoir release will be the values at Flaming Gorge reservoir. Effective storage space in a reservoir(s) may be a negative value if projected mean reservoir releases exceed the mean forecasted inflow volume.

(4) When minimum releases for the months of January through July as determined by the Flood Control Algorithm are less than 28,000 cubic feet per second, it will be permissible to release less than the indicated amounts for a part of a month, provided the average releases for the entire month will equal the release given by the Algorithm, without flows exceeding 28,000 cubic feet per second at the gaging station, Colorado River below Davis Dam.

(5) The Flood Control Algorithm described in Exhibit 1 accounts for storage space in Lakes Powell and Mead. Whenever sufficient runoff occurs, Lake Powell is expected to fill to capacity (water surface

elevation 3700.0 feet) and Lake Mead is expected to fill to capacity (water surface elevation 1219.61), and remain full until 1 August so as to preclude any increase in the flood control releases specified by the Flood Control Algorithm above 28,000 cubic feet per second at the gaging station, Colorado River below Davis Dam.

(6) The objective of the Flood Control Algorithm is to specify releases such that Lake Mead will be no higher than water surface elevation 1219.61 feet (1,500,000 acre-feet of available storage space below elevation 1229.0 feet) on 1 August. Subsequent revisions to the minimum releases specified by the Flood Control Algorithm may be made during July if justified by a forecast of the remaining runoff and comparison with empty reservoir space available.

(e) During the period 1 January through 31 July the larger release specified by the Flood Control Algorithm versus table 1 shall be the required minimum release.

(f) At anytime of the year, Hoover Dam releases shall not result in a flow rate greater than 28,000 cubic feet per second at the gaging station, Colorado River below Davis Dam unless required or authorized by these regulations.

(g) Nothing in this agreement shall be construed to require dangerously rapid changes in magnitudes of releases. Releases will be made in a manner consistent with requirements for protecting the dam, reservoir and appurtenances from major damages.

(h) Hoover Dam is but one of three major flood control reservoirs in the Lower Colorado River Basin. The Corps of Engineers operates Alamo Dam on the Bill Williams River and Painted Rock Dam on the Gila River. In that flows on these tributary streams contribute to the mainstem Colorado River, coordinated operation of all three reservoirs is essential to achieving flood control objectives. Hence temporary deviations from the Hoover Dam releases prescribed in this regulation may be necessary after consideration of the available storage, projected inflows, and required releases from these tributary reservoirs.

(i) The Bureau of Reclamation shall procure such current basic hydrologic data, and make such current calculations of permissible releases from Lake Mead as are required to accomplish the flood control objectives prescribed above.

(j) The Bureau of Reclamation shall keep the Los Angeles District Engineer, Corps of Engineers, Department of the Army, in charge of the locality, currently advised of reservoir releases, reservoir storage, and such other operating data as the District Engineer may request, and also of those basic operating criteria that effect the schedule of operation.

(k) The flood control regulations are subject to temporary modification by the Los Angeles District Engineer, Corps of Engineers, if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communications available. The action taken shall be confirmed in writing the same day to the office of the Regional Director and shall include justification for the action.

(1) The Regional Director may temporarily deviate from the flood control regulations in the event an immediate short-term departure is deemed necessary for emergency reasons to protect the safety of Hoover Dam and Lake Mead, or downstream dams, or the levee systems along the lower Colorado River. Such actions will be immediately reported by the fastest means of communication available. Actions shall be confirmed in writing the same day to the Los Angeles District Engineer, Corps of Engineers, and shall include justification for the action.

(m) The Bureau of Reclamation shall be responsible for providing adequate warnings to downstream interests when changes in release of stored floodwaters are made.

(n) Revisions to the flood control operation for Hoover Dam and Lake Mead may be developed as necessary by the parties of this agreement. Each such revision shall be effective on the date specified.

IN WITNESS WHEREOF, the parties hereto have caused this memorandum of agreement to be executed as of the day and date first above written.

Corps of Engineers

Bureau of Reclamation

BY: _____

Brigadier General, USA
Division Engineer
South Pacific Division

BY: _____

Regional Director
Lower Colorado Region

Table 1. Minimum flood control releases from Hoover Dam throughout the year.

<u>CRITERIA</u>	<u>RELEASES</u>
Water surface elevation between 1219.61 and 1221.40 feet (available storage between 1,500,000 and 1,218,000 acre-feet)	Make releases equal to inflow up to 28,000 cubic feet per second
Water surface elevation between 1221.40 and 1226.90 feet (available storage between 1,218,000 and 340,000 acre-feet)	Make outflow equal to inflow up to 40,000 cubic feet per second
Water surface elevation between 1226.90 feet to 1229.00 (available storage between 340,000 and 0 acre-feet)	Make outflow equal to inflow up to 65,000 cubic feet per second
At water surface elevation 1229.00 (top of the flood control pool)	Maintain outflow equal to inflow

NOTE:

<u>Water surface elevation (feet)</u>	<u>Water in storage(millions of acre-feet)</u>	<u>Available storage(millions of acre-feet)</u>	<u>Level</u>
1205.40	23.708	3.669	Permanent spillway crest
1219.61	25.877	1.500	Minimum required flood control pool
1221.40	26.159	1.218	Top of spillway gates in raised position
1226.9	27.037	0.340	Spillway discharge equals 40,000 cubic feet per second with spillway gates in raised position
1229.00	27.377	0	Top of flood control pool
1232.00	---	0	Top of dam

EXHIBIT 1

FLOOD CONTROL ALGORITHM

The flood control algorithm is applicable during the period of 1 January through 31 July.

Definitions.

FI = the forecasted depleted inflow volume (in million acre-feet) to Lake Mead during the current month through 31 July, which will not be exceeded 19 times out of 20, and has been adjusted for effective storage space in selected upstream reservoirs excluding Lake Powell. FI is referred to as the maximum forecast.

SSM = current storage space (in million acre-feet) in Lake Mead below elevation 1229.0 feet.

SSP = current storage space (in million acre-feet) in Lake Powell below elevation 3700.0 feet.

RRM_N = the Hoover Dam hypothetical average release rate (in cubic feet per second at a specific step rate corresponding to the subscript N) through 31 July excluding the current month. Step values are as follows:

<u>Release Step</u>	<u>Release Rate</u> (cubic feet per second)
RRM ₁	0
RRM ₂	19,000
RRM ₃	28,000
RRM ₄	35,000
RRM ₅	40,000
RRM ₆	73,000

RCM = the Hoover Dam average release rate (in cubic feet per second) during the current month determined from solution of the volumetric equation given below.

FCR = the Hoover Dam average release rate (in cubic feet per second) required for flood control during the current month.

NCM = the number of days in the current month.the number of remaining days from the present through 31 July excluding the current month.

BSM = the Lake Mead water loss (in million acre-feet) to bank storage during the current month through 31 July.

EVM = the Lake Mead water loss (in million acre-feet) due to evaporation at the lake surface during the current month through 31 July.

BSP = the Lake Powell net water loss (in million acre-feet) due bank storage during the current month through 31 July.

EVP = the Lake Powell net water loss (in million acre-feet) due to evaporation and precipitation during the current month through 31 July.

SNC = The Lake Mead net water withdrawal (in million acre-feet) due to consumptive use by the Southern Nevada Water Project during the current month through 31 July.

Detailed procedure and equations used to define the terms BSM, EVM, BSP and EVP are presented in Exhibit 2.

The volumetric equation applied to determine RCM is as follows:

$$FI = SSM + SSP - 1.5 + 1.9835 \times 10^{-6} ((RCM \times NCM) + (RRM_N \times NRM)) \\ + BSM + EVM + BSP + EVP + SNC$$

Solution of equality of the volumetric equation is iterative using progressively increasing step values of RRM_1 through RRM_6 . RRM_N must be the smallest step value satisfying the requirement that RCM must be equal to or less than RRM_N

The required Hoover Dam flood control release FCR during the current month is determined according to either condition a or b as follows:

(a) if RCM is greater than or equal to RRM_{N-1} then, $FCR = RCM$

or

(b) if RCM is less than RRM_{N-1} then, $FCR = RRM_{N-1}$

EXHIBIT 2

WATER LOSS EQUATIONS FOR
LAKES MEAD AND POWELL
July 1982

LAKE MEAD

$$BSM = 0.065 (SSM - 1.5)$$

$$EVM = (NEM) (AAM \times 10^{-6})$$

where:

BSM = the Lake Mead water loss (in million acre-feet) to bank storage during the current month through 31 July.

SSM = current storage space (in million acre-feet) in Lake Mead below elevation 1229.0 feet.

EVM = the Lake Mead water loss (in million acre-feet) due to evaporation at the lake surface during the current month through 31 July.

AAM = the average reservoir surface area (in acres) on Lake Mead from the current month through 31 July.

NEM = the average evaporation depth (in feet) for Lake Mead from the current month through 31 July as follows:

<u>Month</u>	<u>Evaporation Rate (feet)</u>
January	0.36
February	0.33
March	0.37
April	0.46
May	0.53
June	0.64
July	0.80

LAKE POWELL

BSP = 0.15 (SSP)

BSP = the Lake Powell water loss (in million acre-feet) to bank storage during the current month through 31 July.

SSP = current storage space (in million acre-feet) in Lake Powell below elevation 3700.0 feet.

$EVP = (C_1E^4 + C_2E^3 + C_3E^2 + C_4E + C_5)$ (SM)

where:

EVP = the Lake Powell net water loss (in million acre-feet) due to evaporation and precipitation during the current month through 31 July.

E = the average water surface elevation of Lake Powell (in feet above mean sea level) from the current month through 31 July.

SM = a coefficient for the current month through 31 July as follows:

<u>Period</u>	<u>Coefficient</u>
January - July	0.536
February - July	0.486
March - July	0.439
April - July	0.380
May - July	0.313
June - July	0.222
July	0.118

Constants are as follows:

$$C_1 = - 1.06524 \times 10^{-12}$$

$$C_2 = 1.68872 \times 10^{-8}$$

$$C_3 = - 9.51439 \times 10^{-5}$$

$$C_4 = 0.229605$$

$$C_5 = - 2.0211176 \times 10^2$$

The equations in Exhibit 2 may be revised based on prudent engineering analysis without requiring formal revision of the total field working agreement. Revision would be effective following written agreement between the Regional Director and the Division Engineer. All revised versions of Exhibit 2 shall be labeled indicating the date of revision before being effective.

SIMPLIFIED APPLICATION OF THE FLOOD CONTROL REGULATION TO DETERMINE APPROXIMATE RELEASES

The following set of tables 1 through 7 provide approximate values of required January through July flood control releases from Hoover Dam for use as a convenient reference or guide. The simplifying assumption made in deriving these tables is that Lake Powell is full to elevation 3700 feet, and all available storage space for both Lakes Mead and Powell occurs at Lake Mead. Hence all bank storage changes and evaporation loss determinations for both Lake Powell and Lake Mead are assumed to be equivalent to the water losses and/or gains that would occur at Lake Mead only.

The true value of the required flood control release from Hoover Dam must be determined from use of the Flood Control Algorithm in exhibit 1 of the Field Working Agreement.

TABLE 1 - MINIMUM AVERAGE JANUARY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON JAN 1	MAXIMUM JANUARY-JULY FORECAST IN MILLION ACRE-FEET ^{1/}																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	0	0	0	0	19	19	28	33	37	40	40	40	40	40	40	72	73
3	0	0	0	0	12	19	24	28	35	40	40	40	40	40	40	54	73
4	0	0	0	0	0	19	19	28	31	35	40	40	40	40	40	40	70
5	0	0	0	0	0	10	19	22	28	35	40	40	40	40	40	40	52
6	0	0	0	0	0	0	19	19	28	29	35	40	40	40	40	40	40
7	0	0	0	0	0	0	8	19	21	28	35	40	40	40	40	40	40
8	0	0	0	0	0	0	0	19	19	28	28	35	40	40	40	40	40
9	0	0	0	0	0	0	0	6	19	19	28	35	40	40	40	40	40
10	0	0	0	0	0	0	0	0	19	19	28	28	35	40	40	40	40
11	0	0	0	0	0	0	0	0	5	19	19	28	35	40	40	40	40
12	0	0	0	0	0	0	0	0	0	19	19	28	28	35	40	40	40
13	0	0	0	0	0	0	0	0	0	3	19	19	28	35	40	40	40
14	0	0	0	0	0	0	0	0	0	0	18	19	28	28	35	40	40
15	0	0	0	0	0	0	0	0	0	0	1	19	19	28	35	40	40
16	0	0	0	0	0	0	0	0	0	0	0	16	19	28	28	35	40
17	0	0	0	0	0	0	0	0	0	0	0	0	19	19	28	35	39

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

TABLE 2 - MINIMUM AVERAGE FEBRUARY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW
ELEVATION 1,229 PLUS SPACE IN LAKE
POWELL BELOW ELEVATION 3,700 ON

MAXIMUM FEBRUARY-JULY FORECAST IN MILLION ACRE-FEET ^{1/}

FEB 1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	0	0	0	17	19	28	35	40	40	40	40	40	46	73	73	73	73
3	0	0	0	0	19	20	28	35	40	40	40	40	40	63	73	73	73
4	0	0	0	0	15	19	28	35	40	40	40	40	40	44	73	73	73
5	0	0	0	0	0	19	19	28	35	40	40	40	40	40	61	73	73
6	0	0	0	0	0	12	19	28	33	40	40	40	40	40	42	73	73
7	0	0	0	0	0	0	19	19	28	35	40	40	40	40	40	58	73
8	0	0	0	0	0	0	10	19	28	31	40	40	40	40	40	40	73
9	0	0	0	0	0	0	0	19	19	28	35	40	40	40	40	40	56
10	0	0	0	0	0	0	0	8	19	28	29	38	40	40	40	40	40
11	0	0	0	0	0	0	0	0	19	49	28	35	40	40	40	40	40
12	0	0	0	0	0	0	0	0	6	19	28	28	36	40	40	40	40
13	0	0	0	0	0	0	0	0	0	19	19	28	35	40	40	40	40
14	0	0	0	0	0	0	0	0	0	4	19	27	28	35	40	40	40
15	0	0	0	0	0	0	0	0	0	0	19	19	28	35	40	40	40
16	0	0	0	0	0	0	0	0	0	0	2	19	25	28	35	40	40
17	0	0	0	0	0	0	0	0	0	0	0	19	19	28	35	40	40

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

TABLE 3 - MINIMUM AVERAGE MARCH RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW
ELEVATION 1,229 PLUS SPACE IN LAKE
POWELL BELOW ELEVATION 3,700 ON

MAXIMUM MARCH-JULY FORECAST IN MILLION ACRE-FEET ^{1/}

MAR 1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	0	0	3	19	28	35	40	40	40	40	51	73	73	73	73	73	73
3	0	0	0	18	19	28	35	40	40	40	40	66	73	73	73	73	73
4	0	0	0	1	19	28	35	40	40	40	40	49	73	73	73	73	73
5	0	0	0	0	16	19	28	35	40	40	40	40	64	73	73	73	73
6	0	0	0	0	0	19	28	34	40	40	40	40	47	73	73	73	73
7	0	0	0	0	0	14	19	28	35	40	40	40	40	62	73	73	73
8	0	0	0	0	0	0	19	27	32	40	40	40	40	45	73	73	73
9	0	0	0	0	0	0	13	19	28	35	40	40	40	40	60	73	73
10	0	0	0	0	0	0	0	19	25	30	40	40	40	40	43	73	73
11	0	0	0	0	0	0	0	11	19	28	35	40	40	40	40	58	73
12	0	0	0	0	0	0	0	0	19	23	28	40	40	40	40	41	73
13	0	0	0	0	0	0	0	0	9	19	28	35	40	40	40	40	56
14	0	0	0	0	0	0	0	0	0	19	21	28	39	40	40	40	40
15	0	0	0	0	0	0	0	0	0	7	19	28	35	40	40	40	40
16	0	0	0	0	0	0	0	0	0	0	19	19	28	37	40	40	40
17	0	0	0	0	0	0	0	0	0	0	5	19	28	35	40	40	40

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

TABLE 4 - MINIMUM AVERAGE APRIL RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW
ELEVATION 1,229 PLUS SPACE IN LAKE
POWELL BELOW ELEVATION 3,700 ON

MAXIMUM APRIL-JULY FORECAST IN MILLION ACRE-FEET ^{1/}

APR 1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	0	0	19	28	35	40	40	40	59	73	73	73	73	73	73	73	73
3	0	0	5	19	28	40	40	40	41	73	73	73	73	73	73	73	73
4	0	0	0	19	27	35	40	40	40	57	73	73	73	73	73	73	73
5	0	0	0	3	19	28	40	40	40	40	73	73	73	73	73	73	73
6	0	0	0	0	19	25	35	40	40	40	55	73	73	73	73	73	73
7	0	0	0	0	1	19	28	38	40	40	40	71	73	73	73	73	73
8	0	0	0	0	0	17	23	35	40	40	40	53	73	73	73	73	73
9	0	0	0	0	0	0	19	28	36	40	40	40	69	73	73	73	73
10	0	0	0	0	0	0	15	21	33	40	40	40	51	73	73	73	73
11	0	0	0	0	0	0	0	19	28	35	40	40	40	67	73	73	73
12	0	0	0	0	0	0	0	13	19	31	40	40	40	49	73	73	73
13	0	0	0	0	0	0	0	0	19	28	35	40	40	40	65	73	73
14	0	0	0	0	0	0	0	0	11	19	29	40	40	40	47	73	73
15	0	0	0	0	0	0	0	0	0	19	28	35	40	40	40	63	73
16	0	0	0	0	0	0	0	0	0	9	19	28	40	40	40	45	73
17	0	0	0	0	0	0	0	0	0	0	19	28	35	40	40	40	61

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

TABLE 5 - MINIMUM AVERAGE MAY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW
ELEVATION 1,229 PLUS SPACE IN LAKE
POWELL BELOW ELEVATION 3,700 ON

MAXIMUM MAY-JULY FORECAST IN MILLION ACRE-FEET ^{1/}

MAY 1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	0	11	26	35	40	40	68	73	73	73	73	73	73	73	73	73	73
3	0	0	19	28	40	40	50	73	73	73	73	73	73	73	73	73	73
4	0	0	9	24	35	40	40	66	73	73	73	73	73	73	73	73	73
5	0	0	0	19	28	40	40	48	73	73	73	73	73	73	73	73	73
6	0	0	0	7	22	35	40	40	64	73	73	73	73	73	73	73	73
7	0	0	0	0	19	28	40	40	46	73	73	73	73	73	73	73	73
8	0	0	0	0	5	20	35	40	40	62	73	73	73	73	73	73	73
9	0	0	0	0	0	19	28	40	40	44	73	73	73	73	73	73	73
10	0	0	0	0	0	3	19	35	40	40	60	73	73	73	73	73	73
11	0	0	0	0	0	0	19	28	40	40	43	73	73	73	73	73	73
12	0	0	0	0	0	0	1	19	35	40	40	58	73	73	73	73	73
13	0	0	0	0	0	0	0	17	28	40	40	41	73	73	73	73	73
14	0	0	0	0	0	0	0	0	19	33	40	40	56	73	73	73	73
15	0	0	0	0	0	0	0	0	15	28	38	40	40	71	73	73	73
16	0	0	0	0	0	0	0	0	0	19	31	40	40	54	73	73	73
17	0	0	0	0	0	0	0	0	0	13	28	36	40	40	69	73	73

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

TABLE 6 - MINIMUM AVERAGE JUNE RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW
ELEVATION 1,229 PLUS SPACE IN LAKE
POWELL BELOW ELEVATION 3,700 ON

MAXIMUM JUNE-JULY FORECAST IN MILLION ACRE-FEET ^{1/}

JUN 1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	0	24	40	44	73	73	73	73	73	73	73	73	73	73	73	73	73
3	0	15	32	40	60	73	73	73	73	73	73	73	73	73	73	73	73
4	0	0	22	40	42	73	73	73	73	73	73	73	73	73	73	73	73
5	0	0	13	30	40	58	73	73	73	73	73	73	73	73	73	73	73
6	0	0	0	19	40	40	73	73	73	73	73	73	73	73	73	73	73
7	0	0	0	11	28	40	56	73	73	73	73	73	73	73	73	73	73
8	0	0	0	0	19	39	40	72	73	73	73	73	73	73	73	73	73
9	0	0	0	0	9	28	40	54	73	73	73	73	73	73	73	73	73
10	0	0	0	0	0	19	37	40	70	73	73	73	73	73	73	73	73
11	0	0	0	0	0	7	28	40	52	73	73	73	73	73	73	73	73
12	0	0	0	0	0	0	19	35	40	68	73	73	73	73	73	73	73
13	0	0	0	0	0	0	5	28	40	50	73	73	73	73	73	73	73
14	0	0	0	0	0	0	0	19	35	40	66	73	73	73	73	73	73
15	0	0	0	0	0	0	0	3	27	40	48	73	73	73	73	73	73
16	0	0	0	0	0	0	0	0	18	35	40	63	73	73	73	73	73
17	0	0	0	0	0	0	0	0	1	25	40	46	73	73	73	73	73

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

TABLE 7 - MINIMUM AVERAGE JULY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW
ELEVATION 1,229 PLUS SPACE IN LAKE
POWELL BELOW ELEVATION 3,700 ON

MAXIMUM JULY-JULY FORECAST IN MILLION ACRE-FEET ^{1/}

JUL 1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
<u>MILLION ACRE-FEET</u>	<u>RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND ^{2/}</u>																
2	21	54	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
3	4	36	69	73	73	73	73	73	73	73	73	73	73	73	73	73	73
4	0	19	52	73	73	73	73	73	73	73	73	73	73	73	73	73	73
5	0	2	34	67	73	73	73	73	73	73	73	73	73	73	73	73	73
6	0	0	17	50	73	73	73	73	73	73	73	73	73	73	73	73	73
7	0		0	32	65	73	73	73	73	73	73	73	73	73	73	73	73
8	0	0	0	15	47	73	73	73	73	73	73	73	73	73	73	73	73
9	0	0	0	0	30	63	73	73	73	73	73	73	73	73	73	73	73
10	0	0	0	0	13	45	73	73	73	73	73	73	73	73	73	73	73
11	0	0	0	0	0	28	61	73	73	73	73	73	73	73	73	73	73
12	0	0	0	0	0	11	43	73	73	73	73	73	73	73	73	73	73
13	0	0	0	0	0	0	26	59	73	73	73	73	73	73	73	73	73
14	0	0	0	0	0	0	9	41	73	73	73	73	73	73	73	73	73
15	0	0	0	0	0	0	0	24	57	73	73	73	73	73	73	73	73
16	0	0	0	0	0	0	0	7	39	72	73	73	73	73	73	73	73
17	0	0	0	0	0	0	0	0	22	54	73	73	73	73	73	73	73

^{1/} COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS AND LESS SOUTHERN NEVADA WATER PROJECT DIVERSION.

^{2/} VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT I OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

**SAMPLE
FLOOD CONTROL RELEASE CALCULATION**

(Volumes and Storages written in million acre feet)

1. GIVEN INFORMATION

Date 1 April
 Lake Mead 1 April Elevation = 1206.44 ft.
 Lake Powell 1 April Elevation = 3674.71 ft.

Reservoir	Forecasted Inflow*			Projected** Release	Current Space*** Available
	Maximum	Mean	Minimum		
Flaming Gorge & Fontenelle	1.651	1.276	0.936	0.280	1.471
Blue Mesa	1.110	0.980	0.815	0.470	0.489
Navajo	1.346	1.056	0.846	0.610	0.186
Lake Powell	12.400	10.800	9.500	-	3.857
Lake Mead	13.986	12.101	10.611	-	3.515

* provided by the Colorado River Forecasting Service
 ** obtained from the USBR 2-year study
 *** obtained from USBR reservoir reports

Consumptive use (withdrawal minus return) to the Southern Nevada Water Project at 0.04 million acre-feet between 1 April and 31 July by the USBR.

Assume Lake Powell will fill to elevation 3700 and Lake Mead will fill to elevation 1219.61 (1.5 million acre-feet of space) by 1 August. If either lake will be managed with the objective of not filling (say because of maintenance problems) compensating adjustments should be made in the calculations.

2. CALCULATIONS

(symbols correspond to those in the regulations).

A. Adjust Lake Mead Inflow Forecast for Upstream Storage.

(1) Determine Usable Upstream Reservoir Space

Reservoir	Mean Forecasted Inflow Volume	Projected Release	Usable* Space
Flaming Gorge	1.276	0.28	0.996
Blue Mesa	0.98	0.47	0.51
Navajo	1.056	0.61	0.446

* Usable = Mean Forecasted Inflow - Projected Release

(2) Determine Effective Upstream Reservoir Space.

<u>Reservoir</u>	<u>Effective** Space</u>
Flaming Gorge & Fontenelle	0.996
Blue Mesa	0.489
Navajo	<u>0.186</u>
Total Effective	1.671

** Smaller of actual or usable space

(3) Forecast Reduction

Lake Mead Maximum Forecasted Inflow	13.986
Less Effective Space	<u>-1.671</u>
Adjusted Inflow (FI)	12.315

B. Determine Lake Mead Water Losses.

(1) Determine Loss to Evaporation minus Precipitation.

surface area @ elev. 1206.44	149,000 acres
surface area @ elev. 1219.61	156,800 acres
average surface area	152,900 acres

Evaporation - April thru July (from Table 3, Ch 4) = 2.43 feet

Water Loss (EVM) = $2.43 \times 152,900 \times 10^{-6} = 0.372$

Evaporative losses may be estimated more precisely by using average surface areas for each month as determined by monthly routings. The inflow forecast includes precipitation on Lake Mead. Therefore, precipitation is not accounted for as a separate item.

(2) Determine Loss to Bank Storage.

Available Space in Lake Mead (SSM) = 3.515

Bank Storage (BSM) = 0.065 (SSM - 1.5)

BSM = 0.065 (3.515-1.5) = 0.131

This water loss to bank storage will occur only if Lake Mead rises to elevation 1219.61.

C. Determine Lake Powell Water Losses.

(1) Determine Loss to Evaporation Minus Precipitation.

Current Elevation	3674.71
Maximum Elevation	3700.00
Average Elevation (EL)	3687.36

SM = Coefficient for current month thru 31 July
 SM = 0.380 for April thru July

EVP = Net Evaporative Water Loss

$$EVP = (C_1 E^4 + C_2 E^3 + C_3 E^2 + C_4 E + C_5) SM$$

$$EVP = [-1.06524 \times 10^{-12} \times (3687.36)^4 + 1.68872 \times 10^{-8} \times (3687.36)^3 \\ - 9.51439 \times 10^{-5} \times (3687.36)^2 + 0.229605 \times 3687.36 \\ - 2.0211176 \times 10^2] \times 0.380$$

$$EVP = 0.232$$

This water loss to net evaporation will occur only if Lake Powell rises to elevation 3700.

(2) Determine Loss to Bank Storage.

$$\text{Available Space in Lake Powell (SSP)} = 3.857$$

$$\text{Bank Storage (BSP)} = 0.150 (\text{SSP})$$

$$BSP = 0.150 (3.857) = 0.578$$

This water loss to bank storage will occur only if Lake Powell rises to elevation 3700.

D. Determine Required Flood Releases.

(1) Release Equation

$$FI = SSM + SSP - 1.5 + 1.9835 \times 10^{-6} [RCM \times NCM + RRM \times NRM] + BSM + EVM + BSP + EVP + SNC$$

or rearranged

$$RCM = \left[\frac{FI - SSM - SSP + 1.5 - BSM - EVM - BSP - EVP - SNC}{1.9835 \times 10^{-6} \times NCM} \right] - \frac{RRM \times NRM}{NCM}$$

NCM = number days for current month

NCM = 30 days for April

NRM = number of remaining days from the present through 31 July, excluding the current month

NRM = 92 days for May through July

SNC = Consumptive use by Southern Nevada Water Project present through 31 July.

$$SNC = 0.040$$

(2) First Trial Calculation

Try step 2

RRM2 = 19,000 cfs or less

$$RCM = \left[\frac{12.315 - 3.515 - 3.857 + 1.5 - .131 - .372 - .578 - .232 - .040}{1.9835 \times 10^{-6} \times 30} \right] - \frac{19,000 \times 92}{30}$$

$$RCM = 85,539 - 58,267 = 27,272 \text{ cfs}$$

RCM is greater than the second step maximum of 19,000 cfs therefore try next step.

(3) Second trial

Try step 3

RRM3 = 28,000 cfs

$$RCM = 85,539 - \frac{28,000 \times 92}{30}$$

$$RCM = - 328 \text{ cfs}$$

Because RCM computes as less than both 28,000 and 19,000 cfs, the minimum average release for the month of April shall be the second step rate of 19,000 cfs. Lower releases are permissible for part of the month, provided that the average April release from Hoover Dam equals 19,000 cfs and that flow does not exceed 28,000 cfs at the gaging station "Colorado River below Davis Dam."

Releases for the month of May shall be determined using the 1 May forecast.

WATER CONTROL MANUAL
FOR FLOOD CONTROL
HOOVER DAM AND LAKE MEAD
COLORADO RIVER, NEVADA AND ARIZONA

DECEMBER 1982

EXHIBIT B
CODE OF FEDERAL REGULATIONS
TITLE 33, PAR 208.11

absence of any indication that further public comment would shed any new light on the matter, OSHA concludes that no change in the standard is warranted. Accordingly, the ground-fault protection standard at 29 CFR 1910.309(c) and 29 CFR 1926.400(h), as promulgated on December 21, 1976, is hereby reaffirmed.

(Secs. 6(b) and 8(c), Pub. L. 91-596, 84 Stat. 1593, 1599 (29 U.S.C. 655, 657); sec. 107, Pub. L. 91-54, 83 Stat. 96 (40 U.S.C. 333); Secretary of Labor's Order No. 8-76 (41 FR 25059); 29 CFR Part 1911.)

Signed at Washington, D.C., this 3d day of October 1978.

EULA BINGHAM,
Assistant Secretary of Labor.

[FR Doc. 78-28687 Filed 10-12-78; 8:45 am]

[3710-92-M]

Title 33—Navigation and Navigable Waters

CHAPTER II—CORPS OF ENGINEERS, DEPARTMENT OF THE ARMY

[ER 1110-2-241]

PART 208—FLOOD CONTROL REGULATIONS

Use of Storage Allocated for Flood Control and Navigation Purposes

AGENCY: U.S. Army Corps of Engineers, DOD.

ACTION: Final rule.

SUMMARY: This revision of 33 CFR 208.11 regulations prescribes the policy and procedure for regulating reservoir projects capable of regulation for flood control or navigation and the use of storage allocated for such purposes and provided on the basis of flood control and navigation. The revised regulations are applicable to dam and reservoir projects licensed, maintained, and operated under provisions of the Federal Power Act (41 Stat. 1063 (16 U.S.C. 791(A))), Pub. L. 83-436, and other similar authorizing legislation; as well as to reservoir projects constructed wholly or in part with Federal funds as directed by section 7 of the Flood Control Act of 1944. These regulations are intended to establish an understanding between project owners, operating agencies and the Corps of Engineers with regard to certain activities and responsibilities concerning water control management throughout the Nation in the interest of flood control and navigation. Interested persons were given until November 2, 1977 (42 FR 57141) to submit comments. No written comments were received.

DATES: This regulation is effective on October 15, 1978.

ADDRESSES: HQDA (DAEN-CWE-HY) Washington, D.C. 20314.

FOR FURTHER INFORMATION CONTACT:

Mr. Edgar P. Story, Engineering Division, Civil Works Directorate, Office of the Chief of Engineers, Washington, D.C. 20314 202-693-7330.

SUPPLEMENTARY INFORMATION:

This final regulation is essentially the same as the proposed rule (42 FR 53637), however, certain reordering has been done of the reference material presented in § 208.11(b). Specifically, excerpts from sections 4(e), 10(a), and 10(c) of the Federal Power Act have been added for improved clarity. Also Federal Power Commission order No. 540 issued October 31, 1975, and published November 7, 1975 (40 FR 51998), amending § 2.9 of the Commission's general policy and interpretations which prescribed standardized conditions (Forms) for inclusion in preliminary permits and licenses issued under part I of the Federal Power Act has been cited and appropriately excerpted. Reference to and citation from article 33 of Federal Power Commission license No. 2009 have been deleted in lieu thereof.

In addition to the proposed action, certain project names and pertinent data are added to and deleted from the list of projects shown in § 208.11(e), list of projects (42 FR 53637). The following projects are added to the list of projects:

(a) U.S. Army Corps of Engineers, Missouri River Division area: Webster Dam and Lake.

(b) U.S. Army Corps of Engineers, New England Division area:

(i) Bear Swamp Pumped Storage Project.

(ii) Turners Falls Reservoir.

(c) U.S. Army Corps of Engineers, North Pacific Division area:

(i) American Falls Dam and Reservoir.

(ii) Anderson Ranch Dam and Reservoir.

(iii) Arrowrock Dam and Reservoir.

(iv) Brownlee Dam and Reservoir.

(v) Grand Coulee Dam and Franklin D. Roosevelt Lake.

(vi) Heils Canyon Dam and Reservoir.

(vii) Kerr Dam and Flathead Lake.

(viii) Mayfield Dam and Reservoir.

(ix) Mossyrock Dam and Davison Lake.

(x) Oxbow Dam and Reservoir.

(xi) Priest Rapids Dam and Reservoir.

(xii) Ririe Dam and Reservoir.

(xiii) Rocky Reach Dam and Lake Entiat.

(xiv) Ross Dam and Reservoir.

(xv) Upper Baker Dam and Baker Lake.

(xvi) Wanapum Dam and Reservoir.
(xvii) Wells Dam and Lake Pateros.

(d) U.S. Army Corps of Engineers, South Atlantic Division area: Lewis M. Smith Dam and Reservoir.

(e) U.S. Army Corps of Engineers, South Pacific Division area:

(i) Indian Valley Dam and Reservoir.

(ii) Lemon Dam and Reservoir.

(iii) Navajo Dam and Reservoir.

(iv) Paoina Dam and Reservoir.

(v) Vallecito Dam and Reservoir.

The following projects are deleted from the list of projects:

(a) U.S. Army Corps of Engineers, South Atlantic Division area: H. Neely Henry Dam and Reservoir.

(b) U.S. Army Corps of Engineers, South Pacific Division area:

(i) Causey Dam and Reservoir.

(ii) Devil Creek Dam and Reservoir.

NOTE.—The Chief of Engineers has determined that this rule does not contain a major proposal requiring preparation of an inflation impact statement under Executive Order 11821 and OMB Circular A-107 (Statutory Authority Pub. L. 90-483).

Dated: October 10, 1978.

CHARLES I. MCGINNIS,
Major General, USA,
Director of Civil Works.

Section 208.11 is revised to read as follows:

§ 208.11 Regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to prescription of rules and regulations by the Secretary of the Army in the interest of flood control and navigation.

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

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

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

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

(2) Federal Energy Regulatory Commission (formerly Federal Power Commission (FPC)) licenses.

(i) Responsibilities of the Secretary of the Army and/or the Chief of Engineers in Federal Energy Regulatory Commission (FERC) licensing actions are set out in the Federal Power Act. Pertinent sections of that Act are cited herein. The Commission may also stipulate, as part of license conditions, that the licensee enter into an agreement with the Department of the Army providing for operation of the project during flood times, in accordance with rules and regulations prescribed by the Secretary of the Army.

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

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

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

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

(2) Section 10(c). That the licensee shall * * * so maintain and operate said works as

not to impair navigation, and shall conform to such rules and regulations as the Commission may from time to time prescribe for the protection of life, health, and property. * * *

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

The operation of any navigation facilities which may be constructed as part of or in connection with any dam or diversion structure built under the provisions of this Act, whether at the expense of a licensee hereunder or of the United States, shall at all times be controlled by such reasonable rules and regulations in the interest of navigation; including the control of the pool caused by such dam or diversion structure as may be made from time to time by the Secretary of the Army. * * *

(ii) Federal Power Commission order No. 540 issued October 31, 1975, and published November 7, 1975 (40 FR 51998), amending section 2.9 of the Commission's general policy and interpretations prescribed standardized conditions (forms) for inclusion in preliminary permits and licenses issued under part I of the Federal Power Act. As an example, article 12 of standard form L-3, titled: "Terms and Conditions of License for Constructed Major Projects Affecting Navigable Waters of the United States," sets out the Commission's interpretation of appropriate sections of the Act, which deal with navigation aspects, and attendant responsibilities of the Secretary of the Army in licensing actions as follows:

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

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

The operation and maintenance of the dams shall be subject to reasonable rules and regulations of the Secretary of the Army in the interest of flood control and navigation.

NOTE.—This Regulation will also be applicable to dam and reservoir projects operated under provisions of future legislative acts wherein the Secretary of the Army is directed to prescribe rules and regulations in the interest of flood control and navigation. The Chief of Engineers, U.S. Army Corps of Engineers, is designated the duly authorized representative of the Secretary of the Army to exercise the authority set out in the congressional acts. This regulation will normally be implemented by letters of understanding between the Corps of Engineers and project owner and will incorporate the provisions of such letters of understanding prior to the time construction renders the project capable of significant impoundment of water. A water control agreement signed by both parties will follow when deliberate impoundment first begins or at such time as the responsibilities of any corps-owned projects may be transferred to another entity. Promulgation of this regulation for a given project will occur at such time as the name of the project appears in the FEDERAL REGISTER in accordance with the requirements of § 208.11(d)(11). When agreement on a water control plan cannot be reached between the corps and the project owner after coordination with all interested parties, the project name will be entered in the FEDERAL REGISTER and the Corps of Engineers plan will be the official water control plan until such time as differences can be resolved.

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

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

RULES AND REGULATIONS

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

(3) The term "letter of understanding" as used herein includes statements which consummate this regulation for any given project and define the general provisions or conditions of the local sponsor, or owner, cooperation agreed to in the authorizing legislative document, and the requirements for compliance with section 7 of the 1944 Flood Control Act, the Federal Power Act or other special congressional act. This information will be specified in the water control plan and manual. The letter of understanding will be signed by a duly authorized representative of the Chief of Engineers and the project owner. A "field working agreement" may be substituted for a letter of understanding, provided that the specified minimum requirements of the latter, as stated above, are met.

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

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

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

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

(2) *Corps of Engineers involvement.* If the project owner is responsible for real-time implementation of the water control plan, consultation and assistance will be provided by the Corps of Engineers when appropriate and to the extent possible. During any emergency that affects flood control and/or navigation, the Corps of Engineers may temporarily prescribe regulation of flood control or navigation storage space on a day-to-day (real-time) basis without request of the project owner. Appropriate consideration will be given for other authorized project functions. Upon refusal of the project owner to comply with regulations prescribed by the Corps of Engineers, a letter will be sent to the project owner by the Chief of Engineers or his duly authorized representative describing the reason for the regulations prescribed, events that have transpired, and notification that the project owner is in violation of the Code of Federal Regulations. Should an impasse arise, in that the project owner or the designated operating entity persists in noncompliance with regulations prescribed by the Corps of Engineers, measures may be taken to assure compliance.

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

before the Corps of Engineers offers advice on real-time regulation during surcharge storage utilization.

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

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

regulation. Each diagram or schedule will contain a reference to this regulation.

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

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

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

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

project owner. Availability of funds and urgency of data needs are factors which will be considered in reaching decisions on cost sharing.

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

(8) *Notification of the general public.* The Corps of Engineers and other interested Federal and State agencies, and the project owner will jointly sponsor public involvement activities, as appropriate, to fully apprise the general public of the water control plan. Public meetings or other effective means of notification and involvement will be held, with the initial meeting being conducted as early as practicable but not later than the time the project first becomes operational. Notice of the initial public meeting shall be published once a week for 3 consecutive weeks in one or more newspapers of general circulation published in each county covered by the water control plan. Such notice shall also be used when appropriate to inform the public of modifications in the water control plan. If no newspaper is published in a county, the notice shall be published in one or more newspapers of general circulation within that county. For the purposes of this section a newspaper is one qualified to publish public notices under applicable State law. Notice shall be given in the event significant problems are anticipated or experienced that will prevent carrying out the approved water control plan or in the event that an extreme water condition is expected that could produce severe damage to property or loss of life. The means for conveying this information shall be commensurate with the urgency of the situation. The water control manual will be made available for examination by the general public upon request at the appropriate office of the Corps of Engineers, project owner or designated operating agency.

(9) *Other generalized requirements for flood control and navigation.* (i) Storage space in the reservoirs allocated for flood control and navigation purposes shall be kept available for those purposes in accordance with the water control agreement, and the plan

of regulation in the water control manual.

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

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

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

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

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

(vii) The project owner may temporarily deviate from the water control plan in the event an immediate short-term departure is deemed necessary for emergency reasons to protect the safety of the dam, or to avoid other serious hazards. Such actions shall be immediately reported by the fastest

RULES AND REGULATIONS

means of communication available. Actions shall be confirmed in writing the same day to the Corps of Engineers and shall include justification for the action. Continuation of the deviation will require the express approval of the Chief of Engineers, or his duly authorized representative.

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

(10) *Revisions.* The water control plan and all associated documents will be revised by the Corps of Engineers, as necessary, to reflect changed conditions that come to bear upon flood control and navigation, e.g., reallocation of reservoir storage space due to sedimentation or transfer of storage space to a neighboring project. Revision of the water control plan, water control agreement, water control diagram, or release schedule requires approval of the Chief of Engineers or his duly authorized representative. Each such revision shall be effective upon the date specified in the approval. The

original (signed document) water control agreement shall be kept on file in the Office, Chief of Engineers, Department of the Army, Washington, D.C. Copies of the agreement shall be kept on file and may be obtained from the office of the project owner, or from the office of the appropriate Division Engineer, Corps of Engineers.

(11) *Federal Register.* The following information for each project subject to section 7 of the 1944 Flood Control Act and other applicable congressional acts shall be published in the FEDERAL REGISTER prior to the time the projects becomes operational and prior to any significant impoundment before project completion or * * * at such time as the responsibility for physical operation and maintenance of the Corps of Engineers owned projects is transferred to another entity: (i) Reservoir, dam, and lake names, (ii) stream, county, and State corresponding to the damsite location, (iii) the maximum current storage space in acre-feet to be reserved exclusively for flood control and/or navigation purposes, or any multiple-use space (intermingled) when flood control or navigation is one of the purposes, with corresponding elevations in feet above mean sea level, and area in acres at the upper and lower limits of said space, (iv) the name of the project owner, and (v) congressional legislation authorizing the project for Federal participation.

(e) *List of projects.* The following tables, "Pertinent Project Data—Section 208.11 Regulation," show the pertinent data for projects which are subject to this regulation.

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

[FR Doc. 78-29100 Filed 10-12-78; 8:45 am]

PART 208—FLOOD CONTROL REGULATIONS

SUPPLEMENTARY INFORMATION:

Note.—The Commander has determined that this rule is not a "major rule" proposal requiring preparation of a regulatory impact analysis under Executive Order 12291. Dated: November 16, 1981.

James W. Ray,
Colonel, Corps of Engineers, Executive Director, Engineer Staff.

FOR FURTHER INFORMATION CONTACT:

Mr. Earl Eiker, Chief, Water Control/Quality Section, Office, Commander, U.S. Army Corps of Engineers, Department of the Army, Washington, DC 20314 (202) 272-0234.

with regard to certain activities and responsibilities concerning water control management throughout the nation in the interest of flood control and navigation.

EFFECTIVE DATE: November 30, 1981.

§ 208.11 [Amended]
Accordingly 33 CFR 208.11 is amended by revising the table in paragraph (e) as follows:

LIST OF PROJECTS
(Pertinent project data)

Project name ¹	State, county and stream ¹	Exclusive-use				Multiple-use				Project owner ²	Authorizing legislation ³
		Flood control/navigation		Storage (1,000 AF)	Flood control/navigation		Storage (1,000 AF)	Flood control/navigation			
		Elevation limits (feet, m.s.l.)	Area (acres)		Elevation limits (feet, m.s.l.)	Area (acres)					
Alpine Dam.....	IL, Winnebago, Keith Cr.....	Upper 796.0	764.0	0	Upper 3,340.0	3,263.2	1,900	0	City of Rockford, IL	PWA Proj. PL 68-292	
Agency Valley Dam & Res.....	OR, Malheur, N. Fork Malheur R.....	Upper 4,343.2	4,295.6	1,700.0	Upper 4,343.2	4,295.6	56,100	0	USBR	FERC 2259	
American Fall Dam & Res.....	ID, Power, Snake River.....	Upper 4,196.0	4,043.0	423.2	Upper 4,196.0	4,043.0	4,740	1,150	USBR	Act of 1939 53 Stat 1187	
Anderson Ranch Dam & Res.....	ID, Elmore, S. Ft. Boise River.....	Upper 3,216.0	2,967.0	286.6	Upper 3,216.0	2,967.0	3,100	200	USBR	Act of 1902 32 Stat 388	
Arrowrock Dam & Res.....	MO, Marion Ralls, Bear Cr.....	Upper 5,596.4	5,596.4	0	Upper 5,596.4	5,596.4	873	0	City of Hannibal, MO	PL 83-780	
Bear Cr Dam.....	MA, Franklin, Deerfield R Trib.....	Upper 4,717.0	19,560	146.1	Upper 4,717.0	19,560	16,955	0	New England Pwr Co	Fed Pwr Act	
Bear Swamp Pumped Storage.....	CA, Fresno, Big Dry Cr & Dog Cr.....	Upper 2,042	2,042	5,605.0	Upper 2,042	2,042	873	0	Reclamation Board of CA	PL 71-228	
Big Dry Creek and Div.....	CA, Nevada, Little Truckee R.....	Upper 3,160	3,160	41	Upper 3,160	3,160	16,955	0	USBR	PL 67-289, PL 68-292	
Bocu Dam & Res.....	CO, Yuma, S. Fork Republican R.....	Upper 2,523.0	2,456.8	140	Upper 2,523.0	2,456.8	140	0	USBR	PL 78-534	
Bonny Dam & Res.....	WY, Fremont, Wild River.....	Upper 2,051.0	2,051.0	200.0	Upper 2,051.0	2,051.0	7,600	5,507	USBR	PL 78-534	
Boysen Dam & Res.....	OR, Baker, ID, Washington, Snake River.....	Upper 3,797.0	3,797.0	799.1	Upper 3,797.0	3,797.0	34,435	24,126	USBR	PL 86-645	
Brownie Dam & Res.....	OR, Malheur, Bully Creek.....	Upper 5,496.1	5,496.1	50.4	Upper 5,496.1	5,496.1	5,160	4,496	USBR	PL 78-534	
Bully Cr Dam & Res.....	CA, San Joaquin, Mokelumne R.....	Upper 710	710	980.3	Upper 710	710	710	700	USBR	PL 87-874	
Camanche Dam & Res.....	CA, San Joaquin, Mokelumne R.....	Upper 802.0	802.0	340.0	Upper 802.0	802.0	12,900	11,260	USBR	PL 78-534	
Canyon Ferry Dam & Res.....	CA, San Joaquin, Mokelumne R.....	Upper 5,770.0	5,770.0	48.0	Upper 5,770.0	5,770.0	684	127	USBR	PL 81-273	
Cedar Bluff Dam & Res.....	MT, Lewis, Clark, Missouri R.....	Upper 74.0	74.0	74.0	Upper 74.0	74.0	1,455	0	USBR	PL 83-606	
Clark Canyon Dam & Res.....	KS, Trego, Smoky Hill River.....	Upper 4,466.0	4,466.0	400.0	Upper 4,466.0	4,466.0	11,450	9,040	USBR	PL 78-534	
Del Valle Dam & Res.....	MT, Beaverhead, Beaverhead River.....	Upper 578.0	578.0	390.0	Upper 578.0	578.0	4,850	2,101	USBR	PL 78-534	
Don Pedro Dam & Lk.....	CA, Alameda, Alameda Cr.....	Upper 3,400.0	3,400.0	340.0	Upper 3,400.0	3,400.0	11,235	7,632	USBR	PL 78-534	
East Canyon Dam & Res.....	CA, Tuolumne, Tuolumne R.....	Upper 5,705.5	5,705.5	48.0	Upper 5,705.5	5,705.5	1,455	0	USBR	PL 87-874	
East Canyon Dam & Res.....	UT, Morgan, East Canyon Creek.....	Upper 5,560.0	5,560.0	74.0	Upper 5,560.0	5,560.0	1,455	0	USBR	PL 78-534	
Echo Dam & Res.....	UT, Summit, Weber River.....	Upper 801	801	80	Upper 801	801	80	0	USBR	PL 81-273	
Emigrant Dam & Res.....	OR, Jackson, Emigrant Cr.....	Upper 2,405	2,405	1,707	Upper 2,405	2,405	1,707	0	USBR	PL 83-606	
Enders Dam & Res.....	NB, Chase, Frenchman Cr.....	Upper 200.0	200.0	20,300	Upper 200.0	200.0	20,300	0	USBR	PL 78-534	
Folsom Dam & Lk.....	CA, Sacramento, American R.....	Upper 1,455.6	1,455.6	12,602	Upper 1,455.6	1,455.6	12,602	0	USBR	PL 78-534	
Front Dam & Millerton Lk.....	CA, Fresno, San Joaquin River.....	Upper 4,653.0	4,653.0	12,365	Upper 4,653.0	4,653.0	12,365	0	USBR	PL 78-534	
Gaston-Roanoke Rapids Dam Res.....	NC, Northampton, Halifax, Roanoke R.....	Upper 2,094.5	2,094.5	3,400	Upper 2,094.5	2,094.5	3,400	0	VA Elec & Pwr Co	PL 75-392, PL 76-868	
Glen Elder Dam & Res.....	KS, Mitchell, Solomon R.....	Upper 1,219.6	1,219.6	15.7	Upper 1,219.6	1,219.6	2,380	2,280	USBR	PL 78-534, PL 79-526	
Glendo Dam & Res.....	WY, Platte, N. Platte R.....	Upper 3,396.0	3,396.0	156,500	Upper 3,396.0	3,396.0	156,500	83,500	USBR	PL 78-534	
Grand Coulee Dam, FDR Lk.....	WA, Okanogan, Grant, Columbia R.....	Upper 3,336.0	3,336.0	5,400	Upper 3,336.0	3,336.0	156,500	83,500	USBR	PL 89-561	
H. Neely Henry Dam & Res.....	AL, Calhoun, St. Clair, Coosa River.....	Upper 1,454.0	1,454.0	2,555	Upper 1,454.0	1,454.0	2,555	2,085	Alabama, Pwr Co	PL 83-436	
Heart Butte Dam & Res.....	ND, Grant, Heart River.....	Upper 4,099.3	4,099.3	9,394	Upper 4,099.3	4,099.3	9,394	62	USBR	PL 78-534	
Hells Canyon Dam & Res.....	OR, Wallowa, ID, Adams, Snake River.....	Upper 1,757.3	1,757.3	5,073	Upper 1,757.3	1,757.3	5,073	62	USBR	PL 78-534	
Hoover Dam & Lake Mead.....	NV, Clark, AZ, Mohave, Colorado R.....	Upper 5,237.3	5,237.3	0	Upper 5,237.3	5,237.3	574	0	USBR	PL 78-534	
Hungry Horse Dam & Res.....	MT, Flathead, S. Fork Flathead R.....	Upper 1,432.7	1,432.7	2,555	Upper 1,432.7	1,432.7	2,555	2,085	USBR	PL 84-984	
Indian Valley Dam & Res.....	CA, Lake, N. Fork Cache Creek.....	Upper 1,432.7	1,432.7	2,555	Upper 1,432.7	1,432.7	2,555	2,085	USBR	PL 84-984 Cons Dist.	
Jamestown Dam & Res.....	ND, Stutsman, James River.....	Upper 1,432.7	1,432.7	2,555	Upper 1,432.7	1,432.7	2,555	2,085	USBR	PL 84-984	
Kerr Dam, Flathead Lk.....	MT, Lake, Flathead R.....	Upper 1,432.7	1,432.7	2,555	Upper 1,432.7	1,432.7	2,555	2,085	USBR	PL 78-534	
Keyhole Dam & Res.....	WY, Crook, Belle Fourche River.....	Upper 4,111.5	4,099.3	9,394	Upper 4,111.5	4,099.3	9,394	62	USBR	FERC No 5	
Kiwan Dam & Res.....	KS, Phillips, N. Fork Solomon R.....	Upper 1,757.3	1,729.3	5,073	Upper 1,757.3	1,729.3	5,073	62	USBR	PL 78-534	
Lemon Dam & Res.....	CO, La Plata, Florida R.....	Upper 510.0	510.0	21,200	Upper 510.0	510.0	21,200	62	USBR	PL 78-534	
Lewis M. Smith Dam & Res.....	AL, Walker, Cullman, Sipsey Fork Black Warrior River.....	Upper 5,237.3	5,127.8	574	Upper 5,237.3	5,127.8	574	0	Alabama Pwr Co	PL 84-485	
Little Wood.....	ID, Blain, Little Wood River.....	Upper 5,237.3	5,127.8	574	Upper 5,237.3	5,127.8	574	0	USBR	Fed Pwr Act	

LIST OF PROJECTS—Continued
(Pertinent project data)

Project name ¹	State, county and stream ¹	Exclusive-use				Multiple-use				Project owner ²	Authorizing legislation ³	
		Flood control/navigation		Flood control/navigation		Flood control/navigation		Flood control/navigation				
		Storage (1,000 AF)	Elevation limits (feet, m.s.l.)	Area (acres)	Storage (1,000 AF)	Elevation limits (feet, m.s.l.)	Area (acres)	Storage (1,000 AF)	Elevation limits (feet, m.s.l.)			
Logan Martin Dam & Res.	AL, Talladega, Coosa River	245.3	477.0	485.0	26,310	15,280	14.0	353.5	327.8	619	467	PL 83-436, USBR
Los Banos Dam & Detention.	CA, Merced, Los Banos Cr.						20.0	6,005.0	5,912.0	365	93	PL 81-273, PL 78-534, PL 76-476.
Lost Creek Dam & Res.	UT, Morgan, Lost Creek	50.5	1,595.3	1,582.6	5,025	2,986						FPC No 2016-A, PL 78-534.
Lowell Dam & Res.	KS, Jewell, White Rock Cr.	244.2	636.0	619.0	18,000	10,900						FPC No 2016-A, PL 78-534.
Markham Ferry Dam, Lake Wash E. Hudson.	OK, Mayes, Grand Neosho River						21.4	425.0	415.0	2,070	1,925	FPC No 2016-A, PL 78-534.
Mayfield Dam & Res.	WA, Lewis, Cowlitz River	52.2	2,386.2	2,366.1	3,465	1,850						FPC No 2016-A, PL 78-534.
Medicine Cr Dam Harry Strunk Lk.	NB, Frontier, Medicine Cr.											FPC No 2016-A, PL 78-534.
Mossyrock Dam Davison Lk.	WA, Lewis, Cowlitz River						1,397.0	778.5	621.5	11,800	5,000	FPC No 2016-B, PL 84-485, PL 86-645.
Navajo Dam & Res.	NM, San Juan, Arriba, Rio, San Juan R.						1,036.1	6,085.0	5,980.0	15,610	7,400	PL 84-485, PL 86-645.
New Exchequer Dam & Lake.	CA, Tuolumne, Merced River						400.0	867.0	799.7	7,110	4,849	PL 87-874, PL 78-534.
New Melones Dam & Lk.	CA, Tuolumne, Calaveras, Stanislaus R.						450.0	1,088.0	1,049.5	12,500	10,900	PL 87-874, PL 78-534.
Norton Dam Res.	KS, Norton, Prairie Dog Cr.	98.8	2,331.4	2,304.3	5,316	5,316						PL 84-992.
Ochoco Dam & Res.	OR, Crook, Ochoco Creek	51.4	3,136.2	3,048.1	1,150	120						PL 85-500, FERC No 1971-B, PL 78-534.
Oroville Dam & Lake.	CA, Butte, Feather River						750.0	900.0	848.5	15,800	13,346	PL 81-273, PL 84-485.
Oxbow Dam & Res.	OR, Baker, ID, Adams, Snake River						5.0	1,805.0	1,800.0	1,165	1,115	PL 76-640, PL 81-273, PL 84-485.
Pactola Dam & Res.	SD, Pennington, Rapid Creek	34.0	4,621.5	4,580.2	1,232	860						PL 76-640, PL 81-273, PL 84-485.
Palisades Dam & Res.	ID, Bonneville, Snake River	1,202.0	5,620.0	5,452.4	16,100	2,170						PL 81-273, PL 84-485.
Panola Dam & Res.	CO, Gunnison, Muddy Creek						17.0	6,447.5	6,373.0	334	120	PL 81-273, PL 84-485.
Pineview Dam & Res.	UT, Weber, Ogden River	6.0	10,034.0	10,027.5	947	920						PL 76-640, PL 81-273, PL 84-485.
Piatoro Dam & Res.	CO, Conejos, Conejos R.						44.0	488.0	481.0	7,100	6,500	PL 76-640, PL 81-273, PL 84-485.
Priest Rapid Dam & Res.	WA, Grant, Columbia R.	153.0	3,234.8	3,112.0	2,990	120						PL 81-273, PL 84-485.
Pineville Dam & Res.	OR, Crook, Crooked Cr.						20.0	5,741.2	5,703.7	745	334	PL 81-273, PL 84-485.
Prosser Cr & Res.	CA, Nevada, Prosser Cr.						66.0	4,893.8	4,880.6	5,350	4,641	PL 84-992, PL 87-590, PL 78-534, PL 85-783.
Pueblo Dam & Res.	CO, Pueblo, Arkansas R.	27	4,898.7	4,893.8	5,664	5,350						PL 87-590, PL 78-534, PL 85-783.
Red Willow Dam, Hugh Butler Lk.	NB, Frontier, Red Willow	48.9	2,604.0	2,581.8	2,682	1,629						PL 78-534, PL 85-783.
Ririe Dam & Res.	ID, Bonneville, Willow Cr.						99.0	5,119.0	5,023.0	1,560	360	PL 87-874, FERC No 2145.
Rocky Reach Dam Lk Entiat.	WA, Chelan, Columbia R.						37.0	707.0	703.0	9,600	0	PL 87-874, FERC No 2145.
Ross Dam & Res.	WA, Whatcom, Skagit R.						530.5	1,602.5	1,475.0	6,000	2,168	FERC No 553-C, PL 81-898.
Sarnford Dam & Lk Meredith.	TX, Hutchinson, Canadian R.	462.1	2,965.0	2,941.3	21,640	17,320						PL 81-898.
Savage River Dam & Res.	MD, Garrett, Savage R.						16.0	1,468.5	1,400.0	366	127	PL 78-534.
Shadephill Dam & Res.	SD, Perkins, Grand R.	217.7	2,302.0	2,272.0	9,900	4,800						PL 78-534, PL 75-392.
Shasta Dam & Lake.	CA, Shasta, Sacramento R.						1,300.0	1,067.0	1,018.6	29,570	23,894	PL 75-392, Fed Pwr Act.
Smith Mtn & Leesville Dam & Res.	VA, Bedford, Compbell, VA, Pittsylvania, Roanoke River.						(*)	(*)	(*)	(*)	(*)	PL 84-858, PL 78-534, PL 83-774, PL 89-298, FERC 2150-B.
Stamper Dam & Res.	CA, Sierra, Little Truckee R.	133.8	2,773.0	2,752.0	7,975	4,974						PL 84-858, PL 78-534, PL 83-774, PL 89-298, FERC 2150-B.
Trenton Dam & Res.	NB, Hitchcock, Republican R.	89.0	651.5	623.0	3,690	2,650						PL 84-858, PL 78-534, PL 83-774, PL 89-298, FERC 2150-B.
Twitchell Dam & Res.	CA, Santa Barbara, Cuyama River						226.5	5,948.7	5,942.1	3,430	3,230	PL 84-858, PL 78-534, PL 83-774, PL 89-298, FERC 2150-B.
Upper Baker Dam, Baker Lk.	WA, Whatcom, Baker River						220.6	724.0	655.0	4,890	0	PL 84-858, PL 78-534, PL 83-774, PL 89-298, FERC 2150-B.
Vallecito Dam & Res.	CO, La Plata, Los Pinos R.						115.4	7,665	7,600	2,723	693	PL 61-288, PL 68-292, FERC No 2114-B.
Wanapan Dam & Res.	WA, Grant, Columbia R.						151.6	5,715	5,600	14,400	9,600	PL 61-288, PL 68-292, FERC No 2114-B.
Wanship Dam & Res.	UT, Summit, Weber River						61.0	6,037.0	5,930.0	1,077	121	PL 81-273.
Warm Springs Dam & Res.	OR, Malheur, Middle Fork Malheur R.						191.0	3,406.0	3,327.0	4,600	90	PL 78-534, PL 83-436, FERC No 2149, PL 534 78-2, PL 78-534.
Waterbury Dam & Res.	VT, Washington, Little River	27.2	617.5	592.0	1,330	880						PL 78-534, PL 83-436, FERC No 2149, PL 534 78-2, PL 78-534.
Weiss Dam & Res.	AL, Cherokee, Coosa River	397.0	574.0	564.0	50,000	30,200						PL 78-534, PL 83-436, FERC No 2149, PL 534 78-2, PL 78-534.
Wells Dam Lk Paterns.	WA, Douglas, Columbia R.						74.0	799.0	711.0	10,700	7,700	PL 78-534, PL 83-436, FERC No 2149, PL 534 78-2, PL 78-534.
Webster Dam & Res.	KS, Rocks, S. Fork Solomon R.	183.4	1,923.7	1,892.45	8,480	3,766						PL 78-534, PL 83-436, FERC No 2149, PL 534 78-2, PL 78-534.
Yellowtail Dam & Bighorn Lk.	MT, Big Horn, Bighorn R.	259.0	3,657.0	3,640.0	17,298	12,685						PL 78-534, PL 83-436, FERC No 2149, PL 534 78-2, PL 78-534.

¹ Res—Reservoir; Lk—Lake; Div—Division; R—River; Cr—Creek.
² USBR—United States Bureau of Reclamation; Irr—Irrigation District; Mun—Municipal; Fl—Flood; Res—Resources.
³ PL—Public Law; HD—House Document; FERC—Federal Energy Regulatory Commission (formerly Federal Power Commission (FPC)).
 * No specific FC/Nav. storage allocation.
 BILLING CODE 3710-06-M

WATER CONTROL MANUAL
FOR FLOOD CONTROL
HOOVER DAM AND LAKE MEAD
COLORADO RIVER, NEVADA AND ARIZONA

DECEMBER 1982

EXHIBIT C
SUMMARY OF COLORADO RIVER WATER LAW

EXHIBIT C
SUMMARY OF COLORADO RIVER WATER LAW
CONTENTS

I Chronology of Major Legal and Institutional Documents

II General Description of Selected Laws, Compacts, and Treaties

Paragraph	Title	Page
A	Colorado River Compact	C-2
B	Boulder Canyon Project Act (45 Stat. 1057)	C-3
C	Boulder Canyon Project Adjustment Act	C-3
D	California Limitation Act	C-3
E	Seven-Party Agreement	C-4
F	Mexican Water Treaty	C-5
G	Upper Colorado River Basin Compact	C-5
H	Hoover Dam - Lake Mead Flood Control Regulation	C-6
I	The Colorado River Storage Project Act	C-6
J	U.S. Supreme Court Decree in Arizona v. California	C-6
K	Colorado River Basin Project Act	C-9
L	Coordinated Long-Range Operating Criteria for Colorado River Reservoirs	C-10
M	Colorado River Basin Salinity Control Act	C-10

SUMMARY OF COLORADO RIVER WATER LAW

I. CHRONOLOGY OF MAJOR LEGAL AND INSTITUTIONAL DOCUMENTS

Supreme Court Decree in Winters v United States – 1908

Supreme Court Decree in Wyoming v Colorado - June 5, 1922.

Colorado River Compact - November 24, 1922.

Boulder Canyon Project Act December 21, 1928.

California Limitation Act March 4, 1929.

Boulder Canyon Project Water Contracts - April 24 1930, through the present.

Boulder Canyon Project Power Contracts - April 26, 1930, through the present

Seven-Party Agreement - August 18, 1931.

Boulder Canyon Project Adjustment Act - July 19, 1940.

Mexican Water Treaty - February 3, 1944.

Upper Colorado River Basin Compact - October 11, 1948.

Flood Control Regulations - February 18, 1954.

Colorado River Storage Project Act - April 11, 1956.

Colorado River Storage Project, General Power Marketing Criteria - 1962.

U.S. Supreme Court Decree in Arizona v California - March 9, 1964.

Colorado River Basin Project Act (Public Law 90537, 90th Congress, approved September 30, 1968).

Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs - June 10, 1970.
State Water Laws.

United States v District Court, Eagle County, Colorado - 1971.

Contracts for sale of water from Colorado River Storage Project Reservoirs.

Colorado River Basin Salinity Control Act (Public Law 93-320) enacted June 24, 1974.

Supplemental Decree of U.S. Supreme Court of Non-Indian present perfected rights - January 9, 1979. (Indians intervened in 1978 and their additional claims are being litigated.)

Amendments to Colorado River Basin Salinity Control Act (Public Law 96-336) enacted September 4, 1980.

II. GENERAL DESCRIPTION OF SELECTED LAWS, COMPACTS, AND TREATIES

A. Colorado River Compact

As a result of negotiations among the seven Basin States, it was agreed that an interstate compact would establish an equitable division and apportionment of the use of water and protect the Upper Basin States. Congress consented to the negotiations by legislation enacted on August 19, 1921, and the Colorado River Compact Commission convened in January 1922. After 27 meetings, a final agreement on the Compact was signed in Santa Fe, New Mexico, on November 24, 1922. Although the States had hoped to allocate the Colorado River waters among each of the seven Basin States, such agreement was not possible. However, the Colorado River Compact included the following major provisions:

(1) It divided the Colorado River Basin into two divisions – Upper and Lower Basins.

(2) It apportioned from the Colorado River System, in perpetuity, 7.5 million acre-feet per year (MAF/yr) to each of the two Basins for beneficial consumptive use.

(3) The Lower Basin was given the right to increase its beneficial consumptive use by 1 MAF/yr.

(4) It provided that, if (as has proved to be the case) the United States recognized the right of Mexico to a share of the waters of the Colorado River, such waters shall first come from the water surplus to the apportionment of 16 MAF to the two Basins. It also provided that, if sufficient surplus waters are not available for Mexico's allotment, the Mexican deficiency is to be met equally by the Upper and Lower Basins.

(5) It created two classes of states, Upper Division and Lower Division and enjoined the Upper Division States "not to cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 MAF for any progressive period of 10 consecutive years ... "

(6) It provided that the use of Colorado River water for navigation would be subservient to the uses of such waters for domestic, agricultural, and power purposes.

(7) It provided that the impoundment and use of waters for the generation of electrical power would be subservient to the use and consumption of such water for agricultural and domestic purposes.

(8) It provided that nothing in the Compact should be construed as affecting the obligations of the United States to Indian tribes.

(9) It provided that "Present perfected rights to the beneficial use of waters of the Colorado River System are unimpaired by this compact."

In the period following the Colorado River Compact, the seven Basin States attempted to settle the division of the Lower Basin water supply and to bring about a seven-State ratification of the Compact. Six of the seven States ratified it in 1923 but Arizona did not ratify it until 1944. In 1925,

the six ratifying States modified the requirement for seven-State approval and ratified the Compact which was to become effective upon approval of at least six States and the consent of the United States. The United States consent was obtained in Section 13(a) of the Boulder Canyon Project Act of 1928.

On December 21, 1928, the Boulder Canyon Project Act was enacted (45 Stat. 1057) notwithstanding the failure of Arizona to ratify the Compact and the inability of the States of the Lower Basin to agree on the division among themselves of the allocation of Colorado River water.

B. Boulder Canyon Project Act (45 Stat. 1057)

The Boulder Canyon Project Act authorized the Lower Basin States of Arizona, California, and Nevada to enter into an agreement providing that the 7.5 MAF/yr annually apportioned to the Lower Basin by Article 3(a) of the Compact, there shall be apportioned to:

(1) Nevada, 300,000 acre-feet annually;

(2) Arizona, 2.8 MAF annually plus one-half of any excess or surplus waters unapportioned by the Compact and exclusive beneficial consumptive use of the Gila River and its tributaries within the boundaries of Arizona; and

(3) California, 4.4 MAF annually plus not more than one half of any surplus waters unapportioned by the Compact.

By this Act, Congress also authorized the construction of Hoover Dam and Powerplant and of the All-American Canal to Imperial and Coachella Valleys in California. Congress also consented to the Colorado River Compact. As noted above, the Act provided that, in the absence of the seven-State approval, the Act and Congressional approval of the Compact would become effective only when the Compact was approved by California and five of the other States and it further provided that California would be required to limit its consumptive use to 4.4 MAF per year.

The Project Act, with this limitation on California, not only reserved Lower Basin water for the States of Arizona and Nevada, but it provided protection to the Upper Basin against unlimited development in the Lower Basin and assurance that the Colorado River Compact would not be nullified.

C. Boulder Canyon Project Adjustment Act

The Boulder Canyon Project Adjustment Act of July 19, 1940, authorized the Secretary of the Interior to promulgate and effect charges for energy generated at Hoover Dam, provided for application of project revenues and authorized operation of the powerplant by the United States directly or through agents.

D. California Limitation Act

The California Limitation Act was passed by the California legislature in March 1929. It provided that the consumptive use of Colorado River water by California would not exceed 4.4 MAF apportioned to the Lower Basin plus not more than one-half of any surplus waters unapportioned by the Compact.

E. Seven-Party Agreement

Before the Secretary of Interior entered into water delivery contracts under the Boulder Canyon Project Act with users in California, he requested the State to agree on a listing of the relative priorities of rights among the users of Colorado River waters. This was done by the California "Seven-Party Agreement" of August 18, 1931, which contained the following priorities:

A first priority to Palo Verde Irrigation District for beneficial use exclusively upon lands in said District as it now exists and upon lands between said District and the Colorado River, aggregating (within and without said District) a gross area of 104,500 acres, such waters as may be required by said lands.

A second priority to Yuma Project of United States Bureau of Reclamation for beneficial use upon not exceeding a gross area of 25,000 acres of land located in said project in California, such waters as may be required by said lands.

A third priority (a) to Imperial Irrigation District and other lands under or that will be served from the All-American Canal in Imperial and Coachella Valleys, and (b) to Palo Verde Irrigation District for use exclusively on 16,000 acres in that area known as "Lower Palo Verde Mesa" adjacent to Palo Verde Irrigation District, for beneficial consumptive use, 3,850,000 acre-feet of water per annum less the beneficial consumptive use under the priorities designated in Sections 1 and 2 above. The rights designated (a) and (b) in this section are equal in priority. The total beneficial consumptive use under priorities stated in Sections 1, 2, and 3 of this article shall not exceed 3,850,000 acre-feet of water per annum.

A fourth priority to The Metropolitan Water District of Southern California and/or the City of Los Angeles, for beneficial consumptive use, by themselves and/or others, on the Coastal Plain of Southern California, 550,000 acre-feet of water per annum.

A fifth priority, (a) to The Metropolitan Water District of Southern California and/or the City of Los Angeles, for beneficial consumptive use, by themselves and/or others, on the Coastal Plain of Southern California, 550,000 acre-feet of water per annum and (b) to the City of San Diego and/or the County of San Diego, for beneficial consumptive use, 112,000 acre-feet of water per annum. The rights designated (a) and (b) in this section are equal in priority.

A sixth priority (a) to Imperial Irrigation District and other lands under or that will be served from the All-American Canal in Imperial and Coachella Valleys, and (b) to Palo Verde Irrigation District for use exclusively on 16,000 acres in that area known as the "Lower Palo Verde Mesa," adjacent to Palo Verde Irrigation District, for beneficial consumptive use, 300,000 acre-feet of water per annum. The rights designated (a) and (b) in this section are equal in priority.

A seventh priority of all remaining water available for use within California for agricultural use in the Colorado River Basin in California.

These seven priorities total, for beneficial consumptive use, 5,362,000 acre-feet of water per annum. The Secretary of the Interior placed the Seven-Party Agreement of August 18, 1931, in effect by general regulations dated September 28, 1931. The provisions of the Seven-Party Agreement were also incorporated by the Secretary in substantially the same form in all of the California water delivery contracts entered into by the Secretary.

F. Mexican Water Treaty

Mexico's claims to a share of Colorado River water preceded the Colorado River Compact of 1922 which did recognize in Article III(c) the possibility of an agreement thereon with Mexico. Likewise, Section 20 of the Boulder Canyon Project Act referred to Mexico's use of Colorado River water. After unsuccessful negotiations commencing in 1925, negotiations were reinstated in 1941, and a Treaty with Mexico became effective on November 8, 1945 (59 Stat. 1219).

Under the Treaty, Mexico is allotted a guaranteed quantity of 1.5 MAF/yr from any and all sources. In times of surplus in excess of uses in the United States, the United States may deliver in accordance with Mexico's schedule up to a maximum of 1.7 MAF/yr without acquisition of any Mexican rights to the quantity over 1.5 MAF. In the event of extraordinary drought, the 1.5 MAF will be reduced in the same proportion as reductions in consumptive uses in the United States. No such reduction has yet been required.

Under the provisions of Minute No. 242 as related to this Treaty, the Republic of Mexico is entitled to receive at Morelas Dam water of a quality no worse than 115 parts per million (p/m) (+30 p/m) greater than that arriving at Imperial Dam.

The effect of the legal allocations under the Colorado River Compact, the Project Act, and the Mexican Treaty, was to place legal claims upon the Colorado River system totaling 17.5 MAF/yr; i.e., 7.5 MAF/yr for the Upper Basin; 7.5 MAF/yr for the Lower Basin; and 1.5 MAF/yr for Mexico; and 1 MAF/yr of increase in beneficial consumptive use by the Lower Basin.

G. Upper Colorado River Basin Compact

On October 11, 1948, the Upper Basin States executed a Compact relative to the use of the Upper Basin apportionment of water in the Colorado River Compact. The Upper Colorado River Basin Compact apportions the consumptive use of 50,000 acre-feet annually to Arizona and divides the remainder of the Upper Basin entitlement, in terms of percentages, as follows:

Colorado	51.75%
New Mexico	11.25%
Utah	23.00%
Wyoming	14.00%

Congress consented to this Compact on April 6, 1949. No such compact between the States has ever been made apportioning water of the Lower Basin.

H. Hoover Dam - Lake Mead Flood Control Regulations

Flood control regulations were first published in the Federal Register on February 18, 1954 (19 FR 937). They are written pursuant to provisions of Section 7 of the Act of Congress approved December 22, 1944 (58 Stat. 890; 33 U.S.C. 709). The Bureau of Reclamation is the organization charged with the responsibility for the safety of the structure and actual operation of Hoover Dam. The Regional Director of the Lower Colorado Region is required to keep the District Engineer, Corps of Engineers informed as necessary to accomplish the flood control operation plan. The regulations have been revised periodically as a coordinated effort by the Bureau of Reclamation and the Corps of Engineers. The most recent revision was published in the Federal Register October 13, 1978, page 47, 184 vol. 43 No. 199.

I. The Colorado River Storage Project Act

On April 11, 1956, Congress passed the Colorado River Storage Project Act (70 Stat. 105) which authorized the construction of major developments in the Upper Basin consisting initially of four major storage units, the largest of which is Glen Canyon Dam, and eleven "participating" water use projects. Five additional participating projects were later authorized. These facilities are located throughout the Upper Colorado River Basin in Wyoming, Utah, Colorado, Arizona, and New Mexico. The Act followed the apportionment of Upper Basin water to the individual States by the Upper Colorado River Basin Compact and provided projects within each of the Upper Basin States. At the time of the passage of this Act, the Upper Basin had not developed as rapidly as the Lower Basin. At that time, Laguna Dam, Hoover Dam, Davis Dam, Parker Dam, Imperial Dam, the Colorado River Aqueduct, the All American Canal and related facilities had all been constructed in the Lower Basin.

The Act permitted the Upper Basin States to utilize their share of Colorado River water and, at the same time, insure the fulfillment of downstream commitments. Studies were initiated by the Bureau of Reclamation, in consultation with the various interests in the Colorado River Basin, to determine how Lake Powell could accumulate storage with the least possible disruption to the many activities then dependent upon the flow of the river. These studies led to formulation of the "General Principles to Govern, and Operating Criteria for, Glen Canyon Reservoir (Lake Powell) and Lake Mead during the Lake Powell Filling Period" (Filling Criteria).

J. U.S. Supreme Court Decree in Arizona v. California

Failure of the three Lower Basin States to agree on the sharing of the Colorado River Compact water led to the Supreme Court suit filed by Arizona in 1952. Congress would not authorize the long sought Central Arizona Project opposed by California, until Arizona's right to the necessary Colorado River water supply was clarified. The Supreme Court opinion decided June 3, 1963, 373 U.S. 546, was favorable to Arizona.

The Supreme Court in a decree, dated March 9, 1964, 376 U.S. 340 carried out its opinion of June 3, 1963 in that it confirmed Arizona's right to 2.8MAF/yr when there was sufficient mainstream water available for release, as determined by the Secretary of the Interior, to satisfy 7.5 MAF/yr of consumptive use in the three Lower Basin States. The 4.4 MAF/yr was apportioned by the Decree for use in California and 300,000 acre-feet annually

was apportioned for use in Nevada (Article II(B)(1)). The Decree defined "consumptive use" as "... diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican Treaty obligation" (Article I(A)). The Decree defined a "perfect right" (Article I(G)). It also defined "present perfect rights" (Article I(H)) as perfected rights acquired in accordance with State law existing as of June 25, 1929 (the effective date of the Boulder Canyon Project Act).

Article II(A) enjoined the United States and its officers from releasing water other than in accordance with the following order of priority:

"(1) for river regulation, improvement of navigation, and flood control;

"(2) for irrigation and domestic uses, including the satisfaction of present perfected rights; and

"(3) for power."

Provided, however, that the United States may release water for Mexico without regard to the aforesaid priorities. Note that the above order of priorities follows the provisions of Section 6 of the Boulder Canyon Project Act.

Article II(B)(2) also apportioned water in excess of the 7.5 MAF/yr as follows: 50 percent for use in Arizona and 50 percent for use in California provided that if the United States so contracts with Nevada, then 46 percent of such surplus shall be apportioned for use in Arizona and 4 percent for use in Nevada. The Bureau of Reclamation is now in the process of developing an amendatory contract with the State of Nevada to recognize the entitlement to the 4 percent.

Article II(B)(3) provided that if less than 7.5 MAF/yr was available, then the Secretary, after providing for satisfaction of present perfected rights in the order of their priority dates without regard to State lines, and after consultation with the parties to major delivery contracts and State representatives, may apportion the amount remaining available, but in no event shall more than 4.4 MAF/yr be apportioned for use in California including all present perfected rights.

The Decree also provided for delivery to water users only pursuant to valid contracts therefor made with such users by the Secretary(Article II(B)(5)).

Article II(D) provided the following quantities of water for the benefit of the named Federal establishments:

(1) The Chemehuevi Indian Reservation--the lesser of either 11,340acre-feet of diversion or consumptive use of water to irrigate 1,900 acres, with a priority date of February 2, 1907.

(2) The Cocopah Indian Reservation--the lesser of either 2,744acre-feet of diversions or consumptive use of water to irrigate 431 acres, with a priority date of September 27, 1917.

(3) The Yuma Indian Reservation-- the lesser of either 51,616acre-feet of diversions or consumptive use of water to irrigate 7,743 acres, with a priority date of January 9, 1984.

(4) The Colorado River Indian Reservation--the lesser of either 717,148 acre-feet of diversions or consumptive use of water to irrigate107,588 acres, with priority dates of March 3, 1865, November 22, 1873, November 16, 1874, and May 15, 1876.

(5) The Fort Mohave Indian Reservation-- the lesser of either 122,648acre-feet of diversions or consumptive use of water to irrigate 18,974 acres, with priority dates of September 18, 1890 and February 2, 1911.

(6) Lake Mead National Recreation Area-- annual quantities resonably necessary to fulfill the purposes of the recreation area, with priority dates of March 3, 1929 and April 25, 1930.

(7) Havasu Lake National Wildlife Refuge-- annual quantities reasonably necessary to fulfill the purposes of the refuge, not to exceed 41,839 acre-feet of diversions or 37,339 acre-feet of consumptive use, whichever is less, with priority dates of January 22, 1941 and February 11,1949.

(8) Imperial National Wildlife Refuge-annual quantities reasonably necessary to fulfill the purposes of the refuge, not to exceed 28,000 acre-feet of diversions or 23,000 acre-feet of consumptive use of mainstream water, whichever is less, with a priority date of February 14, 1941.

(9) Boulder City, Nevada-- as authorized by the Act of September 2,1958, 72 Stat. 1726, with a priority date of May 15, 1931.

Article III enjoins all the States and all other users of water in said States from diverting water from the mainstream, the diversion of which has not been authorized by the United States for its particular use.

Article IV dealt with diversions by the State of New Mexico and the Upper Gila River Basin.

Article V required the United States to prepare annual reports of water releases, diversions of water from the maintstream, return flows, consumptiveuse of such water, and the quantities delivered to Mexico.

Article VI required that within two years of the Decree that the States and the Secretary agree on "present perfected rights" with their claimed priority dates, in terms of consumptive use, except those relating to Federal establishments. Lacking agreement, any party may apply to the court for determination of such rights by the court.

Article IX provided that any of the parties may apply at the foot of the Decree for its amendment or for further relief.

In 1978 the parties to the litigation and the United States agreed on a stipulation of present perfected rights. The five Indian Reservations along the Colorado River objected to the quantites of water provided to them in Article II(D) of the Decree, and in addition to seeking enlarged quantities of

water, challenged the tentative agreement on the non-Indian present perfected rights. The final determination of non-Indian present perfected rights was made by a judgement of the Supreme Court on January 9, 1979. Indians intervened prior to this action and their rights as determined by the 1964 Decree are being litigated.

K. Colorado River Basin Project Act

This Act was signed September 30, 1968, 83 Stat. 885, and was the result of many years of negotiations and compromise between California, the other Colorado River Basin States, the Columbia River Basin States, the Federal Government, and conservation groups and others. Title II declared that the satisfaction of the Mexican Water Treaty from the Colorado River constitutes a national obligation which shall be the first obligation of any water augmentation project planned pursuant to the Act and authorized by Congress. However, the Basin States are not relieved of this obligation until such time as a feasibility plan showing the most economical means of augmenting the water supply available in the Colorado River below Lee Ferry by 2.8 MAF shall be authorized by Congress and is in operation as provided in this Act.

During hearings leading up to the enactment of the Act, the Upper Basin interests proposed termination of the Filling Criteria. However, the criteria was continued. Nevertheless, the efforts to terminate led to Section 502 which provided for reimbursement to the Upper Colorado River Basin Fund for money "heretofore or hereafter" expended therefrom to meet the deficiencies in generation at Hoover Dam during the filling period.

Section 601 requires that, in the operation of the Federal reservoirs, the Secretary and Federal officials will comply with the Colorado River Compact.

Section 602a requires that the Secretary shall propose criteria for the coordinated long range operation of the reservoirs constructed and operated under the authority of the Colorado River Storage Project Act, the Boulder Canyon Project Act, and the Boulder Canyon Project Adjustment Act. It provides for storage of Colorado River water not required to be released under the Colorado River Compact in Upper Basin reservoirs to the extent the Secretary finds to be reasonably necessary to assure compact deliveries without impairment of annual consumptive uses in the Upper Basin. Other major features of the Act include:

(1) It authorized the Central Arizona Project (Section 301(a)) and six Upper Basin projects (Section 501).

(2) In the event of water shortage, California's 4.4 MAF/yr has priority over the Central Arizona Project (Section 301(b)).

(3) Title IV established the Lower Colorado River Basin Development Fund and provided for the allocation and repayment of costs. Costs incurred to replenish the depletion of the Colorado River flows available for use in the United States occasioned by compliance with the Mexican Water Treaty are to be nonreimbursable.

(4) It directed the Secretary to develop a plan to meet future water needs of the Western States and to make a report in 1977. It provided,

however, that for a period of 10 years the Secretary shall not undertake reconnaissance studies of any plan for the importation of water into the Colorado River Basin from any other natural river drainage basin lying outside the natural drainage basin of the Colorado River (Section 210). This moratorium has since been extended 10 years.

(5) It authorized the Secretary to enter into an agreement with non-Federal interests to construct a thermal generating powerplant whereby the United States shall acquire the right to such portions of the capacity as the Secretary determines is required in connection with the operation of the Central Arizona Project (Section 303). This was done by United States participation in the construction of the Navajo Generating Station near Page, Arizona.

L. Coordinated Long-Range Operating Criteria for Colorado River Reservoirs

As required by the Colorado River Basin Project Act, the Operating Criteria were issued in June 1970 by the Secretary of the Interior. They have as an objective the minimum release of 8,230,000 acre-feet annually from Lake Powell and provide that a reservoir operating plan be developed by the Secretary each year. The criteria provided for a determination by the Secretary of the amount of water to be retained in Upper Basin reservoirs in order to meet obligations to the Lower Basin without impairment of the Upper Basin's consumptive uses. When the Upper Basin storage is greater than the amount determined above, releases above the minimum will be made in order to maintain, as nearly as practicable, active storage at Lake Mead equal to active storage in Lake Powell. They also provide that the reasonable consumptive use requirements of all mainstream users in the Lower Basin will be met without cutback until such time as deliveries commence from the Central Arizona Project.

M. Colorado River Basin Salinity Control Act

Public Law 93-320, enacted June 24, 1974 (88 Stat. 266), authorized a program of works to control salinity of water delivered for use in the United States and Mexico, and to enable the United States to comply with provisions of Minute No. 242. The law also authorized construction of works and directed planning studies on other upstream features to reduce the salinity of waters of the Colorado River arriving at Imperial Dam near Yuma, Arizona. The various works associated with the salinity control project are identified in Title I and Title II in the authorizing legislation. Title I works are located downstream of Imperial Dam and Title II features are located upstream of Imperial Dam in both Upper and Lower Colorado River Basins.

Title I of the Act provides authorization for construction of the works and measures to control the salinity of Colorado River water delivered to Mexico upstream from Morelos Dam within the limits established by Minute No. 242. Specifically, it authorized construction of a desalting complex to treat approximately 129 MGD of Wellton-Mohawk Division irrigation drain water using advanced technology commercially available, plus appurtenant works and measures (Desalting Complex Unit); replacement of the first 49 miles of the unlined portion of the Coachella Canal with a concrete-lined canal to effect a savings of approximately 132,000 acre-feet per year of water to be credited against water lost as bypassed water and reject from the desalting plant; and

construction of a protective and regulatory well field within 5 miles of the Arizona-Sonora Boarder near San Luis.

Up until 1961, Mexico was delivered considerably more water than the 1.5MAF/yr. In the decade preceding 1961, the deliveries averaged 4.2 MAF/yr. Commencing in 1961, highly saline water from the Wellton-Mohawk Irrigation and Drainage District in Arizona entered the Colorado River below the last major American diversion at Imperial Dam, but above the Mexican diversion point at Morelos Dam. At the same time, the Secretary of the Interior began storing water in the newly constructed Glen Canyon Dam. This latter fact led to the reduction of water deliveries to Mexico of the Treaty requirement of 1.5MAF/yr. Since that time, the United States has attempted to confine Mexican water deliveries to the Treaty amount and to minimize overdeliveries.

The salinity problems of the water delivered to Mexico created by these two factors led to several subsequent minutes to the Treaty (Minute Nos. 218 and 242) designed to be a "permanent" solution to the salinity problems of the water delivered to Mexico. Minute No. 242 contemplated construction by the United States of a 100 million gallons per day (Mgal/d) desalting plant near Yuma and the lining of a 49-mile stretch of the Coachella Canal to save 132,000 acre-feet of water annually lost by seepage and for the delivery thereof to Mexico for an interim period until the Central Arizona Project required it. The purpose is to deliver water to Mexico at no more than 115 parts per million (p/m) ± 30 above the salinity of water at Imperial Dam which is delivered to users in the United States.

From May 1979 to January 1981, Mexico received surplus water which was released from Colorado River reservoirs in anticipation of required flood control releases. This strategy was meant to reduce the magnitude and impacts of potentially damaging flood control releases and also to enable all water released to be used for hydroelectric generation. In January 1981, runoff forecasts indicated that the potential for mandatory flood control releases was negligible, and so surplus releases were curtailed.

On September 4, 1980, Public Law 93-336 amended the Colorado River Basin Salinity Control Act by increasing the authorization ceiling and including funding for fish and wildlife mitigation.

WATER CONTROL MANUAL
FOR FLOOD CONTROL
HOOVER DAM AND LAKE MEAD
COLORADO RIVER, NEVADA AND ARIZONA

DECEMBER 1982

EXHIBIT D
PERTINENT DATA
GLEN CANYON DAM AND LAKE POWELL

EXHIBIT D
PERTINENT DATA
GLEN CANYON DAM AND LAKE POWELL

Item	Contents	Page
1	Pertinent Data Sheet	D-1
2	Project Description	D-2
3	Area and Capacity Tables	D-4

GLEN CANYON DAM AND LAKE POWELL
 COLORADO RIVER
 PERTINENT DATA
 Drainage Area — 111,700 square miles
 (Directly Contributing 107,740 Square Miles)

DESCRIPTIVE DATA

DAM

Type Concrete Arch
 Crest Elevation 3715 ft
 Structural Height 710 ft
 Crest Length 1560 ft
 Crest Width 25 ft
 Freeboard Above Maximum
 Design Flood Pool 4 ft

POWER PENSTOCKS

Description Eight 15-ft dia. steel conduits through dam reduced to
 14-ft dia. within dam.
 Centerline Elevation of Intake 3470 ft
 Gate Fixed wheel gates upstream from each intake

SPILLWAYS

Description Two gated spillways discharging through 41 ft dia.
 concrete lined tunnels through abutments, one on each
 side.
 Total Crest Length 160 ft
 Gates
 Description Two radial gates on each spillway.
 Length, Each 40 ft
 Height 52.5 ft

RIVER OUTLETS

Conduits Four 96-inch dia. steel conduits through dam terminating
 in valve structure at downstream end at toe of dam near
 left abutment.
 Valves One 96-inch hollow jet on each conduit, each with an
 emergency ring-follower gate immediately upstream.
 Centerline Elevation of Valves 3374 ft

POWERPLANT

Operating Head 345 to 563 ft
 Number of Units 8
 Capacity 900 MW

AREA, STORAGE AND DISCHARGES AT CRITICAL POOL ELEVATIONS

Point	Elevation ¹ (ft)	Storages (1000 ac-ft)				Maximum Discharge (cfs)			
		Area (1000 ac)	Active ² Contents	Total ³ Contents	Incremental Active	Below Maximum Design Pool	Maximum Power Plant	River Outlets	Spillway
Top of Dam	3715	—	—	—	—	—	—	—	—
Maximum Design Flood Pool	3711	169.8	26823	28821	1821	0	0	15000	275000
Top of Closed Spillway Gates	3700	161.4	25002	27000	7468	1821	21200	15000	208000
Permanent Spillway Crest	3648	126.6	17534	19532	13408	9289	28000	15000	0
Minimum Power Pool	3490	51.6	4126	6124	4126	22697	24400	14800	0
Dead Storage	3370	20.6	1998	1998	—	26823	0	0	0

Notes:

- ¹Elevations refer to mean sea level datum.
- ²Exclusive of dead storage except as indicated.
- ³Includes dead storage.

I. GENERAL DESCRIPTION

Glen Canyon Dam is located on the Colorado River in north-central Arizona, about 18 miles upstream from Lee Ferry and 12 river miles downstream from the Arizona-Utah State line.

The reservoir, named Lake Powell in honor of Major John Wesley Powell, renowned explorer of the Colorado River and its tributaries, has a total storage capacity, including dead storage, of 27,000,000 acre-feet and when full extends 186 miles up the Colorado River and 71 miles upstream on the San Juan River, with approximately 1,900 miles of shoreline.

II. PHYSICAL COMPONENTS

A. DAM

The dam is a constant-radius concrete arch with fillets. It has a structural height of 710 feet and a crest length of approximately 1,560 feet. The crest of the dam is at elevation 3715, 583 feet above the riverbed, and accommodates a 35-foot-wide roadway which is a service road for the dam and provides access between the spillways.

B. RIVER OUTLETS

Four 96-inch-diameter steel-lined river outlets are installed near the left abutment. Each outlet is provided with a 96-inch hollow-jet valve at the downstream end, for regulation, and a 96-inch ring-follower gate in the dam for shutdown emergency closure. One bulkhead gate is provided to close off one outlet at a time for inspection and maintenance of the four ring-follower gates and the upstream conduit. The intakes for each pair of outlets are protected by a trashrack structure. The centerline elevation of the intakes is 3374 feet. The maximum practical outlet works discharge is 15,000 cfs.

C. SPILLWAY

One spillway is provided on each abutment. Each spillway consists of an approach channel, intake structure, spillway tunnel, and deflector bucket. Discharges are controlled by two 40-foot high by 52.5-foot wide radial gates in each intake structure. The deflector bucket flips outflow away from the canyon wall to prevent undercutting. The fixed spillway crest elevation is 3648 feet. The combined spillway discharge at maximum design pool is 278,000 cfs.

D. POWER WATERWAYS

Water is conveyed from the reservoir to the hydraulic turbines by eight 15-foot-diameter penstocks, extending from the upstream face of the dam to the powerplant. The intake to each penstock is protected by a trashrack. The intake centerline elevation is 3470 feet. A 13.96 by 22.45-foot fixed-wheel gate is provided at the face of the dam for emergency closure and for inspection and maintenance of each penstock. Water from the turbines is collected by the draft tubes and carried to the tailrace. Bulkhead gates are provided at the downstream end of the draft tubes for dewatering the draft tubes.

E. POWERPLANT

The powerplant is an indoor-type structure with eight generating units, a service bay, and a machine shop bay. The control area is located on top of the powerplant over unit bays 1 and 2. Each generating unit has a capacity of 125,000 kilovolt-amperes at 0.9 power factor. The turbines, of the Francis type, are rated at 155,500 horsepower at full gate opening when operating at 150 revolutions per minute under an effective head of 450 feet. The effective head on the turbines may range between 341 and 560 feet. The maximum combined discharge of all turbines is about 32,000 cfs. The powerplant provides the principal portion of the electrical energy generated by the Colorado River Storage project. Surplus revenue from sale of this energy assists irrigators in the Upper Basin to repay costs of constructing the participating projects which were authorized for the Colorado River Storage Project.

**LAKE POWELL
ELEVATION — AREA
(Active Area in 10 Acres)**

Elevation Feet	0	1	2	3	4	5	6	7	8	9
3,370	0	18	36	54	72	90	108	127	146	165
3,380	184	203	223	242	262	282	302	323	343	364
3,390	385	406	427	449	470	492	514	536	558	581
3,400	604	621	639	656	674	693	711	730	749	769
3,410	789	809	829	849	870	891	913	934	956	978
3,420	1,001	1,024	1,047	1,070	1,094	1,118	1,143	1,167	1,192	1,218
3,430	1,244	1,270	1,296	1,323	1,350	1,377	1,405	1,433	1,461	1,490
3,440	1,519	1,550	1,581	1,612	1,643	1,675	1,706	1,737	1,768	1,799
3,450	1,831	1,862	1,894	1,925	1,957	1,988	2,020	2,052	2,084	2,115
3,460	2,147	2,179	2,211	2,243	2,275	2,307	2,340	2,372	2,404	2,436
3,470	2,469	2,501	2,534	2,566	2,599	2,631	2,664	2,697	2,729	2,762
3,480	2,795	2,824	2,854	2,883	2,913	2,943	2,973	3,004	3,034	3,065
3,490	3,096	3,127	3,158	3,190	3,221	3,253	3,285	3,317	3,350	3,382
3,500	3,415	3,448	3,481	3,514	3,548	3,582	3,616	3,650	3,684	3,718
3,510	3,753	3,788	3,823	3,858	3,894	3,929	3,965	4,001	4,038	4,074
3,520	4,111	4,148	4,185	4,223	4,262	4,299	4,338	4,377	4,416	4,455
3,530	4,495	4,535	4,575	4,615	4,656	4,697	4,738	4,780	4,822	4,864
3,540	4,906	4,949	4,992	5,035	5,079	5,123	5,167	5,211	5,256	5,301
3,550	5,346	5,392	5,438	5,484	5,531	5,578	5,625	5,672	5,720	5,768
3,560	5,817	5,861	5,906	5,951	5,996	6,041	6,087	6,133	6,179	6,225
3,570	6,272	6,319	6,366	6,413	6,460	6,508	6,556	6,605	6,653	6,702
3,580	6,751	6,800	6,849	6,899	6,949	6,999	7,050	7,101	7,152	7,203
3,590	7,254	7,306	7,358	7,410	7,463	7,515	7,568	7,622	7,675	7,729
3,600	7,783	7,837	7,892	7,947	8,002	8,058	8,113	8,169	8,225	8,280
3,610	8,337	8,393	8,449	8,506	8,562	8,619	8,676	8,733	8,790	8,848
3,620	8,905	8,963	9,021	9,079	9,137	9,195	9,253	9,312	9,371	9,430
3,630	9,489	9,548	9,607	9,667	9,726	9,786	9,846	9,906	9,966	10,027
3,640	10,087	10,150	10,213	10,276	10,339	10,402	10,465	10,529	10,592	10,656
3,650	10,720	10,784	10,848	10,912	10,976	11,040	11,105	11,169	11,234	11,299
3,660	11,364	11,429	11,494	11,559	11,624	11,690	11,755	11,821	11,887	11,953
3,670	12,019	12,085	12,151	12,217	12,284	12,351	12,417	12,484	12,551	12,618
3,680	12,685	12,751	12,816	12,882	12,949	13,016	13,084	13,151	13,220	13,289
3,690	13,358	13,427	13,498	13,568	13,639	13,711	13,783	13,855	13,928	14,001
3,700	14,075	14,149	14,224	14,299	14,375	14,451	14,527	14,605	14,682	14,760
3,710	14,839	14,915	14,992							

LAKE POWELL
ELEVATION — CAPACITY
 (Active Storage in 1000 acre-feet)

Elevation Feet	0	1	2	3	4	5	6	7	8	9
3,370	0	21	41	63	84	105	127	149	171	193
3,380	215	238	261	284	307	330	354	377	401	426
3,390	450	475	499	524	550	575	601	627	653	679
3,400	706	732	759	786	814	841	869	897	925	953
3,410	981	1,010	1,039	1,068	1,097	1,127	1,156	1,186	1,216	1,247
3,420	1,277	1,308	1,339	1,370	1,401	1,433	1,465	1,497	1,530	1,562
3,430	1,595	1,629	1,662	1,696	1,730	1,764	1,799	1,833	1,869	1,904
3,440	1,940	1,976	2,012	2,049	2,085	2,123	2,160	2,198	2,236	2,275
3,450	2,314	2,353	2,392	2,432	2,472	2,512	2,553	2,594	2,635	2,677
3,460	2,719	2,761	2,804	2,847	2,890	2,933	2,980	3,021	3,066	3,111
3,470	3,156	3,201	3,247	3,293	3,340	3,387	3,434	3,481	3,529	3,577
3,480	3,625	3,674	3,723	3,773	3,822	3,870	3,922	3,973	4,024	4,075
3,490	4,126	4,178	4,230	4,282	4,335	4,388	4,442	4,495	4,549	4,603
3,500	4,658	4,713	4,768	4,824	4,880	4,936	4,993	5,050	5,107	5,165
3,510	5,223	5,281	5,340	5,399	5,458	5,518	5,578	5,639	5,699	5,761
3,520	5,822	5,884	5,946	6,009	6,072	6,136	6,199	6,264	6,328	6,393
3,530	6,459	6,524	6,591	6,657	6,724	6,792	6,859	6,928	6,996	7,065
3,540	7,135	7,205	7,275	7,346	7,417	7,489	7,561	7,633	7,706	7,780
3,550	7,854	7,928	8,003	8,075	8,154	8,230	8,307	8,384	8,461	8,539
3,560	8,618	8,697	8,776	8,856	8,937	9,018	9,099	9,181	9,263	9,345
3,570	9,428	9,512	9,596	9,681	9,766	9,851	9,937	10,024	10,111	10,198
3,580	10,286	10,374	10,463	10,552	10,642	10,733	10,824	10,915	11,007	11,099
3,590	11,192	11,286	11,380	11,474	11,568	11,665	11,761	11,857	11,954	12,052
3,600	12,150	12,249	12,348	12,448	12,549	12,649	12,751	12,853	12,956	13,059
3,610	13,163	13,267	13,372	13,477	13,583	13,690	13,797	13,904	14,013	14,121
3,620	14,231	14,341	14,451	14,563	14,674	14,791	14,899	15,013	15,127	15,242
3,630	15,357	15,473	15,589	15,706	15,824	15,942	16,061	16,180	16,300	16,421
3,640	16,542	16,664	16,786	16,909	17,033	17,157	17,282	17,408	17,534	17,661
3,650	17,789	17,917	18,046	18,175	18,305	18,436	18,567	18,699	18,832	18,965
3,660	19,099	19,234	19,369	19,505	19,641	19,779	19,916	20,055	20,194	20,334
3,670	20,474	20,616	20,757	20,900	21,043	21,187	21,331	21,476	21,622	21,769
3,680	21,916	22,064	22,212	22,361	22,511	22,662	22,813	22,965	23,117	23,270
3,690	23,424	23,579	23,734	23,890	24,047	24,204	24,362	24,521	24,680	24,841
3,700	25,002	25,164	25,326	25,489	25,653	25,818	25,984	26,150	26,317	26,485
3,710	26,653	26,823	26,993							

NOTES:

1. Add 1,998,000 acre-feet of dead storage to obtain total storage.
2. The USBR publication "LAKE POWELL AREA AND CAPACITY TABLES" dated April 1, 1963 provides capacity values corresponding to 0.01 foot elevation increments.