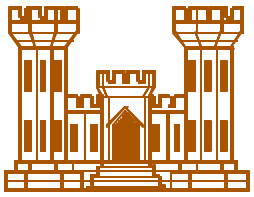

US Army Corps
of Engineers
Los Angeles District

Operation of Alamo and Painted Rock Dams During Jan - Feb 1993 Floods

AUGUST 1993

Prepared by:
Reservoir Regulation Section

OPERATION OF ALAMO AND PAINTED ROCK DAMS
DURING THE JANUARY AND FEBRUARY 1993 FLOODS

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II - Painted Rock Dam

OPERATION OF ALAMO AND PAINTED ROCK DAMS DURING THE JANUARY AND FEBRUARY 1993 FLOODS

Introduction.

During the months of January and February 1993, the State of Arizona was hit by a series of major storm events which caused widespread flooding, damaged properties and threatened the lives of many people. The Corps of Engineers operates 2 flood control projects in the State, namely: 1) Alamo Dam, located on the Bill Williams River Basin, and 2) Painted Rock Dam, located on the Gila River Basin. The Corps operated these two projects, for their authorized project purposes which include flood control, as described in the report. Coordination with different government agencies, both local and federal was essential in the operation of the two projects.

The storm events were so severe that new historic maximums were recorded at both reservoirs, including a spillway flow at Painted Rock Dam, a first time ever for a Corps' Los Angeles District's (LAD) project. The purpose of this report is to present and document the operation of Alamo and Painted Rock Dams and at the same time provide information to the LAD's Hydrologic Section in its preparation of the 1993 Flood Damage Report for Arizona.

I - Alamo Dam

1-1. Project Background.

Alamo Dam was built by the Corps of Engineers to provide flood protection for the valley of the lower Colorado River. Alamo Dam is located on the Bill Williams River, approximately 39 miles from its confluence with the Colorado River in Lake Havasu. The generally mountainous drainage area above Alamo Dam is approximately 4,770 sq. mi. and is shown on Fig 1-1. The reservoir behind the dam has a total storage of 995,300 ac-ft (1985 survey, and 1993 reservoir capacity calculation.). Completed in January 1968, Alamo Dam also provides storage for water conservation and recreation. Figure 1-2 shows the project's pertinent data[1], and Figure 1-3 shows the reservoir's storage allocation diagram[2] .

The maximum scheduled flood control release from Alamo Dam is 7,000 cfs, as specified in the Alamo Dam General Design Memorandum, dated April 1964; however, operation schedules (original version taken from Alamo Dam water control manual dated 1973, and the July 1982 revised version shown on Fig. 1-4[3]) show that up to a maximum release of 7,600 cfs can be made from Alamo Dam. The downstream channel is adequate to handle such flows without significant damage. There are no major structures on the Bill Williams River that have a regulatory effect on the flood flows at Alamo Dam.

Subsequent to initial authorization, Alamo Dam became subject to the stipulations of the Fish and Wildlife Coordination Act of 1958 (P.L. 85-624), Federal Water Project Recreation Act - Uniform Policies (P.L. 89-72), the National Environmental Policy Act of 1969 (P.L. 91-190), the Clean Water Act of 1977 (P.L. 95-217), and the Endangered Species Act of 1973 (P.L. 93-205). Alamo Dam is therefore operated to conform with objectives and specific provisions of the authorizing legislation, as well as in a manner consistent with these subsequent applicable Congressional acts.

1-2. Downstream Development.

Below Alamo Dam, the Bill Williams River flows approximately 39 miles west into the Colorado River. Economic developments protected by Alamo Dam are along the lower Colorado River with a very few improvements on the Bill Williams River. Properties of significant values are situated in the lowlands of the Colorado River between Parker Dam and the Mexican border, a distance of about 200 miles. Areas susceptible to damage contain

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[1]Pertinent data sheet shown on Figure 1-2 is from the Alamo Dam water control manual dated 1973, revised in 1983, and does not reflect the latest information about the project in all categories.

[2] Storage allocation diagram shown on Fig 1-3 was updated in 1993 and is based on 1985 bathymetric survey plus interpolation of historic data. Elevations shown are based on the 1993 storage-elevation information.

[3]The operation schedule shown on Fig 1-4 was last revised in July 1982, and does not agree with the elevations shown on Fig 1-3 for reasons stated in footnote 2 above.

residential, business, and industrial properties, and various facilities such as irrigation, and flood control works, highways and public utilities. Alamo Dam also provides flood protection to the communities and agricultural areas of Sonora and Mexicali Valleys in Mexico.

1-3. Agencies Involved in the Operation of the Dam.

1-3.a. The Corps of Engineers (COE). The COE is responsible for the operation and maintenance of Alamo Dam.

1-3.b. US Bureau of Reclamation (USBR). The USBR operates Parker Dam and controls the elevation of Lake Havasu located at the confluence of the Bill Williams and Colorado Rivers. The USBR is also responsible for the operation of the lower Colorado River system and for flood protective works on the lower Colorado River.

1-3.c. US International Boundary and Water Commission (IBWC). The IBWC is interested in the operation of Painted Rock Dam because of the Commission's responsibilities relating to the United States' 1944 Water Treaty with Mexico.

1-3.d. Arizona State Parks. The Arizona State Parks is recreational licensee for Alamo Reservoir.

1-3.e. Arizona Department of Game and Fish. The Arizona Department of Game and Fish is a licensee for all fish and wildlife areas at Alamo Dam.

1-3.f. Bill Williams River Corridor Technical Committee (BWRTC). The BWRTC's membership includes the Corps of Engineers, U.S. Fish and Wildlife Service, Arizona Bureau of Land Management, Arizona State Parks, and Arizona Fish and Game. The committee was formed to develop a coordinated approach for managing the Bill Williams River including Alamo Dam and Reservoir. It serves as a means of obtaining valuable input from agencies interested in the operation of Alamo Dam and the Bill Williams River.

1-4. Constraints at Alamo Dam.

Several constraints associated with the operation of Alamo Dam exists, they include the following:

1-4.a. Operational Constraints. There are 2 identical sets of gates placed in tandem at Alamo Dam. Each set, called the emergency gates and service gates, consists of three 5.5 ft-wide by 8.5 ft-high slide gates . The service gates are used for discharge regulation. The emergency gates are open most of the time except when the service gates malfunction or require maintenance. There is also a butterfly valve for discharging low flows of 25 cfs or less. Constraints associated with the operation of the gates include the following:

1-4.a.1. Maximum Gate Setting. Operational constraints for the outlet gates restrict the maximum gate setting to 80 percent of the 8.5-ft vertical dimension of the

gates, which is 6.8 ft. Because of this restriction, the minimum elevation within the pool at which the maximum release of 7,000 cfs can be made is 1148.4 ft.

1-4.a.2. Minimum Gate Setting. Pursuant to an inspection and subsequent rehabilitation of the outlet gates in 1990, criteria have been established which prohibit the gates from being set at less than 0.5 ft of opening. Therefore, discharges less than approximately 150 cfs cannot be made from the service gates. The bypass gate, however, can be used to low discharges of up to 25 cfs. This leaves a range of flows, from about 25 cfs to 150 cfs, where releases cannot be met by gate operations.

1-4.b. Environmental Constraints.

1-4.b.1. Bald Eagles. Pairs of Southern Bald Eagles, an endangered species, have been observed nesting within the Alamo Lake area since the early 1980's. As a result of informal consultation with the USFWS and AG&FD, from December to April of each year Alamo lake has to be maintained 1) at a minimum elevation of 1100 ft in order to provide sufficient lake surface foraging area for the nesting eagles, and 2) below 1124 ft which is the approximate elevation of one of the eagle nest.

1-4.b.2. Cottonwood Trees within Lake Havasu National Wildlife Refuge. Approximately 200 species of birds have been observed nesting within the stands of cottonwood trees located within the Lake Havasu National Wildlife Refuge at the mouth of the Bill Williams River. In the past, many trees have died due to high ground water inundating their root zones. To prevent this, the USFWS asked the COE to make larger releases for shorter durations, instead of lesser flows for longer durations, as a means of drawing down Alamo Reservoir. The critical period of preventing inundation is during the budding season from April through June.

1-4.b.3. Bass Spawning and Growing. The Arizona Game and Fish Department (AG&FD) maintains a bass fishery in Alamo Lake. The AG&FD criteria for sustaining the fishery are: 1) a maximum lake level fluctuations of 2 in. per day during 15 Mar - 31 May, and 2) a maximum weekly fluctuation of 9.5 in. during 16 May - 30 Sep of each year.

1-4.c. Water Supply. Water supply releases within the water supply pool are coordinated with the operations of the USBR's Hoover, Davis, and Parker Dams on the lower Colorado River. Releases within the water supply pool is limited to 2,000 cfs.

1-5. Alamo Dam Operation During the Floods of 1993.

During the last months of 1992, the lake level at Alamo Reservoir was maintained steadily within the water conservation pool (just below WSE 1100 ft) with releases limited to about 10 cfs. The dam was being operated in this manner to be in compliance with Section 7 of the Endangered Species Act, and to satisfy downstream water rights. During the 2nd week of January, a series of storm events caused high inflows that raised the reservoir water level significantly, up to elevations above 1143 ft beginning on 12 January 1993. On the same day,

high water conservation discharges were initiated by gradually increasing the releases to 1,500 cfs, and then to 2,000 cfs on the following day. These release rates were maintained for about a month. In the second week of February, another storm event in the basin brought more inflows into the reservoir causing the water surface elevation to go even higher. On 12 February, with the water surface elevation at approximately 1175 ft., discharges were increased up to 5,000 cfs.

During the last week of February, Painted Rock Dam, another COE dam located on the Gila River Basin, started spilling with flows in excess of 20,000 cfs (see Section II of this report). Painted Rock Dam discharges into the Gila River approximately 126 miles upstream of its confluence with the Colorado River. A flow in the magnitude of about 23,000 cfs at the Southerly International Boundary of the Colorado River (SIB) causes serious flooding in Mexico. The Mexican officials understood that high flows would be reaching Mexico as a result of uncontrolled discharges from Painted Rock Dam; however, they were not willing to accept additional flows resulting from releases at other Colorado River dams. In order to prevent further damages, the Mexican Government through the International Boundary and Water Commission (IBWC), requested a reduction of flows from Alamo Dam. The COE concurred with the request and lower releases from Alamo Dam (ranging from 1,200 to 1,500 cfs) were started on 26 February.

As Painted Rock spill reached its peak and begun to recede, higher Alamo releases were possible without causing additional flooding in Mexico. Higher releases were initiated from Alamo Dam starting on 9 March , reaching 5,000 cfs by 11 March. During this time period, Parker Dam, located downstream of Alamo Dam was releasing at a rate equal to the consumptive use rate downstream from Parker Dam; therefore, Alamo releases did not cause an increase in the deliveries of water to Mexico. On 11 March, the USBR informed the COE that with warmer weather, consumptive use was high enough to allow the COE to go as high as the maximum scheduled release of 7,000 cfs from Alamo Dam. On 15 March, with a water surface elevation of 1173.22, releases from Alamo Dam were increased to 7,000 cfs. The Alamo gate regulation schedule calls for a reduction in releases once water surface elevation reaches 1160 ft., which occurred on 21 March. However, the COE kept releasing 7,000 cfs in order to better meet the project purposes of the dam, namely flood control, recreation and water supply. In addition, such an increase in releases minimized the duration of inundation of riparian habitation (Cottonwood stands) in the Havasu Wildlife Refuge located downstream of the dam (see Section 1-4.b.3).

On 29 March, the water surface elevation dropped below 1140 ft, and discharges were gradually reduced. April through July releases of 200 to 300 cfs were made for the primary purpose of enhancing the cottonwood trees located in the Lake Havasu Refuge area; at the same time, during the middle of March to the end of May, the dam was also operated to insure that the water level behind Alamo Dam would not change by more than 2 inches per day in order to enhance bass spawning in the lake area (Section 1-4.b.4).

The 1993 flood season resulted in a record historic maximum release of 7,000 cfs. The previous maximum release was 4,730 cfs in February 1969. A peak water surface elevation of 1182.40 ft and peak storage of approximately 499,500 ac-ft (a little less than 50 percent of capacity) were recorded on 21 February. The peak inflow of 122,800 cfs occurred on 8 January

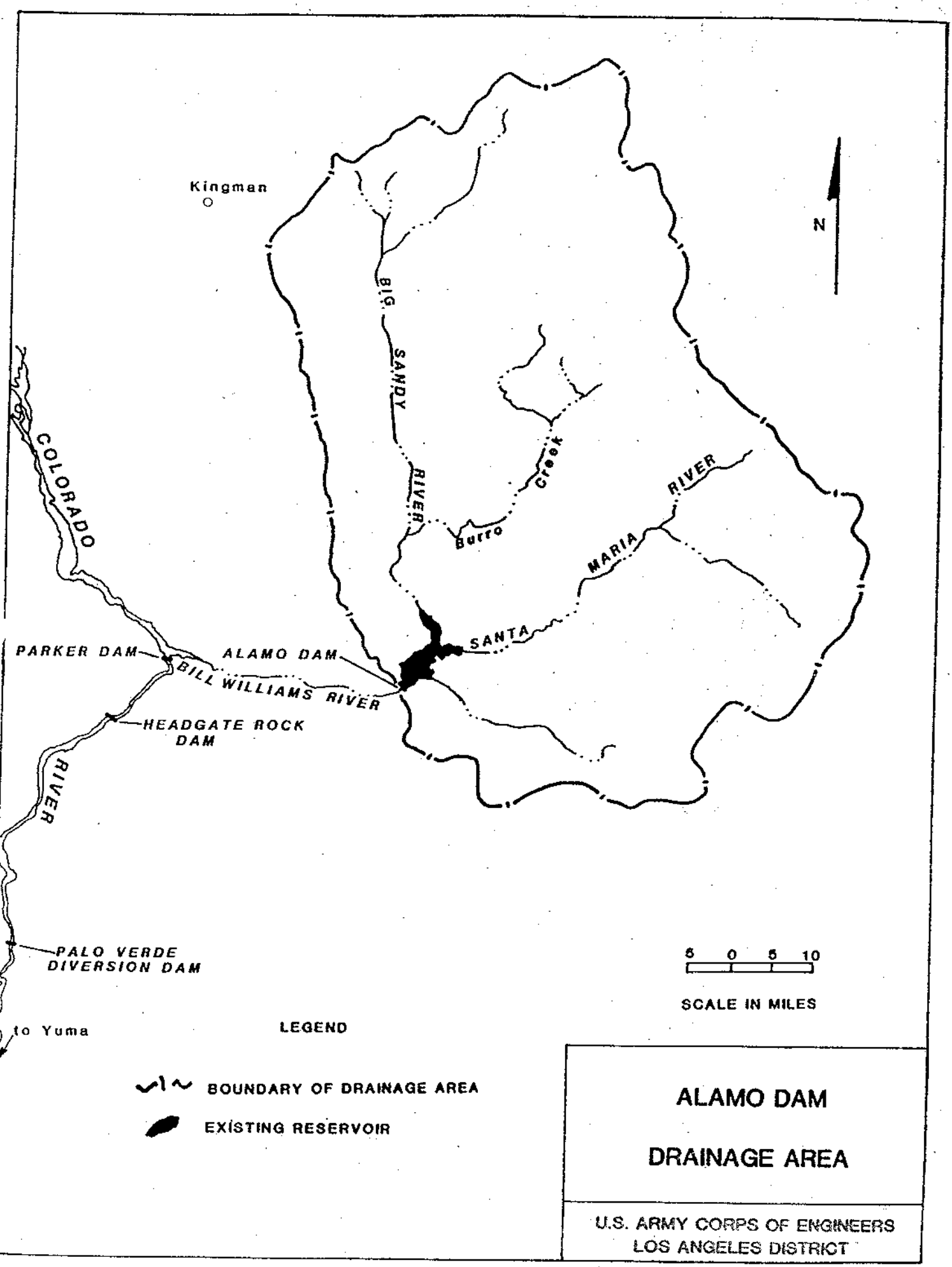
(see Table 1-1). Fig. 1-5 shows inflow and outflow hydrograph from 1 January to 15 April, while Fig 1-6 shows the water surface elevation and the corresponding storage for the same time period. Table 2-2 summarizes the COE's operation of Alamo Dam.

Table 1-1 Maximum Inflow, Outflow, Water Surface Elevation and Storage at Alamo Dam During Jan - Feb 1993 Floods

	Maximum Value	Date
Inflow (cfs)	122,800	8 January
Outflow (cfs)	7,000	17 -29 March
WSE (ft)	1182.40	21 February
Storage (ac-ft)	499,500	21 February

Table 1-2 Summary of COE's Alamo Dam Operation During Jan - Feb 1993 Floods

Date	Discharge	Remarks
12 Jan - 11 Feb	1,500 - 2,000	High water conservation releases.
12 Feb - 25 Feb	5,000	Flood control releases.
26 Feb - 10 Mar	1,200 - 1,500	Releases coordinated with Colorado River system in order to prevent additional flow to Mexico.
11 Mar - 14 Mar	5,000	Flood control releases.
15 Mar - 28 Mar	7,000	Higher flood control releases. Lasted until 29 March.
29 March -	200 - 300	To enhance cottonwood trees downstream. Drop in lake level was limited to 2 in per day during the middle of March through May to enhance bass spawning in the reservoir.


Kingman
N
BIG SANDY RIVER
Burro Creek
MARIA RIVER
SANTA
COLORADO
PARKER DAM
ALAMO DAM
BILL WILLIAMS RIVER
HEADGATE ROCK DAM
RIVER
PALO VERDE DIVERSION DAM
to Yuma
6 0 6 10
SCALE IN MILES
LEGEND
BOUNDARY OF DRAINAGE AREA
EXISTING RESERVOIR
ALAMO DAM
DRAINAGE AREA
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

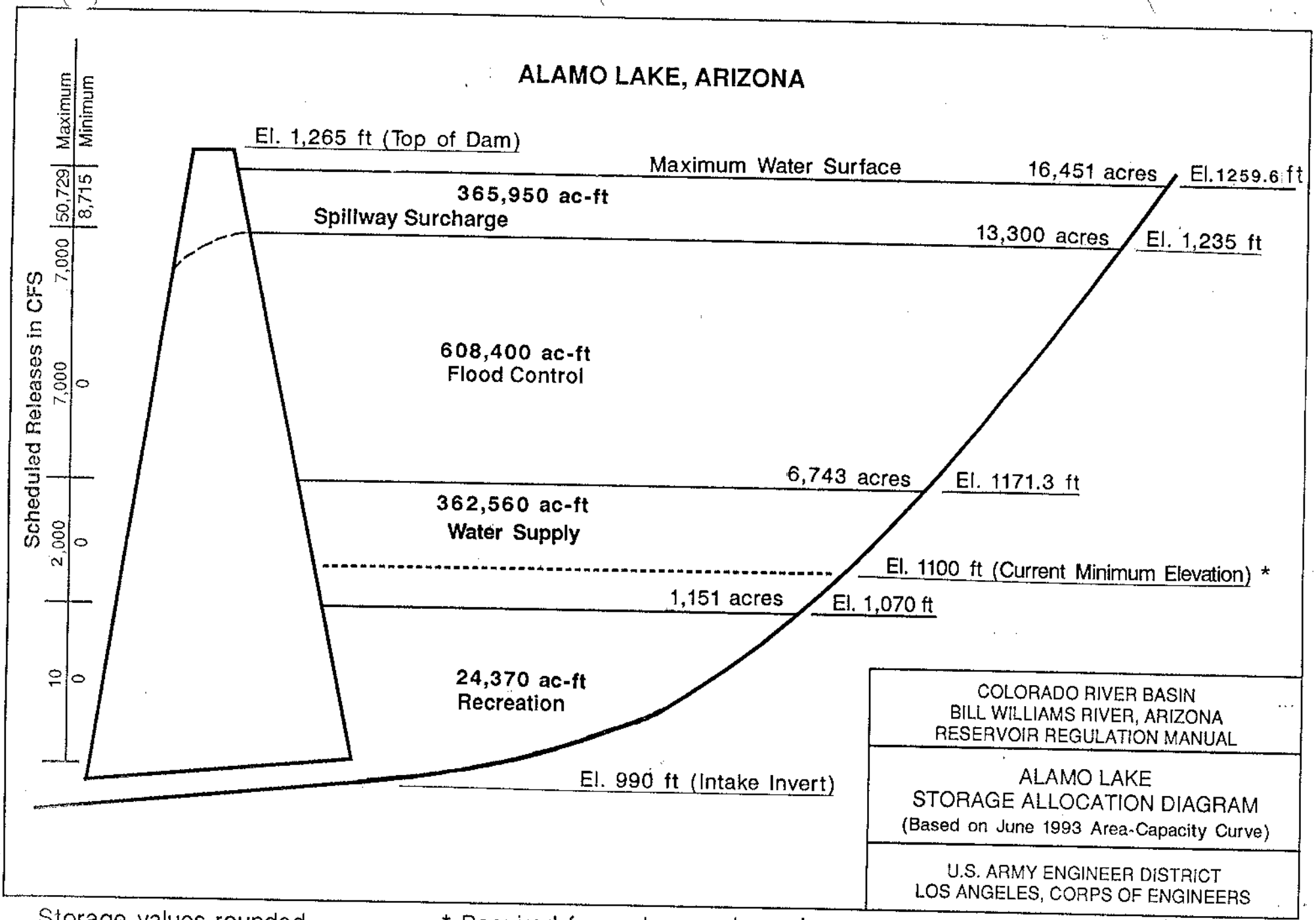
ALAMO DAM AND RESERVOIR
MOHAVE COUNTY AND LA PAZ COUNTY, ARIZONA

PERTINENT DATA
MAY 1983

Stream System	Bill Williams River
Drainage area, sq. miles	4,770
Reservoir:	
Elevation	
Recreation water supply pool, ft., m.s.l.	1,046
Water supply pool, ft., m.s.l.	1,174
Flood control pool (spillway crest), ft., m.s.l.	1,235
Spillway design surcharge level, ft., m.s.l.	1,259.6
Top of dam, ft., m.s.l.	1,265
Area	
Recreation water supply pool, acres	547.8
Water supply pool, acres	7,044.5
Spillway crest, acres	13,307
Spillway design surcharge level, acres	16,452
Top of dam, acres	17,040
Capacity, gross	
Recreation water supply pool, acre-feet	9,762.4 (0.04*)
Water supply pool, acre-feet	437,303 (1.72*)
Spillway crest, acre-feet	1,046,314 (4.11*)
Spillway design surcharge level, acre-feet	1,412,474 (5.55*)
Top of dam, acre-feet	1,503,064 (5.91*)
Allowance for sediment (100-year), acre-feet	200,000 (0.79*)
Dam: - Type	Rolled Earth
Height above original streambed, ft.	283
Top length, ft.	975
Top width, ft.	30
Freeboard, ft.	5.4
Spillway: - type	Ungated, broad-crested
Crest length, ft.	110
Design surcharge, ft.	1,259.6
Design Discharge, c.f.s.	41,500
Outlets:	
Tunnel -	
Length (including gate chamber and transition sections), ft.	1,290
Intake invert elevation, ft., m.s.l.	990
Outlet invert elevation, ft., m.s.l.	980
Discharge at spillway crest, c.f.s.	8,700
Gates - type	Slide, tandem
Number and size -	
Service (downstream)	3 - 5.5'W x 8.5'H
Emergency (upstream)	3 - 5.5'W x 8.5'H
Low-flow bypass around gate No. 3 -	
Pipe size, I.D., in.	18
Control valve - type	Butterfly
Maximum discharge capacity, c.f.s.	25
Water-surface elevation to initiate operation, ft., m.s.l.	1,002.3
Standard project flood:	
Duration (inflow), days	7
Total volume, acre-feet	613,000 (2.41*)
Inflow peak, c.f.s.	389,000
Probable maximum flood:	
Duration (inflow), days	3
Total volume, acre-feet	1,390,000 (5.46*)
Inflow peak, c.f.s.	859,000
Historic Maximums:	
Maximum release on record, c.f.s.	4,730
Date	2-27-69
Maximum water surface elevation, ft., m.s.l.	1207.4
Date	2-23-80

*inches of runoff

Figure 1-2



Storage values rounded.

* Required for endangered species.

Alamo Dam Outlet Gate Operation Schedule
(For rising or falling stages)

Step No.	When reservoir water surface is between elevations	Gate setting for gates as indicated: No. 1	No. 2	No. 3	Computed discharge	Downstream gage height###
	Feet above mean sea level	Feet of Opening	Feet of Opening	Feet of Opening	Cubic feet per second	Feet
1....	990 - 1046*	0	0	0	0 - 10**	5.50 - 6.15
2....	1046 - 1047	0.70	0.70	0.70	525 - 530	8.64 - 8.65
3....	1047 - 1048	1.35	1.35	1.35	1,015 - 1,020	9.26 - 9.26
4....	1048 - 1049	2.00	2.00	2.00	1,495 - 1,505	8.82 - 9.63
5....	1049 - 1058	2.60	2.60	2.60	1,915 - 2,065	9.87 - 9.95
6....	1058 - 1068	2.40	2.40	2.40	1,915 - 2,040	9.87 - 9.94
7....	1068 - 1083	2.25	2.25	2.25	1,915 - 2,080	9.87 - 9.96
8....	1083 - 1103	2.05	2.05	2.05	1,910 - 2,090	9.87 - 9.96
9....	1103 - 1126	1.85	1.85	1.85	1,900 - 2,090	9.86 - 9.96
10...	1126 - 1147	1.70	1.70	1.70	1,920 - 2,060	9.87 - 9.95
11...	1147 - 1172	1.60	1.60	1.60	1,940 - 2,090	9.88 - 9.96
12...	1172 - 1173	2.75	2.75	2.75	3,515 - 3,530	11.2 - 11.2
13...	1173 - 1174	4.00	4.00	4.00	4,970 - 5,000	11.9 - 12.1
14...	1174# - 1194	5.70	5.70	5.70	6,800 - 7,150	11.9 - 12.1
15...	1194 - 1214	5.40	5.40	5.40	6,840 - 7,170	11.9 - 12.1
16...	1214 - 1235	5.10	5.10	5.10	6,825 - 7,140	11.8 - 12.3
17...	1235## - 1237.9	4.60	4.60	4.60	6,525 - 7,565	11.8 - 12.2
18...	1237.9 - 1239.5	3.70	3.70	3.70	6,400 - 7,410	11.8 - 12.2
19...	1239.5 - 1240.7	3.00	3.00	3.00	6,460 - 7,470	11.8 - 12.2
20...	1240.7 - 1241.8	2.30	2.30	2.30	6,470 - 7,480	11.8 - 12.2
21...	1241.8 - 1242.7	1.70	1.70	1.70	6,590 - 7,600	11.8 - 12.2
22...	1242.7 - 1243.6	1.00	1.00	1.00	6,550 - 7,560	11.8 - 12.2
23...	1243.6 - 1244.5	0.30	0.30	0.30	6,470 - 7,470	11.8 - 12.2
24...	1244.5 - 1245.1	0	0	0	7,000 - 7,850	12.0 - 12.3
25...	1245.1 - 1245.8	2.00	2.00	2.00	10,900 - 11,860	13.4 - 13.7
26...	1245.8 - 1246.5	4.10	4.10	4.10	14,820 - 15,780	14.7 - 15.0
27...	Above 1246.5	8.50	8.50	8.50	18,750 Up	16.0 - ----

*Top of recreation pool elevation 1,046.
**Release made through low-flow outlet (outflow = inflow up to 10 cfs)
#Bottom of flood-control pool elevation 1,174.
##Spillway crest elevation 1,235.
###Derived from USGS rating no. 7 (extrapolated above 5000 cfs)
NOTE: Discharges from the conservation pool (elevations 1,046 to 1,174) may be less than scheduled value, dependent on Colorado River System requirements.

FIGURE 2

1. Communication with the District Office is available.

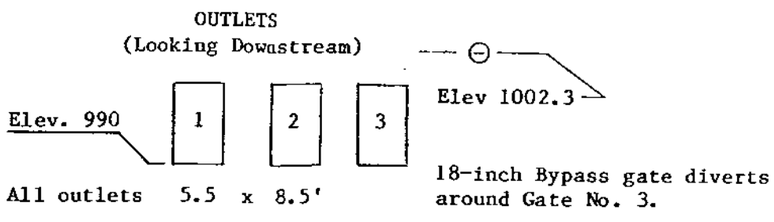
a. Notify the Reservoir Operations Center when a gate change will be required according to the schedule.

b. Notify the Reservoir Operations Center if unable to set the gates as instructed.

2. Communication with the District Office is not available.

a. Allow a period of four hours to pass to reestablish communication with the District Office. Do not operate gates except as follows in 2.b. If after four hours communication is not reestablished send an alternate operator to the nearest public telephone to reestablish communications. If alternate cannot leave project, maintain current discharge and wait for district employee to reach the project.

b. Adjust the gates gradually and uniformly to maintain current downstream gage height until communication is reestablished.



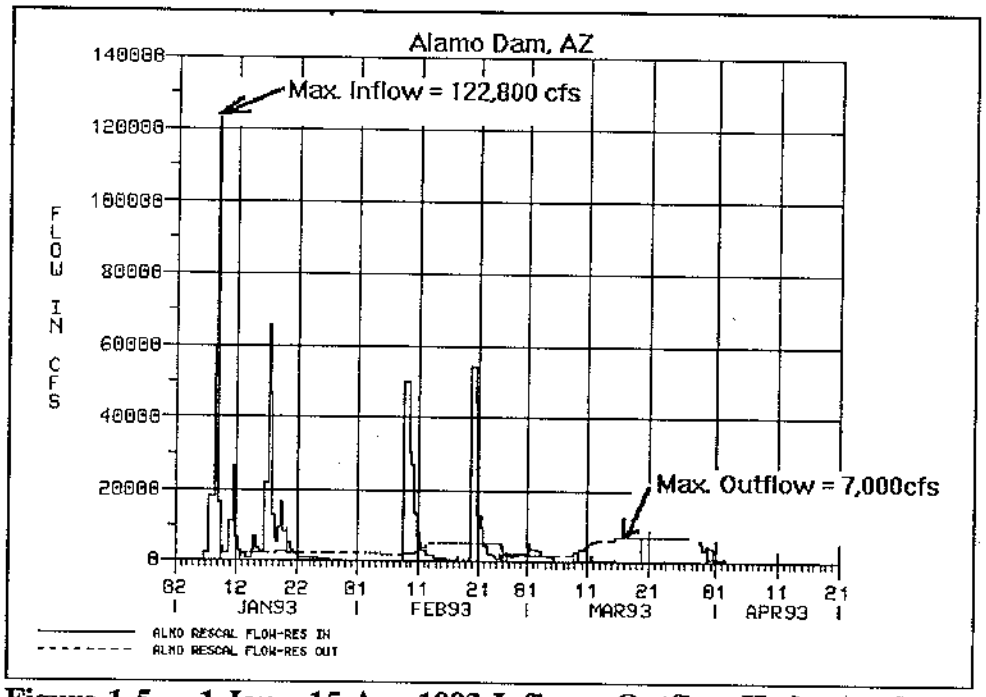


Figure 1-5. 1 Jan - 15 Apr 1993 Inflow - Outflow Hydrograph at Alamo Dam

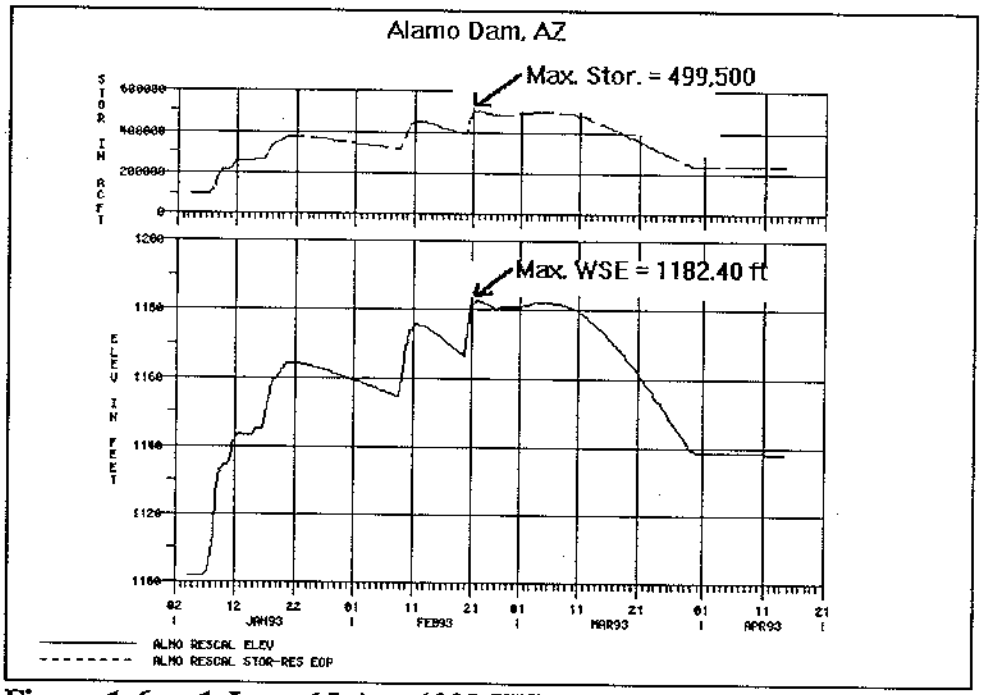


Figure 1-6. 1 Jan - 15 Apr 1993 WSE and Storage at Alamo Dam

II - Painted Rock Dam

2-1. Project Background.

Painted Rock Dam was built by the Corps of Engineers for its congressionally authorized purpose of flood control. Completed in January 1960, Painted Rock Dam is located on the Gila River, approximately 126 miles from its confluence with the Colorado River (see Fig 2-1). The drainage area above Painted Rock Dam is 50,800 sq mi and is shown on Fig 2-1. The reservoir has a total storage of 2,476,339 ac-ft at spillway crest (based on 1985 survey). Fig. 2-2 shows the project's pertinent data, and Figure 2-3 is a diagram showing the reservoir's storage allocation. The approved flood control plan for Painted Rock Dam calls for a maximum reservoir release of 22,500 cfs, as stated in the Painted Rock Dam water control manual dated June 1962. The operation schedules (original versions found on the water control manual, and the 1993 revised versions shown on Figs. 2-4.a and 2-4.b) show that releases of up to 23,000 cfs can be made from the dam; however, the downstream channel has a limited capacity, lower than the maximum flood control releases, as explained in sections 2-2 and 2-4.a.

There are numerous reservoirs in the Gila Basin above Painted Rock Dam. However, only eight influence the regulation of major floods at the dam (see Figure 2-1, and Table 2-1). These reservoirs have a combined usable storage space below spillway crests of approximately 3.25 million ac-ft, and intercept runoff from an area of 26,742 sq. mi, or approximately 53 percent of the total drainage area above Painted Rock Dam. These projects and their operations in 1993 are briefly discussed in section 2-6.

TABLE 2-1 Pertinent Data for Existing Dams [1]
Upstream of Painted Rock

Dam	Reservoir	River	D. A. (sq mi)	Storage [2] (ac-ft)	Purpose	Agency
1. Coolidge	San Carlos	Gila	12,886	884,594	Irrigation and Power	BIA
2. New Waddell	Lake Pleasant	Agua Fria	1,460	902,502	Irrigation	CAWCD
3. Roosevelt	Roosevelt Lake	Salt	5,830	1,075,507	Irrigation and Power	SRP
4. Horse Mesa	Apache Lake	Salt	5,940	188,106	Irrigation and Power	SRP
5. Mormon Flat	Canyon Lake	Salt	6,100	19,886	Irrigation and Power	SRP
6. Stewart Mt.	Saguaro lake	Salt	6,211	44,084	Irrigation and Power	SRP
7. Horseshoe	Horseshoe	Verde	5,991	68,777	Irrigation	SRP
8. Bartlett	Bartlett	Verde	6,185	72,073	Irrigation	SRP

Note: 1. There are other dams loc. upstream; However, only the projects shown above influence the operation of Painted Rock Dam.
2. Up to spillway crest elevation.

2-2. Downstream Development.

Below Painted Rock Dam, the Gila River flows approximately 126 miles to the Colorado River at Yuma. South of the River, Interstate Highway 8 runs the entire distance from Gila Bend to Yuma. There are nine bridges across the Gila River that connect the communities downstream of the dam (see table 2-2), and only six of these nine crossings were designed to handle as much as 10,000 cfs. With only an estimated 5,000 to 7,000 residences scattered throughout the area, there is no major urban development that exists along the Lower Gila River between the dam and the City of Yuma. For 65 miles downstream of the dam, the terrain is sparsely inhabited, with widely scattered pockets of agriculture. The next 45 miles consists of the Wellton Mohawk Irrigation District which is an intensive agricultural area consisting of about 65,000 acres of land. Existing improvements include irrigation canals, pump stations, transmission lines, and flood control structures. In addition to the nine bridge crossings shown on Table 2-2, there are other bridges that are affected in the overflow area created when releases are in excess of current channel capacities.

TABLE 2-2
Major Gila River Crossings
Downstream of Painted Rock Dam

Name	Location from Dam (miles)	Design Capacity (cfs)
1. Sentinel	35	5,000
2. Dateland (Ave 264)	49	10,000
3. Ave 51E	66	7,000
4. Ave 45E	83	10,000
5. Ave 38E	98	10,000
6. Ave 30E	120	10,000
7. Ave 20E	104	10,000
8. US Highway 95	115	25,000
9. Ave 7E	125	7,000

Where the Gila River joins the Colorado River east of Yuma, there is a large irrigated agriculture area owned in part by the North Gila Valley Irrigation District, and in part by the Yuma Irrigation District. To the east and south of Yuma, The Yuma Mesa Irrigation District extends to the US - Mexico International Border. The combined flows from the Colorado River and the Gila River continue to Mexico where water is used primarily for irrigated agriculture on the upper delta and Mexicali Valley.

2-3. Agencies Involved in the Operation of the Dam.

2-3.a. The Corps of Engineers (COE). The COE is responsible for the operation and maintenance of Painted Rock Dam.

2-3.b. US Bureau of Reclamation (USBR). The USBR is responsible for the channel improvements along the lower Gila River and the lower Colorado River system. During the period of the significant storms of 1993 as discussed in this report, the USBR was managing a safety modification for Coolidge Dam for the Bureau of Indian Affairs, the reconstruction of Roosevelt Dam for Salt River Project, and the construction of New Waddell Dam for the Central Arizona Water Conservation District.

2-3.c. Bureau of Indian Affairs (BIA). The BIA owns and operates Coolidge Dam located on the Gila River upstream of Painted Rock Dam.

2-3.d. Wellton-Mohawk Irrigation and Drainage District (WMIDD). Created by Act of the Arizona State Legislature on July 23, 1951, the WMIDD is a political subdivision of the State of Arizona, and is responsible for the irrigation and power within its jurisdiction. The District consisting of 65,000 acres of irrigable farmlands extends 45 miles along the Gila River, from the Gila Gravity Canal Siphon under the Gila River, 15 miles east of Yuma, to Texas Hill. The irrigation system was constructed by USBR and turned over to the WMIDD for operation and maintenance.

2-3.e. Salt River Project (SRP). SRP operates the Salt River system consisting of Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain Dams; and the Verde River system consisting of Horseshoe and Bartlett Dams.

2-3.f. US International Boundary and Water Commission (IBWC). The IBWC is interested in the operation of Painted Rock Dam because of the Commission's responsibilities relating to the United States' 1944 Water Treaty with Mexico.

2-3.g. Central Arizona Water Conservation District (CAWCD). Operates New Waddell Dam located on the Agua Fria River upstream of Painted Rock Dam .

2-4. Constraints at Painted Rock Dam

2-4.a. Limited Downstream Channel Capacity. The currently approved water control plan for Painted Rock Dam calls for a maximum flood control release of 22,500 cfs, as discussed in section 2-1. However, releases in excess of 10,000 cfs could produce devastating social and economic impacts to the downstream areas, especially to the Wellton Mohawk's intensive improvements. Table 2-2 lists the major bridge crossings that connect communities downstream of the dam. Releases in excess of 15,000 cfs would result in closure of all these river crossings and isolation of the north and south sides of the river. According to the local sheriff department's estimate, approximately 3,500 area residents would be isolated on the north bank when all bridges are closed. Travel to schools, work and hospitals would be impossible, except for a 120 mi long alternate route.

2-5. Painted Rock Dam Operation During the Floods of 1993.

Virtually empty before January 4, 1993, Painted Rock Reservoir received high inflows resulting from a series of storms that lasted through late February. As the water surface elevation was on an increasing trend , releases were gradually increased in the first weeks on January, reaching 12,500 cfs near the end of month. The COE deviated from the fixed flood control schedules (Figs. 2-4a and 2-4b) in order to minimize damages downstream, as explained in Section 2-2 and 2-4.a. On 1 February the release rates were reduced to 10,000 cfs because roads and bridges were starting to get washed away or inundated. A week later, on 8 February, release rates had to be increased back up to 12,500 cfs due to significant rainfall in the watershed. This rate (12,500 cfs) was maintained until 21 February when the WSE exceeded the spillway crest elevation of 661 ft. As the spillway discharges increased, the outlet gates were lowered accordingly so as to maintain a total discharge (spillway and outlet gates) of 12,500 cfs, thus minimizing downstream impacts. However, the WSE continued to increase, resulting higher spillway flows, that eventually exceeded 12,500 cfs on 23 February. At this time, all of the outlet gates were completely closed. In the succeeding days, as the water surface elevation continued to rise, the spillway discharges continued to increase. These increases continued and finally exceeded the operational maximum flood control release of 22,500 cfs. The peak outflow occurred on 27 February at about 25,600 cfs on 27 February. The peak WSE was 667 ft. On 1 March, as the spillway discharges dropped below 25,000 cfs, the outlet gates were opened accordingly so as to maintain 24,000 cfs, until the WSE dropped below the spillway crest elevation of 661 ft, on 16 March.

On 17 March, at the requests of downstream interests, the outlet discharge was gradually reduced to 20,000 cfs. This reduction allowed the re-opening of US Highway 95, a major roadway corridor, and Sentinel Road. It also allowed the repairs of other bridges and roadways, such as the one near Dateland. On 9 April, at the requests of local officials, release rates were further decreased to 15,000 cfs, in order to allow the re-opening of other transportation corridors, draining of additional fields for farming, and help the USBR maintain their levees along the lower Gila River. On 29 April, the release rates were decreased to 10,000 cfs to help the WMIDD and the USBR in their flood fighting efforts, and to speed the reconstruction of US Highway 95 bridge, which eventually collapsed due to sustained high flows. On 21 May, the COE inspected and found the outlet works to be in good condition with no emergency repairs required. In order to facilitate this inspection, the releases were gradually decreased to zero. After the inspection, the gates were set back to maintain a release of 10,000 cfs.

On 27 May, at the requests of local officials, including the Governor of Arizona, Painted Rock releases were reduced to 5,000 cfs, as the inflow was projected to drop to near zero. This reduction negated further flood fighting efforts, and enabled the political jurisdictions, and the farmers to begin their recovery measures. It also enabled the USBR to assess damages, begin repairs of their facilities, and coordinate water resources from the Gila and Colorado Rivers. On 7 July, releases were gradually reduced to 2,200 cfs over 7 day period. This reduction was made in order to facilitate the repair and reconstruction of the USBR's Main Outlet Drain Extension (MODE). The MODE is a reach of the channel which carries saline groundwater flows from the WMIDD directly to the Gulf of California without flowing to the Colorado River and adversely affecting the salinity levels of water going to Mexico.

Aside from a first time ever spillway flow from a LAD project, the floods of 1993 also resulted in historic maximums recorded at Painted Rock Dam, including: 1) maximum water surface elevation of 667 ft (6 ft above spillway crest), maximum storage of 2,808,960 (113 percent of flood control capacity), 3) maximum outflow of 25,600 cfs (spillway), and maximum inflow of approximately 186,000 cfs (see table 2-3). Fig 2-3 shows the inflow and outflow hydrographs for Painted Rock Dam during the 1993 floods, and fig. 2-4 shows the water surface elevation and storage for the same time period. Table 2-4 shows the 30- and 60- inflow volumes and their corresponding return periods. Table 2-5 summarizes the COE's operation of Painted Rock Dam during January and February 1993 floods.

Table 2-3
Maximum Inflow, Outflow,
WSE and Storage
at Painted Rock Dam
During Jan - Feb 1993 Floods

	Maximum Value	Date
Inflow (cfs)	186,000	10 Jan 1993
Outflow (cfs)	25,600[1]	26 Feb 1993
Water Surface Elevation (ft)	667.00[2]	26 Feb 1993
Storage (ac-ft)	2,808,960	26 Feb 1993

Notes:
1. Spillway Flow.
2. 6 ft above spillway crest.

Table 2-4
Frequency Perspective On
Painted Rock Dam Inflow
During Jan - Feb 1993 Floods

Time Frame (Days)	Inflow Volume (Ac-ft)	Return Period (Yrs.)
30 (7 Jan -7 Feb)	2,670,000	> 200
60 (7 Jan - 7 Mar)	3,960,000	>500

2-6. Operation of Other Projects above Painted Rock Dam.

While the significant inflow continued to inundate the Painted Rock Reservoir during the months of January and February, very little could be done on the upstream structures in order to prevent Painted Rock Dam from spilling.

During the first week of March, SRP reported that December through March precipitation in the 13,000 sq. mi. Salt River Project watershed resulted in outflows from the six dams located on the Verde/Salt complex. On the Verde system, storage was 9 percent above the planned storage. Roosevelt Dam which had been undergoing rehabilitation, had only one of its 2 spillways in operation. The other spillway was blocked by a construction coffer dam. On 1 March, SRP reported that March 1 storage for Roosevelt Dam was 25 percent above the planned storage.

On the Gila River, Coolidge Dam received significant inflows and started spilling on 11 January. Built and operated by the Bureau of Indian Affairs for agriculture, Coolidge Dam was undergoing safety modifications during this period of significant storms. The spillway discharge peaked on 20 January at 32,800 cfs. Peak WSE was 2,521.68 ft, more than 10 ft above the spillway crest elevation. Previous maximum spill from Coolidge Dam occurred in 1983 at 5,000 cfs. USBR who was managing the safety modification of the dam stated that a reservoir restriction of WSE 2,496.4 ft exists during the period of construction. Coolidge Dam spills which eventually entered Painted Rock Reservoir continued until the 2nd week of March.

On the Agua Fria River, heavy runoff from the January storms added 224,000 ac-ft to the Lake Pleasant Reservoir. On 9 February, the USBR started releasing from the New Waddell Dam which forms the Lake Pleasant reservoir. These releases were gradually increased up to 9,000 cfs. New Waddell Dam recently underwent reconstruction and was on its first year of filling, and the rapid rise in WSE substantially exceeded the USBR's criteria for filling the newly reconstructed dam; therefore, water had to be released rather than stored, hence the storage space behind New Waddell Dam was not used for flood control.

Table 2-5
Summary of COE's
Painted Rock Dam Operation
During Jan - Feb 1993 Floods

Date	Discharge (cfs)	Remarks
28 Jan - 31 Jan	12,500	To utilize max. d/s channel capacity.
1 Feb - 7 Feb	10,000	Prevent/minimize d/s damages.
8 Feb - 20 Feb	12,500	Additional rainfall caused more inflow into the dam.
21 Feb - 26 Feb	12,500	Spillway discharge begun. Maintained total outflow (from spillway and outlet gates) to 12,500 cfs.
27 Feb - 28 Feb	up to 26,000	Spillway flow. Max. reached 26,000 cfs.
1 Mar - 16 Mar	24,000	Total discharge (outlet and spillway) maintained at 24,000 cfs.
17 Mar - 8 Apr	20,000	Spillway flow ended. Gate discharge maintained at 20,000 cfs for repairs and re-opening of roads.
29 Apr - 26 May	10,000	Help USBR and WMIDD in flood fights.
21 May	0	Inspection of outlet works and tunnel. Outflow was back to 10,000 cfs at the end of the day.
27 May - 6 Jul	5,000	Inflow into the reservoir ended.
7 July -	2,200	Reconstruction of USBR's Main Outlet Drain Extension (MODE).

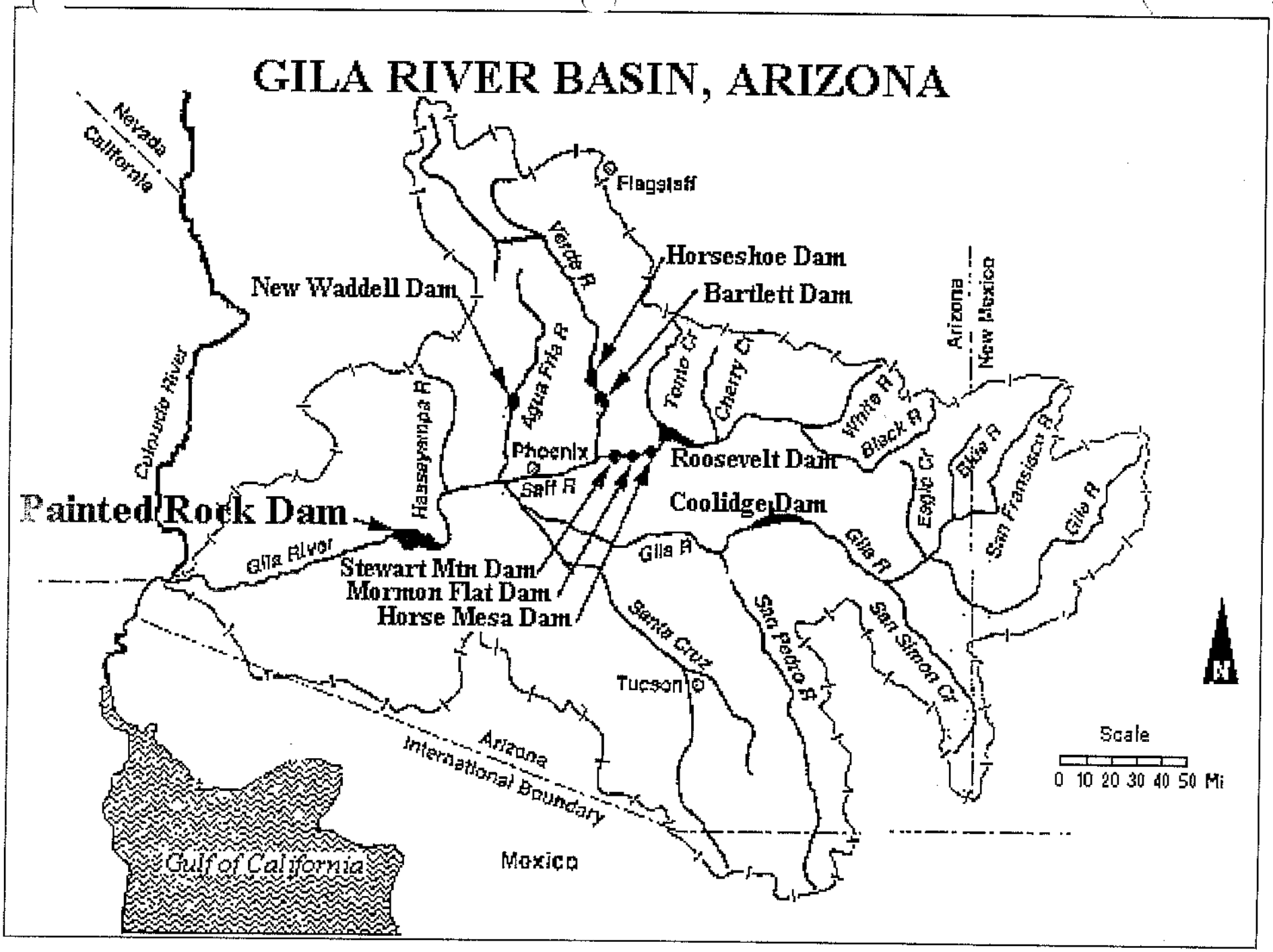

GILA RIVER BASIN, ARIZONA
Nevada
California
Flagstaff
Verde R
Horseshoe Dam
Bartlett Dam
New Waddell Dam
Arizona
New Mexico
Agua Fria R
Tonto Cr
Cherry Cr
White R
Black R
Colorado River
Hassayampa R
Phoenix
Salt R
Roosevelt Dam
Eagle Cr
Blue R
San Francisco R
Gila R
Painted Rock Dam
Coolidge Dam
Gila River
Gila R
Gila R
Stewart Mtn Dam
Mormon Flat Dam
Horse Mesa Dam
Santa Cruz
San Pedro R
San Simon Cr
Tucson
N
Scale
0 10 20 30 40 50 Mi
Arizona
International Boundary
Gulf of California
Mexico

Figure 2-1

Painted Rock Dam and Reservoir
Maricopa County, Arizona
PERTINENT DATA
APRIL 1993

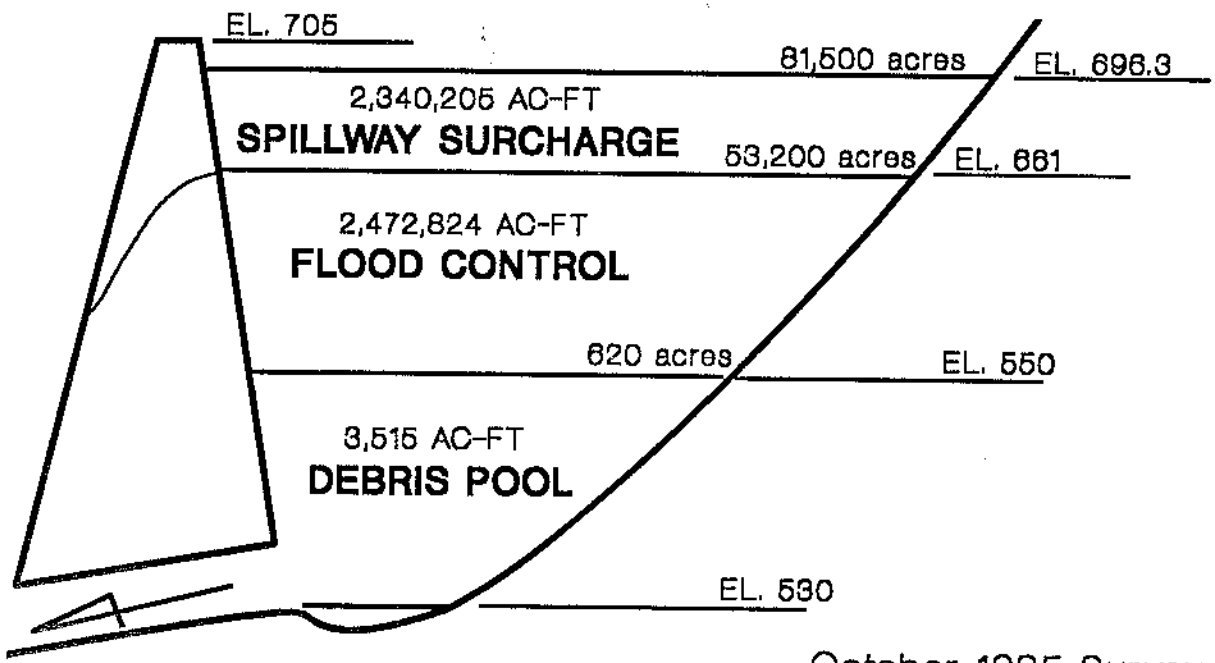
Stream System		Gila River
Drainage Area	sq. mi.	50,800
Reservoir:		
Elevation		
Streambed	ft., msl	524
Debris Pool	ft., msl	550
Flood Control Pool (Spillway Crest)	ft., msl	661
Spillway Design Surcharge level	ft., msl	696.3
Top of Dam	ft., msl	705
Area*		
Debris Pool	acres	620
Flood Control Pool (Spillway Crest)	acres	53,200
Spillway Design Surcharge Level	acres	81,500
Top of Dam	acres	89,600
Capacity*		
Debris Pool	ac-ft	3,515 (0.00**)
Flood Control Pool (spillway crest)	ac-ft	2,476,339 (.91**)
Spillway Design Surcharge Level	ac-ft	4,816,544 (1.79**)
Top of Dam	ac-ft	5,561,470 (2.05**)
Allowance for Sediment (50-yr)	ac-ft	200,000 (0.07**)
Dam: - Type		Earthfill
Height Above Original Streambed	ft	181
Top of Length (excluding saddle dike and spillway)	ft	4,780
Top Width	ft	20
Freeboard	ft	8.7
Spillway: - Type		Ungated, Broad-crested
Crest Length	ft	610
Design Surcharge	ft	35.3
Design Discharge	cfs	401,700
Outlets:		
Gates - type		Tainter
Number and Size		3 - 10'W X 18'H
Gate and Sill Elevation	ft., msl	530
Conduits		
Number and Size - Inside Diameter	ft	1 - 25
Length	ft	925
Maximum Capacity at Spillway Crest	cfs	30,480
Regulated Capacity at Spillway Crest	cfs	23,000
Reservoir Design Flood:		
Duration (Inflow)	days	18
Total Volume	ac-ft	2,800,000 (1.03**)
Inflow Peak	cfs	300,000
Spillway Design Flood		
Duration (Inflow)	days	18
Total Volume	ac-ft	7,680,000 (2.83**)
Inflow Peak	cfs	620,000
Historic Maximums		
Maximum Release	cfs	26,000
Date		2/27/93
Maximum Water Surface Elevation	ft., msl	667.00
Date		2/27/93

* Based on October 1985 survey

**Inches of runoff

Figure 2-2

PAINTED ROCK RESERVOIR
GILA RIVER BASIN, ARIZONA
REVISED: April 1993



October 1985 Survey

Figure 2-3

PLAN A - OUTLET GATE OPERATION SCHEDULE *
PAINTED ROCK DAM and RESERVOIR, GILA RIVER BASIN

Step No.	When reservoir water surface is between elevation	Gate setting for gates indicated**			Computed Discharge
		No. 1	No. 2	No. 3	
1	***530 - 550	0.0	0.0	0.0	0
2	550 - 554	2.7	2.7	2.7	2,350 - 2,600
3	554 - 558	2.5	2.5	2.5	2,430 - 2,650
4	558 - 563	2.2	2.2	2.2	2,360 - 2,575
5	563 - 568	2.1	2.1	2.1	2,470 - 2,660
6	568 - 577	1.8	1.8	1.8	2,300 - 2,570
7	577 - 583	1.7	1.7	1.7	2,440 - 2,600
8	583 - 589	1.6	1.6	1.6	2,450 - 2,600
9	589 - 591	1.5	1.5	1.5	2,440 - 2,480
10	591 - 602	3.0	3.0	3.0	4,710 - 5,140
11	602 - 603	2.9	2.9	2.9	4,980 - 5,015
12	603 - 614	6.0	6.0	6.0	9,665 - 10,415
13	614 - 618	5.8	5.8	5.8	9,960 - 10,215
14	618 - 626	11.9	11.9	11.9	19,530 - 20,490
15	626 - 635	11.3	11.3	11.3	19,550 - 20,530
16	635 - 640	10.8	10.8	10.8	19,690 - 20,200
17	640 - 648	11.9	11.9	11.9	22,090 - 22,950
18	648 - 657	11.4	11.4	11.4	22,060 - 22,950
19	****657 - 661.6	10.5	10.5	10.5	21,250 - 23,000
20	661.6 - 662.4	9.5	9.5	9.5	21,130 - 23,000
21	662.4 - 663.0	8.8	8.8	8.8	21,650 - 23,040
22	663.0 - 663.5	7.7	7.7	7.7	20,885 - 23,040
23	663.5 - 664.1	6.4	6.4	6.4	20,490 - 23,070
24	664.1 - 664.5	5.5	5.5	5.5	21,320 - 23,040
25	664.5 - 664.9	4.6	4.6	4.6	21,260 - 22,980
26	664.9 - 665.2	3.8	3.8	3.8	21,350 - 23,040
27	665.2 - 665.6	2.6	2.6	2.6	20,480 - 22,990
28	665.6 - 665.9	1.8	1.8	1.8	21,170 - 23,050
29	665.9 - 666.2	1.0	1.0	1.0	21,150 - 23,025
30	666.2 - 666.5	0.2	0.2	0.2	21,020 - 22,890
31	666.6 & above	0.0	0.0	0.0	spillway flow only

* Schedule applicable for rising or falling stages
** Gate openings were determined from the revised gate rating curve (dated JUNE 1982).
*** Gates may be 1/2 ft open between elevations 530 - 535 ft to pass low flows
**** Spillway crest elevation 661 ft. Computed discharge above this elevation includes spillway flow.

INSTRUCTIONS

1. **Communications with the District Office, existing.**

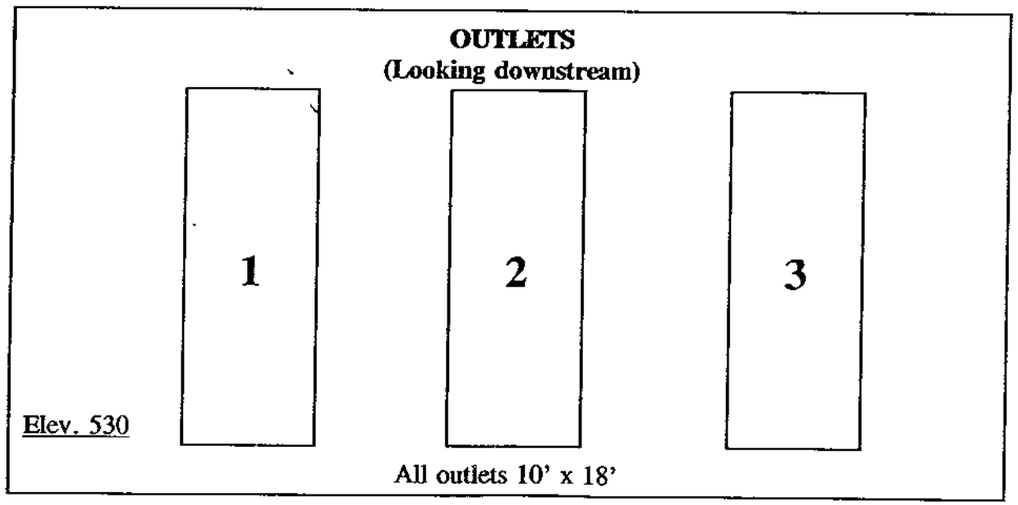
   a. Notify the Reservoir Operations Center when a gate change will be required according to the schedule.

   b. Notify the Reservoir Operations Center if unable to set gates as instructed.

2. **Communications with the District Office, interrupted.**

   a. Follow the gate operation schedule.

   b. If one or more of the gates cannot be operated, adjust the gates that are functioning so that the sum of the gate openings will equal the sum of the openings in the schedule.



NOTE: REVISION BASED ON JUNE 1982 GATE RATING CURVE.

REVISED APRIL 1993

Figure 2-4a

PLAN B - OUTLET GATE OPERATION SCHEDULE *
PAINTED ROCK DAM and RESERVOIR, GILA RIVER BASIN

Step No.	When reservoir water surface is between elevation	Gate setting for gates indicated **			Computed discharge
		No. 1	No. 2	No. 3	
1	***530 - 550	0.0	0.0	0.0	0
2	550 - 554	4.4	4.4	4.4	3,530 - 3,935
3	554 - 558	5.4	5.4	5.4	4,640 - 5,090
4	558 - 562	6.2	6.2	6.2	5,700 - 6,180
5	562 - 566	7.1	7.1	7.1	6,910 - 7,420
6	566 - 570	7.9	7.9	7.9	8,140 - 8,670
7	570 - 574	8.7	8.7	8.7	9,415 - 9,965
8	574 - 578	9.6	9.6	9.6	10,830 - 11,410
9	578 - 582	10.4	10.4	10.4	12,210 - 12,800
10	582 - 586	11.2	11.2	11.2	13,650 - 14,260
11	586 - 590	12.0	12.0	12.0	15,145 - 15,800
12	590 - 594	12.7	12.7	12.7	16,625 - 17,260
13	594 - 598	13.5	13.5	13.5	18,270 - 18,950
14	598 - 602	14.1	14.1	14.1	19,780 - 20,470
15	602 - 611	14.8	14.8	14.8	21,510 - 23,060
16	611 - 617	14.2	14.2	14.2	22,090 - 23,010
17	617 - 624	13.6	13.6	13.6	22,020 - 23,000
18	624 - 631.5	13.0	13.0	13.0	21,995 - 22,960
19	631.5 - 640	12.4	12.4	12.4	21,960 - 22,955
20	640 - 649.5	11.8	11.8	11.8	21,920 - 22,930
21	649.5 - 657	11.3	11.3	11.3	22,030 - 22,760
22	****657 - 661.6	10.5	10.5	10.5	21,250 - 23,000
23	661.6 - 662.4	9.5	9.5	9.5	21,130 - 23,000
24	662.4 - 663.0	8.8	8.8	8.8	21,650 - 23,040
25	663.0 - 663.5	7.7	7.7	7.7	20,885 - 23,040
26	663.5 - 664.1	6.4	6.4	6.4	20,490 - 23,070
27	664.1 - 664.5	5.5	5.5	5.5	21,320 - 23,040
28	664.5 - 664.9	4.6	4.6	4.6	21,260 - 22,980
29	664.9 - 665.2	3.8	3.8	3.8	21,350 - 23,040
30	665.2 - 665.6	2.6	2.6	2.6	20,480 - 22,990
31	665.6 - 665.9	1.8	1.8	1.8	21,170 - 23,060
32	665.9 - 666.2	1.0	1.0	1.0	21,150 - 23,025
33	666.2 - 666.5	0.2	0.2	0.2	21,020 - 22,890
34	666.5 & above	0.0	0.0	0.0	Spillway flow only

* Schedule applicable for rising or falling stages
** Gate openings were determined from the revised gate rating curve (dated June 1982).
*** Gates may be 1/2 ft open between elevations 530 - 535 ft to pass low flows
**** Spillway crest elevation 661 ft

INSTRUCTIONS

1. **Communications with the District Office, existing.**

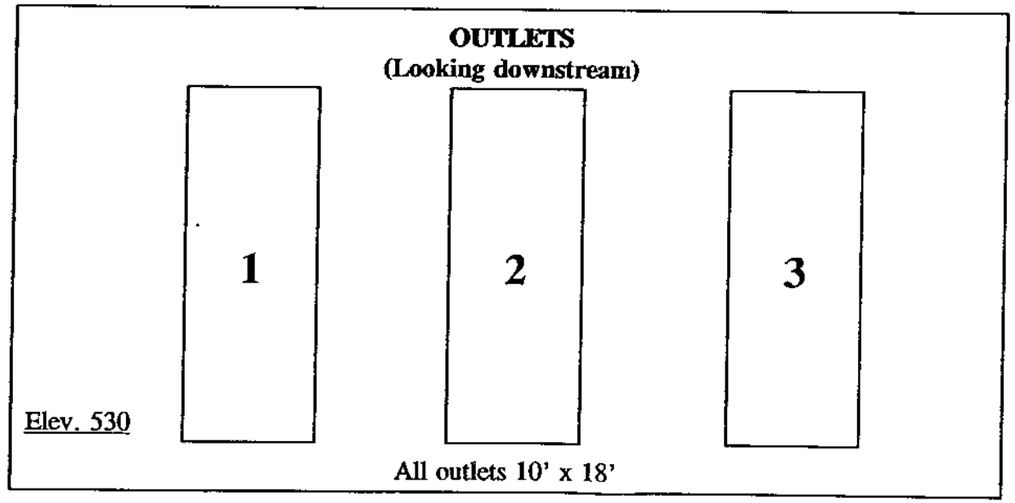
   a. Notify the Reservoir Operations Center when a gate change will be required according to the schedule.

   b. Notify the Reservoir Operations Center if unable to set gates as instructed.

2. **Communications with the District Office, interrupted.**

   a. Follow the gate operation schedule.

   b. If one or more of the gates cannot be operated, adjust the gates that are functioning so that the sum of the gate openings will equal the sum of the openings in the schedule.



NOTE: REVISION BASED ON JUNE 1982 GATE RATING CURVE.

REVISED APRIL 1993

Figure 2-4b

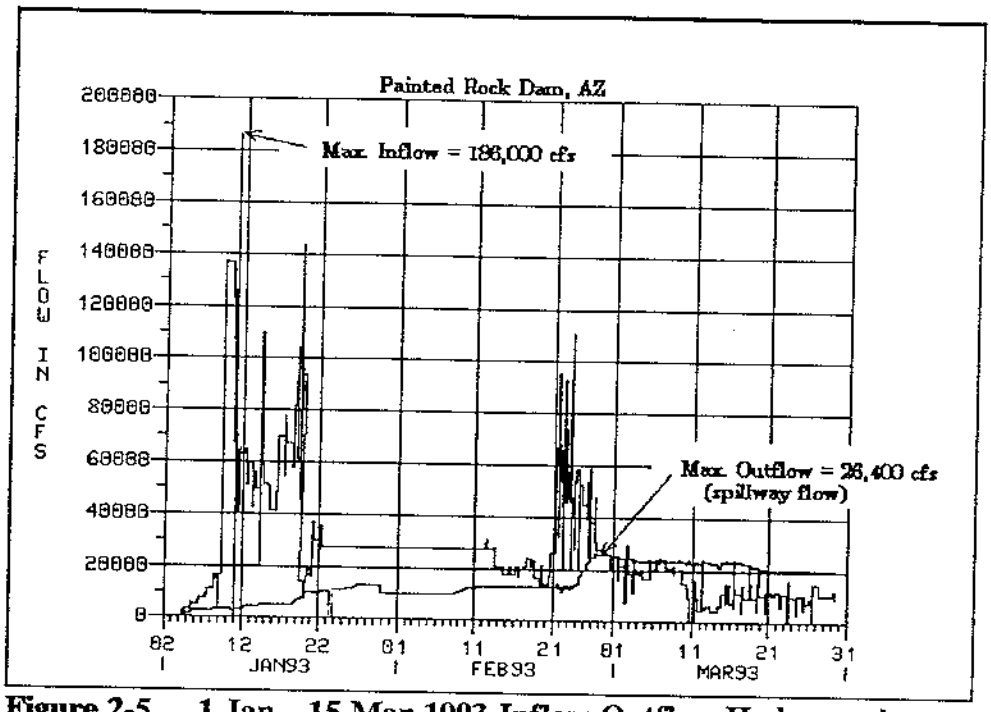


Figure 2-5. 1 Jan - 15 Mar 1993 Inflow-Outflow Hydrograph at Painted Rock Dam.

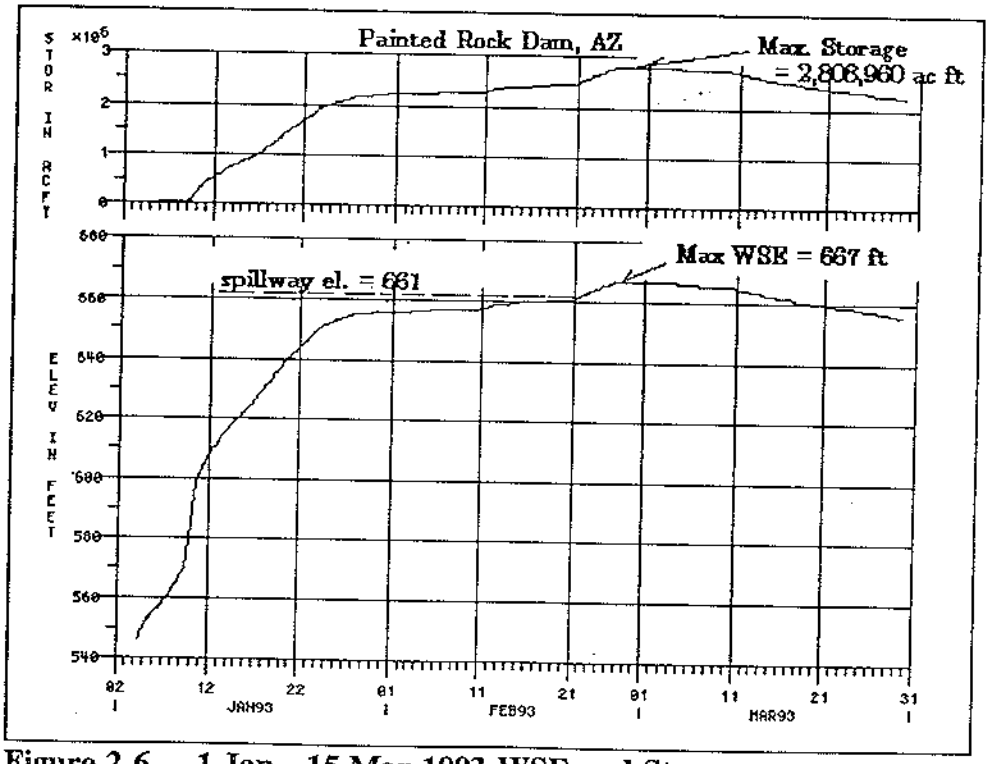


Figure 2-6. 1 Jan - 15 Mar 1993 WSE and Storage at Painted Rock Dam.