US Army Corps
of Engineers
Los Angeles District

WATER CONTROL MANUAL

PRADO DAM & RESERVOIR
SANTA ANA RIVER, CALIFORNIA

SEPTEMBER 1994

WINGERD/KM/28510

CESPD-ED-W (CESPD-ED-W/8 Jan 92) 3rd End WINGERD/272-8510
SUBJECT: Updating Prado Dam and Reservoir Water Control Manual

Cdr, HQUSACE, Washington, DC 20314-1000 15 April 1992

For Commander, South Pacific Division, ATTN: CESPD-ED-W

for SULLIVAN
CECW-EH-W

1. Reference memorandum, CECW-EH-W, 19 April 91, subject: Interim Guidance for implementing Section 310(b), Water Resources Development Act of 1990.

2. To reiterate the referenced requirements, the Corps must: (a) present the proposed Water Control Plan (WCP) to the public, (b) describe the impacts of the WCP, and, (c) receive comments from the public.

EIKER
CECW-EH

3. My understanding is that the Prado Dam Water Control Conservation Study includes a series of alternative WCPs, and this information was presented at the public meeting. Please clarify if a preferred WCP was presented at the public meetings and is this the same WCP included in the revised manual. If not, the referenced requirements have not been satisfied.

McPHERSON
CECW-E

FOR THE DIRECTOR CIVIL WORKS:

BARBER
CECW-E

PAUL D. BARBER, P.E.
Chief, Engineering Division
Directorate of Civil Works

DEPARTMENT OF THE ARMY
SOUTH PACIFIC DIVISION, CORPS OF ENGINEERS
630 Sansome Street, Room 720
San Francisco, California 94111-2206

REPLY TO
ATTENTION OF:

CESPD-ED-W (1110-2-240)

8 JAN 1992

MEMORANDUM FOR CDR, USACE, (CECW-EH-W), 20 Massachusetts Ave. NW, WASH DC 20314-1000

SUBJECT: Updating Prado Dam and Reservoir Water Control Manual

1. Enclosed is the Updated Prado Dam and Reservoir Water Control Manual for file purposes.

2. If you have any question on the above, please contact Mr. Jack Hsu at FTS 465-1550 or commercial (415) 705-1550.

Encl

JAY K. SOPER
Director, Engineering

CHf
Received
15 Jan 1992

CECW-EH-W (CESPD-ED-W/8 Jan 92) 1st End WINGERD/272-8510
SUBJECT: Updating Prado Dam and Reservoir Water Control Manual

Cdr, HQUSACE, Washington, DC 20314-1000 17 March 1992

FOR Commander, South Pacific Division, ATTN: CESPD-ED-W

1. Reference memorandum, CECW-EH-W, 19 Apr 91, subject: Interim Guidance for Implementing Section 310.(b), Water Resources Development Act of 1990.

2. Discussions with Jack Hsu of your staff confirmed that this is a new water control manual, and that public meetings were <u>not</u> held as required by the above reference.

3. Per the above reference a water control manual needs to be sent to this office for review and comments prior to approval by the division commander.

FOR THE DIRECTOR OF CIVIL WORKS:

Encl wd

JOHN A. McPHERSON, P.E.
Acting Chief, Engineering Division
Directorate of Civil Works

CESPD-ED-W (CESPD-ED-W/8 Jan 92) 2nd End Bigornia/ah/705-2415

SUBJECT: Updating Prado Dam and Reservoir Water Control Manual

DA, South Pacific Division, Corps of Engineers, 630 Sansome Street, Room 720, San Francisco, CA 94111-2206 31 MAR 1992

FOR CDR USACE (CECW-EH-W), 20 Massachusetts Ave., NW, WASH DC 20314-1000

1. Reference memorandum, CECW-EH-W, 19 Apr 91, subject: Interim Guidance for implementing Section 310. (b), Water Resources Development Act of 1990.

2. As discussed between Mr. Earl Eiker, CECW-EH-W and Mr. Jaime Merino, CESPD-ED-W, it has been determined that the public meetings held during the development of the Prado Dam Water Conservation Study satisfy the requirements of the above reference.

3. Request review and comment on the subject water control manual that was transmitted with the original correspondence on 8 January 1992. Please forward comments to Mr. Boni Bigornia, CESPD-ED-W, NLT 15 April 1992.

JAY K. SOPER
Director, Engineering

WATER CONTROL MANUAL

PRADO DAM AND RESERVOIR
SANTA ANA RIVER, CALIFORNIA

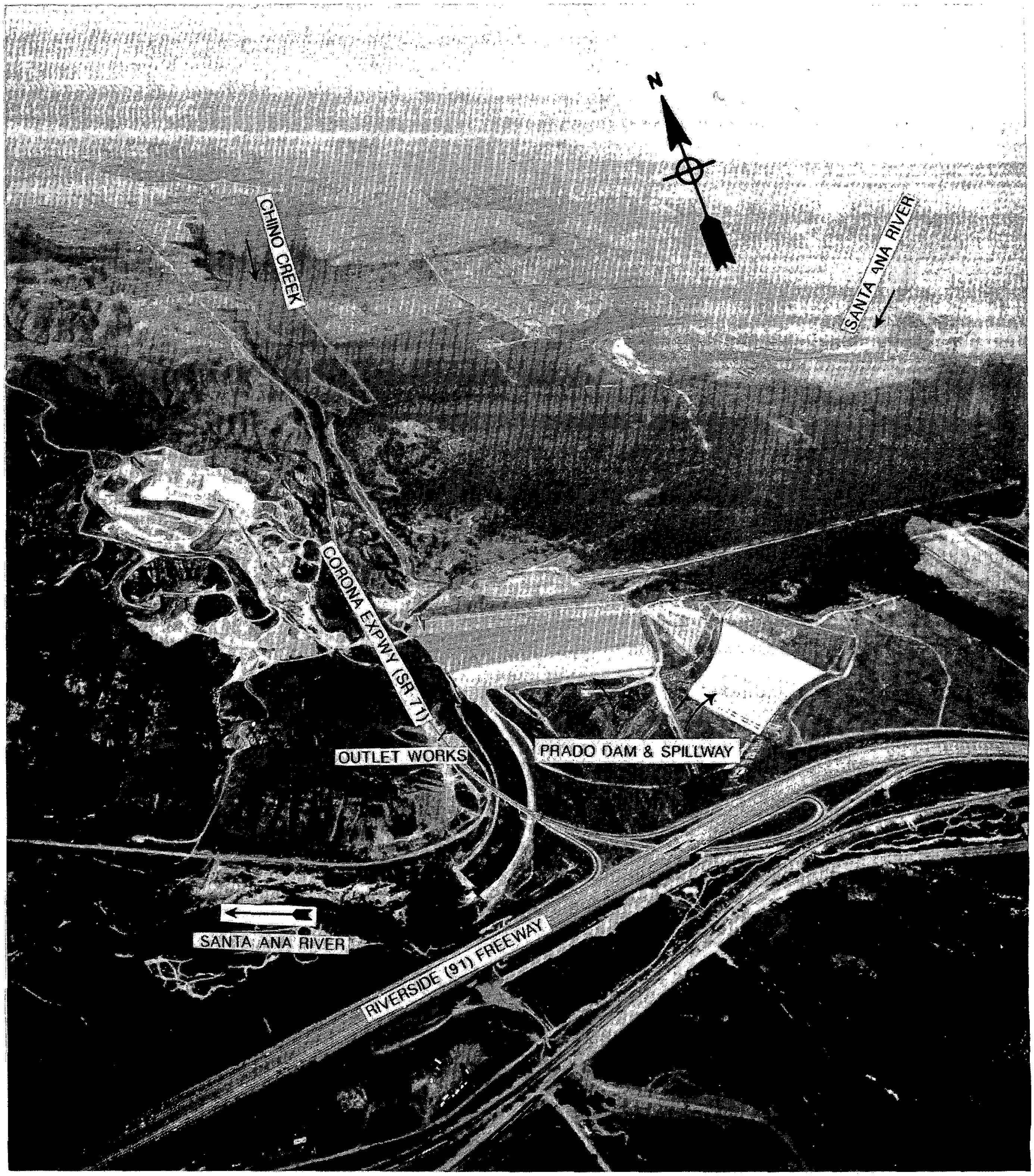
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

September, 1991

Prepared by:

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Reservoir Regulation Section
CESPL-ED-HR



Aerial Photograph of Prado Dam and Reservoir

NOTICE TO USERS OF THIS MANUAL

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

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise, contact can be made by telephone to the U.S. Army Corps of Engineers, Los Angeles District Office, Reservoir Regulation Section at (213) 894-4756. During non-flood periods the contact can be made during regular business hours (0730-1600 Monday through Friday), during flood-events the office is staffed 24 hours a day, 7 days a week.

WATER CONTROL MANUAL

PRADO DAM AND RESERVOIR
SANTA ANA RIVER, CALIFORNIA

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LIST OF ABBREVIATIONS

ac-ft	Acre-feet
ALERT	Automated Local Evaluation in Real-Time telemetry system
API	Antecedent Precipitation Index
AT&SF	Atchison Topeka and Santa Fe Railroad
BLM	U.S. Bureau of Land Management
cfs	Cubic feet per second
CRWQCB	California Regional Water Quality Control Board
DO#	USGS Downstream Order Number
DSS	HEC Data Storage System
DWR	State of California Department of Water Resources
EM	Engineering Manual
EOC	Emergency Operations Center of the U.S. Army Corps of Engineers (Construction-Operations Division)
EPA	U.S. Environmental Protection Agency
ER	Engineering Regulation
ETL	Engineering Technical Letter
ft.	Feet
ft/mi	Feet per mile
GDM	General Design Memorandum
HEC	U.S. Army Corps of Engineers Hydrologic Engineering Center
HEC-1F	Stream Flow Forecast Computer Model
HEC-5	Simulation of Flood-Control and Conservation Systems Computer Model
LAD	U.S. Army Corps of Engineers, Los Angeles District
LATS	Los Angeles Telemetry System
LBVI	Least Bell's vireo (*Vireo bellii pusillus*)
mm	Millimeter
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OCE	Office of the Chief of Engineers
OCEMA	Orange County Environmental Management Agency
OCWD	Orange County Water District
OCFCD	Orange County Flood Control District
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMS	Probable Maximum Storm
QPF	Quantitative Precipitation Forecast
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
RCFCWD	Riverside County Flood Control and Water District
ROC	Reservoir Operations Center (LAD Engineering Division)
SARDCO	Santa Ana River Development Company

SARI	Santa Ana Regional Interceptor
SARRT	Santa Ana River Real-Time Water Control System
SAVI	Santa Ana Valley Irrigation
SAWPA	Santa Ana Watershed Project Authority
SPF	Standard Project Flood
SPS	Standard Project Storm
STORET	EPA's Storage and Retrieval System
TDS	Total Dissolved Solids (mg/l)
WDIS	State of California Water Data Information System
WSE	Water Surface Elevation

I - INTRODUCTION

1-01 Authorization. This water control manual is prepared pursuant to the requirements set forth in the Code of Federal Regulations, Title 33, Part 208.11, subparagraph d-4, entitled, "Water Control Plan and Manual."

The authority and directives for the preparation and publication of this manual are contained in the following U.S. Army Corps of Engineers publications:

Engineering Technical Letter-ETL 1110-2-251: Engineering and Design, Preparation of Water Control Manuals; dated 14 March 1980.

Engineering Regulation-ER 1110-2-240: Engineering and Design, Water Control Management; dated 8 October 1982.

Engineering Manual-EM 1110-2-3600: Engineering and Design, Management of Water Control Systems; dated 30 November 1987.

The chain of correspondence leading to approval of this manual is included in Exhibit H.

1-02 Purpose and Scope. The purpose of the manual is to provide current information about the dam and reservoir, the regulating policy, and a description of the organizations responsible for collecting data and regulating the reservoir. This Manual contains (1) a brief description of the project and its history, (2) a description of the watershed characteristics, (3) the data collection and communications network, (4) a revised reservoir regulation schedule, and (5) a description of the U.S. Army Corps of Engineers, Los Angeles District's (LAD) organization for reservoir regulation and operation.

The following issues directly affect the operation of Prado Dam and are addressed in this water control manual: (1) flood control, (2) water supply, (3) recreational, (4) environmental, and (5) commercial issues. Because Prado Dam does not provide hydroelectric power or aid in navigation, these topics are not discussed.

1-03 Related Manuals and Reports. Manuals and reports relevant to Prado Dam, Prado Reservoir, the drainage areas above and below Prado Dam, and significant hydraulic structures within these drainage areas are listed in Plate 1-01. This list is not exhaustive and is only meant to provide information on key reports and manuals. A more comprehensive list of manuals and reports would include material available from other agencies such as the: U.S. Geological Survey (USGS), Orange County Environmental Management Agency (OCEMA), Orange County Water District (OCWD), and others.

1-04 **Project Owner**. Prado Dam and the reservoir lands behind the dam (sometimes referred to as the Prado Flood Control Basin) are owned or otherwise controlled by the Federal Government. The LAD is charged with the responsibility for the regulation, operation, and maintenance of the project.

1-05 **Operating Agencies**. Prado Dam is operated by personnel from the LAD. The dam is staffed by a dam tender who is on duty throughout the year, Monday through Friday, during regular business hours. The dam tender does not live at the dam site. During flood control operations, Prado Dam is manned 24 hours a day. Staffing of dam tenders is the responsibility of the Operations Branch (CESPL-CO) of the LAD. However, it is the responsibility of the Reservoir Regulation Section (CESPL-ED-HR) of the LAD to issue operating instructions to the dam tender. The Reservoir Regulation Section, therefore, maintains a staff of water control managers and operates a Reservoir Operations Center (ROC) for this purpose.

1-06 **Regulating Agencies**. The LAD is solely responsible for the regulation of Prado Dam. The LAD coordinates its management efforts with other federal, state and local agencies which are affected by impoundments within the reservoir control basin or releases from Prado Dam. These include, but are not limited to:

> **U.S. Bureau of Land Management (BLM)**, which regulates the mineral rights of reservoir lands held in fee by the U.S. Government.
>
> **California State Department of Fish and Game**, which has regulatory responsibility for fishing and hunting activities as well as for protecting habitat and fauna within the basin.
>
> **U.S. Fish and Wildlife Service (USFWS)**, which is responsible for the conservation, protection and enhancement of fish, wildlife, and their habitats.
>
> **San Bernardino County** and **Riverside County**, which operates parks and recreational facilities within the basin.
>
> **City of Corona**, which operates a park, a general aviation airport, and a wastewater reclamation plant and percolation ponds in the southeastern portion of the reservoir.

Orange County Water District (OCWD), which owns land within the basin and operates ground water recharge facilities within and adjacent to the Santa Ana River, downstream of Prado Dam.

Orange County Environmental Management Agency (OCEMA), which is responsible for maintenance of the Santa Ana River channel within Orange County.

Northwest Mosquito Abatement District. Mosquito abatement within the Prado reservoir area falls within the jurisdiction of this agency.

1-07 Public Coordination Draft copies of this Water Control Manual were sent on June 19, 1990 to OCEMA and OCWD, the primary local agencies responsible for flood control and water conservation, respectively, for review and comment. Comments received from these agencies have been incorporated into the manual.

On November 14, 1990 a public meeting was held on the Draft EIS for the Prado Dam Water Conservation Study. The base condition for the water conservation study, which was presented at the public meeting, is essentially the Water Year 1990 Water Control Plan presented in this manual.

The EA prepared for this water control manual underwent a 30 day public review period during January 1991. A copy of the resulting FONSI is included in Appendix G.

II - DESCRIPTION OF PROJECT

2-01 Location. Prado Dam is located on the lower Santa Ana River, approximately 30.5 miles upstream of the Pacific Ocean. The dam is in Riverside County, California approximately 2 miles west of the City of Corona. Portions of the reservoir are in Riverside County and San Bernardino County. The Santa Ana River watershed has an area of 2,450 sq-mi. Ninety-two percent of the watershed (i.e., 2,255 sq-mi) is located upstream of Prado Dam (Plate 2-01).

2-02 Purpose. Prado Dam serves as the principal regulating structure on the Santa Ana River. The original project purposes were to prevent flooding in northwestern Orange County and to provide water conservation for Orange County.

With passage of the Flood Control Act of 1944 (PL 78-534), non-federal participation in the administration of recreational facilities was initiated at Corps Projects. With passage of the Fish and Wildlife Coordination Act (PL 85-62) and the National Environmental Policy Act (NEPA) (PL 91-190), the Corps is required to consider the environmental impacts of new projects and changes to existing projects. Consultation and coordination with such agencies as the U.S. Fish and Wildlife Service and State Wildlife agencies are conducted in preparation of Environmental Impact Statements and Environmental Assessments.

2-03 Physical Components. Prado Dam consists of an earth-filled embankment, outlet works, and a detached reinforced concrete spillway. A general plan of the dam and spillway is shown in Plate 2-02. A brief description of the various features of Prado Dam follows.

a. Embankment. Prado Dam is a compacted multi-zoned earth-filled embankment with a crest length of approximately 2,200-ft, and a height of about 106-ft above the original stream bed (Plate 2-03). The top of the embankment is 30-ft wide and paved with asphaltic concrete, forming a roadway across the dam. The upstream face of the embankment has a slope of 1V on 3H for its lower 50-ft, and a slope of 1V on 2.5H for the remaining upper 56-ft. The downstream face of the embankment has a slope of 1V on 2.5H for the top 30-ft, and a 1V on 6H below elevation 495.0-ft. The upstream slope is revetted with a layer of 12-in. stone over 6-in. bedding material (Photo 2-1) and the downstream slope is covered with a 12-in. thick blanket of gravel.

b. Outlet Works. The outlet works are located in the west abutment of the dam and consist of (1) an approach channel, (2) a 195-ft long intake structure, (3) a 591-ft long double box conduit, and (4) a 366-ft long rectangular concrete outlet channel

(Plate 2-04a). The gated outlet discharge curves are shown in Plate 2-06a-d

(1) Approach Channel. The approach channel to the outlet works is located in the west abutment of the dam and is of irregular shape and variable width, with side slopes and invert of paved rock. A log boom is located upstream of the outlet works to prevent floating debris from entering the outlet works.

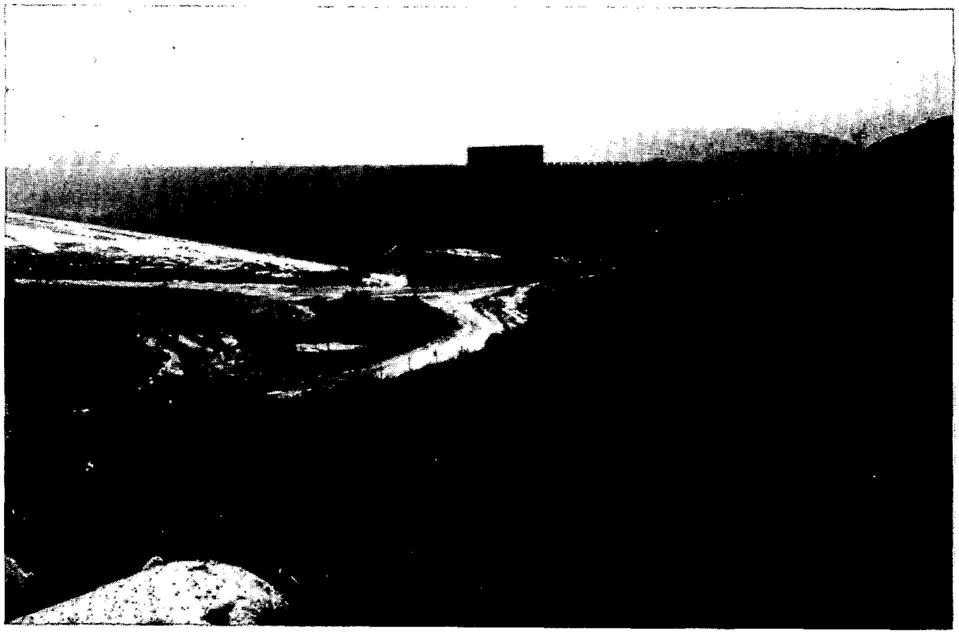

Photo 2-1: Prado Dam - Upstream Embankment

(2) Intake Structure. The intake structure is formed by two gravity-type concrete walls and a reinforced concrete invert (invert elevation is 460.0-ft). The center portion of the intake structure is divided into six bays by five concrete piers (Plate 2-04b). A 7-ft wide by 12-ft high cable operated tractor gate is at the downstream end of each bay (Plate 2-04c). On each side of the intake structure is a 5.5-ft diameter ungated conduit. Both ungated outlets have been permanently sealed with a collar and steel cap bolted in place. The west ungated outlet was sealed in October 1946, and the east ungated outlet was sealed in May 1969. A 90-ft long transition section joins the six gated bays and two ungated conduits with the double box conduit.

At the request of the Orange County Flood Control District (OCFCD), a 5-ft diameter steel pipe encased in reinforced concrete was placed beneath the double box conduit. The steel pipe was originally used to collect groundwater from under the reservoir and pass it under the dam to the downstream channel. This scheme was abandoned and in 1981 rights for use of the pipe were transferred to SAWPA which currently uses it to carry brine and industrial wastes from Riverside and Chino to a wastewater treatment facility in Fountain Valley. This wastewater line is known as the Santa Ana Regional Interceptor or SARI Line.

The trash racks, located in front of each bay, can only be removed when the reservoir is dry. A crane must be brought into the basin to remove them. Photo 2-2 shows the intake structure and control tower.

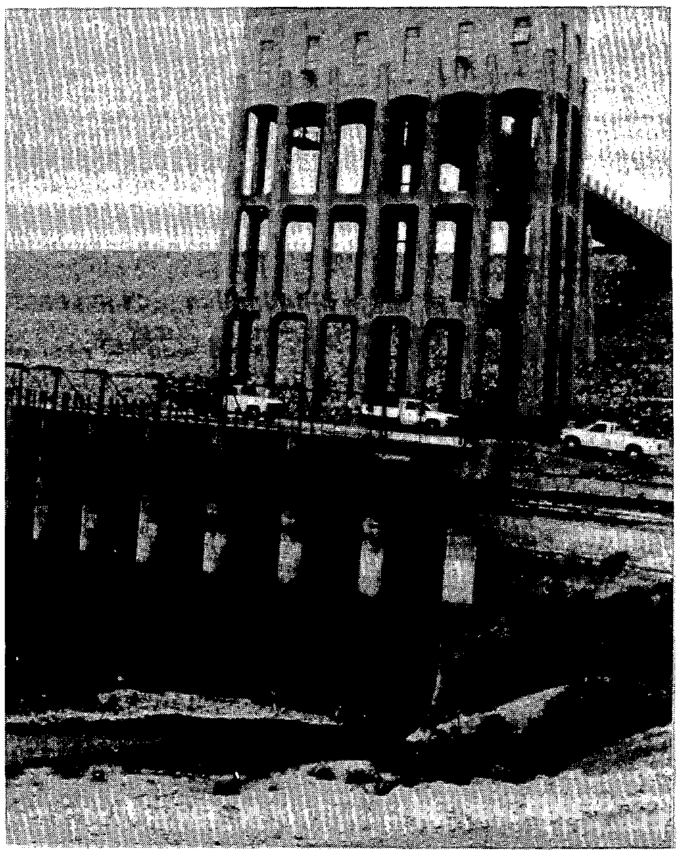

Photo 2-2: Prado Dam - View of the approach channel and intake structure

(3) <u>Double Box Conduit</u>. The double box conduit consists of two box conduits, each being 13.5-ft high by 13.5-ft wide. The maximum design capacity of each box conduit is 8,500 cfs (Plate 2-06d).

(4) **Outlet Channel**. The outlet channel consists of (a) a rectangular channel, (b) a transition chute, and (c) a stilling basin (Photo 2-3).

Photo 2-3: Prado Dam - Outlet Channel

(a) **Rectangular Channel**. The rectangular section is 126-ft long and 31-ft wide, with side walls that are 18.5-ft high. The invert elevation is 459.0-ft at the north end and 457.7-ft at the south end.

(b) **Transition Chute**. The transition chute is 80-ft long, having a variable width which increases from 31- to 70-ft. The side walls vary in height from 18.5-ft at the upper end to 33-ft at the lower end, and the invert slopes from elevation 457.7-ft at the north end to elevation 439.0-ft at the south end. A battery of eight 3-ft high by 3.5-ft wide reinforced concrete baffle piers extends across the channel at elevation 439.0-ft.

(c) Stilling Basin. The stilling basin is 120-ft long, having a tapered cross section which increases in width from 70-ft to approximately 76-ft. Two staggered rows of baffle piers, that are 8-ft long by 3.5-ft wide and 5-ft high, are spaced at 3.5-ft intervals across the basin at elevation 439.0-ft. The baffle piers insure the formation of a hydraulic jump in the basin. The last 50-ft of the basin floor is paved with derrick stone, the voids of which have been grouted. The design capacity of the stilling basin is 10,000 cfs.

The stilling basin, which was designed to dissipate energy from flows of up to 10,000 cfs, normally only passes flows which range from 200 to 2,000 cfs. After years of passing these "low" flows, sediment settles and begins to fill the stilling basin. To ensure that the stilling basin can properly dissipate large flood control releases, the basin is periodically dredged. During May of 1989 the LAD had the stilling basin dredged to both ensure the proper functioning of the basin and to facilitate inspection of the stilling basin.

c. Control Tower. The control tower located on top of the inlet structure is of rigid frame design and consists of reinforced concrete columns and horizontal struts (Photo 2-4 and Plate 2-04b). The frame is constructed as an integral part of the intake structure. The control tower rises up 66-ft from the top of the intake structure at elevation 500.0-ft to the finished floor of the control house at elevation 566.0-ft. The vent stacks for the gate structure consist of two 3-ft diameter pipes supported by steel cross arms which extend to the adjacent center column of the tower. The overall height of the vents is 81-ft.

d. Control House. The control house, constructed of reinforced concrete, forms an integral part of the control tower. The overall outside dimensions are 67-ft by 19-ft with a height of approximately 17.5-ft. The finished floor elevation is 566.0-ft. The structure contains the gate hoists, stand-by generator, communications equipment, and traveling crane. Access from the dam to the control house is provided by a steel girder bridge (Photo 2-4).

e. Spillway. The detached spillway is constructed through a bluff forming the east abutment (Plate 2-05 and Photo 2-5). The approach channel to the spillway has a bottom width of 1,063-ft and side slopes of 1V on 2H at an invert elevation of 530.0-ft. The downstream 85-ft of the approach channel, near the ogee section, has concrete gravity walls that range from 5- to 31-ft in height. The spillway control section is a reinforced concrete ogee with a crest length of 1,000-ft (spillway crest is at elevation 543.0-ft). The spillway channel is a reinforced concrete trapezoidal section, varying in width from 1,000-ft at the ogee crest to 660-ft at the lower end. The face of the 1,147-ft long spillway channel has a slope of 4V on 1H. The spillway terminates with a 190-ft long chute with a flip bucket. To prevent undermining of the flip bucket, a concrete crib cutoff wall, about 92-ft in depth, was provided at the end of the spillway chute under the flip bucket. A discharge curve for the entire operating range of the spillway is shown on Plate 2-07.

f. <u>Flood Control Basin</u>. The March 1980 survey is the latest available source of reservoir elevation-storage information. Area-capacity relationships for Prado Dam are shown in tabular and graphical form on Plates 2-08 and 2-09, respectively. At spillway crest (WSE 543-ft) the reservoir covers 6,630 acres and has a gross capacity of 196,235 ac-ft.

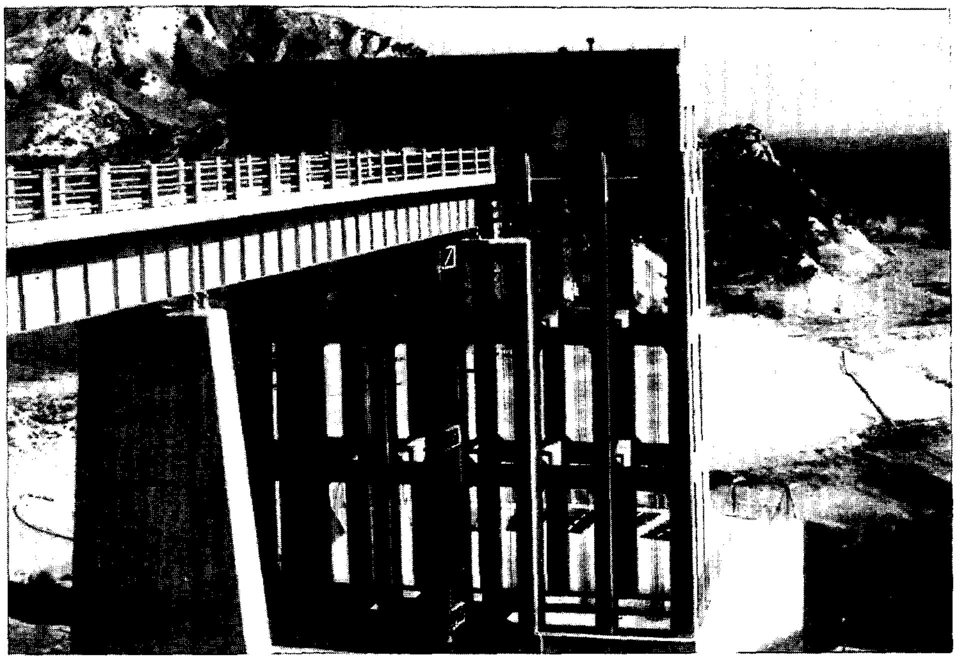

Photo 2-4: Prado Dam - Control Tower

2-04 <u>Related Control Facilities</u>. There are currently four dams within the Santa Ana River watershed which provide some degree of flood control. Prado Dam, San Antonio Dam, and Carbon Canyon Dam are owned and operated by the U.S. Army, Corps of Engineers, LAD. All of the allocated storage at these three facilities is solely for flood control purposes. The fourth dam is the Villa Park Dam which is owned and operated by the OCEMA. The storage at this facility has been allocated for both flood control and water conservation proposes. Exhibit B contains Pertinent Data Sheets for San Antonio, Carbon Canyon, and Villa Park Dams. A pertinent data sheet for Prado Dam is located on the inside front cover of this manual. In addition to these four dams, there are over 100 other water storage facilities within the Santa Ana River watershed having storages which range from 5 ac-ft to 182,000

Photo 2-5: Prado Dam - Spillway

ac-ft. These other facilities affect the flow of the Santa Ana River, but they do not provide any control of flood flows. Table 2-1 is a summary of the major water storage facilities within the Santa Ana River Watershed. Plate 2-10 is a schematic of the Santa Ana River Watershed showing the relative locations of the listed facilities.

Prado Dam is the primary flood control facility within the Santa Ana River Watershed. During flood events, Prado Dam is operated as a component of the Santa Ana River flood control system. Using real-time telemetry, and weather and runoff forecasts, releases from Prado Dam are coordinated with releases from San Antonio Dam and Carbon Canyon Dam to attain maximum flood protection for areas below these facilities.

2-05 Real Estate Acquisition. Prado Reservoir encompasses an area of just under 9,000 acres from the invert at WSE 460-ft to the take line at elevation 556-ft. At the time of construction the guidelines regarding land acquisition required that the government attempt to acquire all lands in fee title up to the spillway crest at 543-ft and attempt to acquire flowage easements for lands between the spillway and the take line at WSE 556-ft. The results of the land acquisition resulted in the government acquiring 6,577 acres in fee title and 3,059 acres of flowage easements. A total of 9,636 acres, therefore, are under some form of Federal Government control. Plate 2-11 shows the 556-ft contour (original take line) and various existing land uses within and adjacent to the reservoir.

Table 2-1

Major Water Storage Facilities
Within the Santa Ana River Watershed

Location	Drainage Area (sq-mi)	Storage (ac-ft)	Flood Control Capability
Prado Dam	2,255.0	196,235	Yes
San Antonio Dam	27.0	7,703	Yes
Carbon Canyon Dam	19.3	6,614	Yes
Villa Park Dam	20.4	16,044	Yes
Big Bear Lake	38.0	63,381	No
Railroad Canyon Res.	641.0	11,459	No
Lake Elsinore	52.0	122,500	Overflow/ Pumped*
Miller Basin	14.2	23	No
Santiago Dam	63.2	25,000	No
Santiago Cr. Gravel Pits	9.1	13,299	No
Lake Mathews	40.0	182,804	No
Lake Hemet	67.0	14,000	No
Lake Perris	10.0	100,000	No

* Lake Elsinore acts as a natural sump for the San Jacinto River sub-basin. Flows from Lake Elsinore only occur during major flood events, when the lake is either pumped or actually overflows into Temescal Creek.

2-06 <u>Public Facilities</u>. Since passage of the Flood Control Act of 1944 (PL 78-534) the Corps has encouraged non-Federal participation in the administration of recreational opportunities provided at Corps projects. The Corps has entered into leases which permit state and local development and administration of recreation areas at Civil Works Projects. In addition to recreational development, public utilities and private businesses have been located within the reservoir. Table 2-2 is a listing of recreational facilities and Table 2-3 is a list of other noteworthy public and private facilities within the Prado Flood Control Basin.

Table 2-2

Recreational Facilities at Prado Reservoir

Owner or Lease Holder/Facility
San Bernardino County
El Prado Golf Course
Tiro Shooting Range
Prado Recreation Inc.
Prado Regional Park
Riverside County
Splatter S. Duck Club Building
Prado Basin Park
City of Corona
Corona Municipal Airport
Butterfield Park
Orange County Water District
Raahauge's Hunting Club

Table 2-3

Noteworthy Public and Private Facilities at Prado Reservoir

Facility
Prado Petroleum Co. Oil Wells
City of Corona Wastewater Percolation Ponds
Chino Basin Water District Wastewater Treatment Plant #2
City of Corona Wastewater Treatment Plant

III - HISTORY OF PROJECT

3-01 Authorization. The Flood Control Act of June 22, 1936 (PL 74-738), authorized the construction of reservoirs and related flood control works for the protection of the metropolitan area of Orange County, California. Section 5 of the Act reads:

> SEC. 5. That pursuant to the policy outlined in sections 1 and 3, the following works of improvement, for the benefit of navigation and the control of destructive flood waters and other purposes, are hereby adopted and authorized to be prosecuted in order of their emergency as may be designated by the President...

The Act reads further:

> SANTA ANA RIVER,CALIFORNIA
>
> Construction of reservoirs and related flood control works for protection of metropolitan area in Orange County, California, in accordance with plans to be approved by the Chief of Engineers on recommendation of the Board of Engineers for Rivers and Harbors, at an estimated construction cost not to exceed $13,000,000; estimated cost of lands and damages, $3,500,000.

On March 12, 1937, the Chief of Engineers approved the report entitled "Definite Project for the Construction of Reservoirs and Related Flood Control Works in Orange County, California" which included Prado Dam. Paragraph 5 of the definite project report gives the following general description of the approved project:

> 5. General: The Prado Retarding Basin is located on the Santa Ana River in Riverside County, California, about two miles north of the Orange County line. Its primary purpose is flood protection for those residents of Orange County whose lands have previously been subject to the destructive action of uncontrolled flood waters. There is also a water conservation feature to be utilized in connection with the automatic release of flood waters. Due to the high absorptive qualities of the material underlying the river bed below the dam, and the large natural underground storage characteristics of the valley, it will be possible through automatic regulation to conserve a large portion of the flood flows heretofore wasted to the ocean.

And paragraph 9 reads further:

> ... The storage capacity of the retarding basin below spillway crest elevation is 180,000 acre-feet. The Orange County Flood Control District has estimated that the practical capacity of the Santa Ana River below Prado Retarding Basin is approximately 6,000 cfs. In order to limit the outflow to this quantity it is necessary to provide the storage capacity of 180,000 acre-feet with the retarding basin operated for flood control and conservation as described below. The Orange County Flood Control District has assumed that the channel downstream from the proposed Prado Dam site will absorb by percolation flows of from 1,000 to 2,000 cfs. It was further assumed that the

retarding basin could safely be operated for conservation to elevation 507.5 (capacity of 54,000 acre-feet). The remaining net storage capacity of 126,000 acre-feet is to be reserved for flood control. It is proposed to secure the conservation operation by omitting the gate on one of the 4 ft. by 8 ft. conduits.

With the authorization found in the Flood Control Act of 1936 and in accordance with the definite project report approved by OCE on March 12, 1937, Prado Dam was constructed in accordance with the May 1938 report entitled "Analysis of Design - Prado Dam". Prado Dam was completed in April 1941 at a cost of about $9,450,000.

3-02 Planning & Design.

a. The Dam. The economic damages from floods prior to 1850 were small due to the sparsely distributed population and lack of development within the Santa Ana River Basin. However, following the historical floods of the late 1800's and early 1900's, considerable urbanization and agricultural development occurred in Orange County along the lower Santa Ana River creating the potential for catastrophic economic losses in the event of flooding.

The largest flood of record occurred on January 22, 1862. The peak flow at Riverside Narrows was about 320,000 cfs, three times greater than the 1938 flood. The small farming community of Agua Mansa, which was located about 2 miles downstream from Colton, was completely destroyed. Only the small church (Capilla San Salvador) and the house of Cornelius Jensen were spared from the flood flows.

Though the potential for destructive floods were well known, it was not until the beginning of the 20th century that the loss to life and the threat to economic stability and growth became unacceptable realities of life along the Santa Ana River. The flood of January 1916 caused severe damage in the Santa Ana River basin as illustrated in Table 3-1. The flood event of February 1927 convinced the citizens of Orange County that a solution to the flooding threat of the Santa Ana River was needed. The Orange County Flood Control District (OCFCD) was formed in 1927 to provide for the control of flood waters in the District and to conserve flood waters for augmenting the local water supply. The District encompassed all of Orange County and had the power of eminent domain over all property within 15 miles of the County line. The Orange County Board of Supervisors was designated to serve as the District's Board of Directors. In 1975 the OCEMA became the "umbrella" organization for the various Orange County public works agencies and therefore assumed the administrative and operational obligations of the OCFCD.

In April 1929 a comprehensive plan for flood control and water conservation in Orange County was presented by the OCFCD to the Orange County Board of Supervisors. The report outlined an ambitious master plan for controlling floods throughout Orange County and for utilizing flood waters to augment a limited water supply, which was almost entirely dependent on the local groundwater basin. The plan called for the construction of nine reservoirs.

Table 3-1

Estimated Direct and Indirect Flood Damages
(1949 Dollars)

Flood of	Orange County ($)	Riverside & San Bernardino Counties ($)	Deaths
January 1916	2,500,000	5,080,000	6
February 1927	438,000	594,000	1
March 1938	6,826,000	13,460,000	43
January 1943	not appreciable	1,840,000	1

Due to the large estimated cost of construction, Orange County applied for Federal Funding through the Federal Emergency Relief Appropriation Act of 1935. Funds, however, were not available through the Act and the project was disapproved. Congress, now aware of the need for flood control in the Santa Ana River basin, authorized the construction of reservoirs and related flood control works for the protection of the metropolitan area of Orange County in the Flood Control Act of 1936 (PL 74-738).

The U.S. Army Corps of Engineers reviewed the plan proposed by the OCFCD and recommended a modified plan. A definite project report recommending the construction of Reservoirs and Related Flood Control Works on the Santa Ana River was submitted by the Chief of Engineers, U.S. Army in December of 1936. The definite project report called for the Federal Government to prepare detailed designs and construct Prado Dam and associated works. Orange County was to provide, at its own expense, all lands, easements, and right-of-ways associated with the project and to assume responsibility for the maintenance of the downstream channel.

It is unfortunate that Prado Dam was not completed in time for the March 1938 flood. As shown in Table 3-1 damages both upstream and downstream of Prado Dam were large both in terms of economic losses and lives. The less severe flood of January 1943 still caused damages upstream of Prado Dam, but downstream from Prado Dam no appreciable damages occurred.

b. The Ungated Outlets. The original plans prepared by the District Engineer in 1937 included a 4-ft x 8-ft ungated outlet for water conservation. At the time it was estimated that the recharge capacity of the downstream Santa Ana River was approximately 2,000 cfs. The final approved designs included two ungated 66-in. diameter outlets. The two ungated outlets were designed to release 1,878 cfs at a WSE of 507-ft. The reservoir design flood at the time could be controlled with the flood control storage above 507-ft. Therefore water conservation was permitted below WSE 507-ft.

After the first two years of operation, it became evident to the OCWD that the estimated 2,000 cfs recharge capacity was an overly optimistic value. In March of 1943 the OCWD first considered requesting the closure of either both or at least one of the ungated outlets. The OCWD decided that they would like to have one of the ungated outlets temporarily sealed so that they could study the effect of the closure on their recharge operation.

The City of Corona, Riverside County, and the Riverside Water Company immediately filed formal protests with the District Engineer regarding the possible closure of an ungated outlet. The protests stemmed from concern of possible increased impoundments within Prado Reservoir and water rights issues.

In 1942 the OCWD was adjudicated the rights to flood waters from portions of the upper basin. Case No. Y-36-M was settled in the U.S. District Court between the OCWD and the cities of Riverside, San Bernardino, Colton, and Redlands. Since the settlement did not include the entire upper basin, the upstream protesters contended that if additional water is conserved, this unappropriated water should belong in part to all water users along the entire length of the river on a pro-rata basis.

Meetings were held between the LAD and the OCWD and the protesting agencies. Based on these meetings and review of available data it was believed that vested appropriative and riparian water rights would not be affected and that little, if any, injury would result to the protestants from the proposed change in operation of Prado Dam.

In June of 1945 the OCWD passed a resolution absolving the U.S. Government of any claims due to the closing of an ungated outlet. In October of 1945 the Office of the Chief of Engineers (OCE) approved the temporary closure, with the stipulation that the resolution wording be slightly modified. In November of 1945 the resolution was changed to the satisfaction of OCE. Design plans for the closing were prepared by the OCWD and submitted to the Corps for approval. Final approval was given to the OCWD in September of 1946 and the west ungated outlet was sealed in October of 1946.

Studies on the effect of the closure on water conservation activities downstream of Prado Dam showed that considerable savings resulted from the closure of the west ungated outlet. Some flood waters, however, were still being wasted to the ocean. Complete control of all flood waters entering Prado Dam would be necessary in order to optimize water conservation activities on the lower Santa Ana River. In May of 1960, meetings were held between the LAD, OCWD, and the OCFCD regarding the possible closure of the remaining east ungated outlet.

The upstream water users were not pleased with the idea of having the remaining ungated outlet sealed. Their position that unappropriated water should be shared among all of the water users of the Santa Ana River Basin was once again voiced. Riverside County filed an application with the LAD to also have the east ungated outlet sealed as well as filling for appropriation of flood water rights with the California State Department of Water Resources (DWR).

The Corps policy regarding water rights issues is to remain neutral and have the disputing agencies settle their differences without Corps intervention. Therefore, the Corps' position regarding the closure of the remaining ungated outlet was to refuse approval until one of the requesting agencies could show that the water rights issue had been settled between the various agencies.

On 18 October 1963 the OCWD filed suit against the upstream water users in the Superior Court of Orange County. The massive suit was settled on 17 April 1969, ending the legal battling which had been occurring between the OCWD and nearly 5,000 upstream water users for the past 18 years. The stipulated judgement to case No. 117628 was reached between the OCWD and the three major water users of the upper basin. All defendants and cross-defendants were dismissed except for the four major public water districts within the Santa Ana River Basin, namely the; 1) San Bernardino Valley Municipal Water District (SBVMWD); 2) Western Municipal Water District (WMWD); 3) Chino Basin Municipal Water District (CBMWD); and 4) OCWD. The judgement substantially settled all of the water rights issues of the Santa Ana River Basin. With regards to the OCWD, the upper basins are responsible for assuring that 42,000 ac-ft of baseflow reach Prado Dam, and the OCWD is entitled to all floodwaters which reach Prado Dam.

With the resolution of the water rights issues, both the OCWD and the OCFCD passed resolutions on 21 May 1969 requesting once again to have the remaining east ungated outlet sealed. LAD approved the closure on 22 May 1969 and the east ungated outlet was sealed on 29 May 1969. On 13 August 1969 OCE approved indefinite closure of the east ungated outlet.

The OCWD victory in the battle for closure of the final ungated outlet was somewhat bitter-sweet in that the revised hydrology for Prado Dam, which was initiated in 1967, required that the debris/water conservation pool be lowered to WSE 490-ft. The 1969 reservoir regulation schedule was therefore adjusted to account for the closure of the east ungated outlet and the revised hydrology.

3-03 <u>Construction</u>. Prado Dam was constructed between October 1938 and April 1941 under the supervision of the U.S. Army Corps of Engineers, LAD. When the dam was completed it had six gated outlets and two ungated outlets. The two ungated outlets were added to maintain a maximum water conservation release of approximately 2,000 cfs. However, after completion it was determined that the estimated 2,000 cfs recharge capacity of the downstream channel had been overestimated. The OCWD in concurrence with the OCFCD requested that the two ungated outlets be sealed so that water conservation activities downstream of Prado Dam could be optimized. With OCE approval; the west ungated outlet was sealed in October 1946 and the east ungated outlet was sealed on 29 May 1969.

3-04 <u>Related Projects</u>.

a. <u>Existing Projects</u>. There are four dams located within the Santa Ana River basin which provide some degree of flood control. They are: 1) Prado Dam, 2) San Antonio Dam, 3) Carbon Canyon Dam, and 4) Villa Park Dam. Prado, San Antonio, and Carbon Canyon Dams are owned and operated by the U.S. Army Corps of Engineers. All of their storage is solely allocated for flood control purposes. Villa Park Dam is owned and operated by the OCEMA. It has storage allocations for both flood control and water supply purposes. Exhibit B contains pertinent data tables for San Antonio, Carbon Canyon, and Villa Park Dams. See the inside cover of this manual for a pertinent data table for Prado Dam. Carbon Canyon Dam is actually located in the San Gabriel River basin, but the OCEMA diverts waters from Carbon Canyon Creek at the Miller Basin Facility to the Santa Ana River via the Carbon Creek Diversion Channel. There are several other reservoirs and lakes (Table 2-1) within the Santa Ana River Basin which affect runoff on the Santa Ana River but do not have allocations of storage space for flood control. Plate 2-10 shows a schematic of the Santa Ana River Basin. See Sections 4-10 and 4-11 for a more detailed description of the above mentioned water resource facilities.

OCEMA maintains the lower Santa Ana River downstream of Weir Canyon Road to the Pacific Ocean and has developed a system of drop structures and grade stabilizers along the channel. There are 11 drop structures and 11 grade stabilizers located along the Santa Ana River as shown on plate 4-22. The drop structures help reduce damage to the channel by controlling scour and streambed degradation. The Survey Division of OCEMA evaluates, on a yearly basis, the scour and degradation of the channel downstream of the dam and OCEMA then performs necessary maintenance to any structures which have been undermined or damaged by flood flows. In addition, the OCEMA has performed a study to determine the channel capacities of various reaches, the most probable breakout locations, and the capacity of the bridges within the study reach. See Section 4-09 for a description of the downstream channel.

OCWD groundwater spreading facilities are located in the lower Santa Ana River basin, downstream of Prado Dam between Imperial Highway and Ball Road. See Section 4-11 for a description of the groundwater spreading facilities.

b. Future Project. The continued urbanization of Orange, Riverside, and San Bernardino Counties has contributed to overtaxing of the existing Santa Ana River flood control system. Increased runoff due to increased urbanization and encroachment onto the existing flood plain have resulted in over two million people and businesses being susceptible to damages from flood flows. The Corps' 1975 Review Report for the Santa Ana River documents the magnitude of the deficiency at Prado Dam.

An ambitious plan for improving the flood protection both upstream and downstream of Prado Dam was described in the Phase I GDM for the Santa Ana River, including Santiago Creek, dated September 1980. The recommended improvements of the Phase I GDM were authorized, in part, by the Water Resources Development Act of 1986 (PL 99-662). The Phase II GDM, dated August 1988, is currently being used as the basis for initiating plans and specifications for the various improvements to the Santa Ana River Mainstem.

The Santa Ana River Mainstem project has been started. To date an exploratory tunnel along the outlet works alignment for Seven Oaks Dam has been excavated. Enhancement of the marshlands at the mouth of the Santa Ana River is scheduled to begin during fiscal year 1990. As improvements to the Santa Ana River flood control system come on-line, re-regulation of Prado Dam will need to be considered, as Prado Dam will remain the primary flood control facility of the Santa Ana River flood control system.

3-05 Modifications to Regulations.

a. 1941 Schedule (Original Schedule). The reservoir regulation schedule was able to control the design inflow hydrograph to the spillway crest elevation of 543.0-ft. The design inflow hydrograph was based on a 100 year frequency rainfall event. The resulting rainfall produced an inflow hydrograph having a duration of seven days and a peak inflow of 193,000 cfs. The total 7 day runoff volume was 275,200 ac-ft.

The design schedule allowed for "automatic" operation of the reservoir in the early stages of a flood event by permitting reservoir inflows to be controlled through the two ungated outlets up to WSE 507.0-ft. This plan "would conserve a large portion of flood flows heretofore wasted into the ocean" (reference 14 May 1938). Local interests had at the time estimated that the downstream groundwater spreading capacity of the Santa Ana River to be about 2,000 cfs.

From WSE 507.0-ft to 507.5-ft, gated discharges were initiated which increased the outflow from 1,878 cfs to 9,200 cfs. From 507.5-ft to spillway crest at WSE 543.0-ft the gates were so adjusted to maintain an average outflow of 9,200 cfs.

b. 1942 Proposed Revision. The report entitled "The Operation of Flood Control and Multi-Purpose Reservoirs in the Los Angeles Engineer District" dated October 1942 proposed a revised water control plan with ungated releases maintained up to WSE 515.0-ft. Above WSE 515.0-ft, gated flood control releases were to be initiated and gradually increased as the reservoir pool rose so that at WSE 518-ft a release rate of 9,750 cfs would be attained. From 518.0-ft to spillway crest only two gate operations would have been made resulting in flows ranging from 9,750 cfs to 11,050 cfs.

Available records indicate that this schedule was never approved by SPD or OCE and hence was never officially adopted for use.

c. 1945 Revision. By 2nd indorsement from OCE dated 18 October 1945, a revised operation schedule was approved which accounted for the closure of the west ungated outlet. The west ungated outlet was closed in October 1946 at the request of OCWD. OCWD requested the closure to enhance its recharge operations and to study the effects of the closure on its downstream groundwater recharge activities.

The revised regulation schedule provided for unregulated flow through one ungated outlet, with the six flood control gates closed, up to WSE 514.0-ft. At 514.0-ft, 64% of the reservoir storage remained available for flood control regulation. The schedule uniformly increased the flow in small increments from 1,240 cfs at WSE 514.0-ft to 9,170 cfs at WSE 518.5-ft. Thereafter the gates would be operated to maintain an average outflow of about 9,200 cfs up to spillway crest, WSE 543.0-ft. At spillway crest the gates were to remain open during uncontrolled spillway flows.

d. 1951 Modification. In 1951 a water control plan was formulated to alleviate the problem of silt accumulation in the forebay of the outlet works.

The revised regulation schedule was essentially identical to the 1945 plan, except that sluicing of water through the gates was scheduled from WSE 460.0-ft to WSE 470.0-ft. This was done to pass silt which had been settling out in the forebay of the outlet works and resulted in increased maintenance costs. From WSE 470.0-ft to 514.0-ft the six flood control gates were once again closed and the regulation paralleled the 1945 schedule.

e. 1968 Revision. By 2nd indorsement from OCE dated 26 February 1969 a revised operation schedule was approved which addressed the revised reservoir design flood for Prado Dam. The newly developed SPF for Prado Dam was much larger than the original reservoir design flood. In fact the SPF could not be controlled by Prado Dam without major spillway outflow. In an effort to achieve a greater level of flood control protection the reservoir regulation schedule was modified to begin gated flood control releases at WSE 490.0-ft. Before initiating larger gated flood control releases it is necessary to build a pool of water (a debris pool) to submerge the gates to prevent vortices from sucking floating or partially submerged debris into the outlet works. A debris pool elevation of WSE 490.0-ft was determined by routing the SPF through Prado Dam using several different debris pool elevations. The percent of the SPF that could be controlled to spillway crest was plotted against the debris pool elevations. From the plot, it was determined that lowering the debris pool below WSE 490.0-ft produced no significant improvements in controlling the SPF.

The revised regulation plan called for unregulated flow through one ungated outlet, with the six flood control gates closed up to WSE 490.0-ft. At WSE 490.0-ft the unregulated release of 890 cfs would be uniformly increased to 9,120 cfs at WSE 491.4-ft. From WSE 491.4-ft to spillway crest 543.0-ft an average outflow of 9,250 cfs would be maintained. Beginning at spillway crest outflow would be transferred to the spillway so that at WSE 545.0-ft all gates would have been closed.

f. 1969 Revision. By 4th indorsement from OCE dated 13 August 1969, a revised regulation schedule was approved which accounted for the downstream channel deficiency and the closing of the remaining ungated outlet (i.e., the east ungated outlet).

Operational experience gained during the January and February 1969 flood events revealed that the lower Santa Ana River was not capable of safely conveying the 9,250 cfs release called for by the 1968 reservoir regulation schedule. Releases of up to 5,000 cfs during the 1969 flood events had caused severe damage to the downstream channel (see section 4-09h). Also, OCWD's request to seal the last remaining ungated outlet was approved. Both of these factors necessitated the formulation of a revised regulation schedule.

The revised schedule called for the formation of a debris pool to WSE 490-ft from which releases would be coordinated with OCWD in order to minimize the wasting of flood waters to the Pacific Ocean. Above WSE 490.0-ft releases would be uniformly increased to 4,870 cfs at WSE 490.8-ft. From 490.8-ft to spillway crest 543.0-ft the gates would be operated to maintain an average outflow of 5,000 cfs. From spillway crest 543.0-ft, outflow would be transferred to the spillway so that at WSE 544.3-ft all gates would be closed.

g. Water Year 1990 Plan. By 2nd indorsement from SPD dated 15 February 1990 a revised water control plan was approved which accounts for the continuing downstream channel deficiency. Operational experience gained during the floods since 1969 indicate that the downstream channel is not capable of passing extended flows in excess of 2,500 cfs without sustaining significant damage (See section 4-09h).

The revised plan introduces a "buffer pool" from WSE 490.0-ft to WSE 494.0-ft which enables the water control manager to limit releases from Prado Dam to below 2,500 cfs. The buffer pool enables the water control manager to:

1. Minimize the oscillation in the magnitude of reservoir releases, thereby reducing the potential of streambank erosion in the lower Santa Ana River.
2. Reduce oscillation in the release magnitude for a safer operation with respect to public use of the Santa Ana River Canyon.
3. Facilitate coordination with OCWD operations by providing the ability to temporarily curtail releases so that in-stream L-dikes can be reconstructed.
4. Simplifies the lengthy public notification process when a smoother release pattern with fewer release rate changes is adopted.

The revised schedule calls for the formation of a debris pool to WSE 490.0-ft from which releases are coordinated with OCWD in order to minimize the wasting of flood waters to the ocean. From WSE 490.0-ft to 494.0-ft releases can be gradually increased to a maximum of 2,500 cfs should runoff and weather forecasts so warrant. Under favorable hydrologic and reservoir conditions, releases from the buffer pool are released at rates that facilitate OCWD's groundwater recharge activities. From WSE 494.0-ft to 520.0-ft releases range from a minimum of 2,500 cfs to the maximum release of 5,000 cfs. The water control manager determines the specific release rate based upon the runoff and weather forecast. From WSE 520.0-ft to spillway crest an average outflow of 5,000 cfs is maintained. Above spillway crest at WSE 543.0-ft, gated outflows are gradually reduced so as to maintain a 5,000 cfs outflow from the combination of outlet works and spillway discharges. At WSE 544.3-ft all gates are closed and only uncontrolled spillway flows in excess of 5,000 cfs occur.

Chapter 7 of this water control manual describes in detail the application of this water control plan to actual storm and flood conditions at Prado Dam.

3-06 __Principal Regulation Problems__. There are several important considerations in determining the operational strategy which will provide the maximum benefits to the public. Items which are considered in the regulation of Prado Dam include:

a. __Downstream Channel Capacity__. Plate 4-21a-b schematically illustrates the long- and short-term channel capacities downstream of Prado Dam. The most restrictive sections are immediately downstream of the dam. Refer to section 7-02 for specific downstream channel constraints.

The short-term capacities define the design flows of the channel that can occur without overtopping the channel. The channel can handle these large flows which are characteristic of flood runoff from the drainage area downstream of Prado Dam for short periods of time.

The long-term capacities indicate the flows which can be passed through the channel for extended periods of time, although significant channel erosion has occurred at these flows in the past.

b. Reservoir Deficiency. The 1988 Phase II GDM of the Santa Ana River Mainstem Project indicates that under present conditions Prado Dam could control a 70-yr. flood to a peak outflow of 5,000 cfs. Under future conditions (i.e., with increased urbanization at the year 2090) only a 40-yr. event would be controllable to a maximum outflow of 5,000 cfs. Any flood of greater magnitude would result in uncontrolled flow over the spillway.

c. Water Conservation. To the extent that flood control protection is not compromised and environmental constraints are met, Prado Dam is utilized to store flood runoff and release water at a rate that can be recharged to groundwater by OCWD. Section 7-09 describes the operation of Prado Dam with regards to water conservation.

d. Recognized Land uses of Reservoir Lands. There are a number of land users with various types of facilities located within the reservoir. All of these land users fall into one or more of five categories:

1. Leases for public parks and recreational purposes from the Corps of Engineers to Riverside County, San Bernardino County and the City of Corona. These leases allow concession agreements to third parties providing appropriate recreational facilities and services to the public.

2. Land leases for parks and recreation purposes may be leased by the Corps for agricultural purposes until the land is needed for public use.

3. Various leases from the Corps for special purposes such as sewage plants and infiltration ponds.

4. Mineral leases from BLM, which controls subsurface rights of federally owned lands within the reservoir, mainly to oil producers.

5. Lands owned in fee by third parties with whom the Corps has flowage easements.

Since the primary purpose of the reservoir is flood control, all lessees, sublessees, and property owners understand and have agreed in writing that their operation, facility, or land is subject to periodic flooding. Leases, easements, licenses, and permits for facilities and activities on reservoir lands are in a constant state of flux. Table 3-2 presents a "1988 Snap-Shot" of outgrants representing areas greater than one acre. Table 3-3 lists important facilities within the basin ranked according to elevation.

Table 3-2

"1988 Snap-Shot" of Real Estate Outgrants at Prado Reservoir

Grantee	Type (*)	Purpose (**)	Acreage (***)	Term From	Term To
Abacherli, Louis J.	LEA	AGR	13.6	11-01-84	10-31-89
Bittel, Denise	LEA	AGR	64.2	11-01-85	10-31-90
	LEA	AGR	516.4		
Calif., State of	EAS	ROW	17.2	05-12-58	INDEF
Calif., State of	EAS	ROW	206.0	12-13-49	INDEF
Chino Basin Muni. Water District	EAS	ROW	411.8	05-09-60	05-08-10
	EAS	ROW	2.4	07-01-81	06-30-01
Ciesla, Thomas R.	LEA	AGR	48.1	11-01-84	10-31-89
Circle/Kirk Farms	LEA	AGR	93.8	12-01-85	11-30-90
Corona, City of	LEA	OTH	48.5	05-01-67	04-30-17
Corona, City of	LEA	PPR	1570.0	02-01-67	01-31-17
Corona, City of	LEA	OTH	57.3	08-01-84	07-31-89
Corona, City of	EAS	ROW	32.1	05-01-67	04-30-17
Corona, City of	EAS	ROW	2.4	03-28-74	INDEF
Devjyst, David J.	LEA	AGR	22.3	12-01-85	11-30-90
Evans, Freeland V.	LEA	AGR	77.0	01-01-84	12-31-88
H & R Barthelemy DA	LEA	GRZ	24.5	04-26-81	04-25-92
Jongsma, Harold	LEA	AGR	61.9	11-01-85	10-31-90
Morena, Manuel V.	LEA	AGR	13.4	11-01-85	10-31-90
Navy Dept.	PER	OTH	34.1	03-19-43	INDEF
Orange County FCD	EAS	ROW	4.0	11-19-46	INDEF
Pacific Bell	LIC	OTH	1.8	10-10-80	10-09-90
Richardson, Donald R.	LEA	AGR	95.3	03-01-83	02-28-88
Riverside County	EAS	ROW	4.6	03-17-67	INDEF
Riverside County	LEA	PPR	1714.0	08-20-67	08-19-97
San Bernardino County	EAS	ROW	1.0	05-15-56	INDEF
San Bernardino County	LEA	PPR	2113.7	10-01-65	09-30-15
San Bernardino County	EAS	ROW	4.3	07-25-68	07-24-18
Santa Ana River Dev.	EAS	ROW	3.0	09-01-47	08-31-97
Santa Ana River Dev.	EAS	ROW	2.6	11-30-48	11-29-98
Santa Ana Watershed	EAS	ROW	7.8	10-08-75	10-07-25
Santa Ana Watershed	EAS	ROW	28.3	10-15-81	10-14-31
Saunders, William W.	LEA	PPR	16.9	11-01-65	10-31-90
So. Cal. Gas Co.	EAS	ROW	5.7	12-21-48	INDEF
So. Cal. Edison	EAS	ROW	28.6	03-25-54	03-24-04
	EAS	OTH	13.9	06-09-49	INDEF
	EAS	ROW	3.9	05-14-70	05-13-20
	EAS	ROW	14.5	07-06-70	07-05-20
	LIC	ROW	1.3	3-02-80	3-01-90

* LEA - Lease
EAS - Easement
LIC - License
PER - Permit

** GRZ - Grazing
AGR - Agricultural
ROW - Right of Way
PPR - Park and Rec
OTH - Other

*** The total acreage in this table does not equal the total acreage of the flood control basin since it only lists grants greater than one acre.

Table 3-3

Elevations of Sites/Facilities at Prado Reservoir

Description	Elevation (ft)
OUTLET INVERT	**** 460 ****
Least Bell's vireo Nesting Habitat	460 - 566
Archeological and Historic Sites	480 - 566
Raahauge's Hunting Club	485 - 525
Club House	611
Splatter S Duck Club	485 520
Club House	520
TOP OF DEBRIS POOL	**** 490 ****
Prado Recreation, Inc. (Dog Training Facility)	490 - 504
Kennel/Trailer	554
Oil Wells	492 - 508
TOP OF BUFFER POOL	**** 494 ****
El Prado Golf Course	510 - 567
Club House	554
City of Corona Municipal Airport	514 - 534
Tiro Shooting Range	516 - 518
Prado Regional Park (San Bernardino Co.)	520 - 560
Camping Area	550 - 552
Archery Range	520 - 560
Prado Basin Park (Developed Area) Riverside Co.	525 - 573
Interpretation Center	573
Butterfield Park (City of Corona)	527 - 550
Bandini Adobe	534
Kobe Power Fluid Station	536
Chino Basin Water District (Waste Water Treatment Plant #2)	537 - 546
City of Corona Waste Water Percolation Ponds (Perimeter Levee)	540
SPILLWAY CREST	**** 543 ****
12 Unauthorized Dwellings	550 - 554
City of Corona Waste Water Treatment Plant (Road Entrance)	556
Oil Treating Facilities	560
California Institution for Women (State Prison)	560 - 572
Yorba Slaughter Adobe	560.2
2 Dwellings within the Corona National Tract	561 - 566
TOP OF DAM	**** 566 ****

IV - WATERSHED CHARACTERISTICS

4-01 General Characteristics. The Santa Ana River basin drains approximately 2,450 sq-mi, excluding a closed area of 32 sq-mi tributary to Baldwin Lake. Of the total watershed, 2,255 sq-mi (i.e., 92%) are above Prado Dam, which is the primary flood control structure on the Santa Ana River. The Santa Ana River basin and the existing water control structures are shown on Plate 4-01a. Approximately 23% of the watershed is within the rugged San Gabriel and San Bernardino Mountains, about 9% is in the San Jacinto Mountains, and 5% is within the Santa Ana Mountains. Most of the remaining area is in valleys formed by the broad alluvial fan along the base of these mountains. The numerous low hills in the alluvial valley areas include a few low hills north of San Bernardino; the Crafton Hills east of Redlands; the Jurupa Mountains north and west of Riverside; the Box Springs Mountains and the Badlands east of Riverside; and the Chino and Peralta Hills northeast of Anaheim. In general, the mountain ranges are steep and sharply dissected. Maximum elevation at San Antonio Peak in the San Gabriel Mountains is 10,064-ft; at San Gorgonio Mountain in the San Bernardino Mountains, 11,499-ft; and at Mount San Jacinto in the San Jacinto Mountains, 10,804-ft.

4-02 Topography. The San Bernardino Mountains are the source of the Santa Ana River and of two of its principal tributaries, Bear and Mill Creeks. Lytle Creek, the largest tributary originating in the San Gabriel Mountains, is in the northwest part of the drainage area. The San Jacinto River has its origin in the San Jacinto Mountains southeast of Beaumont. The major tributary in the lower part of the watershed (i.e., below Prado Dam) is Santiago Creek, which originates in the Santa Ana Mountains. The Santa Ana River has an average gradient of about 240 ft/mi in the mountains, about 20 ft/mi near Prado Dam, and about 15 ft/mi below Prado Dam. The average gradient of the tributaries is about 700 ft/mi in the mountains and 30 ft/mi in the valleys. Plate 4-01b shows the topography of the Santa Ana River watershed area and Plate 4-02 shows the profile of the Santa Ana River from its headwaters to the Pacific Ocean.

Well developed growths of white fir, ponderosa pine, sugar pine, and Jeffrey pine occur above elevations of about 5,000-ft. Sparse growths of conifers and of brush, including chaparral and manzanita, are common on the steep, rocky slopes of the higher mountains. Large areas on the higher slopes are covered by brush that has replaced timber removed by small-scale lumbering or that has been destroyed by forest fires. Oak and other deciduous trees, brush, and native grasses are the principal vegetal cover on the slopes below an elevation of about 5,000-ft. Large areas on the plateaus and hills are covered with grass and brush. Because of extensive urbanization, large segments of the valley areas have been cleared of most native vegetation. The remaining valley areas are covered mainly with orchards and crops.

4-03 Geology and Soils. The entire Santa Ana River basin is underlain by a basement complex of crystalline metamorphic and igneous rocks, which only appear on the surface in the mountainous parts of the area. In the foothills and valleys, the basement complex is overlain by a series of sandstones and shales. Unconsolidated alluvial deposits range in depth from a few feet at the base of the mountains to more than 1,000-ft on the cones and in the valleys. The existence of several precipitous mountain ranges along the upper boundaries of the area indicates that the area has been subjected to extensive folding and faulting. The soils in the mountains, which are derived mainly from metamorphic and igneous rocks, are shallow and stony. On the lower slopes of the mountains and in the foothills, the soils are mainly loams and sandy loams, ranging from less than 1-ft to 6-ft in depth. In the valleys, where the soils are usually more than 6-ft deep, the surface soils range from light, sandy alluvium to fine loams and silty clays with heavier subsoils.

The Santa Ana River basin lies in a seismically active area and has several faults within its boundaries as shown on Plate 4-03. The San Andreas fault zone is the best known of the faults and the one with the potential for the most severe earthquake. Other fault zones within the basin include: the San Jacinto fault zone; the Banning fault; the Sierra Madre-Cucamonga fault zone; the Whittier fault; the Chino fault; the Elsinore Agua Caliente fault zone; and the Newport-Inglewood fault zone.

Prado Dam, located on the east side of the Chino Hills, lies very close to the Chino fault. A total of 14 observed earthquakes with a magnitude ranging from 5.0 to 6.8 on the Richter scale have occurred within a 50 mile radius of Prado Dam. The strongest earthquake experienced by the dam was the San Fernando earthquake in 1971. Observed local earthquakes with magnitudes varying between 3.0 and 6.0 plus are also shown on Plate 4-03.

4-04 Sediment. Bed material in the Santa Ana River varies from a cobble bed, with material between two and four inches in diameter, along the upper reaches of the river to fine and medium sands along the lower reaches. The Santa Ana River is generally considered a sand bed stream with sediment having a mean diameter of 0.5 mm. The median size of the bed material varies from 0.2 mm to 0.8 mm with an average gradation coefficient of 2.

Historically the river was braided in the upper portion of the basin and meandering along the lower portion. The river bed and banks are highly erodible and over time the channel has wandered over significant portions of the floodplain. As the Santa Ana River basin has developed, the channel has been improved and controlled to its present location. However, the inherent instability of the river periodically manifests itself in the form of severe scour and bank erosion at various locations (See section 4-09h).

The sediment yield for Prado Reservoir has been estimated from a determination of sediment deposition in Prado Reservoir during the 29-year period, 1941 to 1969. During this period, sediment accumulation, up to spillway crest elevation, was 24,780 ac-ft. The watershed above Prado Dam is 2,255 sq-mi. There are three major reservoirs and lakes that virtually trap all sediment entering them: (a) San Antonio Reservoir on San Antonio Creek controls sediment from a drainage are of 27 sq-mi; (b) Lake Elsinore on the San Jacinto River traps sediment from an area of 768 sq-mi; and (c) Big Bear Lake, located in the San Bernardino Mountains, traps sediment from a drainage area of 38 sq-mi. There are other numerous small reservoirs that control sediment from approximately 235 sq-mi. Thus, the sediment producing area covers about 1,180 sq-mi and gives a sediment yield for the past 29 years of about 0.75 ac-ft per sq-mi per year.

The most recent area-capacity relation for Prado Dam is based on the survey of March 1980 and is presented on Plates 2-08 and 2-09.

4-05 Climate.

The climate of the drainage area above Prado Dam is generally temperate-subtropical and semi-arid in the lower elevations, with warm, dry summers and mild, moist winters. In the higher mountains, moderate summers and cold winters, with considerable snowfall, prevail. Nearly all precipitation occurs during the months of December to March. Rainless periods of several months during the summer are common. Most precipitation in the drainage area results from general winter storms that are associated with extra-tropical cyclones of North Pacific origin.

a. Temperature. Average daily minimum and maximum temperatures (degrees Fahrenheit) in the vicinity of Prado Dam range from about 40°F and 66°F respectively in winter to about 59°F and 92°F in summer. The corresponding figures near the top of the basin (elevations 8,000-11,000-ft) range from about 10°F and 22°F in winter to about 45°F and 60°F in summer. All-time low and high extremes of temperature are about 22°F and 114°F respectively near the dam and about -30°F and 75°F at the top of the drainage. The lower elevations do not normally experience significant periods of freezing temperatures, but above 6,000-ft subfreezing temperatures are very common for 4 to 6 months of the year.

Plate 4-04a-d, reprinted from the NWS Climatography of the United States No. 20, consists of climatic summaries for four published NWS stations: Corona, Riverside, Upland, and Beaumont, California. Corona is the station nearest to, and most representative of, Prado Dam; Riverside reflects conditions in mid-basin; while Upland and Beaumont are more representative of foothill stations. This plate lists, among other items, the mean daily maximum and minimum temperature and the recorded highest and lowest temperatures for each month of the year at each of the four stations.

b. Precipitation. Plate 4-05 (reproduced from the Santa Ana River Mainstem Phase II GDM) shows the mean annual precipitation over the drainage area above Prado Dam. Within the drainage area, mean annual precipitation ranges from less than 10 inches in the area of March Air Force Base to about 45 inches atop Mt. San Gorgonio, and averages about 20 inches over the entire drainage.

Plate 4-04a-d also lists the mean and maximum monthly and annual precipitation, as well as the maximum daily precipitation for each month of the year, for each of the four climatological stations in the Santa Ana River drainage. Also listed in Plate 4-04a-d are the probabilities (from 5 to 95 per cent) for each month of the year that the monthly total precipitation at each station will be equal to or less than the indicated amounts. This plate demonstrates that there can be great year-to-year variability in annual, monthly, and daily precipitation. Not listed in this plate are the minimum observed monthly precipitation values, which for most stations are at most 0.01 or 0.02 inches for each month of the year.

Plate 4-06 consists of precipitation depth-duration-frequency tabulation for five stations in the drainage, four of which are at the same location as, or at a very nearby locations to, the four stations listed in Plate 4-04a-d, and the fifth being the mountain station of Big Bear Lake Dam. In this plate are listed the computed point-value precipitation depths at each station for durations of from 15 minutes to 24 hours, and for return periods from 2 to 200 years. Data for this plate were obtained from the State of California Department of Water Resources publication, Rainfall Depth-Duration Frequency for California, revised November 1982. These California Water Resources data are similar to those obtained from the National Oceanic and Atmospheric Administration (NOAA) publication, NOAA Atlas 2.

c. Snow. Snow in southern California is relatively uncommon at elevations below 6,000-ft, but occurs frequently at the higher elevations, and often remains on the ground for many weeks during the winter and spring at elevations above 7,000 to 8,000-ft. Snowmelt is normally not a major hydrologic factor in terms of contributing to runoff in the Santa Ana River basin; but, on occasion, the runoff from a warm, heavy rainstorm that has followed a cold storm that had dropped snow over the Santa Ana River basin down to 2,000 or 3,000-ft will be significantly augmented by melting snow.

d. Evaporation. Table 4-1 presents pan evaporation data for three stations located within the drainage area above Prado Dam. The mean monthly evaporation ranges from less than 1 inch in winter to about 8 inches in the summer in higher forested elevations, to about 2-3 inches in winter and 9-11 inches in summer in the lower elevations. On days of very strong, dry Santa Ana winds, evaporation can be greater than one inch in 24 hours.

Table 4-1

Evaporation within the
Santa Ana River Basin

	Monthly Evaporation (inches)		
Month	(712301) Prado Dam (40 year mean)	(747300) Riverside Citrus Exp. Sta. (54 year mean)	(060700) Beaumont Pumping Plant (21 year mean)
Oct	5.67	5.24	5.79
Nov	4.21	3.62	3.54
Dec	3.39	2.68	3.11
Jan	3.42	2.83	3.15
Feb	3.50	3.23	3.43
Mar	4.72	4.57	4.41
Apr	6.14	5.79	5.31
May	7.68	7.05	6.61
Jun	8.62	8.19	8.39
Jul	10.71	9.88	10.67
Aug	10.00	9.25	10.08
Sep	7.91	7.05	8.11

Note: Each evaporation station consists of a Weather Bureau Class A Pan. Readings are adjusted for observed rainfall to yield net evaporation.
Reservoir evaporation may be estimated by multiplying measured pan evaporation by a pan coefficient ranging from 0.6 to 0.8.

Location of Evaporation Stations

CA DWR No.	Latitude	Longitude	Elev (ft)	Period of Record
712301	33°53'30"	117°38'03"	565	7/30-6/69
747300	33°58'00"	117°20'05"	1,015	1/25-6/78
060700	33°58'50"	117°57'35"	3,045	1/55-9/75

e. Wind. The prevailing wind in the Prado watershed is the sea breeze. This gentle onshore wind is normally strongest during late spring and summer afternoons, with speeds in the Santa Ana River basin typically ranging from 10 to 15 miles per hour.

The Santa Ana is a dry desert wind that blows from out of the northeast, most frequently during late fall and winter. The characteristic low humidities and strong gusts of Santa Ana winds usually create very high fire hazards, but can also be instrumental in drying a saturated watershed, thus reducing the flood hazard from later events. Santa Ana winds are often especially strong below Cajon Pass in the corridor from Devore to Fontana, where extreme gusts of more than 100 mph have been recorded. They can also be very strong in the vicinity of Prado Dam and downstream through the Santa Ana River Canyon and into northeast Orange County.

Rainstorm-related winds are the next most common type in southern California. Winds from the southeast ahead of an approaching storm average 20-30 mph, with occasional gusts to more than 40 mph. West to northwest winds behind storms can sometimes exceed 35 mph, with higher gusts.

4-06 Storms and Floods.

a. Storm Types. General storms consist of one or more cyclonic disturbances, which occur over a period of one to four or more days, and result in rain or snow over large areas. Local thunderstorms result in intense precipitation over small areas for short periods of time, and may occur independently or in association with general storms. Tropical cyclones are infrequent, but occasionally occur in late summer. A description of storm types which may impact the project area are as follows:

(1) General Winter Storms. Most precipitation in southern California coastal drainages occurs during the cool season, primarily from November through early April, as mid-latitude cyclones from the northern Pacific Ocean move inland over the area. Most of these storms are the general winter type, characterized by hours of light-to-moderate precipitation, but with occasional heavy showers or thunderstorms embedded within the storm system. Snow is common in these storms above 6,000-ft, but on occasion may fall at 2,000-ft or lower.

(2) Local thunderstorms. Local thunderstorms can occur in southern California at any time of the year. They occur fairly frequently in the coastal areas in conjunction with general winter storms. They can also occur between early July and early October, when desert thunderstorms occasionally drift westward across the mountains into coastal areas, sometimes enhanced by moisture drifting northward from tropical storms off the west coast of Mexico. These local thunderstorms can at

times result in very heavy rain for periods of one to three hours over small areas, causing very rapid runoff from small sub-basins of the Santa Ana River basin.

(3) General Summer Storms. General summer storms in southern California are quite rare; but on occasion between mid-August and late October, a tropical storm from off the west coast of Mexico can drift far enough northward to bring rain, occasionally heavy, to southern California, sometimes with very heavy thunderstorms embedded. On very rare occasions, southern California has received light rain from general summer storms of non-tropical origin.

b. Floods. Records of historical flood events for the Santa Ana River Basin date from 1850. References from 1769 to 1850 compiled from historical accounts, records of court cases, and statements of witnesses, indicate that significant floods occurred in the Santa Ana River basin and other coastal southern California watersheds in 1811, 1815, 1825, 1833, 1840, and 1850. A histogram of the yearly rainfall at Santa Ana since 1769 is shown in Plate 4-07. Records prior to 1909 were compiled by Lynch.

Some quantitative data are available to show that from 1850 to 1987, large winter storms and floods occurred on the Santa Ana River in January 1862, December 1867, February and March 1884, December 1889, and February 1891. Recorded data from 1897 to the present show that medium-to large-winter storms/floods occurred in April 1903, January 1910, January 1916, December 1921, February 1927, February 1937, March 1938, January 1943, April 1958, November and December 1965, December 1966, January and February 1969, February and March 1978, February 1980, February 1981, and March 1983. There was also a major tropical storm in September 1939, but no widespread flooding resulted from this event.

Following is a discussion of the major historical storm and flood events in the Santa Ana River Basin.

(1) Storm and flood of January 1862. An extreme flood event occurred in January 1862. Although very little data concerning the storms are available, it was possible to determine the flood characteristics that led to the peak discharge of January 22, 1862.

According to historical accounts, nearly continuous rainfall began on December 24, 1861. An uninterrupted series of cold storms from out of the north brought heavy snow to low elevations in the mountains. The storm track then changed, and a series of warm storms from east of Hawaii brought very heavy tropical rain to southern California. The combination of this rain, now falling on saturated ground, and massive snowmelt led to a flood with an estimated peak discharge of 317,000 cfs at Riverside Narrows. The San Bernardino County Flood

Control District discussed this estimate in their report "Agua Mansa and the Flood of January 22, 1862, Santa Ana River".

(2) Storms and floods of January 1916. Two heavy storm series hit southern California in January 1916. The 14-19 January storms dropped southward along the coast, bringing deep snowfalls to the mountains and foothills. The second series dropped southward over water, then moved onshore with very heavy warm rain that melted the previously fallen snow. Heavy flooding resulted 27-28 January. Table 3-1 lists the loss of life and property from this and other flood events, while Plate 4-08 shows the hydrographs of these floods.

(3) Storms and floods of February 1927. A series of heavy storms moved into southern California from the west during mid-February 1927, resulting in moderate flooding on the Santa Ana River and elsewhere throughout the coastal basins (see Table 3-1 and Plate 4-08).

(4) Storms and floods of February 1937. After record cold and very low snow levels in January 1937, a series of Pacific storms moved into California from the west. The short-duration rainfall of February 6th and 14th, 1937, combining with snowmelt, caused severe flood damage to both agricultural and urban areas and helped to highlight the area as a vulnerable flood hazard zone. The total damage caused to private and public properties was estimated by several agencies to have been approximately $750,000.

(5) Storm and Flood of February-March 1938. The flood of early March 1938 was, and still is, the most destructive of record since 1862 on the Santa Ana River and many other streams in southern California; and its occurrence played a major role in the justification for the construction of Prado Dam and other flood control structures. The storm developed out of a series of low-latitude north Pacific disturbances, bringing several bands of intense rainfall to southern California during a 5-day period of 27 February - 3 March. Several mountain stations in southern California reported precipitation equalling or exceeding 30 inches during the 5 days. Within the study area, total rainfall ranged from less than 5 inches near Perris to 27 inches at Big Bear Lake Dam. The heaviest rain fell on 2 March between 0000 and 1900 hours, during which Camp Baldy at the northwest edge of the Santa Ana River basin reported nearly 8 inches in 6 hours and more than 12 inches in 12 hours.

At the beginning of the storm, there was snow on the ground at elevations above about 6,000-ft. The snow cover at points of observation was not materially depleted at the end of the storm, indicating that snowmelt probably did not contribute appreciably to the flood runoff. Although accumulated seasonal precipitation at the beginning of the storm was about normal, greater than normal precipitation occurred during the month of February preceding the storm, conditioning the ground for runoff. The resulting low precipitation-loss rates, along with the unusually large precipitation volume and high intensities, caused very high rates of runoff, especially in the mountains and foothills. The result was a peak flow estimated at 100,000 cfs on the Santa Ana River through the Santa Ana Canyon. Plate 4-08 shows the storm runoff hydrograph for the March 1938 runoff event. Table 3-1 lists the loss of life and property caused by the flood.

(6) Storm and flood of January 1943. The storm of 21-24 January 1943, which in many respects is the most severe storm of record in southern California, resulted when a series of warm Pacific cyclones moving generally eastward from the area north of Hawaii combined with an intense, cold storm moving down the west coast of North America from British Columbia. The deep, low pressure center that consequently developed over Northern California and Oregon generated unusually strong southerly and southwesterly winds over southern California and produced very heavy precipitation over much of the area. Exceptionally large rainfall amounts fell in the mountain areas because of the powerful orographic uplift of these strong winds. Continuous precipitation, which included two periods of very high intensity rainfall, occurred from about noon on 21 January into the morning of 23 January. This precipitation was caused by two cold fronts, the first of which occurred about midnight on 21 January, and the second, about midnight on 22 January. Rainfall tapered off on 23 and 24 January, although certain mountain stations continued to receive substantial precipitation during these two days. Total Rainfall recorded for the storm in the study area ranged from 4.3 inches at Riverside to 29.7 inches at Glenn Ranch in the San Gabriel Mountains. Isohyets of maximum 24-hour precipitation for the storm event are shown on Plate 4-09. Plate 4-08 shows the hydrograph for the 1943 event and Table 3-1 tabulates losses caused by the event. Some snow fell during the storm, mostly above elevations of 8,000-ft. Although the storm was severe over and southwest of the mountains in Los Angeles and San Bernardino Counties, the runoff was moderate because of unusually dry antecedent conditions during the month before the storm occurred.

(7) Storm and flood of March 1943. The local storm that occurred between 2200 hours 3 March and 0100 hours 4 March 1943 resulted in short-period precipitation of near record-breaking magnitude for the southern California coastal region. The storm developed out of a moderate general storm, beginning over the southern part of Los Angeles and moving northeast toward the San Gabriel Mountains at about 7 miles an hour. Because many automatic precipitation gages were in operation, the areal distribution of precipitation was well defined. The highest observed intensities were at the Sierra Madre-Carter (7-0-133B) precipitation station located in Sierra Madre, where maximum 15-, 30-, and 60-minute intensities of 5.5, 3.6, and 2.7 inches an hour, respectively, were recorded. Runoff was moderately heavy from local areas where high precipitation intensities occurred. However, as the thunderstorm did not extend appreciably into the Santa Ana River basin, no runoff of consequence was recorded there.

(8) Storms and floods of January 1969. A series of storms that began on January 18 and continued through January 27 was caused by a strong flow into southern California of very warm, moist air originating over the tropical Pacific Ocean south and east of Hawaii. This series of storms was interrupted by a brief ridge of high pressure that moved through the area on January 22 and 23 and caused a short break in the rainfall. Except for this lull on January 22 and 23, heavy precipitation occurred during most of the January 18-26 period. An intense downpour occurred on January 25. Nine-day totals ranged from 10 to 20 inches in the lowlands and from 25 to more than 50 inches over the mountain areas of southern California. In the study area, total storm amounts for Lytle Creek Ranger Station and Big Bear Lake were 42.68 and 35.52 inches, respectively. Plate 4-10 shows a peak 1-hour average inflow to Prado Reservoir of 77,000 cfs on 25 January.

(9) Storms and floods of February 1969. The storm series that occurred in late February 1969 climaxed more than a month of extremely heavy, recurring rainfall in southern California. The storms occurred as a number of Pacific cyclones traveled southward off the west coast of the United States and then curved inland across California carrying copious quantities of moisture. Several cold fronts and other disturbances that moved across southern California from 22 February through 24 February dropped moderately heavy amounts of precipitation. Early on 25 February a strong cold front moved slowly southeastward across southern California; the front was accompanied by strong low-level winds that, when lifted by the mountains, resulted in great quantities of orographic precipitation. As a result, rainfall was generally heavy everywhere and particularly heavy in the mountains. Total storm amounts recorded at selected mountain stations in the study area were 10.03 inches at Trabuco Canyon, 6.80 inches at Santa Ana River Powerhouse, and 6.1 inches at Idyllwild Ranger Station. Plate 4-11 shows a peak inflow to Prado Dam of 75,000 cfs on 25 February.

(10) Storm and flood of February 1978. After several moderately heavy storms during January and early February 1978, one low-latitude Pacific storm developed west of southern California and moved into the area during the night of 9-10 February. After a day of heavy rain in the San Gabriel and San Bernardino Mountains on 9 February, a major cloudburst struck portions of coastal southern California during the early hours of 10 February, with brief intensities exceeding 3 inches per hour. The very heaviest rain fell in Los Angeles County, but several stations in the Santa Ana River basin reported intense rainfall between 0200 and 0400 hours on 10 February, including 1-hour amounts of 1.2 inches at Running Springs and 0.89 inches at Prado Dam. Plate 4-12 shows a peak discharge of 20,210 cfs at Prado Dam on 10 February at 1300 hours.

(11) Storm and flood of March 1978. In a pattern very similar to that of exactly 40 years earlier, a series of low-latitude Pacific storms moved into southern California at the end of February and beginning of March 1978. There were four

major periods of rainfall during the storm period: 28 February, 1 March, 4 March, and 5 March. Total rain from 27 February through 6 March ranged from less than 5 inches in the Riverside-Corona area to 22-24 inches in the San Bernardino Mountains and more than 28 inches in the eastern San Gabriel Mountains. The heaviest sustained rain fell during the mornings of 1 March and again during mid-day 4 March. With the ground highly saturated from an already very wet winter, runoff from these storms was very high, especially in terms of flow volumes. The water surface elevation behind Prado Dam reached 520.45-ft on 7 March. Plate 4-13 shows a peak flow for the storm period at Prado Dam of 34,705 cfs.

(12) Storm and flood of February 1980. The floods of February 1980 resulted from a series of low-latitude Pacific storms that moved into southern California from out of the west. The heaviest bursts of rain occurred on 14, 16, and 19 February. Some rainfall intensities of 1 inch in one hour were observed in some of the upper areas of the Santa Ana River basin. The water surface elevation for Lake Elsinore reached 1265.7-ft and spilled down Temescal Creek into Prado Dam. Plate 4-14 shows a peak 1-hour average inflow to Prado Dam of 36,000 cfs on 17 February.

The volume of water stored in Prado Dam reached 111,000 ac-ft at a maximum recorded water surface elevation of 528-ft on 22 February. This inflow hydrograph in combination with the constrained reservoir operating policy set a new record for storage in Prado Dam. The release rate from Prado Dam reached 5,992 cfs on 22 February. Extended releases of approximately 5,000 cfs were sustained for up to 7 days, after which a reduction in these releases became necessary in order to facilitate emergency channel repairs downstream. Because of the large amount of water stored in the reservoir, releases were necessary through May 1980 in order to fully empty the flood control pool.

(13) Storm and flood of February-March 1983. During the winter of 1982-1983 a series of low-latitude Pacific storms moved into southern California from the west from late November through February. These storms were the result of atmospheric flow patterns associated with the strongest El Nino condition since at least 1891. The rains climaxed between 25 February and 2 March 1983, during which a storm reminiscent of those of 5 and 45 years earlier moved into southern California at the end of February and the first of March 1983. Up to 20 inches fell in the Lytle Creek area, and several cells of intense local precipitation were observed in the upper and lower Santa Ana River basin, including 1.72 inches in 1 hour in the City of Santa Ana. This and other local Orange County rainfall events with durations between 30 minutes and 6 hours experienced return periods of up to 100 years. One Los Angeles County cloudburst of 2 inches in 5 minutes (Bel Air Hotel, 1 March 1983) was more than 4 times the 100-year rainfall for that duration at that station.

The rainfall through late February had saturated the ground everywhere, resulting in very favorable runoff conditions when the storm of 1-2 March dropped the highest volume of warm rain over the Santa Ana River basin. Plate 4-15 shows inflow and outflow at prado dam for the early March storm. Flow discharges in the lower Santa Ana River were 6,500 cfs just below Prado Dam; 11,000 cfs at E Street; and 26,200 cfs at the Metropolitan Water District (MWD) crossing. Discharges of 4,000 cfs were observed at Lytle Creek near Fontana.

4-07 Runoff Characteristics. Streamflow, which is perennial in the canyons of the Santa Ana River and in the headwaters of most of the tributaries, is generally intermittent in the valley sections. Streamflow increases rapidly in response to effective precipitation. High-intensity precipitation in combination with the effects of steep gradients and possible denudation by fire result in intense sediment-laden floods, with some debris in the form of shrubs and trees. Deposition of the sediment occurs on the mountain streams as they flow into the valley where stream gradients become flatter.

The urbanization taking place in the valley areas of the Santa Ana River basin tends to make the watershed more responsive to rainfall. Plate 4-16 shows that the percentage of impervious cover above Prado Dam has increased from about 5% at the time Prado Dam was completed to 26% today. Hence, the same rainfall occurring over an urbanized part of the watershed will generate higher peak discharges with a shorter peaking time and a greater volume than if it had occurred over the natural watershed without urbanization. The 1969 Hydrologic Review documents an increase in the SPF and PMF flood peaks and volumes (Table 4-2). These revised values are due to the increased urbanization within the basin and improved hydrologic analysis techniques and data.

Table 4-2

Revised Design Floods for Prado Dam

	Original Design 1941	Revised Hydrology	
		Present	Future
Reservoir Design			
Peak Discharge (cfs)	193,000	282,000	317,000
Storm Volume (ac-ft)	275,000 (7 day)	488,000 (4 day)	574,000 (4 day)
Spillway Design			
Peak Discharge (cfs)	289,000	670,000	700,000
Storm Volume (ac-ft)	233,000 (1 day)	1,447,000 (6 day)	1,543,000 (6 day)

Plate 4-17 graphically shows the monthly mean, maximum and minimum flows at Prado Dam for the period of Record. Plate 4-18 is a tabulation of this data. The maximum runoff values occur during the winter flood season. During the summer non-flood season the mean flows through Prado Dam range from 90 to 100-cfs for the period of record. Due to the increased urbanization and the consequent increase in the discharge of wastewater effluent to the Santa Ana River from the upper basin over the past ten years, the average mean flow during the non-flood season has increased to approximately 150-cfs. Plate 4-19 shows the wastewater effluent contribution to the Santa Ana River since 1950 projected to the year 2000.

Plate 4-20 tabulates the maximum values for inflow, outflow, and water surface elevation at Prado Dam for the period of record. Plate 8-04 is the inflow and outflow discharge frequency curve for Prado Dam.

4-08 Water Quality. The quality of surface water and groundwater varies considerably throughout the Santa Ana River basin. Generally, the surface waters flowing out of the rugged and undeveloped mountains to the valley floors are of excellent quality. These waters recharge the groundwater in these areas, consequently, groundwater in these areas is also excellent. As one progresses downstream, however, water quality progressively deteriorates due in large part to heavy water use and waste disposal practices, and to the relatively poor quality of some of the imported water (Colorado River water delivered to the watershed has a TDS of about 900 mg/l).

The California Regional Water Quality Control Board, Santa Ana Region, which has set criteria for local water quality, has identified increasing amounts of dissolved minerals (total dissolved solids, or TDS, from multiple reuse) as the major problem in the Santa Ana River. The target for TDS into Prado Reservoir is 700 mg/l and the downstream target is 650 mg/l. Initial runoff will normally exceed these limits and then improve with succeeding events.

Other factors of concern at Prado include high concentrations of organic materials and nutrients (apparently from wastewater treatment plants, dairy runoff, and inundated vegetation), suspended solids, and metals and low dissolved oxygen concentration. While water quality data is generally inadequate to fully assess water quality trends, the data indicate that certain State-established standards have, at times, not been met, including magnesium, iron, mercury, lindane, PCB's, cadmium, and lead.

4-09 Channel and Floodway Characteristics. The Santa Ana River between Prado Dam and the Pacific Ocean is approximately 30.5 miles in length. The upstream 2.5 miles are located in Riverside County, and the remaining 28 miles are within the

Orange County limits. The river winds through the narrow and relatively undeveloped Santa Ana Canyon for a distance of about 10 miles before it turns southwest into the alluvial plain of the metropolitan area of Orange County. Over the years, the lower Santa Ana River has been improved by local interests from the Santa Ana Canyon to the Pacific Ocean.

Plate 4-21a-b is a schematic of the Santa Ana River showing the long- and short-term channel capacities. Plate 4-22 shows the locations of the existing eleven drop structures and eleven bed stabilizers on the lower Santa Ana River. Plate 4-23 shows the typical cross sections of the improved channel and Plate 4-24 shows a typical cross section of one of the eleven drop structures on the Santa Ana River. Table 4-3 lists the location of the existing drop structures and bed stabilizers.

a. Prado Dam to Weir Canyon Road. Much of the upper reach of the river is unimproved. Within the Santa Ana Canyon, slope protection has been constructed by various local entities at freeway and railroad embankments, and at existing private developments adjoining the river. Slope protection for freeway embankments includes rip-rap and soil cement side slopes. The private developments have constructed rip-rap or grouted rip-rap slope protection. The Atchison Topeka and Santa Fe (AT&SF) Railroad has constructed rip-rap slope protection and installed sheet piles at critical areas. The Green River Golf Course, a 345-acre, 36-hole golf course is located within the streambed of the canyon reach. The improved low-flow channel through the golf course has a non-damaging capacity of about 2,000-cfs. Within the Santa Ana Canyon, flows enter an improved channel immediately upstream from the Weir Canyon Road bridge. Just upstream of the Weir Canyon Road bridge, the Santa Ana Valley Irrigation (SAVI) Ranch Development has constructed a levee embankment for flood control protection.

b. Weir Canyon Road to Katella Avenue. From the Weir Canyon Road bridge to approximately 1,100-ft south of Katella Avenue, a distance of about 9.6 miles, the existing channel is trapezoidal in cross section with a soft-bottom invert and stone revetted side slopes. This reach contains eight drop structures which function as hydraulic energy dissipators and streambed stabilizers. The OCWD maintains earthen L-dikes within the river bed beginning at Imperial Highway. Flows in excess of approximately 600-cfs will washout these L-dikes.

c. Katella Avenue to the Garden Grove Freeway. From Katella Avenue to the Garden Grove Freeway, a reach of about 2.1 miles, an upstream 500-ft portion of the soft-bottom channel has concrete side slopes. The remaining channel has stone revetted side slopes. There are two drop structures located approximately 1 mile apart within this reach.

Table 4-3

Drop Structures and Bed Stabilizers on the Lower Santa Ana River

Type	OCEMA Station	General Location
Drop Structure	1198+50	d/s of Weir Canyon Rd.
Bed Stabilizer	1129+00	u/s of Imperial Hwy.
Drop Structure	1022+98	d/s of OCWD intake works
Bed Stabilizer	1119+00	u/s of Imperial Hwy.
Drop Structure	970+00	d/s of Lakeview Ave.
Drop Structure	907+00	d/s of Tustin Ave.
Drop Structure	884+00	d/s of AT&SF crossing
Drop Structure	836+50	d/s of E02 (Carbon Creek Diversion)
Drop Structure	803+50	d/s of Lincoln Ave.
Drop Structure	737+50	d/s of Ball Rd.
Drop Structure	682+00	u/s of 57 Orange Freeway
Drop Structure	637+00	u/s of Chapman Ave.
Drop Structure	593+35	d/s of 22 Garden Grove Freeway
Bed Stabilizer	574+00	d/s of Garden Grove Blvd.
Bed Stabilizer	517+00	u/s of Seventeenth St.
Bed Stabilizer	498+00	d/s of Fairview St.
Bed Stabilizer	474+00	u/s of Fifth St.
Bed Stabilizer	448+50	d/s of First St.
Bed Stabilizer	420+00	d/s of McFadden Ave.
Bed Stabilizer	383+00	d/s of Edinger Ave.
Bed Stabilizer	329+30	d/s of Warner Ave.
Bed Stabilizer	275+00	d/s of Talbert Ave.

d. Garden Grove Freeway to Seventeenth Street. The easterly side of the river is improved with a grouted rock revetment running from the Santiago Creek confluence to approximately 500-ft north of Seventeenth Street, a distance of approximately 3,600-ft. There is a reinforced concrete lining on both sides of the river from Seventeenth Street to the point where it joins the revetted side slope. The westerly side has approximately 700-ft of grouted rip-rap at the confluence with Santiago Creek; the remainder between the concrete lining north of Seventeenth Street and Garden Grove Boulevard has minimal protection of a pipe and wire revetment installed after the 1938 flood. The golf course turf, located just downstream of the Garden Grove Freeway, provides no stabilization except for very minor annual floods. The bicycle trail-crossing near Seventeenth Street functions as a grade stabilizer with heavy rock revetment, which was placed as a protective measure during the floods of 1978 and 1980. There is also a grouted rock stabilizer at the downstream side of the Garden Grove Boulevard bridge.

e. Seventeenth Street to Adams Avenue. From approximately 1,200-ft upstream from Seventeenth Street to about 3,000-ft downstream from Adams Avenue, a reach of 7.4 miles, the existing Santa Ana River is a soft-bottom trapezoidal channel. The side slopes are protected with reinforced concrete.

f. Adams Avenue to the Pacific Coast Highway. From Adams Avenue to 0.6 miles upstream of the Pacific Coast Highway the channel is a soft-bottom trapezoidal channel with side slopes protected with reinforced concrete. From 0.6 miles upstream of the Pacific Coast Highway, the channel invert transitions from grouted stone to concrete. The channel shape transitions from trapezoidal to rectangular within this 0.6 mile section.

g. Santa Ana River Outlet. The outlet channel is located south of the Pacific Coast Highway, discharging into the Pacific Ocean. The 700-ft long outlet channel consists of a transition section, from rectangular concrete to trapezoidal stone jetty with a soft-bottom invert. The existing Santa Ana river mouth includes the Greenville-Banning Channel running parallel to the southeast, the Talbert Channel running parallel to the northwest, and the Santa Ana River Channel in between.

h. Flood Problems. Portions of the existing Santa Ana River channel can convey flows ranging from 30,000 to 40,000-cfs for short periods of time. Severe erosion of the unlined channel invert will occur when long-term releases greater than 2,500-cfs are maintained. Long-term discharges of more than 2,500-cfs from Prado Dam have, in the past, undermined drop structures, bed stabilizers, the toe of channel embankments, and eroded the foundation materials underneath the piers of many bridges. Table 4-4 is a brief chronology of erosion problems on the lower Santa Ana River. Photo 4-1 shows the erosion which occurred at the Fifth Street bridge during the 1980 flood season. The OCEMA has been continuously improving the capacity of the Santa Ana River channel during the last 30 years, but the invert of the entire channel system must be stabilized and the channel banks strengthened before the channel can safely convey large long duration flows. The spillway outflows from Prado Dam under present conditions are 50,000-cfs for the 100-yr flood event and

160,000-cfs for the 200-yr flood event. These flood events would not be contained by the existing channel improvements and would cause widespread flooding within the lower river area (Plate 4-25).

i. **Diverting Flows from the Santa Ana River to Coyote Creek**. Flows from the Santa Ana River can be diverted at Imperial Highway through OCWD's spreading facilities to Coyote Creek via the Anaheim Lake Transfer Facility. Approximately 180-cfs can be accommodated through this diversion. Such a diversion must be approved and coordinated with the OCWD and the OCEMA. Normally such a diversion is only initiated under unusual conditions when water can not be impounded at Prado Dam and the channel downstream of Imperial Highway needs to be free of all flows.

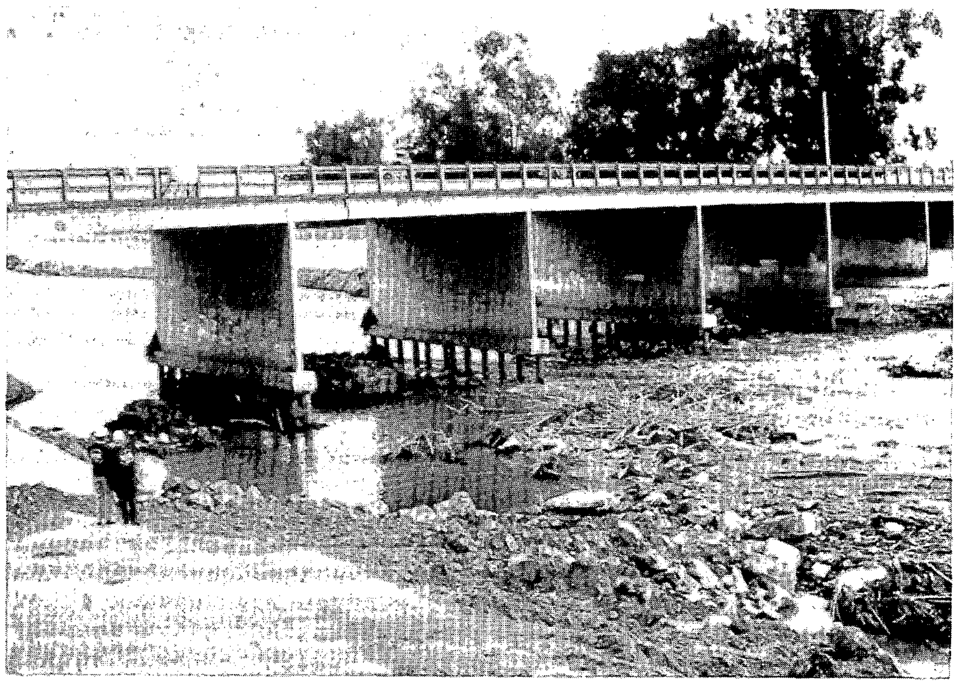

Photo 4-1: Scour under the Fifth Street Bridge downstream of Prado Dam following the floods of February 1980

4-10 **Upstream Structures**. Refer to Plate 4-01a for the location of the following described structures.

a. **Upper Santa Ana River**. Big Bear Dam is the only existing structure which would affect flood flows in this watershed. Big Bear Lake is a water conservation reservoir, owned by the Big Bear Municipal Water District. The lake has a drainage area of about 38 sq-mi and has a surcharge storage of about 8,600 ac-ft between the top of the conservation pool and the top the dam.

b. **Santa Ana River to Prado Dam**. Two major flood control dams are located in the Santa Ana River Basin; Prado Dam and San Antonio Dam.

(1) **San Antonio Dam**. San Antonio Dam, completed by the Corps in 1956, is located on San Antonio Creek and controls runoff from a drainage of 26.7 sq-mi. San Antonio Dam is the second largest flood control facility operated and maintained by the LAD within the Santa Ana River watershed. Releases of up to 8,000 cfs from San Antonio Dam enter Prado Reservoir via San Antonio Creek/Chino Creek. Refer to Exhibit B of this manual and the San Antonio Water Control Manual for additional information.

(2) **Other Improvements**. Other existing flood control improvements, including those on Cucamonga, Deer, Lytle, and Cajon Creeks, have been constructed by the Corps of Engineers and local interests. These improvements include channelization, debris basins, storm drains, levees, stone and wire-mesh fencing, and stone walls along the banks of stream channels. The principal existing water conservation improvements are spreading grounds and reservoirs. The more than 100 water conservation and recreational reservoirs within the basin have storage capacities ranging in volume from less than 5 ac-ft to Lake Mathews' 182,000 ac-ft. Although most of the existing water conservation improvements affect the regimen of lesser flood flows, major flood flows are not appreciably affected.

c. **Lake Elsinore**. Lake Elsinore, the terminus for the 768 sq-mi San Jacinto River basin, has considerable potential influence on flood runoff, especially if its water surface elevation is low at the beginning of a storm. Lake Elsinore has a dead storage capacity of about 130,000 ac-ft. When full, lake Elsinore overflows into Temescal Wash, which joins the Santa Ana River near Prado Dam. The Lake Elsinore overflow is a small manmade outlet channel which allows water to either spill due to gravity flow or by pumping. The lake is only pumped during extreme flood events. During the 1980 and 1983 flood events, the California Department of Water Resources had pumps brought to Lake Elsinore. The pumps operated at a maximum monthly average of 80 cfs.

Table 4-4

Brief Chronology of Erosion on the Lower Santa Ana River

Water Year	Extended Discharge (cfs)	Duration	Description of Damage/Action
1969	4,500-5,000 1,200-2,400 4,000-5,000 1,200-1,000	25Jan-27Jan 27Jan-26Feb 26Feb- 7Mar 7Mar-20Apr	Heavy erosion and silting all along the Santa Ana River
			Erosion to levees required emergency rip-rapping. All gates at Prado were closed, only ungated release were made from Jan 27-29 and Feb 12-26.
			Piping occurred through the levee into Burris Pit
			Foundation of Santa fe RR bridge in the City of Orange was damaged
			3,000 chickens were lost in Santa Ana Canyon due to bank erosion
1978	1,900-1,400 500- 500 2,500-2,000 0- 0 1,000-1,000	10Feb-21Feb 21Feb- 2Mar 2Mar-16Mar 16Mar-20Mar 20Mar-28Mar	Drop structure near Katella Ave failed on 12Feb78.
			Considerable invert erosion results in damage to a Sanitation District Sewer Crossing.
1980	5,000-6,000 1,500-2,000 4,000-5,000 2,600-2,800 0- 0 1,500-1,500	19Feb-28Feb 25Feb- 1Mar 1Mar-10Mar 10Mar-17Mar 17Mar-25Mar 25Mar-19Apr	Damage to downstream channel required reduction of outflow to accommodate flood fight.
			Severe erosion of channel invert and lining, particularly between 17th St. and Harbor Blvd. Scour averaged 6'-8' with localized scour of up to 20'.
			Several bridges undermined exposing pile caps and piles. Bridges affected included: Fairview St. P.E. Railroad 5th St. 1st St. McFadden Ave. Edinger Ave.
1983	4,000-5,000 0- 0 1,000-2,000 0- 0 1,000-1,500	27Feb- 8Mar 8Mar- 9Mar 9Mar-29Mar 29Mar-31Mar 31Mar- 8Apr	Levee just upstream of 405 (San Diego) Freeway experiences severe scour damage at the toe.
			Footing piles are exposed on bridges: 5th St. 1st St. McFadden Ave. Edinger Ave. Bridge scour is not as sever as in 1980, no bridges were closed to traffic.
1990	-	-	Since water year 1983, drop structures, bed stabilizers, new bridges, and other improvements have been added to the OCEMA maintained Santa Ana River. The Corps still considers 5,000 cfs to be the maximum long-term release capacity of the Santa Ana River

d. Mill Creek. The only existing flood control structure in the Mill Creek drainage area is a levee system comprised of levee embankments and masonry walls. The main levee structure is a 13,600-ft compacted earthfill embankment built by the Corps of Engineers in 1960. Local interests had previously built about 2,000-ft of masonry walls which tie into the upstream end of the Corps' levee, and about 2,400-ft of guide levees to control low flows. These structures are protected by rock and wire revetments. The lower 1,800-ft of the Corps' levee is ungrouted stone revetment, with the remaining upstream length being protected by grouted stone revetment.

e. Oak Street Drain. Within the Oak Street Drain watershed, two debris basins have been constructed by the Riverside County Flood Control and Water District (RCFCWD). Mabey Canyon and Oak Street debris basins were completed in late 1973 and 1979, respectively. Together, these basins control debris emanating from Kroonen, Hagador, Tin Mine, and Mabey Canyons. Mabey Canyon debris basin was designed to provide debris storage of 108 ac-ft with a spillway capable of passing 3,100 cfs. Oak Street debris basin was designed to provide 253 ac-ft of debris storage with a spillway capable of passing 7,700 cfs. Other structures affecting runoff are Mangular Border Drain (downstream of Mabey Canyon debris basin), and Main Street Drain. Main Street Drain discharges flow into Oak Street Drain approximately 1,500-ft upstream of the confluence with Temescal Wash. The existing Oak Street Drain channel from the debris basin to the confluence with Mangular Border Drain consist of steel rail and wire mesh bank protection with a natural earth channel bottom. A concrete-lined channel extends from this confluence downstream to Railroad Street. The remaining reach downstream to Temescal Wash is a natural channel.

4-11 Downstream Structures. Refer to Plate 4-01a for the location of the following described structures.

a. Lower Santa Ana River from Prado Dam to the Pacific Ocean. Two major flood control dams are located in the Santa Ana River Basin below Prado Dam; Carbon Canyon Dam and Villa Park Dam. Villa Park Dam is described in paragraph 4-11-b-(1) "Santiago Creek".

(1) Carbon Canyon Dam. Carbon Canyon Dam, completed by the Corps in 1961, is located on the Carbon Canyon Creek in the Chino Hills about 4 miles east of the city of Brea. It is currently operated and maintained by the LAD. The drainage area is 19.3 sq-mi. The reservoir release schedule allows a maximum average outflow of 1,000 cfs. The downstream channel is concrete lined for one mile at which point it becomes an improved earth channel, which diverts flows into the OCEMA's Miller Stilling Basin located a distance of 3.5 miles downstream from Carbon Canyon Dam.

The outflow from the Retarding Basin flows through the Carbon Creek Diversion Channel into the Santa Ana River between Lincoln Avenue and Glassell Street (Plate 2-10). Waters entering the Miller Basin Complex are normally diverted to the Santa Ana River via the Carbon Creek Diversion Channel. Under extreme conditions, flows will be split between the Carbon Creek Diversion Channel and the Carbon Canyon Creek, which flows into Coyote Creek and then into the San Gabriel

River. Refer to Exhibit B of this manual and the Carbon Canyon Water Control Manual for additional information.

(2) Other improvements. Other existing flood control improvements have been constructed by local interests. These improvements include channelization, storm drains, levees, rip-rap and concrete side slope protection, and drop structures. The principle existing water conservation improvements are spreading grounds, recharge basins, and Irvine Lake (i.e., Santiago Dam).

(a) Santa Ana River Infiltration Enhancement Facility. OCWD operates a system of ground water spreading facilities in and along the Santa Ana River between Imperial Highway and Ball Road. This reach of river is composed of two channels. One channel, located on the northerly side of the Santa Ana River, is used for groundwater recharge purposes. The other is the main channel of the Santa Ana River which is used for both flood flows and recharge during low flows. Recharge in the main channel is accomplished through a series of earthen berms, known as L-dikes, which are washed out when flows downstream of Prado Dam exceed 600 cfs. The groundwater recharge system includes permanent gated off-channel basins to maximize percolation capacity. Plate 4-26 shows the general plan of the recharge facilities.

The general characteristics and specifications of the sub-basins are summarized in Table 4-5. The upstream inlet structure to the spreading grounds is located just downstream of Imperial Highway. It consists of a set of three rectangular six by six foot electrically operated gates. A sand dike with a set of four 36 inch diameter pipes is used to backhold water to provide sufficient head to allow flow to be diverted through the gates. The approximate maximum inlet capacity of the Imperial Fore-bay structure is 500 cfs and is highly dependent on the water surface elevation in the Santa Ana River. An additional transfer facility is located at the junction of the Carbon Creek Diversion and the Santa Ana River. The long term percolation rate of the entire system is currently estimated to be approximately 350 cfs.

OCWD has completed (April 1990) a pumped storage facility which will allow it to capture additional storm flows. The capacity of the pumping facility is 200 cfs. Water is pumped from Burris Pit, located along the Santa Ana River, to Bond Pit located about 6 miles away on the Santiago Creek via a 66 inch pipeline. Buttressing of the side walls of the gravel pits with permeable material has been completed to elevation 230-ft.

Because any significant flow within the Santa Ana River overtops and washes away the L-dikes and consequently destroys the in-channel spreading basins, OCWD maintains a full time maintenance crew at the spreading grounds. OCWD estimates that a one week period at a cost of about $10,000 is required to rebuild the in-channel L-dikes.

b. Santiago Creek. Villa Park Dam, a multi-purpose facility is located on the Santiago Creek.

Table 4-5

General Characteristics of the OCWD
Santa Ana River Infiltration
Enhancement Facility

Basin	Invert Elevation (ft)	Maximum WSE (ft)	Maximum Surface Area (ft)	Maximum Storage (ac-ft)
Imperial Desilting Basins	---	---	33	--
Huckleberry	207	246	24	865
Con-Rock Basin	200	241	35	1,205
Warner Basin	190	236	65	2,521
Olive Pit	200	227	3	60
Glassel Basin	---	---	98	--
Fives Coves Basin	170	201	29	690
Lincoln Basin	170	190	10	120
Burris Pit	100	170	60	3,836
Ball Road Basin	155	160	11	53
Anaheim Lake	175	224	73	2,370
Miller/Placentia/ Raymond*	---	---	53	---
Kramer Basin	170	215	38	1,200
Santiago Basins	160	280	179	11,060

* OCEMA allows use for water conservation during non-flood season.

(1) Villa Park Dam. Villa Park Dam is located approximately 2 miles upstream of the Santiago Gravel Pits (i.e., Blue Diamond and Bond Pits) at the foothills of the Santa Ana Mountains. It has a drainage area of 83.4 sq-mi, this includes the 63.1 sq-mi Santiago Dam drainage. Villa Park Dam was constructed by the OCFCD in 1963. The OCEMA, which has assumed the administrative and operational obligations of the Flood Control District, currently maintains and operates the facility. Villa Park Dam is operated as a multipurpose reservoir with varying seasonal storages for both flood control and water supply. Dam releases are scheduled according to the water surface elevations of both the Villa Park Dam and the uncontrolled Santiago Reservoir which is located 3.2 miles upstream of Villa Park Dam. The maximum scheduled release from Villa Park Dam is 6,000 cfs. The flood control and conservation storage allocations are scheduled on a seasonal basis as

shown in Table 4-6. Refer to Exhibit B of this manual and the Villa Park Dam Operation Manual (an OCEMA document) for additional information. The basic operation of Villa Park Dam is as follows:

1. The water surface elevation in Santiago Reservoir determines the water surface elevations in Villa Park Reservoir at which the gates are first opened for flood control releases. The lowest level at which releases from Villa Park Dam are made is when the WSE at Villa Park Dam reaches 510-ft.

2. When the specified WSE's at Villa Park and Santiago Dam are reached, the gates are operated so that outflow is approximately equal to inflow up to the normal maximum of 3,500 cfs (higher gated outflow rates of up to 6,000 cfs are allowable under certain conditions, as described in the "Villa Park Dam Operation Manual").

3. During times when outflow is being set approximately equal to inflow, a deviation of 1-ft in the water surface elevation above or below that specified in the gate regulation schedule is permissible at the discretion of the operator.

Table 4-6

Seasonal Storage Allocations for
Villa Park Dam

Period	Conservation Storage (ac-ft)	Flood Control Storage (ac-ft)
Jan01-Apr01	20	15,324
Apr01-Apr15	6,031	9,313
Apr15-May15	11,130	4,214
May15-Jun01	14,398	946
Jun01-Oct01	15,344	0
Oct01-Oct15	12,997	2,347
Oct15-Nov01	2,296	13,048
Nov01-Dec01	629	14,715
Dec01-Jan01	20	15,324

Flood control releases from Villa Park Dam commence when the WSE at Villa Park exceeds 510-ft and the WSE at Santiago Dam exceeds 710-ft.

(2) Santiago Dam (Irvine Lake). Santiago Dam, located upstream from Villa Park Dam, is a water supply reservoir constructed by the Irvine Company in 1933. Its uncontrolled flood releases enter Villa Park Dam. It has a drainage area of 63.2 sq-mi. The total storage capacity is 25,000 ac-ft.

(3) Other Improvements. The Santiago Creek channel has been improved over the years by local interests. During the 1930's, masonry walls were constructed from the Santa Ana Freeway through Hart Park, Within Hart Park, the channel bottom has been paved for use as a parking lot. Rip-rap was placed along the west bank upstream from Chapman Avenue for the protection of homes along the bank. Downstream from Prospect Avenue, concrete sideslope protection has been placed to protect homes that were damaged by the 1969 floods. On Handy Creek, a concrete channel runs from just downstream of Orange Park Boulevard to its confluence with Santiago Creek. The large gravel pits (Blue Diamond and Bond Pits), downstream from Villa Park Dam, act as reservoirs for floodwater. During minor floods, flows are completely contained within the pits and never reach the downstream channel. However, during major floods, water will fill the pits and overflow to the downstream channel.

4-12 Economic Data.

a. Area of Flood Protection. The Prado Dam Flood Control Basin presently serves as the major flood control facility along the Santa Ana River corridor. The Prado Dam watershed is essentially the heavily populated downstream and upstream areas that lie in the counties of Orange, San Bernardino, and Riverside. This area is commonly referred to as the South Coast hydrologic subregion. The area is among the most populous and economically diverse areas in the nation. Existing flood control features protect approximately 110,000 acres of urbanized area. The majority of this area is located in the cities of Anaheim, Santa Ana, Huntington Beach, Garden Grove, and Fullerton. Plate 4-25 taken from the Santa Ana River GDM depicts the projected Standard Project Flood (SPF) overflow area.

b. Population. The major concentrations of population within the aforementioned overflow area reside and/or work in the cities listed in Table 4-7.

In addition to these cities, an estimated 1 million people are currently living in other portions of the overflow area downstream of Prado Dam. Hence the flood control dam currently protects over 2 million people living in the flood plain.

Statistical information from both the State of California, Department of Finance, Demographic Research Unit and the southern California Association of Governments (SCAG) show steady population increases range between 2.4% and 4% annually. This trend is expected to continue through the year 2010 and add another 1.5 million residents to the overflow area.

Table 4-7

Major Population Centers Downstream of Prado Dam

City	Estimated Population*
Anaheim	244,300
Fountain Valley	56,100
Garden Grove	134,800
Huntington Beach	188,700
Los Alamitos	12,150
Orange	106,400
Santa Ana	237,300
Seal Beach	27,350
Stanton	28,350
Westminster	73,300
TOTAL	1,108,750

*Source: State of California, Department of Finance, Demographic Research Unit; "Population Estimates of California Cities and Counties, January 1, 1988 to January 1, 1989"

c. Economic Activity. The flood plain associated with the Prado Dam is characterized as primarily highly urbanized. Existing residential development is extensive throughout the overflow area. As a result associated service industries have grown in conjunction with residential development. Major industrial activities abound within this area as well. Manufacturing facilities such as McDonnell-Douglas, Rockwell International, Monsanto Chemical, Nabisco Foods, and Georgia Pacific are located within the downstream overflow area of Prado Dam. Key regional warehousing operations for Goodyear, Lucky Foods, Kimberly-Clark, J.C. Penny Company, Radio Shack, and Yamaha are also located in the lower Santa Ana River flood plain. Additionally within this area are several world renown tourist attractions. Disneyland, Knott's Berry Farm, Movieland Wax Museum, Huntington Beach, and Newport Beach Harbors are situated on the flood plain. These activities employ tens of thousands of people and are vital to southern California's diverse economy.

d. Residential Development. Based upon the SCAG Regional Growth Management Plan (1988) and assuming a growth factor of $\pm$3% the estimated number of existing residential units within the overflow area is 806,350. The projected number of housing units for the year 2010 is estimated at 1,186,400.

e. Flood Damages. The Phase II GDM of the Santa Ana River Mainstem (August 1988) estimates expected flood damages to structures and contents in the Lower Santa Ana River area as $14.7 billion in 1987 dollars for a flood with two-tenths of one percent chance of occurrence (500 year frequency). The damages in 1989 dollars are estimated to be $16.2 billion.

V - DATA COLLECTION AND COMMUNICATION NETWORK

5-01 Hydrometeorological Stations.

a. Facilities. Precipitation, stream flow, and reservoir water surface elevation (WSE) data are collected and monitored from gages located throughout the Santa Ana River watershed. Plate 5-01 shows the location of stream gages, and reservoir Water Surface Elevation (WSE) gages, and Plate 5-02 shows the location of precipitation gages pertinent to the operation of Prado Dam. Tables 5-1 and 5-2 list the gages by name and the type of information collected at each station. The data from these stations is available on a real-time basis on the water control minicomputer (Harris 800) via the REPORT and TELEM programs. The data is also used by the Santa Ana River Real-Time (SARRT) Water Control System as well as other forecasting methods described in chapter 6. In addition to the above telemetered data, the WSE, precipitation, downstream gage, and gate settings are manually monitored by the dam tender. Plate 5-03 is a list of the hydrometeorological instrumentation at Prado Dam.

b. Reporting.

(1) Manual. The dam tender observes precipitation, WSE, downstream gage, and gate settings. During the non-flood season (April 15 through November 15) these readings are taken once a week on Monday. During the flood season (November 15 through April 15) they are taken daily Monday through Friday. During flood control operations they are taken as often as the Reservoir Operations Center (ROC) deems necessary.

(2) Recording Instruments. The recording instruments listed on Plate 5-03, record data on paper tape. The paper tape is removed at predetermined intervals and maintained on file by the LAD.

(3) Los Angeles Telemetry System (LATS). Hydrometeorological data measured at the dam and other gages are transmitted to the LAD by the Los Angeles Telemetry System (LATS). These gages automatically transmit reports at 24-hr. intervals. The event mode is the primary means of data collection for the telemetry system. Once a gage is triggered the data is radio-transmitted to a repeater, located on either Pleasants Peak or Mount Disappointment, from which it is sent via microwave to the LAD office. Each gage is programmed to trigger whenever 0.04-in. of precipitation or a 0.25-ft change in WSE is recorded. All gages can also be interrogated at any time for the current condition using a polling option from the Central (Microvax) computer. The data is stored on the Harris 800 minicomputer and is available through the TELEM and REPORT programs. The four letter designation for the LATS WSE station at Prado Dam is PRDO. This WSE gage is

triggered ever 0.1-ft. The downstream stream gage is SAR7 and it is also triggered ever 0.1-ft.

Table 5-1

Los Angeles Telemetry System (LATS) Gages within and adjacent to the Santa Ana River Basin

Gage Name	Location	Rain Gage (PP)	Reservoir Water Surface Elevation (WS)	Stream Gage (GH)
BEAU	Beaumont	PP	–	–
BREA	Brea Dam	PP	WS	–
CCKC	Carbon Creed below CCYN	–	–	GH
CCYN	Carbon Canyon Dam	PP	WS	–
CONV	Converse Fire Station	PP	–	–
CUCM	Cucamonga Creek Near Mira Loma	PP	–	GH
DBAR	Diamond Bar	PP	–	–
DCDB	Demens Creek Debris Basin	PP	–	–
DEVO	Devore Fire Station	PP	–	–
FLTN	Fullerton Dam	PP	–	–
IDYL	Idyllwild	PP	WS	–
LKMA	Lake Mathews	PP	–	–
LYDB	Lytle Creek Detention Basin	PP	WS	–
MTBY	Mt. Baldy	PP	–	–
OAKG	Oak Glen	PP	–	–
PRDO	Prado Dam	PP	WS	–
RIFC	Riverside County Flood Control and Water Conservation District	PP	–	–
RSPR	Running Springs	PP	–	–
SAR5	Santa Ana River at 5th St. in Santa Ana	PP	–	GH
SAR7	Santa Ana River at Hwy. 71	–	–	GH
SARE	Santa Ana River at E St. in San Bernardino	–	–	GH
SARM	Santa Ana River near Mentone	–	–	GH
SBFC	San Bernardino Flood Control District	PP	–	–
SNTO	San Antonio Dam	PP	WS	–
STCL	San Timoteo Creek Near Loma Linda	PP	–	GH
TCKC	Temescal Creek Near Corona		–	GH
VLPK	Villa Park Reservoir	PP	WS	–

Table 5-2

ALERT System Gages within and adjacent to the Santa Ana River Basin

Gage No.	Location	Precipitation Gage (PP)	Reservoir Water Surface (WS)	Stream Gage (GH)
		Orange County		
201	Santiago Peak	PP	–	–
203	Plano Trabuco	PP	–	–
220	Villa Park Dam	PP	–	–
231	Silverado Canyon	PP	–	–
233	Modjeska Canyon	PP	–	–
234	Santiago Dam	–	WS	–
235	Santiago Dam	PP	–	–
236	Santiago Creek at Bristol	–	–	GH
241	Miller Basin	PP	–	–
242	Prado Dam	–	WS	–
244	Prado Dam Outflow	–	–	GH
245	Prado Dam	PP	–	–
246	Santa Ana River at Imperial Hwy.	–	–	GH
251	Oak Flat	PP	–	–
261	Brea	PP	–	–
		Riverside County		
805	Riverside Flood	PP	–	–
810	Gavilan Hills	PP	–	–
855	Camp Scherman	PP	–	–
865	Juniper Flat	PP	–	–
870	Red Mountain	PP	–	–
875	Pigeon Pass Dam	PP	–	–
878	Angeles Hill	PP	–	–
881	Alandale	PP	–	–
884	San Jacinto River	–	–	GH
887	Railroad Canyon Dam	PP	–	–
890	Perris Valley CH	PP	–	–
		San Bernardino County		
819	Chino Creek	–	–	GH
820	Chino Creek	PP	–	–
824	Cucamonga Creek	–	–	GH
825	Cucamonga Creek	PP	–	–
828	San Antonio Dam	PP	–	–
830	Raywood Flat	PP	–	–
832	Camp Angelus	PP	–	–
835	Santa Ana River at Mentone	–	–	GH
836	Santa Ana River at Mentone	PP	–	–
841	Santa Ana River at E St.	–	–	GH

(4) ALERT System. The Automatic Local Evaluation in Real-Time (ALERT) system is a cooperative flood warning system sponsored by the NWS. The ALERT gages are also event recording gages. Information from the gages is sent to the LAD and stored on the Harris 800 minicomputer. The data is available through the REPORT program.

Three ALERT stations are located at Prado Dam. They are station numbers 242, 244, and 245 which monitor WSE, downstream stage, and precipitation, respectively.

c. Maintenance. The instruments at Prado Dam listed in Plate 5-03 and the LATS gages listed in Table 5-1 are maintained by the Water Control Data Unit, Reservoir Regulation Section of the LAD. ALERT gages listed in Table 5-2 are maintained by the individual counties.

5-02 Water Quality Stations.

a. Facilities. The LAD does not maintain any water quality stations at Prado Dam. The USGS, San Bernardino Office, maintains a water quality gage below Prado Dam, and the California Regional Water Quality Control Board (CRWQCB), Santa Ana Region regularly takes samples at Prado Reservoir. Other agencies which collect and monitor water quality on the Santa Ana River include, but are not limited to, the California Department of Water Resources, the Orange County Water District, the Riverside County Health Department, and the Santa Ana Watershed Project Authority (SAWPA).

b. Reporting. At present, water quality data is not available on a real-time basis at the LAD. No formal agreements exist between the above mentioned agencies and the Corps to transmit water quality data directly to the LAD. The LAD does, however, collect water quality data on an annual basis in conjunction with the preparation of the annual Water Quality Management Report. The report is prepared in accordance with ER 1130-2-334, "Reporting of Water Quality Management Activities at Corps Civil Works Projects", dated 16 December 1977.

Many of the agencies which collect the above data publish annual summaries of their findings. Data collected by the DWR and the CRWQCB are published annually on microfilm by the State of California Water Data Information System (WDIS). The USGS data is published in Water Resources Data for California which is published each water year. The EPA's STORET data base is also a source for water quality data.

c. Maintenance. The LAD has no maintenance responsibilities with respect to water quality stations.

5-03 Sediment Stations.

a. Facilities. The USGS, at the request of the LAD, maintains two sediment stations on the Santa Ana River. One is at E Street near San Bernardino (USGS DO# 11059300) and the other is at 5th Street in Santa Ana (USGS DO# 11078000). The periodic sediment stations use U.S. Depth-Integrating Samplers, which accumulate a water-sediment sample as the sampler is lowered to the stream bed and raised to the surface at a uniform rate.

b. Reporting. At present, sedimentation data is not available on a real-time basis at the LAD office. The USGS collects, compiles, and publishes sediment data on an annual basis in Water Resources Data for California.

c. Maintenance. The LAD has no maintenance responsibilities with respect to sediment stations.

5-04 Recording Hydrologic Data. Each agency maintains records of its own data. The NWS Data are archived at the NOAA, National Climatic Data Center in Asheville, North Carolina. Precipitation and other data are published monthly by the National Climatic Data Center in Climatological Data and Hourly Precipitation Data.

The State of California, Department of Water Resources, publishes monthly data from the ALERT telemetry gage network. The OCEMA, Riverside County Department of Public Works and The San Bernardino County Department of Public Works archive their recording and non-recording data and will furnish these data to other agencies upon request. The LAD maintains pertinent hydrologic data files from different sources.

The LAD maintains a file of data from its recording and telemetry gauges and provides selected data to the NWS for publication. The LAD also enters data from its manual observations on various forms, which are maintained on file in the District. The reservoir information, reported to the ROC via radio or telephone is entered into the RESCAL computer program which stores the data in a computer database and generates a "Daily Reservoir Report" for internal distribution.

The dam tender maintains a record of the WSE, downstream gage height, and the gate positions on SPL Form 19 - Flood Control Basin Operation Report (FCBOR). The Water Control Data Unit of the LAD calculates inflows from data collected on the FCBOR's. These calculations are made on SPL Form 30 - Reservoir Computations and are stored at the Base Yard Office, located in El Monte, 11 miles east of the downtown district office. Examples of both forms are on Plate 5-04.

Data from the ALERT and LATS stations are stored in computer-data files at the LAD office.

5-05 Communication Network. The LAD maintains a voice radio communication network connecting the ROC with all of its projects. This FM radio system uses repeaters on Mount Disappointment or Pleasants Peak. When communicating with Prado Dam the Pleasants Peak repeater should be used. This radio network is backed up by a second, parallel radio system.

Power at each dam, is backed up by an emergency generator system. If all systems fail at the District Office there is a complete radio system at the District's Base Yard.

5-06 Communication with the Project.

a. Between the ROC and Prado Dam. During the flood season (15 November through 15 April), a routine radio call is made at least once each weekday from the District Office to the Dam Tender at Prado Dam. A Reservoir Operation Report, or "Morning Report", is usually made at 0800 hours, Monday through Friday. During flood events the reporting interval is usually reduced to one hour, with the ROC originating the call. The Base Yard is used as an alternate communication center.

In the event that all communications with the District Office, including the Base Yard, should be interrupted, a set of Standing Instructions to the dam tender (Exhibit A) has been compiled for Prado Dam.

b. Between Prado Dam and Others. No routine communication exists between Prado Dam and other agencies.

c. Between the ROC and Others. During normal operating conditions, the LAD is in contact with officials of OCEMA's Storm Center and with the OCWD. Continuous coordination with OCEMA is maintained during extended periods of flooding.

A list of agencies to be notified, with applicable office and home telephone numbers, is published annually in the LAD's Instructions for Reservoir Operations Center Personnel (unofficially called the "Orange Book"). The ROC is also in direct radio contact with channel observers dispatched to patrol the downstream channel during significant floods.

5-07 Project Reporting Instructions. During periods of flood control operation, communications between the ROC and the dam tender are made on a frequent basis, normally once each hour. A more frequent interval of communications may be requested by ROC personnel if needed. If a gate change is required, the ROC broadcasts the gate change instructions to the dam tender. When the gate change is completed, the dam tender calls back to the ROC with confirmation of the gate change, time gate change was completed, and current WSE.

Other instructions to the dam tender are conducted in a similar manner. This network of radio communications is also used by the dam tender to report any mechanical failures or other problems at the dam.

Through the utilization of a real-time computerized gaging network, the ROC regularly monitors water surface elevation in the reservoir and the releases and stream flows at various locations within the Santa Ana River watershed.

5-08 Warnings. The responsibility for issuing all weather watches and warnings and all flood and flash flood watches and warnings rests with the NWS. Local emergency officials of cities and counties are responsible for issuing any public warnings regarding unusual overflows, evacuations, unsafe roads or bridges, toxic spills, etc. The LAD makes notifications to local authorities when critical WSE's are reached and critical release rates are initiated. The notifications list is updated on an annual basis and can be found in the LAD's "Instructions For Reservoir Operations Center Personnel" commonly referred to as the "Orange Book". In the event of a dam break the Emergency Action and Notification Subplan notebook for Prado Dam should be consulted. Copies are located in the ROC and the LAD's Emergency Operations Center (EOC).

VI - HYDROLOGIC FORECASTS

6-01 General.

a. Role of the Corps of Engineers. The LAD does not prepare formal published hydrologic forecasts for Prado Dam. Despite the lack of formal hydrologic forecasts, the LAD does carefully monitor the reservoir including the existing and anticipated hydrometeorologic conditions of the entire Santa Ana River watershed. Other agencies are notified of any significant changes or anticipated changes as described in Section 5-06c.

Quantitative Precipitation Forecasts (QPF) for the Santa Ana River Basin are obtained from a private meteorological firm under contract with the LAD. These are used in determining the potential for significant runoff into Prado Reservoir and other reservoirs within the watershed. The Santa Ana River Real-Time (SARRT) Water Control System integrates the QPF and telemetered precipitation and streamflow data to provide a real-time overview of the entire Santa Ana River basin as well as a runoff forecast for the watershed. The SARRT water control system allows the water control manager to more efficiently regulate Prado Dam as a component of the Santa Ana River flood control system during significant runoff events.

In addition to the SARRT, a simplified QPF/API algorithm and a Recession Limb Inflow Forecast Method have been developed which can be used to respectively determine an estimated inflow volume and a recession limb hydrograph for Prado Dam.

b. Role of Other Agencies. Real-Time weather data and forecasts for the southern California region are received from the NWS. This information is received via a weather satellite display system and DATACAL.

Historical precipitation and stream flow data are available from the OCEMA, NWS, USGS, and OCWD. These data, while not of use in real-time, are important to studies of historical storms and floods that aid in the development and refinement of manual and computerized rainfall-runoff forecast models such as the QPF/API algorithm, the Recession Limb Inflow Forecast Model, and the SARRT water control system.

6-02 Flood Condition Forecasts. The LAD uses three forecasting methods to determine the inflow to Prado Dam. For significant flood events the SARRT Water Control System is used. The QPF/API algorithm is also used to determine flood volume inflows. And finally a Recession Limb Inflow Forecasting model is used to predict the recession limb of the inflow hydrograph.

The SARRT Water Control System was first completed in 1987 and then revised due to software changes, in 1989. The purpose of the SARRT water control system is to enhance the regulation of the Santa Ana River flood control system by:

1. The acquisition, management, and display of real-time data that reflects the current status of the watershed and water control facilities.

2. The production of runoff forecasts for the entire Santa Ana River Watershed, based on observed or forecasted precipitation.

3. Allowing the water control manager to evaluate several regulation alternatives for the multi-reservoir system, thereby allowing the water control manager to implement a regulation alternative which best controls the forecast flood event.

SARRT was calibrated for significant flood events and is therefore best suited for use during such events. The SARRT is capable of producing forecast hydrographs at several control points in the Santa Ana River Watershed. Plate 6-01 is a schematic of the Santa Ana River Watershed showing the control points at which hydrographs can be generated. SARRT remains largely untested due to the lack of significant storm events since its completion.

The QPF/API algorithm was developed to aid the water control manager during flood events which impact water conservation regulation. Unlike the SARRT, the QPF/API algorithm does not produce a forecast inflow hydrograph for Prado Dam, but rather, it only determines a forecast inflow volume to Prado Dam.

The recession limb inflow forecast model can be used as a secondary check of the SARRT water control system or to improve a forecast based on the QPF/API algorithm. As the name implies, this model can only be used after the inflow hydrograph has peaked. Also if substantial precipitation is still falling the water control manager should expect a possible secondary peak, which would require reiteration of the recession limb inflow forecast model.

a. Requirements.

(1) Santa Ana River Real-Time (SARRT) Water Control System. The SARRT was developed by adapting computer software developed by the U.S. Army, Corps of Engineers, Hydrologic Engineering Center (HEC). The SARRT accesses telemetered precipitation, stream flow, and reservoir elevation data as well as current QPF's for the Santa Ana River basin. The water control manager specifies zonal hydrologic parameters for ungaged watersheds and future reservoir release schedules.

With this information stored in the master data base, the water control manager can either view the existing conditions or prepare a forecast for the entire watershed. The SARRT also checks for pre-programmed alarm conditions at the various control points in the watershed. The SARRT uses the computer programs HEC-1F and HEC-5 to generate forecast hydrographs for the various control points.

The LAD Harris-800 minicomputer is dedicated to flood control regulation during significant flooding events. The SARRT software package is one of many programs used during flood control regulation. SARRT is capable of generating a forecast of the entire watershed in minutes. Should the forecast results show undesirable conditions, the water control manager can change the regulation schedule of either San Antonio, Carbon Canyon, or Prado Dam in an effort to obtain a desirable result.

A 30 minute simulation time interval is used by both the HEC-1F-Stream Flow Forecast Model and the HEC-5 Reservoir System Simulation program. A 24 hour forecast time window is used by the HEC-5 program.

The Santa Ana River watershed drains 2,450 square miles to the Pacific Ocean (2,255 square miles are above Prado Dam). Although the SARRT allows the water control manager to simulate real-time and forecast flows through this large and complex basin, for the SARRT to be an effective tool during an actual flood event, the water control manager must become familiar with the watershed characteristics as well as the complex SARRT water control system before an actual flood event occurs.

A detailed description of the SARRT operation is beyond the scope of this water control manual. The water control manager should refer to reference 22 (as listed on Plate 1-01) for a comprehensive description of the SARRT water control system.

(2) <u>QPF/API Algorithm</u>. The QPF/API algorithm only forecasts a flood inflow <u>volume</u>, given a basin average Antecedent Precipitation Index (API) and a Quantitative Precipitation Forecast (QPF) or observed basin average rainfall. The basin average API is generated from the zonal average precipitation values which are available from the REPORT software (See Plate 6-02 for the precipitation zones). Should the REPORT software be down, a "back-up" API can be generated using the precipitation gage at Prado Dam, available from the dam tender via radio. During each flood season, a running record of the basin average API is maintained on both the Harris 800 and on paper for a manual "back-up".

Once the basin average API and QPF are obtained, the forecast inflow volume to Prado Dam can be determined as outlined in Exhibit C.

(3) <u>Recession Limb Inflow Model</u>. The recession forecast model is based on a historical analysis of 17 floods. The model employs a graphical procedure to forecast

the recession limb of the inflow hydrograph to Prado Reservoir from the peak to up to seven days into the future.

To prepare a forecast one must determine the total inflow volume to Prado Dam from:

* 1 October to the time of forecast.
* for the past 30 days.

These inflow volumes can be found by using option 6 of the LAD's RESCAL program. Exhibit D outlines the use of this method.

b. Methods.

(1) Santa Ana River Real-Time (SARRT) Water Control System. The primary software used by the SARRT water control system to generate forecasts for the Santa Ana River are "HEC-1F-Stream Flow Forecast" model and "HEC-5-Reservoir System Simulation" program.

Application of HEC-1F to forecast runoff in a multi-sub-basin watershed is generally a two-step process, requiring two separate applications of the program. The first step is to estimate hydrologic parameters (e.g. loss rate, unit hydrograph, and base flow) and discharge hydrographs for gaged headwater sub-basins. An example estimated hydrograph from this process is shown in Plate 6-03. The input file for this step is referred to as the E-model, indicating the parameter Estimation purpose of the model.

The second step of the HEC-1F process accomplishes the following:

1. Sub-basin discharge hydrographs are calculated for all ungaged sub-basins using runoff parameters specified by the water control manager through the MODCON program.

2. Sub-basin hydrographs are routed and combined throughout the basin.

3. Hydrographs are blended at each stream gauge prior to subsequent routing and combining operations. Blending consists of replacing the calculated hydrograph ordinates with observed hydrograph ordinates up to the time of forecast, and providing a smooth transition to the calculated hydrograph over six future time periods following the time of forecast. The blending process is illustrated in Plate 6-04.

The input file for the second step is referred to as the F-model because the end product of this step is a set of Forecasted discharge hydrographs for all the sub-basins and control points.

HEC-5 is used to simulate the sequential operation of the reservoir system. Reservoir releases are determined by HEC-5 in accordance with constraints at downstream control points while keeping the reservoirs of the system "in balance". Reservoir inflow hydrographs and hydrographs of uncontrolled runoff at downstream control points are obtained from previously completed HEC-1F applications via a DSS file. Output from HEC-5 such as hydrographs of discharge, reservoir elevation, and storage are written to a DSS file for subsequent display and analysis. Thus, anticipated runoff from the watershed can be routed through Prado Dam to estimate the maximum water surface elevation, inflow and outflow for a given rainfall event.

(2) QPF/API Algorithm. Exhibit C outlines the QPF/API algorithm and presents an example of its use.

(3) Recession Limb Inflow Model. Exhibit D outlines the recession limb forecast procedure and presents an example of its use.

6-03 Conservation Purpose Forecasts. No forecasts for water conservation are prepared by the LAD. During water conservation regulation, inflows to Prado Dam as well as weather and runoff forecasts are closely monitored to determine if flood control regulation is required (As described in Section 6-02 above).

6-04 Long Range Forecasts. Long-term forecasts of precipitation and runoff (in excess of 1 week) are not normally prepared. In the event of a significant impoundment, long-term forecasts will be made regarding the draw-down time of the impoundment as discussed in Chapter 7.

VII - WATER CONTROL PLAN

7-01 General Objectives. Prado Dam and Reservoir is Congressionally authorized to provide flood protection to the metropolitan area of Orange County. Therefore, the protection of the downstream floodplain shall take priority over protection from inundation of reservoir lands and leaseholders. Prompt advance notification of reservoir land leaseholders will be made whenever predicted water surface elevations will inundate leaseholders.

As recognized in the original project authorization and project design, Prado Dam has and continues to be regulated in order to minimize the waste of water to the Pacific Ocean, whenever such regulation does not interfere with or diminish the primary objective of flood control. During times of low flood threat, Prado Dam can be regulated to control the flows of the Santa Ana River so that outflow from the dam will not exceed the recharge capacity of the OCWD ground water replenishment facilities, located downstream from the dam.

Other Prado Dam regulation objectives include: minimizing adverse environmental impacts, minimizing impacts to endangered species, minimizing maintenance costs to the dam and downstream channel, minimizing impacts to reservoir lands and activities (i.e., to leaseholders), maintaining public health and safety, and minimizing water quality problems.

7-02 Major Constraints.

a. Channel Capacity. From past experience, when sustained flows in excess of 2,500 cfs have been released from Prado Dam, damage to the Santa Ana River channel has occurred. The unlined channel passing through the Green River Golf Course will begin to spill onto the golf course at releases greater than 4,000 cfs. Also the water surface of the Santa Ana River has reached the low cord of the Green River Golf Course access bridge. Other types of damage further downstream include: severe scour around bridge piers and drop structures, failure of drop structures, damages to levee embankments, and the rupture of a sewer line. Releases from Prado Dam have had to be reduced during the flood season so that emergency repairs to the channel could be accomplished.

Given the past performance history of the downstream Santa Ana River channel, releases from Prado Dam will be kept below 2,500 cfs for small to medium magnitude flood events. The maximum controlled release for larger flood events will remain 5,000 cfs. Plate 4-21a-b is a schematic of the lower Santa Ana River channel, showing the long-term and short-term channel capacities. During large releases, channel observers both from the Corps and the OCEMA, must be dispatched along the Santa Ana River to observe the performance of the channel and to report any situation that may be of concern.

During a large flood event, local runoff may fill a major portion of the downstream channel. Because controlled releases from a flood control project should not cause or contribute to downstream flooding, releases from Prado Dam may need to be reduced during the intense portions of a significant flood event when downstream channel capacity is needed to convey runoff from the uncontrolled drainage area downstream of Prado Dam. Telemetry or reports from channel observers are used to determine the appropriate action.

b. <u>Reservoir Deficiency</u>. Because of the increase in the design storm and increased runoff resulting from urbanization of the watershed, the peak inflow for the reservoir design flood increased from 193,000 cfs to 282,000 cfs (for present conditions). The peak inflow for the Probable Maximum Flood (PMF) increased from 289,000 cfs to 670,000 cfs (For present conditions. See Table 4-2). The reservoir, which was originally believed to control a 200-year flood, can currently only control a 70-year flood. Major floods exceeding the capacity of the existing reservoir would cause catastrophic damage in an area inhabited by about two million people. A Standard Project Flood (SPF) would inundate over 110,000 acres of highly urbanized land, and directly involve hundreds of thousands of homes, thousands of businesses and factories and hundreds of schools; the direct damages from a flood of this magnitude are estimated at about 15 billion dollars. In spite of this information, the maximum controlled release from Prado Dam remains 5,000 cfs due to the conveyance limitation of the downstream channel with respect to extended reservoir releases.

Under current conditions, if the revised PMF were to occur, the existing dam would be overtopped by 4.3-ft causing even greater damage than that described for a SPF in the preceding paragraph. In the event that the water surface approaches the top of dam, the water control manager should consider opening the gates in an attempt to increase the release rate to avoid overtopping the dam.

c. <u>Flooding within the Reservoir</u>. As listed in Table 3-3, there are numerous environmental, public, and private concerns and developments located within the Prado Flood Control Basin. Because flood control is the primary purpose for Prado Dam, these concerns and developments are subject to inundation during operations. Although inundation of these concerns and developments during flood control operations is not an operational constraint, the water control manager should be aware of the effects of high water surface elevations on reservoir land uses at Prado Dam. The following paragraphs describe four of the more significant concerns within the Prado Flood Control Basin.

(1) Least Bell's Vireo Nesting Habitat. The willow-dominated riparian habitat within the flood control basin is being considered as critical habitat for the LBVI, which is listed as an endangered species. Taking of an endangered species is considered a federal offense and is punishable by fine and/or imprisonment. As defined in The Endangered Species Act of 1973 (PL 93-205) the term "take" means to harass, harm, pursue, hunt, shoot, wound, trap, kill, capture or collect, or to attempt to engage in any such conduct. Taking of LBVI's, therefore, includes destruction of the nesting habitat or disturbing the birds or their nests in such a way as to cause the birds to abandon their nesting sites. The LBVI are migratory birds which inhabit the flood control basin from about mid-March through September. Impoundment of water during the nesting season is closely monitored and regulated to minimize adverse effects to the habitat and nesting activities of the LBVI.

(2) Corona Municipal Airport. This is a recreational airport managed by the City of Corona and used primarily for small private planes. The airport is located between elevations 514-ft and 536-ft. A rising water surface warning is given by the ROC to avoid inundation of privately owned aircraft and other movable airport facilities.

(3) Corona Percolation Ponds. Land is leased by the City of Corona from the Federal Government for an effluent spreading area (ten ponds covering approximately 60 acres) and effluent pipeline and access road (elevations 534-540-ft.). The spreading grounds are designed to handle five million gallons per day (7.7 cfs) of treated effluent. In the past, the City of Corona has alleged that high water surface elevations within Prado Reservoir have caused a detrimental reduction in the percolation rates of the ponds.

(4) Prado Petroleum Company. The Prado Petroleum Company, which operates 13 oil wells within the Prado Reservoir, has filed an inverse condemnation suit against the United States. Their contention is that water conservation activities have resulted in a taking of Prado Petroleum's mineral rights.

Prado Petroleum has stated that their oil production is curtailed when the reservoir reaches WSE 492.0-ft because of saturated ground conditions that limit their ability to access, service, or repair pipelines that carry oil from the well field area to a central processing plant on the south side of the flood control basin. Although, many of the wells can be operated when submerged, maintenance of the wells is difficult if not impossible.

In addition to reduced profitability, Prado Petroleum is concerned that the meandering Santa Ana River may, once again, cause the rupture of one of their oil lines. On January 23, 1983 the meandering Santa Ana River undermined one of their oil towers causing it to topple and rupture an oil line. Between 2,000 and 3,000 gallons of oil were spilled into Prado Reservoir. The clean-up operation was coordinated through the EPA and the U.S. Coast Guard. The U.S. Government had to file suit against Prado Petroleum in an attempt to recover the costs of the clean-up operation. In an out-of-court settlement Prado Petroleum agreed to reimburse the U.S. Government for 50% of the clean-up costs.

After prolonged inundations it takes as long as three weeks for access roads to dry out sufficiently for oil and gas maintenance vehicles to pass. Surface saturation due to a rise in the ground water table could also cause the access roads to remain impassable for even longer periods of time.

Three of the wells are located on a Federal lease and the remaining ten wells are located on a private lease (SARDCO lease). Table 7-1 lists the elevations at which the wells are located. Plate 2-11 shows the locations of the wells within the flood control basin. The following two sections summarize both the federal and private leases involved in the litigation:

Table 7-1

Prado Dam Oil Well Survey
(June 1990)

Well Number	Elevation (ft)
SARDCO Lease	
1	508.0
2	495.8
3	501.8
4	501.5
6	502.9
7	503.7
8	494.5
9	495.1
10	493.2
11	504.2
Federal Lease	
1	496.7
2	496.5
3	496.2

(a) Federal Lease. The Federal lease was issued by the Bureau of Land Management in 1965 to Prado Petroleum's predecessor-in-interest, Don C. Winkler. Prado Petroleum acquired the Federal Lease in 1983.The Federal lease gives the lessee:

> the exclusive right and privilege to drill for, mine, extract, remove and dispose of all oil and gas deposits ... [in the leased area for a stated primary term, and] ... so long thereafter as oil or gas is produced in paying quantities; ...

A stipulation of the Federal lease reads:

> (1) That all rights under this lease are subordinate to the rights of the United States to flood and submerge the lands, permanently or intermittently in connection with the operation and maintenance of the Prado Flood Control Basin Project.

(b) SARDCO Lease. The private lease is for drilling rights on land which is currently owned by the OCWD. In 1967 OCWD acquired the lands from the Santa Ana River Development Company (SARDCO) by condemnation. Pursuant to the final order of condemnation, OCWD received title to the land for the purpose of:

> augment [ing] water supplies of the ORANGE COUNTY WATER DISTRICT and the conservation of water within and outside said District.

subject to:

1. the perpetual flowage easement which was granted in favor of the United States in 1944, and
2. an oil and gas lease (the SARDCO lease) allowing no more than 8 drilling islands, 2 acres in surface area each, measured at elevation 516 ft.

The perpetual flowage easement gives the United States the following right:

> The right to prohibit human habitation, and a perpetual easement to flood and inundate any or all of said Parcels ... intermittently as may be required from time to time, incidental to the successful operation and maintenance of the Prado Flood Control Basin for controlling storm water run-off, ...

The SARDCO lease gives the lessee the following right:

> the sole and exclusive right ... to drill for, produce, extract and take oil, gas ... (and water for its operations) from the land ... with the right of surface entry ... at all times ... together with rights-of-way for passage over, upon and across, and ingress and egress to and from, said lands, ... for so long as oil or gas ... is produced in paying quantities ...

7-03 **Overall Plan for Water Control**. Flood protection to the lower Santa Ana River floodplain is achieved through the joint functioning of Prado Dam and the OCEMA improved downstream channel. Prado Dam captures and stores flood runoff and the downstream channel safely conveys the reservoir releases through the floodplain to the Pacific Ocean.

The OCEMA channel has sustained severe structural damage in prior flood events (1969, 1978, 1980, and 1983) in which long duration flood control releases were made from Prado Dam. The structural problems were primarily the result of sediment degradation problems in the earth-bottomed channel.

Operational experience in the more recent flood events of 1980 and 1983 along with improvements and repairs to the channel subsequent to these floods, indicate the capability of the channel to handle sustained reservoir releases of up to about 2,500 cfs without significant degradation problems. Therefore, the Prado Dam Water Control Plan has been formulated to utilize up to one-third of the reservoir storage if reservoir releases can be limited to 2,500 cfs. However, whenever more than one-third of reservoir storage is projected to be filled (based on forecasted flood inflow), reservoir releases are increased to greater than 2,500 cfs. The increase in releases to greater than 2,500 cfs is made recognizing the risk of possible structural damage to the downstream channel and the possibility of loss or reductions of channel conveyance capability that could result.

In summary, the Prado Dam Water Control Plan is designed to limit the exposure of the downstream channel to possible structural damage by controlling smaller flood events with smaller non-damaging (to the channel) releases, and reserving larger reservoir releases for larger flood events.

7-04 **Standing Instructions to the Project Operator for Water Control**. The standing instructions to the project operator for regulation of Prado Dam and Reservoir are given in Exhibit A. During periods of normal communications, the dam tender will receive operating instructions from water control managers operating the Reservoir Operations Center (ROC), located at the District Office in Los Angeles. In the event that communication with the ROC is interrupted, the dam tender should follow the standing instructions in Exhibit A.

7-05 **Flood Control**. The water control plan for Prado Dam and Reservoir was developed with primary consideration given to:

(1) The operation plan that was approved by the Office of the Chief in August, 1969.
(2) The operational experience gained from the past 20 years of operation.

(3) The hydraulic performance characteristics of the downstream channel.
(4) The endangered species within the reservoir, specifically, the least Bell's vireo (LBVI).

The Water Control Diagram (Plate 7-01) illustrates the water control plan for Prado Dam. As shown on the water control diagram, release ranges are prescribed for given elevation ranges within the reservoir. Plate 7-02 indicates the storage volumes between each release range.

Under "Normal Communication Conditions" the release rate is determined by the water control manager at the ROC. The water control manager examines the current hydrometeorologic conditions, and the weather and runoff forecast for the Santa Ana River Basin. Section 6-02 of this Water Control Manual describes the use of three inflow forecast methods available to the water control manager; namely: a) the Santa Ana River Real-Time (SARRT) Water Control System, b) the QPF/API algorithm, and c) the Recession Limb Inflow Forecast Model. The following sections provide further information regarding specific regulation constraints for each release range shown on Plate 7-01.

It should be noted that the upper WSE's for each release range are "target" WSE's. The water control manager's decisions regarding the regulation of Prado Dam are based upon available weather and runoff forecasts. Since weather and runoff forecasts are rarely 100% accurate, it is anticipated that the target WSE's will, at times, be exceeded. Whether or not the water control manager deems it necessary to implement the regulation guidelines of the next release range will depend upon the magnitude of encroachment into the next release range and the current weather and runoff forecast.

a. WSE 460.0 - 490.0 (Debris Pool). (Release Range: 0 - 500 cfs) The debris pool is allowed to fill prior to flood control releases in order to prevent debris from entering and plugging the outlet works. There are no seasonal restrictions for inundation of the debris pool. Releases from the debris pool are normally coordinated with the OCWD and are set equal to the spreading capacity of the downstream groundwater recharge facility.

b. WSE 490.0 - 494.0 (Buffer Pool). (Release Range: 200 - 2,500 cfs) The August 1969 water control plan transitioned from low debris pool water conservation releases to a maximum flood control release of 5,000 cfs, between the elevations of 490.0-ft and 490.8-ft (i.e., an increase in WSE of only 0.8-ft). Due to the channel erosion problems experienced on the Santa Ana River when prolonged releases from Prado Dam have exceeded 2,500 cfs (see section 4-09h), a buffer pool has been established which allows the water control manager to control small flood events without using large potentially channel damaging releases. The buffer pool, therefore, allows the water control manager to:

1. Minimize oscillation in the magnitude of reservoir releases, thereby reducing potential stream bank erosion in the Santa Ana River Canyon.
2. Reduce the oscillation in the release magnitude for a safer operation with respect to public use of the canyon.
3. Facilitate coordination with the OCWD groundwater recharge facility by providing the ability to temporarily curtail releases to permit the reconstruction of in-stream diversion dikes for groundwater recharge downstream.
4. Simplify the lengthy public notification process when a smoother, less abrupt transition from low to large releases is adopted.

Due to the presence of the endangered LBVI within the Prado Flood Control Basin, buffer pool regulation differs slightly during the winter flood season and the non-flood season as described below.

(1) Winter Flood Season. (15 September to 15 March) A release rate of between 200 and 2,500 cfs is calculated based on a real-time forecast of inflow volume (as described in Chapter 6) so as not to exceed elevation 494-ft. The drawdown release rate will be coordinated with the OCWD to maximize the conservation of water through ground water recharge (Note: a minimum release of 200 cfs is required except for temporary release cutbacks to facilitate OCWD's reconstruction of in-stream diversion dikes). Note that releases greater than 600 cfs will wash away OCWD's in-channel sand diversion dikes.

If a significant amount of inflow to the dam is forecast, the reservoir can be drawn down to the debris pool elevation of 490-ft within 24 hours, while releasing non-damaging flows i.e., releases at or below 2,500 cfs. Exhibit E outlines the procedure with which the water control manager can determine the required release. Several combinations of initial and forecasted conditions are presented.

(2) Non-Flood Season. (15 March to 15 September) In order to avoid impacts to the LBVI during their nesting season, the regulation is slightly modified during the non-flood season. Starting 15 March, the minimum release will either be: equal to the inflow (up to 2,500 cfs), or the OCWD ground water recharge facility capacity, or 200 cfs, which ever is greatest. The objective is to prevent a rise in the reservoir pool elevation which would adversely impact nesting LBVI.

c. WSE 494.0 - 520.0. (Release Range: 2,500 - 5,000 cfs) The water control manager computes a release magnitude based upon the criteria of not exceeding WSE 520-ft. If 520-ft will be exceeded the release rate should be 5,000 cfs. The forecasted reservoir inflow (current event plus succeeding events) can be determined using the forecast methods described in Chapter 6. Historically, sustained reservoir releases greater than 2,500 cfs have resulted in severe invert degradation and significant structural damage along the lower Santa Ana River. Channel observers should be dispatched to monitor river conditions when releases exceed 2,500 cfs for an extended period of time. Should damage to the OCEMA channel occur, releases from Prado Dam may need to be cut back.

d. WSE 520.0 - 543.0. (Release: 5,000 cfs) Reservoir stages above 520-ft require the maximum scheduled release of 5,000 cfs. Since historical releases of 5,000 cfs have caused significant channel invert and side slope damage, channel observers should be dispatched to monitor river conditions. Should damage to the OCEMA channel occur, releases from Prado Dam may need to be cut back.

e. WSE 543.0 - 544.3 (Spillway Flow). (Release: 5,000 cfs) Flood control releases through the outlet works are reduced as the reservoir pool level rises above the spillway crest so as to maintain outflow from spillway plus outlet works at a maximum outflow of 5,000 cfs. As the WSE approaches the spillway, frequent communication between the ROC and the dam tender should occur so that the transfer of reservoir outflow from the outlet works to the spillway can be closely monitored.

f. WSE 544.3 and above (Spillway Flow). (Release Range: 5,000 cfs and above) All outlet gates are closed at reservoir pool levels of 544.3-ft and above (i.e., uncontrolled spillway discharge only). Under the extremely remote circumstance that the dam embankment were in danger of overtopping, the outlet gates are to be opened to minimize the possibility of dam failure. NOTE that the maximum design release from the outlet works is 17,000 cfs and that the design capacity of the outlet stilling basin is 10,000 cfs.

g. Reservoir Regulation Schedule. Plate A-01 is the reservoir regulation schedule which presents the recommended gate settings for the above described release ranges under both "Normal Communication Conditions" and "No-Communication Conditions". The reservoir regulation schedule can be applied to both the rising and falling limb of a flood event.

7-06 Recreation. Water is neither impounded nor released for either upstream or downstream recreational purposes. Recreational activities within the reservoir are adversely affected when inundation occurs.

Downstream of Prado Dam, the Green River Golf Course and Featherly Park are adversely affected when flood control releases in excess of approximately 2,500 cfs are made. These facilities are within the Santa Ana River flood plain and are therefore subject to flooding.

7-07 Water Quality. This water control plan does not specifically address any water quality concerns. The U.S. Fish and Wildlife Service, Santa Ana Watershed Project Authority (SAWPA), the California Regional Water Quality Control Board (Santa Ana Region), and the OCWD monitor various aspects of water quality upstream and downstream of Prado Dam.

During emergencies, the water control manager can operate Prado Dam to contain pollution spills either in or downstream of Prado Dam and Reservoir. Such was the case in 1983 when an oil spill occurred within the reservoir. The water control manager was requested by the U.S. Coast Guard to maintain a constant water surface elevation to facilitate the clean-up operation.

7-08 Fish and Wildlife. The importance of biological resources has been recognized in several Federal environmental laws, including NEPA, the Fish and Wildlife Coordination Act, and the Endangered Species Act. The first two laws require that the conservation of biological resources, by preventing or minimizing damages, shall receive equal consideration and be coordinated with other features of water resources programs. The Endangered Species Act stipulates that each Federal Agency shall ensure that agency's actions are not likely to jeopardize the continued existence of any endangered or threatened species or result in destruction or adverse impacts to critical habitat for such species. These acts also require Federal agencies to coordinate with the U.S. Fish and Wildlife Service and State agencies regarding such matters.

The LBVI, an endangered species, is a small, gray, migratory songbird that feeds mainly on insects. Their nests are usually low in thickets along willow-dominated riparian habitats with lush understory vegetation (Photo 7-1). The LBVI arrives in its breeding habitat in mid-March to early April, and departs in late August and September for its wintering range, which is unknown but possibly includes southern Baja California. The decline of the LBVI is attributed to the widespread loss of riparian habitats and from brood parasitism by the brown-headed cowbird (*Molothrus ater*).

Areas of the Prado Flood Control Basin are recognized as important habitat for the LBVI. When the LBVI nests within the Prado Basin, the U.S. Fish and Wildlife Service closely monitors the nesting locations. The Water Control Plan, as described in Section 7-05, addresses these concerns by ensuring that maximum flood control releases will be made during the nesting season. This will reduce the likelihood of "taking" LBVI's. The maximum desired WSE during the nesting season is 490.0-ft.

A minimum flow of 60-cfs is desired in the downstream channel to provide a constant flow of water for fish habitat between the dam and the OCWD groundwater spreading facilities. Although there is no formal agreement between the Corps and any other agency requiring this minimum flow, the Corps does attempt to maintain this minimum flow whenever possible.

Photo 7-1: Nesting least Bell's vireo

7-09 **Water Supply**. The water control plan allows the water control manager to release water in a manner that facilitates the OCWD groundwater recharge activities when the weather and runoff forecasts are favorable. Sections 7-05a and 7-05b describe the specific conditions related to water conservation releases.

7-10 **Prado Dam Maintenance**. When Prado Dam was completed in April 1941 the outlet works consisted of two ungated outlets and six gated outlets. At the request of the OCWD and the OCEMA both ungated outlets have been plugged. The 7-ft by 12-ft cable-operated tractor gates were not designed or constructed for year-round reservoir impoundments. Therefore, the months of July, August, and September (typically the lowest runoff months of the year) have been designated as the period when routine maintenance of the dam, outlet works, and embankment will be scheduled. Scheduling of dam maintenance operations has a high priority, in relation to other project objectives.

For maintenance activities requiring a dry reservoir area, such as servicing of the gates, a release schedule which provides for outflow equal to inflow will be prepared. Conversely, for maintenance of the downstream gage, outlet channel, or energy dissipator, it may be necessary to curtail reservoir releases, thereby creating an impoundment. In this latter instance, the month of September is the most favorable time period because the LBVI begin their fall migration in September.

Construction-Operations Division should formally notify Engineering Division at the start of the flood season of the desired maintenance period and the type of maintenance activities.

7-11 Deviation from Normal Regulation. There may be instances when it is necessary for the regulation of Prado Dam to deviate from the established flood control plan described in this chapter. Prior approval of deviations is required from the ROC, except for emergencies as described in paragraph 7-11a below.

a. Emergencies. Emergencies may take the form of drownings or other accidents, chemical spills, and failure of operational facilities. Necessary action should be taken immediately to contend with emergencies. In any action taken, assessment of the situation by the dam tender should rely on his knowledge of the dangers involved. The ROC must be informed of any deviations due to emergencies as soon as practical. Emergency deviations do not require prior approval by SPD, but coordination with SPD must be made as soon as practical.

b. Unplanned Minor Deviations. Instances arise periodically which require minor deviations from the normal regulation of the reservoir. Construction activities are the primary source of these deviations. Downstream maintenance of culverts and channel sections are another reason for minor regulation changes. Each request is analyzed on its own merits. Consideration is given to the potential of flooding and possible alternative measures. Approval for these minor deviations must be obtained from the ROC.

c. Planned Deviations. There are planned instances which require deviations from normal regulation. Each condition will be judged on its own merits. Requests for planned deviations must be coordinated through the Reservoir Regulation Section at CESPL. As per the MEMORANDUM FOR Commander, Los Angeles District, from the Division Commander dated March 20, 1991:

> All planned deviations from approved water control plans for reservoir projects within the South Pacific Division must be coordinated with the Coastal Engineering and Water Management Division at CESPD. Approval must be given prior to implementation of the deviation.

d. Monthly Gate Exercise. In order to ensure that the outlet works gates remain functional throughout the year and to free any accumulations of sediment or debris from the gate pulley and cable mechanisms, a monthly gate exercise is performed on the first Monday of each month. This may be postponed if conditions so warrant. The monthly gate exercise is as follows:

1) The dam tender checks with the ROC to determine the "wait" period between gate exercises (See Appendix F).
2) The dam tender checks the downstream channel from the downstream gage to the outlet works to assure no one is immediately downstream of the outlet works.
3) All gates are closed.
4) Each gate is individually raised to 5-ft and then immediately closed. When an impoundment exists at Prado Dam, the water control manager will determine a wait period between the opening of each individual gate.
5) All gates are returned to the original settings.
6) The downstream gage is checked to verify the outflow has returned to pre-gate exercise conditions.

Appendix F outlines the calculation procedure for determining the wait period between the operation of each individual gate.

The OCWD should be informed of the exercise to verify that no adverse conditions would be encountered downstream as a result of the sudden increase in flow from the gate exercise. OCWD should be informed that the sharp increases in flow will quickly attenuate as they progress downstream. For example an instantaneous outflow of 1,100 cfs will appear as a peak of 500 cfs at the SAR7 gage located a 1/4 mile downstream from Prado.

e. Drought Contingency Plan. Engineer Regulation 1110-2-1941 (Drought Contingency Plans) directs water control managers to "evaluate and establish the limits of flexibility under existing authorities to modify project regulation and to use existing storage to respond to periods of water shortages."

Prado Dam is located in a semi-arid region of the southwest where the consumptive use of water greatly exceeds local supply. Most of the water consumed in southern California is imported at great expense from remote sources such as the Colorado River and the Sierra Nevada Mountains. The entire storage space of the normally dry Prado Reservoir is allocated for flood control, although water conservation is a project purpose. Therefore, the adopted water control plan for Prado Dam was formulated with features that maximize the amount of water that can be conserved without adversely affecting the level of flood protection provided, or significantly impacting environmental resources (reference sections 7-05 through 7-

09). In essence the normal mode of project regulation is specifically geared to drought as this is the normal circumstance for the region.

A seasonal expansion (i.e., from March to September when the flood potential is small) of the water conservation capability of Prado Dam will occur upon formal adoption of the recommendations found in the "Review Report of Prado Dam Operation for Water Conservation", U.S. Army Corps of Engineers, Los Angeles District, dated January 1991. The report recommends adoption of seasonal re-regulation of Prado Dam to permit storage of water for conservation up to WSE 505-ft, provided OCWD agrees to mitigate adverse impacts to reservoir recreational facilities, biological resources, and other land users.

An emergency water conservation operation plan for Prado Dam was implemented during March and April of 1991 in response to the regions five year drought. A March 4, 1991 agreement among the OCWD, the USFWS, and the Corps permitted the operation of Prado Dam for water conservation up to about elevation 500-ft. This emergency water conservation plan was then implemented during the months of March and April of 1991. The emergency water conservation plan, which was only valid for the 1991 water year, permitted the regulation of Prado Dam in a manner consistent with the Prado Dam Water Conservation Study. As part of the arrangements to permit the emergency water conservation operation, the OCWD agreed to either fund or directly implement appropriate environmental mitigation measures to ensure the long term preservation of the least Bells vireo, an endangered migratory songbird which nests within the reservoir area from March to September.

7-12 <u>Rate of Release Change</u>. The maximum permissible rate of change in the release rate is dependent upon the magnitude of the current release. When increasing or decreasing the release rate one should consider the possibility of: structural damage to downstream improvements, levee bank sloughing due to rapid bank de-watering, and public safety, particularly in the Santa Ana Canyon just downstream of Prado Dam. Furthermore, OCEMA and OCWD will be notified prior to any significant change of release. Based upon past operational experience, the maximum permissible rates of release change shown in Table 7-2 should be followed under normal operating conditions.

Table 7-2

Maximum Permissible Rate
of Release Change at Prado Dam

Current Rate of Release (cfs)	Maximum Rate of Change per 1/2 Hour (cfs)
0 - 300	100
300 - 1,000	250
1,000 - 2,500	400
2,500 - 5,000	625

VIII - EFFECT OF WATER CONTROL PLAN

8-01 General. The water control plan presented in this manual gives the water control manager the flexibility needed to optimize diverse and often conflicting objectives under a variety of conditions. With the judicious use of weather and runoff forecasts, Prado Dam is currently able to provide 70-year flood protection to the cities bordering the Santa Ana River in Orange County. In addition, the water control plan increases the quantity of water available for downstream groundwater recharge by carefully managing and coordinating releases from the debris and buffer pools with the OCWD. The needs of the LBVI and its habitat within the Prado Flood Control Basin are also addressed.

8-02 Flood Control. The November 1969 report entitled "Interim Report on Design Features of Existing Dams, Hydrology and Hydraulic Review for Prado, Brea, Fullerton, and Salinas Dams" documents the deficiency which currently exits at Prado Dam. Improved hydrologic methods and data, as well as the increased urbanization of the "Inland Empire" have caused an increase in the Probable Maximum Flood (PMF) and the Reservoir Design Flood from the original design values.

a. Probable Maximum Flood. The PMF is the flood that can be expected from the most severe combination of meteorological and hydrologic conditions reasonably possible in the region. PMF, as the name implies, is an estimate of the upper bound of flood potential for a drainage area. A PMF is required to determine the spillway capacity for a dam.

The PMF is based upon a general winter event for the probable maximum storm (PMS). Data for the storm were obtained from the Hydrometeorological Branch of the U.S. Weather Bureau (i.e., enclosures one and two of a letter dated December 2, 1968; subject: PMP for 18 Los Angeles Basins). The average depths of precipitation for 6, 12, 24, 48, and 72 hours during the PMS for the drainage area above Prado Dam were 5.6, 10.6, 16.5, 23.1, and 26.3 inches, respectively. A time interval of one hour was selected as the shortest interval for which precipitation intensities would be required to define the flood hydrograph.

The PMS has a duration of 72 hours with a total average areal precipitation depth of 26.3 inches. In general, the precipitation runoff relationships used for the SPF, as described in the following section, were judged applicable for use in developing the PMF, with two exceptions. First, the basin lag time is reduced by 15 percent to account for the reduction in time of concentration, a characteristic of large floods where the hydraulic efficiency of the drainage area is increased by the depths of flow. Second, loss rates considered applicable for ground conditions conducive to maximum runoff were used for the PMS.

Plate 8-01 shows the hyetograph of the PMS, and the outflow hydrograph at Prado Dam. The routing assumed that the reservoir is at a WSE of 490.0-ft at the beginning of the PMF. The peak inflow to Prado Dam under current conditions is 670,000 cfs which would cause the reservoir to rise to WSE 570.3-ft. This elevation is 4.3-ft. above the top of dam. Assuming that the dam does not fail, the estimated outflow from Prado Dam would reach 603,000 cfs.

b. Standard Project Flood. The SPF represents the flood that would result from the most severe combination of meteorologic and hydrologic conditions considered reasonably characteristic of the geographical area. The SPF is normally larger than any past recorded flood in the area and would be exceeded in magnitude only on rare occasions. The SPF, therefore constitutes a standard for design or redesign that would provide a high degree of flood protection.

The critical storm for the Santa Ana River is based upon the assumed occurrence of a storm equivalent in magnitude to that of January 21-24, 1943, in which the maximum 24-hour precipitation was transposed and centered in the San Bernardino and San Gabriel Mountains. The maximum 1-, 6-, 24-, and 48-hour (total storm) average precipitation over the total area was 0.64, 3.36, 8.25, and 11.59 inches, respectively.

The SPF has a duration of 48 hours with a total average areal precipitation depth of 12.15 inches. The general storm variable loss rate used for the San Gabriel, San Bernardino, and San Jacinto Mountains and Foothills had an equivalent average of 0.35 in/hr and a minimum of 0.15 in/hr. The valley portions of the watershed (i.e., 60% of the 2,450 sq-mi watershed) had a constant loss-rate of 0.40 in/hr, reduced by the percentage of impervious cover where appropriate. Snow melt was considered to be a negligible factor during the SPF event.

Plate 8-02 shows the hyetograph of the Standard Project Storm (SPS) and the inflow and outflow hydrographs at Prado Dam. Flood routing begins with the reservoir's debris pool full to WSE 490.0-ft. The peak inflow of 282,000 cfs causes the reservoir to rise to a maximum WSE of 554.59-ft. This spillway surcharge of 11.59-ft. results in a peak outflow of 150,000 cfs. The four day flood volume for the SPF is 488,000 ac-ft.

c. Other Floods. The largest inflows (i.e., inflows greater than 30,000 cfs) to Prado Reservoir occurred in 1943, 1965, 1966, 1969, 1978, 1980, and 1983. However, the first flood control releases were not made until the January-February floods of 1969. The initial 28 years of operation (i.e., from 1941-1969) was accomplished, for the most part, by passing inflows through the ungated outlets for water conservation purposes downstream. Note, that the last ungated outlet was sealed after the 1969 flood event. Plate 8-03a-e shows the operational history of Prado Dam from 1941 through 1990.

8-03 Recreation. Recreation facilities within the flood control basin and downstream of Prado Dam are adversely affected during periods of high WSE (i.e., above 494.0 ft.) or when outflows from Prado Dam exceed 2,500 cfs. Consequently, the water control plan minimizes the duration at which the reservoir is above WSE 494.0 ft. The downstream recreational facilities are within the Santa Ana River flood plain and are therefore subject to flooding during major flood control releases.

8-04 Water Quality. The effect of impoundments on reservoir water quality can be beneficial or adverse depending on duration and season of impoundment. Impoundment of water for short periods of time, with rapid drawdown (as for normal flood control operations), has little or no adverse effect on water quality. In fact, when water is impounded behind the dam, the concentration of suspended solids, nitrates, and iron are lower downstream of Prado Dam than upstream. The mean daily TDS of reservoir outflow is also reduced as a result of the dilution of base flow with higher quality runoff. This effect is dependent on the period and amount of storage.

Extended impoundment would be more likely to result in adverse water quality effects. Water quality may be degraded by long storage of deeper, more stable pools, especially over the summer months when higher temperatures cause thermal stratification and associated low concentration of dissolved oxygen. An appropriate example is the situation which occurred at Prado reservoir during the summer of 1980 when water was held over an eight month period, from February through September. The pool was found to be highly stratified, with anaerobic conditions in the bottom half of the storage pool. This could affect the Corps' ability to meet local and State water quality standards. Under anaerobic conditions, heavy metals, concentrated in the bottom sediments, may be released and the generation of hydrogen sulfide can result in odor problems and increased operation and maintenance costs by corroding the outlet works.

8-05 Fish and Wildlife. The flood control basin supports a diversity of resources which makes it a unique and significant area biologically. The most important biological resources of the flood control basin are the extensive and productive riparian and wetland habitats, and the special status species and migratory waterfowl which utilize the area.

In general, extended storage for water conservation would spatially extend and intensify the effects on biological resources which would be associated with normal flood control operations. These include both beneficial and adverse effects. The periodic presence of abundant open water and flooded willow woodland is an extremely unusual situation in southern California, and one that has contributed to the flood control basin's attractiveness to many rare and important species of wildlife.

Water storage for both flood control and water conservation has served to benefit certain species, mostly water-associated birds, at the expense of terrestrial habitat and to the detriment of certain terrestrial species.

Adverse effects can occur to vegetation from extended periods of submersion associated with water conservation storage. Although the mature willows which dominate the wetlands can survive inundation for several months, shrubby riparian undergrowth is more sensitive. It is this shrubby understory growth which provides nesting habitat for the LBVI. The Prado Basin population is one of only four sizeable populations of this species remaining in California. Prolonged inundation within the buffer pool may adversely affect the habitat, while flooding during the nesting season would eliminate suitable nesting habitat.

The magnitude and suddenness of releases and fluctuations in water levels are also important. Rapid lowering of water level during the nesting season of certain water-associated birds may strand nests, eggs, and young in emergent branches which were close to the water level but become suspended too far above the water. Potential impacts of this type of situation were illustrated in the spring of 1983, when an abrupt drop in the water level stranded the nests of a sizeable population of Pied-billed Grebes, a water associated bird. This resulted in the general failure of that year's reproductive efforts of the large nesting populations of this species in southern California. This type of impact could devastate local populations of many of the water-associated bird species for which the Prado Basin wooded wetlands are a primary nesting habitat.

Degraded water quality can also have detrimental effects on fish and wildlife resources. Fisheries may be affected by low levels of dissolved oxygen. Algal and bacterial problems may also occur as a result of high nutrient levels and water temperatures.

8-06 Water Supply. The water control plan increases the water conservation storage capacity by 4,500 ac-ft during the flood season. This is accomplished by careful management and coordination between the Corps and the OCWD when water exists within the debris and buffer pools. This water control plan minimizes wasting of flood waters to the Pacific Ocean.

8-07 Frequencies.

a. Peak Inflow and Outflow Probabilities. Plate 8-04 presents the inflow and outflow discharge frequency curves for Prado Dam. The curves were taken from the Phase II GDM on the Santa Ana River Mainstem dated August 1988. The frequency curves were derived from a discharge frequency analysis of historical flows on the

Santa Ana River.

b. Filling Frequency. Plate 8-05a presents the annual filling-duration frequency curves and Plate 8-05b presents the exceedance filling frequency curve. The curves were derived from a representative set of flows which were adjusted for the urbanization and wastewater effluent to the basin. Plate 8-06 presents the maximum pool elevations for the period of record.

8-08 Other Studies. The "Design Memorandum No. 1, Phase II General Design Memorandum on the Santa Ana River Mainstem, including Santiago Creek", dated August 1988, is comprised of a Main Report and 9 accompanying volumes. This extensive report evaluates a wide range of alternative flood control measures to alleviate potential flood problems within the Santa Ana River system. The report and the progress of the Santa Ana River Mainstem project should be closely followed and appropriate changes and updates noted in future revisions of this water control manual.

IX - WATER CONTROL MANAGEMENT

9-01 Responsibilities and Organization.

a. Corps of Engineers. Prado Dam is owned, operated, and maintained by the U.S. Army Corps of Engineers, LAD which has complete regulatory responsibility.

Reservoir regulation at Prado Dam is directed by water control managers from the Reservoir Operations Center (ROC). The ROC is staffed by personnel from the Reservoir Regulation Section of the LAD. Table 9-1 is an organizational chart depicting the chain of command for reservoir regulation decisions.

Gate regulation instructions to the dam tender are issued by the ROC (see sections 5-04 and 5-05). In the event that communications between the ROC and Prado Dam are interrupted, a set of "Standing Instructions to the Project Operator for Water Control" are included in this manual as Exhibit A. Dam tenders are part of the Operations Branch, under the Construction-Operations Division, LAD.

b. Other Federal Agencies. The U.S. Army Corps of Engineers, LAD is the only federal agency with water control responsibilities at Prado Dam and Reservoir.

c. State and County Agencies. The California Regional Water Quality Control Board (Santa Ana Region) is responsible for setting water quality standards for the Santa Ana River.

The OCEMA is responsible for the maintenance of the downstream portion of the Santa Ana River within Orange County. The improved channel begins at Weir Canyon Road. Flood control releases are coordinated with the OCEMA.

The portion of the Santa Ana River just downstream of Prado Dam in Riverside County is for the most part unimproved. The improvements in this reach have been initiated by agencies or organizations which either have developments which cross the river or lie adjacent to the river.

The OCWD operates a groundwater recharge facility in and along the Santa Ana River downstream of Imperial Highway. Releases from Prado Dam are coordinated with OCWD.

d. Private Organizations. There are no private organizations which have water control responsibilities for waters flowing in or through Prado Dam.

Table 9-1

Chain of Command for Reservoir Operations
Decisions at Prado Dam
(Revised May 1990)

U.S. Army Corps of Engineers Los Angeles District			
District Engineer		(213) 894-5300	
Water Control Decisions		Operation and Maintenance Decisions	
Title	Phone	Title	Phone
Chief, Engineering Division	(213) 894-5470	Chief, Construction-Operations Division	(213) 894-5600
Chief, Hydrology & Hydraulics Branch	(213) 894-5520	Chief, Operations Branch	(213) 894-5620
Chief, Reservoir Regulation Section	(213) 894-6915	Chief, Operations and Maintenance Section	(818) 401-4008
Chief, Reservoir Regulation Unit (ROC)	(213) 894-6916	Dam Tender Foreman	(818) 401-4006
		Dam Tender, Prado Dam	(714) 737-1623

9-02 Interagency Coordination. The U.S. Army Corps of Engineers coordinates with other Federal, State, County, and local organizations concerning water control at Prado Dam and Reservoir.

a. Local Press and Corps of Engineers Bulletins. The Public Affairs Office of the Corps of Engineers, LAD, coordinates with the local press regarding floods and other aspects of project operation. This is accomplished through both telephone and in-person interviews and occasional issuance of press releases. It should be noted that the Corps of Engineers does not publicly issue flood watches or warnings, or other status reports or forecasts to the general public.

b. National Weather Service (NWS). The NWS has the responsibility for issuing flood watches and warnings to the public. The LAD utilizes NWS data to aid in real-time flood control operations. Both real-time and post-event data is shared between the two agencies.

c. U.S. Geological Survey (USGS). The LAD receives streamflow data from the USGS, primarily on a historical basis in southern California. The LAD coordinates data collection with the USGS through the Cooperative Stream Gauging Program.

d. Orange County Environmental Management Agency (OCEMA). During flood events the LAD is in constant communication with the OCEMA. OCEMA is responsible for the condition and maintenance of the downstream Santa Ana River below Weir Canyon Road and, therefore, dispatches channel observes along the Santa Ana River during floods. Information from the OCEMA is used to determine if releases from Prado Dam need to be reduced due to channel problems.

e. Orange County Water District (OCWD). The OCWD operates the groundwater recharge facilities located downstream of Prado Dam. During non-flood operations, releases from Prado Dam are closely coordinated with the OCWD.

f. U. S. Fish and Wildlife Service. In accordance with the Endangered Species Act of 1973 (PL 93-205) and the Fish and Wildlife Coordination Act (PL 85-624) the Corps coordinates with the U.S. Fish and Wildlife Service regarding environmental impacts at Corps projects.

g. California Department of Fish and Game. In accordance with the Fish and Wildlife Coordination Act (PL 85-624) the Corps coordinates with the California Department of Fish and Game regarding environmental impacts at Corps projects located within California.

9-03 Interagency Agreements. There are currently no interagency agreements between the LAD and any other agencies which affect the regulation of Prado Dam.

9-04 Commissions, River Authorities, Compacts, and Committees.

a. Santa Ana River Watermaster. On April 17, 1969, the Orange County Superior Court entered a Stipulated Judgement in Case No. 117628 involving the Orange County Water District vs. City of Chino et al. The judgement, which became effective on October 1, 1970, contained a declaration of rights of the entities in the Lower Area of the Santa Ana River basin (i.e., the Orange County Water District) as against those in the Upper Area (i.e., the San Bernardino Valley Municipal Water District, the Western Municipal Water District, and the Chino Basin Municipal Water District). The arrangement leaves to each of the major hydrologic units in the watershed the determination and regulation of individual rights therein and the development and implementation of its own basin management plans. A court appointed Watermaster, consisting of five persons, prepares an annual report of the

Santa Ana River Watermaster which documents and accounts for flows within the Santa Ana River.

OCWD has the right to receive 42,000 ac-ft annually of base flow waters at Prado Dam in addition to the right to capture any storm flows which reach Prado Dam.

9-05 Reports. As required by ER 1110-2-240 "Water Control Management", the LAD prepares three reports for transmittal to the South Pacific Division Office concerning the regulation of Prado Dam and Reservoir.

a. Annual Division Water Control Management Report (RCS DAEN-CWE-16) (R1)). This report covers significant activities of the previous water year and a description of project accomplishments planned for the current year.

b. Summary of Runoff Potentials in Current Season (RCS DAEN-CWO-2). This report is generally submitted monthly during the storm season (October 15 - April 15), and covers snow accumulation and runoff potential in the District. Supplemental reports are submitted in the event of severe situations.

c. Monthly Water Control Charts (RCS DAEN-CWE-6(R1)). A monthly record of reservoir operations prepared in either a graphical or tabular format is issued when requested.

Two reports are prepared for LAD use. They are:

d. Flood Control Basin Operation Report. A report of daily observations is made at the dam. This record is stored by the Water Control Data Unit of the Reservoir Regulation Section in the Districts Base Yard (Plate 5-04).

e. Daily Reservoir Report. Daily reservoir observations are entered into the RESCAL computer program which stores the records in a computer database and produces a "Daily Reservoir Report" that is distributed to interested LAD offices.

Plate 1-01

Related Manuals and Reports

No.	Title	Date
1.	Orange County Flood Control District "The Control of Floods and Conservation of Water in Orange County California."	APR 1929
2.	Orange County Flood Control District, "Engineering and Geological Reports for Flood Control and Conservation Project of Orange County Flood Control District."	APR 1931
3.	U.S. Engineers Office, Los Angeles, California, "Definite Project for the Construction of Reservoirs and Related Flood-Control Works in Orange County, California, Authorized by the Flood-Control Act of 1936.	DEC 1936
4.	U.S. Engineers Office, Los Angeles, California, "Orange County Flood Control Project for Prado Retarding Basin, Engineering Data and Cost Estimate."	DEC 1936
5.	U.S. Engineers Office, Los Angeles, California, "Basis for Design, Santa Ana River Improvement."	APR 1938
6.	U.S. Engineers Office, Los Angeles, California, "The Santa Ana River, California, Flood Control."	JUL 1939
7.	House Document No. 135, 81st Congress, 1st. Session; A letter from the Secretary of the Army entitled: "Santa Ana River and Tributaries, California". The letter was referred to the Committee on Public Works.	MAR 1949
8.	U.S. Engineers Office, Los Angeles, California, "The Santa Ana Basin, California, Flood Control Operation and Maintenance Manual for Prado Dam."	MAY 1963
9.	U.S. Engineers Office, Los Angeles, California, "Prado Dam - Proposed Plugging of Ungated Outlets."	JUN 1969
10.	U.S. Engineers Office, Los Angeles, California, "Interim Report, Review of Design Features of Existing Dams, Hydrology and Hydraulic Review of Prado, Brea, Fullerton, and Salinas Dams."	NOV 1969
11.	U.S. Engineers Office, Los Angeles, California, "Santa Ana River Basin, California, Prado Dam, Santa Ana River, California, Dam, Outlet Works, and Spillway Periodic Inspection and Continuing Evaluation Report #1.	SEP 1971
12.	U.S. Engineers Office, Los Angeles, California, "Supplement A - Hydraulic Review of Prado Dam."	APR 1972
13.	U.S. Engineers Office, Los Angeles, California, "Hydrology, Santa Ana River Below Prado Dam."	JUL 1974
14.	U.S. Engineers Office, Los Angeles, California, "Review Report on the Santa Ana River Main Stem - Including Santiago Creek and Oak Street Drain, for Flood Control and Allied Purposes."	DEC 1975
15.	U.S. Engineers Office, Los Angeles, California, "Santa Ana River Basin, Riverside County, California, Santiago River, Outlet Works and Spillway Periodic Inspection Report #2."	MAY 1976
16.	U.S. Engineers Office, Los Angeles, California, "Santa Ana River - Phase 1 GDM on the Santa Ana River Main Stem including Santiago Creek."	SEP 1980
17.	U.S. Engineers Office, Los Angeles, California, "Santa Ana River Basin, Riverside County, California, Santa Ana River Dam, Outlet Works and Spillway Period Inspection Report #3."	MAY 1981
18.	U.S. Engineers Office, Los Angeles, California, "Coyote Creek Tributaries, Santa Ana River Basin, Orange County, California, Interim 3 Hydrology Documentation."	1984

Plate 1-01

Related Manuals and Reports

No.	Title	Date
19.	U.S. Engineers Office, Los Angeles, California, "Operation of Prado Dam for Water Conservation/Water Supply."	AUG 1985
20.	U.S. Engineers Office, Los Angeles, California, "Preliminary, Prado Dam Basin, Land Use Analysis Report, Santa Ana River Main Stem including Santiago Creek."	SEP 1985
21.	U.S. Engineers Office, Los Angeles, California, "Upper Santa Ana River, Flood Alternative Study, Supplement to Phase 1 GDM on the Santa Ana River Main Stem including Santiago Creek."	DEC 1985
22.	U.S. Engineers Office, Los Angeles, California, "Santa Ana River Real-Time Water Control System".	FEB 1987
23.	U.S. Engineers Office, Los Angeles, California, Hydrology Appendix H to the "Prado Dam Water Conservation Study".	JUN 1988
24.	U.S. Engineers Office, Los Angeles, California, "Santa Ana River; Design Memorandum No. 1, Phase II General Design Memorandum on the Santa Ana River Mainstem, including Santiago Creek". The GDM is comprised of a Main Report and nine appendixes.	AUG 1988
25.	Historical Correspondence Files	

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

RELATED MANUALS AND REPORTS

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

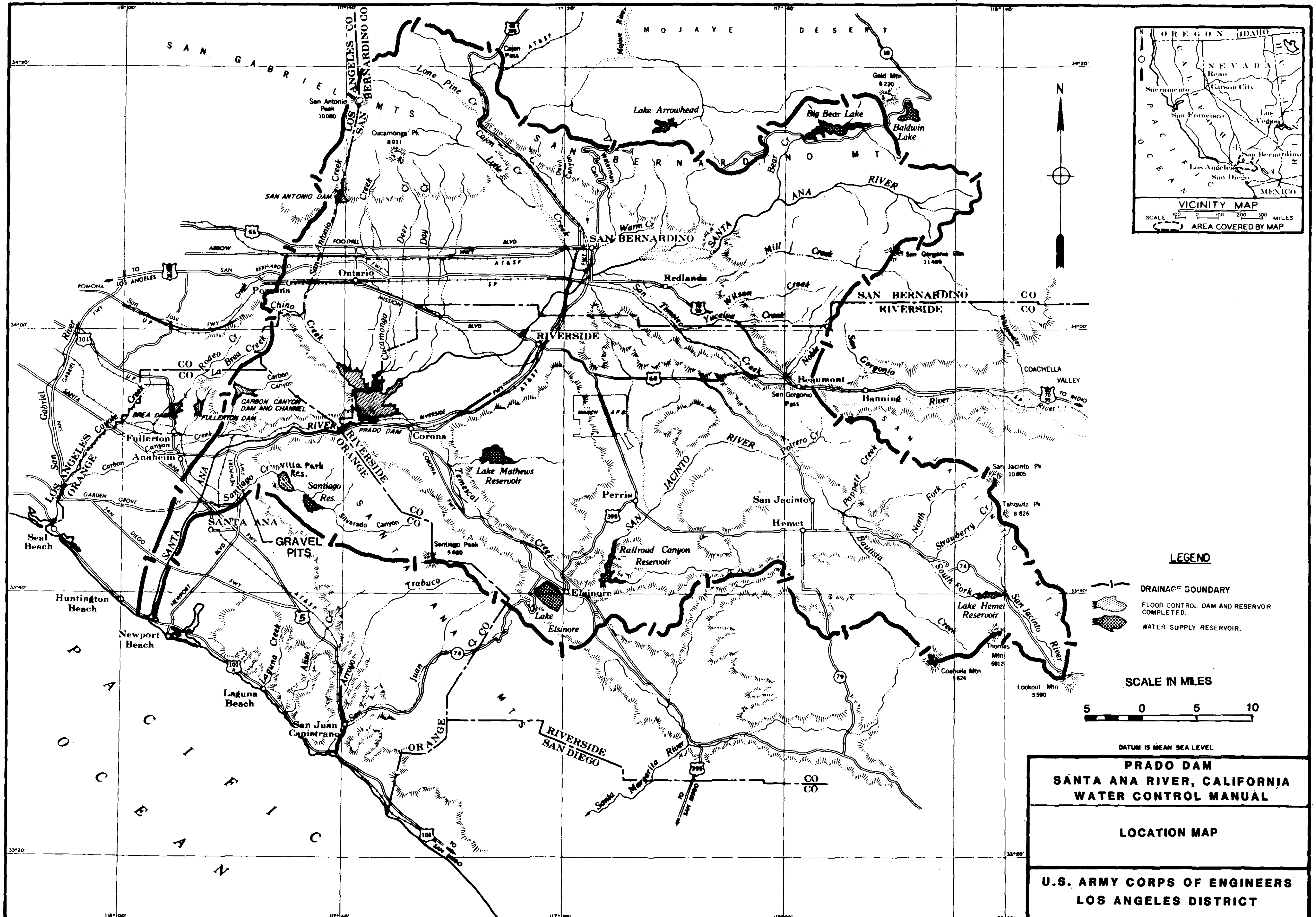
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL
LOCATION MAP
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
VICINITY MAP
AREA COVERED BY MAP
LEGEND
DRAINAGE BOUNDARY
FLOOD CONTROL DAM AND RESERVOIR COMPLETED.
WATER SUPPLY RESERVOIR.
SCALE IN MILES
5 0 5 10
DATUM IS MEAN SEA LEVEL
N
PACIFIC OCEAN
MOJAVE DESERT
SAN GABRIEL MTS
SAN BERNARDINO MTS
SAN JACINTO MTS
SANTA ANA MTS
SANTA ANA RIVER
SAN JACINTO RIVER
PRADO DAM
SAN ANTONIO DAM
CARBON CANYON DAM AND CHANNEL
BREA DAM
FULLERTON DAM
SAN BERNARDINO
RIVERSIDE
Ontario
Pomona
Corona
Redlands
Beaumont
Banning
Perris
San Jacinto
Hemet
Elsinore
Lake Elsinore
Fullerton
Anaheim
SANTA ANA
GRAVEL PITS
Seal Beach
Huntington Beach
Newport Beach
Laguna Beach
San Juan Capistrano
Lake Arrowhead
Big Bear Lake
Baldwin Lake
Lake Mathews Reservoir
Railroad Canyon Reservoir
Lake Hemet Reservoir
Villa Park Res.
Santiago Res.
SAN BERNARDINO CO
RIVERSIDE CO
LOS ANGELES CO
ORANGE CO
SAN DIEGO CO
COACHELLA VALLEY

PLATE 2-01

The Plate you are attempting to access is not currently available.

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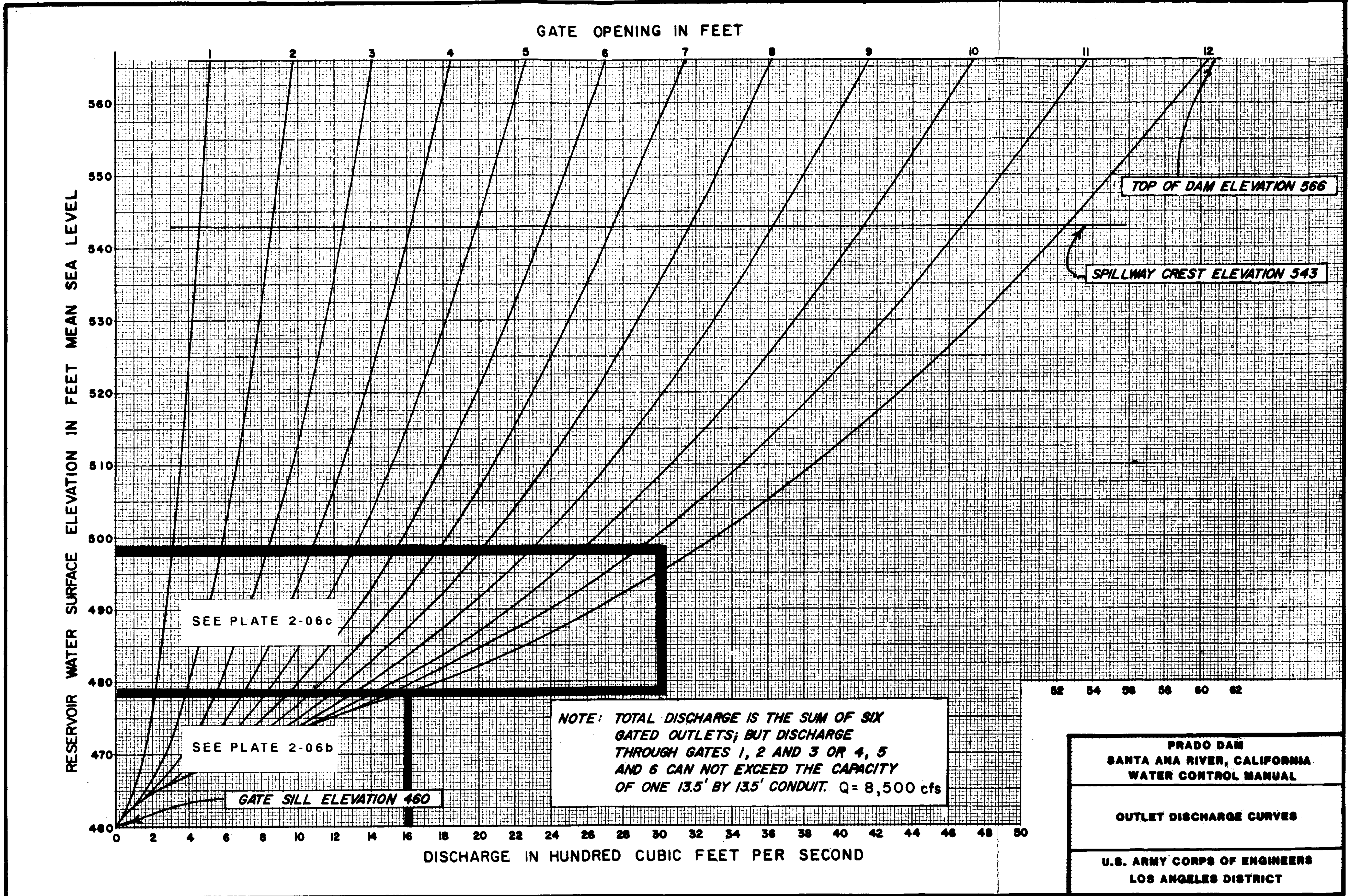
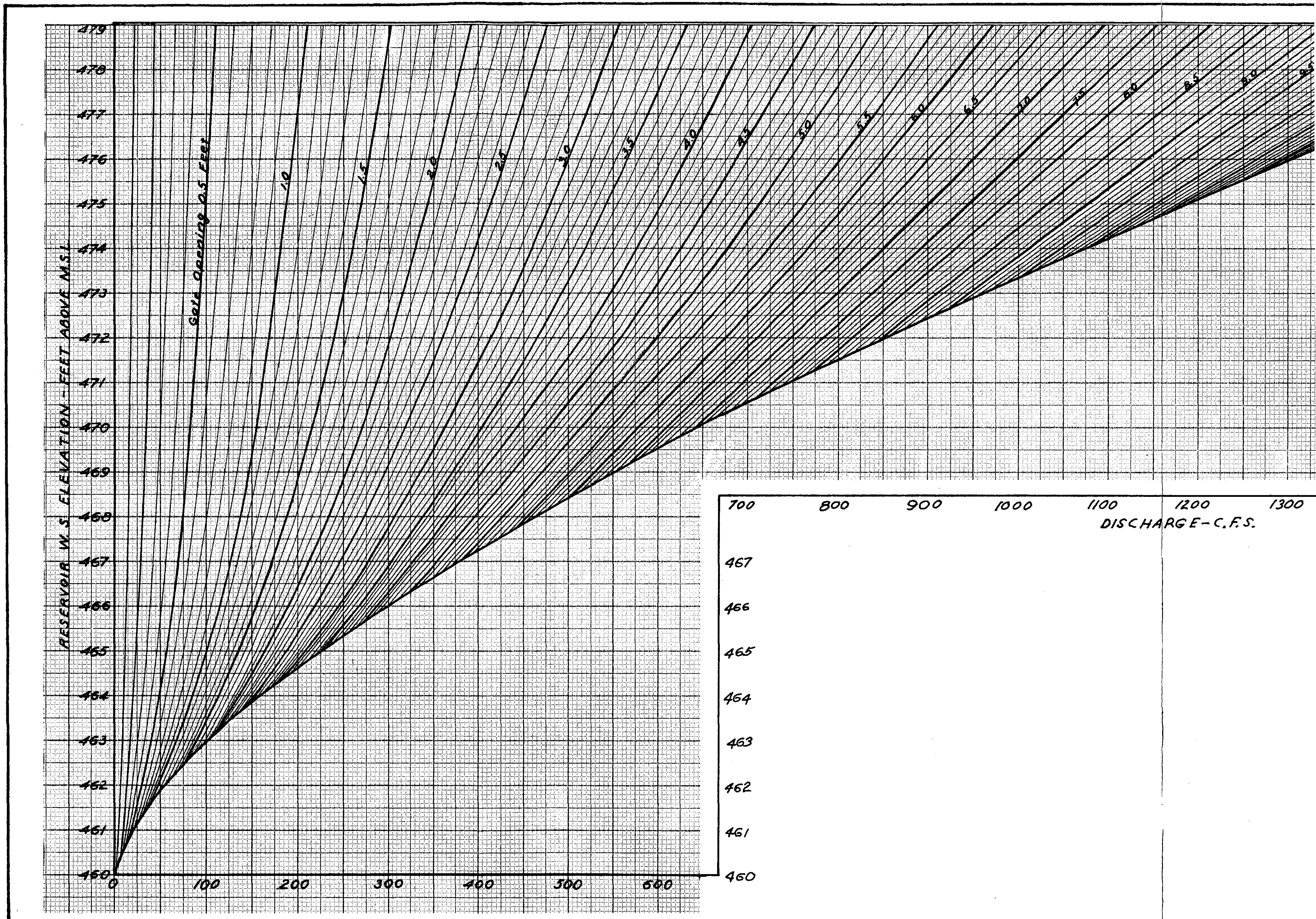
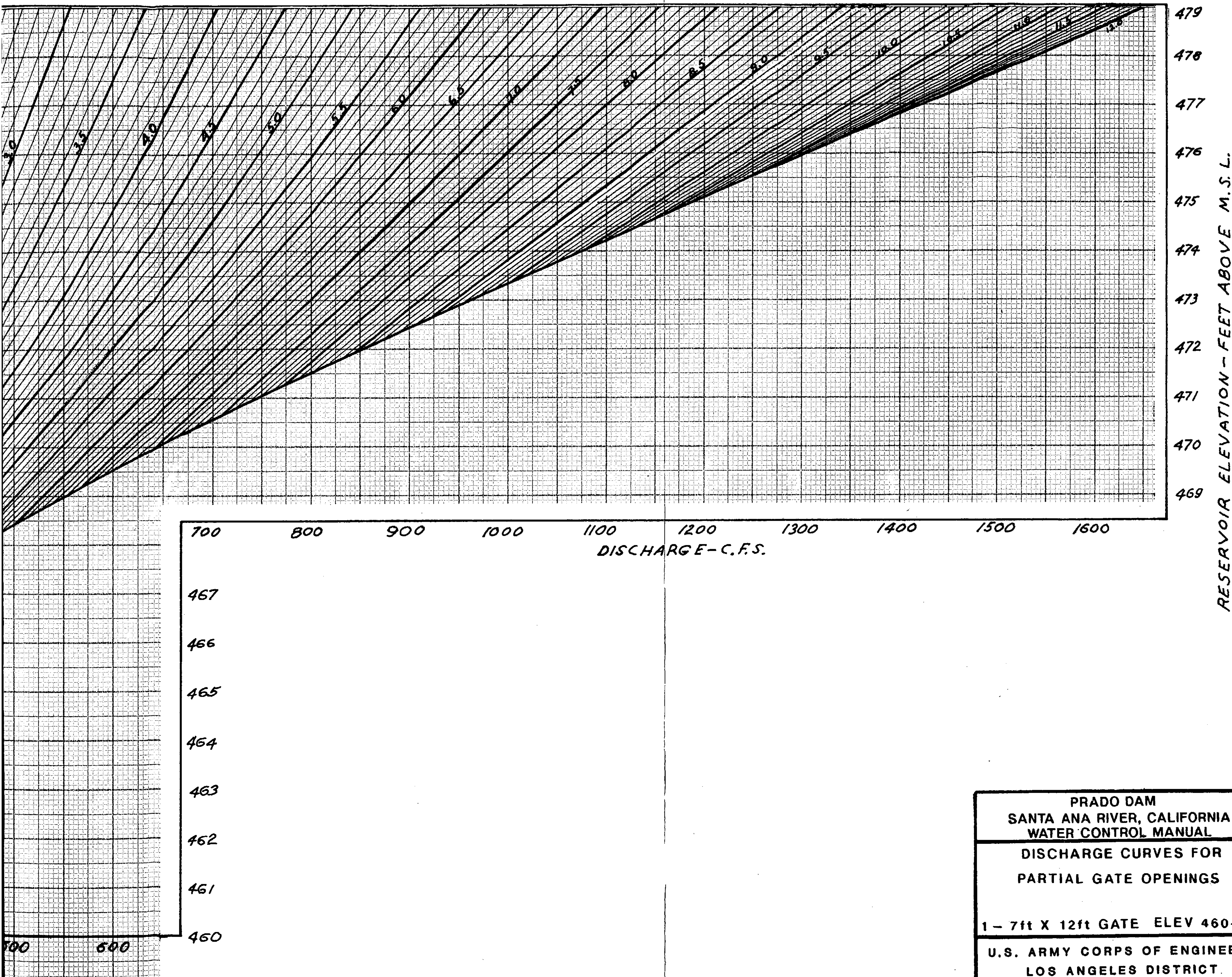

GATE OPENING IN FEET
1
2
3
4
5
6
7
8
9
10
11
12
RESERVOIR WATER SURFACE ELEVATION IN FEET MEAN SEA LEVEL
460
470
480
490
500
510
520
530
540
550
560
DISCHARGE IN HUNDRED CUBIC FEET PER SECOND
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
52 54 56 58 60 62
TOP OF DAM ELEVATION 566
SPILLWAY CREST ELEVATION 543
SEE PLATE 2-06c
SEE PLATE 2-06b
GATE SILL ELEVATION 460
NOTE: TOTAL DISCHARGE IS THE SUM OF SIX GATED OUTLETS; BUT DISCHARGE THROUGH GATES 1, 2 AND 3 OR 4, 5 AND 6 CAN NOT EXCEED THE CAPACITY OF ONE 13.5' BY 13.5' CONDUIT. Q= 8,500 cfs
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL
OUTLET DISCHARGE CURVES
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


RESERVOIR W.S. ELEVATION - FEET ABOVE M.S.L.
DISCHARGE - C.F.S.
Gate Opening 0.5 Feet
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
479
478
477
476
475
474
473
472
471
470
469
468
467
466
465
464
463
462
461
460
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
467
466
465
464
463
462
461
460



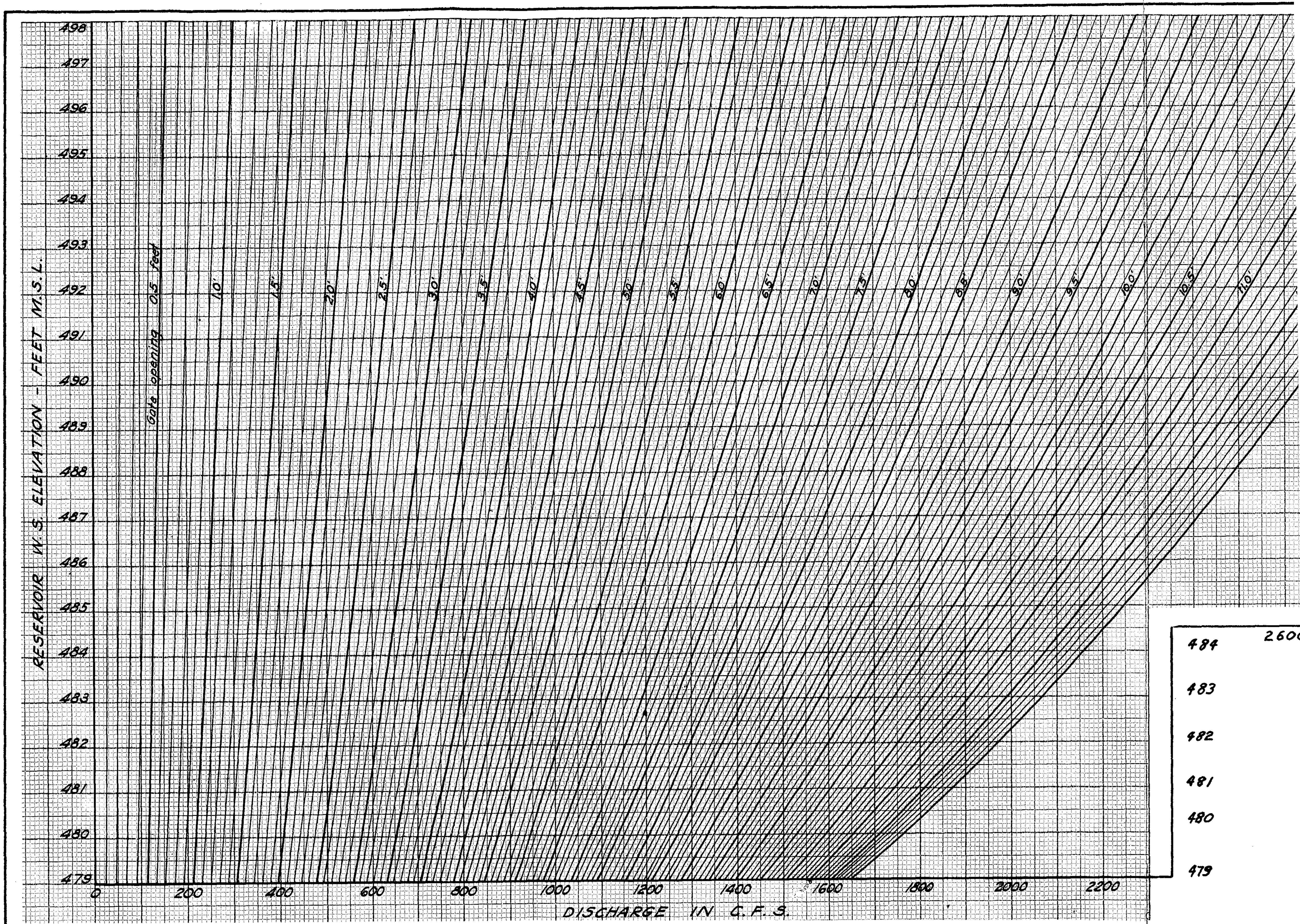
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

DISCHARGE CURVES FOR

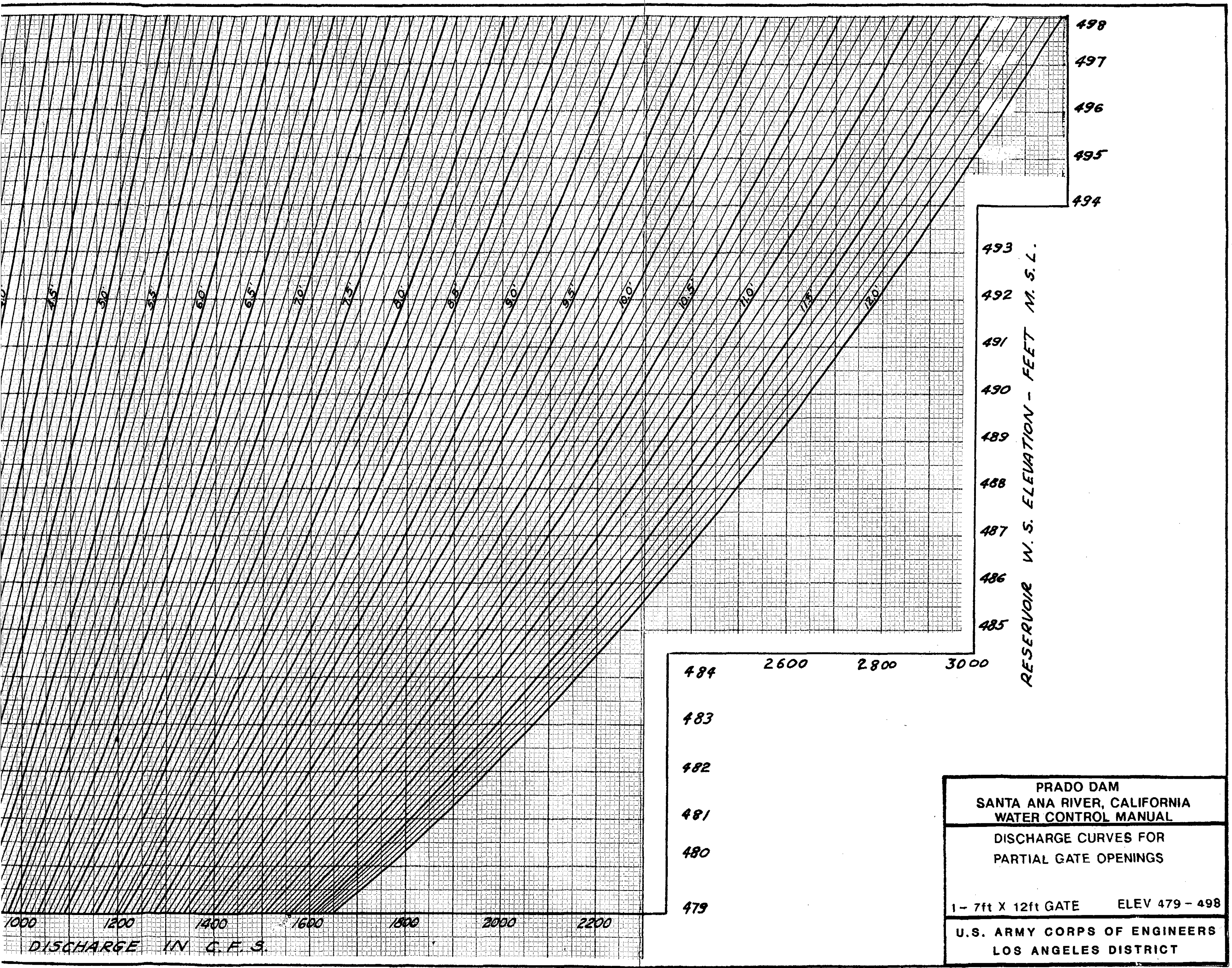
PARTIAL GATE OPENINGS

1 – 7ft X 12ft GATE ELEV 460-479

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



RESERVOIR W.S. ELEVATION - FEET M.S.L.
DISCHARGE IN C.F.S.
Gate opening 0.5 feet
1.0'
1.5'
2.0'
2.5'
3.0'
3.5'
4.0'
4.5'
5.0'
5.5'
6.0'
6.5'
7.0'
7.5'
8.0'
8.5'
9.0'
9.5'
10.0'
10.5'
11.0'
498
497
496
495
494
493
492
491
490
489
488
487
486
485
484
483
482
481
480
479
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2600



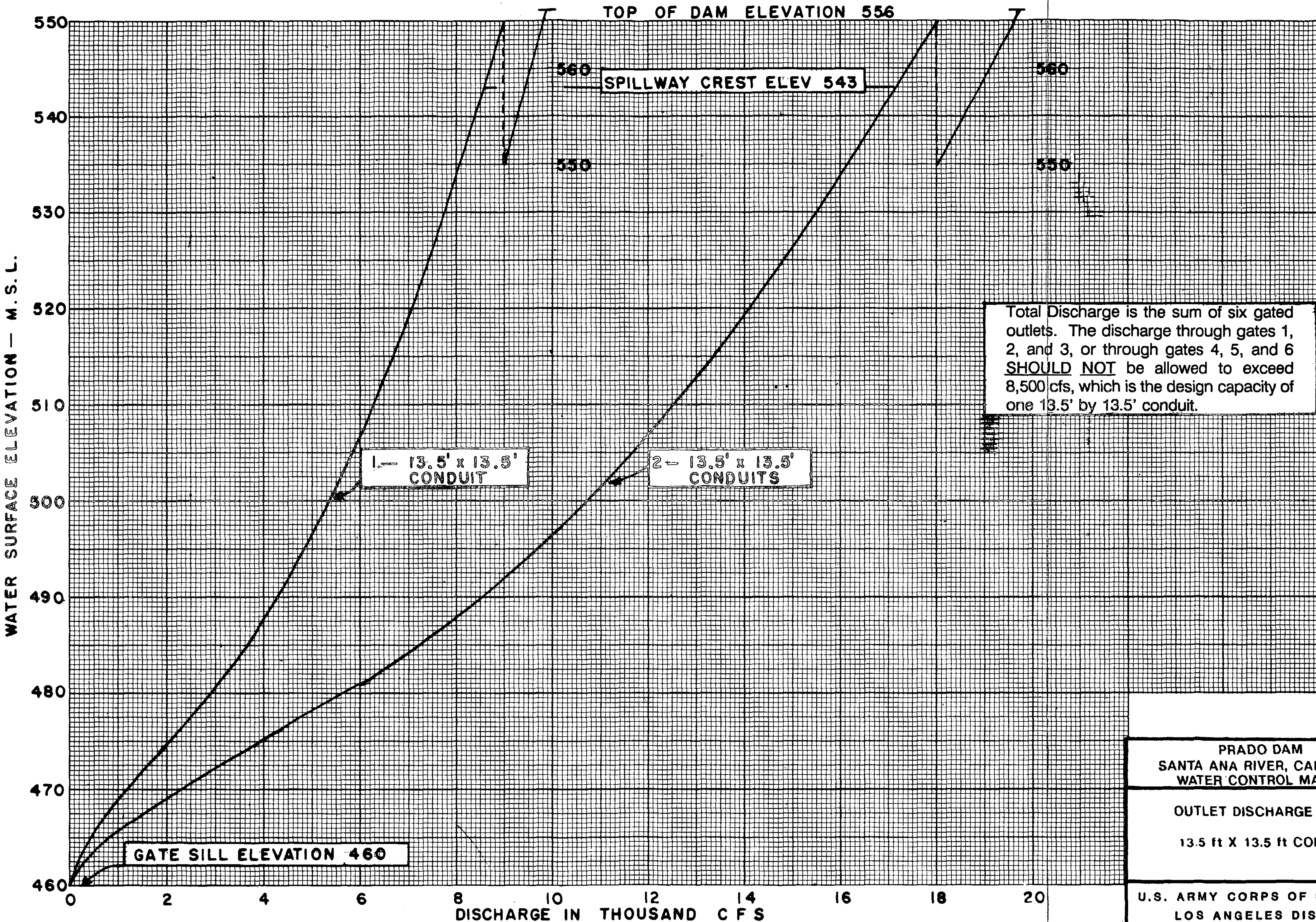
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

DISCHARGE CURVES FOR
PARTIAL GATE OPENINGS

1 - 7ft X 12ft GATE ELEV 479 - 498

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 2-06c

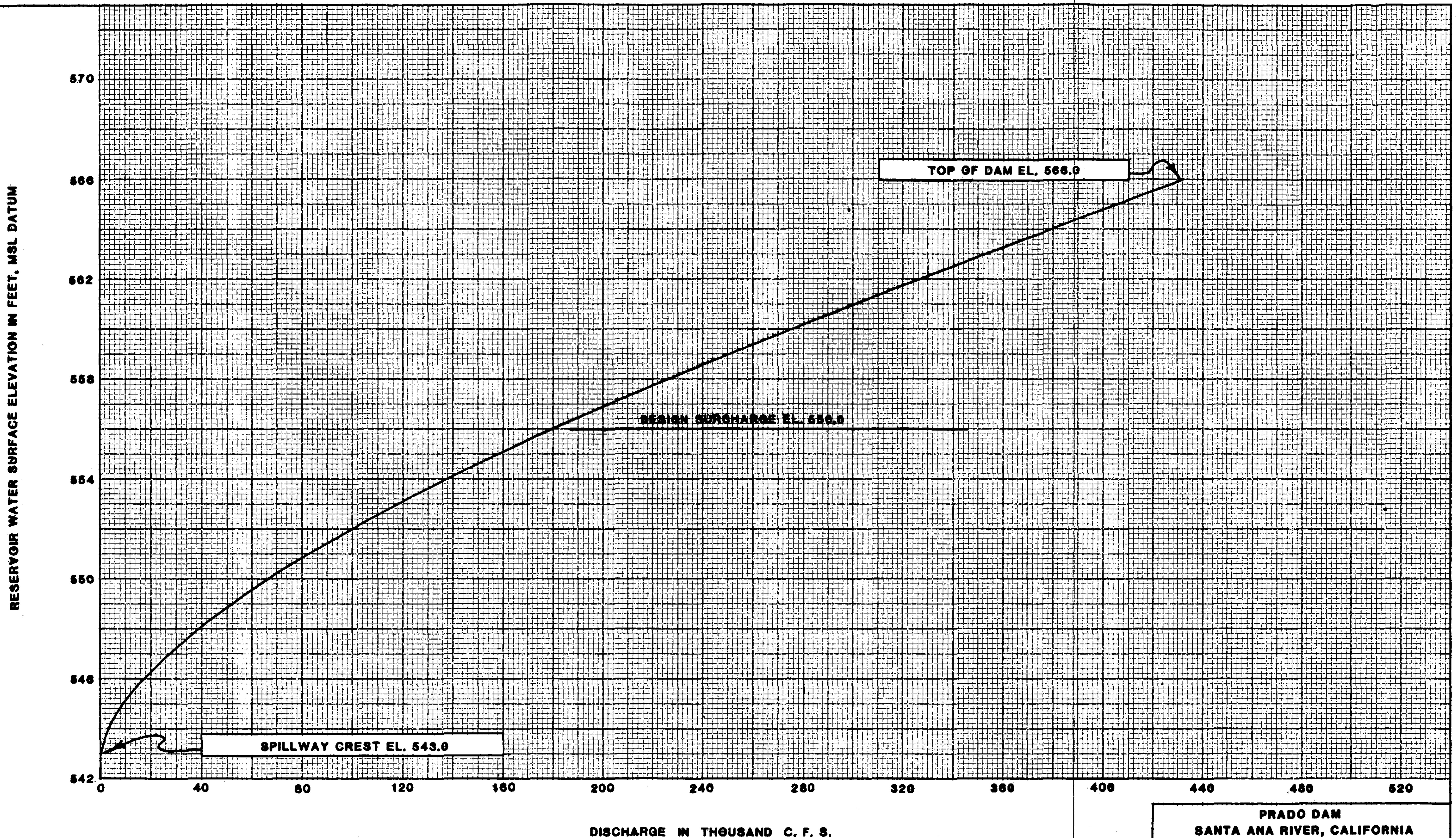


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OUTLET DISCHARGE CURVE

13.5 ft X 13.5 ft CONDUITS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SPILLWAY DISCHARGE CURVE

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

ELEVATION (FEET)	STORAGE (ACRE-FEET)	CAPACITY TO SPILLWAY (PERCENT)	AREA (ACRES)	MAXIMUM DEPTH (FEET)
460	0.0	0.00	0.00	0
461	0.0	0.00	0.00	1
462	0.0	0.00	0.00	2
463	0.1	0.00	0.10	3
464	0.2	0.00	0.20	4
465	0.6	0.00	0.56	5
466	1.3	0.00	0.92	6
467	2.4	0.00	1.23	7
468	3.8	0.00	1.53	8
469	5.5	0.00	1.89	9
470	7.6	0.00	2.25	10
471	10.2	0.01	3.07	11
472	13.7	0.01	3.89	12
473	18.4	0.01	5.53	13
474	24.7	0.01	7.16	14
475	33.6	0.02	10.59	15
476	45.9	0.02	14.02	16
477	67.2	0.03	28.60	17
478	103.1	0.05	43.18	18
479	158.7	0.08	68.04	19
480	239.2	0.12	92.90	20
481	347.7	0.18	104.19	21
482	487.6	0.25	115.48	22
483	664.1	0.34	177.51	23
484	882.6	0.45	239.54	24
485	1,188.4	0.61	372.14	25
486	1,626.9	0.83	504.74	26
487	2,183.3	1.11	608.10	27
488	2,843.1	1.45	711.45	28
489	3,606.5	1.84	815.41	29
490	4,483.1	2.28	919.36	30
491	5,442.0	2.77	1,016.65	31
492	6,507.0	3.32	1,113.94	32
493	7,666.0	3.91	1,203.96	33
494	8,915.0	4.54	1,293.97	34
495	10,257.0	5.23	1,389.02	35
496	11,693.0	5.96	1,484.06	36
497	13,226.0	6.74	1,582.13	37

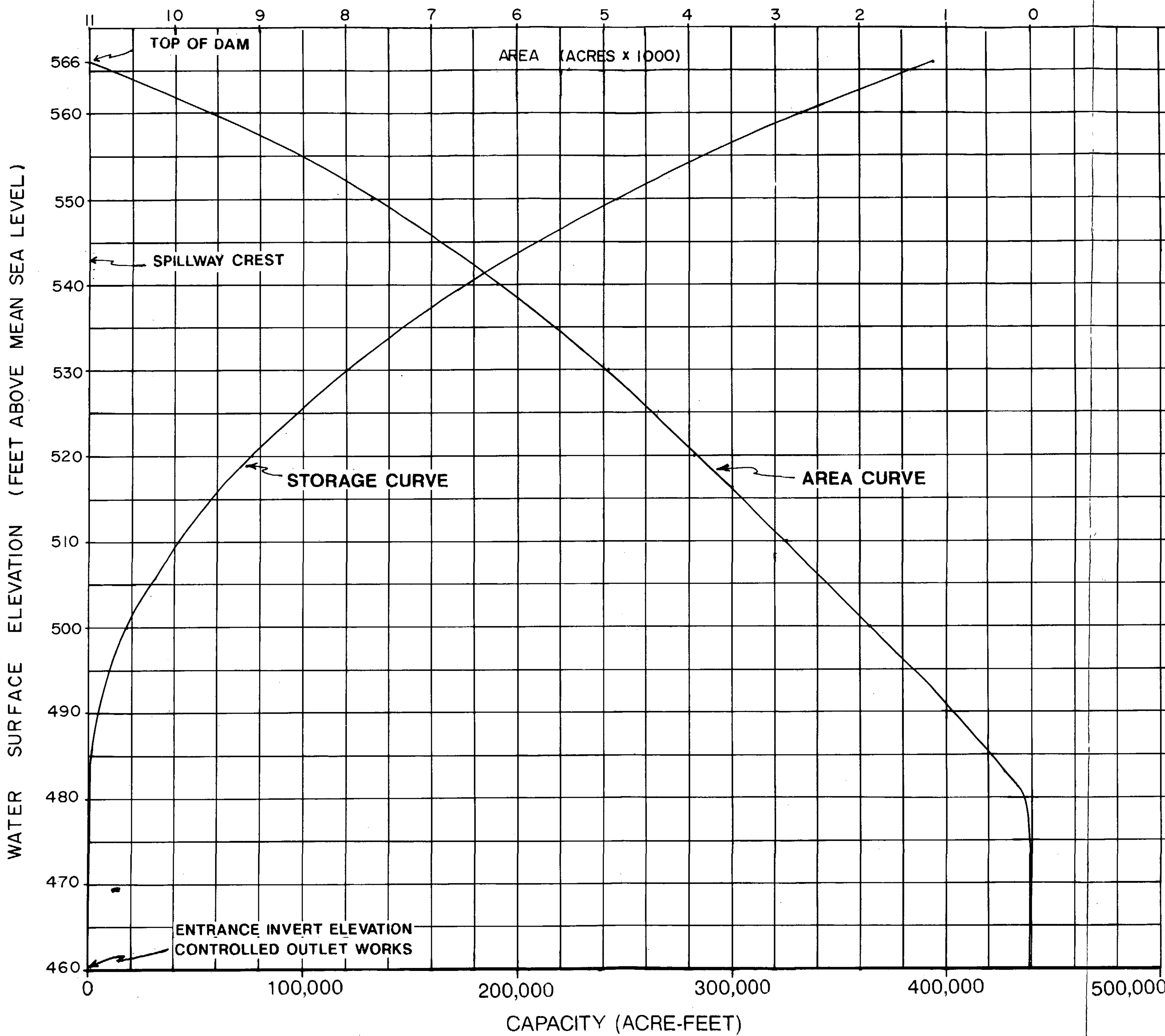
ELEVATION (FEET)	STORAGE (ACRE-FEET)	CAPACITY TO SPILLWAY (PERCENT)	AREA (ACRES)	MAXIMUM DEPTH (FEET)
498	14857	7.57	1,680.19	38
499	16590	8.45	1,759.12	39
500	18426	9.39	1,838.04	40
501	20369	10.38	1,973.65	41
502	22423	11.43	2,109.26	42
503	24580	12.53	2,204.52	43
504	26832	13.67	2,299.78	44
505	29183	14.87	2,402.27	45
506	31636	16.12	2,504.76	46
507	34188	17.42	2,597.39	47
508	36831	18.77	2,690.02	48
509	39566	20.16	2,778.81	49
510	42389	21.60	2,867.60	50
511	45318	23.09	2,990.71	51
512	48370	24.65	3,113.81	52
513	51534	26.26	3,213.23	53
514	54797	27.92	3,312.64	54
515	58167	29.64	3,428.10	55
516	61653	31.42	3,543.55	56
517	65229	33.24	3,649.53	57
518	68952	35.14	3,755.51	58
519	72753	37.07	3,847.18	59
520	76646	39.06	3,938.84	60
521	80635	41.09	4,039.47	61
522	84725	43.18	4,140.10	62
523	88912	45.31	4,233.38	63
524	93192	47.49	4,326.65	64
525	97570	49.72	4,429.88	65
526	102052	52.00	4,533.11	66
527	106634	54.34	4,632.23	67
528	111316	56.73	4,731.35	68
529	116100	59.16	4,835.79	69
530	120988	61.65	4,940.22	70
531	125998	64.21	5,080.24	71
532	131148	66.83	5,220.25	72
533	136430	69.52	5,343.95	73
534	141836	72.28	5,467.64	74
535	147370	75.10	5,600.10	75

ELEVATION (FEET)	STORAGE (ACRE-FEET)	CAPACITY TO SPILLWAY (PERCENT)	AREA (ACRES)	MAXIMUM DEPTH (FEET)
536	153,036	77.99	5,732.55	76
537	158,832	80.94	5,858.14	77
538	164,753	83.96	5,983.72	78
539	170,798	87.04	6,106.04	79
540	176,965	90.18	6,228.35	80
541	183,257	93.39	6,356.52	81
542	189,678	96.66	6,484.69	82
543	196,235	100.00	6,630.01	83
544	202,938	103.42	6,775.33	84
545	209,785	106.90	6,920.00	85
546	216,778	110.47	7,064.66	86
547	223,924	114.11	7,227.28	87
548	231,232	117.83	7,389.90	88
549	238,698	121.64	7,541.45	89
550	246,315	125.52	7,692.99	90
551	254,094	129.48	7,865.32	91
552	262,046	133.54	8,037.64	92
553	270,165	137.67	8,199.70	93
554	278,445	141.89	8,361.75	94
555	286,910	146.21	8,567.65	95
556	295,581	150.63	8,773.54	96
557	304,449	155.15	8,964.40	97
558	313,509	159.76	9,155.25	98
559	322,765	164.48	9,355.41	99
560	332,220	169.30	9,555.57	100
561	341,885	174.22	9,775.03	101
562	351,770	179.26	9,994.49	102
563	361,895	184.42	10,762.08	103
564	372,281	189.71	10,516.68	104
565	382,921	195.13	10,762.08	105
566	393,806	200.68	11,007.48	106

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

AREA - CAPACITY TABLE

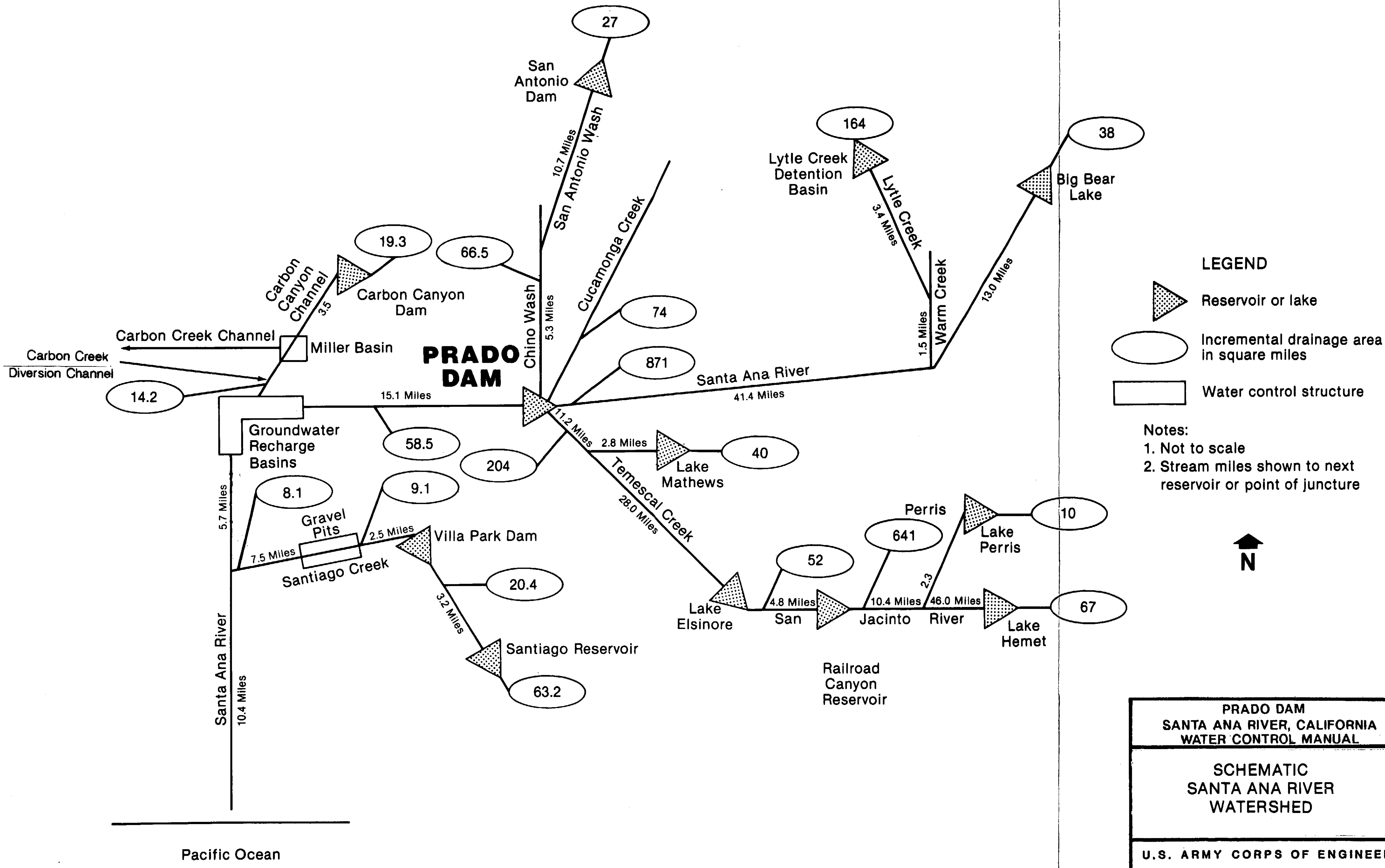
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

AREA-CAPACITY CURVE
PRADO DAM
SURVEY 1980

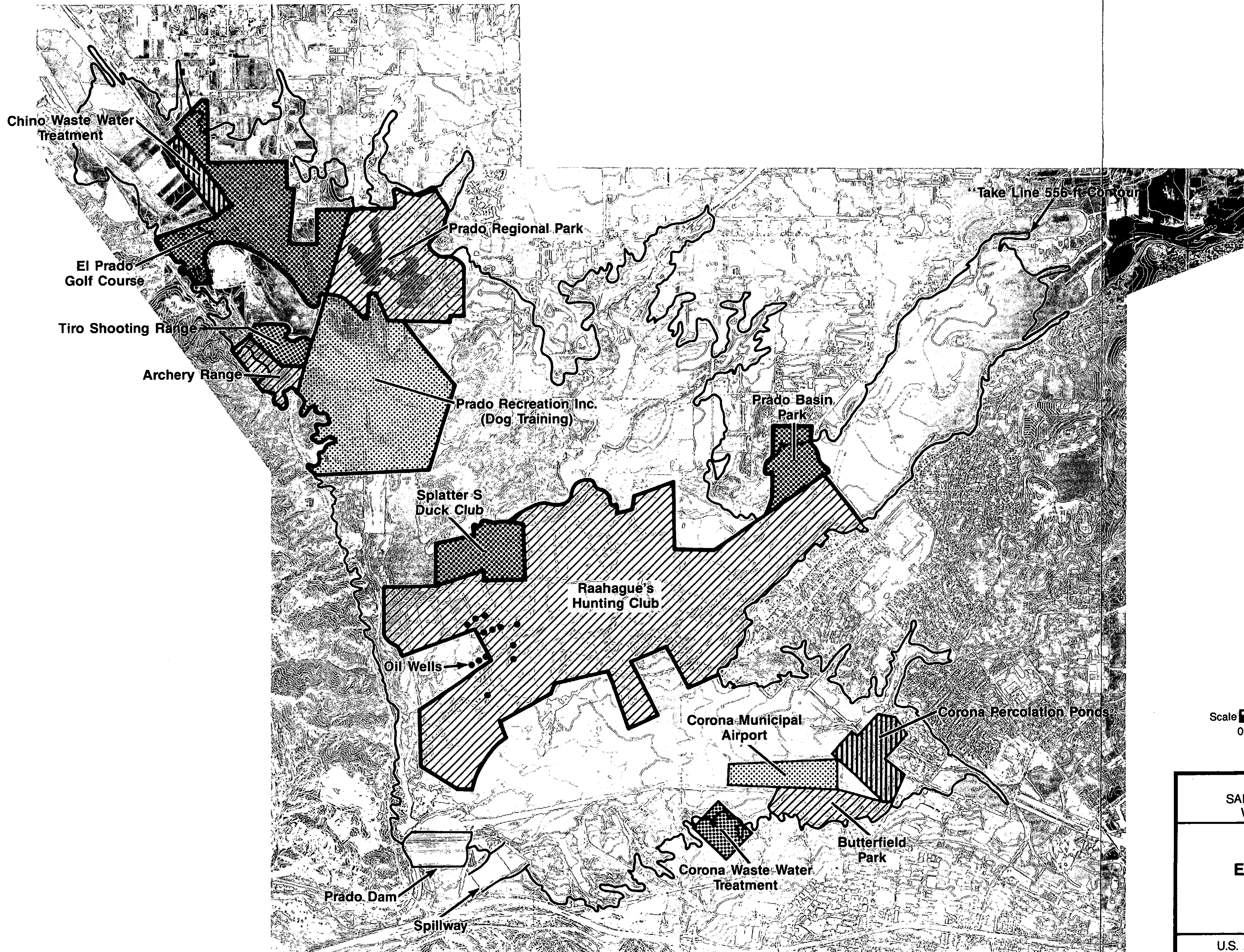
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SCHEMATIC
SANTA ANA RIVER
WATERSHED

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



N

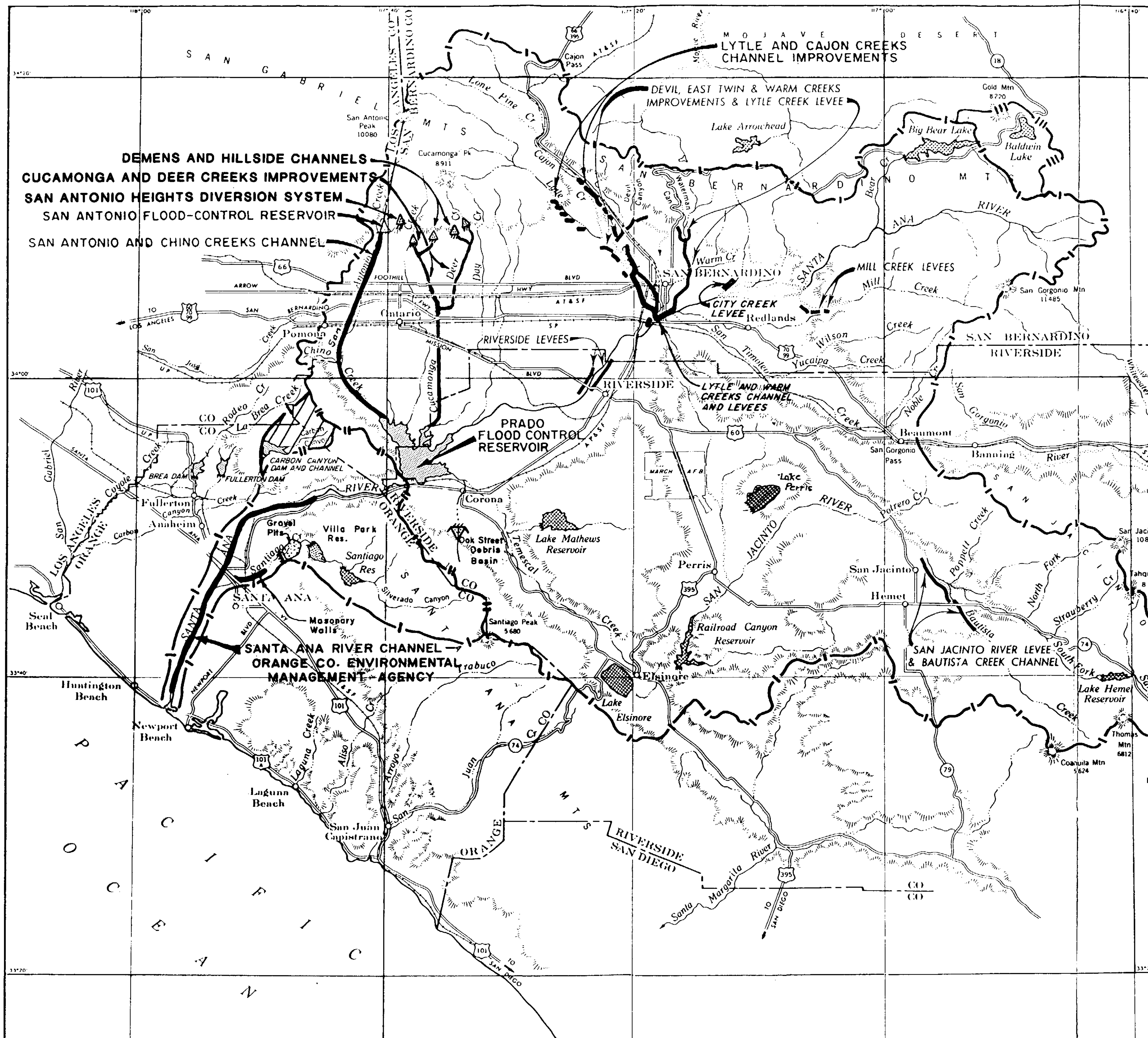
Scale Feet
0 1000 2000 3000

30 Acres

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

EXISTING LAND USES
Revised 1990

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

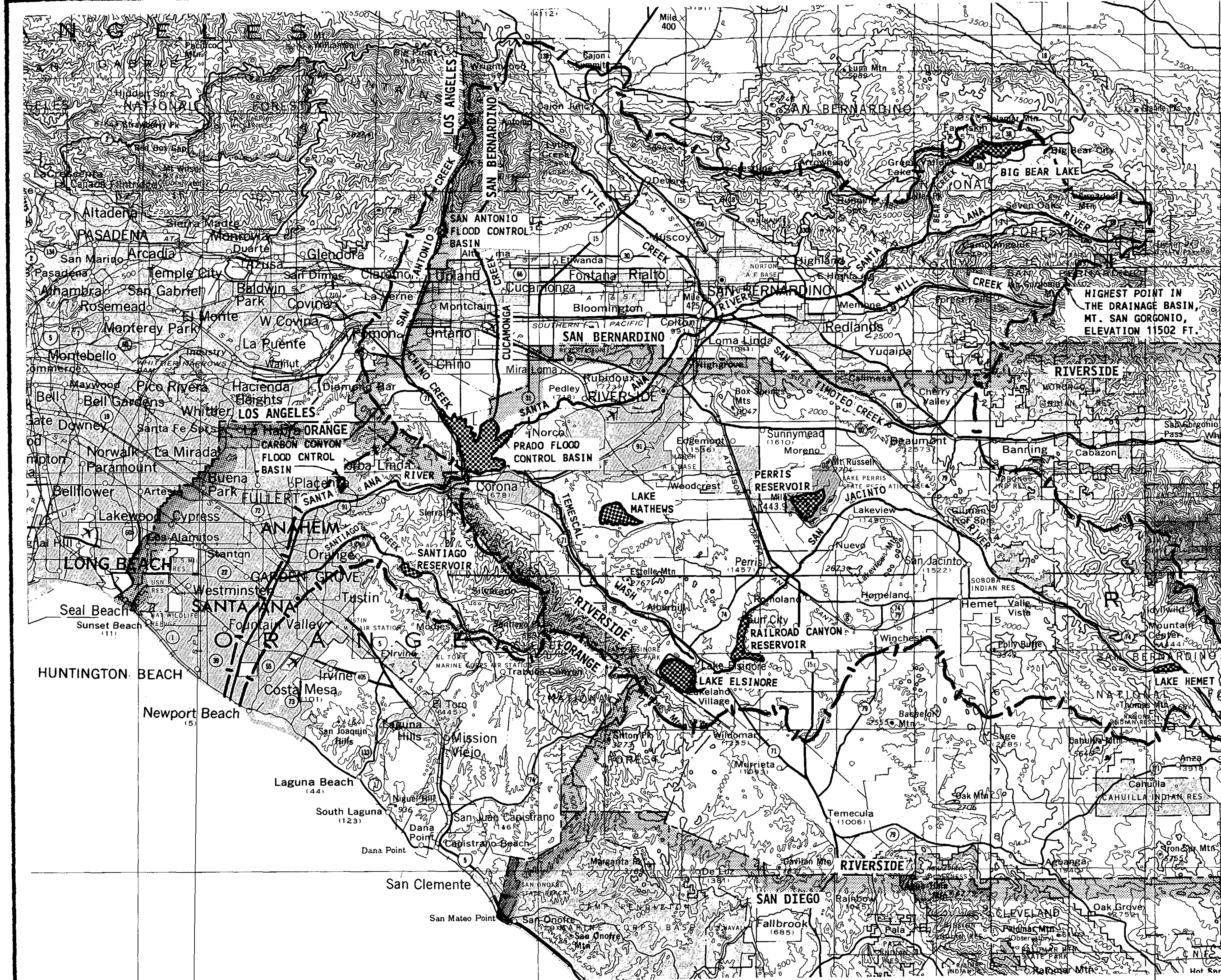


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

EXISTING STRUCTURES

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 4-01a



LEGEND

DRAINAGE AREA BOUNDARY

LAKE OR RESERVOIR

COUNTY BOUNDARY (ORANGE)

N

SCALE 1:500,000

1 inch equals approximately 8 miles

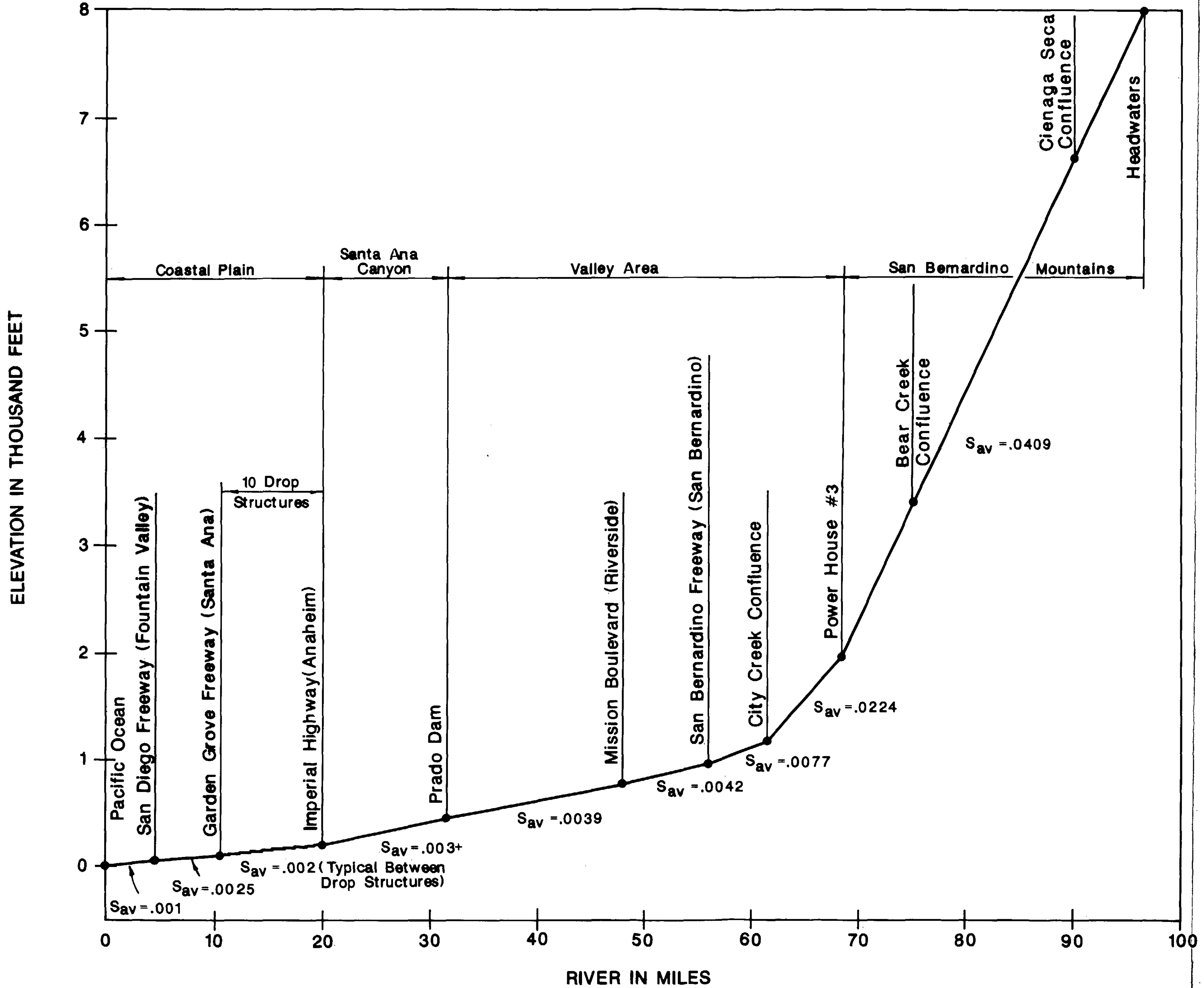
10 0 10

Contour interval = 500 feet

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SANTA ANA RIVER
BASIN TOPOGRAPHY

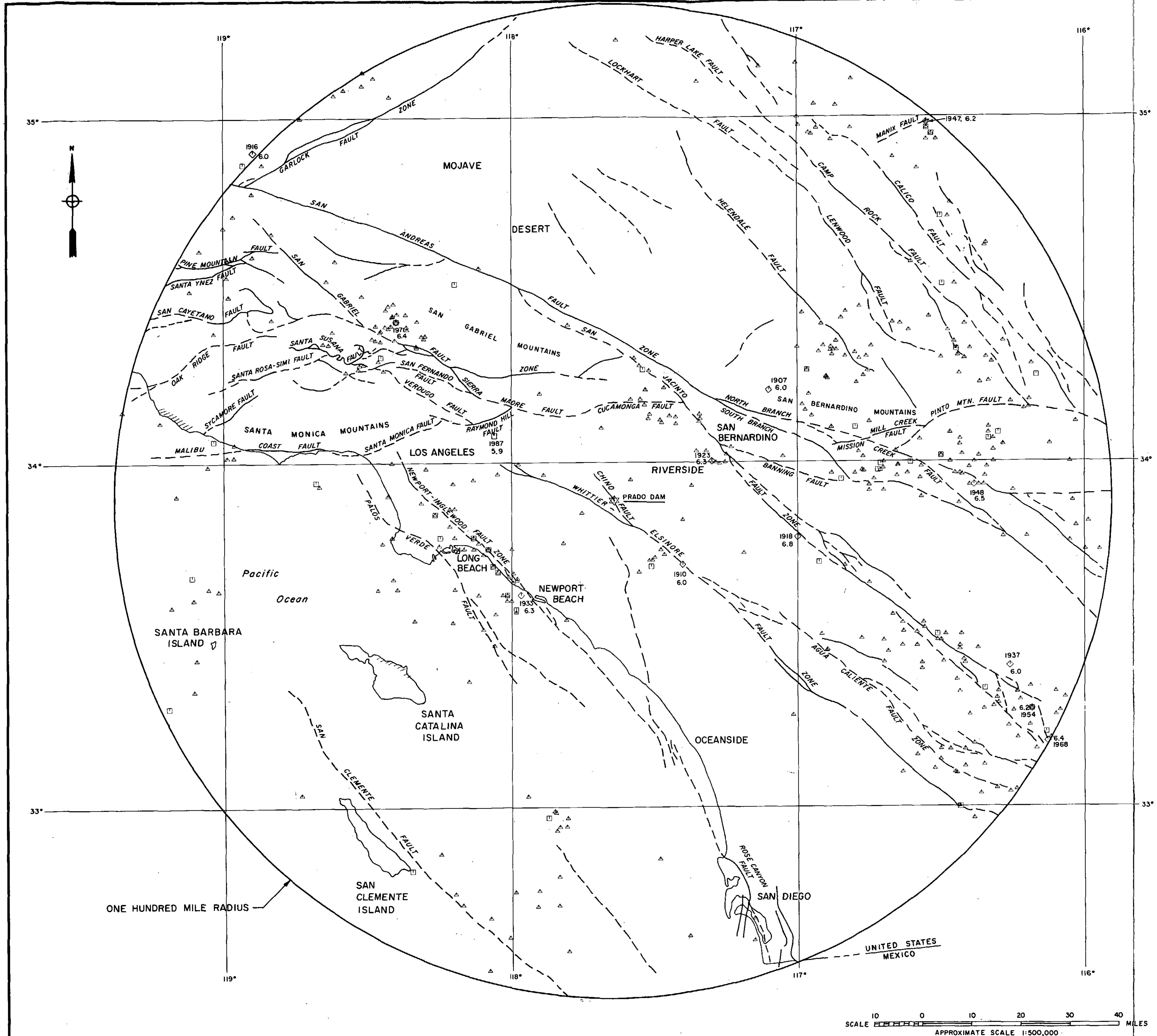
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SANTA ANA RIVER
STREAMBED PROFILE

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



LEGEND

- △ EARTHQUAKE WITH MAGNITUDE 4.0 THRU 4.99
- ◻ EARTHQUAKE WITH MAGNITUDE 5.0 THRU 5.99
- ◇ EARTHQUAKE WITH MAGNITUDE 6.0 THRU 6.99
- ✡ LOCATION OF PROJECT AREA
- TRACE OF FAULT DASHED WHERE INFERRED OR CONCEALED

NOTES:

1. Richter scale magnitudes are a measure of the energy released at the focus (center of the earthquake) as determined by the amplitudes produced on a seismogram.
2. The epicenter is the point on the earth's surface directly above the focus.
3. Earthquake epicenters plotted are from 1932 to 1987, unless earlier dates are shown.
4. Base map modified from state of California (South Half) 1:500,000 topographic map; United States Geological Survey, 1981.
5. Locations of faults are approximate. Data derived from various California Division of Mines and Geology and United States Geological Survey publications.
6. Earthquake epicenter locations are from California Institute of Technology's seismologic data base for Southern California, Nevada, and Arizona; from Toppozada and others (1981), and from Toppozada and Parke (1982).

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

EARTHQUAKE EPICENTER
AND
FAULT LOCATION MAP

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

CLIMATOLOGICAL SUMMARY FOR CORONA, CALIFORNIA

PERIOD: 1951-80
ELEVATION: 710 FT

	TEMPERATURE (F)					PRECIPITATION TOTALS (INCHES)							
	MEANS			EXTREMES							SNOW		
	DAILY MAXIMUM*	DAILY MINIMUM*	MONTHLY*	RECORD HIGHEST	RECORD LOWEST	MEAN*	GREATEST MONTHLY*	YEAR	GREATEST DAILY	YEAR	MEAN	MAXIMUM MONTHLY	YEAR
JAN	66.2	40.2	53.2	91+	23+	2.72	10.90	69	3.66	69	.0	.0	
FEB	68.8	41.4	55.1	93	26+	2.34	9.98	80	2.68	63	.0	.0	
MAR	70.2	42.6	56.4	96+	28+	1.75	5.23	78	2.20	68	.0	.0	
APR	74.2	45.6	59.9	99+	30+	.94	4.42	58	1.37	58	.0	.0	
MAY	78.6	50.3	64.5	105+	36	.21	1.24	77	.71	74	.0	.0	
JUN	84.6	54.4	69.6	110+	42+	.03	.47	72	.33	72	.0	.0	
JUL	91.9	58.5	75.2	110+	47+	.04	.36	68	.3	56	.0	.0	
AUG	91.4	59.0	75.2	109+	43	.12	1.84	77	1.67	77	.0	.0	
SEP	89.2	56.1	72.7	114+	41	.29	3.67	63	1.30	63	.0	.0	
OCT	82.2	50.3	66.3	106+	29	.19	1.66	57	.68	57	.0	.0	
NOV	73.6	43.8	58.7	96+	26	1.25	7.08	65	2.23	65	.0	.0	
DEC	67.7	40.0	53.9	94+	22	1.72	6.24	51	2.26	74	.0	1.0	68
YEAR	78.2	48.5	63.4	114	22	11.60	10.90	JAN 69	3.66	JAN 69	.0	1.0	DEC 68

* FROM 1951 - 80 NORMALS # ESTIMATED VALUE BASED ON DATA FROM SURROUNDING STATIONS + ALSO ON EARLIER DATES

PROBABILITY THAT THE MONTHLY PRECIPITATION WILL BE EQUAL TO OR LESS THAN THE INDICATED PRECIPITATION AMOUNT MONTHLY PRECIPITATION (INCHES) **

	PROBABILITY LEVELS										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
JAN	.00	.16	.56	.98	1.43	1.95	2.57	3.35	4.43	6.25	8.06
FEB	.00	.05	.29	.59	.96	1.43	2.01	2.78	3.89	5.83	7.80
MAR	.00	.00	.38	.68	.98	1.32	1.71	2.20	2.85	3.93	4.98
APR	.00	.00	.06	.18	.34	.54	.79	1.12	1.60	2.43	3.28
MAY	.00	.00	.00	.00	.01	.04	.10	.20	.35	.65	.96
JUN	.00	.00	.00	.00	.00	.00	.00	.00	.02	.1	.22
JUL	.00	.00	.00	.00	.00	.00	.00	.00	.03	.14	.25
AUG	.00	.00	.00	.00	.00	.00	.00	.00	.10	.39	.73
SEP	.00	.00	.00	.00	.00	.00	.00	.08	.33	.96	1.60
OCT	.00	.00	.00	.00	.01	.05	.10	.19	.32	.56	.82
NOV	.00	.00	.13	.30	.50	.76	1.08	1.50	2.10	3.16	4.22
DEC	.00	.00	.13	.34	.62	.96	1.42	2.02	2.90	4.46	6.06

** THESE VALUES WERE DETERMINED FROM THE INCOMPLETE GAMA DISTRIBUTION

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

CLIMATOLOGICAL SUMMARY
FOR
CORONA, CALIFORNIA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

CLIMATOLOGICAL SUMMARY FOR RIVERSIDE, CALIFORNIA

PERIOD: 1951-80
ELEVATION: 840 FT

	TEMPERATURE (F)					PRECIPITATION TOTALS (INCHES)						
	MEANS			EXTREMES							SNOW	
	DAILY MAXIMUM*	DAILY MINIMUM*	MONTHLY*	RECORD HIGHEST	RECORD LOWEST	MEAN*	GREATEST MONTHLY*	YEAR	GREATEST DAILY	YEAR	MEAN	MAXIMUM MONTHLY
JAN	66.0	39.5	52.8	90+	23+	2.17	6.67	69	2.70	56	.0	.0
FEB	68.8	41.1	55.0	92+	25+	1.77	8.00	69	2.41	69	.0	.0
MAR	70.4	42.9	56.7	97	25+	1.55	5.13	78	1.93	68	.0	.0
APR	74.7	46.3	60.5	100+	29+	.86	3.64	65	1.19	56	.0	.0
MAY	79.5	51.2	65.4	106+	37+	.23	1.63	77	.65	77	.0	.0
JUN	86.6	55.5	71.1	110	41+	.03	.37	72	.22	72	.0	.0
JUL	94.2	60.2	77.2	111+	43+	.08	1.26	56	1.26	56	.0	.0
AUG	93.4	60.4	77.0	109+	48+	.14	2.14	77	2.05	77	.0	.0
SEP	90.5	57.3	73.9	115+	44+	.31	3.91	63	1.37	63	.0	.0
OCT	82.5	50.6	66.6	109	30+	.20	1.42	57	.67	60	.0	.0
NOV	73.2	43.3	58.3	95+	25+	1.00	5.72	65	2.11	54	.0	.0
DEC	67.1	39.5	53.3	94+	24+	1.30	5.49	51	2.17	51	.0	.0
YEAR	78.9	49.0	64.0	115	23	9.64	8.00	FEB 69	2.70	JAN 56	.0	.0

* FROM 1951 - 80 NORMALS

ESTIMATED VALUE BASED ON DATA FROM SURROUNDING STATIONS

\+ ALSO ON EARLIER DATES

	PROBABILITY THAT THE MONTHLY PRECIPITATION WILL BE EQUAL TO OR LESS THAN THE INDICATED PRECIPITATION AMOUNT MONTHLY PRECIPITATION (INCHES) **										
	PROBABILITY LEVELS										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
JAN	.00	.13	.45	.78	1.15	1.56	2.06	2.68	3.54	5.00	6.43
FEB	.00	.04	.23	.46	.74	1.09	1.53	2.11	2.94	4.39	5.85
MAR	.00	.00	.31	.57	.84	1.14	1.50	1.94	2.53	3.53	4.50
APR	.00	.00	.02	.11	.25	.43	.67	.99	1.47	2.32	3.19
MAY	.00	.00	.00	.00	.02	.06	.13	.23	.38	.68	.99
JUN	.00	.00	.00	.00	.00	.00	.00	.00	.01	.09	.18
JUL	.00	.00	.00	.00	.00	.00	.00	.00	.06	.27	.52
AUG	.00	.00	.00	.00	.00	.00	.02	.08	.20	.46	.75
SEP	.00	.00	.00	.00	.00	.00	.00	.08	.33	.99	1.62
OCT	.00	.00	.00	.00	.02	.07	.13	.22	.35	.60	.85
NOV	.00	.00	.07	.19	.35	.55	.81	1.17	1.69	2.62	3.57
DEC	.00	.02	.14	.29	.50	.75	1.08	1.52	2.17	3.30	4.46

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PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

CLIMATOLOGICAL SUMMARY

FOR

RIVERSIDE, CALIFORNIA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

CLIMATOLOGICAL SUMMARY FOR UPLAND, CALIFORNIA

PERIOD: 1951-80
ELEVATION: 1605 FT

	TEMPERATURE (F)					PRECIPITATION TOTALS (INCHES)						
	MEANS			EXTREMES							SNOW	
	DAILY MAXIMUM*	DAILY MINIMUM*	MONTHLY*	RECORD HIGHEST	RECORD LOWEST	MEAN*	GREATEST MONTHLY*	YEAR	GREATEST DAILY	YEAR	MEAN	MAXIMUM MONTHLY
JAN	63.4	40.6	52.0	89+	25+	4.79	19.64	69	6.38	69	.0	.0
FEB	66.1	41.6	53.9	88+	29+	3.77	17.79	80	3.65	69	.0	.0
MAR	67.4	42.0	54.7	97+	29+	3.40	14.71	78	3.48	52	.0	.0
APR	71.8	44.5	58.2	100+	31+	1.70	6.81	58	2.75	58	.0	.0
MAY	76.3	48.5	62.4	104+	31	.57	4.03	77	2.01	77	.0	.0
JUN	83.4	52.5	68.0	109+	38+	.06	.42	67	.19	70	.0	.0
JUL	91.8	58.1	75.0	111+	44+	.05	.86	68	.84	68	.0	.0
AUG	90.9	58.6	74.8	108+	45+	.10	2.13	77	1.92	77	.0	.0
SEP	88.3	56.8	72.6	111+	42	.36	3.59	76	1.43	63	.0	.0
OCT	80.0	51.1	65.6	104+	32+	.44	3.93	57	2.02	79	.0	.0
NOV	70.4	45.3	57.9	93#	30+	1.96	10.46	65	3.35	70	.0	.0
DEC	64.8	41.1	53.0	88+	23+	2.69	12.67	66	4.61	66	.0	.0
YEAR	76.2	48.4	62.3	111	23	19.89	19.64	JAN 69	6.38	JAN 69	.0	.0

	PROBABILITY THAT THE MONTHLY PRECIPITATION WILL BE EQUAL TO OR LESS THAN THE INDICATED PRECIPITATION AMOUNT MONTHLY PRECIPITATION (INCHES) **										
	PROBABILITY LEVELS										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
JAN	.00	.43	1.25	2.01	2.80	3.68	4.71	5.95	7.67	10.51	13.27
FEB	.04	.12	.38	.77	1.30	2.01	2.95	4.25	6.21	9.76	13.47
MAR	.00	.00	.84	1.43	2.02	2.66	3.40	4.31	5.50	7.48	9.40
APR	.01	.07	.24	.45	.71	1.04	1.46	2.01	2.81	4.22	5.65
MAY	.00	.00	.02	.09	.18	.29	.45	.66	.96	1.50	2.06
JUN	.00	.00	.00	.00	.00	.02	.04	.07	.11	.19	.26
JUL	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	.35
AUG	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14	.62
SEP	.00	.00	.00	.00	.00	.00	.00	.08	.42	1.23	2.15
OCT	.00	.00	.00	.00	.03	.13	.27	.47	.77	1.33	1.90
NOV	.01	.06	.23	.46	.75	1.13	1.62	2.27	3.24	4.95	6.70
DEC	.00	.04	.28	.61	1.03	1.57	2.25	3.16	4.49	6.84	9.24

* FROM 1951 - 80 NORMALS

\# ESTIMATED VALUE BASED ON DATA FROM SURROUNDING STATIONS

\+ ALSO ON EARLIER DATES

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PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

CLIMATOLOGICAL SUMMARY FOR UPLAND, CALIFORNIA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

CLIMATOLOGICAL SUMMARY FOR BEAUMONT, CALIFORNIA

PERIOD: 1951-80
ELEVATION: 2605 FT

	TEMPERATURE (F)					PRECIPITATION TOTALS (INCHES)							
	MEANS			EXTREMES							SNOW		
	DAILY MAXIMUM*	DAILY MINIMUM*	MONTHLY*	RECORD HIGHEST	RECORD LOWEST	MEAN*	GREATEST MONTHLY*	YEAR	GREATEST DAILY	YEAR	MEAN	MAXIMUM MONTHLY	YEAR
JAN	59.5	38.1	48.9	83+	18	3.56	11.52	69	4.69	69	.9	15.8	79
FEB	62.9	38.4	50.7	84+	20+	3.07	13.20	80	3.50	69	.2	4.0	53
MAR	64.9	39.1	52.0	90+	21+	2.90	8.92	78	2.58	78	.3	5.5	53
APR	70.6	41.5	56.1	94+	25	1.51	6.53	65	2.21	58	.0	.0	
MAY	77.3	46.7	62.0	101	32+	.63	4.14	77	1.91	77	.0	.0	
JUN	86.8	51.9	69.4	108	35+	.11	.75	72	.37	72	.0	.0	
JUL	95.7	58.5	77.1	111+	42+	.16	1.14	68	.61	69	.0	.0	
AUG	94.6	58.5	76.6	108+	38+	.15	2.24	77	1.85	77	.0	.0	
SEP	89.9	55.2	72.6	110+	37+	.44	4.60	76	2.48	76	.0	.0	
OCT	80.2	49.3	64.8	106+	29+	.52	3.18	57	1.71	79	.0	.0	
NOV	68.4	42.8	55.6	91+	20+	1.75	9.02	65	2.85	65	.0	.0	
DEC	61.4	39.3	50.4	83+	20+	2.20	10.88	66	4.19	66	.1	1.0	67
YEAR	76.0	46.6	61.4	111	18	17.00	13.20	FEB 80	4.69	JAN 69	1.5	15.8	JAN 79

	PROBABILITY THAT THE MONTHLY PRECIPITATION WILL BE EQUAL TO OR LESS THAN THE INDICATED PRECIPITATION AMOUNT MONTHLY PRECIPITATION (INCHES) **										
	PROBABILITY LEVELS										
	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
JAN	.00	.24	.79	1.34	1.93	2.60	3.40	4.39	5.77	8.08	10.35
FEB	.04	.20	.55	.97	1.45	2.04	2.76	3.69	5.02	7.30	9.59
MAR	.00	.16	.58	1.01	1.49	2.05	2.72	3.56	4.74	6.72	8.69
APR	.00	.00	.15	.39	.66	.98	1.36	1.86	2.56	3.73	4.91
MAY	.00	.00	.01	.09	.19	.32	.50	.73	1.07	1.68	2.30
JUN	.00	.00	.00	.00	.01	.03	.07	.12	.20	.33	.46
JUL	.00	.00	.00	.00	.00	.01	.07	.16	.29	.53	.77
AUG	.00	.00	.00	.00	.00	.00	.00	.06	.20	.51	.85
SEP	.00	.00	.00	.00	.00	.05	.17	.37	.72	1.40	2.14
OCT	.00	.00	.00	.02	.08	.18	.33	.55	.88	1.50	2.16
NOV	.00	.00	.27	.55	.85	1.20	1.62	1.16	2.90	4.15	5.40
DEC	.01	.08	.28	.54	.87	1.30	1.84	2.57	3.63	5.51	7.43

* FROM 1951 - 80 NORMALS # ESTIMATED VALUE BASED ON DATA FROM SURROUNDING STATIONS + ALSO ON EARLIER DATES

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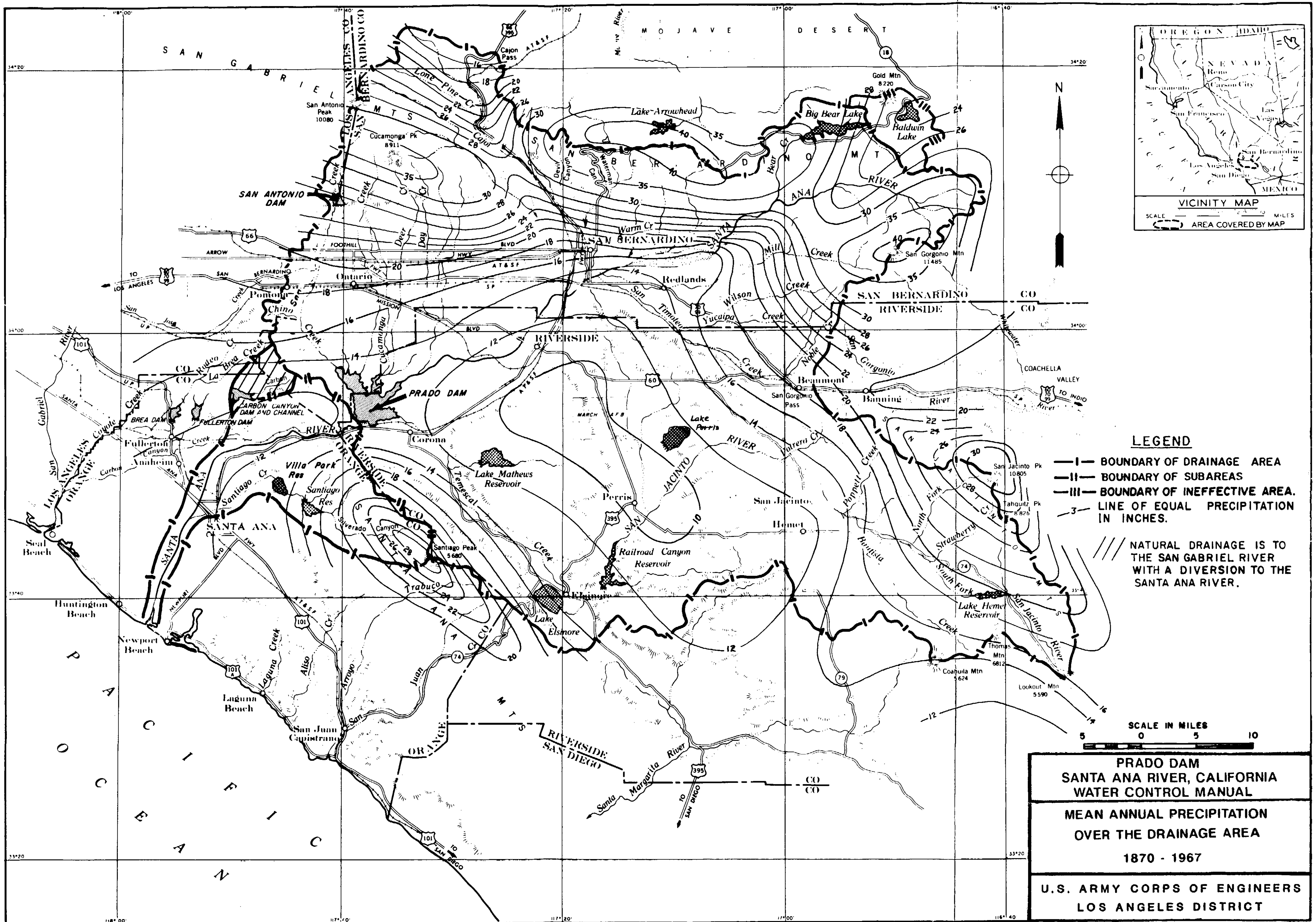
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

CLIMATOLOGICAL SUMMARY FOR BEAUMONT, CALIFORNIA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

MEAN ANNUAL PRECIPITATION OVER THE DRAINAGE AREA

1870 - 1967

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 4-05

MAXIMUM PRECIPITATION FOR INDICATED DURATION***

RETURN PERIOD IN YEARS	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H	C-YR	STATION
2	.12	.18	.23	.33	.43	.60	.75	1.11	1.56	2.07	15.63	NAME:
5	.18	.27	.35	.51	.65	.91	1.13	1.68	2.37	3.14	21.99	BEAUMONT
10	.22	.33	.43	.63	.81	1.12	1.40	2.07	2.91	3.87	25.94	
20	.26	.39	.51	.74	.95	1.32	1.65	2.44	3.44	4.56	29.54	ELEVATION:
25	.27	.41	.53	.77	.99	1.38	1.72	2.56	3.60	4.78	30.65	2610 FT
40	.30	.45	.58	.85	1.09	1.52	1.89	2.80	3.94	5.23	32.92	
50	.31	.47	.60	.88	1.13	1.58	1.96	2.91	4.10	5.44	33.97	LAT/LONG**
100	.35	.52	.68	.99	1.27	1.77	2.20	3.26	4.59	6.09	37.16	33.933/116.967
200	.38	.58	.75	1.09	1.40	1.95	2.43	3.60	5.07	6.73	40.23	
2	.14	.21	.27	.40	.63	1.01	1.37	2.18	3.22	4.35	32.42	NAME:
5	.21	.32	.42	.60	.96	1.56	2.08	3.30	4.88	6.60	45.60	BIG BEAR LAKE
10	.26	.40	.51	.74	1.18	1.89	2.56	4.07	6.01	8.1	53.79	DAM
20	.31	.47	.60	.88	1.39	2.23	3.02	4.79	7.08	8.58	61.25	
25	.33	.49	.63	.92	1.46	2.34	3.16	5.02	7.42	9.04	63.55	ELEVATION:
40	.36	.54	.69	1.01	1.59	2.56	3.46	5.50	8.13	10.99	68.26	6815 FT
50	.37	.56	.72	1.05	1.66	2.66	3.61	5.72	8.46	11.44	70.45	
100	.42	.62	.81	1.17	1.86	2.98	4.04	6.41	9.47	12.80	77.05	LAT/LONG**
200	.46	.69	.89	1.29	2.05	3.29	4.46	7.08	10.46	14.15	83.42	34.233/116.967
2	.13	.18	.24	.32	.44	.67	.84	1.22	1.62	2.09	11.93	NAME:
5	.19	.27	.35	.47	.65	1.00	1.24	1.80	2.38	3.09	16.80	PRADO DAM
10	.23	.32	.43	.57	.78	1.21	1.50	2.18	2.89	3.74	19.88	
20	.27	.37	.50	.67	.91	1.40	1.74	2.54	3.36	4.35	22.72	ELEVATION:
25	.28	.39	.52	.70	.95	1.46	1.82	2.65	3.51	4.54	23.59	560 FT
40	.30	.42	.56	.76	1.03	1.59	1.98	2.88	3.81	4.94	25.39	
50	.31	.44	.58	.79	1.07	1.65	2.05	2.99	3.95	5.12	26.23	LAT/LONG**
100	.35	.49	.65	.87	1.19	1.83	2.27	3.32	4.38	5.68	28.77	33.890/117.635
200	.38	.54	.71	.96	1.30	2.01	2.49	3.64	4.81	6.23	31.23	
2	0.00	0.00	0.00	0.00	.34	.48	.57	.78	1.01	1.26	9.52	NAME:
5	0.00	0.00	0.00	0.00	.51	.73	.87	1.19	1.53	1.91	13.38	RIVERSIDE
10	0.00	0.00	0.00	0.00	.63	.90	1.07	1.47	1.89	2.35	15.79	CITRUS EXP STA
20	0.00	0.00	0.00	0.00	.74	1.06	1.27	1.73	2.23	2.77	17.98	
25	0.00	0.00	0.00	0.00	.78	1.11	1.33	1.87	2.33	2.90	18.6	ELEVATION:
40	0.00	0.00	0.00	0.00	.85	1.21	1.45	1.98	2.56	3.17	20.04	1015 FT
50	0.00	0.00	0.00	0.00	.88	1.26	1.51	2.06	2.66	3.30	20.68	
100	0.00	0.00	0.00	0.00	.99	1.41	1.69	2.31	2.98	3.70	22.62	LAT/LONG**
200	0.00	0.00	0.00	0.00	1.09	1.56	1.87	2.55	3.29	4.09	24.49	33.967/117.334
2	0.00	0.00	.25	.35	.5	.77	0.00	1.45	1.98	2.69	*16.91	NAME:
5	0.00	0.00	.38	.54	.77	1.17	0.00	2.20	3.01	4.08	*23.78	UPLAND
10	0.00	0.00	.46	.66	.95	1.44	0.00	2.71	3.71	5.02	*28.05	
20	0.00	0.00	.55	.78	1.12	1.69	0.00	3.19	4.37	5.92	*31.94	ELEVATION:
25	0.00	0.00	.57	.82	1.17	1.77	0.00	3.35	4.58	6.21	*33.14	1840 FT
40	0.00	0.00	.63	.89	1.29	1.94	0.00	3.66	5.01	6.79	*35.60	
50	0.00	0.00	.65	.93	1.34	2.02	0.00	3.81	5.22	7.07	*36.74	LAT/LONG**
100	0.00	0.00	.73	1.04	1.50	2.26	0.00	4.27	5.84	7.92	*40.18	34.140/117.677
200	0.00	0.00	.81	1.15	1.66	2.50	0.00	4.72	6.46	8.75	*43.50	

* THE DURATION IS FOR FISCAL-YEAR (JULY TO JUNE)

** LATITUDE/LONGITUDE

*** M: MINUTES
H: HOURS
C-YR: CALENDER YEAR

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

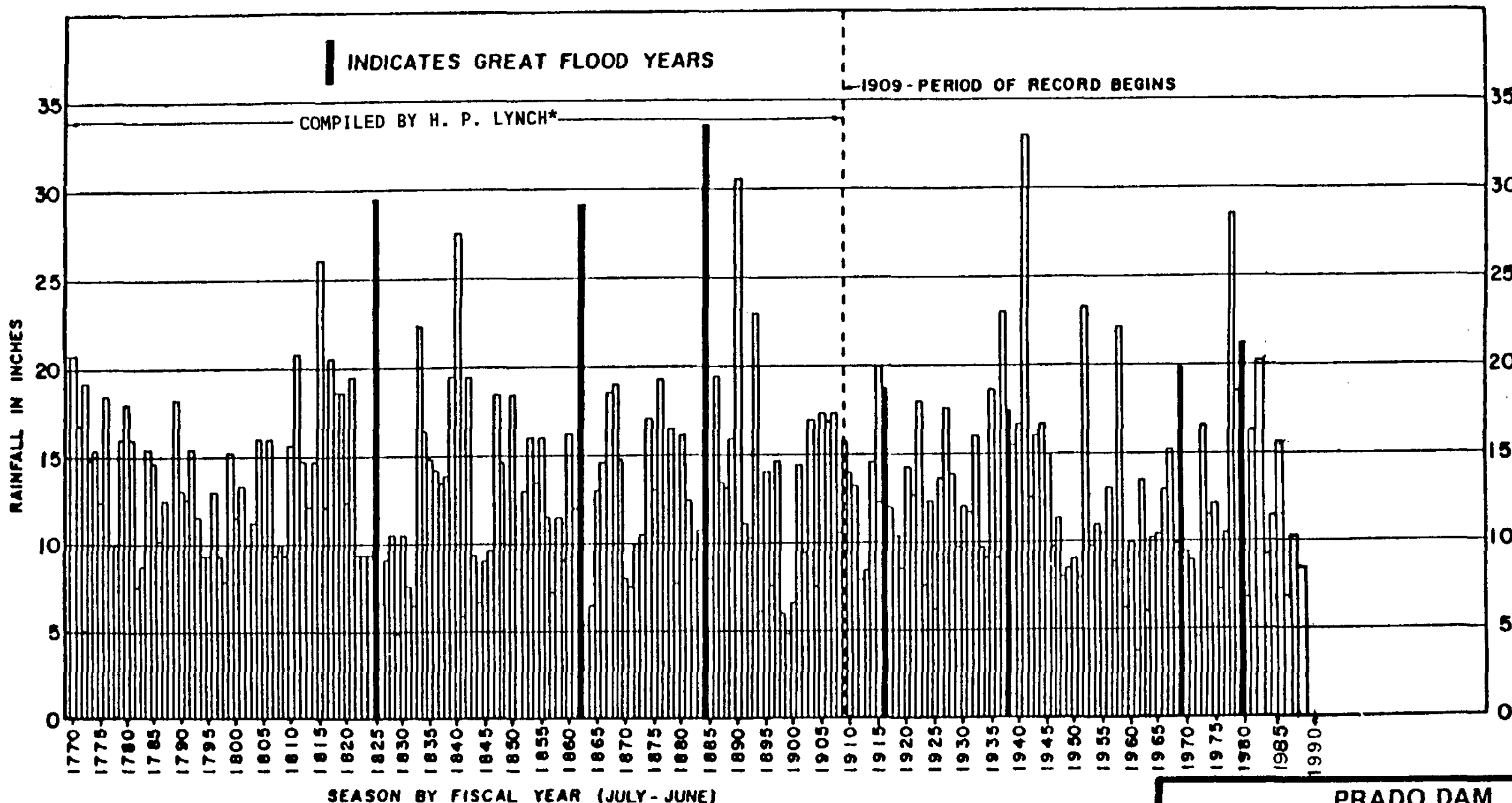
PRECIPITATION

DEPTH - DURATION - FREQUENCY

TABLE

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

FLOOD YEARS AND YEARLY RAINFALL AT SANTA ANA SINCE 1769



* Lynch, H. P., "Rainfall and Stream Run-Off in Southern California," Metropolitan Water District of Southern California, Los Angeles, California, August, 1931

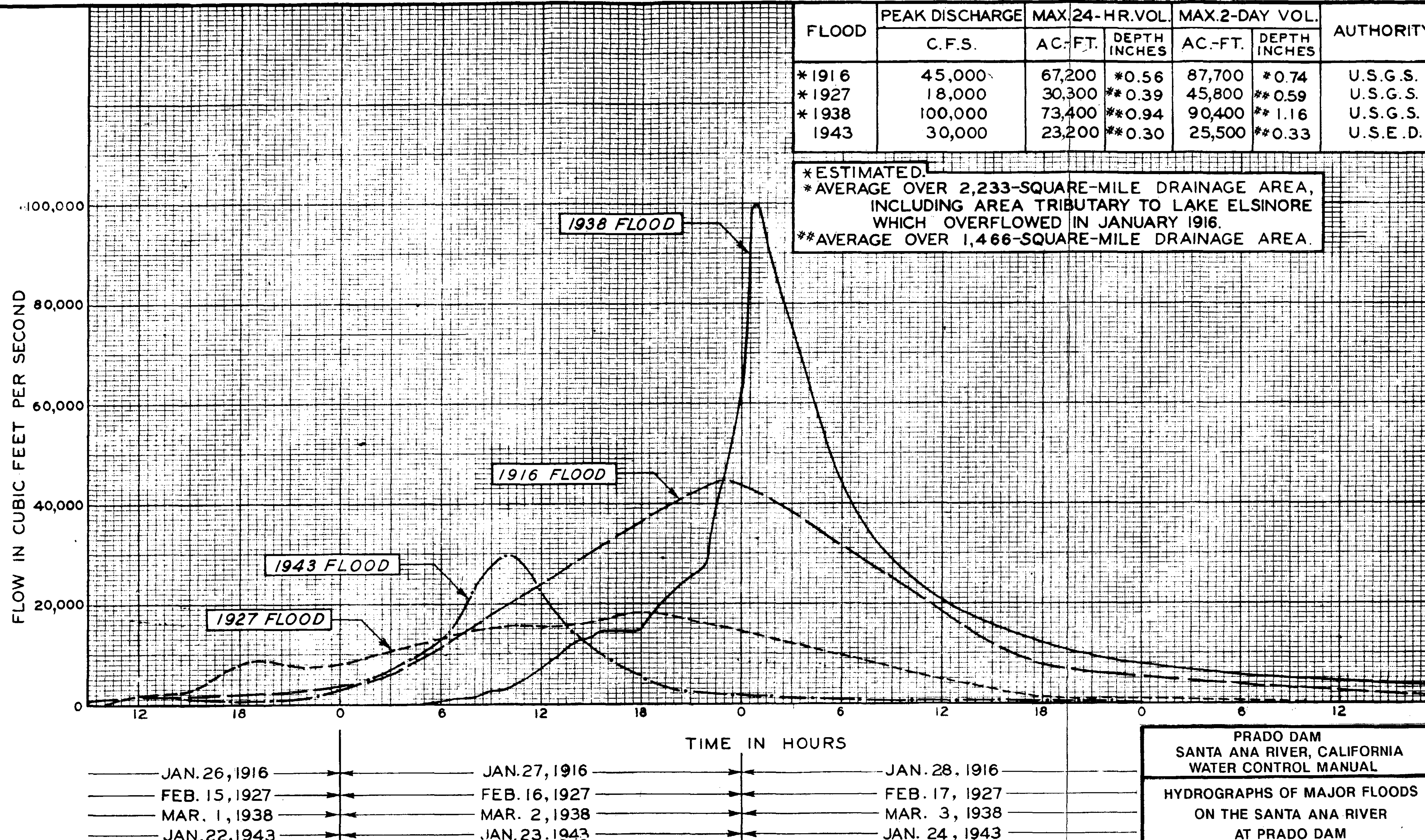
Note: Solid black lines indicate major flood years.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

HISTORICAL RAINFALL

AT SANTA ANA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



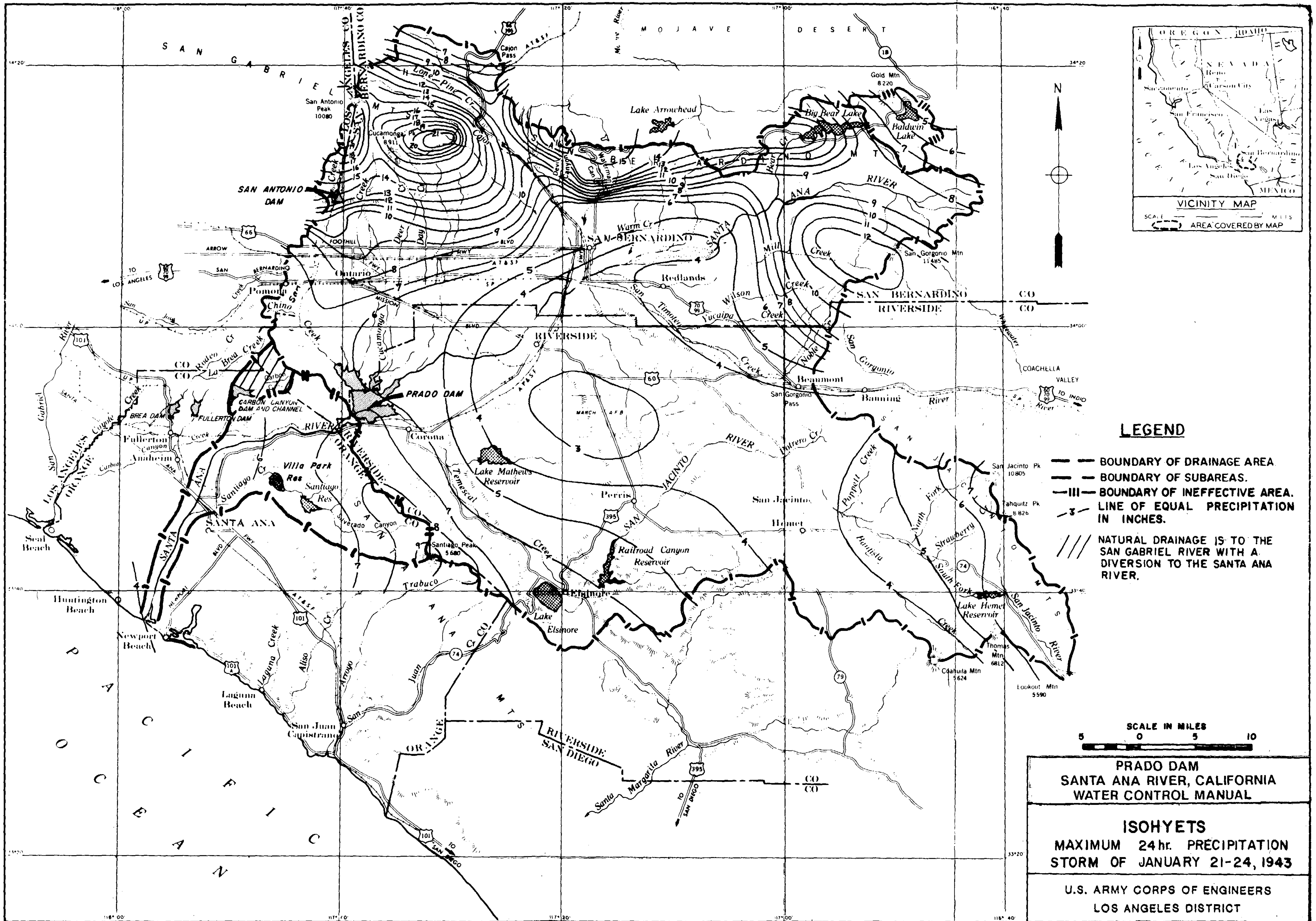
FLOOD	PEAK DISCHARGE C.F.S.	MAX. 24-HR. VOL. AC.-FT.	MAX. 24-HR. VOL. DEPTH INCHES	MAX. 2-DAY VOL. AC.-FT.	MAX. 2-DAY VOL. DEPTH INCHES	AUTHORITY
* 1916	45,000	67,200	* 0.56	87,700	* 0.74	U.S.G.S.
* 1927	18,000	30,300	** 0.39	45,800	** 0.59	U.S.G.S.
* 1938	100,000	73,400	** 0.94	90,400	** 1.16	U.S.G.S.
1943	30,000	23,200	** 0.30	25,500	** 0.33	U.S.E.D.

* ESTIMATED.
* AVERAGE OVER 2,233-SQUARE-MILE DRAINAGE AREA, INCLUDING AREA TRIBUTARY TO LAKE ELSINORE WHICH OVERFLOWED IN JANUARY 1916.
** AVERAGE OVER 1,466-SQUARE-MILE DRAINAGE AREA.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

HYDROGRAPHS OF MAJOR FLOODS ON THE SANTA ANA RIVER AT PRADO DAM

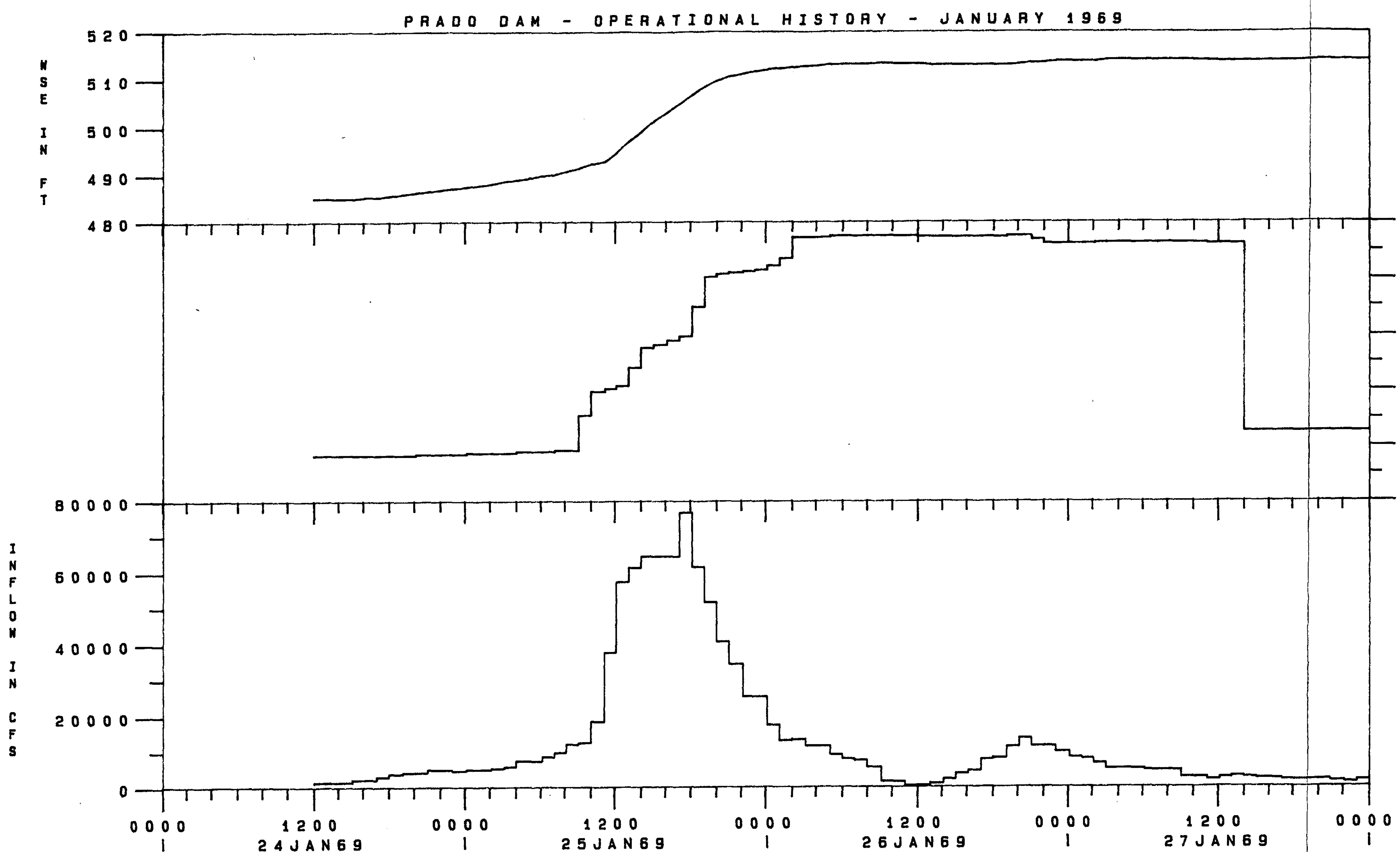
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

ISOHYETS
MAXIMUM 24 hr. PRECIPITATION
STORM OF JANUARY 21-24, 1943

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

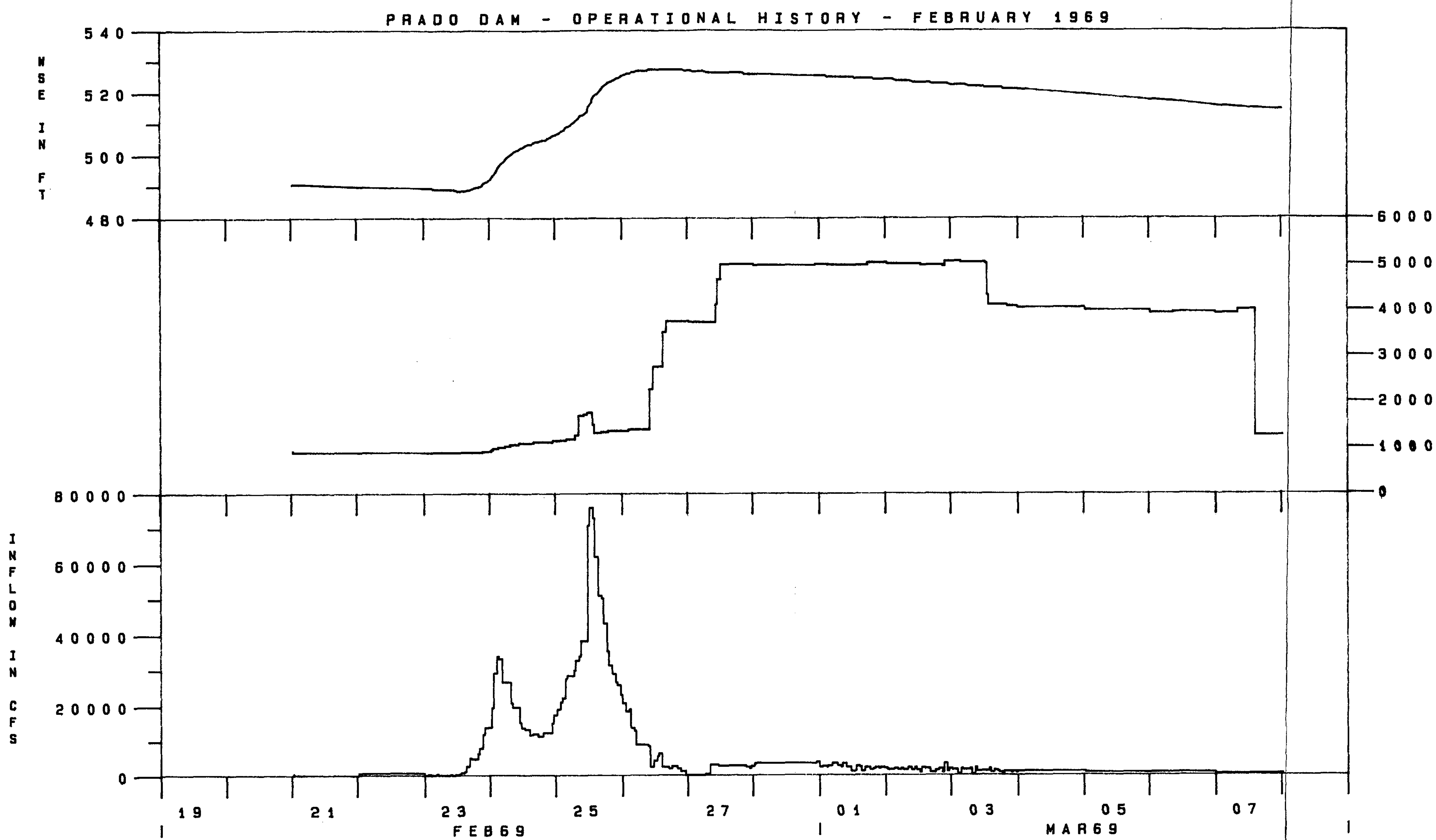


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATION HYDROGRAPHS

JANUARY 1969

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

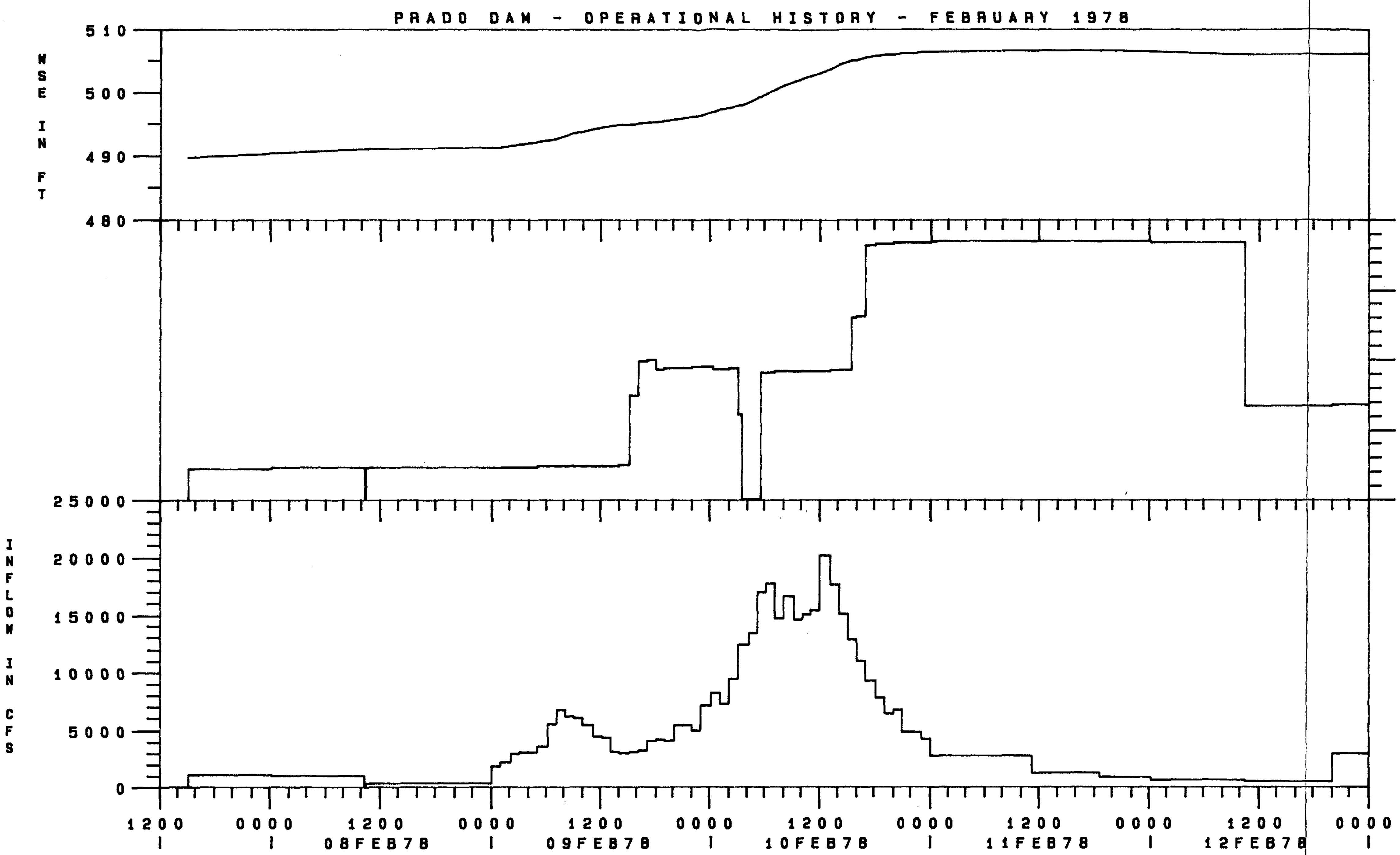


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATION HYDROGRAPHS

FEBRUARY 1969

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

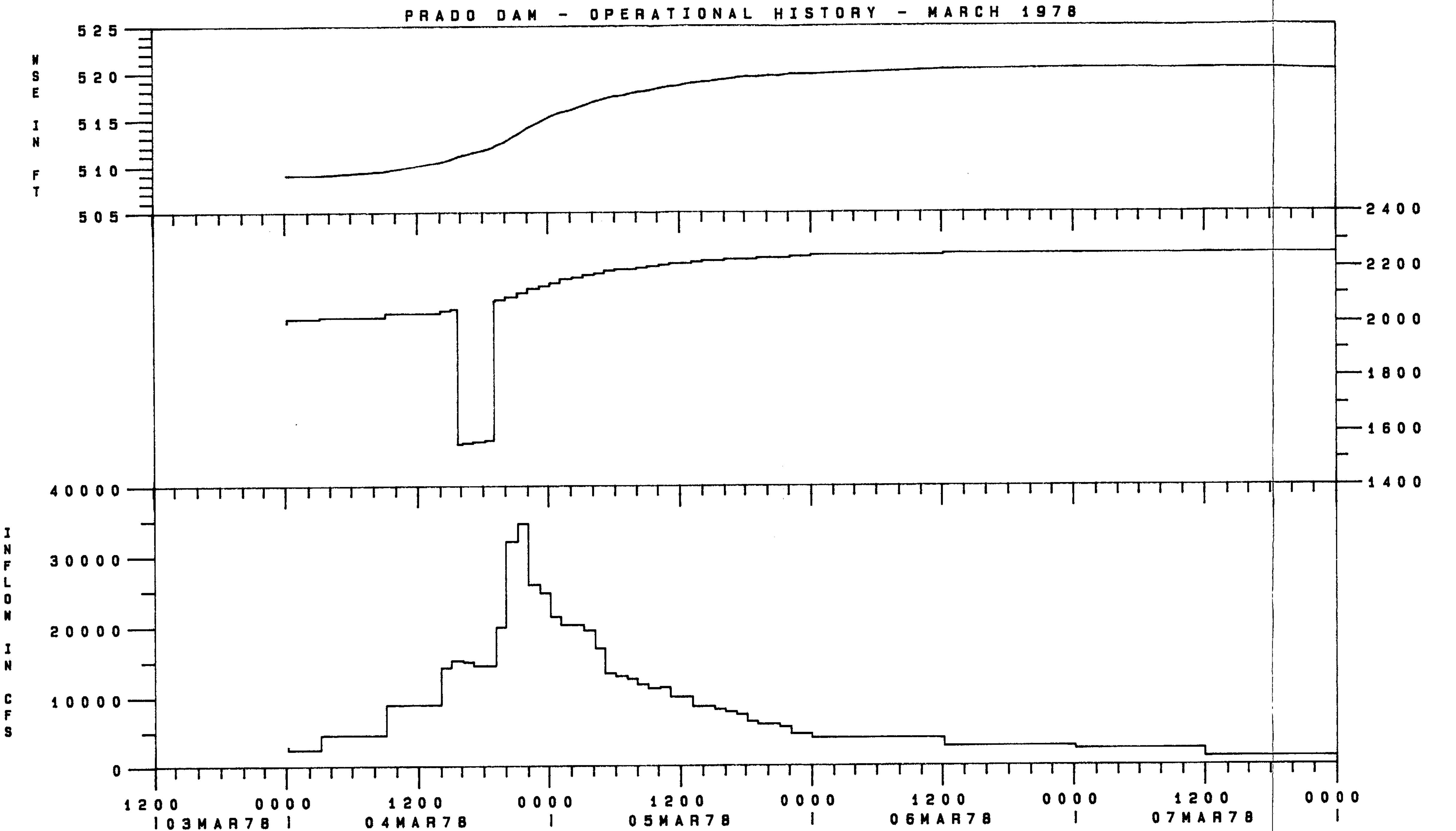


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATION HYDROGRAPHS

FEBRUARY 1978

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

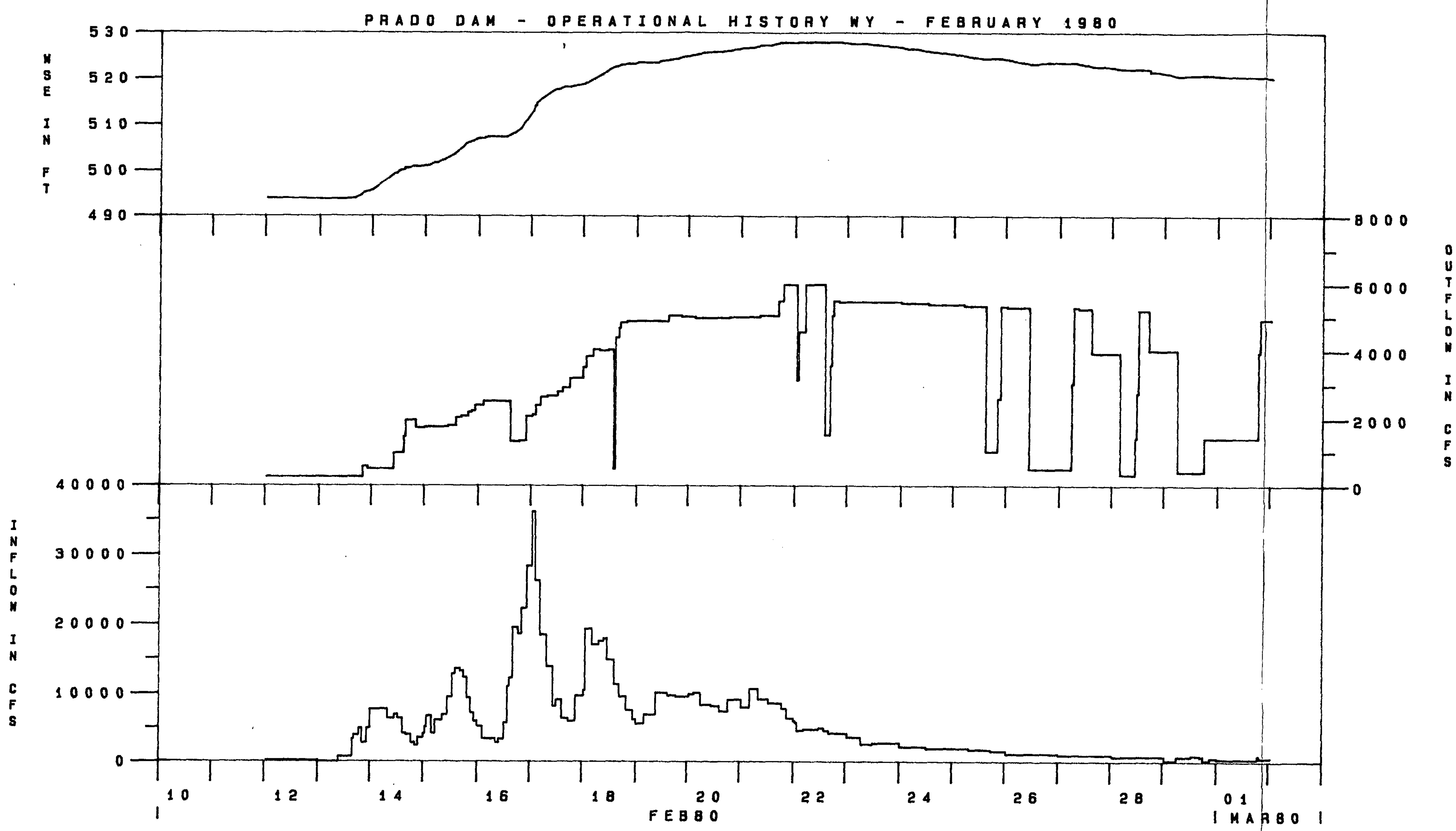


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATION HYDROGRAPHS

MARCH 1978

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

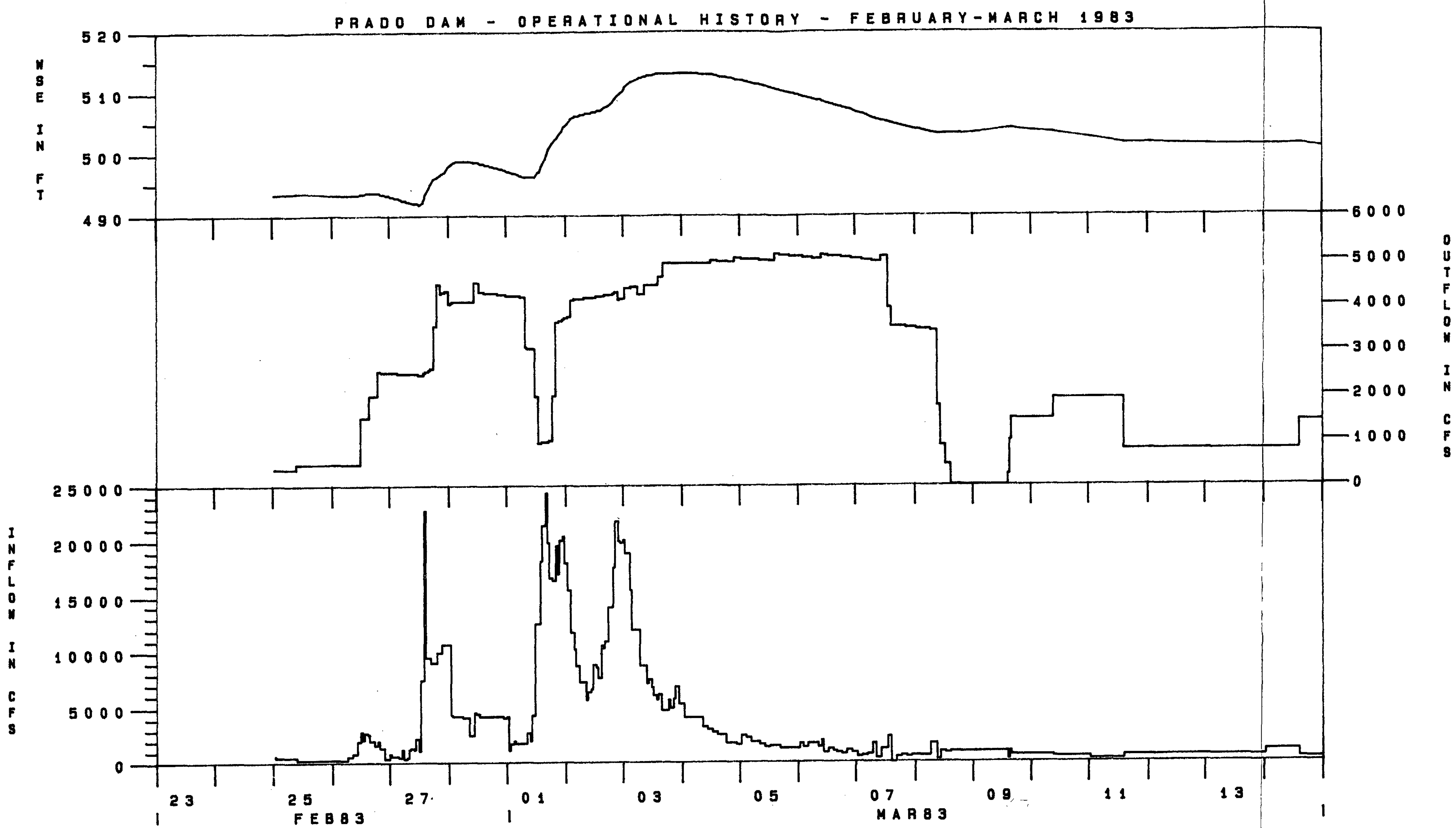


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATION HYDROGRAPHS

FEBRUARY 1980

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

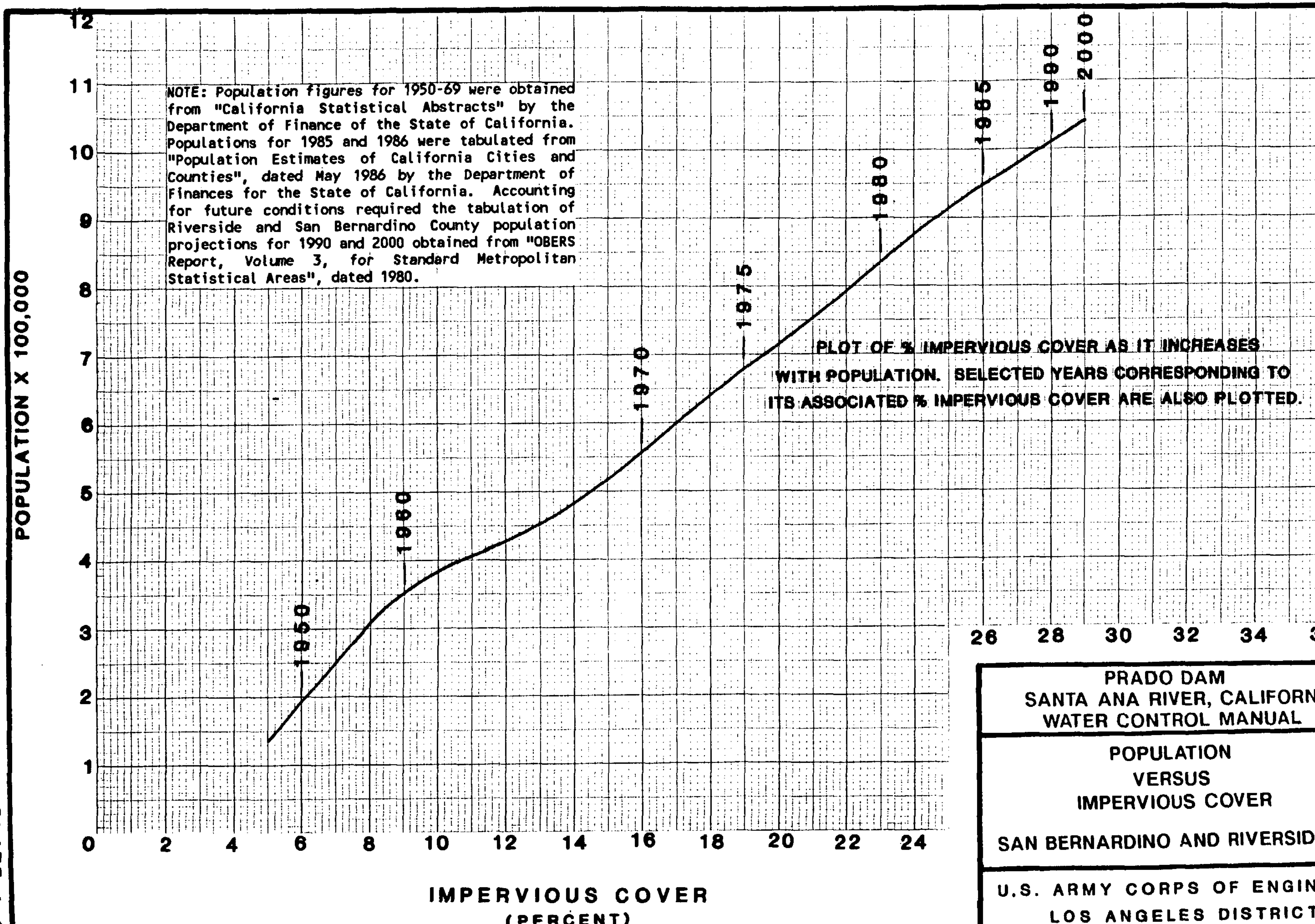


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATION HYDROGRAHS

MARCH 1983

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

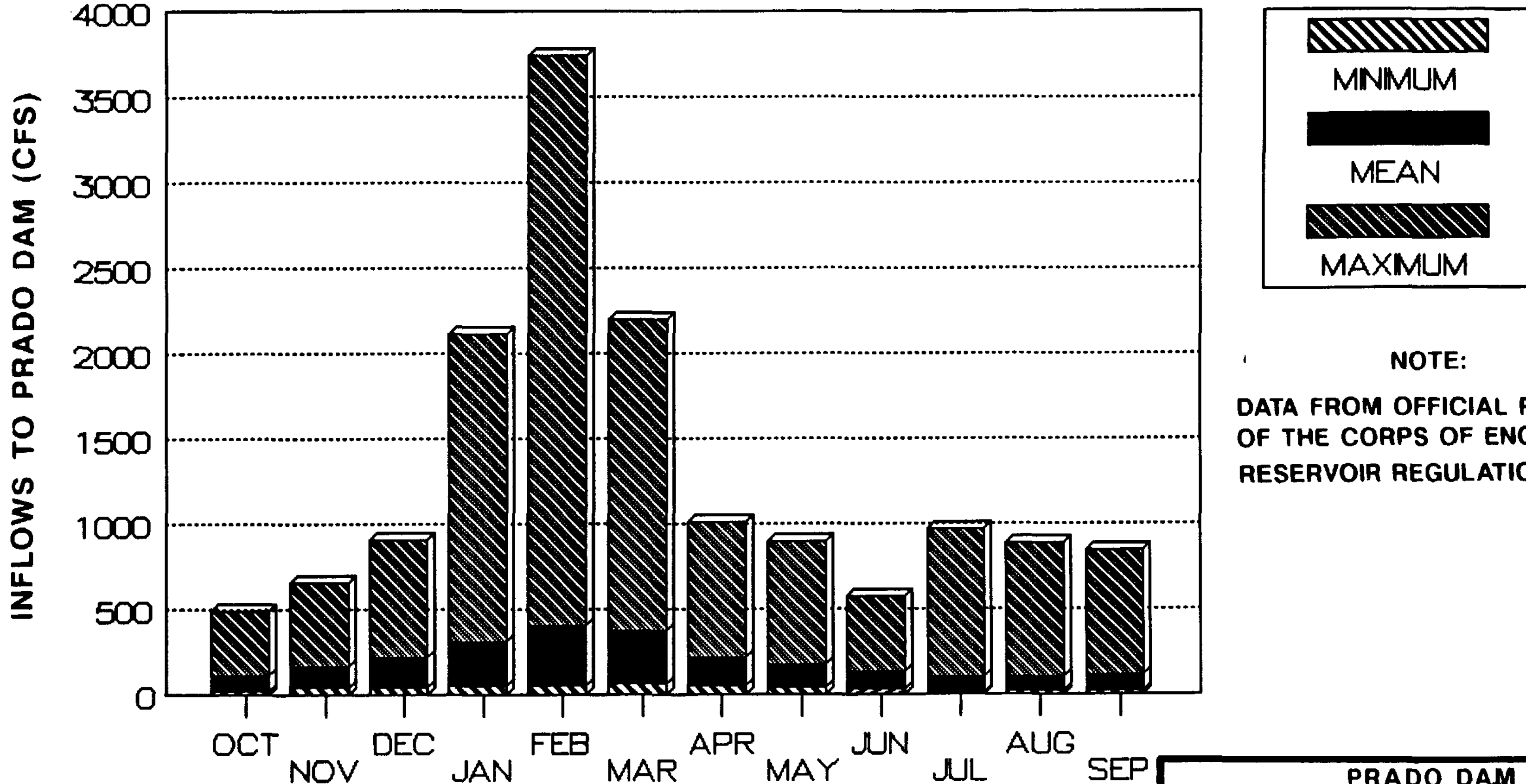


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

POPULATION
VERSUS
IMPERVIOUS COVER

SAN BERNARDINO AND RIVERSIDE CO.

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



NOTE:
DATA FROM OFFICIAL RECORDS OF THE CORPS OF ENGINEERS' RESERVOIR REGULATION SECTION

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

MONTHLY
MAXIMUM, MINIMUM, AND MEAN
INFLOWS TO PRADO DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

MONTHLY AND ANNUAL MEAN VALUES, FLOW, CFS*

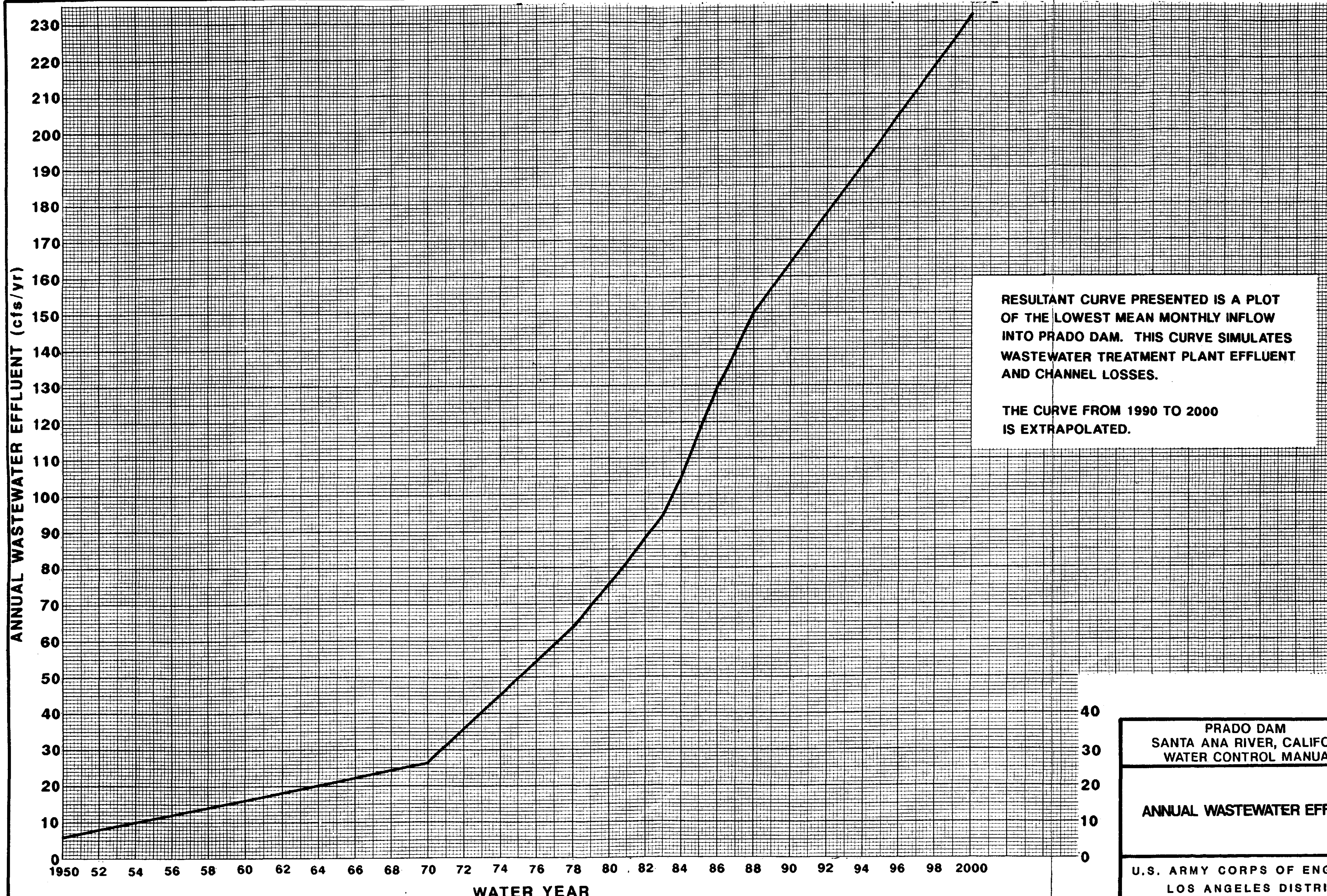
YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1941	61	80	224	135	391	857	590	292	87	61	56	65	241
1942	90	103	164	179	144	149	143	86	72	54	50	60	108
1943	72	87	108	562	349	636	257	93	67	57	53	59	200
1944	94	94	197	169	473	281	143	109	83	67	55	64	151
1945	80	153	155	163	325	325	165	85	76	60	60	61	141
1947	70	229	240	218	169	124	85	77	65	46	45	54	118
1948	66	82	109	98	132	110	111	68	67	49	43	45	81
1949	60	72	92	116	120	132	74	65	49	42	68	72	80
1950	90	101	124	110	125	92	106	132	117	87	82	72	103
1951	55	70	72	84	86	109	138	131	113	117	106	85	97
1952	134	143	240	442	161	313	151	87	111	114	99	106	176
1953	114	111	109	104	126	174	85	55	46	70	113	119	102
1954	122	142	77	185	143	160	154	203	205	199	196	123	159
1955	136	70	178	182	159	212	72	188	135	120	111	36	134
1956	45	57	103	273	87	71	68	98	93	42	44	171	96
1957	108	43	46	107	81	91	71	63	47	33	25	29	62
1958	44	56	97	83	236	202	333	69	49	40	34	34	105
1959	62	46	55	88	95	63	55	45	41	29	22	26	52
1960	33	39	56	78	149	70	53	45	34	18	15	16	50
1961	20	60	69	76	73	54	43	35	23	20	22	23	43
1962	22	35	63	77	203	74	53	43	35	22	19	19	54
1963	23	33	40	49	98	74	66	46	35	21	21	55	46
1964	39	74	48	71	51	69	55	42	34	22	20	24	46
1965	42	74	48	71	50	58	153	50	39	29	23	26	55
1966	24	437	300	94	114	62	49	43	35	29	19	20	102
1967	33	47	681	185	67	73	101	55	43	26	24	31	115
1968	33	105	102	71	73	185	73	47	42	29	23	24	67
1969	34	56	78	1807	3108	519	398	576	113	3	53	53	550
1970	51	89	90	94	112	170	65	67	46	39	28	26	73
1971	39	139	166	116	136	79	67	61	51	25	23	23	77
1972	50	65	217	103	88	78	66	57	55	32	35	33	73
1973	49	114	146	205	369	198	102	85	106	68	51	52	127
1974	80	107	224	355	290	189	170	200	228	275	273	177	214
1975	200	172	207	144	127	185	147	103	146	203	170	141	162
1976	88	232	335	345	293	294	145	144	290	193	117	172	220
1977	142	120	128	304	181	156	118	147	90	74	95	75	136
1978	74	81	166	455	963	1768	296	143	91	66	70	121	355
1979	218	168	169	363	347	481	281	148	97	80	109	101	213
1980	113	147	235	893	3335	1403	724	550	261	119	82	93	652
1981	107	160	276	225	210	268	123	239	216	105	75	77	173
1982	129	156	150	310	245	565	332	169	140	121	99	125	212
1983	126	293	389	611	733	1883	790	722	443	870	777	732	699
1984	377	486	519	357	288	239	201	169	168	157	148	148	272
1985	166	203	528	329	336	296	230	210	173	149	160	157	245
1986	171	341	208	304	550	542	259	159	168	150	144	167	262
1987	184	208	231	328	282	304	187	193	150	152	133	134	207

* Data from official records of the Corps of Engineers' Reservoir Regulation Section.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

MONTHLY FLOWS
FOR
PERIOD OF RECORD

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

ANNUAL WASTEWATER EFFLUENT

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

MAXIMUM PEAK INFLOWS, OUTFLOWS AND WATER SURFACE ELEVATIONS FOR PERIOD OF RECORD*

WATER YEAR**	DATE	WATER SURFACE ELEVATION (FEET)	DATE	AVERAGE INFLOW (CFS)	DATE	AVERAGE OUTFLOW (CFS)
1941	06 MAR	484.72	05 MAR	3,180.0	16 MAR	1,650.0
1942	11 DEC	469.42	11 DEC	896.0	11 DEC	535.0
1943	24 JAN	494.95	23 JAN	29,630.0	24 JAN	1,880.0
1944	23 FEB	486.35	22 FEB	8,540.0	23 FEB	1,580.0
1945	03 FEB	479.48	03 FEB	4,740.0	03 FEB	1,400.0
1946	15 NOV	477.33	01 OCT	59.0	01 OCT	59.0
1947	14 NOV	477.34	14 NOV	2,033.0	15 NOV	645.0
1948	07 FEB	469.27	07 FEB	470.0	07 FEB	460.0
1949	13 JAN	468.83	13 JAN	563.0	13 JAN	255.0
1950	07 FEB	471.11	06 FEB	814.0	07 FEB	420.0
1951	15 MAY	464.88	01 MAY	170.0	01 MAY	170.0
1952	19 JAN	487.94	16 JAN	7,806.0	19 JAN	921.0
1953	20 DEC	470.19	20 DEC	1,449.0	21 DEC	355.0
1954	25 JAN	478.66	25 JAN	4,957.0	14 FEB	956.0
1955	19 JAN	473.20	19 JAN	3,516.0	19 JAN	835.0
1956	27 JAN	485.37	26 JAN	5,678.0	26 JAN	938.0
1957	14 JAN	472.83	13 JAN	2,294.0	13 JAN	748.0
1958	04 APR	485.99	04 APR	3,770.0	04 FEB	1,073.0
1959	06 JAN	471.24	06 JAN	867.0	06 JAN	552.0
1960	02 FEB	468.50	02 FEB	543.0	02 FEB	473.0
1961	26 JAN	463.91	26 JAN	163.0	26 JAN	161.0
1962	21 FEB	475.14	08 FEB	1,179.0	08 FEB	748.0
1963	11 FEB	476.32	10 FEB	1,158.0	11 FEB	608.0
1964	21 NOV	472.50	23 MAR	401.0	22 NOV	377.0
1965	10 APR	475.85	10 APR	1,485.0	10 APR	596.0
1966	23 NOV	493.58	23 NOV	30,650.0	30 NOV	1,040.0
1967	07 DEC	501.72	07 DEC	29,539.0	07 DEC	1,072.0
1968	08 MAR	485.97	08 MAR	13,630.0	22 NOV	995.0
1969	26 FEB	527.63	25 JAN	76,918.0	02 MAR	5,069.0
1970	06 MAR	490.37	01 MAR	2,503.0	21 JUL	198.0
1971	23 DEC	488.88	30 NOV	11,476.0	29 NOV	377.0
1972	28 DEC	491.40	25 DEC	5,198.0	27 DEC	540.0
1973	24 MAR	494.77	11 FEB	5,282.0	27 MAR	482.0
1974	08 JAN	489.62	08 JAN	5,438.0	08 JAN	2,000.0
1975	12 MAR	486.01	04 DEC	1,871.0	05 DEC	790.0
1976	11 FEB	486.63	12 SEP	2,072.0	11 SEP	553.0
1977	08 JAN	486.03	07 JAN	1,278.0	12 JAN	416.0
1978	07 MAR	520.45	04 MAR	34,705.0	07 MAR	2,250.0
1979	24 APR	504.60	06 JAN	6,095.0	07 JAN	510.0
1980	22 FEB	528.00	17 FEB	36,162.0	22 FEB	5,992.0
1981	23 MAR	496.63	30 JAN	4,245.0	14 OCT	990.0
1982	15 APR	501.35	18 MAR	11,023.0	02 APR	3,030.0
1983	04 MAR	513.17	01 MAR	24,392.0	05 MAR	5,140.0
1984	27 DEC	499.33	01 OCT	5,517.0	12 NOV	2,702.0
1985	20 DEC	490.59	19 DEC	6,171.0	20 DEC	2,040.0
1986	16 FEB	495.13	15 FEB	7,799.0	17 MAR	2,130.0
1987	25 MAR	492.88	04 JAN	4,705.0	06 JAN	814.0

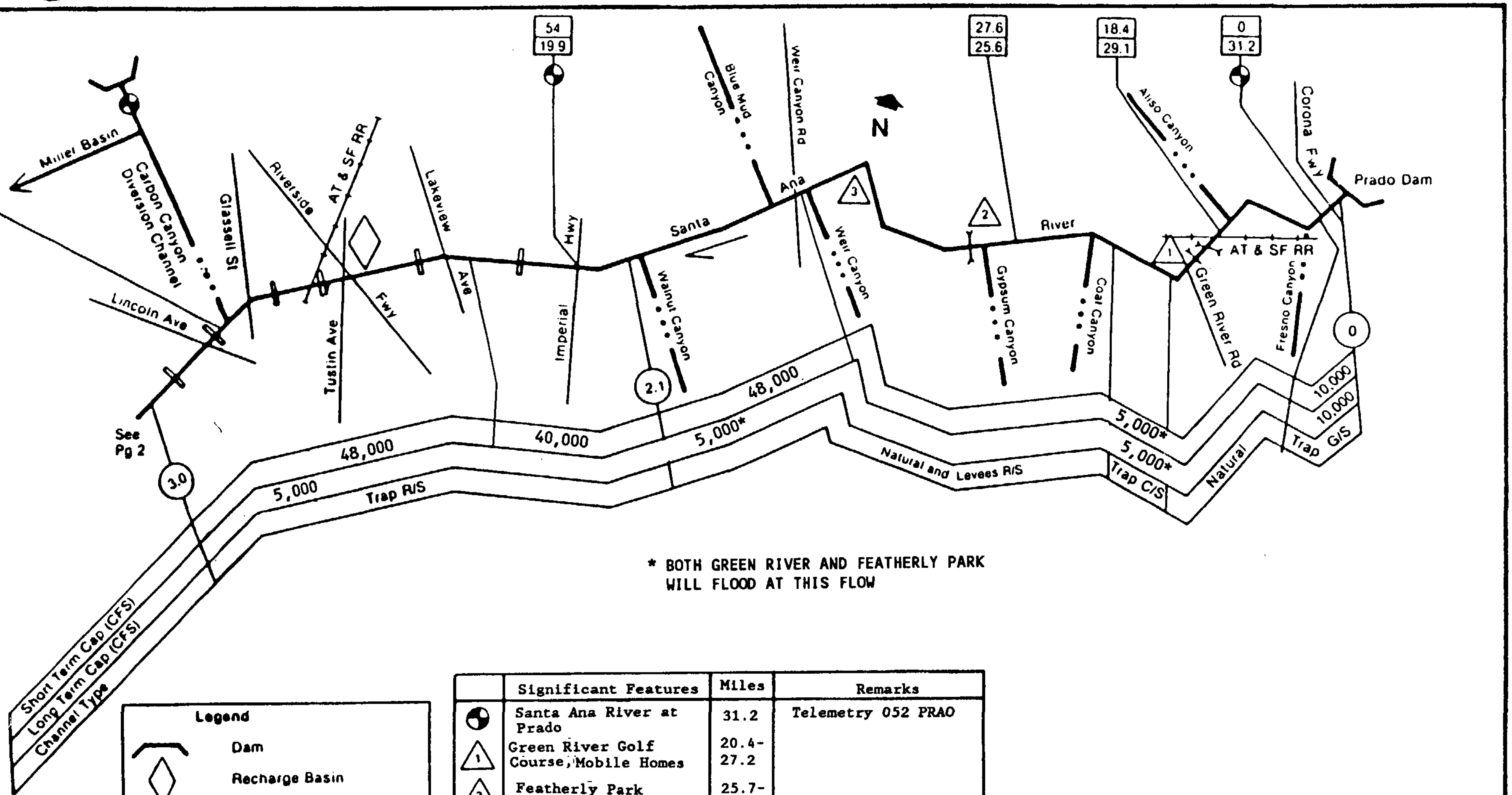
* Data from official records of the Corps of Engineers' Reservoir Regulation Section.

** The WATER YEAR extends from October 1 of the previous year to September 30 of the indicated year. For example, water year 1985 extends from October 1, 1984 to September 30, 1985.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

MAXIMUM PEAK INFLOWS, OUTFLOWS AND WATER SURFACE ELEVATIONS FOR PERIOD OF RECORD

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



* BOTH GREEN RIVER AND FEATHERLY PARK WILL FLOOD AT THIS FLOW

Legend

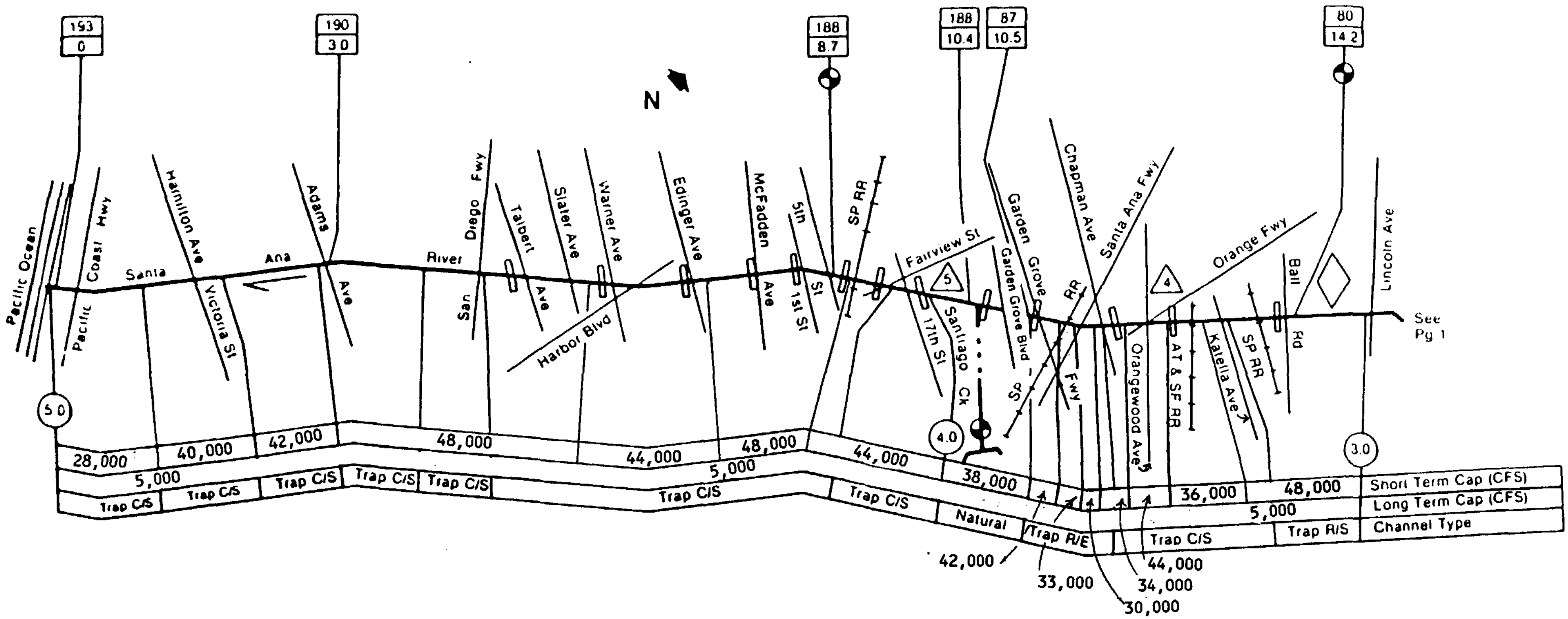
- Dam
- Recharge Basin
- RD Rubber Dam
- Drop Structure
- Stream Gage
- Drainage Area / Miles From Stream Mouth
- Travel Time (Hours)
- Foot Bridge
- U Channel Unlined
- R Rip Rap Side Slopes
- S Soft Bottom
- C Concrete
- G Grouted Stone
- G/C Side Slope / Bottom
- L Levee

	Significant Features	Miles	Remarks
Stream gage	Santa Ana River at Prado	31.2	Telemetry 052 PRAO
1	Green River Golf Course, Mobile Homes	20.4-27.2	
2	Featherly Park	25.7-24.2	
Foot bridge	Footbridge at Featherly Park	24.6	Removable by Tow Truck (4-5 hrs) for flows over 500 CFS
3	Horseshoe Bend	23.6	Orchards, Savi and Bryant Levees
Stream gage	Santa Ana River at Imperial	19.9	
Recharge basin	Santa Ana River Spreading Grounds	19.8-13.8	All flood discharge less than 2200 CFS flows into the Santa Ana River
Stream gage	Carbon Canyon Diversion Channel	16.1	
			Flows exceeding 2200 CFS will split at Miller Retarding Basin

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

DOWNSTREAM CHANNEL CAPACITIES AND CONFIGURATIONS PRADO DAM TO THE PACIFIC OCEAN

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



Legend

- Dam
- Recharge Basin
- RD Rubber Dam
- Drop Structure
- Stream Gage
- Drainage Area
- Miles From Stream Mouth
- Travel Time (Hours)
- Foot Bridge
- U Channel Unlined
- R Rip Rap Side Slopes
- S Soft Bottom
- C Concrete
- G Grouted Stone
- G/C Side Slope / Bottom
- L Levee

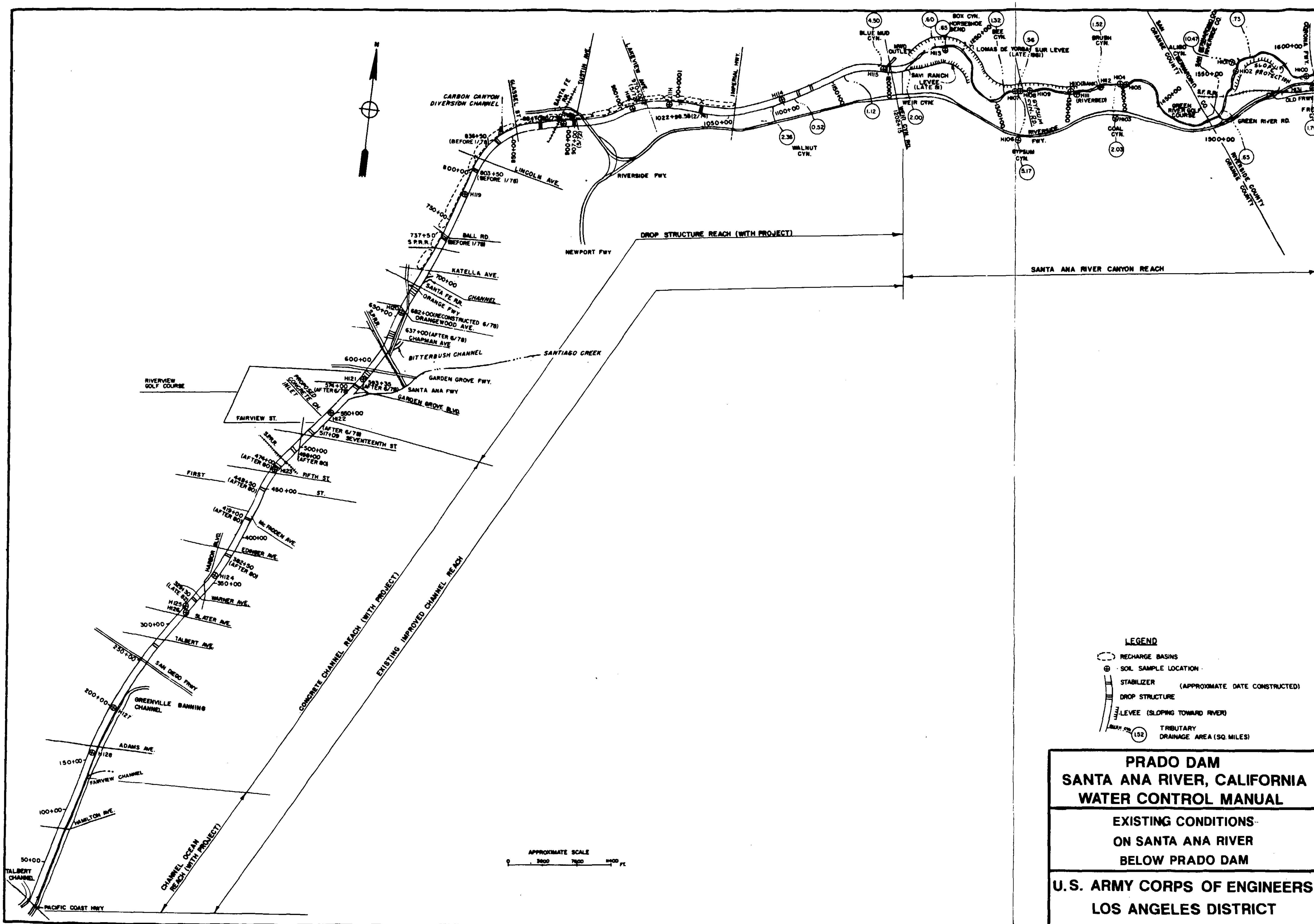
	Significant Features	Miles	Remarks
Stream Gage	Santa Ana River At Ball Road	14.2	
4	Anaheim Stadium	12.8	
5	Riverview Golf Course	11.9-9.9	
Stream Gage	Santiago Creek at Santa Ana	10.4	Flows Regulated by Santiago Dam and Villa Park Dam
Stream Gage	Santa Ana River at Fifth St	8.7	Telemetry 011 SAR5

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

DOWNSTREAM CHANNEL
CAPACITIES AND CONFIGURATIONS
PRADO DAM TO THE PACIFIC OCEAN

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

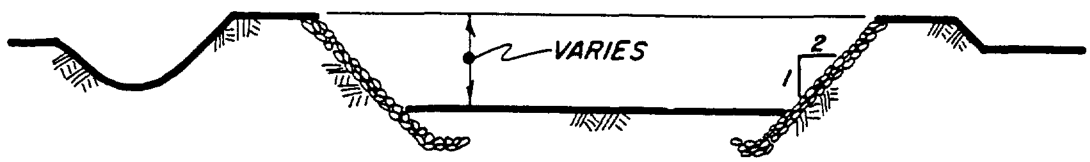
PLATE 4-21b



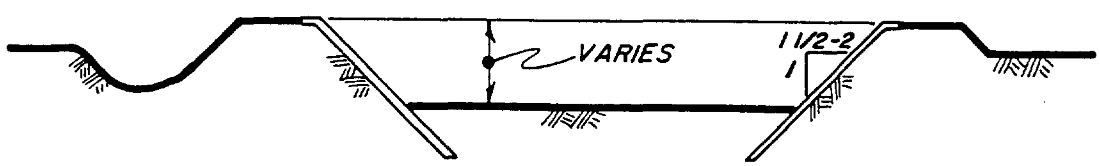
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

EXISTING CONDITIONS ON SANTA ANA RIVER BELOW PRADO DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



TYPE A: ROCK-REVETTED SIDESLOPES

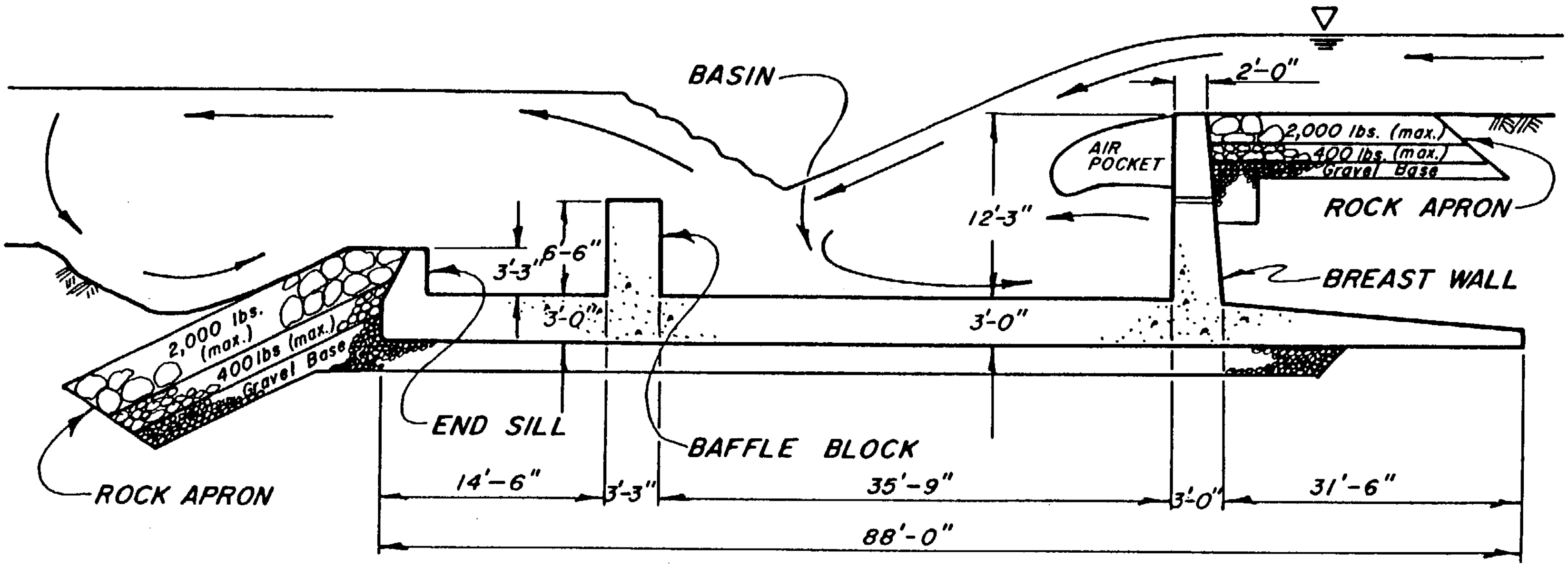


TYPE B: CONCRETE SIDESLOPES

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

TYPICAL IMPROVED SECTIONS
OF THE SANTA ANA RIVER

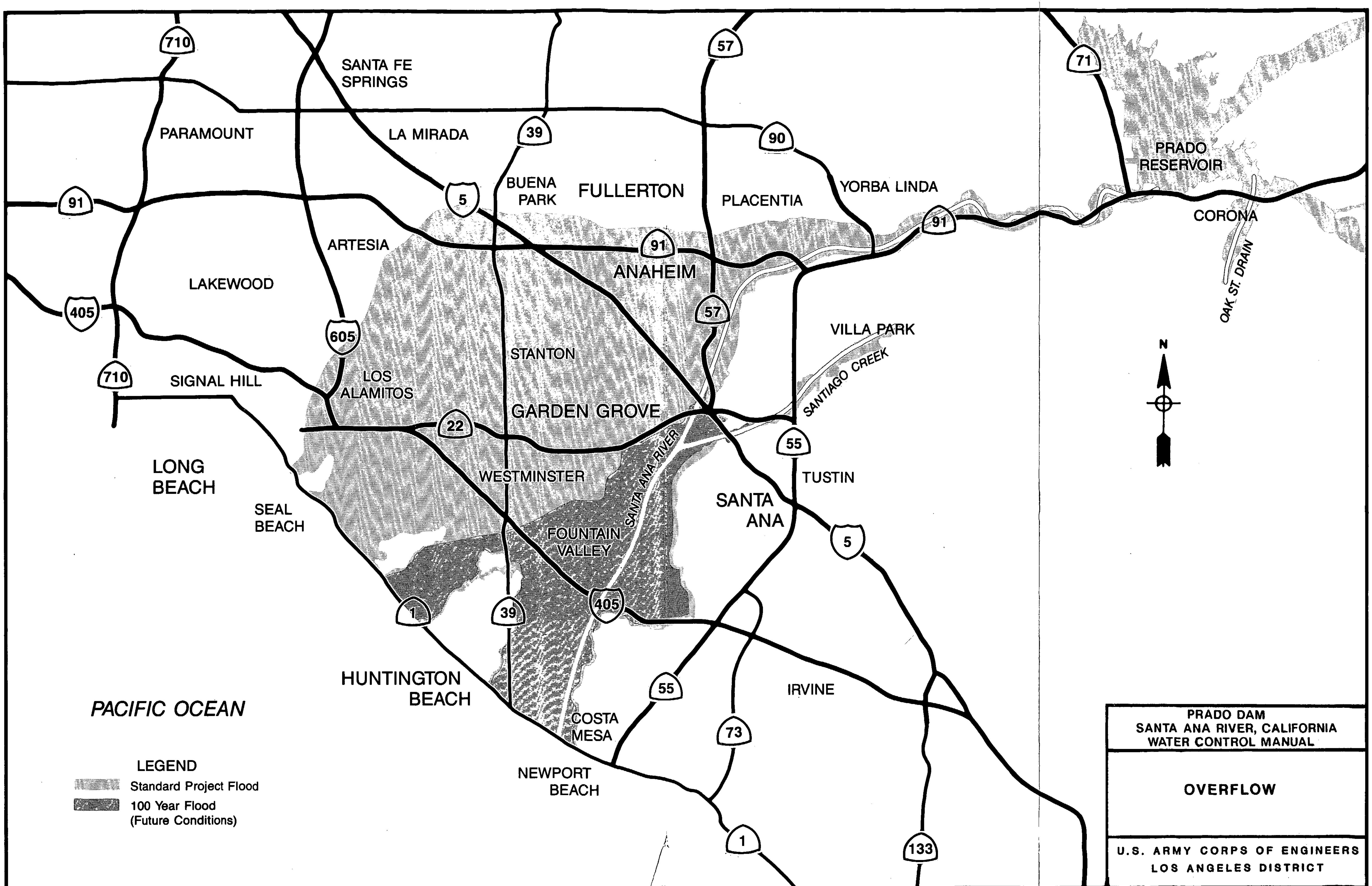
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



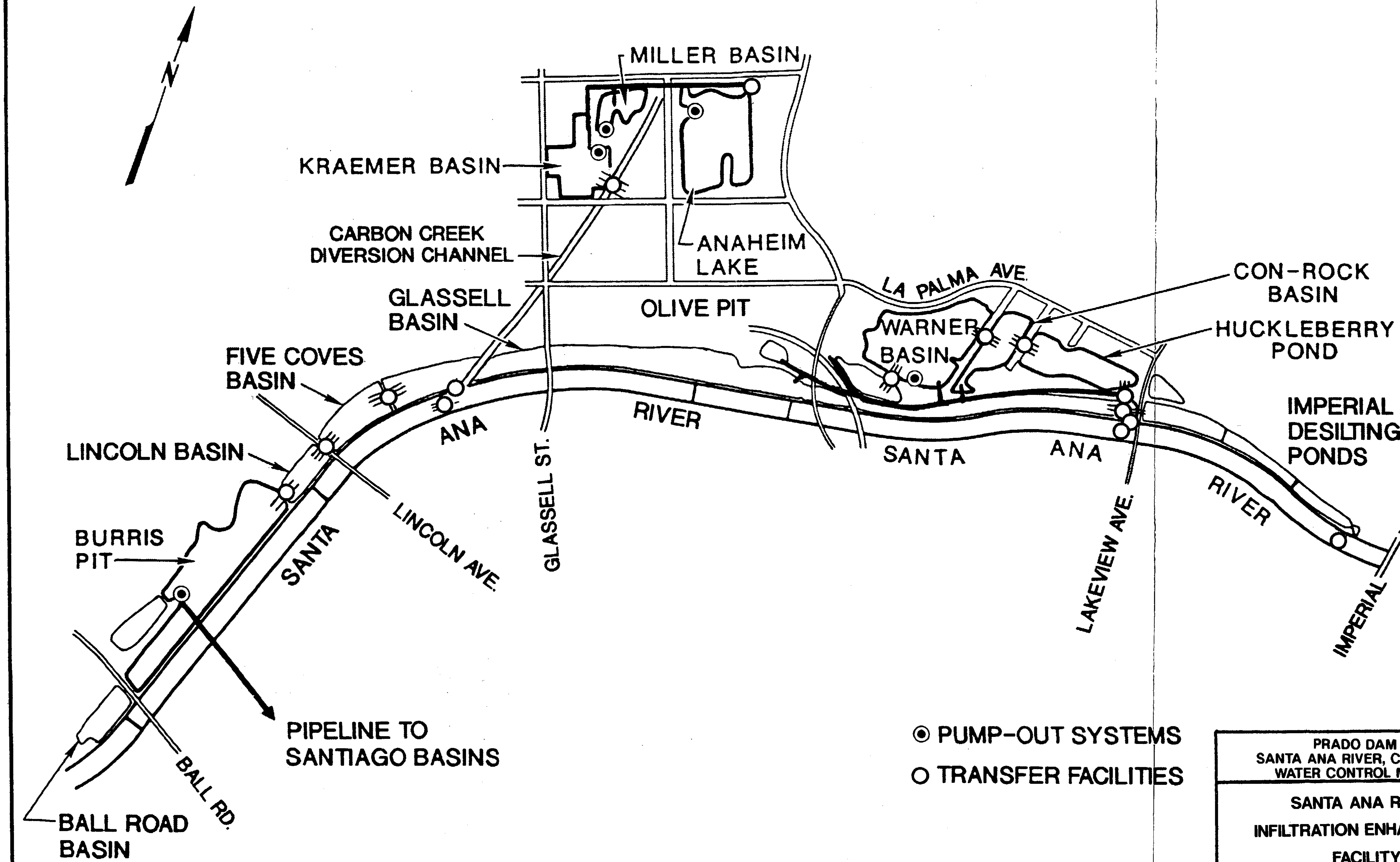
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

TYPICAL DROP STRUCTURE
ON THE SANTA ANA RIVER

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



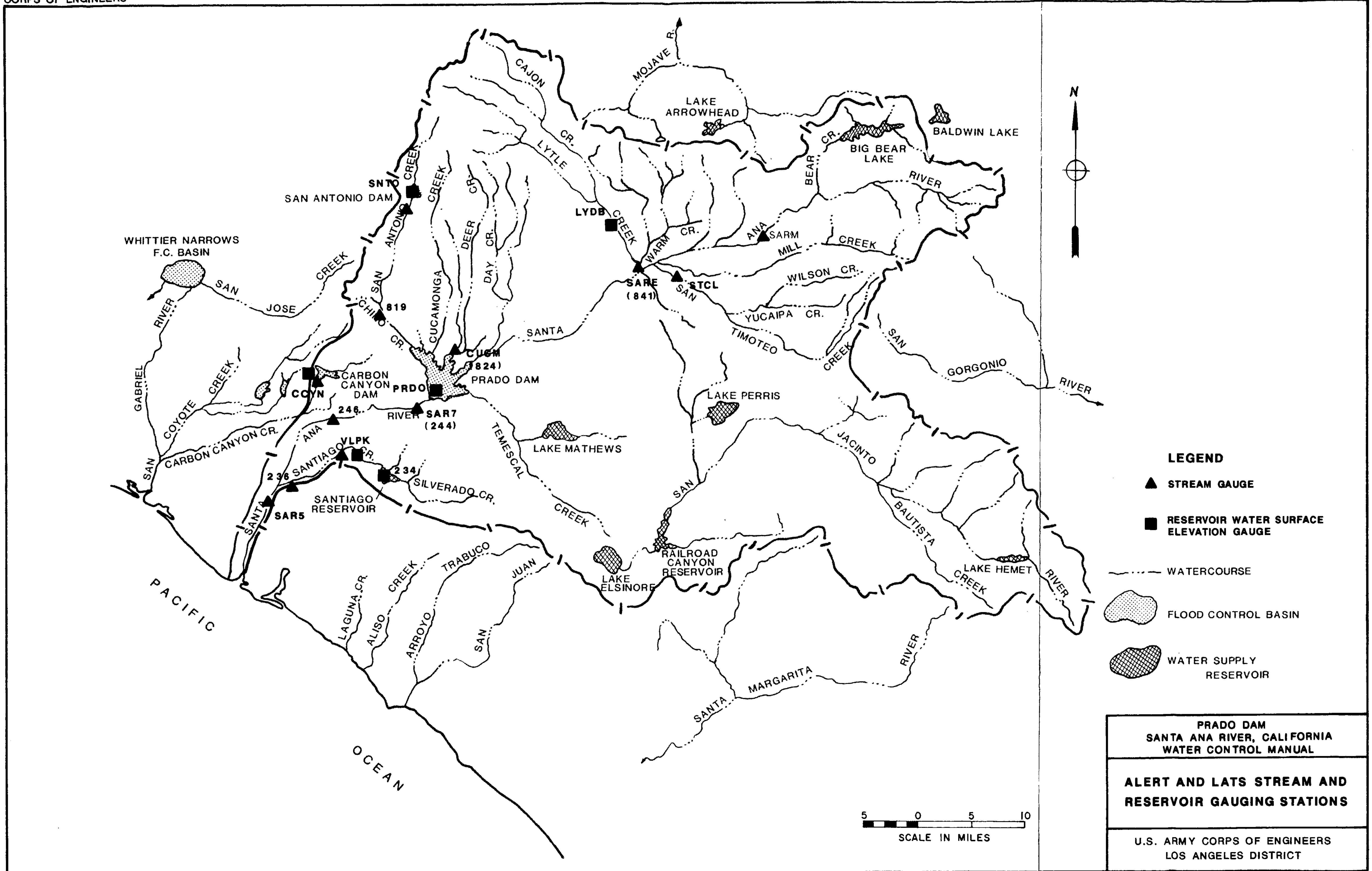
SANTA FE SPRINGS
PARAMOUNT
LA MIRADA
BUENA PARK
FULLERTON
PLACENTIA
YORBA LINDA
PRADO RESERVOIR
CORONA
OAK ST. DRAIN
ARTESIA
LAKEWOOD
ANAHEIM
VILLA PARK
SANTIAGO CREEK
STANTON
SIGNAL HILL
LOS ALAMITOS
GARDEN GROVE
LONG BEACH
WESTMINSTER
SANTA ANA RIVER
TUSTIN
SANTA ANA
SEAL BEACH
FOUNTAIN VALLEY
HUNTINGTON BEACH
PACIFIC OCEAN
IRVINE
COSTA MESA
NEWPORT BEACH
710
91
405
605
5
39
57
90
71
22
55
1
73
133
N
LEGEND
Standard Project Flood
100 Year Flood (Future Conditions)
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL
OVERFLOW
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

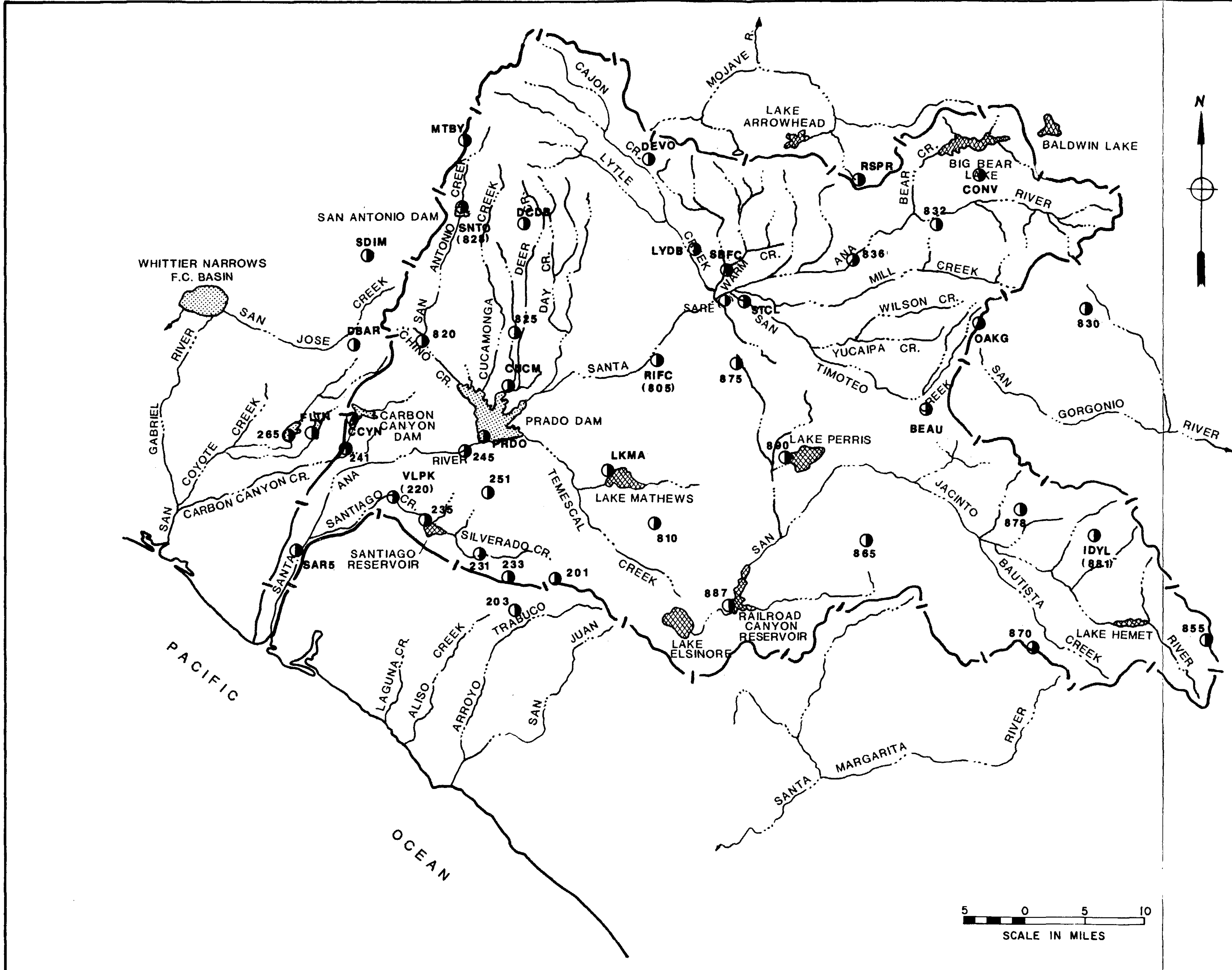


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SANTA ANA RIVER
INFILTRATION ENHANCEMENT
FACILITY

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


MOJAVE R.
CAJON
LAKE ARROWHEAD
BIG BEAR LAKE
BALDWIN LAKE
N
LYTLE CR.
SAN ANTONIO CREEK
SNTO
SAN ANTONIO DAM
CUCAMONGA CREEK
DEER CR.
DAY CR.
LYDB
CREEK
WARM CR.
BEAR CR.
RIVER
ANA
SARM
MILL CREEK
WILSON CR.
SARE
(841)
STCL
SAN
YUCAIPA CR.
TIMOTEO CREEK
WHITTIER NARROWS F.C. BASIN
SAN JOSE CREEK
CHINO CR.
819
SANTA
CUCM
(824)
PRADO DAM
PRDO
CARBON CANYON DAM
CCYN
SAN GORGONIO RIVER
GABRIEL RIVER
COYOTE CREEK
LAKE PERRIS
246
RIVER SAR7
(244)
ANA
TEMESCAL CREEK
LAKE MATHEWS
CARBON CANYON CR.
SAN
VLPK
SANTIAGO CR.
236
234
SILVERADO CR.
SANTIAGO RESERVOIR
SANTA
SAR5
JACINTO
SAN
BAUTISTA CREEK
LAKE HEMET
RIVER
RAILROAD CANYON RESERVOIR
LAKE ELSINORE
TRABUCO
JUAN
LAGUNA CR.
ALISO CREEK
ARROYO
SAN
PACIFIC
OCEAN
SANTA MARGARITA RIVER
5 0 5 10
SCALE IN MILES
LEGEND
STREAM GAUGE
RESERVOIR WATER SURFACE ELEVATION GAUGE
WATERCOURSE
FLOOD CONTROL BASIN
WATER SUPPLY RESERVOIR
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL
ALERT AND LATS STREAM AND RESERVOIR GAUGING STATIONS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

ALERT AND LATS PRECIPITATION STATIONS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Hydrologic Instrumentation of Prado Dam

Parameter	Gauge Type	Report Mode	Stored Record (period available)	Comments
water surface elevation	staff boards	visual	Flood Control Basin Operation Report SPL 19 (1940-present)	
	Stevens A-35 recorder D.R.*	visual telemetry	Reservoir Operation Report SPL 424 (1940 to present) paper strip chart (present) punch tape (1974-present) telemetry data file	float well
downstream gauge height	digital recorder*	visual telemetry	Flood Control Basin Operators Report SPL 19 (1940-present) punch tape (1974-present) telemetry data file	USGS operates the gauge, publishes the daily record and stores the paper punch tape for USGS Station ID #1107400
outlet gate opening	Gate Opening Indicator	visual	Flood Control Basin Operators Report SPL 19 (1940-present)	
	Stevens Type F Recorders		paper chart (1940-present)	
precipitation	tipping bucket gauge connected by magnetic sensor to D.R.*	telemetry	Reservoir Operation Report SPL 424 (1940-present) punch tape (1974-present) telemetry data file	tipping bucket type gauge Installed in 1985
	Belfort recording gauge	none	paper chart (1940-present)	data on paper charts is evaluated for daily rainfall amounts and charts are then sent to NWS in Asheville, N.C. for publication
	glass raintube	visual	Rainfall Record SPL 31 (1940-present)	

*Digital Recorder - A devise that converts gauge motion into coded digital information and records this periodically as a pattern of punched holes in a paper tape.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

HYDROLOGIC INSTRUMENTATION OF PRADO DAM

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

RESERVOIR COMPUTATIONS

☐ HOURLY ☐ DAILY

DAM	TIME OF READING (IF DAILY)	DATE
COMPUTED BY / CHECKED BY	DATA SOURCE	

HR.	DA.	WATER SURFACE ELEV. FT.	STORAGE AC. FT.	GATE STEP NO.	INST. OUTFLOW			HRS.	STORAGE CHANGE		AV. OUT-FLOW CFS	AV. INFLOW CFS	GATE SETTINGS FT.
					OUT-LETS CFS	DOWNSTREAM G.HT. FT.	DOWNSTREAM FLOW CFS		ACRE-FEET	CFS			
PREVIOUS REPORT													
	1												
	2												
	3												
	4												
	5												
	6												
	7												
	8												
	9												
	10												
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	25												
	26												
	27												
	28												
	29												
	30												
	31												

REMARKS

TOTAL				
MEAN				

SPL FORM MAY 67 30 PREVIOUS EDITIONS MAY BE USED: REPLACES SPL FORM 28 WHICH MAY BE USED

ARMY - C. OF E. - LOS ANGELES

FLOOD CONTROL BASIN OPERATION REPORT

Reports Control Symbol SPLCO – 7

Name	Month	Year

Day	Reservoir W.S.Elev			Outlet channel		Gate operation																	OPERATOR
	Time	Type of Gage	Gage reading in feet	Time	Gage height in feet	Time	Gate opening in feet																
							No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13	No.14	No.15	No.16	

REMARKS:

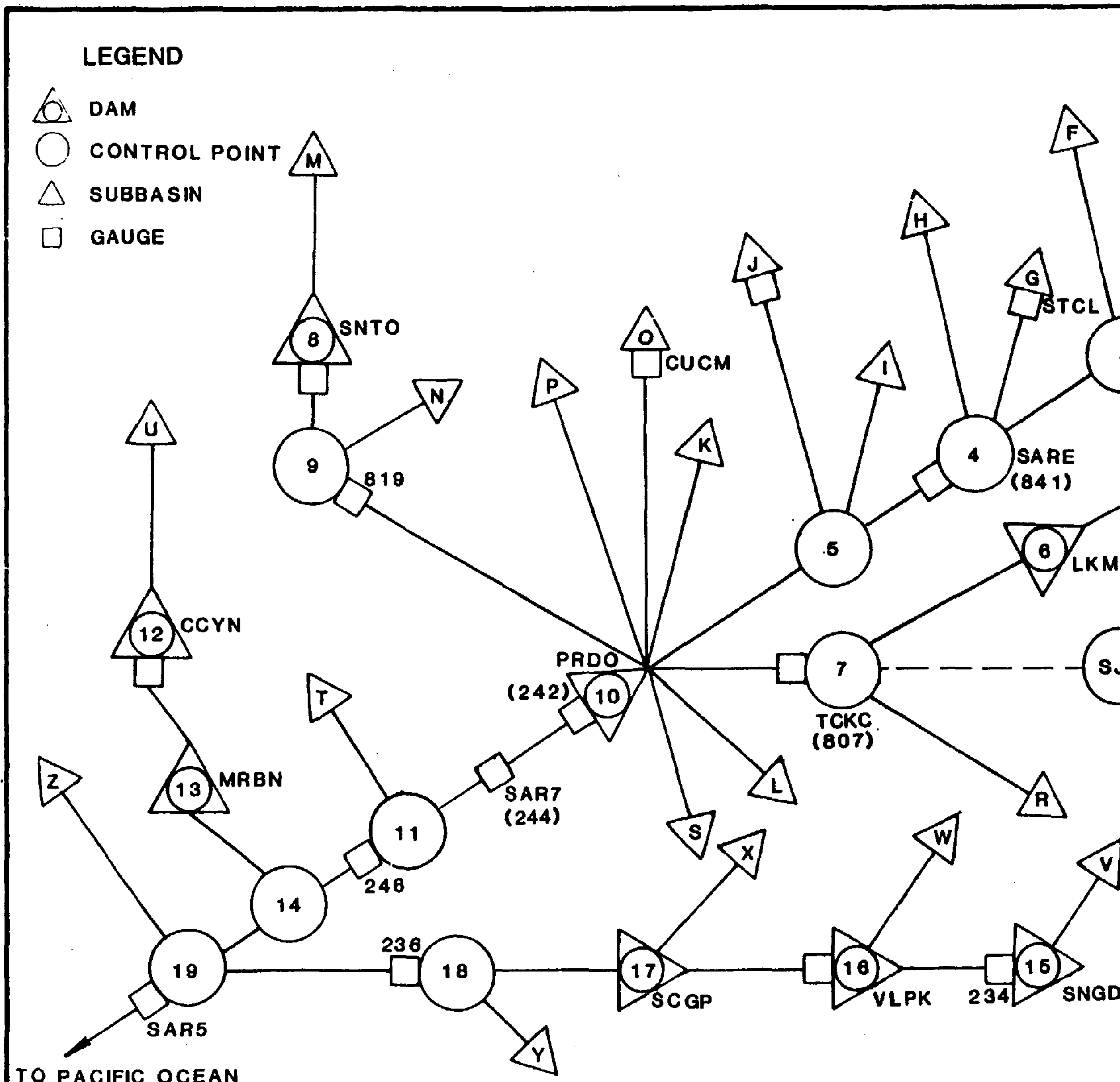
SPL FORM 1 DEC 72 19

EDITION OF 1 MAR 55 MAY BE USED

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

EXAMPLES OF "RESERVOIR COMPUTATIONS" AND "FLOOD CONTROL BASIN OPERATION REPORT" FORMS

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

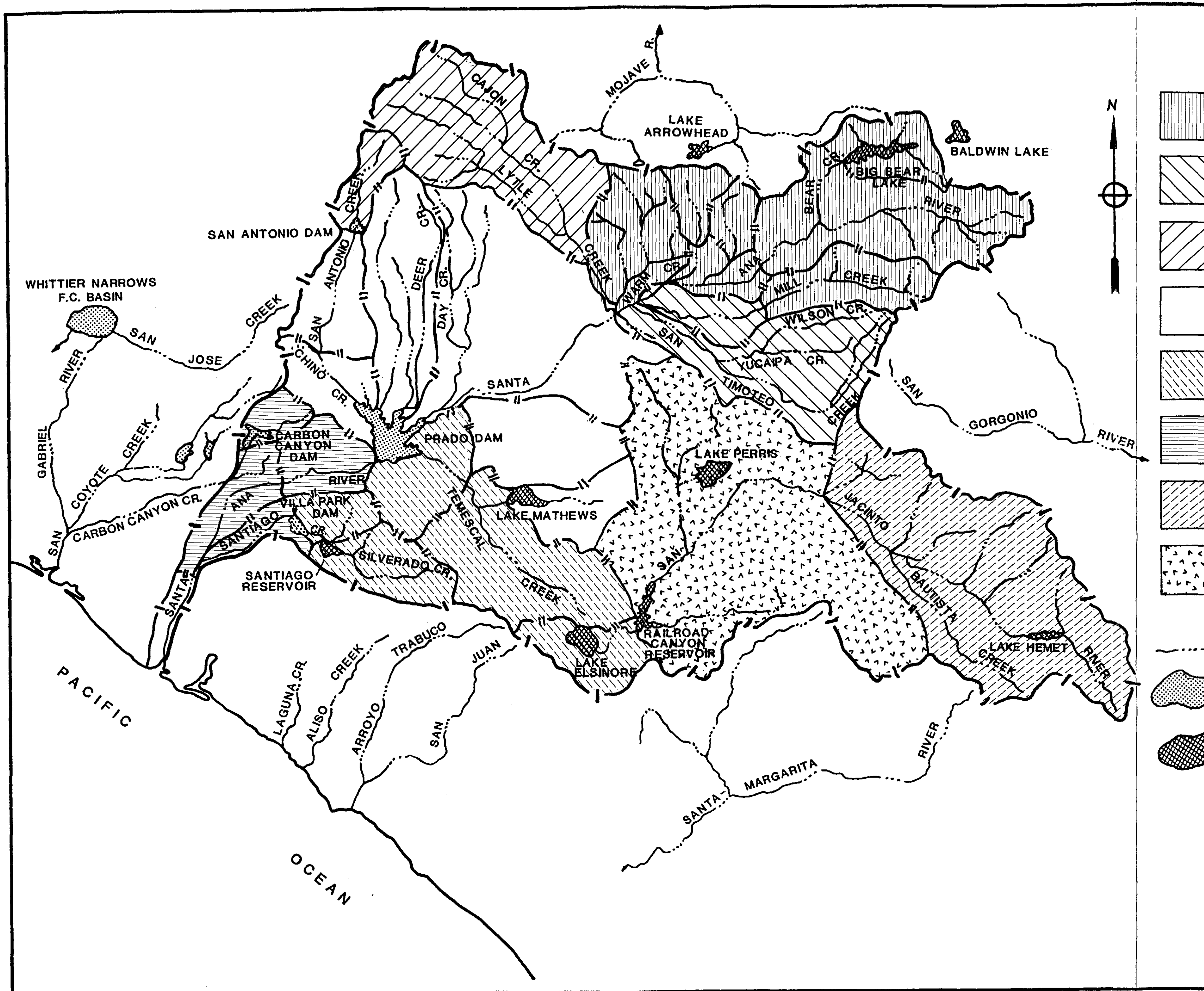


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

HEC 1F MODEL SCHEMATIC

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

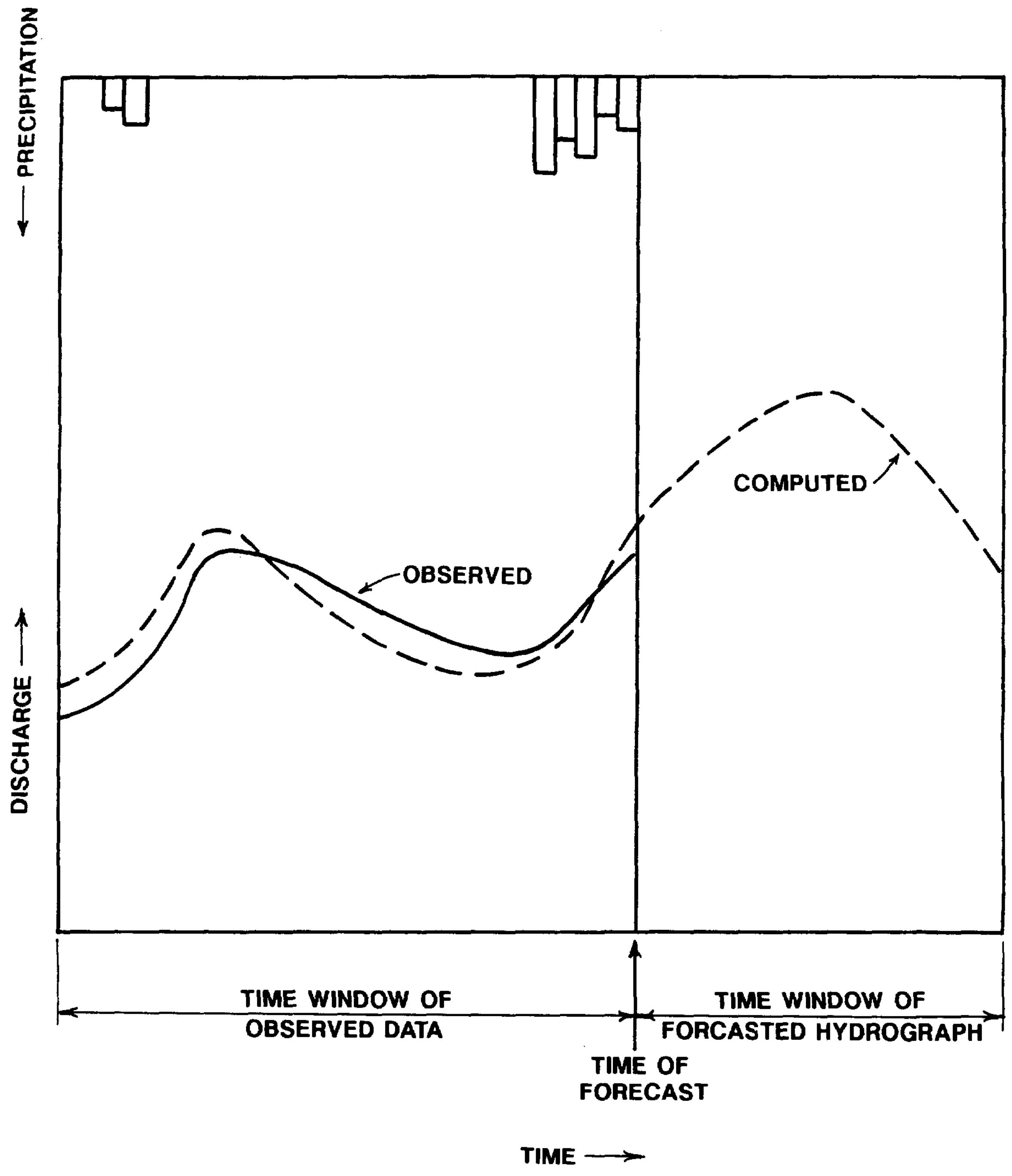
NOTE: — — — — Indicates upstream drainage area rarely contributes to downstream control point.



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

PRECIPITATION ZONES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



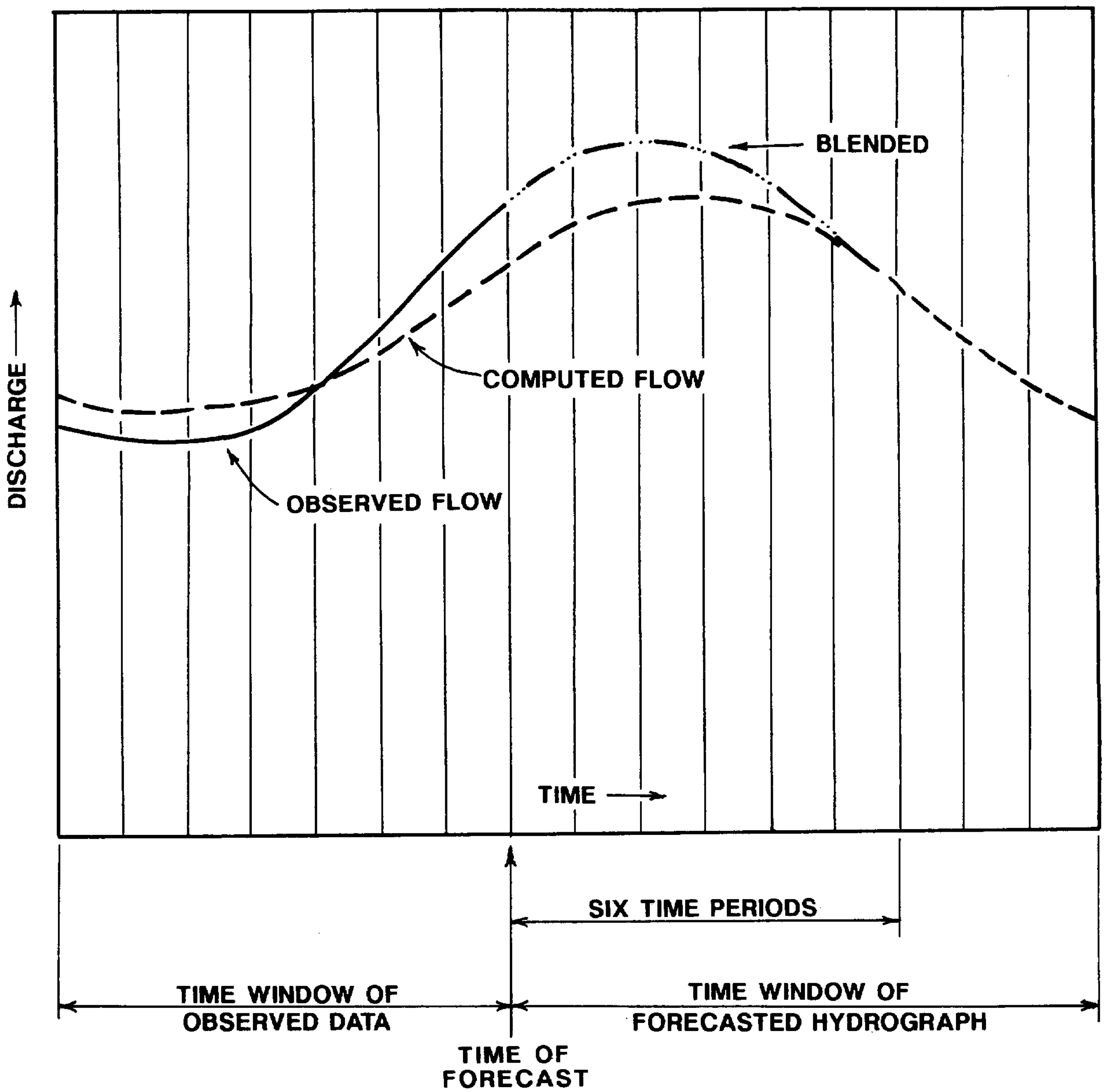
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

HEC1F PARAMETER ESTIMATION

AND

FORECAST HYDROGRAPH PROCESS

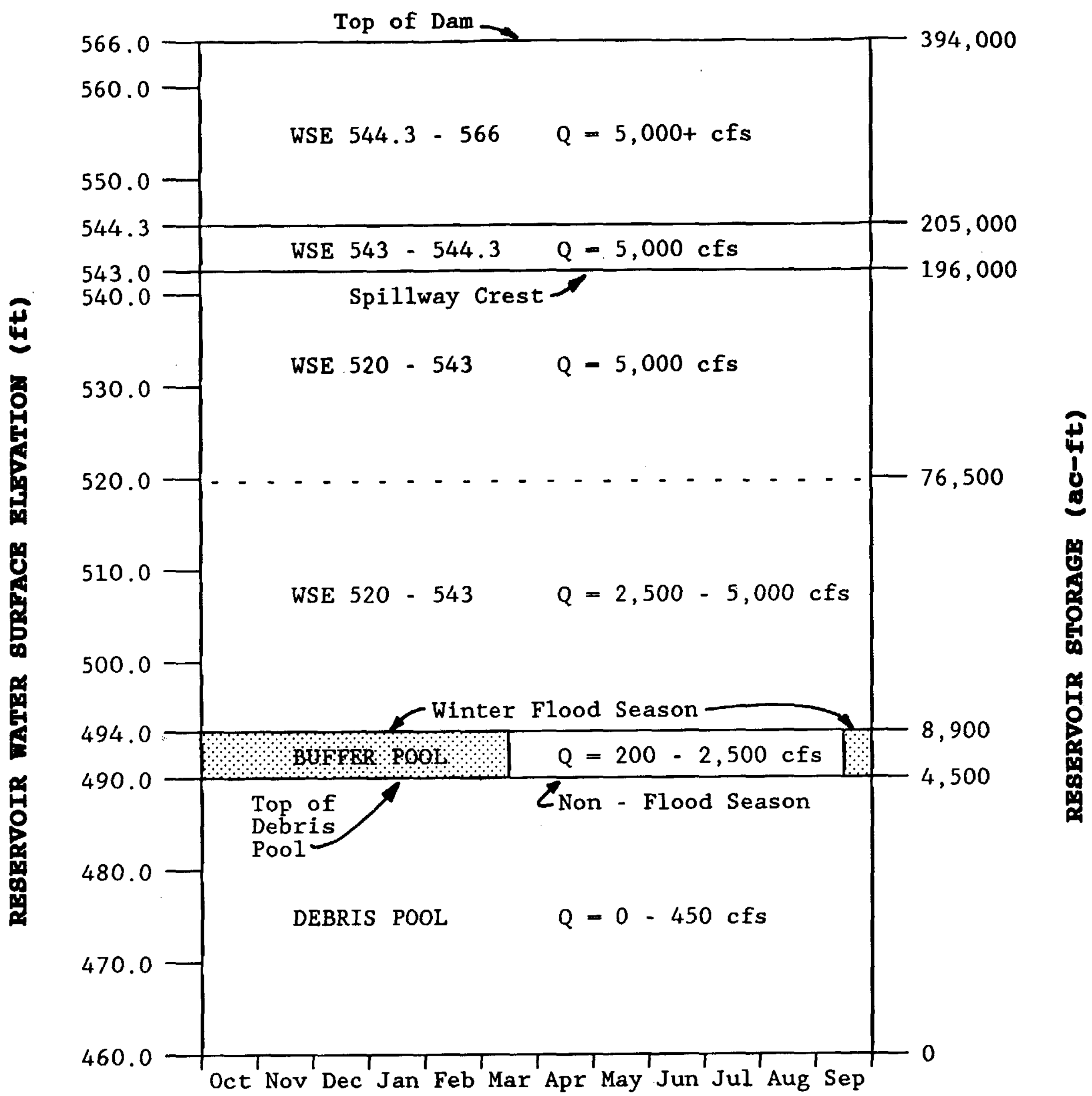
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

HEC1F BLENDING PROCESS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



Prado Dam Release Ranges

Release Range for the following Reservoir Elevations	Description
WSE 460 - 490	A debris pool is allowed to form in order to prevent floating debris from being drawn down into the outlet works. Water within the debris pool is released at rates that equal OCWD capability to recharge the groundwater without waste to the Pacific Ocean.
WSE 490 - 494 *	Reservoir releases are maintained between 200 and 2,500 cfs. This release should produce little or no damage to the improved OCEMA channel downstream, even for long durations releases. Releases greater than 600 cfs will wash out OCWD's in-channel sand diversion dike and L-dikes.
WSE 494 - 520 **	Reservoir releases are maintained between 2,500 and 5,000 cfs. Maximum scheduled reservoir release equals 5,000 cfs. Historically, sustained releases greater than 2,500 cfs have resulted in severe invert degradation and significant structural damage along the lower Santa Ana River.
WSE 520 - 543	Reservoir stages above elevation 520-ft call for the maximum scheduled release of 5,000 cfs provided that the downstream OCEMA channel is in condition to safely covey the release.
WSE 543 - 544.3	Flood control releases through the outlet works are reduced as the reservoir pool level rises above the spillway crest so as to maintain flow from the spillway plus outlet works at a maximum outflow of 5,000 cfs.
WSE 544.3 - 566	All outlet gates are closed at reservoir pool levels above 544.3-ft. Uncontrolled spillway discharge only. Under the extremely remote circumstance that the dam embankment were in danger of overtopping, all outlet gates are to be opened fully to minimize the possibility of dam failure.

Footnotes:

The decision of the exact release will depend on storm and runoff conditions, as well as the condition of reservoirs and channels in the Santa Ana River watershed, and how the operational objectives of the dam can be met. The decision parameters are discussed in Chapter 7 of this water control manual.

* Between 15 September and 15 March a release magnitude between 200 and 2,500 cfs is computed based on a real-time forecast of inflow volume so as not to exceed WSE 494-ft. The minimum release will always be equal to the OCWD groundwater recharge capability.

Beginning March 15, the flexibility to store runoff up to WSE 494-ft must be further curtailed due to the beginning of the nesting season for the federally endangered least Bell's vireo. Reservoir releases will match inflow, up to 2,500 cfs, to prevent a rise in reservoir pool elevation that could inundate any nesting endangered species between WSE 490 and 494-ft.

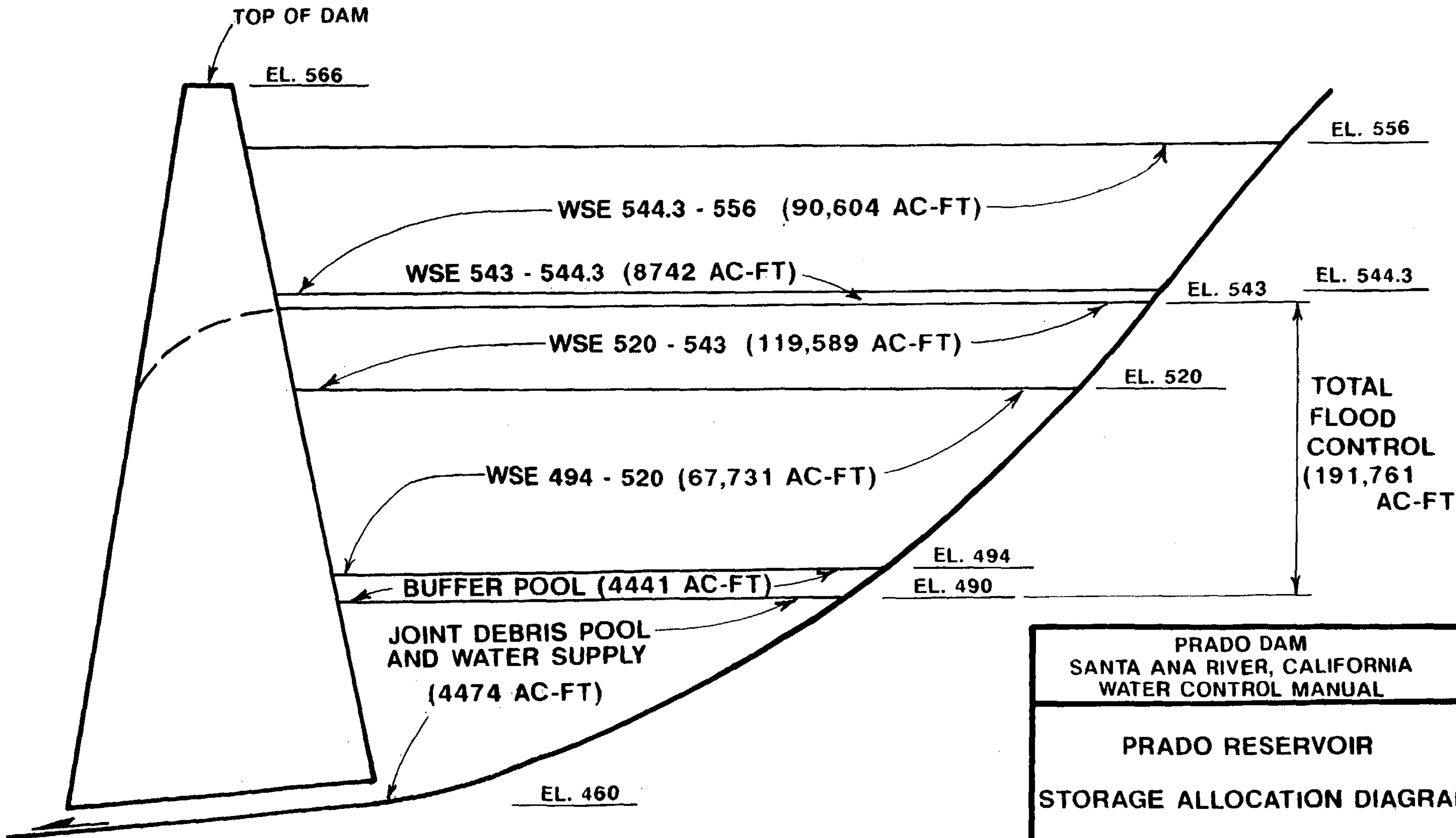
** Release magnitude is computed based on not exceeding a WSE of 520-ft using forecasted reservoir inflow (current event plus succeeding events).

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

PRADO DAM

WATER CONTROL DIAGRAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

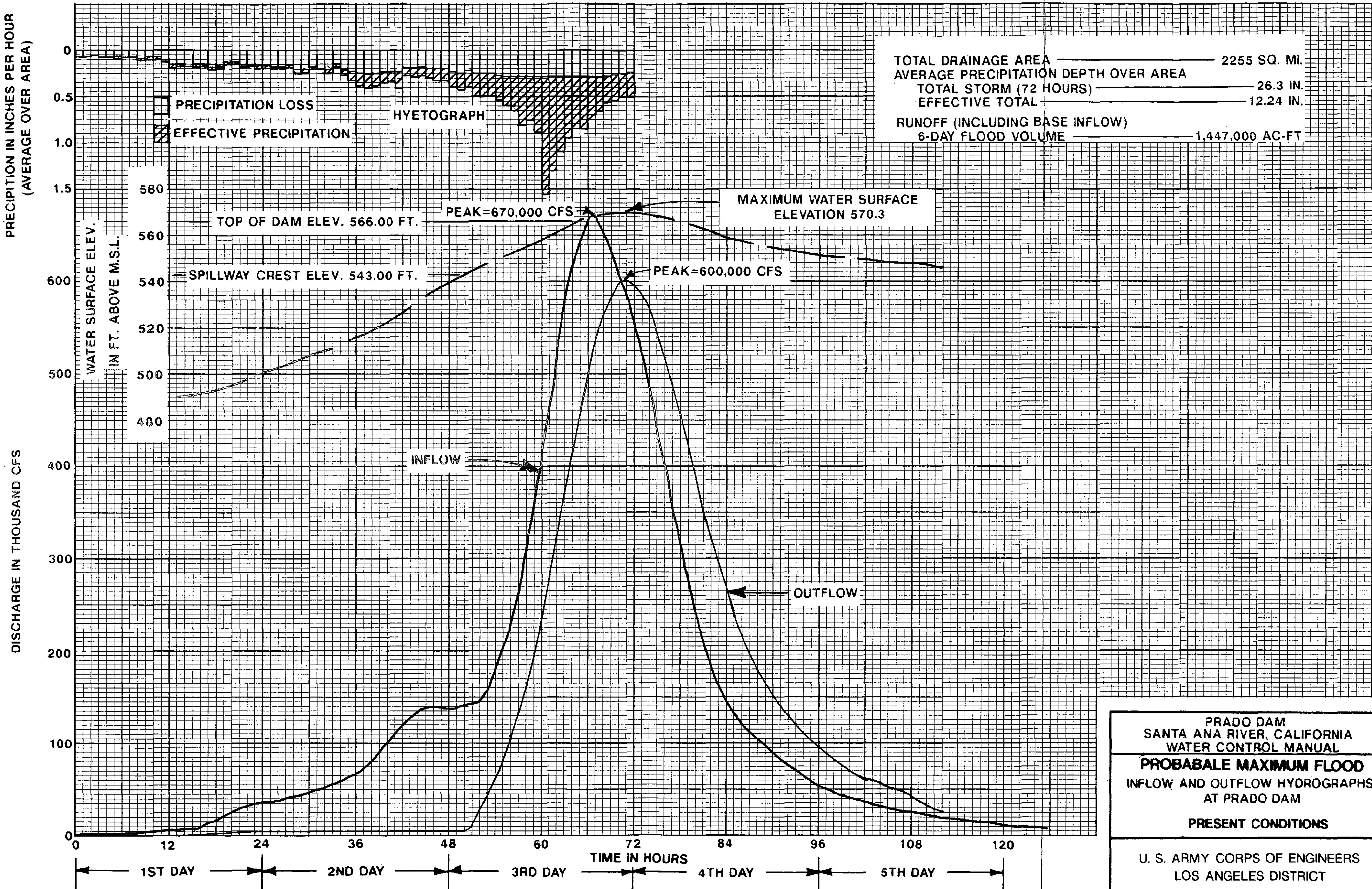


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

PRADO RESERVOIR

STORAGE ALLOCATION DIAGRAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



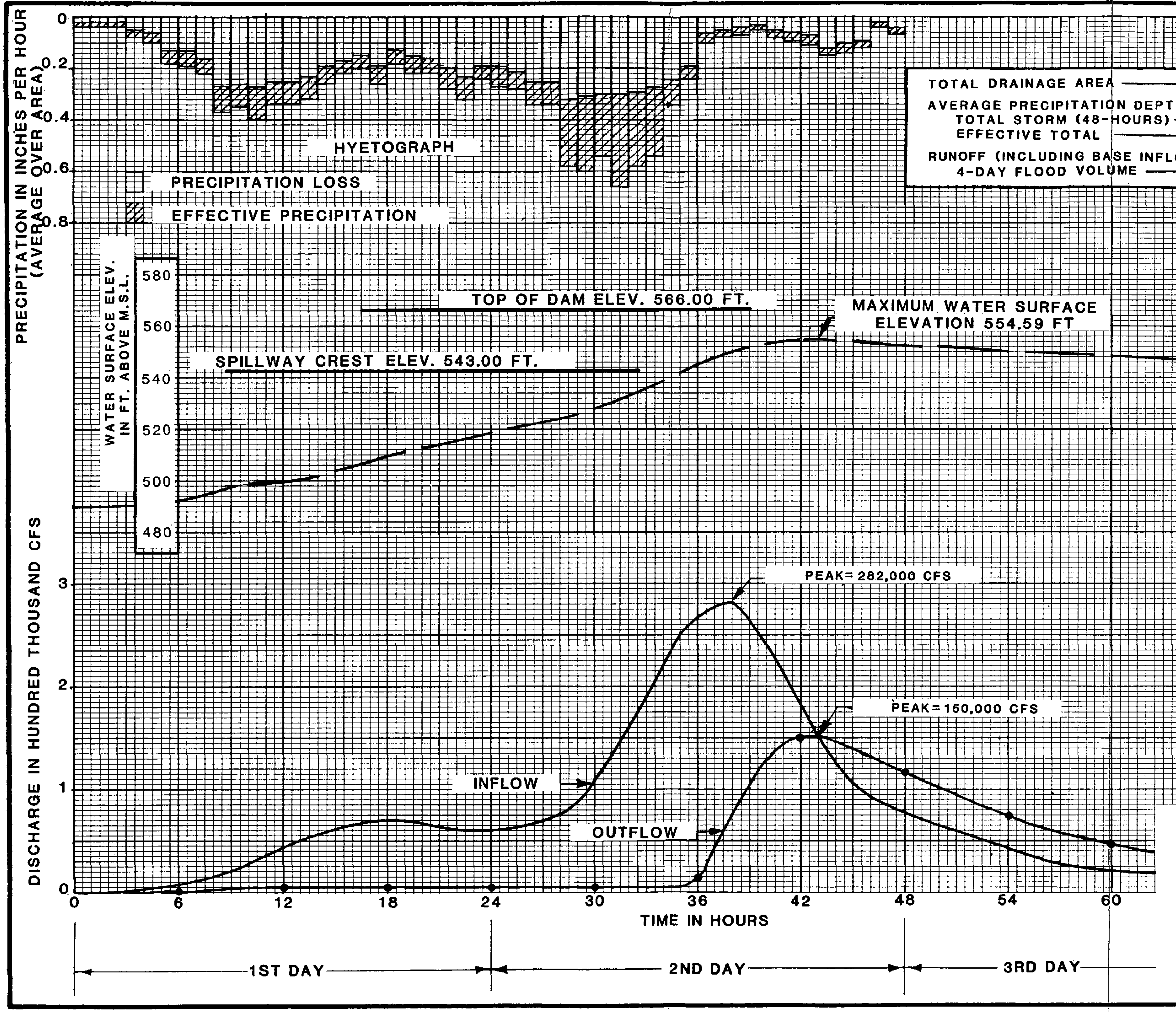
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

PROBABALE MAXIMUM FLOOD

INFLOW AND OUTFLOW HYDROGRAPHS
AT PRADO DAM

PRESENT CONDITIONS

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

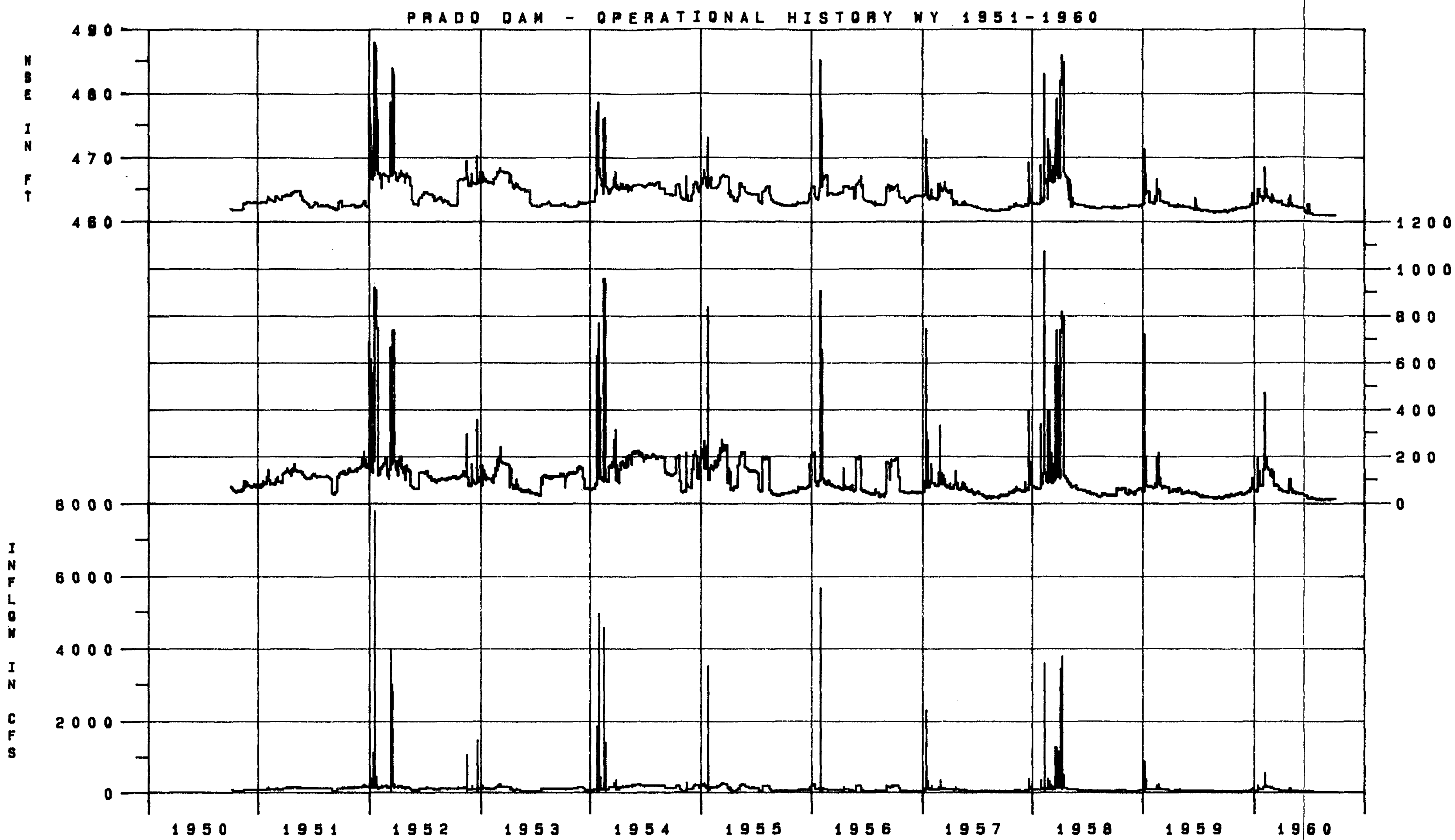
STANDARD PROJECT FLOOD
INFLOW AND OUTFLOW HYDROGRAPHS
AT PRADO DAM
PRESENT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATIONAL HISTORY OF
PRADO DAM
WATER YEAR 1942-1950

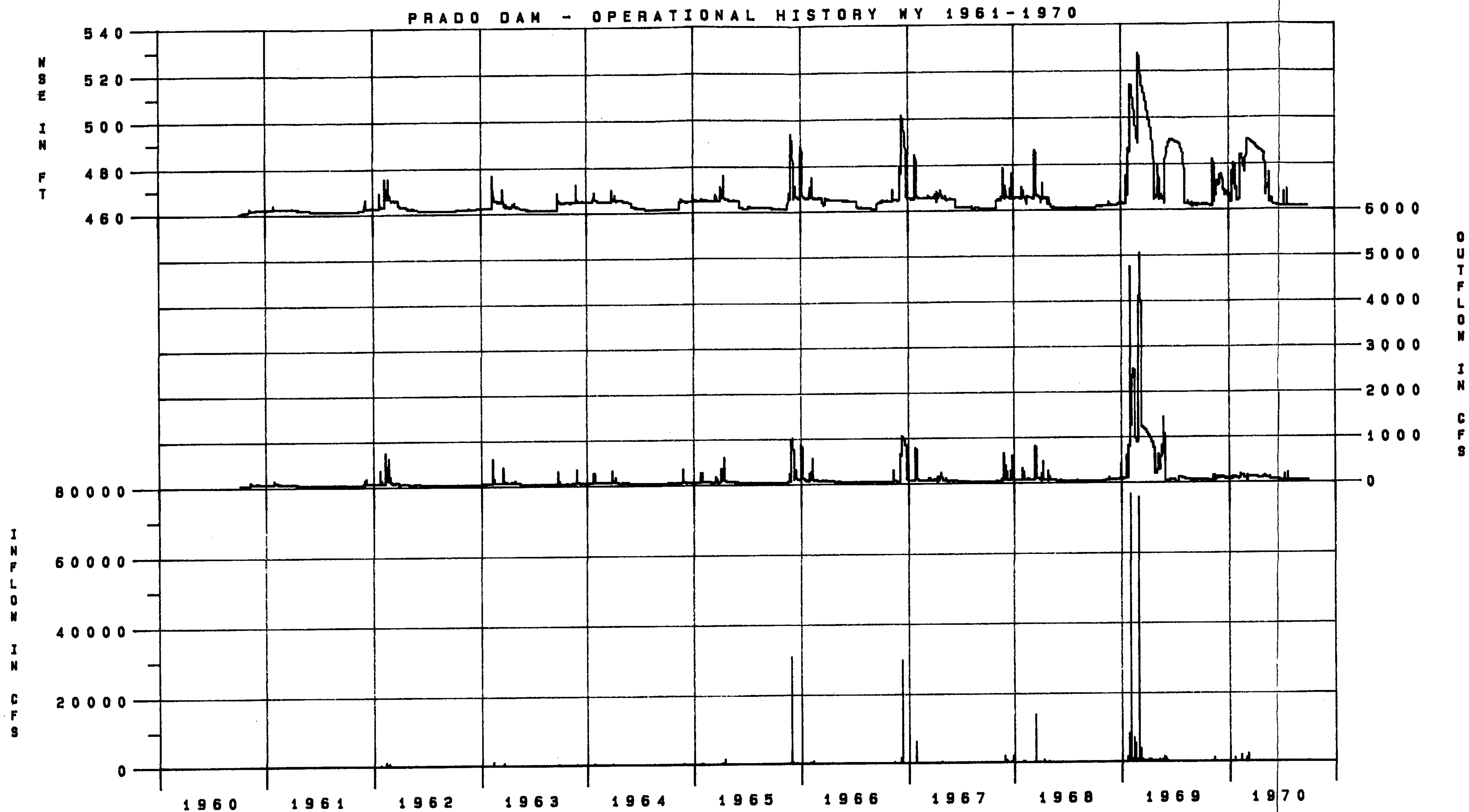
U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATIONAL HISTORY OF
PRADO DAM
WATER YEAR 1951-1960

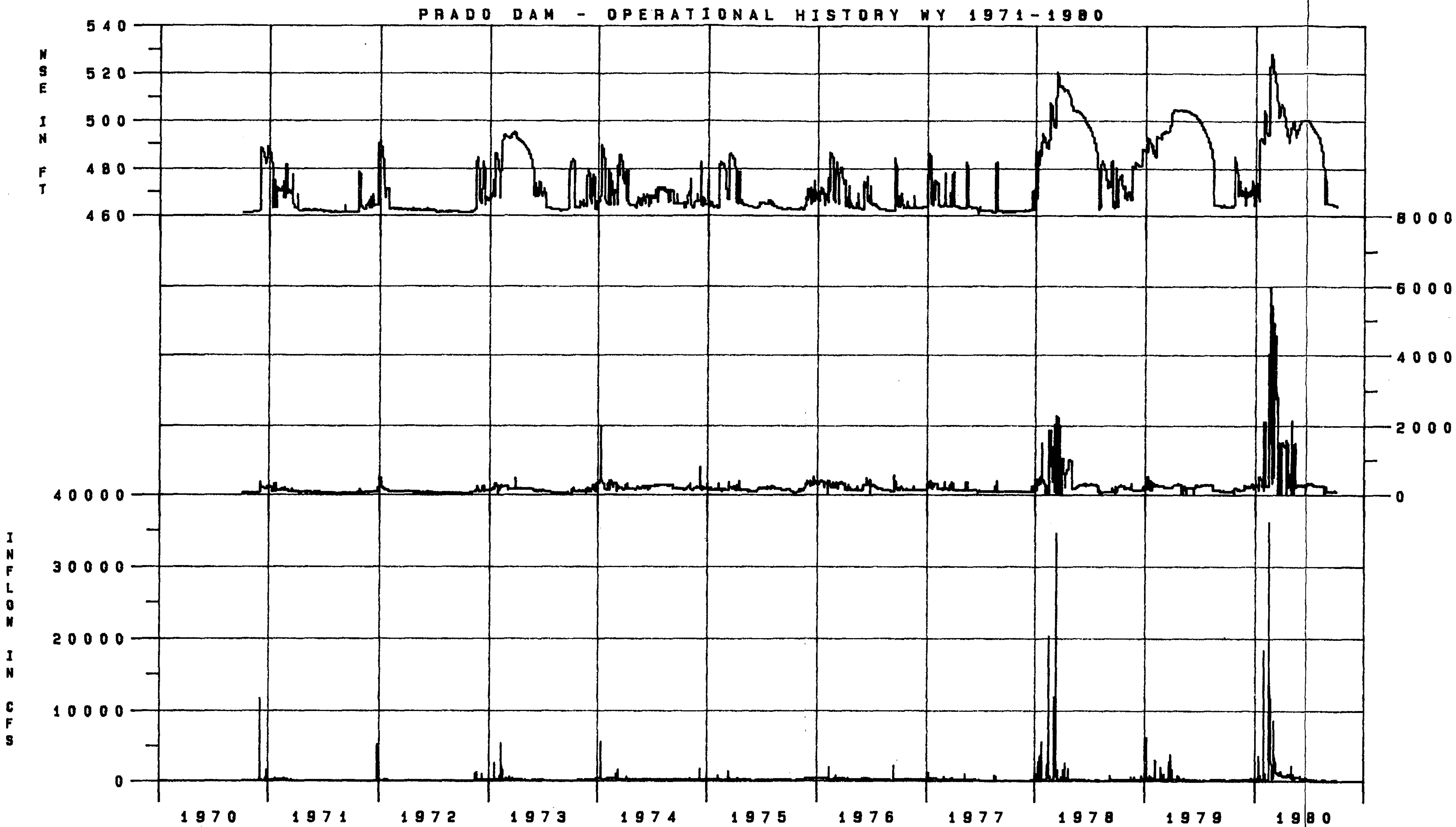
U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATIONAL HISTORY OF
PRADO DAM
WATER YEAR 1961-1970

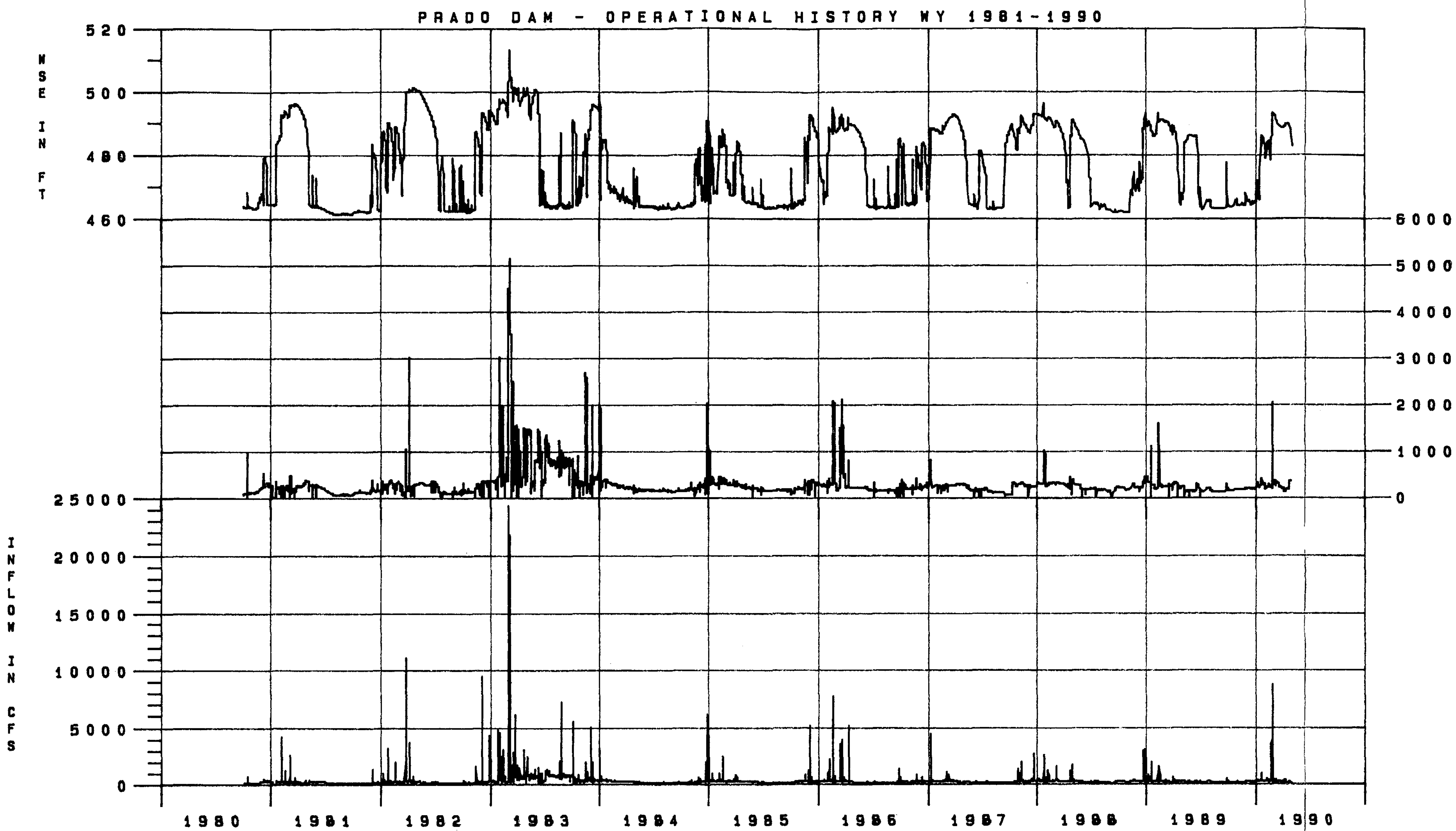
U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATIONAL HISTORY OF
PRADO DAM
WATER YEAR 1971-1980

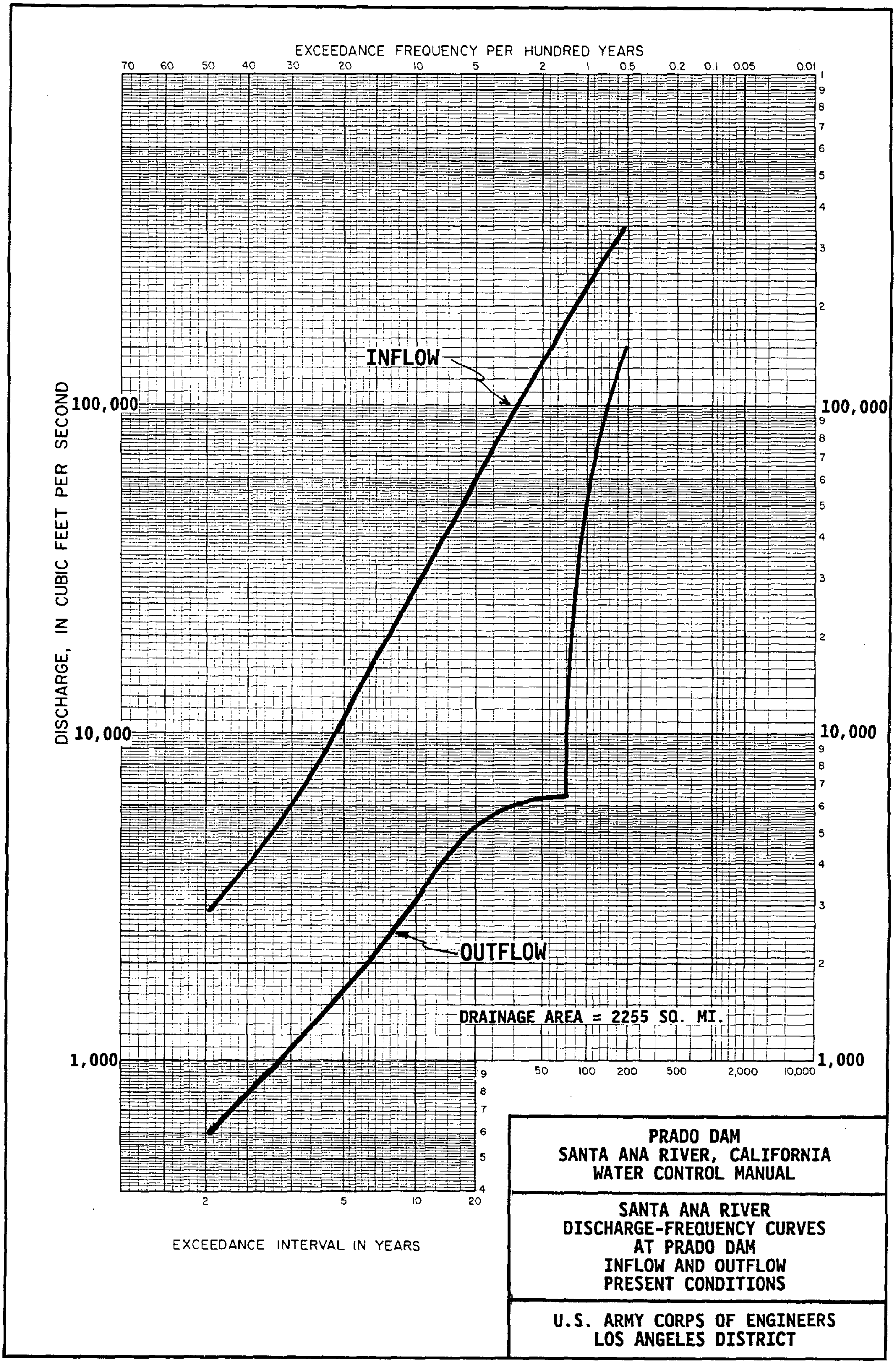
U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

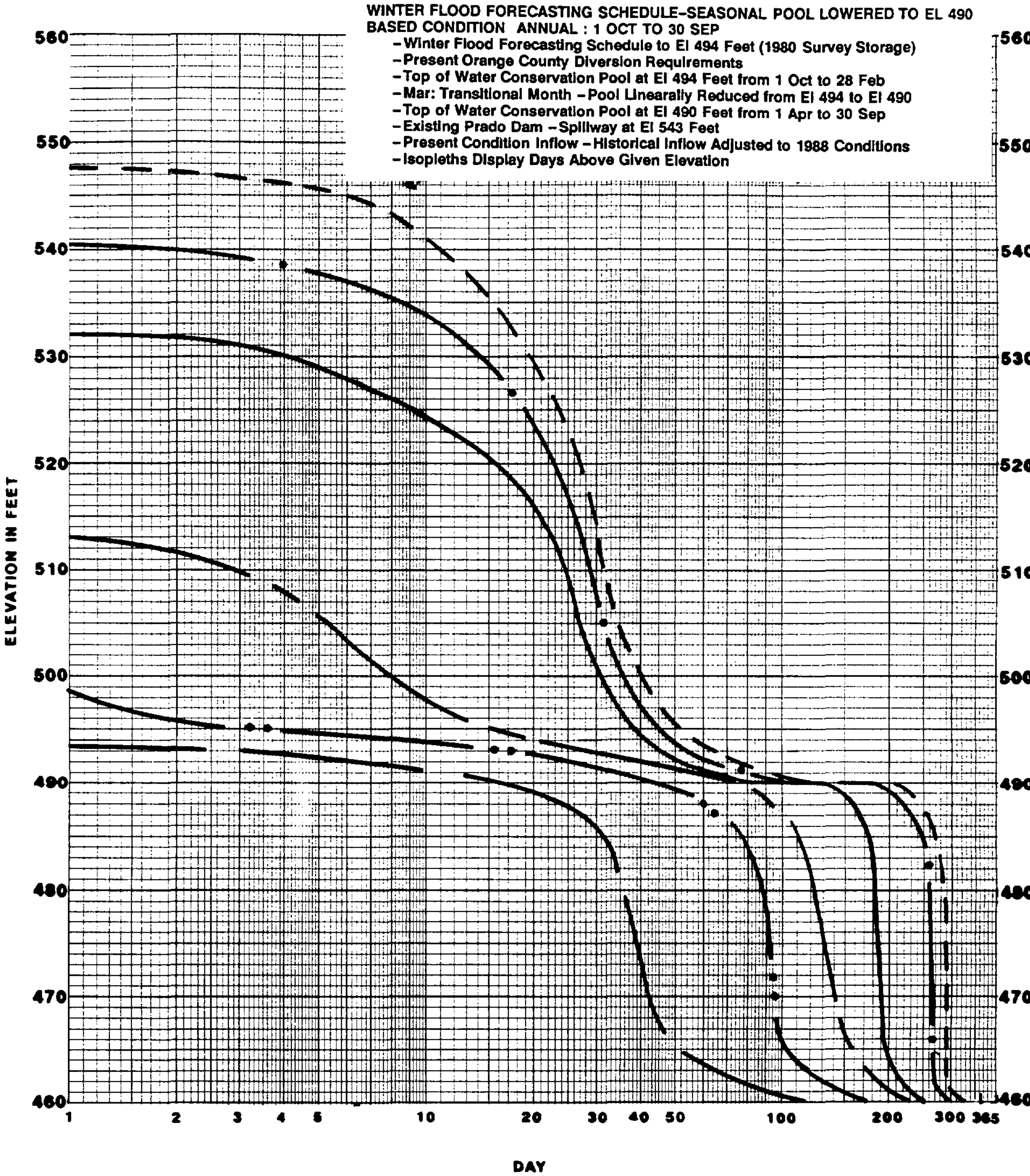


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

OPERATIONAL HISTORY OF
PRADO DAM
WATER YEAR 1981-1990

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


EXCEEDANCE FREQUENCY PER HUNDRED YEARS
70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
DISCHARGE, IN CUBIC FEET PER SECOND
100,000
10,000
1,000
INFLOW
OUTFLOW
DRAINAGE AREA = 2255 SQ. MI.
50 100 200 500 2,000 10,000
2 5 10 20
EXCEEDANCE INTERVAL IN YEARS
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL
SANTA ANA RIVER
DISCHARGE-FREQUENCY CURVES
AT PRADO DAM
INFLOW AND OUTFLOW
PRESENT CONDITIONS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



LEGEND

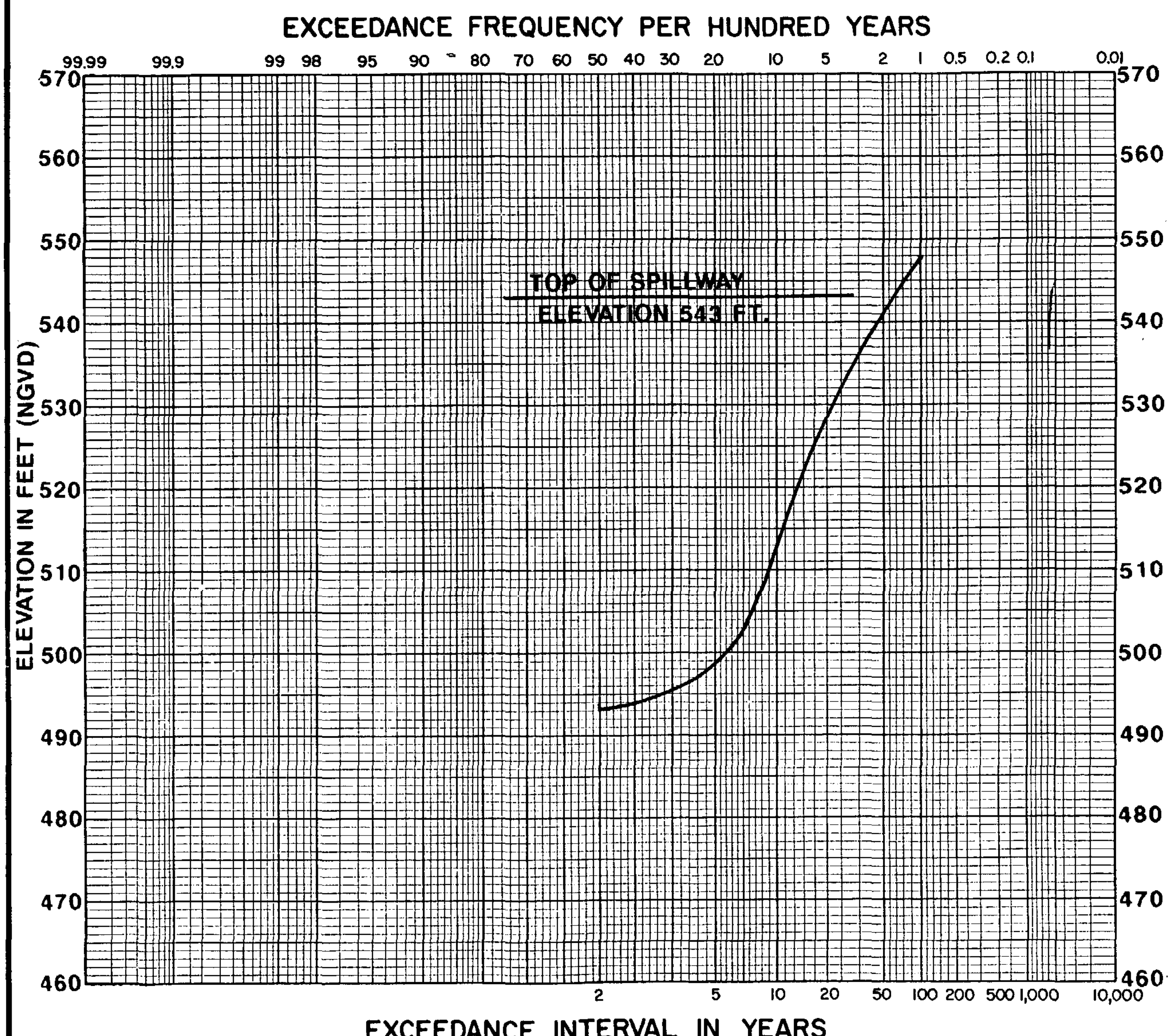
— — — —	100-YR
—— • ——	50-YR
————	25-YR
—— - ——	10-YR
—— • • ——	5-YR
—— ——	2-YR

HIGHER RETURN PERIOD HAS PRIORITY.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

ANNUAL
ELEVATION-DURATION FREQUENCY CURVES
BASE CONDITION
WINTER FLOOD FORECASTING TO EL 494
SEASONAL POOL OPERATED TO EL 490
PRESENT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

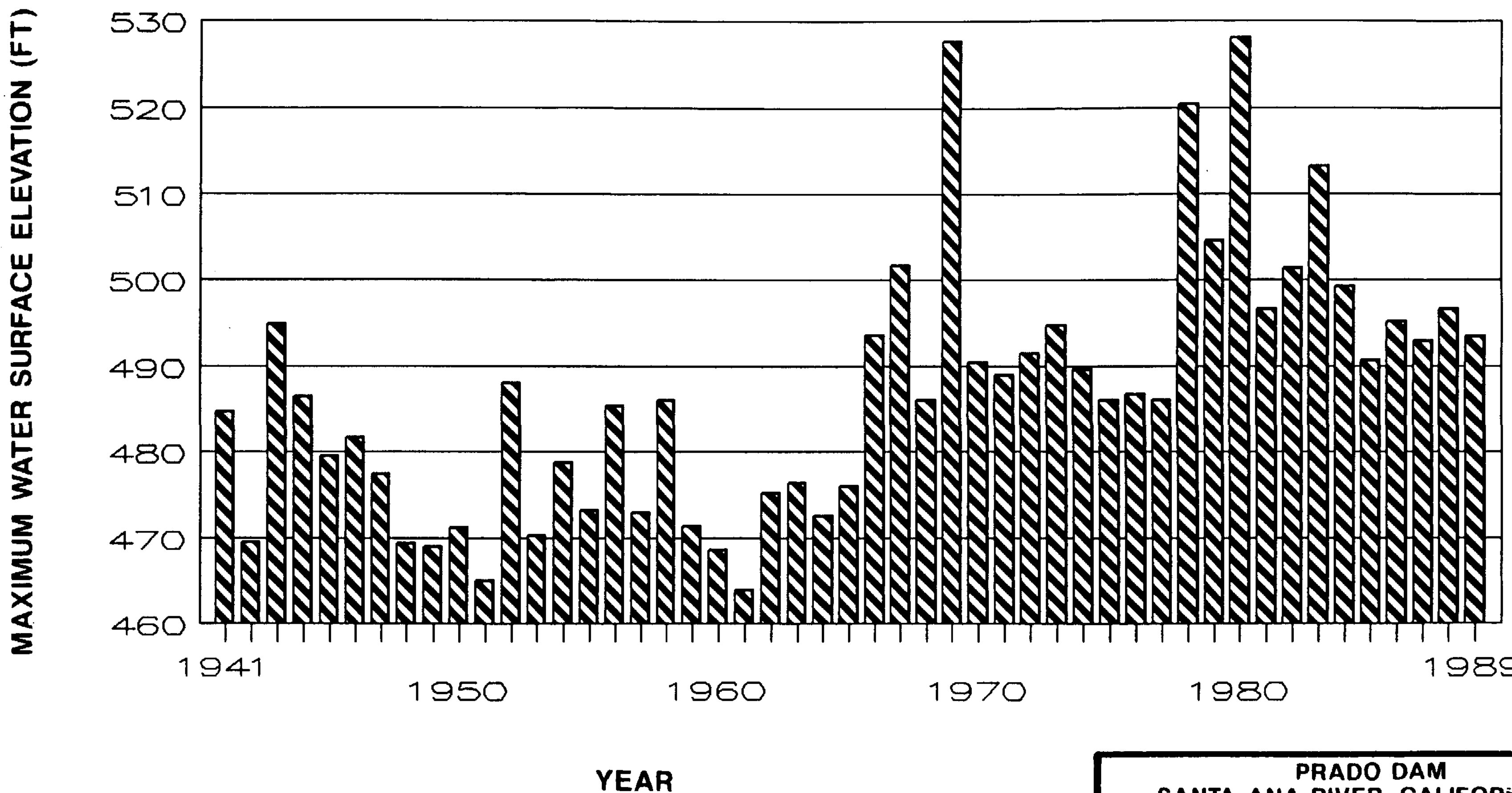


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

PRADO DAM
FILLING FREQUENCY CURVE
1990 WATER CONTROL PLAN
PRESENT CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 8-05b



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

MAXIMUM POOL ELEVATIONS

1941 TO 1989

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT A

STANDING INSTRUCTIONS TO THE PROJECT OPERATOR

FOR WATER CONTROL

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

STANDING INSTRUCTIONS TO THE PROJECT OPERATOR
FOR WATER CONTROL

PRADO DAM WATER CONTROL MANUAL

TABLE OF CONTENTS FOR EXHIBIT A

LIST OF PLATES FOR EXHIBIT A

Exhibit A

I - BACKGROUND AND RESPONSIBILITIES

1-01 General Information.

a. General. This exhibit is prepared in accordance with instructions contained in EM 1110-2-3600, paragraph 9-2, (Standing Instructions to Project Operators for Water Control), and ER 1110-2-240. This exhibit outlines the duties and responsibilities of the Project Operator in connection with the operation of Prado Dam and the reporting of required hydrologic data.

Operational instructions to the project operator are outlined with specific emphasis on flood emergencies when communication between the project operator and the Reservoir Operation Center (ROC) have been disrupted. The exhibit is designed to be used independently as a flood control guide or in conjunction with the rest of the water control manual. Plate A-01 is the Reservoir Regulation Schedule for Prado Dam. Regulation for both Normal Communication and No-Communication situations are outlined.

The project operator is required to have these standing instructions and the following two manuals available at the dam site: 1) the current year's Orange Book - "Instructions for Reservoir Operations Center Personnel"; and 2) the "Operation and Maintenance Manual for Prado Dam". Any deviation from the standing instructions will require the approval of the District Commander.

b. Project Purpose. The primary purpose of Prado Dam and Reservoir is flood control. Other uses and benefits of the dam and reservoir, such as water conservation, are secondary. Prado Dam regulates flows on the Santa Ana River, and is designed to provide protection from floods for the metropolitan areas of Orange County.

c. Reservoir Regulation. Regulation of Prado Dam and other Corps of Engineers facilities within the watershed is conducted from the Reservoir Operations Center which is staffed by water control managers from the Reservoir Regulation Section of the LAD. Table 9-1 is an organizational chart depicting the chain of command for reservoir regulation decisions.

d. Project Location. Prado Dam is located on the lower Santa Ana River, approximately 30.5 miles upstream of the Pacific Ocean. The dam is in Riverside County, California approximately 2 miles west of the City of Corona. Portions of the flood control basin are in Riverside County and San Bernardino County. The Santa

Ana River watershed has an area of 2,450 sq-mi of which 92% of the watershed (i.e., 2,255 sq-mi) is located upstream of Prado Dam (as shown on Plate 2-01).

e. Project Description. Prado Dam consists of an earth-filled embankment, with a reinforced concrete spillway and gated outlet works. The general plan and elevation of the dam are shown on plates 2-02 and 2-03.

Prado Dam has six gated outlets with an invert elevation at 460-ft and a broad-crested ogee spillway with a crest at elevation 543-ft. The discharge rating curves for the gated outlets and the spillway are shown on plates 2-06a-d and 2-07, respectively. The spillway general plan and profile is shown on plate 2-05.

The reservoir capacity below the spillway crest is 196,235 ac-ft, which is fully available for flood control. The area and gross capacity relationships of the Prado Flood Control Basin are shown on plates 2-08 and 2-09.

f. Downstream Channel Constraints. Local runoff can significantly contribute to flows in the Santa Ana River between Prado Dam and the Pacific Ocean during a storm event. The reservoir releases should take into account these uncontrolled local runoff flows together with the downstream channel capacity. The downstream Santa Ana River channel capacity varies along the length of the channel, as shown on plate 4-21a-b. Considering the local runoff and channel capacity along the Santa Ana River, the maximum controlled release is limited to 5,000 cfs when spillway flow does not occur.

When flows exceed 2,500 cfs, the Green River Golf Course and Featherly Park are adversely affected. Also, scour and bank erosion problems exist in the Santa Ana River Channel when large flows exceed 2,500 cfs for extended periods of time.

See section 7-02 for detailed information on downstream constraints to the operation of Prado Dam.

g. Ownership. Prado Dam is owned, operated, and maintained by the U.S. Army Corps of Engineers, Los Angeles District, which has complete regulatory responsibility.

1-02 Role of the Project Operator.

a. Normal Conditions (dependent on day-to-day instruction). The Project Operator (dam tender) will be instructed by the ROC, as necessary, for water control actions under normal hydrometeorological conditions.

The Project Operator is responsible for the project works. This includes insuring that all the equipment is in good operating condition, and that the gates and electrical facilities in the control house are periodically inspected and tested according to the preestablished schedule.

b. Emergency Conditions (flood or drought). The Project Operator will be instructed by the ROC regarding water control actions during flood events and other emergency conditions.

The Project Operator's responsibilities include:

1. Be present at the Dam when rainfall or runoff occurs, as instructed by the Operations Branch.

2. Operate the gates in accordance with instructions from the ROC.

3. Notify the ROC when a gate change will be required according to Plate A-01, Prado Dam Reservoir Regulation Schedule.

4. Notify the ROC if unable to set the gates as instructed.

5. Follow the No-Communication Reservoir Regulation Schedule (Plate A-01) when communication is lost between the project and the ROC for more than four hours.

6. Notify the ROC if any unusual or emergency situations arise or are observed with regard to the dam, reservoir area, or downstream channel.

II - DATA COLLECTION AND REPORTING.

2-01 Normal Conditions. During normal operations, from 15 November to 15 April, measurements are made daily by the Project Operator to determine the water surface elevation (staff and "tape" reading), downstream stage, incremental precipitation since last report, total accumulated precipitation, the setting of each outlet gate and the times of these measurements. For normal conditions, between 15 April to 15 November, measurements are made once a week (every Monday morning).

The Project Operator maintains the record of measurements and logs all radio and telephone communication on the following forms: Rainfall Record, SPL Form 31 (Plate A-02; for manual glass readings of glass tube rain gauges); Record of Calls, SPL Form 188 (Plate A-02; both radio and telephone); and the Flood Control Basin Operation Report, SPL Form 19 (Plate 5-04).

2-02 Emergency Conditions. During flood operations or emergency operations, the Project Operator should follow instructions, as issued by the ROC. Measurements may be required at intervals as short as ten minutes from the staff gage, and other instruments as specified by the ROC personnel.

When reporting to the ROC, the Project Operator should clearly describe any silt and debris situation at the trash racks, gates and downstream gages. When instruments are not working, or are stuck in silt, the Project Operator should not report the erroneous reading, but should state the instrument or staff problem. Care should be taken to avoid issuing misleading reports due to siltation at the reservoir staff boards. When debris or silt cause the flow to be deceptively perched above the invert, or cause a loss of contact with the staff board, the Project Operator should report a descriptive message identifying the limitations, and quantifying the estimated reservoir depth.

If the radio system fails, the Project Operator should try to reestablish communication via telephone.

2-03 Regional Hydrometeorological Conditions. The Project Operator will be informed by the ROC of regional hydrometeorological conditions that may impact the project.

III - WATER CONTROL ACTION AND REPORTING.

3-01 Normal Conditions. During normal hydrometeorological conditions, the Project Operator will be instructed by the ROC for the appropriate water control action. The Project Operator should:

1. Establish communication with the ROC.

2. Implement instructions.

3. Notify the ROC on the status of the water control action.

The Project Operator should not implement any gate change, even if the change will have no effect on the reservoir operation without first obtaining approval from the ROC. Gate setting changes may be requested by the Project Operator for maintenance, etc., but they will have to be approved by the ROC.

3-02 Emergency Conditions. During emergency conditions, the Project Operator will be instructed by the ROC regarding any necessary water control action. During flood conditions, the Project Operator will be instructed according to Plate A-01 and will be required to notify the ROC for upcoming gate changes. The Project Operator should:

1. Establish communication with the ROC.

2. Implement the instructions.

3. Notify the ROC on the status of the water control action.

3-03 Inquiries. All significant inquires received by the Project Operator from citizens, constituents, or interested groups regarding water control procedures or actions must be referred directly to the ROC.

3-04 Water Control Problems. The ROC must be contacted immediately by the most rapid means available in the event that an operational malfunction, erosion, or other incident occurs that could impact project integrity in general or water control capability, in particular.

Emergency departures from the regulation instructions issued by the ROC may be required, because of water control equipment failures, accidents, or other emergencies requiring immediate action. Under these situations, the Project Operator should contact the ROC via radio for instructions. When communications are broken, or the situation demands immediate action, the Project Operator may proceed independently. The ROC should be notified of such action as soon as possible. All other non-emergency deviations from normal procedure should be approved in advance by the ROC. The District Engineer, Los Angeles District, U.S. Army Corps of Engineers, may make temporary modifications to the water control regulations. Permanent changes are subject to approval by the Division Engineer, South Pacific Division, U.S. Army Corps of Engineers.

The Project Operator should immediately alert the ROC (call sign WUK 4ROC) via radio, whenever the requested gate change cannot be fully implemented due to mechanical or physical problems. For example, debris could prevent total gate closure. The ROC will evaluate the problem and provide further instructions to the Project Operator.

3-05 Communication Outage. The ROC maintains close contact with the Project Operator at Prado dam. During flood periods, communication between the Project Operator and ROC may be broken. The Project Operator should try to reestablish communication first by telephone at the project and then second through the Orange County Environmental Management Agency at (714) 567-6300. The project operator should not leave the immediate vicinity of the project.

During the rising stages of the flood, the Project Operator should allow a period of four (4) hours to reestablish communication with the ROC. If communication cannot be reestablished after four (4) hours the Project Operator should follow the No-Communication Reservoir Regulation Schedule as outlined on Plate A-01.

Emergency notifications are normally made by the ROC. However, if the Project Operator loses communication with the ROC and an emergency notification situation arises, such as an imminent dam failure or uncontrolled spillway flow (water surface elevation above 543-ft), the Project Operator should make the necessary notifications. The notification list for WSE's approaching 543-ft are given in the Prado Appendix of the "Instructions for Reservoir Operations Center Personnel" (i.e., the "Orange Book").

The notifications should include: (a) description of the type and extent of existing or impending emergency; (b) advisement for evacuation from the flood plain;

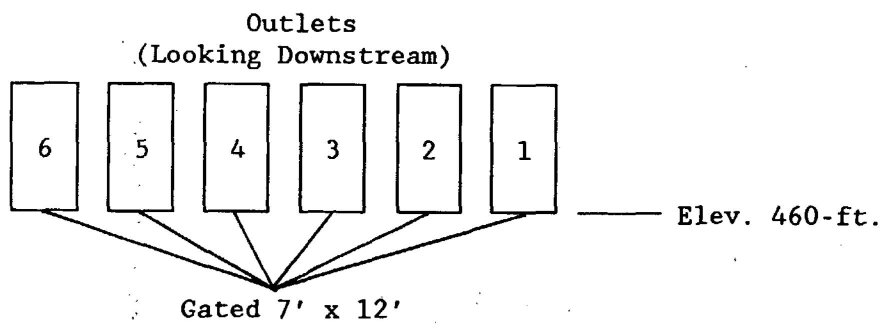
(c) information on the estimated time of initial release of hazardous amounts of water; (d) the depth of water behind the dam; and (e) the Project Operator's name and telephone number.

Upon completing the above notifications, attempt to reestablish communications with the ROC. Document all notifications made on SPL Form 188 (Plate A-02), and refer to the Orange Book ("Instructions for Reservoir Operations Center Personnel") for more information on additional emergency notifications. The Project Operator should not leave the dam unless his safety is in jeopardy.

RESERVOIR REGULATION SCHEDULE
PRADO DAM

(RISING AND FALLING STAGES)

NORMAL COMMUNICATION Between the ROC and Dam Tender		Reservoir Water Surface Elevation (ft)	NO COMMUNICATION Between the ROC and Dam Tender							
Desired Discharge Range (cfs)	Recommended Gate Settings		Recommended Gate Settings (ft) #1	#2	#3	#4	#5	#6	Computed Discharge Range (cfs)	Downstream Gage Height (Rating #20) (ft)
0 - 500	Gate settings are determined by Water Control Manager at the ROC. RESCAL and/or Gate Rating Curves are used to prepare the gate settings.	460.0 - 490.0	0.0	0.0	1.0	1.0	0.0	0.0	0 - 540	1.60 - 3.87
200 - 2,500		490.0 - 494.0	0.0	0.0	1.0	0.9	0.0	0.0	513 - 547	3.82 - 3.88
2,500 - 5,000 Water Control Manager determines the actual release rate.		494.0 - 497.0	0.0	1.3	1.4	1.4	1.3	0.0	1,515 - 1,582	4.87 - 4.92
		497.0 - 500.0	1.4	1.3	1.4	1.4	1.3	1.4	2,400 - 2,504	5.40 - 5.46
		500.0 - 504.0	1.6	1.6	1.6	1.6	1.5	1.6	2,861 - 3,009	5.63 - 5.69
		504.0 - 508.0	1.6	2.0	1.8	1.8	2.0	1.6	3,370 - 3,527	5.85 - 5.91
		508.0 - 512.0	2.2	2.0	1.8	1.8	2.0	2.2	3,869 - 4,052	6.04 - 6.11
		512.0 - 516.0	2.2	2.2	2.1	2.1	2.2	2.2	4,360 - 4,531	6.22 - 6.28
		516.0 - 520.0	2.2	2.9	2.1	2.1	2.9	2.2	4,960 - 5,139	6.42 - 6.47
5,000	Use the NO COMMUNICATION schedule located to the right.	520.0 - 525.0	2.0	2.9	2.0	2.0	2.9	2.0	4,942 - 5,155	6.41 - 6.48
		525.0 - 533.0	2.0	2.0	2.0	2.0	2.9	2.0	4,860 - 5,150	6.39 - 6.48
		533.0 - 543.0	2.0	2.0	2.0	2.0	2.0	2.0	4,830 - 5,150	6.39 - 6.48
		SPILLWAY FLOWS 543.0 - 543.6	2.0	0.5	2.0	2.0	0.5	2.0	3,896 - 5,806	6.05 - 6.67
		543.6 - 544.0	0.0	0.5	2.0	2.0	0.5	0.0	4,086 - 5,355	6.12 - 6.54
		544.0 - 544.3	0.0	0.0	2.0	2.0	0.0	0.0	4,884 - 5,187	6.39 - 6.49
> 5,000		544.3 - ABOVE	0.0	0.0	0.0	0.0	0.0	0.0	4,960 - ABOVE	6.40 - +



DAM TENDER INSTRUCTIONS

1. **NORMAL COMMUNICATION** between the ROC and Dam Tender.

   a. The Reservoir Operations Center will provide gate settings to the dam tender in accordance with the NORMAL COMMUNICATION schedule.

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

2. **NO COMMUNICATION** between the ROC and Dam Tender.

   a. Try to reestablish communication through the Orange County Environmental Management Agency's (OCEMA) Storm Operations Center via telephone at (714) 567-6300.

   b. Attempt to reestablish communication with the District Office for a period of four (4) hours. If after four (4) hours, communication cannot be reestablished, follow the **"NO-COMMUNICATION"** schedule.

   c. When making gate changes, make sure that the "Gate Change Restrictions" as described in the following table are not exceeded.

   Maximum Permissible Rate of Release Change at Prado Dam

Current Release (cfs)	Maximum rate of Change per 1/2 hour (cfs)
0 - 300	100
300 - 1,000	250
1,000 - 2,500	400
2,500 - 5,000	625

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

PRADO DAM

RESERVOIR REGULATION SCHEDULE

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

RAINFALL RECORD

STATION				☐ HOURLY ☐ DAILY		DATE	
HR	DA	TIME OF READING	GAGE READING	STORM TOTAL	SEASON TOTAL	OBSERVER	REMARKS (SNOW, TEMP., ETC.)
0000	1						
0100	2						
0200	3						
0300	4						
0400	5						
0500	6						
0600	7						
0700	8						
0800	9						
0900	10						
1000	11						
1100	12						
1200	13						
1300	14						
1400	15						
1500	16						
1600	17						
1700	18						
1800	19						
1900	20						
2000	21						
2100	22						
2200	23						
2300	24						
2400	25						
	26						
	27						
	28						
	29						
	30						
	31						
TOTAL							

SPL FORM OCT 65 31   PREV. ED. OF THIS FORM MAY BE USED REPLACES SPL FORM 32 WHICH MAY BE USED

RECORD OF CALLS ☐ Radio ☐ Telephone

						DATE
LOCAL TIME	FROM		TO		CHECK REPTBLE CALLS*	MESSAGE OR REMARKS
	PERSON AND/OR CALL SIGN	TELEPHONE AND CITY	PERSON AND/OR CALL SIGN	TELEPHONE AND CITY		

Reportable telephone calls include collect calls, charge calls and long distance calls that can not be dialed without a code number. Calls are chargeable to MA 3-1311 unless otherwise indicated.

SPL FORM 29 APR 59 188   PREVIOUS EDITIONS ARE OBSOLETE

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SPL FORM 31: RAINFALL RECORD
AND
SPL FORM 188: RECORD OF CALLS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT B

PERTINENT DATA SHEETS FOR SAN ANTONIO DAM,

CARBON CANYON DAM, AND

VILLA PARK DAM

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

Exhibit B

SAN ANTONIO DAM AND RESERVOIR
LOS ANGELES AND SAN BERNARDINO COUNTIES, CALIFORNIA

PERTINENT DATA
(REVISED MAY 1983)

Stream System		San Antonio Creek
Drainage Area	sq. mi	26.7
Reservoir:		
Elevation		
Streambed at upstream toe of dam	ft, m.s.l	2,125
Debris pool	ft, m.s.l	2,164
Flood control pool (spillway crest)	ft, m.s.l	2,238
Streambed design surcharge level	ft, m.s.l	2,254.9
Top of dam	ft, m.s.l	2,260
Area		
Debris pool	acres	44.4
Spillway crest	acres	145
Spillway design surcharge level	acres	163.5
Top of dam	acres	168.1
Capacity, gross		
Debris pool	acre-ft	466.9 (0.33*)
Spillway crest	acre-ft	7,703.2 (5.41*)
Spillway design surcharge level	acre-ft	10,298.6 (7.23*)
Top of dam	acre-ft	11,144.2 (7.83*)
Allowance for sediment (50-year)	acre-ft	2,000 (1.40*)
Dam: - Type	Earth	
Height above original streambed	ft	160
Top length	ft	30
Top width	ft	3,960
Freeboard	ft	5.1
Spillway: - Type		Ungated ogee
Crest length	ft	200
Design surcharge	ft	16.9
Design discharge	c.f.s	53,700
Outlets:		
Gates - Type		Vertical lift
Number and size		3-5'-8"W x 10'H
Gate sill elevation	ft., m.s.l	2,125
Conduits		
Number and size - diameter	ft	1-14.5
Length	ft	508
Maximum capacity at spillway crest	c.f.s	11,800
Regulated capacity at spillway crest	c.f.s	8,000
Reservoir design flood:		
Duration (inflow)	Days	2
Total volume	acre-ft	22,500 (15.68*)
Inflow peak	c.f.s	19,000
Spillway design flood:		
Duration (inflow)	Days	1
Total volume	acre-ft	18,200 (12.69*)
Inflow peak	c.f.s	60,000
Historic maximums:		
Maximum release	c.f.s	8,420
Date		1-25-69
Maximum water surface elevation	ft., m.s.l	2225.6
Date		2-19-80

Inches in runoff

Exhibit B

CARBON CANYON DAM AND RESERVOIR
ORANGE COUNTY, CALIFORNIA

PERTINENT DATA
(REVISED MAY 1983)

Stream System		Carbon Creek
Drainage Area	sq. miles	19.3
Reservoir:		
Elevation		
Streambed at dam	ft, m.s.l	403
Flood control pool (spillway crest)	ft, m.s.l	475
Spillway design surcharge level	ft, m.s.l	493.7
Top of dam	ft, m.s.l	499
Area		
Spillway crest	acres	224.6
Spillway design surcharge level	acres	287.2
Top of dam	acres	305.6
Capacity, gross		
Spillway crest	acre-ft	6,614.1 (6.43*)
Spillway design surcharge level	acre-ft	11,322.8 (11.0*)
Top of dam	acre-ft	12,898.7 (12.53*)
Allowance for sediment (50-year)	acre-ft	1,500 (1.46*)
Dam: - Type	Earthfill	
Height above original streambed	ft	99
Top length	ft	2,610
Top width	ft	20
Freeboard	ft	5.3
Spillway: - Type		Ungated, broad-crested
Crest width	ft	125
Design surcharge	ft	18.7
Design discharge	c.f.s	36,800
Outlets:		
Gates - Type		Hydraulic slide
Number and size		2-5'W x 6.5'H
Sill elevation	ft., m.s.l	403
Conduits - Type		Rectangular
Number and size		1-4.75'W x 7'H
Length (including transition section)	ft	549
Invert elevation at intake	ft., m.s.l	403
Discharge at spillway crest elevation	c.f.s	1,270
Discharge at top of dam elevation	c.f.s	1,480
Reservoir design flood:		
Duration (inflow)	Days	2
Total volume	acre-ft	8,030 (7.80*)
Inflow peak	c.f.s	9,300
Spillway design flood:		
Duration (inflow)	Days	1
Total volume	acre-ft	11,800 (11.46*)
Inflow peak	c.f.s	52,000
Historic maximums:		
Maximum release	c.f.s	446
Date		2-25-69
Maximum water surface elevation	ft., m.s.l	430.9
Date		3-1-83

*Inches in runoff

Exhibit B

VILLA PARK DAM AND RESERVOIR
ORANGE COUNTY, CALIFORNIA
PROJECT OWNER AND OPERATOR: OCEMA

PERTINENT DATA
(FROM "VILLA PARK OPERATION MANUAL" DATED NOVEMBER 1984)

Construction Completed		1963
Stream System		Santiago Creek
Drainage Area	sq. miles	83.4
Reservoir:		
Elevation		
Streambed at dam	ft, m.s.l	480
Debris pool	ft, m.s.l	510
Spillway crest	ft, m.s.l	566
Spillway design surcharge level	ft, m.s.l	577
Top of dam	ft, m.s.l	584
Area		
Debris pool	acres	65
Spillway crest	acres	480
Spillway design surcharge level	acres	540
Top of dam	acres	570
Capacity, gross (January 1971 Survey)		
Debris pool	acre-ft(in.)	700 (0.16*)
Spillway crest	acre-ft	16,000 (3.60*)
Spillway design surcharge level	acre-ft	21,800 (4.91*)
Top of dam	acre-ft	25,000 (5.63*)
Dam: - Type	Earthfill	
Height above original streambed	ft	104
Top length	ft	1,460
Top width	ft	20
Freeboard	ft	7
Spillway: - Type		Detached, broad-crested
Crest width	ft	200
Crest elevation	ft	566
Design surcharge	ft	11
Design discharge	c.f.s	29,000
Outlets:		
Gates - Type		Hydraulic slide
Number and size		3 - 6'W x 12'H
Sill elevation	ft., m.s.l	484
Conduits		
Number and Size		1 - 13'W x 13'H
Length	ft	440
Discharge at spillway crest elevation	c.f.s	6,000
Regulated capacity at spillway	c.f.s	6,000
Reservoir Project Design Flood (OCEMA routing - 6,000 cfs max outflow):		
Duration (inflow)	Days	1
Total volume	acre-ft	33,500 (7.54*)
Maximum Water Surface Elevation	ft	571.5
Inflow peak	c.f.s	24,500
Outflow peak	c.f.s	9,200

*Inches in runoff

EXHIBIT C

PRADO DAM QPF/API INFLOW VOLUME FORECAST METHOD

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

PRADO DAM QPF/API INFLOW VOLUME FORECAST METHOD

PRADO DAM WATER CONTROL MANUAL

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LIST OF PLATES FOR EXHIBIT C

Exhibit C

I - PROCEDURE OUTLINE

PURPOSE: Given a current Antecedent Precipitation Index (API) value for the Prado Basin and a 24hr basin average Quanitative Precipitation Forecast (QPF), a forecast inflow volume to Prado Reservoir can be determined.

1-01 <u>QPF/API Inflow Volume Forecast Method</u>. The QPF/API inflow volume forecast method was developed by the Reservoir Regulation Section, LAD. An unpublished study dated August 1989 entitled "Inflow Forecasting for Incidental Flood Season Water Conservation" was prepared using historical precipitation data from the NWS and historical inflow records from the Corps. In order to obtain a flood inflow volume forecast a BASIN AVERAGE API and BASIN AVERAGE QPF must be generated from the ZONAL AVERAGE precipitation and the ZONAL AVERAGE QPF values. The zones of interest are zones 1 through 5 of the Santa Ana River Watershed (Plate 6-02). The basin average API and QPF values are not required for zones 7 and 8 because Lake Elsinore normally traps the runoff from these two sub-basins. Zone 6 is not considered because it is downstream of Prado Dam.

The method of determining the basin average precipitation and the QPF is as follows:

$$P_j=\sum_{i=1}^{5} C_i P_{ij} \qquad \text{(Eq. C-01)}$$

$$QPF=\sum_{i=1}^{5} C_i QPF_i \qquad \text{(Eq. C-02)}$$

where:

P_j	=	the basin average precipitation for day j;
QPF	=	the basin average Quantitative Precipitation Forecast (QPF);
C_i	=	the zonal weighting factor for zone i;
P_{ij}	=	the zonal precipitation for zone i, day j; and
QPF_i	=	the QPF for zone i.

Table C-1 gives the zonal weighting factors for the five zones. These values were determined by considering the basin size and physiography.

The API is calculated using:

$$API_j = k\,(API_{j-1}) + P_j \qquad \text{(Eq. C-03)}$$

where:

API_j	=	the API on the day j;
k	=	a recession constant (assumed to be 0.90);
API_{j-1}	=	the API of the previous day (i.e., at 2400 hours of the previous day); and
P_j	=	the basin average precipitation for day j (i.e., from 0000 hours to the present time).

Once the basin average API_j (Eq. C-03) and the basin average QPF (Eq. C-02) have been calculated, the forecast inflow volume to Prado Dam is read off of Plate C-01.

The QPF/API Algorithm was newly developed in 1989. Care should be exercised when using it. As experience is gained in actual use, modifications may be necessary.

II - EXAMPLE APPLICATION OF THE METHOD

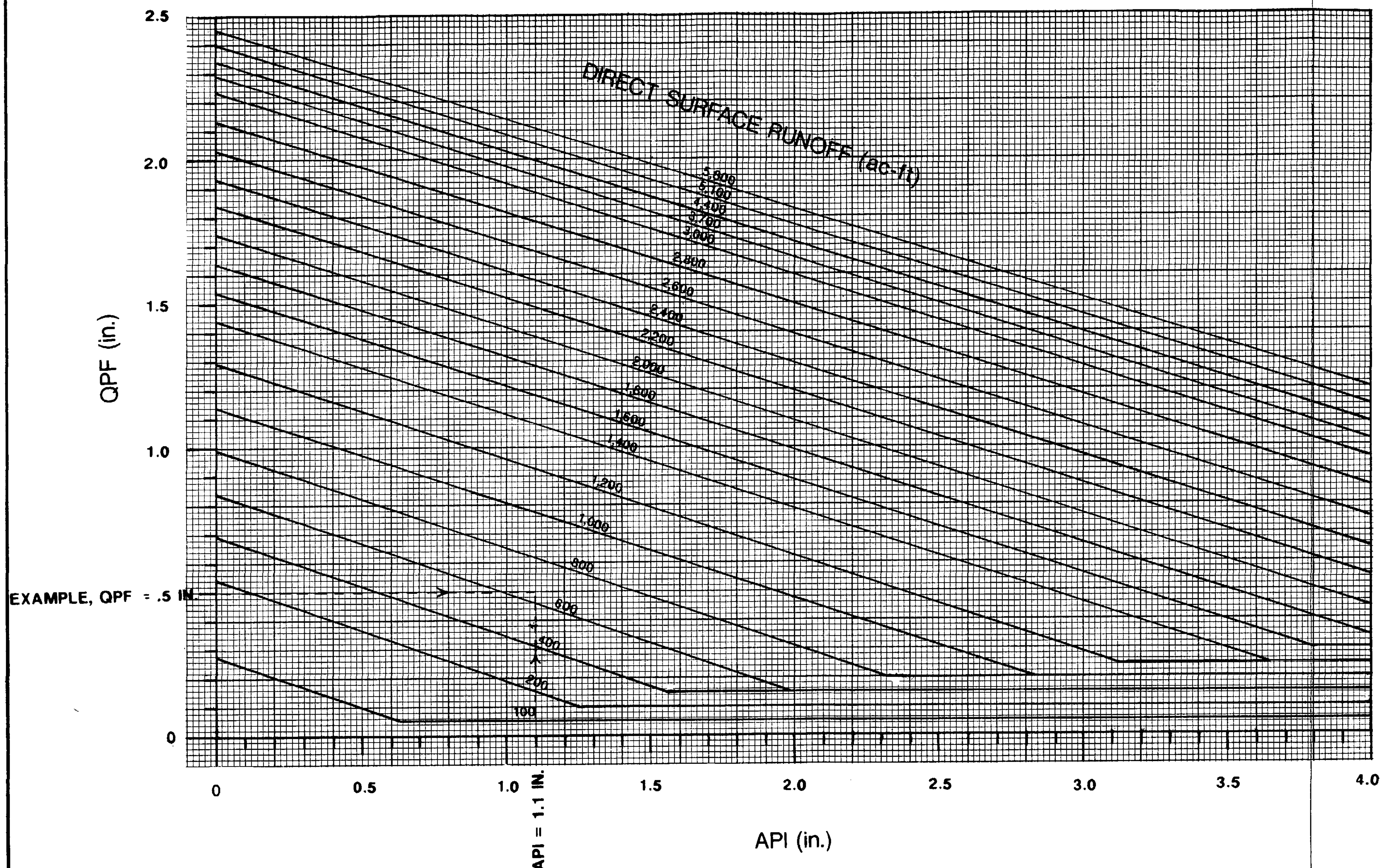
2-01 Example Problem. An example problem is illustrated on Plate C-01.

Exhibit C

Table C-1

Precipitation Zone
Weighting Factors

Zone (i)	Zonal Weighing Factor (c_i)
1	0.12
2	0.14
3	0.12
4	0.41
5	0.21



For Example: If the QPF for the five zones are:

Zone	Zonal QPF (inches)
SA01	0.9
SA02	0.5
SA03	0.8
SA04	0.3
SA05	0.4

The Average Basin QPF is calcilated using the Zonal weighting factors:

Zone	Zonal QPF (inches)		Zonal weighing factor		
1	0.9	X	0.12	=	0.1
2	0.5	X	0.14	=	0.1
3	0.8	X	0.12	=	0.1
4	0.3	X	0.41	=	0.1
5	0.4	X	0.21	=	0.1
	Average Basin QPF				0.5

If the API were currently 1.1 inches, as determined by the calculation described in Exhibit C, the forecasted inflow into Prado would be approximately 700 ac-ft as shown on the QPF/API correlation to the left.

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

QPF/API FORECAST INFLOW

VOLUME CORRELATION

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT D

PRADO DAM RECESSION LIMB INFLOW FORECAST MODEL

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

PRADO DAM RECESSION LIMB INFLOW FORECAST MODEL

PRADO DAM WATER CONTROL MANUAL

TABLE OF CONTENTS FOR EXHIBIT D

LIST OF PLATES FOR EXHIBIT D

Exhibit D

I - PROCEDURE OUTLINE

PURPOSE: This procedure produces a recession limb hydrograph for a flood event. It can only be used after the peak inflow to Prado Reservoir has occurred.

1-01 Introduction. The recession forecast model is based on a historical analysis of 17 floods which was prepared by the Reservoir Regulation Section of the LAD in the early 1980's. The model employs a graphical procedure to forecast the recession curve from the peak to seven days into the future.

1-02 Procedure. The following outlines the eleven step procedure for preparing a forecast recession limb inflow hydrograph to Prado Dam.

a. Step 1. Plot the existing inflow hydrograph on 3-cycle semi-log paper with a range of 100,000 cfs on the log scale and 2 hours per division on the arithmetic scale.

b. Step 2. Determine the volume of inflow for the current water year, i.e., 1 October to the time of forecast. Option 6 of the LAD's RESCAL program can be used to determine this volume.

c. Step 3. Determine the first inflection point from Plate D-01. Note that the first inflection point must be less than the peak inflow. If this is not the case, one cannot use this forecast model. Retain this value for Step 5.

d. Step 4. Determine the time in hours between the peak and the first inflection point using the following equation:

$$T_1 = 20.41\ (\log(Q_{peak}) - \log(Q_{1st\ IP})) \qquad \text{(Eq. D-1)}$$

where:

T_1 = the time in hours between the peak inflow and the first inflection point;
Q_{peak} = the peak inflow in cfs;
$Q_{1st\ IP}$ = the first inflection point flow in cfs. Obtained from Plate D-01. Note that Q_{peak} must be greater than $Q_{1st\ IP}$.

e. Step 5. Draw a straight line from the peak inflow to the 1st inflection point (determined in step 3) using the T_1 calculated from Eq. D-1.

f. Step 6. Determine the volume of inflow for the past 30 days. Again option 6 of the LAD's RESCAL program can be used to determine this volume.

g. Step 7. Determine the second inflection point from Plate D-02. Note that the second inflection point must be less than the first inflection point. If this is not the case, this method cannot be used. Retain this value for Step 9.

h. Step 8. Determine the time in hours between the first inflection point and the second inflection point using the following equation:

$$T_2 = 81.65\ (\log(Q_{1st\ IP}) - \log(Q_{2nd\ IP})) \qquad \text{(Eq. D-2)}$$

where:

T_2 = the time in hours between the first inflection point and the second inflection point;
$Q_{1st\ IP}$ = the first inflection point in cfs;
$Q_{2nd\ IP}$ = the second inflection point flow in cfs. Obtained from Plate D-02. Note that $Q_{1st\ IP}$ must be greater than $Q_{2nd\ IP}$.

i. Step 9. Draw a straight line from the first inflection point to the second inflection point (determined in step 7) using the T_2 calculated from Eq. D-2.

j. Step 10. Determine the time in hours between the second inflection point and the base flow using the following equation:

$$T_3 = 228.62\ (\log(Q_{2nd\ IP}) - \log(Q_{BF})) \qquad \text{(Eq. D-3)}$$

where:

T_3 = the time in hours between the second inflection point and the base flow;
$Q_{2nd\ IP}$ = the second inflection point in cfs;
Q_{BF} = the base flow in cfs.

Draw a straight line from the second inflection point to the base flow using the T_3 calculated from Eq. D-3.

k. Step 11. The resulting plot is the forecast inflow hydrograph.

II - EXAMPLE APPLICATION OF THE FORECAST MODEL

2-01 Storm of 17-18 February 1990. The following example uses the inflow hydrograph from the storm of 17-18 February 1990. The winter storm was winding down at the time the forecast was prepared. The peak of 4,400 cfs shown on Plate D-03 was a secondary peak. The primary peak of 8,000 cfs had occurred about 10 hours earlier. The time of forecast was 1000 on 18 February 1990.

a. Step 1. The dashed line on Plate D-03 shows the inflow hydrograph for the recession portion of the storm event. At the time of forecast only the portion of the hydrograph up to 1000 on 18 February 1990 was known.

b. Step 2. Using option 6 of the RESCAL program, the total inflow volume from 1 October 1989 to 1000 18 February 1990 was determined to be 168,800 ac-ft.

c. Step 3. From Plate D-01 the first inflection point inflow is found to be 1,300 cfs.

d. Step 4. Using Eq. D-1 the T_1 is calculated to be:

$T_1 = 20.41\ (\log(4{,}400) - \log(1{,}300))$

$T_1 = 10.8$ hours = 11 hours

e. Step 5. Therefore the first inflection point occurs at 1900 hours on 18 February 1990. A straight line is drawn from the peak at 0800 18FEB90 to the first inflection point at 1900 18FEB90.

f. Step 6. The inflow volume for the past 30 days is also found by using option 6 of the RESCAL program. The inflow volume was 23,329 ac-ft.

g. Step 7. From Plate D-02 the second inflection point is found to be 775 cfs.

h. Step 8. Using Eq. D-2 the T_2 is calculated to be:

$T_2 = 81.65\ (\log(1{,}300) - \log(775))$

$T_2 = 18.3$ hours = 18 hours

Therefore the second inflection point occurs at 1300 19 February. A straight line is drawn from the first inflection point at 1900 18FEB90 to the second inflection point at 1300 19FEB90.

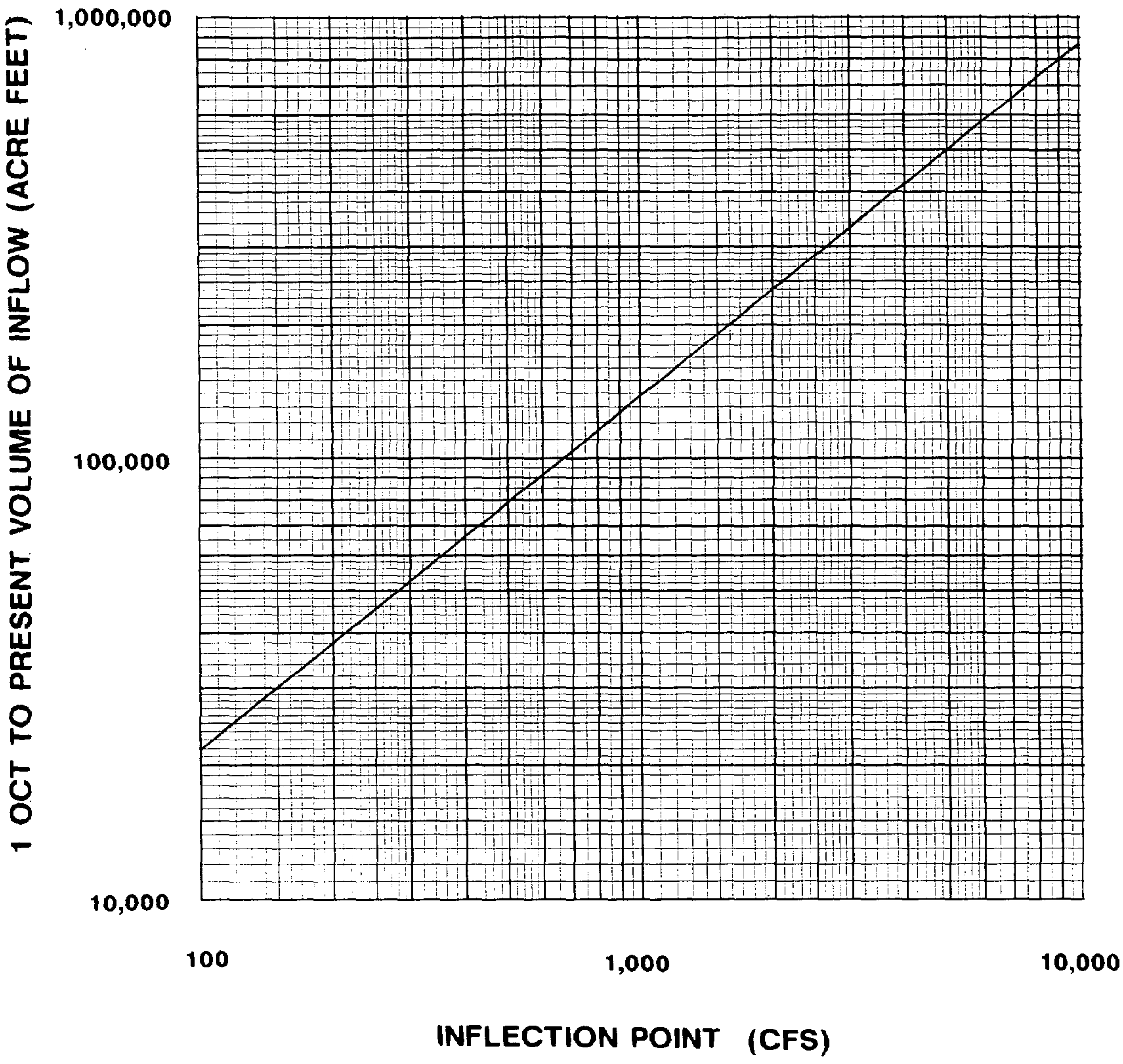
i. <u>Step 9</u>. The base flow for prior to the runoff event was approximately 200 cfs. Using Eq. D-3 the T_3 is calculated to be:

T_3=228.62 (log(775) - log(200))

T_3=134.5 hours = 135 hours

j. <u>Step 10</u>. Therefore the base flow is reached at 0400 25 February. A straight line is drawn from the second inflection point at 1300 19FEB90 to the base flow at 0400 25FEB90.

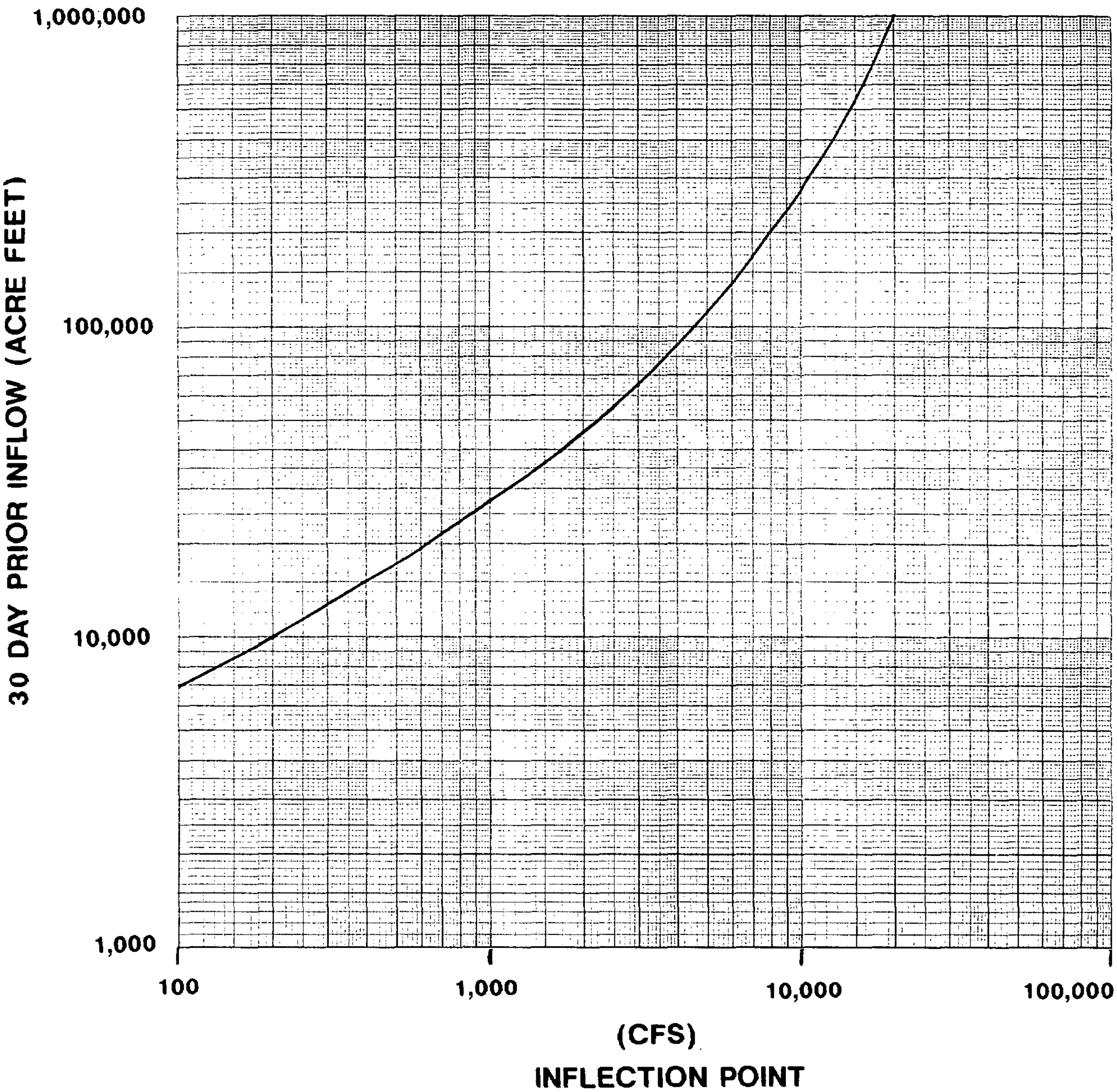
k. <u>Step 11</u>. The resultant plot (Plate D-03) is the forecast inflow hydrograph, which compares favorably with the actual inflow hydrograph.



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

FIRST INFLECTION POINT

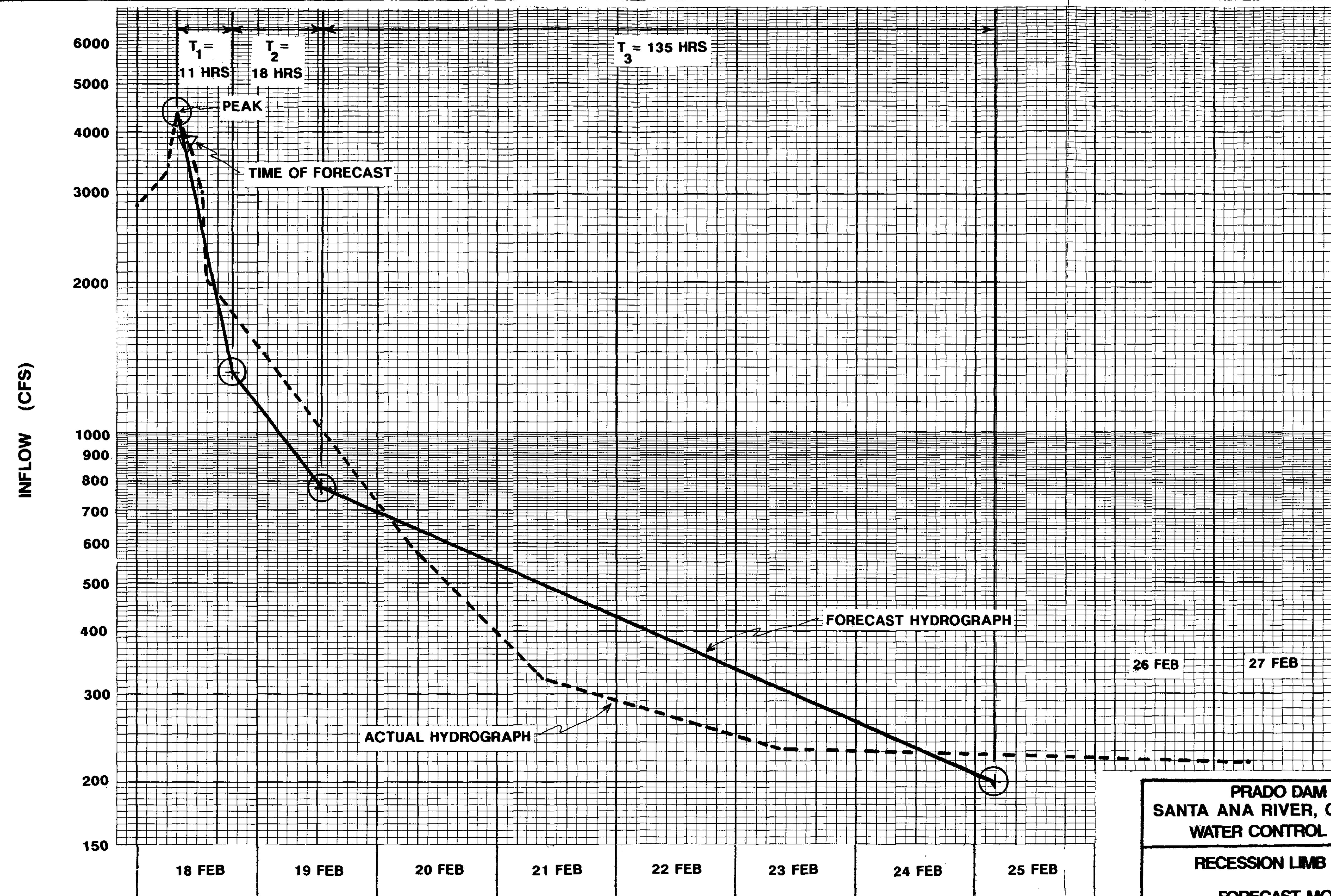
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

SECOND INFLECTION POINT

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

RECESSION LIMB INFLOW
FORECAST MODEL

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT E

EXAMPLES OF BUFFER POOL RELEASE SCHEDULE CALCULATIONS

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

EXAMPLES OF BUFFER POOL RELEASE SCHEDULE CALCULATIONS

PRADO DAM WATER CONTROL MANUAL

TABLE OF CONTENTS FOR EXHIBIT E

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Exhibit E

I - BUFFER POOL RELEASE SCHEDULE CALCULATION

PURPOSE: This algorithm determines the release rate necessary to accomplish one of the following two objectives: 1) to not exceed the buffer pool WSE 494-ft, or 2) to return the WSE to 490-ft so that flood control releases can be initiated. The magnitude of the inflow forecast and the current state of Prado Reservoir will determine which one of the above objectives will be meet.

1-01 Introduction. The following method of calculating a release schedule when the WSE is within the buffer pool was prepared by the Reservoir Regulation Section and was presented in an unpublished report entitled "Prado Dam - Flood Season Water Conservation", dated May 1989. The drawdown release rate can be determined using the algorithm described in Section I below or by a set of rule curves described in the following Section II. The graphical rule curves described in Section II provide a means of obtaining a quick and approximate drawdown release rate.

1-02 Step 1: Determine Drawdown Volume. The volume of water which must be released is the lesser of V_{dd1} and V_{dd2}:

$$V_{dd1} = V_{cur} + V_{for} - 8{,}915 \qquad \text{(Eq. E-1)}$$

$$V_{dd2} = V_{cur} - 4{,}474 \qquad \text{(Eq. E-2)}$$

where:

V_{dd} = the drawdown volume which is either V_{dd1} or V_{dd2} whichever is the smallest). If either V_{dd1} or V_{dd2} is negative then no release is required because the resulting forecast inflow will not cause the WSE at Prado to exceed 494-ft;

V_{cur} = the current reservoir volume in ac-ft;

V_{for} = the forecast inflow volume in ac-ft (obtained from either the QPF/API algorithm, the SARRT Water Control System, or the Recession Limb Inflow Forecast Model;

8,915 = the combined volume of the debris pool (4,474 ac-ft) and the buffer pool (4,441 ac-ft).

Exhibit E

IMPORTANT NOTE:

> If V_{dd1} is the smallest value then the resulting release rate will result in a WSE of 494-ft AFTER the forecast inflow arrives. In this case, this algorithm accounts for both the existing pool and the forecasted inflow.
>
> If V_{dd2} is the smallest value then the resulting release rate will result in drawing the pool down to WSE 490-ft BEFORE the forecast inflow arrives. For this case, this algorithm only accounts for the existing pool. It does not address the forecasted inflow. This means that a release schedule must still be prepared to handle the forecast inflow. (i.e., this case returns Prado to WSE 490-ft in anticipation of the incoming flood volume.)
>
> If either V_{dd1} or V_{dd2} is negative then the forecasted inflow will not cause the WSE to exceed 494-ft. Therefore no release schedule needs to be generated.
>
> In all cases the drawdown volume should not lower the water surface elevation below the debris pool elevation of 490-ft.

1-03 Step 2: Determine Drawdown Discharge. Once the drawdown volume is calculated, the drawdown discharge can be calculated by:

$$Q_{dd} = (12.1)\ (V_{dd} / T_{dd}) + Q_{bf} \qquad \text{(Eq. E-3)}$$

where:

Q_{dd}	=	the drawdown discharge in cfs;
V_{dd}	=	the drawdown volume obtained from Eq-1 or Eq-2;
12.1	=	the unit conversion constant;
T_{dd}	=	the time available to drawdown the reservoir in hours;
Q_{bf}	=	the current base flow in cfs.

1-04 Examples of Formulating a Reservoir Release Schedule. When water is impounded in the Buffer Pool the Water Control Manager will need to decide on which of the following types of releases need to be made from Prado Dam:

1. Water conservation releases which range from 200 to 500 cfs.

2. Flood-control releases which range from 500 to 2,500 cfs.

Flood control releases are initiated when inflow from a storm is so large that, even though the reservoir had been drawn-down to the top of the debris pool (WSE 490-ft.) prior to the onset of the storm, conservation drawdown releases are not sufficient to lower the pool back to elevation 490-ft. prior to the onset of the second forecast storm. The following four examples demonstrate the application of the buffer pool algorithms to different situations.

a. Example 1. A storm has been forecasted for the Santa Ana River basin. Current storage (V_{cur}) is 6,000 ac-ft (WSE 491.6-ft), forecasted inflow (V_{for}) is 8,000 ac-ft, and base flow (Q_{bf}) is 200 cfs. The runoff is expected to begin in 24 hours (i.e., T_{dd} is 24 hours) The drawdown volume is calculated using Eq. E-1:

$$V_{dd1} = V_{cur} + V_{for} - 8{,}915$$

$$V_{dd1} = 6{,}000 + 8{,}000 - 8{,}915 = 5{,}095 \text{ ac-ft}$$

however, Eq. E-2 results in a lower release volume:

$$V_{dd2} = V_{cur} - 4{,}474$$

$$V_{dd2} = 6{,}000 - 4{,}474 = 1{,}526 \text{ ac-ft}$$

Therefore, the drawdown volume is only 1,526 ac-ft.

The drawdown discharge is then calculated from Eq. E-3:

$$Q_{dd} = 12.1\ (V_{dd}/T_{dd}) + Q_{bf}$$

$$Q_{dd} = 12.1\ (1{,}526/24) + 200 = 969 \text{ cfs}$$

Since V_{dd2} was the lowest release volume, the resulting Q_{dd} will cause the pool to lower to WSE 490-ft in 24hrs., at which time a decision must be made regarding the 6,000 ac-ft of forecasted inflow.

b. Example 2. A storm has been forecasted for the Santa Ana River basin. Current storage (V_{cur}) is 6,000 ac-ft (WSE 491.6-ft), forecasted inflow (V_{for}) is 4,000 ac-ft, and base flow (Q_{bf}) is 200 cfs. The runoff is expected to begin in only 12 hours (i.e., T_{dd} is 12 hours) The drawdown volume is calculated using Eq. E-1:

$V_{dd1} = V_{cur} + V_{for} - 8{,}915$

$V_{dd1} = 6{,}000 + 4{,}000 - 8{,}915 = 1{,}085$ ac-ft

Eq. E-2 results in a higher release volume:

$V_{dd2} = V_{cur} - 4{,}474$

$V_{dd2} = 6{,}000 - 4{,}474 = 1{,}526$ ac-ft

Therefore, the drawdown volume from Eq. E-1 is used, i.e., 1,085 ac-ft.

The drawdown discharge is then calculated from Eq. E-3:

$Q_{dd} = 12.1\ (V_{dd}/T_{dd}) + Q_{bf}$

$Q_{dd} = 12.1\ (1{,}085/12) + 200 = 1{,}294$ cfs

Since V_{dd1} was the smallest release volume, the resulting Q_{dd} will cause the pool elevation to reach an elevation of 494-ft after the forecasted inflow arrives at Prado Dam.

c. Example 3. A storm has been forecasted for the Santa Ana River basin. Current storage (V_{cur}) is 6,000 ac-ft (WSE 491.6-ft), forecasted inflow (V_{for}) is 2,000 ac-ft, and base flow (Q_{bf}) is 200 cfs. The runoff is expected to begin in 24 hours (i.e., T_{dd} is 24 hours) The drawdown volume is calculated using Eq. E-1:

$V_{dd1} = V_{cur} + V_{for} - 8{,}915$

$V_{dd1} = 6{,}000 + 2{,}000 - 8{,}915 = -915$ ac-ft

Since the drawdown volume is negative, the pool will not rise above the buffer pool and no release is required prior to the storm.

d. Example 4. Same as example 3 above except that the actual storm produced 5,000 ac-ft of runoff instead of the forecasted 2,000 ac-ft. Since no drawdown release was made prior to the onset of the storm, the reservoir rose to an elevation of 495.5-ft (11,000 ac-ft). A new QPF is issued indicating that an additional 30,000 ac-ft of inflow will occur, beginning in 24 hours. The release determined by this new forecast is:

$$V_{dd1} = V_{cur} + V_{for} - 8,915$$

$$V_{dd1} = 11,000 + 30,000 - 8,915 = 32,085 \text{ ac-ft}$$

Eq. E-2 results in a lower release volume:

$$V_{dd2} = V_{cur} - 4,474$$

$$V_{dd2} = 11,000 - 4,474 = 6,526 \text{ ac-ft}$$

Therefore, the drawdown volume from Eq. E-2 is used, i.e., 6,526 ac-ft.

The drawdown discharge which would return the reservoir to the debris pool in preparation for the forecasted 30,000 ac-ft storm would be:

$$Q_{dd} = 12.1\ (V_{dd}/T_{dd}) + Q_{bf}$$

$$Q_{dd} = 12.1\ (6,526/24) + 200 = 3,490 \text{ cfs}$$

Note that this release is in excess of the 2,500 cfs maximum release from the buffer pool. The water control manager would therefore prepare a schedule which smoothly increases the outflow from Prado Dam to 2,500 cfs in preparation for WSE 494-520 regulation.

Note also that the buffer pool release determination is updated at intervals corresponding to receipt of revised QPF information and flood inflow volume forecasts.

II - BUFFER POOL RULE CURVES

2-01 Buffer Pool Rule Curves. The following set of rule curves has been developed which can be utilized in place of the algorithm described in the preceding sections of this exhibit. Following these rule curves will result in bringing the WSE to 494-ft after the forecasted inflow arrives at Prado Dam. To use the rule curves the water control manager requires:

1. The current pool elevation at Prado Dam.

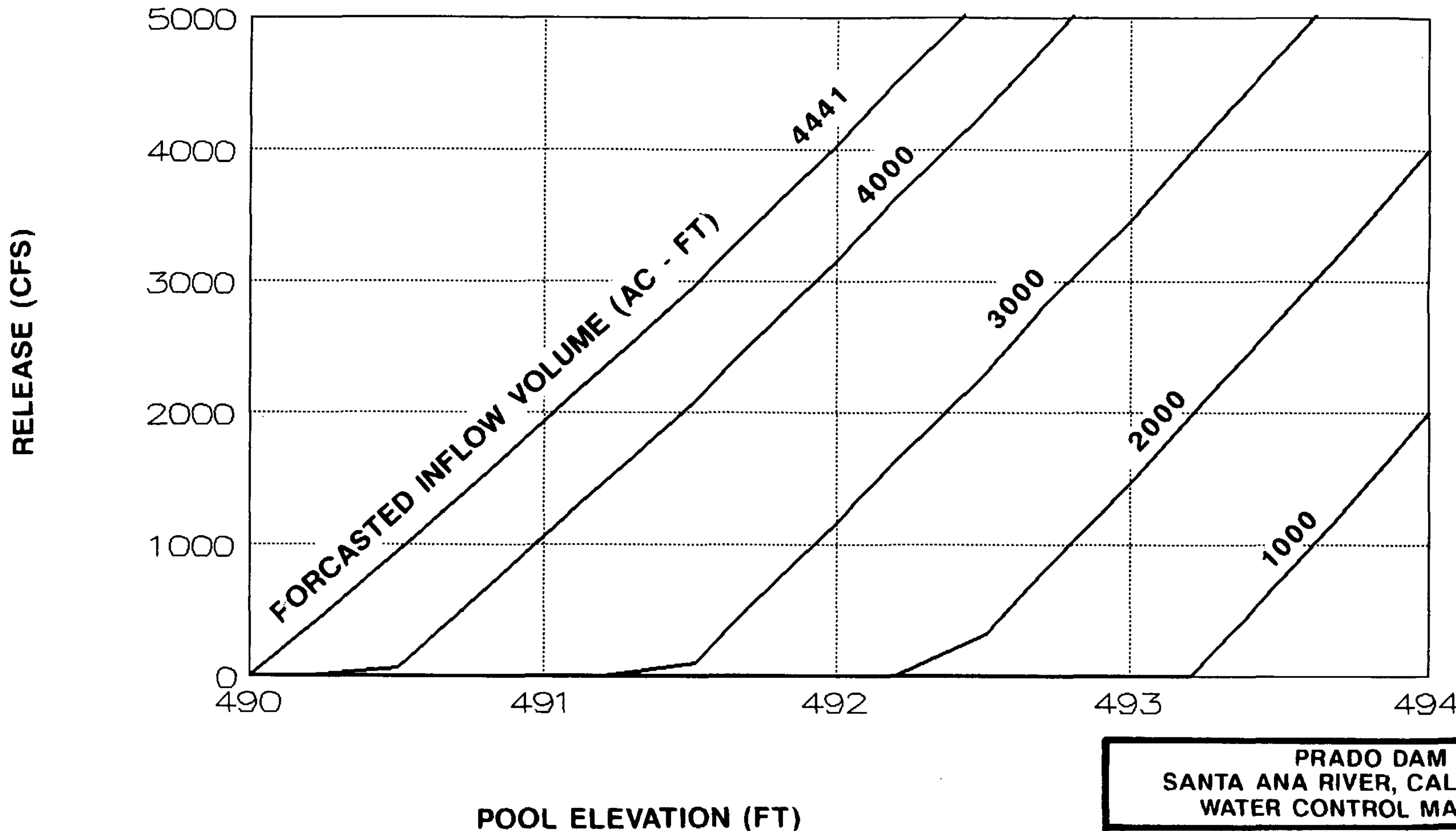
2. The forecast inflow volume in ac-ft (See Exhibit C).

3. The time to drawdown, T_{dd}, usually equal to the forecast time.

4. The base flow in cfs.

NOTE: IF YOUR CURRENT WSE OR THE FORECASTED INFLOW VOLUME FALL OUTSIDE THE LIMITS SHOWN ON THESE RULE CURVES, THEN YOU CANNOT USE THESE RULE CURVES. YOU MUST USE THE ALGORITHM OUTLINED IN SECTION I OF THIS EXHIBIT.

For example: If the current pool elevations were at 491.6-ft. and the forecasted inflow were 4,000 ac-ft twelve hours from now, one could use the 12 hour rule curve (Plate E-02) to determine that the required drawdown release rate should be approximately 1,200 cfs plus the base flow of 200 cfs making the required release 1,400 cfs.

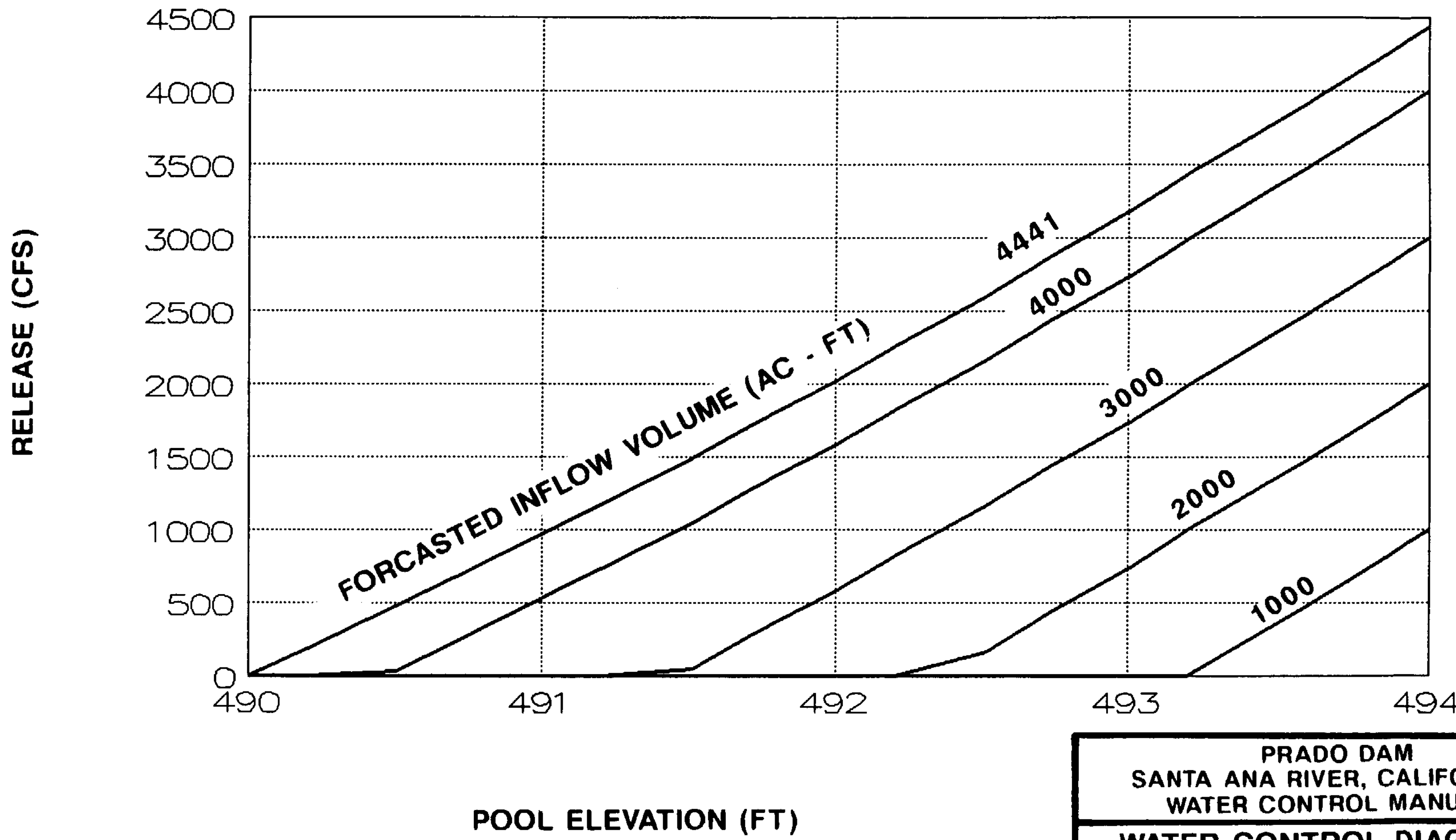


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH
DURATION OF DRAWDOWN: 6 HOURS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE E-01

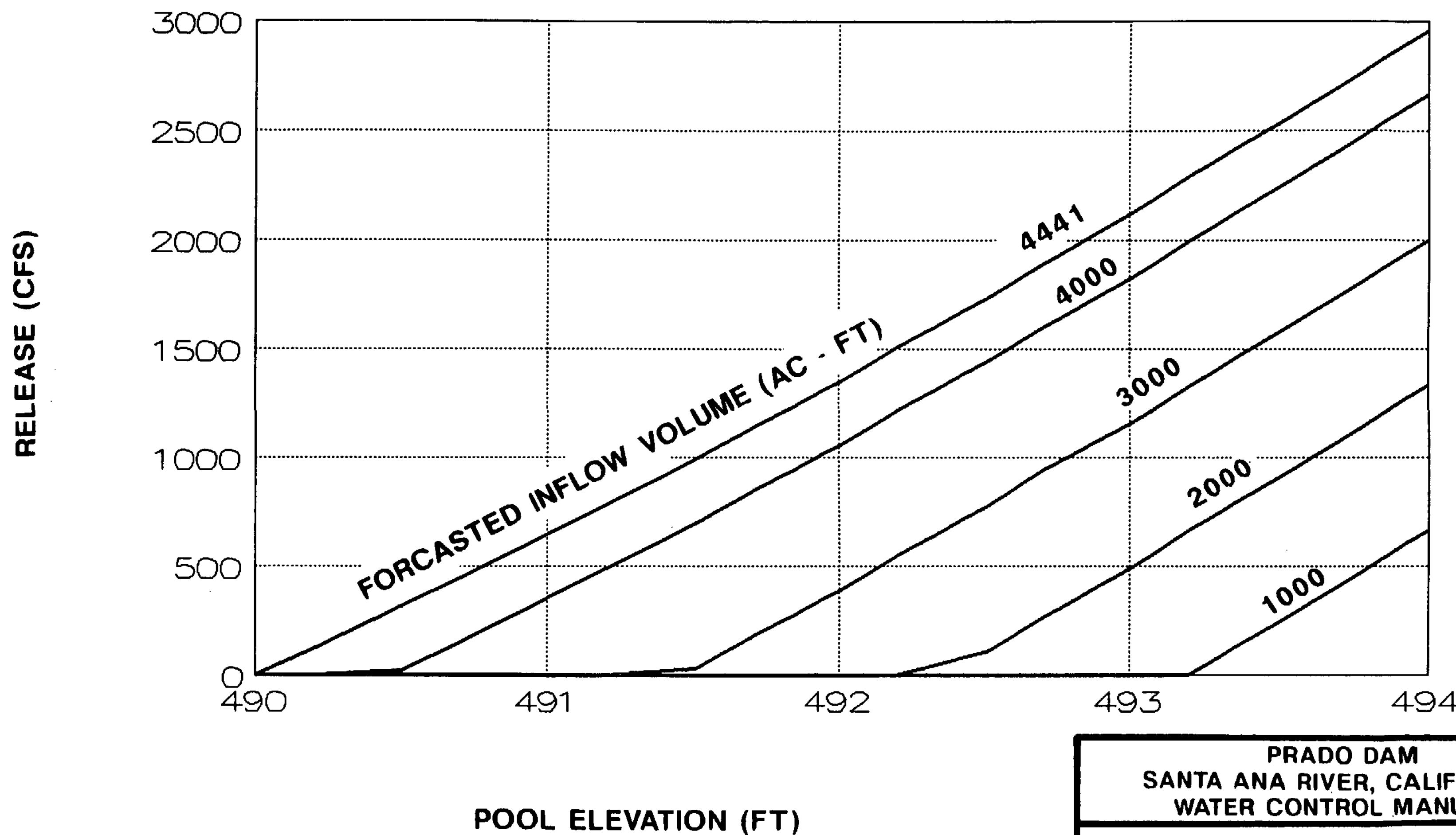


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH

DURATION OF DRAWDOWN: 12 HOURS

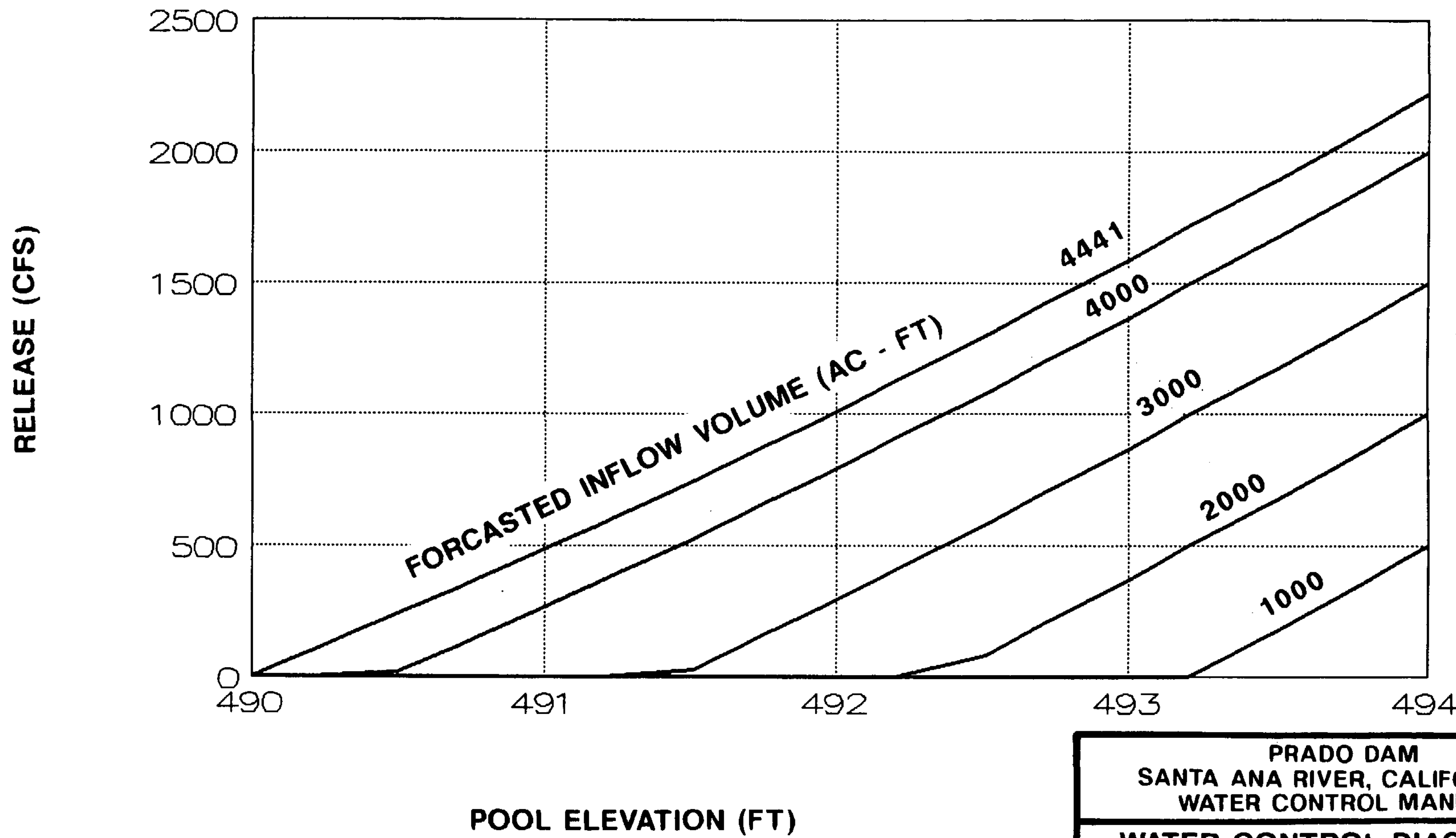
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH
DURATION OF DRAWDOWN: 18 HOURS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

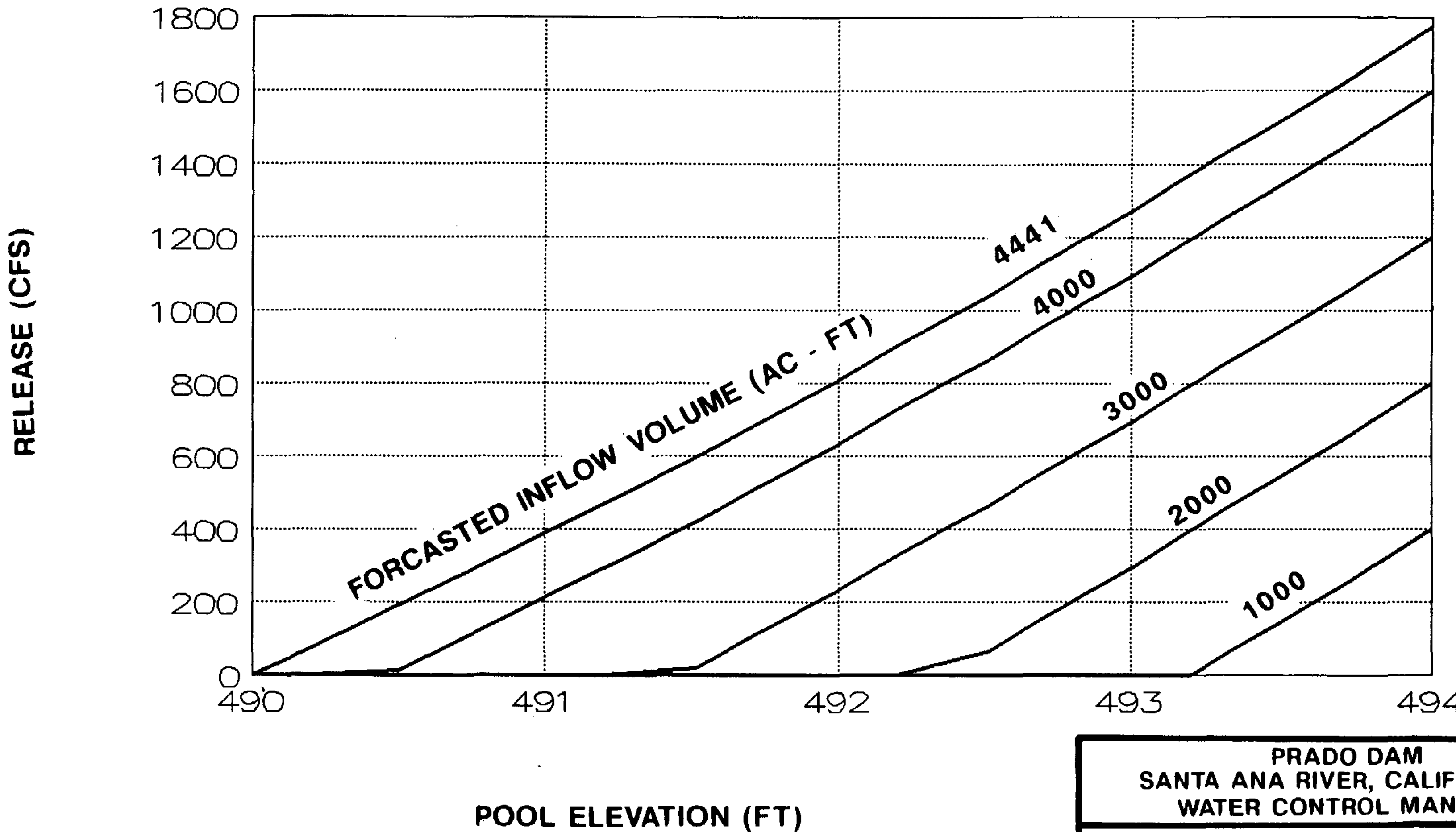


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH

DURATION OF DRAWDOWN: 24 HOURS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



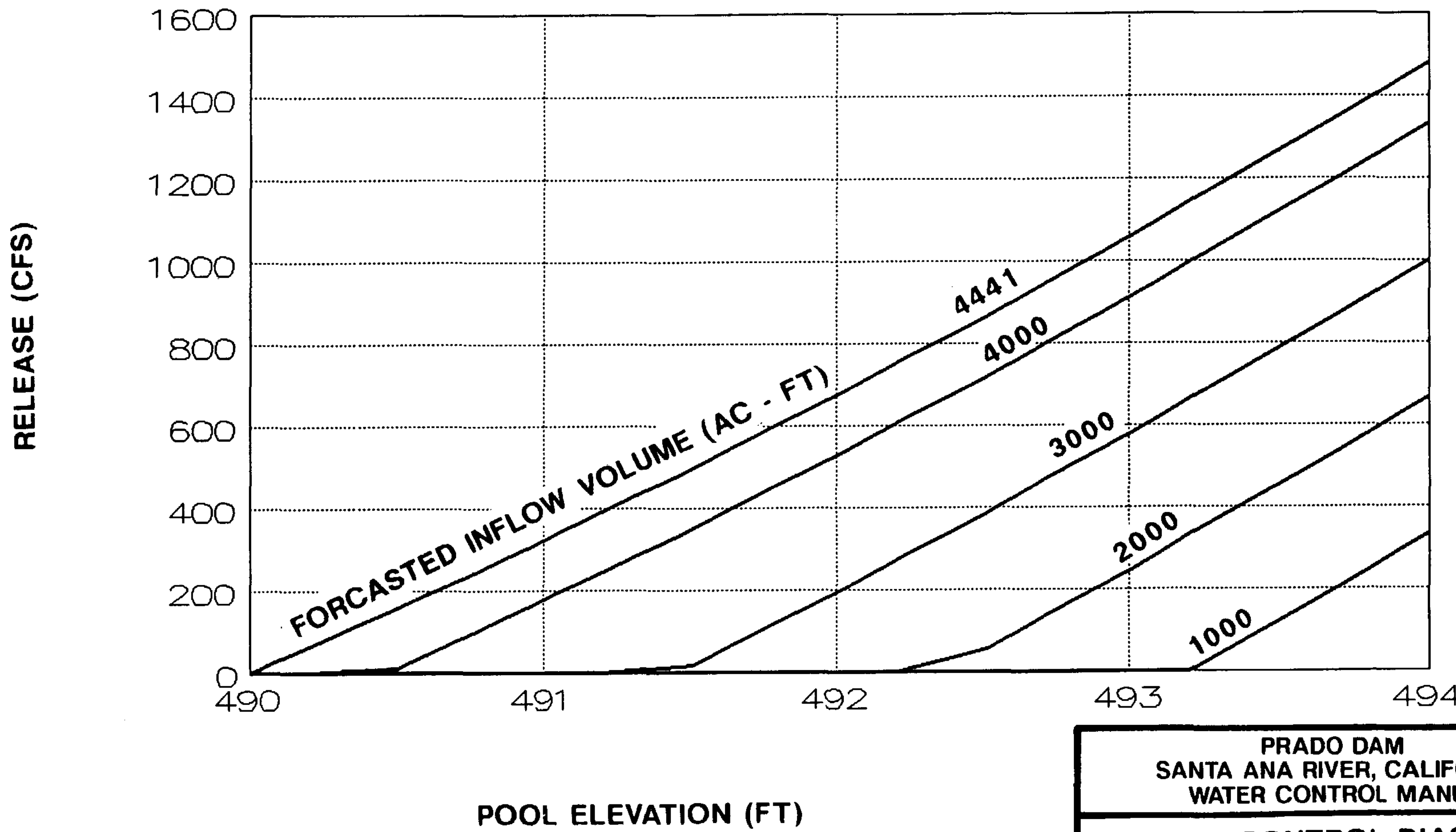
PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE

1 OCTOBER - 1 MARCH

DURATION OF DRAWDOWN: 30 HOURS

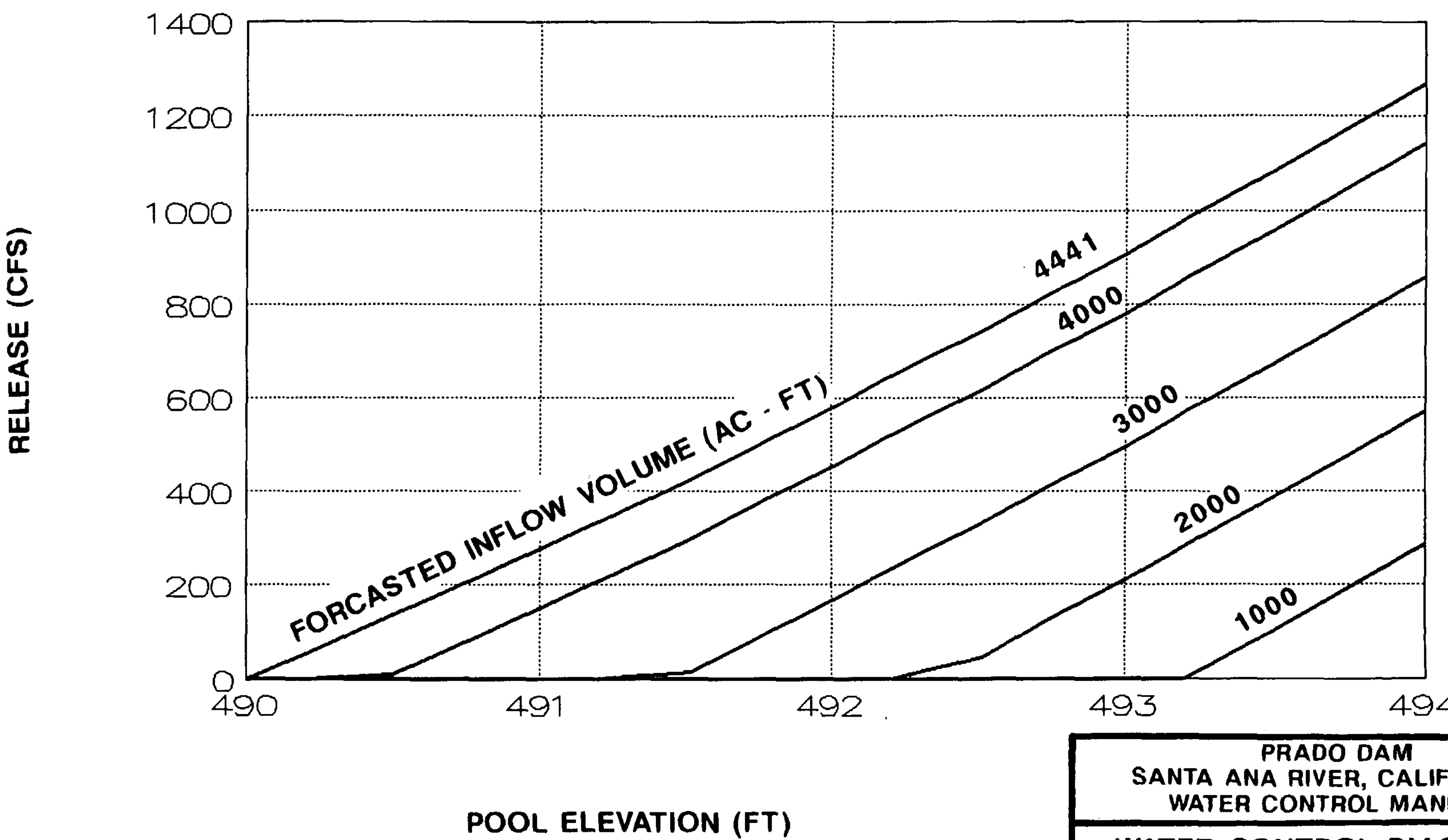
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH
DURATION OF DRAWDOWN: 36 HOURS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

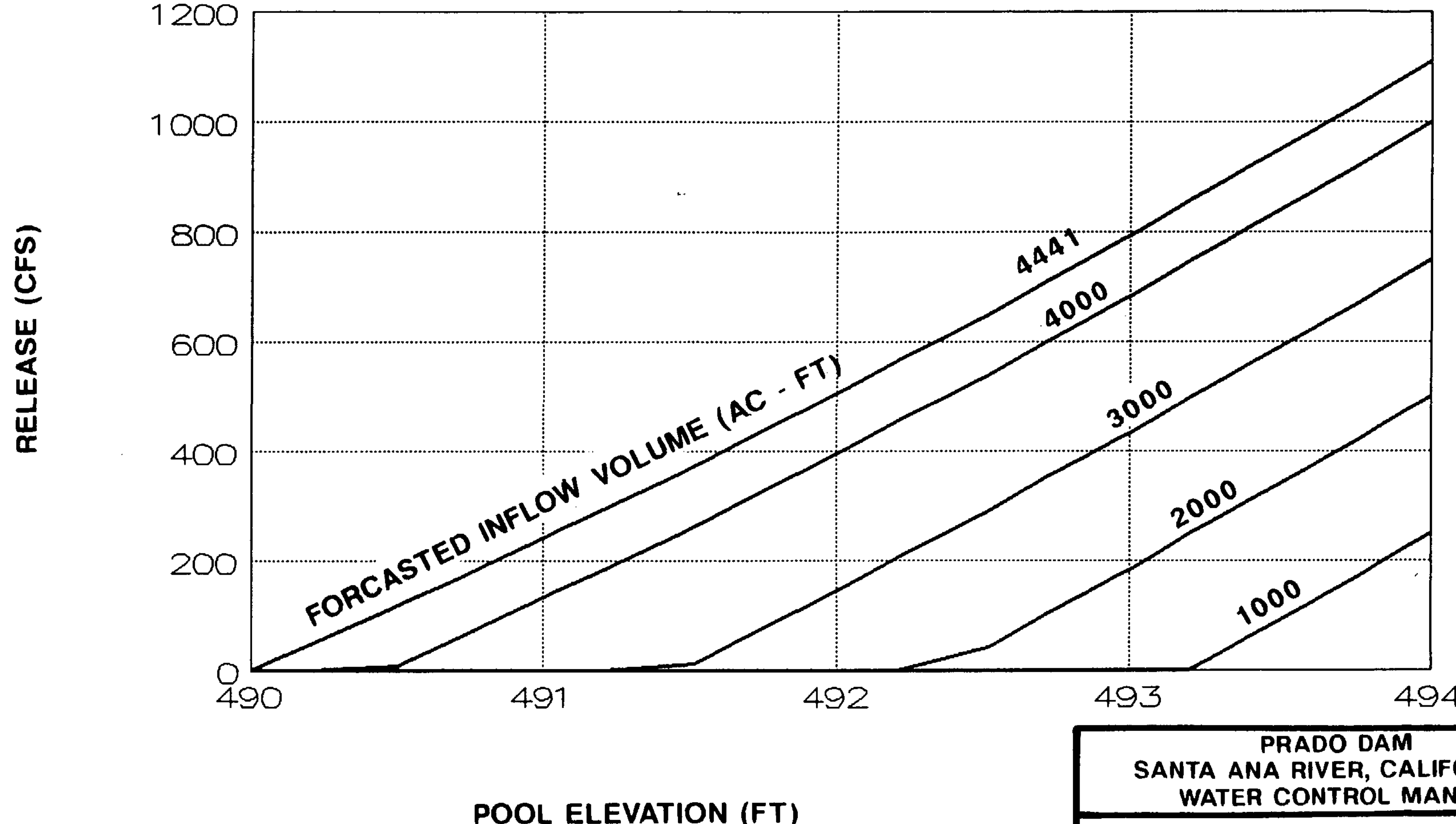


PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH

DURATION OF DRAWDOWN: 42 HOURS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

WATER CONTROL DIAGRAM
FOR RELEASE OF TEMPORARY WATER CONSERVATION STORAGE
1 OCTOBER - 1 MARCH
DURATION OF DRAWDOWN: 48 HOURS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT F

MONTHLY GATE EXERCISE

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

MONTHLY GATE EXERCISE

PRADO DAM WATER CONTROL MANUAL

TABLE OF CONTENTS FOR EXHIBIT F

LIST OF PLATES FOR EXHIBIT F

Exhibit F

I - PROCEDURE OUTLINE

1-01 Introduction. In order to ensure the operability of the Prado Dam outlet gates, it has been found necessary to periodically (normally monthly) raise and lower (exercise) each gate. When water is impounded at Prado Dam the water control manager must determine the time period between the exercising of each individual gate. These calculations are made to balance the outflow volume of the gate exercise with the outflow volume that would have been discharge without the gate exercise.

IMPORTANT NOTES

Gates are not to be exercised during Flood Control Operations.
Gates are not to be exercised when the WSE is above 494-ft.
During a gate exercise only one gate is ever open at any one time.

1-02 Procedure. The following three step calculation is used to determine the "time between gate openings" for each individual gate at Prado Dam (See Plate F-01). Note that the "time between gate openings" is not the time duration in which a gate is in the open position. During a gate exercise the gate is opened five feet and immediately closed. The "time between gate openings" includes the time that the single gate is opened and closed and a wait period when all gates remain closed. Plate F-01a graphically illustrates the "time between gate openings".

a. Step 1. Determine the instantaneous outflow of a single gate, open to 5.0-ft at the current WSE. Either option 12 of the RESCAL program or the gate rating curves on Plate 2-6a-d can be used to determine the instantaneous outflow.

b. Step 2. Calculate the volume of water released from opening one gate to 5.0-ft and then immediately closing it. Assume the gate can be opened and closed one foot per minute and that the resultant outflow hydrograph has a simple triangular form. The following equation can be used to determine the volume of a single gate opened to 5.0-ft and then immediately closed:

$$V = 0.007\ (Q_{Inst}) \qquad \text{(Eq. F-1)}$$

where:

V	=	the outflow volume in ac-ft of opening to 5.0-ft and immediately closing a single gate;
Q_{Inst}	=	the instantaneous outflow in cfs for a single gate open to 5.0-ft at the existing WSE.

c. Step 3. Determine the "time between gate openings" for each gate using:

$$T = 726 (V / Q_o) \qquad \text{(Eq. F-2)}$$

where:

T	=	the "time between gate openings" in minutes for the exercise of one gate. Note this is **not** the duration of time in which the gate is in the open position. The gate is opened to five feet and then immediately closed. See Plate F-01;
V	=	the outflow volume in ac-ft opening to 5.0-ft and immediately closing a single gate as calculated from Eq. F-1;
Q_o	=	the outflow in cfs prior to the gate exercise.

II - EXAMPLE APPLICATION OF A MONTHLY GATE EXERCISE

2-01 Example Problem. The following example assumes that the current WSE at Prado Dam is 493.0-ft and the current outflow from the Dam is 300 cfs.

a. Step 1. Using option 12 of the RESCAL program the instantaneous outflow for a single gate open to 5.0-ft and a WSE of 493.0-ft is 1,191 cfs.

b. Step 2. Plate F-01a graphically illustrates the simple triangular hydrograph of opening to 5.0-ft and immediately closing one gate. The outflow volume of this hydrograph can be calculated from Eq. F-1:

V = 0.007 (1,191 cfs)

V = 8.3 ac-ft

c. Step 3. Plate F-01b graphically illustrates the outflow prior to the gate exercise. To balance the release from the gate exercise with the prior release, it is necessary to determine the length of time that a 300 cfs release would take to equal 8.3 ac-ft. Eq. F-2 can be used to determine this length of time:

T = 726 (8.3 ac-ft / 300 cfs)

T = 20.1 minutes

Therefore the "time between gate openings" for exercising each individual gate is 20 minutes. The dam tender will start timing the gate exercise at the time the gate is opened. The gate is opened to five feet and then immediately closed. The dam tender will then wait until 20 minutes have passed before exercising the next gate or returning to the original gate settings. Plate F-01a illustrates this example gate exercise.

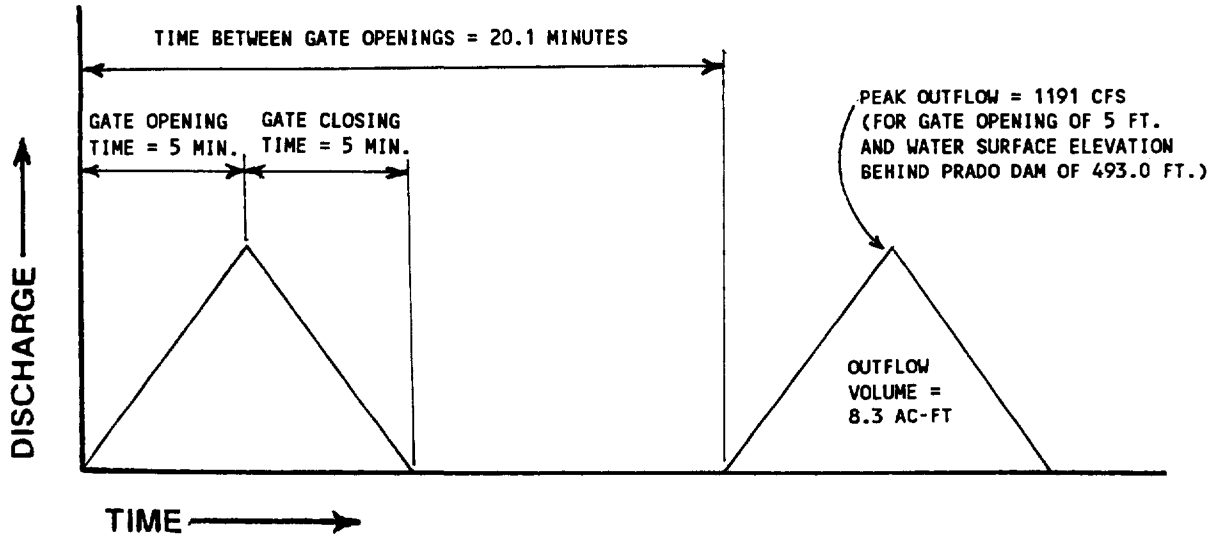


PLATE F-01a OUTFLOW DURING GATE EXERCISE

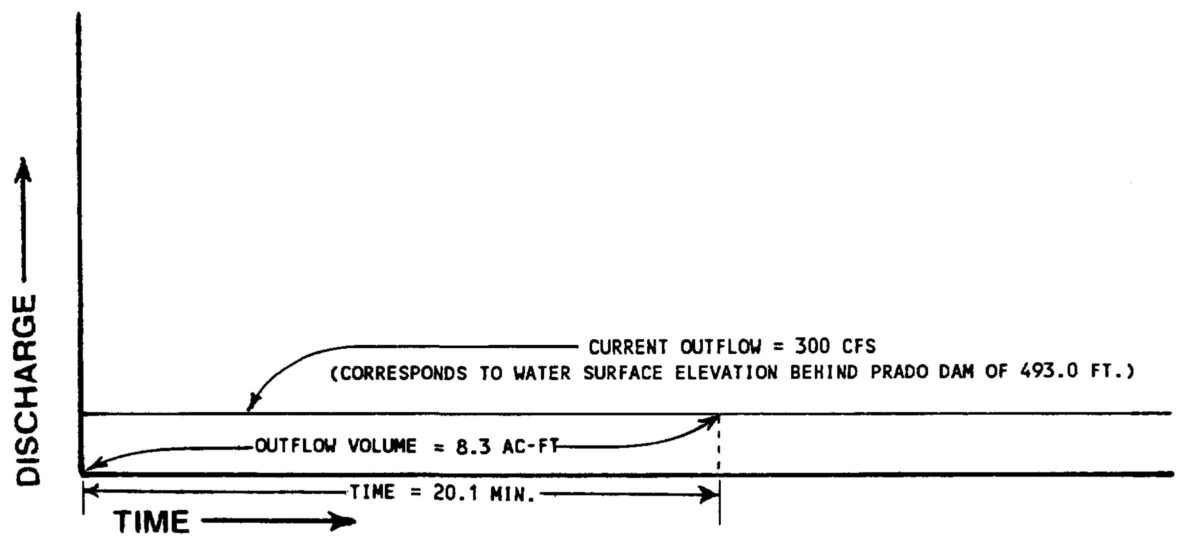


PLATE F-01b OUTFLOW PRIOR TO GATE EXERCISE

PRADO DAM
SANTA ANA RIVER, CALIFORNIA
WATER CONTROL MANUAL

EXAMPLE APPLICATION

OF A MONTHLY GATE EXERCISE

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT G

FINDING OF NO SIGNIFICANT IMPACT (FONSI)

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

U. S. Army Corps of Engineers
Los Angeles District

FINDING OF NO SIGNIFICANT IMPACT

For:

Prado Dam Water Control Manual
Santa Ana River, California

I have reviewed the attached Environmental Assessment (EA) prepared for the new Water Control Manual for Prado Dam, Santa Ana River, California. It provides information about the dam and reservoir, the Buffer Pool, water conservation activities, and descriptions of the organizations responsible for collecting data.

This Manual authorizes the reservoir manager the flexibility needed to optimize the diverse and often conflicting objectives under a variety of conditions. It also assists in protecting the habitat and continued presence of the least Bell's vireo, an endangered species. The Rincon Townsite, a National Register of Historic Places eligible property, is within the area of potential effects. It will not however be adversely effected by the implementation of the manual. Pursuant to Section 106 of the National Historic Preservation Act (36 CFR 800) we have informed the State Historic Preservation Officer of our determination. Subsequent concurrence from the Advisory Council on Historic Preservation constitutes compliance with the Act.

Consideration of all of the significant factors outlined in the EA and all pertinent environmental legislation indicates that the actions outlined in the proposed Manual would not significantly affect the quality of the human environment nor would there be adverse environmental effects. Due to the absence of significant project impacts I have determined that the preparation of an Environmental Impact Statement is not required.

Approved by:

Charles S. Thomas
Colonel, Corps of Engineers
District Engineer

14 Jun 91
Date

EXHIBIT H

CHAIN OF CORRESPONDENCE FOR APPROVAL OF THE PRADO DAM WATER CONTROL MANUAL

PRADO DAM

SANTA ANA RIVER

RIVERSIDE COUNTY, CALIFORNIA

Los Angeles District Office

U.S. Army Corps of Engineers

September 1991

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2711
LOS ANGELES, CALIFORNIA 90053-2325

REPLY TO
ATTENTION OF

CESPL-ED-HR

27 September 1991

MEMORANDUM FOR Commander, South Pacific Division,
ATTN: CESPD-ED-W

SUBJECT: Prado Dam and Reservoir Water Control Manual

1. Reference (CESPL-ED-HR/19 Jun 90) 1st End from CESPL-ED-W dated 28 September 1990.

2. Enclosure 1 is eight copies of the approved subject manual which has been modified as per comments provided in paragraph 2 of the referenced endorsement. Enclosure 2 is a summary of LAD's responses to each of the SPD comments.

3. Regarding paragraph 3 of the referenced endorsement, Enclosure 3 is a revised estimate of the average annual cost of operating an expanded pool (i.e., WSE 490-494 ft during the winter flood season) for water conservation activities. Enclosure 3 shows the breakdown of the $32,400 estimate to be $26,400 for regulation of the facility by the Reservoir Regulation Section and $6,000 for additional maintenance due to the increased inundation duration of the gates.

4. Regarding paragraph 4 of the referenced endorsement, coordination with the Orange County Water District (OCWD) regarding reimbursement of costs to the Corps has occurred in conjunction with the Prado Dam Water Conservation Study. Article 1 of the DRAFT MOA, scheduled for SPD review in November 1991, between the LAD and the OCWD on "The Regulation of Prado Dam for Seasonal Water Conservation", states that:

> OCWD shall pay all costs associated with regulation of the reservoir for water conservation.

Three costs are identified in Article 1 of the DRAFT MOA. They are (1) the additional maintenance costs due to prolonged gate inundation, (2) the costs for regulating Prado Dam for a Seasonally Expanded Pool, and (3) the costs for regulating Prado Dam for water conservation under the currently approved Water Control Plan (referred to as the "Base Plan" in the Prado Dam Water Conservation Study). Therefore, reimbursement of costs for the currently approved Water Control Plan will commence with the signing of the above mentioned MOA.

CESPL-ED-HR
SUBJECT: Prado Dam and Reservoir Water Control Manual

5. Enclosure 4 is a copy of the final EA which was prepared for the subject Water Control Manual. A copy of the signed FONSI is located in Exhibit G of the subject Water Control Manual.

FOR THE COMMANDER:

4 Encls

ROBERT E. KOPLIN, PE
Chief, Engineering Division

CESPL-ED-HR 15 August 1991

LOS ANGELES DISTRICT RESPONSES TO SPD
COMMENTS DATED 20 AUGUST 1990
REGARDING THE
PRADO DAM WATER CONTROL MANUAL

1. Concur. Title to paragraph 3-05g has been changed to "Water Year 1990 Plan".

2. Concur. The source of QPF's has been identified in paragraph 6-01.

3. Concur. The word "Range" has been removed from paragraphs 7-05c & d. The paragraphs simply read "(Release: 5,000 cfs).

4. Concur. Paragraph 7-11e has been added which describes the District's drought contingency plan.

5. Concur. The note on Plate 2-06d has been revised to accurately reflect conditions.

6. Concur. Precipitation data for plate 4-07 has been extended through fiscal year 1989.

7. Do not Concur. The base plate for plate 4-08 has not been revised because the original is from an older report and is not readily revised.

8. Concur. The Reservoir Operation data has been reviewed and verified. The sudden and numerous decreases in outflow from Prado Dam were due to requests from Orange County Environmental Management Agency. The scheduled releases caused damage to the downstream levees and bridges as well as utilities passing under the channel. Orange County requested these decreases so that the downstream channel could be inspected and emergency repairs initiated.

9. Concur. Plate 8-05a has been removed and replaced with an exceedance filling frequency curve. The previous set of curves were used to evaluate different water conservation alternatives and the effect these alternatives had on non-flood season conditions. CESPL-ED-HR feels that this information is not necessary for the water control manual and has, therefore, removed it.

10. Concur. The source of data for the methodologies presented in appendices C, D, and E have been included in the introductory paragraphs of each appendix. A means of storing Prado Dam inflow forecasts in the WCDS is under development.

Enclosure 2

11. Concur. A paragraph was added to section 1-07 that addresses public involvement accomplished as part of the preparation of the water control manual.

12. Concur. Paragraph 9-02f has been added which indicates that the Corps coordinates with The California Department of Fish and Game regarding environmental issues at Prado Dam.

13. Concur. Paragraph 9-02g has been added which indicates that the Corps coordinates with U.S. Fish and Wild Life Service regarding environmental issues at Prado Dam.

14a. Concur. The EA includes, as Appendix B, the Fish and Wildlife Services's Comments on the EA.

14b. Concur. Appendix B, of the EA, contains the comments from the Fish and Wildlife Service and the Corps' responses. As of this date comments from the California Department of Fish and Game have not been received.

15. Concur. The reference to "Operations Section" has been changed to "Operations Branch".

16. Do not Concur. H&H branch has reevaluated the four hour waiting period for implementation of the "no-communication Reservoir Regulation Schedule". The branch feels that four hours is an appropriate time to wait for Prado Dam. Prado Dam reacts relatively slowly when compared to other LAD projects. Also the travel time for emergency relief personnel from the baseyard to Prado Dam is about one-hour.

Enclosure 2

CESPL-ED-HR 17 September 1991

MEMORANDUM FOR RECORD

SUBJECT: Revised Estimate of the Average Annual Cost for Regulation of Prado Dam for Water Conservation Under the Currently Approved Water Control Plan

1. Reference.

a. 1st End dated 28 September 1990 from CESPD-ED-W "Prado Dam and Reservoir Water Control Manual". The "currently approved Water Control Plan" referenced in this memorandum is the Water Control Plan found in the Water Control Manual approved by this endorsement.

b. MFR dated 12 June 1990, subject "Increased Costs due to Interim Water Year 1990 Prado Dam Water Control Plan". On file at CESPL-ED-HR.

2. This memorandum presents a revised estimate for subject costs. This memorandum supersedes the MFR referenced in paragraph 1 above. Table 1 summarizes the revised estimate of average annual costs for regulation of Prado Dam for water conservation under the currently approved Water Control Plan.

TABLE 1
Summary of Average Annual Costs for Regulation of Prado Dam for Water Conservation Under the Currently Approved Water Control Plan

Description	Average Annual Cost
Reservoir Regulation	$26,400
Gate Maintenance (Con-Ops)	$6,000
Total Cost to Corps	$32,400

3. The following four steps were used to prepare this estimate. The estimated daily cost of running the Reservoir Operation Center (ROC) for the regulation of Prado Dam for Flood Control (FC) is $3,500/day and for Water Conservation (WC) is $1,150/day.

Step 1. Cost for 1969 Schedule:

From Table 2, under the 1969 schedule, Prado Dam is operated for Flood Control an average of 7 days per year. The cost to the ROC is:

(7 days FC) x ($3,500/day) = $24,500

Step 2. Cost of the currently approved Water Control Plan:

From Table 2, under the current Water Control Plan, Prado Dam will on average be operated for flood control (i.e., WSE'S above 494-ft) for 6 days and for water conservation (i.e., WSE's between 490-ft and 494-ft) for 26 days. The cost to the ROC for this Water Control Plan is therefore:

Enclosure 3

(6 days FC) x ($3,500/day) + (26 days WC) x ($1,150/day) = $50,900

Step 3. <u>Net increased Cost to the ROC for the Currently Approved Water Control Plan</u>:

The net increased cost to the ROC for adopting the currently approved Water Control Plan is the difference between the 1969 Schedule (i.e., $24,500) and the current Water Control Plan cost (i.e., $50,900).

Net Cost to ROC = $50,900 - $24,500
Net Cost to ROC = $26,400

Step 4. <u>Total Cost to Corps</u>:

Con-Ops has estimated that an average annual cost for gate maintenance for prolonged inundation of the gates for water conservation operations is $6,000. Therefore the total cost of the currently approved water Control Plan would be:

Total Cost to Corps = $26,400 + $6,000
Total Cost to Corps = $32,400

TABLE 2
Annual Inundation Frequencies for
PRADO DAM

Frequency (years)	Duration of Inundation (in days) above indicated Elevation << PRESENT HYDROLOGIC CONDITIONS >> OCWD Recharge Capacity = 450 cfs			
	Water Year 1990 Water Control Plan		1969 Water Control Schedule	
	WSE > 490	WSE > 494	WSE > 490	WSE > 494
2	16	0	2	0
5	3	8	5	2
10	75	20	20	9
25	130	42	54	38
50	180	47	56	44
100	205	56	58	48
Annual Average	32	6	7	4
Number of days between 490 - 494	26		3	

4. The POC for this MFR is Gerhard Krueger at X2374.

GERHARD KRUEGER
Hydraulic Engineer

CESPD-ED-W (CESPL-ED-HR/19 Jun 90) (1110-2-240b)1st End Krhoun/5-1433
SUBJECT: Prado Dam and Reservoir Water Control Manual

DA, South Pacific Division, Corps of Engineers, 630 Sansome Street, Room 720, San Francisco, CA 94111-2206

28 SEP 1990

FOR Commander, Los Angeles District, ATTN: CESPL-ED-HR

1. Reference ASA(CW) letter dated 21 August 1989 to Mr. John V. Fonley, President of the Board of Directors, Orange County Water District.

2. Subject manual is approved subject to the attached comments and the following paragraphs.

3. The referenced letter indicates Department of Army policy concerning operating the conservation pool greater than elevation 490 feet to enhance water conservation. District has determined that the average annual charges of operating an expanded pool for water conservation activities would be $12,600 for the operating plan in the manual, however, adequate justification has not been provided for these costs.

4. Along with additional justification for the costs shown, District should provide documentation indicating coordination has taken place with Orange County Water District and it has agreed to make the necessary payments to the Corps for operating the project to enhance the water conservation activities of Orange County.

5. District is requested to provide this office its responses to all Division comments and concerns on the water control manual.

6. Any questions on the above should be addressed to Mr. Frank Krhoun of the Water Management Branch at FTS 465-1433.

FOR THE COMMANDER:

Encl

Walter C. Day
JAY K. SOPER
Director, Engineering

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P O BOX 2711
LOS ANGELES CALIFORNIA 90053-2325

REPLY TO
ATTENTION OF

CESPL-ED-HR (1110-2-240b)   19 June 1990

MEMORANDUM FOR Commander, South Pacific Division,
Attn: CESPD-ED-W

SUBJECT: Prado Dam and Reservoir Water Control Manual

1. Enclosed are three copies of the Prado Dam and Reservoir Water Control Manual prepared in accordance with ETL 1110-2-251. Approval of the manual is requested.

2. The Draft Environmental Assessment for the Water Control Manual is being finalized and will be transmitted to you shortly.

3. Enclosure 1 is an assessment of the increased costs of implementing that portion of the Prado Dam water control plan which enhances the ground water recharge activities of Orange County Water District. This assessment was requested in paragraph 5 of CESPD-ED-W's 2nd endorsement, dated 15 February 1990, subject: Water Year 1990 Interim Prado Dam Water Control Plan.

4. If there are any questions, please contact Boniface Bigornia of the Reservoir Regulation Section at (213) 894-6915.

FOR THE COMMANDER:

Encls

Robert E. Koplin, PE
Chief, Engineering Division

CESPL-ED-HR 12 June 1990

Assessment of Increased Costs to the Corps Caused by the Prado Dam Water Control Plan

1. Reference paragraph 5 of CESPD-ED-W's 2nd endorsement, dated 15 February 1990, subject: Water Year 1990 Interim Prado Dam Water Control Plan.

2. Reservoir Regulation Section estimates that the total annual increased cost to the Corps for implementing that portion of the Prado Dam water control plan which improves ground water recharge activities of the Orange County Water District are as outlined in the following table:

Type of Cost	Estimated Cost
Separate Capital Costs	$ 0 [1]
Increased Reservoir Regulation Costs	$ 6,600 [2]
Share of Joint Operational and Maintenance Costs	$ 6,000 [3]
Costs of Benefits Foregone	$ 0 [4]
Costs of Compensation Due Others	$ 0 [5]
Total Annual Increased Cost to the Corps	$12,600

1. The interim plan required no new capital costs.
2. Accounts for the additional costs of reservoir regulation caused by that portion of the water year 1990 water control plan which enhances ground water recharge activities of Orange County Water District.
3. Reference draft report "Prado Dam Water Conservation Study" dated August 1990. There are increased maintenance costs due to extended inundation of the gates.
4. The water control plan does not require the abstention of any existing benefits.
5. The water control plan does not impact existing leases or landowners in a manner which requires compensation.

Enclosure 1

CESPD-ED-W 20 Aug 1990

SOUTH PACIFIC DIVISION
COMMENTS ON
PRADO DAM
WATER CONTROL MANUAL

1. Page 3-9, paragraph g- Change title of this paragraph to Water Year 1990 Plan. (CESPD-ED-W)

2. Page 6-1, paragraph 6-01- Indicate source of QPF's. (CESPD-ED-W)

3. Page 7-8, paragraphs d & e- Releases from Prado Dam should be a constant of 5,000 cfs between elevations 520 and 544.3. Suggest these paragraphs indicate release of 5,000 cfs instead of release range of 5,000cfs. (CESPD-ED-W)

4. In chapter 7 include a sub-paragraph on District's drought contingency plan. (CESPD-ED-W)

5. Plate 2-06b- Revise the note on this figure to accurately reflect conditions. (CESPD-ED-W)

6. Plate 4-07- Extend data through Water Year 1989 or to the last data available. (CESPD-ED-W)

7. Plate 4-08- Revise symbols to make chart easier to read. The estimated values should be by the flows instead of the year of the flood. (CESPD-ED-W)

8. In plates 4-12 to 4-15 there are numerous sudden decreases in the outflow of the dam that appear inappropriate in the operation of the project. District is requested to review this data to ensure its accuracy. (CESPD-ED-W)

9. Provide the difference in plates 8-05a and 8-05b as both title boxes appear the same. (CESPD-ED-W)

10. Appendices C, D and E contain the methodologies for forcasting reservoir inflows, recession inflows and buffer pool releases. These are based on alogorithms determined from historical storms and rely on forecasted amounts of precipitation. District should indicate in the appendices the source of this data. In addition, all forecasted data and resultant inflows and outflows should be presented and stored on the District's WCDS. (CESPD-ED-W)

11. Include in the package information on the public notification and public involvement accomplished as part of the preparation of the manual. (CESPD-PD-R)

12. Page 9-2, paragraph 9-01c- Add California Department of Fish and Game, an agency with which coordination is required pursuant to the Fish and Wildlife Coordination Act. (CESPD-PD-R)

13. Page 9-2, paragraph 9-02- Add the U. S. Fish and Wildlife Service, an agency with which coordination is required pursuant to the Endangered Species Act and the Coordination Act. (CESPD-PD-R)

14. The following comments pertain to the Environmental Assessment:

a. Page 15, Paragraph 11E- Include documentation from Fish and Wildlife Service that they agree with the Corps' determination that the proposed action will not adversely affect the least Belle's vireo.

b. Obtain recommendations from the Fish and Wildlife Service and California Department of Fish and Game and respond to each of those recommendations. (CESPD-PD-R)

15. Page 1-2, Paragraph 1-05- Change Operation Section to Operation Branch. (CESPD-CO)

16. Page A-6, Paragraph 3-05- District should reevaluate waiting four hours before implementing the "no-communication Reservoir Regulation Schedule" as Plate 4 shows changes in release rate for past floods more frequent. Provide justification for time selected. (CESPD-CO)