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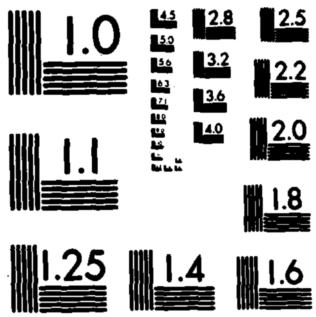

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Santa Ana River Basin, California

AD-A171 639

Evaluation of San Bernardino Valley Municipal Water District

THREE DAM PROPOSAL

Upper Santa Ana River & Mill Creek

September 1982

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This evaluation proposes a system of three dams on the Santa Ana River and Mill Creek that could provide for flood control, water conservation and hydropower generation. It was found that the most suitable dam type was earthfill for all three sites. Gravity concrete, to include roller compacted concrete (rollcrete) is unsuitable at two sites for geotechnical reasons and noncompetitive cost benefits.

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Santa Ana River Basin, California

Evaluation of
San Bernardino Valley
Municipal Water District

T H R E E   D A M   P R O P O S A L

Upper Santa Ana River & Mill Creek

September 1982

Evaluation of San Bernardino Valley Municipal Water District

THREE DAM PROPOSAL

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Evaluation of San Bernardino Valley Municipal Water District Three Dam Proposal

A. <u>SUMMARY</u>.

The San Bernardino Valley Municipal Water District has proposed a system of three dams on the Santa Ana River and Mill Creek which would provide for flood control, water conservation and hydropower generation. General locations and specific gross storage allocations were also provided.

This evaluation of the proposal was conducted at the request of the Assistant Secretary of Army (Civil Works) made during a visit to the Los Angeles District in May 1982. It was found that the most suitable dam type was earthfill for all three sites and that gravity concrete, to include roller compacted concrete (rollcrete), was unsuitable at two of the three general sites (Upper Mentone and Crafton) for geotechnical reasons and was not cost competitive at the third (Forks); net benefits are $35,300,000, compared to $62,800,000 for the recommended Mentone Dam, based on first added incremental analysis. The total cost of the Three Dam Proposal to include mitigation for project effects is $534,000,000. This compares to $386,000,000 for the recommended Mentone Dam, a difference of $148,000,000.

B. INTRODUCTION.

1. Background Leading to Evaluation of Three Dam Proposal.

During the plan formulation process on the main stem of the Santa Ana River, the enlargement of Prado Reservoir was limited by severe socio-economic impacts imposed around the reservoir fringe. Flood storage upstream of Prado Dam became a consideration in 1972 to limit the increase in flood storage requirements at Prado Reservoir and to provide added flood protection in San Bernardino and Riverside Counties. An upstream flood storage component on the main stem of the Santa Ana River in the vicinity of Mentone was determined to be the most cost efficient location to provide maximum flood control benefits in San Bernardino and Riverside Counties and to minimize socio-economic impacts throughout the three counties. The plan, which has come to be known as the All River Plan, would provide flood control along the full length of the Santa Ana River main stem and has received broad local support in the three county area. It was recommended by the Chief of Engineers to the Secretary of the Army in January 1982.

In early 1981 water districts and citizens in the vicinity of the proposed Mentone Dam expressed concerns over a number of issues, chiefly the impact of the dam on groundwater recharge capability and dam safety. In September of 1981 the Los Angeles District Corps of Engineers established a task force of citizens (the Mentone Task Force) to identify major concerns and to make sure that these they were adequately addressed in the continuing planning and engineering process. One task force meeting was conducted in 1981; in 1982 a total of four meetings will be held.

A task force meeting in May 1982 focused on the upstream dam alternatives considered by the Corps in the 1975 Review Report which summarized the planning and engineering process used to arrive at the selection of the recommended Mentone site. A three dam proposal, providing benefits nearly equivalent to those at Mentone, had been evaluated. The conclusions arrived at in earlier studies were that (1) control of flow on the Santa Ana River and Mill Creek could maximize flood control benefits in San Bernardino and Riverside Counties and effectively reduce flood storage requirements at Prado Reservoir, and (2) a system of multiple upstream dams to control a drainage area equivalent to Mentone and to provide equivalent downstream benefits would be more costly than a single dam at Mentone. At the third task force meeting, the San Bernardino Valley Municipal Water District (SBVMWD), an agency established in 1954 to supply imported water to the area, contended that a modification of a three upstream dam plan presented by the Corps would be less costly and would provide multi-use benefits from water conservation and hydroelectric power generation in addition to flood control. The SBVMWD three dam proposal called for two dams on the Upper Santa Ana River and one on Mill Creek. These, except for one dam on the Santa Ana River, would be located upstream of sites selected by the Corps in earlier planning studies. A map displaying the SBVMWD proposal is shown on plate 1. The proposal was submitted to the Secretary of the Army, Civil Works (ASA-CW), with an indication that the SBVMWD would be willing to participate financially in such a plan. The proposal was also presented at a California Water Commission meeting on 7 May 1982. In May 1982 the Los Angeles District was directed by ASA-CW to evaluate the SBVMWD three dam proposal, which is hereafter referred to as the Three Dam Proposal.

2. Purpose and Scope of the Evaluation.

The Three Dam Proposal was evaluated, at a reconnaissance level, to assess economic and technical viability and to identify environmental impacts. Specifically the study produced (1) total and annualized cost, (2) annualized benefits, (3) environmental effects of the plan, and (4) gross economic evaluation for specific project purposes of flood control, water conservation and hydroelectric power generation. Flood control benefits and hydrologic evaluations utilized data developed during earlier Corps planning studies. Appropriate data are extracted from these sources and presented in this report. Surficial evaluations of area biological and cultural resources were made. Site geology was assessed based on visual inspection and a literature research was conducted. Essential physical requirements pertinent to project design and construction such as site feasibility, borrow areas, materials requirements, transportation and access (both construction and permanent) were evaluated at a conceptual level but in sufficient detail to assess resource utilization and impact. Post construction conditions were evaluated to assess long term operation and maintenance requirements and resource impact.

3. Description of the Three Dam Proposal.

A brief presentation of the Three Dam Proposal was made at the Mentone Task Force meeting on 5 May 1982 and at a meeting of the California Water Commission on 7 May 1982. Approximate location and reservoir storage allocations were identified. Due to lack of other information, the proposed dam alinements were assumed to be consistent with dam alinements provided in the State of California-Bulletin 19, Santa Ana Investigation, December 1928. Dam sites extracted from this bulletin are presented on plate 2. Two dams were proposed in the Santa Ana River and one dam on Mill Creek for flood control, water conservation and hydroelectric projects. Gross storage allocations were provided by SBVMWD. Table 1 summarizes available data on the proposed dams.

Table 1. Data for the Three Dam Proposal

Dam	Reservoir Storage (acre-feet)
Forks	39,000
Upper Mentone	95,000
Crafton	56,000

C. DISCUSSION.

The Three Dam Proposal was evaluated primarily for flood control. Hydropower generation and water conservation were evaluated as secondary purposes, recognizing that previous planning conclusions suggest that flood control would emerge as the predominant water resource need. Therefore, storage for flood control was assigned a priority allocation at the dams and any excess was evaluated as secondary joint use for delivery of hydropower and water conservation benefits.

1. Assumptions and Supplemental Data.

Assumptions were made which relate primarily to dam alinement and identification of dedicated storage requirements. Supplemental data were developed for necessary technical support and to evaluate environmental and economic considerations.

a. Assumptions.

(1) Dam Alinement. State of California Bulletin 19 identified approximate alinements for dam sites and used the same site names as the Three Dam Proposal. Because alinements shown in Bulletin 19 are displayed at a relatively small scale, each site was assumed to represent a generalized location. The most geotechnically suitable and cost efficient alinements were selected within the generalized Bulletin 19 locations.

(2) Spillway Crest Elevation. The spillway crest at each dam site was established at the elevation corresponding to gross storage allocations specified in the Three Dam Proposal.

(3) Storage Allocation on the Santa Ana River.

The use of a two dam combination on the Santa Ana River requires allocation of storage for sediment and for hydropower/water conservation. Sufficient total storage must be available for flood control purposes. Sediment will accumulate at each site in proportion to the contributing drainage area. Drainage areas for the Three Dam Proposal are shown on plate 3. The hydropower and water conservation allocation was specified at the Forks Dam site to permit water delivery to downstream powerhouses for extended 'Run-of-River' operation. Approximately 9000 acre-feet was assumed to be available as excess storage at the two dams on the Santa Ana River for hydropower/water conservation use.

(4) Hydroelectric Power. Hydropower generation was evaluated by extending the period of 'Run-of-River' operation at existing powerhouses through use of upstream storage.

b. Supplemental Data. A summary of supplemental data derived for this evaluation is described in the following paragraphs and shown in table 2.

(1) Unit Price Analysis. Unit prices of quantities for the Three Dam Proposal were taken from the Phase I General Design Memorandum (October 1979, Price Levels) (ref. 1). Where site conditions or materials availability were substantially different from those in the Phase I GDM, separate unit price evaluations were conducted.

(2) Geotechnical Considerations. Geologic, soils design and materials availability information were developed to permit selection of the most suitable site and embankment cross section.

(3) Hydrologic and Hydraulic Considerations. Hydrologic support data were obtained from data developed for the Phase I GDM (ref. 1), the first interim review report (ref. 2) and earlier Corps studies (ref. 4). Hydraulic design data were developed for the current evaluation.

(4) Environmental Considerations. A preliminary assessment of biological and cultural resources was conducted and a preliminary impact evaluation was made.

(5) Economic Evaluation. Evaluation of flood control benefits was based on data developed for the Phase I GDM (ref. 5). Adjustments using derived data reflect reduced flood control benefits and increased hydropower generation and water conservation benefits.

c. Limitations of the Evaluation.

Reconnaissance level evaluations of dam sites were performed to assess economic and technical viability and to identify major impacts. Because suitable dam sites and materials utilization were based on surficial observation, final site recommendation would be contingent on more detailed geotechnical evaluation, hydraulic and other design considerations, and impact assessment. Significant geotechnical and hydraulic problem areas have been identified in this evaluation and appropriate compensating design considerations and cost contingencies have been incorporated. However, institutional and legal considerations pertaining to additional water conservation and hydroelectric power generation resulting from the Three Dam Proposal have not been evaluated.

Table 2. Summary of Derived Data.

Forks Dam		
Drainage area	sq mi	146
Dam (earthfill)		
Crest elevation	ft, msl	3860
Approx. Streambed Elevation		3400
Maximum height above streambed	ft	460
Crest length	ft	1450
Spillway (detached, broadcrested - concrete lined)		
Crest elevation	ft, msl	3830
Crest length	ft	500
Outlet works (gated conduit)		
Diameter of conduit	ft	10
Length of conduit	ft	3400
Reservoir		
Area at spillway crest	acre	280
Capacity (gross) at spillway crest	acre-ft	39,000
Access Road (paved 2-way)	miles	9
Storage allocation below spillway crest		
Flood control	acre-ft	12,000
Hydropower/Water Conservation	acre-ft	9000
Sedimentation (100-year storage)	acre-ft	18,000 1/
Standard project flood		
Total volume	acre-ft	98,000
Peak inflow	ft^3/s	70,000
Probable Maximum flood		
Peak inflow	ft^3/s	170,000

1/ Contributing drainage area excludes 38 sq. mi. which is controlled by Big Bear Dam.

Table 2. Summary of Derived Data (Continued).

Upper Mentone Dam		
Drainage area	sq mi	177
Dam (earthfill)		
Crest elevation	ft, msl	2500
Approx. streambed elevation	ft, msl	2060
Maximum height above streambed	ft	440
Crest length	ft	2690
Spillway (detached, broadcrested - unlined)		
Crest elevation	ft, msl	2470
Crest length	ft	500
Outlet works (gated conduit)		
Diameter of conduit	ft	10
Length of conduit	ft	1900
Reservoir		
Area at spillway crest	acre	480
Capacity (gross) at spillway crest	acre-ft	95,000
Access Road (paved-2 way)	miles	1.2
Storage allocation below spillway crest		
Flood control	acre-ft	90,000
Hydropower/Water Conservation	acre-ft	0
Sedimentation (100-year storage)	acre-ft	5000 1/
Standard project flood (without Forks Dam)		
Total volume	acre-ft	110,000
Peak inflow	ft^3/s	82,000
Probable Maximum flood		
Peak inflow	ft^3/s	180,000

1/ Contributing drainage area is between Forks and Upper Mentone dams.

Table 2. Summary of Derived Data (Continued).

Crafton Dam		
Drainage area	sq mi	43
Dam (rolled earthfill)		
Crest elevation	ft, msl	3500
Approx. streambed elevation	ft, msl	2980
Maximum height above streambed	ft	520
Crest length	ft	2570
Spillway (detached, broadcrested - concrete lined)		
Crest elevation	ft, msl	3475
Crest length	ft	200
Outlet works (gated conduit)		
Diameter of conduit	ft	10
Length of conduit	ft	4300
Reservoir		
Area at spillway crest	acre	380
Capacity (gross) at spillway crest	acre-ft	56,000
Access Road (paved - 2 way)	miles	0.2
Storage allocation below spillway crest		
Flood control	acre-ft	35,000
Hydropower/Water Conservation	acre-ft	14,000
Sedimentation (100-year storage)	acre-ft	7000
Standard project flood		
Total volume	acre-ft	40,000
Peak inflow	ft^3/s	29,000
Probable maximum flood		
Peak inflow	ft^3/s	45,000

2. **Design Considerations.** This section defines criteria and engineering considerations used to establish components and a site plan for each dam and appurtenant works.

a. Storage Allocation. With primary use of available storage for flood control and secondary joint use of remaining storage for hydropower generation and water conservation, total flood control allocation for a site was established by subtracting the volume of a constant outflow of 1000 ft^3/sec from the standard project flood inflow hydrograph. Inflow hydrographs for Upper Mentone and Crafton Dam sites are shown on plates 4 and 5.

(1) Santa Ana River. Storage was divided between Forks and Upper Mentone Dams to maximize benefits. Sufficient total storage would be available at the two dams to accommodate estimated flood control and sedimentation requirements based on inflow hydrograph and allocation procedures described below. Flood storage was allocated at both dams. Sediment would accumulate at each site in proportion to the contributing drainage area. Excess storage was allocated for joint hydropower/water conservation use at the Forks site so that the storage would be capable of enhancing operation of existing 'Run-of-River' powerhouses due to the higher elevation at that site. By allocating sediment and hydropower/water conservation storage at the Forks site, flood storage would be provided substantially at Upper Mentone. As a result of insufficient capacity for flood storage at Forks, its spillway flow would approach Standard Project Flood (SPF) peak discharge during an SPF event. Spillway flow would occur more frequently over time as sediment accumulates. Storage allocations at both dams on the Santa Ana River are given in table 3.

(2) Mill Creek. At Crafton Dam, storage would be allocated to sedimentation, flood control and joint use hydropower/water conservation. Storage allocation at Crafton Dam is shown in table 3.

Table 3. Reservoir Storage Allocations.

Dam	Storage Allocation		(acre-feet)	
	Total	Sedimentation	Flood Control	Hydropower/Water Conservation
Forks	39,000	18,000	12,000	9,000
Upper Mentone	95,000	5,000	90,000	0
Crafton	56,000	7,000	35,000	14,000

b. Controlling Elevations. A summary of controlling elevations at each damsite is shown in table 2.

(1) Spillway Crest. The spillway crest elevation was based upon specified storage allocation and area capacity relationships at each site. Area capacity relationships were derived from 1 inch = 2000 feet U.S.G.S.

Quadrangle maps dated 1973 (Forks site) and 1980 (Upper Mentone and Crafton sites). Elevation capacity relationships are shown on plate 6.

(2) Top of Dam. Top of dam elevation was established by determining the maximum water surface elevation required to discharge Probable Maximum Flood flow through the spillway under conditions of a reservoir pool, full to spillway crest, and adding a minimum of 5 feet freeboard. The spillway hydraulic surcharge was maintained at approximately 25 feet.

(3) Design Data for Existing Powerhouses. Design data for existing powerhouses on the Upper Santa Ana River and Mill Creek was provided by the Southern California Edison Company.

c. Geotechnical Considerations. This section provides evaluation of site geology based upon surficial evaluation and geotechnical and soils design information.

(1) Geological Evaluation of Dam Sites. Geologic information for evaluation of dam sites and the locations of their appurtenant structures was obtained during on-site reconnaissance and was supplemented with geologic data published in "Regional Geologic Map of San Andreas and Related Faults in Eastern San Gabriel Mountains, San Bernardino Mountains, Western San Jacinto Mountains and Vicinity," U.S.G.S. preliminary Open File Map, (1970). More detailed geologic exploration would be required to confirm site feasibility. All sites are within a highly seismic environment due to their close proximity to the San Andreas fault. The sites are located sufficiently close to the fault that a ground acceleration of 0.75 g from a magnitude 8+ event on the faulting may be expected. Observed site conditions are presented in the following paragraphs.

(a) Forks Dam Site. Two potential sites were evaluated, an upstream site at streambed elevation 3400 and a downstream site at elevation 3320.

Upstream Site (Streambed Elevation 3400.) The site crosses the streambed about 500 feet downstream from the confluence with Bear Creek. The canyon is less than 100 feet wide and is flanked, in approximately the lower two hundred feet, by steep to near-vertical walls. Above that level on the west side, the slopes flatten some, then become considerably flatter at elevation 3800. The east side is uniformly steep to about elevation 4000. The alluvium in the riverbed, estimated to be 50 feet deep, is coarse with boulders up to 20 feet wide. The walls consist of hard granite with variable joint spacing. In the east wall joints are spaced mostly 6 feet apart, but these are generally not continuous for more than about a hundred yards. One major set of joints trends near east-west and dips 45° to 60° north. Joints in this set are spaced 10 to 15 feet apart and influence the east wall topography. A local fault parallels these joints daylighting out of the slope at streambed level. The west side is somewhat more jointed, especially in the upper reach with maximum spacing from 3 to 4 feet; thin local faults may exist which would be transverse to the proposed dam alinement. Generally, most local faults contain compressible materials. Weathering is deeper in this reach and considerable scaling may be required to reach intact rock. Above elevation 3800, on the west side, the rock type changes from granite to unconsolidated sediments consisting of sands and gravels--an old terrace deposit. The site is located approximately 5 miles from the San Andreas fault, the closest known active fault.

Downstream Site (Streambed Elevation 3320). This location is approximately 1000 feet downstream from the confluence with Bear Creek. Many of the site conditions are similar to those at elevation 3400. The canyon at the axis is about 100 feet wide with steep to precipitous walls in the lower 100 feet. Above that level the slopes become moderately steep. The streambed alluvium consists of coarse material with boulders as much as 20 feet across and is estimated to be 50 feet deep. The bedrock is hard and competent granite with little surface weathering in the lower slopes but increasing in the upper slopes. The rock is strongly jointed with spacing generally less than 3 feet; many joints appear to be open. The joints dip steeply and trend predominantly in two directions--parallel and normal to the river.

The right or west ridge is steep along the downstream side and narrow. The slopes are covered with brush, very little soil and some loose blocks of rock from scattered outcrops. A distinct saddle at elevation 3600 appears to have been formed by rock falls from more closely jointed rock. Although no obvious faults were observed, localized faults may cross the saddle as segments of a zone exposed in the next ridge several hundred yards downstream and could contain compressible materials. The east abutment side, although heavily covered with brush, indicates that the bedrock conditions are similar to those on the west side.

In the area of the proposed spillway, off the west side, the bedrock appears to be softer with more broken granite in the upper levels. The most feasible tunnel alinement would be through the west side. The tunnel would be about 4000 feet long and would be entirely in blocky granite bedrock.

(b) Upper Mentone Dam Site.

(Streambed Elevation 2060.) This site crosses the streambed approximately 0.6 miles upstream from the canyon mouth. Slopes are moderately steep and rise to approximately 1800 feet above the streambed, which at the axis, is a little less than 600 feet wide and contains coarse alluvium with boulders up to 4 feet across. The depth of alluvium is unknown, but is estimated to be 200 feet. The gneissoid granite abutments are surprisingly massive and intact for being so close to the San Andreas fault, the trace of which is approximately 1/2-mile downstream from the site. The rock is relatively hard with major joints typically from 1 to 4 feet apart; most joints appear to be tight. The joint pattern is generally random, but one set roughly parallels the canyon dipping 60° to 70° west. No faulting was observed in the east side of the canyon, although some local faults exist directly upstream from the gaging station; further studies would be necessary for verification. An outlet could be tunneled in granite though either abutment. The excavation would encounter mostly "good" rock, but some crushed rock may be intercepted if faulting is present. A detached spillway located above the east side would be founded in granite where excavation would require some blasting.

(c) Crafton Dam Site. Two potential locations were evaluated, an upstream site at streambed elevation 3120 and one downstream at streambed elevation 2980.

Upstream Site (Streambed Elevation 3120.) The location is approximately one-third mile upstream from the elevation 2980 site. A large road cut on the west side, that required blasting for excavation, exposes very massive and competent sandstones and shales, although very little parting between strata or joints was evident. One thin local fault bisects the face trending normal to the river. The east side is partially covered with heavy brush, however, a large steep fault that passes through the wall has bent the strata (drag folds). In the same wall, seepage was also evident from a stratum about 50 yards above the streambed. Similar to the downstream site, another large landslide exists on the west side upstream from the road cut. This slide also apparently is the result of adversely dipping strata.

Downstream Site (Streambed Elevation 2980.) The site is located in Mill Creek Canyon approximately 0.3 miles upstream from the canyon mouth. Abutment slopes are moderately steep to heights from 800 to 1600 feet above the streambed and are mostly covered with brush. The streambed, less than 300 feet wide, consists of coarse alluvium estimated to be less than 100 feet deep. Scattered outcrops and highway road cuts indicate that the bedrock is sediments of the Potato formation. These sediments are interbedded strata of consolidated sandstones and compressible shales, some of which are distinctly bedded. On the east side of the creek the strata appear to be slightly warped and dip between 20° and 30° east. Some of the rock appears to be punky and contains several seeps. On the west side, the strata also appear to be somewhat warped, but trend obliquely to the canyon dipping about 45° into it. Upstream from the west abutment, the bed dips adversely about 25° and a large slide has developed. Although the State of California, Department of Transportation (Caltrans), has treated the slide and re-routed the highway away from its toe, the slide remains active.

d. Selection of Site and Type of Dam.

At the reconnaissance level of study, geotechnical feasibility for the dam sites was based on judgments made from the observed conditions. Future investigations could reveal adverse geologic conditions that would make the dam site foundation unsuitable, and could require relocation to an alternate site or increased foundation treatment. Specific conditions that could require more specialized foundation treatment or could lead to site elimination are identified in the course of this evaluation.

Also during this evaluation, two spillway types were considered for earthfill dams. (Spillways for concrete dams would be incorporated into the structure.) One, sited over the embankment, was eliminated due to settlement characteristics of the embankment materials for the heights under consideration. The other type, a detached spillway (lined or unlined as appropriate to the foundation conditions) was identified at each site. Spillways were located to obtain reasonable cost and hydraulic acceptability. Spillway flow pattern in relation to the toe of the dam was a significant consideration. Spillway channel excavations and stone protection were provided at the toe of the embankment to improve the spillway flow patterns and to protect the toe of the dam from scour. Detailed hydraulic analysis, geologic investigations and model studies may require changes in spillway and embankment plans. Spillway width corresponds to a hydraulic surcharge of approximately 25 feet.

(1) Forks Dam.

Upstream Site (Streambed Elevation 3400). Both gravity concrete (including rollcrete) and earthfill dams were considered. As stated in the geological evaluation of this site, above elevation 3800 the abutment material changes from relatively incompressible granite to unconsolidated sediments. The compressible, unconsolidated sediments extend for a considerable distance from the surface. The differing deformation characteristics of the abutment material renders the site unacceptable for a 460-foot high concrete dam. An earthfill embankment at the same location would be acceptable although construction would encounter a restrictive work area from streambed elevation to approximately 200 feet above streambed, where the width is approximately 100 feet and slopes are steep. For an earthfill structure conservative assumptions for foundation treatment including considerable scaling and abutment shaping would be made to account for uncertainties in the condition of the bedrock. The upstream slope toe would also place fill in Bear Creek and Santa Ana Canyon and excavation of a drainage channel would be required. Spillway length would be approximately 2600 feet. The dam crest length would be approximately 1450 feet.

Downstream Site (Streambed Elevation 3320). A concrete gravity and an earthfill dam were considered at this location. The canyon is about 100 feet wide with steep to precipitous walls in the lower 100 feet, but flattens to moderately steep above that point. The foundation and topographic conditions at this site are suitable for either an earthfill or concrete gravity dam. The use of roller compacted concrete construction method for the concrete gravity dam is not recommended since the present state-of-art for design and construction has not been developed for a structure greater than 230 feet high. Considerable foundation shaping and treatment would be required for an embankment at this site; the treatment for a concrete structure may be much greater. For an embankment, the upstream toe would be downstream from the Bear Creek-Santa Ana River confluence. Adjusting the embankment further downstream would increase the quantity of embankment materials required, lengthen the spillway and tend to block spillway flow. Much of the the spillway excavation, would not require blasting due to the weathered bedrock at higher elevations. The dam crest length would be approximately 1950 feet.

Selected Site.

(a) Dam. The upper Forks site (Elevation 3400) was selected for an earthfill structure over the lower Forks site on the basis of estimated construction costs. See plate 7.

(b) Spillway. Spillway locations were evaluated in both the east and west abutments. Because of the steep relief of the east abutment, spillway excavation requirements would be unacceptably high. The most suitable spillway site is on the west abutment where slopes are moderate, so significantly less spillway excavation would be required. The spillway site appears to be located predominantly in older alluvial terrace deposits consisting of sands and gravels and would be concrete lined upstream of its crest. It is assumed that "competent" bedrock would be encountered at the crest and concrete lining would not be needed downstream from the crest. Because sediment would occupy a substantial part of overall reservoir storage, spillway flow would occur frequently. Spillway channel excavation and embankment toe protection would be required. Spillway flow characteristics and geologic conditions would be a significant detailed design consideration and could require substantial site modification.

(c) Outlet Works. Although geotechnical conditions are suitable on either side, the east abutment was selected for the outlet works alinement, primarily on the basis of minimum length. A hydropower outlet would be incorporated into the outlet works. The ten foot diameter tunnel would be used for diversion and control of water during construction and would be subsequently gated for operational use. Access to the gate chamber would be through a vertical tower and control house on the crest of the dam. A vertical intake shaft would be provided to the outlet conduit on the abutment slope to permit the outlet works to remain operational as sediment accumulates within the reservoir area. Maximum sediment deposition, based on elevation/capacity relationships, would be about 300 feet.

(d) Access Road. An all weather, paved, two way access road would be required along the west bank of the Santa Ana Canyon and above the Upper Mentone Dam reservoir maximum pool elevation. The road would rise approximately 600 feet in elevation from Greenspot road to the top of Upper Mentone Dam at the west abutment. Using the west side of the river, the Forks Dam site may be reached over relatively flat terrain across Manzanita Flat. Access from Highway 30 near Running Springs was also considered but pre-empted by more favorable access and topographic conditions. Total length of the access road would be approximately nine miles from Upper Mentone Dam to Forks Dam.

(2) Upper Mentone Dam Site.

(Dam at Streambed Elevation 1980.) This site was placed at the approximate location shown in Bulletin 19. A concrete and an earthfill dam were considered. The rock type is massive, intact granite with few major joints. Streambed alluvium is estimated to be at a depth of 200 feet so a positive cutoff to bedrock would be precluded. The canyon is about 600 feet wide with moderately steep slopes to approximately 1800 feet above streambed. Adjustments in the embankment alinement immediately upstream would have nominal effect on quantities of embankment and spillway excavation material. Siting the embankment downstream would impact an existing Southern California Edison powerhouse. Because of the depth of alluvium, which would preclude excavation to bedrock, concrete structures were not considered suitable at this location. The site, however, is suitable for an earthfill structure.

(Dam at Streambed Elevation 2060.) Rock type characteristics and alluvium depths are similar to those at the lower site. Both earthfill and concrete (including rollcrete) dams were considered. Because of the depth of alluvium, which would preclude excavation to bedrock, concrete structures were not considered suitable at this site. A saddle located at the east side provides a more suitable spillway site than would be available at downstream locations. Adjustments in the embankment alinement immediately downstream would increase the volume of embankment required and would encroach on the spillway flow. Adjustment in the embankment upstream would cause increased blockage in Government Canyon and the length of the outlet tunnel would have to be increased. A power line crossing the reservoir area would be relocated. An excavated channel would be provided at the upstream toe of the dam to drain Government Canyon which would be partially blocked by the embankment.

Selected Site.

(a) Dam. The upper site (elevation 2060) was selected for an embankment because topographic characteristics provide a more economical spillway and outlet works location than the lower site. A lower elevation saddle on the east abutment permits significantly less excavation than at the downstream site (elevation 1960). See plate 8.

(b) Spillway. At the streambed elevation 2060 dam site, the saddle near the east abutment provides the most suitable spillway location. The downstream site would require more extensive excavation in the steep canyon walls. The spillway flow would affect the toe of the embankment; spillway channel excavation and embankment toe protection would be required. A rock knoll located in the streambed downstream of the spillway would also be excavated to facilitate conveyance of spillway flows away from the toe of the dam. Spillway flow characteristics in relation to the dam would be a significant detailed design consideration.

(c) Outlets Works. An alinement through the east side was selected as the shortest and most economical outlet works location. A ten-foot diameter tunnel would be used for diversion and control of water during construction and would be subsequently gated for operational purposes. Access to the gate chambers would be through a vertical tower and control house on the crest of the dam. Detailed design would have to address impacts of spillway flow on the downstream portal of the outlet works.

(3) Crafton Dam Site. This site is located as shown in Bulletin 19 at *streambed elevation* 2980. Applicability of the site for earthfill and concrete dams was considered. The canyon walls are moderately steep for a height up to 1600 feet above streambed, with bedrock consisting of interbedded sandstones and compressible shales. Streambed alluvium is estimated to be less than 100 feet deep and consists of course alluvium. An adverse dip of bedrock has caused a landslide in the west side accompanied by some seeping. The site is considered extremely marginal geologically for an earthfill structure because of the landslide and adversely dipping strata. It is unsuitable for concrete due to the presence of compressible shale layers in the abutments. When the slide is removed, future slides may recur and make the site unacceptable. Costs have been included in the estimate for landslide treatment, which includes slide removal. Sites immediately upstream exhibit similar topographic and geologic conditions. Locating the embankment upstream of streambed elevation 3040 would cause inundation of developments in Mountain Home village. An alinement further downstream would encroach on a Southern California Edison powerhouse and aqueduct, and increase quantity of fill for the embankment.

Selected Site.

(a) Dam. A more suitable site, based on geotechnical, hydraulic and topographic considerations, could not be identified. The landslide in the west side makes this site extremely marginal for an embankment structure. Because of the compressible shale layers in the bedrock, the site is not suitable for concrete structures. See plate 9.

(b) Spillway. Both sides are relatively steep and undesirable as spillway sites. The west side was selected because it provides a more desirable downstream flow pattern in relation to the embankment, avoids impacting the Southern California Edison powerhouse downstream and is not as steep as the east side. The alinement and length of the spillway were selected to convey flow away from the embankment. The spillway would be concrete lined to protect the foundation from erosion and to provide more positive direction to spillway flow.

(c) Outlet Works. An outlet works alinement through the east abutment was selected as the most economical and one that permits minimum disturbance by spillway flow. A ten-foot diamter tunnel would be used for diversion and control of water during construction. Subsequently, the tunnel would be gated for flood control operation and incorporated with a hydropower outlet. Access to the gate chamber would be through a vertical tower and control house on the crest of the dam.

(d) Access Road. The existing Highway 38 would be relocated to the east bank of Mill Creek Canyon and over Crafton Dam to obtain sufficient length to meet maximum grade requirements. Design speed may have to be reduced from the existing limit. The relocated roadway would provide access to the dam and a bridge would be required near Mountain Home village to return the roadway to the west bank of the river. The total length of relocated roadway would be approximately 3.2 miles.

e. Earthfill Embankment Materials Selection.

Embankment materials were selected on the basis of engineering requirements and economic considerations. All materials from required spillway, outlet works, and foundation excavations can be placed in the embankments for earthfill dams. Borrow areas for the random, transition, pervious, and rock toe materials can be from upstream or downstream locations in the riverbed or spillway excavations. Processing of the streambed materials would be required to obtain the embankment shell materials, while core materials could be obtained from the Manzanita flat area or from terrace deposits near the mouths of Santa Ana and Mill Creek canyons. Should subsequent studies find these sites unsuitable, core materials could be obtained from the Prado Basin. Sources of construction materials for the embankment are shown on plate 10.

(1) Forks Dam.

Pervious material and rock for earthfill construction would be obtained from the upstream and downstream streambed and from the spillway excavation, which would be processed prior to utilization in the embankment. Transition material would be processed from the upper spillway excavation or obtained from the Manzanita Flat area, while core material would be obtained from the Manzanita Flat area. Materials sources and utilization for Forks Dam are summarized below.

Random	-	Streambed Borrow & Spillway Excavation
Rock	-	Spillway Excavation
Pervious	-	Streambed Borrow
Transition	-	Streambed Borrow
Core	-	Manzanita Flat area or Prado Basin

(2) Upper Mentone.

Pervious material and rock for construction could be obtained from the streambed two miles downstream from the dam and from spillway excavation. The spillway excavation would be processed prior to utilization in the embankment. Transition material could be processed from the streambed materials, though an intermediate transition zone may be required depending on the nature of the materials from the spillway excavation. Core material could be obtained from terrace deposits, two miles downstream from the dam, an area that is now in orange groves. Materials sources and utilization for Upper Mentone Dam are summarized below.

Random	-	Streambed Borrow and Spillway Excavation
Rock	-	Spillway Excavation
Pervious	-	Streambed Borrow
Transition	-	Streambed Borrow
Core	-	At Mouth of Santa Ana Canyon or Prado Basin

(3) Crafton Dam.

Pervious material and rock for construction could be obtained from the streambed of Mill Creek downstream from the damsite. The streambed material would have to be processed to remove oversized rock material while processing of streambed borrow materials would produce random, pervious, transition and rock. Although the nature of the spillway materials has not been established, it was assumed that they could be utilized in the random zone of the embankment. Core material would be obtained from terrace deposits approximately two miles downstream from the dam. The area is presently in orange groves. Materials sources and utilization for Crafton Dam are summarized below.

Random	-	Streambed Borrow and Spillway Excavation
Rock	-	Spillway Excavation and Streambed Borrow
Pervious	-	Streambed Borrow
Transition	-	Streambed Borrow
Core	-	At Mouth of Mill Creek Canyon or Prado Basin

f. Hydrology and Hydraulics. General hydrology for flood control and water conservation evaluation utilized in this report has been taken from references 2, 3 and 4 (see Section E). Daily flows used to determine flow duration relationships were obtained from the Hydrologic Engineering Center Data File (GET USGS). The data were used to assess hydropower production at existing SCE power plants. Drainage areas tributary to the Three Dam Proposal are shown on plate 3.

(1) Standard Project Flood (SPF) Volume and Peak Inflow. Drainage boundaries for the Forks, Upper Mentone, and Crafton Dam sites correspond with subarea boundaries used in references 2 and 3. SPF peak inflow and 4-day inflow volumes for the Forks and Upper Mentone sites were available from the studies performed in reference 2 (see plates 4 and 5, and table 4). SPF for the Crafton site was developed from rainfall date given in reference 4 and basin characteristics taken from reference 2.

Table 4. Standard Project Flood Peak Discharge and 4-Day Volume.

Dam	Drainage Area (sq mi)	Peak Inflow (ft^3/s)	4-Day Volume (acre-feet)
Forks	146	70,000	98,000
Upper Mentone	177 1/	82,000 1/	110,000 1/
Crafton	43	29,000	40,000

1/Includes contributing drainage area, inflow, and 4-day volume from Forks Dam.

(2) Sediment Yield. A sediment yield of 1.65 acre-feet per square mile per year was taken from reference 2. Historical records for sediment production for similar geomorphic conditions, summarized in reference 2, are shown in table 5. Sediment allocations for the Three Dam Proposal are shown in table 2. Thirty-eight square miles above Big Bear Lake are excluded because the existing dam traps all sediment production above that point.

Table 5. Sediment Production for Similar Geomorphic Conditions.

Dam	Net Drainage Area, (sq mi)	Accumulated Sediment (Acre-feet)	Years of Record	Sediment Yield Rate (acre-ft/ sq. mi/yr)
Hansen	146.0	6,100	29	1.44
Big Tujunga	82.2	3,779	38	1.20
Devil's Gate	31.7	2,981	49.5	1.90
Pacoima	28.2	2,291	39.5	2.06
Cogswell	29.0	3,542	34	2.67
San Gabriel System 1/	210.7	21,026	37.1	2.69

1/ Includes Cogswell Dam, San Gabriel Dam, and Morris Dam.

(3) Probable Maximum Flood (PMF). Methodolgy for development of the probable maximum storm, representing an upper bound for precipitation, is discussed in reference 2. Subarea probable maximum precipitation corresponding to the Upper Mentone, Forks and Crafton Dam sites were used to determine PMF peak discharges. These discharges were used to size spillway structures. PMF discharges are shown in table 6.

Table 6. Probable Maximum Flood Peak Discharges.

Dam	Drainage Area (ft^3/s)	Peak Inflow (ft^3/s)
Forks	146	170,000
Upper Mentone	177	180,000
Crafton	43	45,000

(4) Additional Hydropower Generation.

Additional hydropower generation on the Upper Santa Ana River and Mill Creek was evaluated using the Hydrologic Engineering Center (HEC) computer program "Hydropower Analysis Using Streamflow Duration (HYDUR)." Flow duration relationships for Forks Dam were determined from the combined flow record for the Santa Ana River streamgage near Mentone for the period March 1912 - July 1981 by adjusting flow for the difference in drainage area between Forks Dam and the streamgage. For Mill Creek, the relationships were derived from the streamgage records near Yucaipa for water years 1920 to 1938 and 1948 to March 1981. Data provided by Southern California Edison Company for existing powerhouses on the Santa Ana River and Mill Creek Canyons are shown in table 7.

Table 7. Design Characteristics of Existing Southern California Edison Powerhouses.

Location	Year Built (year)	Static Head (ft)	Penstock Capacity (ft^3/s)	Unit Power Generation Capacity 1/ (kwh/acre-foot)
SANTA ANA RIVER				
#1 (Below Forks)	1903	726	93.3	506
#2	1905	312	83.0	226
#3 (at Canyon Mouth)	1904	346	81.0	267
MILL CREEK				
#1 (Near Treatment Plant)	1893	519	35.0	314
#2 (at Canyon Mouth)	1899	627	8.8	446
#3 (at Canyon Mouth)	1903	1905	24.4	1294

1/ Based on Observed Data.

Based upon total surface flows for the record period, a flow duration analysis was performed to determine additional 'Run-of-River' hydropower generation based on a storage condition of 9000 acre-feet at Forks Dam and of 14,000 acre-feet at Crafton Dam. Table 8 shows flow duration relationships for Santa Ana River and Mill Creek. The average flow derived in the analysis was used to evaluate annual increased hydropower generation with storage. The storage condition at Forks and Crafton Dams extended the operating period for existing 'Run-of-River' downstream powerhouses. The capacity duration curves for Forks Dam indicate that capacity operating times would be increased from about 20% to about 30%. On Mill Creek capacity operation would increase from about 25% of the time to about 65%. Extended operation would apply to powerhouses on #1, 2, and 3 on the Santa Ana River and to powerhouse #1 on Mill Creek. Powerhouses #2 and #3 on Mill Creek are unaffected because their intakes are at a higher elevation than the proposed dam site. "Capacity power generation" at Forks and Crafton Dams would add about 30% to the annual power increase afforded by extended 'Run-of-River' operation. "Capacity power generation" is the power that could be generated by a turbine at the base of the dam from the head provided by the power storage pool. Storage effects of dams and increased annual power generation are shown on tables 9 and 10, respectively.

Table 8. Flow-Duration Relationships.

Santa Ana River at Forks Dam site			Mill Creek at Crafton Dam Site		
	Flow			Flow	
Percent Exceedence	Run-of-River	With Power Storage	Percent Exceedence	Run-of-River	With Power Storage
1.0000	0	31.49			
1.0000	0.21	31.49	1.0000	0	25.87
1.0000	0.48	31.49	1.0000	0.26	25.87
1.0000	0.82	31.49	1.0000	0.58	25.87
1.0000	1.25	31.49	1.0000	1.00	25.87
1.0000	1.78	31.49	1.0000	1.51	25.87
1.0000	2.46	31.49	0.9999	2.16	25.87
1.0000	3.31	31.49	0.9999	2.98	25.87
1.0000	4.38	31.49	0.9999	4.01	25.87
1.0000	5.73	31.49	0.9995	5.31	25.88
1.0000	7.43	31.49	0.9954	6.94	25.93
0.9997	9.56	31.50	0.9662	9.00	26.27
0.9973	12.25	31.57	0.8699	11.59	27.45
0.9738	15.64	32.32	0.7074	14.85	29.55
0.8988	19.90	34.83	0.5357	18.95	31.96
0.8023	25.26	38.34	0.3563	24.12	34.67
0.6669	32.02	43.88	0.2629	30.62	36.18
0.5032	40.52	51.65	0.1860	38.81	39.86
0.3775	51.23	58.54	0.1276	49.12	52.12
0.2546	64.71	66.16	0.0990	62.10	59.40
0.1560	81.68	102.57	0.0736	78.43	66.74
0.1096	103.04	129.40	0.0591	99.00	71.33
0.0756	129.93	153.43	0.0461	124.89	75.72
0.0557	163.78	169.44	0.0317	157.49	80.91
0.0391	206.41	184.14	0.0192	198.53	85.67
0.0255	260.06	197.13	0.0147	250.19	87.45
0.0173	327.61	205.38	0.0098	315.23	89.44
0.0108	412.65	212.16	0.0068	397.11	90.68
0.0082	519.71	215.00	0.0031	500.19	92.22
0.0055	654.50	217.83	0.0018	629.96	92.79
0.0036	824.18	219.91	0.0014	793.33	92.95
0.0023	1037.79	221.35	0.0011	999.00	93.06
0.0018	1306.71	221.96	0.0008	1257.93	93.19
0.0012	1645.27	222.58	0.0006	1583.89	93.28
0.0008	2071.48	223.07	0.0004	1994.26	93.39
0.0005	2608.05	223.38	0.0003	2510.89	93.44
0.0003	3283.56	223.60	0.0002	3161.28	93.46
0.0002	4133.97	223.73	0.0002	3980.07	93.48
0.0001	5204.57	223.82	0.0001	5010.87	93.50
0.0001	6552.38	223.82	0.0000	6308.57	93.55
0.0001	8249.18	223.86			
0.0001	10385.31	223.86			
0.0000	13074.54	223.91			
0.0000	16460.09	223.95			

Note:
Percent of time, expressed as a decimal, corresponding flow is exceeded.

Table 9. Effects of Storage on Flow to Powerhouses.

Tributary	Total Average Inflow (ft^3/s)	Average Flow Used for Power Generation: Run of River (ft^3/s)	Average Flow Used for Power Generation: With Power Storage (ft^3/s)
Santa Ana River	67	50	60
Mill Creek	38	23	33

Table 10. Increased Annual Power Generation.

Tributary	Power House	Static Head (ft.)	Increased Average Flow Available (ft^3/s)	Computed Efficiency (%)	Annual Power Increase (MWH)
Santa Ana River	#1	726	10	68	3700
	#2	312	10	71	1600
	#3	346	10	75	1900
Mill Creek	#1	519	10	59	2300
Total Increased Annual Power					9500 MWH

(5) Water Conservation.

An assessment of total yield of the basin above Prado Dam and percent yield recharged to groundwater, based on the total period of record and basin recharge capability, is provided in reference 3 and shown on table 11. The average annual inflow to Prado Dam for the 60 year period of record (1920-1979) is 97,900 acre-feet/year. The average annual waste to the ocean, using the Prado reservoir operating scheme recommended under the All River Plan, is approximately 10,500 acre-feet/year. This means that about 90% of the average annual flow leaving Prado Dam is recharged to the groundwater basin before reaching the ocean. The average annual flow on the Santa Ana River at the streamgage near Mentone (above Mill Creek) is 26,650 acre-feet/year (based on a 66-year average from 1915 to 1980); on Mill Creek at the streamgage near Yucaipa, it is 11,810 acre-feet/year (based on a 52-year average from 1920 to 1938 and from 1948 to 1980). The combined flow is 38,460 acre-feet/year or 39% of the average inflow to Prado (97,900 acre-feet/year) assuming no percolation losses between the subject streamgages and Prado Dam.

Based on this analysis, the Upper Santa Ana River and Mill Creek generate approximately 39 percent of the present condition waste, or about 4100 acre-feet/year. Storage-yield relationships indicate that to conserve 100 percent of the yield would require storage of approximately 8 times yield, because the last increments come from very large infrequent floods. The

10,500 acre-feet/year average wasted to the ocean is an average, over the 60 year record, of the waste during 6 large flood years. The storage increments required on the Santa Ana River and Mill Creek and the increase in annual water conservation with the Three Dam Proposal is shown on table 12.

Table 11. Water Conservation Evaluation - Prado Dam to the Pacific Ocean.

Water Year	Annual Inflow (acre-feet)	Annual Waste to Ocean (acre-feet)	Water Year	Annual Inflow (acre-feet)	Annual Waste to Ocean (acre-feet)
1920	138,451	0	1961	31,177	0
21	115,488	0	62	38,099	0
22	304,872	129,175	63	33,701	0
23	139,841	0	64	32,890	0
24	104,514	0	65	40,001	0
25	80,968	0	66	72,157	0
26	110,062	0	67	83,581	4,119
27	158,563	33,092	68	48,808	0
28	81,583	0	69	364,630	220,867
29	71,975	0	1970	51,630	0
1930	66,002	0	71	55,439	0
31	57,382	0	72	53,077	0
32	82,532	0	73	91,976	0
33	58,140	0	74	154,787	0
34	56,438	0	75	117,049	0
35	56,365	0	76	159,132	0
36	51,144	0	77	98,081	0
37	120,093	7,940	78	253,766	99,221
38	229,040	98,457	1979	142,808	0
39	63,145	0			
1940	61,003	0			
41	174,250	24,306			
42	77,878	0			
43	144,583	2,241			
44	108,859	0			
45	96,090	0			
46	89,164	0			
47	85,200	0			
48	58,915	0			
49	57,832	0			
1950	74,636	0			
51	70,176	0			
52	122,996	0			
53	73,363	0			
54	113,917	0			
55	96,354	0			
56	69,098	0			
57	45,244	0			
58	77,573	0			
59	37,407	0			
1960	34,970	0			

Notes:

1. Demonstrates annual inflow at Prado Dam for the period of record and annual waste to the Ocean after regulated flows from Prado are diverted to off-channel spreading facilities in Orange County.

2. Analysis assumes a seasonally expanded debris pool at Prado.

3. Mean annual inflow at Prado - 97,900 AC-FT.
Mean annual waste to Ocean - 10,500 AC-FT.

Table 12. Increased Annual Water Conservation.

Tributary	Percent of Annual Inflow at Prado	Mean Annual 1/ Waste to Ocean (acre-feet)	Dedicated 2/ Storage Req'd (acre-feet)	Maximum Available Storage (acre-feet)	Water Conservation Increase (acre-feet)
Mill Creek	12	1,260	10,080	14,000	1,260
Santa Ana River	27	2,840	22,680	9,000	1,130
Total Increased Annual Water Conservation					2,390 acre-feet

1/ Estimated mean annual waste from contributing watershed area.

2/ Based on a dedicated storage equal to 8 times annual yield.

(6) Flood Control Storage.

A maximum outflow of 1000 ft^3/s was assumed for determination of the required flood control storage, which was computed by the following relationship. Results are shown in table 13.

Required storage = Total inflow volume - (outflow volume during time period of inflow)

Table 13. Flood Control Storage.

Dam	Drainage Area	SPF 4-Day Volume (acre-feet)	Outflow Volume (acre-feet)	Required Flood Control Storage (acre-feet)
Forks	146	1/		1/
Upper Mentone	177	110,000	8,000	102,000
Crafton	43	40,000	5,000	35,000

1/ Included with Upper Mentone. Total required flood control storage divided between Forks and Upper Mentone Dams.

In the Three Dam Proposal evaluation, a combined gated outflow of 2000 ft^3/s from Upper Mentone and Crafton Dams was maintained until the water surface peaked at Prado, as was done with the All River Plan. Outflow at each dam would then be increased to a maximum of 5000 ft^3/s. Because the Plunge Creek watershed and the area between proposed Mentone Dam and the intervening area between Upper Mentone and Crafton Dams would be left uncontrolled by the Three Dam Proposal, the maximum water surface at Prado, under an SPF condition, would rise 1.5 feet higher than it would under the All River Plan with additional inflow to Prado. See table 14. Prado water surface was estimated with a hydraulic basin model that can assess effects at Prado by controlling upstream tributaries during an SPF event.

Table 14. Water Surface Elevations at Prado Dam with Control on Upstream Tributaries.[1/]

Upstream Tributary Controlled	Upstream Drainage Area Controlled (sq mi)	Prado Reservoir Water Surface Elevation (ft, msl)
Upper Santa Ana River and Mill Creek (3 Dam Proposal)	220	564.5
Upper Santa Ana River, Plunge Creek and Mill Creek (All River Plan)	260	563.0

1/ Under Standard Project Flood conditions.

g. Relocations.

The Three Dam Proposal would directly affect a number of existing utilities, roadways, streamflow diversion and steamflow measurement devices, while other facilities would be inundated by sediment accumulation or reservoir pool and would require additional real estate interest. Thus, relocations of these facilities had to be considered in site plan development. Table 15 summarizes the major relocation requirements resulting from the proposal.

Table 15. Major Relocations.

Relocated Feature	Relocation Requirement
FORKS DAM	
Santa Ana Truck Road	Use as Project Access Road
SCE Breakneck Creek Diversion Structure	Relocate Upstream
Two Upstream Gaging Stations	Remove and Replace
Bear Creek and Santa Ana River Diversion Structure and Aqueduct	Provide Diversion Upstream of Dam. Incorporate Aqueduct into Outlet Works

Table 15. (Continued).

Relocated Feature	Relocation Requirement
UPPER MENTONE DAM	
Santa Ana Truck Road	Use as Project Access Road
Downstream Gaging Station	Remove and Replace
Spreading Grounds	Remove and Replace
Power Line	Remove and Replace
CRAFTON DAM	
Mill Creek Road (Highway 38)	Relocate to East
Two Downstream Gaging Stations	Remove and Replace

3. **Real Estate Considerations.**

Dams and reservoir areas considered in the Three Dam Proposal are predominantly within National Forest Service (NFS) boundaries, with the exception of a small downstream portion of the Crafton Dam and spillway. Downstream borrow areas and some relocated facilities would utilize both public and private lands. It was assumed that acquisition of property interest within NFS boundaries and other public lands could be accomplished at nominal cost ($1000/acre), and that lands in private ownership would be acquired at fair market value. It was also assumed that Santa Ana power plant #2, periodically inundated by flood storage at Upper Mentone Dam, would remain in service but that appropriate property interest would be acquired. A summary of major acquisition requirements is shown in table 16.

Table 16. Real Estate Requirements.

Description of Property Area Required	Type of Ownership	Area of Acquisition (acres)
FORKS DAM		
Dam and Reservoir Area	Public (NFS)	420
Permanent Access Road	Public (NFS)	180
Additional Downstream Haul Road Access	Public (NFS)	180

Table 16. (Continued).

Description of Property Area Required	Type of Ownership	Area of Acquisition Acres
Downstream Streambed and Core Borrow Areas	Public (NFS)	260
Total		1040
<u>UPPER MENTONE DAM</u>		
Dam and Reservoir Aea	Public (NFS)	780
Permanent Access Road	Public (NFS)	20
Additional Haul Road Access	Public (NFS)	230
Downstream Pervious Borrow Area	Public (BLM) and Private	580
Downstream Core Borrow Area	Public (NFS - Orange Groves)	140
Total Upper Mentone Dam		1750
<u>CRAFTON DAM</u>		
Dam and Reservoir Area	Assumed Private	70
	Public (NFS)	700
Permanent Access Road	Public (NFS) and Private	40
Additional Haul Road Access	Public (NFS) and Private	150
Downstream Pervious Borrow Area	Assumed Private	550
Downstream Core Borrow Area	Assumed Private	130
Total Crafton Dam		1640

4. Environmental and Cultural Effects.

The following biological evaluation is based on two brief surveys conducted in the spring of 1982. No field survey of cultural resources were conducted as part of this preliminary site reconnaissance. To comply with NEPA requirements, more detailed biological, archeological, and social studies would need to be conducted, and formal coordination with other agencies, such as the U.S. Fish and Wildlife Service, would be required. Specific mitigation plans would need to be developed and coordinated. All environmental laws, such as the National Historic Preservation Act, the Fish and Wildlife Coordination Act, the Endangered Species Act, and Section 404 of the Clean Water Act would have to be complied with fully and the Water Resources Council's Principles and Guidelines would have to be followed.

a. Environmental Setting.

(1) Forks Site. The site is located approximately 3.7 miles upstream from the Upper Mentone site and is just downstream from the confluence of the Santa Ana River (SAR) with Bear Creek. Unlike the downstream reach this area is relatively undisturbed and maintains a high species diversity. The riparian growth in the channel and along the banks consists of stands of mature cottonwoods (Populus species), alders (Alnus species), maples (Acer species), sycamores (Platanus species) and two species of willows (Salix species). Understory vegetation includes thickets of young willows, mule fat and wild watercress (Nasturtium species) in reaches of reduced velocity. At the base of the slopes, yerba santa (Eriodictyon crassifolium), two buckwheat species (Eriogonum species), Salvia species and Spanish bayonet (Yucca whipplei) were observed.

On the western side of the canyon, the south to southeast facing slopes have dense to moderate growth with at least two species of oak (Quercus species). The eastern slope has a dense cover of predominantly oaks and mountain mahogany (Cercocarpus species) and some type of conifer (possibly Big-cone Spruce - Pseudotsuga macrocarpa) at the ridges.

(2) Upper Mentone Site. Vegetation in the channel is sparse, consisting predominantly of mule fat (Baccharis viminea) and broom baccharis (B. sarothroides). The north-facing canyon walls have a dense oak-woodland cover of excellent habitat quality. South-facing slopes are covered by a coastal sage type community.

(3) Crafton Site. The channel bottom and banks are highly disturbed and vegetation is sparse, mainly mule fat, buckwheat, and California sagebrush (Artemisia californica). South to southeast-facing slopes support an oak woodland community and north to northwest-facing slopes are covered with a coastal sage community of yerba santa, Yucca species, and oaks. Upstream from the dam alinement an increase in channel vegetation was observed.

b. Impacts.

(1) Forks Site.

(a) Dam and Appurtenant Facilities. The dam and spillway structures would occupy 100 acres of the canyon. The majority of this area has stands of riparian and oak woodlands of excellent habitat quality. An estimated additional 180 acres would be impacted by construction activities. Since the haul roads would be cutting into the canyon slopes, they would create erosional problems. The 180 acres is considered a conservative estimate since this site is relatively inaccessible and machinery required for earth-moving would have to be transported a considerable distance, creating more disturbance downstream and along the roads leading to the borrow sites.

(b) Borrow Areas. Ninety (90) acres within the channel bottom downstream from the proposed site would be excavated to obtain pervious material for the dam. This would include removal of habitat of excellent quality and high species diversity. Since the area is in a fairly inaccessible, isolated reach of the canyon, high animal and bird use is expected. Revegetation of disturbed areas is anticipated but a considerable length of time would be required to regain the quality of the existing environment. With the establishment of a 9.0-mile-long, 150-foot-wide permanent access road, approximately 160 acres would be permanently disturbed and the access roads may have a secondary impact by making this reach of the canyon potentially more accessible to the public. Greater public use would increase fire risk, would add to general watershed deterioration and would result in avoidance of the area by animals and birds. The overall quality of the habitat would be adversely impacted.

Excavation of the required quantity of core material would impact 170 acres of chamise-manzanita chaparral that provide excellent cover and foraging areas for various animals and birds. Since this location is somewhat remote from the dam site, extensive haul roads would need to be established to and from the proposed site. Use of these would create severe dust, noise and erosional problems by large earth-moving machinery. This would result in overall deterioration of the habitat and decreased wildlife usage.

(c) Reservoir Area. Sediment accumulation is severe and is estimated to occupy about 140 acres of the 270-acre reservoir pool. This predicted amount of sediment has been included in the storage of the dam (for a 100 year life) and would not be removed. Forks Dam would function much as a sediment trap and Upper Mentone Dam would serve as a flood control dam with much of its sediment yield retained at Forks Dam.

None of the existing vegetation upstream from the site within the taking line would be removed during dam construction, except for vegetation located in areas required for the structures and related construction activities. However, inundation of the sycamores, alders, cottonwoods, and maples for any prolonged period would result in severe and irreparable damage. This is also true for the oaks on the slopes.

(d) Rare, Threatened or Endangered Species. The habitat is potentially suitable for Least Bell's vireo (State endangered species, Federal candidate; references 11, 13), although habitation of this area has never been documented. Verification of use of this area by the vireo (*Vireo bellii pusillus*) would be required. No endangered or rare plant species are know to utilize this area (references 6, 8, 13).

(e) Cultural Resources. Based on a search of maps and site records of the San Bernardino County Museum, no archeological sites are recorded within the area impacted by the proposed construction. Absence of recorded sites is probably due to a lack of systematic cultural resource surveys rather than to low cultural resource sensitivity and a more complete literature search and field surveys would be required.

(f) Other. Studies pertaining to impacts on water resources and water quality would be required. No impacts on prime and/or unique farmlands would result.

(2) Upper Mentone Site.

(a) Dam and Appurtenant Facilities. One hundred fifty (150) acres would be taken up by the dam and spillway structures. Of this, approximately 70 acres of vegetation would be permanently removed by dam construction. Another 230 acres would be directly or indirectly disturbed by construction activities (temporary and permanent haul roads, etc). Areas disturbed by temporary haul roads and by the use of large equipment (creation of noise, dust, etc.) are expected to regenerate vegetation upon project completion. However, construction of this magnitude would disturb the ecosystem for a considerable period and these areas would be avoided by wildlife. A 1.2-mile-long permanent access road would be established and would disturb about 20 acres, assuming a 150-foot-wide strip. Erosional and dust problems would result from clearing and miscellaneous construction activities, especially during construction due to use of heavy earth moving equipment. After project completion, re-seeding and planting of impacted areas would help to reduce erosion and dust problems and would enhance and encourage re-habitation by foraging animals.

(b) Borrow Areas. Five hundred eighty (580) acres of the alluvial fan downstream from the proposed Upper Mentone site would be directly impacted since it would be excavated to provide pervious material for the dam. The excavation would be 20-30 feet deep. Greenspot Road, located within the borrow site area, may be impacted.

The borrow site for the core material would impact 140 acres of citrus groves. No prime or unique farmlands would be impacted. However, the projected borrow site is adjacent to citrus groves on prime and unique farmlands that could be impacted by minor borrow area changes.

(c) Reservoir Area. The taking line is near elevation 2500 feet and could potentially inundate as much as 480 acres. The vegetation located within the reservoir basin behind the dam would not be cleared or removed except for the area required for the dam and spillway structure. Since the predicted figure for the amount of sediment accumulation is accounted for in the storage of the dam (for a 100 yr. life of the dam), the sediment would not be removed as part of the routine maintenance. The sediment would encourage the growth of willows, reeds and other plants that may be removed periodically. The canyon walls would be left undisturbed, although the oak woodland would be irreparably damaged if subjected to any prolonged period of inundation. The canyon is within the boundaries of the San Bernardino National Forest; the esthetic value of the canyon would be adversely impacted by the dam structure.

(d) Rare, Threatened or Endangered Species. A brief literature search (references 6, 8, 11 and 13) has indicated that no rare, threatened, or endangered species (Federal or State listed) are known to inhabit the proposed site.

(e) Cultural Resources. A brief search of archeological data on file with the San Bernardino County Museum was conducted and no archeological sites were identified within the proposed area. However, the absence of recorded sites is probably due to a lack of systematic cultural resource surveys rather than to low cultural resource sensitivity. A more complete literature search, consultation with archeologists familiar with San Bernardino County, and field surveys would need to be conducted at a detailed design level.

(f) Other. Possible impacts to water quality were not examined and would need to be studied if this project is developed further.

(3) Crafton Site.

(a) Dam and Appurtenant Facilities. The dam and spillway structure would occupy a total of 140 acres. Of these, 30 acres of vegetation would be permanently removed by dam construction. An additional estimated 150 acres would be disturbed by construction activities (temporary and permanent haul roads, etc.) Vegetation in areas cleared and disturbed by construction activities associated with the dam would eventually return. However, the establishment of a 0.2-mile-long access road would permanently impact about 4 acres (assuming a 150-foot width). Habitat destruction, either temporary or permanent, and noise during construction would result in avoidance of the area by foraging animals and birds. Increased erosion may result from clearing of vegetation and the use of the earth moving equipment in the construction zone. Once the dam construction is complete, revegetation of the impacted areas would aid in restabilizing slopes and enhancing the habitat quality of the area more quickly.

(b) Borrow Areas. The borrow site for the pervious material required for dam construction would impact 550 acres of streambed downstream from the proposed dam site. Impacts to habitat would be insignificant as vegetation is fairly sparse. Excavation would leave a fairly deep pit (approximately 20-30 feet deep). The borrow site for the dam core material would impact about 130 acres of citrus groves, 60 acres of which are classified as prime and unique farmland.

(c) Highway 38 Relocation. Mill Creek Road would need to be relocated due to dam construction and would be replaced by a road with a lower design speed. This would disrupt traffic and temporarily inconvenience the residents of Mountain Home Village and Home Falls during road relocation.

(d) Reservoir Area. The predicted amount of sediment accumulation would be relatively low (50 acres out of a reservoir pool surface area of as much as 380 acres), and would probably encourage growth of willows and various annual weeds. This amount of sediment has been accounted for in the storage of the reservoir (for a 100-year life) and would not be removed. However, regrowth in the sediment may be subjected to periodic clearing. The oak woodland would be irreparably damaged if subjected to any periods of prolonged inundation.

(e) Rare, Threatened or Endangered Species. It is unlikely that construction at this site would impact any rare or endangered species. According to a preliminary search of appropriate literature (see references 6, 8, 10 and 13) the site is within the historic range of the slender horned spineflower (*Centrostegia leptoceras*), although it is considered to be extinct in this area.

(f) Cultural Resources. Maps and site records on file at the San Bernardino County Museum show an historic site on the National Register of Historic Places located near the southern boundary of the borrow pit associated with the proposed Crafton dam. This has been identified as Mill Creek Zanja which is between Sylvan Boulevard and Mill Creek Road. A complete literature search, which would include ethnographic and historic data concerning the project area, consultation with archeologists familiar with San Bernardino County, and field surveys would need to be conducted.

(g) Other. Studies pertaining to impacts on water resources and water quality would be required.

5. **Analysis of Costs.**

The total estimated first cost for the Three Dam Proposal is $533,787,000, based on quantity estimates and unit prices at October 1979 price levels. In general, unit cost data was taken from Santa Ana River, Phase I General Design Memorandum (ref. 1). First cost includes flood control, hydropower, water conservation, esthetic treatment, land acquisition, relocations, engineering and design, supervision and administration of construction and mitigation. A 25% contingency has been applied to construction costs. Because of uncertainties regarding geotechnical and other design considerations, total cost could exceed this contingency value. Tables 17 through 20 provide a summary and detailed cost estimates for each dam. Operation and maintenance costs are shown on table 21. The sources of construction materials, processing requirements and approximate haul road distances are discussed in section C.2.e.

Table 17. Summary of First Costs - Three Dam Proposal
(October 1979 Price Levels)

Dam and Appurtenant Works	Estimated Cost ($)	Unit Storage Cost ($/acre-feet)
Forks	$145,667,000	$3,740
Upper Mentone	173,469,000	1,830
Crafton	189,296,000	3,380
Subtotal	$508,432,000	
Mitigation Program	$ 25,355,000	
Total First Cost - Three Dam Proposal (October 1979 Price Levels)	$533,787,000	

Table 18. Detailed Cost Estimate--Forks Dam-Earthfill
(October 1979 Price Level)

Description	Estimated Quantity	Unit	Unit Cost	Total Cost
CONSTRUCTION				
Dam				
Care & Diversion of Water	1	Job	LS	$300,000
Clearing & Grubbing	100	Ac	500.00	50,000
Borrow, Random	9,500,000	CY	1.55	14,725,000
Borrow, Pervious	3,900,000	CY	1.55	6,045,000
Borrow, Transition	1,100,000	CY	1.55	1,705,000
Borrow, Impervious	1,900,000	CY	2.30	4,370,000
Borrow, Rock	3,400,000	CY	1.55	5,270,000
Excavation, Drainage Channel	450,000	CY	6.00	2,700,000
Excavation, Cutoff	25,000	CY	1.80	45,000
Excavation, Abutment	60,000	CY	18.00	1,080,000
Excavation, Foundation	100,000	CY	1.25	125,000
Foundation Drill & Grout	115,000	LF	65.00	7,475,000
Embankment, Random	8,660,000	CY	0.20	1,732,000
Embankment, Pervious	3,550,000	CY	0.20	710,000
Embankment, Transition	1,050,000	CY	0.25	263,000
Embankment, Impervious	1,700,000	CY	0.20	340,000
Embankment, Rock	3,060,000	CY	0.20	612,000
A.C. Pavement	750	Ton	40.00	30,000
Spillway:				
Excavation, Common	3,600,000	CY	2.00	7,600,000
Excavation, Rock	400,000	CY	8.00	3,200,000
Excavation, Evacuation Channel	200,000	CY	8.00	1,600,000
Concrete, Sills	1	Job	LS	400,000
Concrete	145,000	CY	50.00	7,250,000
Portland Cement	870,000	CY	6.00	5,220,000
Reinforcing Steel	7,250	Tons	7.20	5,220,000
Subdrain System	1	Job	LS	150,000
Toe Protection Stone	135,000	CY	4.00	540,000
Beautification	1	Job	LS	200,000
Instrumentation	1	Job	LS	300,000
Access Road	1	Job	LS	15,000,000
Outlet Works 1/				
Tunnel, Excavation	16,700	CY	170.00	2,839,000
Tunnel, Concrete	6,800	CY	200.00	1,360,000
Tunnel, Cement	41,000	Cwt	6.00	246,000
Tunnel, Reinforcing Steel	340	Ton	720.00	245,000
Intake Tunnel, Excavation	2,000	CY	170.00	340,000
Intake Tunnel, Concrete	700	CY	200.00	140,000

1/ Includes cost of hydropower outlet.

Table 18. Detailed Cost Estimate--Forks Dam-Earthfill (Cont'd)
(October 1979 Price Level)

Description	Estimated Quantity	Unit	Unit Cost	Total Cost
Intake Tunnel, Reinforcing Steel	35	Ton	720.00	25,000
Intake Tunnel, Cement	4,000	Cwt	6.00	24,000
Shaft, Excavation	7,100	CY	200.00	1,420,000
Shaft, Concrete	1,700	CY	200.00	340,000
Shaft, Reinforcing Steel	90	Ton	720.00	65,000
Shaft, Cement	10,400	Cwt	6.00	62,000
Intake and Trash Structure	1	Job	LS	200,000
Gate Structure and Access	1	Job	LS	400,000
Outlet Structure	1	Job	LS	300,000
Slide Gates	1	Job	LS	600,000
Control House and Equipment	1	Job	LS	300,000
Subtotal				$102,763,000
Contingency (25%)				25,691,000
Subtotal				128,454,000
Engineering and Design (7%)				8,990,000
Supervision and Administration (5%)				6,423,000
Total Construction				$143,867,000
LANDS AND RELOCATIONS				
Lands				1,600,000
Relocations				
Relocate Aqueduct				200,000
Total-Lands and Relocations				1,800,000
TOTAL-FORKS DAM				$145,667,000

Table 19. Detailed Cost Estimate--Upper Mentone Dam-Earthfill
(October 1979 Price Level)

Description	Estimated Quantity	Unit	Unit Cost	Total Cost
CONSTRUCTION				
Dam				
Care & Diversion of Water	1	Job	LS	$300,000
Clearing & Grubbing	150	Ac	500.00	75,000
Borrow, Random	17,500,000	CY	1.55	27,125,000
Borrow, Pervious	7,100,000	CY	1.55	11,005,000
Borrow, Transition	2,100,000	CY	1.55	3,255,000
Borrow, Impervious	3,400,000	CY	2.30	7,820,000
Borrow, Rock	6,100,000	CY	1.55	9,455,000
Excavation, Drainage Channel	460,000	CY	6.00	2,760,000
Excavation, Cutoff	340,000	CY	1.80	612,000
Excavation, Abutment	13,000	CY	18.00	234,000
Excavation, Foundation	390,000	CY	1.25	488,000
Foundation Drill & Grout	100,000	LF	65.00	6,500,000
Embankment, Random	15,900,000	CY	0.20	3,180,000
Embankment, Pervious	6,500,000	CY	0.20	1,300,000
Embankment, Transition	1,900,000	CY	0.25	475,000
Embankment, Impervious	3,100,000	CY	0.20	620,000
Embankment, Rock	5,600,000	CY	0.20	1,120,000
A.C. Pavement	750	Ton	40.00	30,000
Spillway:				
Excavation, Common	2,850,000	CY	2.00	5,700,000
Excavation, Rock	2,850,000	CY	8.00	22,800,000
Excavation, Evacuation Channel Rock	730,000	CY	8.00	5,840,000
Excavation, Evacuation Channel Common	100,000	CY	2.00	200,000
Toe Protection Stone	160,000	CY	4.00	640,000
Concrete Sill	1	Job	LS	200,000
Beautification	1	Job	LS	200,000
Instrumentation	1	Job	LS	300,000
Outlet Works: 1,880'				
Tunnel Excavation	9,300	CY	170.00	1,581,000
Tunnel lining, Concrete	3,800	CY	200.00	760,000
Tunnel, Reinforcing Steel	190	Ton	720.00	137,000
Tunnel, Portland Cement	23,000	Cwt	6.00	138,000
Shaft Excavation	5,900	CY	200.00	1,180,000
Shaft Concrete	1,400	CY	200.00	280,000
Shaft, Reinforcing Steel	75	Ton	720.00	54,000
Shaft, Portland Cement	8,600	Cwt	6.00	52,000
Intake & Trash Structure	1	Job	LS	200,000
Gate Structure and Access	1	Job	LS	400,000

Table 19. Detailed Costs Estimate--Upper Mentone Dam-Earthfill (Cont'd)
(October 1979 Price Level)

Description	Estimated Quantity	Unit	Unit Cost	Total Cost
Control House and Equipment	1	Job	LS	300,000
Slide Gates	1	Job	LS	600,000
Outlet Structure	1	Job	LS	300,000
Access Road	1	Job	LS	690,000
Subtotal				$118,906,000
Contingency (25%)				29,727,000
Subtotal				$148,633,000
Engineering and Design (7%)				10,404,000
Supervision and Administration (5%)				7,432,000
Total Construction				$166,469,000
LANDS AND RELOCATIONS				
Lands				$ 5,000,000
Relocations				
Transmission lines				2,000,000
Total - Lands and Relocations				$ 7,000,000
TOTAL - UPPER MENTONE DAM				$173,469,000

Table 20. Detailed Cost Estimate--Crafton Dam-Earthfill
(Oct 1979 Price Level)

Description	Estimated Quantity	Unit	Unit Cost	Total Cost
CONSTRUCTION				
Dam				
Care & Diversion of Water	1	Job	LS	$300,000
Clearing & Grubbing	150	Ac	500.00	75,000
Borrow, Random	19,300,000	CY	1.55	29,915,000
Borrow, Pervious	7,900,000	CY	1.55	12,245,000
Borrow, Impervious	3,700,000	CY	2.30	8,510,000
Borrow, Transition	2,300,000	CY	1.55	3,565,000
Borrow, Rock	6,800,000	CY	1.55	10,540,000
Excavation, Cutoff	175,000	CY	1.80	315,000
Excavation, Abutment (Rock)	20,000	CY	4.00	80,000
Excavation, Foundation	270,000	CY	1.25	338,000
Abutment Treatment	1	Job	LS	720,000
Foundation, Drill & Grout	50,000	LF	65.00	3,250,000
Embankment, Random	17,500,000	CY	0.20	3,500,000
Embankment, Pervious	7,200,000	CY	0.20	1,440,000
Embankment, Transition	2,100,000	CY	0.25	525,000
Embankment, Impervious	3,400,000	CY	0.20	680,000
Embankment, Rock	6,200,000	CY	0.20	1,240,000
A.C. Pavement	750	Ton	40.00	30,000
Spillway:				
Excavation, Common	2,500,000	CY	2.00	5,000,000
Excavation, Rock	800,000	CY	8.00	6,400,000
Concrete	125,000	CY	50.00	6,250,000
Portland Cement	750,000	Cwt	6.00	4,500,000
Reinforcing Steel	6,200	Ton	720.00	4,464,000
Subdrain System	1	Job	LS	200,000
Beautification	1	Job	LS	200,000
Instrumentation	1	Job	LS	300,000
Outlet Works:				
Tunnel Excavation	20,900	CY	170.00	3,553,000
Tunnel, Concrete	8,500	CY	200.00	1,700,000
Tunnel, Reinforcing Steel	425	Ton	720.00	306,000
Tunnel, Portland Cement	51,000	Cwt	6.00	306,000
Shaft, Excavation	7,100	CY	200.00	1,420,000
Shaft, Concrete	1,730	CY	200.00	346,000

Table 20. Detailed Cost Estimate--Crafton Dam-Earthfill (Cont'd)
(October 1979 Price Level)

Description	Estimated Quantity	Unit	Unit Cost	Total Cost
Shaft, Reinforcing Steel	90	Ton	720.00	65,000
Shaft, Portland Cement	10,400	Cwt	6.00	62,000
Intake & Trash Structure	1	Job	LS	200,000
Gate Structure and Access	1	Job	LS	400,000
Control House and Equipment	1	Job	LS	300,000
Slide Gates	1	Job	LS	600,000
Outlet Structure	1	Job	LS	300,000
Subtotal				$114,140,000
Contingency (25%)				28,535,000
Subtotal				$142,675,000
Engineering and Design (7%)				9,987,000
Supervision and Administration (5%)				7,134,000
Total Construction				$159,796,000
CONSTRUCTION				
LAND ACQUISITION				
Lands				$5,700,000
Relocations				
Relocate Highway 38 (3.2 miles)				23,800,000
Total - Lands and Relocations				$ 29,500,000
TOTAL-CRAFTON DAM				$189,296,000

Table 21. Annual Operation and Maintenance Costs. ($1000's)

Operational or Maintenance Feature	Forks	Upper Mentone	Crafton	Total
Dam Operation				
Dam Tender	45	45	45	135
Residence and Vehicle Maintenance	10	10	10	30
Maintenance				
Roads1/	150	10	10	170
Outlet Works1/	225	95	245	565
Spillway and Dam	25	25	25	75
Dam Instrumentation	10	10	10	30
Hydrologic Facilities	15	15	15	45
Inspection and Management				
Periodic Inspection	3	3	3	9
Topographic Surveys	2	2	2	6
Real Estate Management	2	2	2	6
Total Annual O&M Costs	$487	$217	$367	$1,071

1/ *Taken at approximately 1% of Capital Cost.*

The mitigation program at an estimated cost of $25,355,000, would consist of the following items:

(a) Acquisition of 1,864 acres to replace habitat which would be permanently affected by the three dams (e.g., dams and spillways, reservoir pools, and permanent access roads), location of this acreage to be determined through public and agency coordination. A cost estimate of this land was based on acquisition of high-habitat-value riparian lands along the upper Santa Ana River above Prado basin ($13,048,000).

(b) Revegetation by hydroseeding of about 2,220 acres to be affected by borrow activities ($11,807,000).

(c) Mitigation of cultural resource impacts by preservation and protection of sites, where possible; data recovery, consisting of mapping, recording, collection, excavation, and analysis; report writing; and interpretation to the public ($500,000).

6. Economic Analysis.

Incremental evaluation was performed using the Three Dam Proposal as a first added flood control increment to the downstream elements of the All River Plan. This approach analyzes benefits and costs of the Three Dam Proposal separately from those of the rest of the system.

a. Flood Control. The Three Dam Proposal was evaluated for flood control as an entity unto itself. Flood control benefits for this study were derived from the economic analysis in the Santa Ana River Phase I General Design Memorandum (GDM) (ref. 5). The Three Dam Proposal, provides slightly less than SPF protection between Mentone Dam site and Prado Dam because the Plunge Creek watershed area is left uncontrolled. (See table 14) Spillway crest at Prado Dam would need to be raised 1.5 feet higher than in the All River Plan to contain this increased runoff. This analysis does not assume raising Prado Dam, therefore SPF protection is not obtained downstream from Prado Dam. Using the Phase I GDM as a base condition and adjusting for reduced flood control benefits between Mentone and the Pacific Ocean, total flood control benefits would be $78,200,000 annually using 1979 price levels and a 7 1/8 percent discount rate.

b. Hydropower Generation. Hydropower production from the Three Dam Proposal is estimated at 9,500,000 KWH per year. (See Section C.2.f). The value of hydropower generation can vary considerably with availability of alternate fuels, reliability, season and time of day. The evaluation of hydropower used 23 mils per KWH, which was the average generation cost to the Southern California Edison Company during 1979 (Southern California Edison Company Monthly Operating Report, December 1979). Power generation of 9,500,000 KWH at 23 mils per KWH yields $218,000 in annual benefits.

c. Water Conservation. The increase in water supply would be a maximum of 2,390 acre-feet per year (see Section C.2.f). Significant factors to determine the value of water include its purpose, destination, user, and legal restrictions under which it is delivered. The evaluation used $104 per acre-foot, which represents the highest wholesale price charged by the Metropolitan Water District during 1979. At $104 per acre foot, conservation of of 2,390 acre-feet of a water yields $249,000 in annual benefits.

d. Benefit and Cost Summary. The total first cost of the project described in the Three Dam Proposal is $534,000,000 (1979 price level), with operation and maintenance costs of $1,070,000 annually. The equivalent annual cost would be $43,400,000. The benefit-cost ratio would be 1.8 and the net annual benefits would be $78,700,000. The economic evaluation, including the incremental analysis, is summarized in table 22. The economic evaluation of the Mentone Dam is included for comparison. Were the Three Dam Proposal to be added to the All River Plan for the Santa Ana River in place of the recommended Mentone Dam, as a last added increment, it would not be justified. In this latter case, the B/C ratio would be 0.8 for the Three Dam Proposal while the recommended Mentone Dam would be 1.2.*

*Errata (16 November 1982). Corrected to read 1.2 in lieu of 1.0.

Table 22. First Added Incremental Analysis.
(1979 $1000's @ 7 1/8%
3 Significant Digits)

Benefits:	Mentone 1/	3 Dam Proposal
Flood Control	92,400	78,200
Water Supply	--	249
Hydropower	--	218
Total Benefits	92,400	78,700
First Costs: Construction	386,000	534,000
Equivalent Annual Costs		
First Costs of Construction 2/	28,620	42,300
Operations and Maintenance	950	1,070
Total	29,600	43,400
Net Benefits	62,800	35,300
Benefit-to-Cost Ratio	3.1	1.8 3/

1/ As presented in Phase I General Design Memorandum.
2/ Includes interest during construction.
3/ Were the Three Dam Proposal to be added to the All River Plan for the Santa Ana River in place of the recommended Mentone Dam, as a last added increment, it would not be justified with a B/C ratio of 0.8.

D. CONCLUSIONS.

The evaluation of the San Bernardino Valley Municipal Water District Three Dam Proposal leads to the following basic conclusions:

- The Three Dam Proposal provides a lower level of protection to the downstream communities in San Bernardino, Riverside and Orange Counties than the recommended Mentone Dam. Incorporation of the Three Dam Proposal into the All River Plan, would require additional modifications with commensurate costs at Prado Dam or on the channel downstream from Prado to provide SPF protection in Orange County.

- The most suitable type of dam for the three dam sites under consideration is earthfill.

- Concrete (including Roller Compacted Concrete) dams are technically unsuitable at two of the three general sites (Upper Mentone and Crafton) for geotechnical reasons and are not cost competitive at the third (Forks).

- The Crafton Dam site is geotechnically very marginal and further investigation may determine it to be unsuitable for an earthfill dam.

- The hydropower generation increase afforded by the Three Dam Proposal for Run-of-River operation with power storage is about 30% annually or about 9500 MWH.

- The Three Dam Proposal would conserve about 20 percent or about 2390 acre-feet annually of the water which would be lost to the ocean using the Prado Dam operating plan proposed under the All River Plan.

- The total cost of the Three Dam Proposal is more expensive than the recommended Mentone Dam, $534,000,000 and $386,000,000, respectively, a difference of $148,000,000 at October 1979 price levels. The unit storage cost ($/acre-foot) is $2810 for the Three Dam Proposal and $2130 for Mentone Dam (October 1979 price levels).

- The net benefits of the Three Dam Proposal are $35,300,000 compared to $62,800,000 for the recommended Mentone Dam, a difference of $27,500,000 based upon a first added incremental analysis.

- Were the Three Dam Proposal to be added to the All River Plan for the Santa Ana River in place of the recommended Mentone Dam, as a last added increment, it would not be justified with a B/C ratio of 0.8.

REFERENCES.

1. "Santa Ana River-Phase I General Design Memorandum Main Report and SEIS", U.S. Army Corps of Engineers (September 1980).

2. Review Report on the Santa Ana River Main Stem - Appendix 1, Volume 1, Technical Information, Section H, Hydrology, U.S. Army Corps of Engineers (December 1975).

3. Santa Ana River, Phase I General Design Memorandum, Santa Ana River Main Stem, Technical Appendix B, Hydrology U.S. Army Corps of Engineers (September 1980).

4. Santa Ana River Basin, California, Flood Control Design Memorandum No. 1, Hydrology for Mill Creek Levees, U.S. Army Corps of Engineers (June 1958).

5. Santa Ana River, Phase I General Design Memorandum, Santa Ana River Main Stem, Appendix J, Economics, U.S. Army Corps of Engineers (September 1980).

6. California Native Plant Society Inventory of Rare and Endangered Vascular Plants of California, 1980.

7. Federal Register, Vol. 45, No. 166, Part VIII, "Environmental Quality: Policy and Procedures for Implementing NEPA" (ER 200-2-2), 25 August 1980.

8. Federal Register, Vol. 45, No. 242, Part IV, "Endangered and Threatened Wildlife and Plants: Review of Plant Taxa for Listing as Endangered or Threatened Species", 15 Dec 1980.

9. Little, Elbert L., The Audubon Society Field Guide to North American Trees, Western Region, 1980.

10. Munz, Phillip A., A California Flora, 1970.

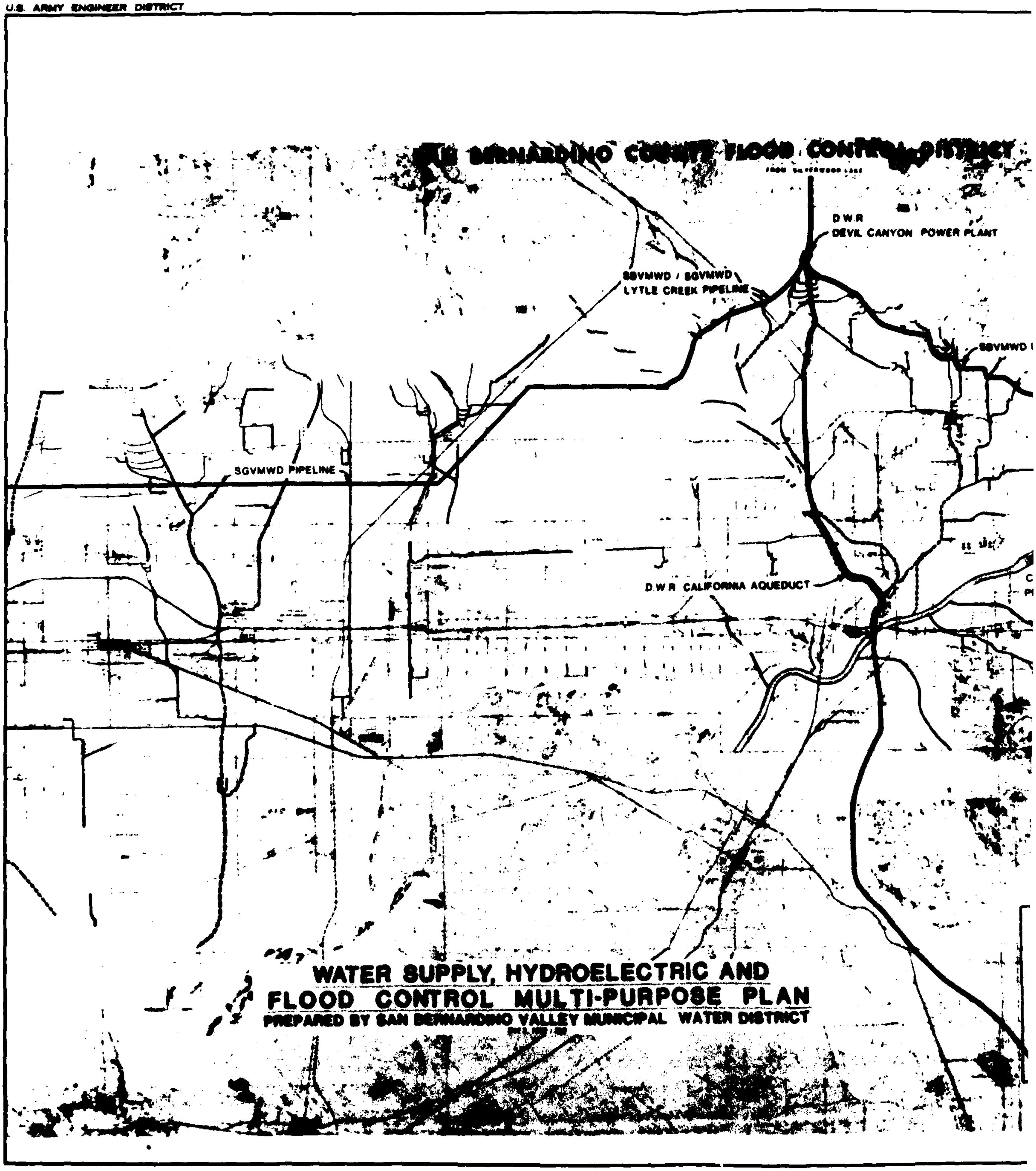
11. State of California, Dept. of Fish and Game, At the Crossroads, A Report on California's Endangered and Rare Fish and Wildlife, Dec 1980.

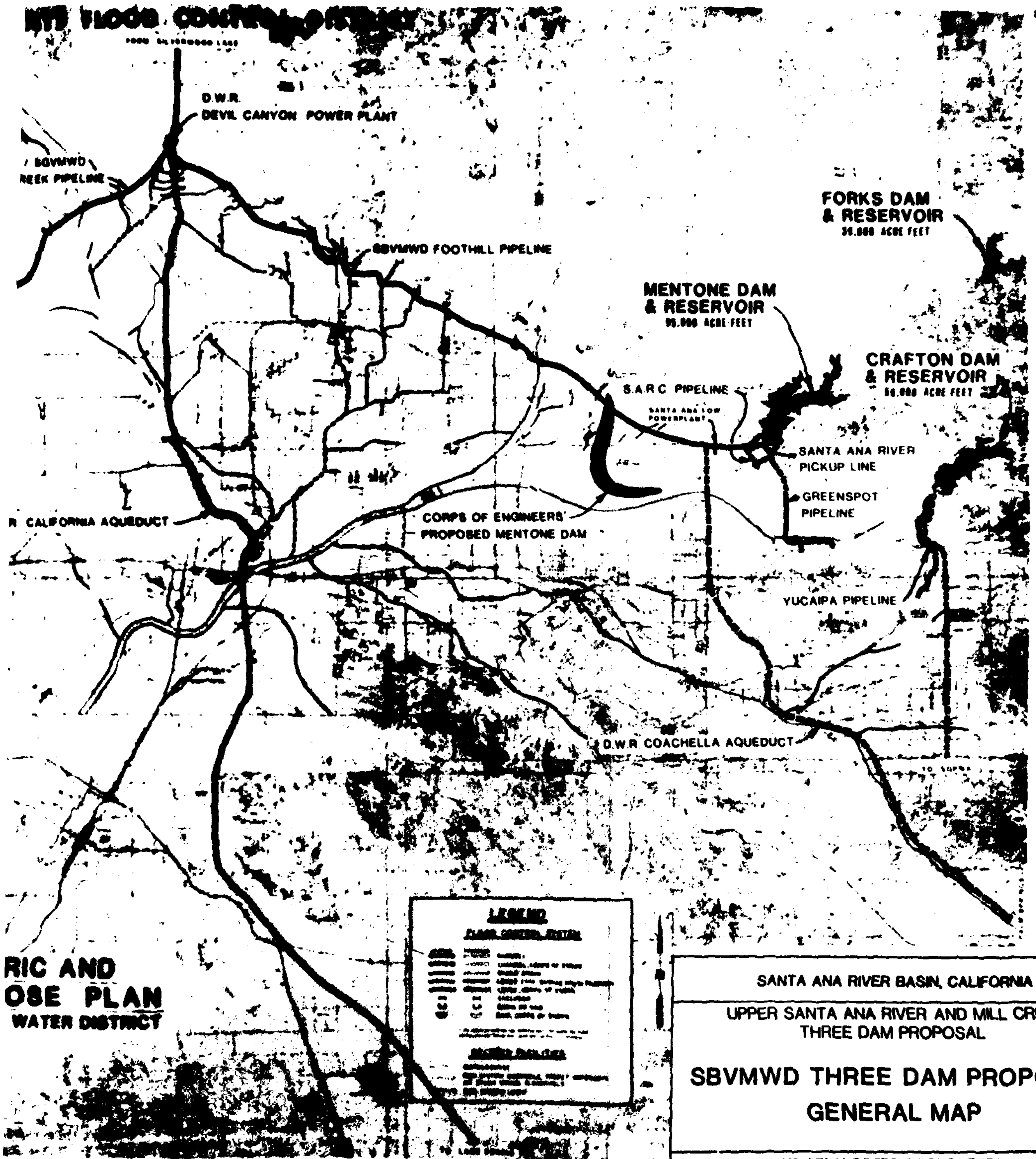
12. U.S. Dept. of Interior, National Parks Service, "The Nationwide Rivers Inventory, Western Region Component", Jan. 1982.

13. U.S. Fish and Wildlife Service, "Candidate Endangered and Threatened Species, California-Nevada", 1980.

14. Regional Geologic Map of San Andreas and Related Faults in Eastern San Gabriel Mountains, San Bernardino Mountains, Western San Jacinto Mountains and Vicinity, USGS Preliminary Open File Map, 1970.

U.S. ARMY ENGINEER DISTRICT





SANTA ANA RIVER BASIN, CALIFORNIA

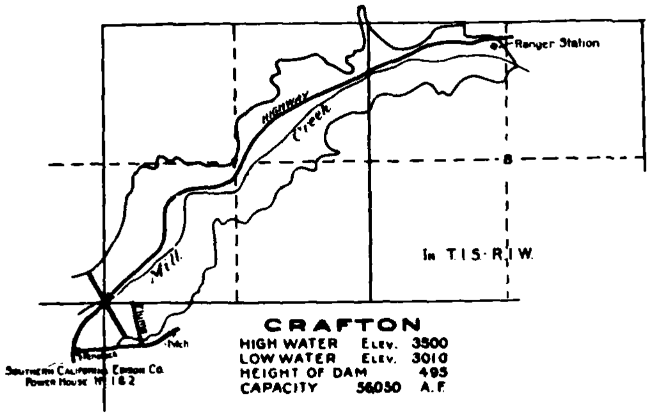
UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

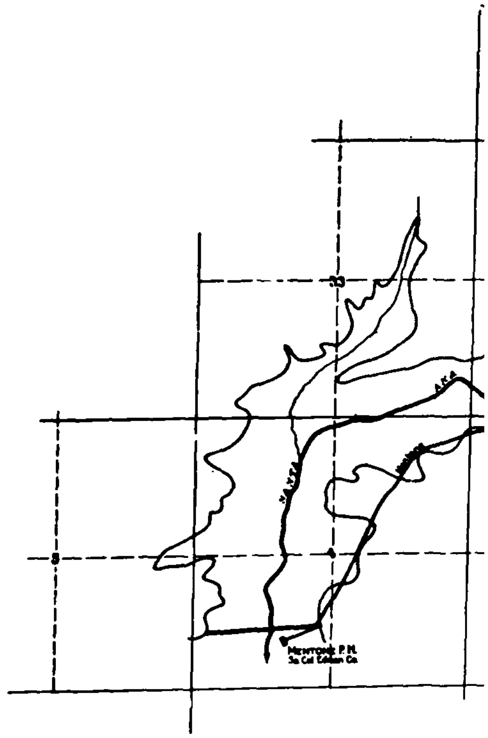
SBVMWD THREE DAM PROPOSAL
GENERAL MAP

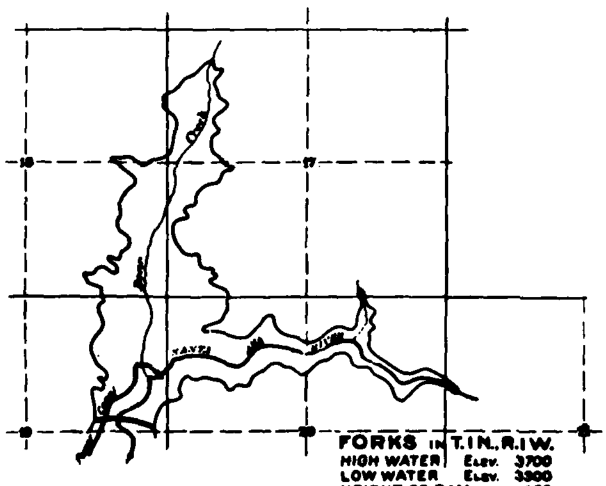
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 1

2







SANTA ANA INVESTIGAT

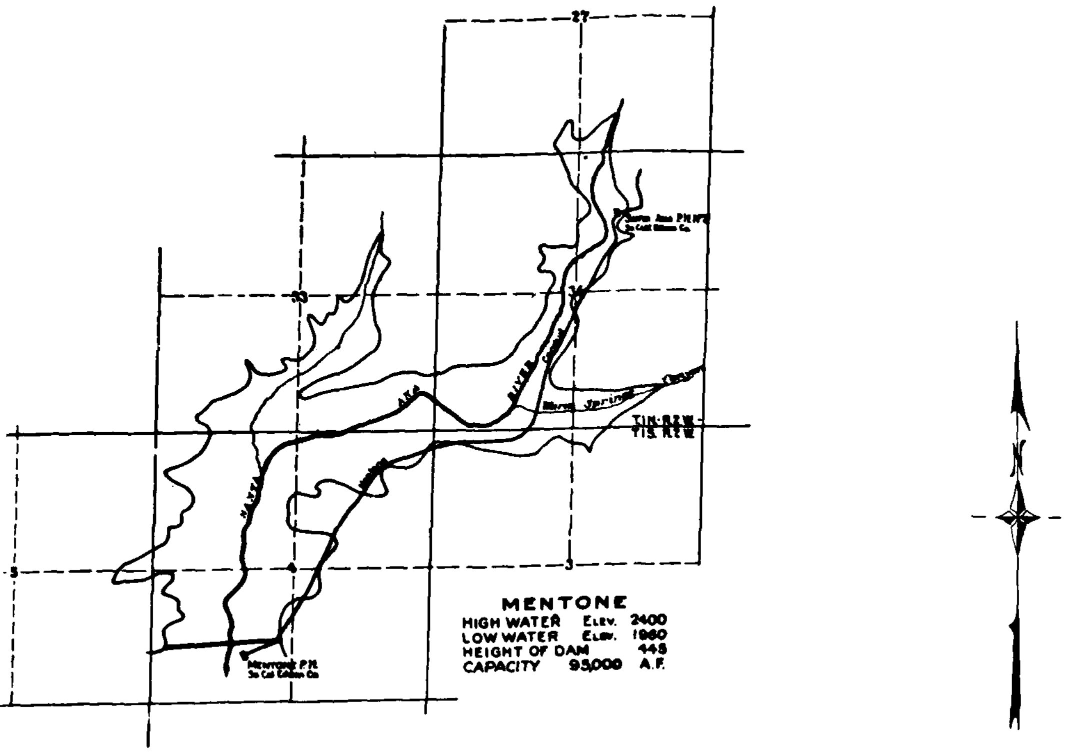
SURVEYS OF
RESERVOIR SITES

For Sites in Lower Santa Ana Canyon See

SCALE

2000' 1000' 500' 0 ¼ ½ 1 MIL

CORPS OF ENGINEERS



EXTRACTED FROM:

MAP 13
SHEET 1, OF 2 SHEETS.

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT - STATE ENGINEER

NTA ANA INVESTIGATION

SURVEYS OF RESERVOIR SITES

ites in Lower Santa Ana Canyon See Sheet 2

SCALE

2000' 1000' 500' 0 1/4 1/2 1 MILE

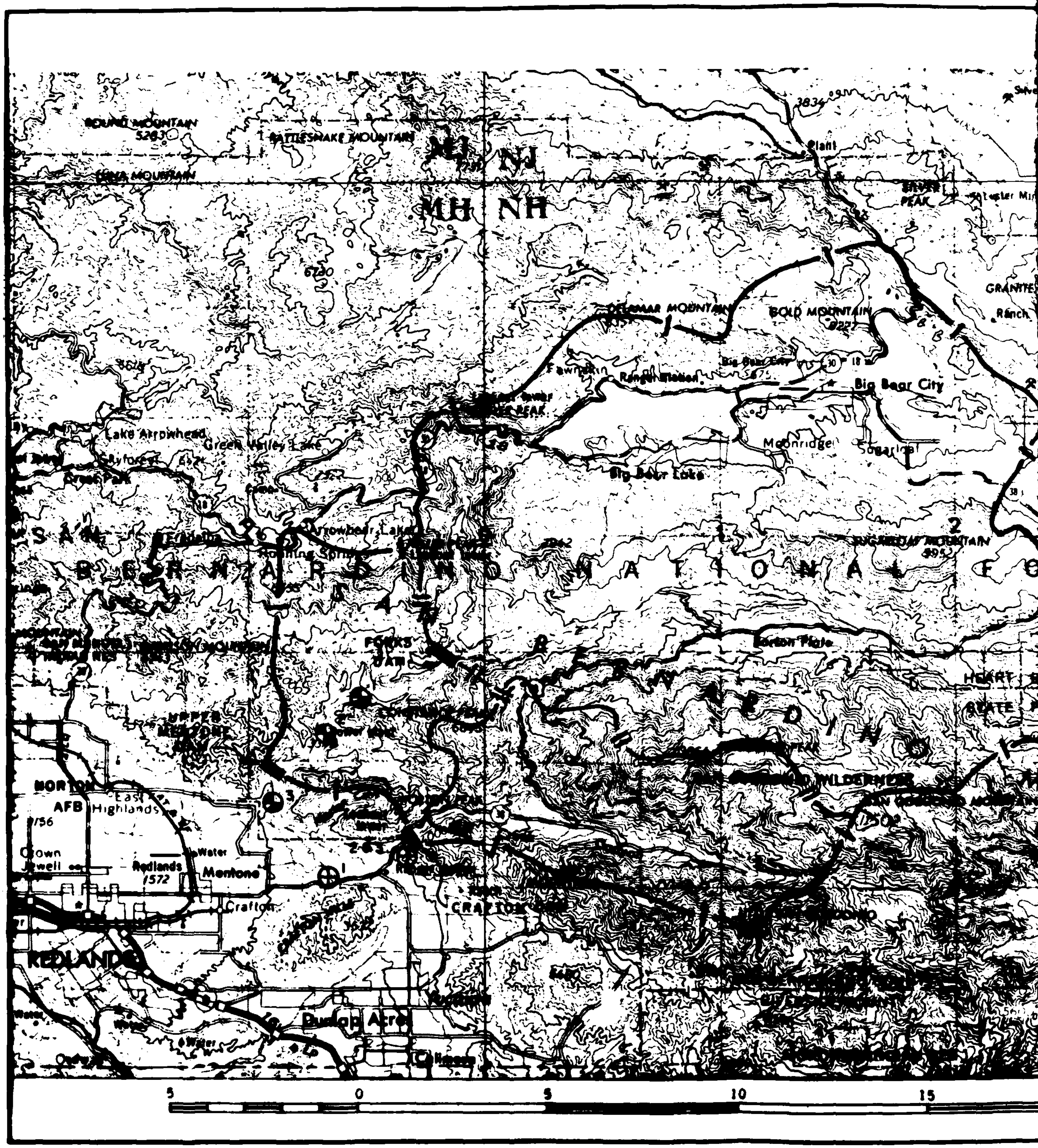
SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

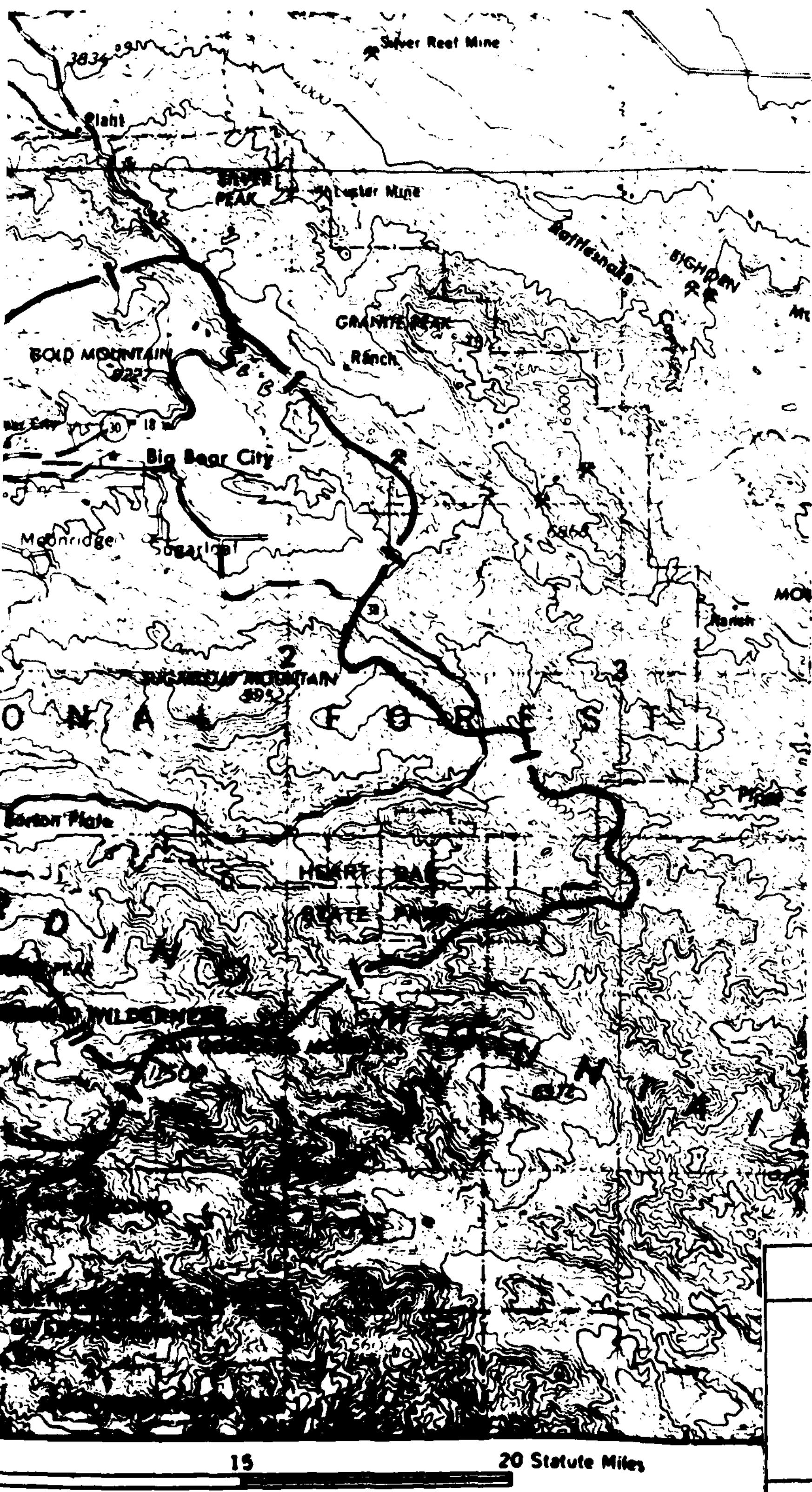
BULLETIN 19 DAM SITES

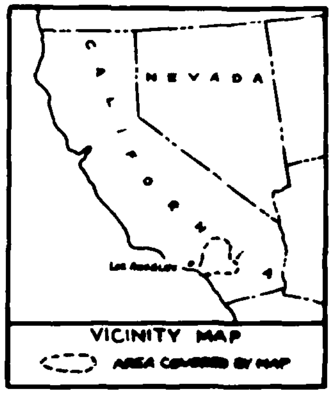
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 2



ROUND MOUNTAIN
5283
RATTLESNAKE MOUNTAIN
MJ NJ
MH NH
3834
Plant
PEAK
GRANITE
Ranch
DELAMAR MOUNTAIN
BOLD MOUNTAIN
Fawnskin
Ranger Station
Big Bear City
Lake Arrowhead
Green Valley Lake
Moonridge
Sugarloaf
Big Bear Lake
Arrowbear Lake
Running Springs
S A N
B E R N A R D I N O
N A T I O N A L
F O
SUGARLOAF MOUNTAIN
2
FORKS DAM
HEART
STATE
UPPER MENTONE
NORTON AFB
East Highlands
Crown Jewell
Redlands
1572
Mentone
Crafton
CRAFTON
REDLANDS
Dunlap Acres
Calimesa
5
0
5
10
15





LEGEND

—I— BOUNDARY OF DRAINAGE AREA

—II— BOUNDARY OF DRAINAGE SUB AREA.

EXISTING SANTA ANA RIVER POWER-HOUSE LOCATION & NUMBER.

EXISTING MILL CREEK POWER-HOUSE LOCATION & NUMBER.

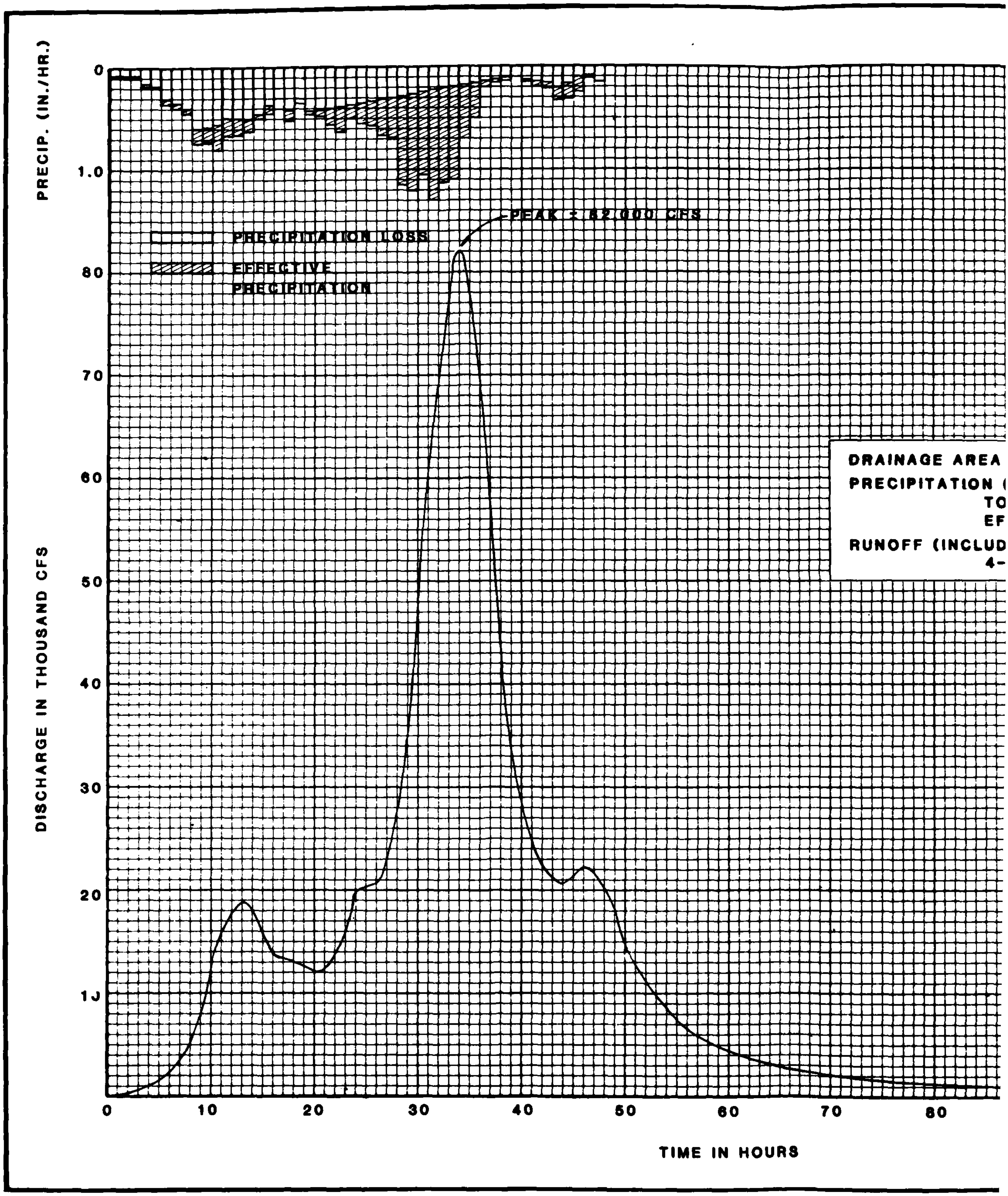
SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

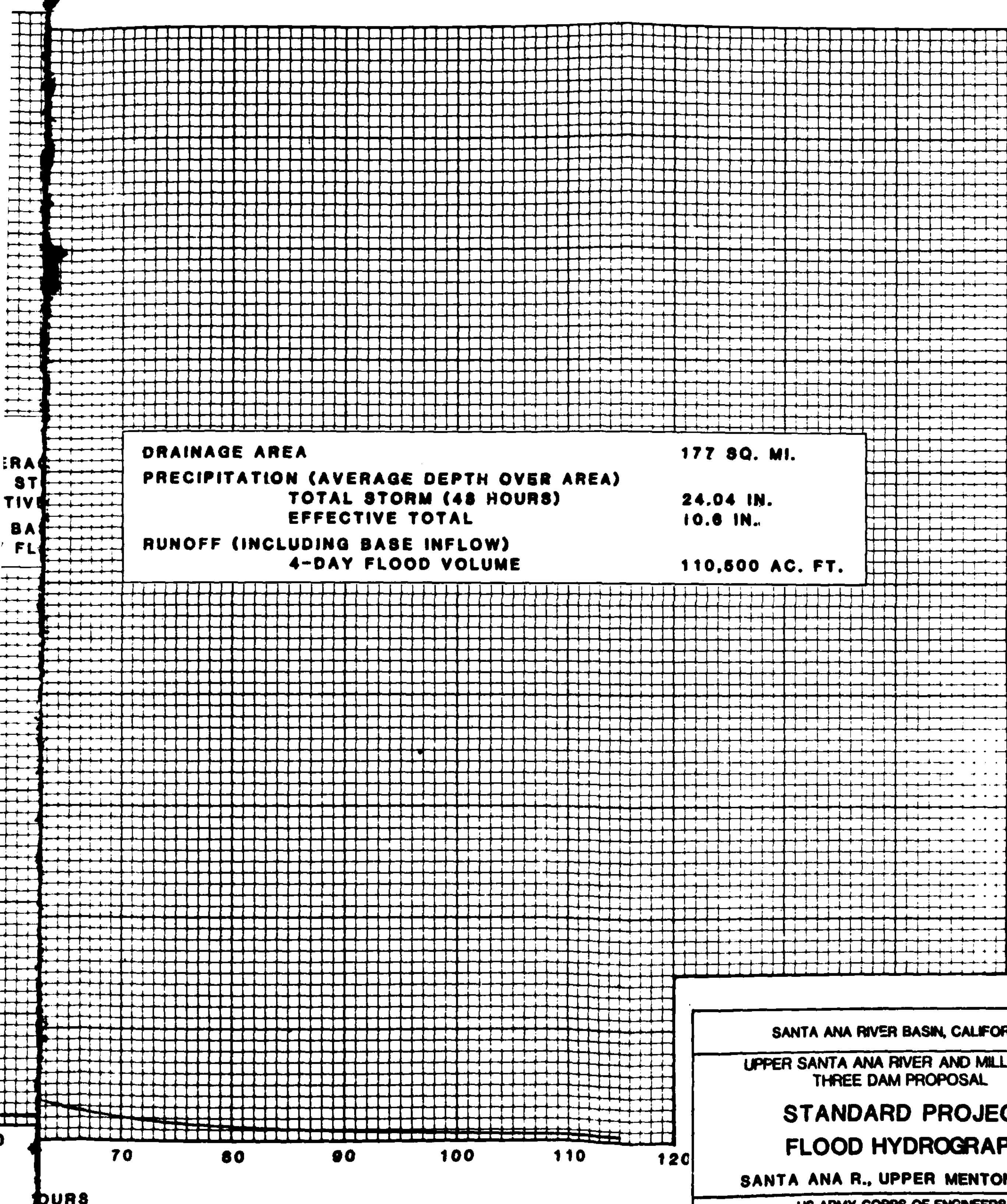
DRAINAGE AREA

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 3



PRECIP. (IN./HR.)
0
1.0
PEAK = 82,000 CFS
PRECIPITATION LOSS
EFFECTIVE PRECIPITATION
DISCHARGE IN THOUSAND CFS
80
70
60
50
40
30
20
1J
0
10
20
30
40
50
60
70
80
TIME IN HOURS
DRAINAGE AREA
PRECIPITATION (
TO
EF
RUNOFF (INCLUD
4-



SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

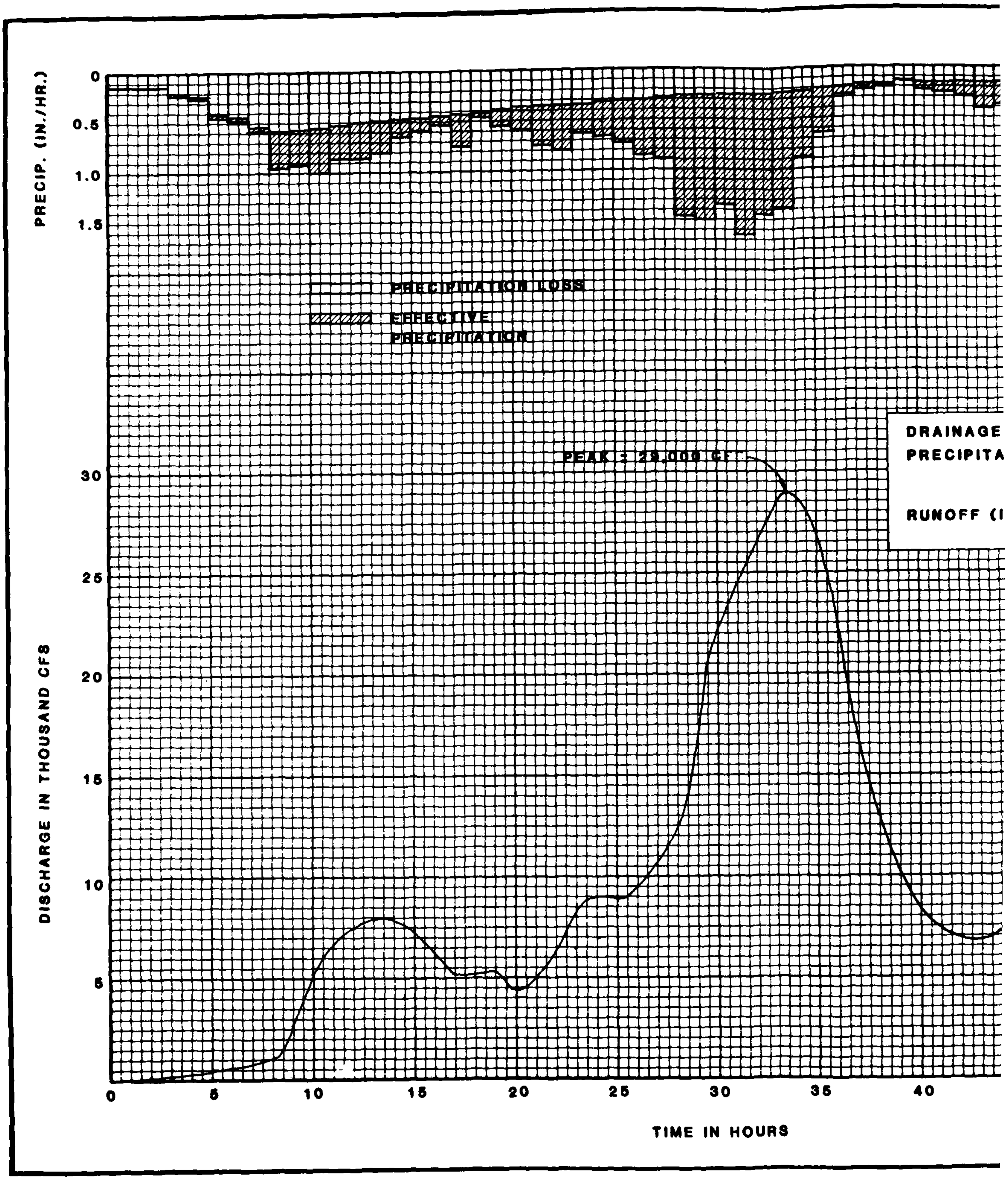
STANDARD PROJECT
FLOOD HYDROGRAPH

SANTA ANA R., UPPER MENTONE DAM

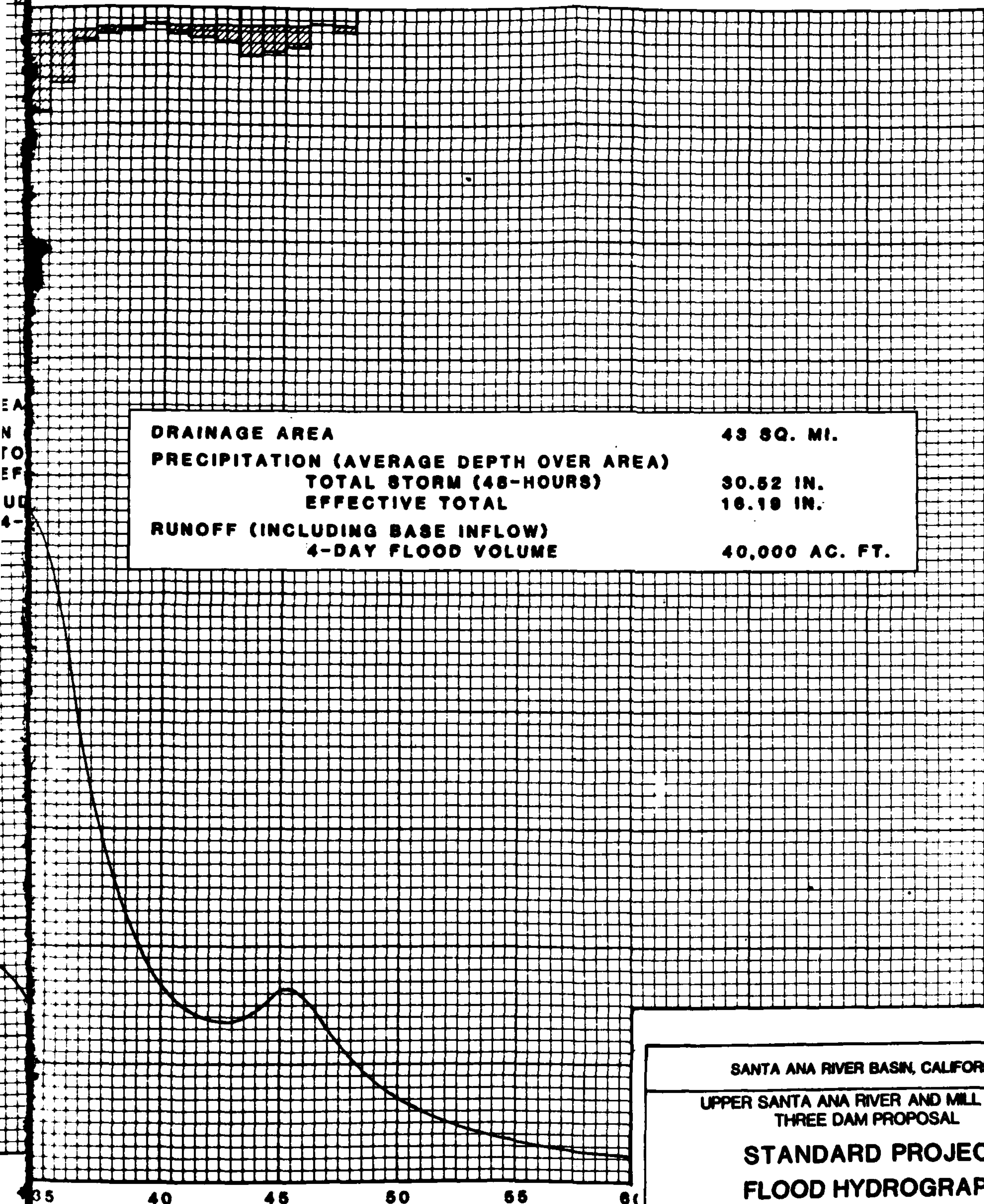
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 4

2



PRECIP. (IN./HR.)
0
0.5
1.0
1.5
PRECIPITATION LOSS
EFFECTIVE PRECIPITATION
DRAINAGE
PRECIPITA
RUNOFF (I
PEAK = 29,000 CFS
DISCHARGE IN THOUSAND CFS
30
25
20
15
10
5
0
5
10
15
20
25
30
35
40
TIME IN HOURS



SANTA ANA RIVER BASIN, CALIFORNIA

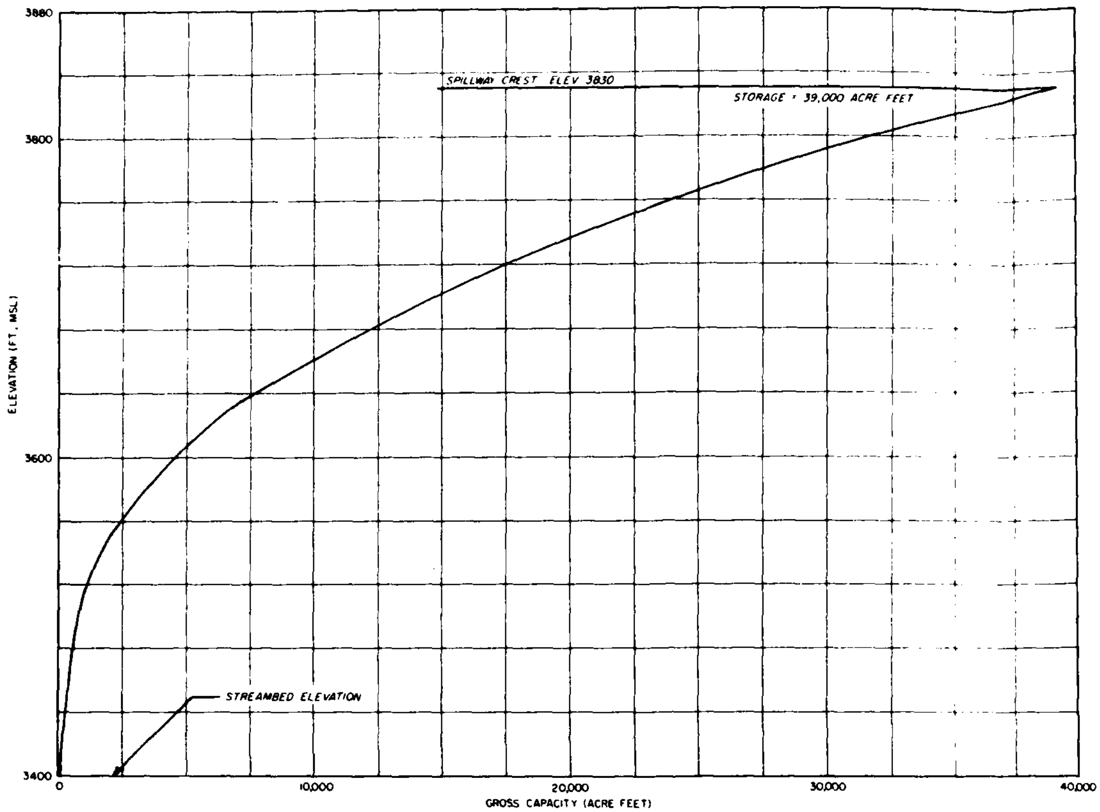
UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

STANDARD PROJECT FLOOD HYDROGRAPH

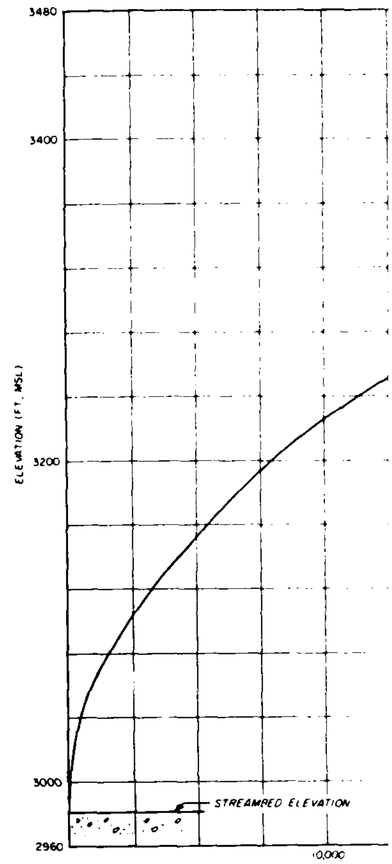
MILL CREEK AT CRAFTON DAM

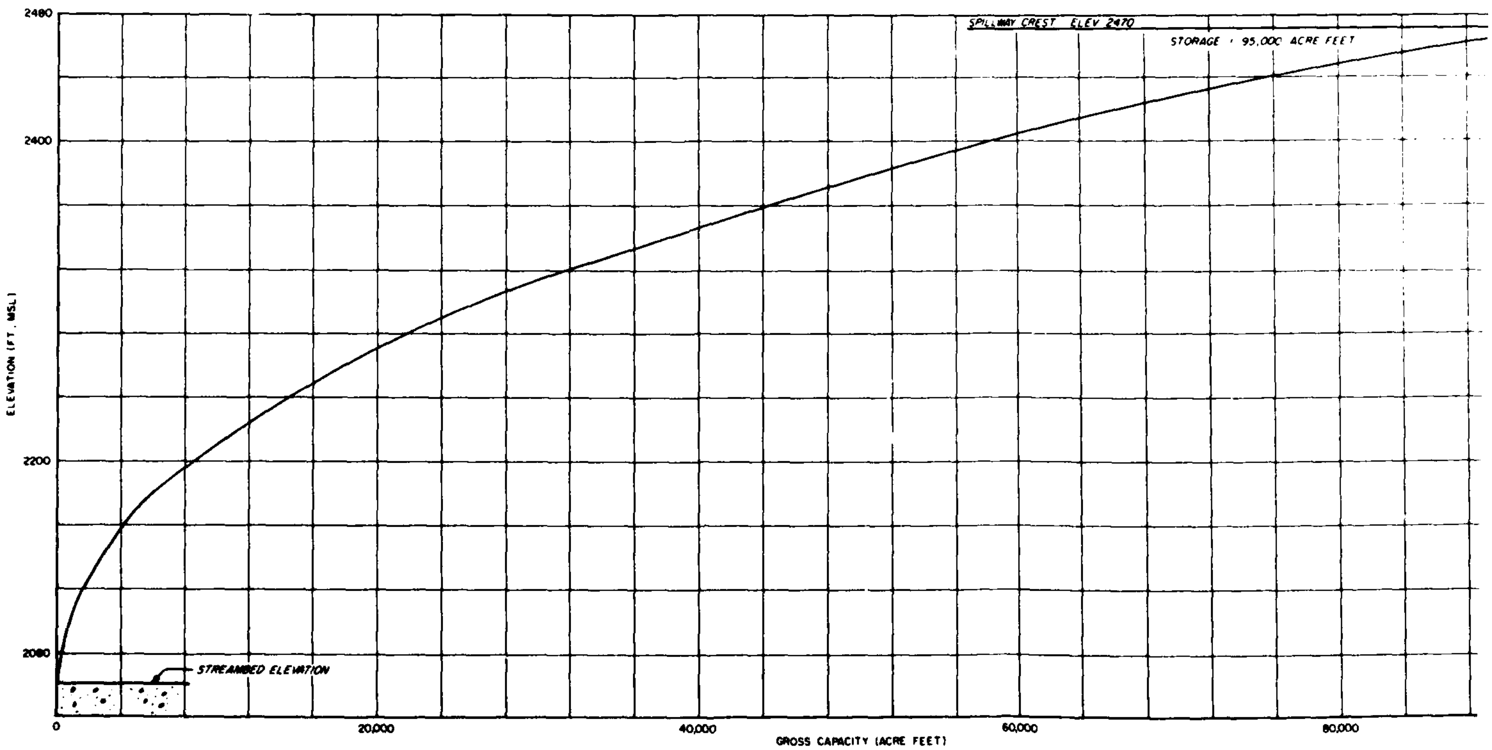
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 5



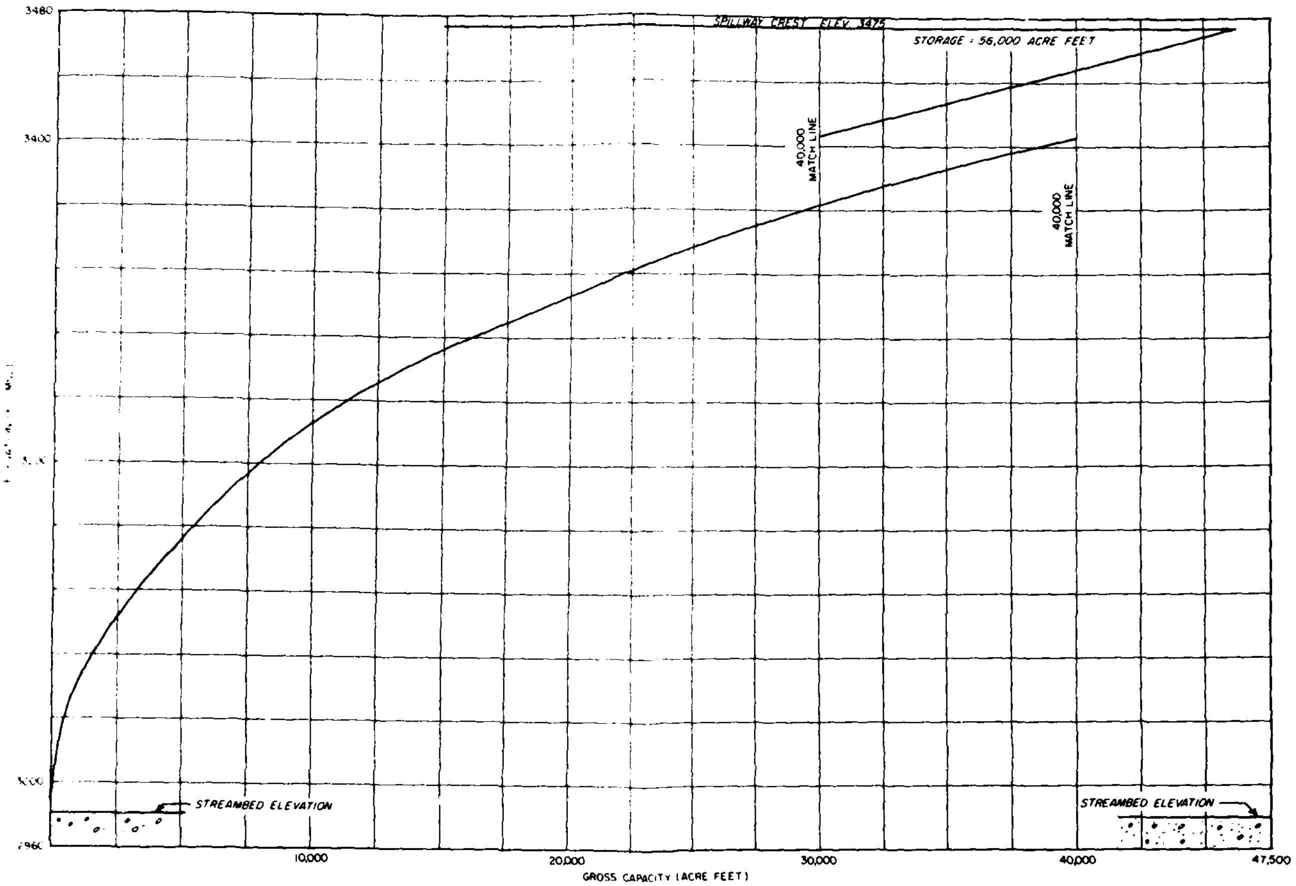
FORKS DAM



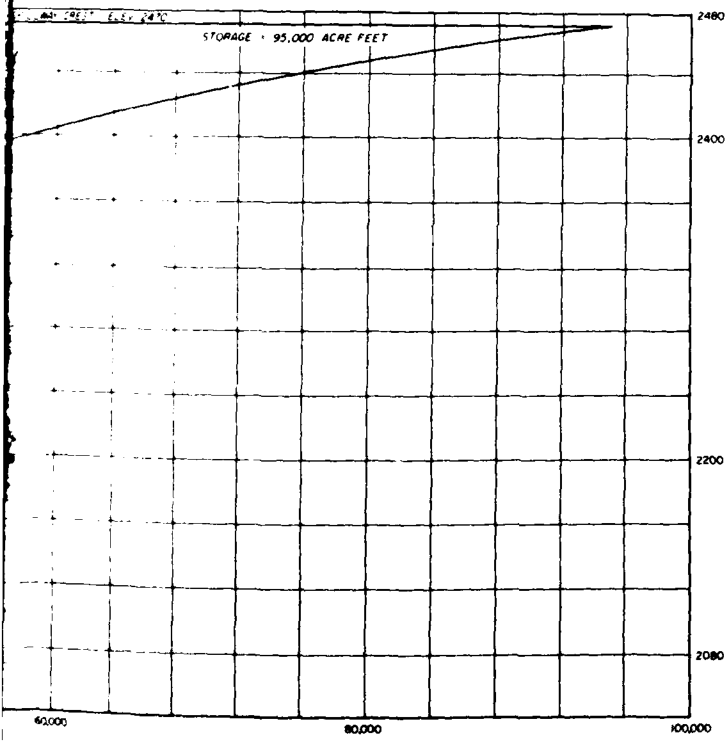


UPPER MENTONE DAM

VALUE ENGINEERING PAYS



CRAFTON DAM



SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

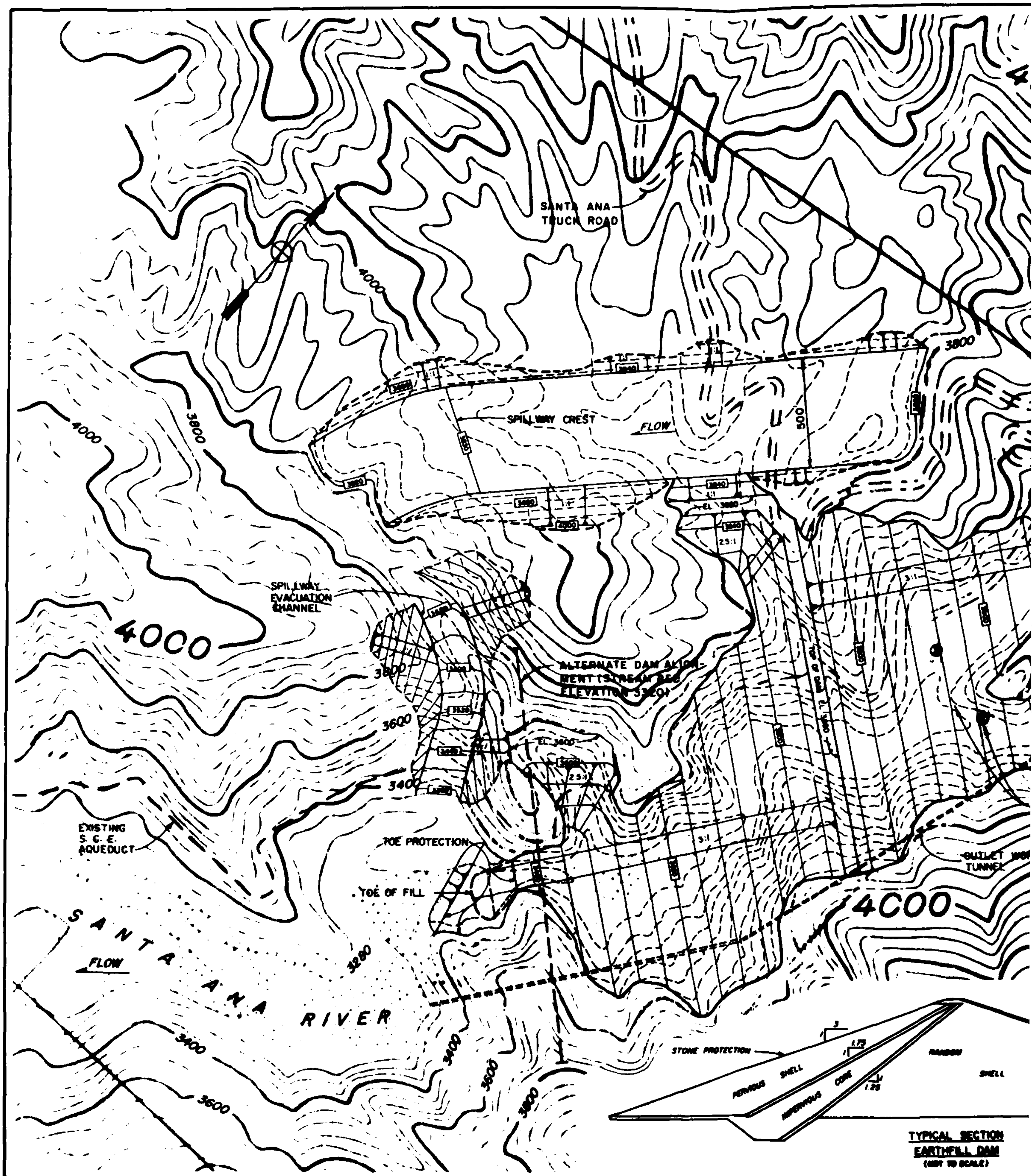
ELEVATION CAPACITY RELATIONSHIPS

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

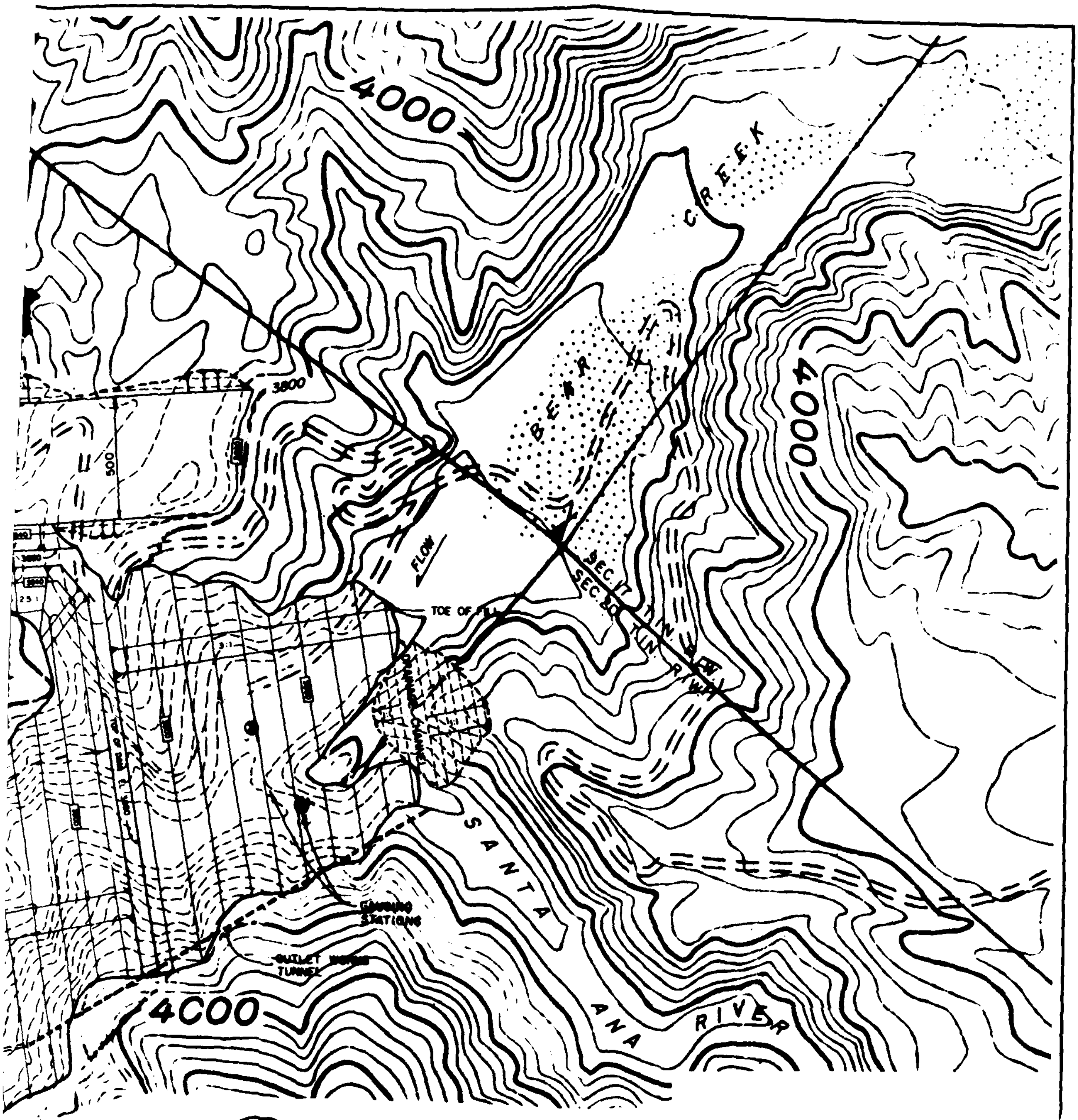
SAFETY PAYS

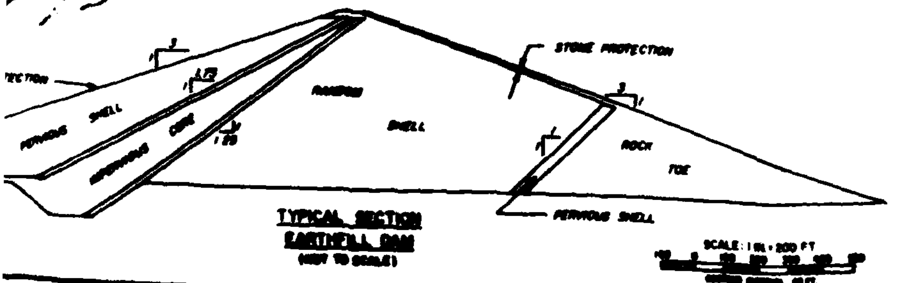
PLATE 6

2


SANTA ANA TRUCK ROAD
SPILLWAY CREST
FLOW
500
SPILLWAY EVACUATION CHANNEL
4000
3800
3600
3400
3280
ALTERNATE DAM ALIGNMENT (STREAM BED ELEVATION 3320)
EL 3800
2.5:1
3:1
EXISTING S. C. E. AQUEDUCT
TOE PROTECTION
TOE OF FILL
SANTA ANA RIVER
OUTLET TUNNEL
STONE PROTECTION
PERVIOUS SHELL
IMPERVIOUS CORE
RANDOM
SHELL
TYPICAL SECTION
EARTHFILL DAM
(NOT TO SCALE)

1





TYPICAL SECTION
EARTHFILL DAM
(NOT TO SCALE)

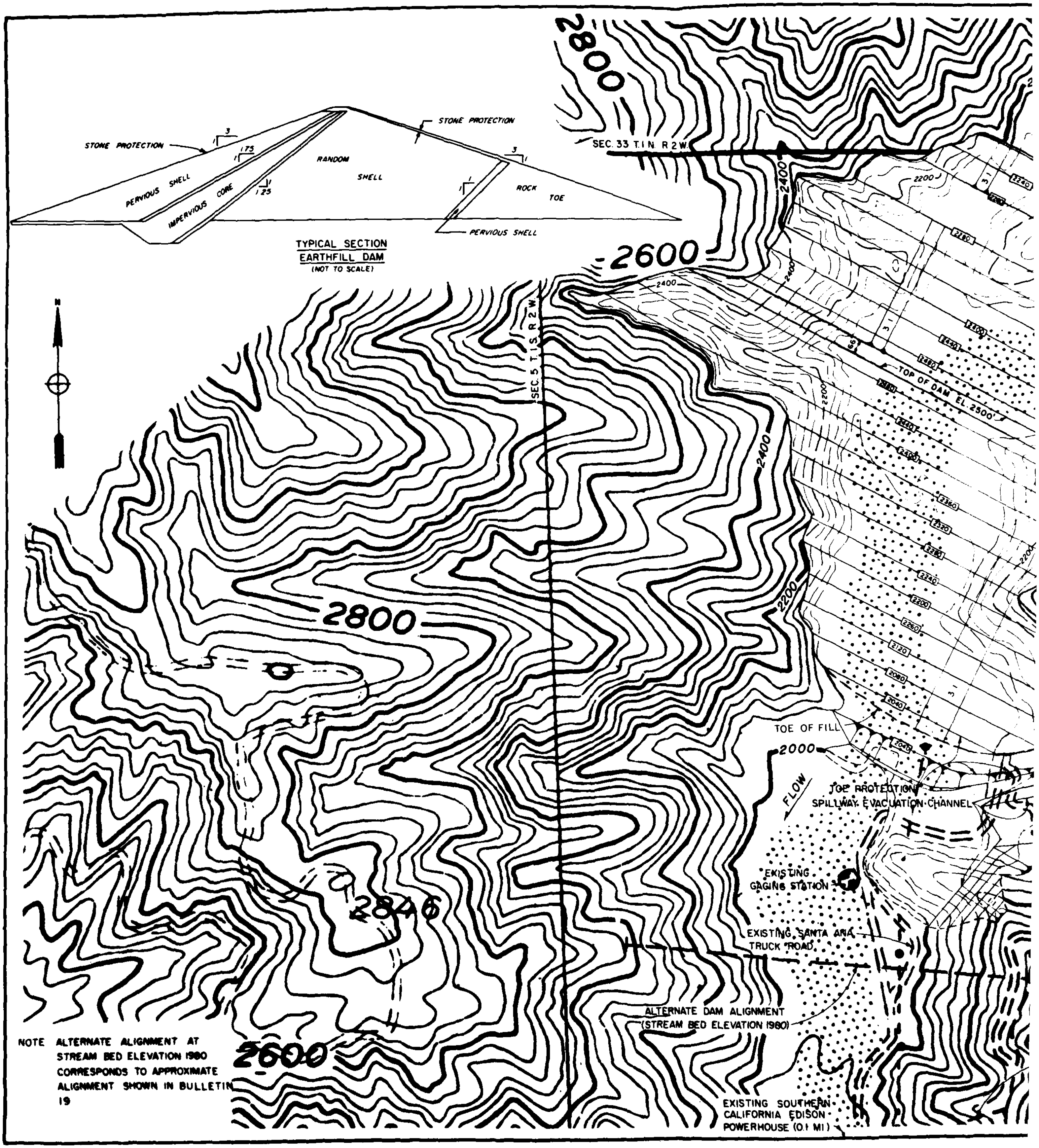
SCALE: 1 IN = 200 FT

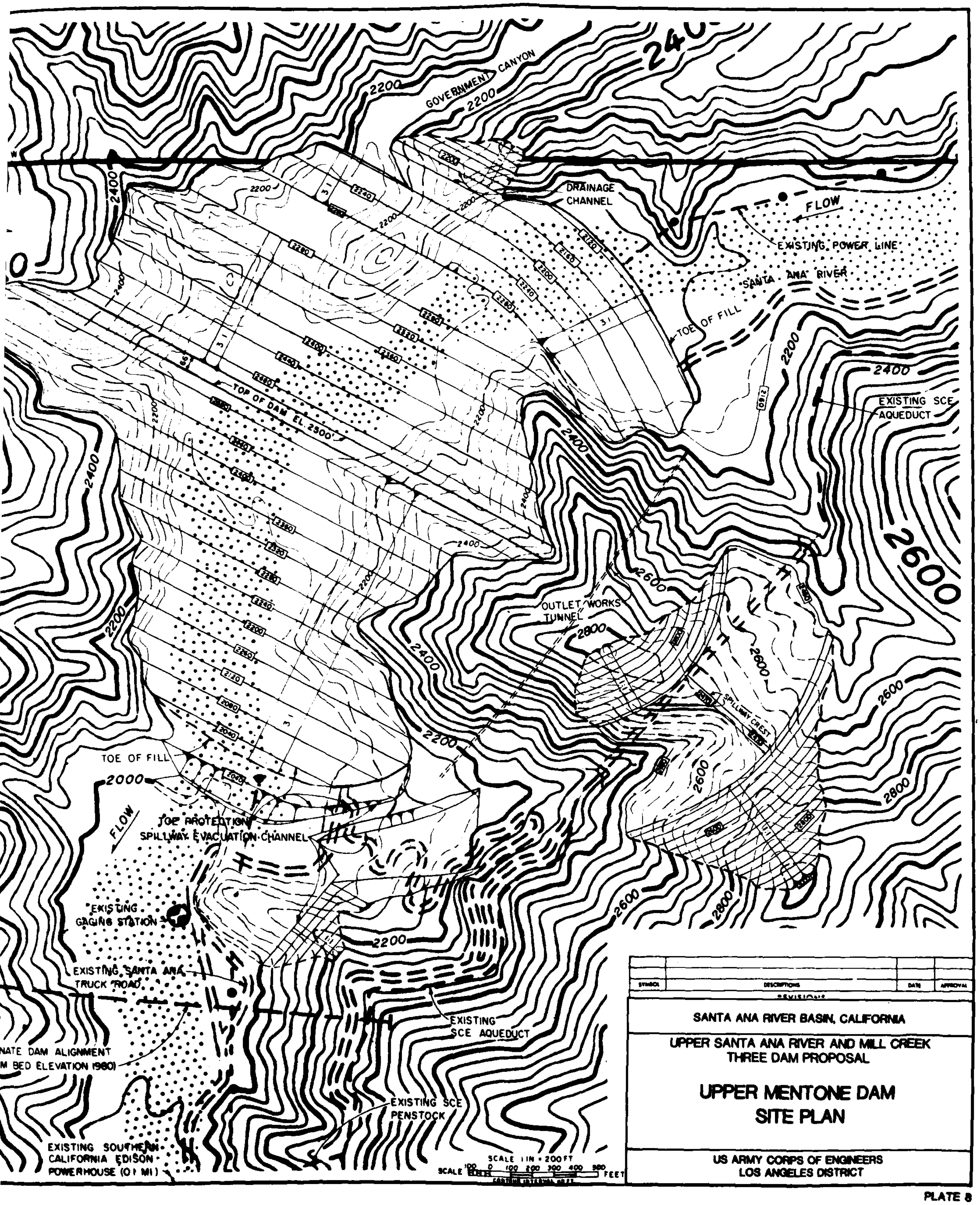
SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

FORKS DAM SITE PLAN

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


STONE PROTECTION
STONE PROTECTION
PERVIOUS SHELL
IMPERVIOUS CORE
RANDOM SHELL
ROCK TOE
PERVIOUS SHELL
TYPICAL SECTION
EARTHFILL DAM
(NOT TO SCALE)
N
SEC. 33 T.1 N R 2 W.
SEC. 5 T.1 S. R 2 W.
2800
2600
2400
2200
2000
2846
TOP OF DAM EL. 2500'
TOE OF FILL
FLOW
TOE PROTECTION
SPILLWAY EVACUATION CHANNEL
EXISTING GAGING STATION
EXISTING SANTA ANA TRUCK ROAD
ALTERNATE DAM ALIGNMENT
(STREAM BED ELEVATION 1980)
EXISTING SOUTHERN CALIFORNIA EDISON POWERHOUSE (0.1 MI)
NOTE ALTERNATE ALIGNMENT AT STREAM BED ELEVATION 1980 CORRESPONDS TO APPROXIMATE ALIGNMENT SHOWN IN BULLETIN 19



SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SANTA ANA RIVER BASIN, CALIFORNIA

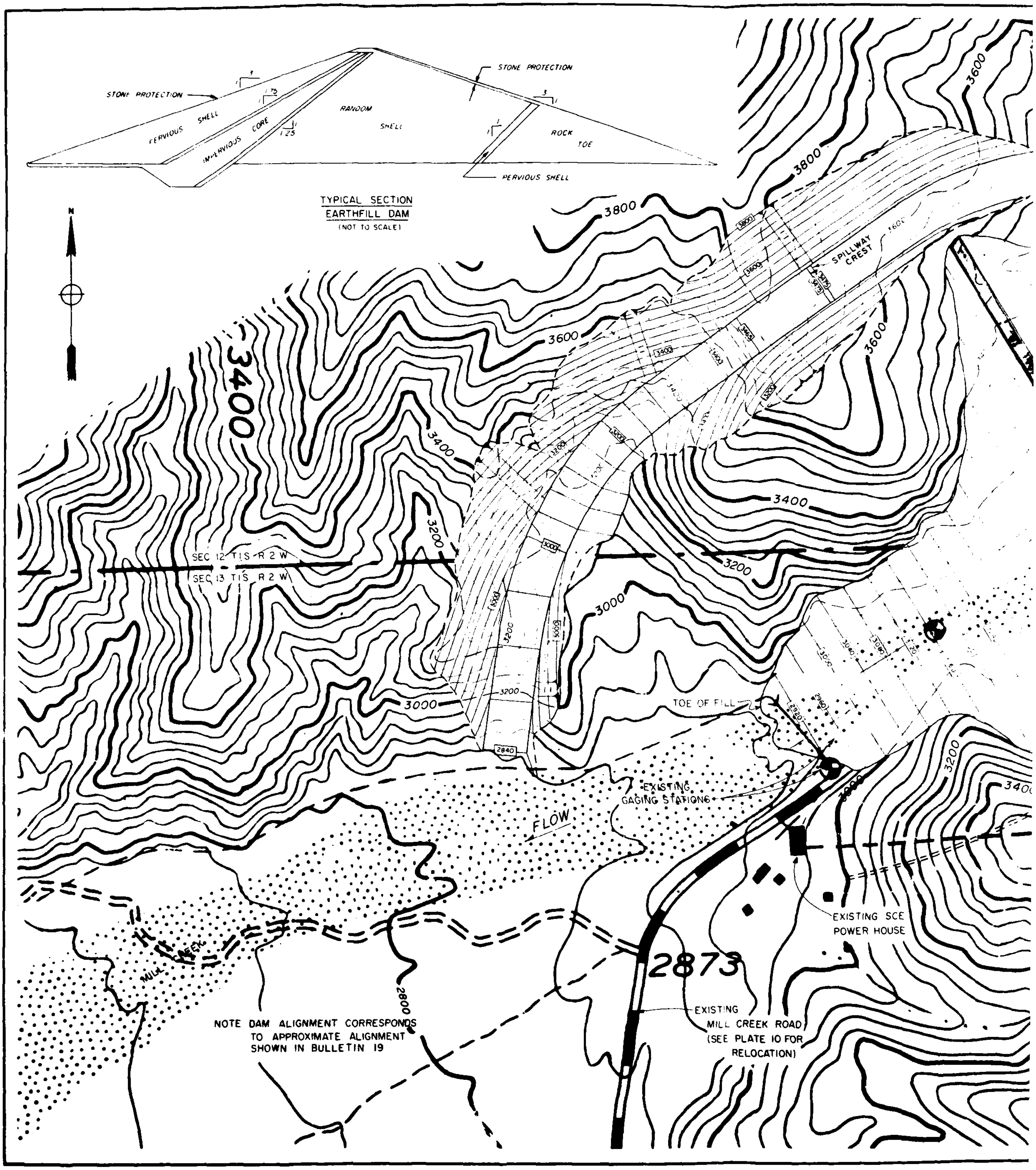
UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

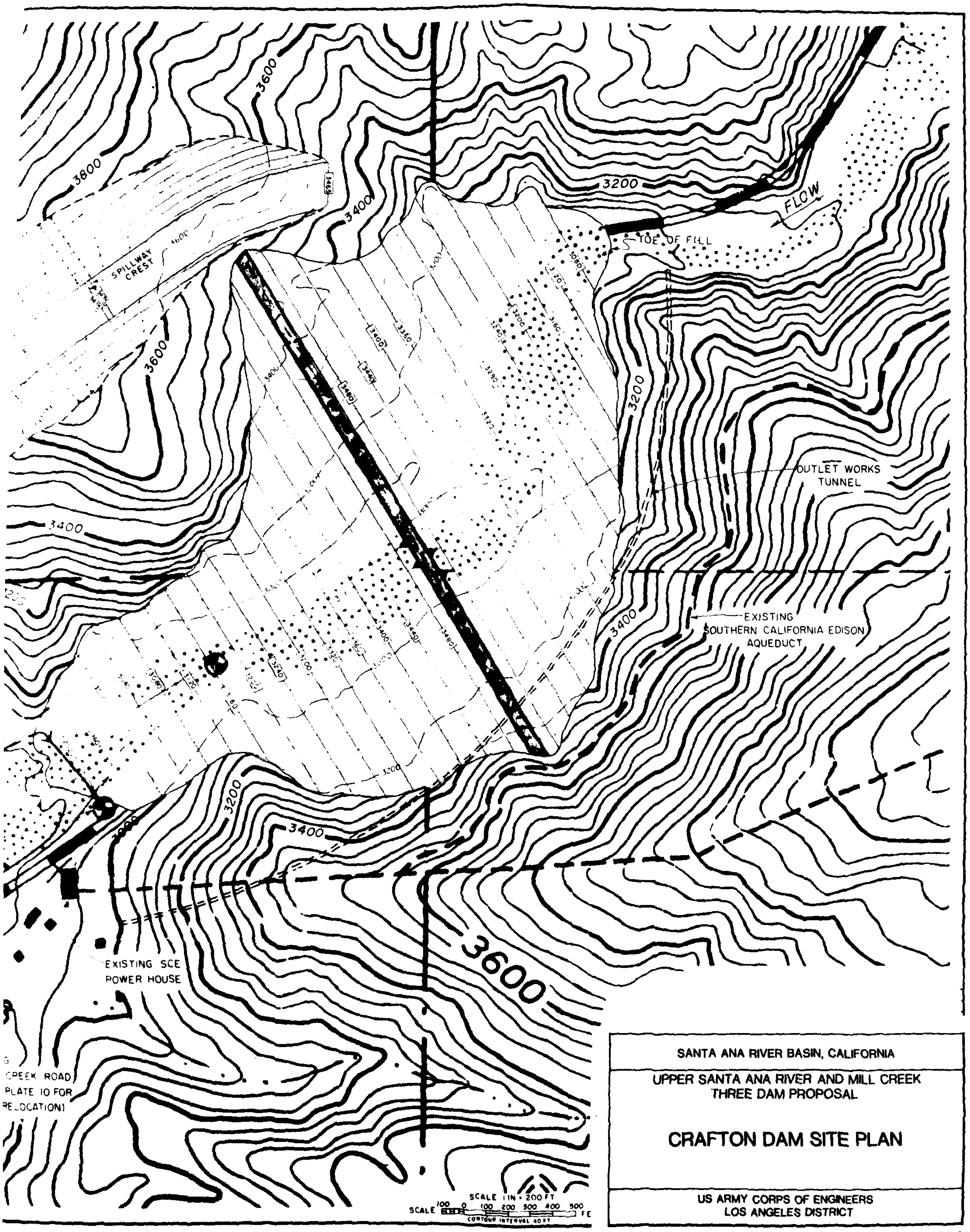
UPPER MENTONE DAM
SITE PLAN

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 8

2


STONE PROTECTION
STONE PROTECTION
PERVIOUS SHELL
IMPERVIOUS CORE
RANDOM SHELL
ROCK TOE
PERVIOUS SHELL
TYPICAL SECTION
EARTHFILL DAM
(NOT TO SCALE)
N
3800
3600
3400
3200
3000
2800
SPILLWAY CREST
SEC 12 T1S R2W
SEC 13 T1S R2W
TOE OF FILL
EXISTING GAGING STATIONS
FLOW
MILL CREEK
EXISTING SCE POWER HOUSE
2873
EXISTING MILL CREEK ROAD (SEE PLATE 10 FOR RELOCATION)
NOTE DAM ALIGNMENT CORRESPONDS TO APPROXIMATE ALIGNMENT SHOWN IN BULLETIN 19



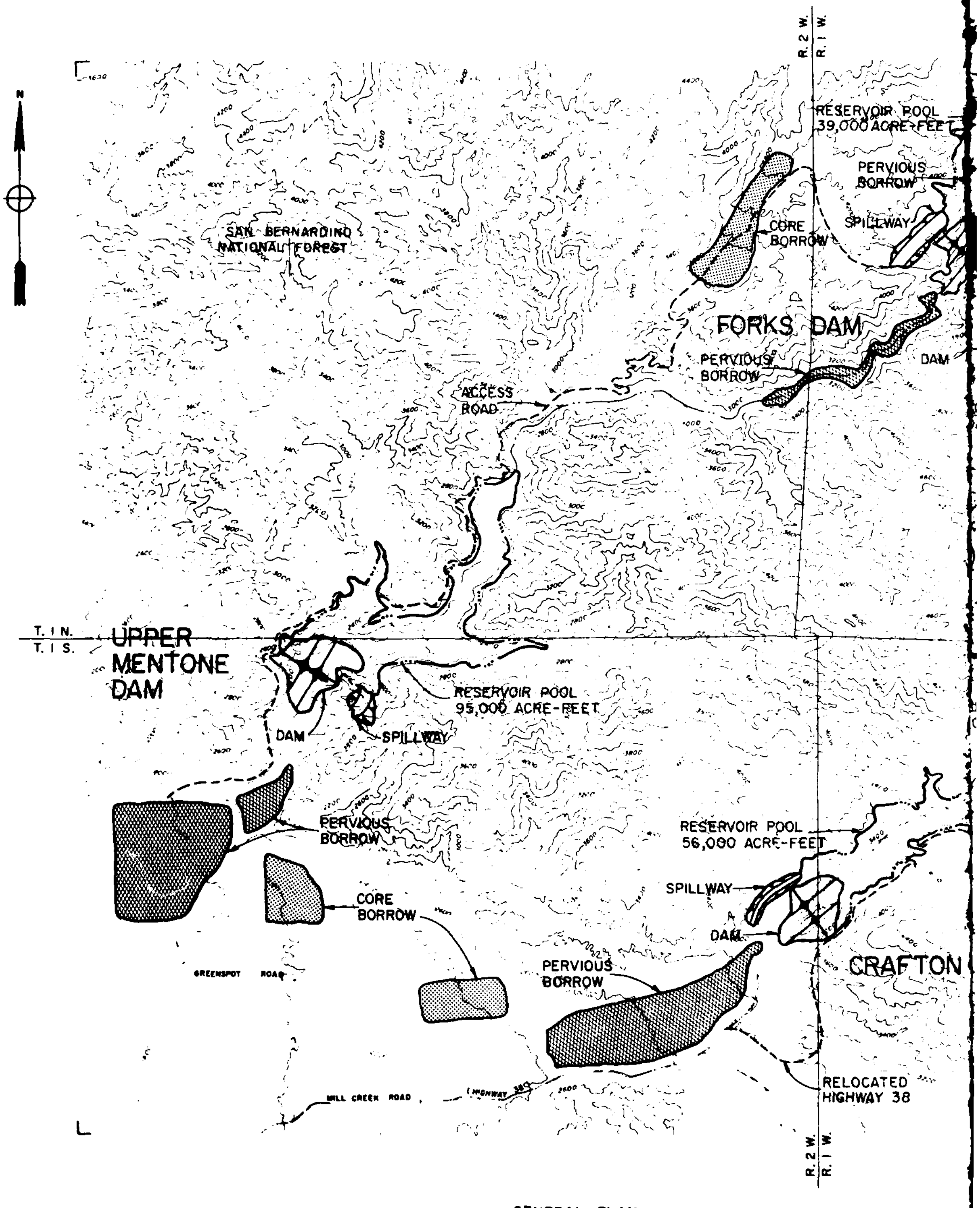
SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

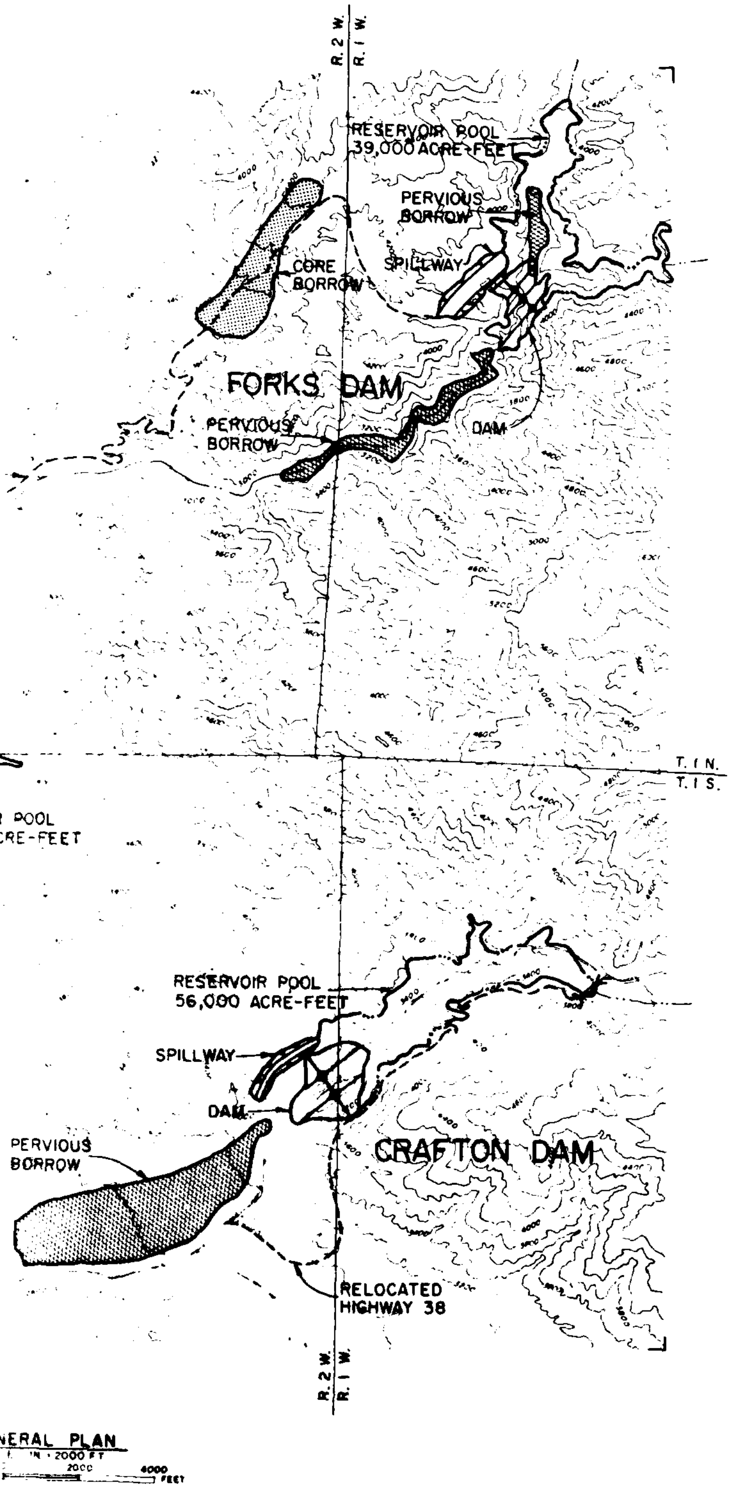
CRAFTON DAM SITE PLAN

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 9



GENERAL PLAN
SCALE: 1 IN. = 2000 FT.



LEGEND

- PERVIOUS BORROW AREAS
- CORE BORROW AREAS
- MAXIMUM RESERVOIR LIMITS

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SANTA ANA RIVER BASIN, CALIFORNIA

UPPER SANTA ANA RIVER AND MILL CREEK
THREE DAM PROPOSAL

THREE DAM PROPOSAL
GENERAL PLAN

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 10

DAT

FILM

0-