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REPORT ON LEVEE FAILURES AND DISTRESS SAN JACINTO RIVER LEVEE AND BAUTISTA CREEK CHANNEL, RIVERSIDE COUNTY, SANTA ANA RIVER BASIN, CALIFORNIA

by

ENGINEER TEAM

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An Engineer team studied the course of failure of the San Jacinto River Levee project. Initial investigation consisted of data review and site reconnsaissance as basic for the field investigation. Many possible causes of Levee failure were considered. Althoug no evidence was found, surface erosion was a significant factor. Undersiged riprap protection would lately be subject to failure by surface erosion during larger floods.. Remedail constru-ction and application of experience to this Levee will be also be applied to other projects.

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Summary

The San Jacinto River levee project, located in Riverside County, California, consists of a 3.7-mile levee on the left side of the San Jacinto River and a 1.3-mile levee on the left side of Bautista Creek. The project is designed to protect San Jacinto, Hemet, Valle Vista, and nearby agricultural lands. At about 7 a.m., 21 February 1980, the San Jacinto River levee was breached by a flood event estimated to be about a 25-year event. Eyewitness estimates of the flow through the breach ranged from 75 to 95 percent of the riverflow.

An Engineer Team was formed to determine the probable cause or causes of failure and to provide "lessons learned." The initial investigation consisted of data review and site reconnaissance, which formed the basis for recommended field investigations. Four major types of field investigations were conducted: (1) gradations of in-place riprap, (2) soil borings, (3) test trenches, and (4) scour gage recovery along the Bautista Creek reach.

The Engineer Team considered the following possible causes of levee failure: (1) overtopping, (2) internal erosion (piping), (3) slides within the levee embankment and/or foundation soils, (4) surface erosion, (5) undermining of bank protection (scour), and (6) channel configuration. The Team concluded: (a) undermining of the bank protection by scour appears to be the principal cause of the San Jacinto River levee failure; (b) channel configuration contributed indirectly to levee failures by producing flow impingement on levees that, in turn, produced deeper scour and undermining of the levees; and (c) although no evidence was found that surface erosion was a significant factor in levee failure, the undersized riprap protection compared with present criteria would likely be subject to failure by surface erosion during larger floods up to design flood magnitude.

Recommendations are made for remedial construction and application of experience to other projects.

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SAN JACINTO RIVER LEVEE AND BAUTISTA CREEK CHANNEL, RIVERSIDE COUNTY, SANTA ANA RIVER BASIN, CALIFORNIA

Introduction

Background

During February 1980, flooding caused the San Jacinto River flood control project to undergo distress. Levees on both San Jacinto River and Bautista Creek reaches were, in fact, breached, as evidenced in the aerial mosaics presented in Plates 1 and 2. Because of this occurrence and at the request of the U. S. Army Engineer District, Los Angeles, an Engineer Team was formed and tasked with determining the probable cause or causes of failure, recommending remedial construction measures, and making recommendations as to the application of this experience to existing and future projects. Team members (specialists in hydraulic, geotechnical, and construction engineering) are:

Hydraulics	Geotechnical	Construction
Ted Albrecht, Jr., SPD	Richard Davidson, OCE	Charles Hooppaw, SPL/SPD
Jacob Douma	Dave Hammer, WES	
Al Robles, Jr., SPL	Joe Sciandrone	

In addition, Dave Mann, Riverside County Flood Control and Water Conservation District (RCFC and WCD), supported the team by providing data and observations from his agency. Personnel of the Los Angeles District, who also supported the team, included: Vance Carson, Civil Design Section B, who was the team's liaison with the flood control district; Dave Cozakos, Hydraulics Section, who provided hydrologic and hydraulic information; and Terry King, Construction Operations Division, who had first-hand knowledge of flooding and emergency construction. Field investigations were conducted under the supervision of Richard Gutschow, Chief, Materials and Investigation Section, Foundation and Materials Branch.

A preliminary report was submitted by the Engineer Team following an initial investigation consisting of data review and site reconnaissance. This investigation was the basis for the field investigations conducted. This final report briefly describes the project design and construction, presents results of field investigations and findings on the cause of failures, and makes recommendations for revisions to the interim remedial measures plan of the Los Angeles District and for additional remedial construction as well as application of this experience to other projects.

Project description

The San Jacinto River levee and the Bautista Creek channel improvements are located in Riverside County. They consist of a 3.7-mile levee on the left side of San Jacinto River, a 1.3-mile levee on the left side of Bautista Creek, and a 3.25-mile concrete-lined channel on Bautista Creek upstream from State Highway 74. The federal cost of constructing this project was $3 million. The project units are designed to protect San Jacinto, Hemet, Valle Vista, and nearby agricultural areas. Since their completion in November 1961, the units have been maintained by the RCFC and WCD. During the 1969 floods, they prevented damages estimated at $1.3 million.

Project Design

References

The bases for design are included in the following reports prepared by the Los Angeles District:

a. Design Memorandum No. 1, "Hydrology for San Jacinto River and Bautista Creek Improvements," July 1959.

b. Design Memorandum No. 2, "General Design for Bautista Creek Channel," September 1959.

c. Design Memorandum No. 3, "General Design for San Jacinto River Levee," September 1960.

The following paragraphs contain pertinent information on the bases for design presented in these three reports.

Hydrology

Design Memorandum No. 1 presents the hydrologic information pertaining to the design of the project. After publication of that report, the project plan was changed to provide for the extension of the upstream end of the San Jacinto River levee to the downstream end of the Bautista Creek channel.

The project drainage area map, including the location of rain gages, is shown in Figure 1.

The San Jacinto River Project drainage area, which includes the Bautista Creek drainage area, comprises about 253 square miles. The drainage area lies generally on the southwest slopes of the San Jacinto Mountains. Elevations in the San Jacinto River subarea range from 10,805 ft at San Jacinto Peak to about 1,500 ft at the downstream end of the improvement. The main watercourse is fed principally by a series of generally parallel streams from the San Jacinto Mountains. The longest watercourse is about 35 miles. The gradient ranges from about 450 ft per mile in the headwaters to about 30 ft per mile near the downstream end of the improvement.

The Bautista Creek Project drainage area, which comprises about 50 square miles, adjoins the San Jacinto River drainage area on the southwest. Bautista Creek enters San Jacinto River about 4 miles east of the city of Hemet. Elevations in the area range from about 6,800 ft in the headwaters to about 1,600 ft at the confluence with San Jacinto River. The longest watercourse in the Bautista Creek drainage area is about 19 miles. The gradient ranges from 1,050 ft per mile in the headwaters to about 50 ft per mile near the mouth.

The standard project flood was used as the basis for design. The flood was developed in accordance with guidelines presented in Civil Works Engineer Bulletin No. 52-8, dated 26 March 1952. The standard project storm, general winter type, was employed for the drainage area tributary to the San Jacinto River levees. This storm is based on the assumed occurrence of a storm equivalent to that of January 1943 transposed and centered over the area tributary to the pertinent area. The standard project storm, local type, was used for the drainage tributary to the Bautista Creek improvement. This storm is based on the assumed occurrence of a storm equivalent in magnitude to that of March 1943 transposed and centered over the area.

The resulting standard project flood peak discharges are 86,000 cfs for the San Jacinto River improvement and 16,500 cfs for the Bautista Creek improvement. The standard project flood peak discharge for San Jacinto River is about 50 percent larger than the peak discharge that occurred during the flood of record of February 1927.

Hydraulics

The hydraulic design was based on the theoretical analyses and design practices previously approved for similar projects. The design conformed to the criteria, which applied at the time, in published chapters of the Engineering Manual, "Civil Works Construction," and Civil Works Engineer Bulletin No. 52-15.

Design Memorandum No. 3 describes the proposed plan of improvement and functional characteristics. Levee alinement, curve data, and profiles are shown on contract drawings, File No. (D.O. Series) 172/90 through 172/94, included as Plates 3 through 7. The preproject San Jacinto River channel flood control levees were constructed by local interests and were protected on the channelward side with pipe-and-wire fencing. The estimated channel capacity was about 8,000 to 20,000 cfs, and the slope ranged from 0.00526 to 0.00935 ft per foot.

The levee along Bautista Creek was built in a reach where local interests had constructed sand levees and a pilot channel. The channelward sides were protected with pipe-and-wire fencing. The capacity of the preproject Bautista Creek channel was about 75 percent of the design flood flow, and the slope of the channel ranged from 0.0100 to 0.0182 ft per foot.

The water-surface computations were made by the reach method, using Manning's n. The computations were made on the basis of a design discharge of 86,000 cfs in San Jacinto River downstream from the confluence with Bautista Creek and a design discharge of 16,500 cfs in Bautista Creek. The maximum water-surface computations to determine levee heights were based on an n value of 0.040. Depths ranging from 5.7 to 13.0 ft were computed for San Jacinto River; and from 3.0 to 6.6 ft, for Bautista Creek. The maximum mean velocities used to determine the slope and toe protection were based on an n value of 0.025. Velocities ranging from 7.3 to 15.5 fps were computed for San Jacinto River; and from 9.4 to 16.9 fps, for Bautista Creek. The water surface for San Jacinto River was computed based on the assumption that the existing left levee would be removed and the existing right levee would remain in place. However, for Bautista Creek, the water surface was computed based on the assumption that flow would be contained in an area bounded on the left by the levee and on the right by high ground.

A minimum freeboard of 3 ft above the computed water surface is provided along both streams. Superelevation was computed by the formula $V^2 T/gRc$ where V is the velocity of flow, T is the top width of flow, g is the gravitational constant, and Rc is the radius of the curve. The superelevation of the water surface ranged from 0.2 to 1.0 ft.

Confluence computations were based on a flow of 74,000 cfs in San Jacinto River upstream from the confluence and a flow of 12,000 cfs in Bautista Creek. This combination produces the maximum water-surface elevation in the confluence for the design discharge in San Jacinto River downstream from the confluence.

Under the project-document plan, the thickness of the revetment would range from 2 ft at the top of the levee to 5 ft at the toe; the revetment would be underlain by a 1-ft layer of filter material. The adopted stone revetment, a 1.5-ft layer of riprap over a 6-in. filter blanket, is shown in Figure 2. The revised thicknesses were based on the then "present-day criteria."

Depth of toe was an item of considerable concern during the design of the project, as indicated by a review of District records. The adopted depths of toe for the Bautista Creek channel and the San Jacinto River levee are 5 and 10 ft, respectively, below the low point of the streambed.

Scour gages were constructed along the Bautista Creek levee. The plan and profile locations are shown on Plate 3.

Embankment and foundation

The foundation materials are principally silty sands, sand-silty sands, and silts, with occasional gravel and cobbles. The upper 6 to 12 ft are loose to medium dense.

Groundwater was not found in any of the test holes that were drilled to a maximum depth of 35 ft along the project reach. The 1957 well records indicate that groundwater was about 10 ft below the streambed at the downstream end of the project levees and 60 ft below the streambed at the upstream end.

A typical embankment section is shown on the project map in Figure 2. Analysis of the slopes was based on drained strengths. Using the infinite slope method, the factor of safety for the end of the construction condition is 1.4. Steady seepage and drawdown conditions were not analyzed because the influence of seepage into the levee fills and foundations was considered to be negligible due to short-duration flows.

Project Construction

The dates for the completion of construction of the various reaches of the San Jacinto River levee and the Bautista Creek channel are presented in Figure 2. The Bautista Creek Channel Project is a concrete-lined trapezoidal channel with an energy dissipator at the downstream end. The portion of the Bautista Creek channel downstream of the concrete channel is a left-bank levee with a typical section similar to that shown for the San Jacinto River levee. It was constructed as part of the San Jacinto River Levee Project.

Bautista Creek

The Bautista Creek levee has a maximum height of 10 ft, and the stone revetment toe is 8 to 9 ft below the line of backfill at the face of the levee. This distance corresponds to 5 ft below the low point of the streambed. The levee section was built with streambed materials and borrow that was obtained by removing an existing riverward levee. These materials were placed in 12-in. layers, compacted with four passes of a 50-ton rubber-tired roller.

San Jacinto River

The borrow for the San Jacinto River levee was obtained by removing about 4 miles of existing levee between Cedar Avenue and the downstream end of the project. The remainder of the levee fill came from streambed materials similar to the foundation materials previously described. Construction of the levee was the same as for Bautista Creek. The construction control data show that the densities varied from 96 to 106 percent of the standard AASHTO maximum density.

Riprap

Stone for the project was obtained from the Bernasconi Pass Quarry and the Juaro Quarry. The locations of these quarries are shown on quadrangle sheets on file in the Geology Section, Los Angeles District. The stone tested had a bulk specific gravity of 2.71 to 2.76 and an apparent specific gravity of 2.73 to 2.78.

The construction control riprap gradations are limited to the data shown in Figure 3. These gradations, which were taken at the plant located at the quarry, are not representative of the stone gradation on the levee, in part, because of segregation that results from handling and placement. It was been verified that a jaw crusher was used to control the maximum size of stone, but it is not known whether a screen was used to remove the finer stone throughout the production. The stone was transported to the levee crown in end-dump trucks and then was dumped into a "skip" that was crane operated. The skip was used to place the stone and drag the slope.

Modifications After Construction

San Jacinto River

The right levee in the vicinity of the Main Street (Soboba Road) crossing was constructed by the RCFC and WCD in 1965. The right levee has the same cross section as the left levee, the depth of toe revetment is the same as that of the opposite bank of the left levee, and the stone revetment specifications are the same as those for the left levee.

Bautista Creek

A 12-in. concrete-encased sanitary sewerline crosses the Bautista Creek channel at about sta 80+00. During the 1969 flood, the sewerline was exposed. This experience prompted the design and construction of anchored, cable-tied, gabion stabilizers. Seven stabilizers were constructed and strengthened during the period from 1969 to 1978.

Flood History

Major floods

Major floods that occurred before and after the construction of the San Jacinto River levee in 1961 are as follows:

Date of Flood	Peak Discharge, cfs*
Before 1961	
February 1927	45,000
March 1938	14,300
January 1943	1,400**
After 1961	
November 1965	6,300
December 1966	5,700
January 1969	7,400
February 1969	4,100
March 1978	5,300
February 1980	17,300

* Above confluence with Bautista Creek at USGS gage No. 11069500, San Jacinto River near San Jacinto (above Bautista Creek).

** Low runoff due to extremely dry ground conditions at the beginning of the storm.

February 1980 flood

Rainfall occurred over the watershed for a period of 9 consecutive days, from 13 to 21 February 1980. The daily precipitation for seven stations in or near the project area is summarized below. These station locations are shown in Figure 1. Mean seasonal precipitation ranged from about 14 in. at San Jacinto to about 45 in. at San Jacinto Peak, averaging about 20 in. over the total area. Isohyets for the mean seasonal precipitation are also shown in Figure 1.

Daily Rainfall 18-21 February 1980

	Daily Rainfall, in.			
Station Name	2/18	2/19	2/20	2/21
Anza SDF	1.74	0.98	1.38	2.93
Elsinore SDF	1.96	1.27	1.36	1.43
Hemet Reservoir	0.66	0.61	1.18	1.51
Idyllwild Fire	2.63	1.36	2.05	6.63
Pine Cone SDF	NA	0.82	3.95	1.94
Poppet Flat	NA	1.25	1.71	1.86
San Jacinto SDF	NA	0.73	0.75	1.50

The peak discharge of 21 February 1980 in San Jacinto River above Bautista Creek is 17,300 cfs. Figure 4 shows the flood hydrograph. The 17,300-cfs discharge represents a 30-year flood. The estimate of a 6,000-cfs peak discharge on Bautista Creek represents about a 70-year flood. Based on these two discharges, the peak discharge, which occurred at the San Jacinto levee, is estimated to be about 25,000 cfs, representing a flood frequency of about once in every 25 years.

Project Performance

Before the February 1980 flood

Since the completion of the project, high flows have occurred in 1965, 1966, 1969, and 1978. In November 1965, a multiple (10) corrugated metal pipe and dip crossing with concrete overflow at Main Street were washed out. During the February 1969 storms, the Bautista Creek channel was degraded. Afterwards, the seven stabilizers previously mentioned were constructed. Five of the stabilizers were damaged during the 1978 storm and were repaired in 1978 by an RCFC and WCD contract. The RCFC and WCD has kept a record of degradation and aggradation in Bautista Creek and has furnished a drawing showing streambed profiles at various times. Severe degradation of the streambed, about 10 ft, was noted before the floods of 1969. The RCFC and WCD has noted that the energy dissipator derrick stone has been repaired since the original construction.

A review of the aerial mosaics presented in Design Memorandum No. 3 and post-construction aerial photographs indicate that topographic features have directed flows into the San Jacinto River levee in the general vicinity of the February 1980 breach. A long-time resident of the area commented after the break that it was the third time that the water broke through the same reach. The first two breaks occurred in locally constructed levees before the construction of the Corps of Engineers (CE) levee.

During the February 1980 flood

On 21 February 1980, the Bautista Creek and San Jacinto River levees were breached. The breach in the Bautista Creek levee extended from approximately sta 61+00 to 59+00. The breach in the San Jacinto River levee extended from approximately sta 169+00 to 154+00, before flood fighting operations controlled the erosion. At several other locations erosion occurred, generally below the "line of backfill."

The RCFC and WCD has provided eyewitness accounts of the San Jacinto River levee breach. Excerpts from these eyewitness reports state: "Water Master for the Hemet-San Jacinto Area of Eastern Municipal Water District...was on Mountain Avenue at approximately 7:00 a.m. and observed a twenty-foot wide breach in the levee at that time and reported to their headquarters." Other eyewitness accounts following the initial breach give an account of the progress of the failure. An eyewitness account of observations at 7:45 a.m. reports: "Levee disintegrating on the upstream side of breach rapidly. Flood through breach surging in river in waves 5' to 10' high. . . . ± 8:30 a.m. Breach ± 700' wide at this time . . . At the location of breach the main direction of the river flow was ± 25° to the downstream tangent as observed." Eyewitness estimates of the flow through the breach ranged from 75 to 95 percent of the riverflow.

Investigations

The initial investigation consisted of data review and site reconnaissance, which formed the basis for recommended field investigations. The following paragraphs describe the site reconnaissance and field investigations, present observations and conclusions, and evaluate results.

Site reconnaissance

Contract drawings, topographic surveys, and aerial photographs were reviewed before site reconnaissance. The site reconnaissance itself consisted of a helicopter tour and an on-site inspection of the project. During this reconnaissance, several photographs were taken of breached and distressed areas. Typical photographs are presented in Figures 5 and 6. A news photograph of the San Jacinto River levee breach is shown in Figure 7. Observations made during reconnaissance and from photographs revealed the areas that needed field investigations.

The three areas of major damage cited on the project were: (1) Bautista Creek--one breach, (2) San Jacinto River--one breach, and (3) extensive loss of the riverside levee downstream of Main Street. Other areas of erosion on both projects were noted.

The existence of the ring levee around a well field near the mouth of Bautista Creek, the bar deposit at the mouth of Bautista Creek, and the upper end of the Soboba Indian levee appear to have caused flow to be directed into the San Jacinto River levee breach area. Subsequently, flow was directed into the right-side levee and then back across the streambed into the CE levee downstream of Main Street. As previously mentioned, damage was sustained at both areas of the CE levees as well as at the right-side levee where these impingements occurred.

Existing riprap is sound, exhibiting no evidence of deterioration. Areas having near-surface concentrations of smaller stone were noted. In each case where erosion of riprap was observed, it was in an area where the levee was directly attacked by flow.

There was no evidence of overtopping or water levels even approaching the top of levee. Minor rodent activity was observed in and near the levees. Minor erosion at the landside toe of the San Jacinto River levee upstream of the breach was noted. This feature had also been observed in the last annual inspection report.

Field investigations

Four major types of field investigations were conducted: (1) gradations of in-place riprap, (2) soil borings, (3) test trenches, and (4) scour gage recovery. All of the above investigations were performed along the San Jacinto River levee reach except for the scour gage recovery, which was along the Bautista Creek reach. No scour gages were located along the San Jacinto River reach. Appendix A presents locations of the investigations along the San Jacinto River reach as well as test results. Appendix B contains results from the scour gage investigation along the Bautista Creek levee.

Riprap gradations. Riprap gradations were performed on samples from the six areas shown on the location map on page A-1. Each area was approximately 10 × 10 ft. Test areas 1 and 1A were located just upstream of the San Jacinto levee breach, while 2 and 2A were just downstream of the breach. Test areas 3 and 4 were located further downstream of the breach in areas of apparent coarser size stone and finer size stone, respectively. Results of these gradations are shown on pages A-16 and A-17.

Results of the six riprap gradations made during construction for control purposes are presented in Figure 3. Results of tests 1A and 2A were judged to be erroneous after it was discovered that the scale used for stone weight determination was not calibrated properly. Therefore, tests 1 and 2 were performed to replace 1A and 2A. Results of tests 1 through 4 are considered valid.

The gradation data were analyzed by determining the mean and the standard deviation for both the six construction control plant gradations and the four valid in-place gradations. The mean plus or minus one standard deviation was then used as a basis for evaluating data fit. Gradation C-1 did not fit because it was taken at the start of production before plant adjustments were made. Gradation 4 is considered representative of the finer size riprap. Gradations 1 and 2, taken in the vicinity of the breach, are finer than gradation 4. The in-place gradations are, on the whole, finer than the construction control gradations. It was observed during sampling that some areas contain near-surface fine rock underlain by coarser rock.

Soil borings. Five 16-in.-diam bucket auger holes were drilled during early March to determine embankment and foundation material types and condition. Borings TH-1, 2, and 3 were drilled from the levee crest through the embankment and into the foundation. Total depths varied from 18 to 23 ft. Borings TH-4 and 5 were drilled to approximate depths of 35 ft in the breach area at the landside toe of the reconstructed levee. For reasons subsequently explained, three additional borings (TH-6 through TH-8) were drilled downstream of the breach during late June. Boring locations are shown on page A-1; boring logs are presented on pages A-8 through A-10.

All borings indicate that the levee and its foundation consist of sands with some silts, both highly erodible materials. They also indicate that the groundwater table was at or near original ground during the flood. Borings

TH-1 (immediately upstream of the breach) and TH-3 (approximately 275 ft downstream of the breach) had high blow counts (N values), indicating that the levee embankment consists of well-compacted material in a relatively dense state. However, boring TH-2, located approximately 200 ft downstream of the breach, had low blow counts (1 to 2) in a 7.5-ft thickness of embankment material. Blow counts of this order of magnitude denote very loose material, not at all representative of a compacted fill. Thus, three additional borings (TH-6 through TH-8) were drilled to check boring TH-2. These three borings were all located on the levee crest, each approximately 5 ft from TH-2: TH-6 riverward, TH-7 upstream, and TH-8 downstream of TH-2. Since no loose material was encountered in any of these borings, either the blow count from boring TH-2 was incorrect, or the condition is localized. Further investigation (most likely backhoe excavation) will be undertaken by the District, and appropriate remedial measures will be implemented as necessary.

Test trenches. Three test trenches were excavated with a hydraulic backhoe at the locations shown on page A-1 to determine the depth to which scouring occurred in relation to the levee toe. Scour depth was determined in the trenches by observation of the contact between a fairly dense silty sand layer that exhibited no stratification and overlying sands that were highly stratified. The underlying unstratified silty layer was assumed to be undisturbed material that existed from the time of original construction, and the overlying stratified sands were assumed to be material deposited by streamflow; hence the contact between the two could reasonably be taken as the maximum depth of scouring.

Sketches of trench cross sections are shown on page A-2, and logs of test trenches on page A-11. It can be safely concluded that in both areas explored (i.e., about 1,500 ft downstream of Main Street and just downstream of the main breach) scouring could have occurred to depths at or below the levee toe.

Scour gages. Bautista Creek is about 400 to 500 ft wide at the sections where scour gages were installed at the time of levee construction. During installation, the tops of the scour gages were set even with the channel invert existing at the time of construction. However, the survey records for the original invert elevations are unavailable. Consequently, the two riverward gage top elevations had to be estimated from the original levee backfill line.

Results from the excavation and location of the scour gages are presented in Appendix B. The deposition line given was the streambed elevation of the day of survey, 8 May 1980. The scour line was located the same day by excavating the streambed at the gage locations until the reddish stones of the gages were encountered. The measured magnitude of the elevation difference between the initial invert and the scour line is the accumulated scour that has occurred since the time the gages were installed in 1960. These investigations indicate that: (a) scour is not uniform across the creek; (b) a new gage will be needed at sta 54+58 for future measurement since only a small fraction of the first gage remains; and (c) the scour line is lower than the levee toe at sta 47+58, 54+58, and 64+58.

Causes of Levee Failures

The Engineer Team considered the following possible causes of levee failures and their application to the subject project:

- a. Overtopping.
- b. Internal erosion (piping).
- c. Slides within the levee embankment and/or foundation.
- d. Surface erosion.
- e. Undermining of bank protection (scour).
- f. Channel configuration.

Overtopping

Based on high-water marks, probable maximum height of ride-up, speculative height of waves, and their influence on probable maximum water levels, overtopping did not occur and, therefore, was not a cause of failure.

Internal erosion (piping)

There was no evidence to suggest the occurrence of piping, even though the characteristics of embankment and foundation materials make them susceptible to internal erosion. Observed rodent activity is not considered to be significant. The small differential head does not produce sufficient hydraulic gradient in levee sections to develop piping. Thus, internal erosion (piping) was not a cause of levee failure.

Slides within the levee embankment and/or foundation

Levee design exploration and stability analyses indicated levee embankment and foundations to be stable. Minor erosion at the landslide toe of the levee upstream of the San Jacinto River levee breach is not considered to be significant. The levee has a conservative cross section, embankment and foundation materials have high strengths, and no evidence of through or underseepage exists. Consequently, it is concluded that since slides did not occur within the levee embankment or foundation, they were not a cause of levee failure.

Surface erosion

Levee failures can be caused by surface erosion of riprap bank protection because of action from excessive stream currents and/or waves. When riprap bank protection is subjected to currents without waves, then surface erosion will occur when the tractive force produced by flow velocity exceeds the critical tractive force for stone stability. Waves, caused by unstable streambed formations near the bank or flow impingement on the bank (both conditions occurred in San Jacinto River), produce uplift pressures on bank protection stone that, in combination with stream velocity, can cause surface erosion when tractive forces are smaller than critical. Consequently, when riprap bank protection is designed for flow velocity alone and significant waves occur along the bank, surface erosion may occur for flows substantially smaller than the design discharge.

In order to determine whether surface erosion was a cause of levee failure on San Jacinto River, observations of in-place stone were made and four in-place gradations were taken as previously noted. Based on visual observations, there was no evidence that significant surface erosion had occurred, although some localized areas of stone were judged to be fine and others to be coarse. The gradations, shown on page A-16, indicate one sample to be undersized with respect to project specifications. However, the original design appears to be following the criteria used at the time of construction, namely, gradation control at the quarry only. Therefore, the areas of undersized stone may be due, in part, to segregation that occurred during handling and placement.

Observations and sampling of in-place riprap indicate that since removal of the bedding layer from beneath the riprap has not occurred, it is an unlikely cause of surface erosion leading to levee failure. Although two of the in-place gradations show the bedding layer to be finer than specified, this condition could have resulted from silting by flow sediments and/or contamination from sampling procedures since demarcation between bedding and embankment materials probably was not distinct. In any event, it is believed that the finer gradation of the bedding material was not a significant factor in levee failure.

In trench T2, where scour depths were near the bottom of the riprap protection, some riprap was located at the scour level riverward of the riprap toe. This stone was either removed from the riprap layer by surface erosion or undermined in the breach area and transported downstream along the scoured streambed. The latter case appears to be the most likely reason for finding displaced riprap in trench T2.

Based on present criteria (ETL 1110-2-120), a significantly thicker layer of heavier stone would be required to withstand flood velocities (Figure 8). Although no evidence was found that surface erosion was a significant factor in levee failure, the undersized riprap protection compared with present criteria would probably be subject to failure by surface erosion during larger floods up to design flood magnitude.

Undermining of bank protection (scour)

Inspection of Bautista Creek upstream of the levee suggests that construction of the concrete channel caused sediments, naturally carried by the creek, to be deposited upstream of the channel inlet. The resultant delivery of relatively sediment-free water to the leveed reach along with the steep slope of this reach (greater than one percent) caused general streambed degradation downstream of the concrete channel. The subsequent nearly complete filling of the valley immediately upstream of the concrete channel inlet with deposited sediment and the construction of channel stabilizers by the RCFC and WCD have reduced, and in the upstream part of the reach have reversed, the general tendency of the streambed to degrade.

The RCFC and WCD has documented the general degradation of Bautista Creek through most of the leveed reach. The level of backfill (still evident along much of the levee) provides a reference plane for evaluating the approximate depth of scour and/or channel degradation. Comparing the design depth of riprap toe with the depth of the existing streambed below the backfill reference level indicates that the streambed is at about the same level as the riprap toe along much of the levee. Visual inspection of exposed riprap at the streambed tends to confirm that the riprap toe is exposed and damaged in some locations. Examination of the scour gage data (see Appendix B) indicates that scour along the levee was approximately to the rock toe, except in the breach area where scour was several feet below the rock toe, as shown in Figures B-3 and B-4. These figures indicate that scour was 4 to 5 ft below the levee toe at sta 54+58 and 64+58, upstream and downstream of the breach. Based on observed conditions and scour gage information, it is quite evident that undermining of the bank protection caused the levee failure at Bautista Creek.

During the initial field inspection and preparation of the preliminary report, there was no readily apparent or obtainable information upon which to determine the cause or causes of levee failure at the main breach in the San Jacinto River levee, other than the evidence that most of the riverflow impinged on and then flowed along the levee in the area where the breach subsequently occurred. This evidence suggested the possibility that deep scour occurred along the levee in the area of flow impingement, which undermined the levee toe and caused failure of the levee. Subsequent excavation and inspection of trenches (see Appendix A) provided positive evidence of scour depths. Trench T2, located a short distance downstream of the breach, revealed that the depth of scour was approximately to the bottom of the rock toe. Trench T3, located within the breach area and approximately 50 ft riverward of the original levee rock toe, indicated the depth of scour to be approximately at the same level as the bottom of the original rock toe. Considering the magnitude of the 1980 flood compared with other floods that occurred subsequent to completion of the project, it is reasonable to conclude that the maximum depth of postconstruction scour occurred during the 1980 flood. This evidence suggests that the maximum depth of scour at the rock toe resulting from impingement of flow on the levee face during the February 1980 flood was at or below the bottom of the rock toe at the time of the levee breach. Consequently, undermining of the bank protection by scour appears to be the principal cause of the San Jacinto levee failure.

Below the Main Street crossing, the similar evidence of impingement and flow along the levee face suggests that the levee distress there was caused in the same manner as it was for the main breach.

Channel configuration

The channel configuration in plan appears to have been a significant factor contributing to levee failure, inasmuch as the resulting flow impingement on the levee causes deeper scour at the toe of rock protection. Flow impingement was particularly significant on the left levee of San Jacinto River between sta 164+00 and 169+00. Upstream of this location, the abrupt junction of Bautista Creek with San Jacinto River and the protection wall upstream of the water-well area resulted in impingement of flows at the upstream end of the right Indian levee with some distress at that point. The upstream end of the Indian levee deflected flows across San Jacinto River to impinge at an angle of approximately 25 deg on the left levee at the above-referenced failure location. This angle of impingement contributed to 75 to 95 percent of the flow that passed through the levee break. Similar, but less noticeable, irregularities in channel bank alignment farther downstream on San Jacinto River and on Bautista Creek resulted in flow impingement at several locations where levee distress occurred. Thus, it is evident that channel configuration contributed to levee failures by producing flow impingement on levees that, in turn, produced deeper scour and undermining of the levees.

Conclusions

Based on the information available, the Engineer Team has reached the following conclusions regarding the causes of levee failures:

a. Failure of the levees, in whole or in part, was caused by undermining of the levee toe, influenced by flow impingement due to adverse channel configuration.

b. There is no evidence that inadequate or improper maintenance contributed to the failure.

c. Considering the customary practices and procedures at the time of construction, the project was constructed substantially according to plans and specifications. These procedures did result, however, in riprap levee slope protection that was, at some locations, somewhat smaller than called for in the design.

d. The riprap protection was designed based on the criteria in effect at the time. Present criteria would call for a thicker layer of heavier and more uniformly graded riprap.

e. The depth of scour was properly recognized in the original design of the levee slope protection as an important design consideration. However, the effect of flow impingement on producing greater depths of scour in certain locations was not recognized, as riprap toe protection was not taken to greater depths in those locations.

f. Two factors contributed to the failure of the Bautista Creek levee: (1) inability to provide sufficient depth of riprap protection to accommodate the increased streambed degradation caused by reduction in sediment load due to the presence of the upstream concrete channel and inlet; and (2) the excessively steep streambed slope in the levee reach.

Interim Remedial Measures

In the preliminary report, the Engineer Team concluded that interim remedial measures, in addition to the emergency repairs made in February 1980, should be constructed to ensure that project levees would be reasonably safe in the interim period before the construction of permanent remedial measures. Subsequently, the Los Angeles District Engineer submitted to higher authority a rehabilitation report, dated 11 April 1980, under the provisions of Public Law 84-99, requesting authorization for the construction of remedial measures before the onset of the 1980-81 rainy season. Authorization for this work has been received, and a contract has been awarded. A description of the interim measures included in the rehabilitation report follows.

Bautista Creek

A stone apron, 5 ft thick and 9 ft wide, containing well-graded riprap material, will be constructed longitudinally along the existing left levee toe from sta 76+00 to 43+25. The displaced derrick stone in the energy dissipator downstream of Florida Avenue will be replaced.

San Jacinto River

Interim rehabilitation work will be accomplished throughout the length of this federal project. The existing 18-in. layer of stone above the design invert will be grouted. At the contractor's option, an 18-in. layer of stone will be added below the original design invert and extended 15 ft below the existing invert, and grouted, or the existing stone will be processed, supplemented with new stone, and grouted. At the location of the repaired breach, the levee has a wider cross section than the original levee. This levee would be reshaped and blended into the existing original levee in accordance with recommended revisions by the Engineer Team presented below. The eroded back slope of the levee between sta 149+00 and 137+00 will be reconstructed.

Recommended revisions

The Engineer Team reviewed the rehabilitation report and agreed with the proposed treatment subject to the following recommended revisions:

a. Minor revisions in details of the stone apron at Bautista Creek should provide a more stable apron and extension of the apron toe protection upstream 600 ft.

b. Along the length of the breach in the San Jacinto River levee and for a distance of 500 ft upstream and downstream therefrom, the grouted stone toe should be at least 10 ft below the original toe elevation; upstream and downstream therefrom, gradual transitions in depth of toe to those indicated in the rehabilitation report should be provided; in addition, an apron of ungrouted stone with a minimum base of 10 ft and a minimum thickness of 5 ft should be provided at the toe of the grouted stone protection through the breach and for a distance of 500 ft upstream and downstream therefrom.

c. The overbuilt section in the breach area should be trimmed to the original riverside levee alignment minus a 12-ft width. A 12-ft width of compacted earth embankment should then be constructed on the riverside to provide a stable foundation for the grouted stone. Stone salvaged from the overbuilt section and emergency construction toe trench should be utilized in the ungrouted stone apron at the toe of the grouted stone revetment. The stone should be placed on a 12-in. cushion of sand and gravel to prevent cracking of the grouted stone section during construction of the apron.

The interim treatment, as modified above, is compatible with the Engineer Team's views on the additional permanent treatment for Bautista Creek and San Jacinto River.

Recommendations for Additional Remedial Measures

The following works should be constructed on Bautista Creek and San Jacinto River, in addition to the interim remedial measures, to ensure long-term project protection for major floods up to design flood magnitude.

Bautista Creek

Construction, in addition to the interim treatment, is required on Bautista Creek to prevent continuing damage to the existing levee and concrete channel, to preclude flanking of the levee along San Jacinto River, and to provide improvement to flow conditions at the confluence of the creek and the river (Plates 8 and 9). Stabilizing the invert of Bautista Creek will eliminate the continuing damage and possibility of flanking of the river levee. This stabilization can be accomplished by the construction of about eight, grouted-rock, drop structures appropriately spaced throughout the length of the leveed reach of the creek. These drop structures, each about 5 ft high, would be similar to those constructed by the Los Angeles District on the upper San Gabriel River. To prevent flanking of these structures, they would have to be well rooted into the unimproved right bank. Also, the right side of the structures should be raised to prevent flow concentrations along the right bank. Flow conditions at the confluence can be improved by constructing a rock training dike on the right bank (Figure 9) to turn flow in the creek so it more closely parallels the riverflow, or by relocating the existing levee and creek channel downstream of about sta 48+00 so they will continue to parallel Mountain Avenue. Bautista Creek flows would then be directed more nearly parallel to the levees along San Jacinto River downstream of the curves in these levees (Figure 10).

Consideration of the probable costs of the above recommended work indicates that for a nominal increase in cost (or possibly even for a decrease in cost) additional benefits can be gained by the project. The additional benefits would consist of the elimination of continuing erosion damage to the right bank of the creek, reduced maintenance costs to local interests, and/or the prevention of flood damage to improvements located on lands to the right of the creek. Some or all of these benefits can be gained by providing bank protection to the right bank, by constructing a right-bank levee (which would also permit the construction of shorter drop structures), or by continuing the existing concrete channel to the confluence below Cedar Avenue. A concrete channel should definitely include relocation of the creek as described above and would require an energy dissipator below Cedar Avenue. Therefore, it is recommended that the Bautista Creek portion of the project be fully reevaluated before the initiation of any work other than that included in the interim treatment.

San Jacinto River

While the interim remedial measures for San Jacinto River are believed to provide sufficient protection against levee failure for moderate floods of the magnitude experienced in February 1980, additional works are required to provide adequate protection for major floods. The interim protection of grouted stone with greater depths of toe than for the original riprap revetment is believed to be adequate for major floods, except in flow impingement areas. Therefore, additional construction, as described below, is recommended to reduce depths of scour by flow impingement.

The combined effects of the vertical well-field wall, located at right angles to San Jacinto River upstream of the confluence, and the abrupt junction of Bautista Creek with San Jacinto River cause flows to be deflected to the upstream end of the right Indian levee, then across the San Jacinto River channel to the left CE levee, back across the channel to the upstream end of the RCFC and WCD levee, back to the CE levee just below the Main Street crossing, and generally parallel to the CE levee downstream of sta 60+00. The recent survey, showing streambed topography, clearly indicates this meandering path of flow and areas of flow impingement on the levees (Plates 10 through 13).

The additional construction should include measures that will reduce flow meandering and therby decrease scour in impingement areas. Flow meandering would be reduced by the construction of a training dike (Plate 10) from the riverward end of the vertical well-field wall upstream, approximately parallel to the right bank of San Jacinto River for a distance of nearly 2000 ft to the left bank of the river. The training dike could be constructed of large stone, which would be overtopped by flood exceeding a frequency of once in 25 to 50 years. Flow meandering would also be reduced by the alternative plans of additional construction, previously described, for the mouth of Bautista Creek.

Even though the additional construction to reduce flow impingement on the levee should reduce scour somewhat in impingement areas, it is recommended that greater protection against undermining the grouted stone revetment be provided by constructing groins along the CE levee in the breached area from sta 145+00 to 180+00 (Plate 11) and downstream of the Main Street crossing from sta 50+00 to 85+00 (Plate 12).

Consideration should be given to the economy of constructing either straight groins, as provided in the Santa Clara River, or L-head groins. Either type of groin used should be 100 ft long, angled downstream 15 deg, and have the groin top sloping downward into the river channel. L-head groins should terminate with a 20-ft section parallel to the levee. Straight and L-head groins should be spaced 150 and 200 ft on centers, respectively. The groins should be constructed with large stone placed sufficiently deep to prevent undermining and destruction of groins by impinging flows.

The Engineer Team believes that construction of the groins would not have a detrimental effect on the RCFC and WCD right levee and most likely would improve conditions there. The effects of reduced flow meandering and impingement on levees by the construction of the recommended upstream training dike and improvements at the mouth of Bautista Creek, together with significant flow dispersion and energy dissipation at the groins, would reduce flow impingement on the RCFC and WCD levee.

Since additional construction after the interim remedial measures are completed may be delayed for a number of years, it is recommended that a number of scour gages be installed along the CE levee to provide information on the adequacy of the grouted stone revetment, in the event that a major flood should occur before the additional construction.

Application of Experience to Other Projects

Existing projects

Project review. The San Jacinto River project experience and other experiences suggest that existing nonrectilinear channels should be reviewed to determine if conditions exist that would produce flow impingement on channel banks. Priority review and evaluation should be given to nonrectilinear, leveed, soft-bottom channels. Particular attention should be given to adverse channel alignment and to wide streams in which smaller than design flows are free to meander, producing cross streamflow and levee impingement. Aerial photographs of preproject and postconstruction conditions may be useful in determining locations of adverse channel alignment, reaches of probable levee impingement, and adverse conditions at stream junctions.

The Bautista Creek experience suggests that existing nonrectilinear, leveed, soft-bottom channels on relatively steep slopes should be reviewed to determine if conditions exist that might cause excessive streambed degradation, in addition to possible flow impingement. Also, tributary streams that produce adverse flow conditions at the junction with larger streams, similar to Bautista Creek, should be reviewed.

Several reports on slope protection have been prepared by the Los Angeles District. An updating and expansion of the 1971 "Report on Criteria for Riprap Bank Protection" prepared by the Los Angeles District Hydraulic Section may be used in an initial evaluation of soft-bottom channel performance. The report indicates that "layer thicknesses requirements of riprap may be larger for flows less than the maximum." It is noteworthy that damages to the Santa Maria levees in 1969 and to the Bautista Creek and San Jacinto River levees in 1980 occurred during flows less than maximum. As for the San Jacinto River levee, the Santa Maria levees were damaged by meandering flows that undermined the stone protection at isolated points and by cross streamflows that eroded parts of the levees.

For those reaches of levees identified for investigation and additional evaluation, in-place riprap gradation tests should be obtained. Riprap gradations taken at the plant are not representative of in-place gradations.

Current criteria (EM 1110-2-1601) require testing of in-place samples of riprap material.

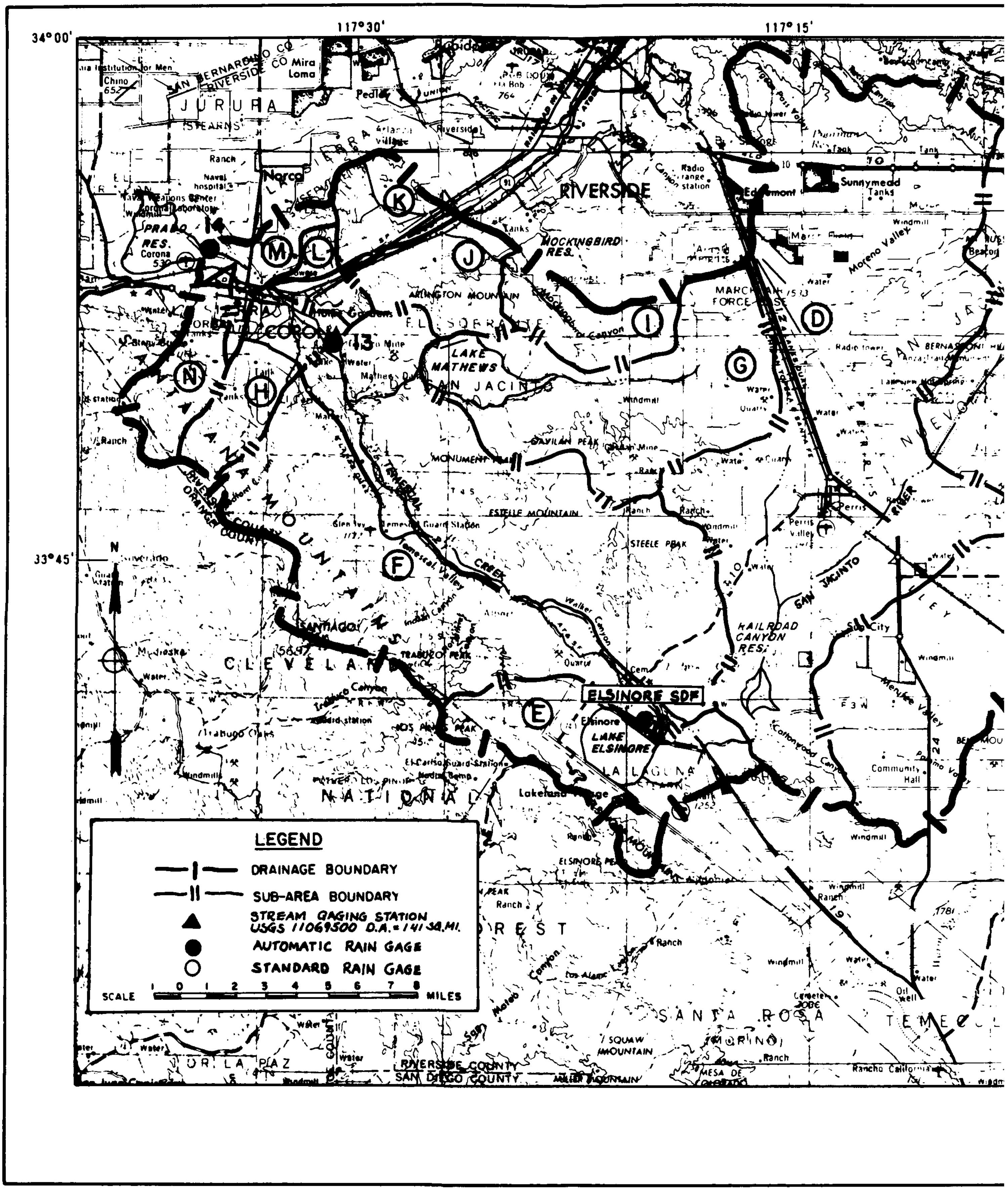
Inspection and evaluation program. The San Jacinto River levee failure signifies the need for a levee safety assurance program. An authorized program of inspection and evaluation by engineering personnel would permit review of soft-bottom channels considering current criteria, practices, and experience. The most meaningful time for such an inspection would be during periods of flow. The purpose of the program would be to identify, through data collection and review, those levees requiring early detailed investigation because of actual or suspect conditions. The detailed investigations, determination of the need for additional defensive measures, and their construction, where needed to ensure project integrity, could be included under the periodic inspection and continuing evaluation program.

After the evaluation of existing projects and identification of locations that are likely to be damaged by design or smaller flows, defensive measures should be provided, as described below, to improve project integrity.

Future projects

In a wide stream free to meander, the points of low-water-flow impingement vary and may be indeterminate. Considering the uncertainties involved in the design and construction of bank protection, defensive measures should be provided in locations where the bank may be subject to severe angles of attack. The use of groins, as constructed on the Santa Clara levee, proposed for Santa Maria levees, and recommended herein for San Jacinto levees should be considered, as well as deeper stone toe protection, in impingement reaches. The use of channel stabilizers and/or deeper stone toe protection should be considered for channels with relatively steep slopes. Improvements in channel alignment should be made at abrupt junctions.

The construction of a rectilinear low-flow channel would channelize flow away from the bank. Considering the ephemeral nature of an excavated low-flow channel, local interests would not likely provide assurances; therefore, the low-flow channel cannot be considered as part of the permanent works. The low-flow channel would have to be designated as a borrow area so that local assurances for maintenance would not apply. Solutions requiring less maintenance, such as groins or deeper toe protection, are more desirable because it seems that soft-bottom, nonrectilinear channels require more maintenance than considered in project planning.



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AUTOMATIC RAIN GAGE
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SCALE 1 0 1 2 3 4 5 6 7 8 MILES
RIVERSIDE
PRADO RES.
Corona
LAKE MATHEWS
MOCKINGBIRD RES.
MARCH AIR FORCE BASE
ELSINORE SDF
LAKE ELSINORE
RAILROAD CANYON RES.
Sunnymead
Moreno Valley
Perris
Sun City
Norco
Lakeland Village
ARLINGTON MOUNTAIN
GAVILAN PEAK
ESTELLE MOUNTAIN
STEELE PEAK
SANTIAGO
TRABUCO PEAK
LOS PINOS PEAK
SQUAW MOUNTAIN
SANTA ROSA
RIVERSIDE COUNTY
SAN DIEGO COUNTY
ORANGE COUNTY
SAN BERNARDINO CO
RIVERSIDE CO
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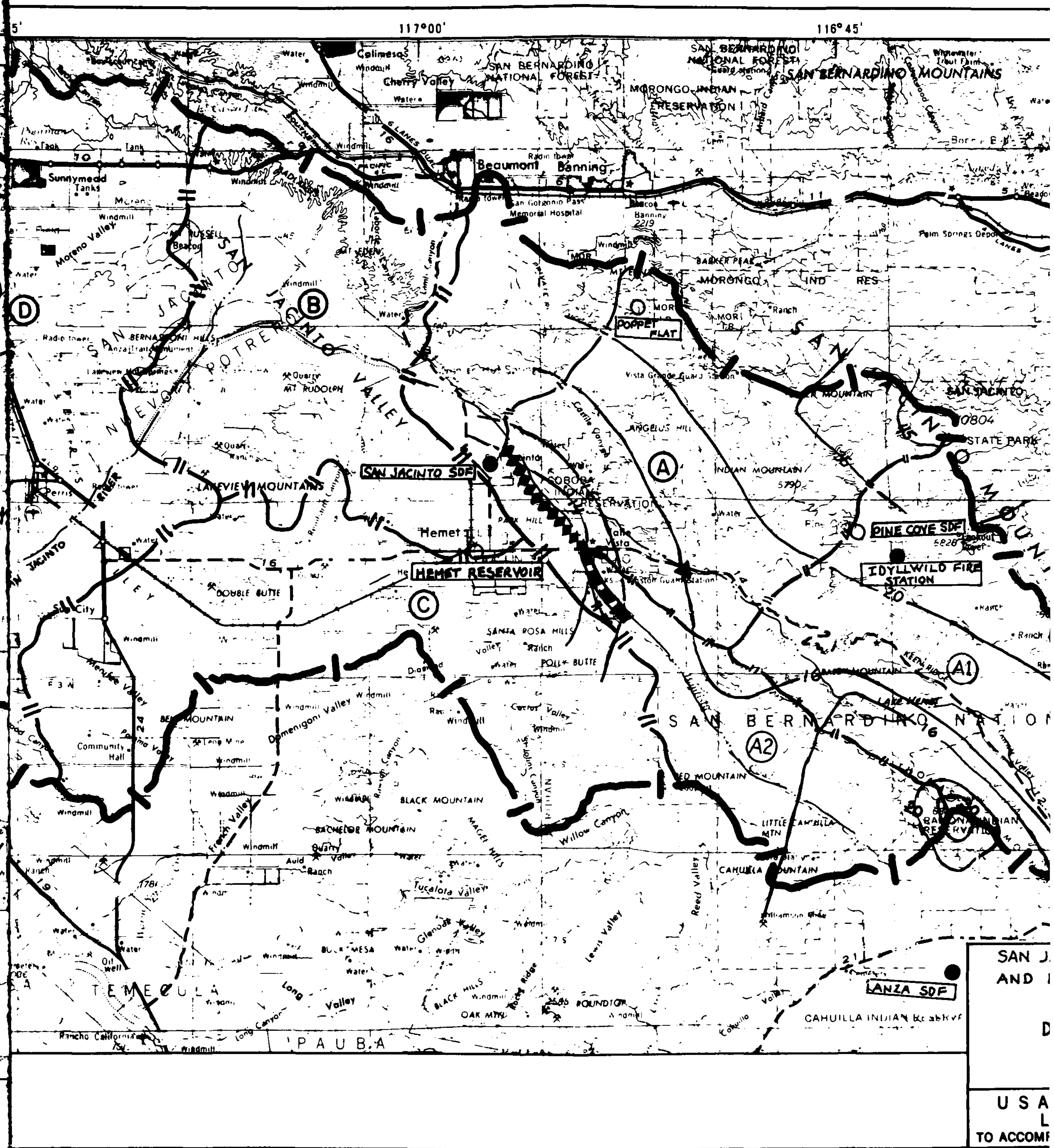
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SAN BERNARDINO MOUNTAINS
Sunnymead
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Banning
San Gorgonio Pass Memorial Hospital
Moreno Valley
MT RUSSELL
SAN JACINTO
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A2
BARKER PEAK
MORONGO IND RES
POPPET FLAT
Vista Grande Guard Station
SAN JACINTO
10804
STATE PARK
SAN BERNARDINO HILLS
Lakeview Hot Springs
NUEVO
POTRERO
MT RUDOLPH
SAN JACINTO VALLEY
ANGELUS HILL
INDIAN MOUNTAIN
5790
SAN JACINTO SDF
LAKEVIEW MOUNTAINS
SOBOBA INDIAN RESERVATION
PINE COVE SDF
Hemet
PARK HILL
Valle Vista
IDYLLWILD FIRE STATION
HEMET RESERVOIR
Perris
DOUBLE BUTTE
SANTA ROSA HILLS
Sun City
POLLY BUTTE
Menifee Valley
BELL MOUNTAIN
Domenigoni Valley
SAN BERNARDINO NATION
Community Hall
RED MOUNTAIN
BLACK MOUNTAIN
LITTLE CAHUILLA MTN
BACHELOR MOUNTAIN
Willow Canyon
French Valley
Auld Ranch
CAHUILLA MOUNTAIN
Tucalota Valley
Reed Valley
Lewis Valley
Glenoak Valley
BUCK MESA
TEMECULA
Long Valley
BLACK HILLS
OAK MTN
ROUNDTOP
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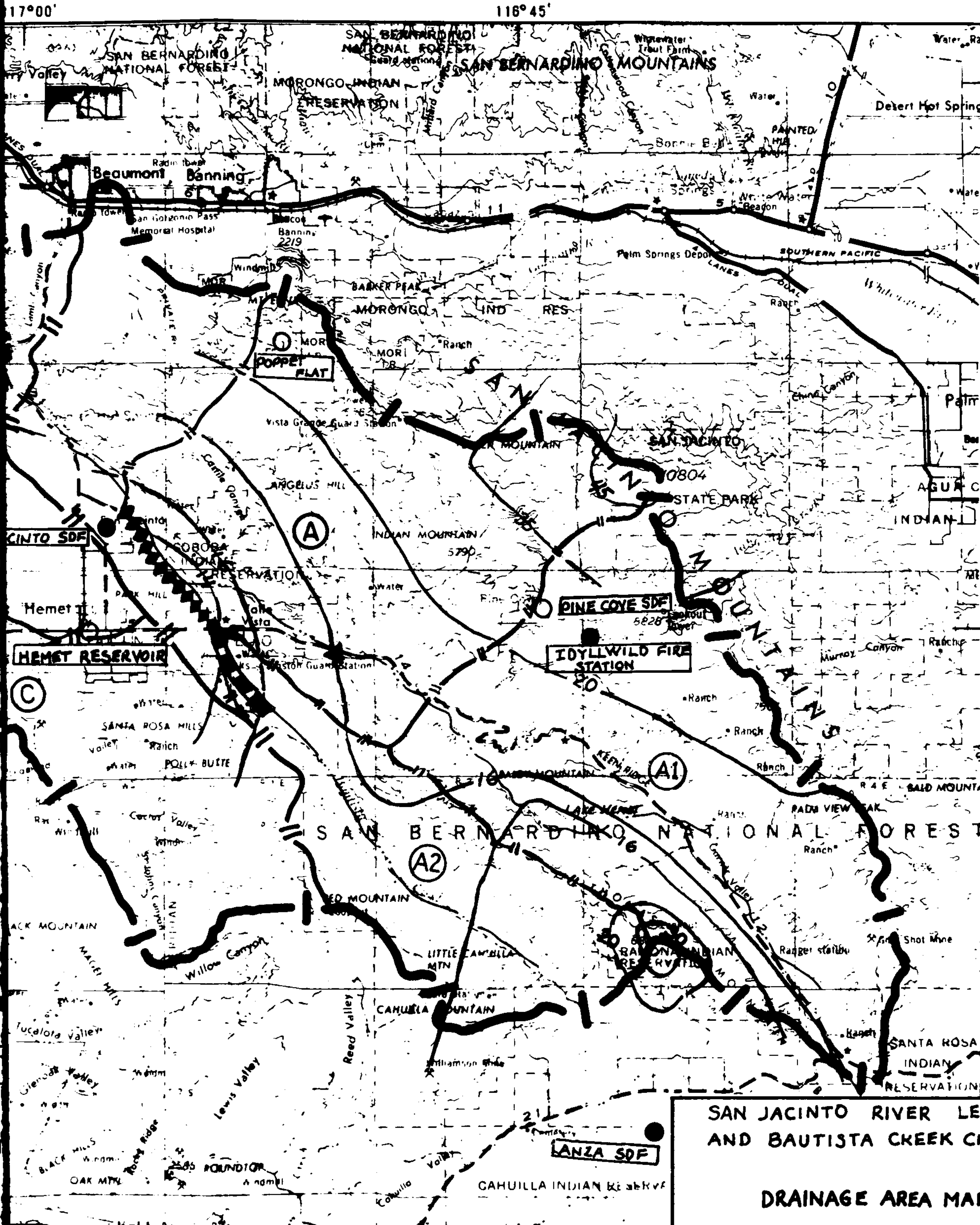

SAN JACINTO RIVER LEVEE
AND BAUTISTA CREEK CHANNEL

DRAINAGE AREA MAP

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
TO ACCOMPANY REPORT DATED:

FIGURE NO. 1

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CORPS OF ENGINEERS U. S. ARMY

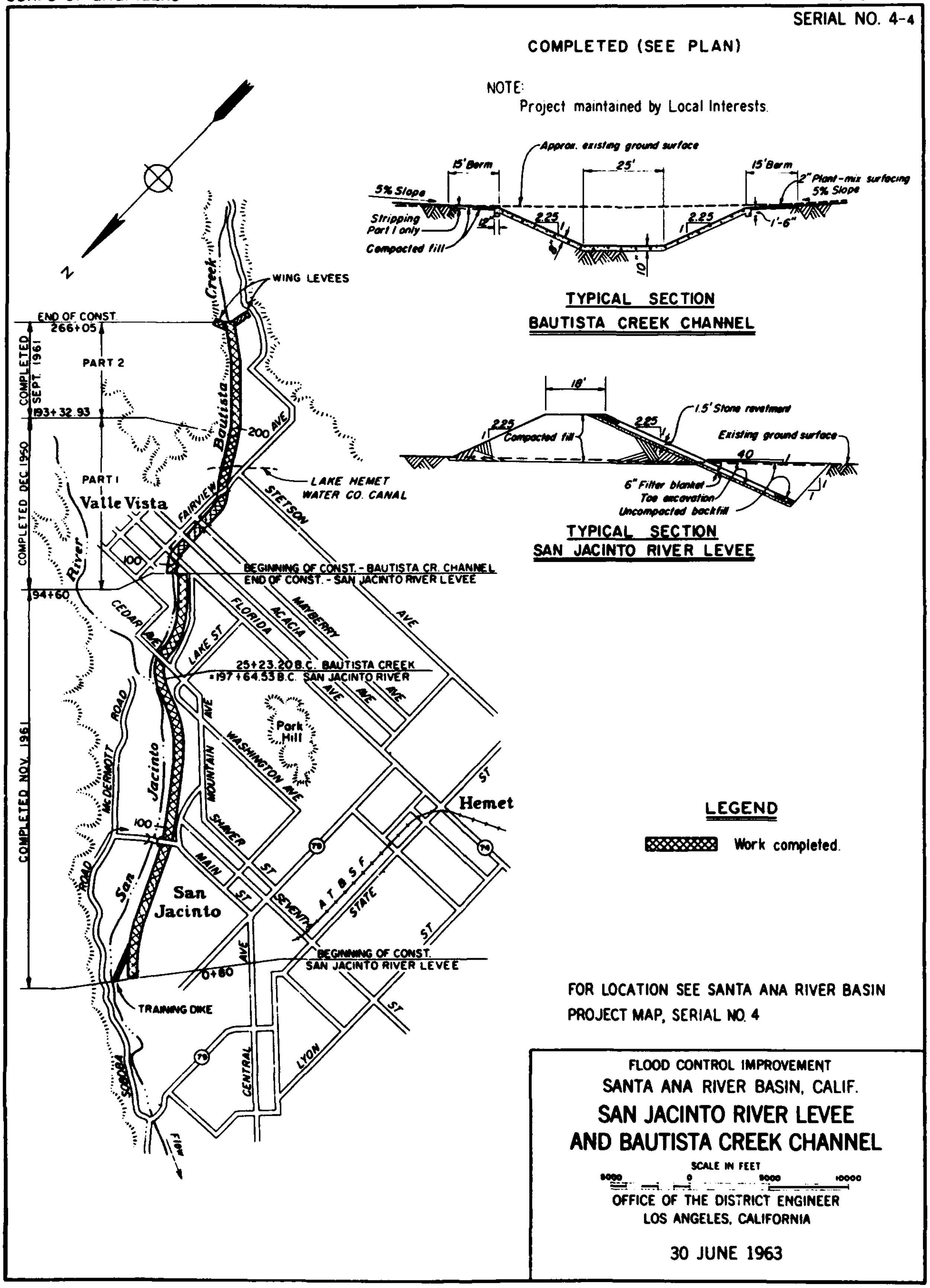
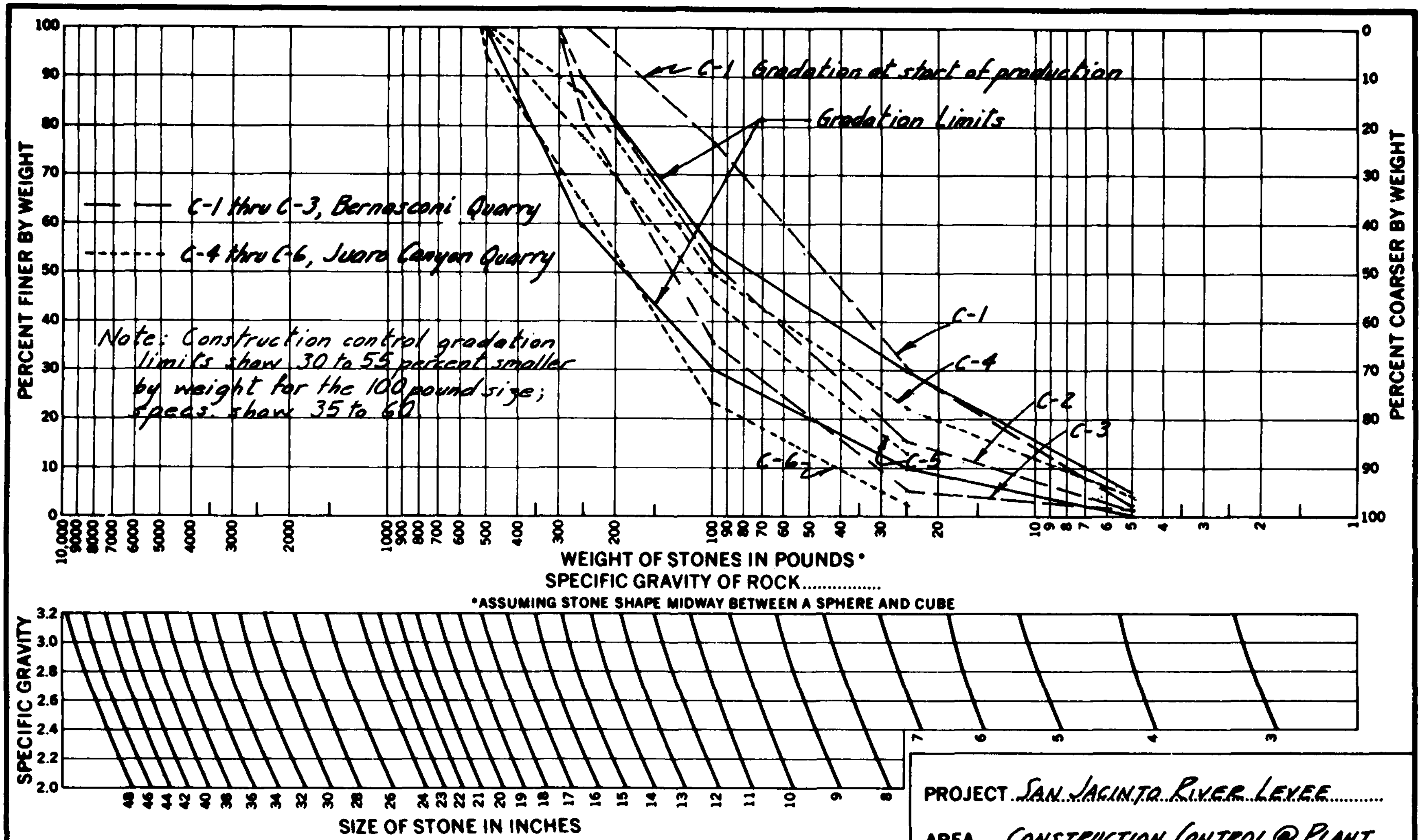


FIGURE 2



PROJECT San Jacinto River Levee

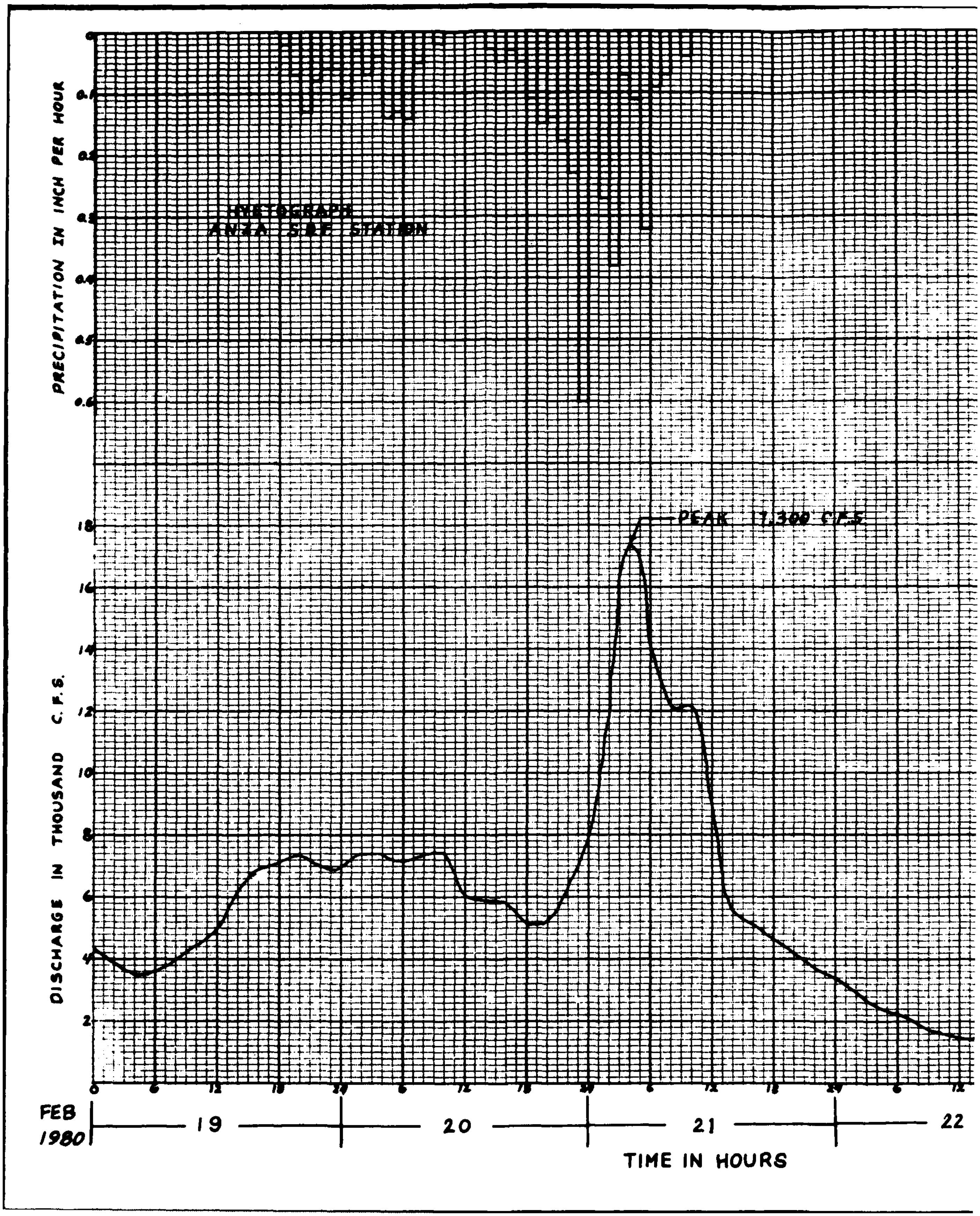
AREA Construction Control @ Plant

DATE 4/25/61, 10/25/61

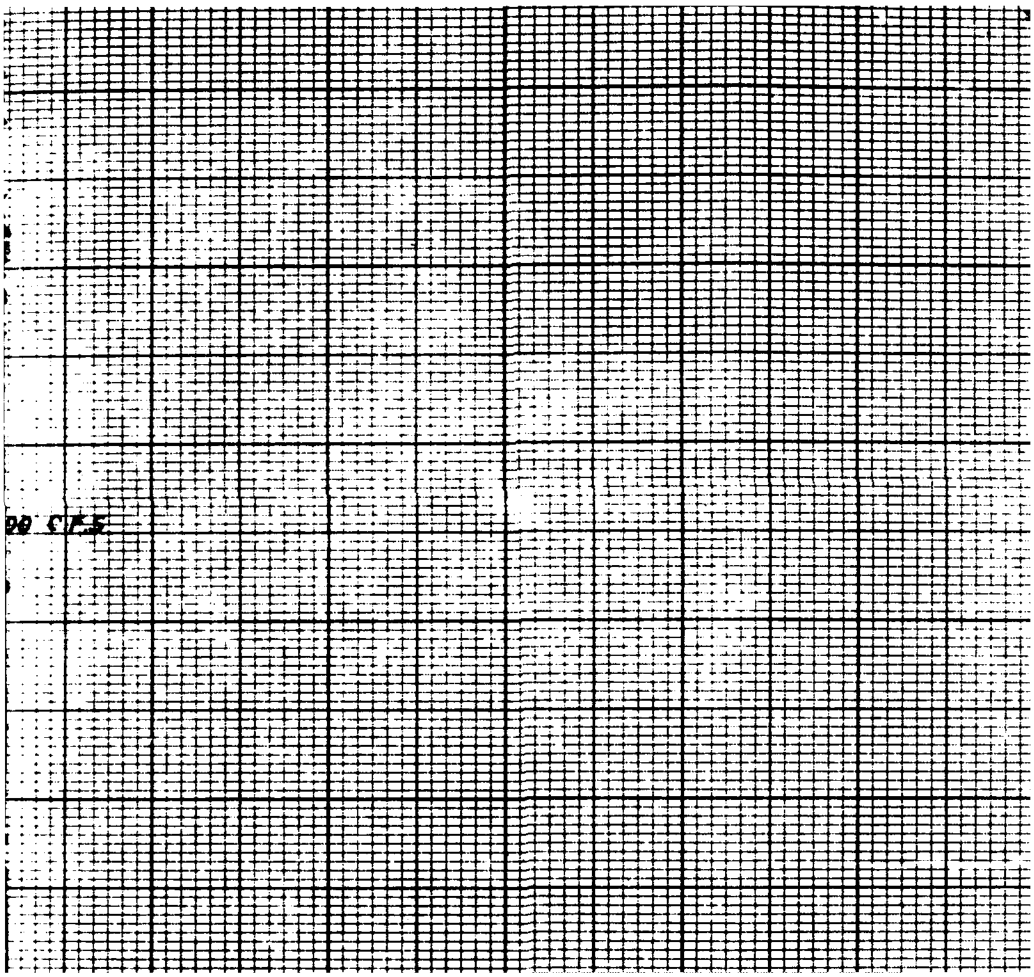
RIPRAP GRADATION CURVES

ENG FORM 4055
APR 67

FIGURE 3



PRECIPITATION IN INCH PER HOUR
HYETOGRAPH
PEAK 17,300 C.F.S.
DISCHARGE IN THOUSAND C.F.S.
FEB
1980
19
20
21
22
TIME IN HOURS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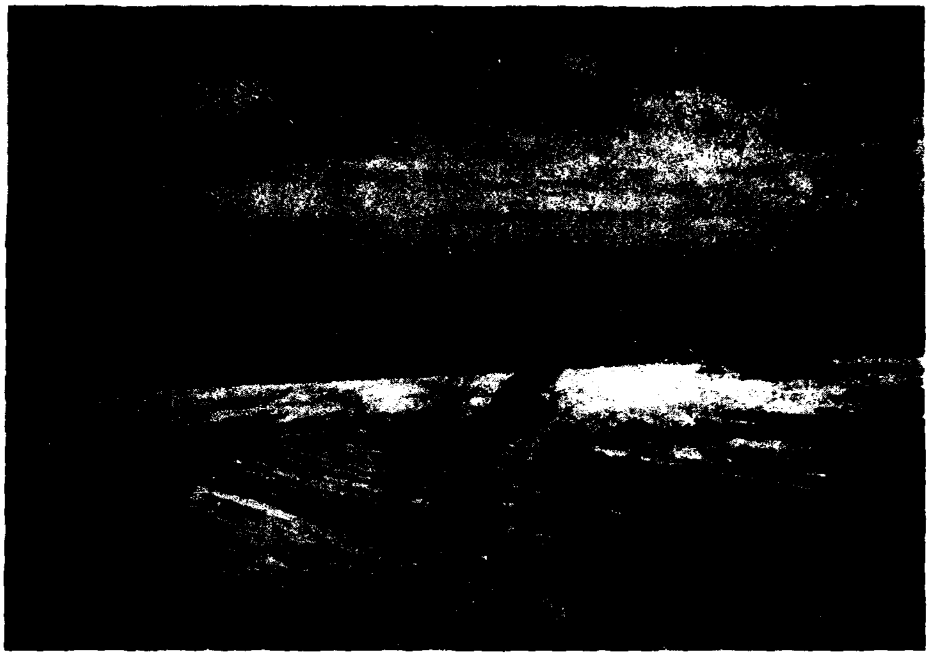
Bautista Creek levee looking downstream at the breach area.

Bautista Creek Levee with flood fight embankment in the background.

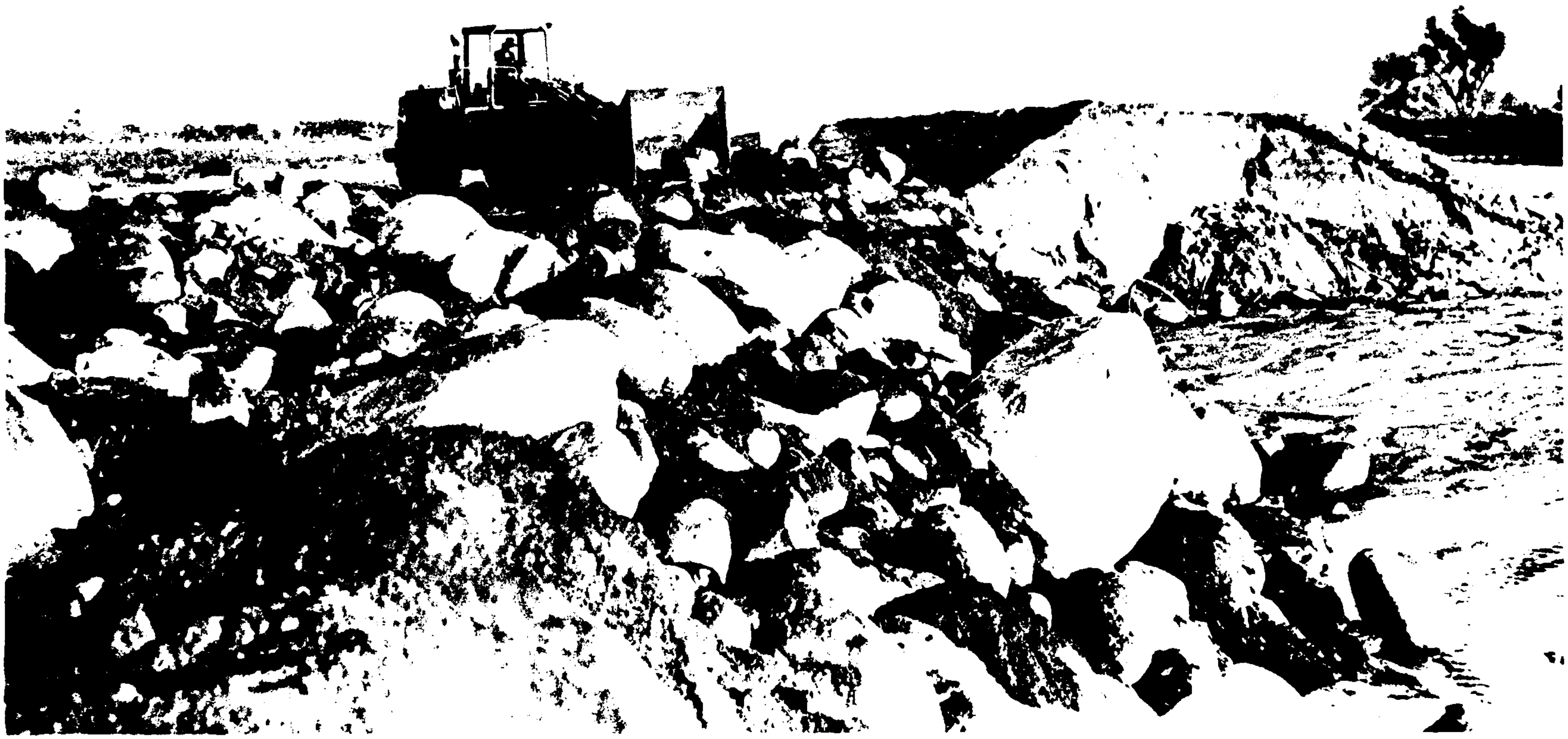
Figure No. 5



San Jacinto River levee embankment shows project levee on the left and flood fight construction on the right.

San Jacinto River Levee in the foreground and flood fight embankment in the background.

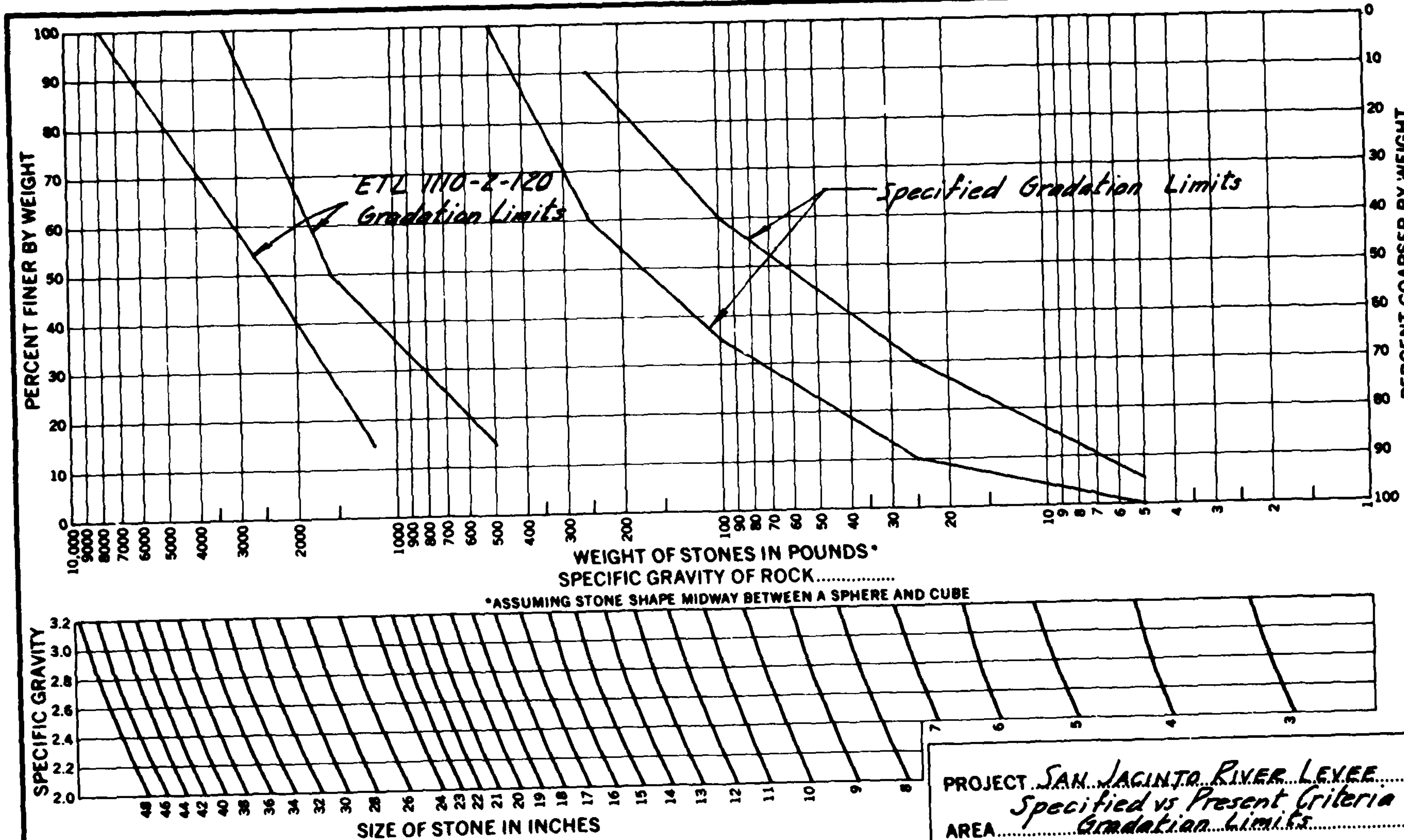
Figure No. 6



San Jacinto River Levee Breach (Bautista Creek)

(Hemet News)

Figure No. 7



PROJECT San Jacinto River Levee

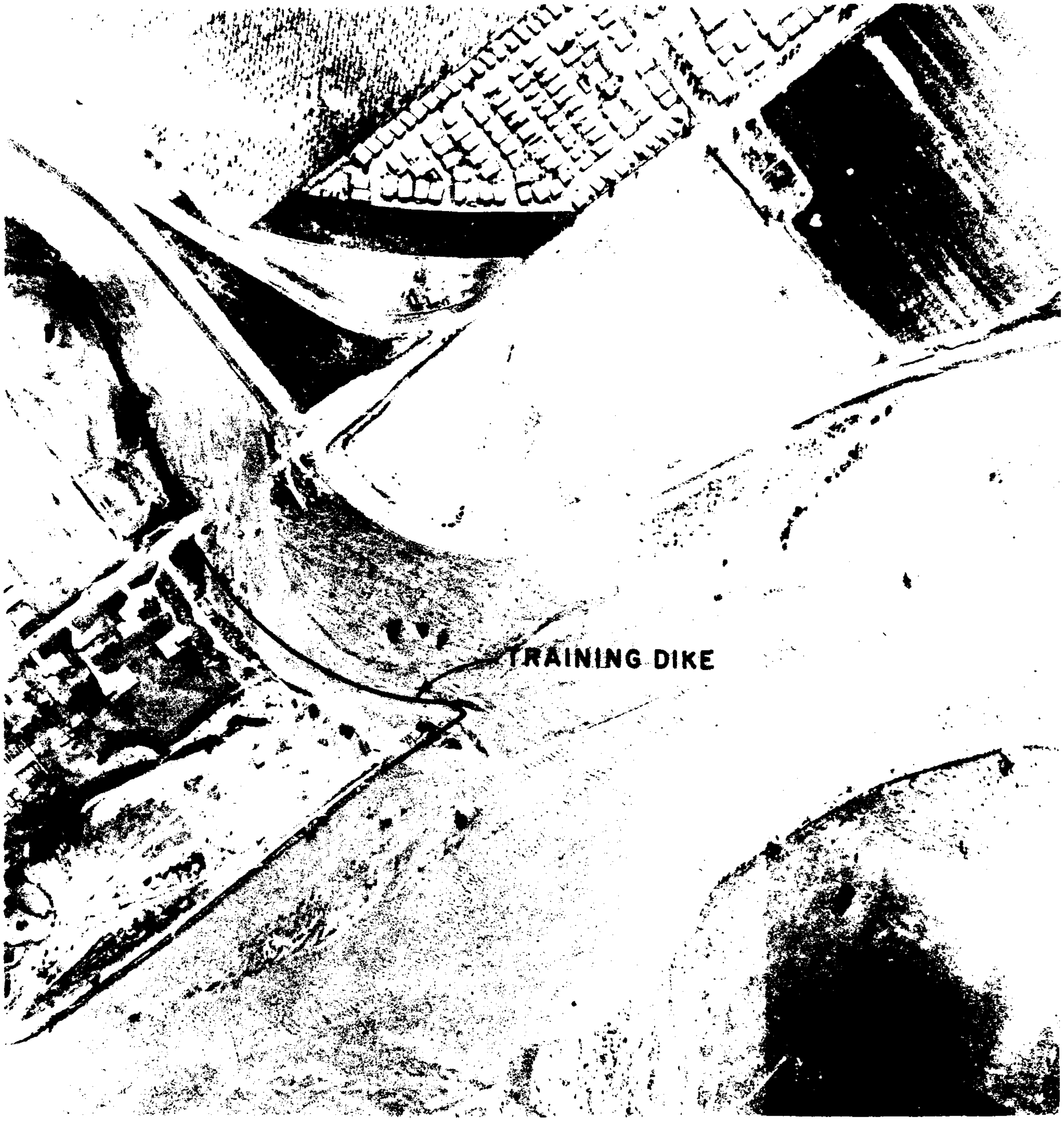
AREA Specified vs Present Criteria Gradation Limits

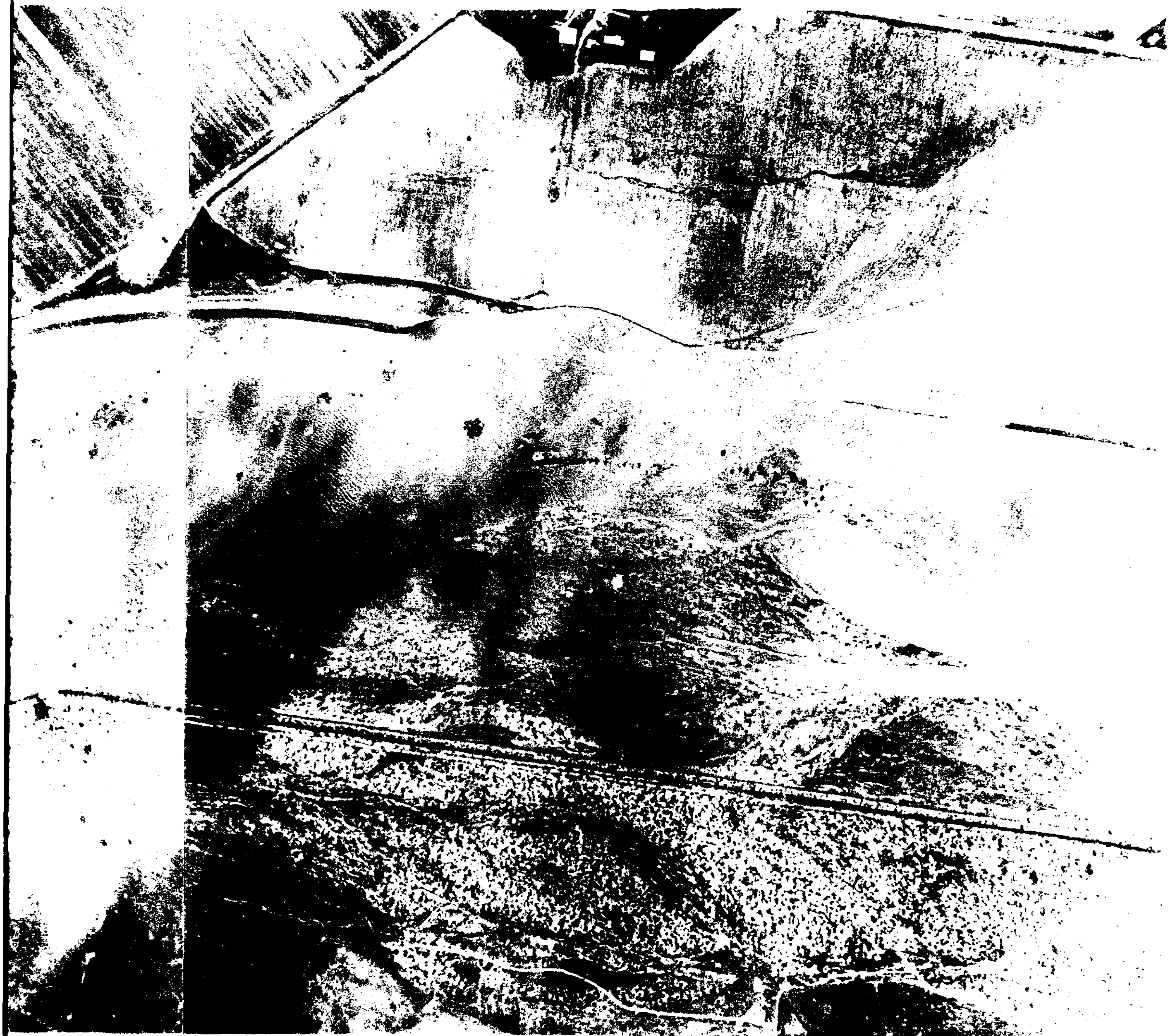
DATE June 1980

RIPRAP GRADATION CURVES

ENG FORM 4055
APR 67

FIGURE 8


TRAINING DIKE



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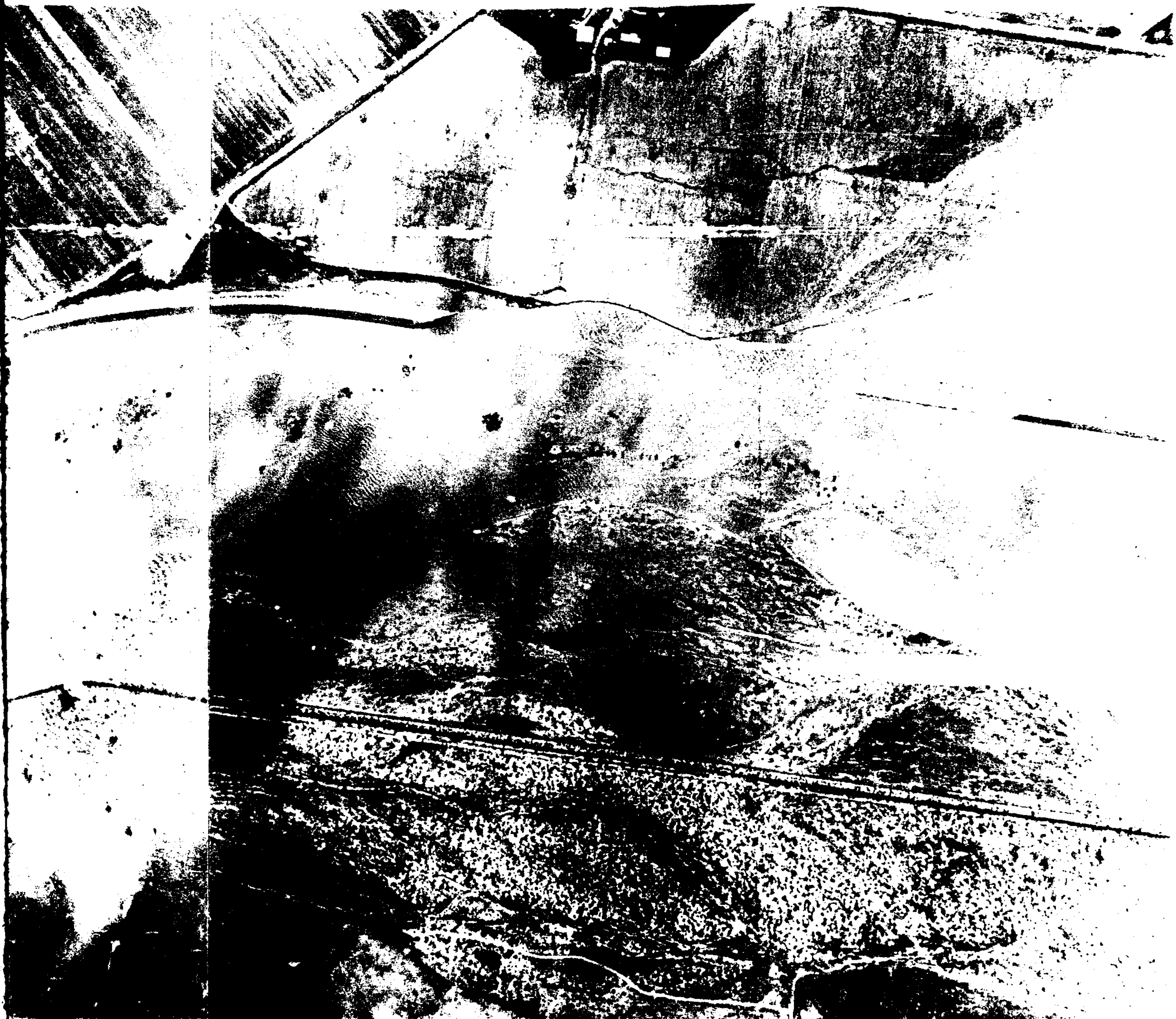
SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

BAUTISTA CREEK

TRAINING DIKE

FIGURE 9


LEVEE
DIKE or LEVEE



2

SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

BAUTISTA CREEK
CHANNEL RELOCATION

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FIGURE 10

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SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

SAN JACINTO RIVER

AERIAL MOSIAC

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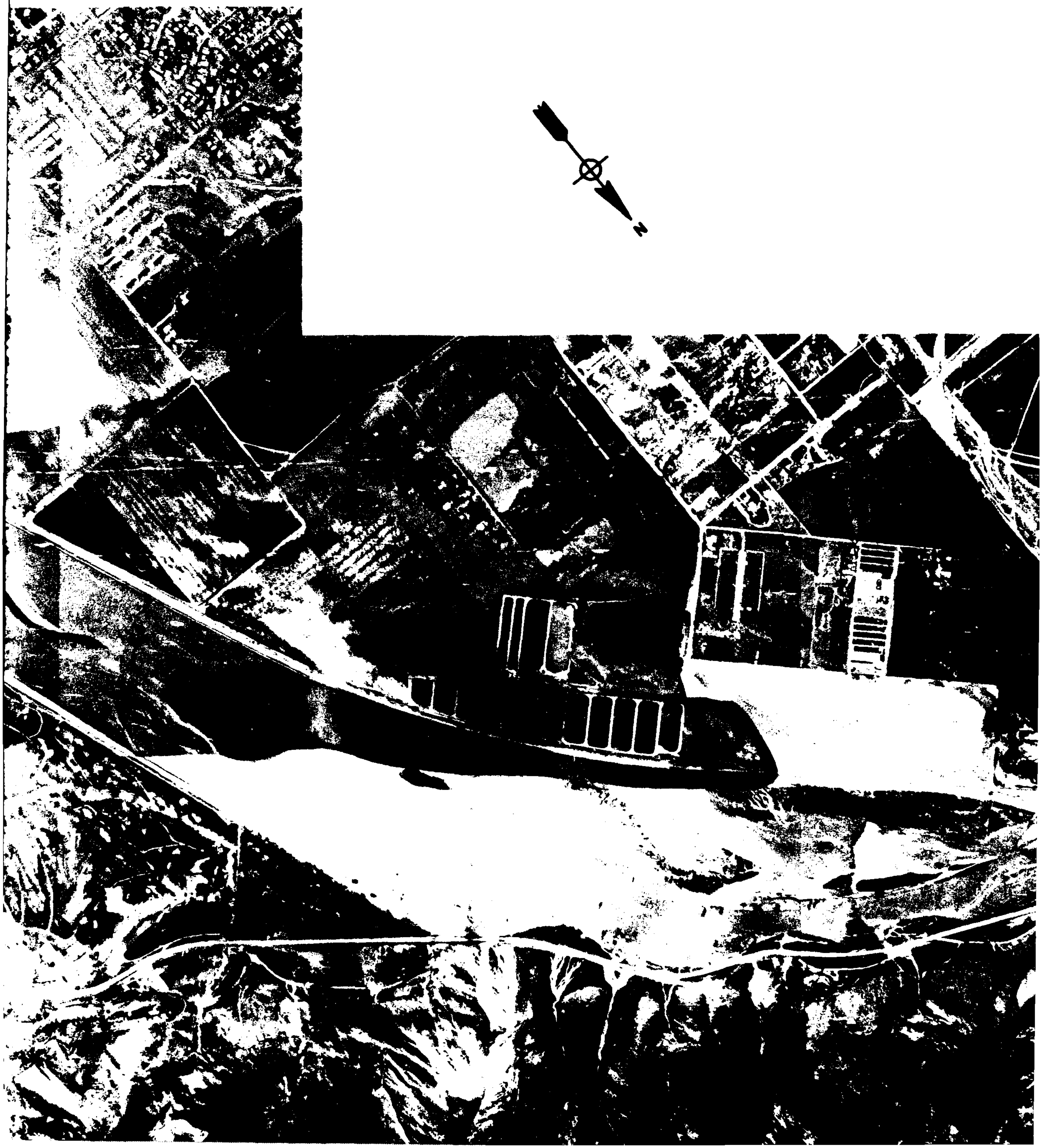
PLATE I 3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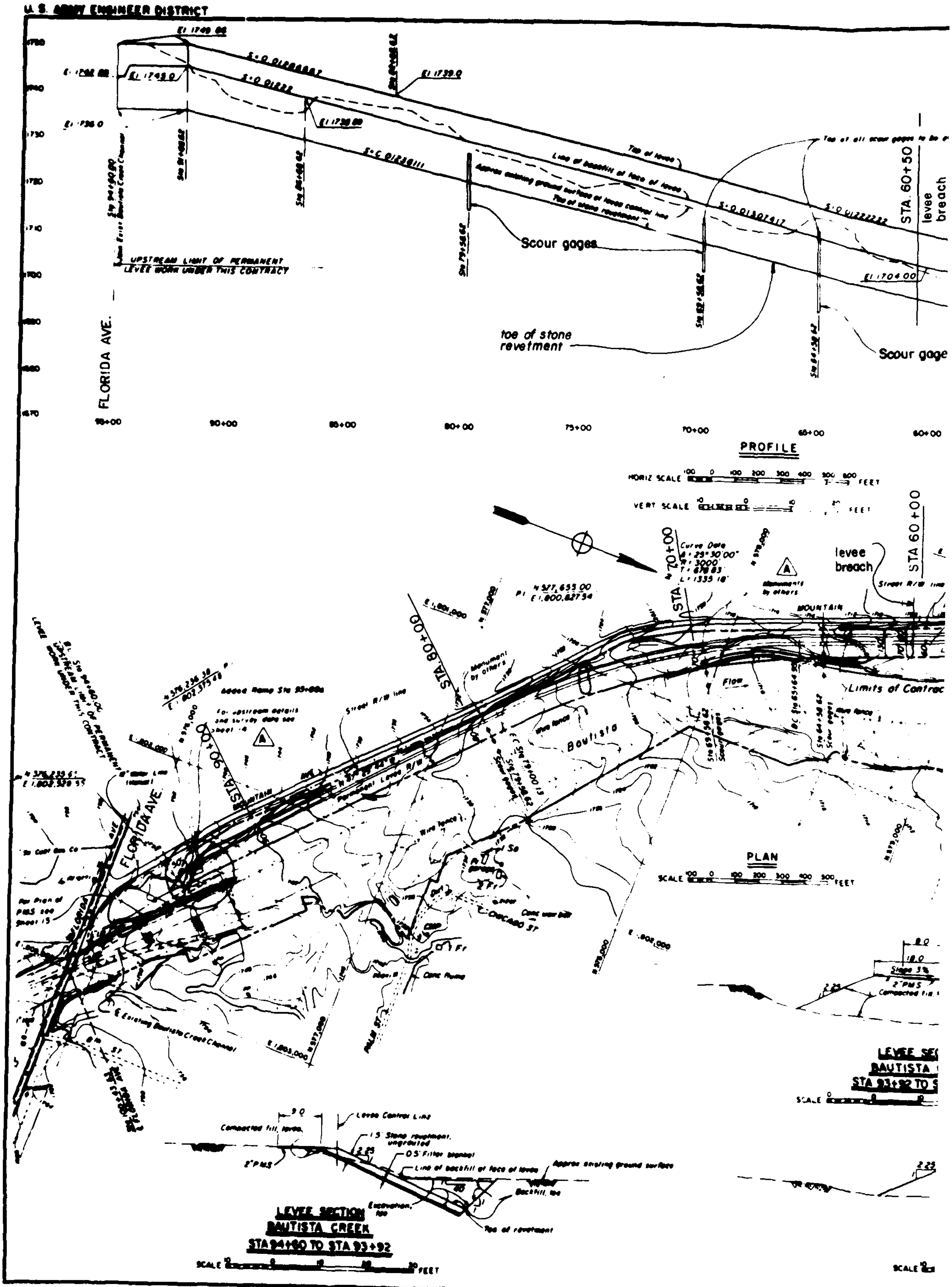
SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

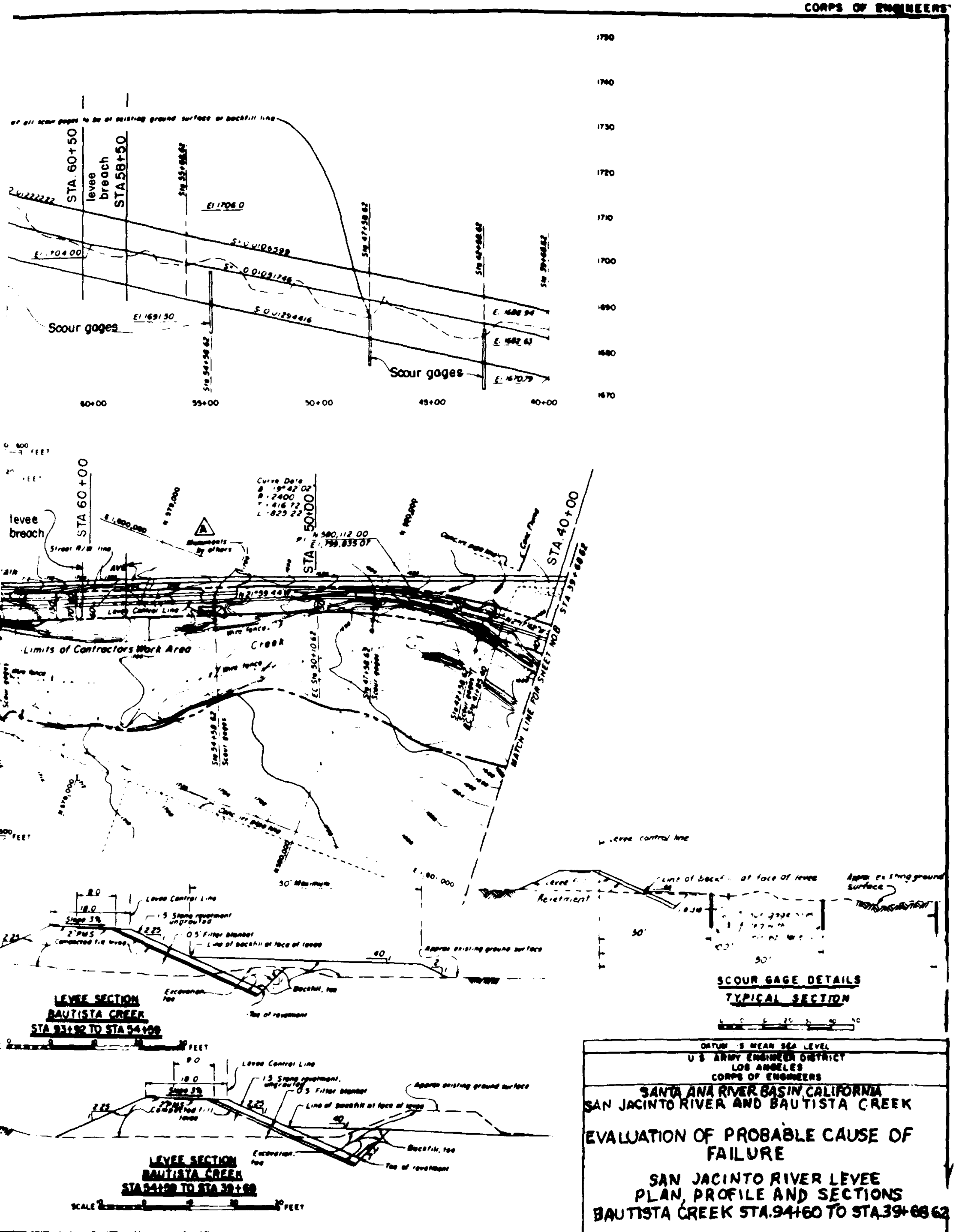
SAN JACINTO RIVER

AERIAL MOSIAC

PLATE 2

U. S. ARMY ENGINEER DISTRICT





DATUM IS MEAN SEA LEVEL

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

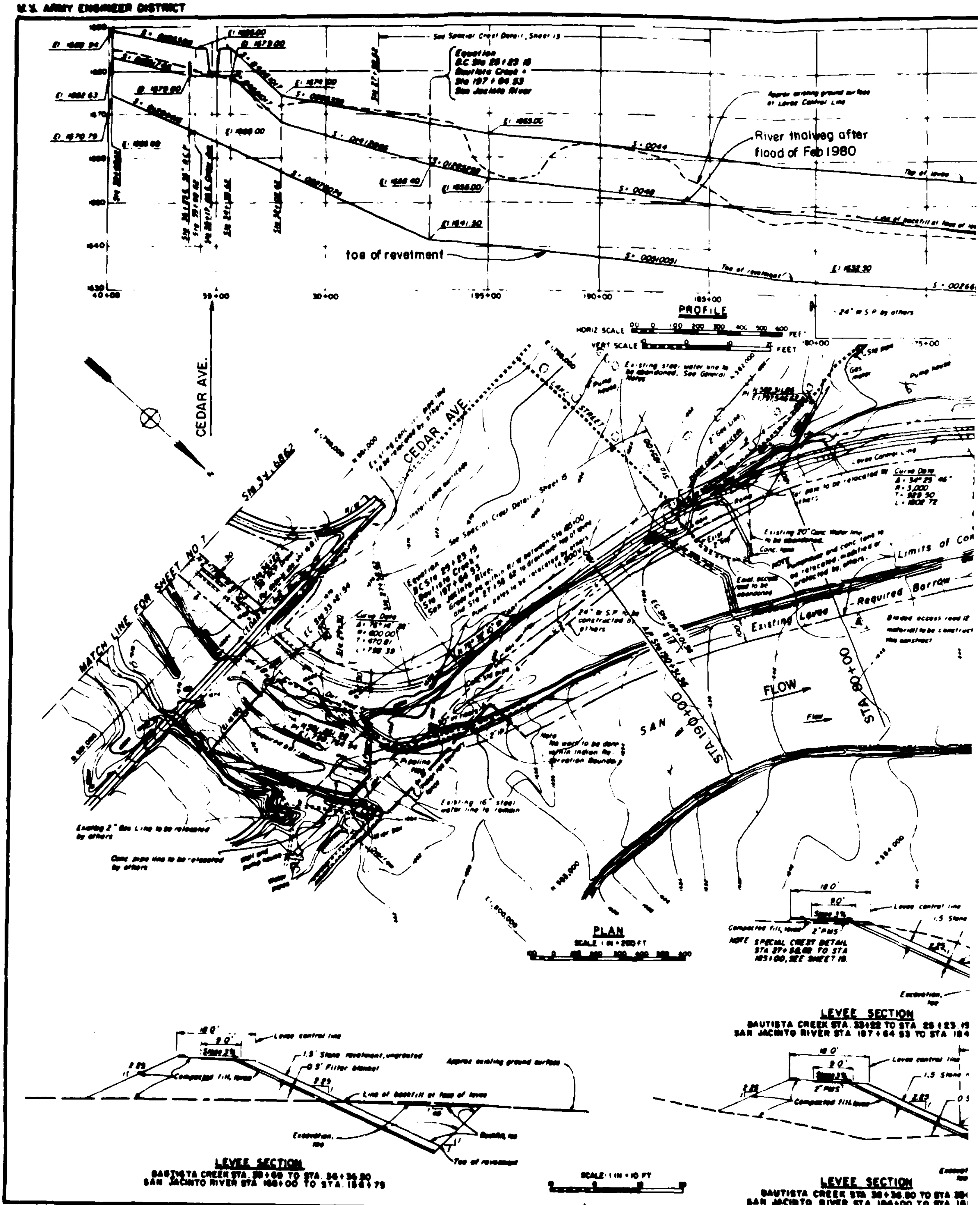
SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

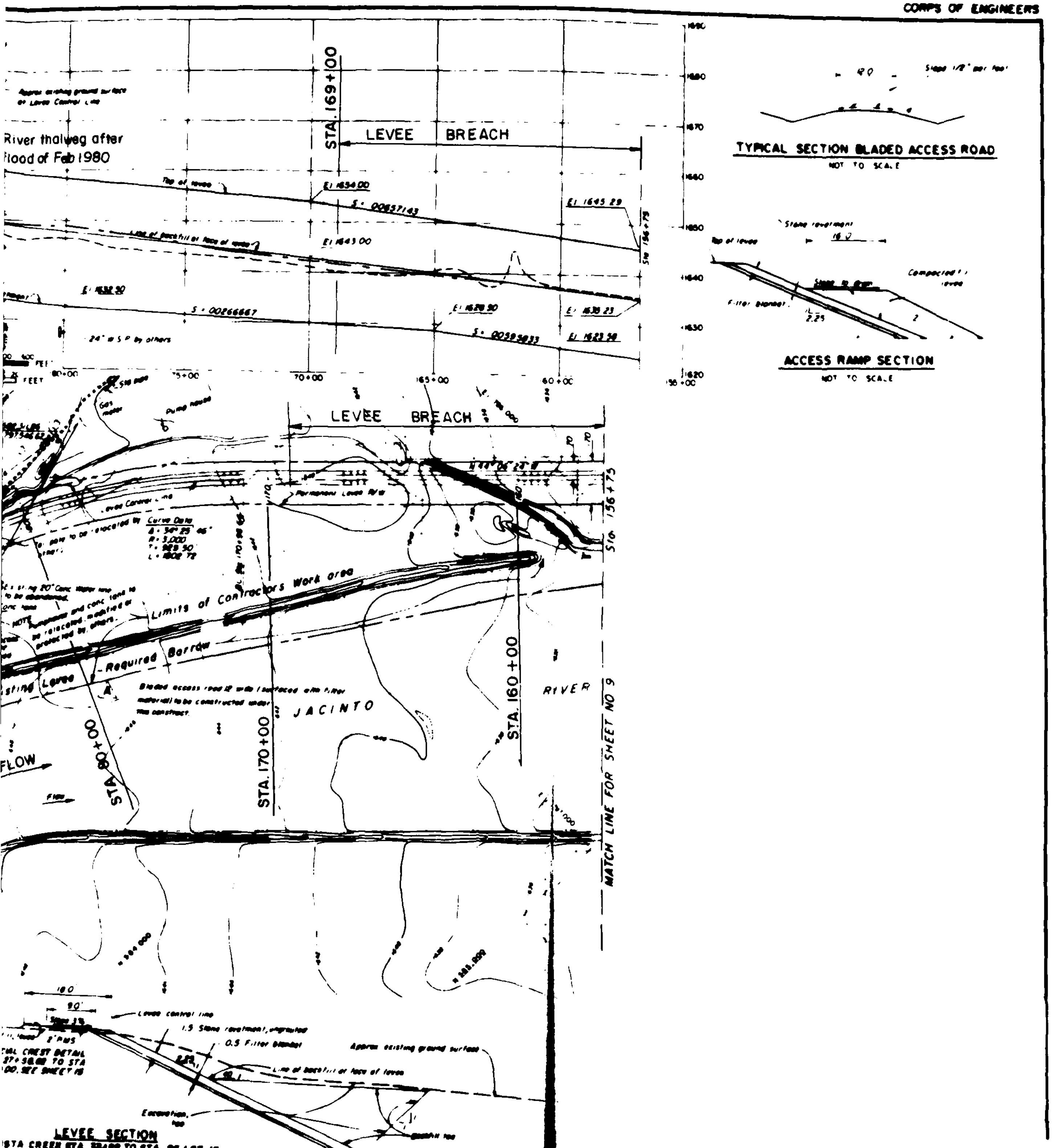
EVALUATION OF PROBABLE CAUSE OF FAILURE

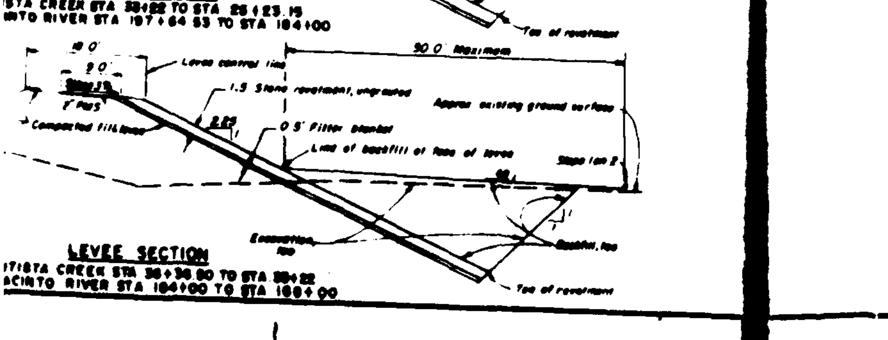
SAN JACINTO RIVER LEVEE
PLAN, PROFILE AND SECTIONS
BAUTISTA CREEK STA.94+60 TO STA.39+68.62

2

U.S. ARMY ENGINEER DISTRICT







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

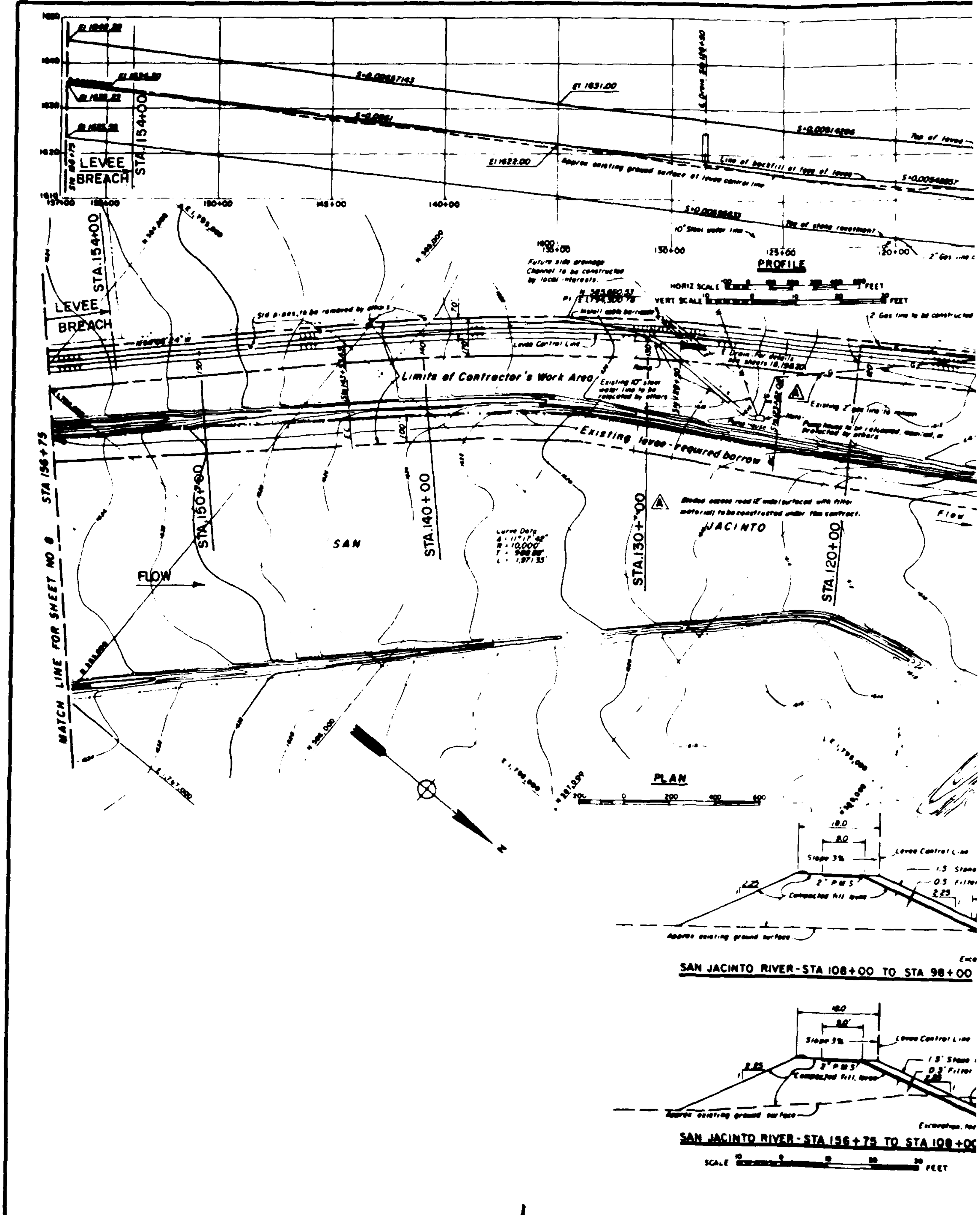
SANTA ANA RIVER BASIN, CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

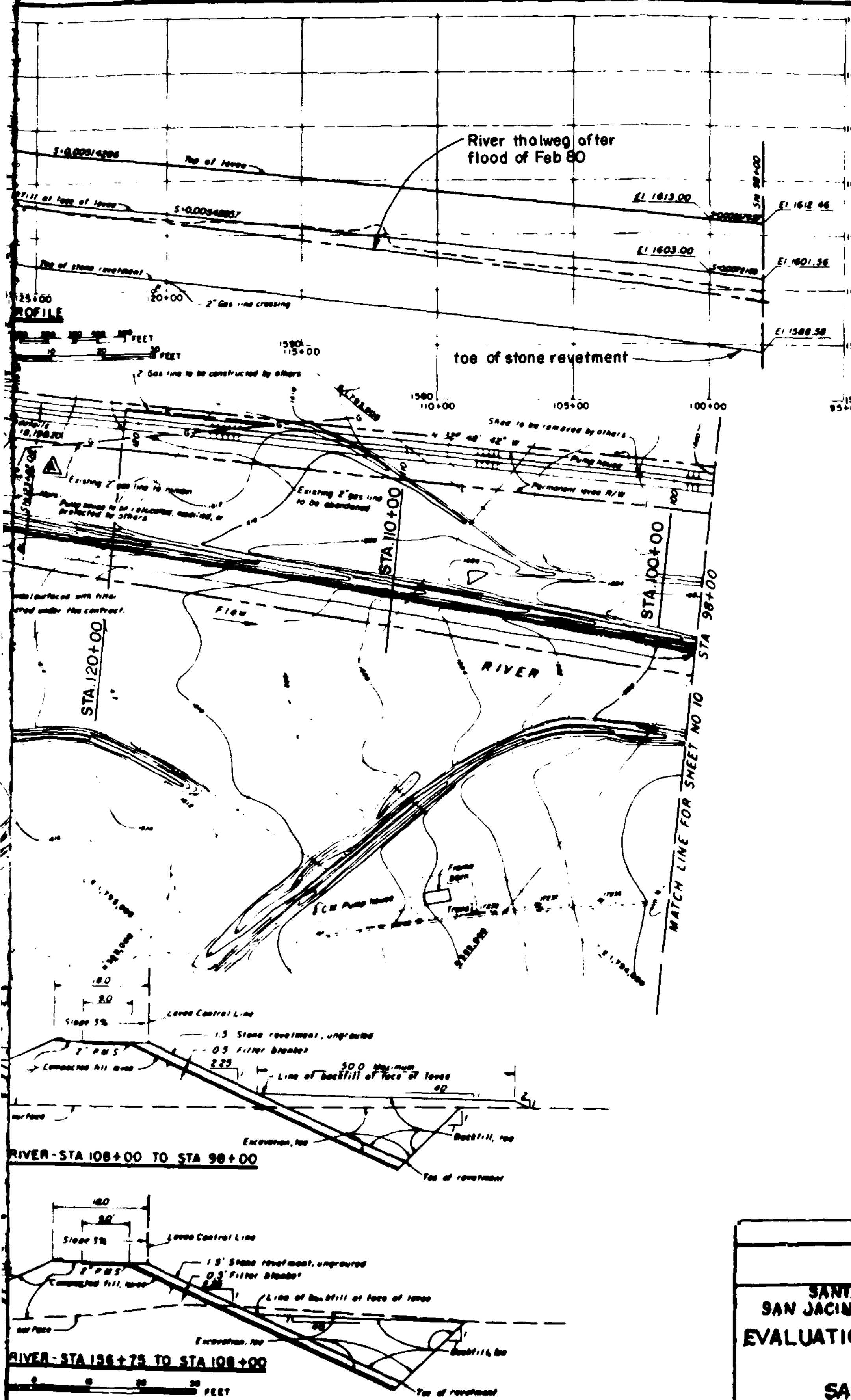
EVALUATION OF PROBABLE CAUSE OF FAILURE

SAN JACINTO RIVER LEVEE
PLAN, PROFILE AND SECTIONS
BAUTISTA CREEK STA. 39+68.62 TO STA. 25+23.15
SAN JACINTO RIVER STA. 197+64.53 TO STA. 156 + 75

PLATE 4

US ARMY ENGINEER DISTRICT





DATUM IS MEAN SEA LEVEL

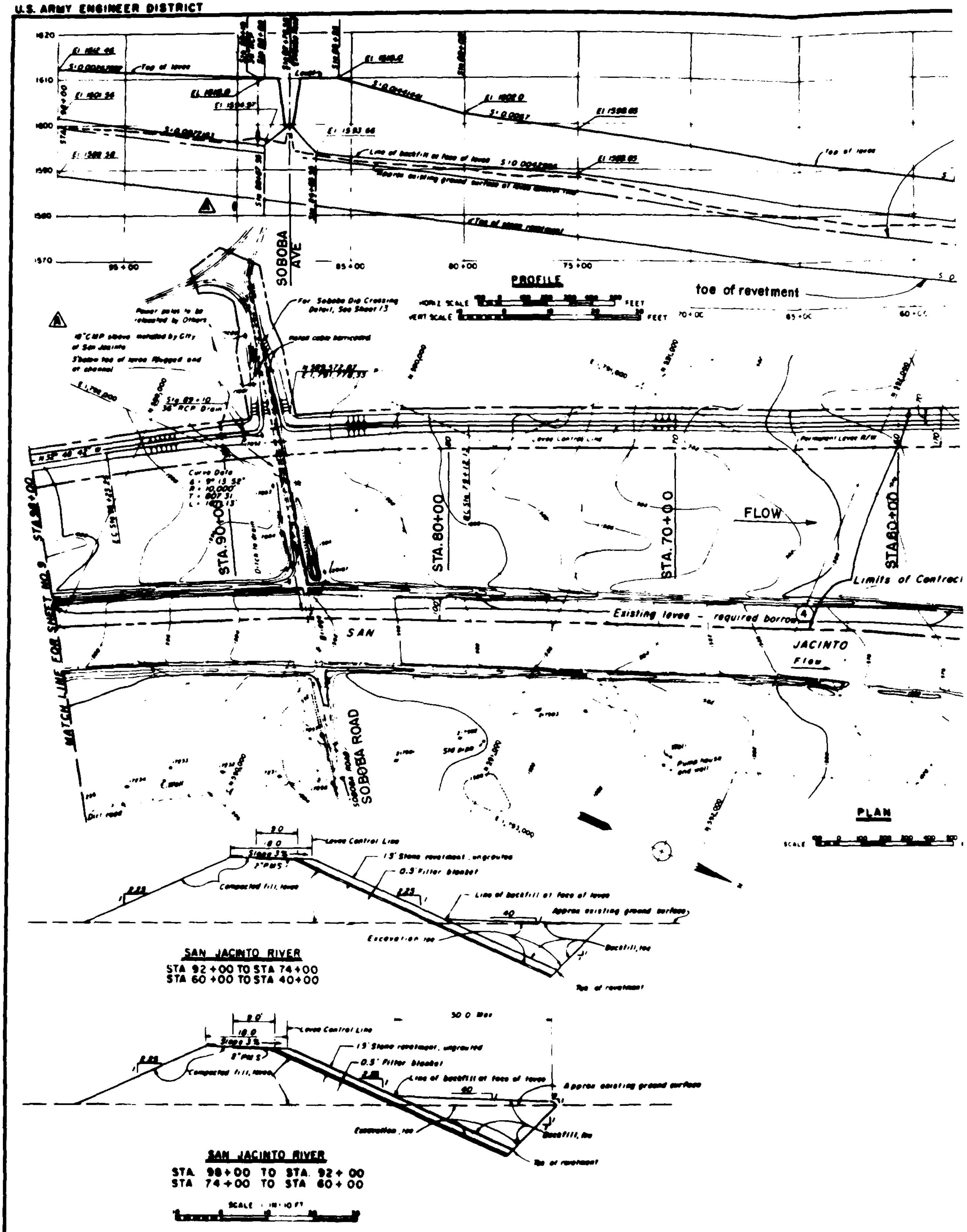
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

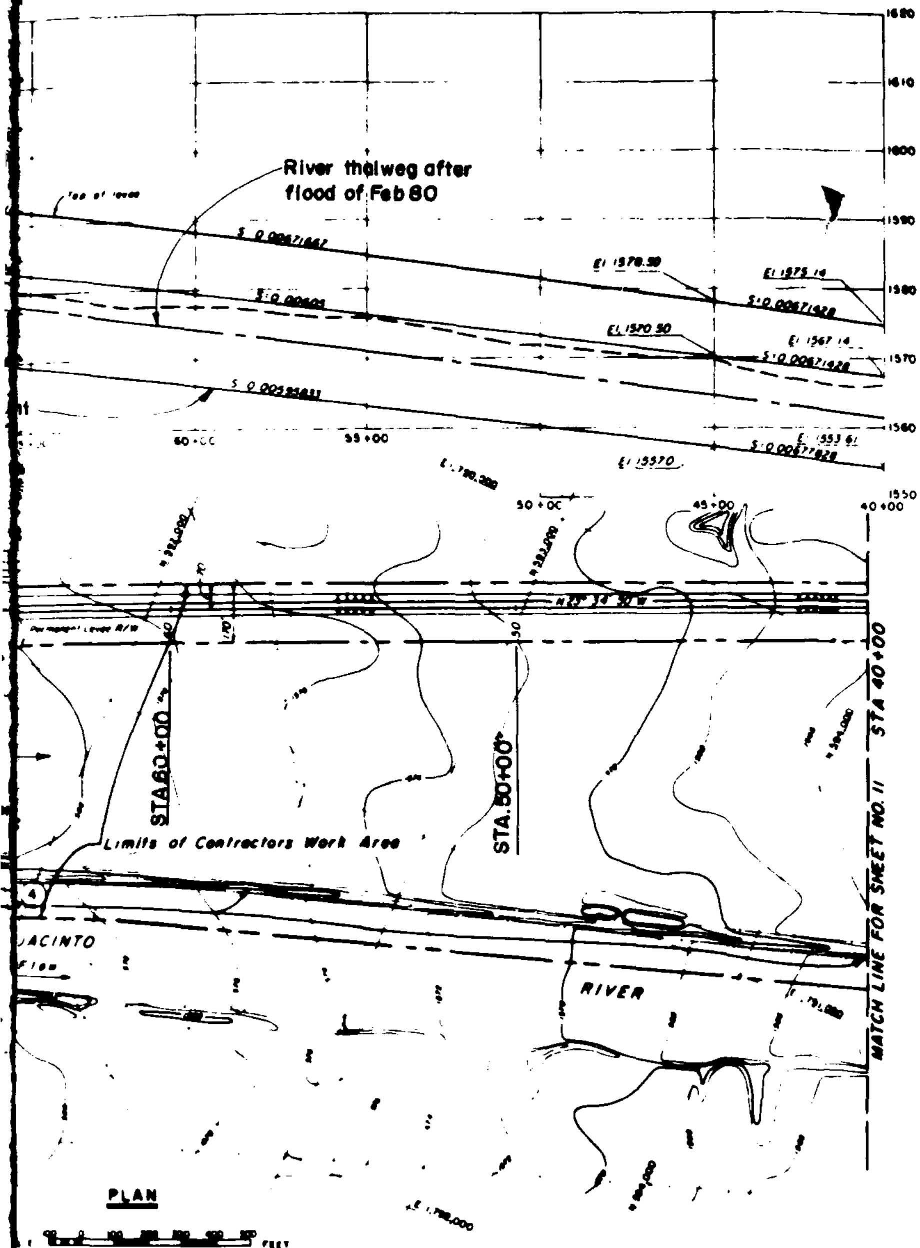
SANTA ANA RIVER BASIN, CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

EVALUATION OF PROBABLE CAUSE OF FAILURE

SAN JACINTO RIVER LEVEE
PLAN, PROFILE AND SECTIONS
SAN JACINTO RIVER STA 156+75 TO STA 96+00

U.S. ARMY ENGINEER DISTRICT





DATUM IS MEAN SEA LEVEL

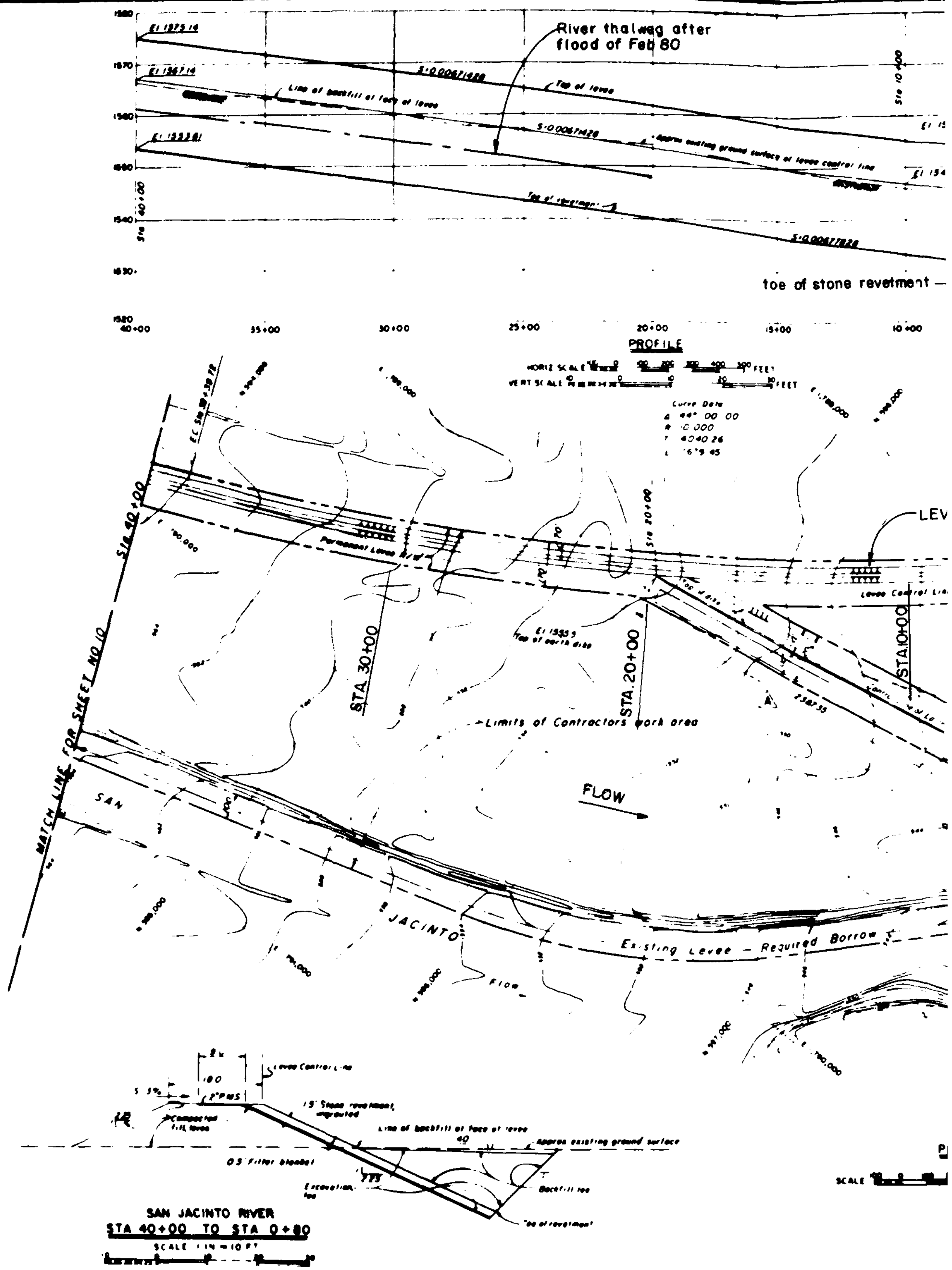
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER BASIN, CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

EVALUATION OF PROBABLE CAUSE OF FAILURE

SAN JACINTO RIVER LEVEE
PLAN, PROFILE AND SECTIONS
SAN JACINTO RIVER STA. 98+00 TO STA. 40+00

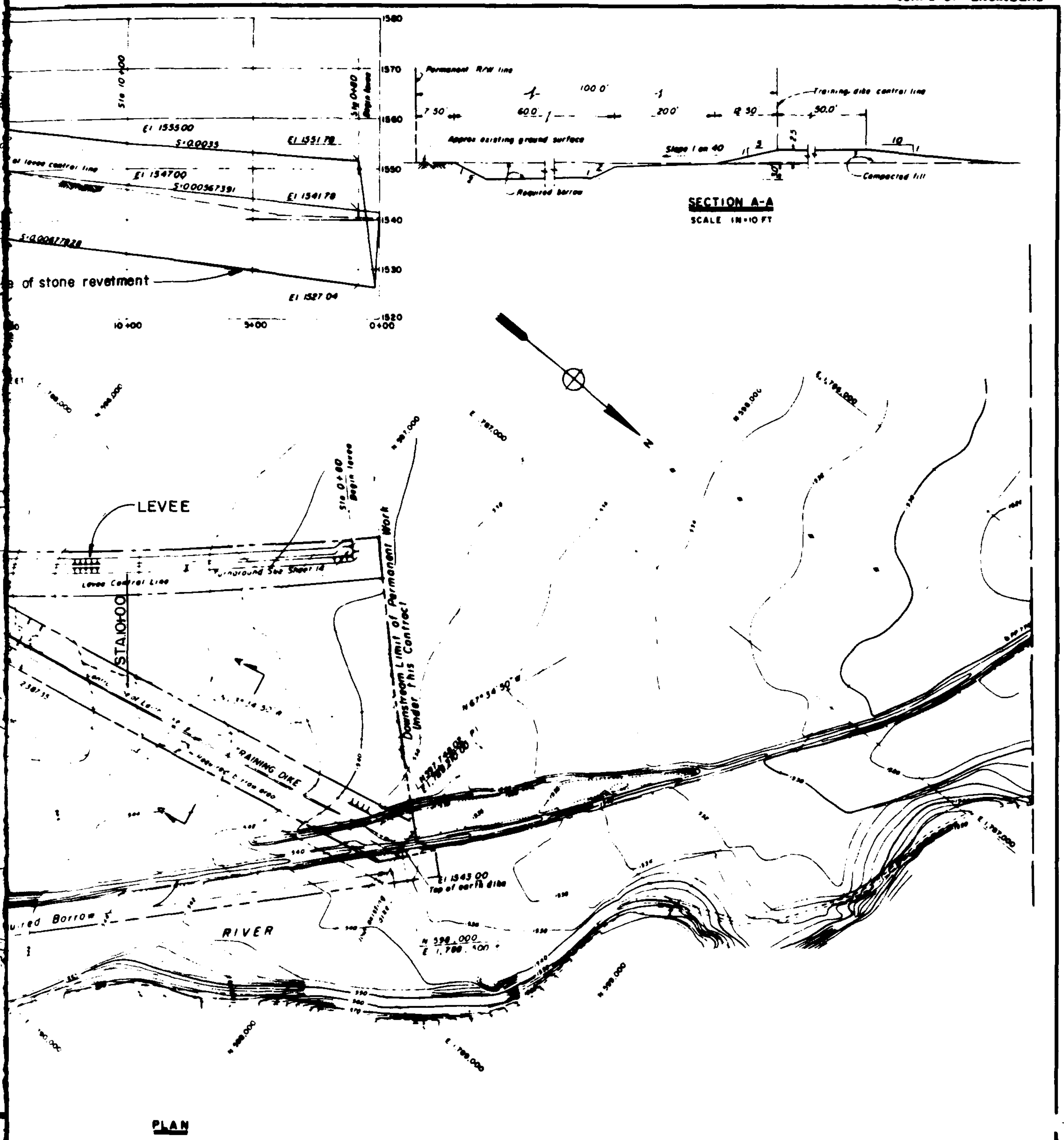
US ARMY ENGINEER DISTRICT



REFERENCE

TOPOGRAPHY TAKEN FROM PLANE TABLE SHEETS 554-17 554-18
SURVEY OF JUNE 1958 BY CONTRACT UNDER THE DIRECTION OF

CONTOUR INTERVAL IS 2 FEET



DATUM IS MEAN SEA LEVEL

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

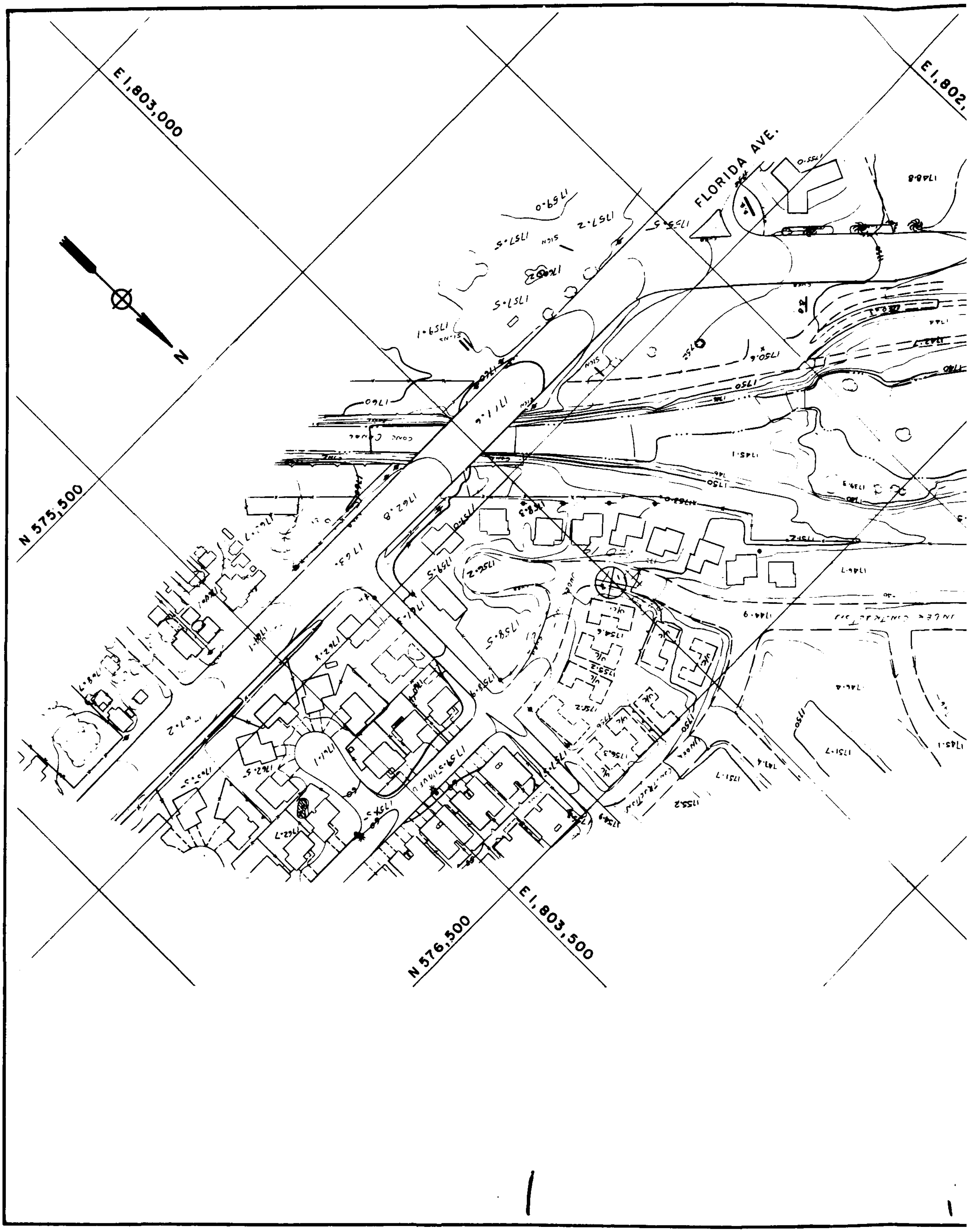
SANTA ANA RIVER BASIN, CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

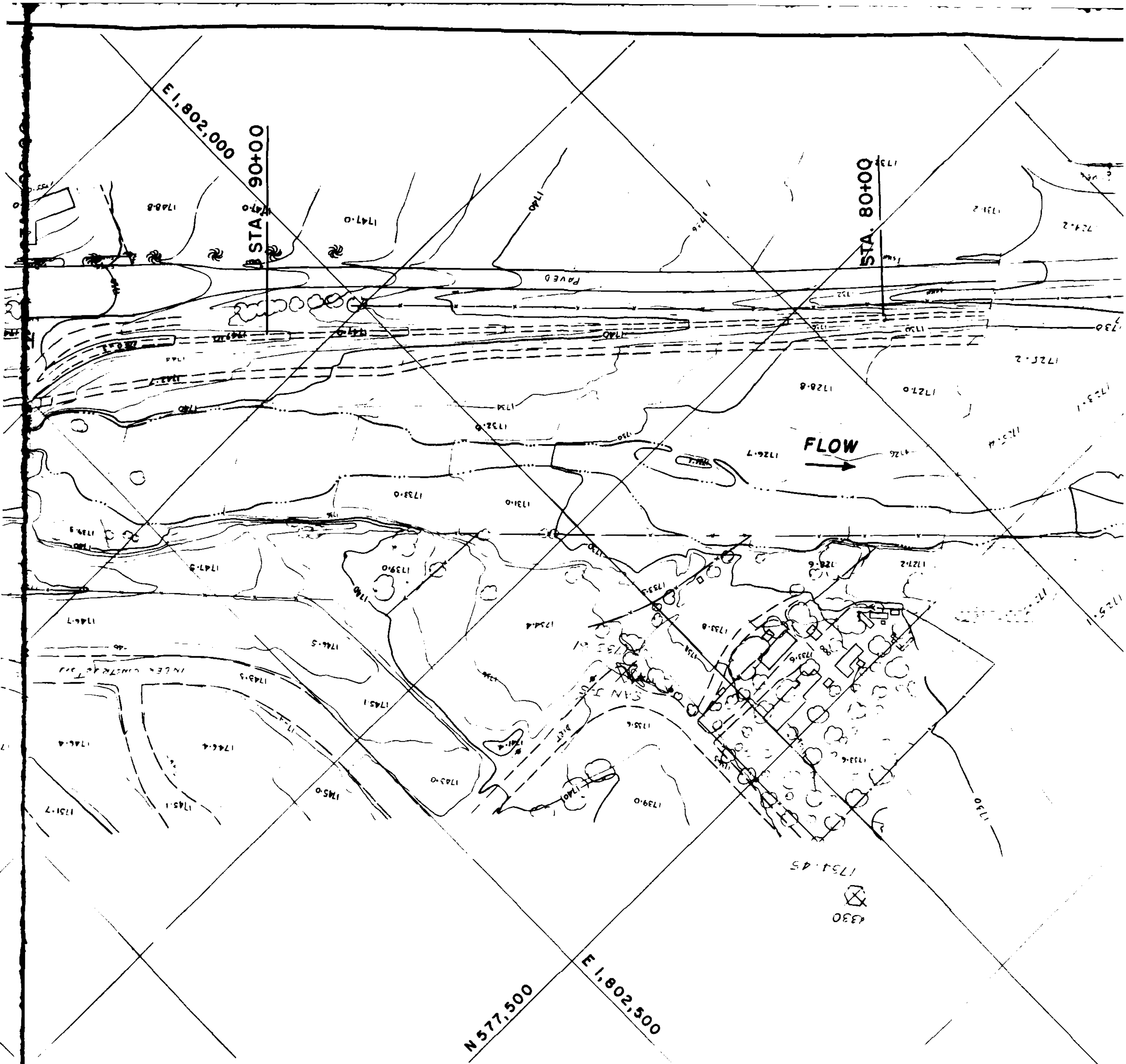
EVALUATION OF PROBABLE CAUSE OF FAILURE

SAN JACINTO RIVER LEVEE
PLAN, PROFILE AND SECTIONS
SAN JACINTO RIVER STA.40+00 TO STA.0+80

E TABLE SHEETS 554-17 554-18 AND 584-19
ACT UNDER THE DIRECTION OF CORPS OF ENGINEERS

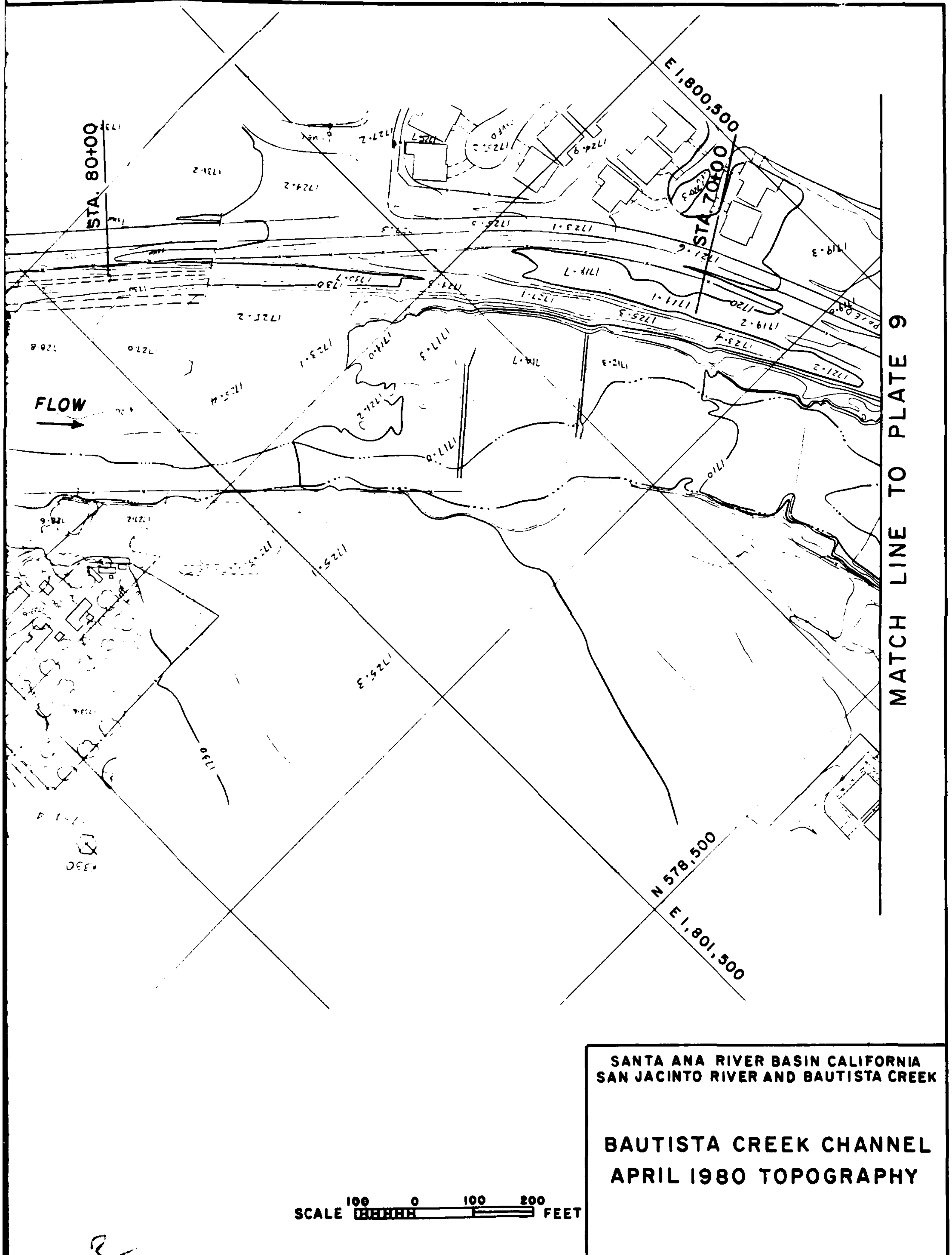
2


E1,803,000
FLORIDA AVE.
N 575,500
N 576,500
E1,803,500
N



PLAN
1 IN = 200 FT

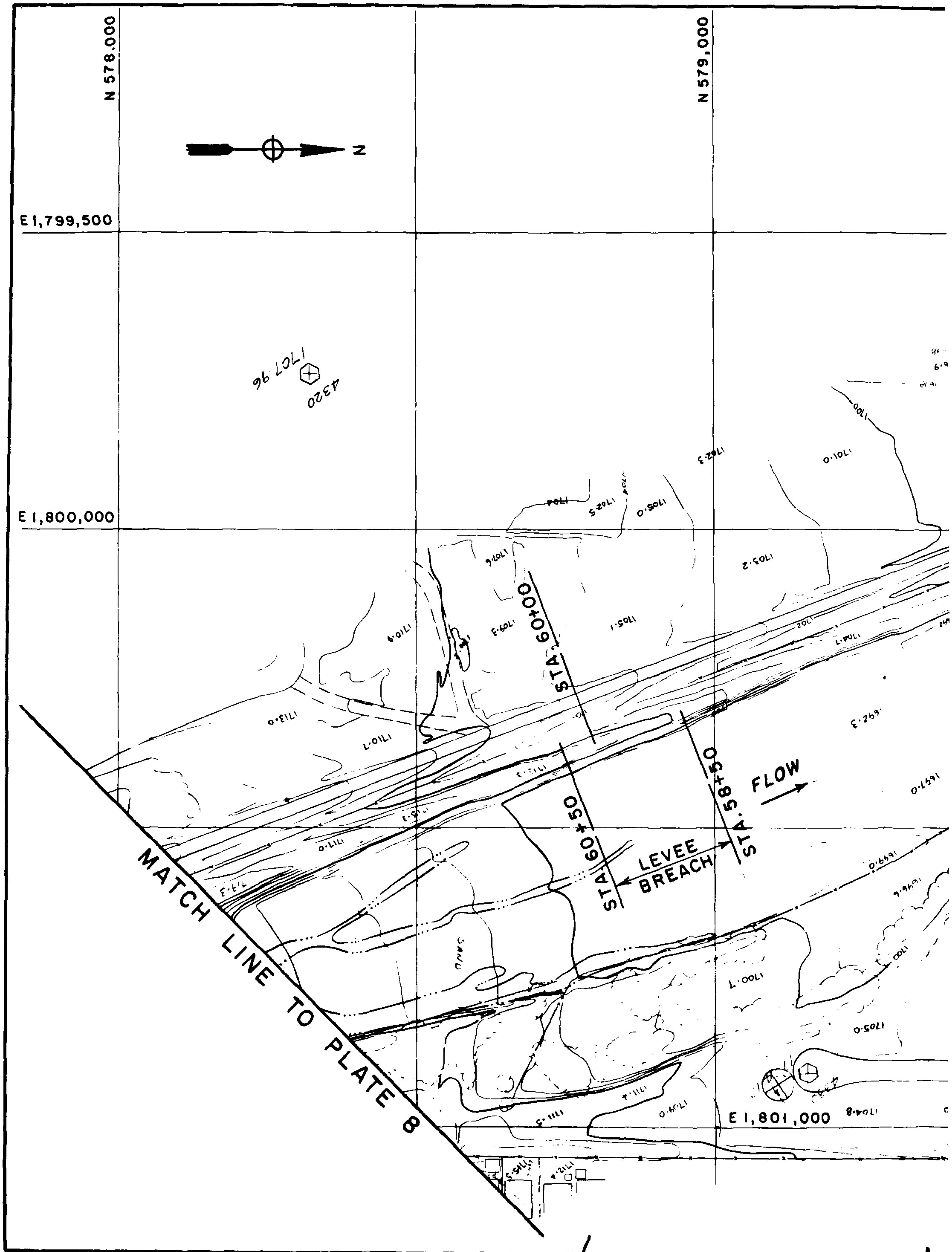
SCALE

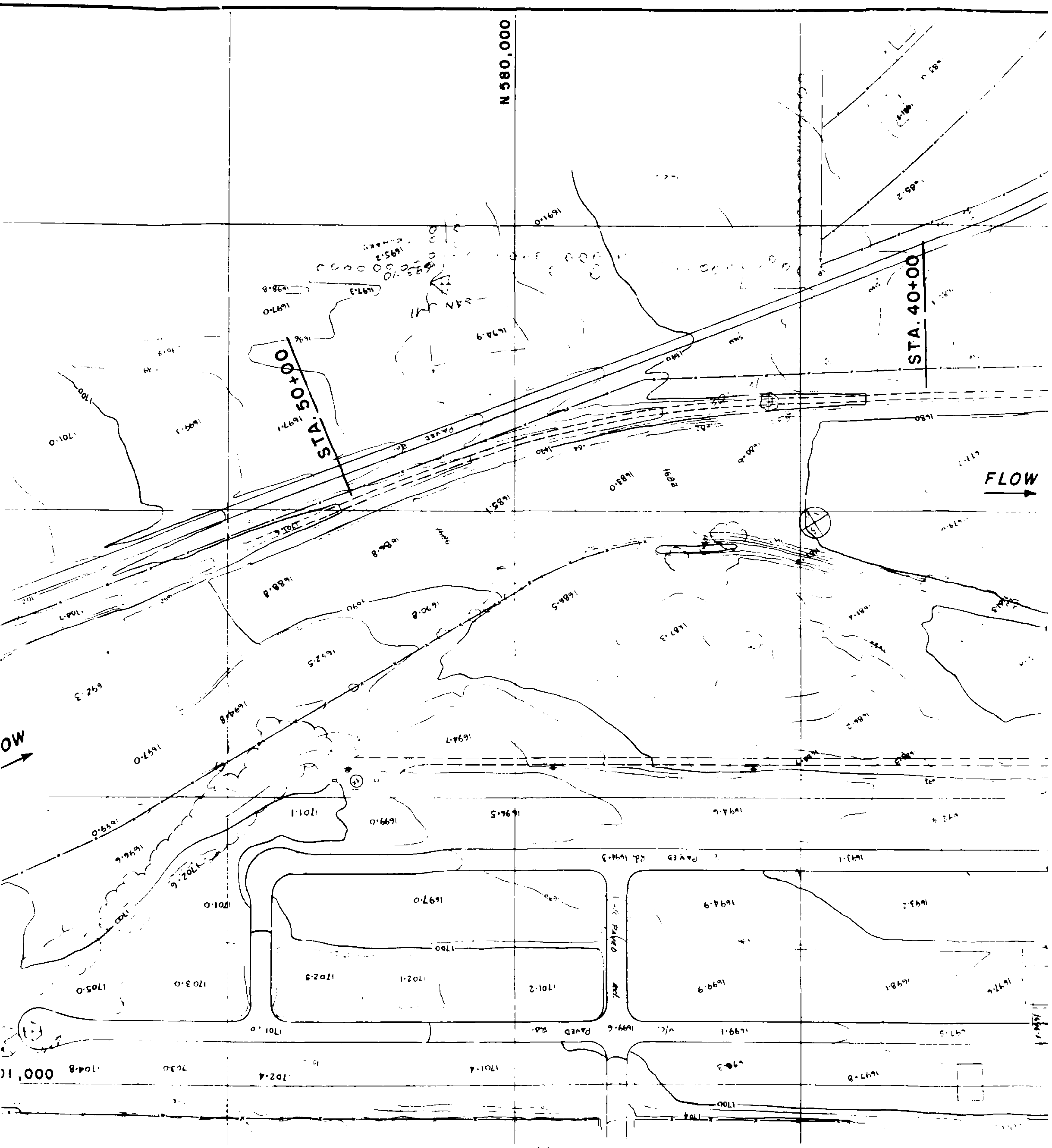


SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

BAUTISTA CREEK CHANNEL
APRIL 1980 TOPOGRAPHY

PLATE 8


N 578,000
N 579,000
N
E 1,799,500
E 1,800,000
E 1,801,000
1707.96
4320
STA. 60+00
STA. 60+50
STA. 58+50
FLOW
LEVEE BREACH
MATCH LINE TO PLATE 8



PLAN
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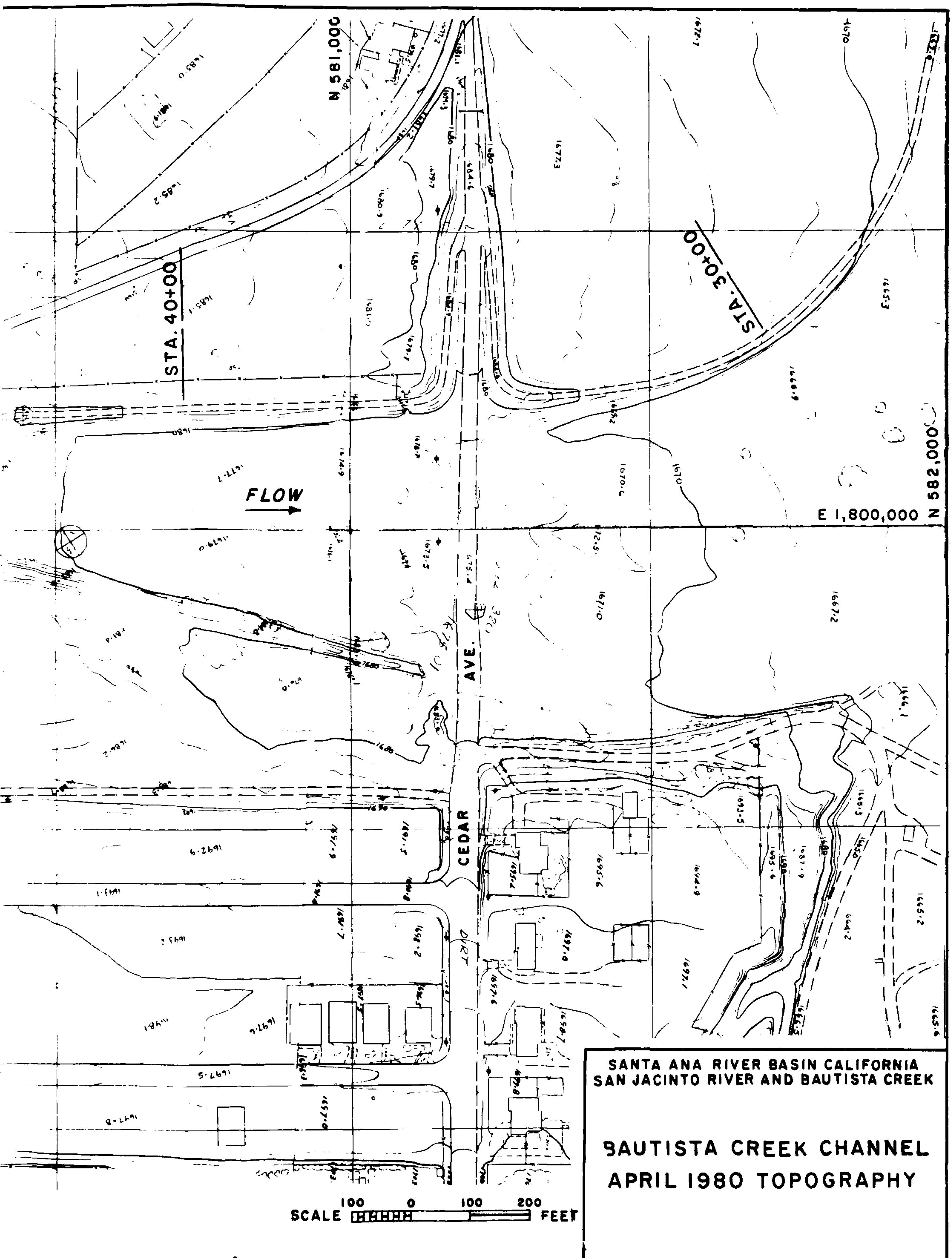
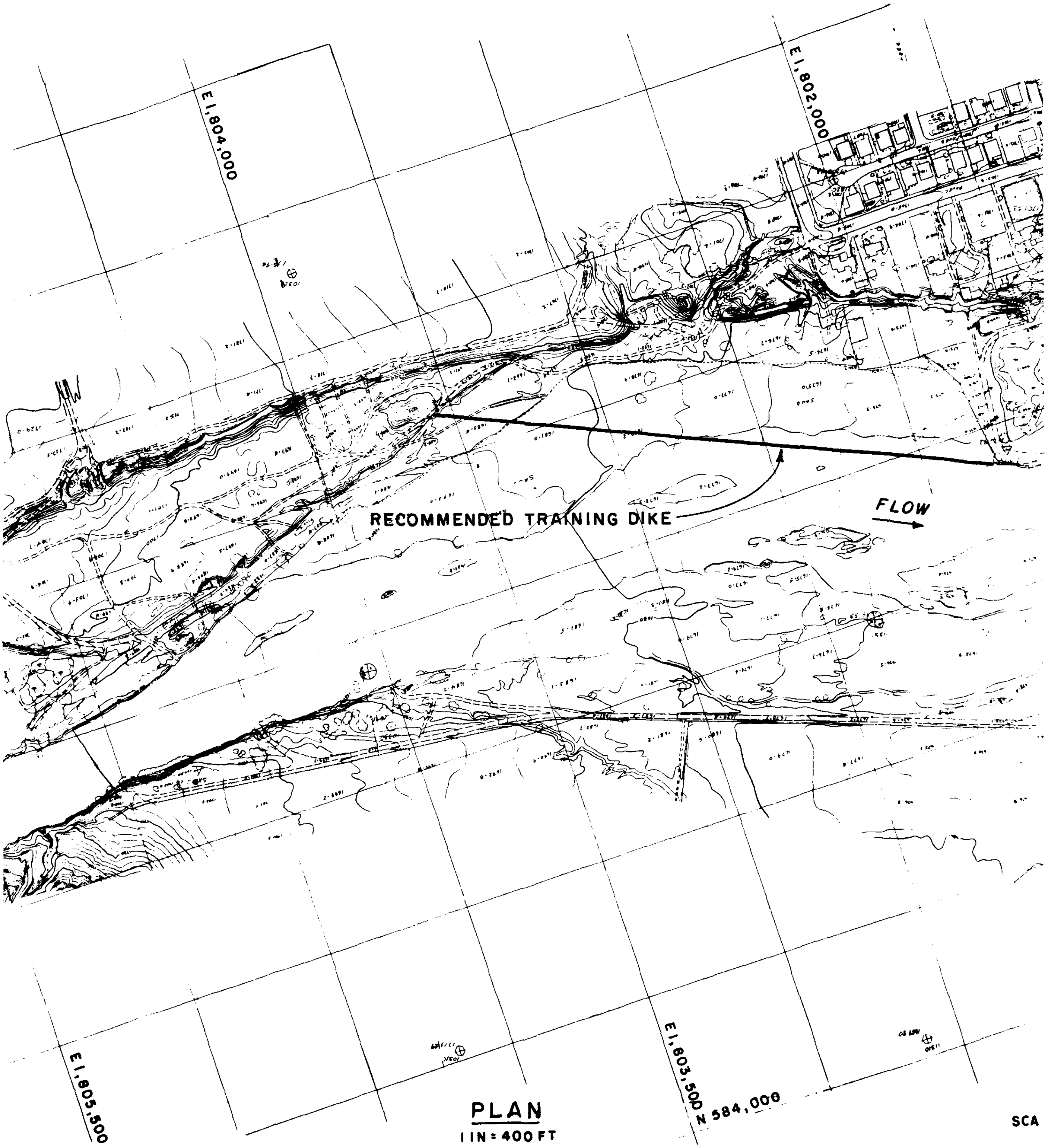


SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

BAUTISTA CREEK CHANNEL
APRIL 1980 TOPOGRAPHY

E 1,806,000
N
N 580,500
FLOW
E 1,807,500
N 582,500
E 1,805,500



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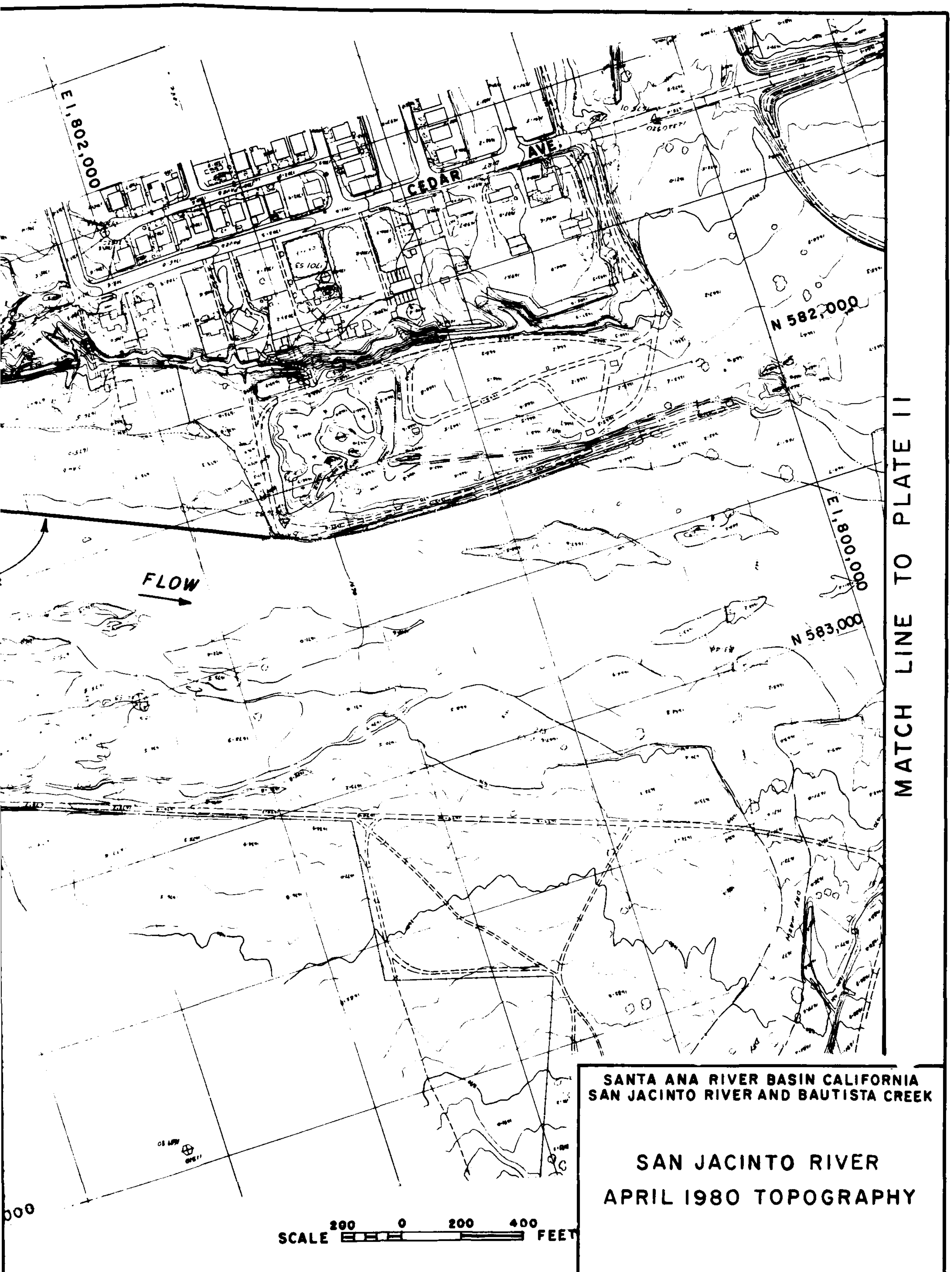
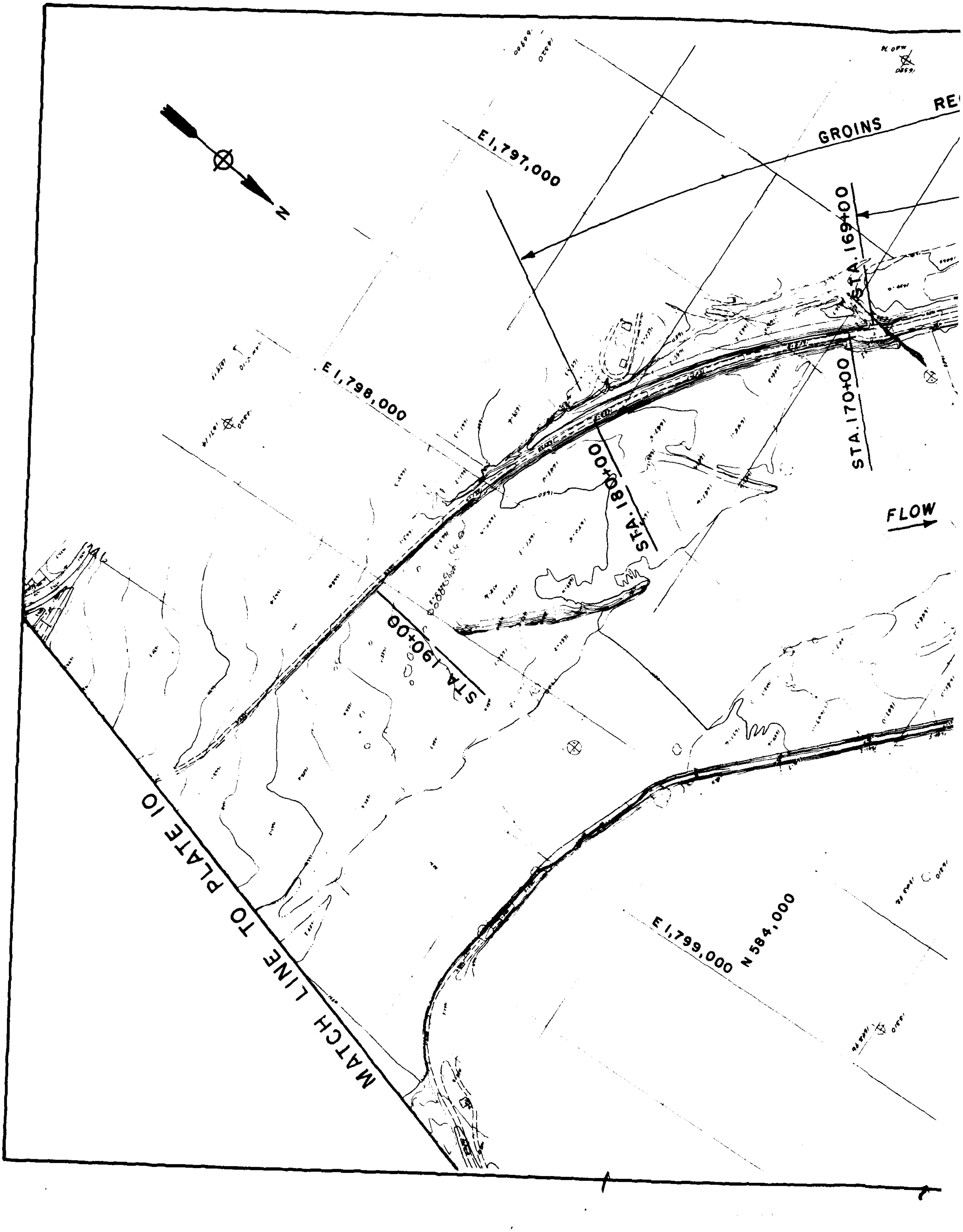
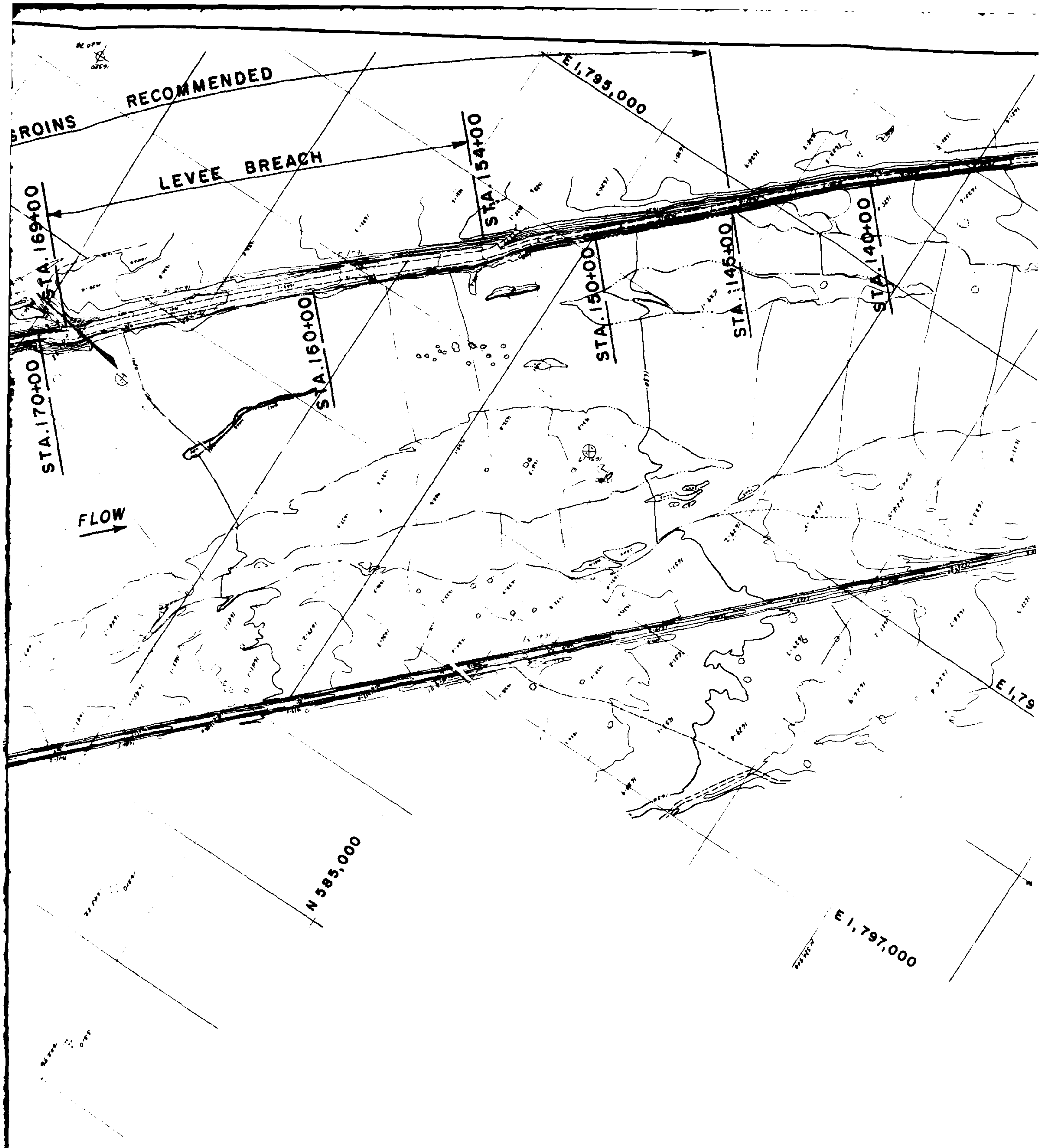


SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

SAN JACINTO RIVER
APRIL 1980 TOPOGRAPHY



N
E 1,797,000
GROINS
E 1,798,000
STA. 169+00
STA. 170+00
STA. 180+00
STA. 190+00
FLOW
E 1,799,000
N 584,000
MATCH LINE TO PLATE 10

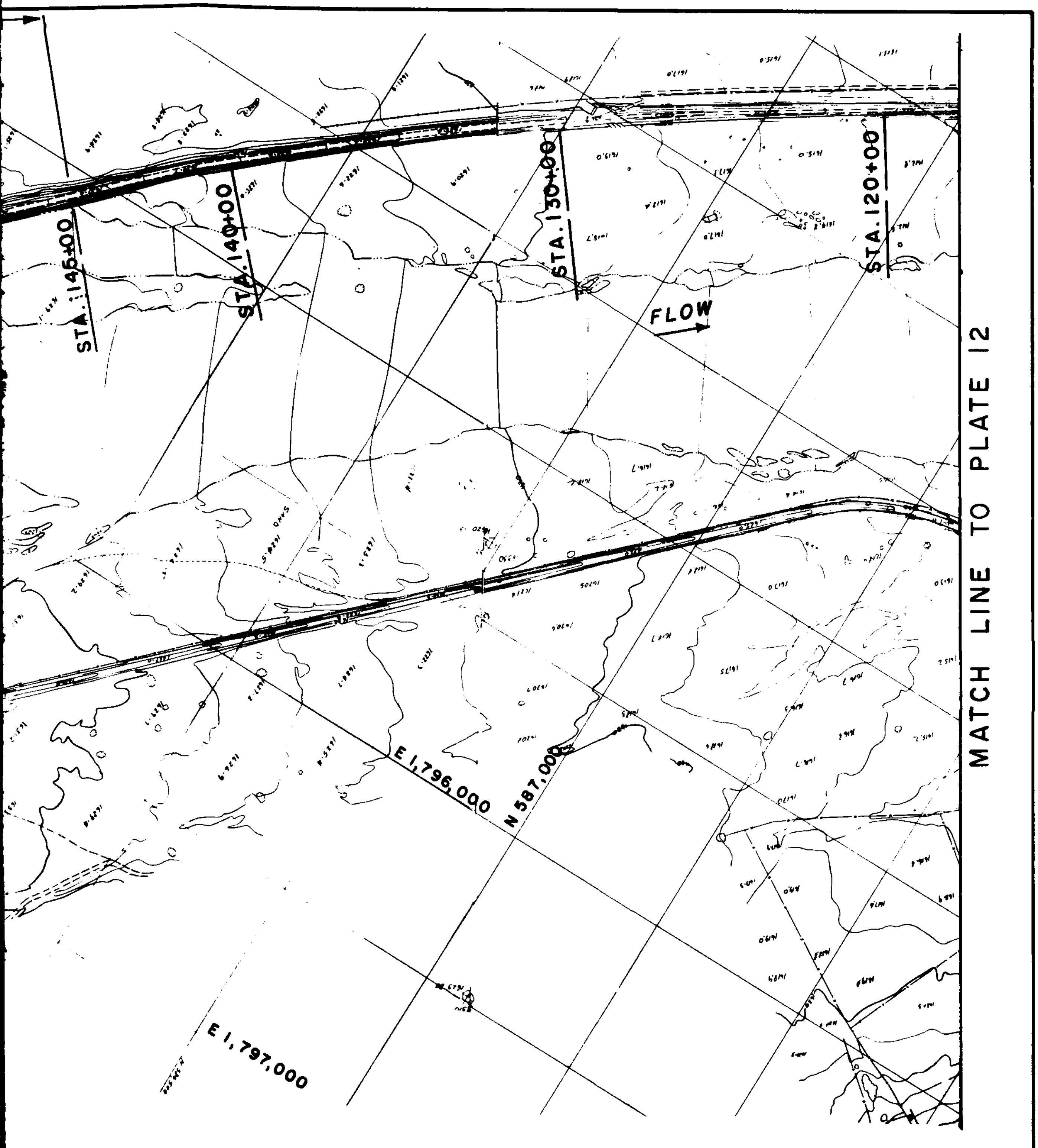


PLAN

1 IN = 400 FT

SCALE 200 0

2

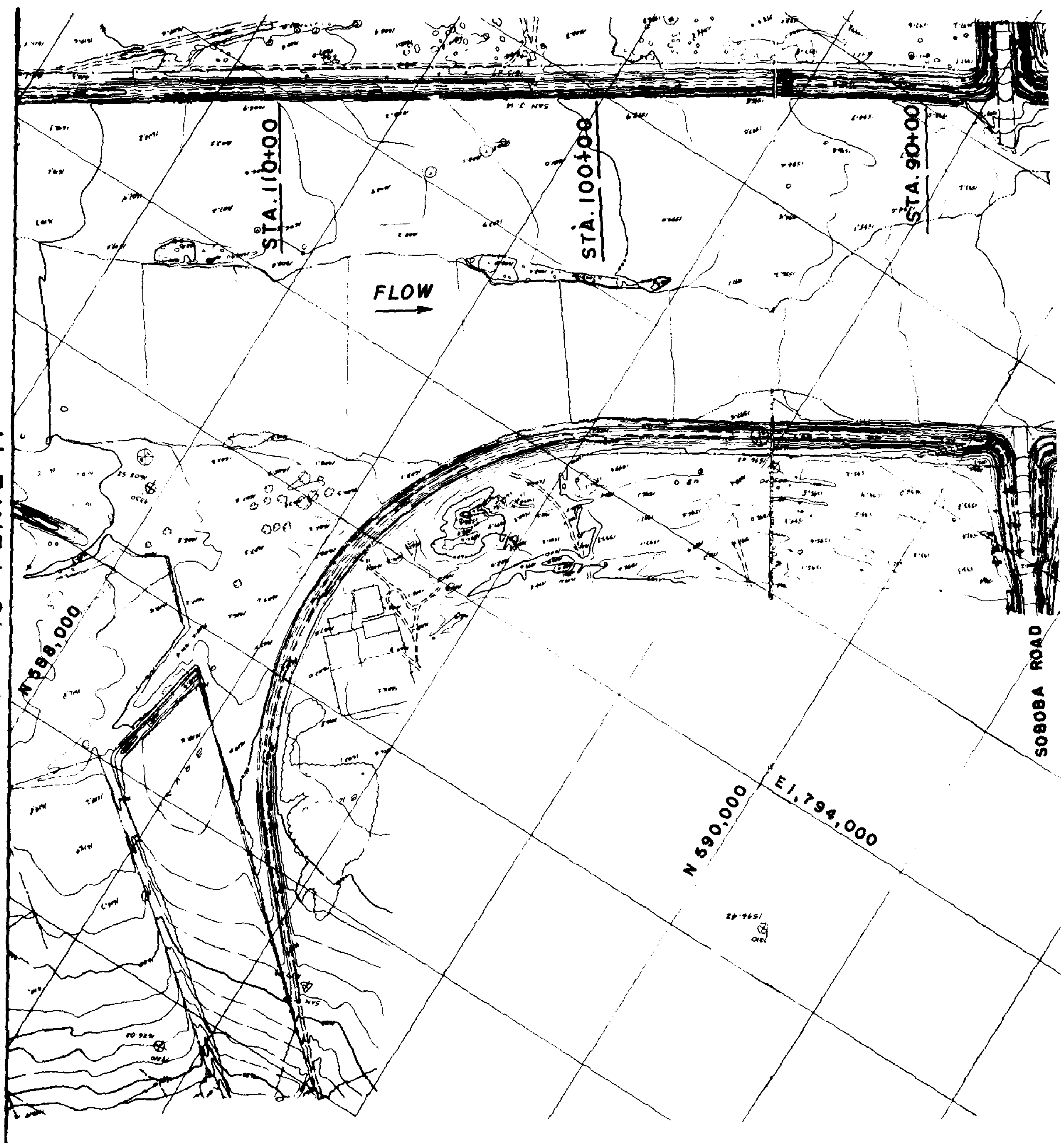


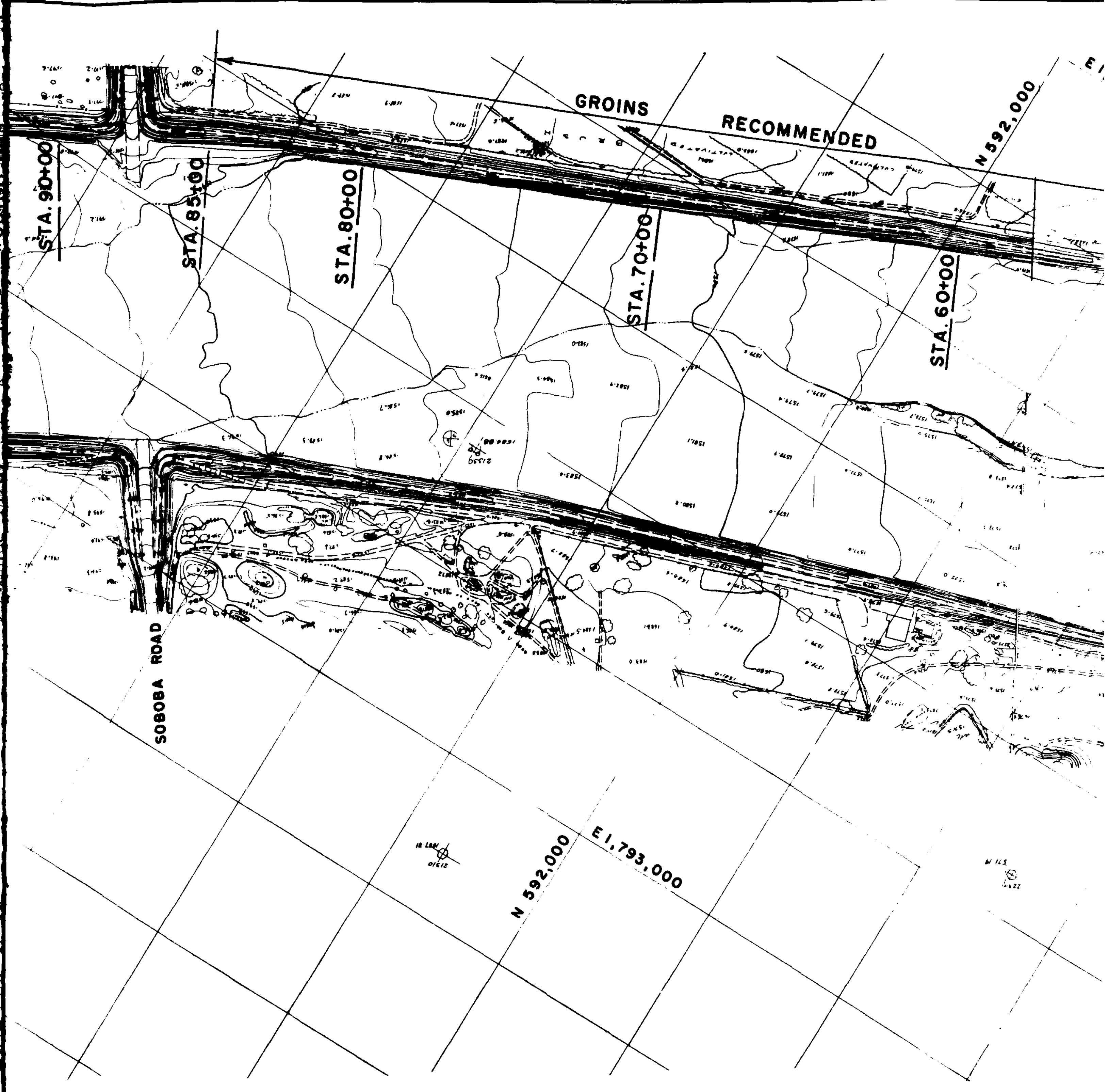
SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

SAN JACINTO RIVER
APRIL 1980 TOPOGRAPHY

2 1

PLATE 11 3


MATCH LINE TO PLATE II
STA. 110+00
STA. 100+00
STA. 90+00
FLOW
N 588,000
N 590,000
E 1,794,000
SOBOBA ROAD



PLAN
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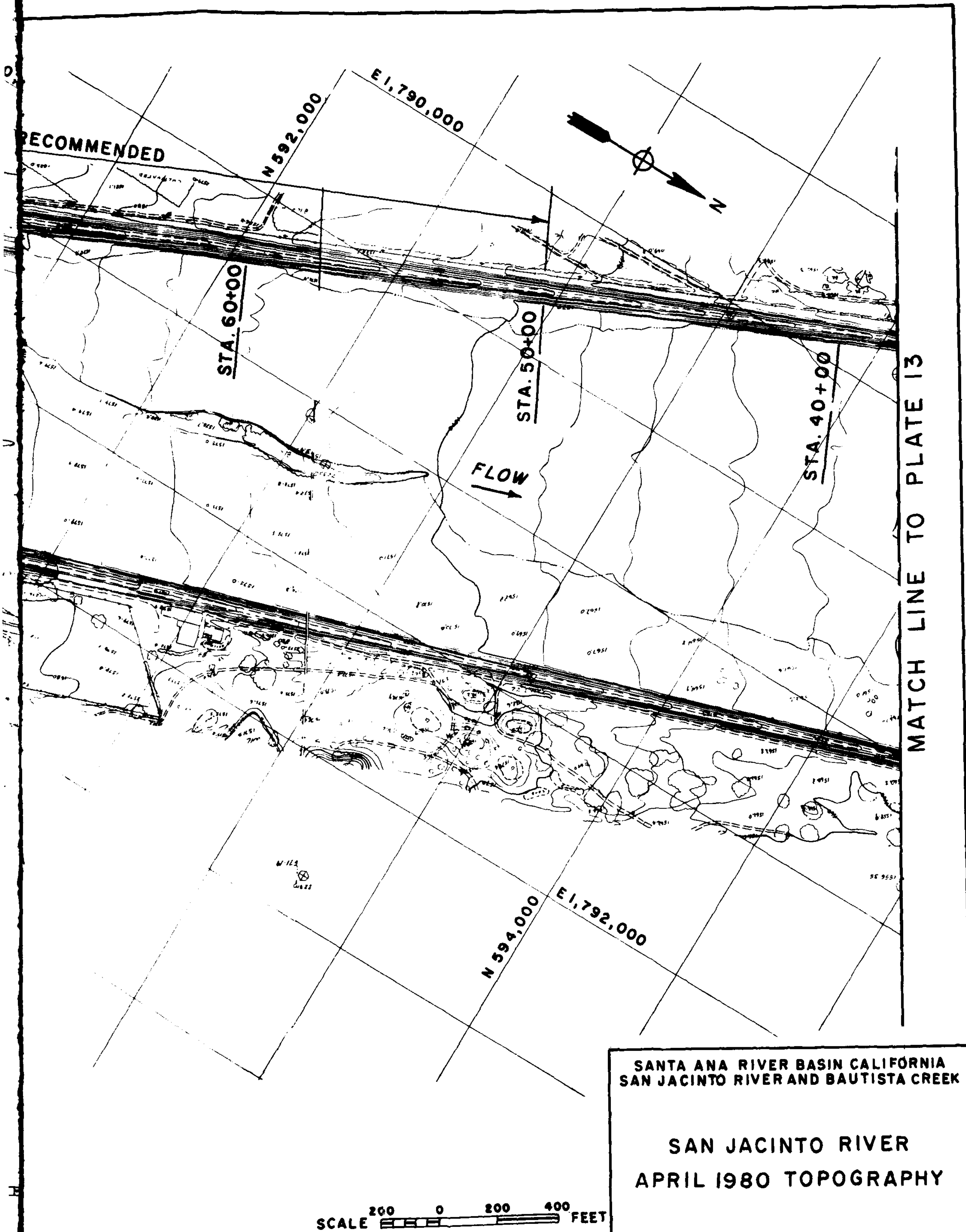
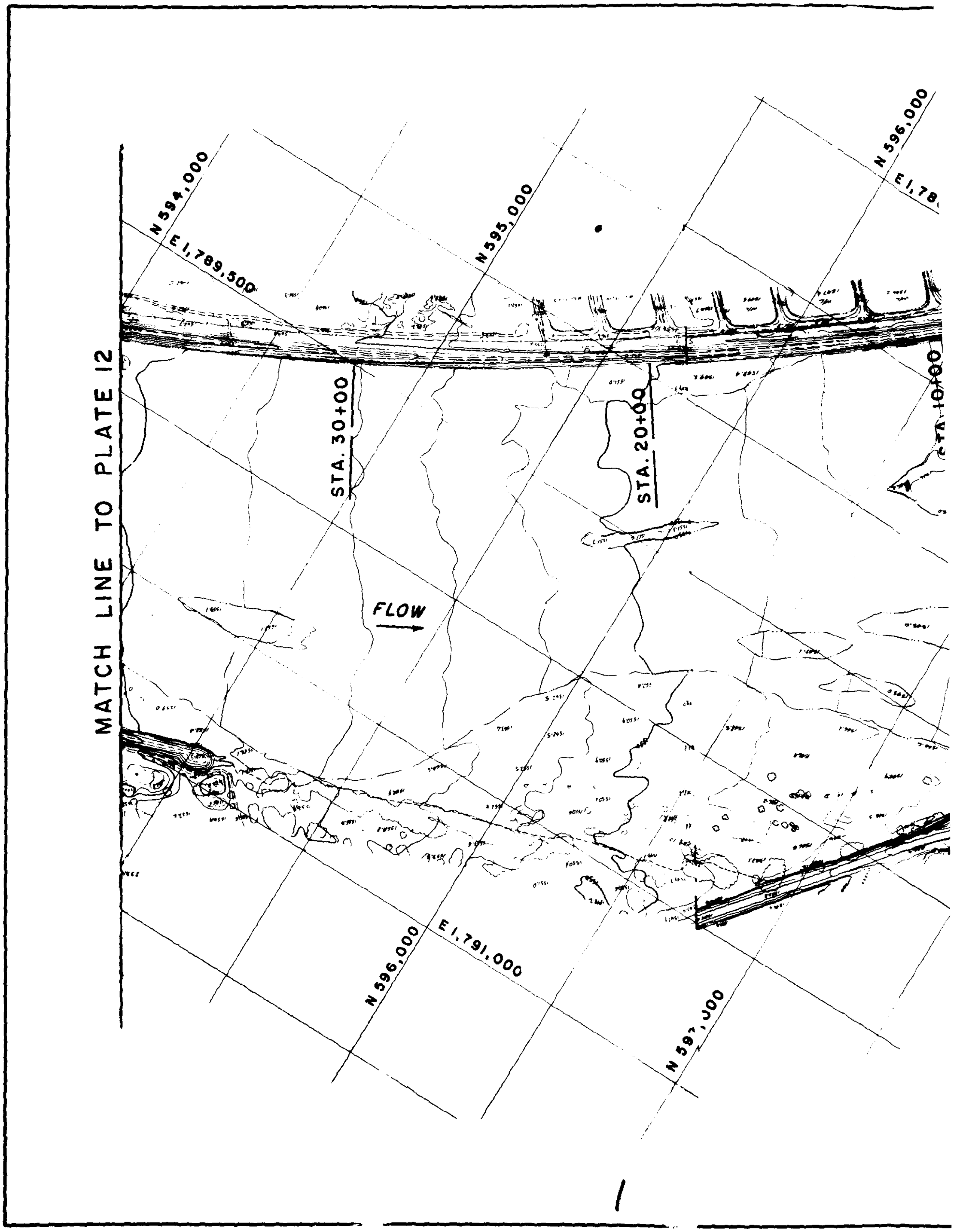


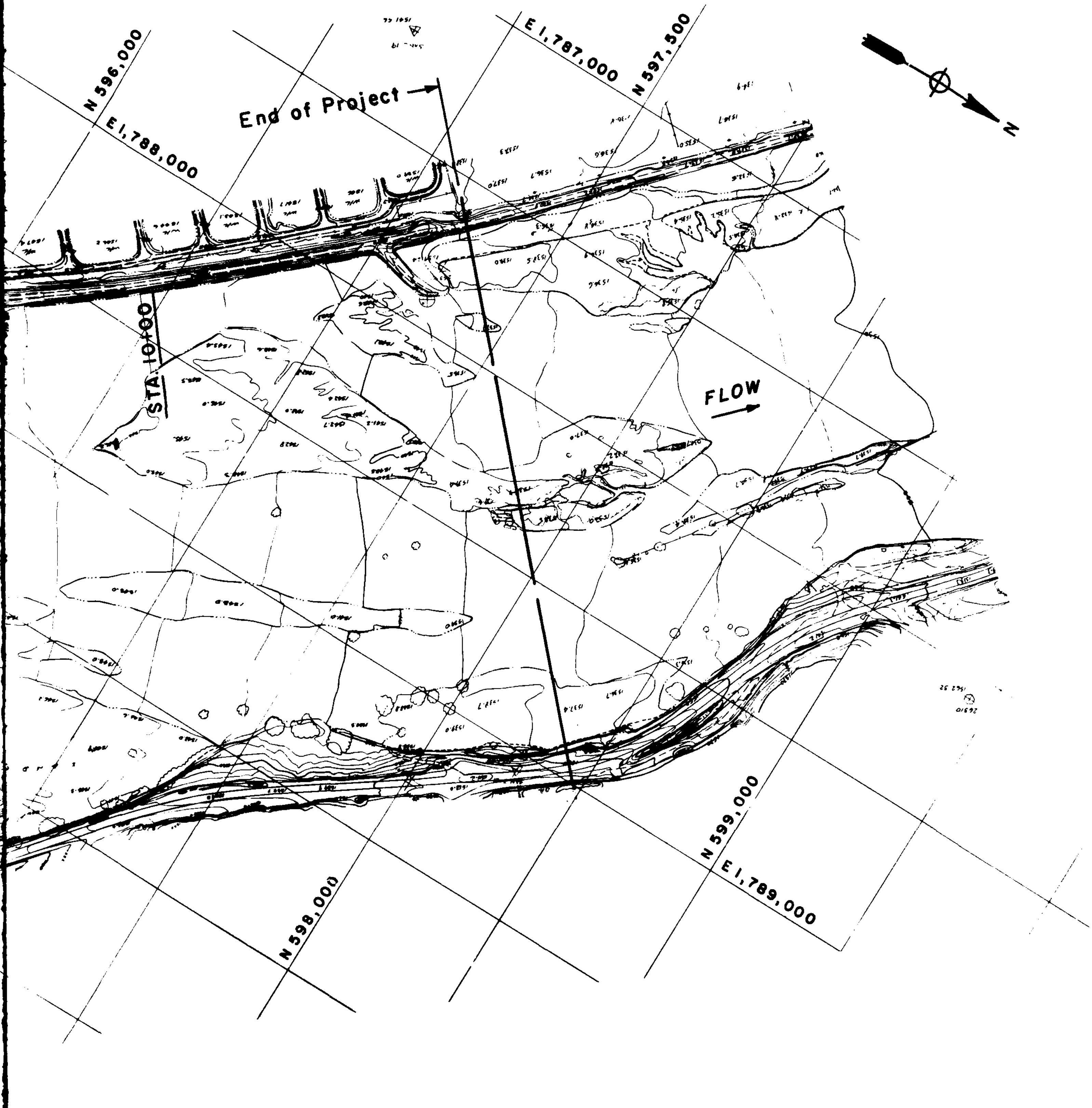
SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

SAN JACINTO RIVER
APRIL 1980 TOPOGRAPHY

PLATE 12

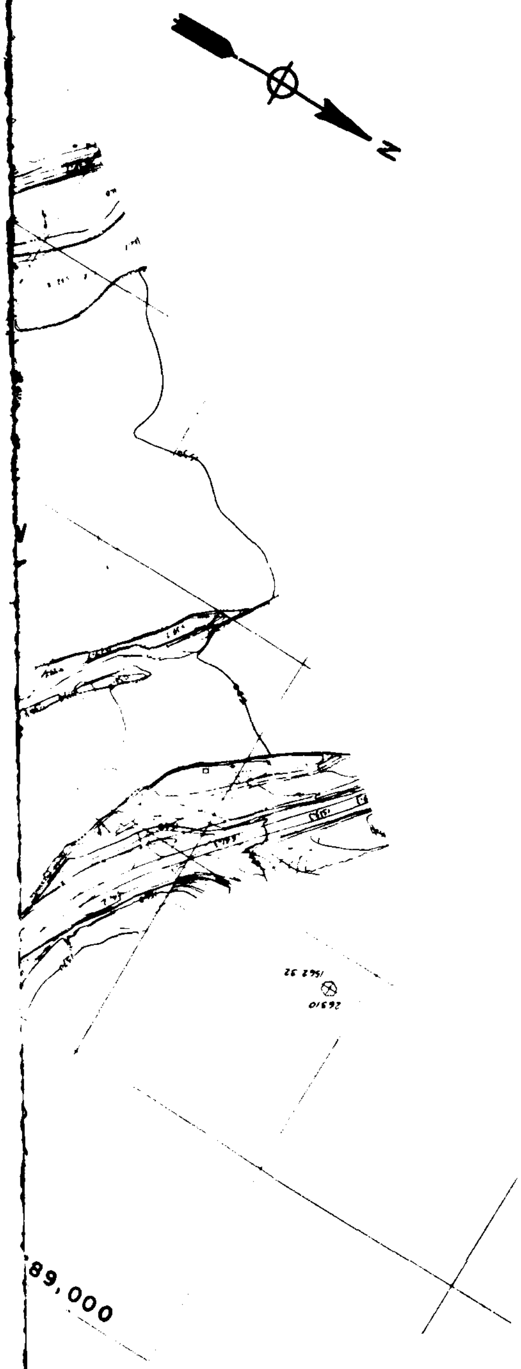


MATCH LINE TO PLATE 12
N 594,000
E 1,789,500
N 595,000
N 596,000
STA. 30+00
STA. 20+00
FLOW
N 596,000
E 1,791,000



PLAN
1 IN = 400 FT

SCALE



SCALE 200 0 200 400 FEET

SANTA ANA RIVER BASIN CALIFORNIA
SAN JACINTO RIVER AND BAUTISTA CREEK

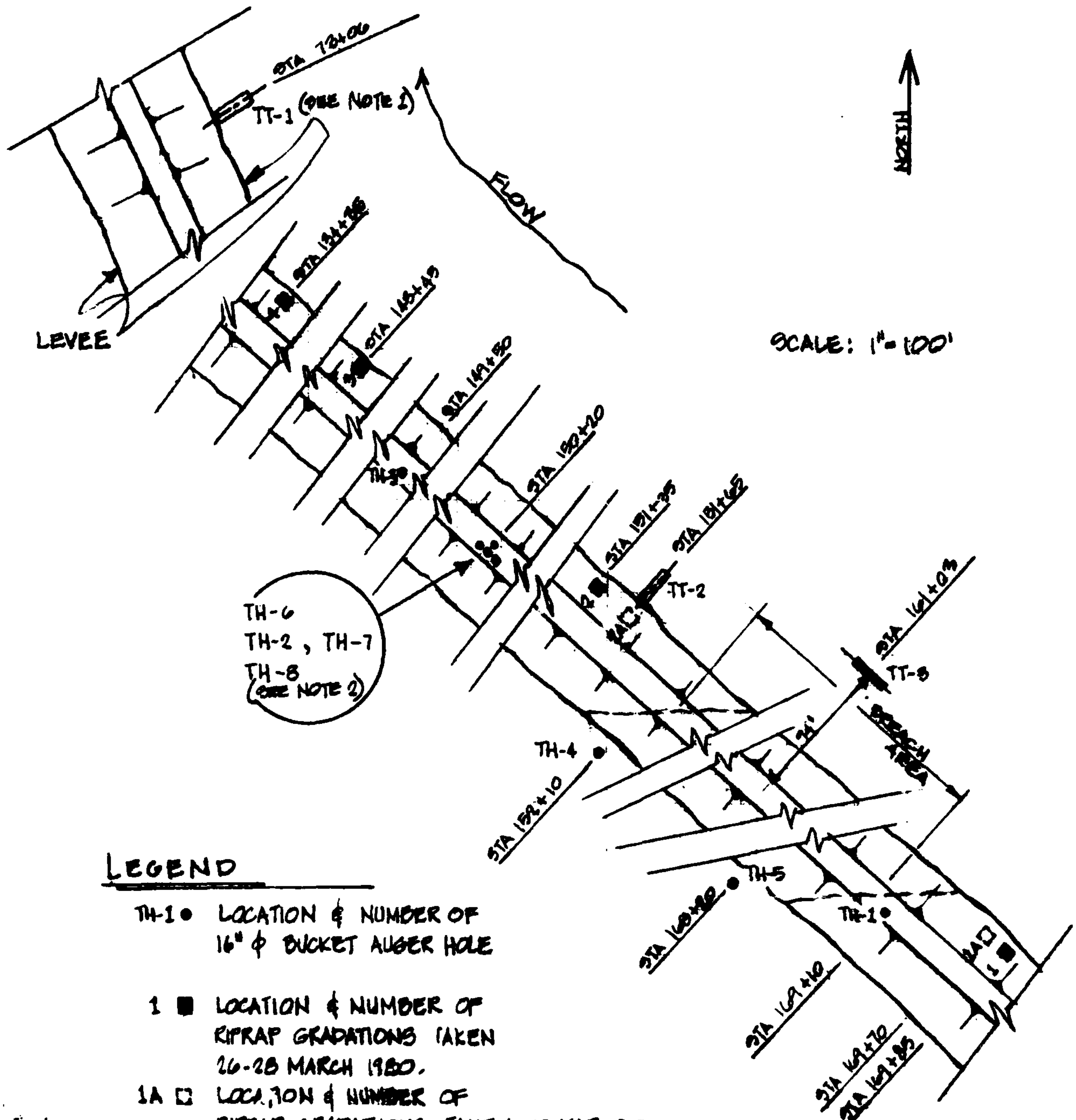
SAN JACINTO RIVER
APRIL 1980 TOPOGRAPHY

PLATE 13

APPENDIX A

FIELD INVESTIGATIONS OF SAN JACINTO LEVEE

TABLE OF CONTENTS



LEGEND

TH-1 ● LOCATION & NUMBER OF 16" ϕ BUCKET AUGER HOLE

1 ■ LOCATION & NUMBER OF RIPRAP GRADATIONS TAKEN 26-28 MARCH 1980.

1A □ LOCATION & NUMBER OF RIPRAP GRADATIONS TAKEN 10 MAR. 80 FOR THE PRELIMINARY REPORT.

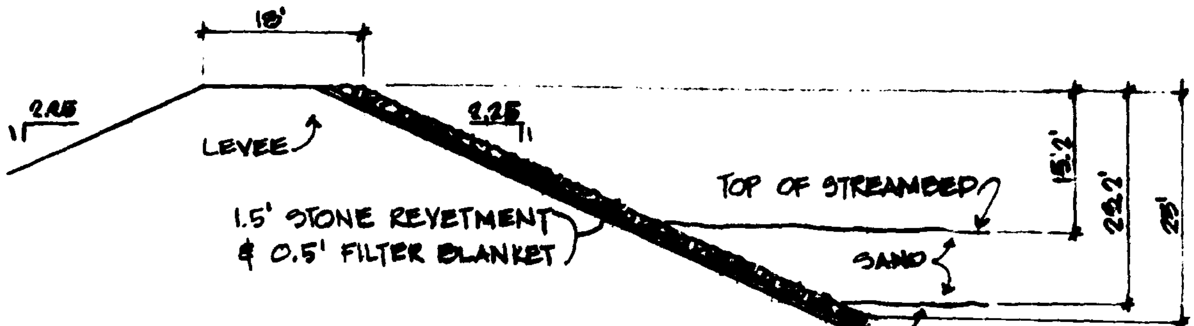
TT-1 ▮ LOCATION & NUMBER OF TEST TRENCHES (BY BACKHOE) TAKEN 10 JUNE 80.

NOTES

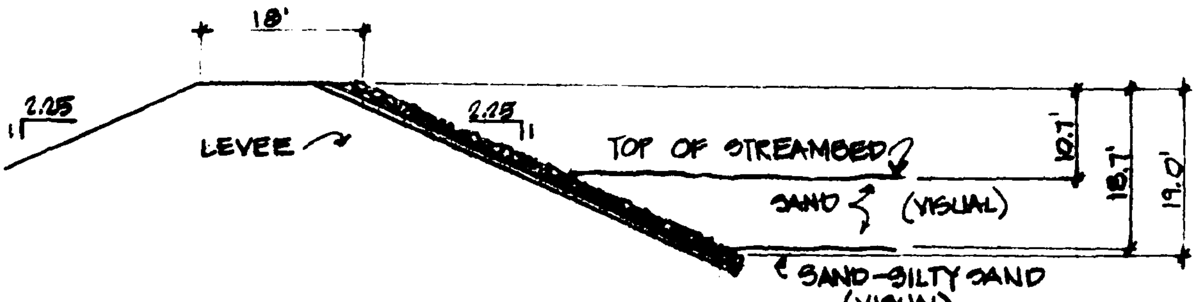
1. TEST TRENCH 1 IS LOCATED 1470 FEET DOWNSTREAM OF MAIN ST. CROSSING OR JUST D.S. OF LEVEE SLOPE FAILURE.
2. TEST HOLES 6, 7, & 8 ARE 5 FEET FROM TEST HOLE 2.

SAN JACINTO LEVEE

LOCATION OF FIELD INVESTIGATIONS



TT-1, STA 73+06
(TEST TRENCH 1)



TT-2, STA 151+65

SCALE: 1" = 20'

NOTE : VERTICAL DIMENSIONS ARE RESULTS OF SURVEYS. SURVEYS INDICATE THE SAND-SILTY SAND PROFILE (UPPER LIMIT) TO BE NEARLY HORIZONTAL.

SAN JACINTO LEVEE

LOCATIONS OF TOE STONE AND STREAMBED PROFILE PER TRENCHING & SURVEY

LOG OF EXPLORATION

DATE: 5 MARCH 80

PROJECT: SAN JACINTO LEVEE

ITEM: TH - 1

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.5'	SP/SM			NP	94	6	51	SAND-SILTY SAND, brown, very dense.
4.5'	SW/SM			NP	97	7	58 45	
7.5'	SP/SM			NP	85	7	* *	GRAVELLY SAND-SILTY GRAVELLY SAND, brown, dense.
10.5'	SW/SM			NP	99	10	46 41	SAND-SILTY SAND, brown, dense.
	SP/SM			NP	98	6	40 33	
16.5'				NP	99	6	* *	
18.0'	SW/SM			NP	99	7	27	— estimated location of foundation, medium dense. Rock encountered prevented further drilling.
19.5'	SP/SM			NP	100	8	*	
21.0' 23.0'	SP			NP	98	3	12 *	

* gravel encountered in penetrometer

LOG OF EXPLORATION

DATE: 5 MARCH 80

PROJECT: SAN JACINTO LEVEE

ITEM: TH-2

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	SW/SM			NP	97	10	15, 6	SAND–SILTY SAND, brown, medium dense to very loose.
	SP/SM			NP	99	5	1, 2	
10.5'				NP	99	6	1, 1, 1	
	SM			NP	99	35	20	SILTY SAND, brown, medium dense, foundation estimated to be @ 12'.
15.0'				NP	96	13	12, *	
18.0'	SP/SM			NP	80	6	21, 25	GRAVELLY SAND–SILTY GRAVELLY SAND, brown, medium dense.
21.0'	SW/SM			NP	68	5	*, 22	

* gravel encountered in penetrometer.

LOG OF EXPLORATION

DATE 10 MARCH 80

PROJECT SAN JACINTO LEVEE

ITEM TH-3

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SP/SM			NP	92	7	37	SAND-SILTY SAND, brown, dense
3.0'							34	
	SW/SM			NP	99	9	22	
							*	
				NP	86	10	*	
9.0'							32	
	SM			NP	93	19	18	SILTY SAND, brown, loose to medium dense.
							8	
				NP	99	25	17	
15.0'							15	
	SP/SM			NP	92	6	33	SAND-SILTY SAND, brown, medium dense, drilling discontinued because of encountering cobbles.
18.0'							21	
								* gravel encountered.

LOG OF EXPLORATION

DATE: 10 MARCH 80

PROJECT: SAN JACINTO LEVEE

ITEM: TH-4

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SP/SM			NP	99	6	29 28	SAND-SILTY SAND, brown, medium dense, gravel = 2-inch max. size.
				NP	86	7	* *	
9.0'				NP	70	7	* 27	GRAVELLY SAND-SILTY GRAVELLY SAND, brown, medium dense, 3-inch max. size.
	SW/SM			NP	87	8	* 28	SAND-SILTY SAND, brown, medium dense, 1-inch max. size, revert added @15'.
15.0'				NP	99	6	23 15	
16.5'	SM			NP	100	31	*	SILTY SAND, brown,
18.0'	SW/SM			NP	98	11	*	SAND-SILTY SAND, brown, cobble encountered.
	SM			NP	98	19	44	SILTY SAND, brown, dense.
21.0'				NP	99	13	46	
24.0'	SP			NP	98	4	45 *	SAND, brown, dense.
	SW/SM			NP	99	8	47	SAND-SILTY SAND, brown, dense.
27.0'				NP	98	8	33	
28.5'	SM			NP	99	15	38	SILTY SAND, brown, dense.
	SW/SM			NP	98	7	38	SAND-SILTY SAND, brown, dense.
				NP	98	6	46	
32.0'				NP	99	7	41	
34.5'	SM			NP	98	16	38	SILTY SAND, brown, dense.

* gravel & cobbles encountered

LOG OF EXPLORATION

DATE: 12 MARCH 80

PROJECT: SAN JACINTO LEVEE

ITEM: TH - 5

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.5'	SW/SM			NP	95	8	—	SAND-SILTY SAND, brown, dense to medium dense.
3.0'	SP/SM			NP	97	7	47	
	SW/SM			NP	98	5	31	
				NP	95	5	20	
7.5'				NP	98	5	11	
	SW			NP	94	3	6	SAND, brown, loose, groundwater @ 9', used revert below 9'.
10.5'				NP	94	4	6	
	SW/SM			NP	90	5	7	SAND-SILTY SAND, brown, loose.
				NP	87	5	10	
				NP	76	6	12	GRAVELLY SAND-SILTY GRAVELLY SAND, brown, medium dense.
				NP	90	5	6	SAND-SILTY SAND, brown, loose to dense, some caving at 24 to 27 feet.
18.0'				NP	99	8	12	
19.5'	SP/SM			NP	99	9	12	
	SW/SM			NP	97	8	7	
				NP	98	6	11	
				NP	97	7	8	
25.5'				NP	98	6	10	
27.0'	SP/SM			NP	99	6	24	
	SW/SM			NP	97	9	41	
				NP	98	8	38	
				NP	97	9	35	
				NP	97	6	31	
34.5'				NP	98	8	—	

LOG OF EXPLORATION

DATE: 18 JUNE 80

PROJECT: SAN JACINTO LEVEE

ITEM: TH-6

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SW SM	5		NP	96	12	55	SAND-SILTY SAND, brown, dense to very dense.
		4		NP	97	7	38	
							60+	
		6		NP	99	9	60+	
7.5'							60+	
	SM	7		NP	99	15	32	SILTY SAND, brown, dense to medium dense.
							10	
12.5'		8		NP	100	20	16	

LOG OF EXPLORATION

DATE: 18 JUNE 80

PROJECT: SAN JACINTO LEVEE

ITEM: TH-7

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	SW SM	4		NP	95	10	19 20	SAND-SILTY SAND, brown, medium dense to dense
6.0'	SP SM	4		NP	92	8	29 36	
9.5'	SW SM	6		NP	97	11	47 18	
	SM	7		NP	99	15	18	SILTY SAND, brown, medium dense.
12.0'		11		NP	100	29	8	

LOG OF EXPLORATION

DATE 18 JUNE 80

PROJECT SAN JACINTO LEVEE

ITEM TH-8

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SW SM	4		NP	92	8	30 / 30	SAND-SILTY SAND, brown, dense.
		5		NP	99	11	19 / 32	
9.5'		6		NP	97	10	43 / 26	
	SM	7		NP	99	21	10	SILTY SAND, brown, loose.
12.0'		9		NP	100	24	7	

LOGS OF TEST TRENCHES

(Excavated 10 June 1980 by a Backhoe)

No.	Depth	Remarks
TT-1	0-8'	SAND(SP), brown, four 15 to 25 pound stones similar to quarried riprap encountered at 8 feet, groundwater encountered at 8 feet.
	8'-9'	SAND-SILTY SAND(SW-SM), brown. See page A14 for gradations.
TT-2	0-8'	SAND, brown, visual classification, one 25 pound stone similar to quarried riprap encountered at 4 feet.
	8'-10'	SAND-SILTY SAND, brown, visual classification.
TT-3	0-8'	SAND, brown, visual classification
	8'-11'	SAND-SILTY SAND, brown.

SAN JACINTO LEVEE

SUMMARY OF MATERIALS

HOLE NO.	DEPTH RANGE (FT.)		GRAVEL (IN.) 3.0	1.5	3/4	3/8	SAND (SIEVE NO.) 4	10	16	40	100	FINES 200	ATTWBRG LIMITS LL	PI	FIELD MOIST (PCT)	DENS. (PCF)		
TH 1	.5	1.5	100	100	97	97	94	84	72	39	12	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 1	1.5	4.5	100	100	100	99	97	82	68	35	12	7	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 1	4.5	7.5	100	92	90	88	85	74	65	39	13	7	0	0	0.	0.	SP/SM,	GRVLY SAND/SILTY GRVLY SAND
TH 1	7.5	10.5	100	100	100	100	99	88	79	50	21	10	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 1	10.5	13.5	100	100	99	99	98	88	78	42	11	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 1	13.5	16.5	100	100	100	100	99	87	74	38	11	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 1	16.5	18.0	100	100	100	100	99	92	83	44	12	7	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 1	18.0	19.5	100	100	100	100	100	95	89	59	17	8	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 1	19.5	23.0	100	100	100	100	98	92	85	51	9	3	0	0	0.	0.	SP,	SAND
TH 2	.5	3.0	100	100	99	99	97	83	70	39	17	10	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 2	3.0	6.0	100	100	100	100	99	88	76	37	10	5	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 2	6.0	10.5	100	100	100	100	99	90	81	42	11	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 2	10.5	12.0	100	100	100	100	99	95	91	71	47	35	0	0	0.	0.	SM,	SILTY SAND
TH 2	12.0	15.0	100	98	98	97	96	86	76	49	23	13	0	0	0.	0.	SM,	SILTY SAND
TH 2	15.0	18.0	100	84	83	82	80	68	57	35	11	6	0	0	0.	0.	SP/SM,	GRVLY SAND/SILTY GRVLY SAND
TH 2	18.0	21.0	75	70	70	70	68	48	36	19	8	5	0	0	0.	0.	SW/SM,	GRVLY SAND/SILTY GRVLY SAND
TH 3	.5	3.0	100	97	97	94	92	81	71	44	13	7	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 3	3.0	6.0	100	100	100	100	99	90	83	56	21	9	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 3	6.0	9.0	100	94	94	92	86	77	70	47	19	10	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 3	9.0	12.0	100	94	94	94	93	91	88	67	36	19	0	0	0.	0.	SM,	SILTY SAND
TH 3	12.0	15.0	100	100	100	100	99	97	94	74	44	25	0	0	0.	0.	SM,	SILTY SAND
TH 3	15.0	18.0	100	96	95	95	92	79	68	44	14	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 4	.5	3.0	100	100	100	100	99	93	86	50	14	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 4	3.0	6.0	100	91	89	88	86	77	68	43	16	7	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TH 4	6.0	9.0	100	74	72	71	70	62	53	30	12	7	0	0	0.	0.	SP/SM,	GRVLY SAND/SILTY GRVLY SAND
TH 4	9.0	12.0	100	91	91	89	87	74	59	28	12	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	12.0	15.0	100	99	99	99	99	89	71	29	10	6	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	15.0	16.5	100	100	100	100	100	91	79	53	38	31	0	0	0.	0.	SM,	SILTY SAND
TH 4	16.5	18.0	100	100	99	99	98	89	74	41	19	11	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	18.0	19.5	100	100	100	100	98	88	75	47	27	19	0	0	0.	0.	SM,	SILTY SAND
TH 4	19.5	21.0	100	100	100	100	99	90	78	44	20	13	0	0	0.	0.	SM,	SILTY SAND
TH 4	21.0	24.0	100	100	100	100	98	84	67	28	8	4	0	0	0.	0.	SP,	SAND
TH 4	24.0	25.5	100	100	100	100	99	86	72	36	13	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	25.5	27.0	100	100	100	100	98	88	74	37	14	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	27.0	28.5	100	100	100	100	99	92	81	58	28	15	0	0	0.	0.	SM,	SILTY SAND
TH 4	28.5	30.0	100	100	100	100	98	85	69	36	14	7	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	30.0	31.5	100	100	100	100	98	78	57	28	11	6	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	31.5	33.0	100	100	100	100	99	84	64	29	12	7	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TH 4	33.0	34.5	100	100	100	99	98	88	74	41	23	16	0	0	0.	0.	SM,	SILTY SAND

SAN JACINTO LEVEE

SUMMARY OF MATERIALS

HOLE NO.	DEPTH RANGE (FT.)	MECHANICAL ANALYSIS (PERCENT FINER) GRAVEL (IN.) 3.0	1.5	3/4	3/8	SAND (SIEVE NO.) 4	10	16	40	100	FINES 200	ATTBRG LIMITS LL	PI	FIELD MOIST (PCT)	DENS. (PCF)		
TM 5	0. - 1.5	100	100	100	99	95	90	81	45	15	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	1.5- 3.0	100	100	100	99	97	81	70	42	12	7	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TM 5	3.0- 4.5	100	100	100	100	98	89	76	32	10	5	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	4.5- 6.0	100	100	98	98	95	77	60	27	9	5	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	6.0- 7.5	100	100	100	100	98	84	67	28	9	5	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	7.5- 9.0	100	100	100	99	94	63	42	15	5	3	0	0	0.	0.	SW,	SAND
TM 5	9.0- 10.5	100	100	100	97	94	79	64	29	9	4	0	0	0.	0.	SW,	SAND
TM 5	10.5- 12.0	100	100	98	96	90	70	54	23	8	5	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	12.0- 13.5	100	95	94	93	87	63	47	22	9	5	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	13.5- 15.0	100	100	100	99	76	61	48	24	9	6	0	0	0.	0.	SW/SM,	GRVLY SAND/SILTY GRVLY SAND
TM 5	15.0- 16.5	100	100	94	93	90	75	59	28	9	5	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	16.5- 18.0	100	100	100	100	99	90	81	51	18	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	18.0- 19.5	100	100	100	100	99	89	79	54	22	9	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TM 5	19.5- 21.0	100	100	99	99	97	86	74	39	15	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	21.0- 22.5	100	100	100	100	98	87	70	30	11	6	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	22.5- 24.0	100	100	100	100	97	78	61	29	11	7	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	24.0- 25.5	100	100	100	100	98	84	67	33	11	6	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	25.5- 27.0	100	100	100	100	99	87	74	44	12	6	0	0	0.	0.	SP/SM,	SAND/ SILTY SAND
TM 5	27.0- 28.5	100	100	99	98	97	90	80	50	17	9	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	28.5- 30.0	100	100	100	99	98	88	78	44	15	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	30.0- 31.5	100	100	100	99	97	84	72	41	16	9	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	31.5- 33.0	100	100	100	99	97	78	62	31	11	6	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND
TM 5	33.0- 34.5	100	100	100	100	98	82	63	32	12	8	0	0	0.	0.	SW/SM,	SAND/ SILTY SAND

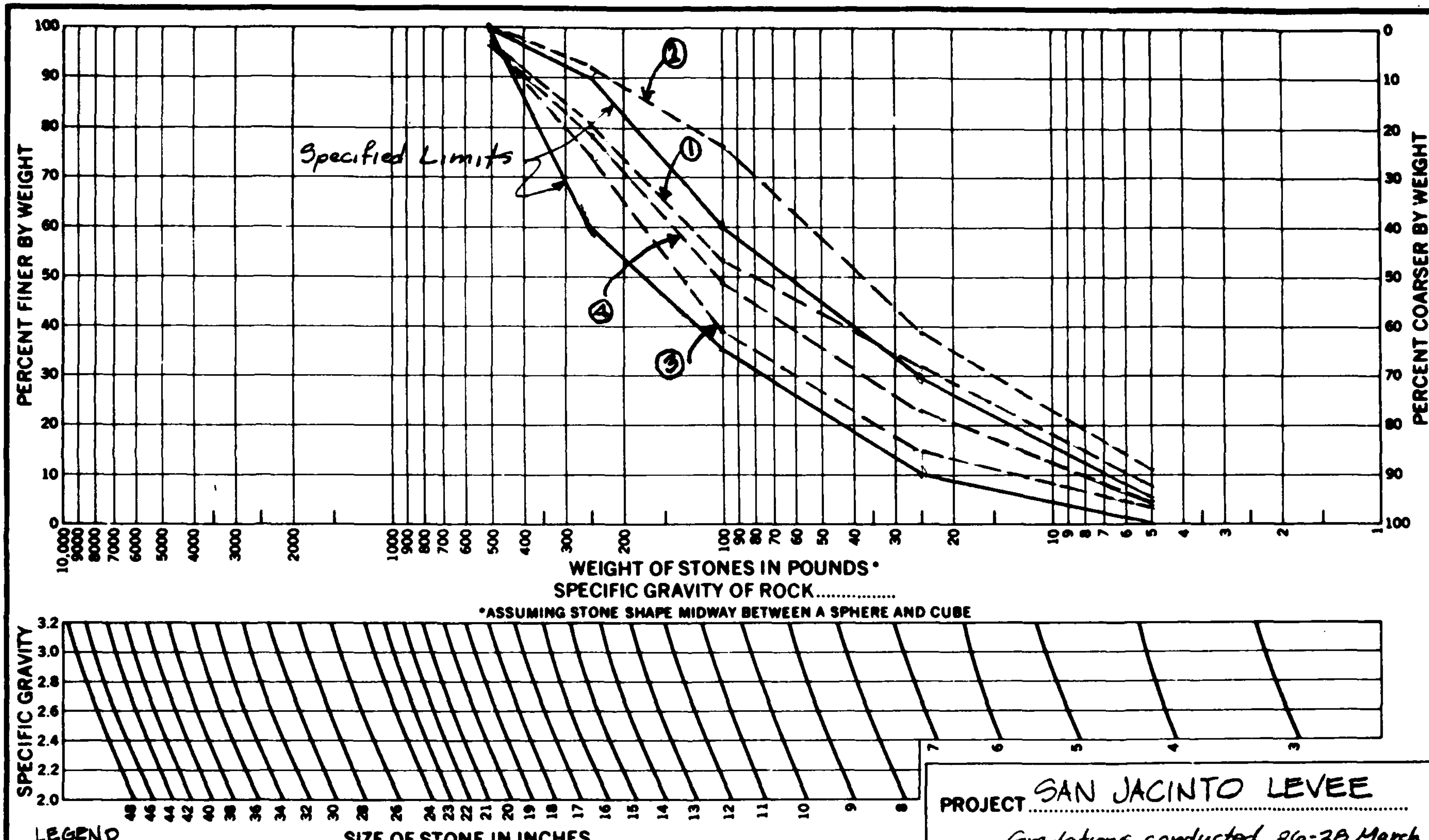
SAN JACINTO LEVEE

SUMMARY OF MATERIALS

HOLE NO.	DEPTH RANGE (FT.)	GRAVEL (IN.) 3.0	1.5	3/4	3/8	SAND (SIEVE NO.) 4	10	16	40	100	FINES 200	ATTBERG LIMITS LL	PI	FIELD MOIST (PCT)	DENS. (PCF)			
TH 6	.5- 1.5	100	100	100	98	96	86	75	46	19	12	0	0	4.6	0.	SW/SM,	SAND/	SILTY SAND
TH 6	1.5- 4.5	100	100	100	99	97	89	80	52	17	7	0	0	4.1	0.	SW/SM,	SAND/	SILTY SAND
TH 6	4.5- 7.5	100	100	100	100	99	92	84	52	14	9	0	0	5.6	0.	SW/SM,	SAND/	SILTY SAND
TH 6	7.5- 10.5	100	100	100	100	99	93	85	57	27	15	0	0	7.3	0.	SM,	SILTY SAND	
TH 6	10.5- 12.5	100	100	100	100	100	94	88	62	31	20	0	0	7.6	0.	SM,	SILTY SAND	
TH 7	.5- 3.0	100	100	100	99	95	88	81	55	20	10	0	0	3.9	0.	SW/SM,	SAND/	SILTY SAND
TH 7	3.0- 6.0	100	96	96	95	92	81	69	43	16	8	0	0	3.8	0.	SP/SM,	SAND/	SILTY SAND
TH 7	6.0- 9.5	100	100	100	100	97	88	78	48	20	11	0	0	5.7	0.	SW/SM,	SAND/	SILTY SAND
TH 7	9.5- 10.5	100	100	100	100	99	93	86	57	26	15	0	0	7.1	0.	SM,	SILTY SAND	
TH 7	10.5- 12.0	100	100	100	100	100	96	92	71	43	29	0	0	11.1	0.	SM,	SILTY SAND	
TH 8	.5- 3.0	100	95	95	95	92	83	74	48	15	8	0	0	3.5	0.	SW/SM,	SAND/	SILTY SAND
TH 8	3.0- 6.0	100	100	100	100	99	91	85	61	23	11	0	0	4.6	0.	SW/SM,	SAND/	SILTY SAND
TH 8	6.0- 9.5	100	100	100	100	97	90	80	48	19	10	0	0	5.7	0.	SW/SM,	SAND/	SILTY SAND
TH 8	9.5- 10.5	100	100	100	100	99	96	91	68	35	21	0	0	7.0	0.	SM,	SILTY SAND	
TH 8	10.5- 12.0	100	100	100	100	100	97	94	70	39	24	0	0	8.6	0.	SM,	SILTY SAND	
TT 1	0. - 8.0	100	100	100	100	99	86	71	20	3	1	0	0	0.	0.	SP,	SAND	
TT 1	8.0- 9.0	100	100	100	100	98	88	76	44	17	9	0	0	0.	0.	SW/SM,	SAND/	SILTY SAND

SUMMARY OF RIPRAP GRADATION TESTS - SAN JACINTO RIVER LEVEES
(Conducted 26 - 28 March 1980)

	Test #1	Test #2	Test #3	Test #4	Specified
% Wt - 500 lb.	97	100	97	96	100
% Wt - 250 lb.	80	92	74	79	60-90
% Wt - 100 lb.	53	77	39	49	35-60
% Wt - 25 lb.	32	39	15	23	10-30
% Wt - 5 lb.	8	11	4	5	0-5
Area of Test	100 SF	85.5 SF	100 SF	80 SF	-
Total Yield (lbs)	17,462	13,327	16,134	13,250	-
Average Thickness	1.5'	1.5'	1.5'	1.5'	1.5'



LEGEND

① Gradation taken 100' US of breach and 10' US of previous gradation (#1)

② Gradation taken 25' DS of previous gradation (located DS of Breach)

③ Taken @ area visually judged to be coarse

④ Taken @ area visually judged to be fine

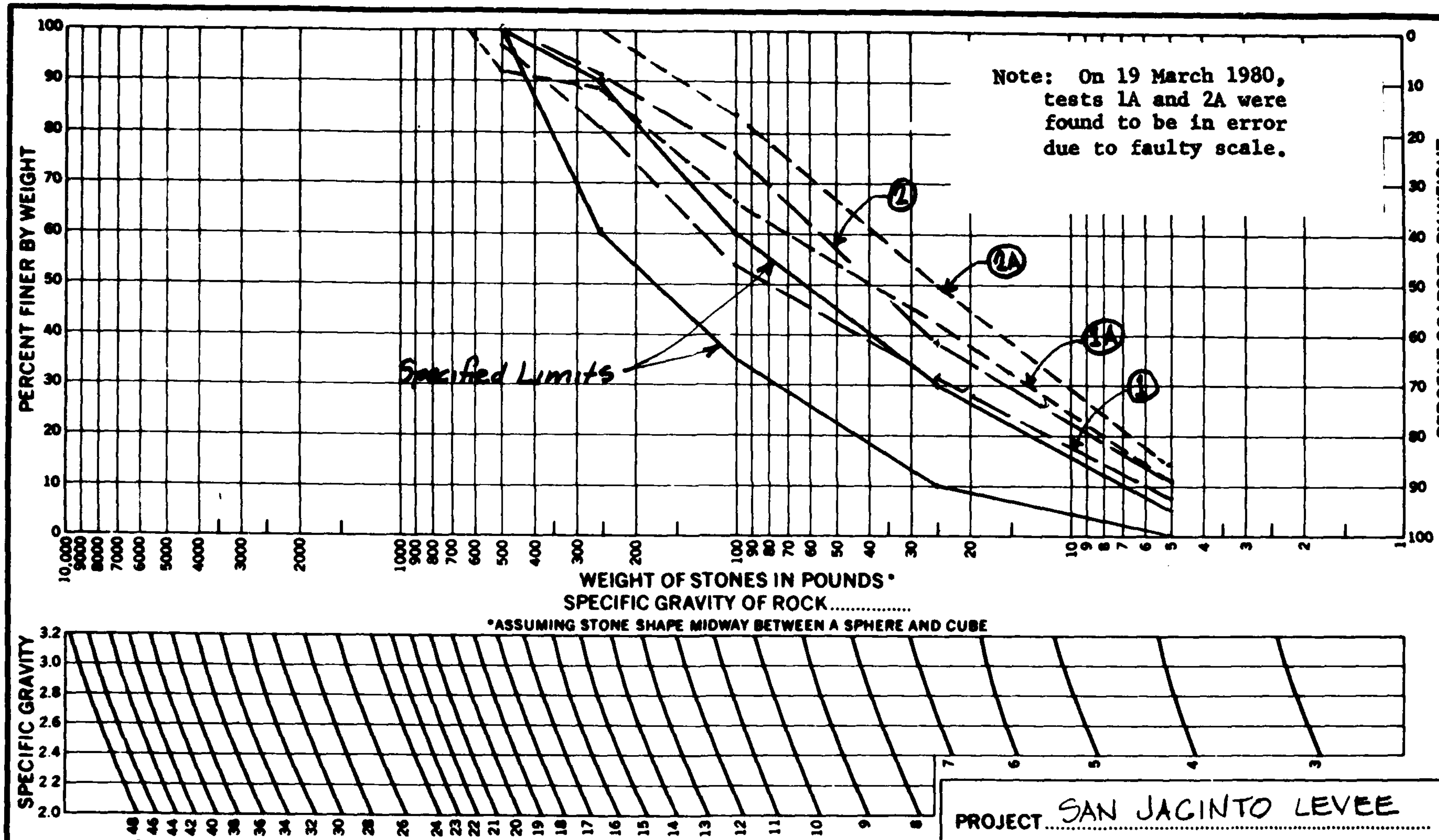
PROJECT SAN JACINTO LEVEE

AREA Gradations conducted 26-28 March

DATE MARCH 1980

RIPRAP GRADATION CURVES

ENG FORM 4055
APR 67



LEGEND

(1A) Original gradation (10 March) upstream of breach.

(1) Gradation (26 March) located 10' US of (1A)

(2A) Original gradation (10 March) downstream of breach.

(2) Gradation (27 March) located 25' DS of (2A)

PROJECT SAN JACINTO LEVEE

AREA Riprap Gradations

DATE MARCH 1980

RIPRAP GRADATION CURVES

ENG FORM 4055 APR 67

APPENDIX B

Field Investigations of Bautista Creek Channel Scour Gages.

TABLE OF CONTENTS

BAUTISTA CREEK CHANNEL TABLE OF SCOUR GAGES						
Scour Gage Elevations (MSL) May80						
Station	Gage	Levee Top	Revetment Toe	Initial Invert	Deposition Line	Scour Line
42+58		1692.0	1674.5			
	1			1683.0	1680.2	1674.6
	2			1684.0	1680.0	1676.7
	3			1683.0	1680.2	1676.6
47+58		1697.4	1681.0			
	1			1689.6	1684.4	1680.2
	2			1688.4	1684.6	1681.2
	3			1688.6	1684.6	1681.6
54+58		1704.8	1690.1			
	1			1697.3	1691.5	1684.8
	2			1698.0	1691.2	1688.0
	3			1696.0	1691.4	1689.5
64+58		1715.5	1703.0			
				1707.8	1702.5	1698.9
				1706.3	1703.3	1699.9
				1705.9	1703.5	1699.1
69+58		1721.8	1709.5			
	1			1715.0	1714.2*	1713.5
	2			1712.9	1709.3	1703.4
	3			1712.7	1709.9	1700.5

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Notes:

1. Elevations of initial invert are estimated from Plate No. 3.
2. Both elevations of deposition and scour were measured on 5/9/80.
3. Gage numbered 1,2,3 are located 50', 100', 150' respectively from level control line.

* Deposition elevation 1709.3' at 51' from levee control line.

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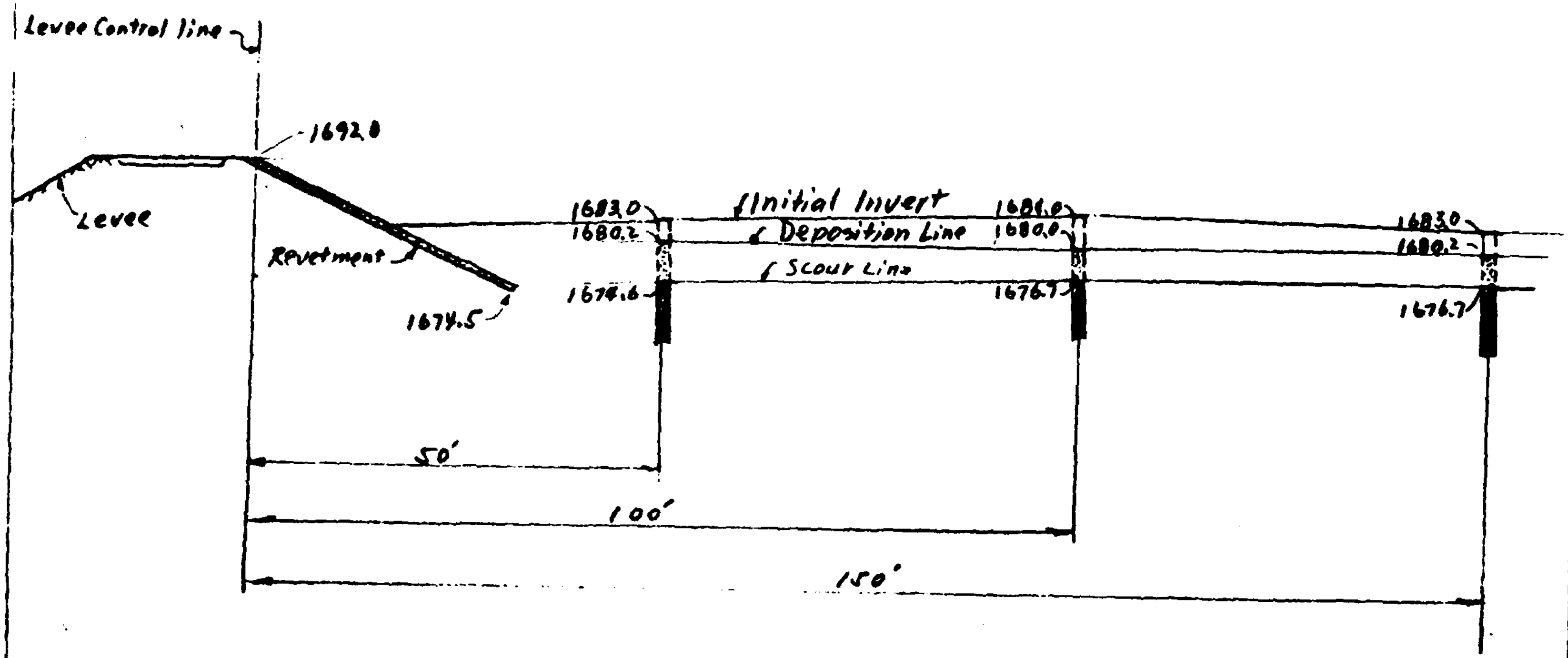


STATION 42+58

SCOUR GAGES

1" = 20'

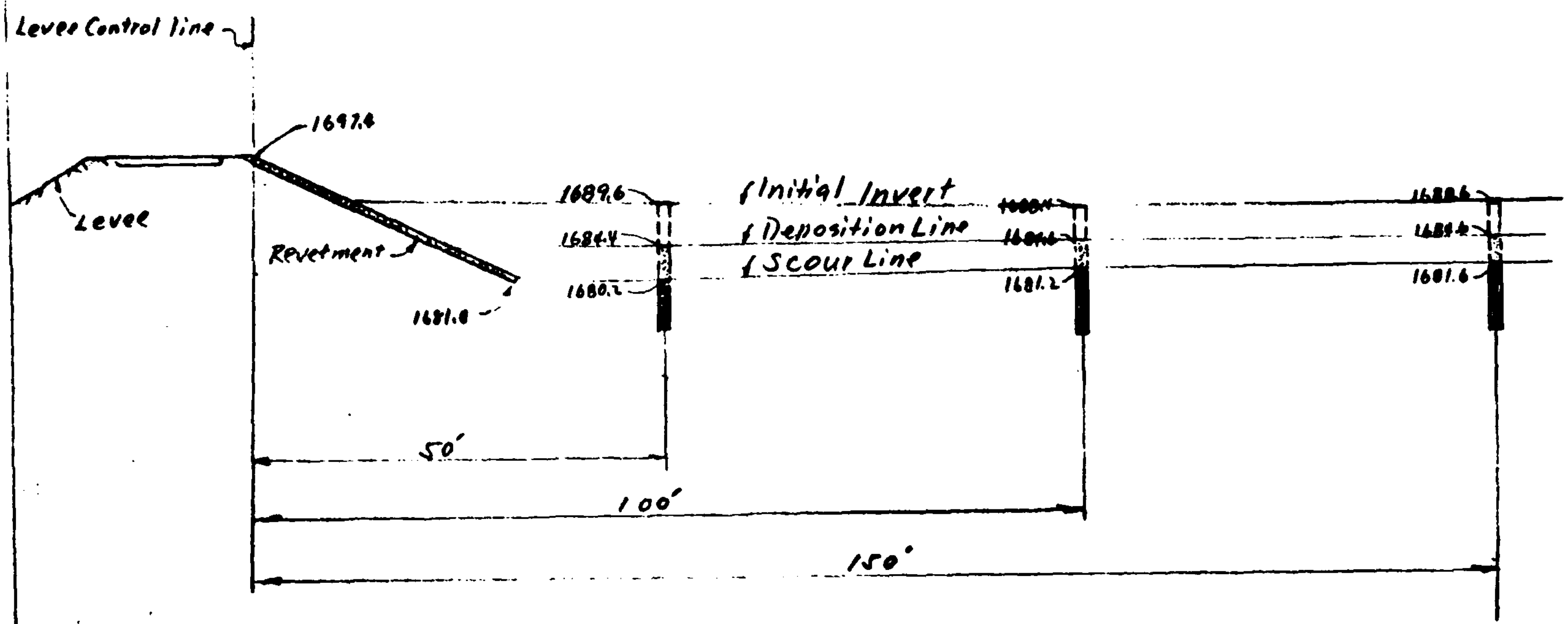
NOTE: All four figures values are elevations

DATA RECOVERED BY J. SHOW MAY 80

BAUTISTA CREEK

SCOUR GAGES

CORPS OF ENGINEERS U.S. ARMY



STATION 47+58

SCOUR GAGES

1" = 20'

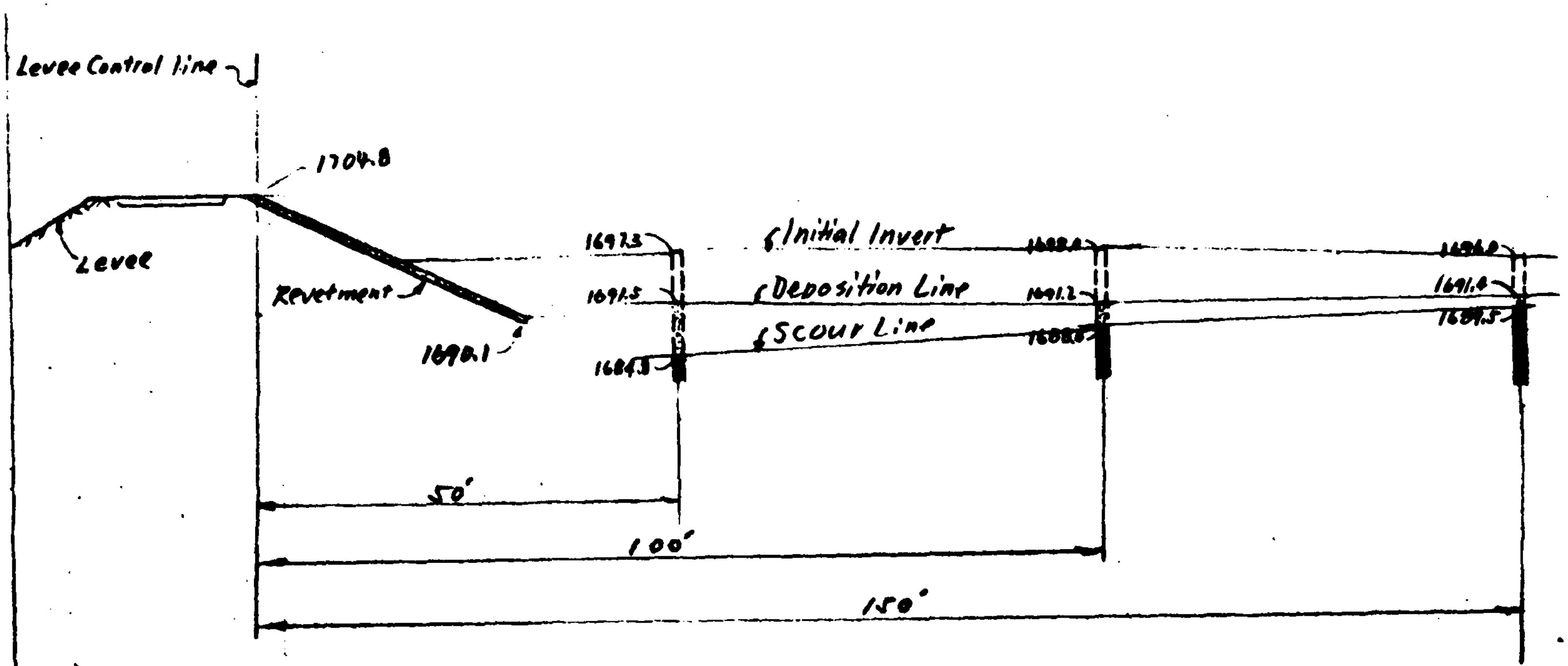
NOTE: All four figures values are elevations

DATA RECOVERED BY J. SHOW MAY 80

BAUTISTA CREEK

SCOUR GAGES

CORPS OF ENGINEERS U.S. ARMY



STATION 54+58

SCOUR GAGES

1" = 20'

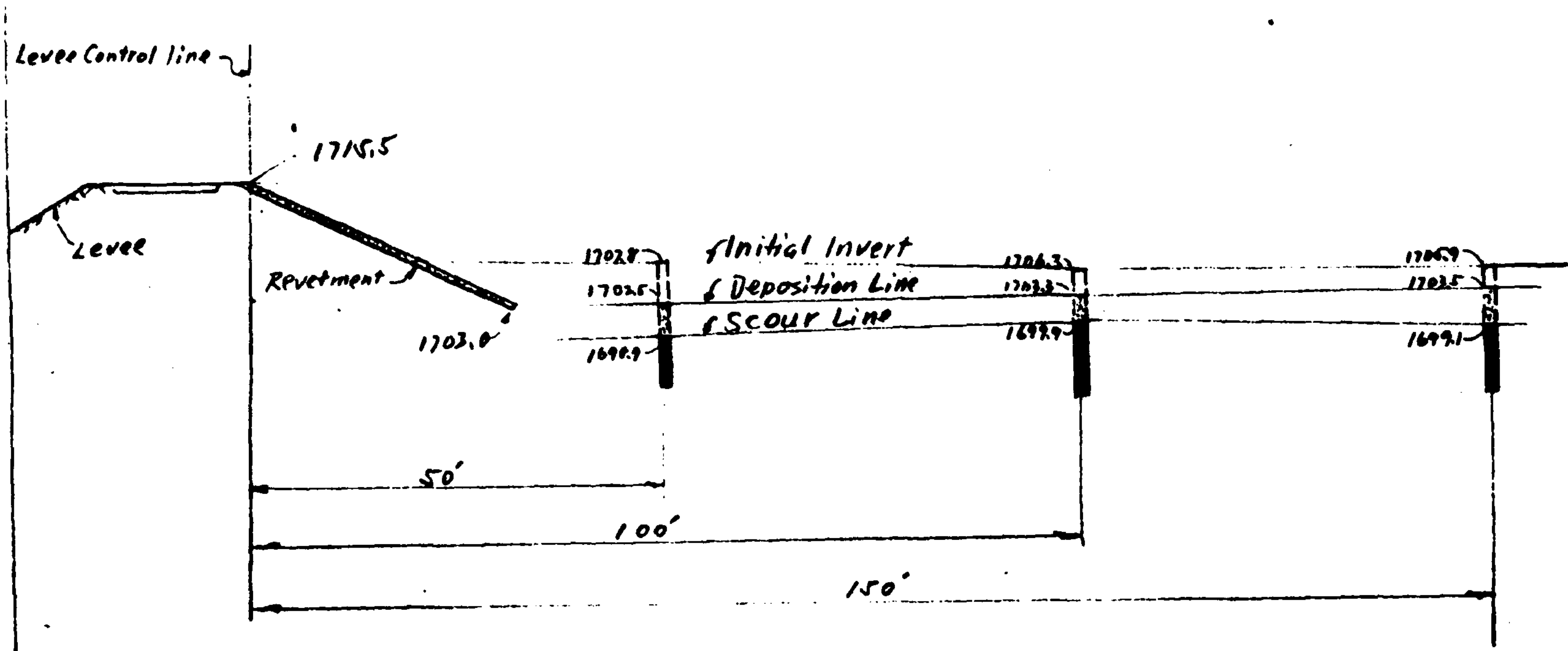
NOTE: All four figures values are elevations

DATA RECOVERED BY J. SHOW MAY 80

BAUTISTA CREEK

SCOUR GAGES

CORPS OF ENGINEERS U.S. ARMY



STATION 64+58

SCOUR GAGES

1" = 20'

NOTE: All four figures values are elevations

	BAUTISTA CREEK
DATA RECOVERED BY J. SHOW MAY 80	SCOUR GAGES

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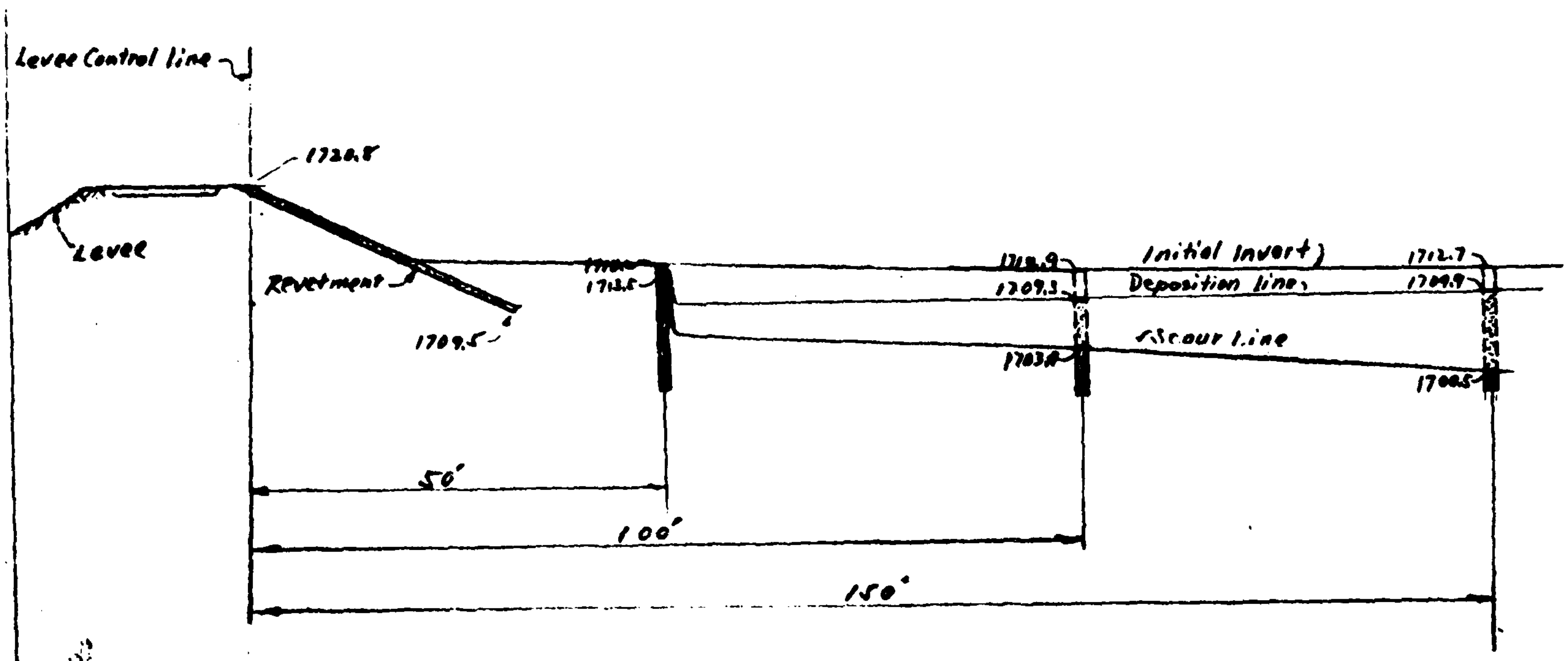
CORPS OF ENGINEERS U.S. ARMY



STATION 69+58

SCOUR GAGES

1" = 20'

NOTE: All four figures values are elevations

	BAUTISTA CREEK
DATA RECOVERED BY J. SHOW MAY 80	SCOUR GAGES

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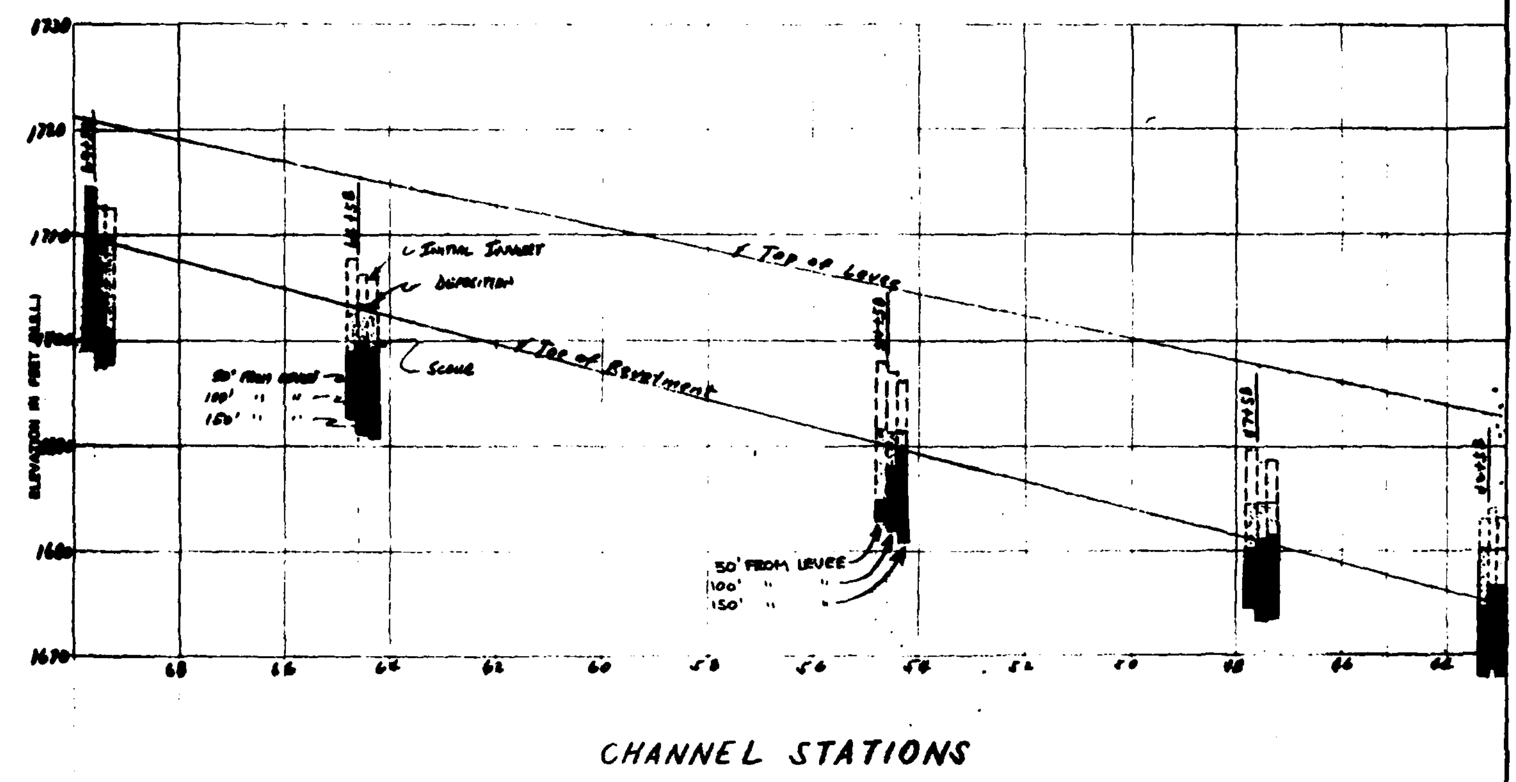
CORPS OF ENGINEERS U.S. ARMY



DATA RECOVERED BY J. SHOW MAYBO	BAUTISTA CREEK SCOUR GAGE PROFILE

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