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of Engineers

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SAN RAMON BYPASS CHANNEL OVERFLOW WEIR CONTRA COSTA COUNTY, CALIFORNIA

Hydraulic Model Investigation

by

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DEPARTMENT OF THE ARMY

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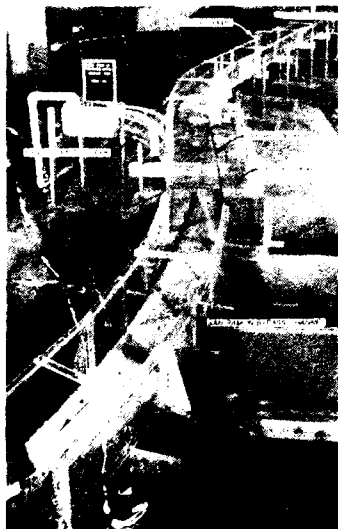
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Tests were conducted on a 1:25-scale model of the San Ramon Bypass Channel, Contra Costa County, California, to develop an overflow weir to remove flows from the channel in excess of the 100-year frequency discharge. The overflow weir would remove flows upstream of the covered channel reach to maintain open channel flow conditions through the covered reach and to not exceed channel capacity downstream of the covered reach. The model reproduced approximately 900 ft of the San Ramon Bypass Channel, 100 ft of the Sans Crainte Creek channel, and 400 ft of the catch channel. The model was constructed so that the slopes of the channels could be adjusted to reproduce various energy gradients equivalent to those resulting from different prototype Manning's n roughness factors. The slopes of the model were initially adjusted to produce an energy gradient resulting from a Manning's n roughness factor of 0.012 in the prototype. Based on initial (Continued)					
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water-surface profiles measured in the model without the overflow weir installed, the weir height was set at 13.25 ft above the center line invert elevation and the weir length was set at 200 ft. With the overflow weir installed in the model, water-surface profiles and discharges over the weir were recorded with various flow conditions. The weir length was shortened from the upstream end by 25, 50, and 75 ft. Test results indicated that a weir length of 125 ft set at 13.25 ft above the center-line invert provided satisfactory results. Discharges over the weir were recorded with various channel discharges for each weir length.

The slopes of the high-velocity channels were adjusted to reproduce the energy gradient resulting from a Manning's n roughness factor of 0.014 in the prototype. These tests were conducted with an overflow weir length of 125 ft and weir height of 13.25 ft. Water-surface profiles and discharges over the weir were recorded with various channel discharges. The divider wall at the downstream end of the weir was streamlined by reducing the angle 15 deg where the flow was being deflected and placing a 3-in. radius on the nose of the divider to split the flow. This resulted in satisfactory flow conditions at the weir for all discharges tested.

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PREFACE

The model investigation reported herein is a supplement to studies authorized by the Headquarters, US Army Corps of Engineers, on 20 June 1983 at the request of the US Army Engineer District, Sacramento (SPK). The local sponsor for the project is the Contra Costa County Flood Control and Water Conservation District.

The studies were conducted by personnel of the Hydraulics Laboratory (HL), US Army Engineer Waterways Experiment Station (WES), during the period September 1988 to March 1989. All studies were conducted under the direction of Messrs. F. A. Herrmann, Jr., Chief, HL; and G. A. Pickering, Chief, Hydraulic Structures Division (HSD), HL. The model was constructed by Messrs. J. Lyons and M. A. Simmons, Engineering and Construction Services Division, WES. The tests were conducted by Mr. W. G. Davis, Locks and Conduits Branch, HSD, under the supervision of Mr. J. F. George, Chief of the Locks and Conduits Branch. This report was prepared by Mr. Davis and edited by Mrs. M. C. Gay, Information Technology Laboratory, WES.

Mr. Harold Huff of SPK visited WES during the course of the model study to observe model operation and correlate results with design studies.

Commander and Director of WES during preparation of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

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CONTENTS

	<u>Page</u>
PREFACE.....	1
CONVERSION FACTORS, NON-SI TO SI (METRIC)	
UNITS OF MEASUREMENT.....	3
PART I: INTRODUCTION.....	5
Background.....	5
Purpose and Scope of Model Investigation.....	5
PART II: THE MODEL.....	7
Description.....	7
Model Appurtenances.....	7
Scale Relations.....	7
PART III: TESTS AND RESULTS.....	11
Initial Tests ($n = 0.012$).....	11
Increased Roughness ($n = 0.014$).....	13
Recommended Design.....	14
PART IV: SUMMARY AND CONCLUSIONS.....	15
TABLES 1-16	
PHOTOS 1-10	
PLATES 1-20	

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI
(metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
square miles	2.589998	square kilometres

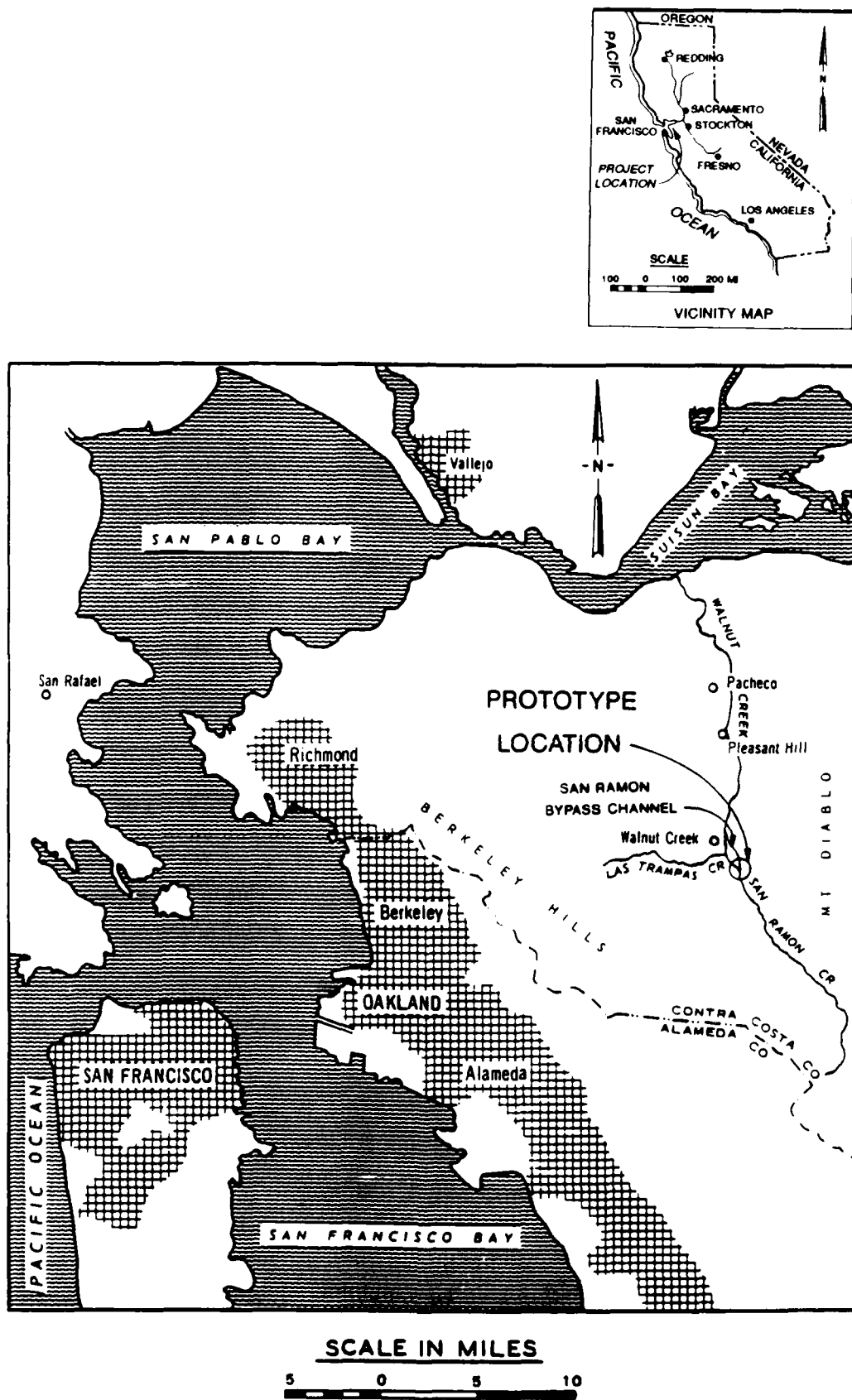


Figure 1. Location and vicinity maps

SAN RAMON BYPASS CHANNEL OVERFLOW WEIR
CONTRA COSTA COUNTY, CALIFORNIA
Hydraulic Model Investigation

PART I: INTRODUCTION

Background

1. The San Ramon Bypass Channel is part of the Walnut Creek Flood Control Project and is located approximately 15 miles* east of San Francisco Bay in a depression between the Berkeley Hills and Mount Diablo (Figure 1). The watershed of San Ramon Creek is located on the western face of Mount Diablo in north-central Contra Costa County and drains an area of about 48 square miles. The bypass channel will divert flood flows from the natural channel of San Ramon Creek to the Walnut Creek Channel.

2. The model study was concerned with the uppermost reach of the San Ramon Bypass Channel and its confluence with the Sans Crainte Creek at the proposed location of the overflow weir (Figure 2).

Purpose and Scope of Model Investigation

3. The purpose of the model investigation was to develop an ungated overflow weir to maximize diversion of flows from the San Ramon Bypass Channel in excess of the 100-year-frequency discharge, 15,200 cfs, consequently providing flood protection for downstream reaches of the project, which were designed to contain the 100-year-frequency flow. The model was also used to determine if flow conditions in the catch channel affected the discharge over the weir, and the required culvert height for the road crossing the catch channel.

* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 3.

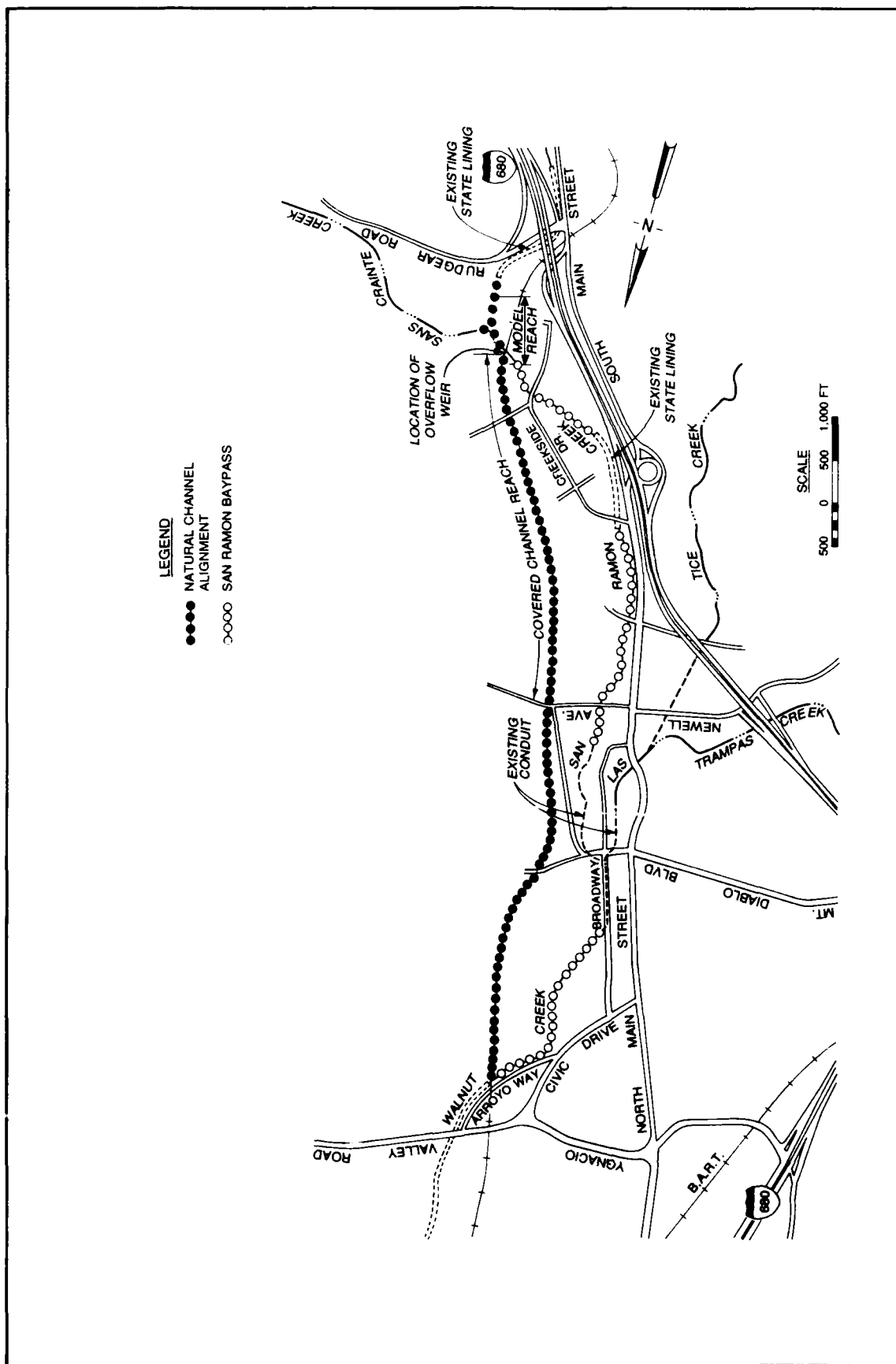


Figure 2. Project and model reaches

PART II: THE MODEL

Description

4. The model was constructed to a scale of 1:25 and reproduced approximately 900 ft of the San Ramon Bypass Channel (from sta 668+83.76 to sta 677+79.04), 100 ft of the Sans Crainte Creek channel, and 400 ft of the catch channel (from sta 668+00 to sta 671+95) (Figure 3, Plates 1 and 2). The channel sections were constructed of transparent plastic with the invert slopes adjustable to reproduce various energy gradients equivalent to those resulting from different prototype Manning's n roughness factors. The inverts of the curved sections of the high-velocity channel requiring super-elevation were constructed of concrete with a very smooth finish.

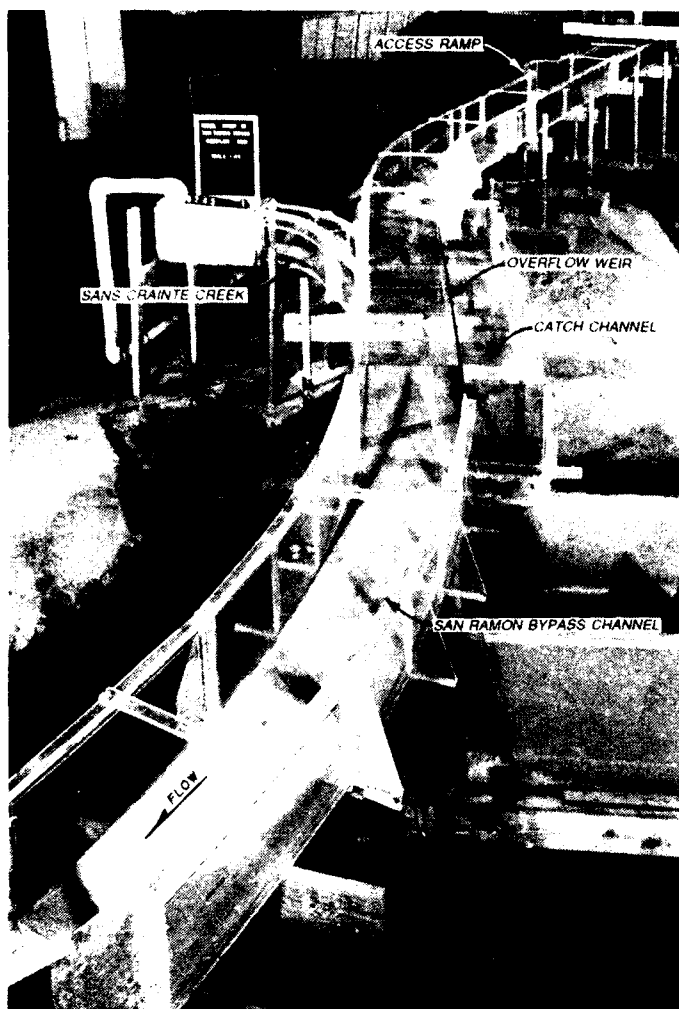
5. The coefficient of roughness of the model surface of the channels had previously been determined to be approximately 0.009 (Manning's n). Basing similitude on the Froudian relation, this n value would be equivalent to a prototype n of 0.0154. The n value used in the design and analysis of the prototype channels varied from 0.012 to 0.014; therefore, supplementary slopes were added to the model to correct for this difference in the n values of the model and prototype.

Model Appurtenances

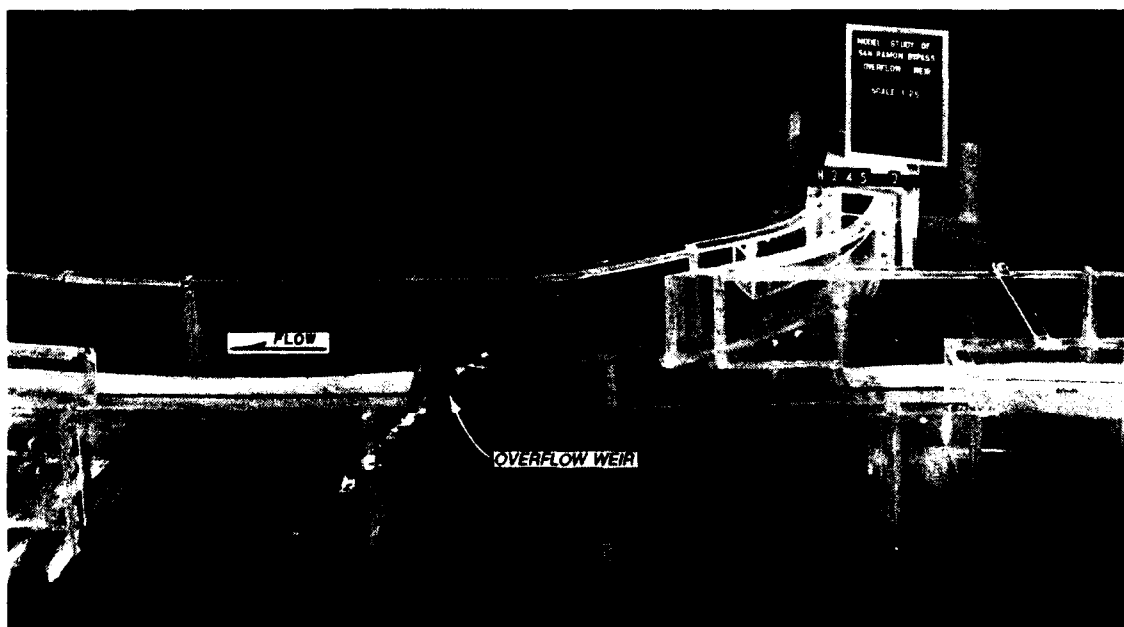
6. Water used in the operation of the model was supplied by a circulating system. Inflow discharges were measured with venturi meters installed in the flow lines and were baffled when entering the model. Discharges exiting the model through the overflow weir were baffled and measured with a v-notch weir. Water-surface elevations were measured with point and rule gages. The tailwater in the lower end of the catch channel was maintained at the desired depth by means of an adjustable tailgate. Different designs along with various flow conditions were recorded photographically.

Scale Relations

7. The accepted equations of hydraulic similitude, based on Froudian relations, were used to express mathematical relations between dimensions of



a. Looking upstream,
weir length 200 ft



b. Looking from right in the vicinity of the confluence
and the overflow weir, weir length 200 ft

Figure 3. General view of the model (Continued)



c. Looking downstream with the catch channel installed,
weir length 125 ft

Figure 3. (Concluded)

hydraulic quantities of the model and prototype. General relations for transference of model to prototype equivalents are as follows:

<u>Characteristic</u>	<u>Dimension*</u>	<u>Scale Relations</u> <u>Model:Prototype</u>
Length	$L_r = L$	1:25
Area	$A_r = L_r^2$	1:625
Velocity	$V_r = L_r^{1/2}$	1:5
Time	$T_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3,125
Roughness Coefficient	$N_r = L_r^{1/6}$	1:1.71

* Dimensions are in terms of length.

Model measurements of discharge and water-surface elevations can be transferred quantitatively to prototype equivalents by means of the preceding scale relations.

PART III: TESTS AND RESULTS

8. Tests were conducted to observe general flow conditions and determine the adequacy of the proposed channel geometry and alignment for the San Ramon Bypass Channel, Sans Crainte Creek, and the catch channel for the overflow weir. The Manning's n roughness coefficient of the prototype channels could range from 0.012 to 0.014 depending on the quality of construction and the abrasive characteristics of the flows during the design life of the channel.

Initial Tests ($n = 0.012$)

9. The invert slopes of the channels initially tested were adjusted to reproduce an energy gradient resulting from a Manning's n roughness factor of 0.012 in the prototype. Initial tests were conducted with the overflow weir completely blocked to obtain water-surface elevations with various flow conditions to estimate the required weir height. Water-surface profiles were recorded with discharges of 13,200, 14,900, and 15,200 cfs. The distribution of flow between the San Ramon Bypass Channel and Sans Crainte Creek for these discharges were 13,000 and 200 cfs, 13,200 and 1,700 cfs, and 15,000 and 200 cfs, respectively. These discharges represent a range of concurrent hydrograph inflow. It should be noted that the physical model was capable of reproducing only 1,700 cfs of the 2,000-cfs peak inflow from Sans Crainte Creek. However, the difference between 14,900 cfs and 15,200 cfs was not considered significant. The profiles are shown in Plates 3-5, and water-surface elevations are tabulated in Tables 1-3. The wall heights shown on the profiles were designed to retain the 100-year-frequency flow (15,200 cfs). However, the walls in the model were constructed high enough to contain all expected model flows; therefore, no flow escaped the channel upstream from the weir.

10. Because of the alignment of the downstream wall at the junction of the San Ramon Bypass Channel and the access ramp, the flow hit the downstream wall (Photo 1), which resulted in flow overtopping the right wall in this vicinity as shown in Plates 3-5. Various modifications to this area were tested in an effort to eliminate the overtopping. Initially, the downstream corner of the wall was set back 1 ft (type 2 design access, Plate 6) from the

channel. This modification reduced the overtopping somewhat, but flow exceeded the wall height by 1.8 ft with the 100-year-frequency discharge. The corner was then set back 2 ft, using a 100-ft radius (type 3 design access, Plate 7). Test results indicated that the flow exceeded the proposed wall height by 1.9 ft with the type 3 design access and the 100-year-frequency flow. The corner was set back 2 ft with a straight-line transition (type 4 design access, Plate 7). Again, flow exceeded the proposed wall height by 1.2 ft with the type 4 design access and the 100-year-frequency discharge. Due to time and cost limitations on the model study, a solution to this problem was not fully documented. However, it was concluded from observations of flow conditions that the downstream corner of the access ramp wall could be set back a minimum of 3 ft with an access opening of 20 ft to prevent flow impingement on the downstream corner of the access opening. To minimize disturbances created by changes in channel width (the 3-ft offset of the downstream corner of the access opening), Engineer Manual (EM) 1110-2-1601* recommends a convergence transition rate of 1:20 (horizontal to longitudinal wall flare) for channels with mean velocities in this range (approximately 32 ft/sec). It was also concluded from observations of flow conditions that overtopping of the wall could be prevented by bridging the access ramp opening, placing an overhanging deflector at the downstream corner, or raising the wall in this vicinity.

11. Significant overtopping of the San Ramon Bypass Channel walls occurred in the vicinity of the confluence with Sans Crainte Creek and a total discharge of 14,900 cfs (Plate 4). This increase in water surface was caused by the increased discharge from Sans Crainte Creek.

12. Based on the water-surface profiles obtained without the overflow weir installed (Plates 3-5), the weir height was set at 13.25 ft above the center-line invert elevation for the entire 200-ft length of the weir. Figure 3 shows the weir installed in the model, and Plate 8 shows details of the weir crest. Water-surface profiles recorded with discharges of 13,200, 14,900, 15,200, and 17,500 cfs are shown in Plates 9-12; and water-surface elevations are tabulated in Tables 4-7. These flow conditions are shown in Photos 2-5. The 17,500-cfs discharge is that portion of the Standard Project

* Headquarters, US Army Corps of Engineers. 1970 (1 Jul). "Hydraulic Design of Flood Control Channels," EM 1110-2-1601, US Government Printing Office, Washington, DC.

Flood (20,200 cfs) estimated to remain in the bypass channel upstream of the overflow weir. With a total channel discharge of 17,500 cfs, the weir intercepted 1,950 cfs, resulting in satisfactory flow conditions and a channel discharge of 15,550 cfs downstream from the weir.

13. The weir length was shortened to 175, 150, and 125 ft with the downstream end of the weir remaining at sta 670+70. Discharges over the weir were recorded with channel discharges of 13,200, 14,900, 15,200, and 17,500 cfs. The largest reduction of discharge over the shortened weirs, compared with the 200-ft-long weir, was 150 cfs and occurred with a channel discharge of 17,500 cfs and a weir length of 125 ft. This small reduction in discharge over the overflow weir (7.7 percent) compared with the reduction in weir length (37.5 percent) was due to the nature of flow conditions, channel geometry, and weir location. More flow passed over the downstream portion of the weir due in part to the crosswave created by the confluence with Sans Crainte Creek. The crosswave intersected the overflow weir near the downstream end of the weir, which resulted in an increase in flow over the weir compared to flow conditions in the absence of any crosswave for each discharge tested. This crosswave was critical for getting flows over the weir, especially for the smaller discharges tested, due to the small head on the weir over most of the weir length except in the vicinity of the crosswave. A summary of these test results with a Manning's n of 0.012 is presented in Table 8.

Increased Roughness ($n = 0.014$)

14. The slopes of the model were adjusted to reproduce the energy gradient for a roughness coefficient (Manning's n) of 0.014. These tests were conducted with an overflow weir length of 125 ft and a height of 13.25 ft as determined from previous tests conducted with the channel invert slopes adjusted to reproduce the energy gradient for a Manning's n value of 0.012.

15. Water-surface profiles recorded with discharges of 13,200, 14,900, 15,200, and 17,500 cfs are shown in Plates 13-16; and water-surface elevations are tabulated in Tables 9-12.

16. Discharges measured over the weir for various flow conditions with a Manning's n value of 0.014 are presented in Table 13. Test results indicated that the discharges over the weir were greater with an n value of 0.014 than with an n value of 0.012 due to the increased water depths with

the rougher n value. Flow conditions in the catch channel and in the vicinity of the weir with main channel discharges of 16,800 and 17,500 cfs are shown in Photos 6 and 7. Water-surface profiles recorded in the catch channel with these discharges and with a discharge of 19,300 cfs are shown in Plates 17-19, and water-surface elevations are tabulated in Tables 14-16. The 19,300-cfs discharge represents a worst-case scenario for flows remaining in the channel during the Standard Project Flood, and was run to determine how the project would function for this scenario.

17. Because of the alignment and geometry of the divider wall at the downstream end of the weir (type 1 design divider wall, Plate 20), the high-velocity flow struck the wall and sprayed upward resulting in overtopping of the channel walls in this vicinity (Photo 8). An overhanging deflector alleviated the overtopping in this vicinity (Photo 9); however, flow conditions were not hydraulically desirable. The divider wall was then modified by extending the divider 0.34 ft and placing a 3-in. radius on the nose of the divider (type 2 design divider wall). This reduced the spray somewhat, but not enough. The divider wall was then streamlined by reducing the angle by 15 deg where the flow was being deflected and placing a 3-in. radius on the nose of the divider to split the flow (type 3 design divider wall, Plate 20). This resulted in satisfactory flow conditions for all discharges observed. Photo 10 shows the type 3 design divider wall installed in the model with a discharge of 17,500 cfs.

Recommended Design

18. The recommended modifications to the original design determined from test results for a Manning's n of 0.012 incorporate raising the walls upstream from the overflow weir to contain flood flows greater than the 100-year-frequency flow, using an overflow weir length of 125 ft from sta 670+70 to 671+95, and modifying the access ramp opening. The access ramp could be modified by either bridging the access ramp, offsetting the downstream corner 3 ft with a 1:20 transition extending downstream back to a 32-ft-wide channel, placing an overhanging deflector at the downstream corner, or raising the wall in this vicinity to prevent overtopping.

19. Recommendations determined from test results for a Manning's n of 0.014 incorporate streamlining the divider wall at the downstream end of the weir (Plate 20, type 3 design divider wall).

PART IV: SUMMARY AND CONCLUSIONS

20. A satisfactory overflow weir was designed to prevent downstream overtopping of the San Ramon Bypass Channel during flood events greater than the 100-year design event up to the Standard Project Flood.

21. It was anticipated that the Manning's roughness coefficient of the prototype concrete-lined channel could range from 0.012 to 0.014, depending on the quality of construction, aging, and maintenance. Water-surface elevations would be slightly higher with the larger n value, and flow velocities and waves created by disturbances would be slightly higher with the smaller n value. Thus, tests were conducted to simulate the energy gradient resulting from both of the n values.

22. With a Manning's n value of 0.012, the weir height was set at 13.25 ft above the center-line invert elevation. This height was based on water-surface profiles obtained with various discharges with the weir blocked off. With the overflow weir installed in the model, water-surface profiles and discharges over the weir were recorded with various flow conditions. The weir length was shortened from the upstream end by 25, 50 and 75 ft. Discharges over the weir were recorded with various channel discharges for each weir length. Reducing the length of the weir from 200 to 125 ft resulted in only a small decrease in discharge over the weir; therefore, a weir length of 125 ft was selected. Because of the alignment of the right wall of the San Ramon Bypass Channel at the access ramp opening, flow overtopped the right wall in this vicinity for all flows tested. By offsetting the downstream corner of the access ramp opening 3 ft with a 1:20 transition extending downstream back to a 32-ft-wide channel, overtopping of the channel wall in this vicinity may be eliminated. Additional possible solutions are also suggested under the Recommended Design section, Part III of this report.

23. With a Manning's n value of 0.014 reproduced, discharges over the 125-ft-long weir were greater than with an n value of 0.012, due to the increased water depths with the rougher n value. Unsatisfactory flow conditions were observed at the divider wall located at the downstream end of the weir. The flow impacted the divider wall resulting in flow overtopping proposed wall heights in this vicinity. By streamlining the divider wall, reducing the angle by 15 deg, and placing a 3-in. radius on the nose of the

divider wall, satisfactory flow conditions were observed along the weir for all discharges tested.

24. A crosswave was generated by the confluence with Sans Crainte Creek that propagated downstream and across the channel for both Manning's n values tested (Photos 2-7). The crosswave intersected the overflow weir near the downstream end of the weir, which resulted in an increase in flow over the weir compared to flow conditions in the absence of any crosswave for each discharge tested. This crosswave was critical for getting flows over the weir, especially for the smaller discharges tested, due to the small head on the weir over most of the weir length except in the vicinity of the crosswave. As a result, the weir length could be shortened from 200 ft to 125 ft without a significant reduction in spillage over the weir. It should be stressed that the resulting flows over the weir are highly dependent on channel geometry upstream from the weir and the relative weir location.

Table 1

Water Surface Elevations, San Ramon Discharge 13,000 cfs
Sans Crainte Discharge 200 cfs, $n = 0.012$

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	174.31	174.05
676+50	174.33	174.33
676+35	173.12	177.87
676+15	171.55	172.18
675+80	173.34	172.34
675+33.5	170.35	170.92
675+00	171.71	171.34
674+70	170.91	170.28
674+15	169.34	173.47
673+50	169.80	171.30
673+00	167.12	169.99
672+70	168.24	170.56
672+45	169.65	168.65
672+05	168.88	167.58
671+75	168.93	171.43
671+50	168.14	168.39
671+18	170.95	167.92
670+70	167.57	167.20
670+25	170.09	166.50
670+00	169.46	164.46
669+46	168.48	169.18
669+00	167.94	165.49

Note: Sides of channel are referenced to downstream direction. Water-surface elevations in tables are referenced to the National Geodetic Vertical Datum (NGVD).

Table 2

Water-Surface Elevations, San Ramon Discharge 13,200 cfsSans Crainte Discharge 1,700 cfs, $n = 0.012$

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	173.43	173.68
676+50	173.88	174.08
676+35	173.12	178.12
676+15	171.83	172.33
675+75	173.27	172.27
675+33.5	170.17	171.17
674+85	171.61	170.99
674+50	169.67	170.79
674+15	169.08	173.70
673+50	169.43	171.30
673+00	167.57	169.99
672+70	169.57	170.69
672+45	173.65	170.41
672+05	176.63	179.63
671+50	175.26	172.76
671+00	171.49	171.23
670+70	172.01	169.02
670+00	170.71	168.97
669+50	171.46	168.71
669+00	169.94	169.32

Note: Sides of channel are referenced to downstream direction.

Table 3

Water-Surface Elevations, San Ramon Discharge 15,000 cfs
Sans Crainte Discharge 200 cfs, $n = 0.012$

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	176.26	176.81
676+60	174.97	174.85
676+38	174.50	178.37
676+00	174.00	174.50
675+50	173.41	173.29
675+00	173.09	171.96
674+50	170.92	172.92
674+10	169.43	174.55
673+50	170.30	172.31
673+00	169.75	171.87
672+70	169.44	171.81
672+35	171.27	169.42
672+05	169.71	169.13
671+75	169.93	172.93
671+39.56	169.94	170.19
671+05	172.26	168.51
670+70	169.07	168.67
670+15	171.68	166.86
669+46	169.76	170.18
669+00	169.20	166.70

Note: Sides of channel are referenced to downstream direction.

Table 4

Water-Surface Elevations, San Ramon Discharge 13,000 cfsSans Crainte Discharge 200 cfs, $n = 0.012$ Weir Length 200 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	174.31	174.05
676+50	174.33	174.33
676+35	173.12	177.87
676+15	171.55	172.18
675+80	173.34	172.34
675+33.5	170.35	170.92
675+00	171.71	171.34
674+70	170.91	170.28
674+15	169.34	173.47
673+50	168.95	171.25
673+00	167.39	169.84
672+70	168.81	170.19
672+50	169.49	--
672+22	168.50	167.00
672+00	168.98	169.23
671+75	169.06	171.18
671+40	168.04	167.70
671+00	169.58	167.23
670+70	167.57	166.82
670+25	169.67	165.67
669+75	168.08	164.83
669+46	167.98	166.93
669+00	167.07	165.19

Note: Sides of channel are referenced to downstream direction.

Table 5

Water-Surface Elevations, San Ramon Discharge 13,200 cfsSans Crainte Discharge 1,700 cfs, $n = 0.012$ Weir Length 200 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	173.43	173.68
676+50	173.88	174.08
676+35	173.12	178.12
676+15	171.83	172.33
675+75	173.27	172.27
675+33.5	170.17	171.17
674+85	171.61	170.99
674+50	169.67	170.79
674+15	169.08	173.70
673+50	169.15	171.43
673+00	167.59	170.24
672+70	168.94	170.31
672+50	169.69	169.69
672+22	168.75	167.25
672+05	169.01	171.26
671+90	170.25	172.88
671+50	172.89	169.76
671+25	169.99	169.36
671+00	168.73	168.56
670+70	168.45	167.07
670+25	170.34	165.09
670+00	168.34	165.84
669+46	168.56	166.56
669+00	167.99	165.94

Note: Sides of channel are referenced to downstream direction.

Table 6

Water-Surface Elevations, San Ramon Discharge 15,000 cfsSans Crainte Discharge 200 cfs, $n = 0.012$ Weir Length 200 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	176.26	176.81
676+60	174.97	174.85
676+38	174.50	178.37
676+00	174.00	174.50
675+50	173.41	173.29
675+00	173.09	171.96
674+50	170.92	172.92
674+00	168.11	174.61
673+50	170.65	172.13
673+00	169.32	172.04
672+70	169.56	171.94
672+25	170.30	168.65
672+05	170.21	168.38
671+75	169.53	171.93
671+40	169.25	169.33
671+10	170.03	167.96
670+70	168.47	167.05
670+25	170.44	165.77
669+75	169.58	165.71
669+46	168.68	166.68
669+00	168.02	166.69

Note: Sides of channel are referenced to downstream direction.

Table 7

Water-Surface Elevations, San Ramon Discharge 17,200 cfsSans Crainte Discharge 300 cfs, $n = 0.012$ Weir Length 200 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	177.56	177.69
676+60	176.97	177.22
676+35	175.70	180.87
676+10	175.14	175.76
675+80	176.19	175.59
675+30	173.50	174.25
674+80	174.70	174.35
674+50	172.46	173.86
674+10	171.00	176.92
673+50	171.58	173.68
673+20	172.71	173.44
672+90	170.58	173.81
672+70	170.56	173.56
672+35	171.34	171.09
672+05	170.96	169.51
671+75	170.48	171.78
671+40	169.78	170.45
671+10	170.16	168.68
670+70	169.45	167.07
670+10	171.01	165.81
669+50	169.70	167.08
669+00	168.44	166.94

Note: Sides of channel are referenced to downstream direction.

Table 8

Summary of Test Results for Manning's n of 0.012

<u>San Ramon Discharge, cfs</u>	<u>Sans Crainte Discharge cfs</u>	<u>Weir Length ft</u>	<u>Upstream End of Weir, Sta</u>	<u>Discharge Over Weir cfs</u>	<u>Channel Discharge Downstream from Weir cfs</u>
13,000	200	125	671+95	200	13,000
		150	672+20	200	13,000
		175	672+45	200	13,000
		200	672+70	200	13,000
13,200	1,700	125	671+95	1,650	13,250
		150	672+20	1,700	13,200
		175	672+45	1,700	13,200
		200	672+70	1,700	13,200
15,000	200	125	671+95	850	14,350
		150	672+20	850	14,350
		175	672+45	900	14,300
		200	672+70	900	14,300
17,200	300	125	671+95	1,800	15,700
		150	672+20	1,900	15,600
		175	672+45	1,900	15,600
		200	672+70	1,950	15,550
19,000	300	200	672+70	2,550	16,750

Note: Weir height = 13.25 ft; downstream end of weir at sta 670+70.

Table 9

Water-Surface Elevations, San Ramon Discharge 13,000 cfsSans Crainte Discharge 200 cfs, $n = 0.014$ Weir Length 125 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	174.49	174.49
676+50	173.26	173.46
676+35	172.87	175.87
676+15	--	173.08
675+75	172.65	171.90
675+33.5	170.42	171.67
675+00	171.96	170.54
674+50	170.04	171.29
674+10	168.42	172.92
673+75	168.76	170.71
673+50	169.18	171.43
673+06	168.36	170.41
672+70	169.81	170.71
672+35	168.84	168.17
672+00	169.78	169.48
671+80	168.86	171.18
671+50	169.01	169.14
671+25	168.74	169.79
670+70	168.02	166.95
670+30	169.84	166.47
669+75	168.58	166.58
669+00	168.07	166.19

Note: Sides of channel are referenced to downstream direction.

Table 10

Water-Surface Elevations, San Ramon Discharge 13,200 cfsSans Crainte Discharge 1,700 cfs, $n = 0.014$ Weir Length 125 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	174.81	174.69
676+50	173.51	173.46
676+35	173.00	176.62
676+00	172.70	173.00
675+75	172.82	171.90
675+33.5	170.67	172.05
675+00	172.09	170.76
674+50	170.44	171.71
674+10	168.50	173.42
673+50	169.40	171.38
673+00	168.44	170.79
672+55	170.20	170.08
672+30	169.43	168.80
672+05	171.20	173.63
671+83	171.06	173.06
671+60	173.46	170.96
671+25	170.24	169.86
670+70	168.70	166.75
670+30	169.34	166.72
669+75	169.46	166.18
669+00	167.59	166.69

Note: Sides of channel are referenced to downstream direction.

Table 11

Water-Surface Elevations, San Ramon Discharge 15,000 cfsSans Crainte Discharge 200 cfs, $n = 0.014$ Weir Length 125 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+82.5	175.44	175.81
676+50	174.83	174.63
676+35	174.37	177.75
676+00	173.62	174.12
675+60	173.75	173.30
675+33.5	172.17	172.72
675+00	173.59	172.34
674+50	171.16	172.61
674+05	169.27	175.04
673+50	170.30	172.18
673+00	170.24	172.24
672+30	171.85	170.18
672+05	170.81	170.01
671+75	169.98	173.36
671+50	170.26	171.14
671+15	170.79	168.41
670+70	168.90	168.00
670+15	170.48	166.05
669+75	169.46	166.33
669+00	168.62	166.57

Note: Sides of channel are referenced to downstream direction.

Table 12

Water-Surface Elevations, San Ramon Discharge 17,200 cfsSans Crainte Discharge 300 cfs, $n = 0.014$ Weir Length 125 ft

<u>Station</u>	<u>Elevation</u>	
	<u>Left Side</u>	<u>Right Side</u>
676+83.5	175.81	176.56
676+50	175.26	175.58
676+35	175.37	179.12
676+00	174.77	174.92
675+50	174.41	174.16
675+00	173.54	173.24
674+50	172.51	174.16
674+05	169.22	176.14
673+50	172.18	173.80
673+15	172.08	172.73
672+70	170.69	174.11
672+25	172.88	170.63
671+95	172.55	172.30
671+68	170.48	173.85
671+25	171.49	170.36
670+70	169.70	167.32
670+20	170.55	166.93
669+70	170.56	166.06
669+00	168.44	167.69

Note: Sides of channel are referenced to downstream direction.

Table 13

Summary of Test Results for Manning's n of 0.014

<u>San Ramon Discharge, cfs</u>	<u>San Crainte Discharge, cfs</u>	<u>Discharge Over Weir, cfs</u>	<u>Channel Discharge Downstream from Weir, cfs</u>
13,000	200	300	12,900
13,200	1,700	1,850	13,050
15,000	200	950	14,250
16,500	300	1,600	15,200
17,200	300	1,900	15,600
19,000	300	2,300	17,000

Note: Weir height = 13.25 ft; weir length = 125 ft.

Table 14

Water-Surface Elevations in Catch Channel.Main Channel Discharge 16,800 cfs.Catch Channel Discharge 1,600 cfs

<u>Station</u>	<u>Water-Surface Elevation Left Side of Channel</u>
671+95	--
671+50	165.29
671+00	165.81
670+83	163.41
670+50	165.93
670+30	169.81
670+00	169.91
669+74.58	169.55
669+24.58	170.15

Table 15

Water-Surface Elevations in Catch Channel.Main Channel Discharge 17,500 cfs.Catch Channel Discharge 1,900 cfs

<u>Station</u>	<u>Water-Surface Elevation Left Side of Channel</u>
671+95	--
671+50	165.91
671+00	165.91
670+50	164.91
670+40	164.61
670+30	167.06
670+20	165.26
670+00	168.66
669+74.58	169.30
669+24.58	170.05

Table 16

Water-Surface Elevations in Catch Channel.Main Channel Discharge 19,300 cfs.Catch Channel Discharge 2,300 cfs

<u>Station</u>	<u>Water-Surface Elevation Left Side of Channel</u>
671.95	164.11
671+75	165.64
671.50	167.44
671+25	165.89
671+00	164.94
670+70	164.76
670+50	167.64
670+30	168.01
670+10	162.21
669+74.58	168.05
669+50	168.68
669+24.58	168.80

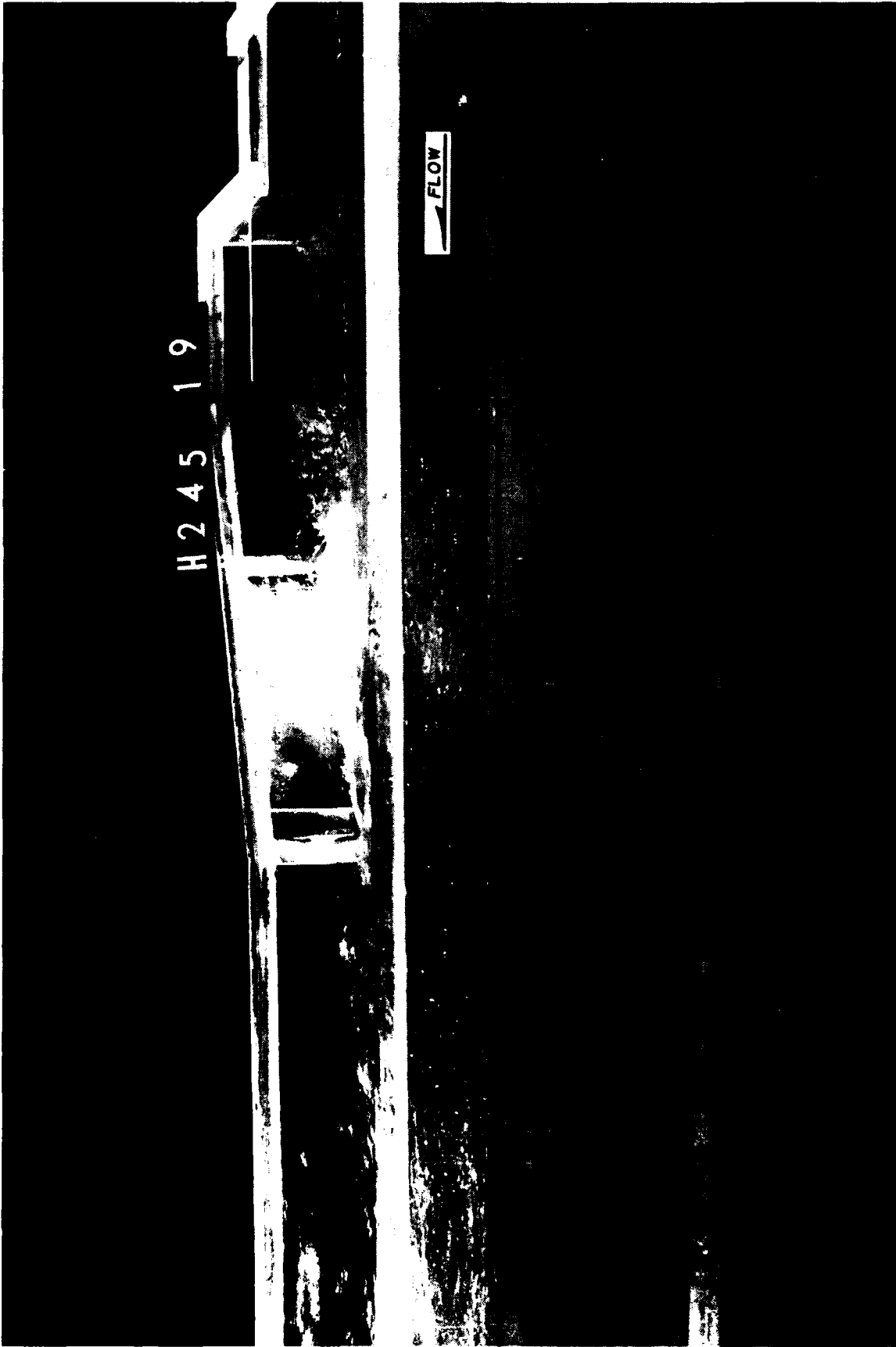
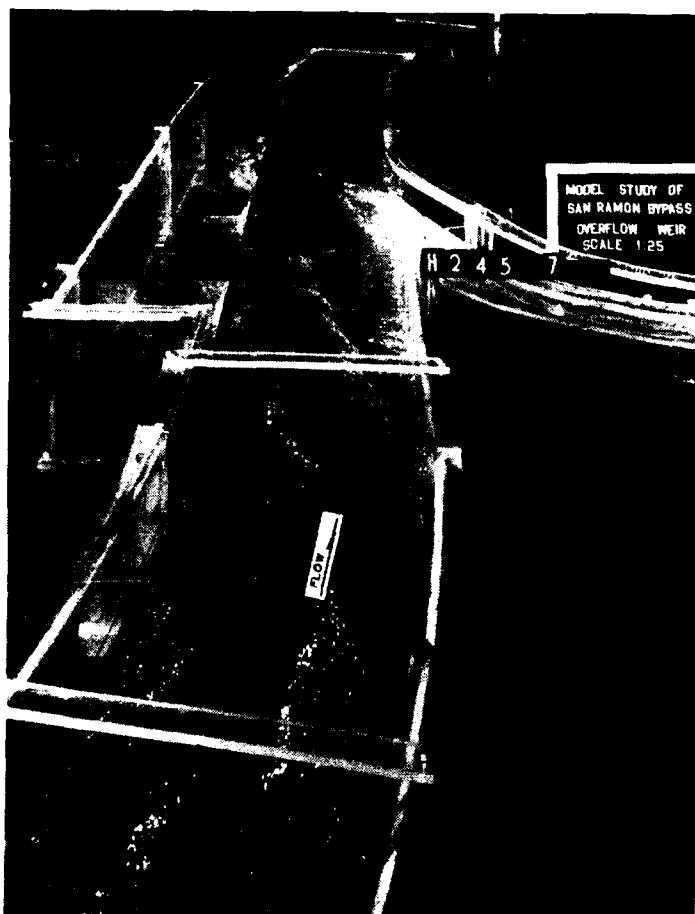
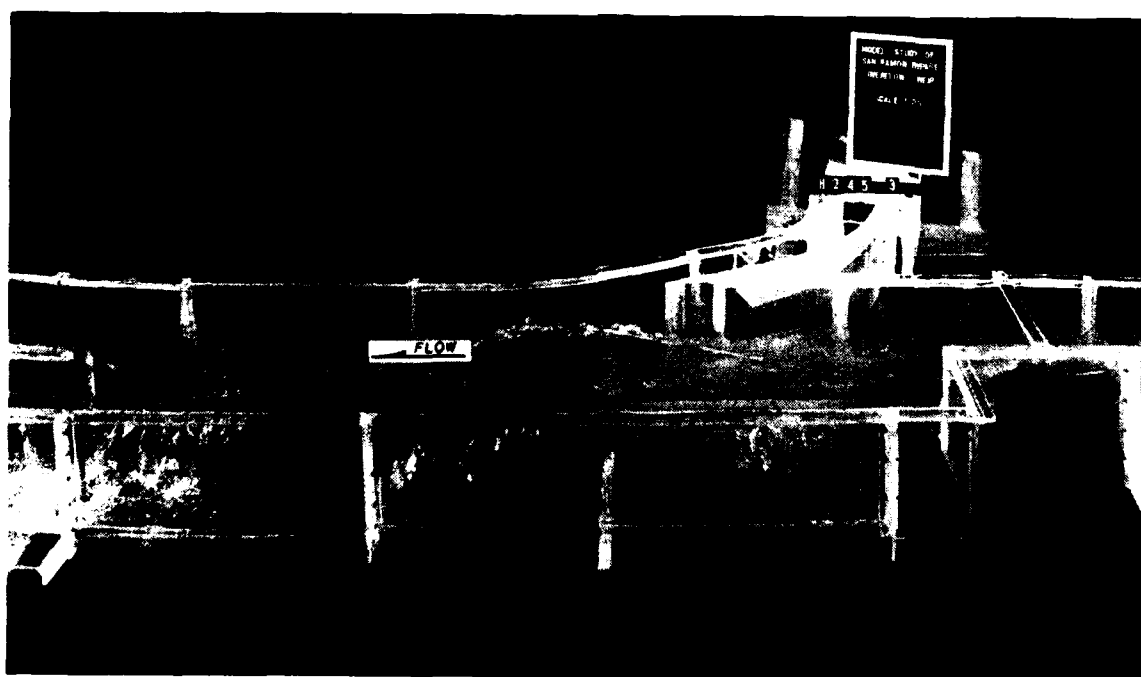


Photo 1. Flow conditions in the vicinity of access ramp



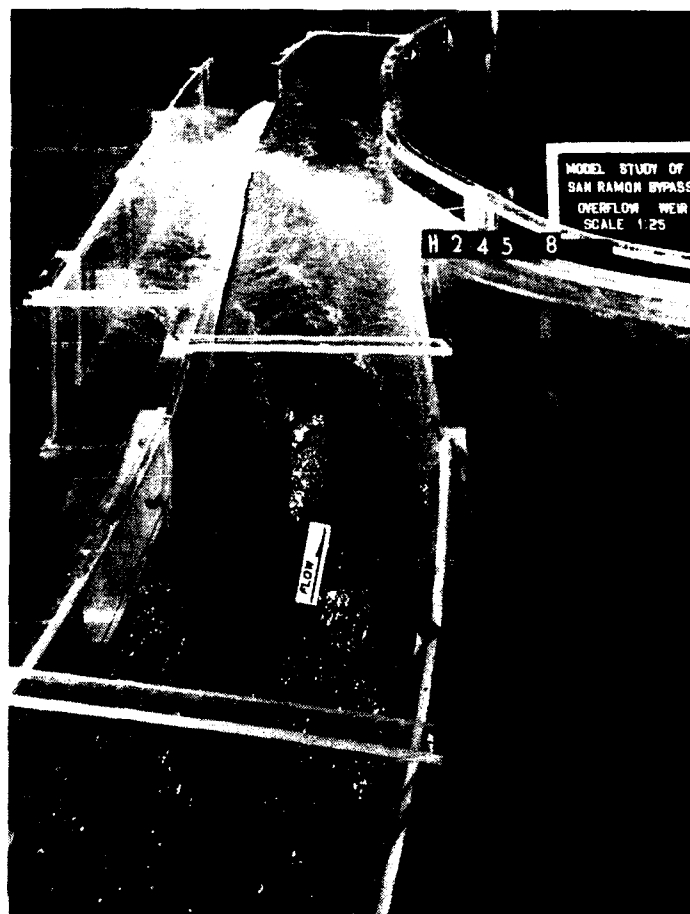
a. Looking downstream



b. Between sta 670+50 and sta 673+50

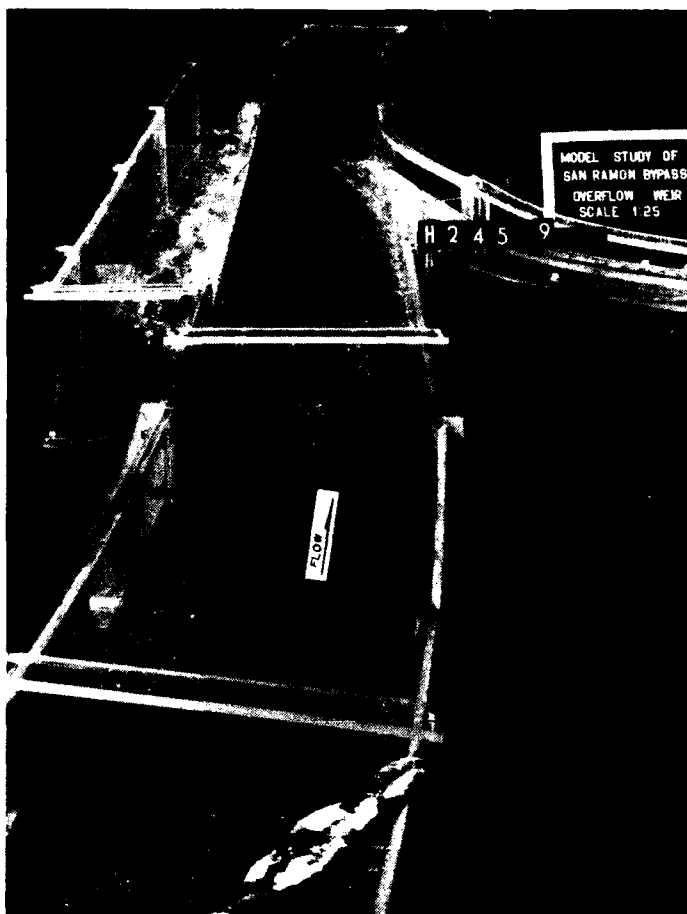
Photo 2. Flow conditions in the vicinity of the weir;
discharge 13,200 cfs; $n = 0.012$; weir length = 200 ft

a. Looking downstream



b. Between sta 670+50 and sta 673+50

Photo 3. Flow conditions in the vicinity of the weir;
discharge 14,900 cfs; $n = 0.012$; weir length = 200 ft



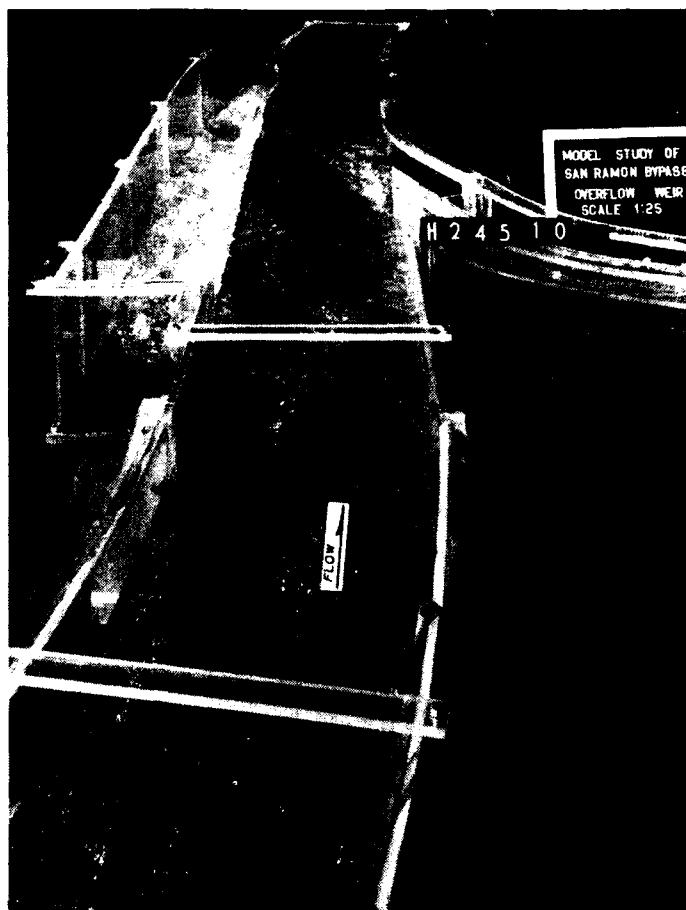
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b. Between sta 670+50 and sta 673+50

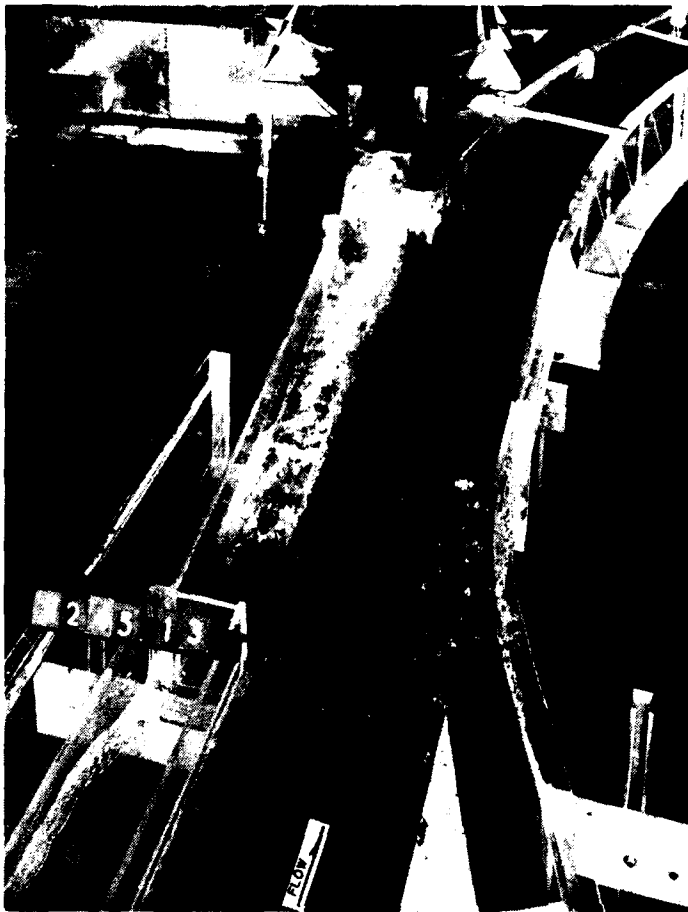
Photo 4. Flow conditions in the vicinity of the weir;
discharge 15,200 cfs; $n = 0.012$; weir length = 200 ft

a. Looking downstream

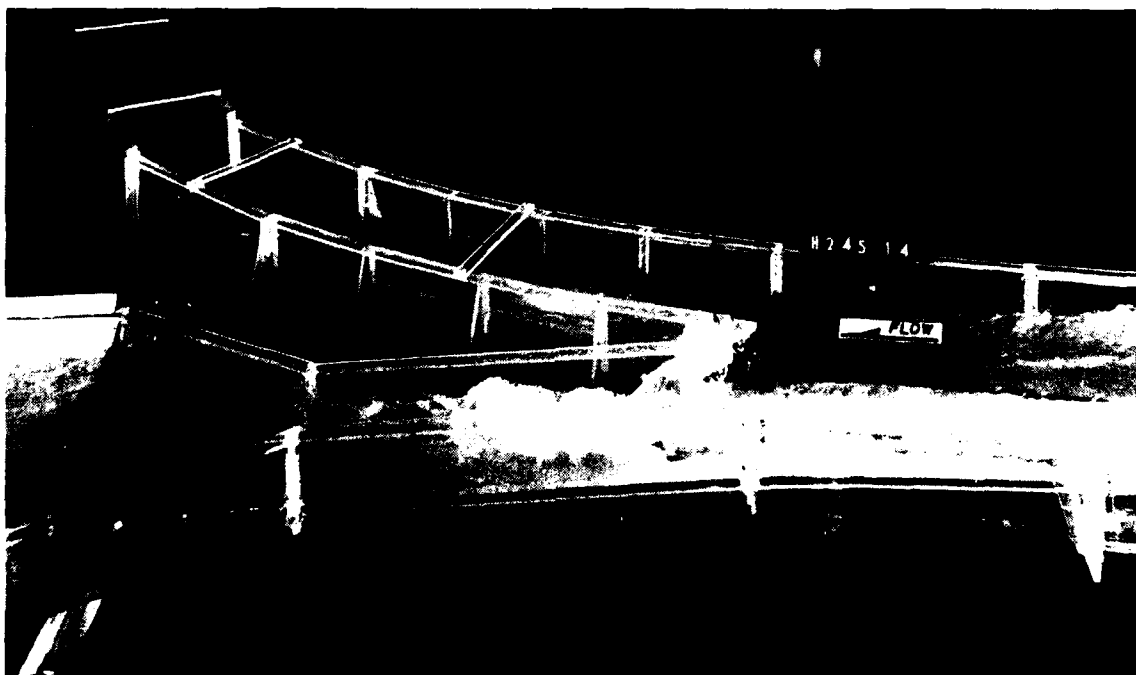


b. Between sta 670+50 and sta 673+50

Photo 5. Flow conditions in the vicinity of the weir;
discharge 17,500 cfs; $n = 0.012$; weir length = 200 ft



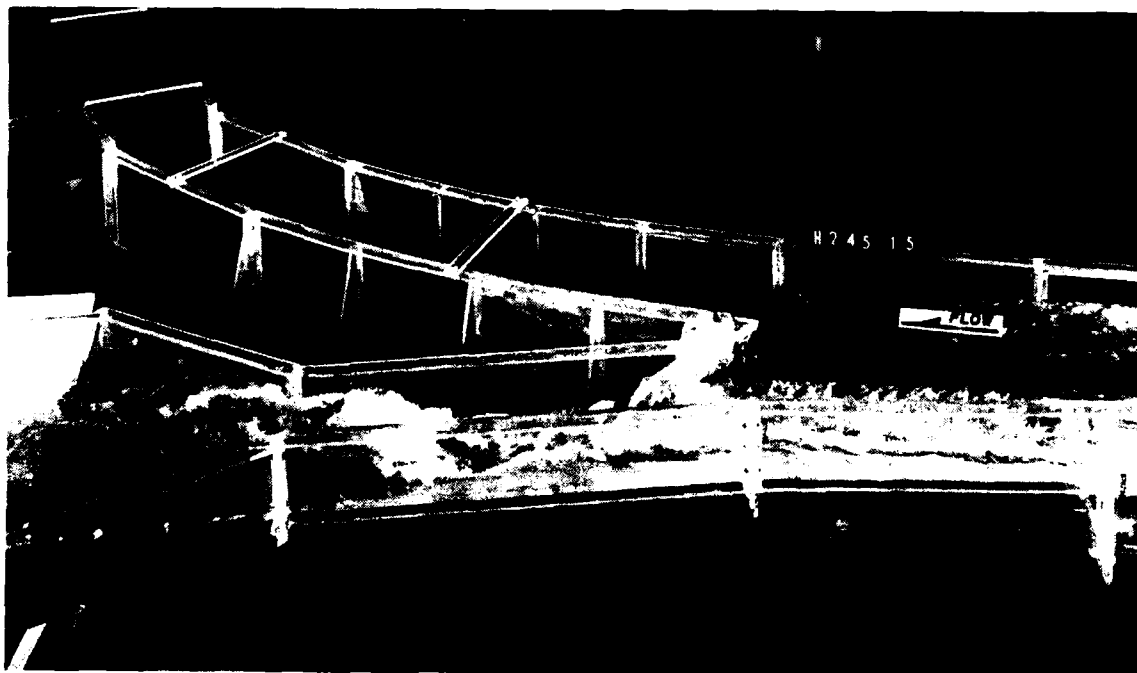
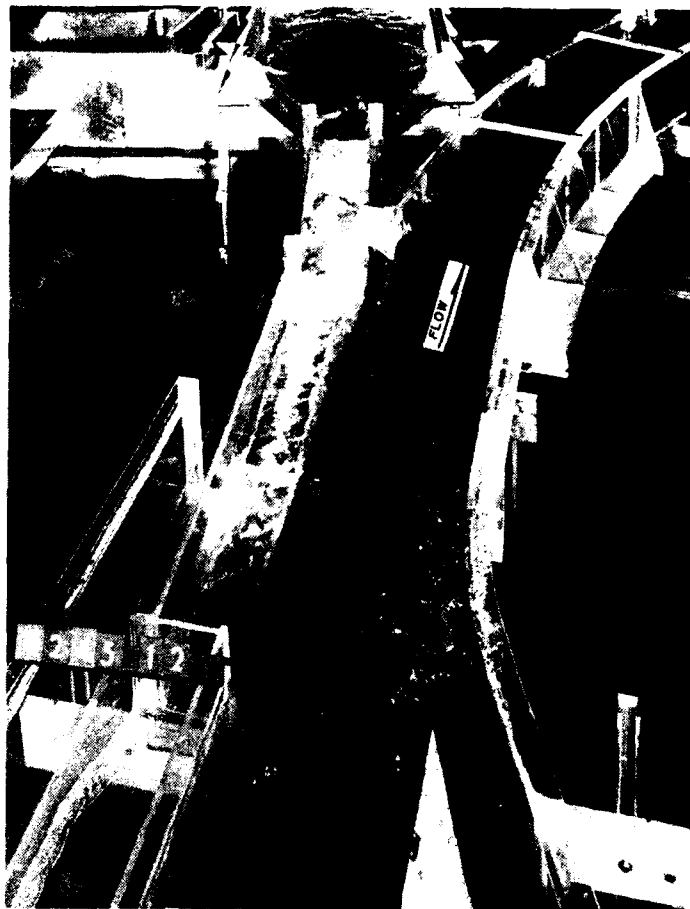
a. Looking downstream



b. Between sta 669+00 and sta 671+50

Photo 6. Flow conditions in the vicinity of the weir;
discharge 16,800 cfs; $n = 0.014$; weir length = 125 ft

a. Looking downstream



b. Between sta 669+00 and sta 671+50

Photo 7. Flow conditions in the vicinity of the weir;
discharge 17,500 cfs; $n = 0.014$; weir length = 125 ft

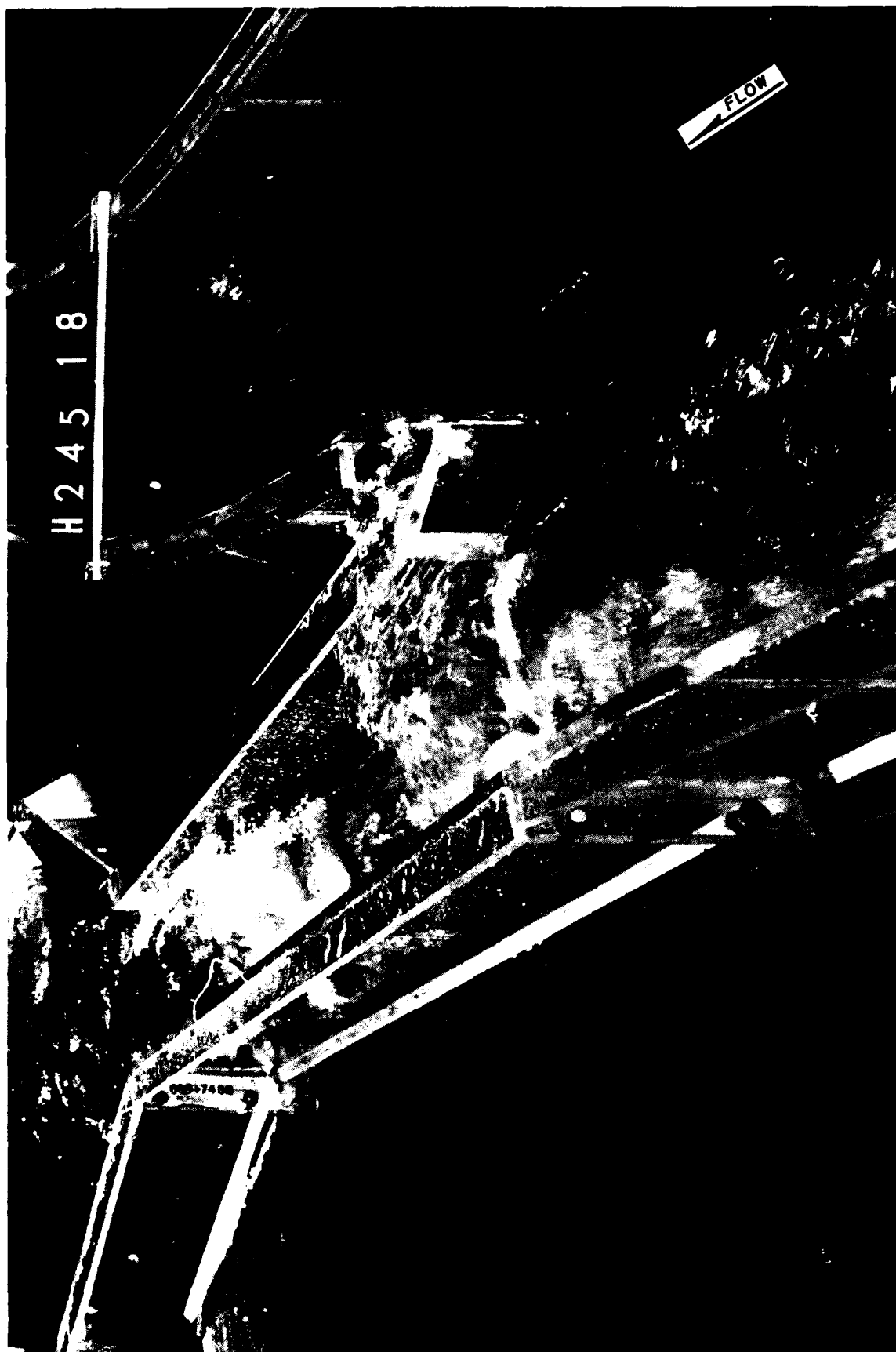


Photo 8. Flow conditions in the vicinity of the downstream end of the weir;
original design; discharge 17,500 cfs

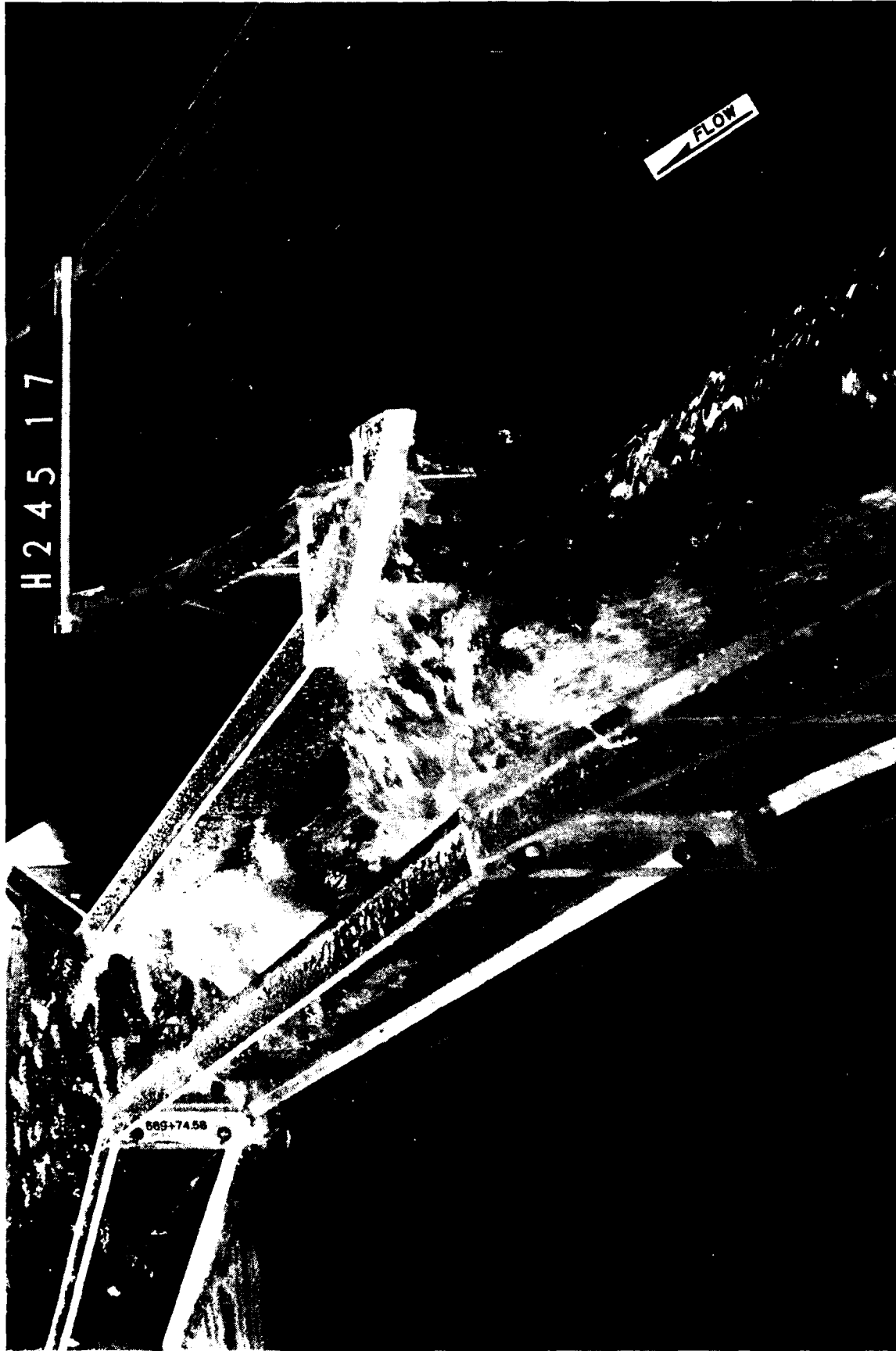
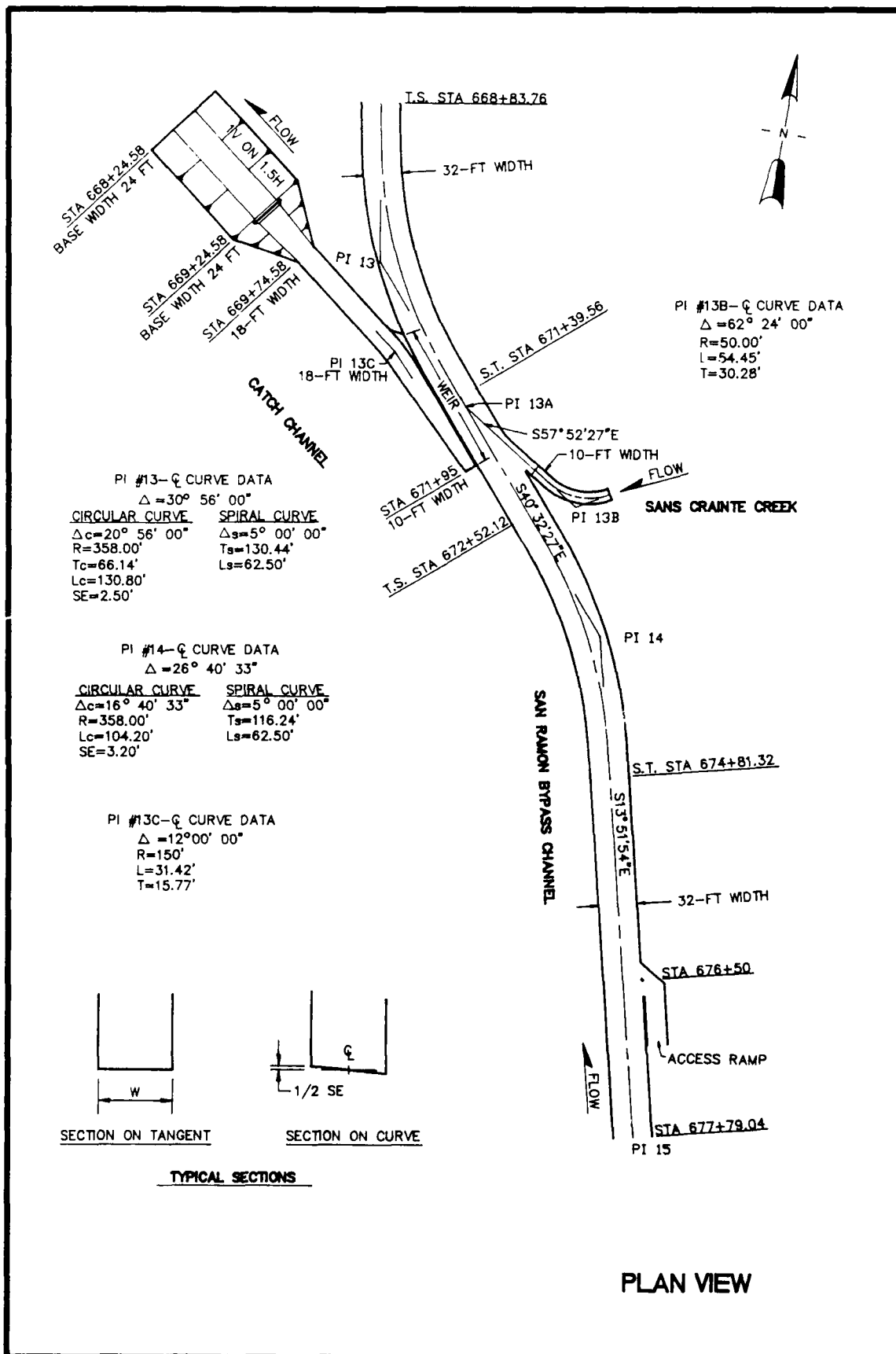
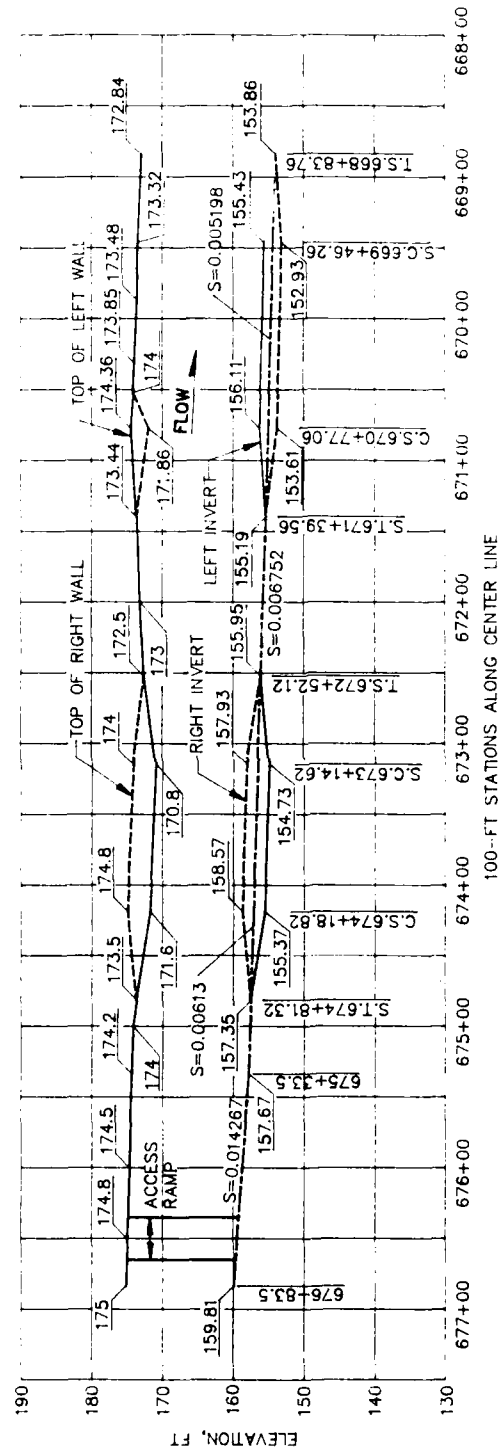


Photo 9. Flow conditions in the vicinity of the downstream end of the weir; overhanging deflector installed; discharge 17,500 cfs

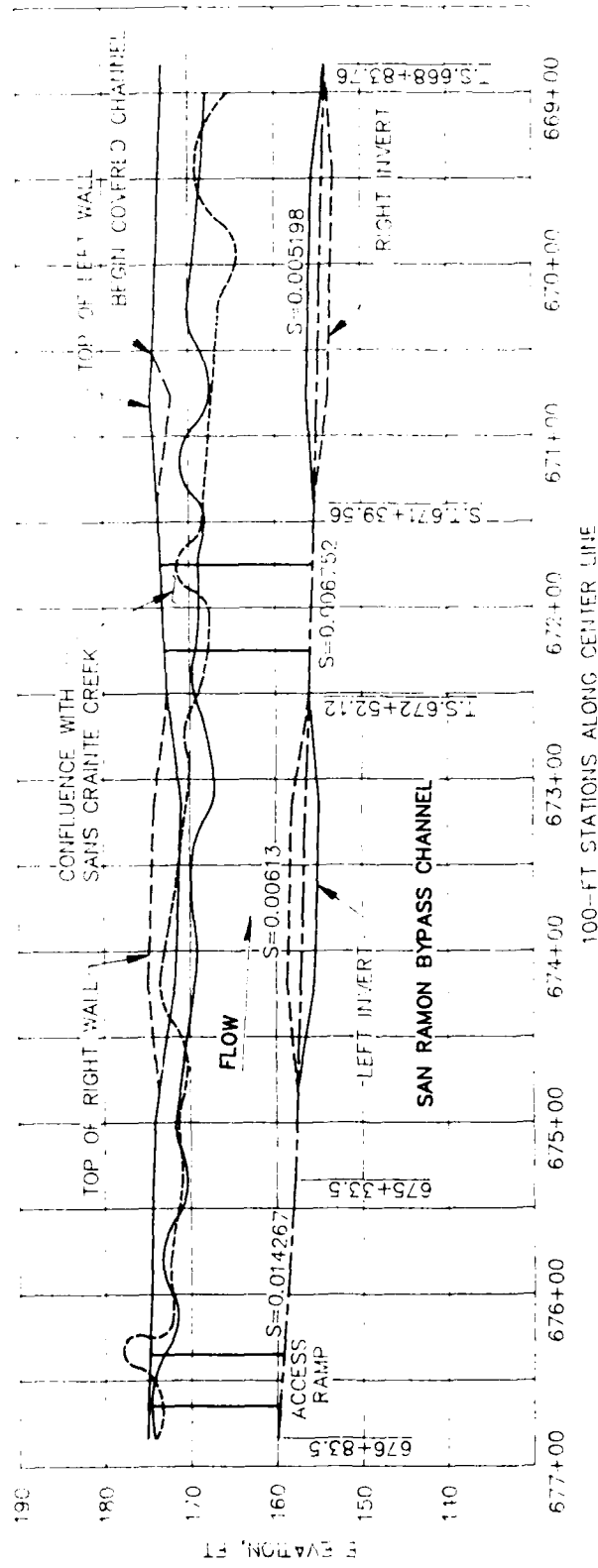


Photo 10. Flow conditions in the vicinity of the downstream end of the weir; type 3 design divider wall installed; discharge 17,500 cfs





PROFILE
SAN RAMON BYPASS CHANNEL

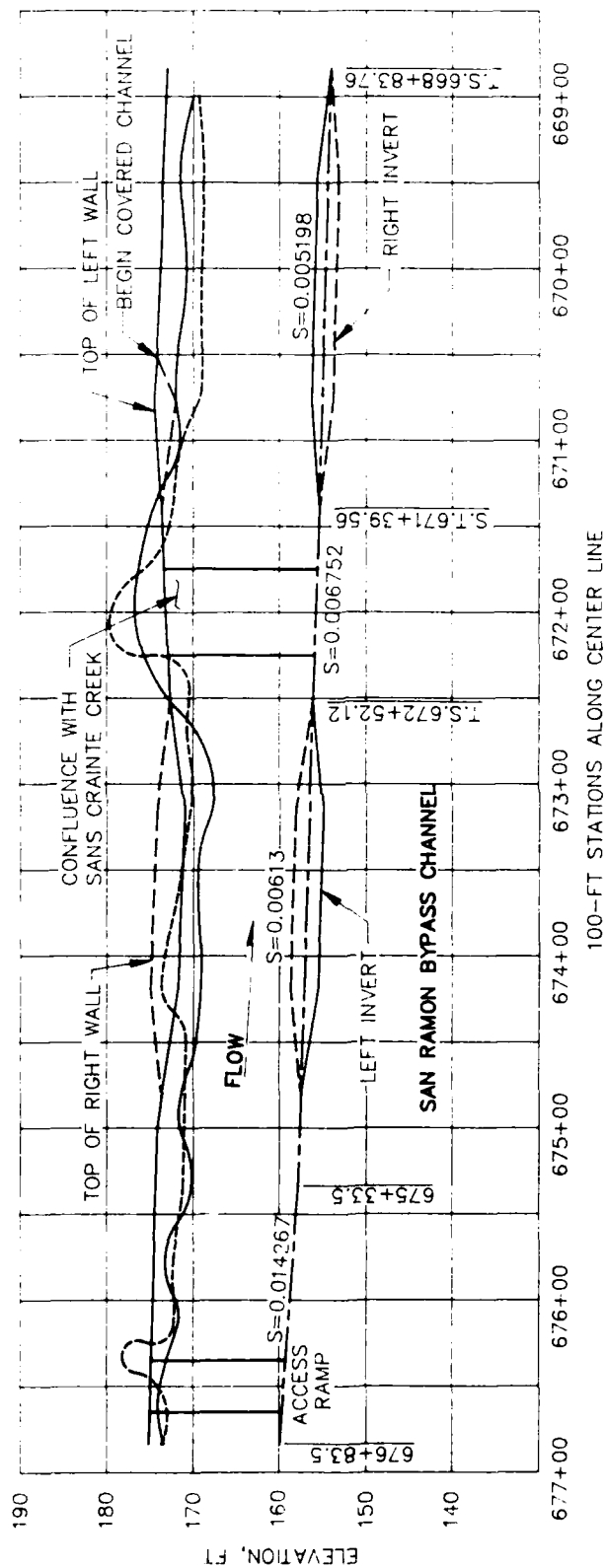


LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL

WATER-SURFACE PROFILES

SAN RAMON CHANNEL 13,000 cfs
 SANS CRAINTE CREEK 200 cfs
 ORIGINAL DESIGN
 $n=0.012$

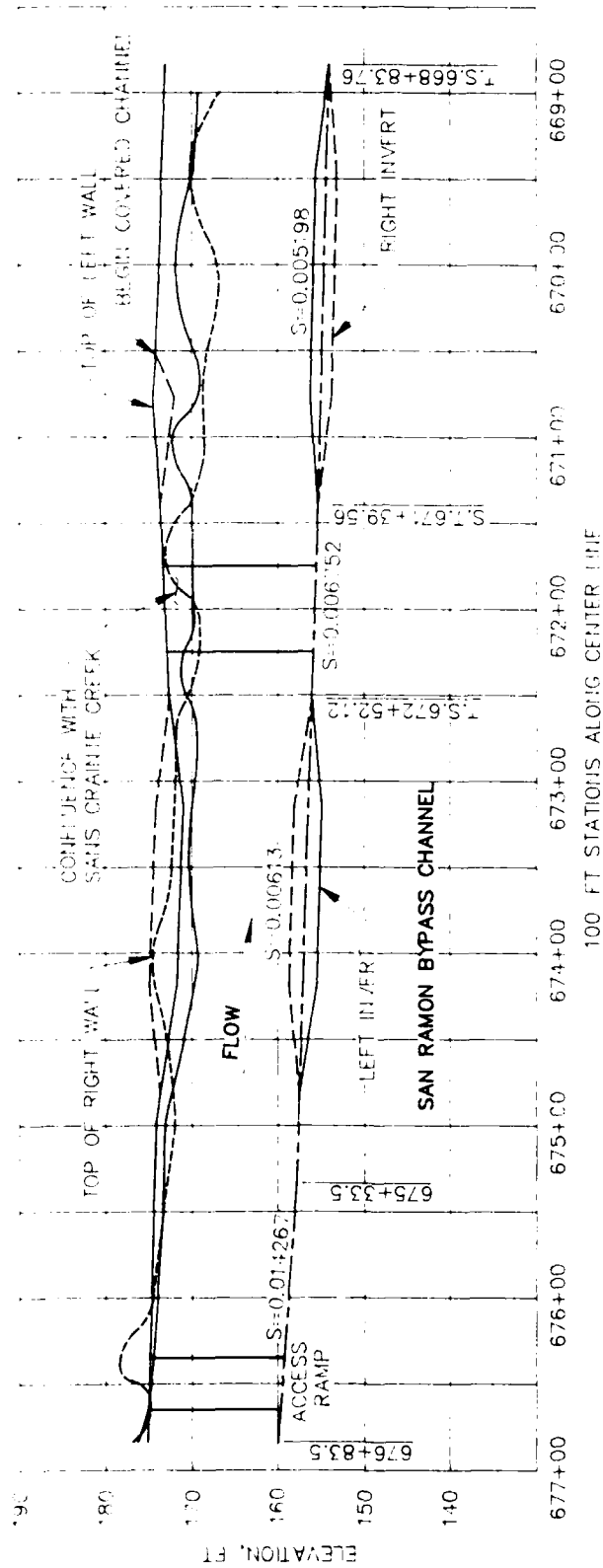


LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL

WATER-SURFACE PROFILES

SAN RAMON CHANNEL 13,200 cfs
 SANS CRAINTE CREEK 1,700 cfs
 ORIGINAL DESIGN
 $n=0.012$

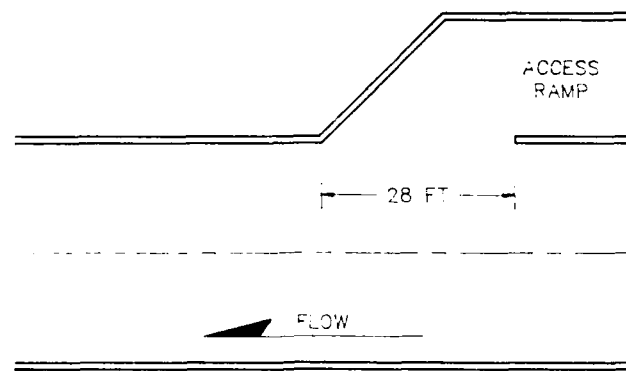


LEGEND

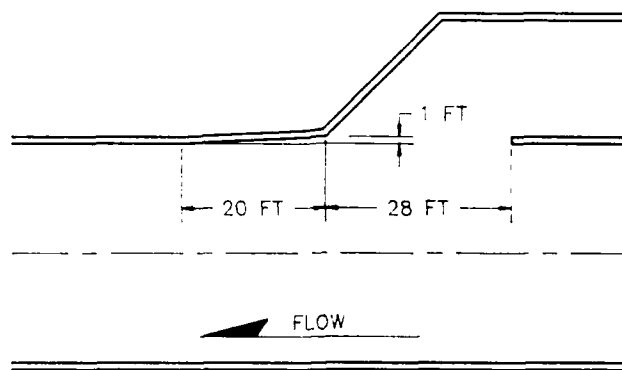
— LEFT SIDE OF CHANNEL
- - - RIGHT SIDE OF CHANNEL

WATER-SURFACE PROFILES

SAN RAMON CHANNEL 15,000 cfs
SANS CRAINTE CREEK 200 cfs
ORIGINAL DESIGN
 $n=0.012$

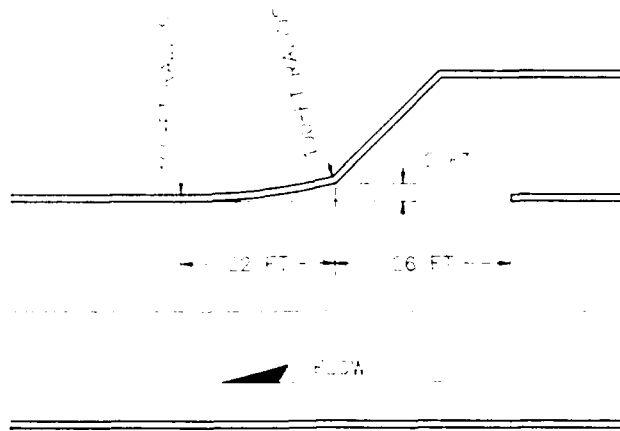


TYPE 1 (ORIGINAL) DESIGN

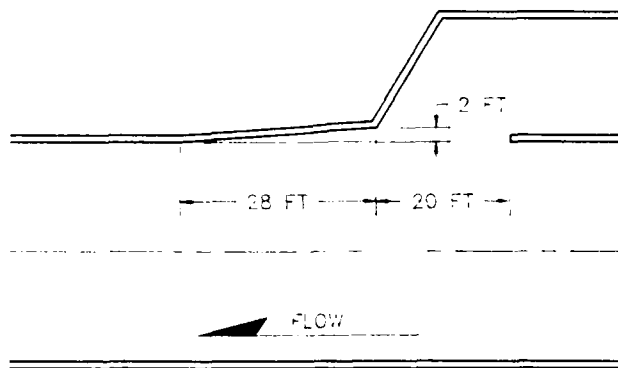


TYPE 2 DESIGN

DETAILS OF ACCESS RAMP ENTRANCE
TYPES 1 AND 2 DESIGN ACCESS

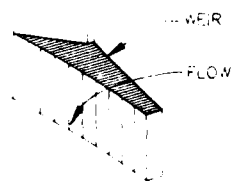
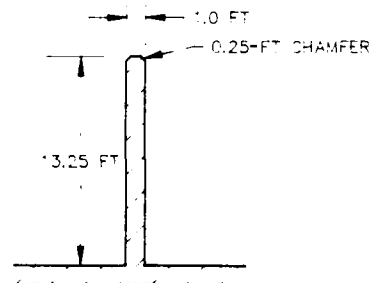
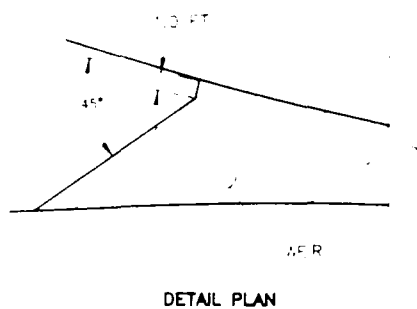
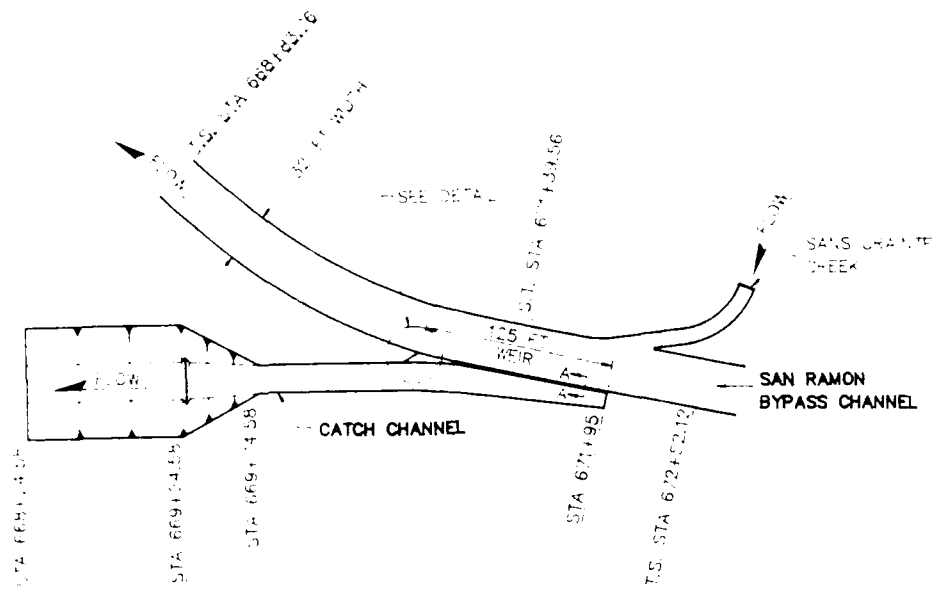


TYPE 3 DESIGN

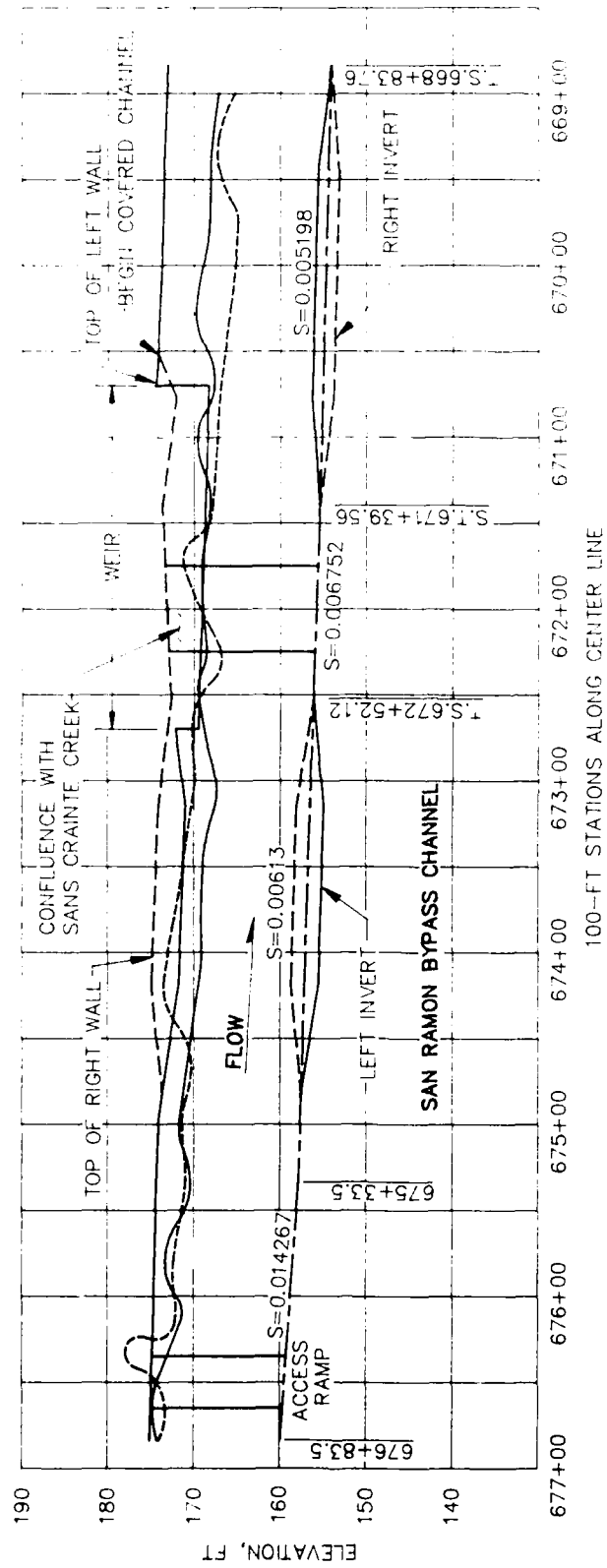


TYPE 4 DESIGN

DETAILS OF ACCESS RAMP ENTRANCE TYPES 3 AND 4 DESIGN ACCESS



WEIR DETAILS

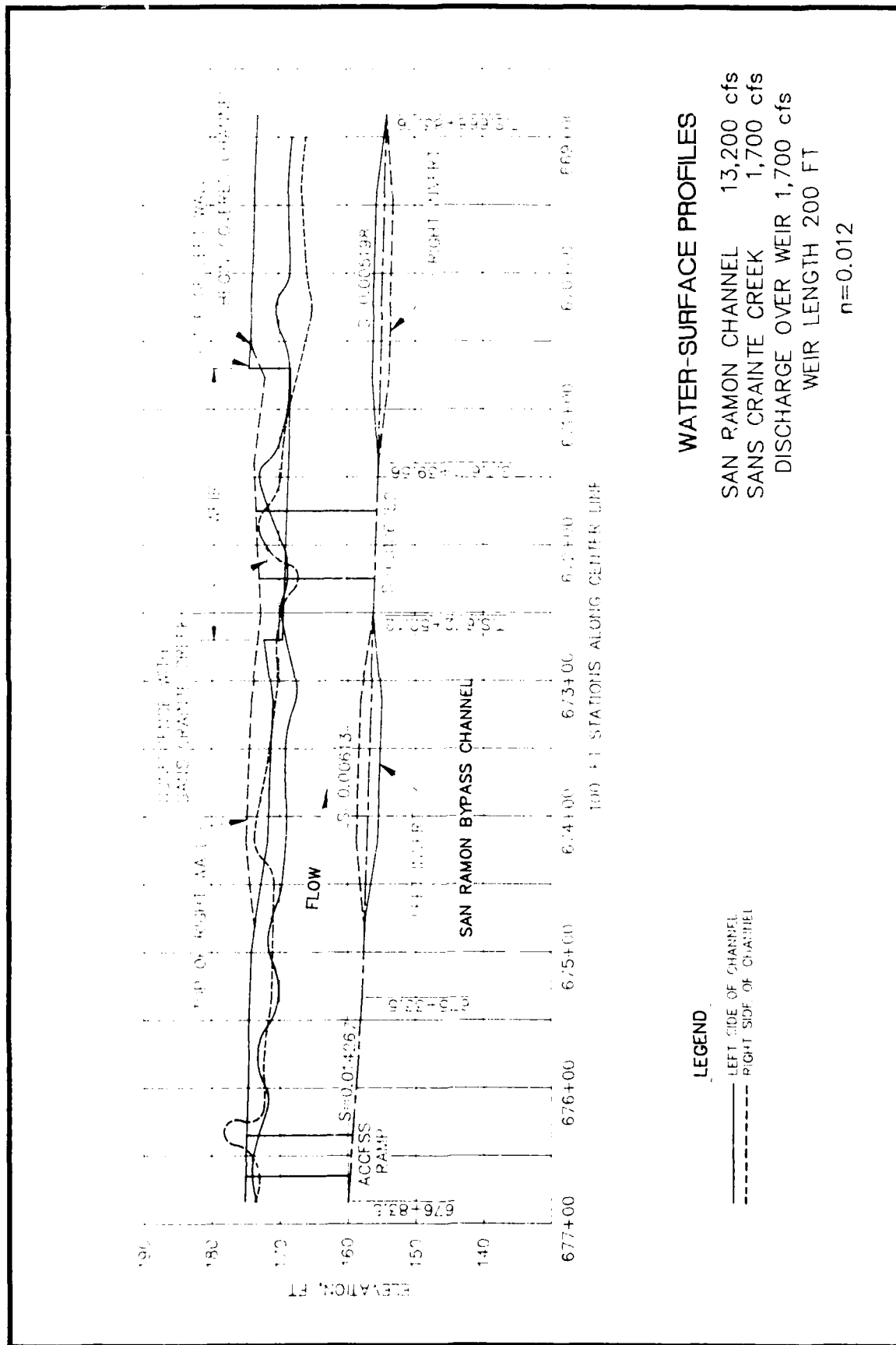


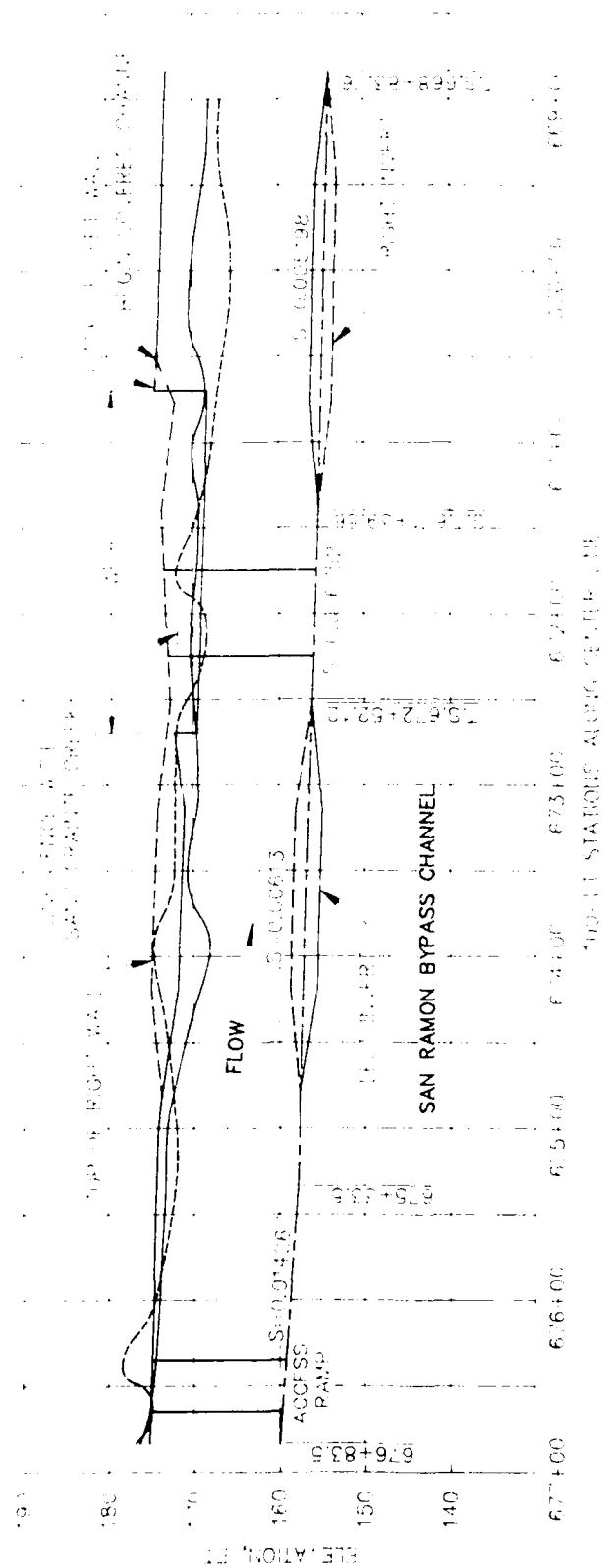
WATER-SURFACE PROFILES

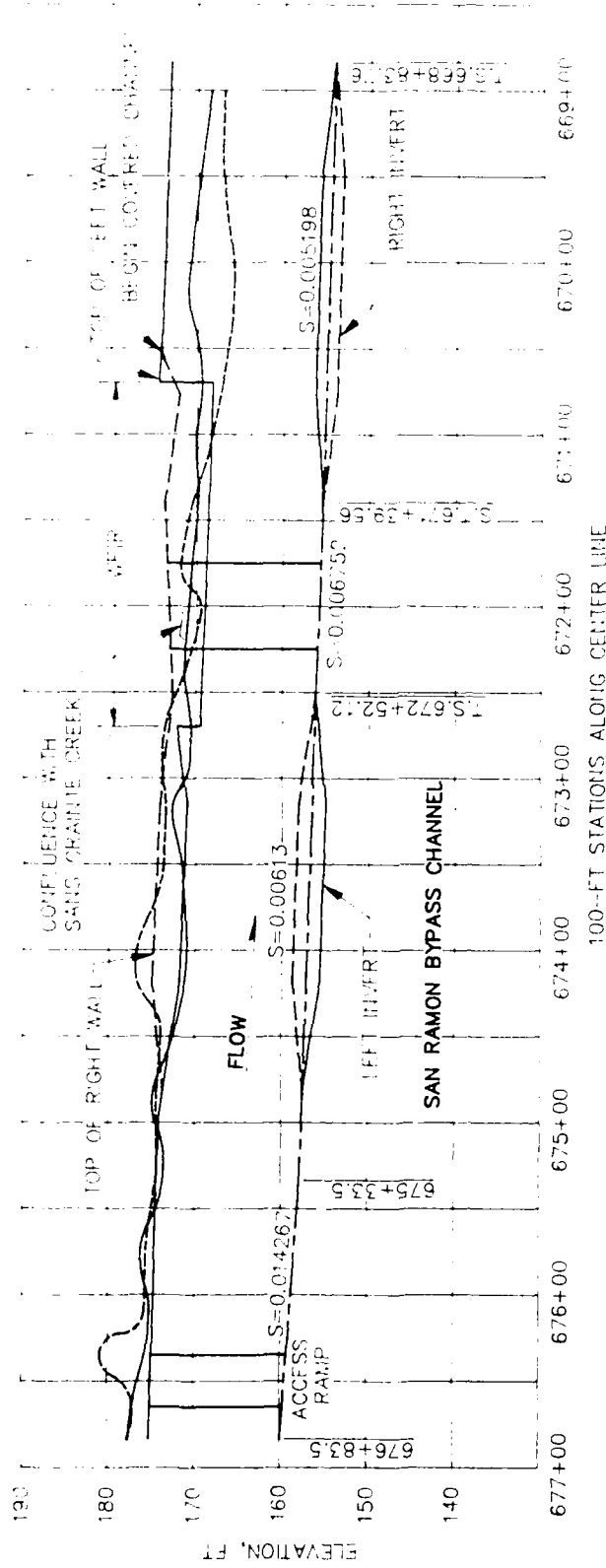
SAN RAMON CHANNEL 13,000 cfs
 SANS CRAINTE CREEK 200 cfs
 DISCHARGE OVER WEIR 200 cfs
 WEIR LENGTH 200 FT
 n=0.012

LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL





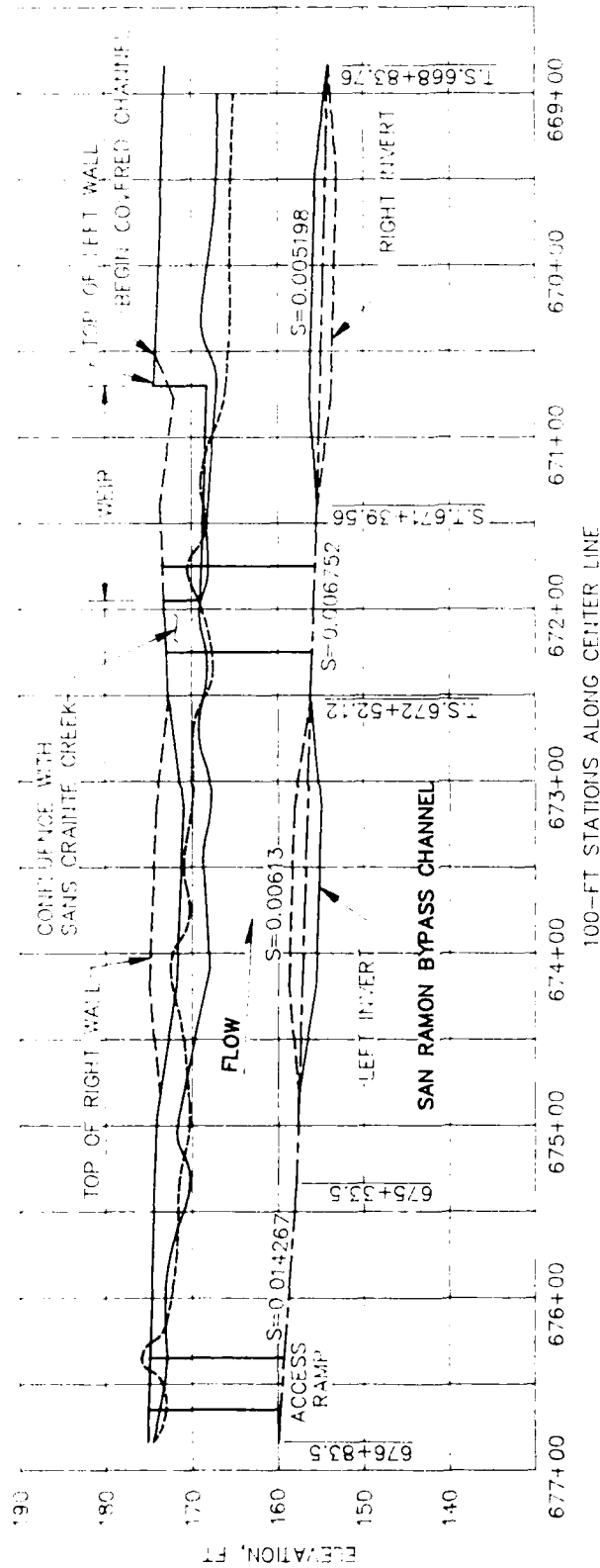


WATER-SURFACE PROFILES

SAN RAMON CHANNEL 17,200 cfs
 SANS CRAINTE CREEK 300 cfs
 DISCHARGE OVER WEIR 1,950 cfs
 WEIR LENGTH 200 FT
 n=0.012

LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL

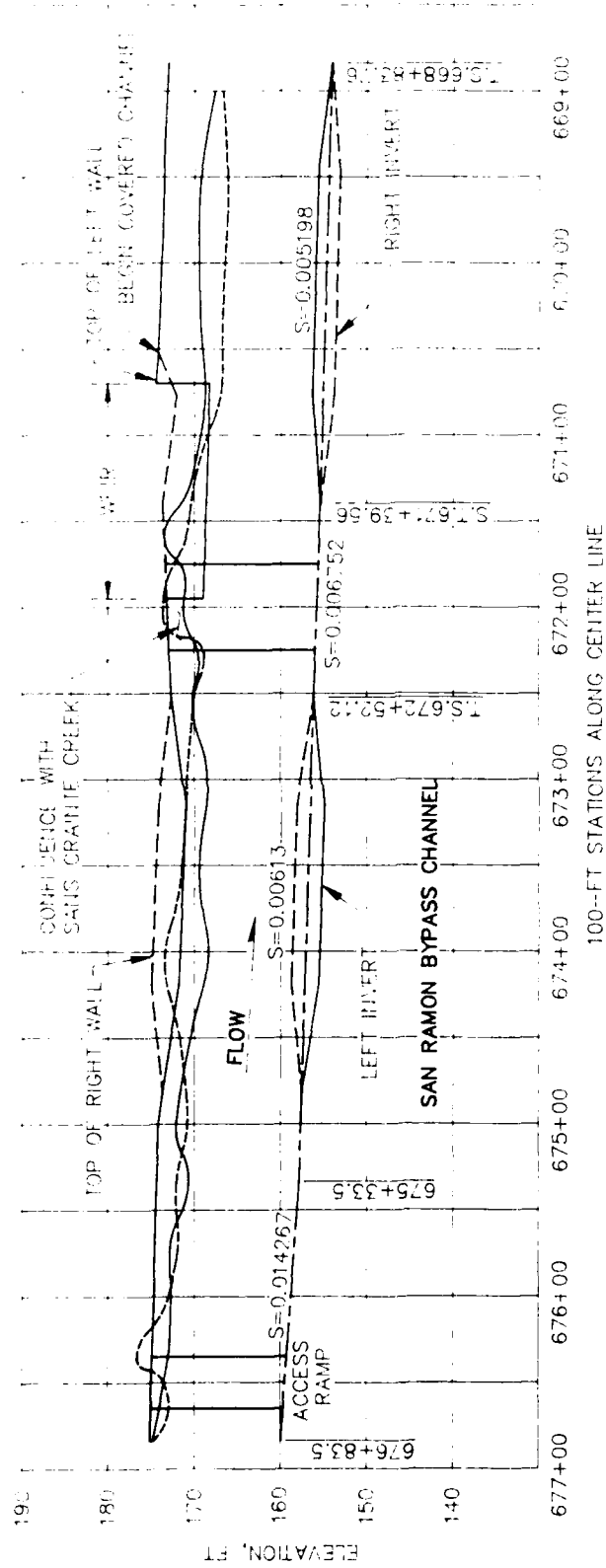


WATER-SURFACE PROFILES

SAN RAMON CHANNEL 13,000 cfs
 SANS CRAINTE CREEK 200 cfs
 DISCHARGE OVER WEIR 300 cfs
 WEIR LENGTH 125 FT
 $n=0.014$

LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL

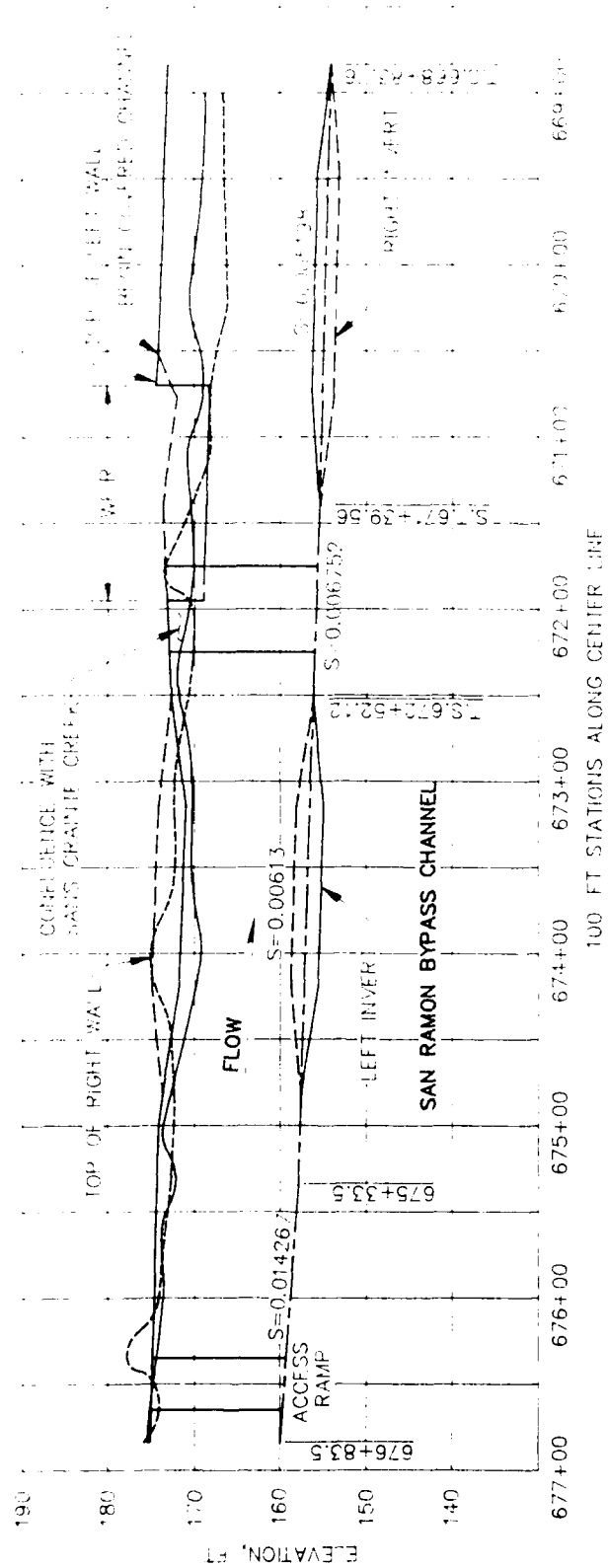


WATER-SURFACE PROFILES

SAN RAMON CHANNEL 13,200 cfs
 SANS CRAINTE CREEK 1,700 cfs
 DISCHARGE OVER WEIR 1,850 cfs
 WEIR LENGTH 125 FT
 $n=0.014$

LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL

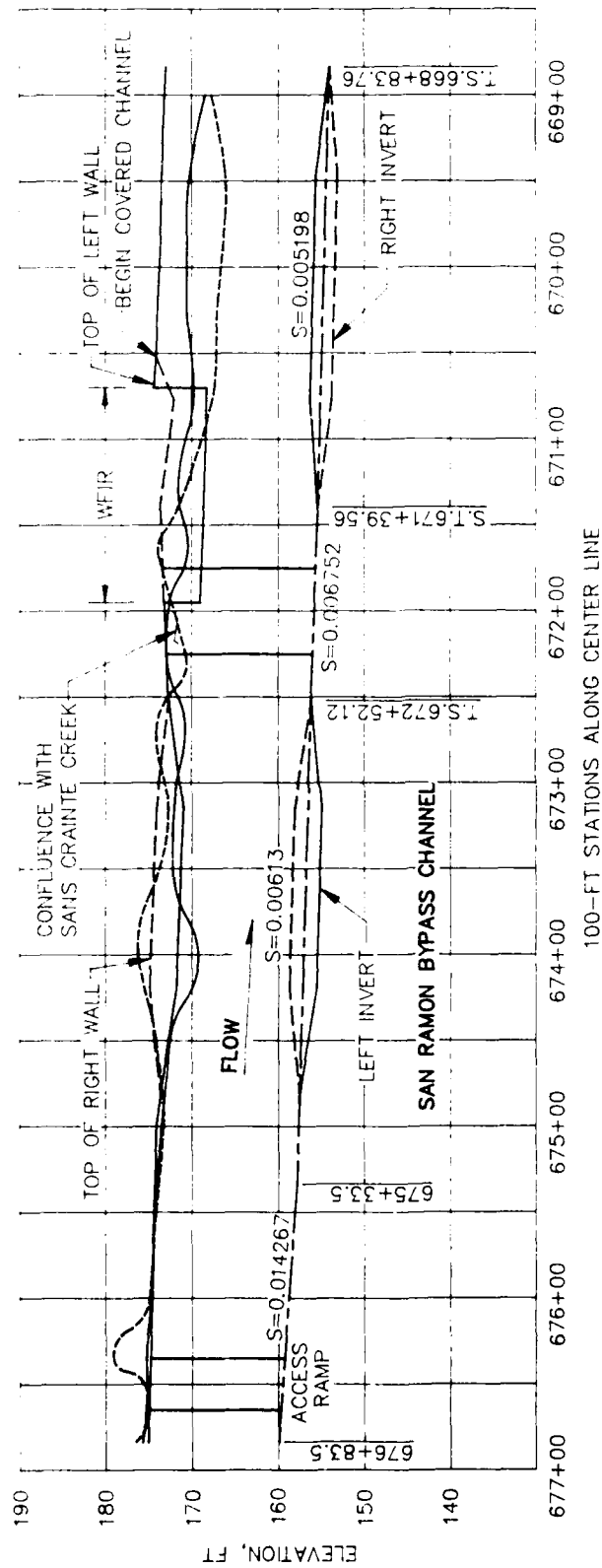


WATER-SURFACE PROFILES

SAN RAMON CHANNEL 15,000 cfs
 SANS CRAINTE CREEK 200 cfs
 DISCHARGE OVER WEIR 950 cfs
 WEIR LENGTH 125 FT
 $n=0.014$

LEGEND

— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL

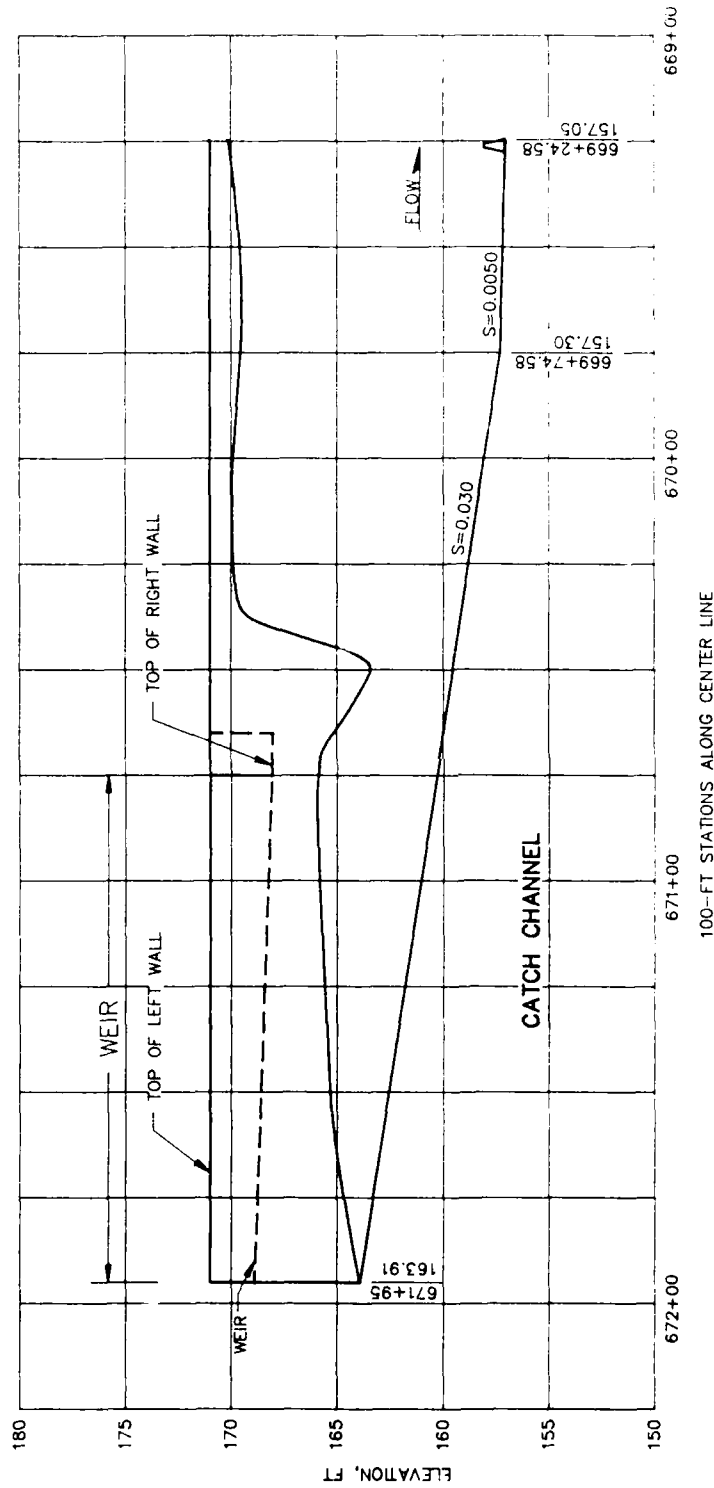


WATER-SURFACE PROFILES

SAN RAMON CHANNEL 17,200 cfs
 SANS CRAINTE CREEK 300 cfs
 DISCHARGE OVER WEIR 1,900 cfs
 WEIR LENGTH 125 FT
 $n=0.014$

LEGEND

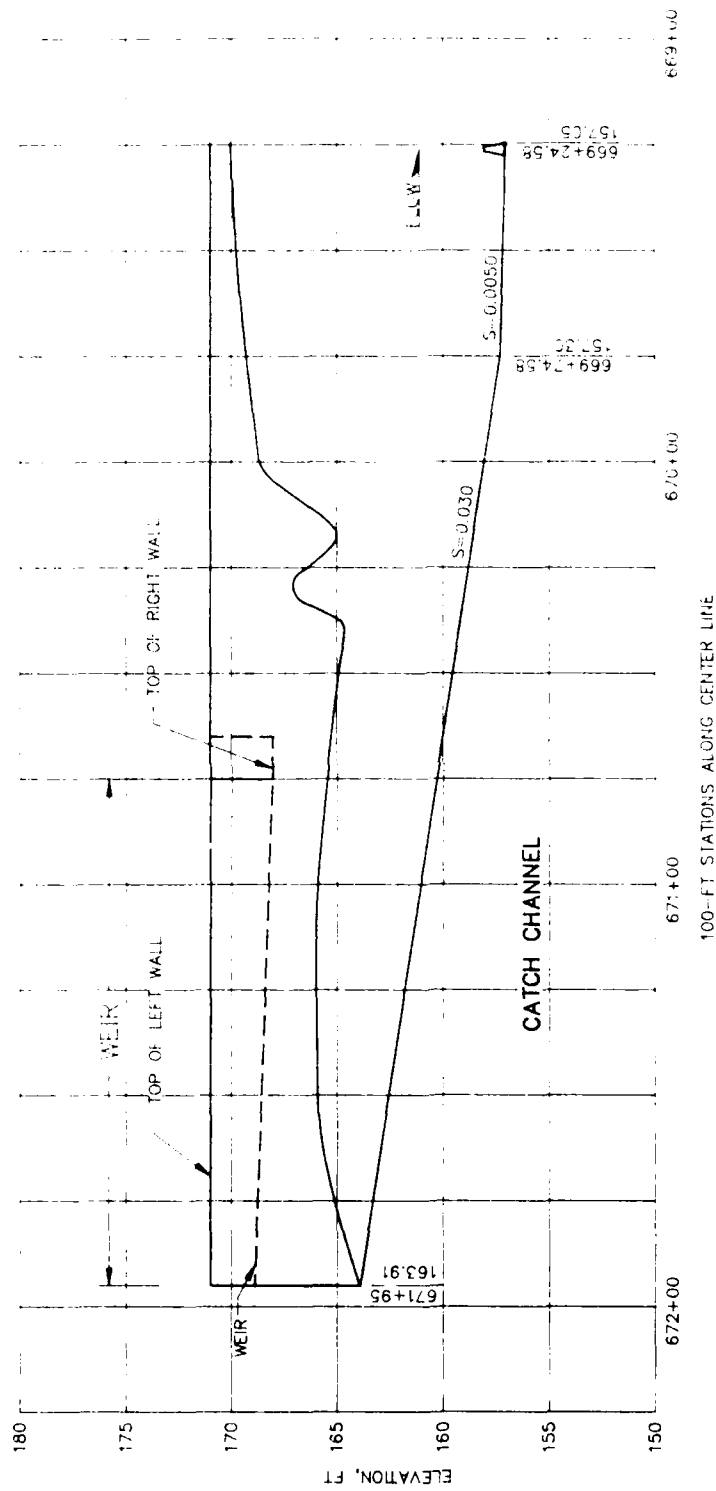
— LEFT SIDE OF CHANNEL
 --- RIGHT SIDE OF CHANNEL



NOTE: PROFILE MEASURED ALONG LEFT WALL
LOOKING DOWNSTREAM

WATER-SURFACE PROFILES

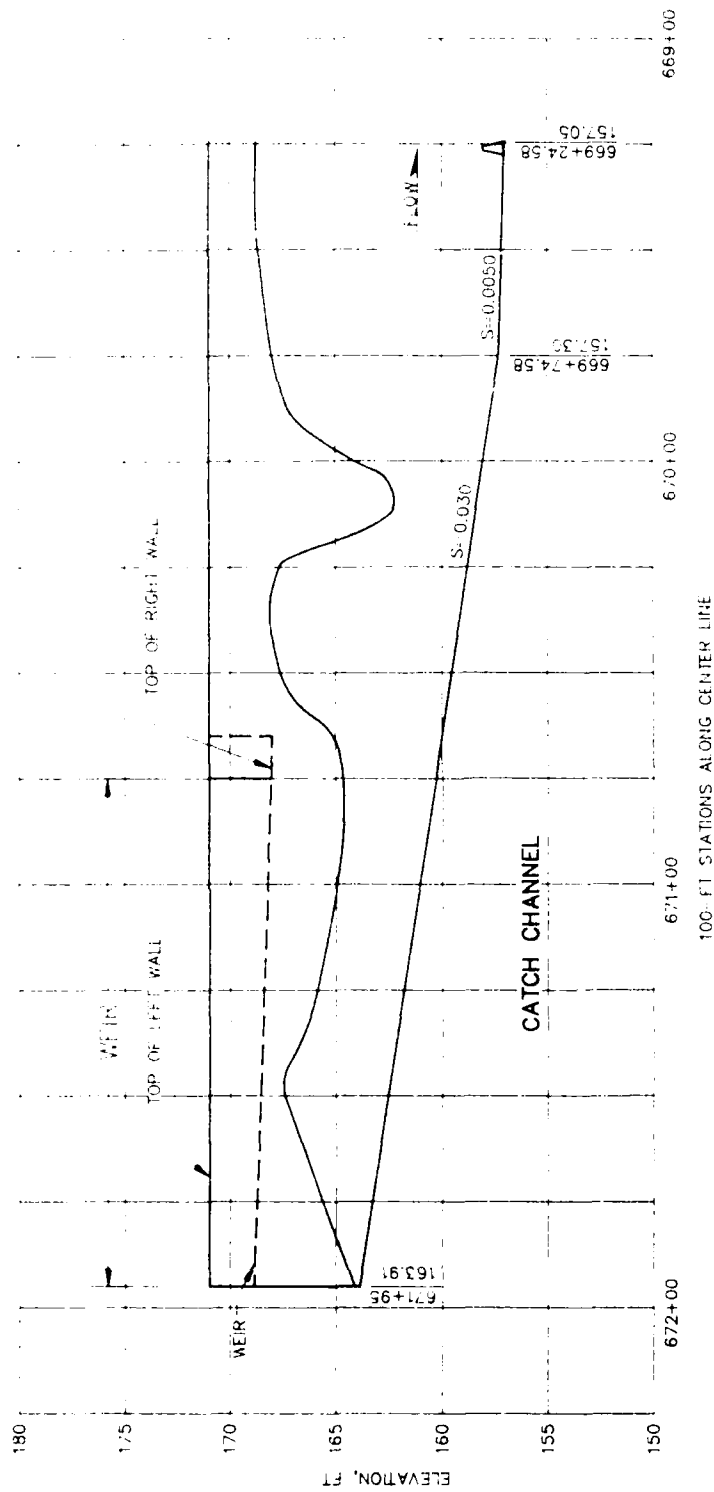
SAN RAMON CHANNEL 16,500 cfs
SANS CRAINTE CREEK 300 cfs
DISCHARGE OVER WEIR 1,600 cfs
TAILWATER EL 170.4



WATER-SURFACE PROFILES

SAN RAMON CHANNEL 17,200 cfs
 SANS CRAINTE CREEK 300 cfs
 DISCHARGE OVER WEIR 1,900 cfs
 TAILWATER EL 169.9

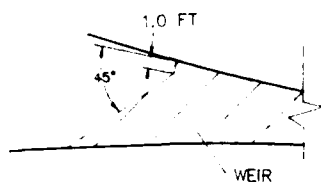
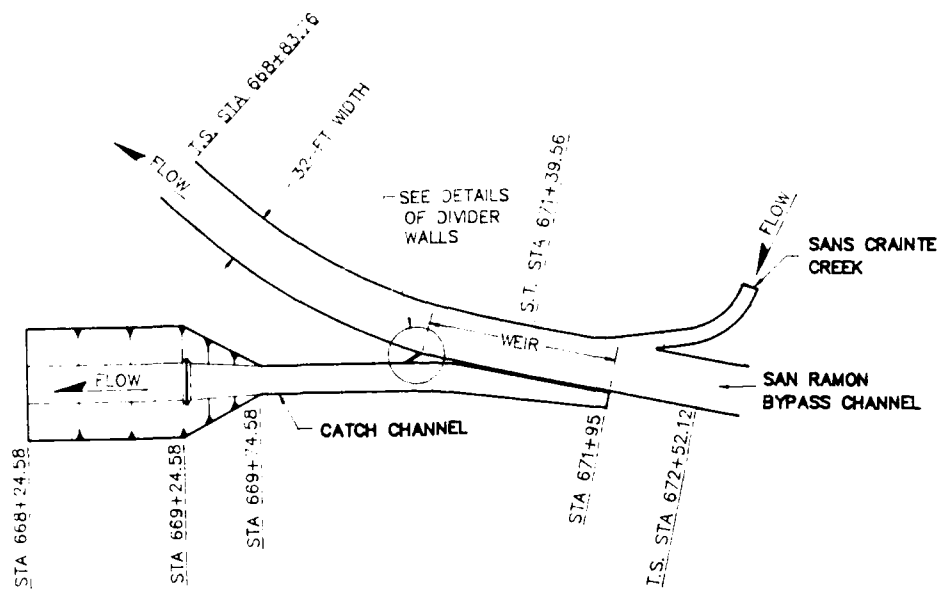
NOTE: PROFILE MEASURED ALONG LEFT WALL
 LOOKING DOWNSTREAM



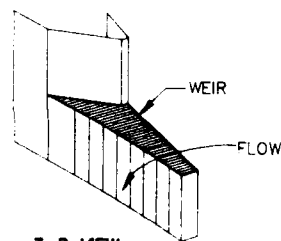
WATER-SURFACE PROFILES

SAN RAMON CHANNEL 19,000 cfs
 SANS CRAINTE CREEK 300 cfs
 DISCHARGE OVER WEIR 2,300 cfs
 TAILWATER EL 168.7

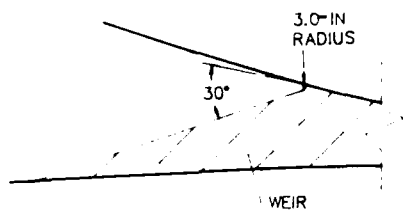
NOTE: PROFILE MEASURED ALONG LEFT WALL
 LOOKING DOWNSTREAM



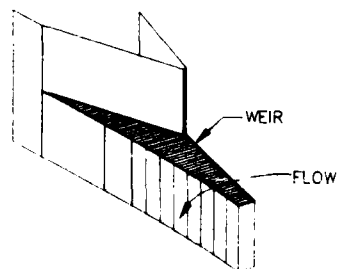
PLAN VIEW
TYPE 1 DIVIDER



3-D VIEW
TYPE 1 DIVIDER



PLAN VIEW
TYPE 3 DIVIDER



3-D VIEW
TYPE 3 DIVIDER

DETAILS OF TYPES 1 AND 3 DESIGN DIVIDER WALLS