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July 1993

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Berryessa Creek Channel Junctions, Santa Clara County, California

Hydraulic Model Investigation

by W. Glenn Davis
Hydraulics Laboratory

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Prepared for U.S. Army Engineer District, Sacramento

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Waterways Experiment Station
3909 Halls Ferry Road
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Final report

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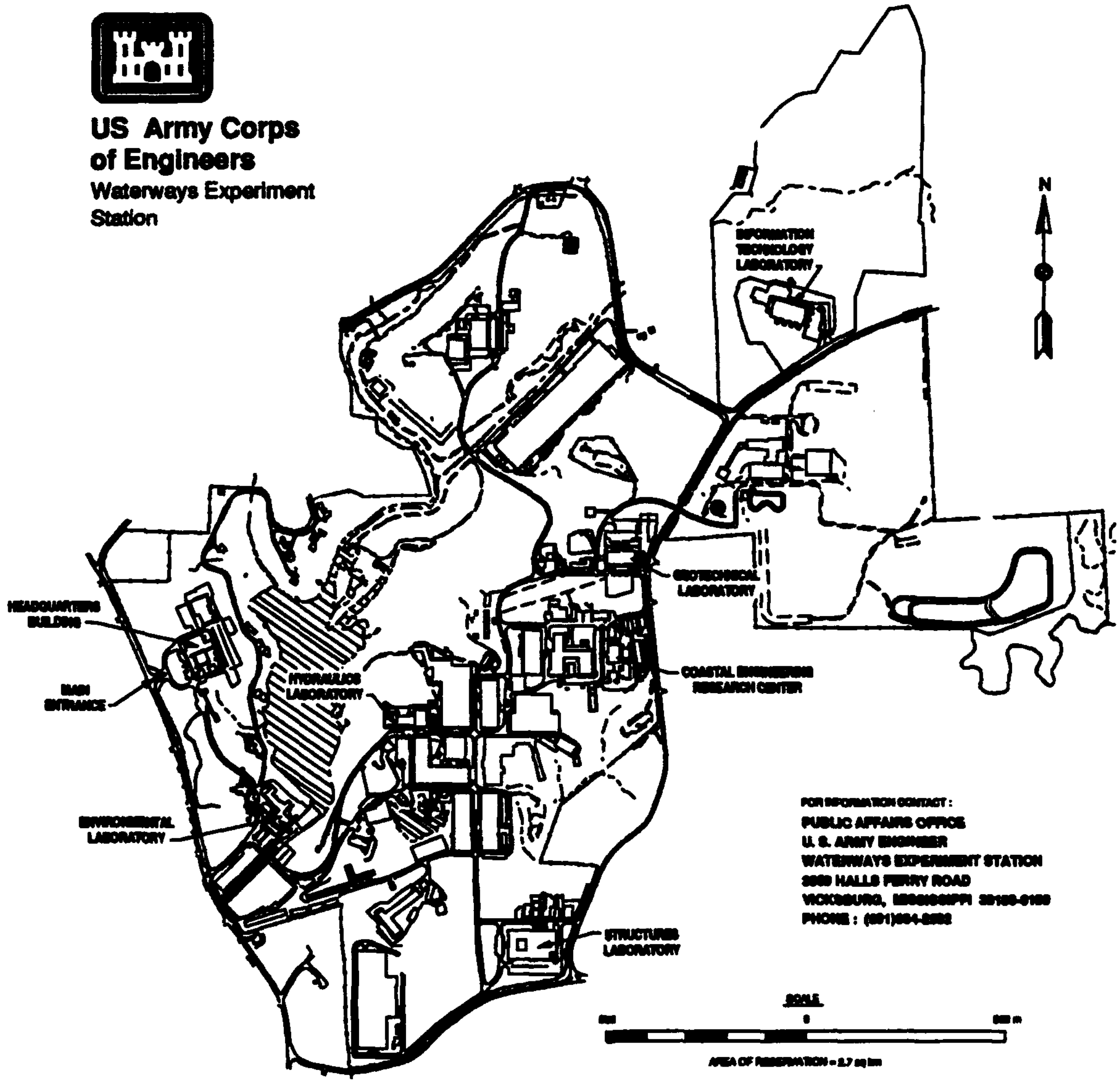
Prepared for U.S. Army Engineer District, Sacramento
1325 J Street, Sacramento, CA 95814-2922

US Army Corps of Engineers
Waterways Experiment Station



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Contents

Preface

The model investigation reported herein was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), on 3 September 1991 at the request of the U.S. Army Engineer District, Sacramento (SPK).

The studies were conducted by personnel of the Hydraulics Laboratory (HL), U.S. Army Engineer Waterways Experiment Station (WES), during the period September 1991 to December 1991. All studies were conducted under the direction of Messrs. F. A. Herrmann, Jr., Director, HL; R. A. Sager, Assistant Director, HL; and G. A. Pickering, Chief, Hydraulic Structures Division (HSD), HL. The tests were conducted by Messrs. V. E. Stewart, Sr., M. W. Ott, and 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.

The models were constructed by Messrs. Ed A. Case, C. H. Hopkins, and Joe A. Lyons under the supervision of Mr. Sid Leist, Engineering and Construction Services Division, WES.

During the course of the investigation the following personnel visited WES to observe model operation, discuss test results, and correlate these results with concurrent design work: Mr. Frank Khroun of the U.S. Army Engineer Division, South Pacific, and Messrs. Ed Sing and Dan Pridal of SPK.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

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

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
inches	25.4	millimeters
miles (U.S. statute)	1.609344	kilometers

1 Introduction

The Prototype

The Berryessa Creek flood control project is designed to provide 100-year flood protection to portions of Santa Clara County, California (Figure 1). Berryessa Creek flows through the rapidly urbanizing area of the city of Milpitas. The project reach extends approximately 4 miles[1] from its upstream limit near Old Piedmont Road (foothill line) downstream to Calaveras Boulevard where it joins an existing flood control channel constructed by the project's local sponsor, the Santa Clara Valley Water District (SCVWD).

The model studies were concerned primarily with the channel junctions of Berryessa Creek and three of its major tributaries.

Purpose of Model Studies

The purpose of the model investigation was to evaluate the performance of the proposed designs and develop desirable modifications, if needed, to safely pass the 100-year-frequency discharges through three channel junctions of Berryessa Creek and three of its major tributaries. These tributaries will enter the main channel either at a right angle or a sharp angle with a small radius of curvature. Specifically, the Sierra Creek, Los Coches Creek, and Piedmont Creek junctions with Berryessa Creek were investigated. Flow conditions at the Sierra junction are expected to be supercritical flow and are complicated by the need to transition through an existing box culvert less than 100 ft downstream from the junction. Flow conditions at the Los Coches and Piedmont Creek junctions are expected to be high velocity, but subcritical, on both the main channel and tributaries of each junction. Physical model studies of these junctions were desired because of the possibility of significant cross waves and turbulence generated at the junctions, which could reduce flow conveyance. Also, the problem of the lack of available design guidance for sharp angle, low radius of curvature flow junctions, and the deficiencies of analytical methods

[1] A table of factors for converting non-SI units of measurement to SI units is found on page v.

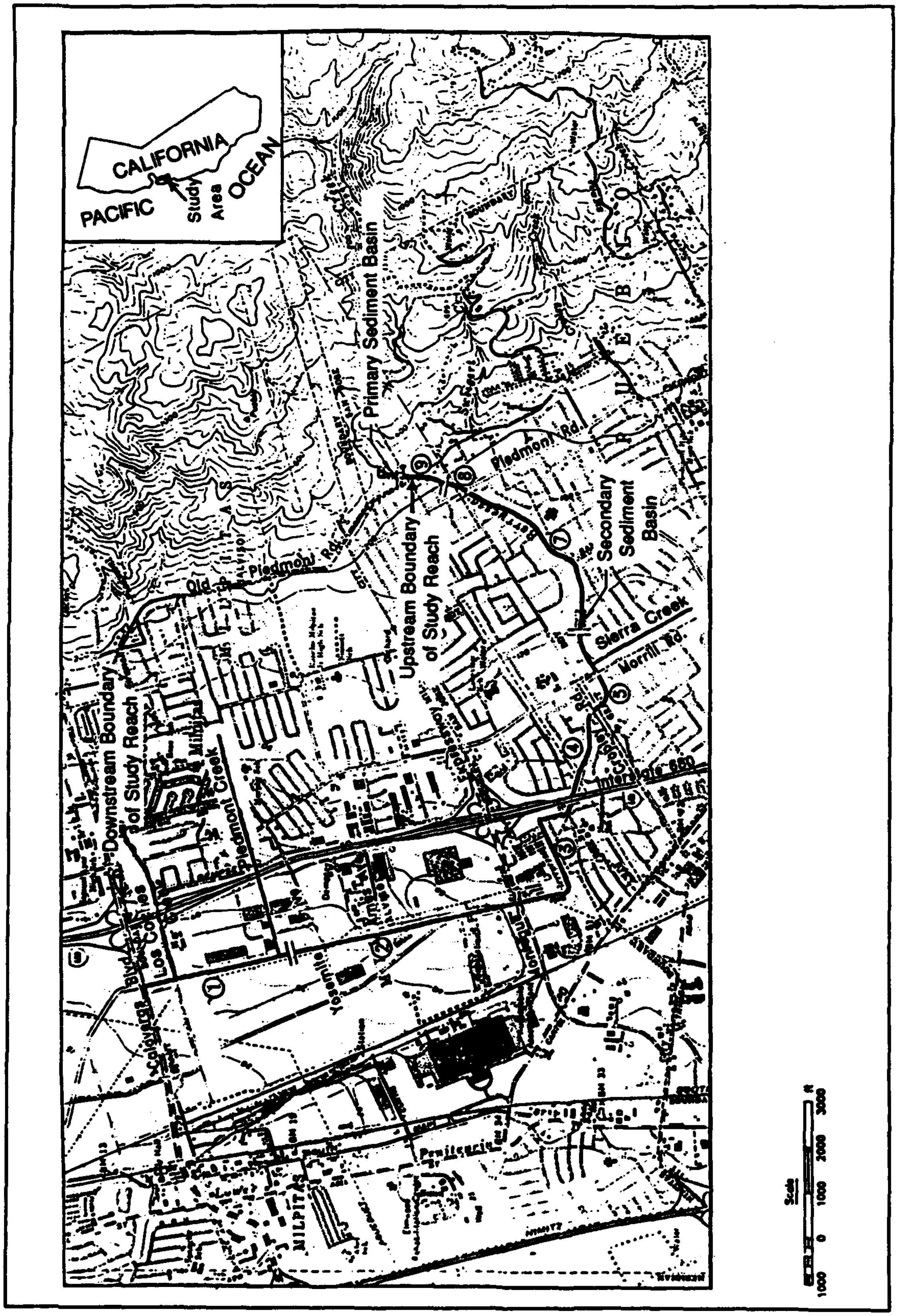


Figure 1. Location map

for estimating hydraulic losses at such junctions dictated the need for the physical model studies. Specifically the model studies were to determine the following:

a. Flow conditions and water-surface profiles throughout the Sierra junction model for a range of discharges for Manning's n roughness values of 0.014 and 0.012.

b. Flow conditions resulting from expansions, contractions, confluence, and bridge piers.

c. Effective methods for modifying the channels to increase the hydraulic capacity and improve flow conditions.

2 The Models

Description

Berryessa/Sierra Junction

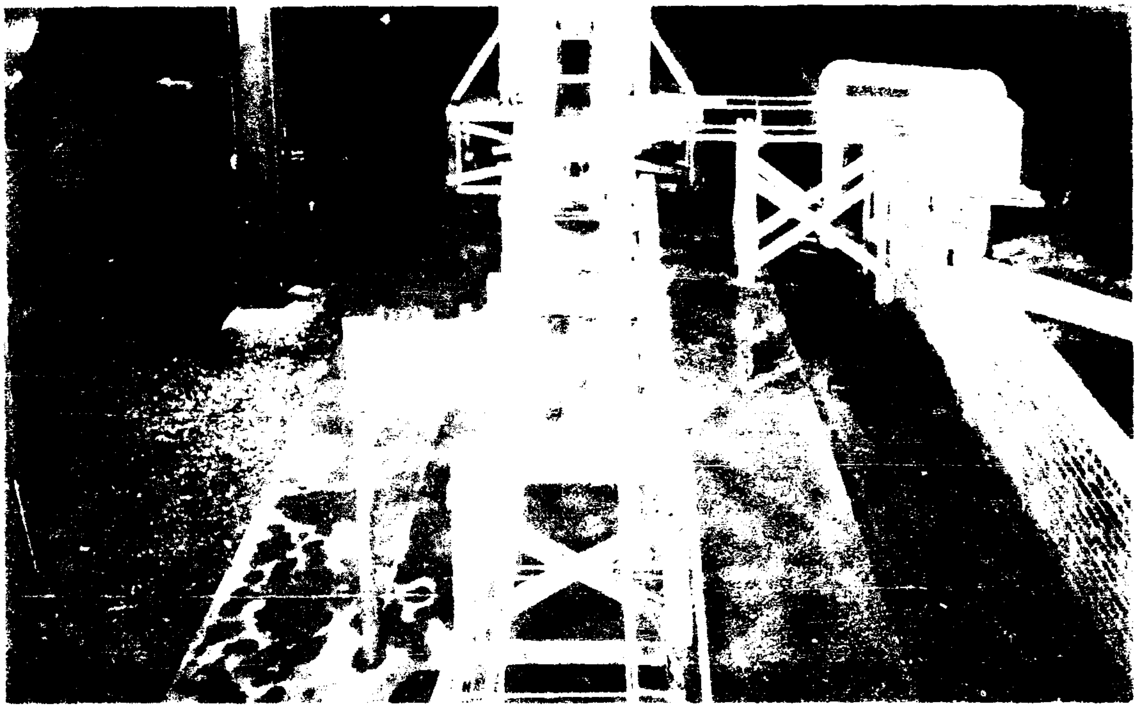
The 1:16-scale model of the Berryessa/Sierra Creek junction reproduced approximately 500 ft of the Berryessa channel (170 ft upstream from the junction) and 200 ft of the Sierra channel. A general plan and profiles of the modeled reach are provided in Plates 1 and 2, respectively.[1] Dry-bed photographs of the model are shown in Figure 2.

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 0.0143. The *n* value used in the design and analysis of the prototype channels for the Berryessa/Sierra Junction 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.

Berryessa/Los Coches Junction

A 1:20-scale model of the Berryessa/Los Coches creek junction reproduced approximately 600 ft of the Berryessa channel and 200 ft of the Los Coches channel. The channels were constructed of plastic-coated plywood and installed on a tilting flume enabling the invert slopes to be adjusted to reproduce an energy gradient equivalent to that resulting from a Manning's roughness coefficient *n* of 0.016 in the prototype. This was the only roughness value simulated for this study and the Berryessa/Piedmont Junction study. A general plan and profile of the modeled reach are provided in Plates 3 and 4, respectively. Dry-bed photographs of the model are shown in Figure 3.

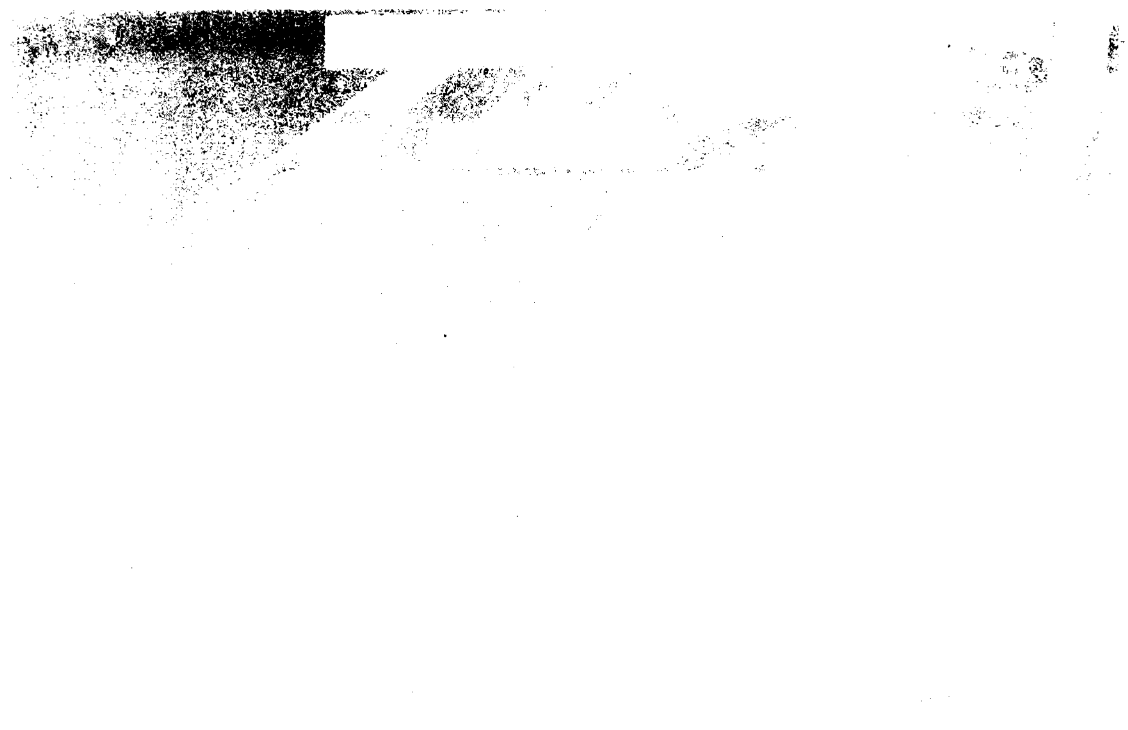
[1] All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).



a. Looking upstream

b. Looking downstream

Figure 2. The Berryessa/Sierra channel junction model (Continued)



c. Morrill Avenue box culvert

Figure 2. (Concluded)

Berryessa/Piedmont Junction

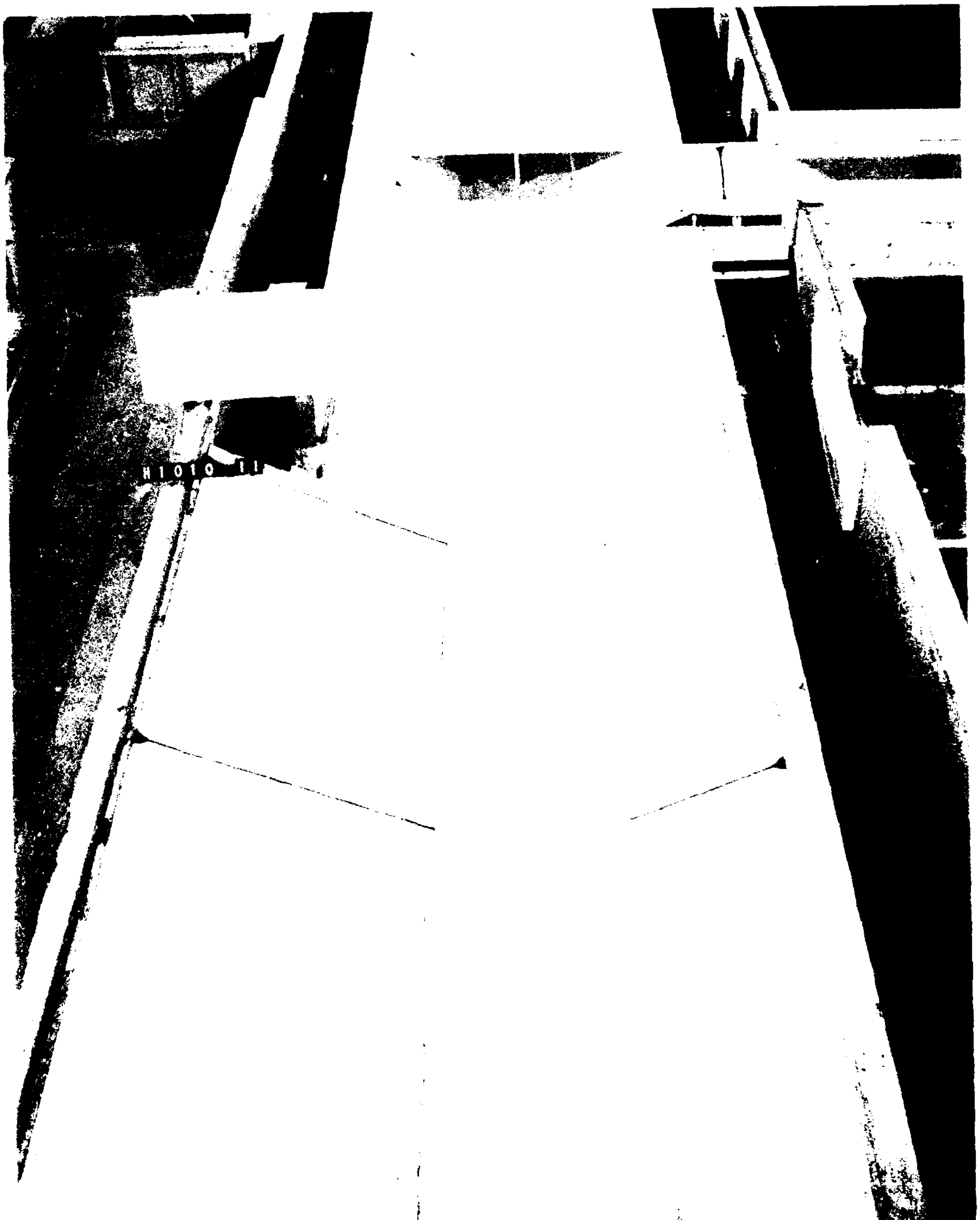
The Los Coches model was modified to simulate the Piedmont junction at a 1:20 scale. These modifications included removing the bridge and pier, removing the constriction from sta 108+30 to sta 109+05, and increasing the invert elevation of the tributary channel to a height of 8.5 ft above the Berryessa invert. A general plan view of the modeled reach is provided in Plate 5.

Model Appurtenances

Water used in the operation of the models was supplied by a circulating system. Discharges in the models, measured with venturi meters and commercial paddle wheel flowmeters, were baffled when entering the models. Water-surface elevations were measured with point gages. Velocities were measured with commercial meters mounted to permit measurement of flow from any direction and at any depth. Tailwater elevations in the lower end of the Los Coches and Piedmont junction models were maintained at the desired depth by means of an adjustable tailgate. Different designs, along with various flow conditions, were recorded photographically.

a. Looking upstream

Figure 3. The Berryessa/Los Coches junction model (Sheet 1 of 3)



b. Looking downstream

Figure 3. (Sheet 2 of 3)

c. Junction

Figure 3. (Sheet 3 of 3)

Scale Relations

The accepted equations of hydraulic similitude, based on the Froudian criteria, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for transference of model data to prototype equivalents are presented in the following tabulation:

Characteristic	Dimension[1]	Model:Prototype	
		Berryessa/Sierra	Berryessa/Los Coches Berryessa/Piedmont
Length	$L_r=L$	1:16	1:20
Area	$A_r=L_r^2$	1:256	1:400
Velocity	$V_r=L_r^{1/2}$	1:4	1:4.472
Discharge	$Q_r=L_r^{5/2}$	1:1,024	1:1,788.854
Time	$T_r=L_r^{1/2}$	1:4	1:4.472

[1]Dimensions are in terms of length.

Measurements in the model of discharges, water-surface elevations, and velocities can be transferred quantitatively from model to prototype equivalents by means of these scale relations.

3 Tests and Results

Berryessa/Sierra Junction

Tests were conducted to observe general flow conditions and determine the adequacy of the proposed channel improvements for the Berryessa Creek channel and its junction with Sierra Creek. 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 project. Therefore, tests were conducted to simulate the energy gradient resulting from both *n* values (0.012 and 0.014).

The invert slopes of the channels initially tested were adjusted to reproduce an energy gradient resulting from a Manning's n roughness coefficient of 0.014 in the prototype. Water-surface profiles measured with total discharges of 670, 2,180, and 2,680 cfs (design discharge) are provided in Plates 6-8. The distribution of flow between Berryessa Creek and Sierra Creek for these discharges was 100 and 570 cfs; 2,130 and 50 cfs; and 2,130 and 550 cfs, respectively. Flow was contained within the channel walls for all discharges tested up to the design discharge. The wall heights shown on the profile plates were provided by the U.S. Army Engineer District, Sacramento. The model walls were constructed taller to ensure that all flow was confined to the channel. Flow conditions with the design discharge of 2,680 cfs are shown in Photo 1.

Velocities recorded at the junction are shown in Plate 9. Water-surface differentials between the left and right walls of the channel occurred in the vicinity of the junction for each flow condition tested. These differentials resulted from cross waves created by the abrupt width expansion at the junction, the change in wall alignment on the left wall due to the width transition beginning at sta 247+80, and the differences in depth and energy between Berryessa and Sierra Creeks entering the junction.

At the entrance to the Morrill Avenue box culvert, the high-velocity flow struck the bridge pier causing flow separation and spray. It should be noted that this disturbance was very localized and did not significantly affect channel capacity for discharges up to the design flow. A radial pier nose extension (type 2 design pier nose, Plate 10) installed on the original pier did not significantly improve flow conditions. The bridge pier was then modified by adding a triangular pier extension (type 3 design pier nose, Plate 10). This pier nose design virtually eliminated the flow separation and spray caused by the original flat pier nose. Flow conditions at the entrance to the box culvert for the design discharge with the original pier and with the type 3 pier nose are provided in Photos 2a and 2b, respectively.

Tests were conducted to determine the discharge that would cause the box culvert to prime (flow full) with the type 3 pier nose installed. The discharge in Berryessa Creek was held constant at 2,670 cfs while the flow in Sierra Creek was gradually increased to 700 cfs (3,370 cfs total, 690 cfs higher than the design discharge). This combination of discharges caused the box culvert to prime. The left side of the culvert initially primed due to the reflected cross waves from the junction. Once the culvert primed, a hydraulic jump formed upstream from the culvert. The toe of the jump occurred upstream from the junction. The downstream sequent depth of the jump was higher than the proposed wall heights in Berryessa upstream from the Morrill Avenue box culvert. The jump also resulted in the flow in Sierra Creek increasing to a depth that was higher than the proposed wall heights. This flow condition is shown in Photo 3 and water-surface profiles are provided in Plate 11. To determine the discharge at which the box culvert would again reach free-surface flow, the discharge in Sierra Creek was gradually reduced from 700 cfs while maintaining 2,670 cfs in Berryessa Creek. Test results indicated that the flow in Sierra Creek had to be reduced to zero before free-surface flow was again achieved in the box culvert.

The invert slopes of the model were adjusted to reproduce the energy gradient for a roughness coefficient (Manning's n) of 0.012. Water-surface profiles recorded with combined discharges of 670, 2,180, and 2,680 cfs are shown in Plates 12-14, respectively. Again, cross waves were present in the vicinity of the junction, as discussed previously for an n value of 0.014. Flows were contained within the channel walls for all discharges tested up to the design discharge. Due to discharge limitations in the model, the box culvert would not prime with the lower n value. The maximum discharge tested was 2,670 cfs in Berryessa and 1,100 cfs in Sierra, for a total discharge of 3,770 cfs (1,090 cfs higher than the design discharge).

Water-surface elevations for the various flow conditions and the different n values tested are tabulated in Tables 1-7. As expected, water-surface elevations were slightly higher with the higher n value, and flow velocities and waves created by disturbances were slightly higher with the lower n value.

Berryessa/Los Coches Junction

Water-surface profiles measured through the Berryessa Creek and Los Coches Creek junction with total discharges of 1,630, 3,570, 4,780 (design discharge), and 5,800 cfs are provided in Plates 15-18, respectively. The distribution of flow between Berryessa Creek and Los Coches Creek for these discharges was 100 and 1,530 cfs; 3,470 and 100 cfs; 3,470 and 1,310 cfs; and 4,210 and 1,590 cfs, respectively. Flow conditions with the design discharge of 4,780 cfs are shown in Photo 4. Water-surface elevations measured, which are tabulated in Tables 8-11, were compared with Sacramento District's computed values for the design discharge. The measured elevations were approximately 1.0 ft lower than the computed and occurred upstream from the junction from sta 109+00 to sta 111+00. This indicated that less head loss occurred in the model at the transition and junction than was used by Sacramento District to compute the profile. Flow was contained within the channel walls for all discharges tested for a Manning's n value of 0.016.

Berryessa/Piedmont Junction

Two flow conditions were documented at the Berryessa Creek and Piedmont Creek junction: (a) 100 cfs in Berryessa and 600 cfs in Piedmont and (b) 2,970 cfs in Berryessa and 500 cfs in Piedmont. Satisfactory flow conditions were observed for both conditions tested with water-surface elevations lower than proposed channel slope heights for a Manning's n value of 0.016. Water-surface profiles and the corresponding elevations are provided in Plates 19 and 20 and Tables 12 and 13, respectively.

4 Conclusions

Tests to determine the adequacy of channel improvements for the Berryessa/Sierra Creek junction indicated that the original design would effectively convey the design flow conditions, and with minor modifications, flow conditions could be improved.

It was anticipated that the Manning's n roughness coefficient of the prototype concrete-lined channel at the Berryessa/Sierra Creek junction 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 higher n value, and flow velocities and waves created by disturbances would be slightly higher with the lower n value. Thus, tests were conducted to simulate the energy gradient resulting from both n values.

Tests indicated that flow conditions at the Morrill Avenue box culvert could be improved with the addition of a triangular pier extension (type 3 design pier nose). Tests indicated that the channel design for Manning's n values of 0.014 was adequate for flows less than a discharge of 2,670 cfs in Berryessa Creek and 700 cfs in Sierra Creek (3,370 cfs total, which is 690 cfs high than the design discharge). Test results also indicated that the channel design for a Manning's n of 0.012 was adequate for flows less than discharges of 2,670 in Berryessa and 1,100 cfs in Sierra Creeks (3,770 total, which is 1,090 cfs higher than the design discharge). With discharges greater than 3,370 cfs ($n = 0.014$) the Morrill Avenue box culvert would prime (flow full), resulting in significant overtopping of the proposed channel wall heights upstream.

Tests to determine the adequacy of channel improvements for the Berryessa/Los Coches Creek junction for a Manning's n value of 0.016 indicated that the original design would effectively convey the design flow conditions.

Tests to determine the adequacy of channel improvements for the Berryessa/Piedmont Creek junction indicated that the original design would effectively convey design flow conditions for a Manning's n value of 0.016.

Table 1
Water-Surface Elevations, Berryessa Discharge 100 cfs, Sierra Discharge 570 cfs, n = 0.014

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+50	100.80	100.80	100.80
248+03	99.72	99.71	99.85
248+00	——	99.85	——
247+96	100.84	101.11	100.57
247+80	101.04	101.28	101.10
247+50	99.69	100.19	100.72
247+35	98.56	99.87	99.97
247+15	99.90	99.03	99.26
247+00	99.32	98.79	98.61
246+79	98.76	98.44	98.76
246+69.5	——	——	99.23
246+50	98.72	——	98.40
246+42	98.83	——	——
246+34.8	——	——	99.03
246+24.2	98.41	——	——
246+19.7	——	——	98.22
246+11.4	98.17	——	——
245+97	98.11	98.03	98.31
245+50	97.87	97.93	97.99
245+00	97.65	97.80	97.56
Sierra Creek			
1+00	108.27	108.29	108.34
0+64	108.02	108.20	108.30
0+50	107.73	108.07	108.20
0+30	108.12	108.30	108.73
0+25	107.85	107.80	107.87
0+20	106.26	106.21	106.11
0+00	102.45	103.32	102.82

Note: Sides of channel are referenced to looking downstream.

Table 2
Water-Surface Elevations, Berryessa Discharge 2,130 cfs, Sierra Discharge 50 cfs, n = 0.014

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+50	105.97	105.41	105.91
248+00	104.10	104.30	104.07
247+80	103.38	103.50	103.73
247+73.6	101.23	102.61	104.21
247+35	103.78	100.90	100.70
247+24.6	102.87	102.11	99.84
247+05.4	101.08	101.16	103.56
246+86.4	100.14	100.89	101.42
246+76	100.45	101.75	101.03
246+59.6	102.46	-----	-----
246+50	-----	-----	101.29
246+43.6	-----	-----	101.72
246+35.6	100.07	-----	-----
246+25	-----	-----	100.33
246+23.4	102.40	-----	-----
246+07	-----	-----	101.83
245+97	100.17	101.26	100.68
245+50	100.54	100.47	100.07
245+27.7	99.71	100.12	101.25
245+00	100.00	100.49	00.00

Note: Data for Sierra Creek not available.

Table 3
Water-Surface Elevations, Berryessa Discharge 2,130 cfs, Sierra Discharge 550 cfs, n = 0.014

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+75	106.42	106.15	106.41
248+50	105.97	105.67	105.78
248+25	104.40	105.04	104.70
248+00	104.65	103.94	104.20
247+80	103.18	103.86	103.68
247+70	101.50	103.23	104.28
247+53	104.06	102.88	103.83
247+42	104.14	104.65	102.78
247+17	103.29	102.92	104.81
247+00	102.69	103.01	102.71
246+88	103.05	103.05	102.03
246+76	103.45	102.55	102.42
246+67	102.67	-----	-----
246+50	102.24	-----	103.20
246+37	102.16	-----	-----
246+23	-----	-----	102.72
246+15	103.05	-----	-----
246+11	-----	-----	102.82
245+97	102.43	102.30	101.69
245+75	101.54	101.83	102.20
245+50	101.83	102.07	101.79
245+33	101.98	101.69	101.61
245+17	-----	101.69	101.97
245+10	101.25	-----	-----
244+97	101.90	101.53	101.45
Sierra Creek			
1+25	107.54	107.52	107.56
1+00	107.50	107.46	107.54

(Continued)

Note: Sides of channel are referenced to looking downstream.

Table 3 (Concluded)			
	Elevation		
Station	Left Side	Center	Right Side
Sierra Creek (Continued)			
0+64	107.24	107.33	107.48
0+30	107.21	107.39	107.82
0+25	106.86	106.84	106.94
0+20	105.14	105.18	104.94
0+15	103.56	103.72	103.48
0+00	102.29	102.66	102.43

Table 4
Water-Surface Elevations, Berryessa Discharge 2,670 cfs, Sierra Discharge 700 cfs, n = 0.014

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+75	107.69	107.00	107.65
248+50	108.40	108.21	109.19
248+35.6	110.67	111.47	112.00
248+25	111.76	110.65	110.63
248+00	110.66	112.73	112.17
247+85	112.73	112.17	112.57
247+47	111.42	112.07	112.02
247+20.6	111.24	111.05	110.46
247+07.2	111.64	111.75	112.84
246+70	113.24	113.24	113.24
246+60.4	110.83	110.83	110.83
246+50	106.56	106.56	106.56
245+98.6	106.08	106.08	106.08
245+92.2	106.48	106.48	106.48
245+50	104.07	104.07	104.07
245+00	104.01	104.01	104.01
Sierra Creek			
1+00	111.92	111.92	111.92
0+64	111.97	111.97	112.05
0+50	111.70	111.96	112.17
0+30	111.96	111.98	112.27
0+25	111.80	111.80	111.80
0+20	110.99	110.91	111.23
0+16.8	110.[illegible]9	110.29	110.26
0+08	111.42	111.47	111.52
0+00	111.31	111.38	111.44

Note: Sides of channel are referenced to looking downstream. Box culvert is primed, sta 46+76 to sta 245+97. Water surface upstream from box culvert is above top of walls.

Table 5
Water-Surface Elevations, Berryessa Discharge 100 cfs, Sierra Discharge 570 cfs, n = 0.012

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+50	100.34	100.27	100.27
248+00	99.16	99.16	99.16
247+92.5	99.04	99.00	98.96
247+87.2	99.92	99.94	99.92
247+80	100.22	100.22	100.13
247+70.4	100.55	100.28	100.33
247+50	99.18	99.23	100.53
247+35	98.38	99.30	99.62
247+09.4	97.49	98.66	99.06
247+00	99.41	98.32	98.68
246+76	98.33	97.72	97.75
246+59.6	-----	-----	97.65
246+50	98.16	-----	-----
246+30	-----	-----	97.80
246+25	98.09	-----	-----
246+18.6	-----	-----	97.82
246+09	97.92	-----	-----
246+07.4	-----	-----	97.59
246+04.2	100.21	-----	-----
245+97	97.83	97.72	97.75
245+83	97.61	97.67	97.56
245+62.8	97.29	97.56	97.93
245+50	97.21	97.31	97.58
245+25	97.19	97.12	97.27
245+00	97.32	97.22	97.11
Sierra Creek			
1+00	107.81	107.74	107.84
0+64	107.56	107.73	107.8

(Continued)

Note: Sides of channel are referenced to looking downstream.

Table 5 (Concluded)			
Station	Elevation		
	Left Side	Center	Right Side
Sierra Creek (Continued)			
0+50	107.17	107.70	108.07
0+30	107.37	107.53	108.14
0+25	106.91	106.99	106.97
0+20	106.03	106.10	106.00
0+10	103.05	102.57	102.97
0+00	101.62	101.92	101.89

Table 6
Water-Surface Elevations, Berryessa Discharge 2,130 cfs, Sierra Discharge 50 cfs, n = 0.012

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+75	106.12	105.82	106.58
248+50	105.49	105.35	105.38
248+25	104.45	104.50	104.48
248+00	104.04	103.91	103.82
247+80	103.02	103.23	103.31
247+74.8	100.91	102.72	103.44
247+50	103.21	101.15	102.35
247+35	103.66	101.87	100.98
247+20.8	102.68	102.29	99.67
247+10.9	——	——	99.71
246+76	99.75	100.29	101.17
246+70.8	99.56	——	——
246+66	——	——	101.05
246+50	100.56	——	101.76
246+38	——	——	102.49
246+37.2	100.24	——	——
246+20	99.50	——	——
246+16.2	——	——	101.52
246+04.2	100.21	——	——
245+97	100.28	100.44	101.79
245+75	99.77	100.30	99.95
245+55.6	101.19	100.49	99.02
245+34.8	100.06	99.47	100.97
245+12.8	98.98	100.05	100.39
245+00	99.32	99.91	100.76
244+84	100.74	99.56	99.05
Sierra Creek			
1+00	102.78	102.78	102.78

(Continued)

Note: Sides of channel are referenced to looking downstream.

Table 6 (Concluded)			
	Elevation		
Station	Left Side	Center	Right Side
Sierra (Continued)			
0+64	102.77	102.77	102.77
0+30	102.56	102.56	102.60
0+25	102.28	102.33	102.40
0+20	99.20	99.04	99.14
0+11.7	98.65	98.03	98.55
0+00	100.35	100.59	100.29

Table 7
Water-Surface Elevations, Berryessa Discharge 2,130 cfs, Sierra Discharge 550 cfs, n = 0.012

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
248+75	105.94	105.69	105.96
248+50	105.38	105.52	105.46
248+25	104.38	104.46	104.40
248+00	103.96	103.67	103.64
247+80	103.06	103.23	103.36
247+74.2	101.19	103.04	103.58
247+56.6	103.79	102.71	103.11
247+35	103.52	103.66	102.32
247+11.8	----	----	101.40
247+00	101.99	101.94	103.83
246+76	101.67	102.25	101.59
246+62	102.47	----	----
246+50	102.32	----	102.56
246+35.1	101.51	----	----
246+25	----	----	101.53
246+19.6	102.22	----	----
246+00	----	----	102.91
245+75	101.18	101.74	100.84
245+50	101.35	101.05	101.47
245+25	100.40	101.22	101.08
245+09.6	101.06	101.62	101.72
245+00	101.43	101.63	101.05
244+87.2	101.08	101.09	100.94
Sierra Creek			
1+00	107.78	107.71	107.84
0+64	107.54	107.73	107.88
0+30	107.40	107.55	107.95
0+25	102.02	106.88	107.04

(Continued)

Note: Sides of channel are referenced to looking downstream.

Table 7 (Concluded)

Station	Elevation		
	Left Side	Center	Right Side
Sierra Creek (Continued)			
0+20	106.24	107.63	107.54
0+00	101.98	102.43	102.42

Table 8
Water-Surface Elevations, Berryessa Discharge 100 cfs, Los Coches Discharge 1,530 cfs, n = 0.016

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
111+00	22.84	22.72	22.82
110+50	22.77	22.63	22.73
110+00	22.59	22.65	22.61
109+50	22.68	22.60	22.66
109+05	22.53	22.49	22.55
108+81	22.72	22.64	22.70
108+36	22.82	22.58	22.62
108+00	22.56	21.82	21.92
107+46	25.41	20.91	20.00
106+99	20.71	20.17	18.79
106+75	20.14	18.12	19.31
106+50	18.94	17.88	18.06
106+20	20.43	22.15	20.18
105+90	21.27	19.45	21.45
105+86	20.65	22.05	21.03
105+50	21.06	20.54	20.90
Los Coches Creek			
0+36.5	27.42	27.30	27.44
0+49.3	27.98	27.02	27.46
0+61.3	27.59	27.77	27.60

Note: Sides of channel are referenced to looking downstream.

Table 9
Water-Surface Elevations, Berryessa Discharge 3,470 cfs, Los Coches Discharge 100 cfs, n = 0.016

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
111+00	26.36	26.46	26.30
110+50	26.33	26.35	26.29
110+00	26.31	26.31	26.27
109+50	26.18	26.16	26.20
109+05	26.06	25.94	26.12
108+81	25.64	25.14	25.60
108+64	20.19	22.73	21.03
108+30	21.77	20.75	21.87
108+16	23.37	23.55	22.71
108+00	22.84	22.42	22.72
107+46	23.10	23.56	22.66
106+99	23.01	22.47	22.93
106+50	23.28	23.30	23.26
106+00	23.40	23.60	23.38
105+50	23.19	23.03	23.17
Los Coches Creek			
0+36.5	22.86	23.08	22.98
0+49.3	24.10	23.60	24.08
0+61.3	24.51	24.43	24.43

Note: Sides of channel are referenced to looking downstream.

Table 10
Water-Surface Elevations, Berryessa Discharge 3,470 cfs, Los Coches Discharge 1,310 cfs, n = 0.016

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
111+00	27.24	27.12	27.06
110+50	27.07	27.03	27.03
110+00	27.05	26.99	27.01
109+50	26.92	26.90	26.90
109+05	26.76	26.88	26.84
108+81	26.42	26.06	26.18
108+30	25.91	25.15	26.19
108+00	25.76	25.80	25.94
107+46	25.44	25.34	24.24
106+99	24.97	25.07	25.19
106+50	25.04	25.02	25.36
106+00	25.12	25.02	25.24
105+50	24.84	24.74	25.02
Los Coches Creek			
0+36.5	26.82	25.40	25.78
0+49.3	27.22	26.20	26.82
0+61.3	26.81	26.91	26.95

Note: Sides of channel are referenced to looking downstream.

Table 11
Water-Surface Elevations, Berryessa Discharge 4,210 cfs, Los Coches Discharge 1,590 cfs, n = 0.016

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
111+00	28.24	28.16	28.10
110+50	28.11	28.09	28.07
110+00	28.03	28.03	28.11
109+50	27.96	27.94	27.98
109+05	27.81	27.65	27.89
108+81	27.42	27.03	27.48
108+64	25.97	25.95	25.83
108+49	25.88	26.34	25.90
108+30	26.25	25.99	26.59
108+00	26.80	26.78	26.56
107+46	26.84	26.16	24.80
106+99	26.15	25.77	26.21
106+50	26.30	26.24	26.34
106+00	26.56	26.62	26.52
105+50	26.60	26.54	26.22
Los Coches Creek			
0+36.5	26.68	26.42	26.18
0+49.3	27.88	27.14	27.24
0+61.3	27.59	27.39	27.65

Note: Sides of channel are referenced to looking downstream.

Table 12
Water-Surface Elevations, Berryessa Discharge 100 cfs, Piedmont Discharge 600 cfs, n = 0.016

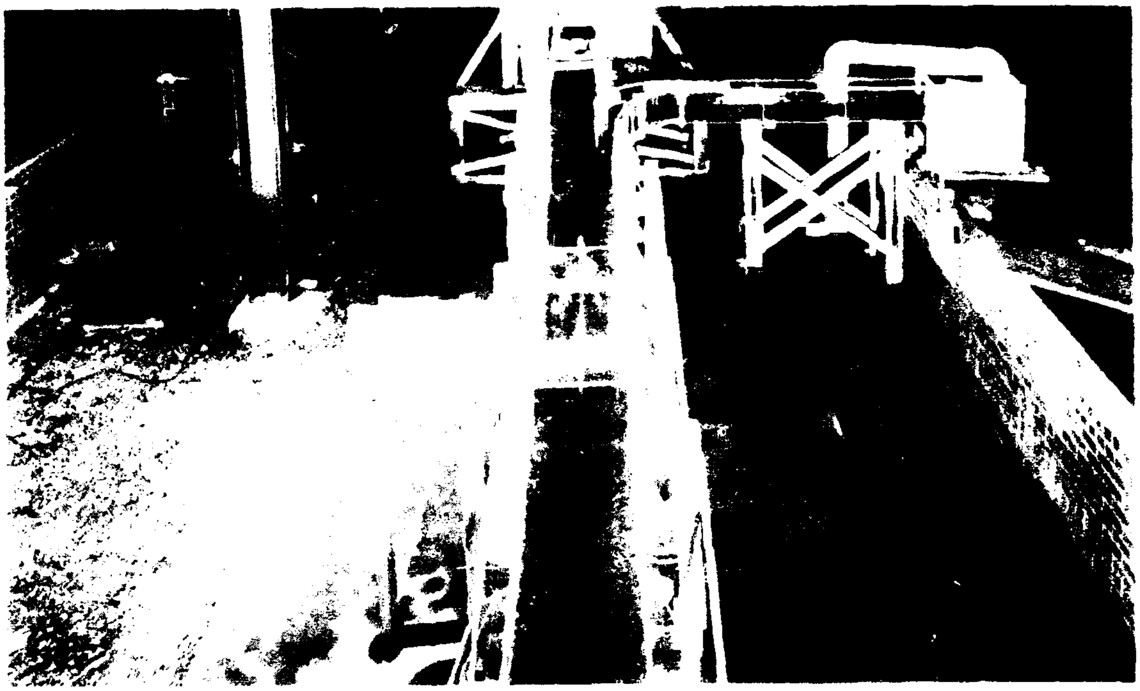
Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
127+50	24.10	24.08	24.04
128+00	24.16	24.02	24.10
128+50	24.24	23.92	24.22
129+00	24.30	23.96	24.14
129+25	23.00	23.72	24.06
129+50	26.67	23.67	23.97
130+00	24.01	23.99	23.97
130+50	20.06	20.01	—
131+00	24.61	24.51	24.57
131+50	24.78	24.70	24.74
132+00	24.80	24.78	24.84
132+50	24.84	24.82	24.72
133+00	24.86	24.76	24.90
Piedmont Creek			
0+36.5	23.47	23.73	22.57
0+49.3	30.46	27.92	30.32
0+52.5	30.46	29.34	30.04
0+61.3	30.73	30.35	30.69

Note: Sides of channel are referenced to looking downstream.

Table 13
Water-Surface Elevations, Berryessa Discharge 2,970 cfs, Piedmont Discharge 500 cfs, n = 0.016

Station	Elevation		
	Left Side	Center	Right Side
Berryessa Creek			
127+50	31.42	31.48	31.44
128+00	31.42	31.48	31.30
128+50	31.30	31.46	31.38
129+00	31.32	31.44	31.34
129+25	31.38	31.30	31.36
129+50	31.47	31.47	31.55
130+00	31.53	31.53	31.07
130+50	31.33	31.39	31.37
131+00	31.54	31.50	31.48
131+50	31.56	31.58	31.54
132+00	31.62	31.68	31.64
132+50	31.66	31.60	31.64
Piedmont Creek			
0+36.5	31.39	31.25	31.41
0+49.3	31.42	31.12	31.26
0+52.5	30.82	30.44	30.68
0+61.3	31.47	31.15	31.21

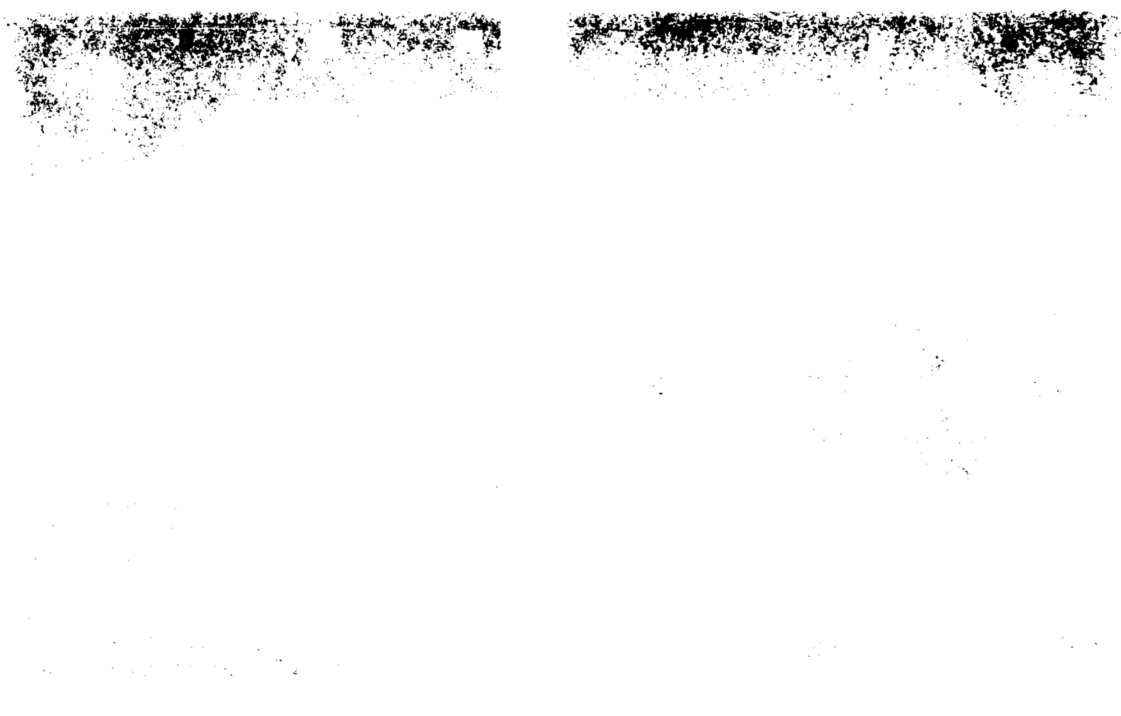
Note: Sides of channel are referenced to looking downstream.



a. Looking upstream

b. Looking downstream

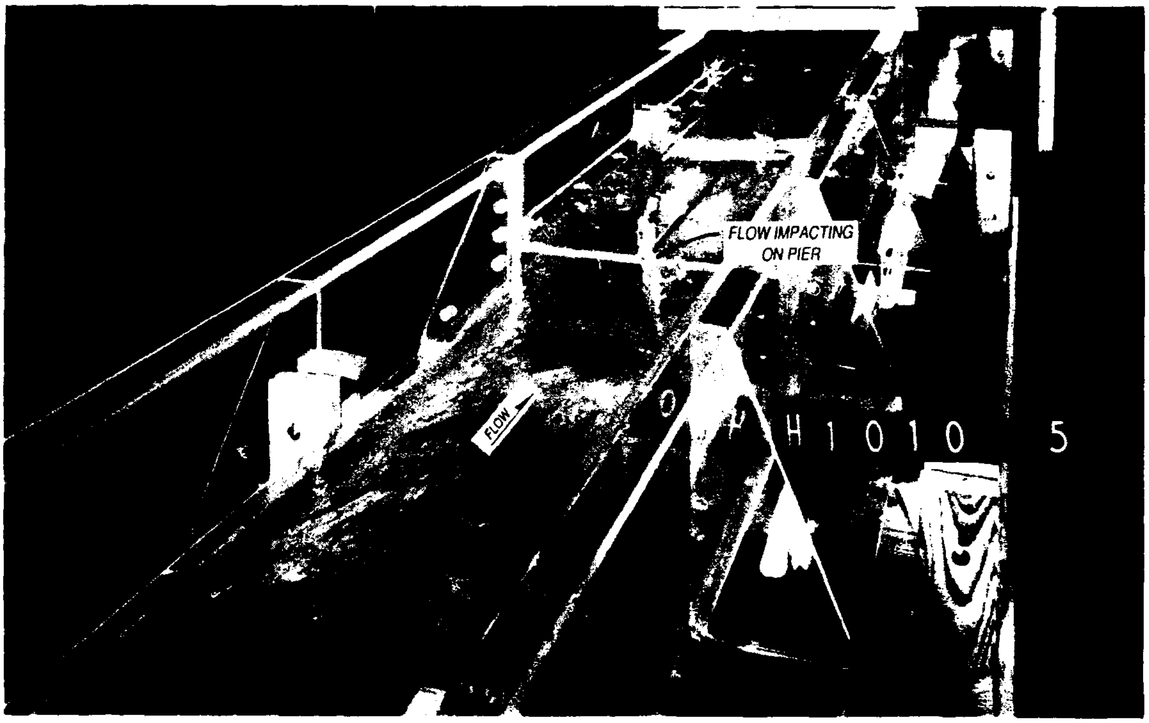
Photo 1. Berryessa/Sierra model with design discharge of 2,680 cfs (Sheet 1 of 3)



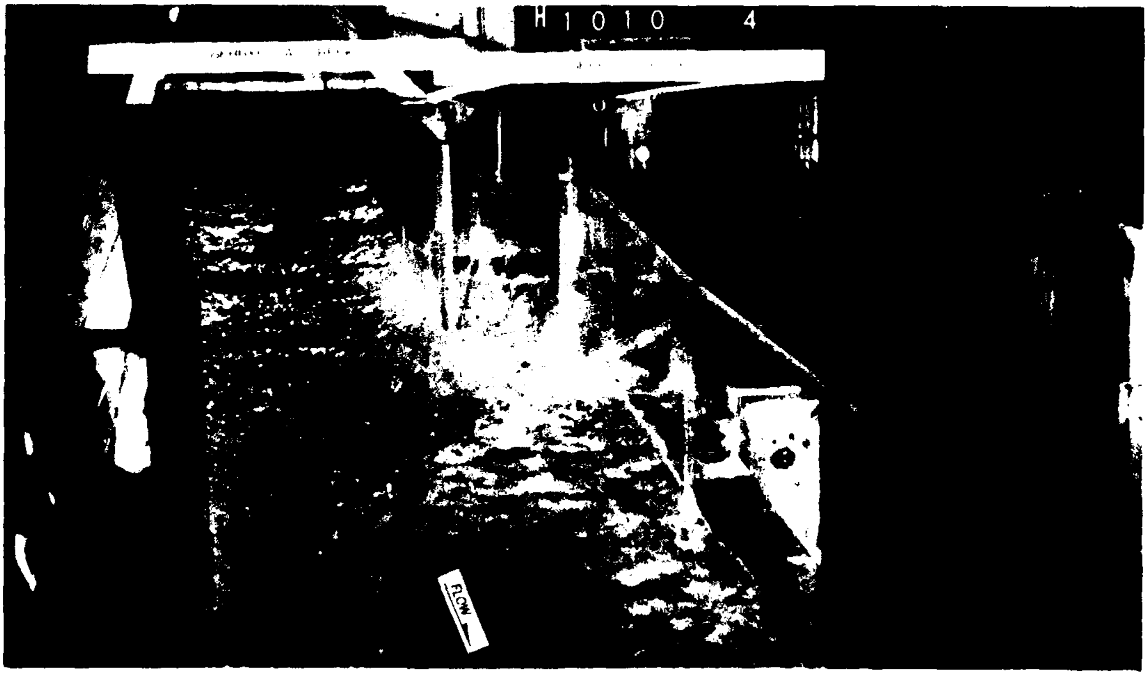
...king from the left side in the vicinity of the [illegible]

d. Looking from the right side from sta 247+80 to sta 24[illegible]+97

Photo 1. (Sheet 2 of 3)



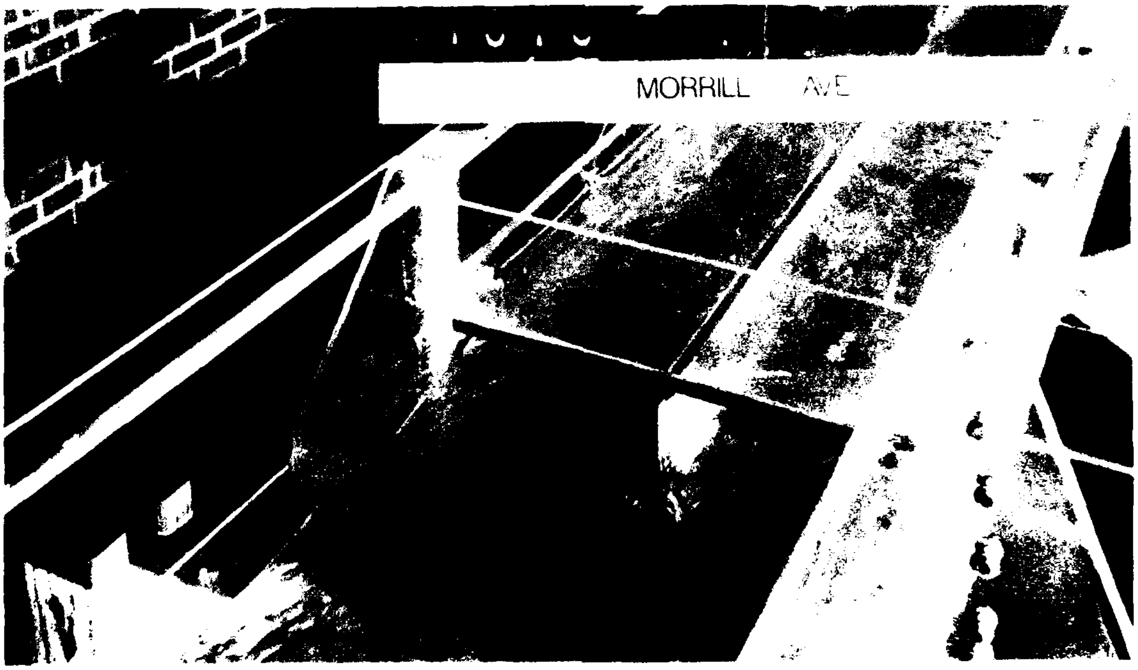
e. Looking downstream at Morrill Avenue box culvert



f. Looking upstream at junction

Photo 1. (Sheet 3 of 3)

a. Type 1 (original) design pier nose



b. Type 3 design pier nose

Photo 2. Morrill Avenue box culvert entrance, discharge 2,680 cfs

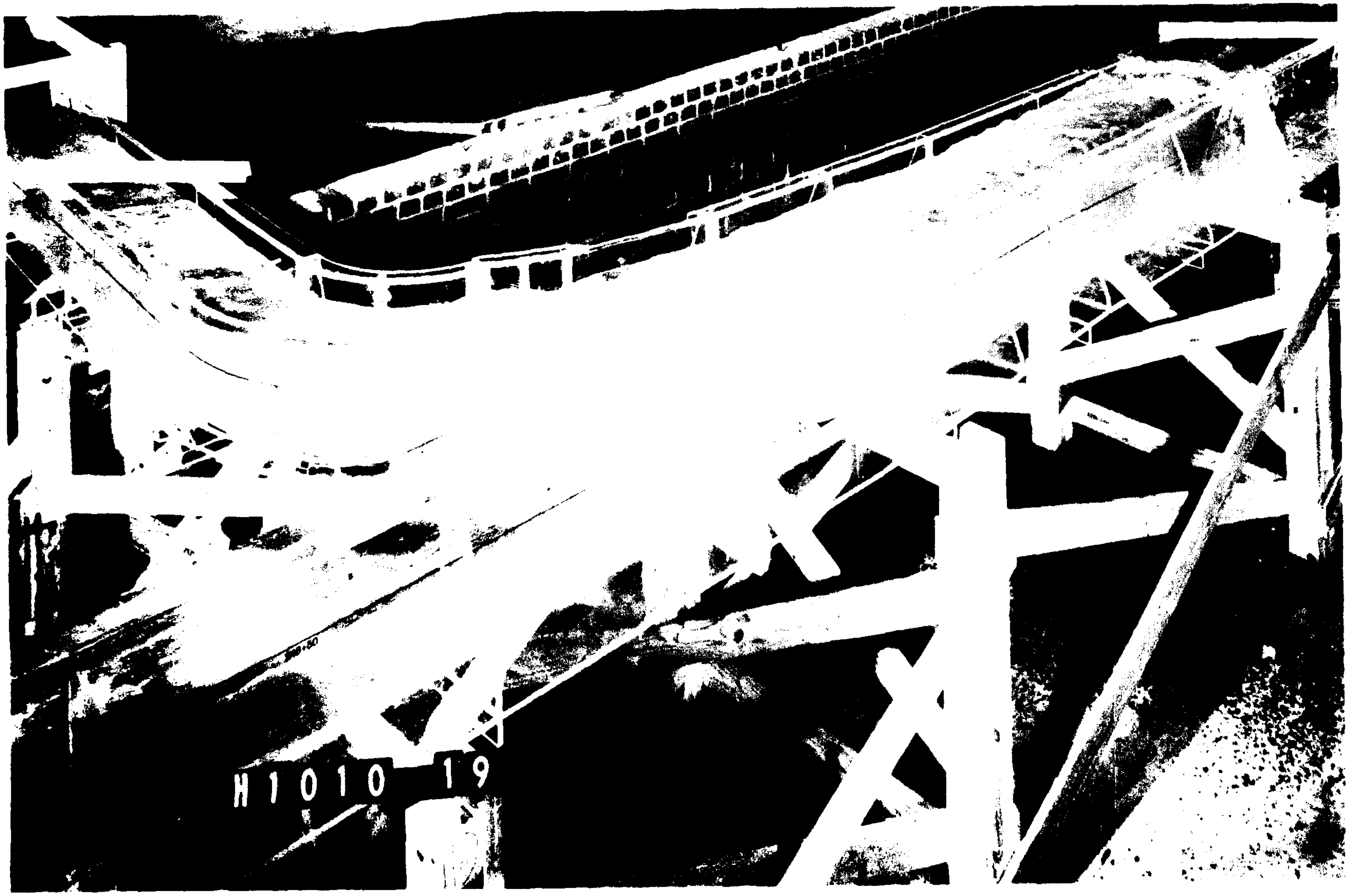
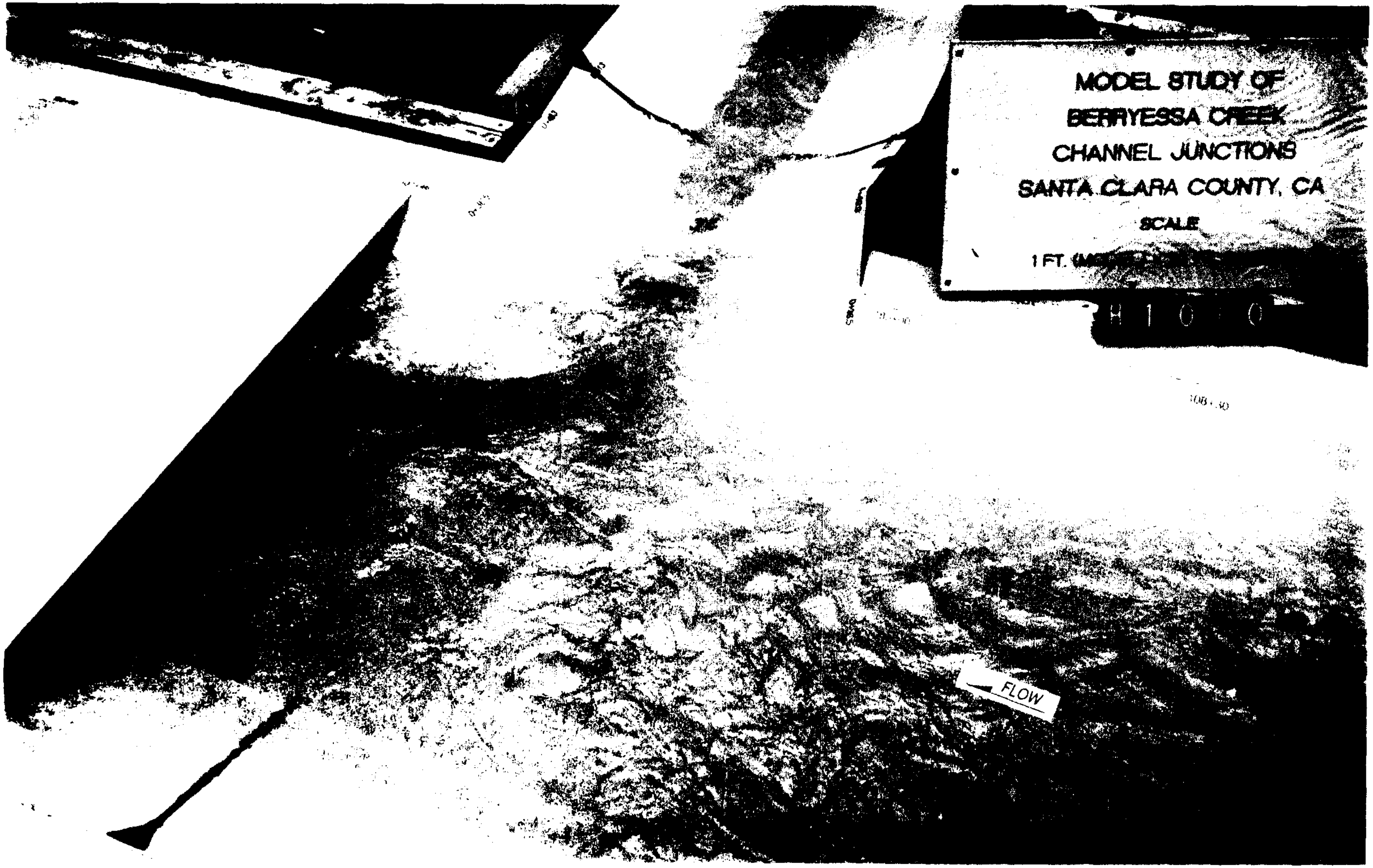


Photo 3. Berryessa/Sierra model, discharge 3,370 cfs

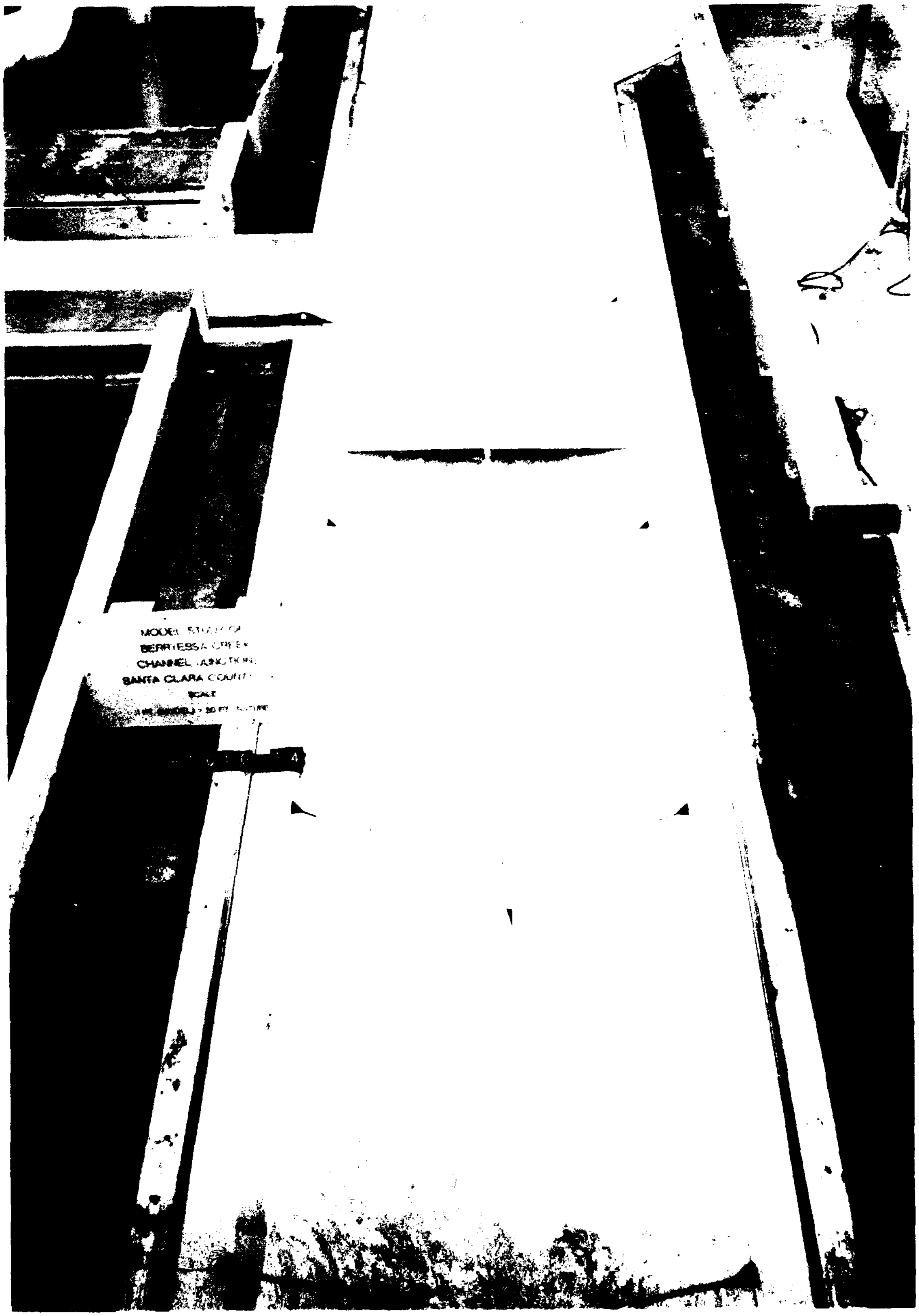
a. Looking downstream

Photo 4. Berryessa/Los Coches model with design discharge of 4,780 cfs (Sheet 1 of 3)



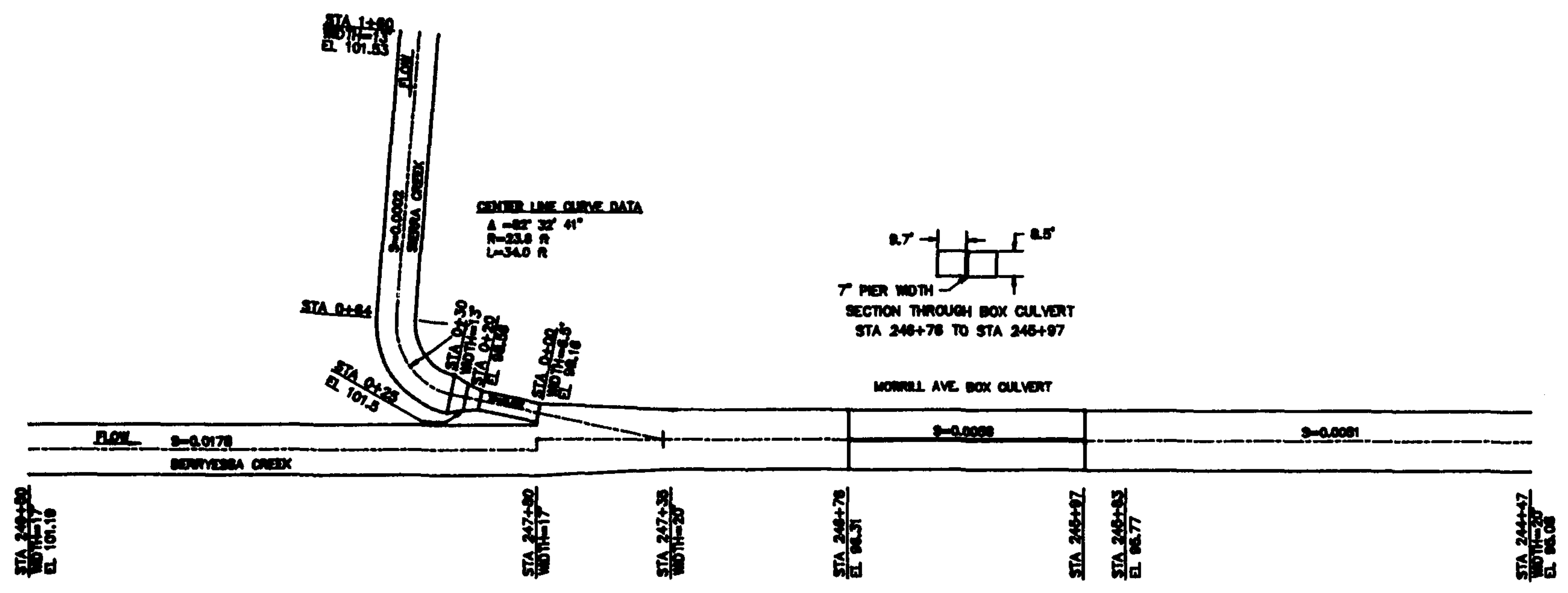
b. Berryessa/Los Coches Junction

Photo 4. (Sheet 2 of 3)

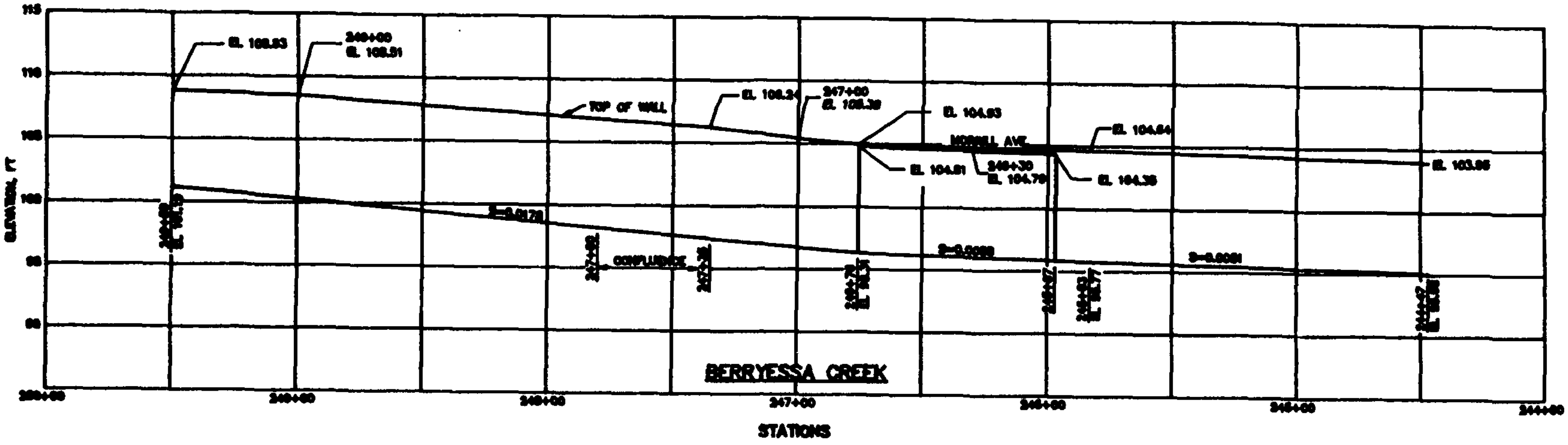


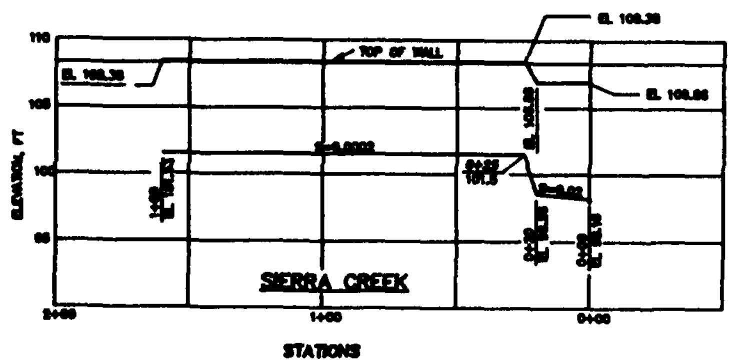
c. Looking upstream

Photo 4. (Sheet 3 of 3)



GENERAL PLAN
BERRYESSA/SIERRA JUNCTION





PROFILES
BERRYESSA AND SIERRA CREEKS

Plate 2

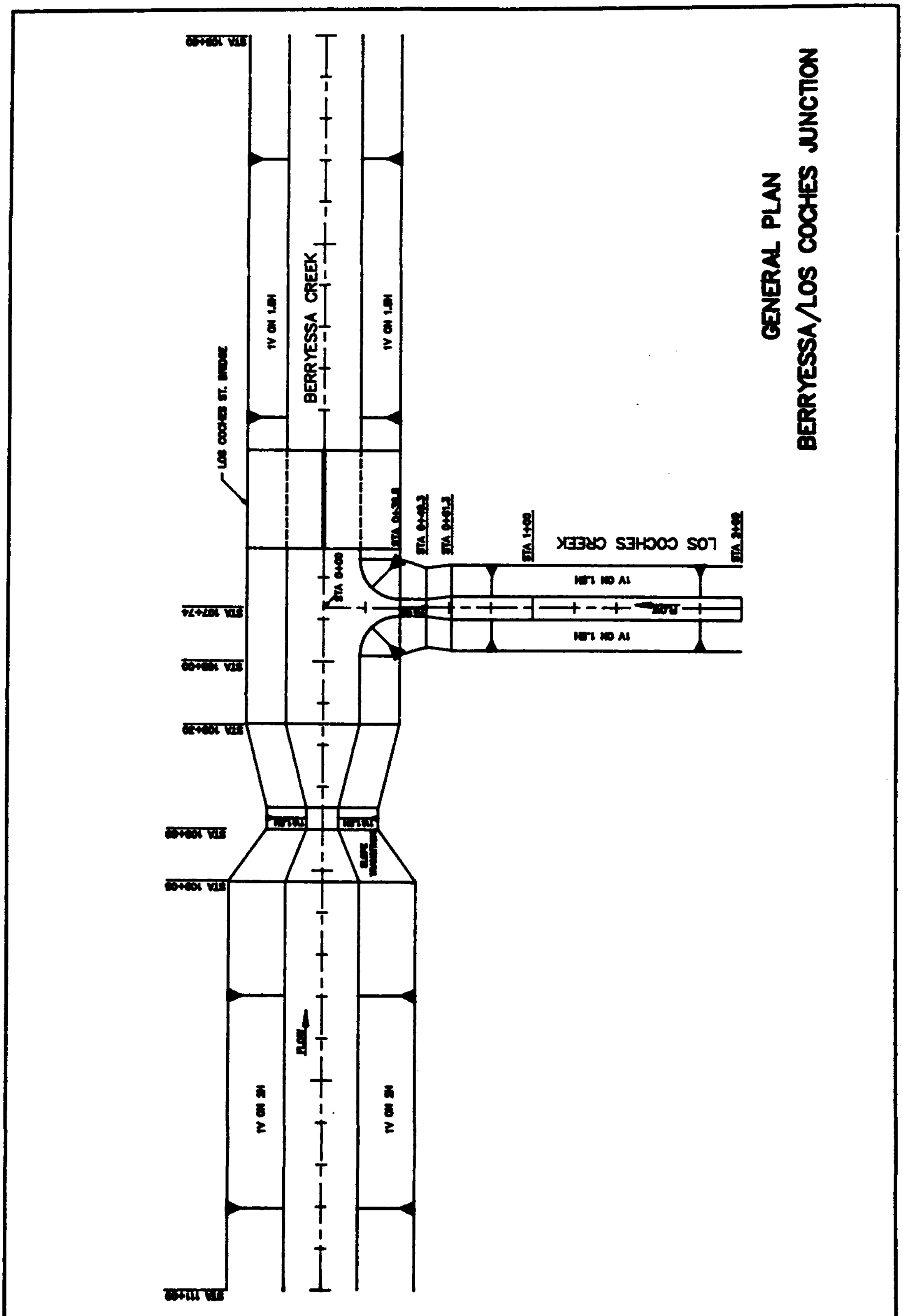
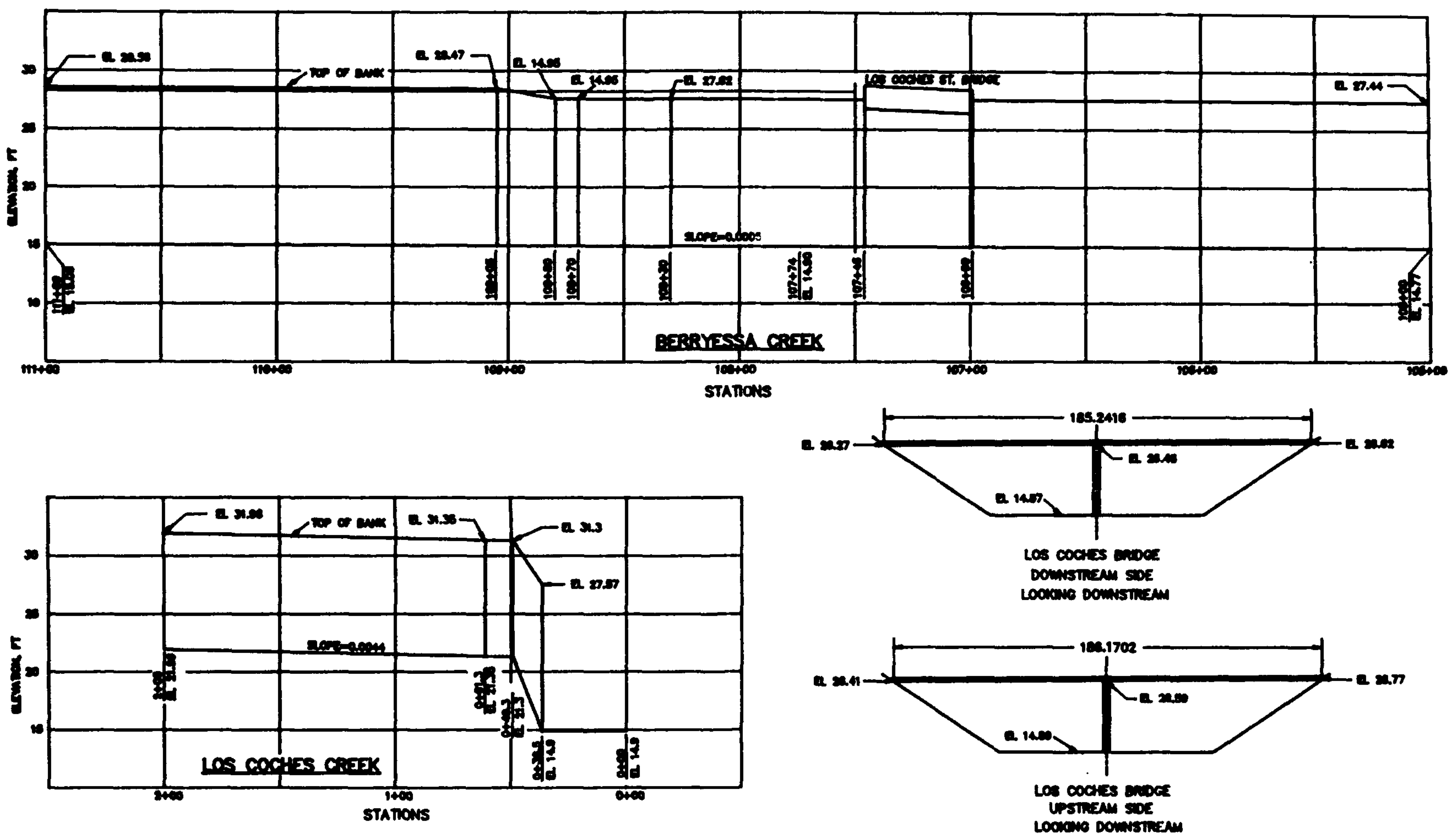

GENERAL PLAN
BERRYESSA/LOS COCHES JUNCTION
BERRYESSA CREEK
LOS COCHES CREEK
LOS COCHES ST. BRIDGE
1V ON 1.5H
1V ON 1.5H
1V ON 3H
1V ON 3H
STA 107+74
FLOW

Plate 4



PROFILES
BERRYESSA AND LOS COCHES CREEKS

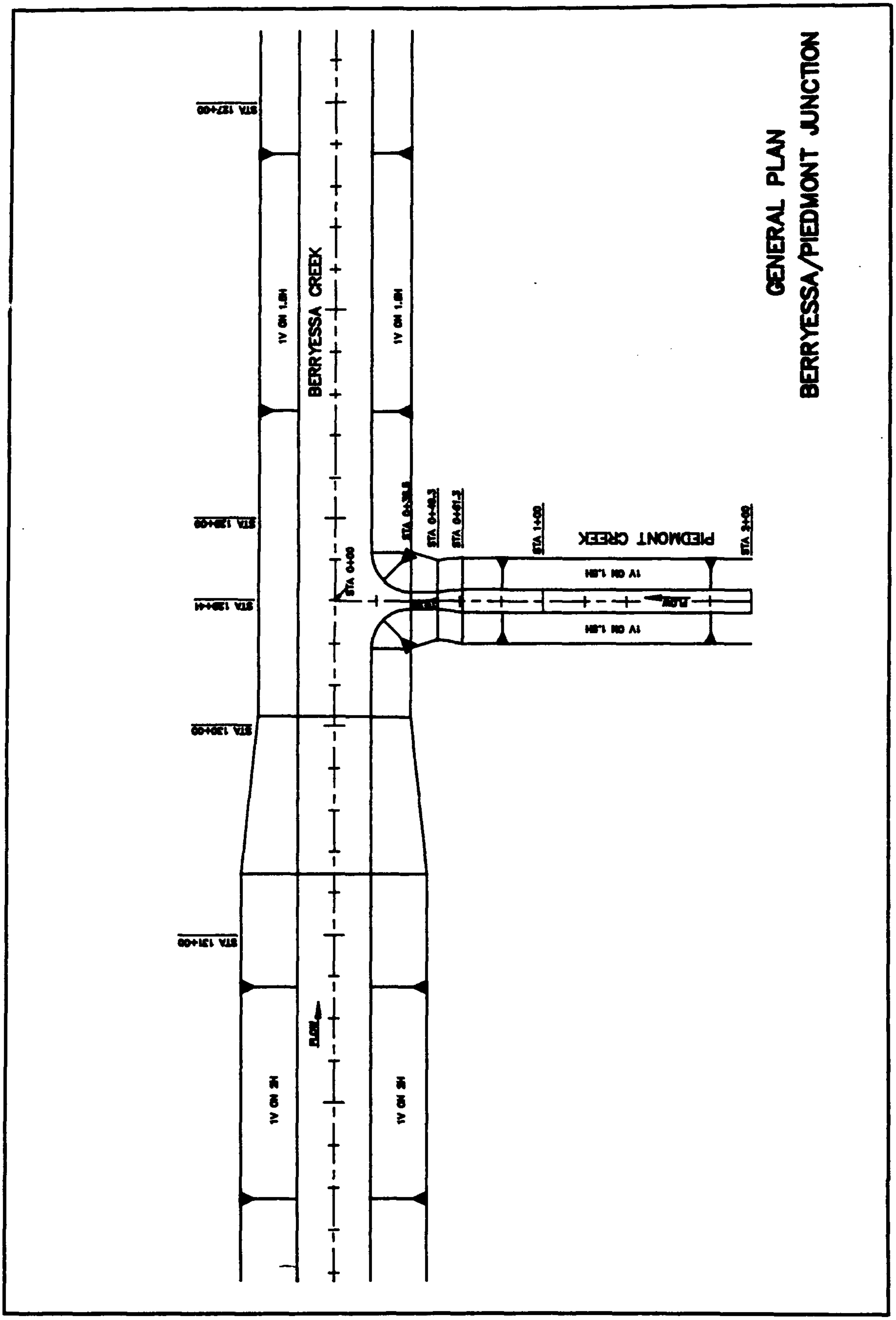
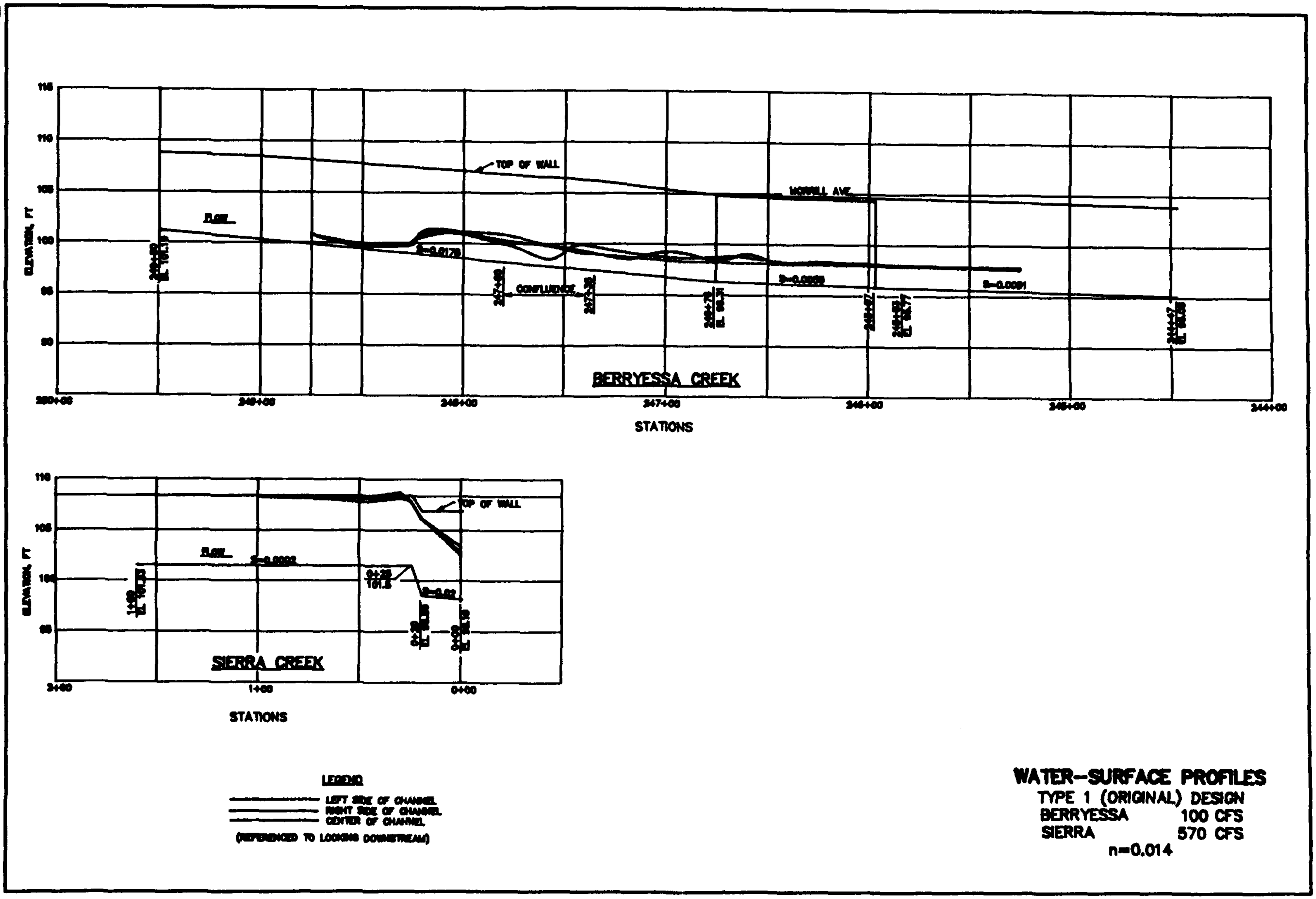
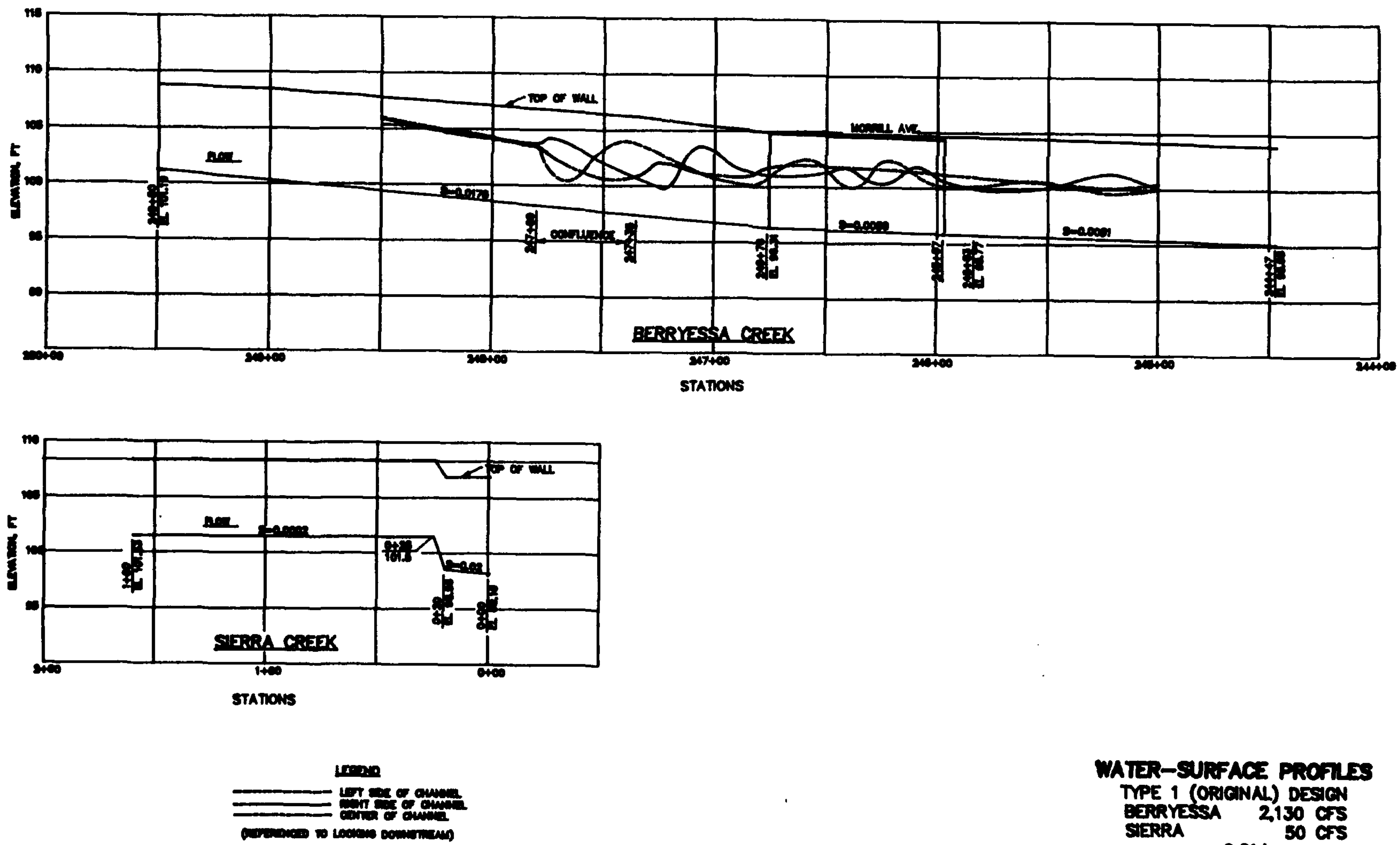

GENERAL PLAN
BERRYESSA/PIEDMONT JUNCTION
BERRYESSA CREEK
PIEDMONT CREEK
1V ON 1.5H
1V ON 2H
FLOW
STA 127+00
STA 129+00
STA 129+41
STA 130+00
STA 131+00
STA 0+00
STA 1+00
STA 2+00

Plate 5

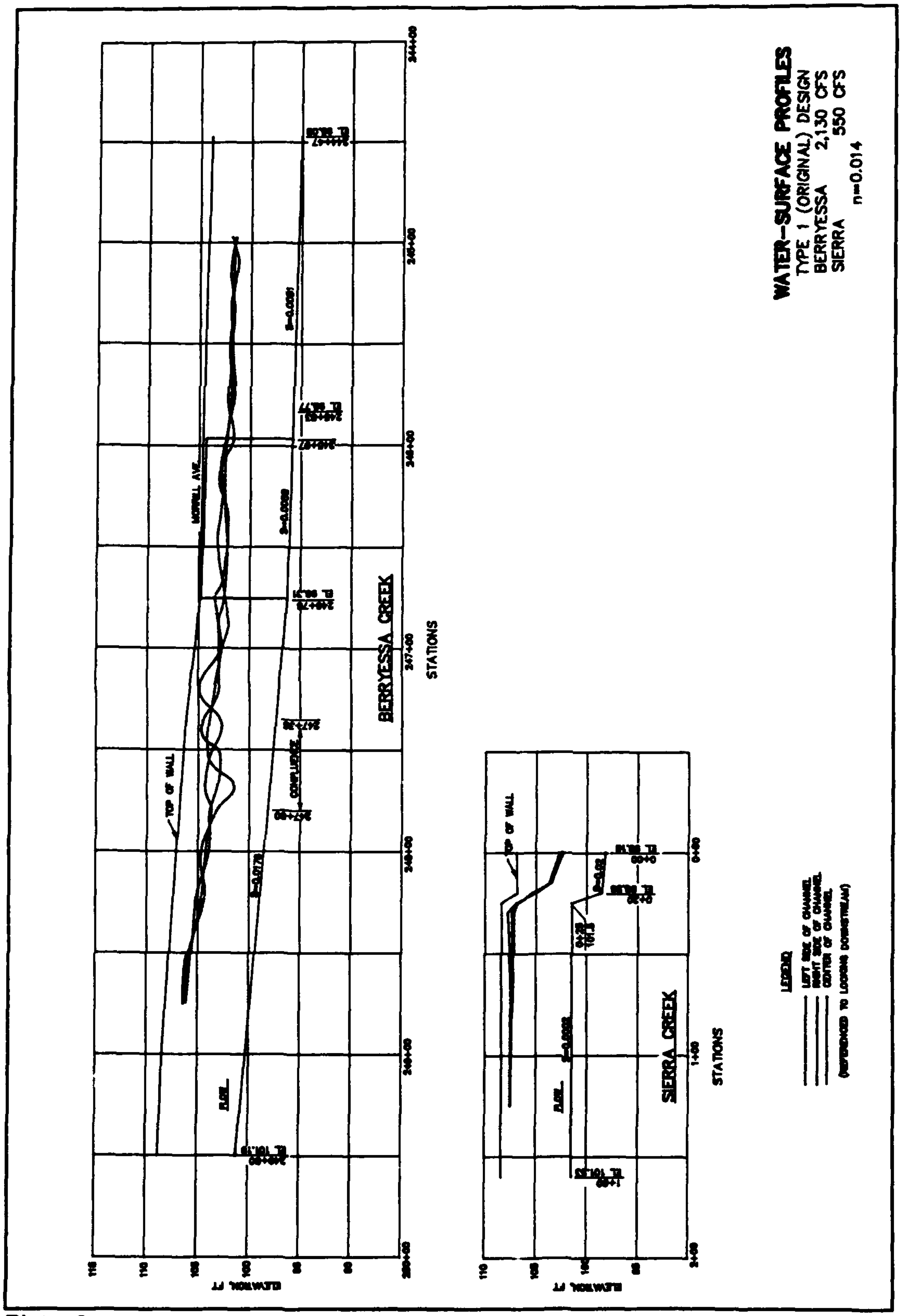
Plate 6


TOP OF WALL
MORRILL AVE.
FLOW
CONFLUENCE
BERRYESSA CREEK
STATIONS
ELEVATION, FT
SIERRA CREEK
STATIONS
ELEVATION, FT
TOP OF WALL
FLOW
LEGEND
LEFT SIDE OF CHANNEL
RIGHT SIDE OF CHANNEL
CENTER OF CHANNEL
(REFERENCED TO LOOKING DOWNSTREAM)
WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 100 CFS
SIERRA 570 CFS
n=0.014



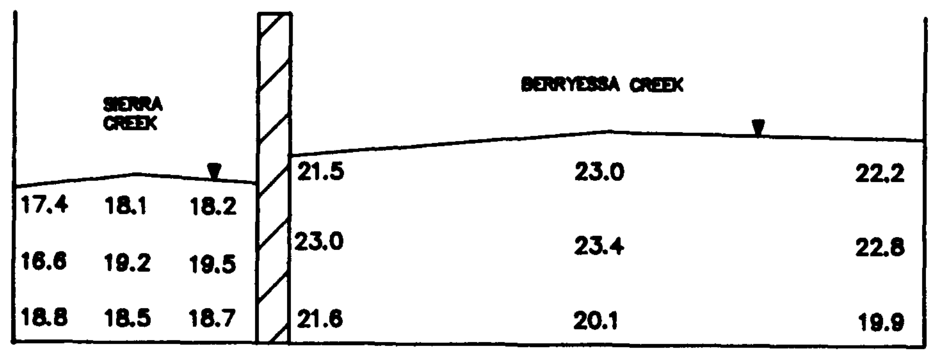
WATER–SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 2,130 CFS
SIERRA 50 CFS
n=0.014

Plate 7



WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 2,130 CFS
SIERRA 550 CFS
n=0.014
BERRYESSA CREEK
SIERRA CREEK
STATIONS
STATIONS
TOP OF WALL
TOP OF WALL
CONFLUENCE
LEGEND

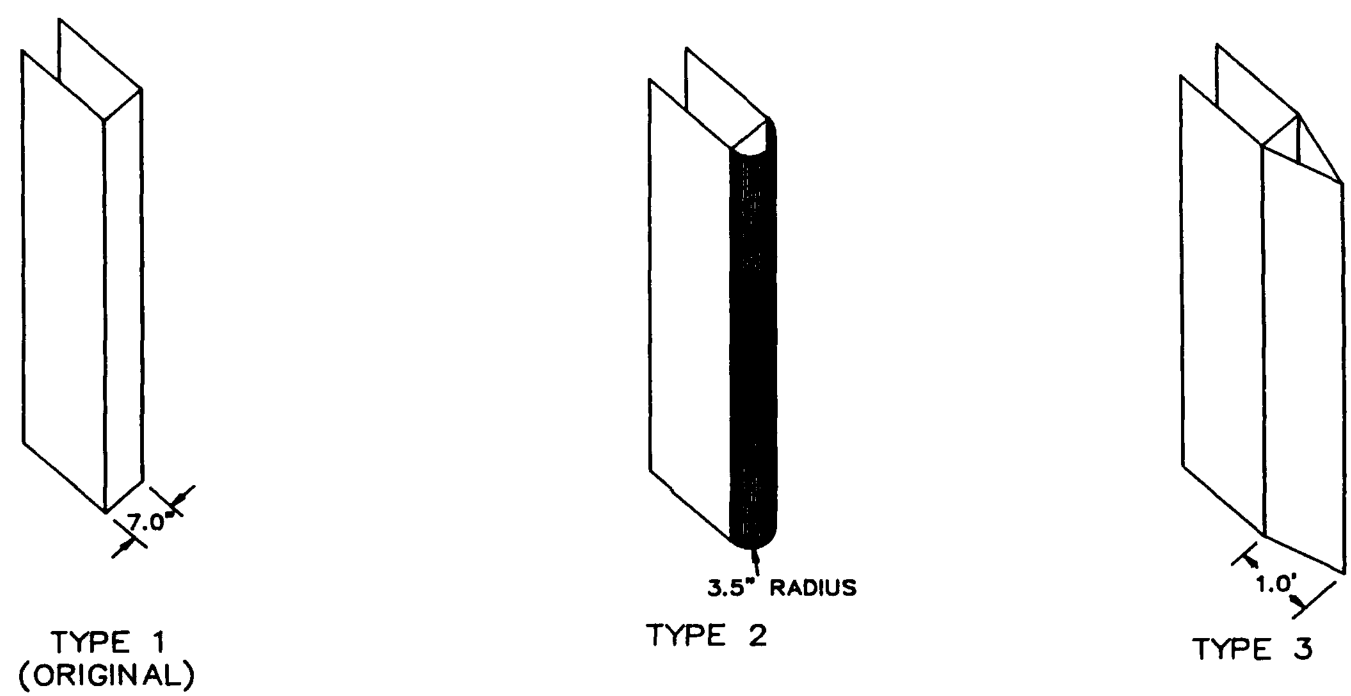
Plate 8



STATION 247+80

NOTE: VELOCITIES ARE IN FT/SEC
LOOKING DOWNSTREAM

VELOCITIES
BERRYESSA 2,130 CFS
SIERRA 550 CFS
n=0.014



TYPES 1, 2, AND 3
DESIGN PIER NOSES

Plate 10

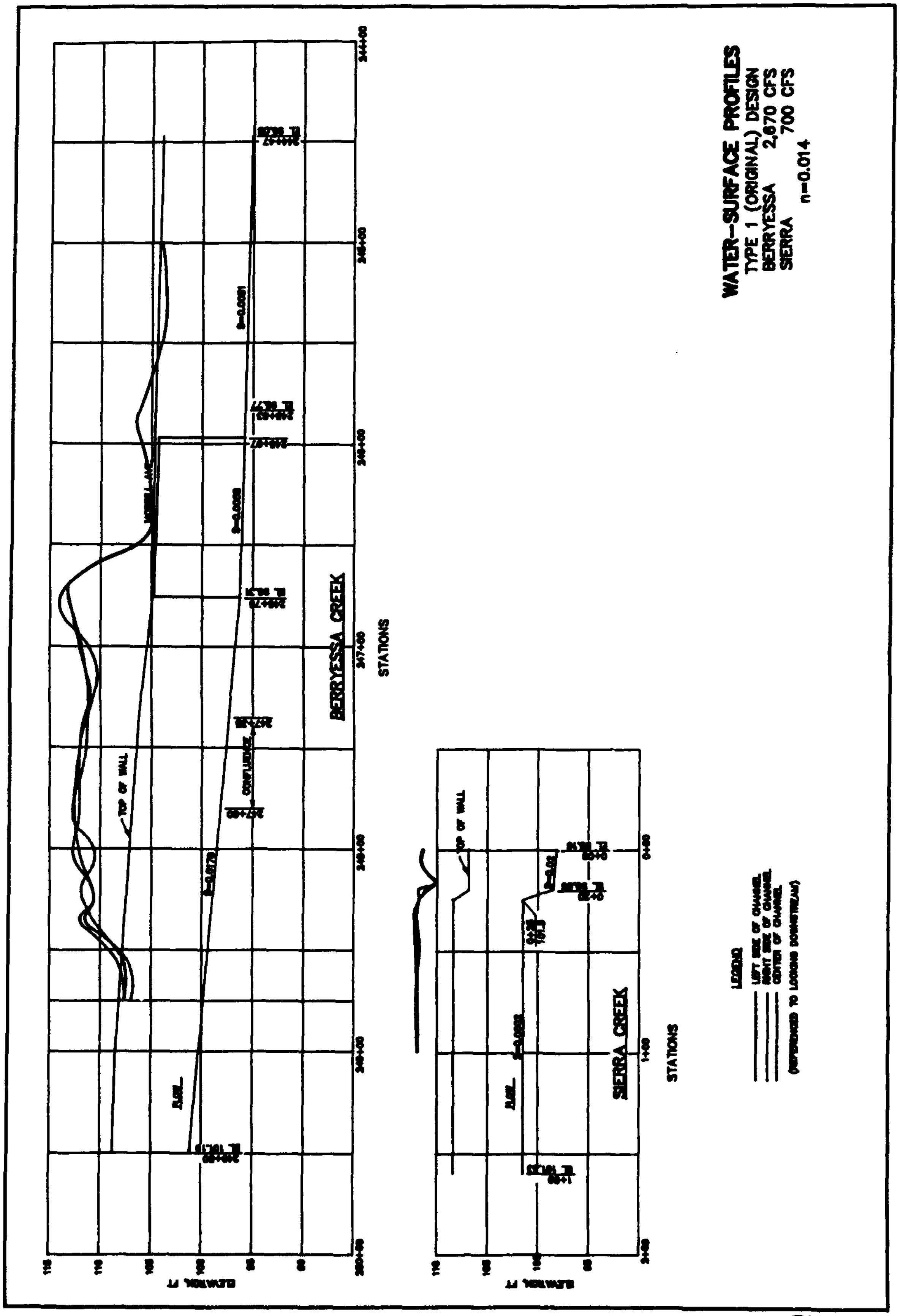

WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 2,670 CFS
SIERRA 700 CFS
n=0.014
BERRYESSA CREEK
SIERRA CREEK
STATIONS
STATIONS
ELEVATION, FT
ELEVATION, FT
TOP OF WALL
TOP OF WALL
CONFLUENCE
LEGEND

Plate 11

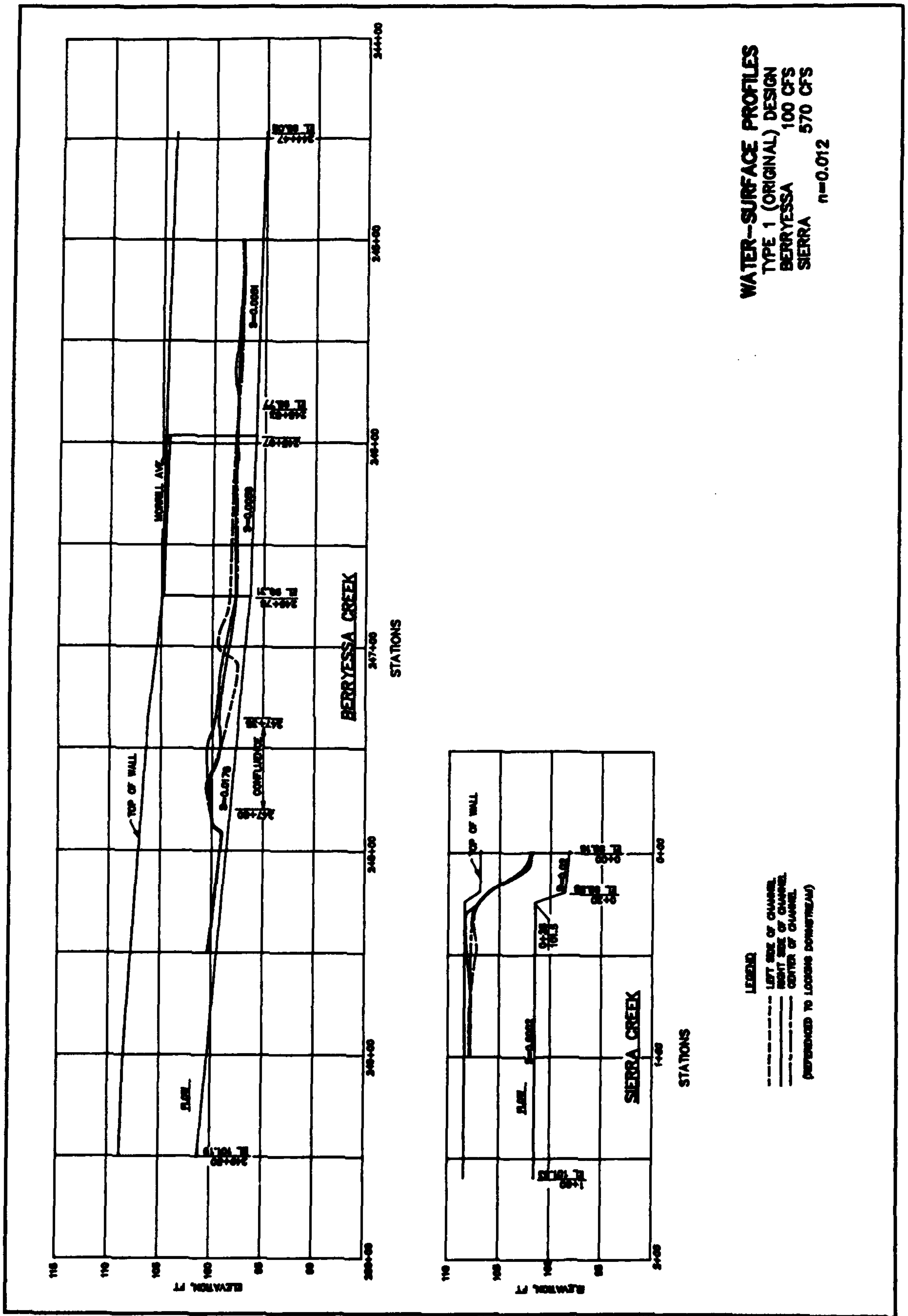
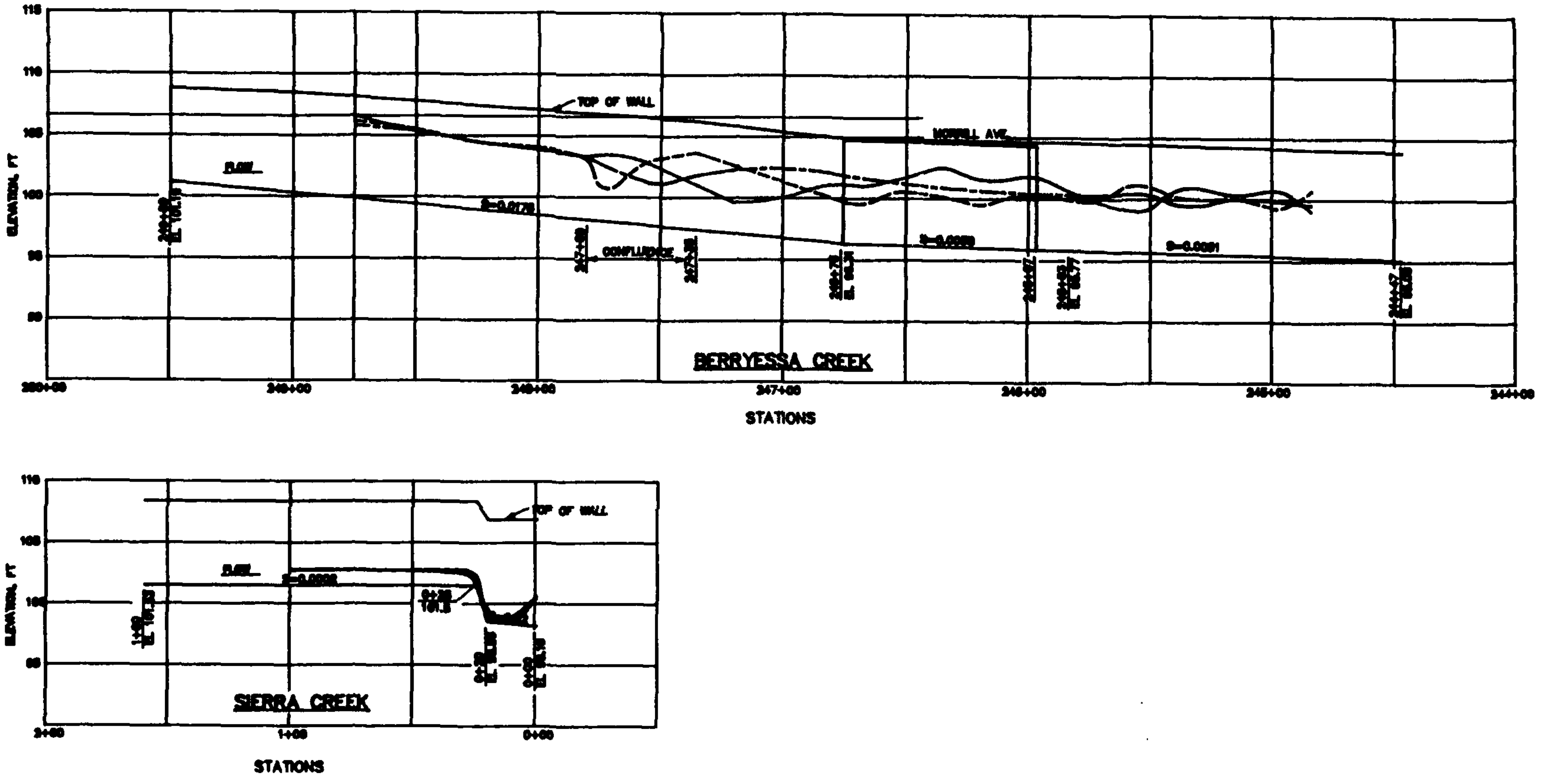

WATER—SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 100 CFS
SIERRA 570 CFS
n=0.012
BERRYESSA CREEK
SIERRA CREEK
STATIONS
STATIONS
TOP OF WALL
TOP OF WALL
MORRILL AVE
CONFLUENCE
ELEVATION, FT
ELEVATION, FT
LEGEND

Plate 12



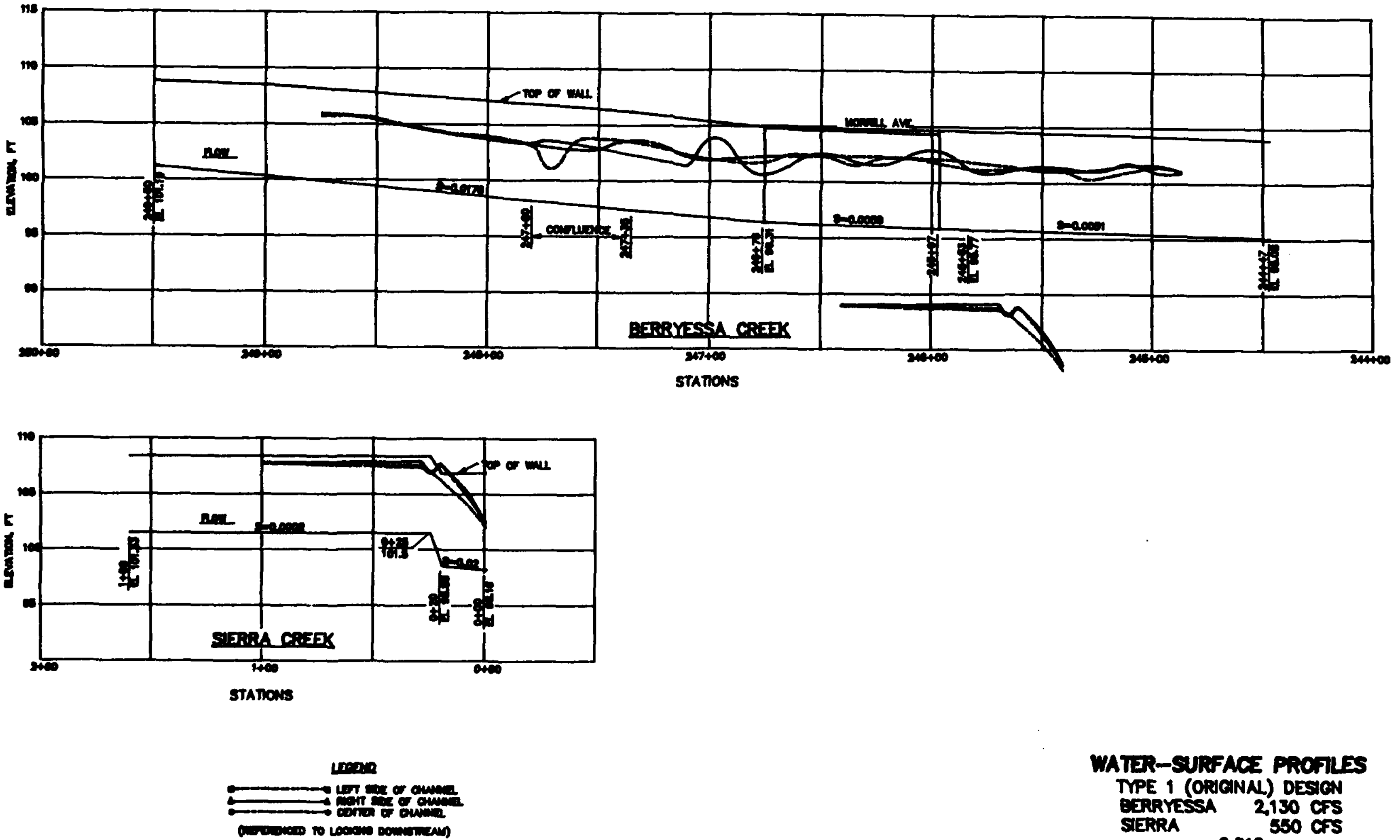
LEGEND

- LEFT SIDE OF CHANNEL
- RIGHT SIDE OF CHANNEL
- CENTER OF CHANNEL

(REFERENCED TO LOOKING DOWNSTREAM)

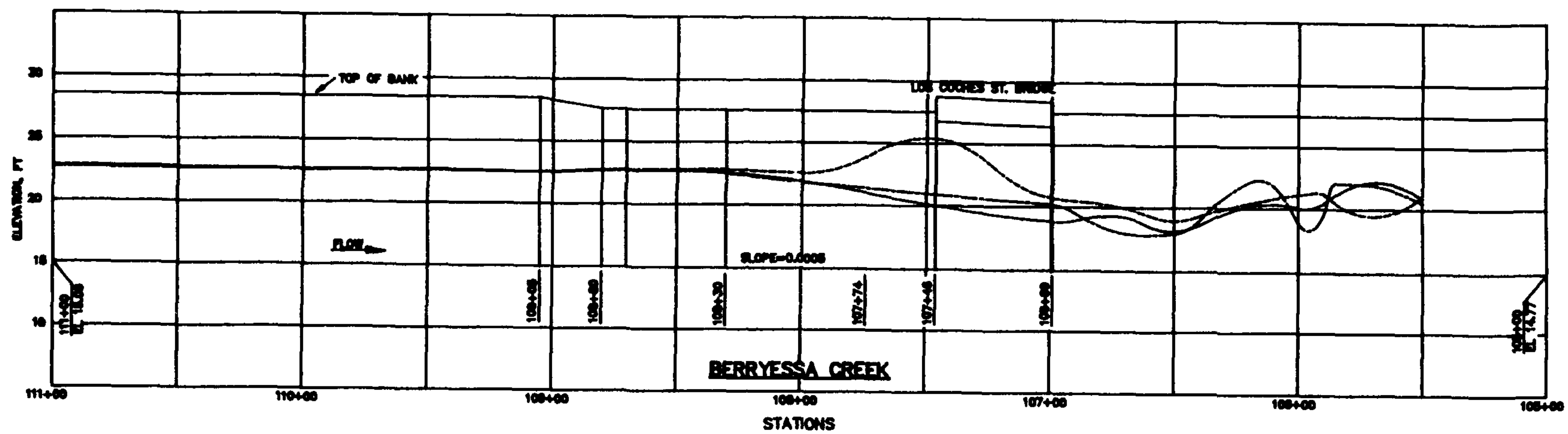
WATER–SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 2,130 CFS
SIERRA 50 CFS
n=0.012

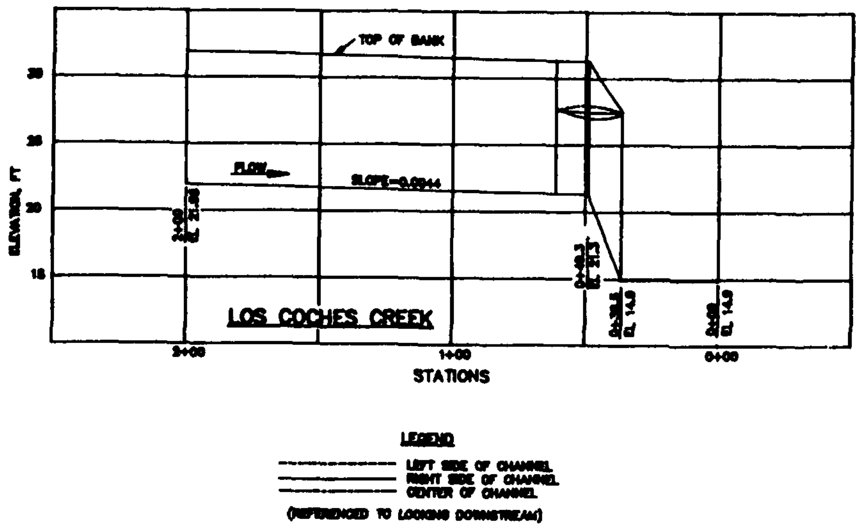
Plate 13



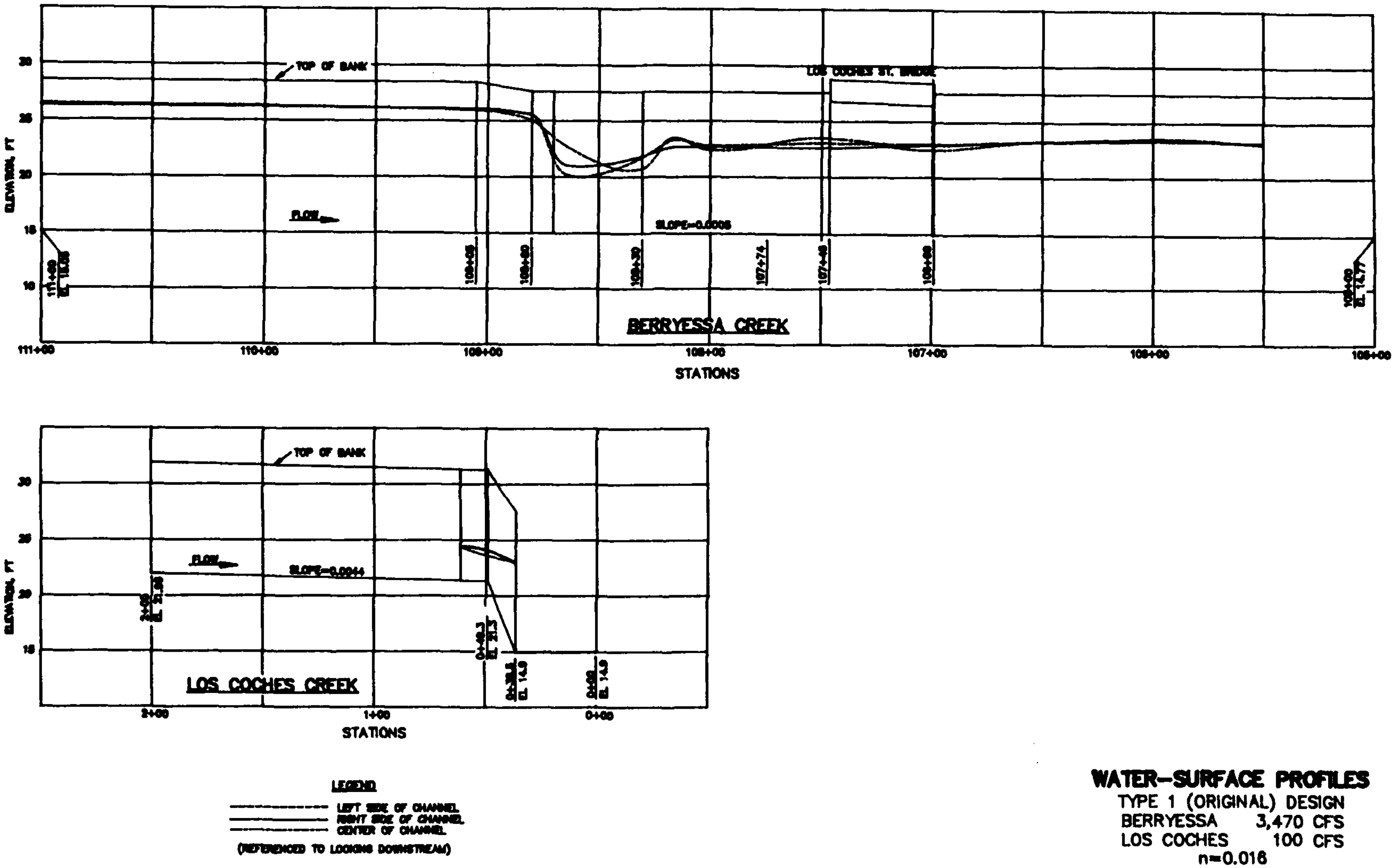
WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 2,130 CFS
SIERRA 550 CFS
n=0.012

Plate 14

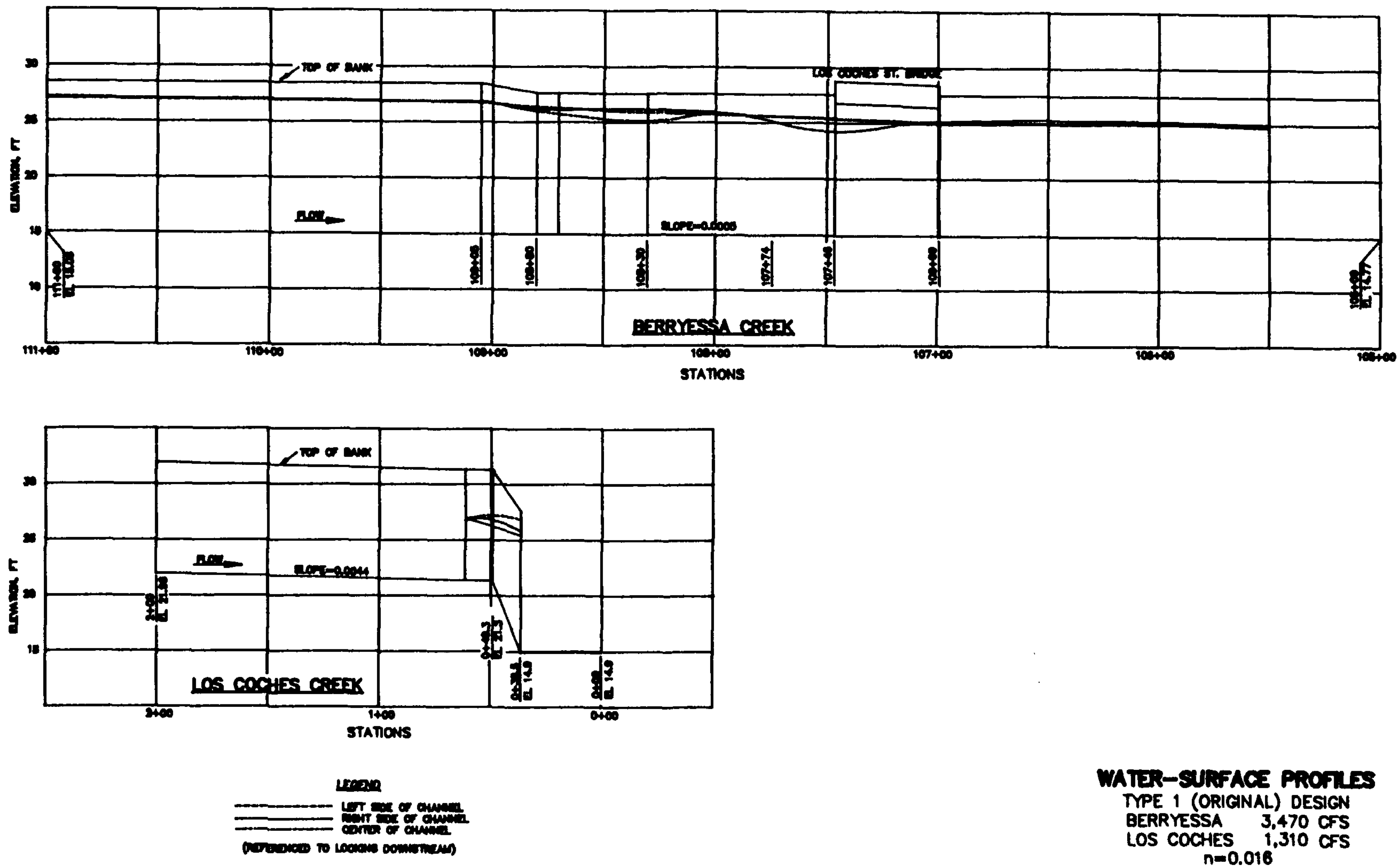




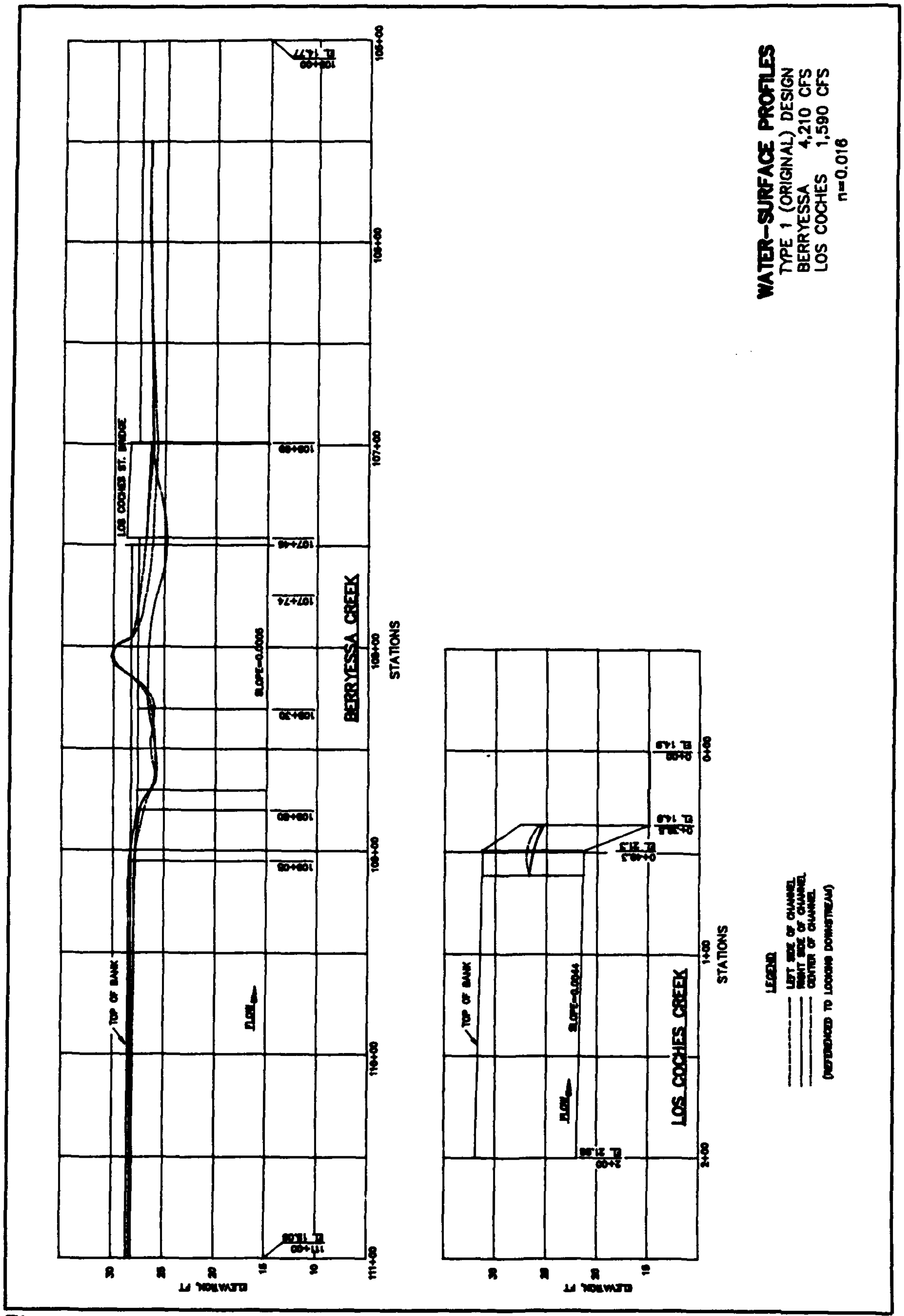
WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 100 CFS
LOS COCHES 1,530 CFS
n=0.016



WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 3,470 CFS
LOS COCHES 100 CFS
n=0.016

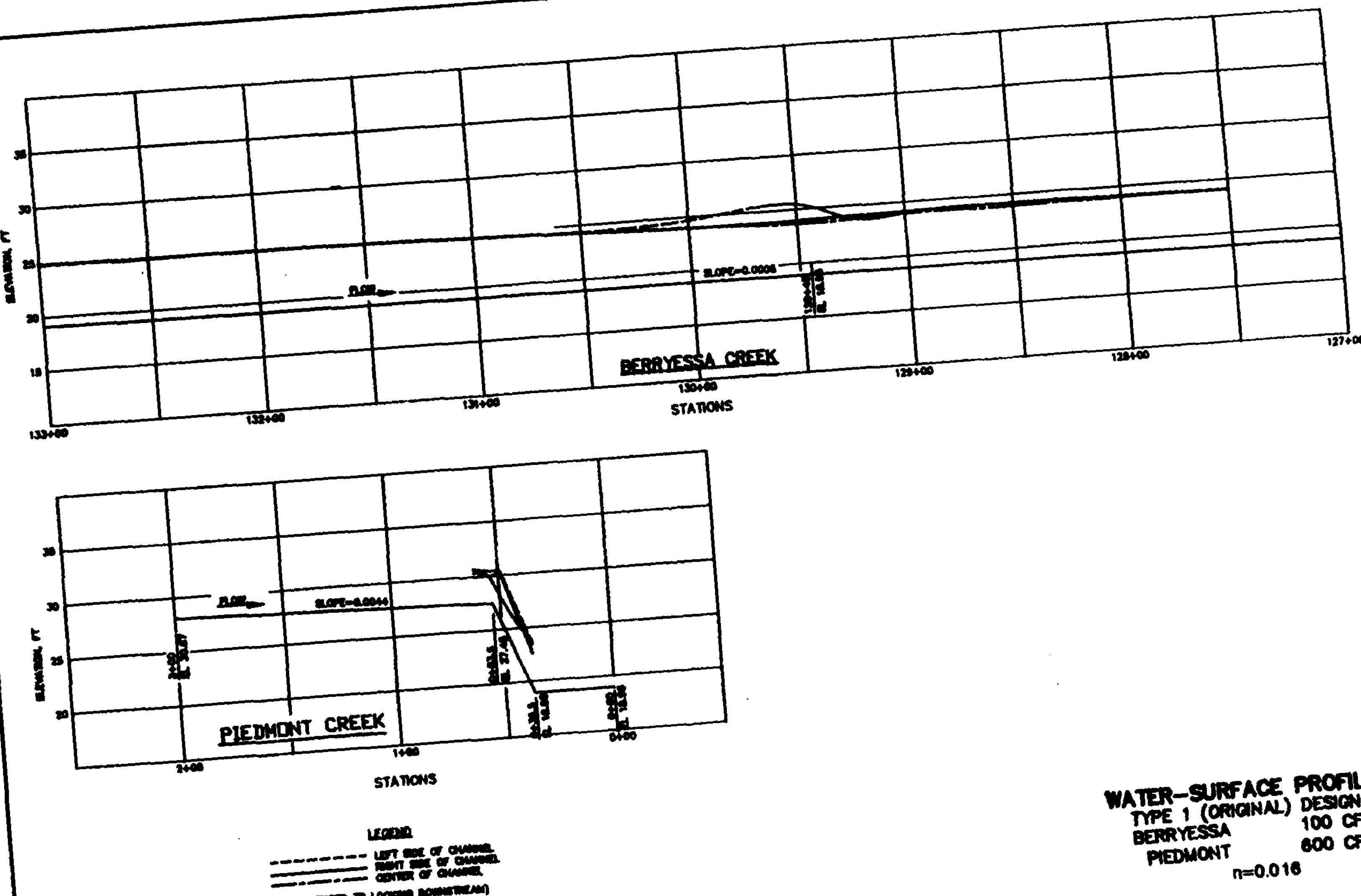


WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 3,470 CFS
LOS COCHES 1,310 CFS
n=0.016



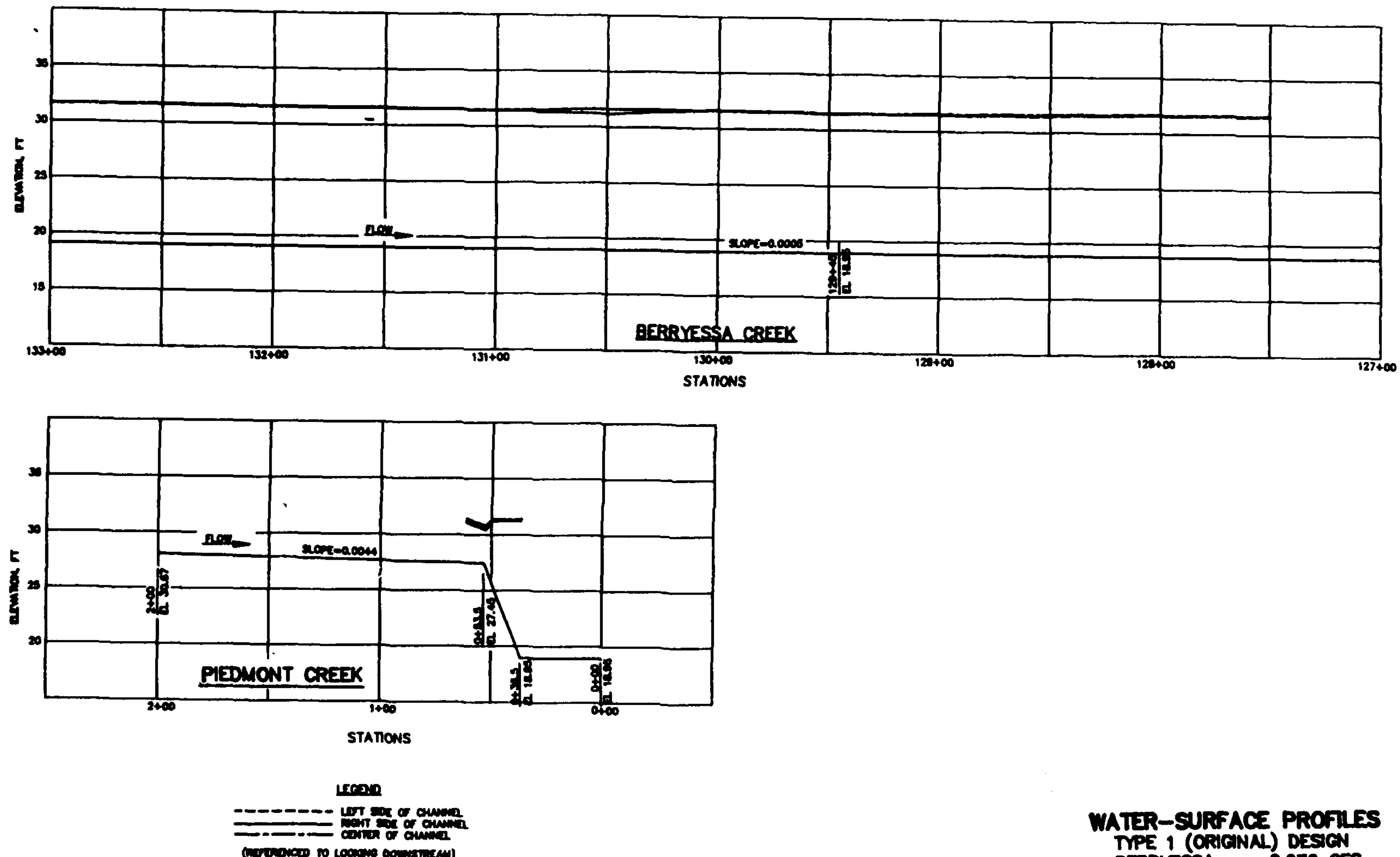
WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 4,210 CFS
LOS COCHES 1,590 CFS
n=0.016
BERRYESSA CREEK
LOS COCHES CREEK
STATIONS
ELEVATION, FT
TOP OF BANK
FLOW
LOS COCHES ST. BRIDGE
SLOPE=0.0044
LEGEND
LEFT SIDE OF CHANNEL
RIGHT SIDE OF CHANNEL
CENTER OF CHANNEL
(REFERENCED TO LOOKING DOWNSTREAM)

Plate 18



WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 100 CFS
PIEDMONT 600 CFS
n=0.016

Plate 20



WATER-SURFACE PROFILES
TYPE 1 (ORIGINAL) DESIGN
BERRYESSA 2,970 CFS
PIEDMONT 500 CFS
n=0.016

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

Tests were conducted on a 1:16-scale and two 1:20-scale models of the Berryessa Creek and three of its major tributaries to evaluate the performance of the proposed designs and develop desirable modifications, if needed, to safely pass the 100-year-frequency discharges through the three channel junctions. Specifically, the Sierra Creek, Los Coches Creek, and Piedmont Creek junctions with Berryessa Creek were investigated.

The Berryessa/Sierra junction model (1:16 scale) reproduced approximately 500 ft of the Berryessa channel and 200 ft of the Sierra channel. The model was constructed so that the slopes of the channels could be adjusted to reproduce energy gradients equivalent to those resulting from prototype Manning's n values of 0.012 and 0.014.

Initial tests, conducted with the invert slopes adjusted to reproduce an energy gradient resulting from a Manning's n value of 0.014, indicated that the original design would effectively convey the design flow (2,680 cfs), and with minor modifications, flow conditions could be improved at the Morrill Avenue box culvert. Tests indicated that flow conditions at the Morrill Avenue box culvert could be improved with the

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addition of a triangular pier extension. Tests also indicated that with a total discharge of 3,370 cfs (2,670 cfs in Berryessa Creek and 700 cfs in Sierra creek) the Morrill Avenue box culvert would prime (flow full) and significant overtopping would occur upstream from the box culvert.

Additional tests were conducted with the invert slopes adjusted to reproduce the energy gradient for a Manning's n value of 0.012. Test results indicated that the original design was adequate to convey the design discharge of 2,680 cfs. Test results also indicated that the Morrill Avenue box culvert would prime for flows greater than 3,770 cfs (2,670 cfs in Berryessa Creek and 1,100 cfs in Sierra Creek), resulting in significant overtopping upstream of the box culvert.

The Berryessa/Los Coches Junction model (1:20-scale) reproduced approximately 600 ft of Berryessa Creek and 200 ft of the Los Coches channel. The invert channel slopes were adjusted to reproduce the energy gradient for a Manning's n value of 0.016.

Tests to determine the adequacy of channel improvements for the Berryessa/Los Coches Creek junction indicated that for the original design, flow conditions were satisfactory for the design discharge.

The Berryessa/Los Coches Creek model was modified somewhat to reproduce the Berryessa/Piedmont junction by removing the bridge and the constriction from sta 108+30 to sta 109+05, and increasing the channel invert of Piedmont to a height of 8.5 ft above the Berryessa invert.

Tests to determine the adequacy of channel improvements for the Berryessa/Piedmont Creek junction for a Manning's n value of 0.016 indicated that the original design would effectively convey design flow conditions.