UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF TULE RIVER PARSHALL FLUME--FRIANT-KERN CANAL CENTRAL VALLEY PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd-406

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

November 14, 1955

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Laboratory Report No. Hyd-406
Hydraulic Laboratory
Compiled by: W. E. Wagner
Reviewed and
checked by: A. J. Peterka

Subject: Hydraulic model studies of Tule River Parshall flume--Friant-Kern Canal--Central Valley Project, California

Hydraulic model studies to reduce the turbulence in the subject flume have been completed. This report contains a discussion of the essential tests made in developing the necessary corrective measures, together with the conclusions and recommendations.

The Problem

Water releases during the past summer through the Tule River Parshall flume have shown that turbulence and surface waves in the flume approach made accurate measurement of the flow in the flume impossible. Differences up to 39 percent between current meter measurements and the theoretical discharge as measured by the automatic recorder were observed, Figure 1. The jets from the gate openings struck the 7-foot 5-inch step at the entrance to the flume, causing large boils and surface disturbances which extended downstream into the converging section of the flume, Figure 2. Surface undulations at the flume staff gage varied between 0.25 and 0.60 foot during prototype test runs.

A complete report from Region 2 on the operation of the prototype flume is contained in the Appendix. Essential data from this report is tabulated below:

Canal depth (feet)	Ha (feet)	Theoretical flume Q	Actual Q	Percent variation	Drop across gates (feet)	W.S. variation at staff gage (feet)
14.7	2.0	175	243	39	4-1/2-5	0.25
14.3	3.75	478	500	5	2-2-1/2	.60
14.0	4.64	636	673	6	1-1-1/2	.60

Model studies were undertaken to determine the corrective measures necessary to eliminate or reduce the turbulence in the flume approach and thereby make the flume an accurate measuring device.

The Model

A 1:18 scale model of the structure was used in the studies, Figure 3. The model included a 216-foot length of the Friant-Kern Canal between Stations 5160+95.93 and 5163+11.93, the flume gate structure, and the Parshall flume. The extent of the model is outlined by the heavy black line in Figure 4.

The quantity of water flowing in the Friant-Kern Canal was measured by a venturi meter. Releases through the Parshall flume were measured by a staff gage in the flume.

Test Procedure

The tests were made with 3,500 second-feet flowing through the Friant-Kern Canal. The depth of water in the canal was varied with an adjustable tail gate to correspond to depths observed in the prototype. Releases through the Parshall flume were controlled by slide gates and were varied between 250 second-feet and the maximum design discharge of 700 second-feet.

The efficiency of the various corrective measures was evaluated by visual observations of the flow in the flume approach and by measuring the height of waves or surges at the flume staff gage. The water surface fluctuations were measured with a point gage as the vertical distance between the minimum trough and the maximum crest of the waves or surges passing the gage in a period of about 1 minute.

The Investigation

To verify that the model accurately represented flow conditions in the prototype, the model first was operated with the flume approach similar to the prototype, Figure 5, and checked later with 16-mm motion pictures furnished by the field. For comparison with the prototype, discharges of 250, 500, 630, and 700 second-feet with canal depths varying from 14.1 to 17 feet were set up in the model flume. The close similarity between model and prototype is apparent by comparing Figures 2 and 5. The boils at the entrance to the flume and the waves and surges in the flume are very pronounced in both model and prototype. Water surface fluctuations measured in the model varied from 0.25 to 0.54 foot as compared to 0.25 to 0.60 foot in the prototype.

Observations of the prototype design indicated that the boils in the flume approach were caused primarily by the jets from the gates striking the vertical step at the flume entrance. It appeared that by replacing the vertical step with a curved floor, the boils would be reduced. Six approach floors, designated Approaches 1 through 6, were tested. Wave heights measured with each approach in place indicated that Approaches 1 and 5, Figure 6B and F, reduced the fluctuation at the gage the greatest amount. Approach 5, which is a simpler design and more easily constructed in the field, reduced the wave heights to 0.09 foot for a discharge of 630 second-feet and to 0.23 foot for 500 second-feet. The boils at the flume entrance were materially reduced and the flow in the flume was fairly uniform, Figure 7.

It was evident from the above tests that the approach floor alone would not sufficiently reduce the surges in the flume to permit accurate measurement of the flow. Several types of wave suppressors in the form of sloping and vertical curtain walls were tested in combination with Approach 5, Figure 6H, I, and J. The curtain walls provided only slight improvement in the flow approaching the flume. The jets from the gates were directed under the curtain wall and continued downstream with no appreciable reduction in the height of boils or surges at the flume entrance.

It therefore became apparent that some means should be provided to break up the jet as it left the gates. Tests on slotted walls (Designs 5-D and 5-E, Figure 6K and L) showed that some form of baffle placed on the floor of the approach would reduce the boils or surges from 0.23 foot to approximately 0.10 foot, a considerable improvement over any of the designs previously tested.

Therefore, tests were conducted on various sizes and spacing of baffle piers placed on the approach channel floor. Preliminary tests showed that the best effect was obtained when the piers were located approximately 2 feet downstream from the gates. Tests were made on piers varying from 12 to 18 inches in width and from 3 feet 9 inches to 6 feet 9 inches in height. Both upstream and downstream faces of the pier were vertical with a sill 9 inches high placed between the piers, Figure 6M through P.

The baffle piers helped materially in further reducing the fluctuations in the flume. They served to break up the flow from the gates and prevented the jets from striking the approach floor and causing the boils and turbulence at the flume entrance. Wave heights measured with the piers installed varied from 0.04 to 0.13 foot and there was very little difference in performance for piers 4 feet 9 inches to 6 feet 9 inches in height. Since the tests on the preliminary pier shapes showed that the height of pier had no appreciable effect on the amount of turbulence, a pier height of 5 feet was arbitrarily chosen for more detailed study.

Conventionally shaped piers having a width of 12 and 18 inches were tested, Figure 6Q through T. Tests, which were made both with and without a sill placed between the piers, showed that the sills were desirable and helped to reduce the wave heights a maximum of approximately 0.07 foot. Also, slightly lower wave heights were observed when piers having a width of 18 inches were installed.

Figure 8 shows that the flume operation with 18-inch-wide piers and 9-inch sills and Approach 5 installed in the model. For flows below 600 second-feet, the water surface was comparatively smooth with surges varying between 0.04 and 0.09 foot, depending on the discharge. There was no evidence of the prominent boils observed in the prototype design, Figure 5. When the canal depth was increased to 17 feet and 700 second-feet was released through the flume, a slight hump in the water surface was noted near the flume entrance, Figure 8. However, the maximum surge at the flume staff gage was 0.09 foot, or the same as that observed for a discharge of 620 second-feet and a canal depth of 14.1 feet. A fluctuation of 0.09 foot in the staff gage reading represents an error in discharge of less than 1 percent, which is well within the accuracy of the theoretical discharge tables for a Parshall flume.

To determine if further reduction of the surges could be obtained, a slotted wall was placed between the baffle piers and the approach to the flume. Tests were made using Walls D and E having slots 12 and 18 inches wide, Figure 6U and V. The slotted wall slightly reduced the turbulence in the flow entering the flume, Figure 9. The flow downstream from the slotted wall appeared more uniform especially at the maximum discharge of 700 second-feet. Observed wave heights showed that the surges in the flume were further reduced approximately 0.02 foot when the slotted wall was used.

Conclusions and Recommendations

The model study indicated that the turbulence in the flume was caused by the jet from the gates striking the vertical step at the entrance to the flume. By replacing the step with a sloping approach floor, the boils and surface disturbances were materially reduced. Further reduction of the turbulence was obtained by placing a row of baffle piers immediately downstream from the gate openings. With the approach floor and the baffle piers installed in the model, the surges at the Parshall flume gage were reduced to a maximum of 0.09 foot. This variation on the gage amounts to less than 1 percent of the total indicated discharge. Minor improvement of the fluctuating water surface can be obtained by installing a slotted wall between the baffle piers and the sloping approach floor.

A summary of the wave heights observed in the model for the more important designs is shown below:

Canal depth ft	Flume Q cfs	Height of waves (feet, prototype)				
			Model			
		Prototype	Proto design	Design 5	Design 5-5A	Design 5-D-5A
14.8	250	0.25	0.25	0.14	0.04	0.04
14.4	500	.60	.38	.23	.07	.05
14.1	630	.60	.54	.09	.09	.07
17.0	700		.61		.09	.05

It is recommended that the structure be modified to include an approach floor (Approach 5) and a row of baffle piers 5 feet high and 18 inches wide with a 9-inch-high sill between the piers (Pier 5A), Figure 6S. Details of the approach floor and the baffle are shown in Figure 10. If the best possible flow conditions are desired a slotted wall, shown in Figure 10, may be installed at the upstream toe of the approach floor. However, the slight improvement in the flow conditions gained by the slotted wall is probably not justified by the additional cost of the wall.

Approximately 150 feet of black and white, 16-mm motion picture film was taken of the more important designs tested during the model study. It is requested that motion pictures of the performance of the prototype structure be obtained after the corrective measures have been installed. Motion pictures of the revised structure, combined with the pictures of the original structure and the model which are already available, will provide an excellent opportunity for model-prototype comparisons.

APPENDIX

October 6, 1955

Memorandum

To: Regional Engineer
Through: Head, Canals Section and Chief, Design Branch

From: C. G. Liden

Subject: Observation of flow conditions during test operation of Tule River Parshall flume--Friant-Kern Canal--Central Valley Project

A test operation of the Tule River Parshall flume on the Friant-Kern Canal was made on September 29, 1955 for the purpose of observing the flow conditions through the flume for varying discharges. The following personnel were present during the test:

Fresno Office
William Meyer

Lindsay Office
T. R. Meyer, Canal Superintendent
Richard Lawrence
Jack Rosenthal
Rex Moore

As noted in correspondence relative to this matter, it has been found that current meter measurements made during this year reveal that the flows through the flume were consistently higher at releases ranging between 240 cfs and 500 cfs than the theoretical rated discharges. Turbulence of the water and increased approach velocity at the entrance to the flume, resulting from increased drop in the water surface across the turnout gates upstream from the flume with greater canal depths, have been advanced as the principal factors which have caused the variation in discharge. Former current meter measurements made in 1950 indicated close agreement between the observed flow and the rated discharge for a release of 200 cubic feet per second. The water depth in the canal was 12.5 feet during the year 1950, whereas it was 14.9 feet when the measurements of this year were made.

In the letter of September 20, 1955 to the Regional Director from Assistant Commissioner and Chief Engineer, subject "Turbulence in Tule River Parshall flume--Friant-Kern Canal--Central Valley Project," it was requested that data pertaining to flume discharges of 200 cfs and 500 cfs with canal depths at 12.5 feet and at 15 feet be obtained during the test operation. Since it is necessary to keep the canal water surface checked to an approximate 15.0-foot depth in order to satisfy deliveries to the Lindmore Irrigation District, it was not possible to run any test releases at a canal depth of 12.5 feet. Further, since no current meter measurements had been made for releases lower than 240 cfs, it was believed that extrapolation of the discharge curve based on such measurements to determine the head for a flow of 200 cfs could introduce some error. It was thus concluded that the lowest flow to be used in the tests should be that corresponding to a head of 2.0 feet. Test releases were made for discharges of 243 cfs, 500 cfs, and 636 cfs. The canal water depth dropped from 14.9 feet to 14.0 feet during the test.

For the first test release the turnout gates upstream from the flume were opened until a reading of 2.0 feet was obtained on the stage recorder which measures the head in the converging section of the flume. The flow for this head, based on the rating curve obtained from current meter measurements made in 1955, was 243 cfs. The theoretical free flow discharge curve shows the flow for this head to be 175 cfs, which indicates the actual discharge exceeds the theoretical by approximately 39 percent. The canal depth was 14.9 feet at the beginning of this test release and had dropped to 14.65 during the period the release was held at 243 cfs. The water surface below the turnout gates and upstream from the entrance to the flume was fairly smooth for this flow. A drop in the water surface estimated to be approximately 6 inches occurred about 1 foot downstream from the entrance to the flume. The flow through the flume below this point was somewhat turbulent, and the depth of flow appeared to vary. This variation in depth was not indicated on the automatic recorder operated by the float in the stilling well. Operating personnel stated that a plug had been inserted in the 4-inch pipe leading to the stilling well, reducing the intake opening to 3/4 inch in order to eliminate the fluctuations of the recorder. During the time the flow was maintained at 243 cfs the recorder registered a constant depth of 2.0 feet. Observation of the visual depth gage on the left side of the flume indicated that the depth fluctuated between a minimum of 1.95 feet and a maximum of 2.20 feet. The critical depth for a flow of 243 cfs through the 15-foot throat would be 2.03 feet. It thus appears that the control may shift upstream from the throat during periods of the depth fluctuations and flow at critical depth at a section wider than the throat occurs at certain times which would account for a flow in excess of the theoretical. Based on the difference in the depths of water surface at the entrance to the flume which, as noted above could only be estimated, the drop in water surface across the turnout gates was indicated to be 4.5 to 5.0 feet. It was not possible to determine the turnout gate opening as the stems are fully enclosed and no calibrating devices have been provided for the gates.

The turnout gates were next raised until the stage recorder registered a head of 3.75 feet which corresponds to a flow of 500 cfs based on data obtained from 1955 current meter measurements. The theoretical discharge curve indicates the flow to be 478 cfs at this head. For the flow at this head the water surface upstream from the flume was turbulent with a hump or standing wave occurring approximately 1 foot back of the entrance to the flume. This crest of the hump was estimated to be 8 inches above the upstream water surface and 12 inches above the downstream water surface. Observation of the flow at the surface indicated water movement upstream and downstream from the crest of the hump. Flow in the flume appeared to be somewhat turbulent and water surface had a white foamy appearance immediately below the flume entrance. No variation from the 3.75-foot head was shown on the automatic recorder. Fluctuations from a minimum of 3.50 feet to a maximum of 4.10 feet in the head were indicated on the visual staff gage. The critical depth for this quantity at the throat is 3.26 feet. It is thus indicated that the control remains at the throat for releases at this stage. The depth of water in the canal dropped from 14.65 feet to 14.3 feet during the period release of 500 cfs was made. Based on estimated differences in water surfaces, it appears that the drop in water surface across the turnout gates was between 2.0 feet and 2.5 feet.

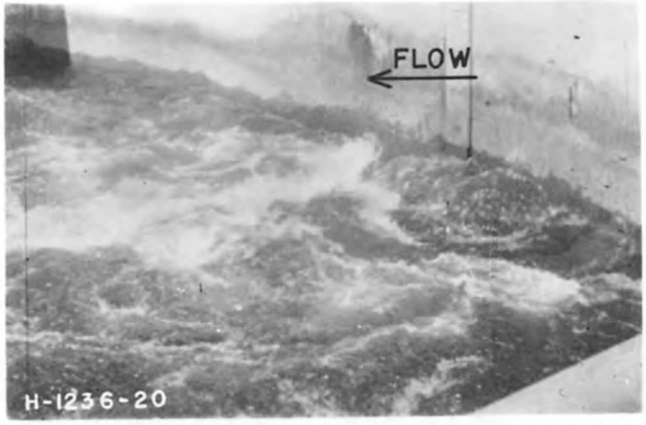
The turnout gates were then raised to full opening and for this condition the automatic stage recorder indicated the head on the flume to be 4.64 feet. No current meter measurements have been made for a flow of this magnitude. Extrapolation of the discharge curve based on current meter measurements indicated the flow to be 636 cfs. No points for this curve have been obtained for heads in excess of 4.0 feet and it is thus evident that the actual discharge may be appreciably different than this flow. The theoretical free flow discharge curve shows the flow to be 673 cfs for this head. For this condition of flow, the water surface upstream from the entrance to the flume appeared level and no standing wave or hump was noted. Just below the entrance to flume the water surface dropped an estimated 8 inches. There was no white foam on the water surface in the flume. The automatic recorder indicated a constant head of 4.64 feet during the period of the test at this flow. A head variation from a minimum of 4.50 feet to a maximum of 5.10 feet was indicated from observation of the visual staff gage. For a flow of 636 cfs the critical depth through the throat is 3.83 feet. Based on these data, it appears that control remains at the throat for this flow. The depth of water in the canal dropped from 14.3 feet to 14.0 feet during the period of this test flow. It was estimated that the drop in water surface across the turnout gates was between 1.0 foot and 1.5 feet.

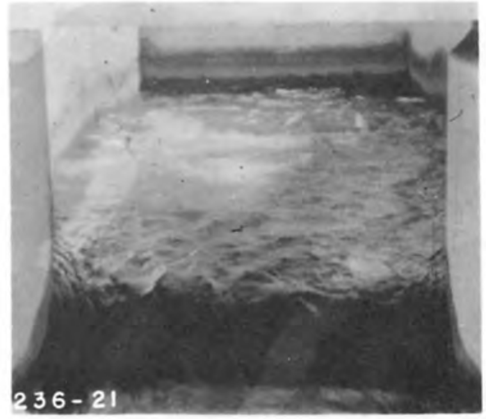
Conclusions

Observation of the Tule River Parshall flume during test discharges on September 29, 1955 indicates that, under operation at canal depths of approximately 15.0 feet, some turbulence occurs at flows in the range from 240 cfs to 640 cfs. A rather wide variation in flow between the theoretical and actual at the lower discharges has been noted. Based on observed flume heads at an actual flow of 243 cfs, it appears that control may shift upstream from the throat and flow at critical depth may occur in a section somewhat wider than the throat. An appreciable velocity of approach to the flume may exist at this discharge which could cause such a condition of flow in the flume. For actual flows of 500 cfs and 636 cfs, the observed flume heads are appreciably greater than computed critical depths at the throat for these discharges. Fairly close agreement between theoretical and actual discharges is indicated for these flows, and it thus appears that the velocity of approach does not affect the operation of the flume to such a marked degree within this range of discharges.

/s/ C. G. Liden

Noted: W. J. McCrystle (Regional Engineer), 10-7-55 Date

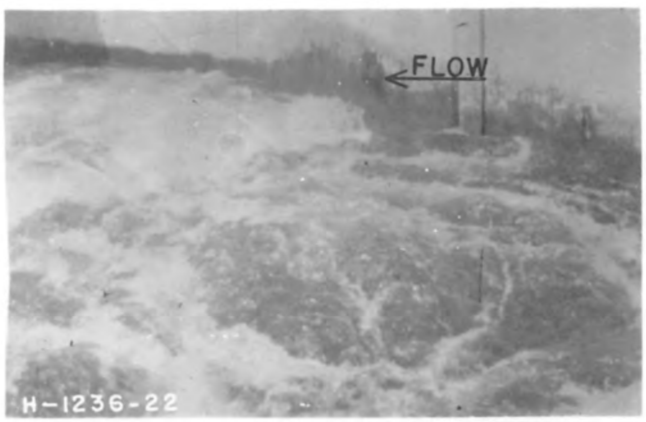


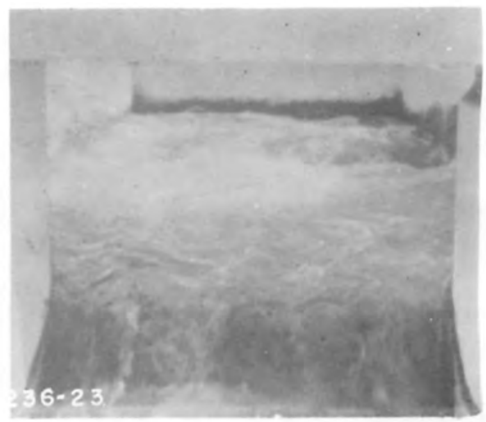


Flow at vertical step

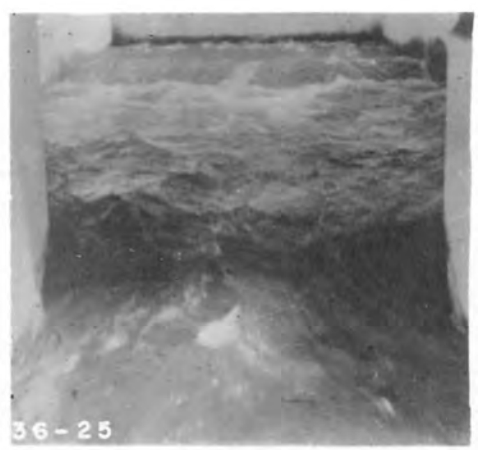
Flow in flume

Q = 243 cfs



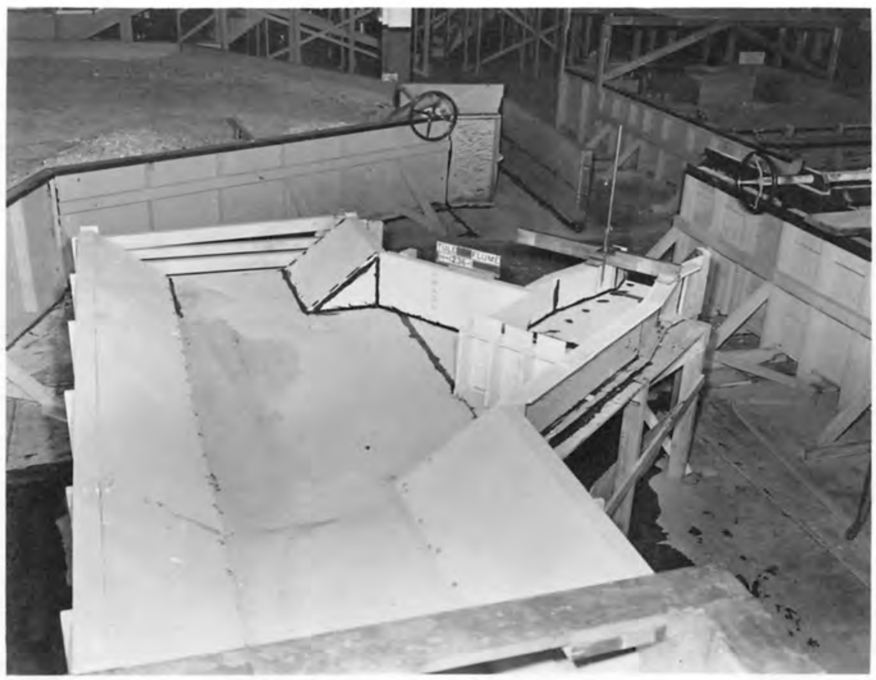


Q = 500 cfs



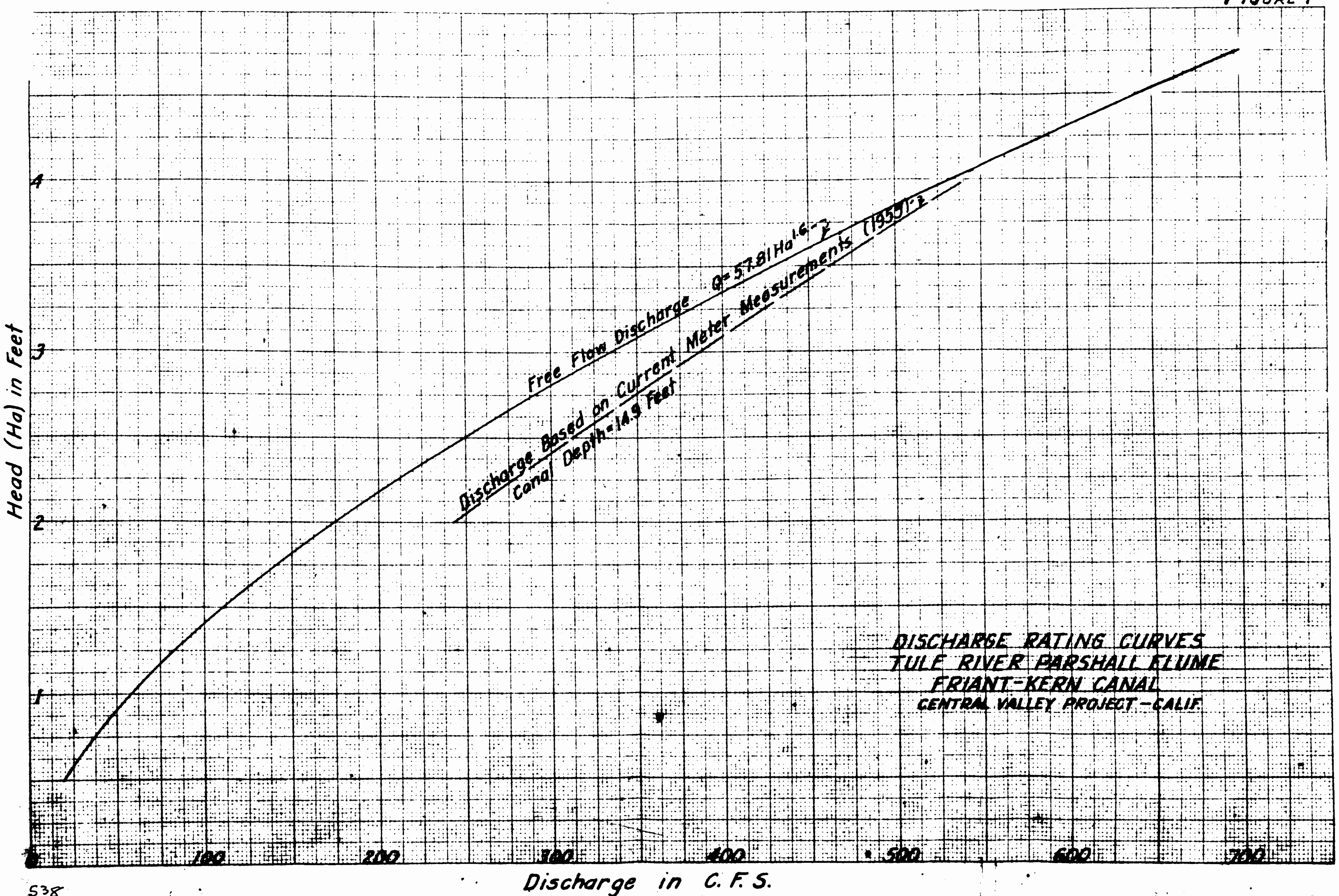
Q = 636 cfs

TULE RIVER PARSHALL FLUME
Operation of Prototype



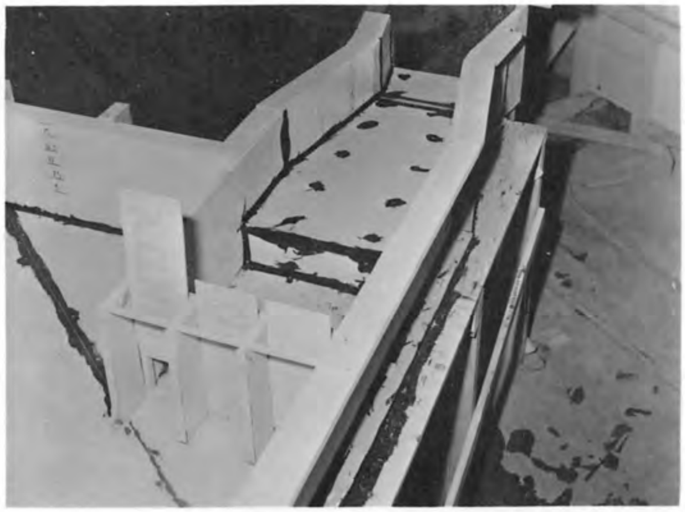
THE 1:18 MODEL

FIGURE I

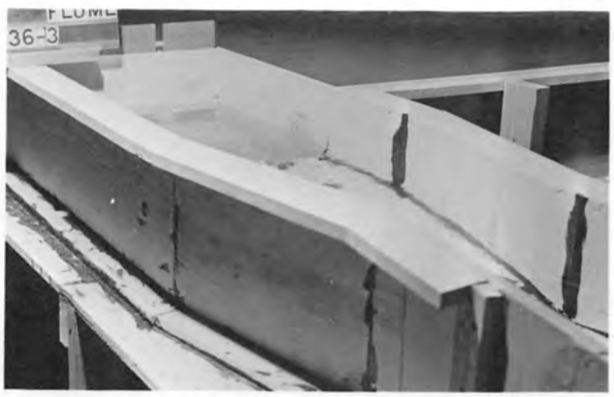


DISCHARGE RATING CURVES
TULE RIVER PARSHALL FLUME
FRIANT-KERN CANAL
CENTRAL VALLEY PROJECT-CALIF.

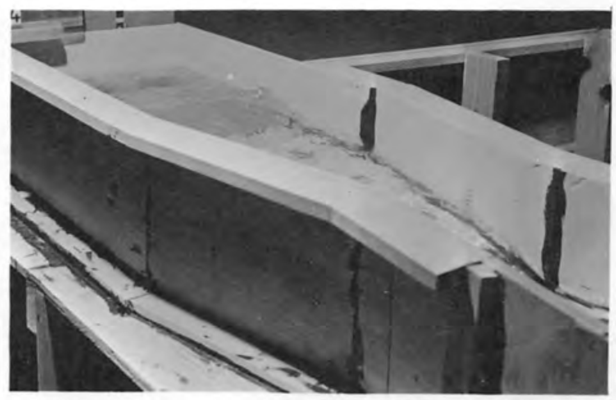
538



PROTOTYPE DESIGN



Q = 250 cfs.   d = 14.8'



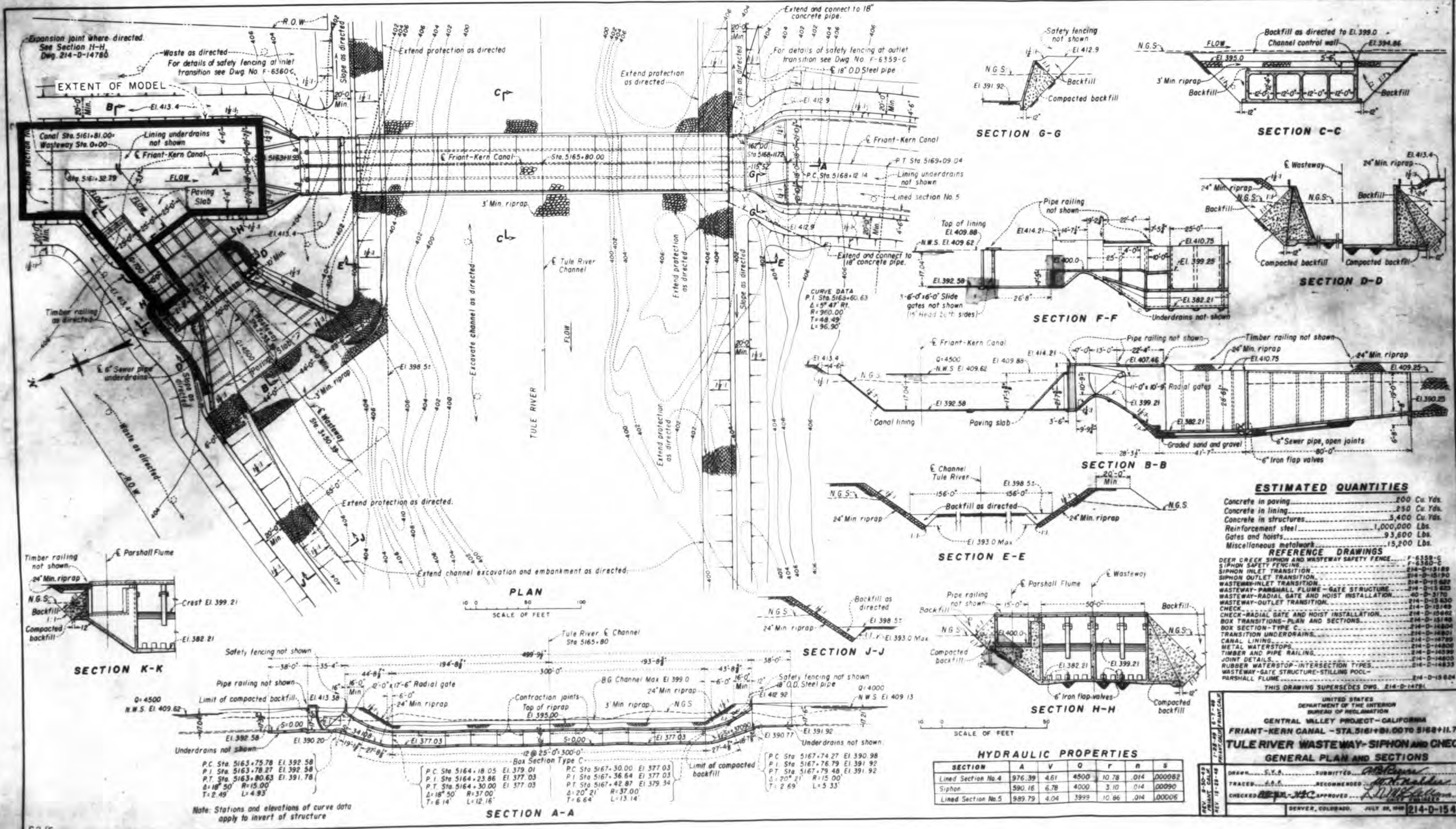
Q = 500 cfs.   d = 14.4'

Q = 630 cfs.   d = 14.1'

Q = 700 cfs.   d = 17.0'

TULE RIVER PARSHALL FLUME
Operation of Prototype Design
1:18 Model

FIGURE 4



HYDRAULIC PROPERTIES

SECTION	A	V	Q	r	n	s
Lined Section No. 4	976.39	4.61	4500	10.78	.014	.000082
Siphon	590.16	6.78	4000	3.10	.014	.00090
Lined Section No. 5	989.79	4.04	3999	10.86	.014	.00006

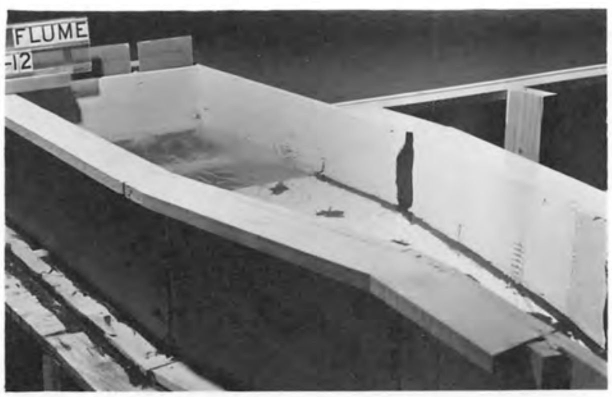
. DESIGN 5.

Q = 250 cfs. d = 14.8'

Q = 500 cfs. d = 14.4'

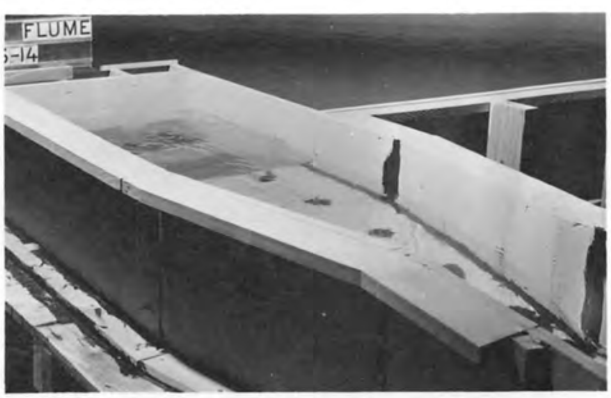
TULE RIVER PARSHALL FLUME
Operation of Design 5
1:18 Model

DESIGN 5-5a

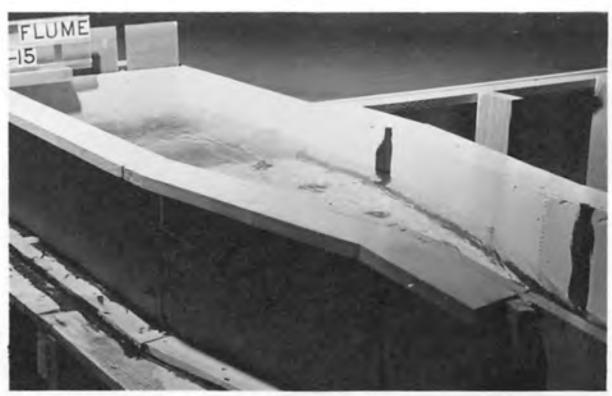


Q = 250 cfs. d = 14.8'

Q = 500 cfs. d = 14.4'

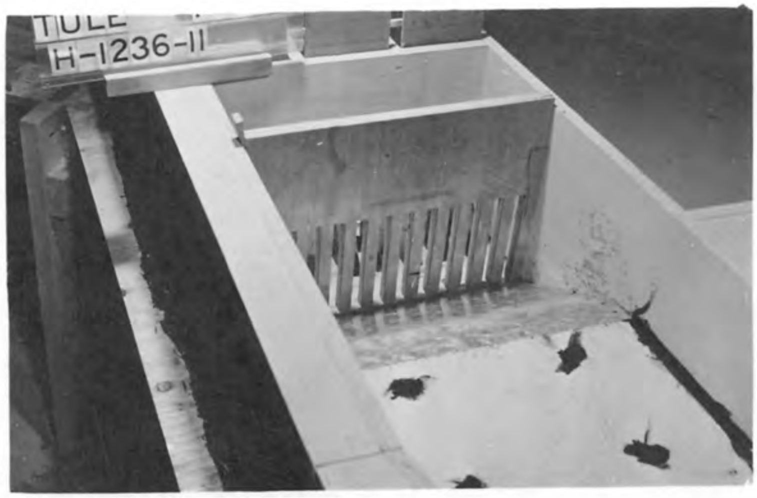


Q = 620 cfs. d = 14.1'



Q = 700 cfs. d = 17.0'

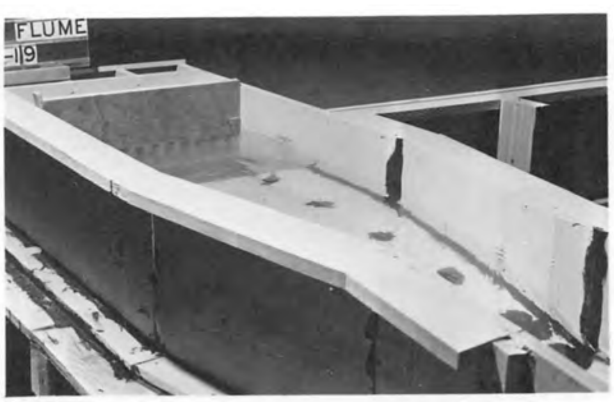
TULE RIVER PARSHALL FLUME
Operation of Design 5-5a
(Recommended)
1:18 Model



DESIGN 5-D-5a

Q = 250 cfs. d = 14.8'

Q = 500 cfs. d = 14.4'

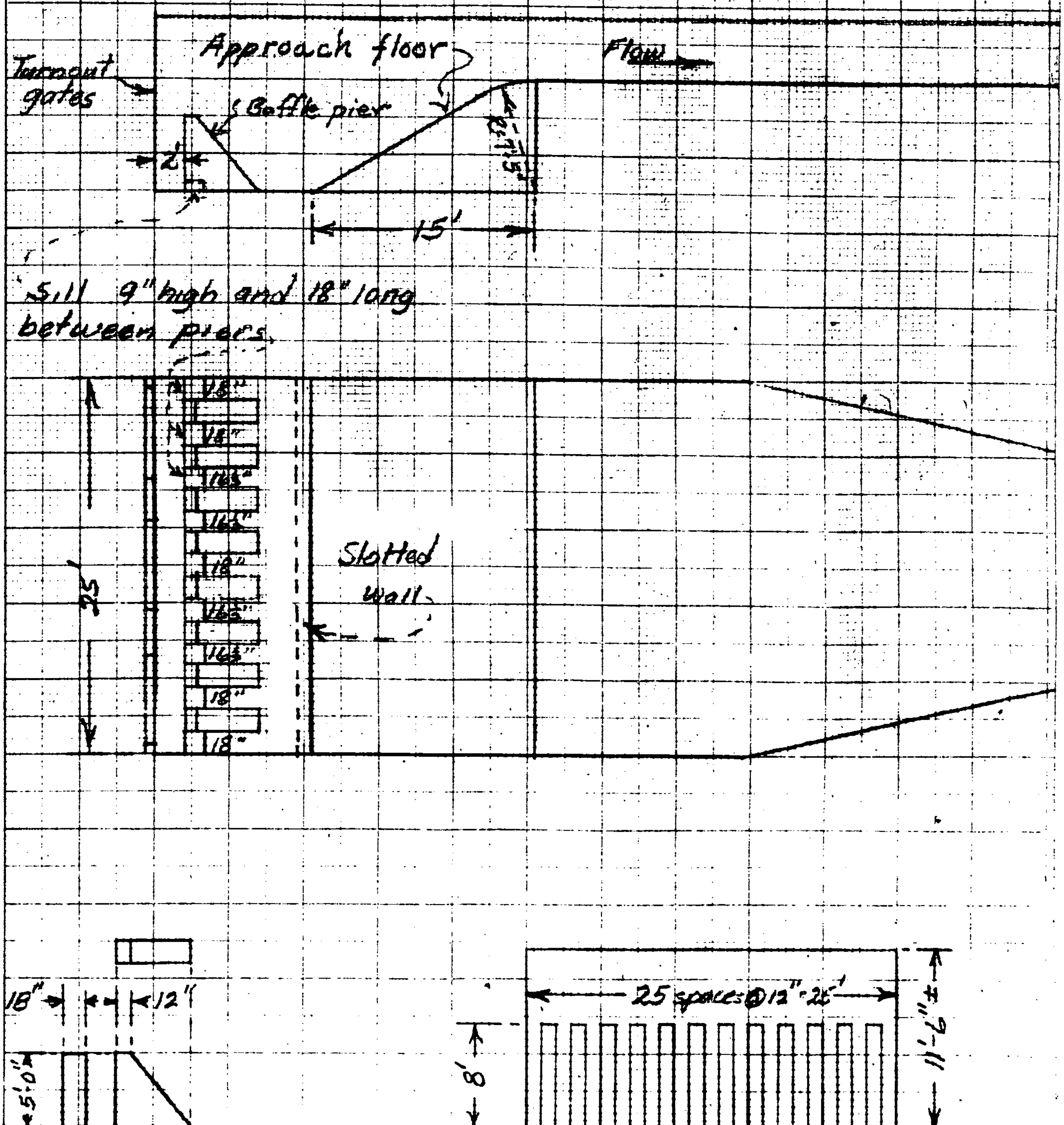


Q = 610 cfs. d = 14.1'

Q = 700 cfs. d = 17.0'

TULE RIVER PARSHALL FLUME
Operation of Design 5-D-5a
1:18 Model

FIGURE 10

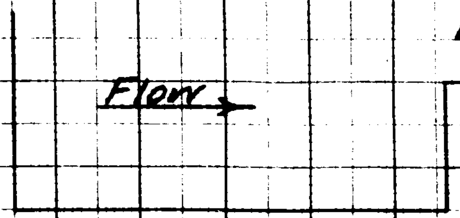


Pier Detail

Slotted Wall
(Gives only slight improvement)

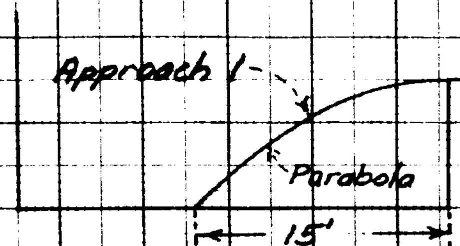
TULE RIVER PARSHALL FLUME
RECOMMENDED MODIFICATIONS (DESIGN 5-5a)
1:18 Scale Model

FIGURE 6



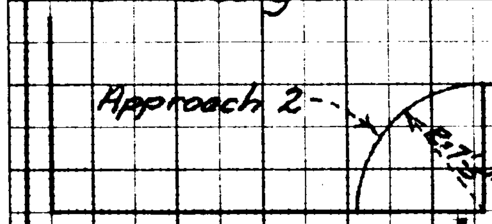
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.25
14.4	500	0.38
14.1	630	0.54

A. PROTOTYPE DESIGN



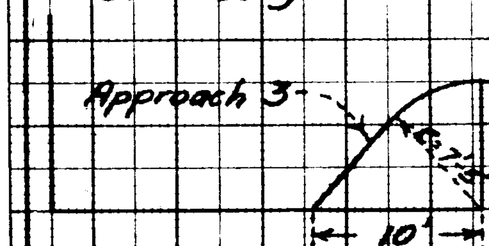
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.16
14.4	500	0.23
14.1	630	0.09

B. Design 1



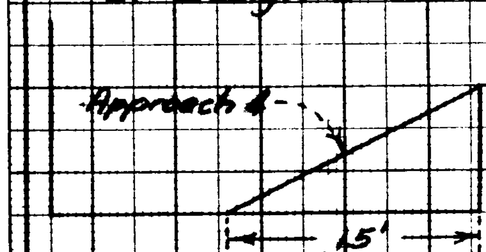
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.25
14.4	500	0.22
14.1	630	0.13

C. Design 2



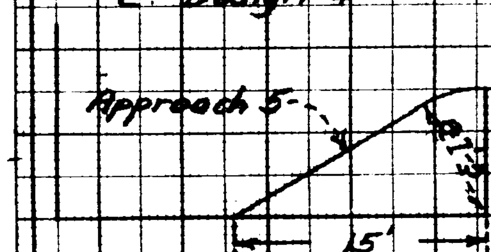
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.18
14.4	500	0.25
14.1	630	0.13

D. Design 3



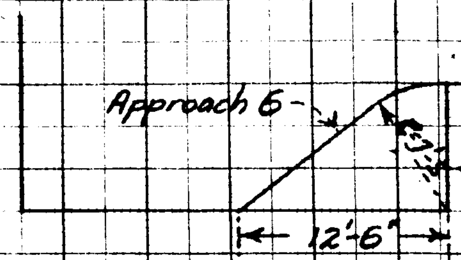
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.16
14.4	500	0.20
14.1	630	0.11

E. Design 4



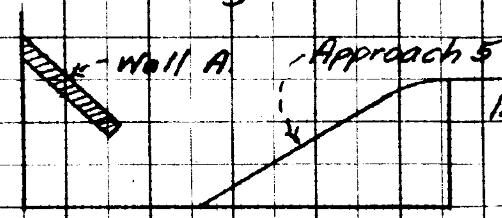
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.14
14.4	500	0.25
14.1	630	0.09

F. Design 5



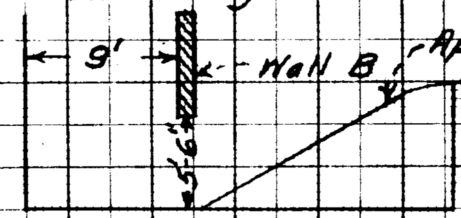
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.16
14.4	500	0.32
14.1	630	0.11

G. Design 6



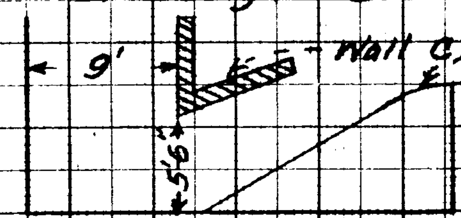
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.4	500	0.20'

H. Design 5-A



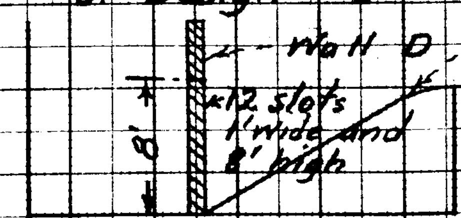
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.4	500	0.27'

I. Design 5-B



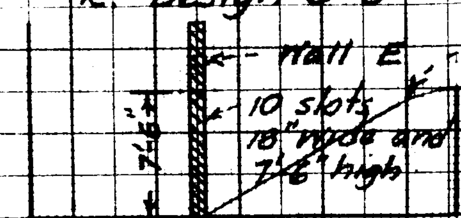
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.4	500	0.20'

J. Design 5-C



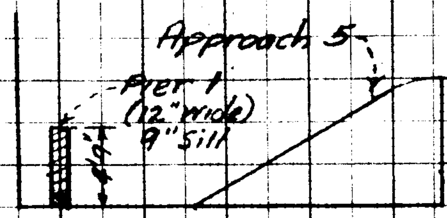
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.4	500	0.09'

K. Design 5-D



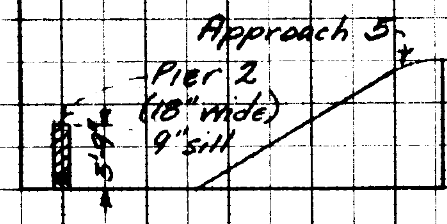
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.4	500	0.11'

L. Design 5-E



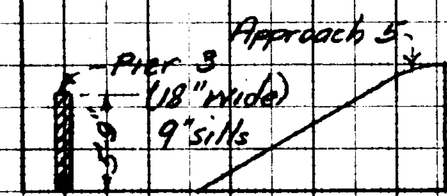
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.05
14.4	500	0.05
14.1	620	0.05
17.0	700	0.09

M. Design 5-1



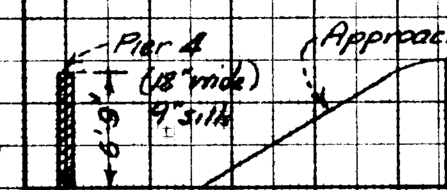
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.05
14.4	500	0.05
14.1	620	0.07
17.0	700	0.13

N. Design 5-2



Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.04
14.4	500	0.05
17.0	700	0.07

O. Design 5-3

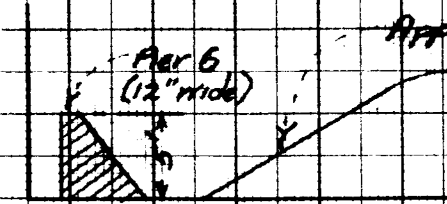


Canal Depth ft	Q cfs	Ht. of Waves* ft
14.4	500	0.05
17.0	700	0.07

P. Design 5-4

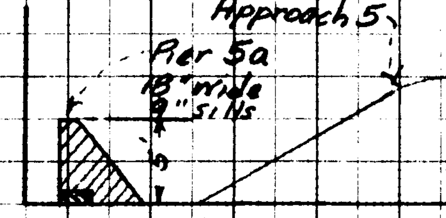
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.04
14.4	500	0.07
14.1	620	0.13
17.0	700	0.16

Q. Design 5-5



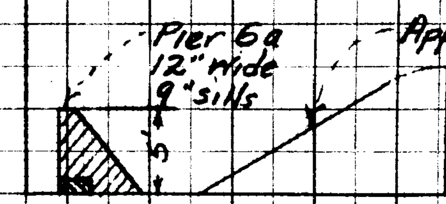
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.07
14.4	500	0.11
14.1	620	0.09
17.0	700	0.13

R. Design 5-6



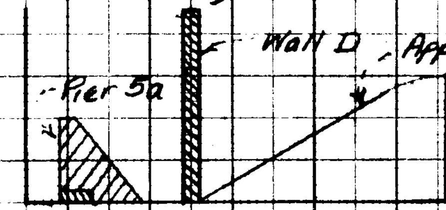
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.04
14.4	500	0.07
14.1	620	0.09
17.0	700	0.09

S. Design 5-5a (Recommended)



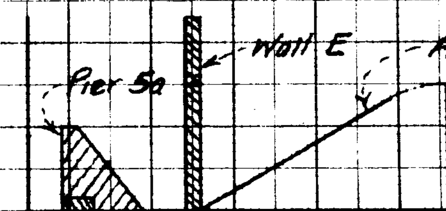
Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.05
14.4	500	0.07
14.1	630	0.09'
17.0	700	0.11'

T. Design 5-6a



Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.04
14.4	500	0.05
14.1	620	0.07
17.0	700	0.05

U. Design 5-D-5a



Canal Depth ft	Q cfs	Ht. of Waves* ft
14.8	250	0.04
14.4	500	0.07
14.1	620	0.07
17.0	700	0.07

V. Design 5-E-5a

* Height of waves is the distance from minimum trough to maximum crest measured at flume gage.

TULE RIVER PARSHALL FLUME

RECAPITULATION OF WAVE HEIGHT DATA

1:18 scale Model

W.E.W. 11/1/55