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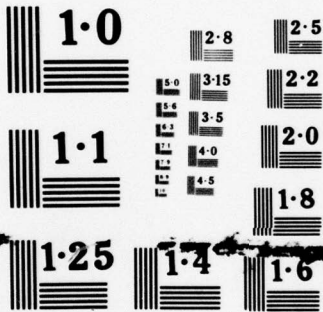
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TECHNICAL REPORT HL-79-6

OUTLET WORKS FOR CERRILLOS DAM
CERRILLOS RIVER, AND PORTUGUES DAM
PORTUGUES RIVER, PUERTO RICO

Hydraulic Model Investigation

by

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March 1979

Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Tests were conducted on a 1:24-scale model of the outlet works for the Cerrillos and Portugues Dams located in Puerto Rico. The purpose of the model investigation was to determine the performance of the stilling basins for the full range of discharges with minimum head pool and the optimum riprap protection plan for the exit channel. The model reproduced a schematic of the intake tower, conduit transition, CONT → (Continued)		

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20. ABSTRACT (Continued).

CONT → 60 percent of the conduit length, the stilling basins, and exit channel. The original design stilling basin (type 1) for the Cerrillos outlet works performed satisfactorily for low discharges of 500 cfs and less, and for the higher range of discharges between 1500 and 2500 cfs (design discharge). However, with the intermediate discharge of 1000 cfs, eddy conditions developed. Recommended modifications (type 14 stilling basin) incorporated into the original design included extending the invert immediately downstream from the outlet portal horizontally for 10 ft, raising the basin apron, relocating and reducing the size of the baffle blocks, and terminating the basin with a sloping end sill. These modifications produced satisfactory flow conditions for the full range of discharges. The optimum riprap protection plan was developed for the exit channel.

Performance of the type 1 stilling basin design for the Portugues outlet works was generally satisfactory with discharges ranging from 250 to 1100 cfs (design discharge). Eddy conditions did not develop for any discharge observed, but the water surface in the basin was rougher with the design discharge of 1100 cfs than that desired. Recommended modifications (type 4 stilling basin) incorporated into the original design included extending the invert immediately downstream from the outlet portal horizontally 10 ft, reducing the width of the baffle blocks, and terminating the basin with a sloping end sill. The overall length of the structure was increased 10 ft to retain the original apron length. The optimum riprap plan was also determined for the exit channel.

→ The conduits of both Cerrillos and Portugues outlet works were designed to provide for river diversion during construction of the dams. When the dams are completed, the flow will be regulated so that only bank-full capacities will be passed through the stilling basins. The conduit capacities were 4500 cfs for Cerrillos and 5300 cfs for Portugues. However, the stilling basins were designed for 2500 cfs (Cerrillos) and 1100 cfs (Portugues), the bank-full capacities downstream. Therefore, considerable damage to the downstream exit channel will occur should it become necessary to pass the conduit design flow through the outlet works.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers, U. S. Army, on 12 December 1974, at the request of the U. S. Army Engineer District, Jacksonville. The studies were conducted by personnel of the Hydraulics Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), during the period September 1976 to August 1977. All studies were conducted under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Chief of the Hydraulic Structures Division. The tests were conducted by Messrs. J. F. George and H. H. Allen under the supervision of Mr. G. A. Pickering, Chief of the Locks and Conduits Branch. This report was prepared by Mr. George.

Commander and Director of WES during the testing program and the preparation and publication of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)	
UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	5
The Prototype	5
Purpose of Model Investigation	5
PART II: THE MODEL	7
Description	7
Model Appurtenances	8
Scale Relations	9
Model Adjustment	9
PART III: TESTS AND RESULTS	11
Cerrillos Outlet Works	11
Portugues Outlet Works	15
PART IV: DISCUSSION OF RESULTS	19
PHOTOS 1-13	
PLATES 1-18	



CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms

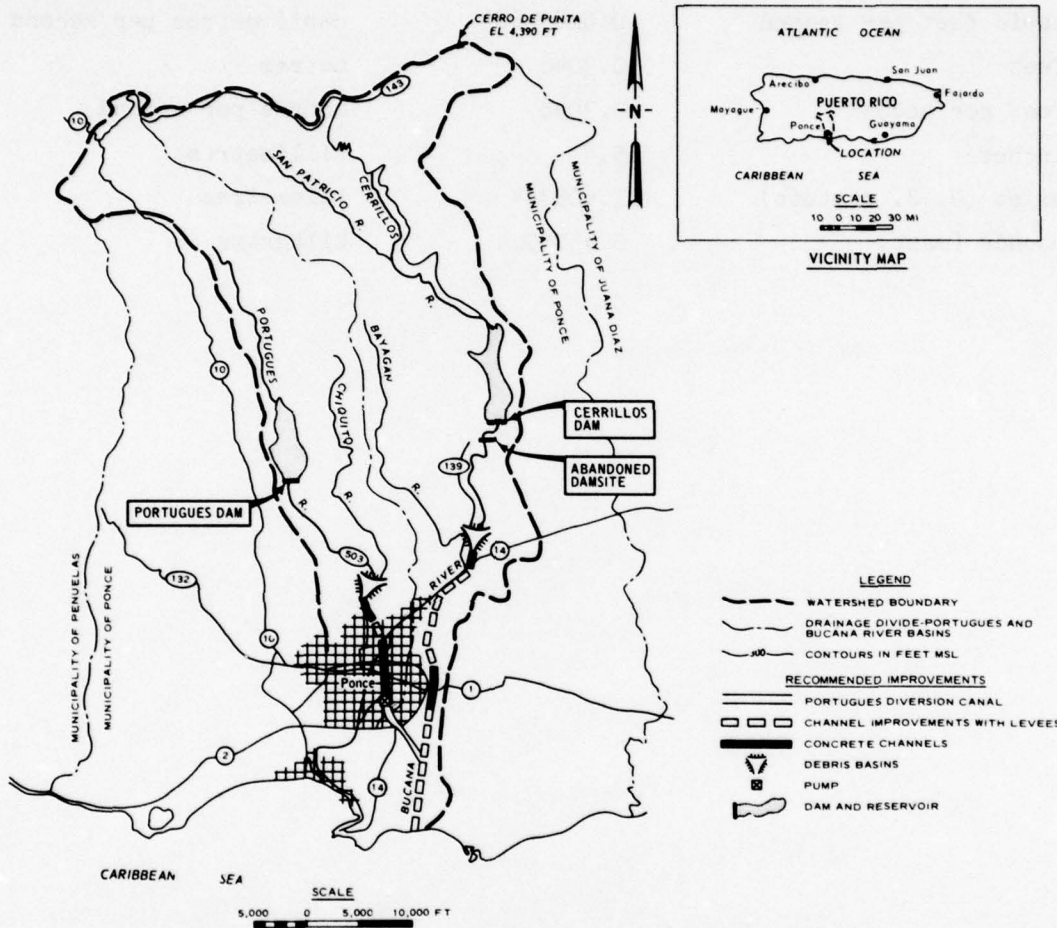


Figure 1. Location map

OUTLET WORKS FOR CERRILLOS DAM, CERRILLOS RIVER, AND
PORTUGUES DAM, PORTUGUES RIVER, PUERTO RICO

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Cerrillos Dam is located on the Cerrillos River between the Cordillera Central Mountains and the low coastal plain of the south coast in Puerto Rico. Portugues Dam is located on the Portugues River just west of the Cerrillos project, and is also between the Cordillera Central Mountains and the low coastal plain of the south coast in Puerto Rico (Figure 1). Both rivers flow in a southerly direction to the Caribbean Sea at Ponce, the second largest city in Puerto Rico.

2. Outlet works for both Cerrillos and Portugues Dams have a 12-ft-diam* conduit through the base of the dam to control pool levels and provide for river diversion during construction of the dam. The size of the conduit was based on diversion requirements during construction rather than for regulating pool levels. Both outlet works have an approach channel with concrete wing walls, a two-bay gated intake tower, conduit, and flared horizontal stilling basin with a single emergency gate serving each intake. The stilling basins were designed to accommodate downstream bank-full capacities of 2500 cfs for Cerrillos Dam and 1100 cfs for Portugues Dam.

Purpose of Model Investigation

3. The invert elevations of the Portugues and Cerrillos outlet portals were relatively low with respect to the basin apron elevation

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

and the exit channel invert. Strong possibilities were present that eddies would form in the stilling basins during low flows where tailwaters were greater than those required to maintain a good hydraulic jump. Model studies of the stilling basins were considered desirable to permit detailed studies of the outlet works for a full range of flow conditions. Specifically, it was expected that the model study would provide information on the following:

- a. The performance of the stilling basins for the full range of discharges with minimum head pool
- b. The optimum riprap protection plan for the exit channel.

PART II: THE MODEL

Description

4. The Cerrillos model, constructed to a scale of 1:24, reproduced a schematic of the intake tower, conduit transition, 840 ft of conduit, the stilling basin, and 165 ft of exit channel (Plate 1). The intake tower, conduit transition, and conduit were constructed of transparent plastic (Figure 2, Plate 2). The stilling basin was constructed of

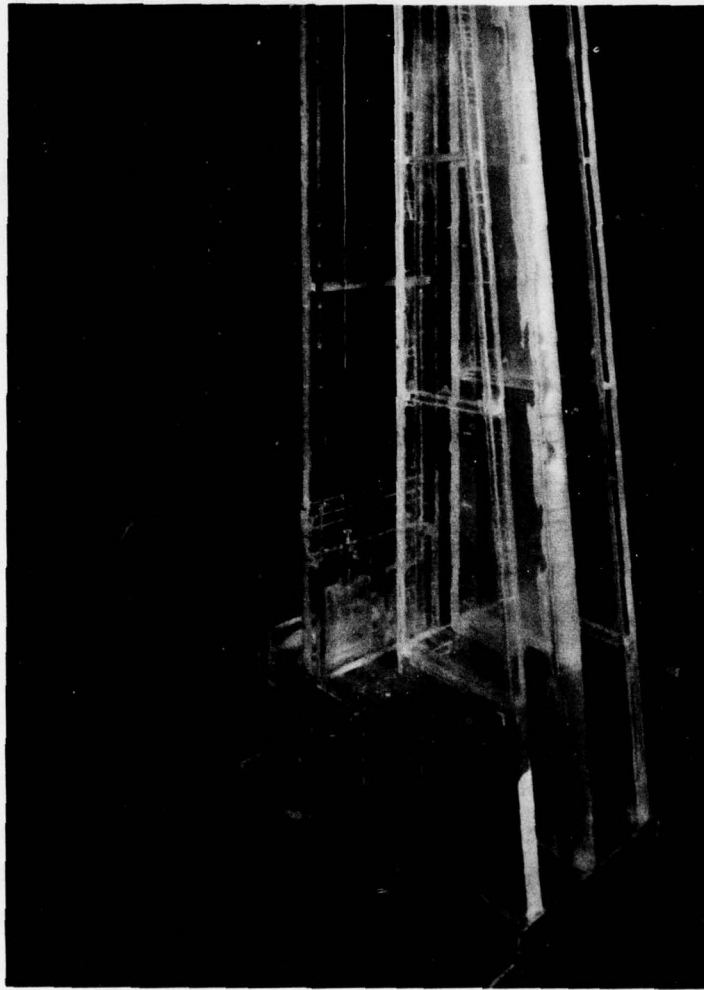


Figure 2. Dry bed of intake structure and transition

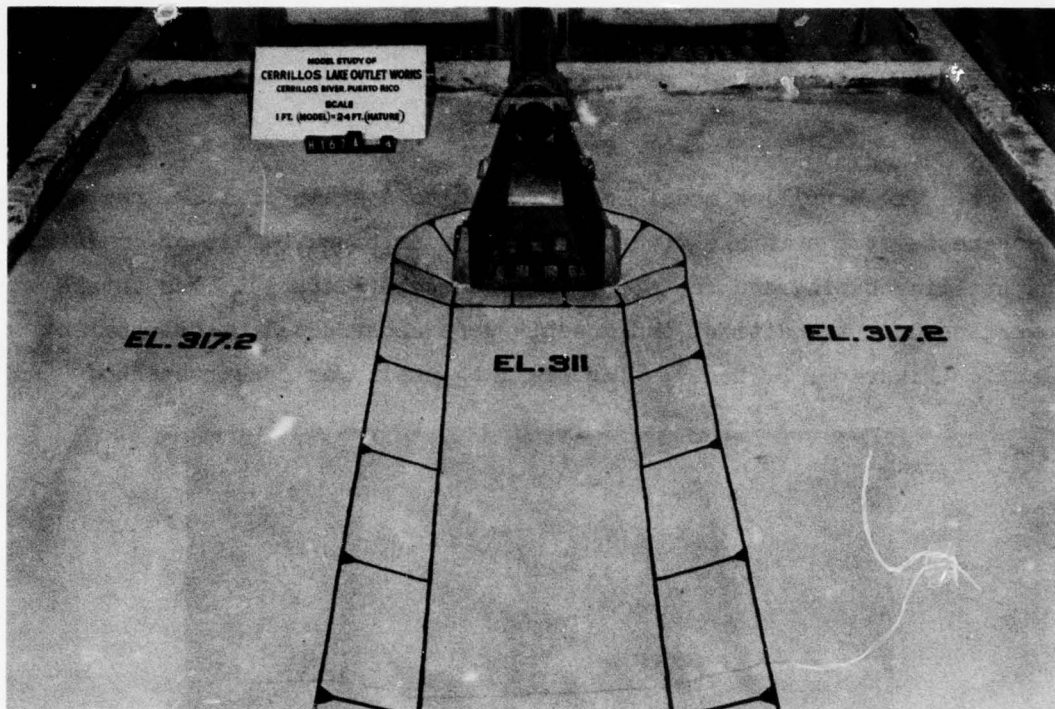


Figure 3. General view of the Cerrillos stilling basin (type 1), conduit, and exit channel

plastic-coated plywood and the stilling basin trajectory was constructed of sheet metal (Figure 3, Plate 3). The downstream exit channel was shaped in sand and molded with cement mortar. Crushed limestone (riprap) on filter cloth over the sand replaced the cement mortar before testing to determine the minimum downstream riprap requirements.

Model Appurtenances

5. Water used in the operation of the model was supplied by a circulating system. Discharges were measured by means of venturi meters installed in the flow lines and were baffled when entering the model. Steel rails graded to specific elevations were placed along both sides of the model to serve as supports for measuring devices and to provide a convenient means of establishing stations and elevations in the model. Velocities were measured with pitot tubes which were mounted to permit

measurement of flow from any direction and at any depth. Water-surface elevations were measured with point gages. Different designs, along with various flow conditions, were recorded photographically.

Scale Relations

6. 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 the transference of model data to prototype equivalents are presented below:

<u>Characteristic</u>	<u>Dimension*</u>	<u>Model:Prototype</u>
Length	L_r	1:24
Area	$A_r = L_r^2$	1:576
Velocity	$V_r = L_r^{1/2}$	1:4.9
Discharge	$Q_r = L_r^{5/2}$	1:2,821.8
Volume	$V_r = L_r^3$	1:13,824
Weight	$W_r = L_r^3$	1:13,824
Time	$T_r = L_r^{1/2}$	1:4.9

* Dimensions are in terms of length.

Model measurements of discharge, water-surface elevations, and velocities can be transferred quantitatively to prototype equivalents by means of the scale relations. Experimental data also indicate that the prototype-to-model scale ratio is valid for scaling riprap in the sizes used in this investigation.

Model Adjustment

7. In the model design, geometric similitude was preserved between model and prototype by means of an undistorted scale ratio.

Making a valid study of flow conditions in the outlet works required that the hydraulic grade line be simulated accurately in the model. It is not possible to satisfy the requirements of both the Froudian and Reynolds criteria for complete similitude by using water in the model. Since water is also the fluid in the prototype and hydraulic similitude between the model and prototype was based on Froudian relations, the Reynolds number with the design flow in the model was lower than that in the prototype. Therefore, the resistance coefficient of the model was higher than that of the prototype, and the excess losses in the model were compensated for by shortening the length of model conduit by 40 percent.

PART III: TESTS AND RESULTS

Cerrillos Outlet Works

Stilling basin tests

8. The Cerrillos stilling basin as originally designed (type 1) consisted of a 23-ft-long parabolic trajectory beginning from the outlet portal that dropped to a 55-ft-long horizontal apron. The horizontal apron contained two rows of 4-ft-high baffles with varying widths, and a vertical-faced, 4-ft-high end sill. The sidewalls of the stilling basin had continuous 1-on-8 flared walls from the outlet portal to the downstream end of the basin, with the width varying linearly from 12 ft at the outlet to 31.5 ft at the downstream end of the stilling basin. The invert elevations of the outlet portal and stilling basin apron were 311.0 and 300.0, respectively (Plate 3).

9. Initial tests were conducted to determine the performance of the type 1 stilling basin for a range of discharges up to bank-full capacity with a minimum pool of el 428.0. Flow conditions were observed for discharges up to 2500 cfs with one and two gates operating. The number of gates used had little effect on stilling basin performance.

10. Flow conditions were satisfactory in the type 1 stilling basin with a discharge of 500 cfs and a tailwater elevation of 313.4 (Photo 1); however, a surface eddy developed when the tailwater was increased to el 314.0. Eddies developed with discharges around 1000 cfs (Photo 2), which could cause abrasive damage to the basin apron if debris were trapped in the stilling basin. Flow conditions were generally satisfactory with discharges between 1500 and 2500 cfs, although the water surface was very rough with the higher discharge of 2500 cfs, as shown in Photo 3. The type 1 stilling basin design was adequate for low discharges of 500 cfs and less and discharges of 1500 cfs and greater. Velocities measured with discharges of 500, 1000, and 2500 cfs are shown in Plate 4.

11. Various designs of the Cerrillos stilling basin were tested to develop satisfactory hydraulic performance. The stilling basin was

tested with a 1V-on-1H sloping end sill, with one row of 4-ft-high baffle blocks located 35 and 38 ft downstream from the trajectory, and without baffle blocks. Little improvement in the general flow conditions was obtained with these modifications.

12. The invert immediately downstream from the outlet portal was extended horizontally for various distances to spread and redistribute the flow before it reached the curved trajectory. Horizontal extensions of 5, 10, and 18 ft were tested, with the original distance between the outlet portal and the end of the stilling basin being retained for these tests.

13. Tests were initially conducted with an 18-ft horizontal extension (type 7, Plate 5) which allowed the entering jet to spread uniformly across the invert before reaching the curved trajectory. This produced satisfactory flow conditions for discharges of 1000 cfs and less. The eddy condition that had been observed with the original design did not develop with any of the flows observed. However, for flows greater than 1000 cfs, the water surface in the basin was very rough due to the short apron.

14. The horizontal extension was shortened to 10 ft, which increased the length of the basin apron 8 ft (type 9, Plate 5). Eddy conditions did not develop with low flows and flow conditions with the higher discharges were improved. However, the water surface in the basin with the maximum discharge of 2500 cfs was still rougher than desired. Thus, the basin apron was raised 2 ft to el 302.0 and the baffles blocks and end sill heights were reduced to 2 ft (type 10, Figure 4). Flow conditions with this design were generally satisfactory for the full range of discharges, but the water surface was still very rough during the design discharge of 2500 cfs (Photo 4).

15. Although the 10-ft extension functioned satisfactorily, tests were conducted to determine if the extension could be reduced to 5 ft (type 11, Plate 6). Performance of the stilling basin with low flows was satisfactory; however, the toe of the hydraulic jump became unstable with higher flows. Therefore, no further tests were conducted with this design.

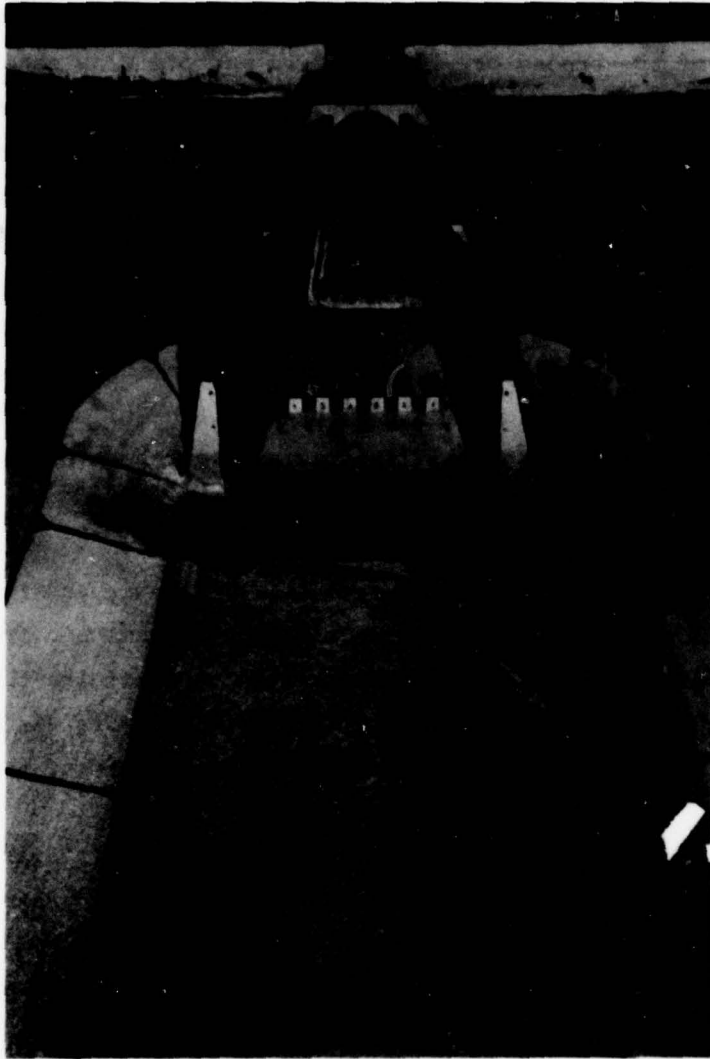


Figure 4. Dry bed of the type 10 stilling basin, looking upstream

16. Tests were continued with the 10-ft horizontal extension to further improve flow conditions in the stilling basin and reduce exit velocities. The apron was lowered to el 301.0 with one row of 3-ft-high baffle blocks placed 25 ft downstream from the trajectory (type 13, Plate 6). Flow conditions were satisfactory throughout the range of discharges tested; but the water surface was again rougher than desired with the design discharge.

17. The row of baffle blocks was repositioned to 30 ft downstream from the toe of the trajectory (type 14) to improve flow conditions with the maximum discharge. Flow conditions, shown in Photo 5, were satisfactory for the full range of discharges with a notable improvement in the water surface in the stilling basin with the design discharge of 2500 cfs. Test results indicated that the type 14 design (Plate 7) was the optimum stilling basin using basin walls with a continuous flare from the outlet portal to the end of the basin. Tests results also indicated that the Cerrillos stilling basin with continuous flared walls caused the water surface to pulsate along each side of the flared walls at the downstream end of the stilling basin, regardless of modifications tested in the stilling basin.

Riprap protection

18. Using the recommended type 14 stilling basin design, tests were conducted to determine riprap requirements downstream from the basin. Various schemes of riprap were tested to determine the minimum size and extent of exit channel protection required with discharges up to 2500 cfs. The channel invert immediately downstream of the basin was sloped upward 1V on 4H during these tests.

19. Riprap with an average diameter (D_{50}) of 18 in. was the minimum size required immediately downstream of the basin. Tests of the type 14C riprap plan, shown in Plate 8 and Photo 6, were conducted in an effort to determine riprap requirements for the entire length of channel reproduced in the model. Failure did not occur with this riprap plan for the full range of discharges tested, including a 10-hr (prototype) test with a discharge of 2500 cfs. Flow conditions with this design are shown in Photo 5 and velocities are presented in Plate 9.

20. Additional tests were conducted with the type 14D riprap plan (Photo 7) which eliminated the 8-in. (D_{50}) riprap. The last 5 ft of the 12-in. (D_{50}) riprap was extended down 2 ft below the channel invert and backfilled (Plate 8). Tests indicated that this plan of riprap provided adequate protection for the full range of discharges. However, considerable sloughing occurred at the downstream end of the riprap due

to severe scour of bed material in this area as shown in Photo 7b.

Conduit capacity test

21. A 5-hr (prototype) test was conducted using the type 1⁴ stilling basin and the type 1⁴D riprap plan with a discharge of 4700 cfs (conduit capacity) to observe the hydraulic performance of the stilling basin and the stability of the riprap protection plan. The hydraulic jump was contained in the basin (Photo 8), but failure occurred in the 18-in. riprap, mainly on the upward slope immediately downstream of the basin.

Recommended design

22. A reduction in the channel invert slope immediately downstream of the basin from a 1V-on-4H to a 1V-on-10H upward slope with the channel invert elevation at the downstream side of the end sill set 2 ft below the end sill elevation was recommended to improve the stability of the riprap and reduce the likelihood of this riprap entering the basin should any displacement occur. The recommended stilling basin and riprap protection (type 1⁴E design) are shown in Plate 7. Gradation of the riprap tested in the model is shown in Plates 10 and 11.

Portugues Outlet Works

23. The intake structure used in the Cerrillos stilling basin tests was used for the Portugues outlet works tests. The length of the Portugues conduit was adjusted to compensate for the excessive resistance of the model relative to the prototype and to provide for the accurate simulation of the prototype hydraulic grade line. A general plan of the model is shown in Plate 12.

Stilling basin tests

24. Initial tests were conducted to determine the performance of the stilling basin for a range of discharges with the minimum pool (el 430.0). Flow conditions were observed for discharges ranging from 250 to 1100 cfs (design discharge) with one and two gates opened. The number of gates used had little effect on the performance of the stilling basin.

25. Flow conditions in the type 1 stilling basin (Figure 5, Plate 13) were generally satisfactory, with no eddy conditions developing for the discharges observed. Flow conditions with discharges of 250 and 500 cfs are shown in Photos 9a and 9b. With the bank-full discharge of 1100 cfs (Photo 9c), the water surface in the basin was rougher than desired. The jet at the outlet portal did not spread properly across the trajectory with the design discharge, and this caused the rough flow conditions in the basin. Flow conditions in the exit channel downstream from the basin were satisfactory. Velocities measured with discharges of 250, 500, and 1100 cfs are shown in Plate 14.

26. Performance of the stilling basin was evaluated for various flow conditions with the apron raised to el 307.0 and one row of 2-ft-high baffle blocks placed 20 ft downstream from the toe of the trajectory (type 2, Plate 15). Flow conditions were generally satisfactory, with the exception of the maximum discharge of 1100 cfs, with which the jet at the outlet portal still did not spread properly across the

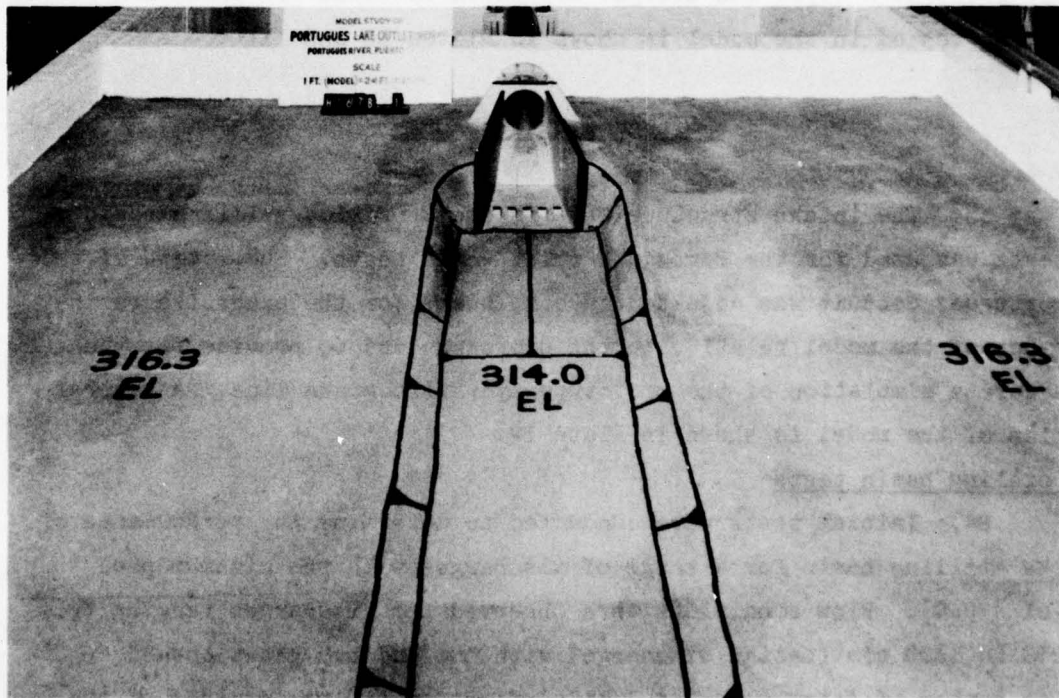


Figure 5. General view of Portugues stilling basin (type 1), conduit, and exit channel

trajectory and the water surface in the basin was very rough (Photo 10).

27. Tests were conducted with the type 3 stilling basin (Plate 15), which consisted of a 10-ft horizontal extension immediately downstream from the outlet portal, one row of 2-ft-high by 2-ft-wide baffle blocks spaced 2 ft apart placed 20 ft downstream of the trajectory, and the stilling basin apron at el 305.0. The 10-ft horizontal extension was installed to spread and redistribute the flow before it reached the curved trajectory. The overall length of the structure between the outlet portal and the end of the basin was increased 10 ft to retain the original apron length. Flow conditions were generally satisfactory for discharges ranging from 250 to 1100 cfs (bank-full capacity), and no eddy conditions developed. The 10-ft horizontal extension caused the jet at the outlet portal to spread properly across the trajectory and improved hydraulic performance of the stilling basin for all flow conditions.

28. Since the baffle width and spacing of 2 ft resulted in baffles only 1 ft wide on each end of the row, tests were conducted using baffle blocks with a uniform width of 1.5 ft positioned 20 ft downstream of the trajectory (type 4, Plate 16). Flow conditions were satisfactory for the full range of discharges and no eddies developed. An improvement in the general flow conditions and a reduction in the exit velocities (Plate 17) were noted with the type 4 stilling basin design relative to previous designs tested. Tests indicated that the type 4 design was the optimum stilling basin using basin walls with a continuous flare from the outlet portal to the end of the basin. Test results also showed that the Portugues stilling basin with continuous flared walls caused the water surface to pulsate along each side of the flared walls at the downstream end of the stilling basin, regardless of modifications tested, as was the case with the Cerrillos stilling basin design.

Riprap protection

29. Using the recommended type 4 stilling basin design, different riprap schemes were tested to determine the minimum size and extent of exit channel protection required with discharges up to 1100 cfs. The type 4A plan consisted of riprap with an average diameter (D_{50}) of 12 in.

and a blanket thickness of 18 in. (Photo 11a). Tests were conducted with flows ranging from 250 to 1100 cfs, with each test lasting a minimum of 10 hr (prototype). Failure occurred immediately downstream of the end sill after a 15-hr (prototype) test with the design discharge of 1100 cfs (Photo 11b).

30. The size of the riprap on the invert of the channel immediately downstream from the basin for a distance of 100 ft was increased to an average diameter (D_{50}) of 18 in. and a blanket thickness of 27 in. (type 4B, Plate 18). Tests were conducted with discharges up to 1100 cfs and each test duration was equivalent to a minimum of 10 hr (prototype). No failure was observed after these tests. From the results of the tests, the type 4B riprap plan was recommended for the prototype. The last 5 ft of the 12-in. (D_{50}) riprap was extended down 2 ft below the channel invert and backfilled. Flow conditions with the type 4 stilling basin and type 4B riprap design with discharges of 250, 500, and 1100 cfs are shown in Photo 12.

Basin capacity tests

31. Additional tests were conducted using the type 4 stilling basin design with the type 4B riprap plan to determine the maximum discharge that could be passed through the structure and maintain a hydraulic jump in the stilling basin; tests indicated that this discharge was 2500 cfs (Photo 13). However, with this discharge, flow conditions were very rough in the stilling basin and exit channel, and failure of the riprap occurred just downstream of the end sill and on the side slopes. With discharges greater than 2500 cfs, the hydraulic jump swept out of the basin and caused considerable damage to the exit channel.

PART IV: DISCUSSION OF RESULTS

32. The conduits for both Cerrillos and Portugues outlet works were designed to provide for river diversion during construction of the dams. After construction is completed, the flow will be regulated so that only bank-full capacity will be passed through the stilling basins. The conduit capacities were 4500 cfs for Cerrillos and 5300 cfs for Portugues. However, the stilling basins were designed for 2500 cfs (Cerrillos) and 1100 cfs (Portugues), the bank-full capacities downstream. Therefore, considerable damage to the downstream exit area will occur should it become necessary during construction to pass the conduit design flow through the outlet works.

33. The original design stilling basin (type 1) for the Cerrillos outlet works performed satisfactorily for discharges of 500 cfs and less. With the intermediate discharge of 1000 cfs, eddy conditions developed that were prevalent throughout the depth of flow in the basin. In the higher range of discharges between 1500 cfs and 2500 cfs (design discharge), the type 1 stilling basin performed satisfactorily; however, the water surface in the stilling basin with the design discharge was rougher than desired. With the higher discharges, the jet at the outlet portal failed to spread properly across the trajectory, causing rough flow conditions in the stilling basin.

34. Various modifications to the Cerrillos outlet works were tested to develop satisfactory stilling basin action for discharges up to 2500 cfs. Recommended modifications (type 14 stilling basin) incorporated into the original design included extending the invert immediately downstream from the outlet portal horizontally for 10 ft, raising the basin apron to el 301.0, providing one row of 3-ft-high by 2.5-ft-wide baffle blocks 30 ft downstream from the toe of the trajectory, and terminating the basin with a 1V-on-1H sloping end sill. The 10-ft horizontal extension allowed the entering jet to spread uniformly across the invert before reaching the curved trajectory and produced stable flow conditions for the full range of discharges. Tests results also indicated that the continuous flared walls of the Cerrillos stilling

basin caused the water surface to pulsate along each wall at the downstream end of the basin, regardless of modifications tested in the stilling basin.

35. The recommended riprap protection plan (type 14E) for the Cerrillos exit channel consisted of 18-in. (D_{50}) riprap extending downstream from the end sill 100 ft, and 12-in. (D_{50}) riprap extending an additional 50 ft downstream. A 1V-on-10H upward slope in the channel invert immediately downstream of the basin was recommended to improve the stability of the riprap and reduce the chance of riprap entering the stilling basin should any displacement occur.

36. A hydraulic jump was maintained in the Cerrillos basin with the conduit capacity of 4500 cfs, but considerable movement of the riprap was observed.

37. Performance of the type 1 stilling basin design for the Portugues outlet works was generally satisfactory with discharges ranging from 250 cfs to 1100 cfs (design discharge). Eddy conditions did not develop for any discharge observed, but the water surface in the basin was rougher than that desired with the design discharge of 1100 cfs. With the higher discharges, the jet at the outlet portal did not spread properly across the trajectory which caused the rough flow conditions in the basin.

38. Modifications to the Portugues outlet works were tested to develop satisfactory stilling basin action for discharges up to 1100 cfs. Recommended modifications (type 4 stilling basin) incorporated into the original design included extending the invert immediately downstream from the outlet portal horizontally for 10 ft, placing one row of 2-ft-high by 1.5-ft-wide baffle blocks 20 ft downstream from the toe of the trajectory, and terminating the basin with a 1V-on-1H sloping end sill. The overall length of the structure was increased 10 ft to retain the original apron length. Tests conducted on the Portugues outlet works indicated that the continuous flared walls of the stilling basin caused the water surface to pulsate along each wall at the downstream end of the basin. This flow condition was present at the downstream end of the basin regardless of any modifications tested in the stilling basin.

39. The recommended riprap protection plan (type 4B) for the Portugues exit channel consisted of 18-in. (D_{50}) riprap extending downstream from the end sill 100 ft on the channel invert, and 12-in. (D_{50}) riprap extending an additional 50 ft. The side slopes of the exit channel were protected with 12-in. (D_{50}) riprap. A 1V-on-10H upward slope in the channel invert immediately downstream of the basin was also recommended to improve the stability of the riprap and reduce the chance of riprap entering the stilling basin should any displacement occur.

40. With discharges greater than the design flow through the Portugues outlet works, some movement of the downstream protection was observed; and with discharges greater than 2500 cfs, the jump swept out of the basin and caused considerable damage to the exit channel.

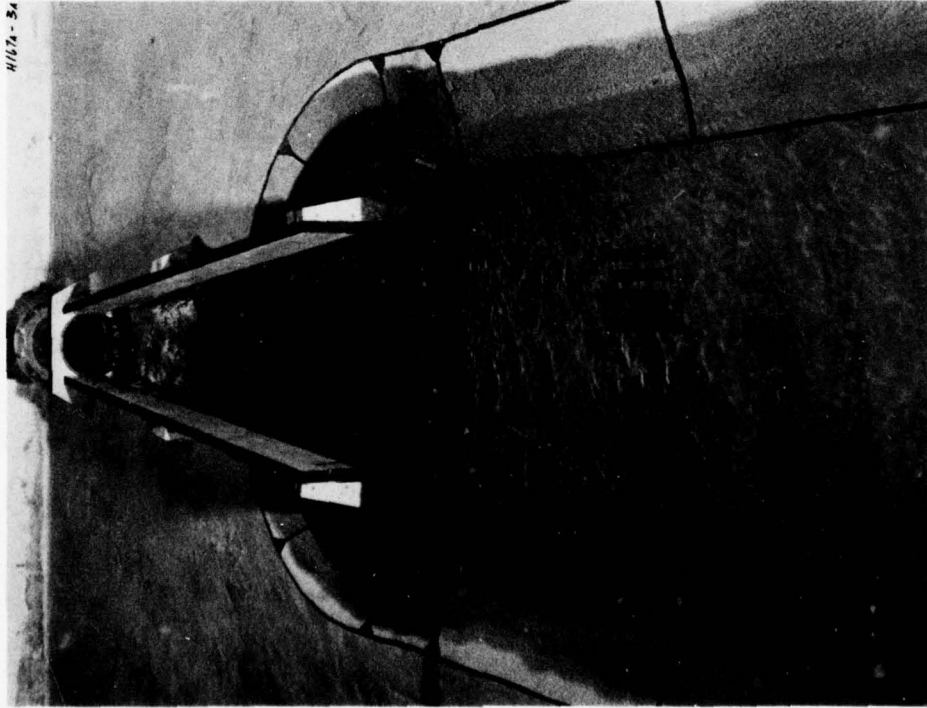


Photo 1. Cerrillos outlet works, flow conditions in type 1 stilling basin, looking upstream; discharge 500 cfs, tailwater el 313.4 ft

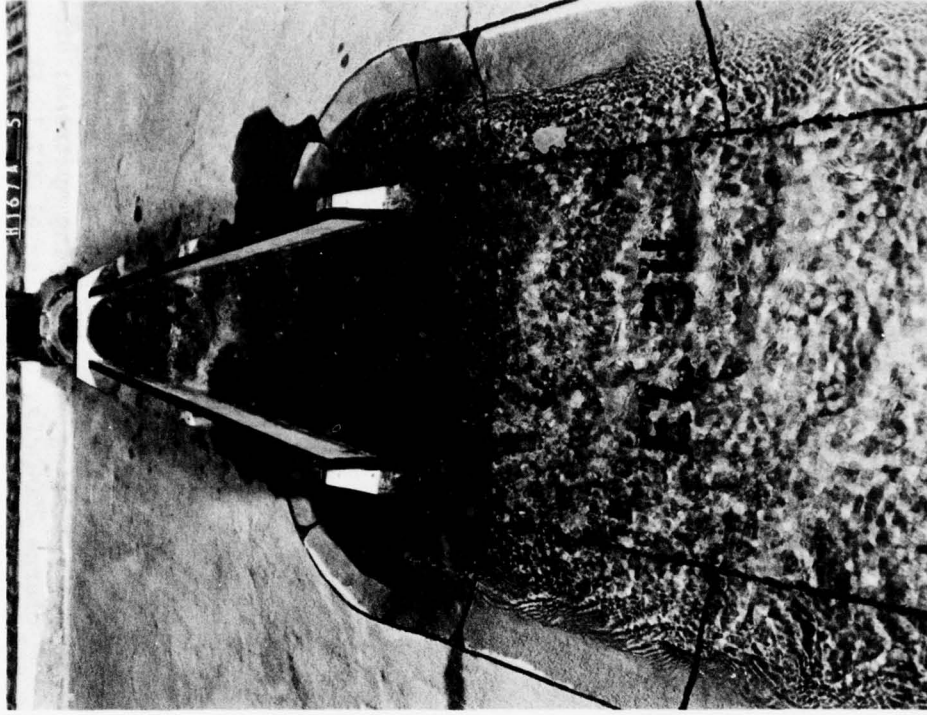


Photo 2. Cerrillos outlet works, eddy conditions in type 1 stilling basin, looking upstream; discharge 1000 cfs, tailwater el 314.7 ft

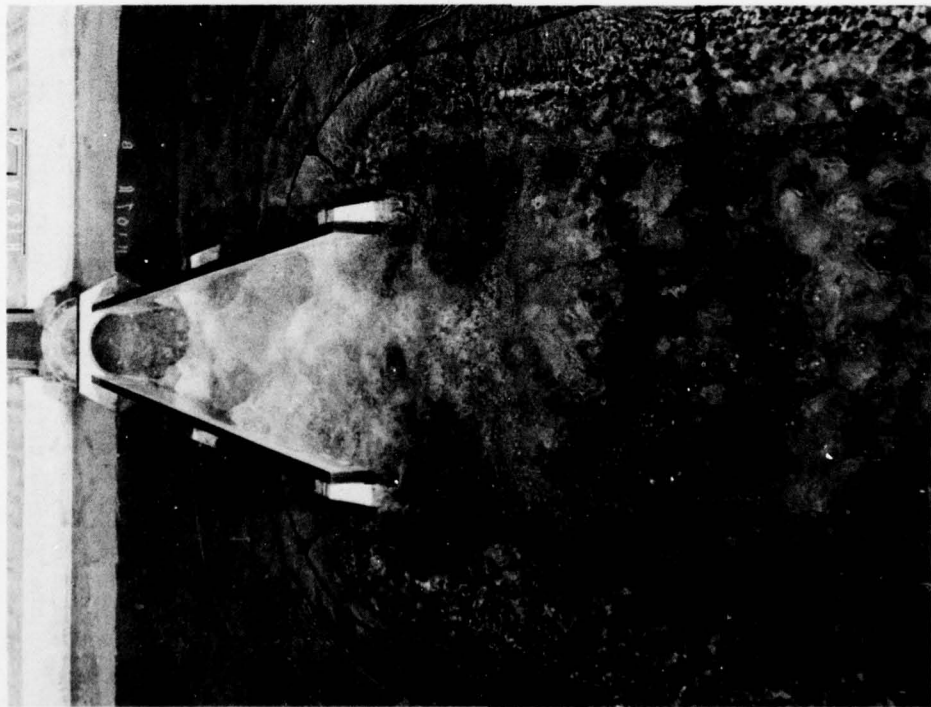


Photo 3. Cerrillos outlet works, flow conditions in type 1 stilling basin, looking upstream; discharge 2500 cfs, tailwater el 317.1 ft

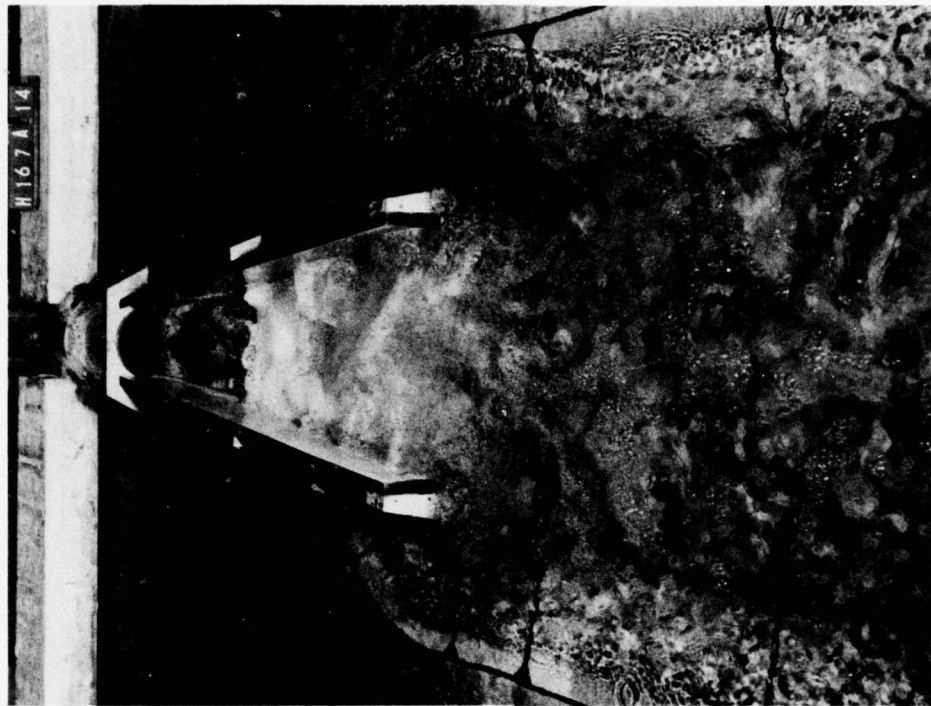
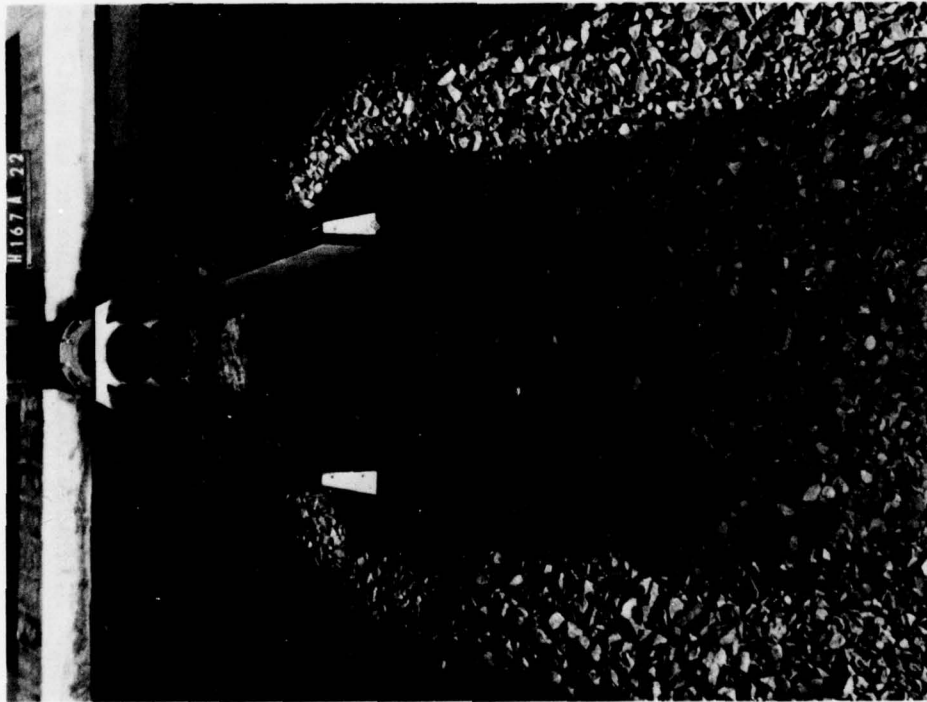
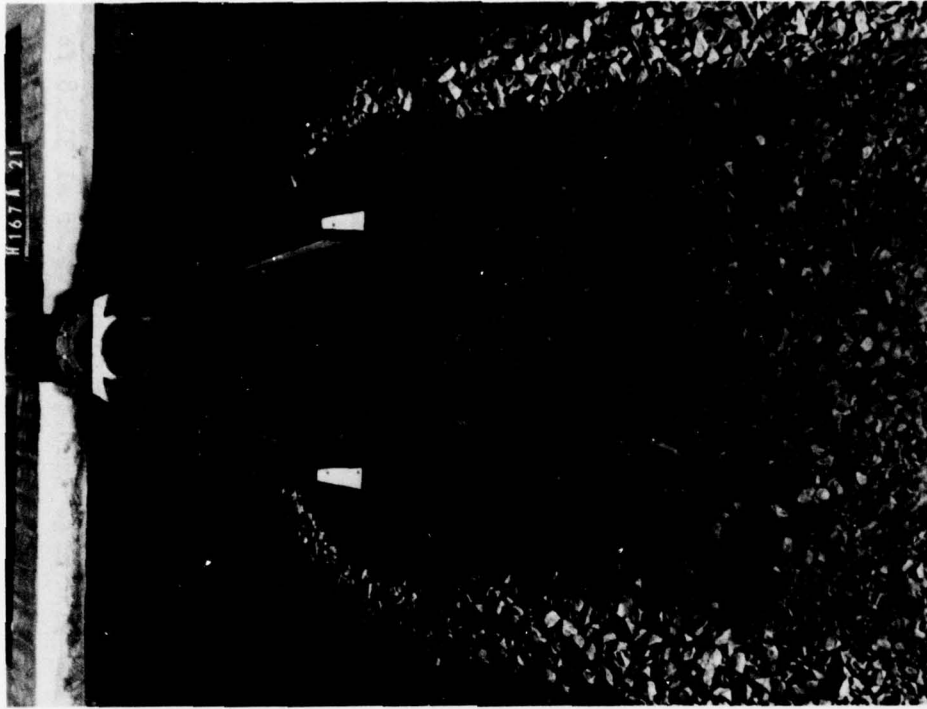


Photo 4. Cerrillos outlet works, flow conditions in type 10 stilling basin, looking upstream; discharge 2500 cfs, tailwater el 317.12 ft

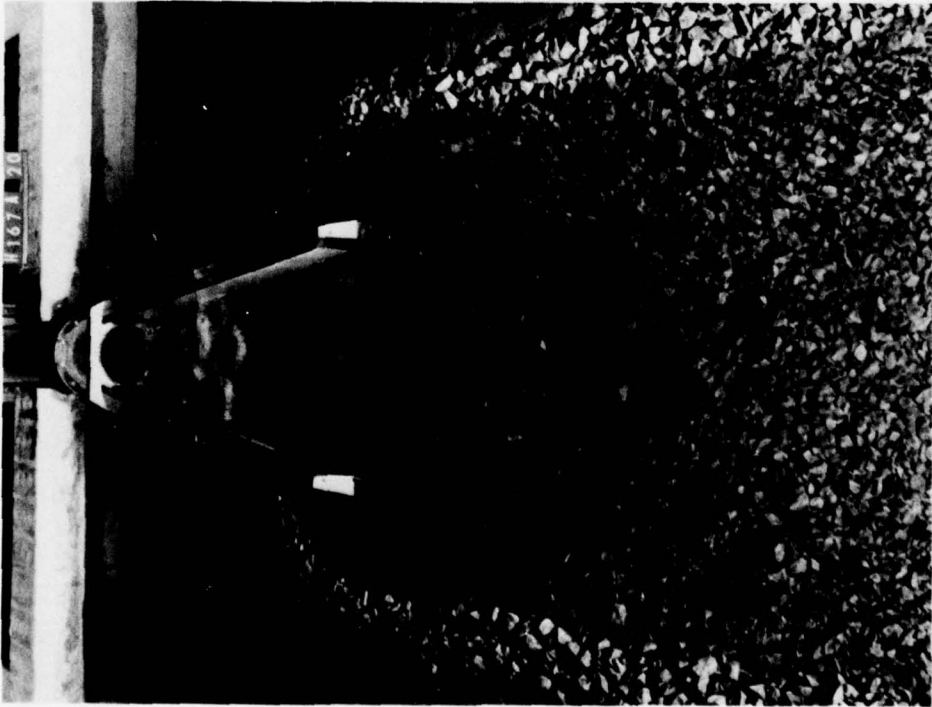


a. Discharge 250 cfs, tailwater el 312.5 ft

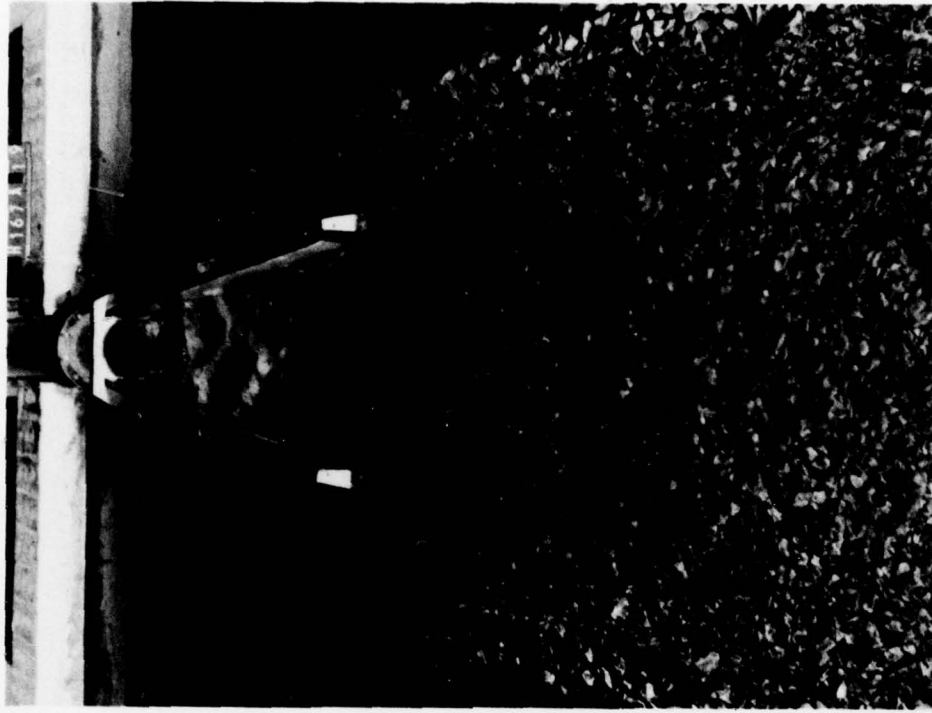


b. Discharge 500 cfs, tailwater el 313.4 ft

Photo 5. Cerrillos outlet works, flow conditions in the type 14 stilling basin, looking upstream, with the type 14C riprap protection plan (sheet 1 of 3)

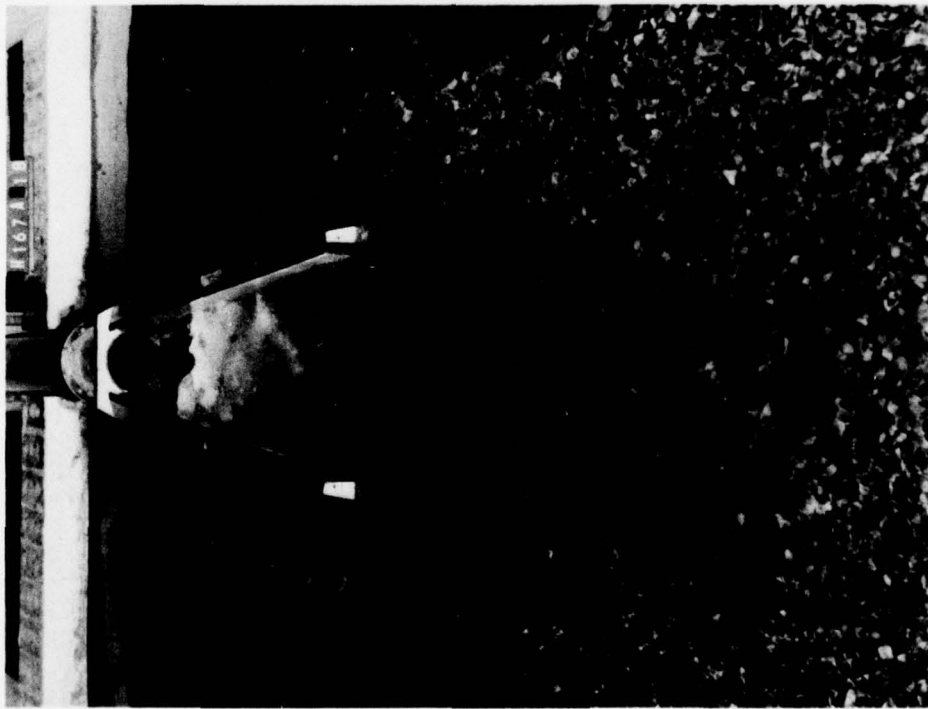


c. Discharge 1000 cfs, tailwater el 314.7 ft

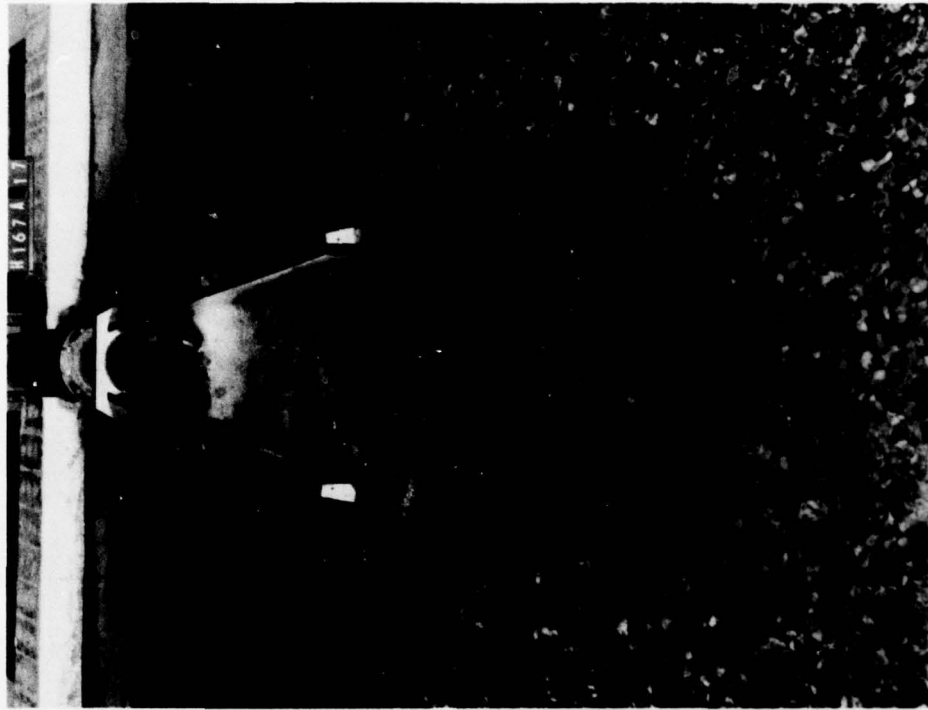


d. Discharge 1500 cfs, tailwater el 315.8 ft

Photo 5 (sheet 2 of 3)



e. Discharge 2000 cfs, tailwater el 316.6 ft



f. Discharge 2500 cfs, tailwater el 317.12 ft

Photo 5 (sheet 3 of 3)

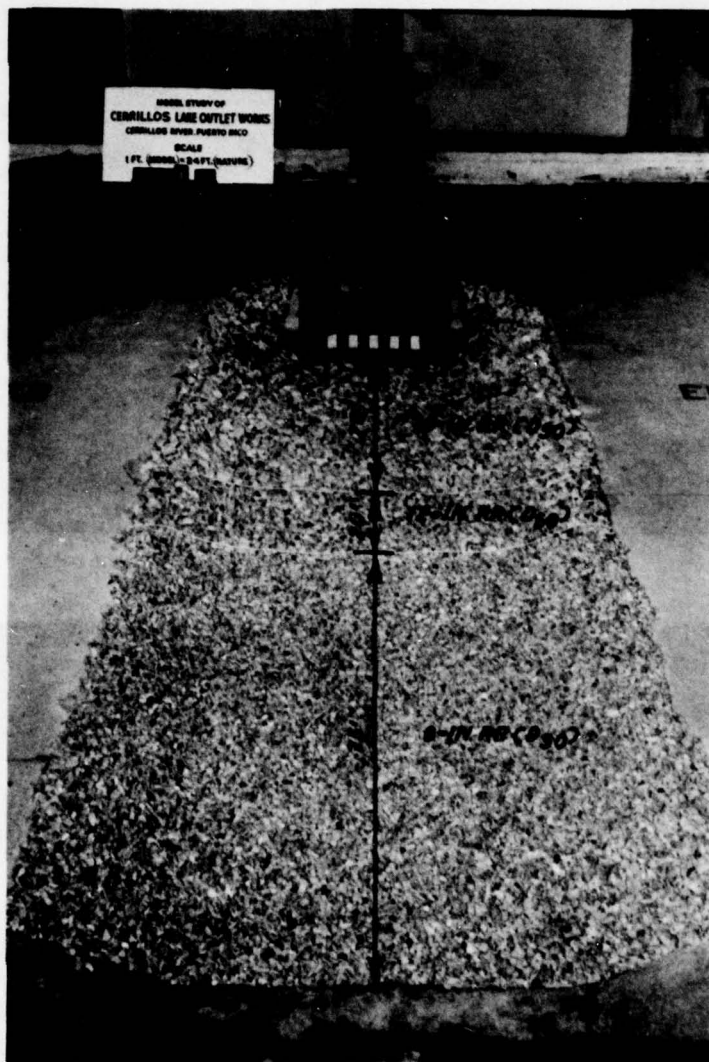
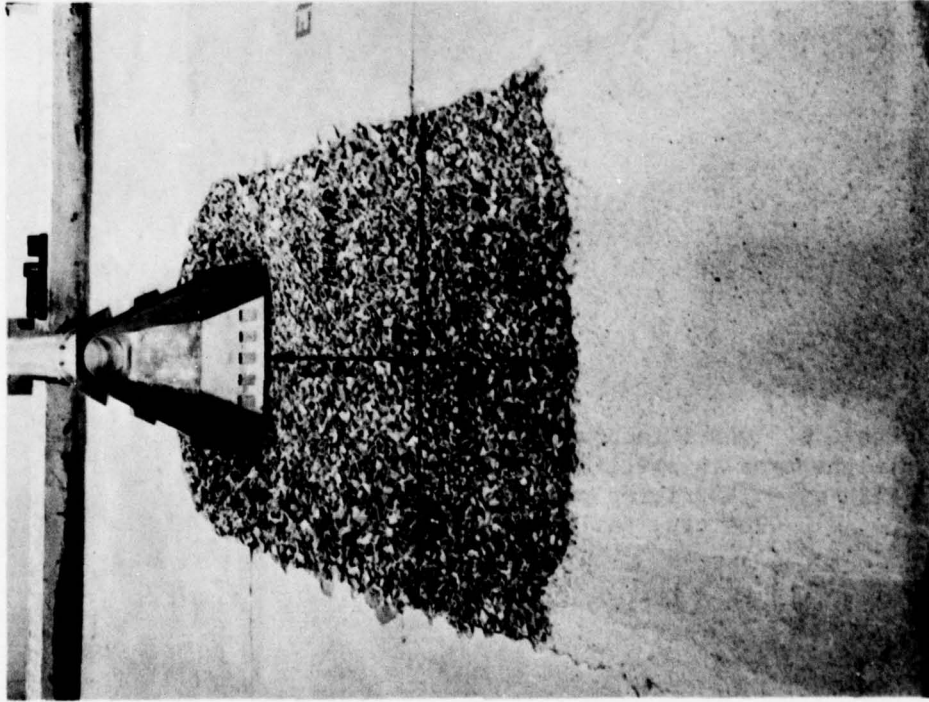
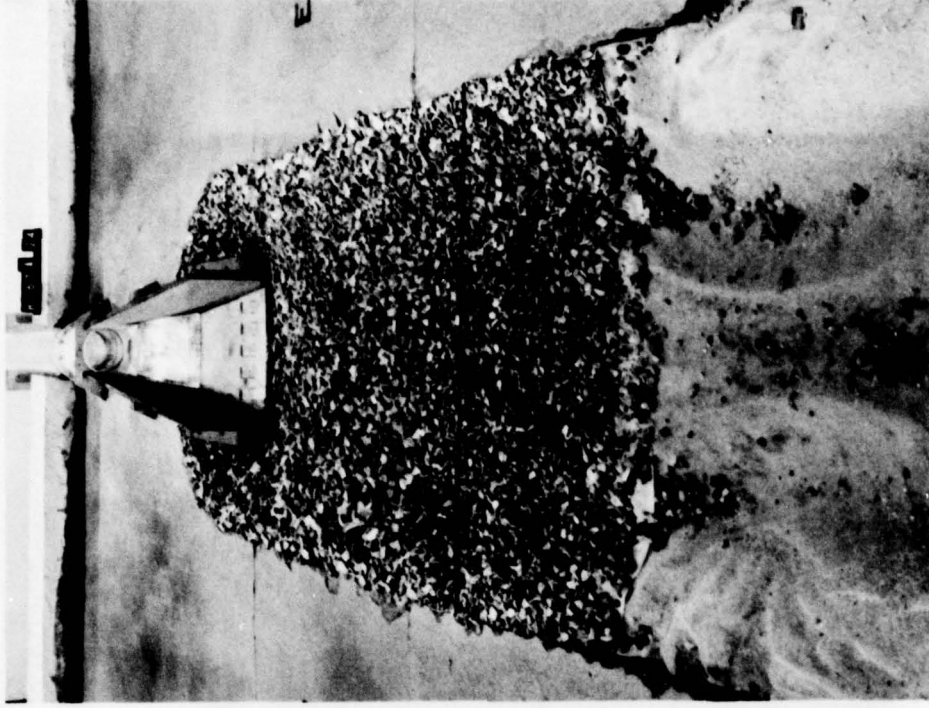


Photo 6. Cerrillos outlet works, type 14C riprap protection plan



a. Before testing



b. Sloughing of riprap after an 8-hr (prototype) test with discharge 2500 cfs and tailwater el 317.12 ft

Photo 7. Cerrillos outlet works, type 14D riprap protection plan

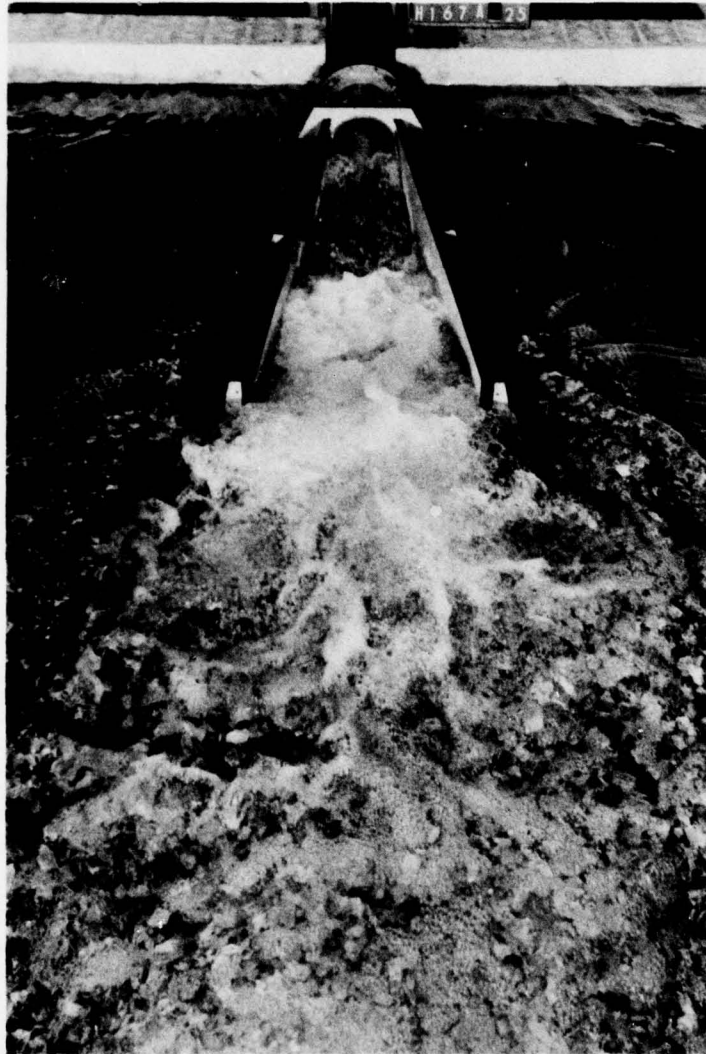
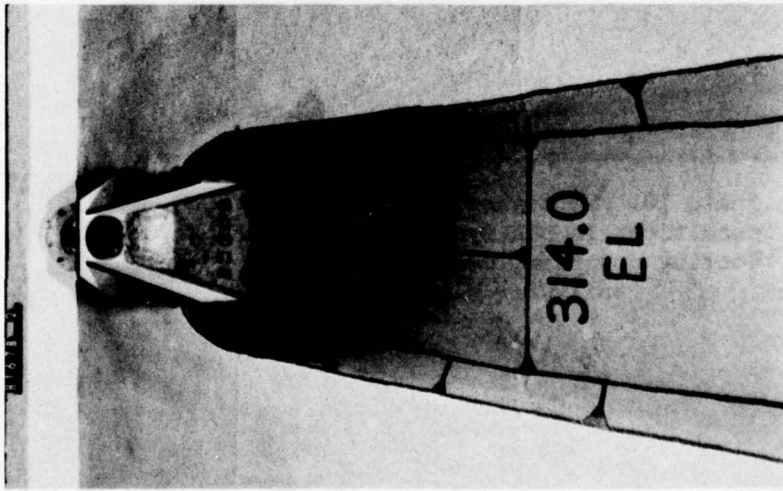
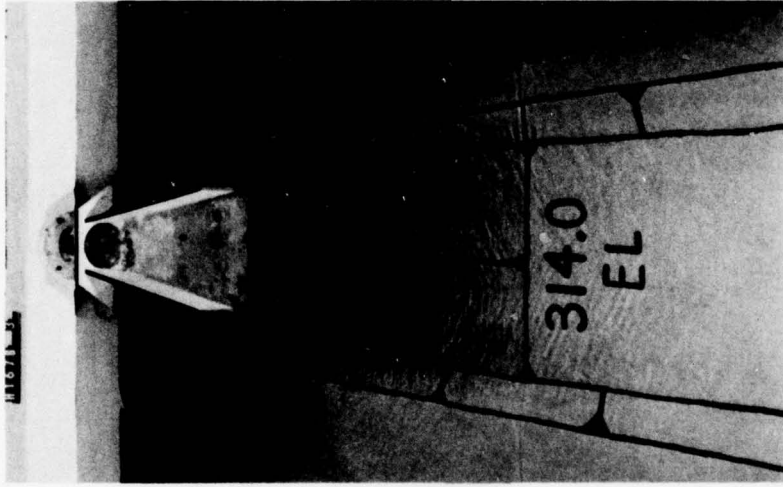


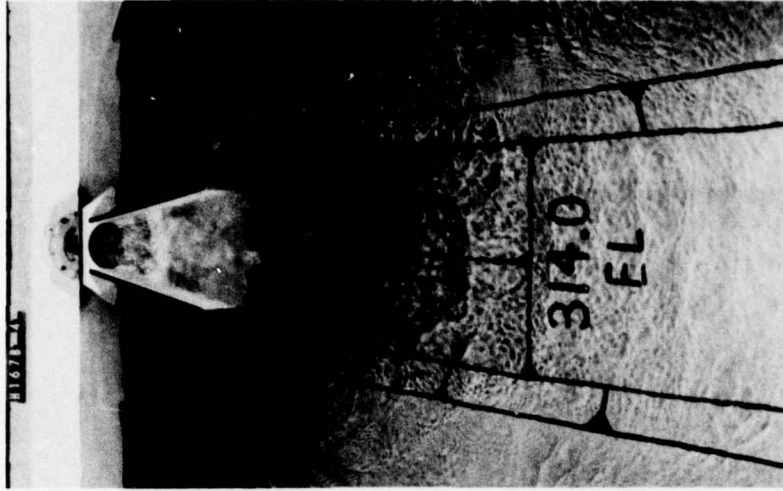
Photo 8. Cerrillos outlet works, flow conditions
in the type 14 stilling basin, looking upstream,
with type 14D riprap protection plan, discharge
4700 cfs, tailwater el 318.93 ft



a. Discharge 250 cfs, tail-
water el 314.8 ft



b. Discharge 500 cfs, tail-
water el 315.3 ft



c. Discharge 1100 cfs, tail-
water el 316.3 ft

Photo 9. Portugues outlet works; flow conditions in the type 1 stilling basin, looking upstream

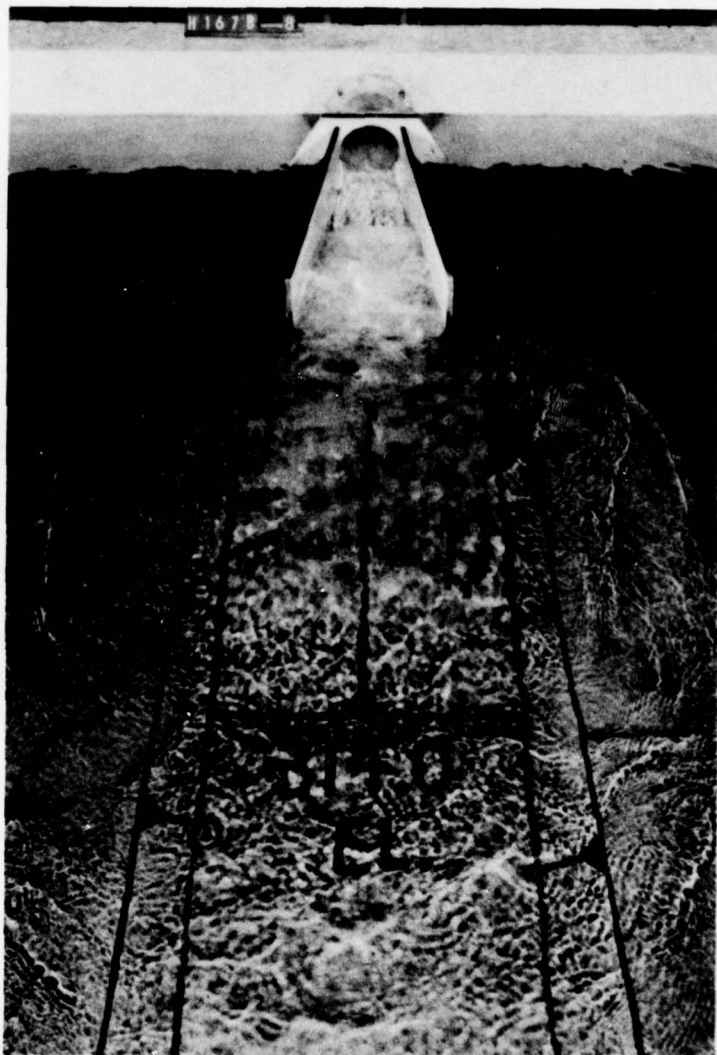
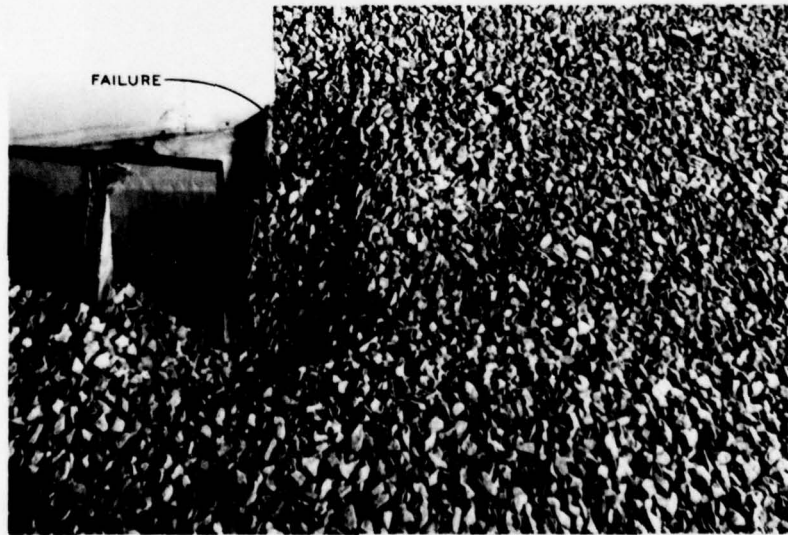


Photo 10. Portugues outlet works, flow conditions in the type 2 stilling basin, looking upstream, discharge 1100 cfs, tailwater el 316.3 ft

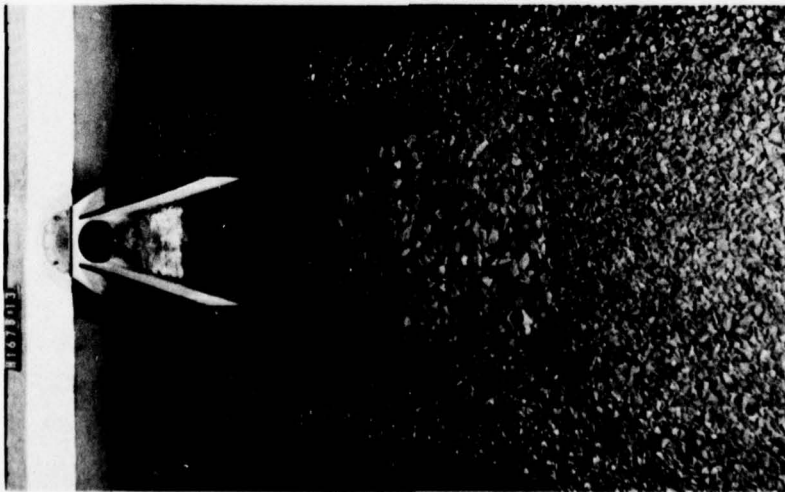


a. Before testing

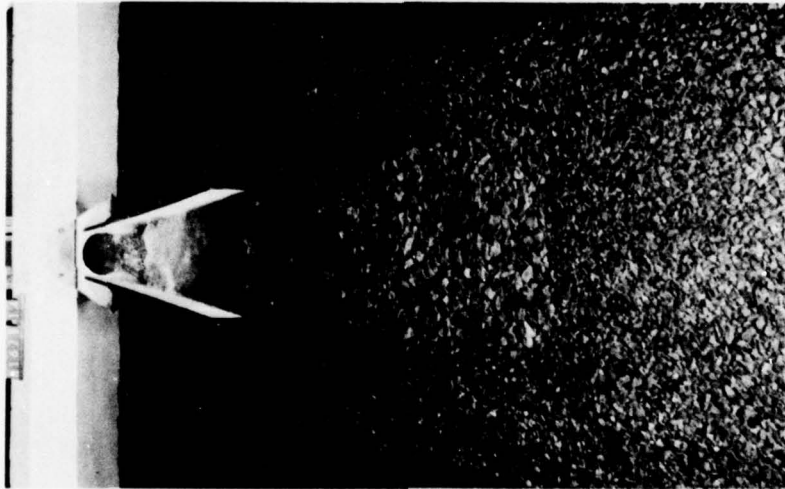


b. Failure after a 15-hr (prototype) test with discharge 1100 cfs and tailwater el 316.3 ft

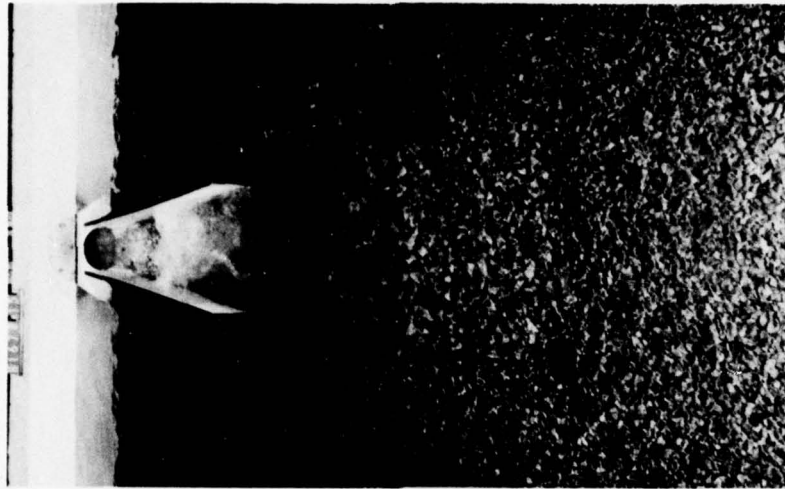
Photo 11. Portugues outlet works, type 4A riprap protection plan



a. Discharge 250 cfs, tail-
water el 314.8 ft



b. Discharge 500 cfs, tail-
water el 315.3 ft



c. Discharge 1100 cfs, tail-
water el 316.3 ft

Photo 12. Portugues outlet works, flow conditions with the type 4 stilling basin and the type 4B riprap protection plan, looking upstream

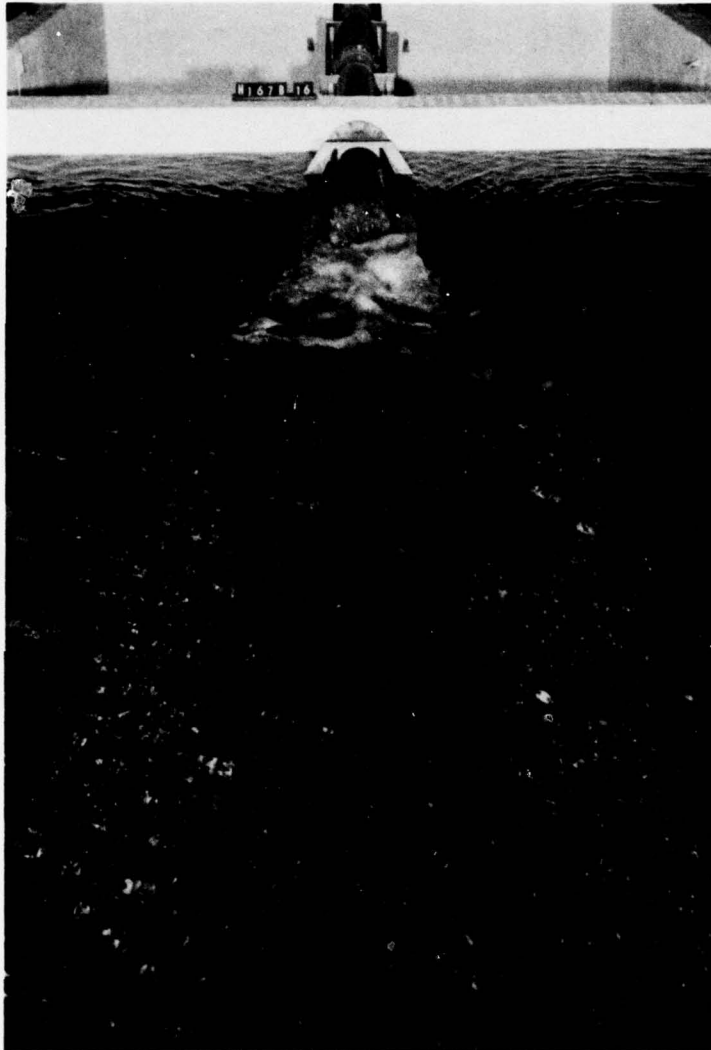
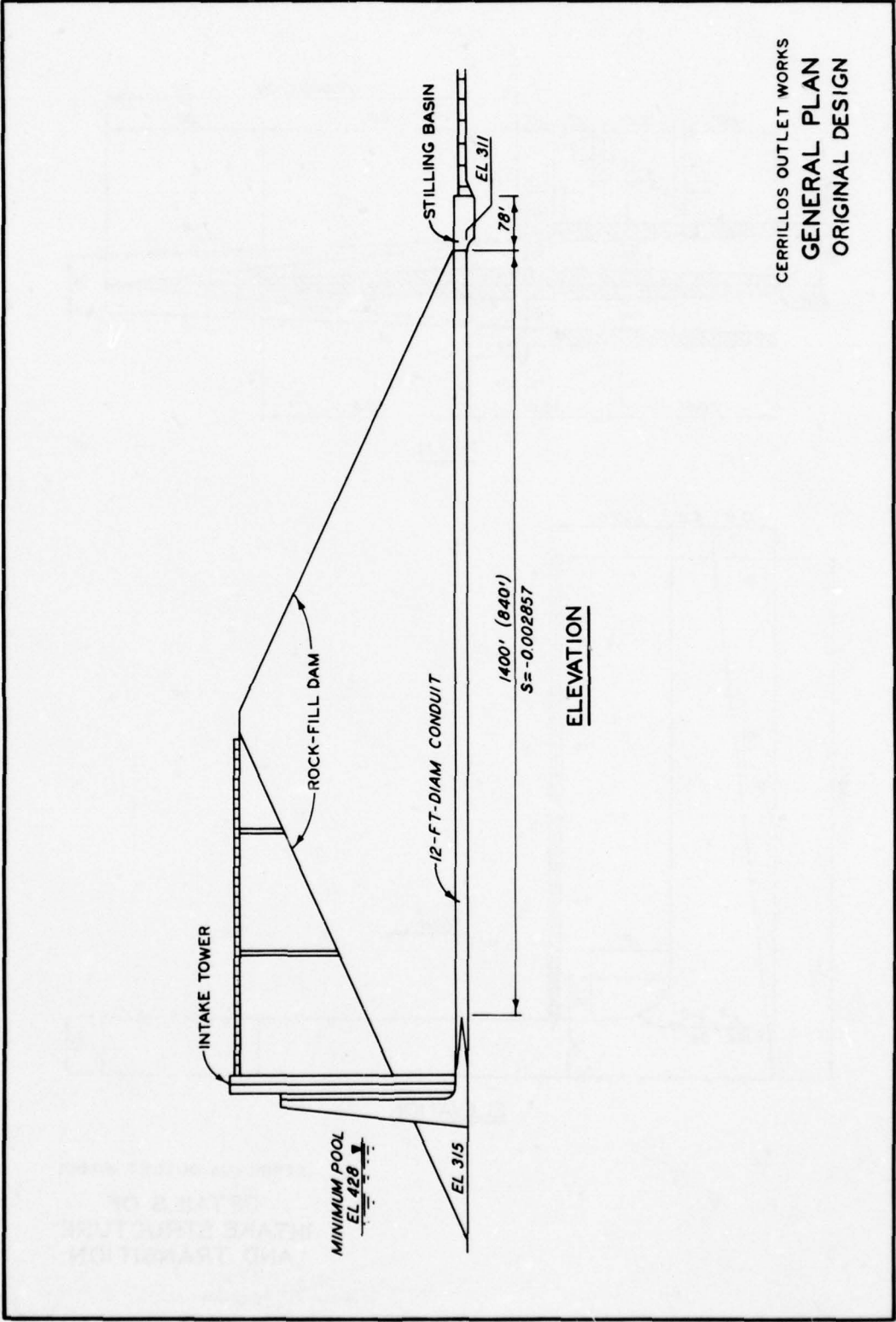
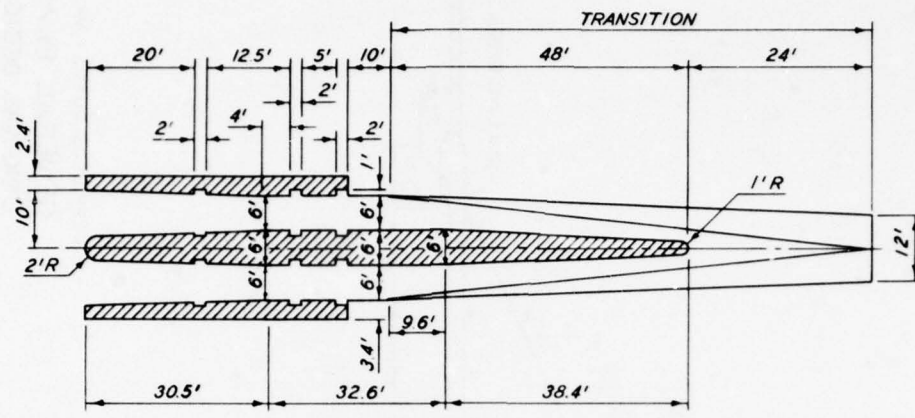


Photo 13. Portugues outlet works, flow conditions
in the type 4 stilling basin, looking upstream,
discharge 2500 cfs, tailwater el 317.8 ft

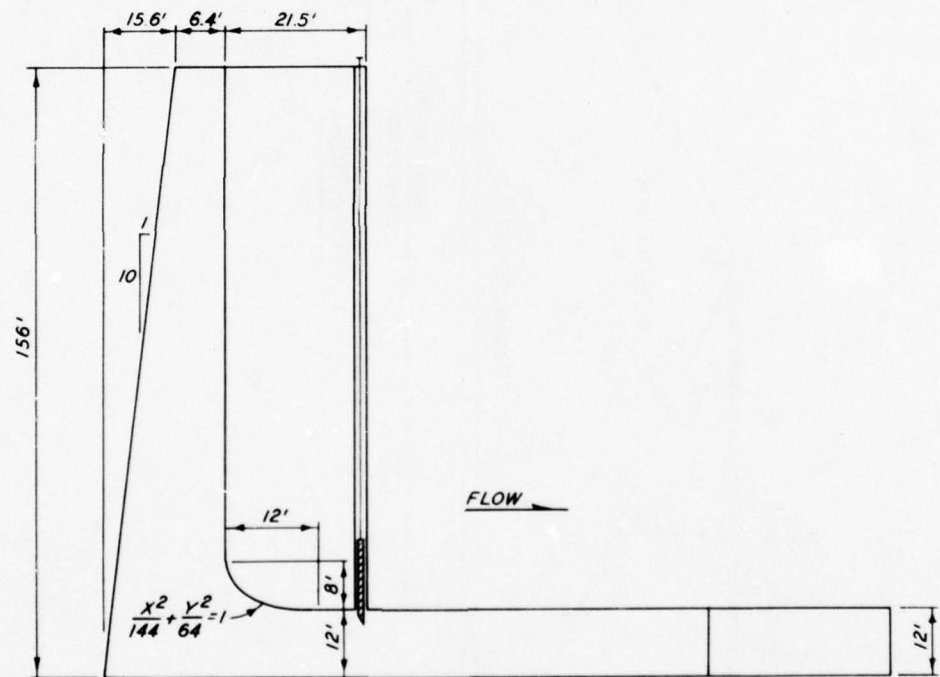


ELEVATION

CERRILLOS OUTLET WORKS
 GENERAL PLAN
 ORIGINAL DESIGN

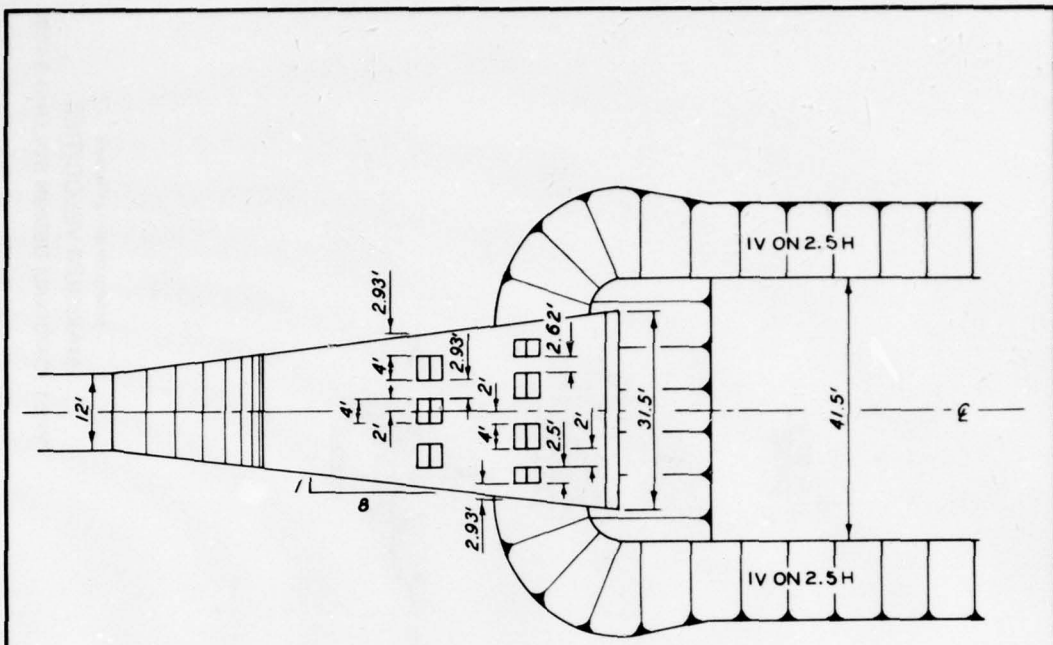


PLAN

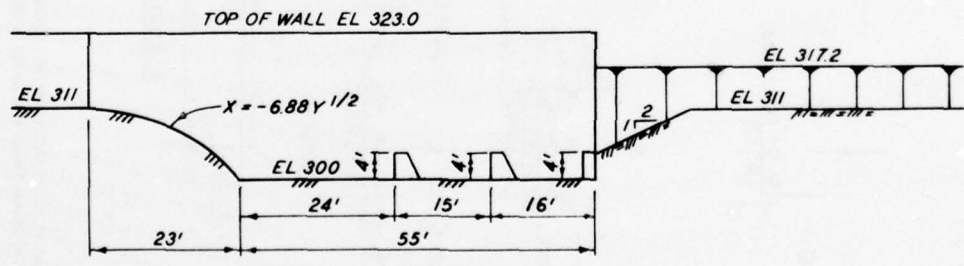


ELEVATION

CERRILLOS OUTLET WORKS
 DETAILS OF
 INTAKE STRUCTURE
 AND TRANSITION



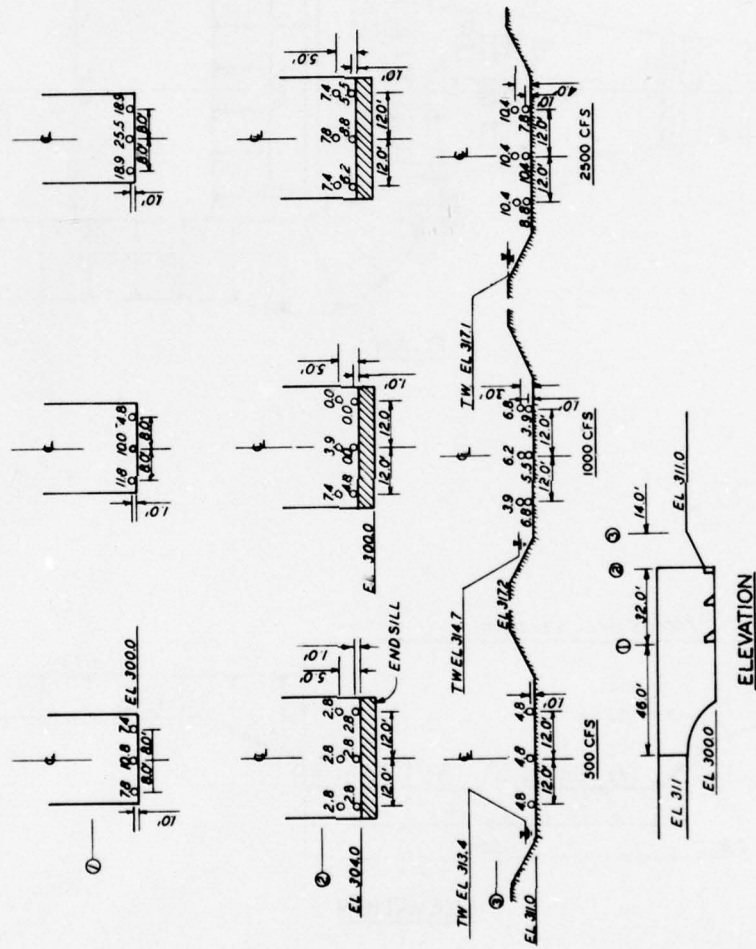
PLAN



ELEVATION

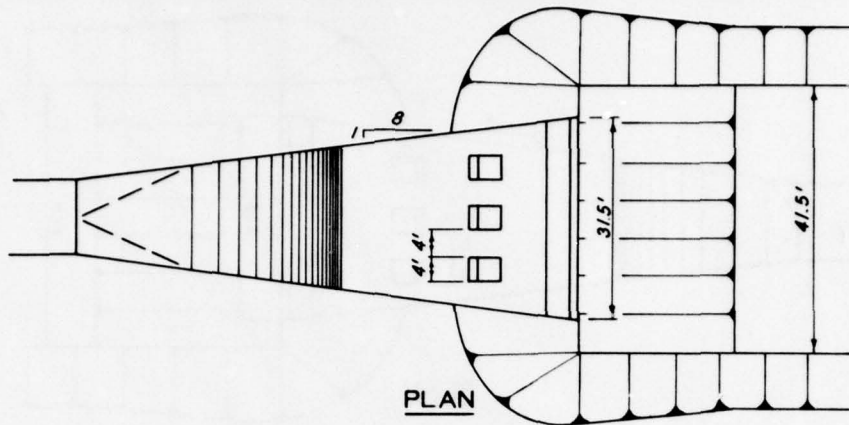
CERRILLOS OUTLET WORKS
 DETAILS OF
 STILLING BASIN
 TYPE I (ORIGINAL) DESIGN

PLATE 4

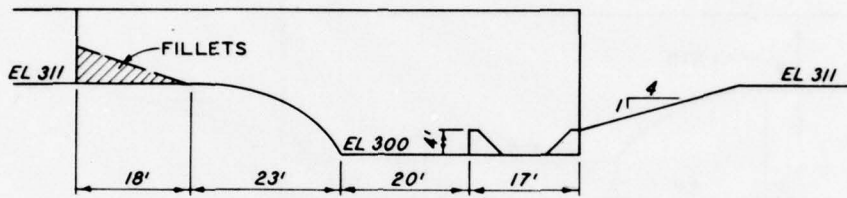


CERRILLOS OUTLET WORKS
MAXIMUM VELOCITIES
 TYPE 1 (ORIGINAL) DESIGN STILLING BASIN

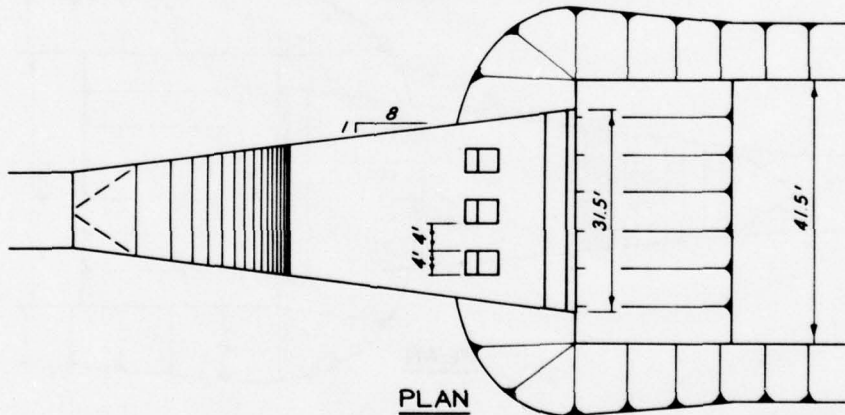
NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND
 LOOKING DOWNSTREAM, TWO GATES OPERATING



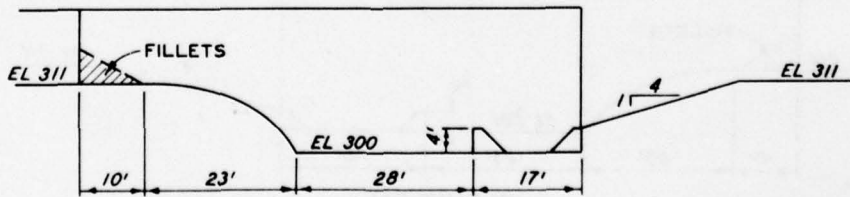
PLAN



ELEVATION
TYPE 7

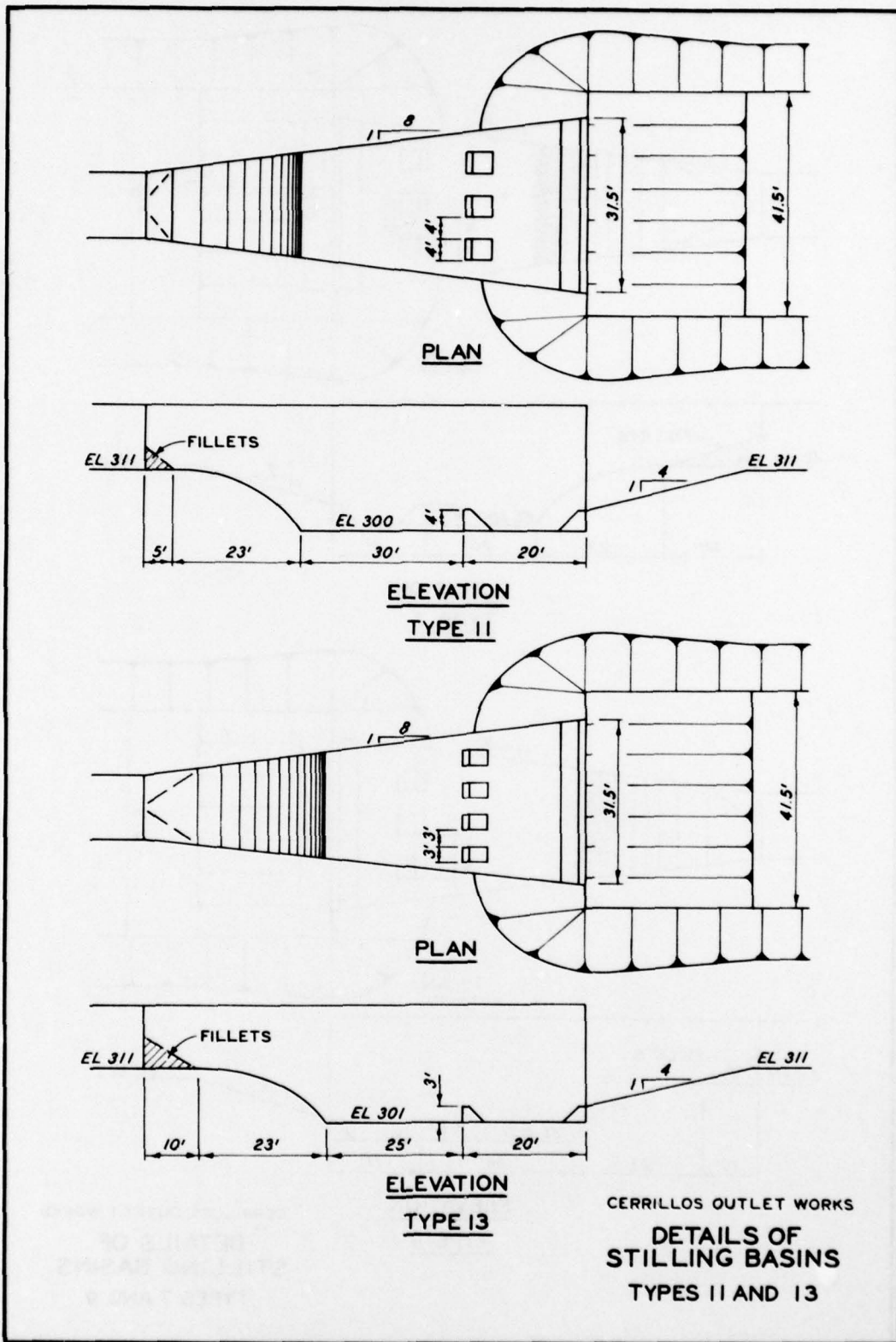


PLAN

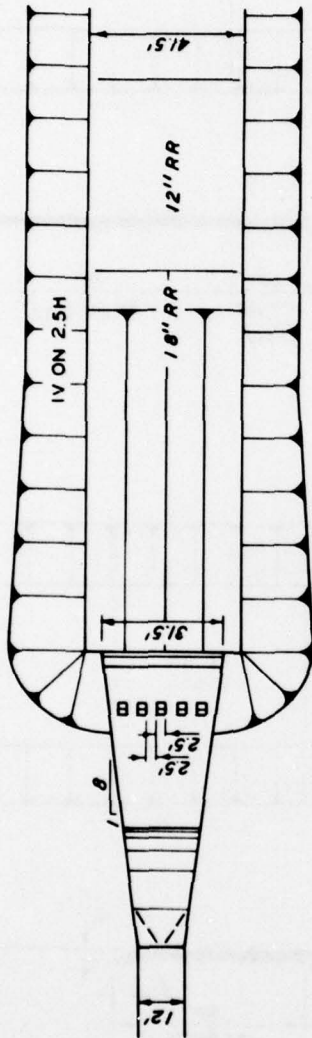


ELEVATION
TYPE 9

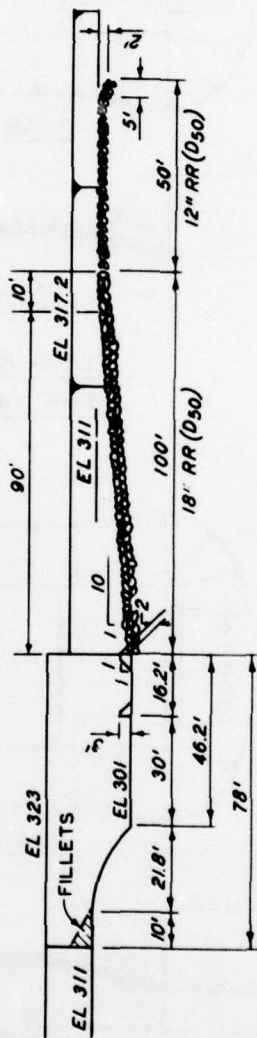
CERRILLOS OUTLET WORKS
DETAILS OF
STILLING BASINS
TYPES 7 AND 9



CERRILLOS OUTLET WORKS
 DETAILS OF
 STILLING BASINS
 TYPES II AND 13



PLAN

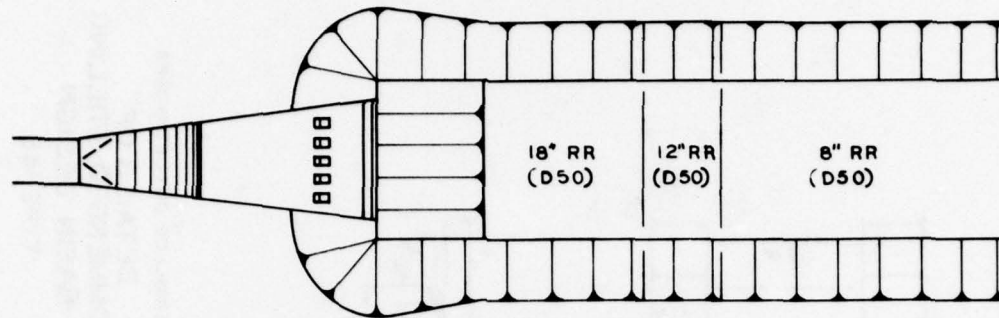


ELEVATION

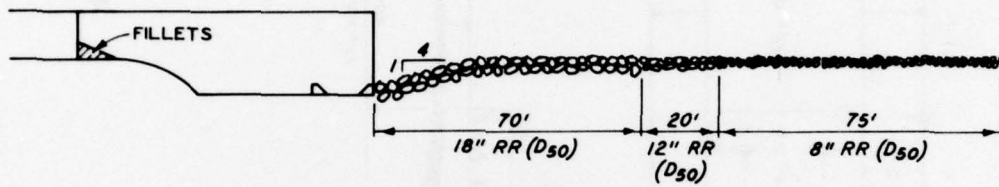
RIPRAP GRADATION

BLANKET THICKNESS, IN.	PERCENT LIGHTER BY WEIGHT	LIMITS OF STONE WEIGHT, LB
27 (18 IN. D ₅₀)	100	984 - 394
	50	292 - 197
	15	146 - 62
18 (12 IN. D ₅₀)	100	292 - 117
	50	86 - 58
	15	43 - 18

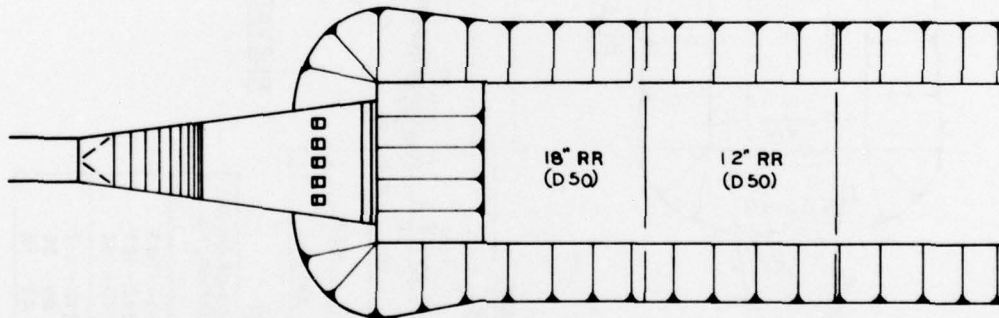
CERRILLOS OUTLET WORKS
 DETAILS OF
 RECOMMENDED STILLING
 BASIN DESIGN
 TYPE 14E



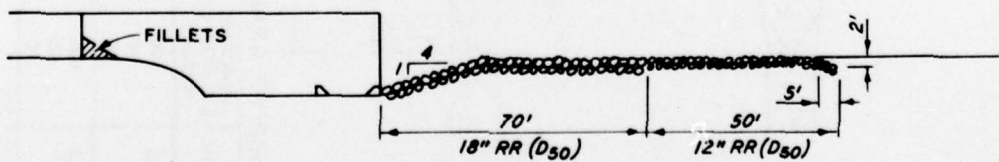
PLAN



ELEVATION
TYPE 14C



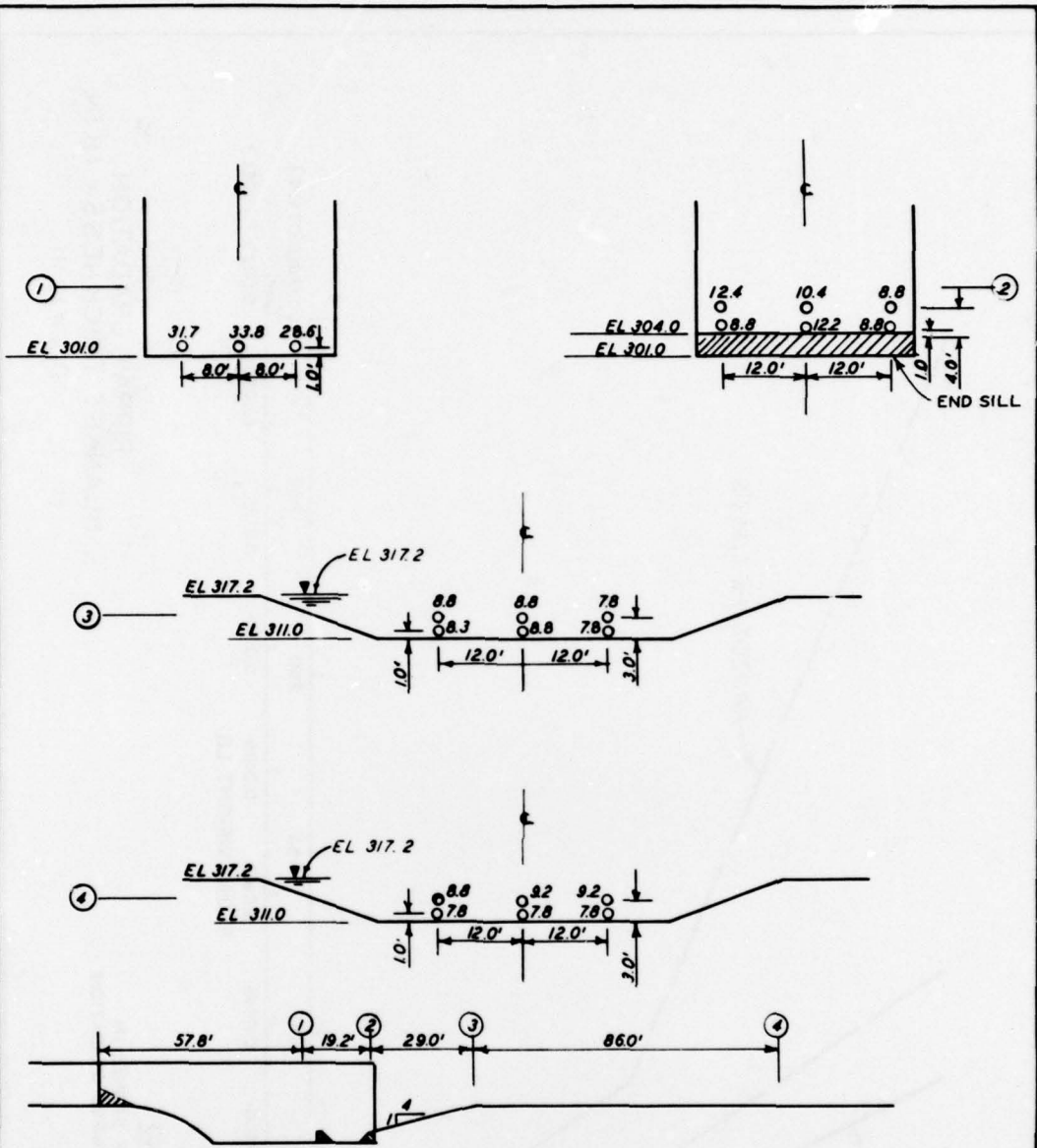
PLAN



ELEVATION
TYPE 14D

CERRILLOS OUTLET WORKS

**DETAILS OF
RIPRAP PROTECTION PLANS
TYPES 14C AND 14D**



ELEVATION

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.
 LOOKING UPSTREAM, DISCHARGE 2500 CFS.

CERRILLOS OUTLET WORKS
MAXIMUM VELOCITIES
 TYPE 14C STILLING BASIN

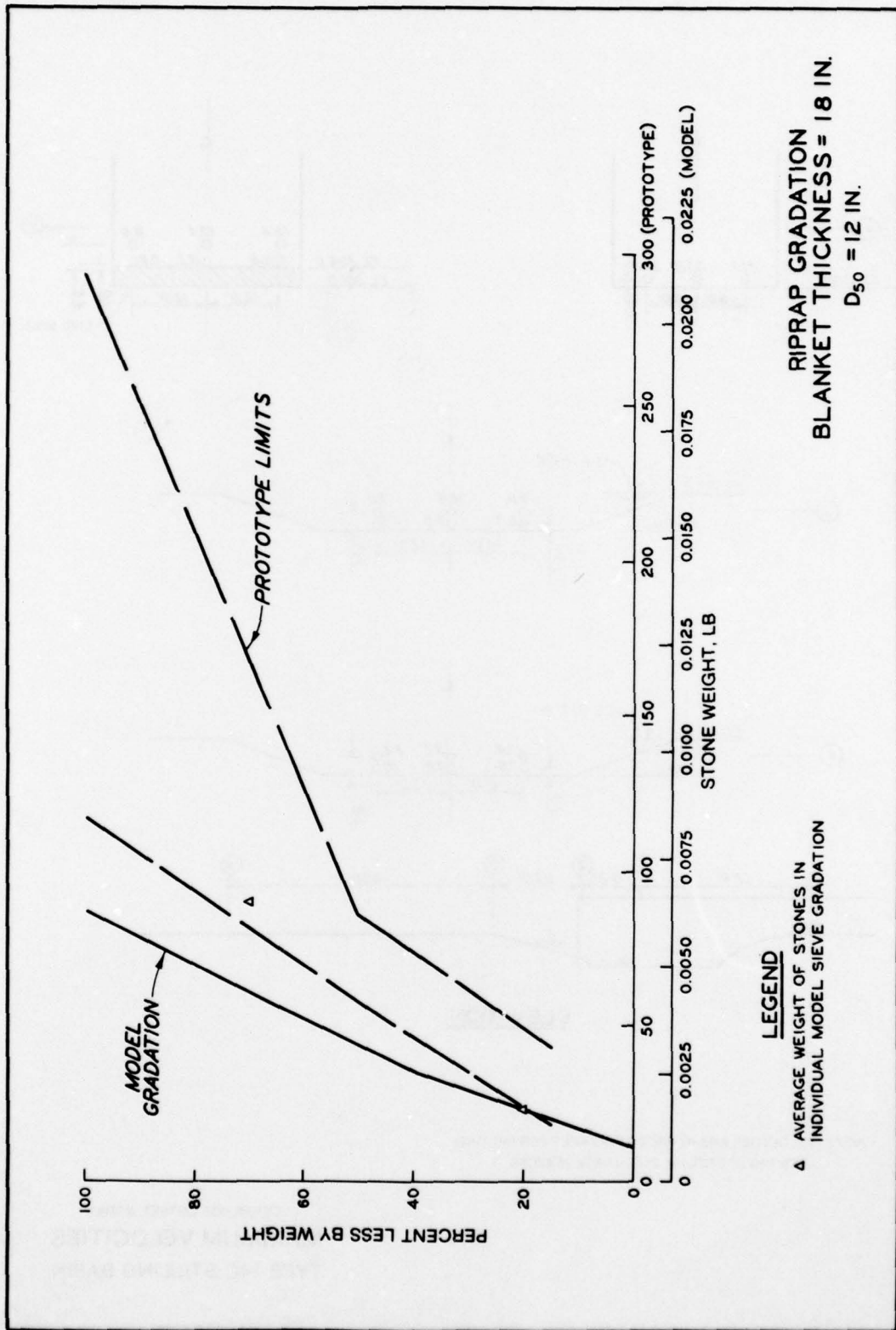
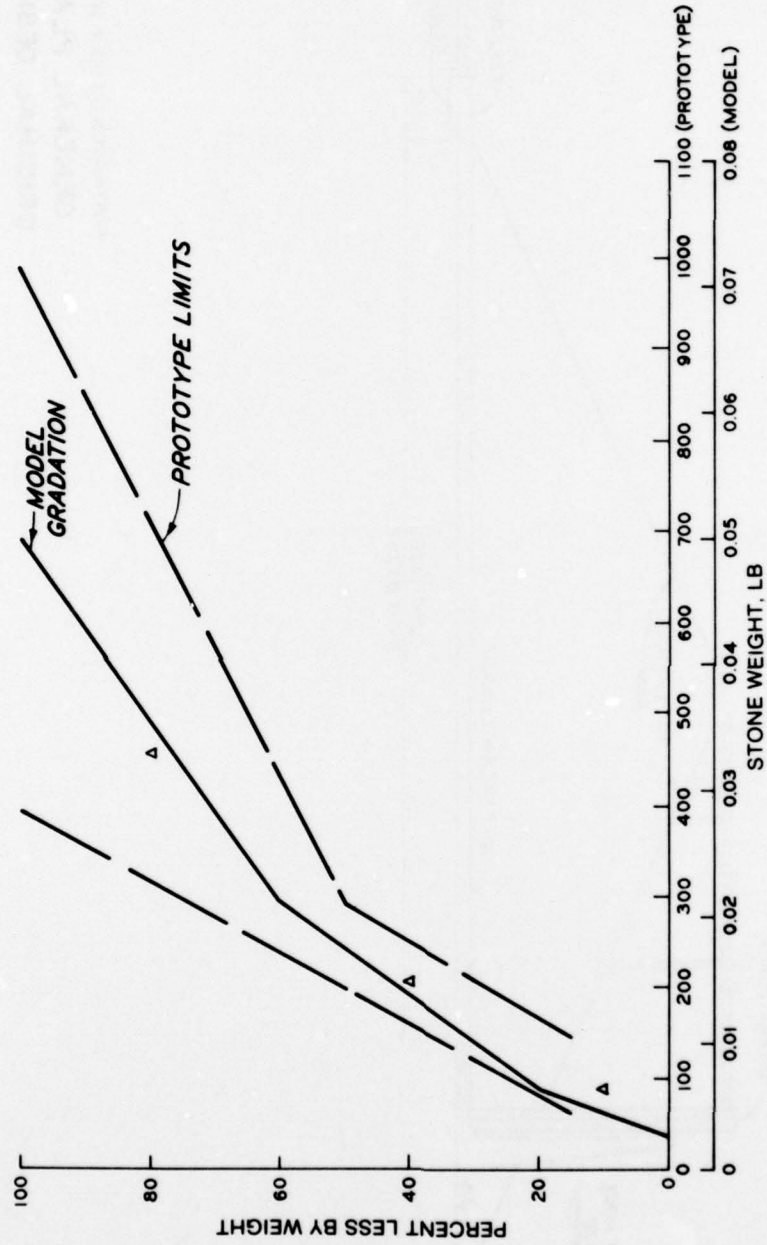
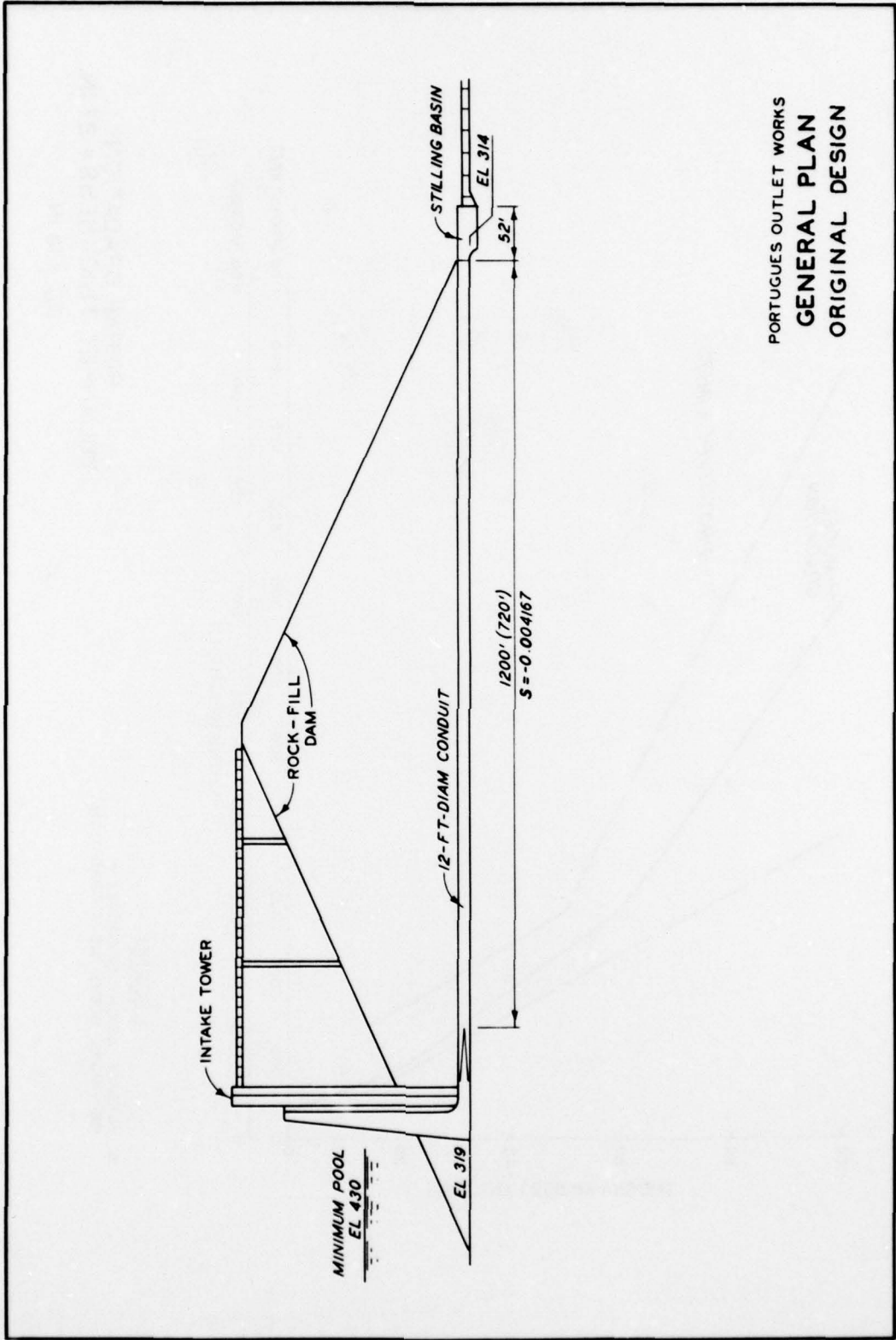


PLATE 10



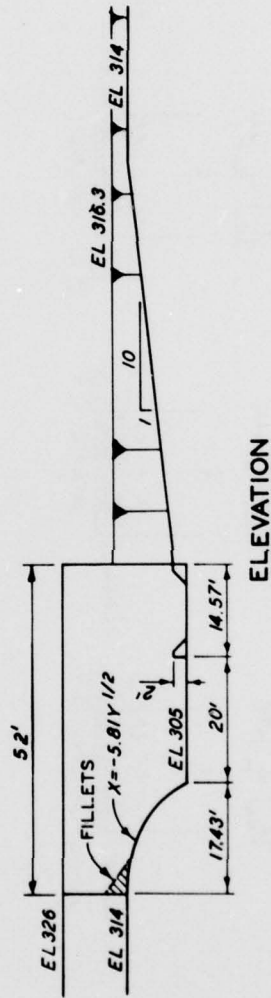
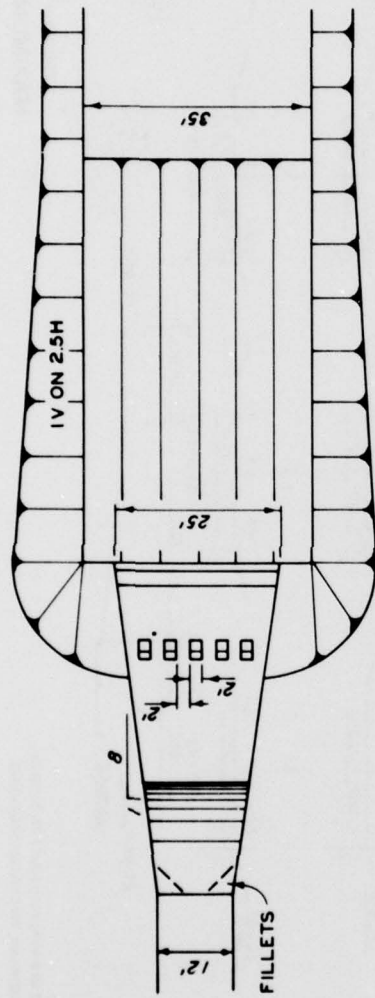
LEGEND
 Δ AVERAGE WEIGHT OF STONES IN
 INDIVIDUAL MODEL SIEVE GRADATION

RIPRAP GRADATION
BLANKET THICKNESS = 27 IN.
 $D_{50} = 18$ IN.

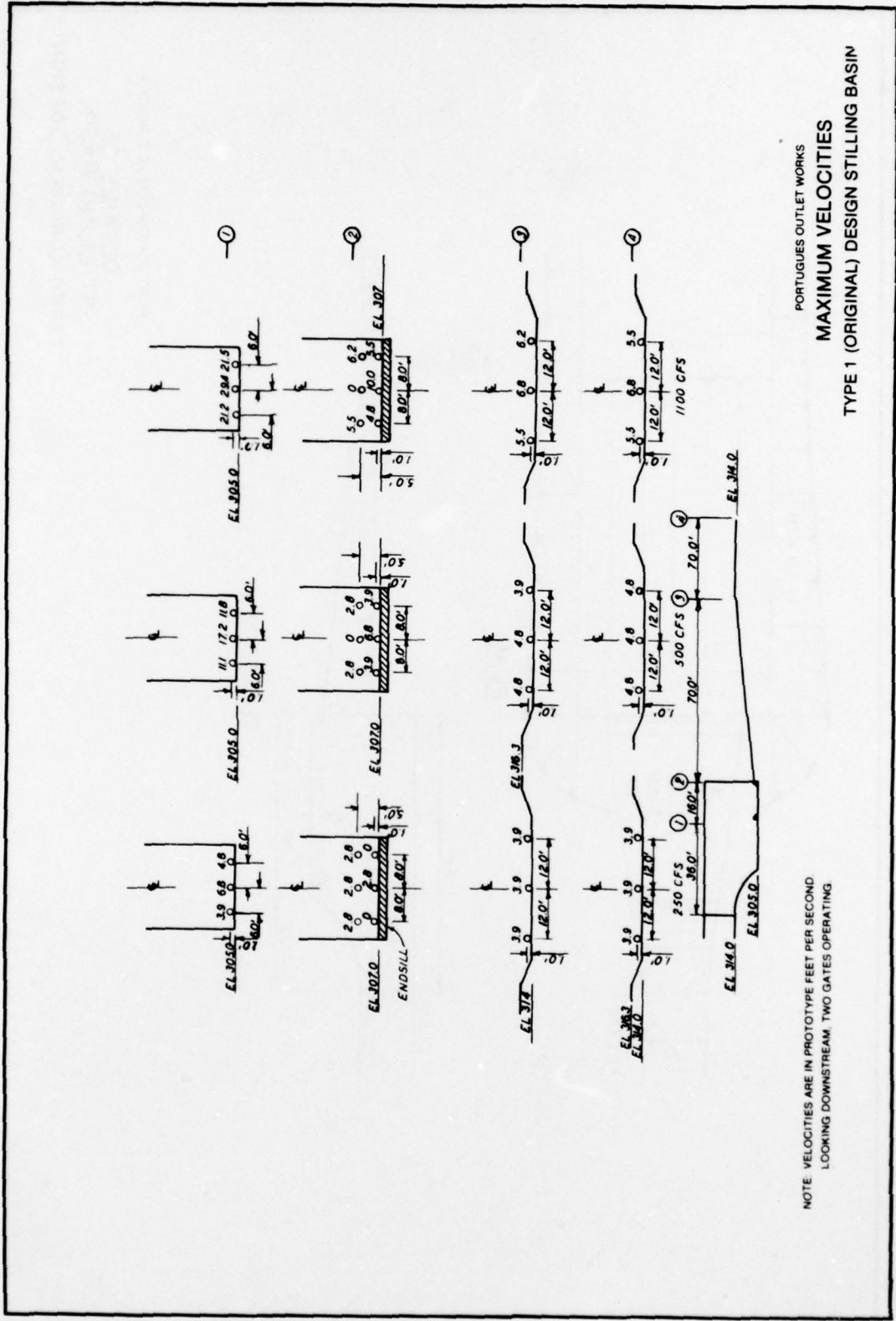


PORTUGUES OUTLET WORKS
GENERAL PLAN
ORIGINAL DESIGN

PLATE 12

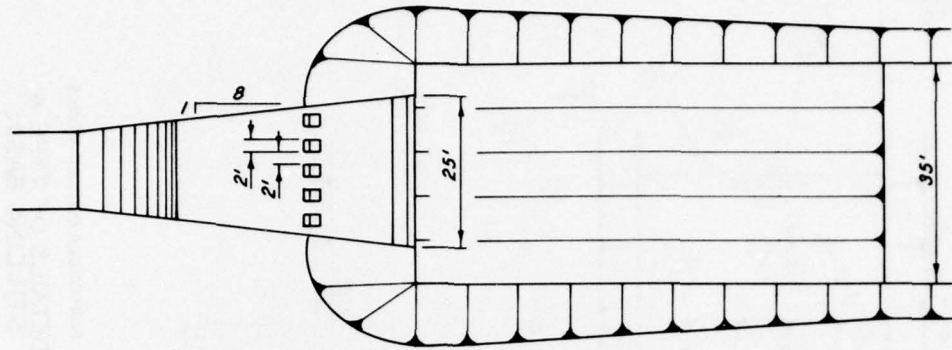


PORTUGUES OUTLET WORKS
 DETAILS OF
 STILLING BASIN
 TYPE 1 (ORIGINAL) DESIGN

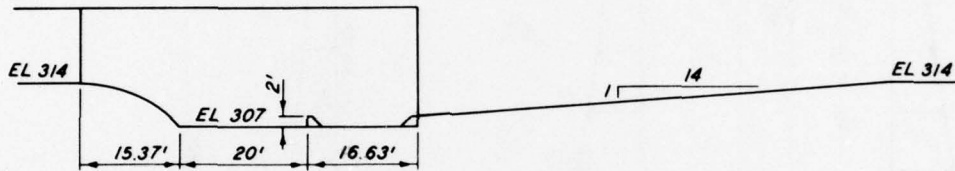


PORTUGUES OUTLET WORKS
MAXIMUM VELOCITIES
 TYPE 1 (ORIGINAL) DESIGN STILLING BASIN

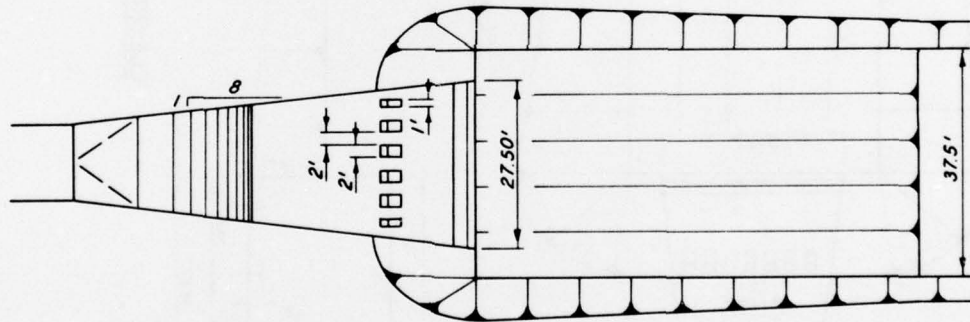
NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND
 LOOKING DOWNSTREAM, TWO GATES OPERATING



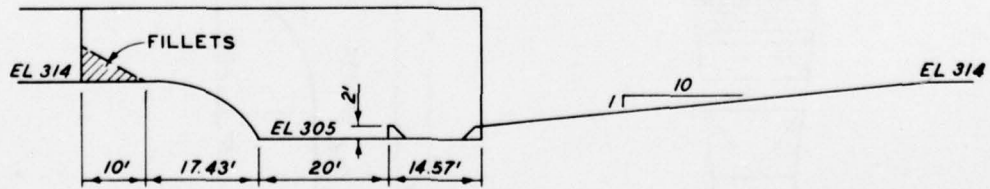
PLAN



ELEVATION
TYPE 2

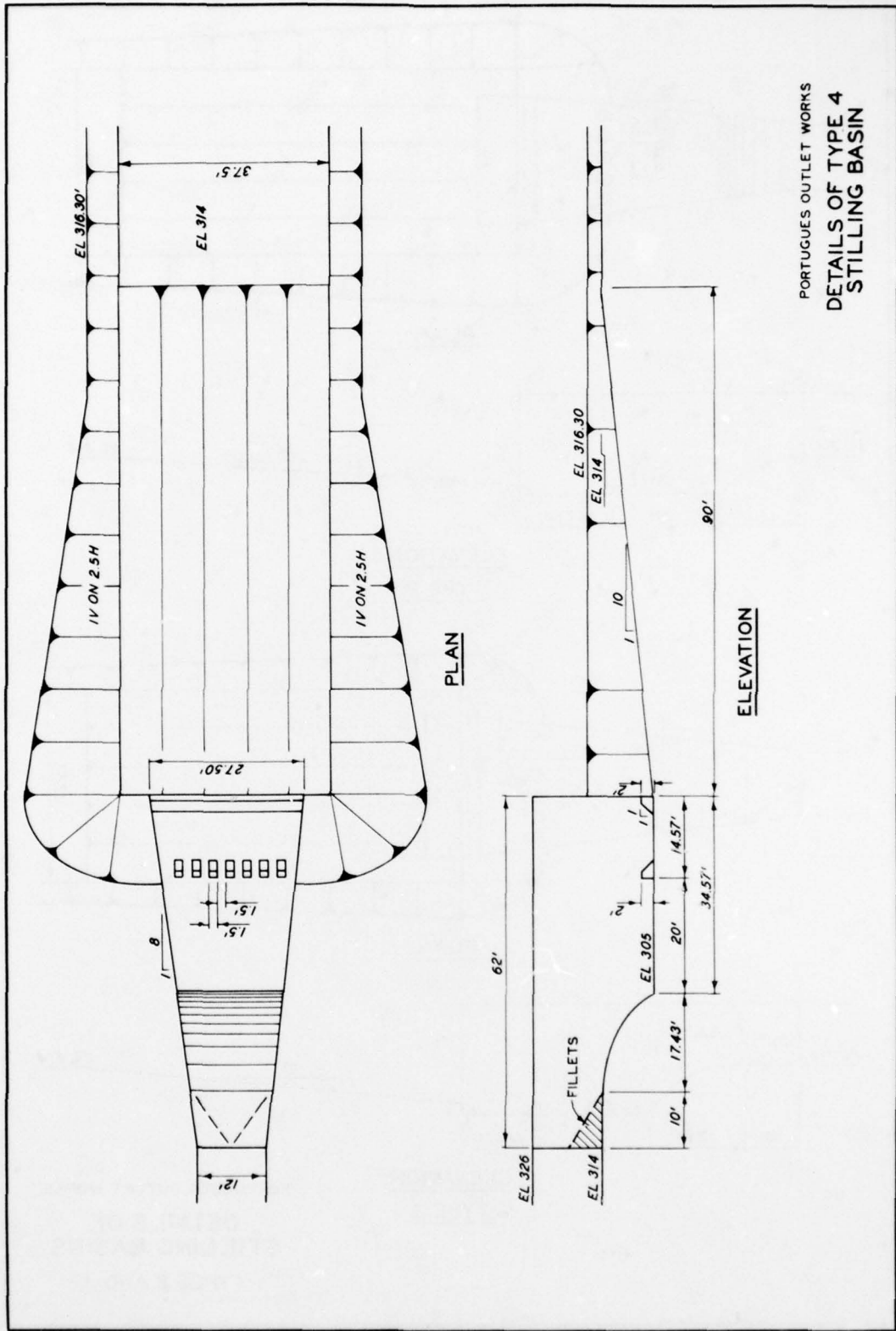


PLAN

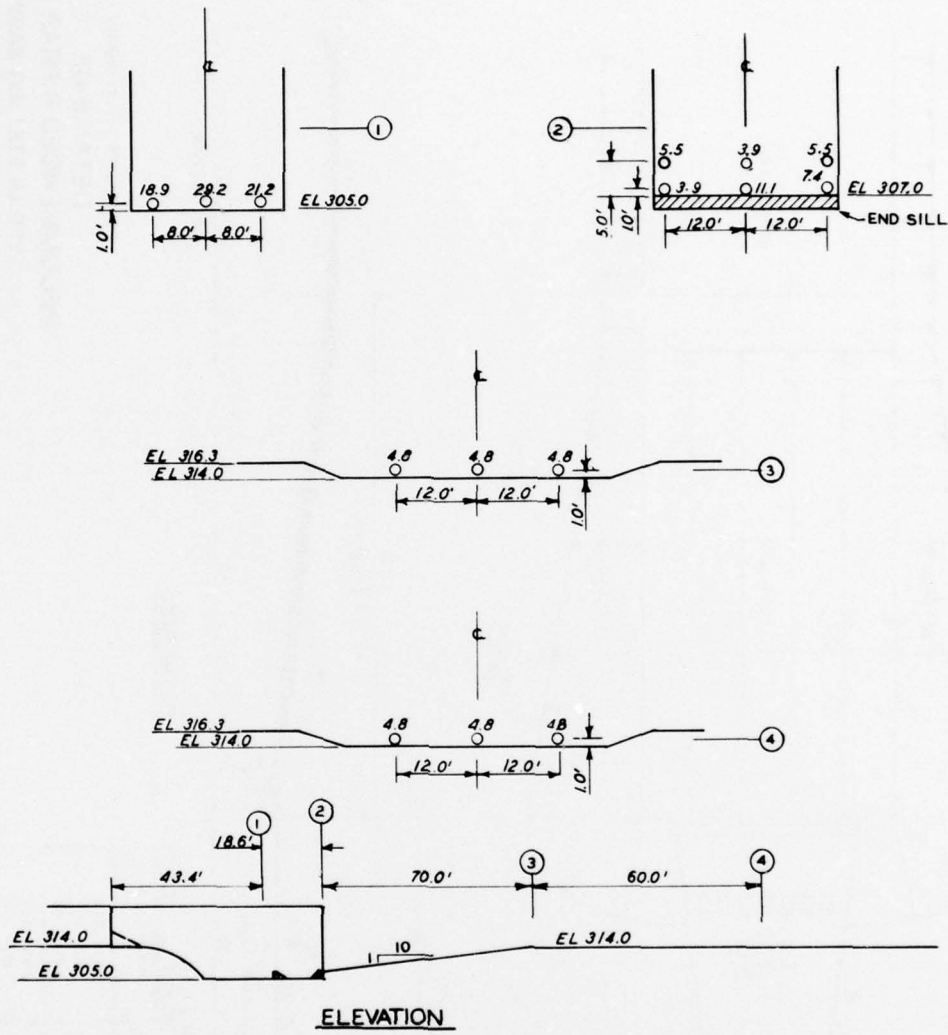


ELEVATION
TYPE 3

PORTUGUES OUTLET WORKS
DETAILS OF
STILLING BASINS
TYPES 2 AND 3



PORTUGUES OUTLET WORKS
 DETAILS OF TYPE 4
 STILLING BASIN



NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.
 LOOKING DOWNSTREAM, DISCHARGE 1100 CFS.

PORTUGUES OUTLET WORKS
MAXIMUM VELOCITIES
 TYPE 4 STILLING BASIN

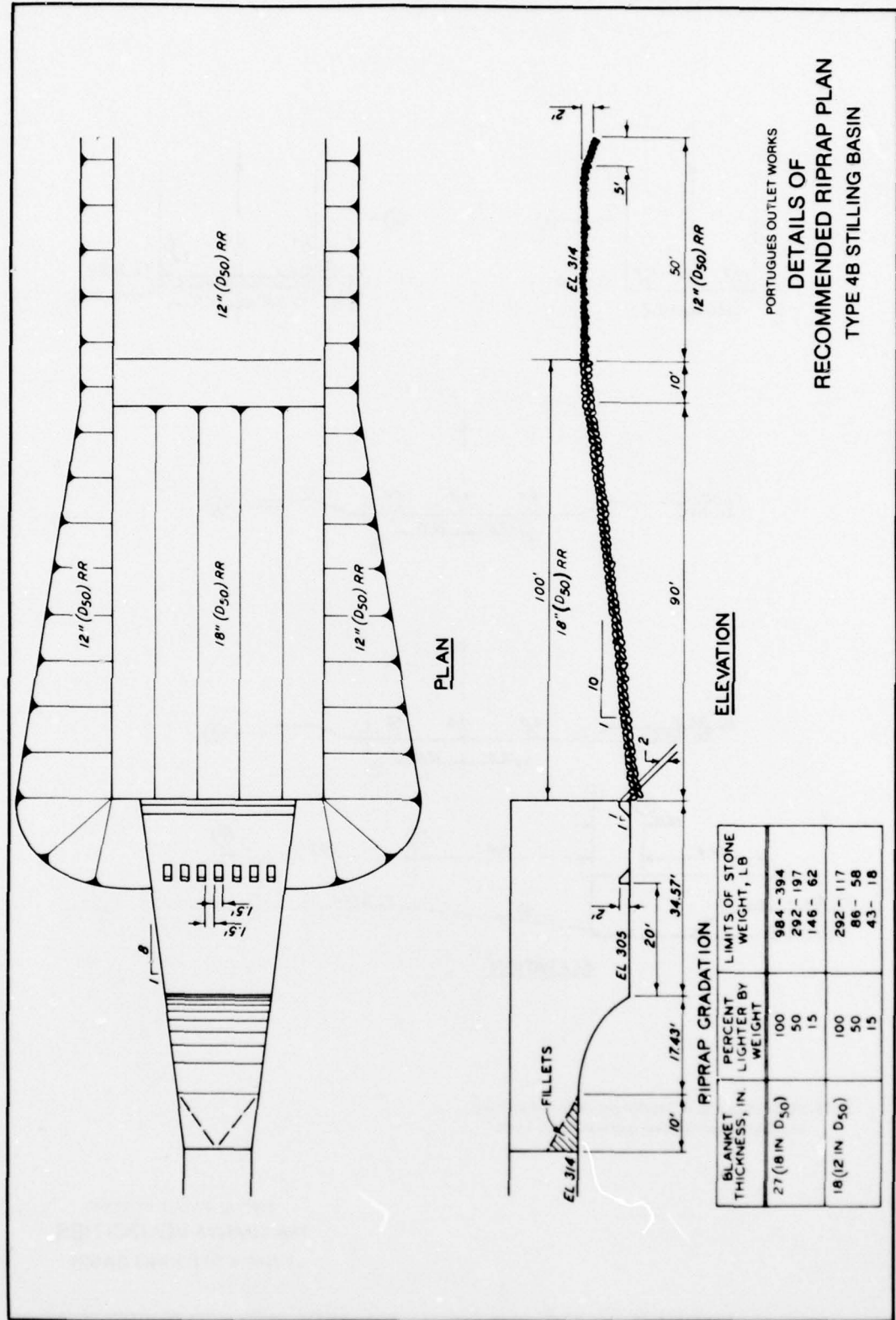


PLATE 18

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

George, John F

Outlet works for Cerrillos Dam, Cerrillos River, and Portugues Dam, Portugues River, Puerto Rico; hydraulic model investigation / by John F. George. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.

21, [13] p., 18 leaves of plates : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; HL-79-6)

Prepared for U. S. Army Engineer District, Jacksonville, Jacksonville, Florida.

1. Cerrillos Dam. 2. Hydraulic models. 3. Outlet works. 4. Portugues Dam. 5. Stilling basins. I. United States. Army. Corps of Engineers. Jacksonville District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; HL-79-6.
TA7.W34 no.HL-79-6