UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE OUTLET CONTROL STRUCTURE, CULVERT UNDER DIKE, AND WASH OVERCHUTE AT STATION 938+00-- WELLTON-MOHAWK DIVISION GILA PROJECT, ARIZONA

Laboratory Report No. Hyd-359

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

January 7, 1953

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FOREWORD

As a part of the Wellton-Mohawk Division, Gila Project, the Mohawk and Wellton-Mohawk Canals are used to deliver irrigation water from the Colorado River to land along the lower reaches of the Gila River, east of Yuma, Arizona. Water is supplied to the Wellton-Mohawk Canal by the Gravity Main Canal which carries the water from Imperial Dam to the Gila River Valley, Figure 1. By gravity flow and lifts of 27 and 85 feet at Pumping Plants No. 1 and 2, respectively, the Wellton-Mohawk Canal delivers the water to Pumping Plant No. 3, located about 5 miles southwest of Wellton. At Pumping Plant No. 3, the water is lifted 57 feet to the Mohawk Canal, which irrigates the land along the Gila River east of Pumping Plant No. 3.

The Mohawk and Wellton-Mohawk Canals cross several washes, which are normally dry, but subject to flash floods during periods of heavy rainfall. To evacuate the flash floodwaters and protect the canals from damage, a number of wash overchutes, siphons, and protective dikes with outlet structures were constructed at the washes and along the upwash side of the canals, Figures 2 and 3.

This report covers the hydraulic model studies made on three of these structures, namely: the outlet control structure, Figure 4; the culvert under dike, Figure 5; and the wash overchute at Station 938+00, Figure 6. The studies on the three structures were conducted more or less simultaneously and the results of one were applied to the other two. Each of the above structures has a baffled apron, placed on a 2:1 slope at the downstream end of the stilling basin. The baffled apron is designed to lower the flow from the stilling basin to the outlet channel with a minimum of scour in the channel. Since the channels below the structures are expected to degrade, which precludes the use of a flip bucket or conventional stilling basin, the baffled apron extends below the channel bed to provide adequate protection against a major flood. As the channels degrade with succeeding floods, the baffled apron may be extended downward, as required, to protect each structure.

The three structures are covered separately in the report. Although only a particular structure was modeled and tested, the studies covered a wide range of flow conditions so that the experimental results may be applied to other structures of similar design in the project.

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Design and Construction Division
Engineering Laboratories Branch
Denver, Colorado
January 7, 1953

Laboratory Report No. Hyd-359
Hydraulic Laboratory Section
Compiled by: W. E. Wagner
Reviewed and
checked by: A. J. Peterka and
J. N. Bradley

Subject: Hydraulic model studies of the outlet control structure, culvert under dike, and wash overchute at Station 938+00--Wellton-Mohawk Division--Gila Project, Arizona

SUMMARY

Included in this report is a discussion of the results obtained from hydraulic model studies of three structures, namely: the outlet control structure, the culvert under dike, and the wash overchute at Station 938+00. A model of each structure was constructed and tested. To avoid confusion in presenting the results, each is discussed under a separate heading.

PART I--OUTLET CONTROL STRUCTURE

The hydraulic model studies discussed in this report were made to calibrate the control slots, to determine the performance of the stilling basin, and to check the effectiveness of the baffled apron. The results and recommendations are based on studies conducted on a 1:24 scale model, Figures 7 and 8A.

Four stilling-basin designs, which varied in length and location of the basin, were tested. Each test basin was fairly acceptable in performance, and the stilling basin studies were concerned primarily with determining the optimum length of structure without sacrificing any of the efficiency of the stilling action in the basin. The basin length was reduced from 78 feet 6 inches in the preliminary design to 42 feet 6 inches in the recommended design, Figure 9. The studies also indicated that the chute blocks and basin baffle piers were unnecessary and these were omitted in the recommended design. Figures 8, 10, 11, 12, and 13 show the operation and the results of scour tests for the different stilling basins. Table I, page 8, contains a recapitulation of the scour test results.

A head-discharge curve for the structure, obtained by calibrating the model, is shown in Figure 15, which indicates that the structure will pass the maximum discharge of 7,000 second feet at a head of 14.5 feet.

Water-surface profiles for a discharge of 7,000 second feet are shown in Figures 16 and 17

PART II--CULVERT UNDER DIKE

The studies of the culvert under dike were made on a 1:12 scale model to determine what alterations to the structure, if any, were required to limit the discharge to 1,250 second feet at a head of 15 feet and to lower the flow to the outlet channel with a minimum of scour.

Eleven different stilling basin designs, Figure 20, were tested in developing the outlet structure to meet the above design requirements. Tests on the preliminary design disclosed that the structure would pass 1,250 second feet at heads of 12.5 to 17.5 feet, depending on whether the culvert transition flowed full or partly full. Since the culvert was designed to flow full throughout its length at a head of 15 feet for this discharge, it was necessary to install baffle piers in most of the stilling basin designs to maintain the 15-foot head. However, it was found that the 15-foot head could be maintained by using a step 2 feet high at the downstream end of the stilling basin in Designs 10 and 11 Design 10 is recommended for construction in the field, Figure 20. Figures 26 and 27 show the operation of the recommended design and the resulting scour patterns with the outlet channel at different elevations. Table II, **page 16,** is a recapitulation of the scour tests on all the stilling basin designs.

Water-surface profiles from the recommended design for discharges of 600 and 1,250 second feet are shown in Figure 28.

Piezometric pressures for Design 2 and the recommended design at discharges of 600 and 1,250 second feet are shown in Figure 29. The lowest recorded pressure in the tunnel was 9.5 feet of water below atmospheric. Pressures were also obtained on four baffle piers on the 2:1 apron. These results are shown in Figure 30.

PART III--WASH OVERCHUTE AT STATION 938+00

A 1:12 scale model was used to develop the outlet structure for the wash overchute. The model studies were made primarily to study the acceleration of flow resulting from the 3-foot drop immediately upstream from the baffled apron, Figure 6, and the effectiveness of the baffled apron.

Extensive studies of the size, shape, and spacing of the baffle piers on the 2:1 apron were made in this investigation. Of the six different baffle-pier arrangements tested, Figure 34, it was found that the arrangement in the preliminary design, with an extra row of piers added at the downstream end of horizontal apron, gave the best flow distribution and a minimum of scour in the outlet channel. The addition of the extra row of baffle piers caused a hydraulic jump to form on the horizontal apron which was effective in slowing the high velocity flow over the chute, Figure 38. The results of scour tests for the recommended design at discharges of 600, 1,250, and 1,875 second feet are shown in Figure 42. A summary of the tests using the various baffle-pier arrangements is tabulated in Table III, page 26.

Profiles of the water surface for discharges of 600, 1,250, and 1,875 second feet are shown in Figure 44.

Piezometric pressures on the baffle piers on the 2:1 apron are given in Figure 45.

PART I--OUTLET CONTROL STRUCTURE

Introduction

The outlet control structure is located about one-half mile southwest of the Wellton-Mohawk Pumping Plant No. 3, approximately 22 miles east of Yuma, Arizona, Figures 2 and 3. Together with the culvert under dike, its purpose is to control the evacuation of the storm run-off waters retained by Mohawk Protective Dike No. 1, which extends approximately 13 miles along the upwash side of the Mohawk Canal, Figure 2.

The outlet control structure consists of a check wall with four 10-foot-wide slots, a stilling basin, and a baffled apron on a 2:1 slope immediately downstream from the stilling basin, Figure 4. The slots in the check wall are designed to limit the flow through the structure to a maximum discharge of 7,000 second feet at a head of 15 feet. This discharge is the maximum flow which can be safely handled by the outlet channel without overloading the wash siphon at Wellton-Mohawk Canal Station 822+17.17 or endangering bridges and embankments of the Southern Pacific Railroad.

Hydraulic model studies of the structure were made to check the size of the control slots, to determine the performance and adequacy of the stilling basin, and to check the effectiveness of the baffled apron.

The 1:24 Scale Model

The model of the outlet control structure was built to a geometrical scale of 1:24 and consisted of an inlet channel, 6 feet in length; the outlet structure; and an outlet channel approximately 9 feet in length, Figure 7. Since the structure is symmetrical about the center line and to keep the model construction costs to a minimum, only one-half of the structure was built for the model studies. Therefore, one side wall of the model was vertical and straight, representing a plane of symmetry on the center line of the prototype structure, Figure 8A.

Water was supplied to the inlet channel by one of the portable laboratory pumps and was metered through a combination venturi and orifice meter. Since a tail-water curve was not available for the outlet channel, flashboards were placed at the downstream end of the outlet channel to act as a flow control and to hold the movable sand in the bottom of the outlet channel.

The Investigation

General

The model studies of the outlet control structure concerned primarily the distribution of flow downstream from the notches as it affected the stilling basin performance, the adequacy of the stilling basin, and the size of the control slots required to pass 7,000 second feet at a head of 15 feet. Four stilling-basin designs, which varied in length of basin, were studied. Comparison of the different basins was made by observing the distribution of flow downstream from the notches and obtaining scour patterns for each design. The scour tests were made with the downstream channel at two elevations, 333.8 feet (original channel elevation) and 324.6 feet (assuming degradation had occurred) with the model operating at the maximum discharge of 7,000 second feet for 30 minutes, which is equivalent to approximately 2-1/2 hours in the prototype. Similarly, the scour tests were used to evaluate the effectiveness of the baffle piers in the basin.

Visual observations of the flow distribution in the stilling basin were made for discharges of 2,000 and 7,000 second feet. No changes in the size or arrangement of the baffle piers on the 2:1 sloping apron were made, since extensive studies on the wash-overchute model, Part III of this report, showed that the baffle piers, as originally designed, were satisfactory.

Preliminary Basin

Initially, the model was constructed according to the preliminary basin design, Figure 4. The model, shown in Figures 7 and 8A, was operated at the maximum discharge of 7,000 second feet.

The flow spread fairly well after leaving the slots in the check wall. There was a tendency for the water to "pile up" along the training wall and between the slots where the spreading jets converged downstream from the check wall, but the water entered the stilling basin fairly uniform, Figure 8C. From visual observations, the stilling basin appeared to be much longer than necessary and the baffle piers appeared to be too far downstream to aid in dissipating the high velocity flow. Practically all of the stilling action took place in the upstream half of the stilling basin and the flow was evenly distributed at the downstream end of the basin. Results of the scour test for the preliminary basin, with the bottom of the outlet channel at 333.8 feet, showed that the maximum depth of scour in the outlet channel was 4.8 feet, Figure 8D.

Figure 8B shows the model operating at a discharge of 2,000 second feet. At this discharge, the pile-up of water between the slots and along the training wall was negligible and flow through the stilling basin was very quiet with little visible turbulence.

Basin No. 2

Since the preliminary tests indicated that the stilling basin was too long, the length was radically changed from 36 feet to 12 feet in Basin No. 2, Figure 9. In addition, the basin baffle piers were removed, since their usefulness was questionable with a short basin.

Figure 10A shows the operation of Basin No. 2 at the maximum discharge of 7,000 second feet. The flow immediately downstream from the slots was similar to that observed in the preliminary basin. The operation of the stilling basin was satisfactory, with the full length of the basin being used in dissipating the high velocity flow. The scour in the downstream channel, Figure 10B, was 5.3 feet--or 0.5 foot deeper than that obtained with the longer basin in the preliminary design.

To determine the effectiveness of the chute blocks, a scour test was run at maximum discharge with the chute blocks removed, Figure 10C. Results of this test showed the scour to be 5.8 feet

which is 0.5 foot deeper than that obtained with the chute blocks installed. Since the depth of scour was only slightly greater with the chute blocks removed, and the stilling basin performance was satisfactory, it was decided to determine the proper size of basin without the use of either the chute blocks or baffle piers.

All the previous scour tests were made with the outlet channel at elevation 333.8 feet. To ascertain the effectiveness of the baffle piers on the 2:1 sloping apron downstream from the stilling basin, the bottom of the outlet channel was lowered to elevation 324.6 feet and a scour test run at the maximum discharge of 7,000 second feet, Figures 10D and 11A. The depth of scour with the lower outlet channel was 5.6 feet or approximately the same as that observed with the higher outlet channel. Thus, assuming the depth of scour is proportional to the velocity of the flowing water, the baffle piers were very effective in retarding and breaking up the water as it flowed down the 2:1 slope.

Basin No. 3

From the tests on Basin No. 2, it was concluded that the 12-foot basin length was adequate and any shorter stilling basin would probably sacrifice some of the stilling basin performance and increase the scour in the outlet channel. However, it appeared that the pile-up of water between the slots downstream from the check wall could be reduced if the horizontal floor were shortened. For Basin No. 3 the length of the horizontal section downstream from the check wall was reduced from 26 to 18-1/2 feet and the 16-1/2-foot curved section was replaced with a sloping section 12 feet long, Figure 9. This alteration was made without moving the 2:1 sloping apron. Thus, the stilling basin was 24 feet long for Basin No. 3, but the studies were concerned only with the distribution of flow immediately downstream from the control slots.

Basin No. 3 gave an improved flow pattern downstream from the check wall at maximum discharge, Figure 11B. By comparing Figure 11B with Figure 10D, it can be seen that the pile-up between the slots was materially reduced. Results of the scour test with this design are shown in Figure 11B.

Since there was a definite improvement in the flow pattern downstream from the check wall, it was decided to accept the shorter horizontal and sloping sections between the check wall and the stilling basin.

Basin No. 4

The tests on Basin No. 2 showed that a 12-foot-long stilling basin gave satisfactory results. Therefore, Basin No. 4 combined the stilling basin of Basin No. 2 and the horizontal and sloping sections of Basin No. 3, Figures 9 and 12A.

With the maximum discharge of 7,000 second feet passing through the model, Figure 12B, the performance of the stilling basin was satisfactory with the flow well distributed at the downstream end of the basin. Downstream from the check wall the pile-up of water between the slots and along the training walls was still evident but materially reduced in height. Results of the scour test, Figure 12C, showed the maximum depth of scour with the outlet channel at elevation 324.6 feet to be 5.6 feet, or the same as that obtained with the longer and more costly structure in Basin No. 2.

Figures 13A and 13B, respectively, show the operation of the model at discharges of 7,000 and 2,000 second feet with the outlet channel at elevation 333.8 feet. At the maximum discharge of 7,000 second feet, the appearance of the flow in the stilling basin was the same as that observed with the outlet channel at the lower elevation of 324.6 feet. A scour test made with the outlet channel at elevation 333.8 feet at maximum discharge, Figure 13C, showed the maximum depth of scour to be similar to that obtained with the outlet channel at the lower elevation. With 2,000 second feet, the flow through the structure was excellent with no pile-up of water between the slots and well distributed flow through the stilling basin.

From the results of the above tests, Basin No. 4 is recommended for construction in the field.

The Recommended Design

A detailed drawing of the recommended structure is shown in Figure 14. In length, the recommended structure is 36 feet shorter than the preliminary design which represents a considerable saving in materials and construction costs. From the scour tests, which are tabulated in Table I, it can be seen that only a slightly greater depth of scour was obtained using the recommended structure with its shorter length of stilling basin.

Table I

RESULTS OF SCOUR TESTS
Discharge of 7,000 cfs

Basin No.	Tail water el, ft	El of outlet channel, feet	Length of basin, feet	Maximum depth of scour, ft.
Preliminary	340.7	333.8	78.5	4.8
2	340.7	333.8	54.5	5.3
2a*	340.7	333.8	54.5	5.8
2a	332.7	324.6	54.5	5.6
3	332.7	324.6	54.5	6.6
4 (Recommended)	332.7	324.6	42.5	5.6
4	340.7	333.8	42.5	5.8

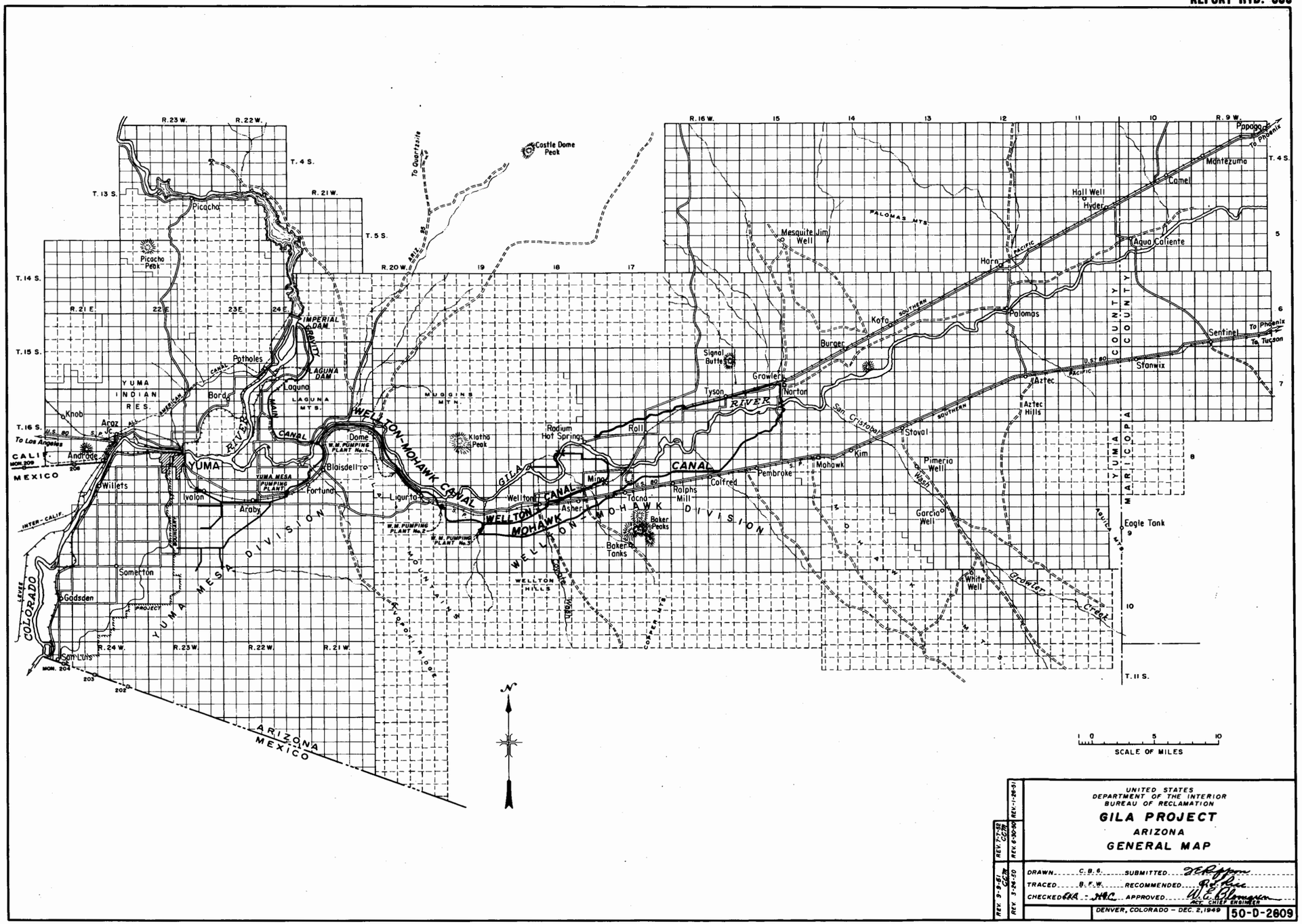
*Basin No. 2 with chute blocks removed.

A scour test was also run to determine the extent of scour upstream from the slots in the check wall. Results of this test are shown in Figure 13D. The maximum depth of scour, which was 4 feet, occurred at the corners of each slot and extended from 10 to 11 feet upstream from the slots. Therefore, it is recommended that a concrete slab, 10 feet or more in length, be placed upstream from the check wall.

The results of the calibration of the control slots are shown in Figure 15, where the discharge in cubic feet per second is plotted versus the head in feet. This curve indicates that the maximum discharge of 7,000 second feet will be reached at the head of 14.5 feet in the inlet channel.

Water-surface profiles were obtained at the maximum discharge of 7,000 second feet with the bottom of the outlet channel at elevations 324.6 and 333.8 feet. These profiles are shown in Figures 16 and 17, respectively.

FIGURE 1
REPORT HYD. 359



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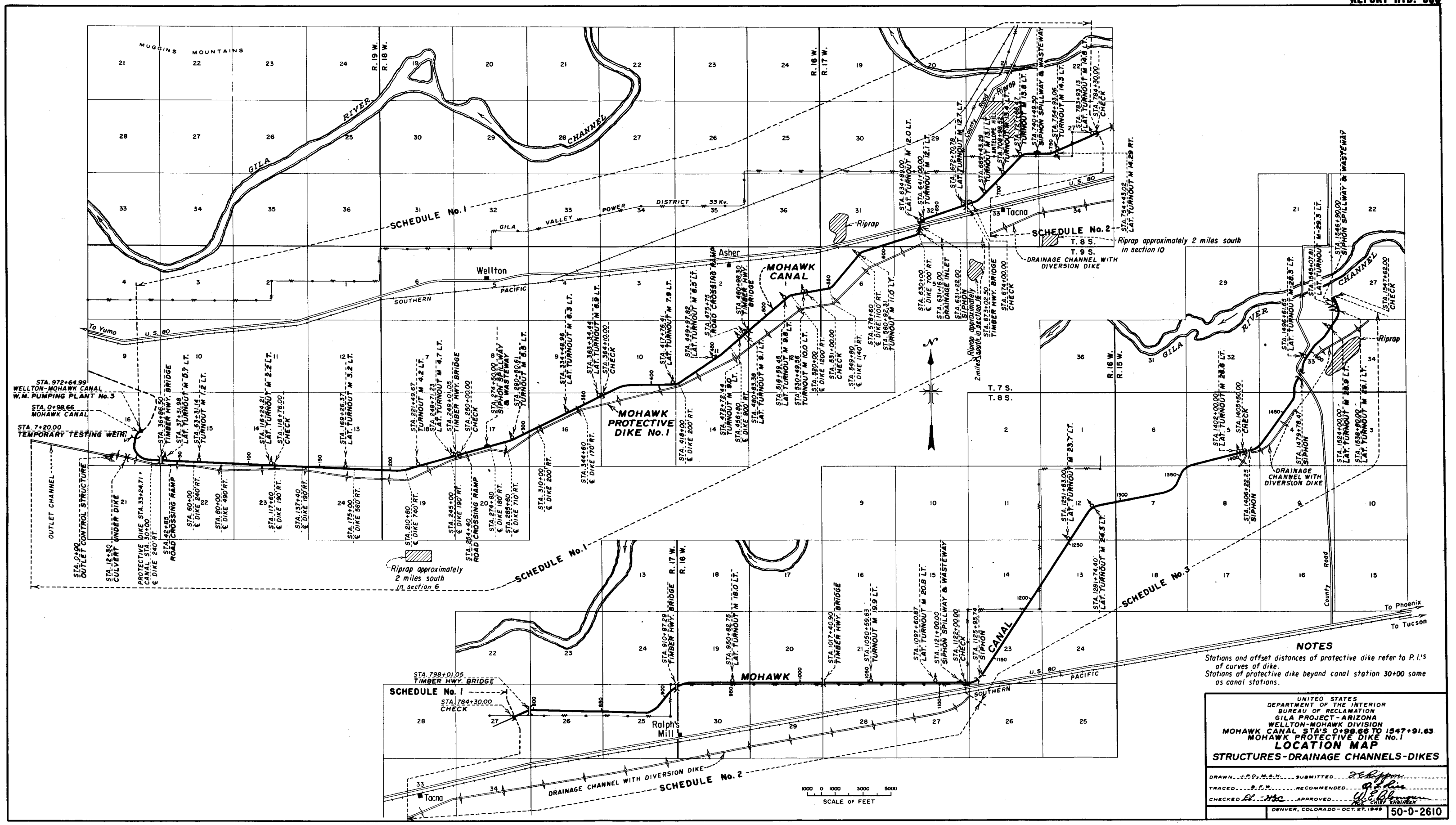
GILA PROJECT
ARIZONA
GENERAL MAP

DRAWN C.B.G. SUBMITTED
TRACED B.F.W. RECOMMENDED
CHECKED APPROVED
ACT. CHIEF ENGINEER

DENVER, COLORADO – DEC. 2, 1949 | 50-D-2609

REV. 9-8-49 REV. 3-24-50 REV. 2-2-50 REV. 6-30-50 REV. 1-19-51

FIGURE 2
REPORT HYD. 359



NOTES

Stations and offset distances of protective dike refer to P.I.'s of curves of dike.
Stations of protective dike beyond canal station 30+00 same as canal stations.

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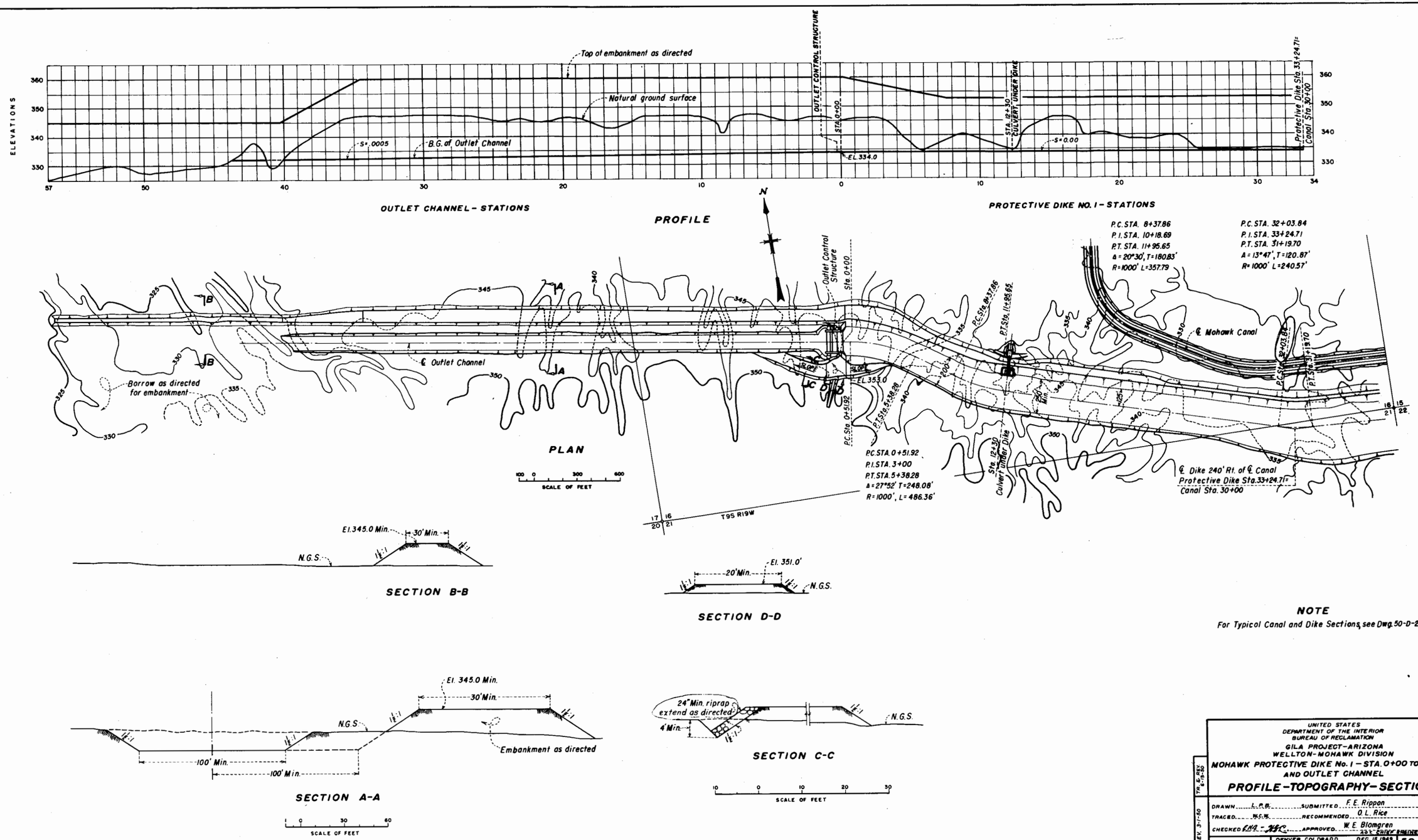
WELLTON-MOHAWK DIVISION
MOHAWK CANAL STA'S 0+98.66 TO 1547+91.63
MOHAWK PROTECTIVE DIKE No. 1

LOCATION MAP

STRUCTURES-DRAINAGE CHANNELS-DIKES

DRAWN J.P.D., M.A.H. SUBMITTED
TRACED S.F.W. RECOMMENDED
CHECKED APPROVED ACT. CHIEF ENGINEER
DENVER, COLORADO - OCT. 27, 1948
50-D-2610

FIGURE 3
REPORT HYD. 359



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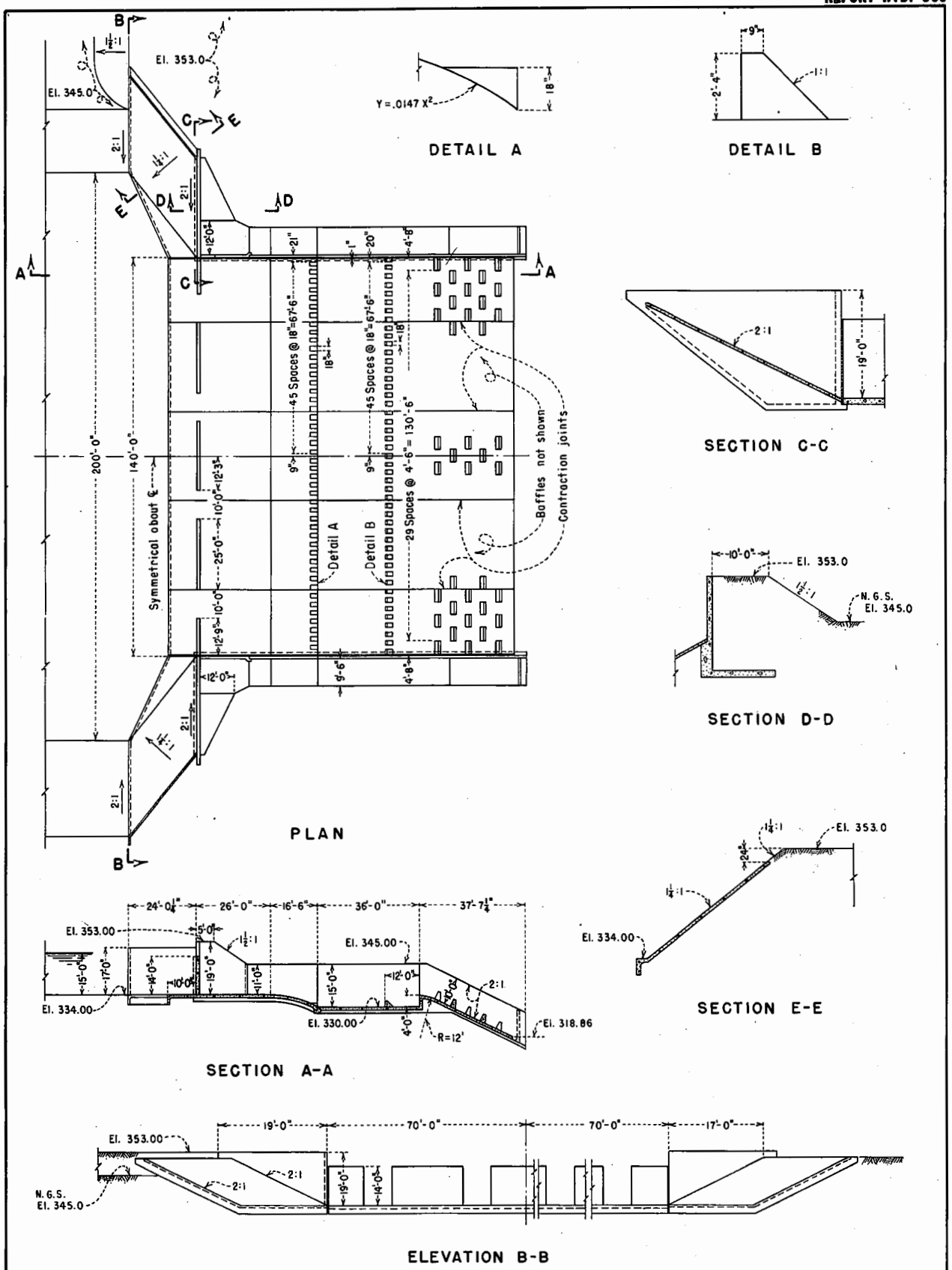
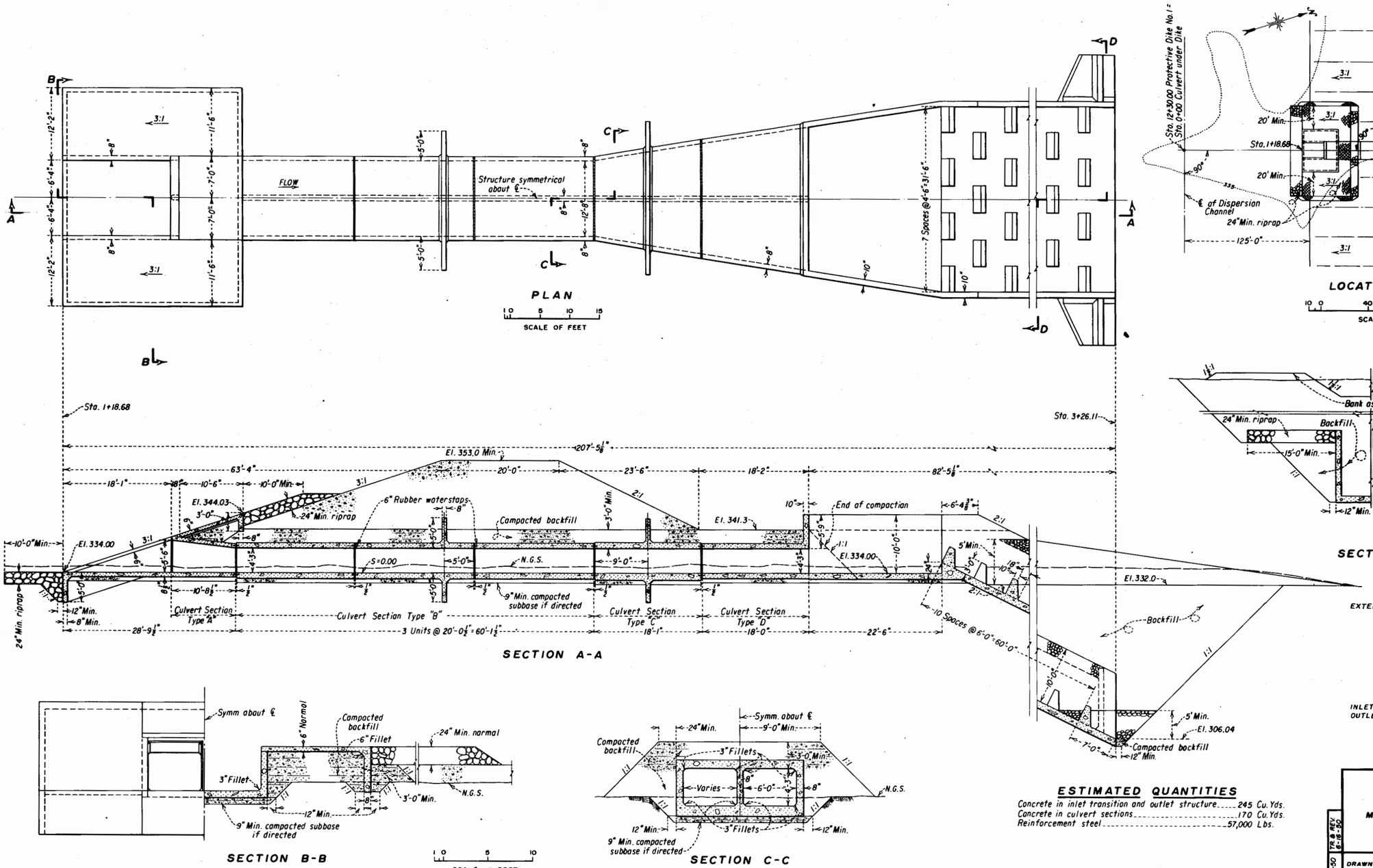
WELLTON-MOHAWK DIVISION
MOHAWK PROTECTIVE DIKE No. 1 - STA. 0+00 TO 33+24.71
AND OUTLET CHANNEL
PROFILE-TOPOGRAPHY-SECTIONS

TR. E. REV. 6-19-50
REV. 3-7-50

DRAWN L.C.B. SUBMITTED F.E. Rippon
TRACED H.S.W. RECOMMENDED O.L. Rice
CHECKED E.H.G. - M.F.C. APPROVED W.E. Blomgren
CHIEF ENGINEER
DENVER, COLORADO DEC. 15, 1949 50-D-2664



WELLTON-MOHAWK DIVISION
MOHAWK PROTECTIVE DIKE NO. 1—STA. 0+00
OUTLET CONTROL STRUCTURE
GENERAL PLAN AND SECTIONS
(PRELIMINARY)



NOTE

EXTERNAL DESIGN LOAD FOR CULVERT SECTIONS

SECTION TYPE	LBS. PER SQ. FT.
A	890
B	1800
C	1690
D	660

REFERENCE DRAWINGS

INLET TRANSITION AND CULVERT BOX 50-D-2678
OUTLET STRUCTURE 50-D-2679

ESTIMATED QUANTITIES

Concrete in inlet transition and outlet structure ..... 245 Cu. Yds.
Concrete in culvert sections ..... 170 Cu. Yds.
Reinforcement steel ..... 57,000 Lbs.

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WELLTON-MOHAWK DIVISION

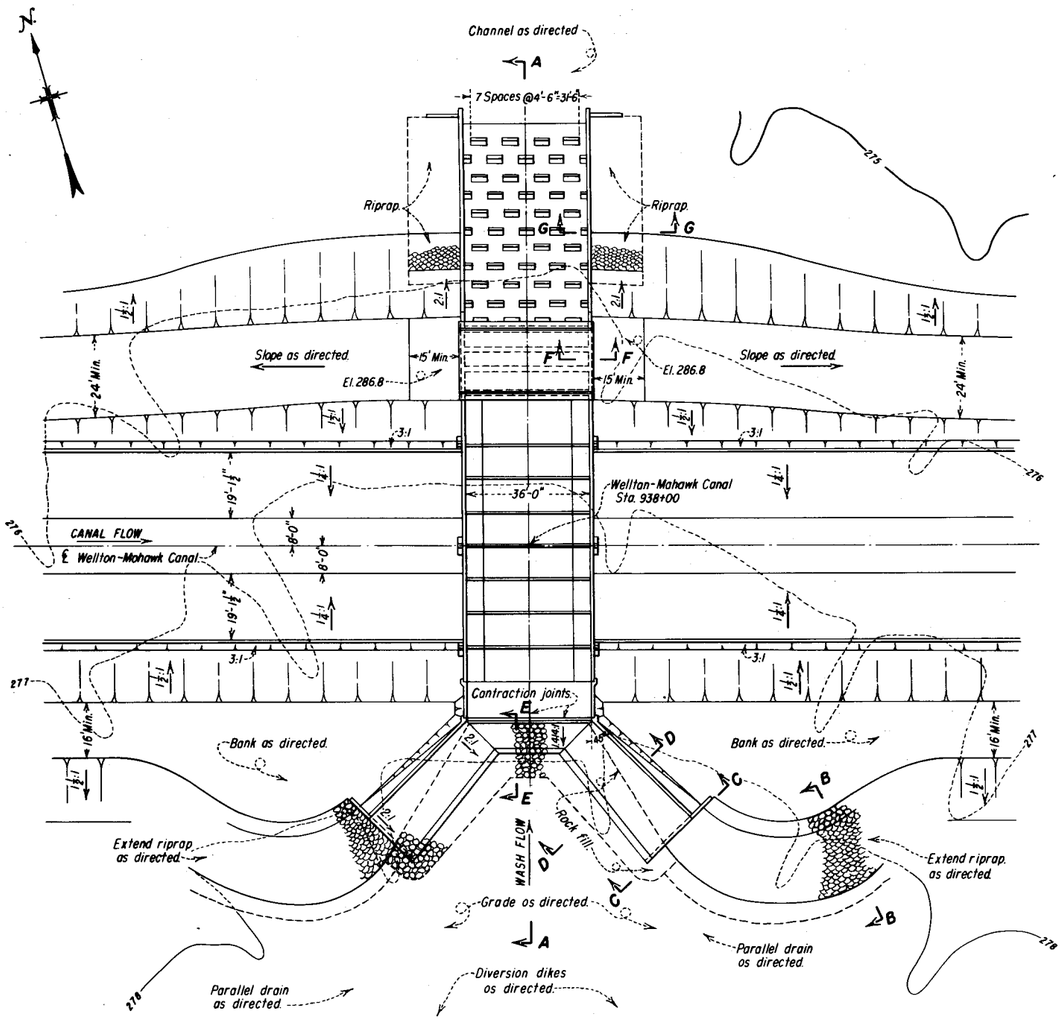
MOHAWK PROTECTIVE DIKE No. 1 STA. 12+30

CULVERT UNDER DIKE
GENERAL PLAN AND SECTIONS

DRAWN L.P.B., M.A.H.	SUBMITTED F.E. Rippon		
TRACED B.F.W.	RECOMMENDED O.L. Rice		
CHECKED D.W.R., H.G.C.	APPROVED W.E. Blomgren, ACT. CHIEF ENGINEER		

DENVER, COLORADO-DEC. 27, 1949 — 50-D-2677

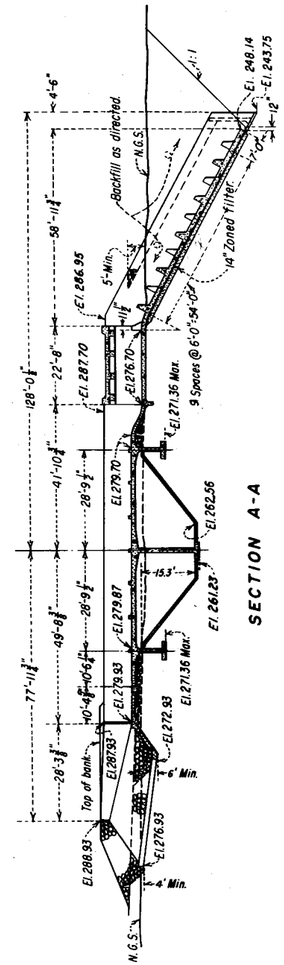
REV. 5-25-50 TR.& REV. 6-15-50



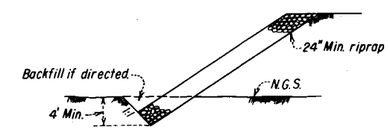
PLAN

Note: Opposite sides symmetrical except as shown.

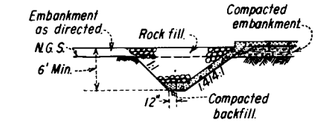
10 0 10 20 30 40
SCALE OF FEET



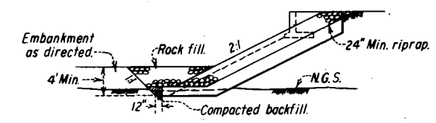
SECTION A-A



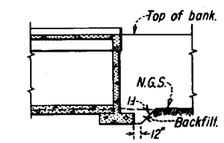
SECTION B-B



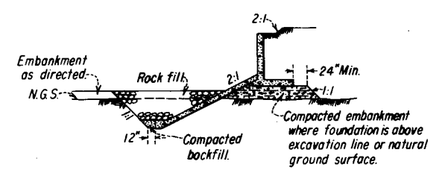
SECTION E-E



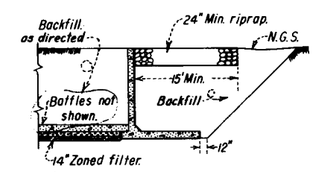
SECTION C-C



SECTION F-F



SECTION D-D



SECTION G-G

5 0 5 10 15
SCALE OF FEET

ESTIMATED QUANTITIES

Concrete in structures	433	Cu. Yds.
Concrete in floor slabs and paving	50	Cu. Yds.
Concrete in wash outlet, paving, and baffles	148	Cu. Yds.
Reinforcement steel	106,600	Lbs.
Lumber	900	F.B.M.

REFERENCE DRAWINGS

WASH CHANNEL INLET-WALLS AND PAVING	50-D-2436
CENTER UNIT	50-D-2472
WASH CHANNEL OUTLET-WALLS-PAVING-BAFFLES	50-D-2473
BRIDGE-PLAN-ELEVATION-SECTIONS	50-D-2474

NOTE

Timber railing not shown, for details see Dwg. 50-D-2474

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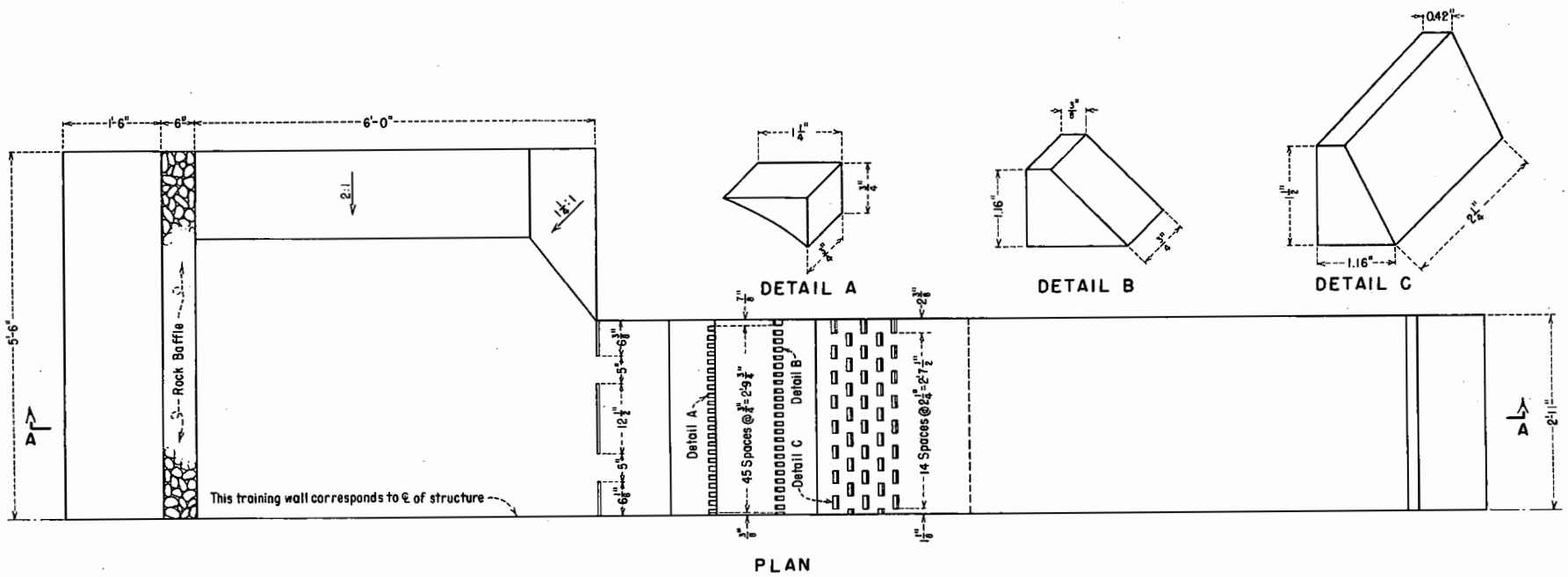
GILA PROJECT-ARIZONA
WELLTON-MOHAWK DIVISION
WELLTON-MOHAWK CANAL-STA. 938+00

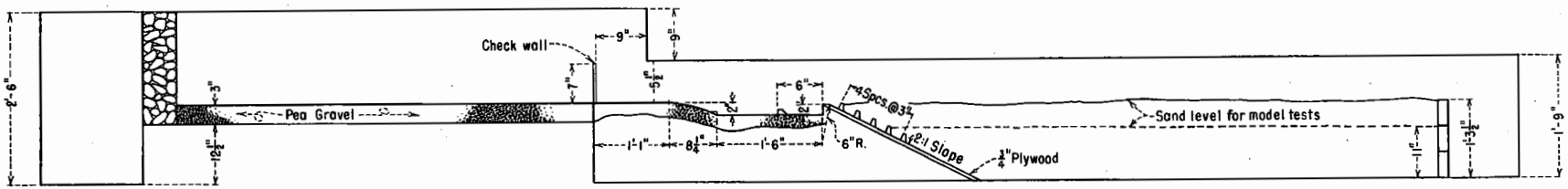
WASH OVERCHUTE
GENERAL PLAN AND SECTIONS

DRAWN: L.P.B. SUBMITTED: D. E. Rippon
TRACED: C.M.A. RECOMMENDED: J. W. Holder
CHECKED: E.O.H. G.S.T. APPROVED: L. N. McClellan
CHIEF ENGINEER

REV. 8-14-50

DENVER, COLORADO, MARCH 23, 1949 | 50-D-2471



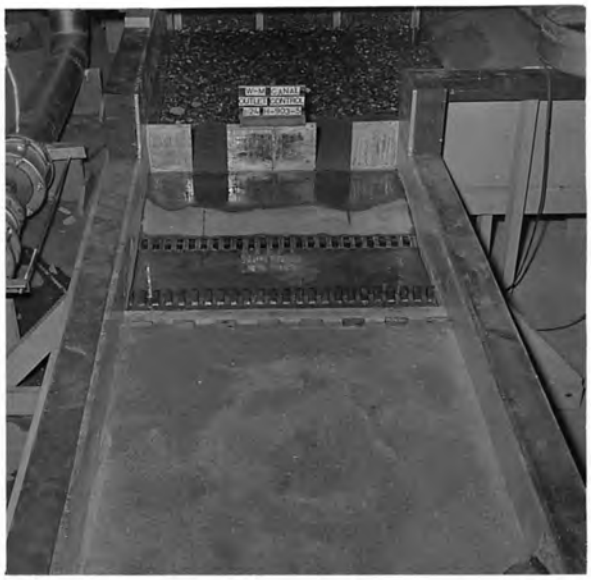


WELLTON-MOHAWK DIVISION

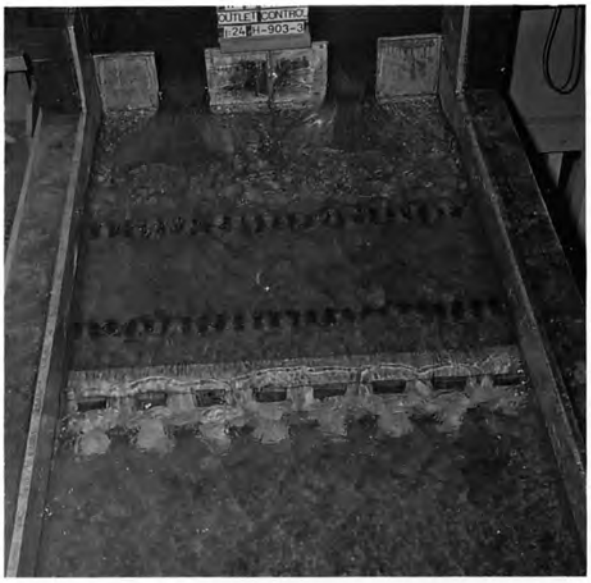
OUTLET CONTROL STRUCTURE

1:24 SCALE MODEL

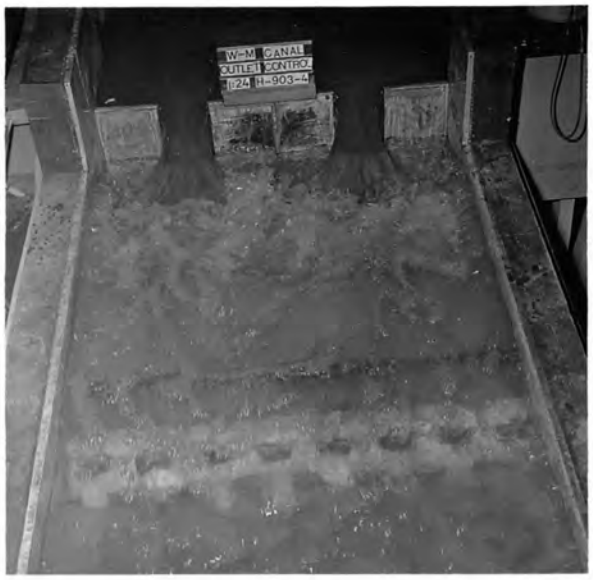
FIGURE 7
REPORT HYD. 359



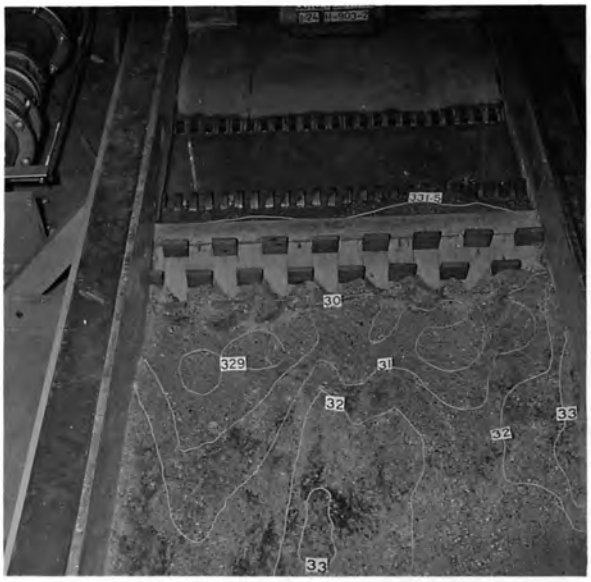
A. The Model.



B. Discharge of 2000 second-feet.

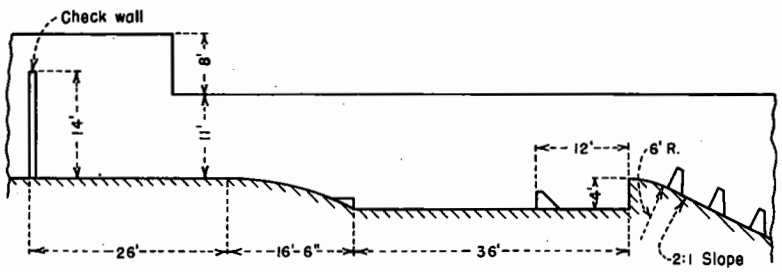


C. Discharge of 7000 second-feet.

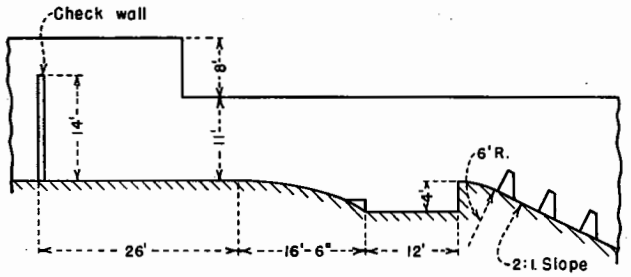


D. Scour pattern after discharge of 7000 second-feet for $2\frac{1}{2}$ hours (prototype).

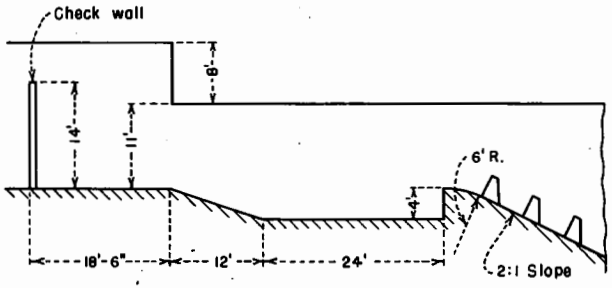
WELLTON-MOHAWK OUTLET CONTROL STRUCTURE
Operation of the Preliminary Basin
(Outlet channel at Elevation 333.8 feet)
1:24 Scale Model



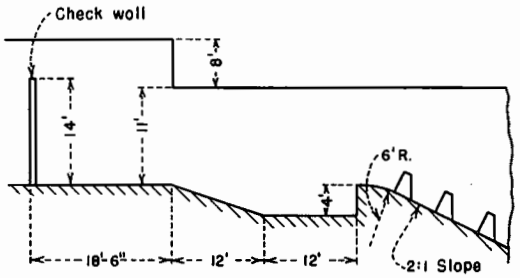
A. PRELIMINARY BASIN



B. BASIN NO. 2



C. BASIN NO. 3



D. BASIN NO. 4
RECOMMENDED

WELLTON-MOHAWK DIVISION

OUTLET CONTROL STRUCTURE

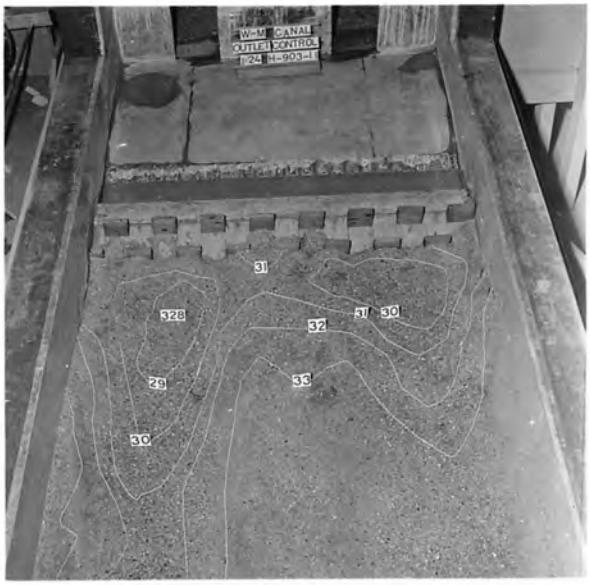
VARIOUS BASINS TESTED

1:24 SCALE MODEL

FIGURE 9
REPORT HYD. 359

A. Outlet Channel at elevation of 333.8 feet.

B. Scour pattern with channel at elevation of 333.8 feet.



C. Scour pattern with chute blocks removed and channel at elevation of 333.8 feet.

D. Chute blocks removed and channel at elevation of 324.6 feet.

WELLTON-MOHAWK OUTLET CONTROL STRUCTURE
Operation of Basin No. 2
Discharge of 7000 second-feet and resulting scour
1:24 Scale Model

FIGURE 11
Report Hyd-359

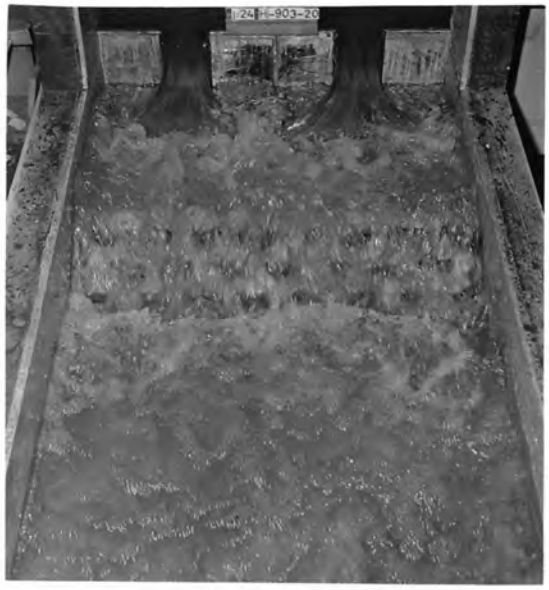
A. Scour pattern below
Basin No. 2.

B. Basin No. 3.

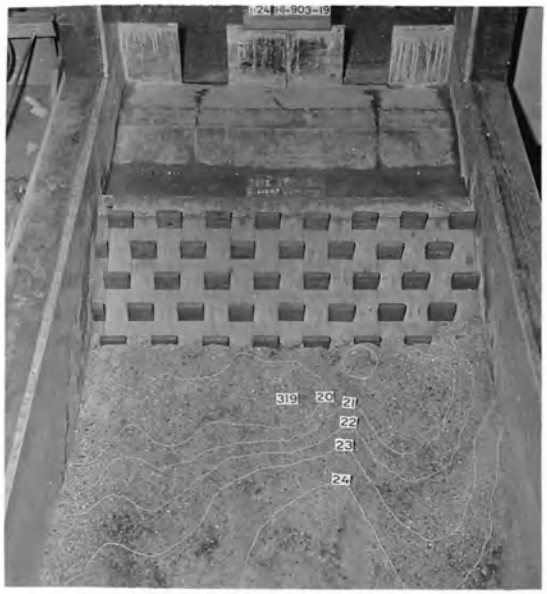
WELLTON-MOHAWK OUTLET CONTROL STRUCTURE
Operation of Basins No. 2 and 3
Discharge of 7000 second-feet and resulting scour
(outlet channel at elevation of 324.6 feet)
1:24 Scale Model

FIGURE 12
Report Hyd-359

A. The Model.



B. Discharge of 7000 second-feet.

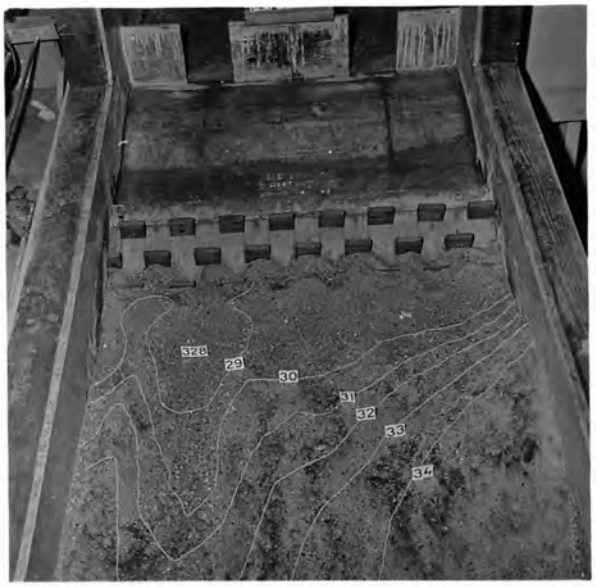


C. Scour pattern after discharge of 7000 second-feet.

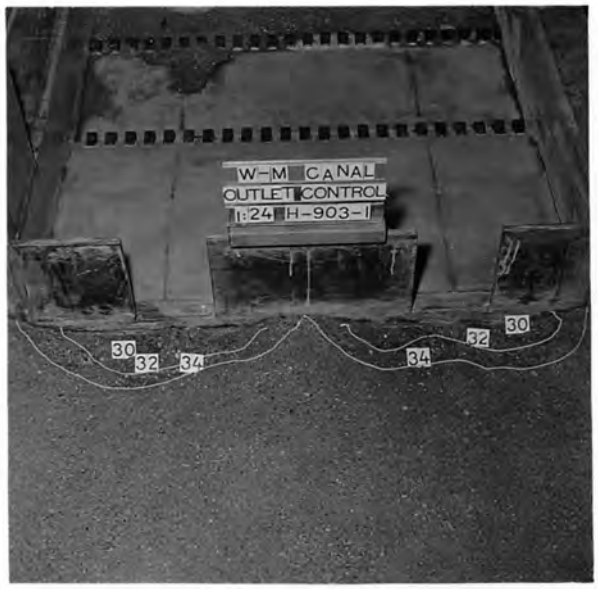
WELLTON-MOHAWK OUTLET CONTROL STRUCTURE
Operation of Basin No. 4. (Recommended)
(outlet channel at Elevation 324.6 feet)
1:24 Scale Model

A. Discharge of 7000 second-feet.

B. Discharge of 2000 second-feet.

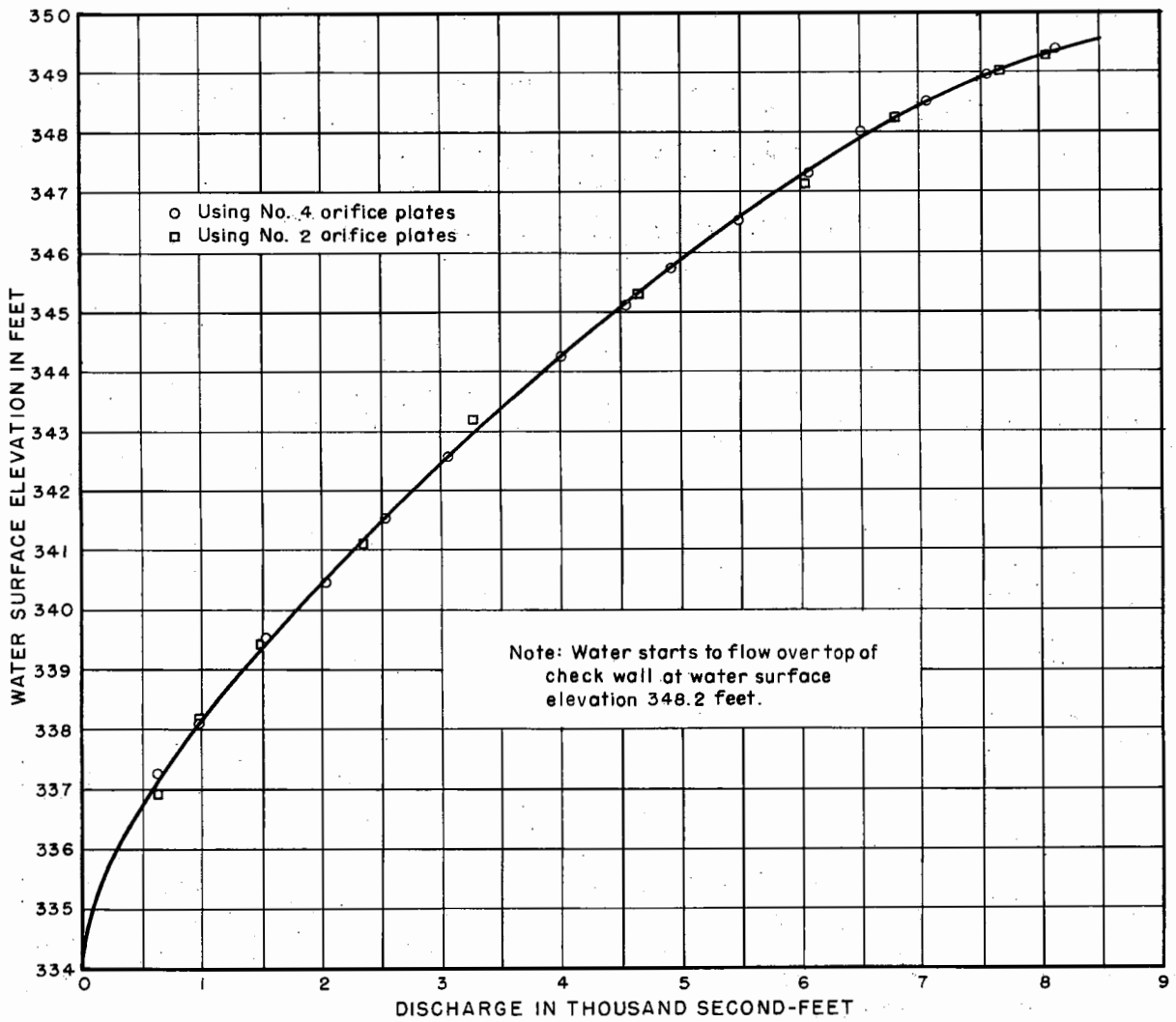


Scour pattern after discharge of 7000 second-feet.



D. Scour pattern upstream from check wall after discharge of 7000 second-feet.

WELLTON-MOHAWK OUTLET CONTROL STRUCTURE
Operation of Basin No. 4 (Recommended).
(Outlet channel at Elevation 333.8 feet)
1:24 Scale Model



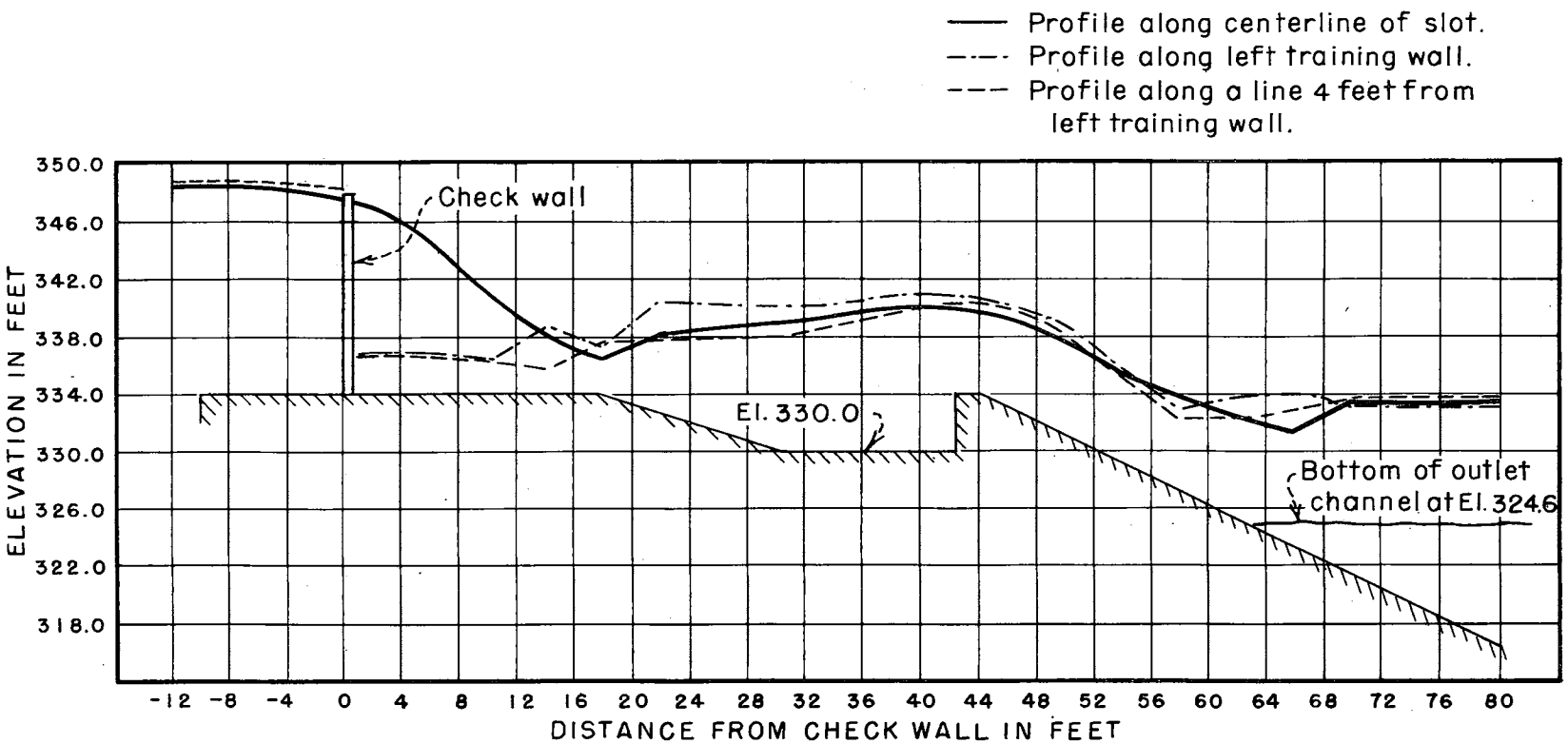
WELLTON MOHAWK DIVISION

OUTLET CONTROL STRUCTURE

HEAD-DISCHARGE CURVE

1:24 SCALE MODEL

FIGURE 15
REPORT HYD. 359



WELLTON-MOHAWK DIVISION

OUTLET CONTROL STRUCTURE

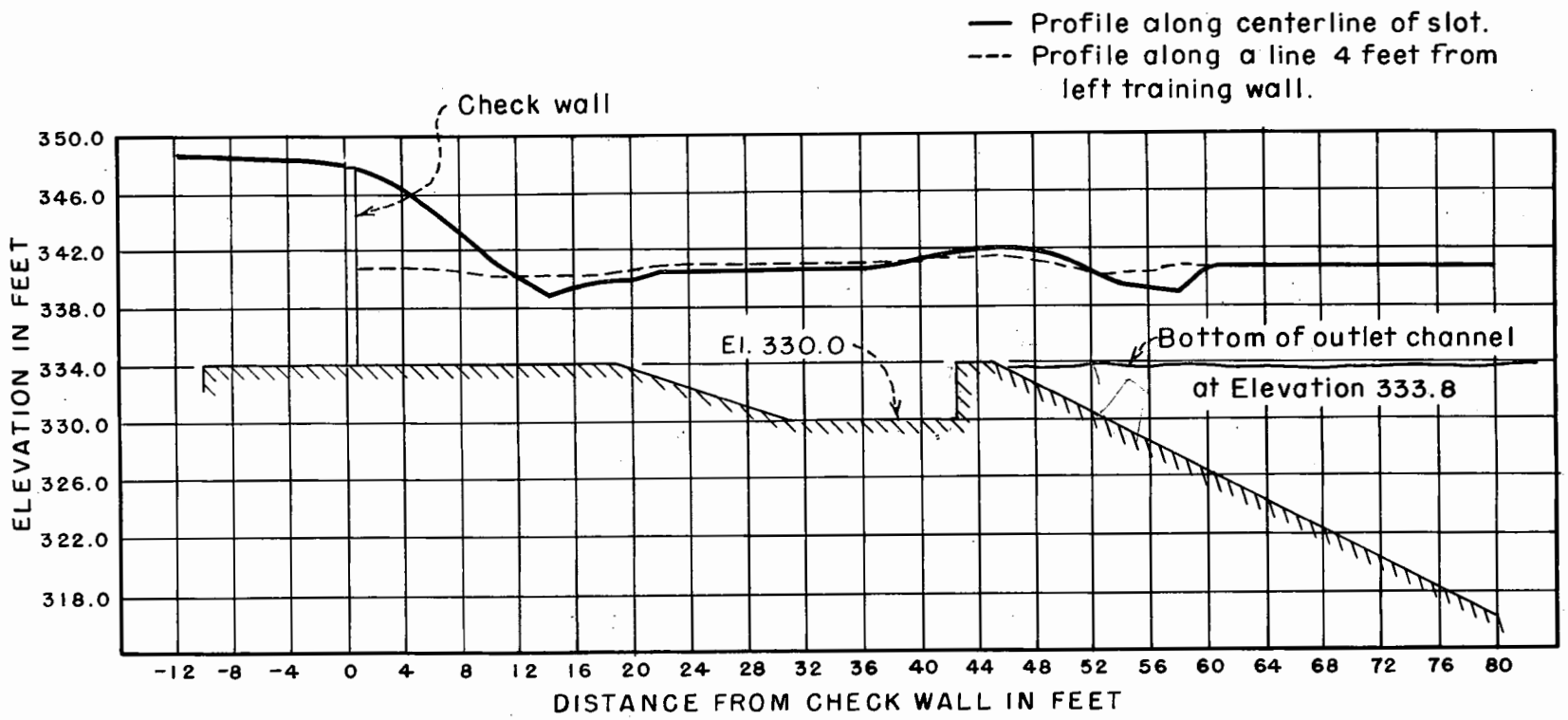
RECOMMENDED DESIGN

WATER SURFACE PROFILES

WITH BOTTOM OF OUTLET CHANNEL AT ELEVATION 324.6'

1:24 SCALE MODEL

FIGURE 16
REPORT HYD. 359



WELLTON-MOHAWK DIVISION

OUTLET CONTROL STRUCTURE

RECOMMENDED DESIGN

WATER SURFACE PROFILES

WITH BOTTOM OF OUTLET CHANNEL AT ELEVATION 333.8'

1:24 SCALE MODEL

FIGURE 17
REPORT HYD. 359

PART II--CULVERT UNDER DIKE

Introduction

In conjunction with the outlet control structure, the culvert under dike is designed to control the evacuation of storm run-off waters retained by Protective Dike No. 1, Figures 2 and 3. The culvert under dike is located approximately 22 miles east of Yuma, Arizona, and about 1/2 mile south of Wellton-Mohawk Pumping Plant No. 3, Figure 2.

The structure, Figures 5 and 18, consists of a culvert which passes under Protective Dike No. 1, a horizontal section or stilling basin at the downstream end of the culvert, and a 2:1 baffled apron which drops the flow from the stilling basin to the outlet channel. The structure is designed for a discharge of 1,250 second feet at a head of 15 feet above the culvert invert.

Model studies of the culvert under dike were made to insure that its capacity was limited to 1,250 second feet for an approximate head of 15 feet, and that the flow would enter the outlet channel with a minimum of scour.

The 1:12 Scale Model

The model, which was built to a geometrical scale of 1:12, Figure 19, consisted of a head box, 8 feet long and 10 feet wide, representing the reservoir upstream from the culvert; a tail box, 10 feet long and 6 feet wide, containing the outlet structure and a portion of the outlet channel; and the culvert joining the head and tail boxes. The head and tail boxes were constructed of wood and lined with galvanized sheet metal while the culvert was fabricated from transparent plastic to permit observation of the flow through the structure. Three-fourth-inch plywood, impregnated with linseed oil, was used to construct the stilling basin, 2:1 apron, and training walls, while the baffle piers were made of redwood.

Water for the model was supplied by a portable vertical turbine pump and metered through a combination venturi and orifice meter. Since no data were available on the channel downstream from the culvert, the model was operated with the channel at several elevations representing different degrees of degradation. Flashboards were used as a flow control and to hold the sand, used to represent the channel, in the tail box at the desired elevation.

The Investigation

General

Eleven different stilling basin designs were tested in the model, Figure 20. These designs varied either in length and width of basin or in the elevation of the upstream end of the 2:1 apron. In addition, several different baffle pier arrangements, consisting of combinations of rows of baffle piers shown in Figure 21, were tested in each of the stilling basin designs. In the following discussion, the various designs are referred to as Designs 1, 1A, 2A, 4EF, etc. The numeral refers to the stilling basin design shown in Figure 20 and the letter (s) denotes the rows of baffle piers, Figure 21, installed in the stilling basin.

Design requirements for the culvert under dike were: (1) the maximum discharge should be 1,250 second feet for a head of approximately 15 feet above the invert of the culvert, and (2) the scour in the outlet channel immediately downstream from the structure should be nominal. Normally, if the former condition was not satisfied, the model arrangement was modified by changing the size, number, or location of the baffle piers in the basin until the head approximated 15 feet. Larger or additional baffle piers in the basin increased the head required to pass 1,250 second feet, while the head was decreased when the size or number of baffle piers was reduced.

The hydraulic efficiency of the various basin designs was determined primarily from the appearance of the flow through the structure, and from the amount of scour in the outlet channel. The scour pattern was obtained by operating the model at the maximum discharge of 1,250 second feet for 1/2 hour which is equivalent to approximately 1-3/4 hours in the prototype.

Design 1 (Preliminary)

The model was initially constructed as shown in Figures 5 and 18 except that Stilling Basin 1 (Preliminary), Figure 20, was installed at the downstream end of the culvert.

In general, the operation of the preliminary design was unsatisfactory. Under a head of 15 feet, the culvert passed only 1,190 second feet, while about 17.5 feet of head was required to pass the maximum discharge of 1,250 second feet. The culvert flowed full from the entrance to the upstream end of the transition section, and partially full throughout the transition, Figure 22A. Upon leaving the transition section, the flow was concentrated along the training walls and, after striking the first row of baffle piers on the 2:1 apron, the flow sprung free and fell into the channel at the lower end of the 2:1 apron, Figure 22B. Results of the scour test for the maximum discharge of 1,250 second feet are shown in Figure 22B.

The capacity of the culvert was insufficient because the culvert did not flow full throught its length. It was found that by manually increasing the discharge above 1,250 second feet, or by placing an obstruction between the culvert and the baffled apron, the transition flowed full and continued to flow full when the obstruction was removed. When the transition was flowing full, the head above the culvert invert dropped to 12.5 feet for a discharge of 1,250 second feet. The culvert, under these flow conditions, acted as a draft tube, with negative pressures on the roof along its entire length. With the increased depth of water flowing from the culvert, the flow no longer sprang clear of the first row of baffle piers but followed the slope of the apron, resulting in a fairly uniform performance.

Since the culvert was designed to flow full throughout its length and the headwater dropped to 12.5 feet when flowing full, a row of baffle piers was placed between the culvert and the 2:1 apron, Row A, Figure 21. The baffle piers put sufficient back pressure on the culvert, by obstructing the outlet, to cause it to flow full and raised the headwater to 15 feet, the design head. Figure 23A shows the model discharging 1,250 second feet with Row A of baffle piers in place and the resulting scour pattern. The depth of scour using this arrangement was 9.5 feet as compared to 12.5 feet observed with the preliminary design.

Scour tests were also run using baffle piers, 4 and 5 feet in height, on the 2:1 apron. Results of these tests disclosed the depth of scour to be approximately the same as that obtained with the 3 feet high piers. Table II is a recapitulation of all the scour tests made on the culvert under dike. Figure 23B shows the model discharging 1,250 second feet and the resulting scour with 5 feet high baffle piers on the 2:1 apron.

Design 2

In Design 2, the length of the stilling basin was increased from 10 to 15 feet, and the stilling basin and apron were widened by diverging the training walls to coincide with the alignment of the transition walls, Figure 20. For a discharge of 1,250 second feet, the flow failed to follow the diverging walls and caused excessive scour in the outlet channel, Figure 24A. To determine the effectiveness of the baffle piers on the 2:1 apron, a scour test was run with the piers removed from the apron. Figure 24B shows the resulting scour pattern, in which the greatest depth of scour was 16 feet, or 3 to 7 feet deeper than that observed with baffle piers on the apron. Thus, the apron baffle piers are effective in reducing the scour in the outlet channel.

To obtain better flow distribution over the 2:1 apron by forcing more flow along the training walls, the baffle piers were concentrated in the center of the stilling basin, Rows B and C, Figure 21. These arrangements improved the flow distribution, and the depth of scour was 8 and 10 feet, Table II.

Design 3

Since the flow failed to follow the diverging training walls in Design 2, the width of the baffled apron in Design 3 was held constant at 30 feet by using parallel training walls, Figure 20. Rows C and D of basin baffle piers, Figure 21, were tested with this design. The parallel training walls confined the flow, and the flow distribution over the baffled apron was fairly uniform. Scour tests with Design 3 gave results similar to those obtained with Design 2, Table II.

Design 4

From the results of the tests on Designs 2 and 3, it was felt that a longer stilling basin was necessary to obtain better flow distribution over the baffled apron. Design 4 consisted of lengthening the stilling basin from 15 to 30 feet and installing parallel training walls along the stilling basin and baffled apron, Figure 20. To maintain a headwater elevation of 15 feet, various combinations of two and three rows of baffle piers were placed in the stilling basin and tested, Table II.

Figure 25A shows the operation of Design 4 at a discharge of 1,250 second feet with Rows E and F of baffle piers installed. In general, this design gave the best distribution of flow through the structure, and the resulting scour was not excessive.

Design 5

Design 4 required two or three rows of baffle piers in the stilling basin to cause sufficient back pressure on the culvert to maintain a headwater elevation of 15 feet. For Design 5, Figure 20, the baffled apron was raised 2 feet, making a step at the upstream end of the apron which provided sufficient back pressure to maintain a 15-foot head and eliminated the need for basin baffle piers. Tests on this design showed a slight concentration of flow in the center of the baffled apron, but the scour was only slightly deeper than that obtained with Design 4, Table II. Tests were also run with different baffle-pier arrangements in the basin, but the additional baffle piers increased the headwater 0.2 to 0.8 foot above 15 feet and slightly increased the depth of scour.

The elevation of the outlet channel was lowered 1.3 feet to elevation 332.7 feet for the scour tests with Design 5 to simulate a greater degree of degradation of the channel.

Designs 6 and 7

Designs 6 and 7 were similar to Designs 4 and 5, respectively, except that the length of stilling basin was reduced from 30 to 22.5 feet, and the vertical curve between the stilling basin and the 2:1

apron was removed, Figure 20. Table II gives the results of scour tests on these designs which were tested with various baffle-pier arrangements. In general, the depth of scour was slightly less with the shorter stilling basin.

Design 8

The basin training walls were diverged at the same angle as the culvert transition in Design 8. Also, the baffled apron was extended downstream to permit scour tests with the outlet channel at lower elevations. With the diverging basin, it was necessary to add a row of baffle piers in the stilling basin to obtain a headwater elevation of 15 feet. Scour tests, which were run with the outlet channel at elevations 327.3 and 319.2 feet, indicated that the depth of scour increased from 6.3 to 6.6 feet when the outlet channel was lowered, Table II. Figure 25B shows a discharge of 1,250 second feet through Design 8 and the resulting scour pattern.

Design 9

Except for a fillet immediately upstream from the baffled apron, Figure 20, Design 9 was the same as Design 8. Tests on this design showed the headwater elevation to be 14.2 feet without using baffle piers in the stilling basin. The depth of scour was slightly greater than that obtained with Design 8.

Designs 10 and 11

The baffle piers on the 2:1 apron were moved upstream in Designs 10 and 11, such that the first row of piers was at the 2-foot step, Figure 20. Otherwise, the designs were the same as Designs 8 and 9. The apron baffle piers provided sufficient back pressure on the culvert to raise the headwater elevation to 15.3 feet for a discharge of 1,250 second feet and thus eliminated the need for baffle piers in the stilling basin.

Design 10 was operated at discharges of 600 and 1,250 second feet with the outlet channel at three elevations: 320.3, 328.0, and 333.5 feet. In general, the depth of scour increased as the outlet channel was lowered, and the depth of scour for the three channel elevations varied from 3.5 to 4.8 feet for a discharge of 600 second feet and from 6 to 7.1 feet for 1,250 second feet, Table II. The flow through the stilling basin and over the baffled apron was well distributed, Figures 26 and 27.

A fillet was placed upstream from the step in Design 11, Figure 20. Although the headwater elevation was lowered slightly for 1,250 second feet, the depth of scour increased with the fillet installed, Table II. Therefore, no further testing was done on Design 11.

The Recommended Design

From the test results tabulated in Table II, stilling basin Designs 4, 6, 8, 9, and 10 gave the least depth of scour for similar discharges and elevations of the outlet channel. With each of these designs, the flow through the stilling basin and over the baffled apron was evenly distributed over the width of the structure. However, to maintain the headwater at an elevation of approximately 15 feet, it was necessary to install auxiliary baffle piers in each of the stilling basins except Design 10. Although all five designs would probably operate equally well, the use of auxiliary piers adds to the cost of the structure and increases the possibility of weeds and other debris catching on the baffle piers. Therefore, Design 10 is recommended for construction in the field.

Water-surface Profiles

Profiles of the water surface for discharges of 600 and 1,250 second feet were observed in the recommended design and are shown in Figure 28. The minimum amount of free board on the training walls is approximately 2 feet at the maximum discharge of 1,250 second feet.

Piezometric Pressures

Piezometric pressures along the roof of the culvert and on the surface of the apron baffle piers were obtained from the model.

Culvert Pressures

Pressures were observed at 11 points along the roof of the culvert, Figures 29 and 31, for Design 2 and the recommended design. With Design 2, pressures were recorded at the maximum discharge of 1,250 second feet and the following conditions of flow, which are tabulated in order in Figure 29: (1) The head on the culvert invert was 17.5 feet with the transition flowing partly full; (2) The head was 12.5 feet with the transition flowing full; (3) A row of baffle piers (Row A, Figure 21) was placed in the stilling basin to cause the transition to flow full at a head of 15 feet; (4) As in (3), baffle piers were placed in the stilling basin, and the vortex in the head box was eliminated by placing a piece of plywood, 1/4 inch thick, on the water surface over the inlet which reduced the head on the culvert to 14.5 feet.

The lowest observed pressure with these arrangements was recorded at Piezometer No. 5 under flow condition (4), where a piezometric pressure of 9.5 feet of water below atmospheric pressure was observed, Figure 29.

With the recommended design, pressures were recorded for discharges of 600 and 1,250 second feet under normal flow conditions, Figure 29. The lowest observed pressure was near the entrance to the culvert at Piezometer No. 2 where 8.6 feet of water below atmospheric was recorded at a discharge of 1,250 second feet.

A close study of the pressures listed in the table, Figure 29, indicates some apparent inconsistencies between Design 2A and the recommended design for a discharge of 1,250 second feet, especially at Piezometers No. 2 and 5. The pressures in the culvert were difficult to obtain due to air which entered the culvert through the vortex and collected along the culvert roof where the piezometers were located. Every effort was taken to remove the air from the piezometer leads prior to each observation, and it is believed the pressures tabulated in Figure 41 were as representative of the true pressure as could be obtained under the existing conditions.

Pressure on the Baffle Piers

Piezometric pressures on the upstream and downstream faces of the apron baffle piers were obtained from four test piers--each fitted with six piezometers--as shown in Figure 30. The greatest range of pressures were recorded on Pier A where a maximum pressure of 8.3 feet of water above atmospheric was observed on the upstream face, and a minimum pressure of 0.2 foot of water below atmospheric was recorded on the downstream face.

Table II

SUMMARY OF TESTS
Using Different Stilling Basin Designs and Baffle-pier Arrangements

Stilling basin design	Model arrangement: Baffle piers in basin: Row	Model arrangement: Baffle piers in basin: *x (ft)	Height of baffle piers on 2:1 apron (ft)	Head on culvert (ft)	Discharge (cfs)	Elevation of outlet channel (ft)	Maximum depth of scour (ft): At center of channel	Maximum depth of scour (ft): Rt or lt of center of channel	Remarks
1 (Prelim)	None	-	3	17.5	1,250	334.0	12.0		Open channel flow in transition. No stilling action
1	A	7.5	3	15.0	1,250	334.0	9.5		Transition flows full. Good stilling action. Height of piers on apron has little effect on flow or scour pattern
1	A	7.5	5	15.0	1,250	334.0	9.0		
1	A	7.5	4	15.0	1,250	334.0	9.5		
2	A	7.5	3	15.0	1,250	334.0	13.0		Flow concentrated in center of structure
2	A	7.5	None	15.0	1,250	334.0	16.0		Excessive scour in outlet channel
2	B	7.5	3	14.8	1,250	334.0	8.0	7.0	Flow over apron evenly distributed
2	C	7.5	3	14.5	1,250	334.0	10.0		Slight concentration in center
3	C	7.5	3	14.5	1,250	334.0		10.0	Slight concentration along training walls
3	D	7.5	3	14.5	1,250	334.0	8.5	8.5	Flow evenly distributed
4	E D	18.0 27.0	3 3	15.0	1,250	334.0	6.6	7.2	Flow evenly distributed and nominal scour
4	E D	5.0 30.0	3	15.0	1,250	334.0	6.0	8.0	
4	E G F	5.0 16.0 30.0	3	15.0	1,250	334.0	7.8		
4	E G D	5.0 16.0 30.0	3	15.0	1,250	334.0	7.2		
5	None		3	15.0	1,250	332.7	8.7		Outlet channel lowered. Good flow distribution

Table II--Continued

SUMMARY OF TESTS
Using Different Stilling Basin Designs and Baffle-pier Arrangements

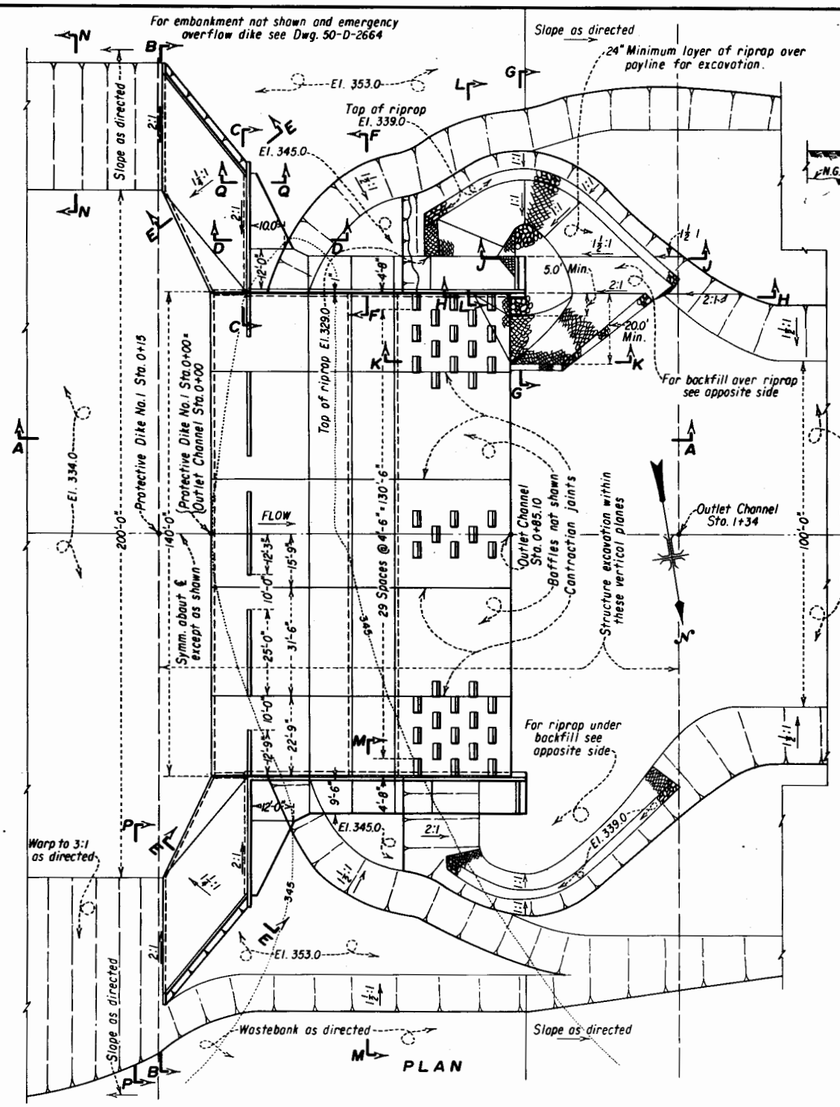
Model arrangement										
Stilling basin design	Baffle piers in basin Row	Baffle piers in basin *x (ft)	Height of baffle piers on 2:1 apron (ft)	Head on culvert (ft)	Discharge (cfs)	Elevation of outlet channel (ft)	Maximum depth of scour (ft) At center of channel	Maximum depth of scour (ft) Rt or lt of center of channel	Remarks
5	G	30.0	3	15.4	1,250	332.7		9.7	Basin baffle piers slightly increased the headwater elevation and depth of scour
5	H	10.0	3	15.8	1,250	332.7	9.2		
5	F	10.0	3	15.2	1,250	332.7	9.3		
5	F	10.0	3	15.5	1,250	332.7	9.5		
	I	20.0							
5	I	7.0	3	15.7	1,250	332.7	9.3		
	E	14.0							
	F	21.0							
6	F	18.0	3	13.7	1,250	332.7		7.0	Headwater too low
6	E	7.0	3	15.0	1,250	332.7	6.7		Good flow distribution
	F	16.0							
6	F	6.0	3	15.2	1,250	332.7		7.9	Good flow distribution
	I	14.5							
	E	20.0							
6	I	17.0	3	14.5	1,250	332.7	7.2	7.2	Headwater too low
6	E	7.0	3	15.0	1,250	327.3		9.3	Outlet channel lowered
	F	16.0							
7	None		3	15.0	1,250	330.9	7.9	7.9	Outlet channel raised
7	None		3	15.0	1,250	327.3		8.3	Outlet channel lowered
7	I	6.0	3	15.8	1,250	327.3		9.1	Satisfactory flow distribution
	F	13.0							
7	D	6.0	3	15.8	1,250	327.3		8.8	
8	None		3	14.8	1,250	327.3	5.4	6.1	Good flow distribution and nominal scour
8	J	5.8	3	15.0	1,250	327.3	5.9	6.3	
8	None		3	14.8	1,250	319.2	6.6		
9	None		3	14.2	1,250	319.2		7.2	Headwater too low

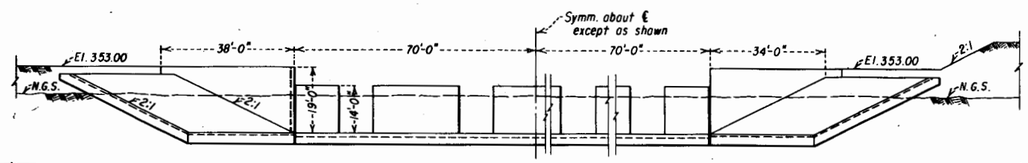
Table II--Continued

SUMMARY OF TESTS
Using Different Stilling Basin Designs and Baffle-pier Arrangements

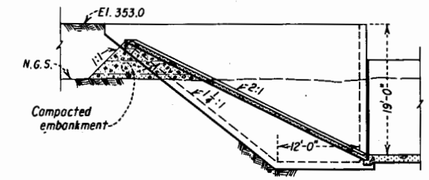
Model arrangement						Maximum depth of scour (ft)		
Stilling basin design	Baffle piers in basin Row	Baffle piers in basin *x (ft)	Height of baffle piers on 2:1 apron (ft)	Head on culvert (ft)	Discharge (cfs)	Elevation of outlet channel (ft)	At center of channel	Rt or lt of center of channel	Remarks
10	None		3		600	320.3	4.3	4.8	Good flow distribution and nominal scour
10	None		3	15.3	1,250	320.3	6.0	7.1	
10	None		3		600	328.0	4.5	4.3	
10	None		3	15.3	1,250	328.0	6.3	6.8	
10	None		3		600	333.5	4.3	3.5	
10	None		3	15.3	1,250	333.5	7.1	7.0	
11	None		3	15.2	1,250	320.3	7.6	7.2	Good flow distribution and nominal scour

*x is the distance from the downstream end of the culvert to the baffle piers, Figure 21.

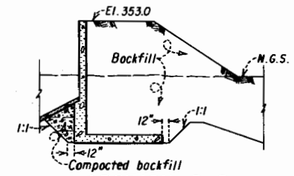




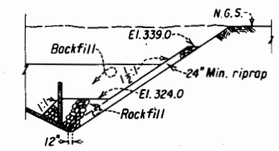
ELEVATION B-B



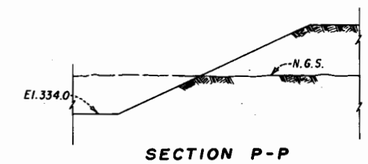
SECTION C-C



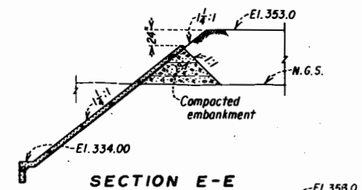
SECTION D-D



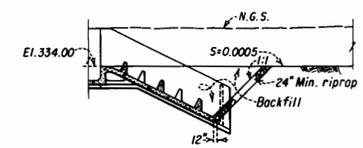
SECTION J-J



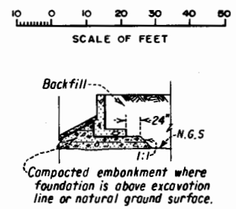
SECTION P-P



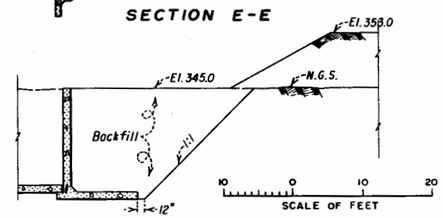
SECTION E-E



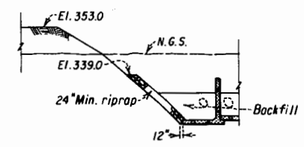
SECTION K-K



SECTION Q-Q



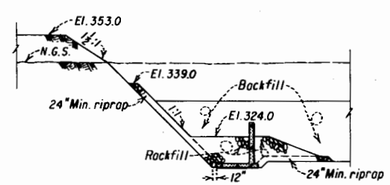
SECTION F-F



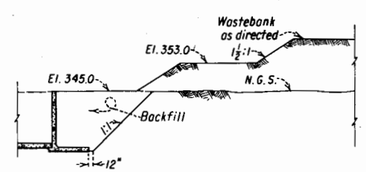
SECTION L-L

ESTIMATED QUANTITIES

Concrete in structures	265	Cu. Yds.
Concrete in floor slab, paving, and baffles	625	Cu. Yds.
Reinforcement steel	135,000	Lbs.



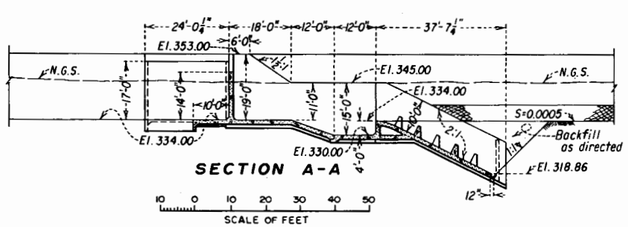
SECTION G-G



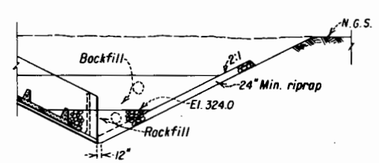
SECTION M-M

REFERENCE DRAWINGS

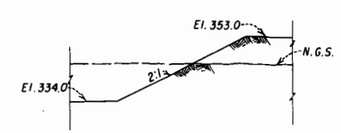
INLET TRANSITION	50-D-2666
CHUTE AND POOL	50-D-2667
OUTLET-WALLS-PAVING-BAFFLES	50-D-2668
MOHAWK PROTECTIVE DIKE No. 1 - STA. 0+00 TO 33+24.71 AND OUTLET CHANNEL	50-D-2664



SECTION A-A



SECTION H-H



SECTION N-N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GILA PROJECT - ARIZONA
WELLTON-MOHAWK DIVISION

MOHAWK PROTECTIVE DIKE No. 1 STA. 0+00

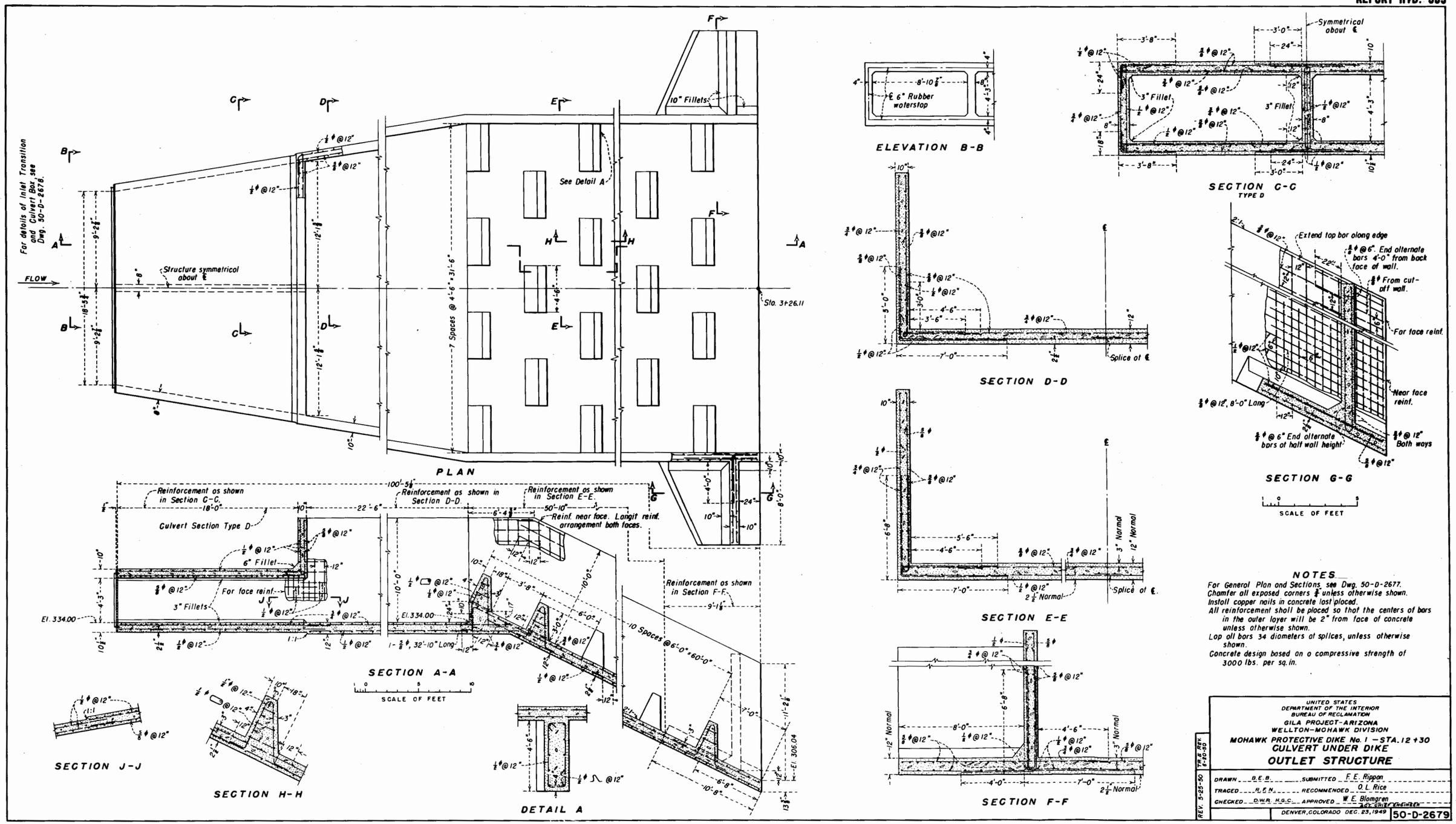
OUTLET CONTROL STRUCTURE

GENERAL PLAN AND SECTIONS

DRAWN M.A.H. SUBMITTED F.E. Rippon
TRACED B.F.W. RECOMMENDED O.L. Rice
CHECKED [illegible] APPROVED W.E. Blomgren
ASST. CHIEF ENGINEER

DENVER, COLORADO - DEC. 8, 49 | 50-D-2665

REV. 4-12-50 T.R.S. REV. 6-13-50



NOTES

For General Plan and Sections, see Dwg. 50-D-2677.
Chamfer all exposed corners ¾" unless otherwise shown.
Install copper nails in concrete last placed.
All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete unless otherwise shown.
Lap all bars 34 diameters at splices, unless otherwise shown.
Concrete design based on a compressive strength of 3000 lbs. per sq. in.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GILA PROJECT-ARIZONA
WELLTON-MOHAWK DIVISION

MOHAWK PROTECTIVE DIKE No. 1 — STA. 12+30
CULVERT UNDER DIKE
OUTLET STRUCTURE

DRAWN O.E.B. SUBMITTED F.E. Rippon
TRACED R.E.N. RECOMMENDED O.L. Rice
CHECKED D.W.R. H.G.C. APPROVED W.E. Blomgren
ACT. CHIEF ENGINEER

DENVER, COLORADO DEC. 23, 1949 — 50-D-2679

REV. 5-25-50 — TR.E REV. 6-20-50

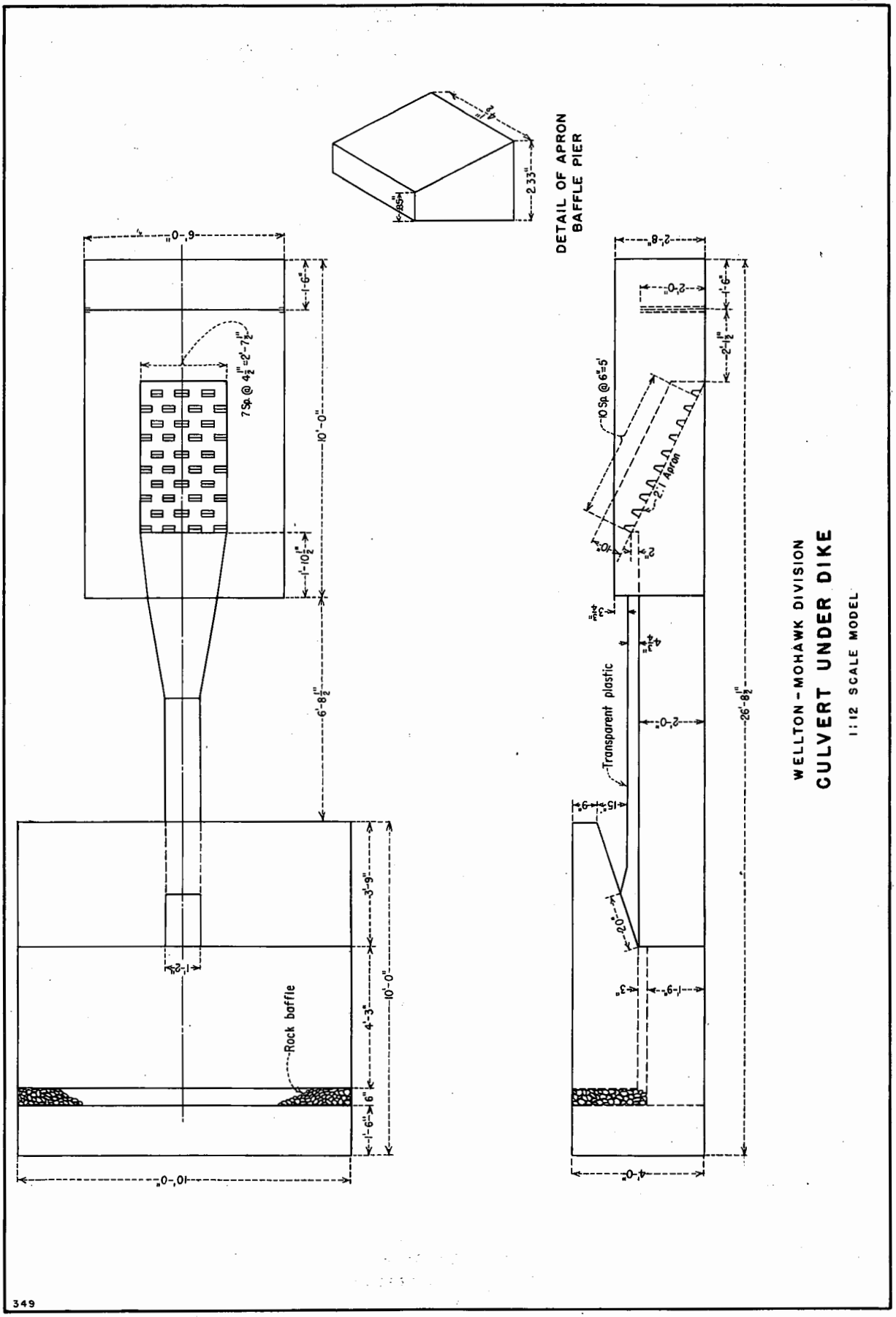
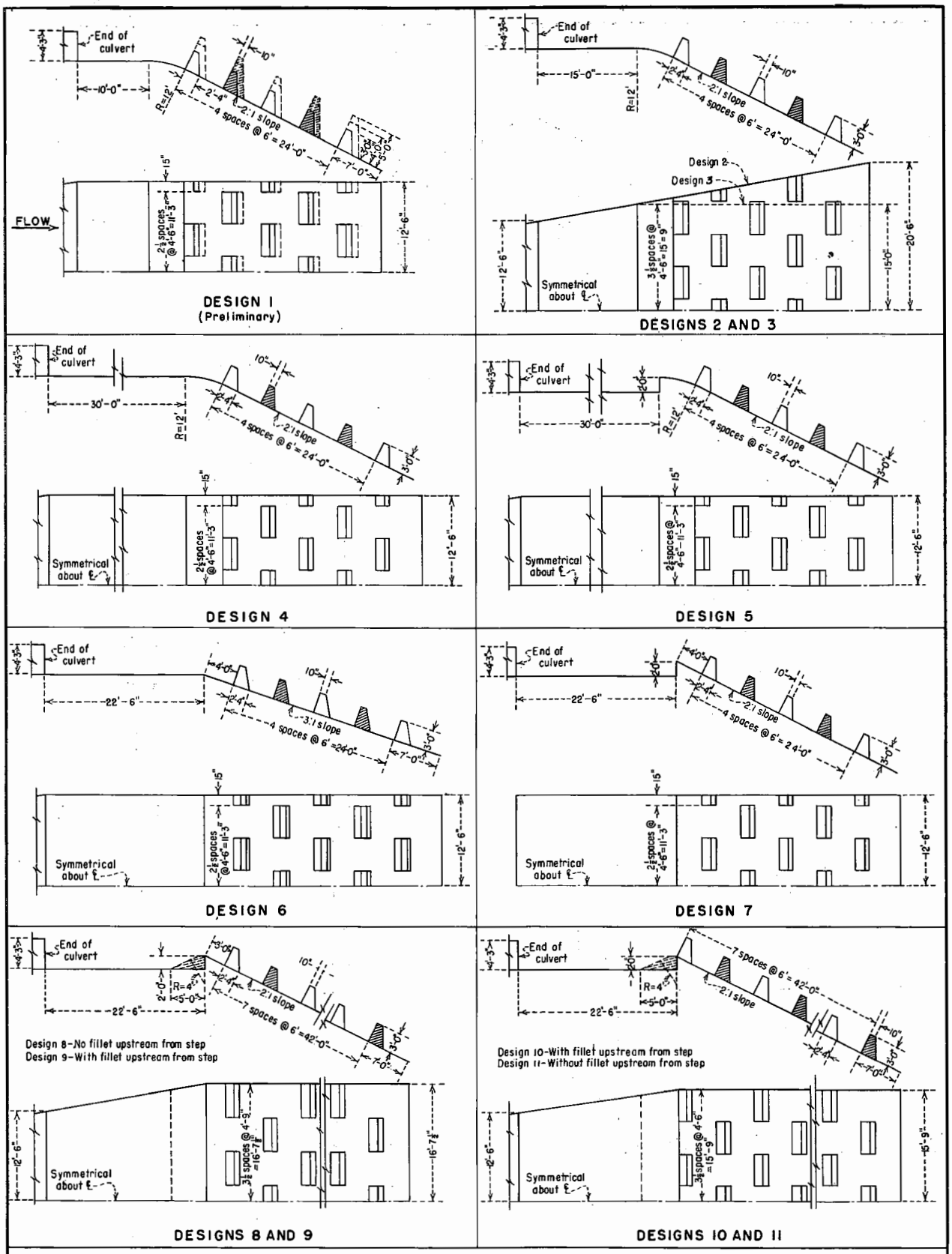

DETAIL OF APRON BAFFLE PIER
2.33"
.85"
4"
10'-0"
1'-6"
7 Sp @ 4½" = 2'-7½"
1'-10½"
6'-8½"
3'-9"
4'-3"
1'-6"
6"
1'-2"
Rock baffle
10'-0"
2'-8"
2'-0"
2'-1½"
10 Sp @ 6" = 5'
2:1 Apron
10"
2"
3/16"
1/4"
Transparent plastic
15"
9"
20"
3"
1'-9"
26'-8½"
4'-0"
WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
1:12 SCALE MODEL

FIGURE 20
REPORT HYD. 359.

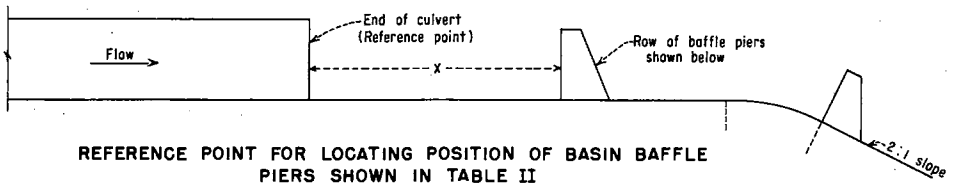


WELLTON-MOHAWK DIVISION

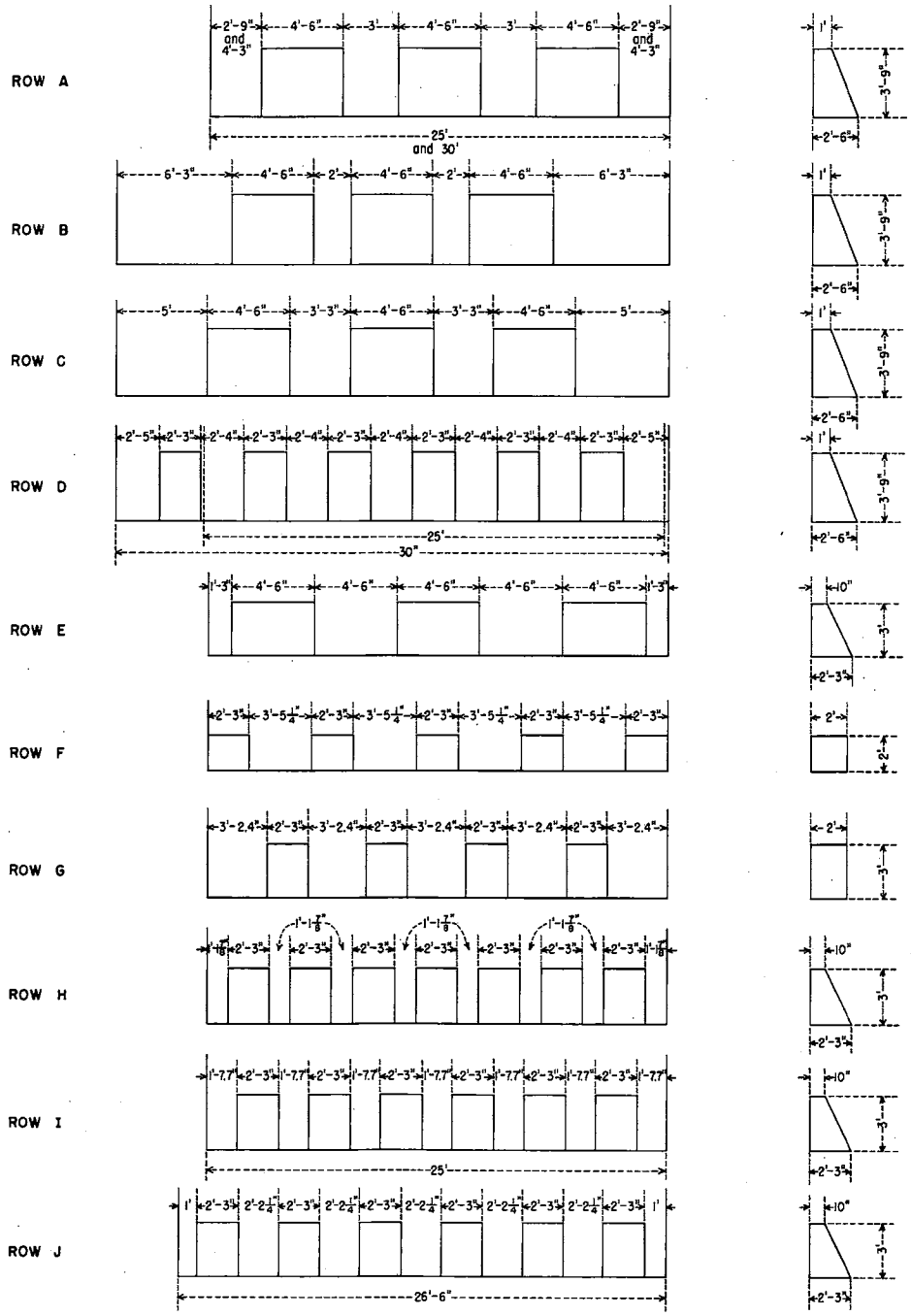
CULVERT UNDER DIKE

VARIOUS STILLING BASIN DESIGNS

1:12 SCALE MODEL



REFERENCE POINT FOR LOCATING POSITION OF BASIN BAFFLE PIERS SHOWN IN TABLE II



WELLTON – MOHAWK DIVISION

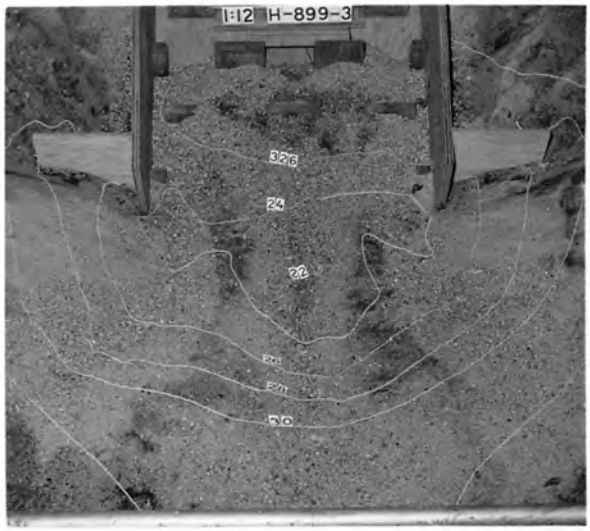
CULVERT UNDER DIKE

BAFFLE PIERS TESTED IN STILLING BASIN

1:12 SCALE MODEL

A. Culvert transition flowing partly full.

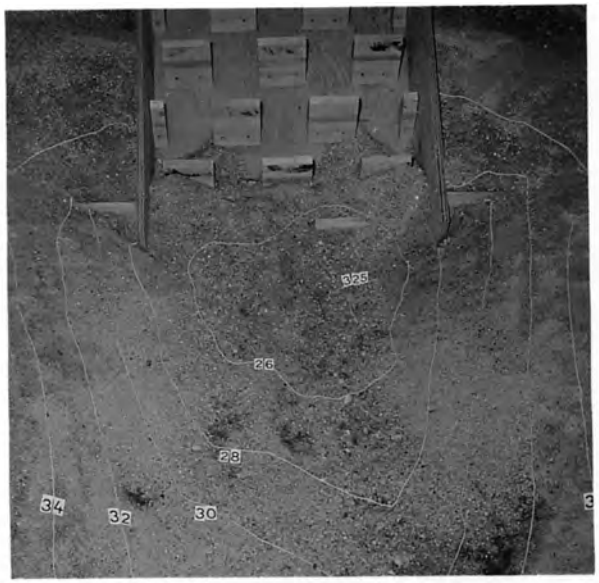
B. Flow over baffled apron.



C. Resulting scour pattern.

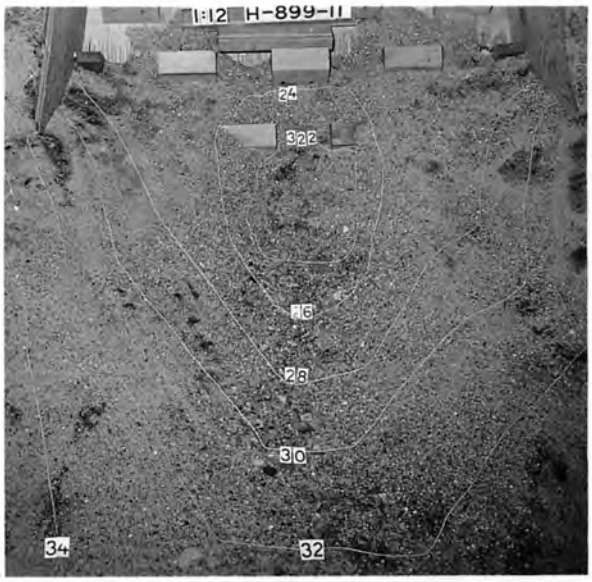
WELTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Operation of Design 1 (Preliminary) with
outlet channel at Elevation 334 feet.
Discharge = 1250 second-feet at head of 17.5 feet
1:12 Scale Model

A. Baffle piers, 3-feet high, on apron.



B. Baffle piers, 5-feet high, on apron.

WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Discharge of 1250 cfs and resulting scour for Design 1A
with 3- and 5-foot piers on apron.
Outlet channel elevation = 334 ft.
1:12 Scale Model

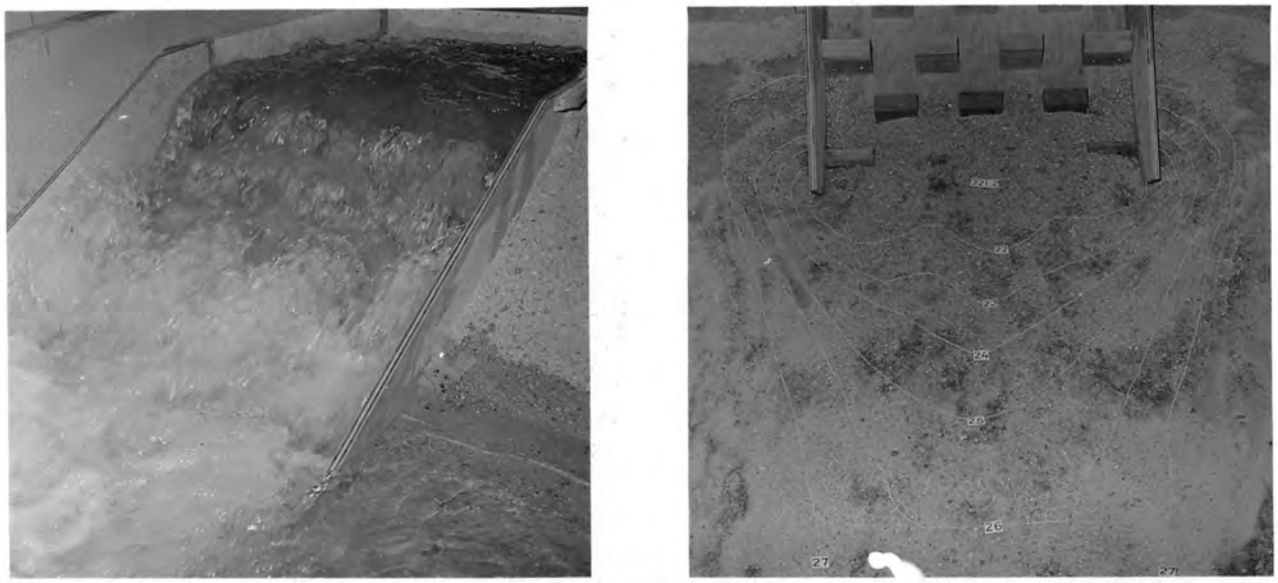


A. Baffle piers, 3-feet high on apron.

B. Apron baffle piers removed.

WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Discharge of 1250 cfs and resulting scour for Design 2A
with and without piers on apron.
Outlet channel elevation = 334 ft.
1:12 Scale Model

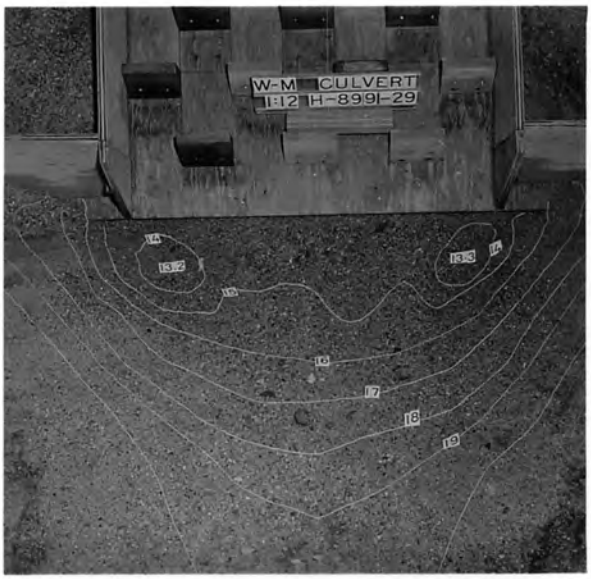
A. Design 4A. Outlet channel elevation = 334 feet.



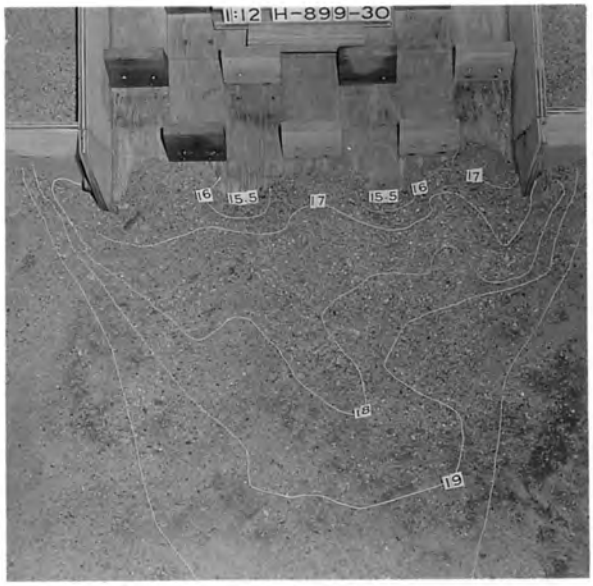
B. Design 8. Outlet channel elevation = 327.3.

WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Discharge of 1250 cfs and resulting scour
for Designs 4A and 8.
1:12 Scale Model

A. The model prior to scour tests.

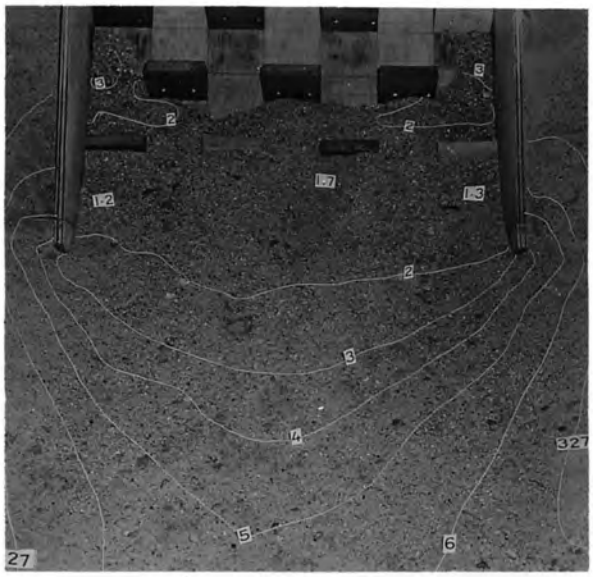


B. Scour pattern after discharge of 1250 cfs.



C. Discharge of 1250 cfs and resulting scour pattern.

WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Operation of the recommended design.
Outlet channel elevation = 320.3 feet.
1:12 Scale Model



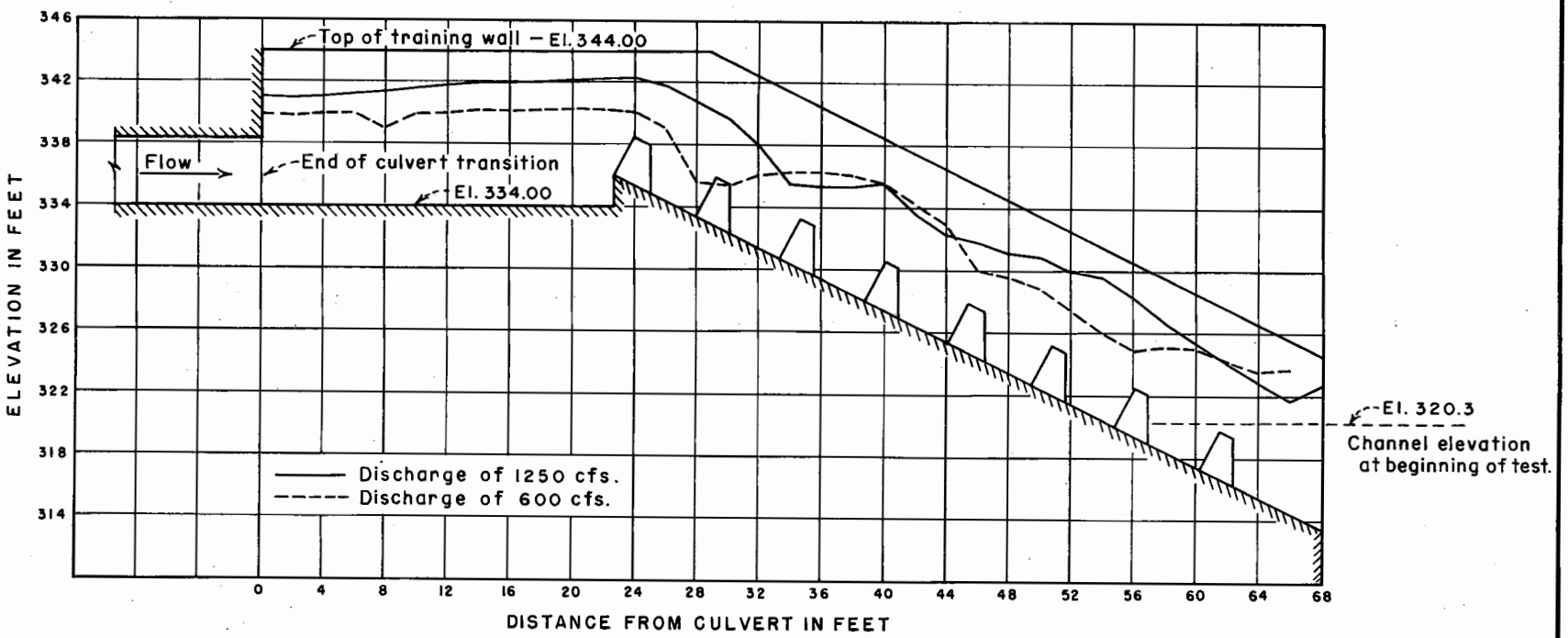
A. Discharge of 1250 cfs and resulting scour with outlet channel at elevation of 328 feet.

B. After discharge of 600 cfs.

C. After discharge of 1250 cfs.

Scour patterns with outlet channel at Elevation 333.5 feet.

WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Operation of the recommended design
1:12 Scale Model



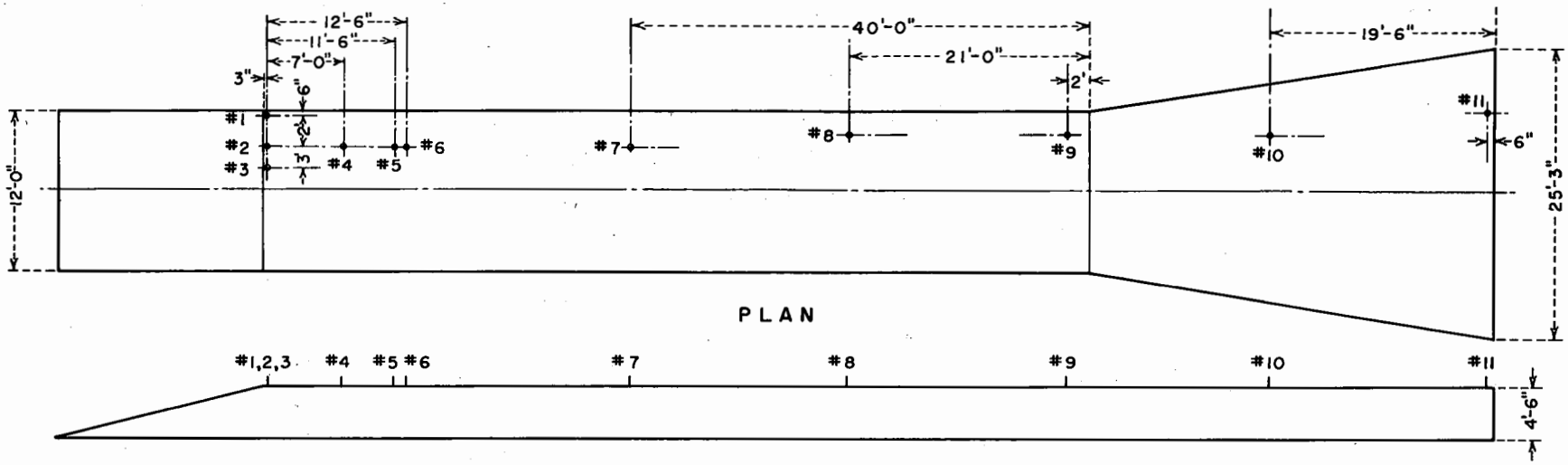
WELLTON - MOHAWK DIVISION

CULVERT UNDER DIKE

WATER SURFACE PROFILES

1:12 SCALE MODEL

FIGURE 28
REPORT HYD. 359



ELEVATION

LOCATION OF PIEZOMETERS

PIEZOMETER		PIEZOMETRIC PRESSURE IN FEET OF WATER											REMARKS
		1	2	3	4	5	6	7	8	9	10	11	
DESIGN 2	1250 cfs.	−0.9	+1.8	0.0	+10.7	−0.8	−0.6	−0.4	0.0	−1.0	+1.2	+0.2	H=17.5' Transition party full.
DESIGN 2	1250 cfs.	−5.0	−1.2	+0.9	+2.0	−8.6	−4.6	−4.8	−4.5	−1.5	−1.7	−1.9	H=12.5' Transition flowing full.
DESIGN 2A	1250 cfs.	−3.5	+1.8	+2.0	+2.3	−8.1	−4.6	−3.0	−2.6	−1.1	−2.4	−2.4	H=15.0' Vortex in headwater
DESIGN 2A	1250 cfs.	−4.9	−0.1	+1.6	−3.5	−9.5	−4.4	−4.0	−3.9	−1.1	−2.8	−2.9	H=14.5' Vortex removed.
RECOM-MENDED DESIGN	1250 cfs.	−6.0	−8.6	−4.0	−2.5	−2.0	−3.0	−3.6	−4.1	−4.2	+0.6	+2.6	H=15.3'
	600 cfs.	+0.1	+4.0	—	+0.7	+0.9	+0.6	+0.9	+0.7	+0.5	+1.7	+1.5	

WELLTON-MOHAWK DIVISION

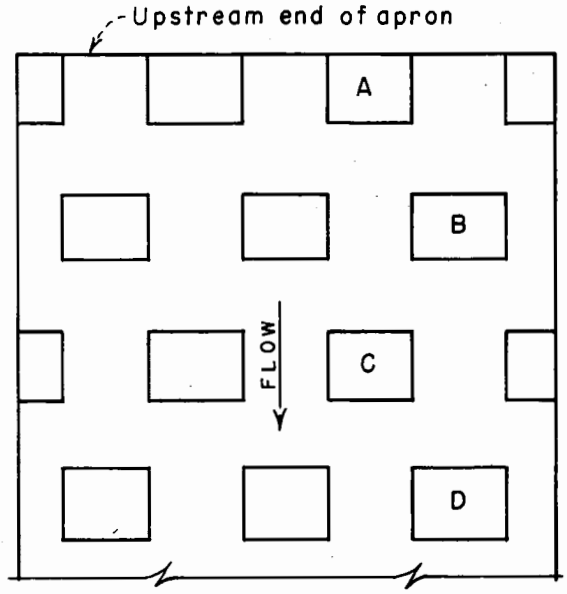
CULVERT UNDER DIKE

PIEZOMETRIC PRESSURES IN CULVERT

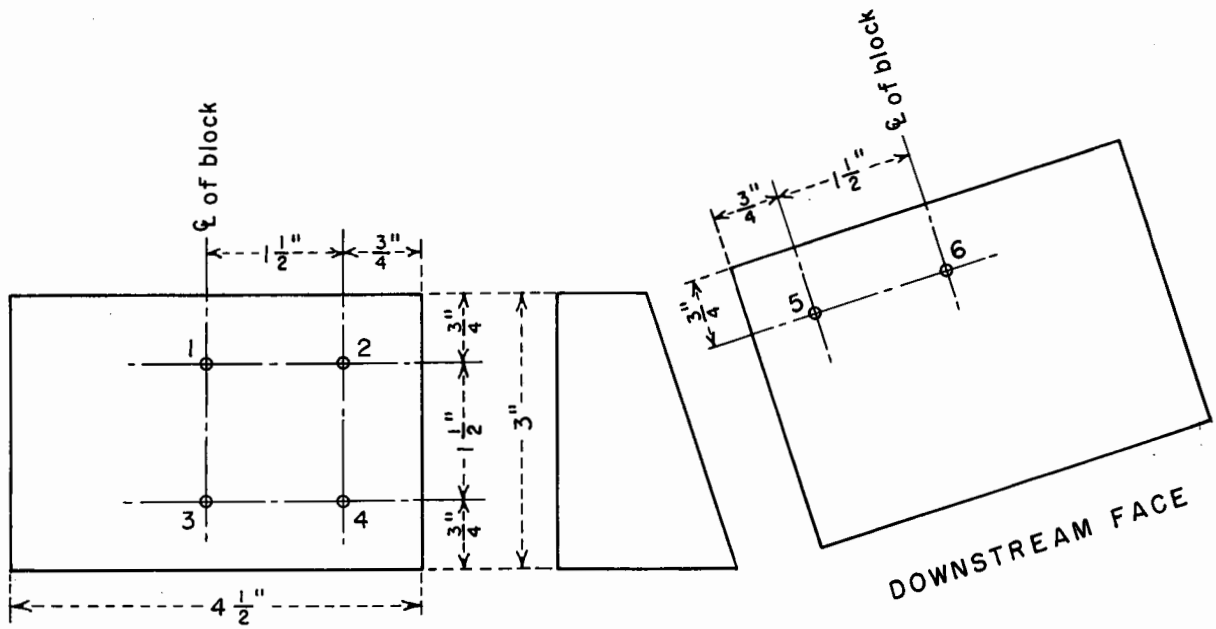
1:12 SCALE MODEL

PIEZ. NO.	PIEZOMETRIC PRESSURE IN FEET OF WATER			
	PIER A	PIER B	PIER C	PIER D
1	+8.3	+8.1	+0.7	+5.8
2	+7.9	+4.3	+1.6	+4.6
3	+5.9	+6.0	+1.5	+7.8
4	+3.0	+3.7	+1.4	+5.6
5	-0.2	0.0	0.0	0.0
6	-0.2	-0.3	0.0	0.0

TABLE OF PRESSURES
FOR Q = 1250 c.f.s.



POSITIONS OF TEST BLOCK
ON APRON



LOCATION OF PIEZOMETERS ON TEST PIERS

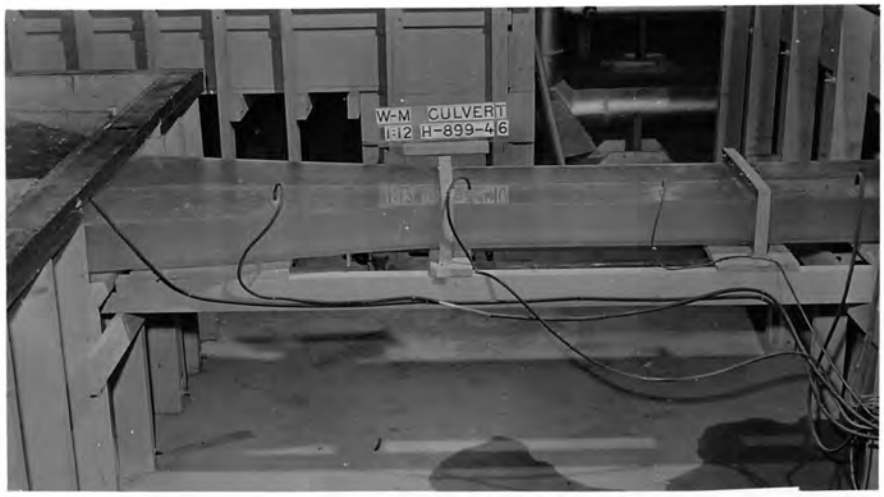
WELLTON-MOHAWK DIVISION

CULVERT UNDER DIKE

PRESSURES ON BAFFLE PIERS

1 : 12 SCALE MODEL

A. Piezometers at entrance to culvert.



B. Piezometers in roof of culvert.

WELLTON-MOHAWK DIVISION
CULVERT UNDER DIKE
Location of Culvert Piezometers
1:12 Scale Model

PART III--WASH OVERCHUTE AT STATION 938+00

Introduction

The wash overchute at Station 938+00 is one of four overchutes on the Wellton-Mohawk Canal. The other three overchutes which are similar in design except for width of structure are located at Stations 234+60, 563+50, and 660+00, Figure 32. Although model studies were conducted only on the wash overchute at Station 938+00, the results and recommendations evolved from the study may be applied to the other three structures.

The wash overchute at Station 938+00 is located 1/2 mile north of Wellton-Mohawk Pumping Plant No. 3, Figure 32 and is designed to carry the discharge from the culvert under dike over the Wellton-Mohawk Canal into a natural channel which enters the Gila River approximately 1 mile downstream from the overchute.

The overchute, Figure 6, consists essentially of a concrete slab with training walls bridging the canal; a vertical curve which results in a 3-foot drop in grade after crossing the canal; a horizontal section, 22 feet 8 inches in length, referred to as a stilling basin in this report; and a baffled apron on a 2:1 slope at the downstream end of the structure. Like the culvert under dike, the overchute is designed for a maximum discharge of 1,250 second feet.

The model studies were used primarily to observe the acceleration of flow resulting from the 3-foot drop and the effectiveness of the baffled apron.

The 1:12 Scale Model

The hydraulic studies of the wash overchute were conducted on a model built to a geometrical scale of 1:12, Figures 33 and 36A. The model consisted of a head box 7 feet long and 10 feet wide containing the topography upstream from and the entrance to the overchute, and a tail box 11 feet long and 7 feet 6 inches wide containing the stilling basin and baffled apron. A flume which connected the two boxes represented the concrete slab over the Wellton-Mohawk Canal. The head box, tail box, and flume were constructed of wood and lined with galvanized sheet metal. The topography in the head box, the bottom of the flume, the vertical curve and the stilling basin were made to grade by forming concrete to metal templates. The 2:1 sloping apron and training walls were constructed of 3/4-inch plywood while the baffle piers were made of redwood.

Water was supplied to the model by a vertical turbine pump and metered through a combination venturi and orifice meter. No tail-water data on the channel downstream from the overchute were available. Therefore, flashboards were placed at the downstream end of the tail box to act as a control and to hold the sand in the tail box.

The Investigation

General

Six different baffle-pier arrangements, which varied in size, shape, and spacing of the piers on the 2:1 sloping apron, were tested in the investigation. These arrangements are designated as Designs 1 through 6 in Figure 34. In addition, tests were made with different baffle-pier arrangements on the floor of the stilling basin (the horizontal section immediately upstream from the baffled apron). The baffle-pier arrangements in the stilling basin are shown as Designs A through G in Figure 35. In the following discussion, the various baffle-pier arrangements are referred to as Designs 1, 1A, 1B, etc. The numeral and letter, respectively, designate the baffle-pier arrangements on the sloping apron and on the stilling basin floor, Figures 34 and 35.

The effectiveness of the various baffle-pier arrangements was determined by erosion tests and visual observations of the flow throughout the structure. The erosion tests were made with sand molded in the tail box before each test to conform to the channel downstream from the structure. Most of the tests were run with the sand at elevations 275 and 264.5 feet for 30 minutes which is equivalent to approximately 1-3/4 hours in the prototype.

Design 1 (Preliminary)

The model, Figure 36A, was initially constructed according to the preliminary design shown in Figures 6 and 34A, and operated at discharges of 600, 1,250 (design discharge), and 1,875 second feet, Figure 37. Although the structure was designed for a maximum discharge of 1,250 second feet, it was later determined that the overchute might carry flows greater than anticipated, and the model was operated at 50 percent above the design discharge.

For discharges above approximately 1,000 second feet, the baffled apron failed to retard the flow before it entered the downstream channel, Figure 37B. At these discharges, the flow swept through the stilling basin, struck the upstream row of baffle piers on the 2:1 sloping apron, and was deflected above and over several of the lower rows of baffle piers, Figures 37B and C. Thus, the effectiveness of the lower rows of baffle piers was considerably diminished. With a

discharge of 600 second feet, the baffle piers appeared very effective, Figure 37A. The scour pattern for the preliminary design after the maximum discharge of 1,250 second feet had passed through the overchute for 1-3/4 hours (prototype) is shown in Figure 36C. The deepest scour was 12 feet below the original channel bottom (elevation 275.0 feet) and occurred near the center of the channel immediately downstream from the baffled apron.

Design 1A

Since the flow swept through the stilling basin at all discharges, it appeared that if a hydraulic jump were made to form upstream from the sloping apron, the velocity of water would be decreased and the baffled apron made more effective. For Design 1A a row of baffle piers, similar to those on the baffled apron, was placed at the downstream end of the stilling basin, Figure 35A.

Figure 38 shows the model discharging 600, 1,250, and 1,875 second feet. At all flows the hydraulic jump remained in the stilling basin and the baffle piers on the sloping apron appeared to be effective. Results of a scour test with this pier arrangement showed the greatest depth of scour to be 7 feet which is 5 feet less than that obtained with Design 1.

Design 1B

To determine the best location for the row of baffle piers on the stilling basin floor, the piers were moved 6 feet from the downstream end of the stilling basin in Design 1B, Figure 35B. From tests on this design, it appeared that the water accelerated between the baffle piers in the stilling basin and the baffled apron. Thus, to keep this acceleration at a minimum, the best location for the stilling basin baffle piers is at the downstream end of the stilling basin. The greatest depth of scour for Design 1B was 9 feet, Figure 39A.

Design 1D

A row of nine piers, 2 feet square in plan and 3 feet high, was placed at the downstream end of the stilling basin, Figure 35D. This pier arrangement gave results similar to those obtained with Design 1A. Figure 39B shows the model operating at a discharge of 1,250 second feet, while Figure 39C shows the scour pattern after the model had operated for a time period equivalent to 1-3/4 hours prototype. The greatest depth of scour was 7 feet--the same as that observed with Design 1A.

Design 2A

For design 2, the spacing of the original baffle piers on the 2:1 apron was reduced from 6 feet to 4 feet 3 inches, Figure 34B. This change caused no apparent difference in the operation of the

model. The hydraulic jump and the flow down the 2:1 apron were similar to that observed in Design 1A. The greatest depth of scour for Design 2A was 7 feet, Figure 39D.

Design 3

To determine the feasibility of using narrower but a greater number of piers on the 2:1 apron, baffle piers having a width of 2 feet 3 inches and a cross section the same as Design 1, were used in Design 3, Figure 34C. Figure 40A shows Design 3 operating at the maximum discharge of 1,250 second feet and Figure 40B shows the resulting scour. By comparing Figure 40A with Figure 38A, it appeared that the narrower baffle piers gave a slightly rougher water surface as the water spilled over the 2:1 apron. The results of the scour test also showed that the narrower piers gave a scour depth of 8 feet, Figure 40B, or 1 foot deeper than Design 1A.

Design 4

In Design 4, stepped baffle piers, 3 feet high and 2 feet 3 inches wide, were placed on the 2:1 apron, Figure 34D. With the stepped piers installed, the appearance of the flow was similar to that observed with Design 1. However, results of a scour test, Figure 40C, showed that more of the apron baffle piers were covered with sand, indicating the formation of a ground roller which moved the sand back on the apron.

All scour tests up to this point had been made with the outlet channel at elevation 275 feet. The outlet channel was lowered to elevation 271 feet and another scour test made, Figure 40D. By comparing Figures 40C and D, it can be seen that the depth of scour was 7 feet in both cases, and very little sand was moved back onto the apron when the outlet channel was lowered. Thus, it appears that the ground roller forms only when the outlet channel is at certain elevations.

Designs 4A and 4E

Tests on Designs 4A and 4E were made to determine the effect on the flow over the baffled apron and the depth of scour in the channel when different rows of baffle piers were placed in the stilling basin. Figure 35A and E shows the size of baffle piers tested, and Figure 41A shows the scour pattern using Design 4E. Although the extra row of baffle piers caused a hydraulic jump to form in the stilling basin, there was no apparent change in the appearance of the flow over the baffled apron, and the depth of scour was 6.5 and 7 feet or approximately the same as observed with Design 1A.

Design 5

For Design 5, the height of the upper row of stepped blocks in Dseign 4 was reduced from 3 to 2 feet, Figure 34E. It was felt, that

by reducing the height of the first row of blocks, the resistance of the baffle piers to the flow over the sloping apron would be more gradual, resulting in a more even flow distribution over the apron.

At maximum discharge, the flow over the baffled apron was well distributed, and the resulting scour pattern, which showed a maximum depth of 5.5 feet, was the best obtained thus far in the study, Table III.

Design 5F

In Design 5F, three rows of baffle piers, 1 and 2 feet high, were spaced along the stilling basin floor, Figure 35F. The three rows of baffle piers caused a hydraulic jump to form in the stilling basin reducing the velocity of the flow over the baffled apron. A scour test at maximum discharge with these baffle piers showed the maximum depth of scour to be 4.5 feet or 1 foot lower than Design 5.

Design 5G

Design 5G differed from Design 5F in that the height of the center row of basin baffle piers was reduced from 2 to 1-1/2 feet. Figure 35G. This change made no difference in the operation of the model. The depth of scour was 4.5 feet, or the same as observed for Design 5F.

In all the previous tests on Designs 5, 5F, and 5G, the downstream channel was at elevation 271 feet and the depth of scour varied from 4.5 to 5.5 feet as compared to 7 feet or more with Designs 1 through 4, which were run with the channel at elevation 275 feet. To determine if the elevation of the outlet channel had any effect on the depth of scour, the outlet channel was raised to elevation 275 feet and another scour test made using Design 5G. Results of this test showed the scour depth to be 6.5 feet, Figure 41B, or about the same as obtained using Designs 1 through 4. Thus, it appears that the elevation at which the outlet channel intercepts the flow down the baffled apron has a marked effect on the depth of scour.

The fact that a greater depth of scour was observed at the higher channel elevation is probably due to the varying flow pattern as the water passes down the sloping apron. At one elevation the flow pattern may be such that the flow is deflected away from the sloping apron, while at another elevation the deflected flow may be striking the apron. If the outlet channel intercepts the flow at these different flow patterns, varied depth of scour will no doubt result.

Design 6

Baffle piers, 2 feet square in cross section and 6 feet high, were placed on the 2:1 apron in Design 6, Figure 34F. For all flows, the water "piled up" considerably in front of the first

row of piers, Figure 41C, indicating the piers were too high and offering too much resistance to the flow. In general, the operation was poor. The scour test showed that the maximum depth of erosion in the channel was 9 feet, Figure 41D.

Design 6C

To prevent the "pile up" of water at the first row of piers, a row of blocks, 2 feet high, were placed in the stilling basin, Figure 35C. The 2-foot blocks caused a jump to form in the stilling basin, but a scour test showed very little improvement in the scour pattern. The deepest scour measured 8.5 feet.

The Recommended Design

A summary of the tests using the various arrangements of baffle piers is tabulated in Table III. In general, the appearance of the flow over the baffled apron was improved and the depth of scour was reduced when a hydraulic jump formed in the stilling basin. Without the formation of a jump, the water swept through the basin and, on striking the first row of piers on the baffled apron, the flow was deflected upward and tended to pass over the remaining rows of piers. The tests also indicated that a ground roller formed for some baffle-pier arrangements when the outlet channel was at certain elevations. However, when the channel was lowered or raised to another elevation, the ground roller apparently no longer formed. See Designs 4 and 5G, Table III.

It is recommended that Design 1A, with a longer baffled apron, be used for construction in the field. The model study indicated this design gave a satisfactory jump in the stilling basin and an evenly distributed flow over the baffled apron, Figure 38. Results of scour tests using Design 1A, with the channel bottom at elevations of 275 and 264.5 feet, showed a maximum depth of scour of 7 feet in the outlet channel for a discharge of 1,250 second feet. A nominal depth of scour also occurred for discharges of 600 and 1,875 second feet with the channel bottom at elevation 264.5 feet. However, the end of the 2:1 apron is uncovered for all discharges indicating that the apron is too short, Figure 42. Therefore, assuming the channel will degrade to approximately elevation 265 feet, it is recommended that the length of the 2:1 apron be increased to include a total of at least seven rows of baffle piers.

Although Designs 5F and 5G showed the least depth of scour when the channel was at elevation 271 feet, the maximum depth of scour increased to approximately the same as Design 1A when the channel elevation was raised to 275 feet, Table III. A detailed drawing of the recommended basin is shown in Figure 43.

Water-surface Profiles

Figure 44 shows the water-surface profiles for discharges of 600, 1,250, and 1,875 second feet for the recommended design. Profiles for each discharge are shown from the upstream end of the chute to the upstream end of the 2:1 apron.

Pressures on Baffle Piers

To aid in the structural design of the baffle piers on the 2:1 apron, piezometric pressures were observed on three test piers placed as shown in Figure 45A. The test piers were constructed from sheet metal and six piezometers were located at points along the surface of the piers, Figure 45B. Pressures on the three test piers were recorded for Designs 1 and 1A, at the design discharge of 1,250 second feet (see table in Figure 45).

Table III

SUMMARY OF TESTS USING VARIOUS BAFFLE-PIER ARRANGEMENTS

Baffle-pier arrangement: On 2:1 sloping apron (Figure 34)	Baffle-pier arrangement: In stilling basin (Figure 35)	Discharge: second feet	Elevation of outlet channel, feet	Maximum depth of scour feet	Remarks
Design 1	None	1,250	275	12	No hydraulic jump. Water deflected over lower rows of piers
Design 1	Design A	1,250	275	7	Good jump in basin. Water evenly distributed over baffled apron
Design 1	Design A	1,250	264.5	7	
Design 1	Design A	600	264.5	4.1	
Design 1	Design A	1,875	264.5	11.3	
Design 1	Design B	1,250	275	9	Good jump. Water accelerated after leaving basin piers
Design 1	Design D	1,250	275	7	Fair jump. Similar operation to Design 1A
Design 2	Design A	1,250	275	7	Operation similar to Design 1A
Design 3	See Figure 34C	1,250	275	8	Fair jump. Rougher water surface over baffled apron
Design 4	None	1,250	275	7	No jump. Ground roller formed. Good scour pattern
Design 4	None	1,250	271	7	No jump. Less evidence of ground roller forming
Design 4	Design A	1,250	275	7	Good jump. Operation similar to 1A
Design 4	Design E	1,250	275	6.5	Good jump. Flow over baffled apron satisfactory
Design 5	None	1,250	271	5.5	No jump. Operation similar to Design 4
Design 5	Design F	1,250	271	4.5	Good jump. Flow over baffled apron well distributed
Design 5	Design G	1,250	271	4.5	Similar to Design 5F
Design 5	Design G	1,250	275	6.5	Similar to Design 5F
Design 6	None	1,250	275	9.0	No jump. Flow deflected upward by first row of piers
Design 6	Design C	1,250	275	8.5	Fair jump. Apron piers appear to be too high

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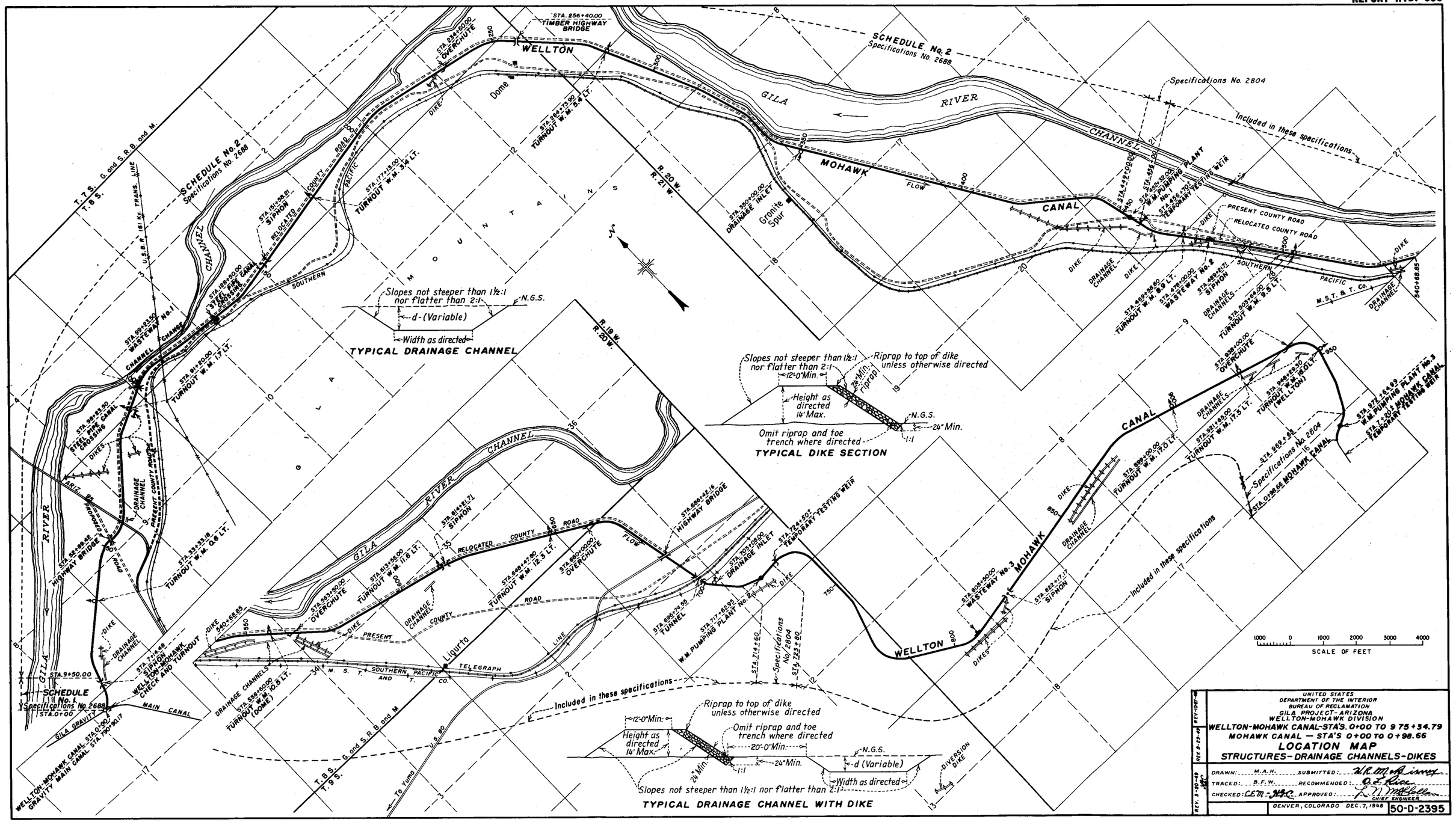


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GILA PROJECT-ARIZONA
WELLTON-MOHAWK DIVISION

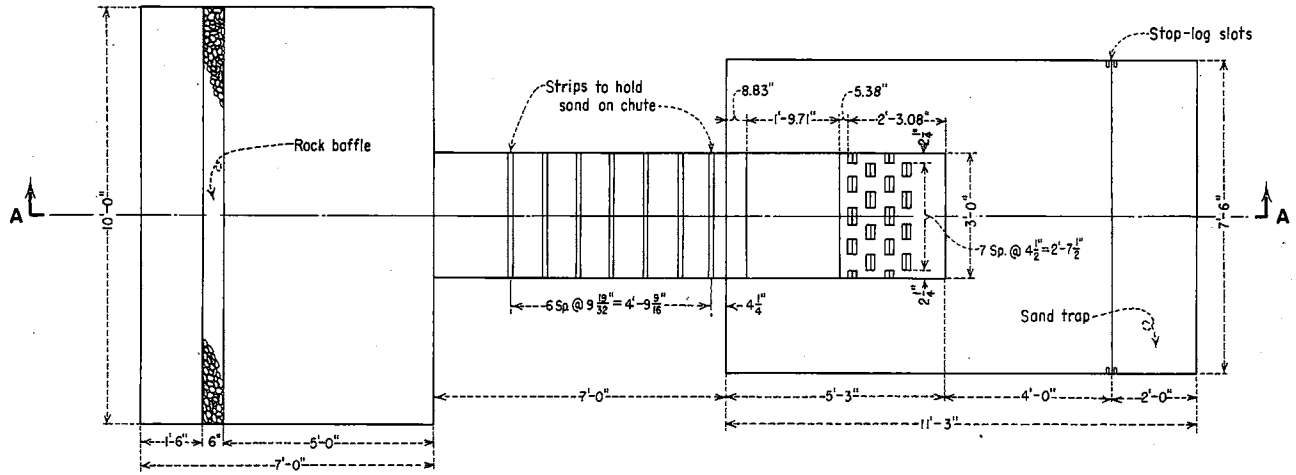
WELLTON-MOHAWK CANAL-STA'S. 0+00 TO 9.75+34.79
MOHAWK CANAL — STA'S 0+00 TO 0+98.66

LOCATION MAP
STRUCTURES-DRAINAGE CHANNELS-DIKES

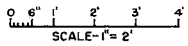
DRAWN: M.A.H. SUBMITTED: W.R. McGinnis
TRACED: B.F.W. RECOMMENDED: O.E. Rice
CHECKED: C.E.M.-M.A.C. APPROVED: L.N. McClellan
CHIEF ENGINEER

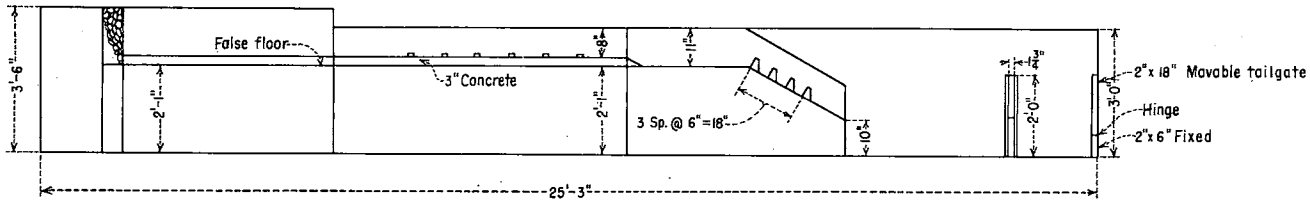
DENVER, COLORADO DEC. 7, 1948 **50-D-2395**

REV. 3-20-49 REV. 8-23-49 REV. 10-18-49



PLAN





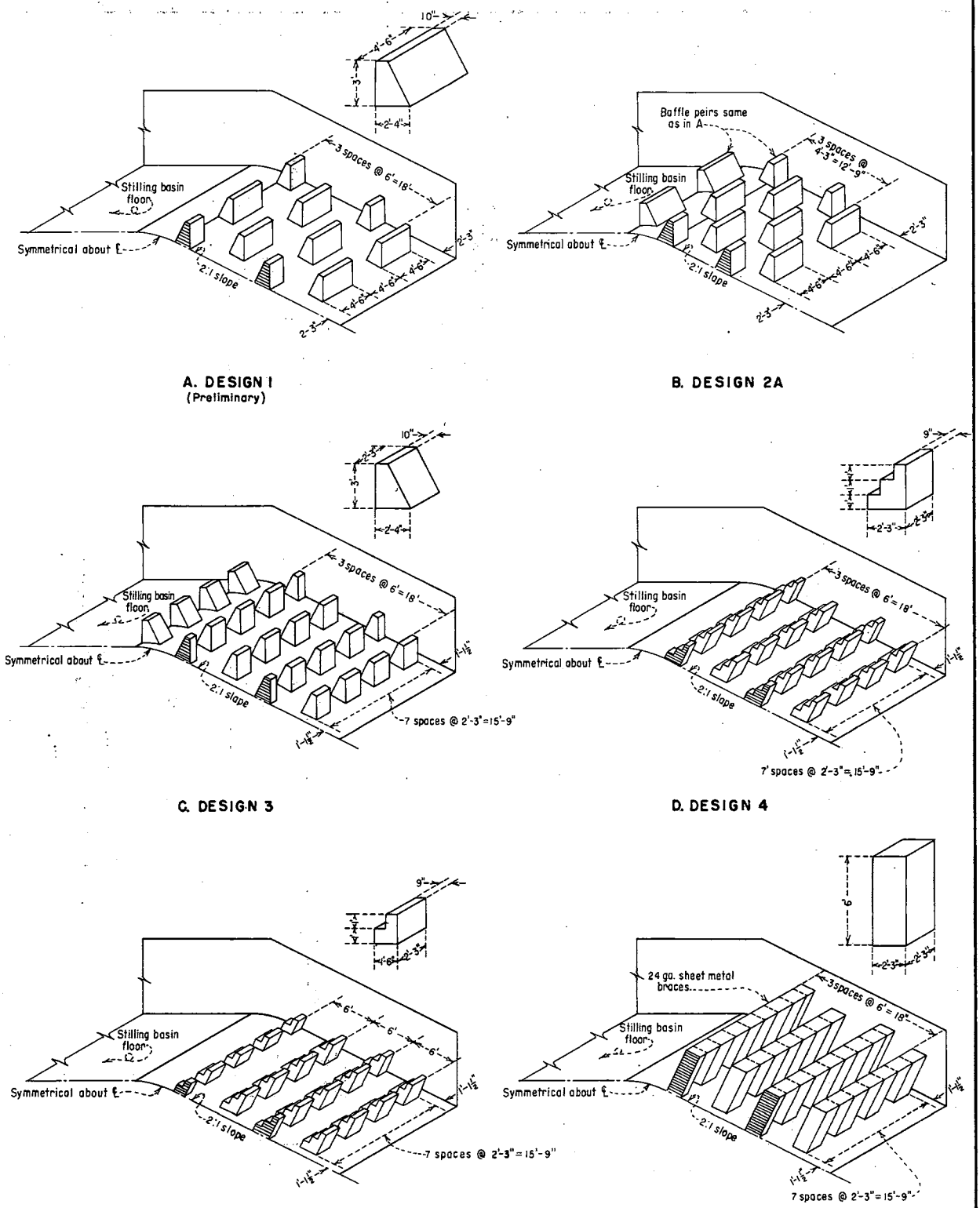
SECTION A-A

WELLTON-MOHAWK DIVISION

WASH OVERCHUTE AT STA. 938+00

1:12 SCALE MODEL

FIGURE 33

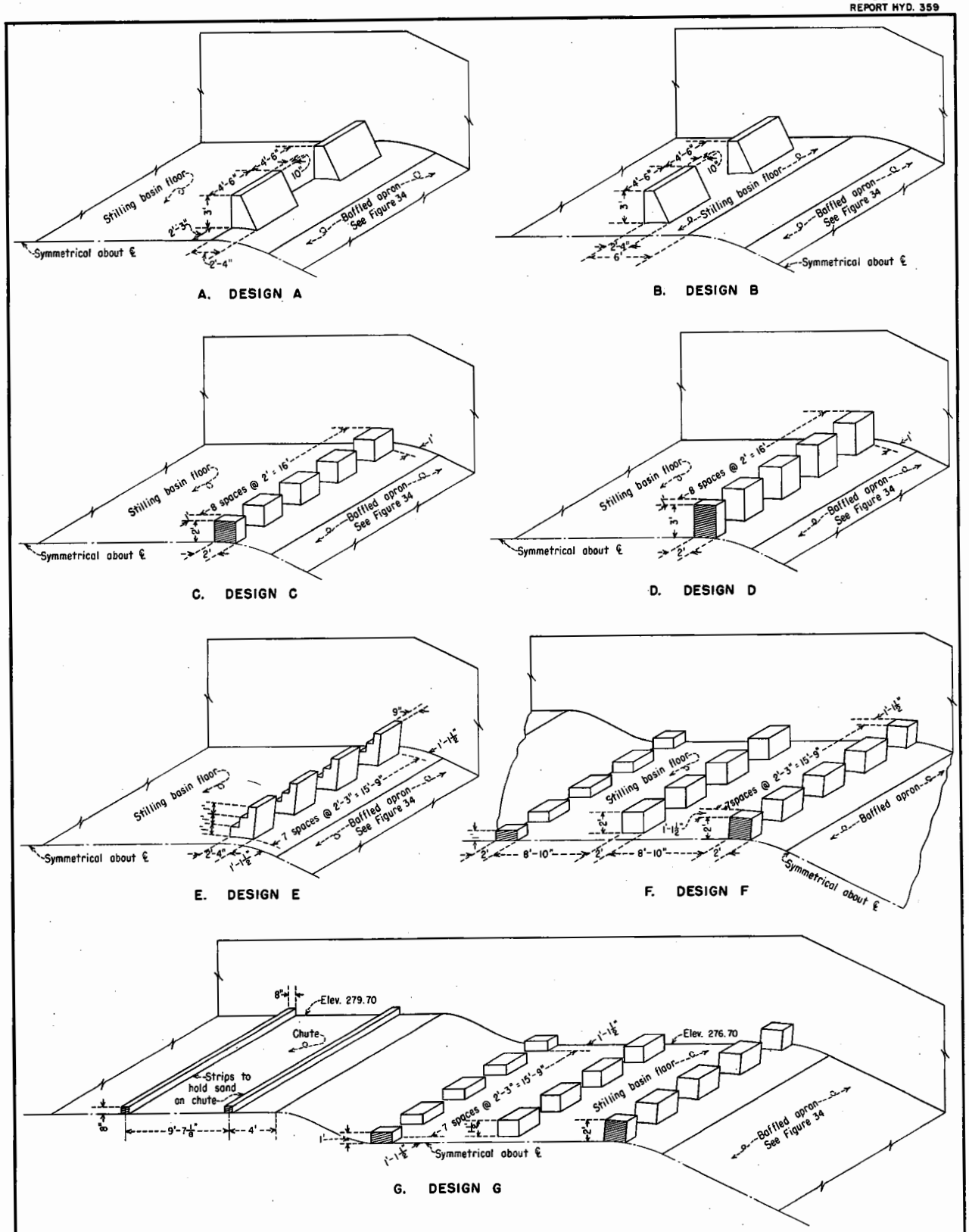


WELLTON—MOHAWK DIVISION

WASH OVERCHUTE AT STA. 938+00

DIFFERENT BAFFLE PIER ARRANGEMENTS ON 2:1 SLOPING APRON

1:12 SCALE MODEL



WELLTON–MOHAWK DIVISION

WASH OVERCHUTE AT STA. 938+00

DIFFERENT BAFFLE PIER ARRANGEMENTS IN STILLING BASIN

1:12 SCALE MODEL

A. The Model.

B. Tail box with outlet, channel at Elev. 275.0'.

C. Scour pattern after discharge of 1250 cfs. Outlet channel at Elev. 375.0'.

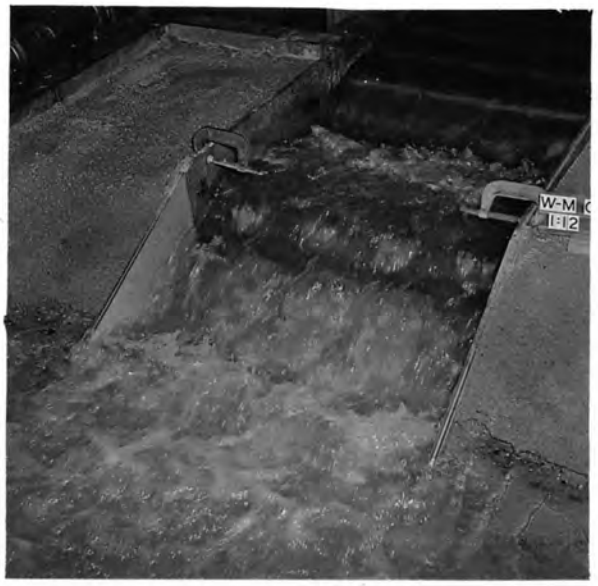
WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Design 1 (Preliminary)
1:12 Scale Model

A. Discharge = 600 cfs.

B. Discharge = 1250 cfs.

C. Discharge = 1875 cfs.

WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Operation of Design 1 (Preliminary)
1:12 Scale Model



A. Discharge = 1250 cfs.

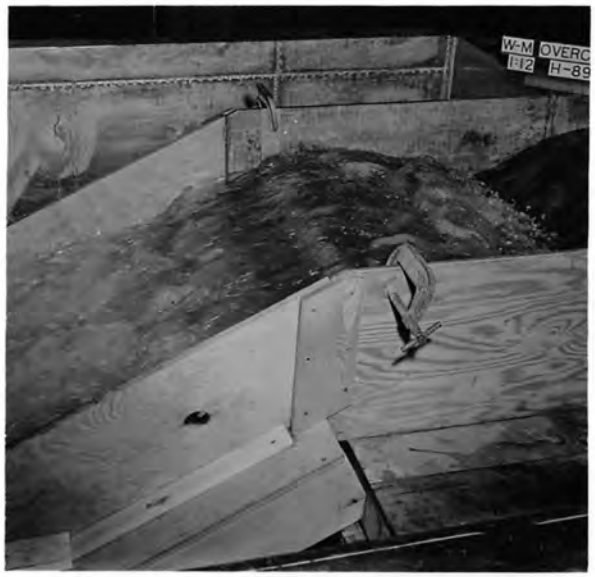
B. Scour pattern after discharge of 1250 cfs. Outlet channel at 275.0 feet.

C. Discharge = 600 cfs.

D. Discharge = 1875 cfs.

WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Operation of Design 1A.
1:12 Scale Model

A. Scour pattern for Design 1B.



B. Flow in Design 1D.

C. Scour pattern for Design 1D.

D. Scour pattern for Design 2A.

WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Operation of Designs 1B, 1D and 2A.
Discharge = 1250 second-feet with outlet channel
at Elev. 275.0 feet
1:12 Scale Model

A. Discharge = 1250 cfs.

B. Scour pattern after discharge of 1250 cfs. Outlet channel at Elev. 275.0'

C. Outlet channel at Elev. 275.0'.

D. Outlet channel at Elev. 271.0'.

DESIGN 4. Scour patterns after discharge of 1250 cfs.

WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Operation of Designs 3 and 4
1:12 Scale Model

A. Scour pattern for Design 4E.

B. Scour pattern for Design 5G.

C. Flow in Design 6.

D. Scour pattern for Design 6.

WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Operation of Designs 4E, 5G and 6
Discharge = 1250 second-feet: with outlet channel
at Elev. 275.0 feet
1:12 Scale Model

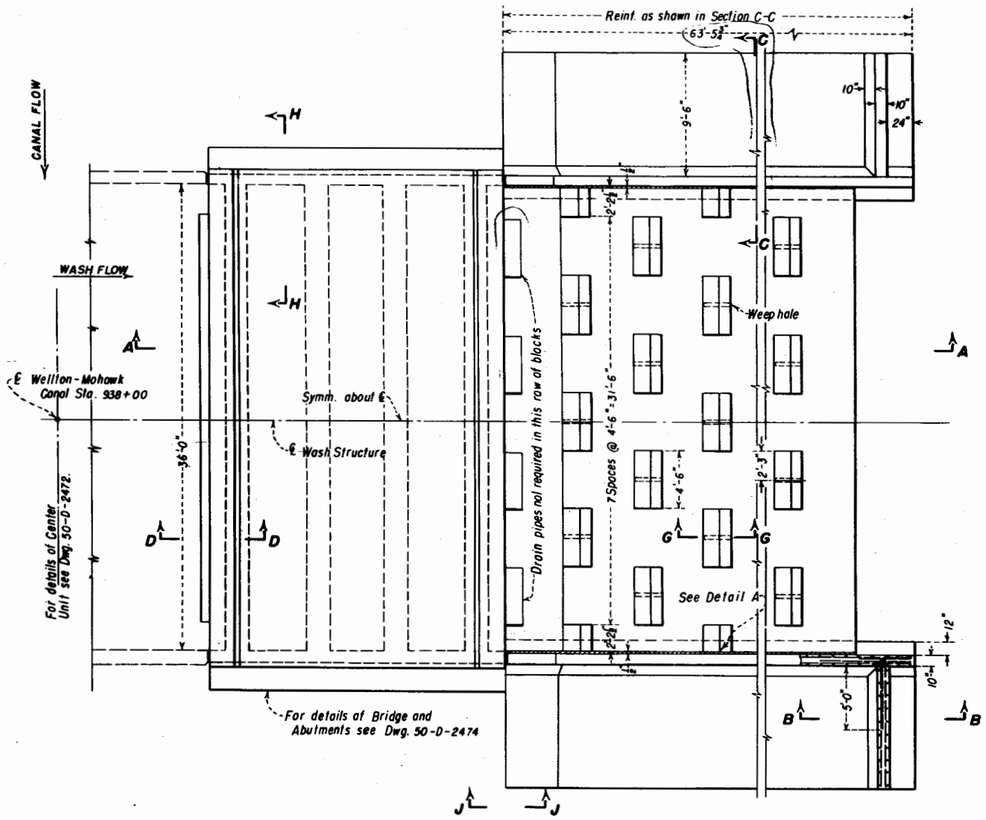
A. Before scour tests.

B. Scour pattern after discharge of 1250 cfs.

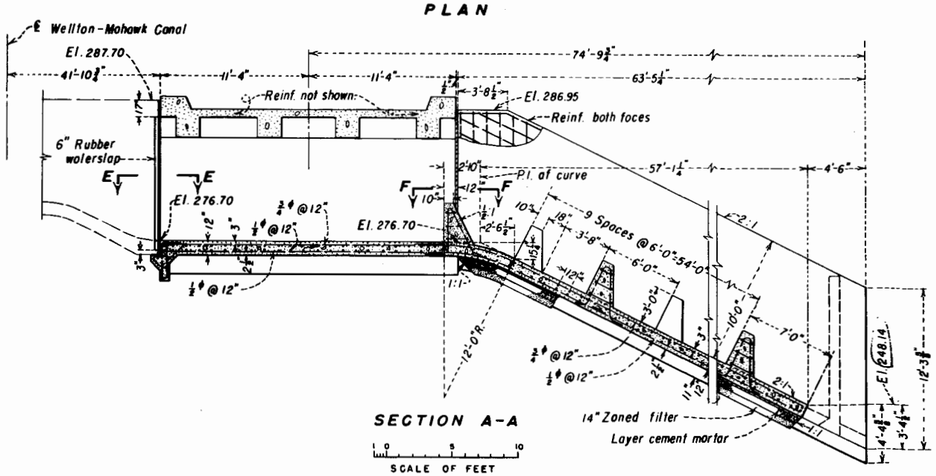
C. Scour pattern after discharge of 600 cfs.

D. Scour pattern after discharge of 1875 cfs.

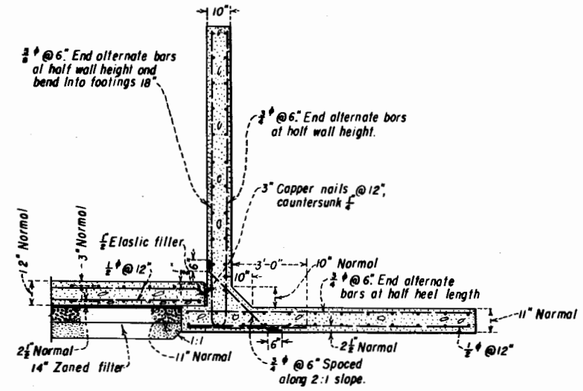
WELLTON-MOHAWK DIVISION
WASH-OVERCHUTE at Sta. 938+00
Operation of Design 1A (Recommended) with
outlet channel at Elev. 264.5
1:12 Scale Model



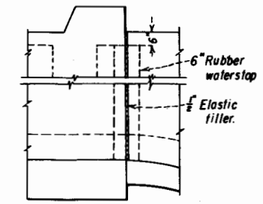
PLAN



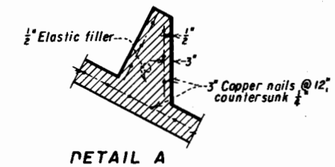
SECTION A-A



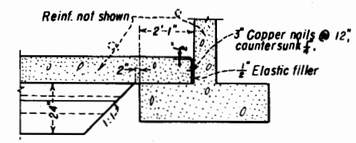
SECTION C-C



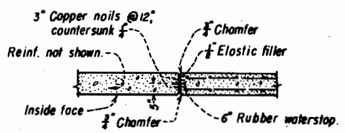
ELEVATION J-J



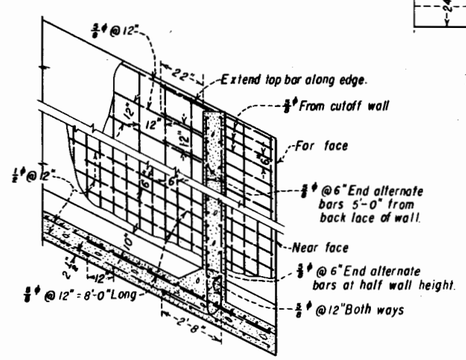
DETAIL A



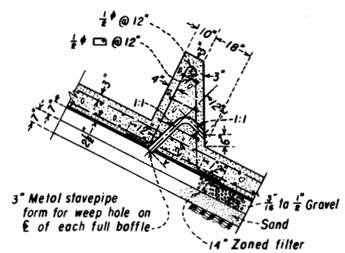
SECTION H-H



SECTION F-F

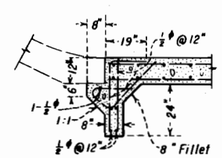


SECTION B-B

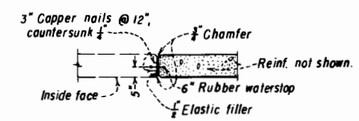


SECTION G-G

SCALE OF FEET



SECTION D-D



SECTION E-E

NOTES

For General Plan and Sections see Dwg. 50-D-2471.
Chamfer all exposed corners ¾", unless otherwise shown.
Install copper nails in concrete last placed.
All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete, unless otherwise shown.
Lap all bars 34 diameters at splices, unless otherwise shown.
Concrete design based on a compressive strength of 3000 lbs. per sq. in.

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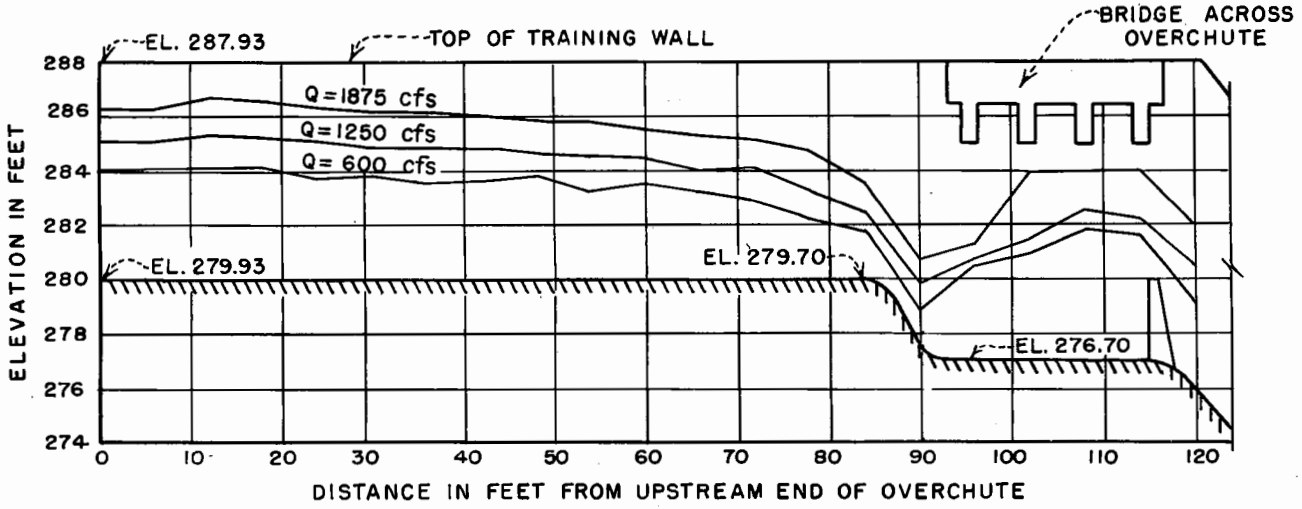
GILA PROJECT-ARIZONA
WELLTON-MOHAWK DIVISION
WELLTON-MOHAWK CANAL-STA. 938+00

WASH OVERCHUTE

WASH CHANNEL OUTLET - WALLS - PAVING - BAFFLES

DRAWN: L.P.B. SUBMITTED: N. E. Rapp
TRACED: R.F.N. RECOMMENDED: W. H. Nalder
CHECKED: APPROVED: L. N. McClellan
CHIEF ENGINEER
DENVER, COLORADO - NOV. 12, 1948
50-D-2473
REV. 2-14-50

NOTE: Drawing distorted-one horizontal equals three vertical



WELLTON-MOHAWK DIVISION

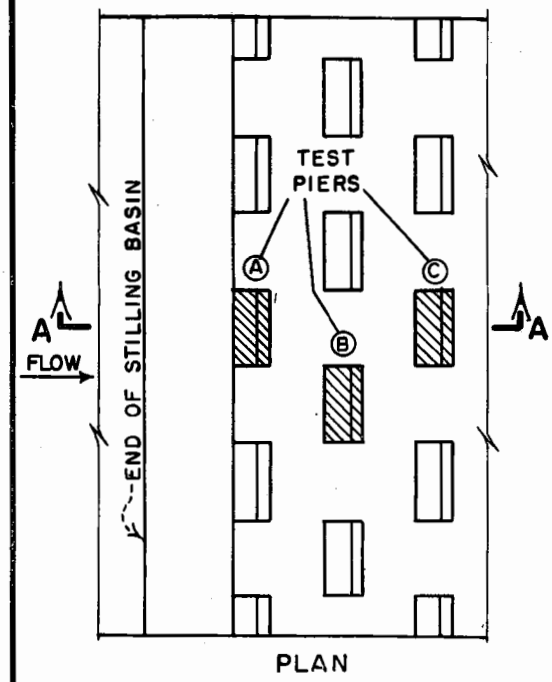
WASH OVERCHUTE AT STA. 938+00

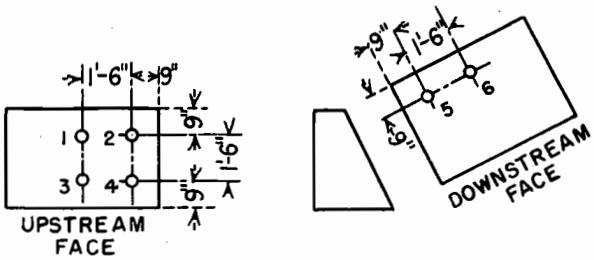
WATER SURFACE PROFILES

DESIGN 1A (RECOMMENDED)

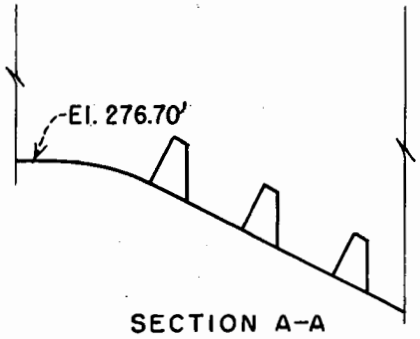
1 : 12 SCALE MODEL

FIGURE 44
REPORT HYD. 359





B. LOCATION OF PIEZOMETERS ON EACH TEST PIER



A. POSITION OF TEST PIERS ON 2:1 APRON

PIEZOMETER No.	PIEZOMETRIC PRESSURES IN FEET OF WATER					
	DESIGN I (NO JUMP IN BASIN)			DESIGN IA (JUMP IN BASIN)		
	PIER A	PIER B	PIER C	PIER A	PIER B	PIER C
1	+5.8	+9.0	+2.7	+4.8	+7.6	+5.3
2	+5.0	+5.1	+2.9	+4.0	+4.5	+4.4
3	+4.4	+6.0	+2.7	+4.6	+7.6	+4.3
4	+4.0	+3.8	+2.7	+4.3	+4.3	+3.9
5	0	+1.5	+3.6	0	+1.5	+3.6
6	0	+1.5	+3.6	0	+1.5	+3.6

WELLTON-MOHAWK DIVISION

WASH OVERCHUTE AT STA. 938+00

PRESSURES ON BAFFLE PIERS

1 : 12 SCALE MODEL