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UNITED STATES
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HYDRAULIC LABORATORY REPORT NO. 172

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HYDRAULIC MODEL STUDIES OF THE ALL-AMERICAN CANAL CHECK STATION 60+00± ALL-AMERICAN CANAL SYSTEM - CALIFORNIA

By

FRED LOCHER, ASSOCIATE ENGINEER

- - -

Denver, Colorado
May 14, 1945

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SUBJECT: HYDRAULIC MODEL STUDIES OF THE ALL-AMERICAN CANAL CHECK STATION 60+00± ALL-AMERICAN CANAL SYSTEM - CALIFORNIA

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By FRED LOCHER, ASSOCIATE ENGINEER

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Under Direction of

J. E. WARNOCK, SENIOR ENGINEER

and

R. F. BLANKS, SENIOR ENGINEER

- - -

Denver, Colorado,
May 14, 1945

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
May 14, 1945

Laboratory Report No. 172
Hydraulic Laboratory

Compiled by: Fred Locher
Reviewed by: J. E. Warnock

Subject: Hydraulic model studies of the All-American canal check station 60+00± - All-American canal system, California.

1. General. Since the All-American canal has been placed in operation, the discharge from the desilting works into the canal has not exceeded 10,000 second-feet and this was maintained for only a short period when water was being diverted into Mexico. At present, the steady flow varies between 4,000 and 6,000 second-feet.

Because the canal was designed for maximum discharge of 15,155 second-feet and no check was provided for controlling water surfaces at partial discharges, excessively high velocities occurred in the channels and effluent weirs at the desilting works. The resulting scour removed the sand from beneath the dry-rock paving causing washouts in the channel which were so severe that it was necessary to suspend operation of the canal while repairs were being made.

The scour and other operating difficulties could be eliminated by the use of a check-drop structure downstream from the desilting works, which would maintain the water surface nearly constant at the maximum depth of 20.61 feet for all flows and reduce the velocity in the channels at the desilting works to a value below that which is capable of producing scour.

Investigations of the hydraulic properties of a check-drop structure in the canal revealed that maintaining the upstream water depth constant at 20.61 feet, in combination with the various downstream water surfaces expected at the different flows, a hydraulic jump would not form. At all of the discharges above 2,000 second-feet the downstream depth was too great for a jump to form and a condition called a "drowned jump" would exist. When this occurs the energy of the drop does not dissipate rapidly and carries through the pool causing considerable bottom scour and bank erosion, especially in the sandy soil which characterizes this part of the All-American canal.

The uncertainties surrounding the character of the flow and the desire to obtain the most economical structure that would serve the requirements and provide ample protection against downstream erosion lead to the instigation of model tests.

2. Initial tests. The design shown on figure 1 was modeled on a 1:30 scale for the first tests. It was a 7-gate structure set level with the canal bottom and without transitions. The banks were paved on a 1-3/4:1 slope with the triangular area between the outside piers and the slopes closed by a solid concrete wall. Initial tests of this design indicated considerable bottom scour and in addition, large vortices having sufficient velocities to cause bank erosion formed against the canal banks a short distance downstream. Both of these conditions were corrected by the addition of dentates between the piers. The dentates produced a "choppy" water surface which was considered undesirable in view of previous difficulties with canal bank erosion, due to wave action.

To obtain a measure of the relative roughness of the water surface between models, a condenser type of surface gage was developed. The instrument was designed so that the variation of the air gap between one of the condenser plates and the water surface upset an electronic bridge and caused a small current to flow through to the connected oscillograph. The greater the change in air gap the more current flow, hence, producing a greater deflection of the oscillograph galvanometer. If the air gap remained constant which would correspond to no waves in the model, the position of the light spot did not change. When the apparatus was installed in the model the condenser plates and amplifying equipment were mounted on the end of a point gage making it possible to set the condenser plates the same distance from the average water surface for each test. As the instrument was not linear, the oscillograms obtained did not indicate the actual amplitude of the wave and served only to indicate if the wave amplitude in one design was greater or lesser than in another design.

The equipment was not completed at the time the initial tests were made and no record of the water surface was obtained for either the original installation or the same arrangement with dentates placed between the piers.

3. Designs for minimum wave action. By increasing the submergence on the model of the original design the roughness of the downstream water surface decreased considerably so the next test consisted of depressing the downstream part of the structure 7.5 feet below the canal grade and maintaining the gate seat at the canal grade. The transition

between the two levels was effected by a 45-degree slope. A row of dentates 45 inches high was placed in each pier section downstream from the 45-degree slope. The arrangement was not satisfactory because the jet did not follow the 45-degree slope and rendered the dentates ineffective. Side eddies also formed which added considerably to the roughness of the water surface. These difficulties were overcome by causing the gates to seat on the 45-degree slope and increasing the length of the two outside piers. The oscillogram of the water surface is shown on figure 2A, where the transverse lines represent 0.10 second on the model.

Due to certain design difficulties inherent with seating the gate on the 45-degree slope and with sliding friction for stability of the structure, it was decided to lower the gates as shown on figure 3. Tests with the design gave the most satisfactory water surface of all the designs tested, figure 2B. In the model the bank erosion due to wave action was negligible and the bottom scour was eliminated. The cost of this structure was $150,000 more than the original design.

To reduce the cost, the structure was tested with five gates instead of the original seven. Otherwise the design was the same as shown on figure 3. This increased the roughness of the water surface, figure 2C, and caused erosion of both the banks and the bottom. Better performance of the five-gate arrangement could have been obtained by lowering the bottom of the gate section still farther below the canal grade but as this would not have been a saving in cost, the five-gate design was not given any further consideration.

A suitable compromise design was developed from a hydraulic viewpoint by changing the elevation of the seven-gate arrangement of figure 3 to a point 2.5 feet below the canal grade. The tests did not indicate any bottom scour and the wave action as shown on figure 2D did not cause any serious bank erosion, but as the estimated cost of this design was more than that of the original design, it was not given further consideration.

4. The selected design. As it was not possible to obtain a hydraulic jump below the gates with the bottom of the structure at or below canal grade the floor of the check through the pier section was raised 5 feet with a 7:1 slope from the downstream end of the piers to canal grade. Assuming that a jump would form on the 7:1 slope this condition would be obtained for all flows below 11,000 second-feet. At flows above 11,000 second-feet, the drop through the structure was reduced sufficiently to be of no great importance so far as energy dissipation was concerned.

Tests with the design showed that a hydraulic jump formed at all flows up to and including 10,000 second-feet and that at 12,000 second-feet a semblance of a jump was still present. However, in the previous designs the worst condition for roughness of the water surface occurred at 10,000 second-feet for which the records were taken, but with this arrangement the worst condition was obtained at a discharge of 12,000 second-feet. In addition there was considerable scour at flows below 8,000 second-feet due to interference of the piers when the jump formed downstream from them. The absence of downstream flow in the area

adjacent to and immediately downstream of the piers caused an upstream flow in this area. This eventually became an unstable standing wave shifting from one gate section to another, which seriously disrupted the jump and produced large eddies and bottom scour. The condition was corrected by placing the 7:1 slope between the piers as shown on figure 4. This caused the jump to form in the pier section at all flows. The scour was eliminated by the addition of dentates on the 7:1 slope as shown on figure 4. They also aided materially in holding the jump between the piers at low flows.

Wave action was most pronounced at a discharge of 12,000 second-feet, figure 2E, and by comparison with the other records shown on figure 2 the most severe wave action was obtained with this design. The waves were only a surface condition. Their action did not extent much more than 200 feet downstream from the structure and it appeared that 200 feet of riprap on the banks, and 50 feet on the bottom, downstream from the structure would be adequate protection in the prototype.

The design of figure 4 with the additional riprap was considered less costly than any of the previous designs and inasmuch as it performed satisfactorily, it was selected for the prototype installation.

5. Conclusions.

A satisfactory hydraulic jump will form on a 7:1 slope extending an indefinite distance below the water surface.

A considerable amount of wave action will occur below a hydraulic jump.

Wave action resulting from energy dissipation can be eliminated by sufficient submergence of the jet.

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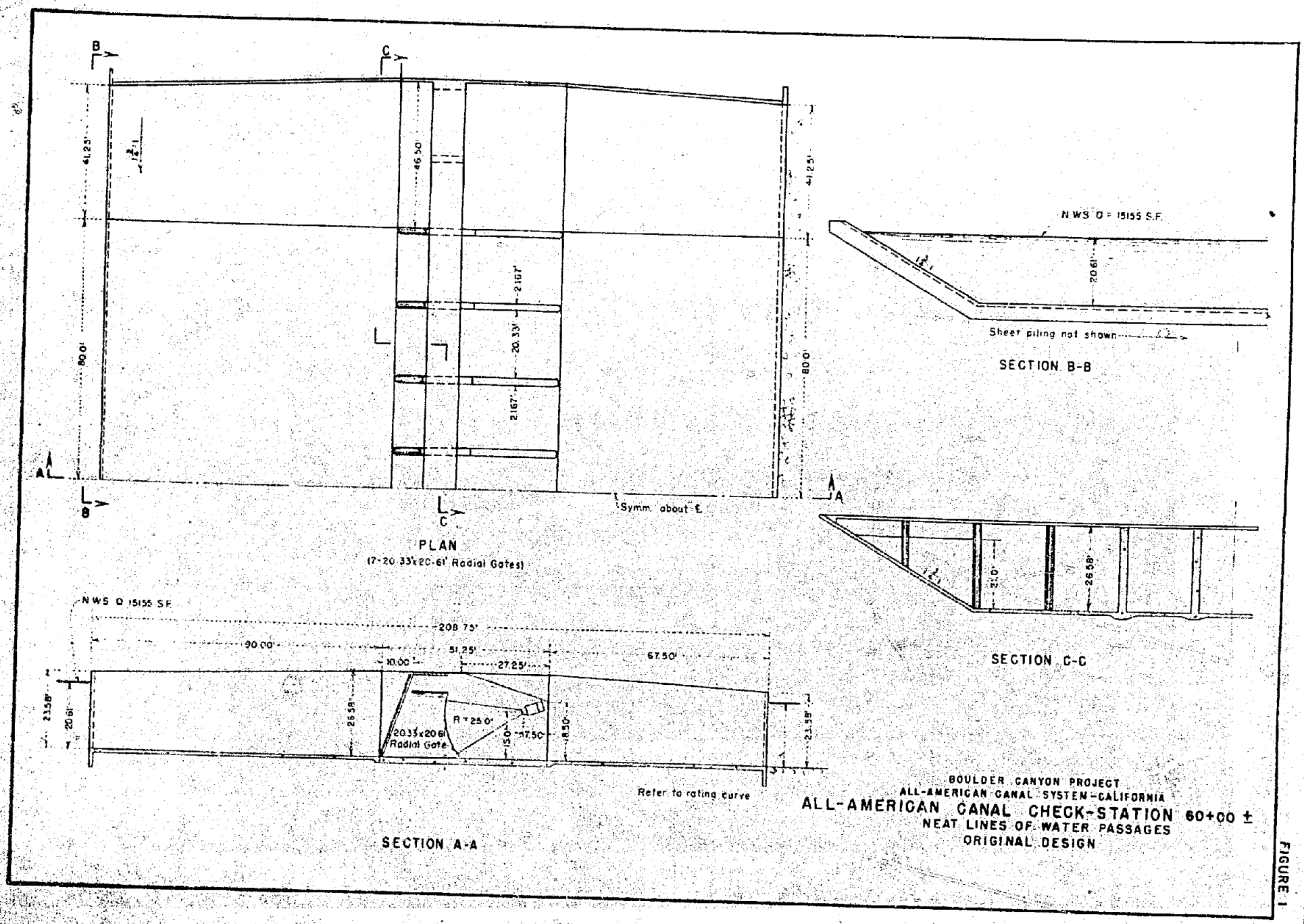
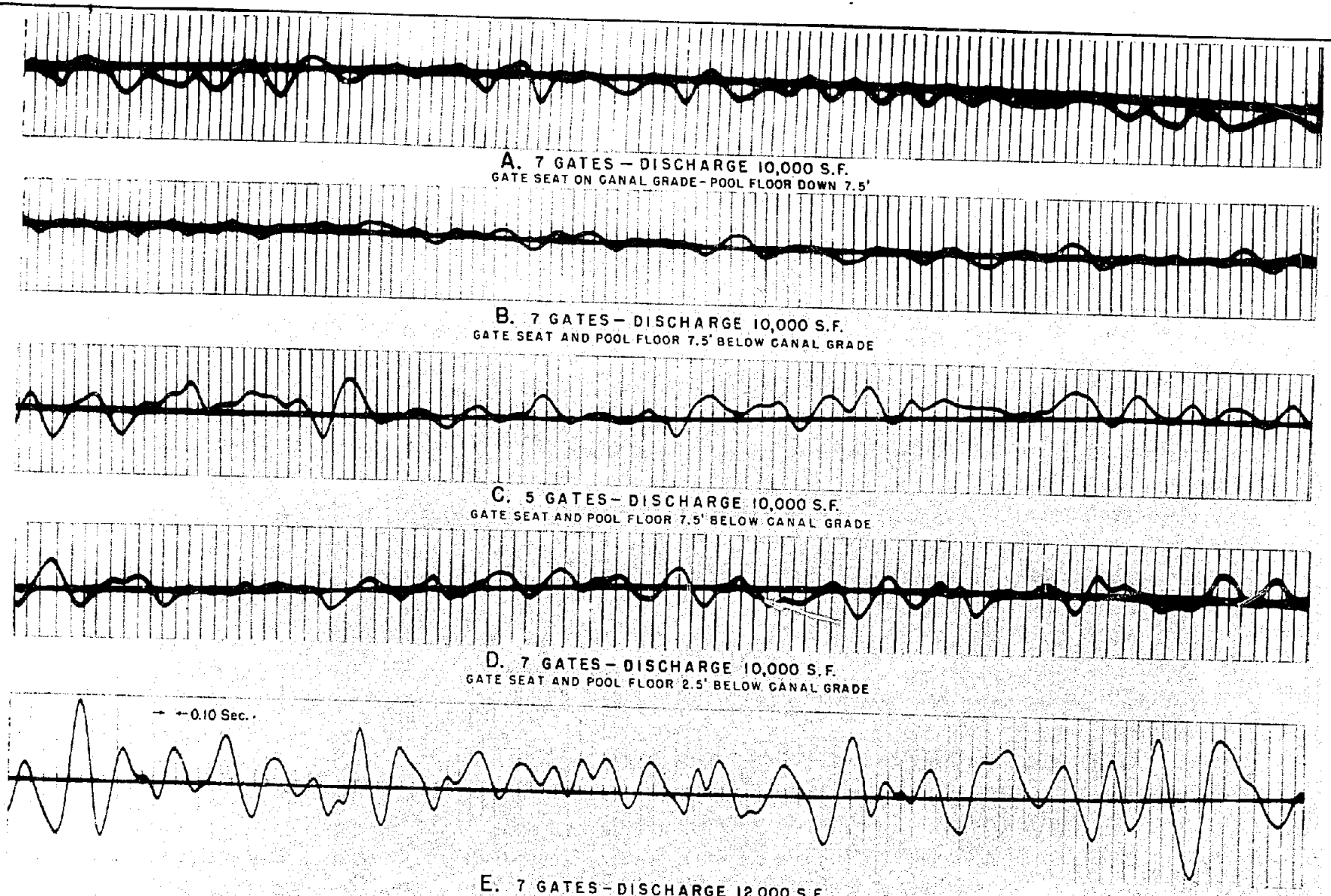


BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM—CALIFORNIA
ALL-AMERICAN CANAL CHECK-STATION 60+00 ±
NEAT LINES OF WATER PASSAGES
ORIGINAL DESIGN

FIGURE 1



RELATIVE ROUGHNESS OF WATER SURFACES BELOW CHECK-DROP STA. 60+00±

ALL AMERICAN CANAL SYSTEM

FIGURE 2

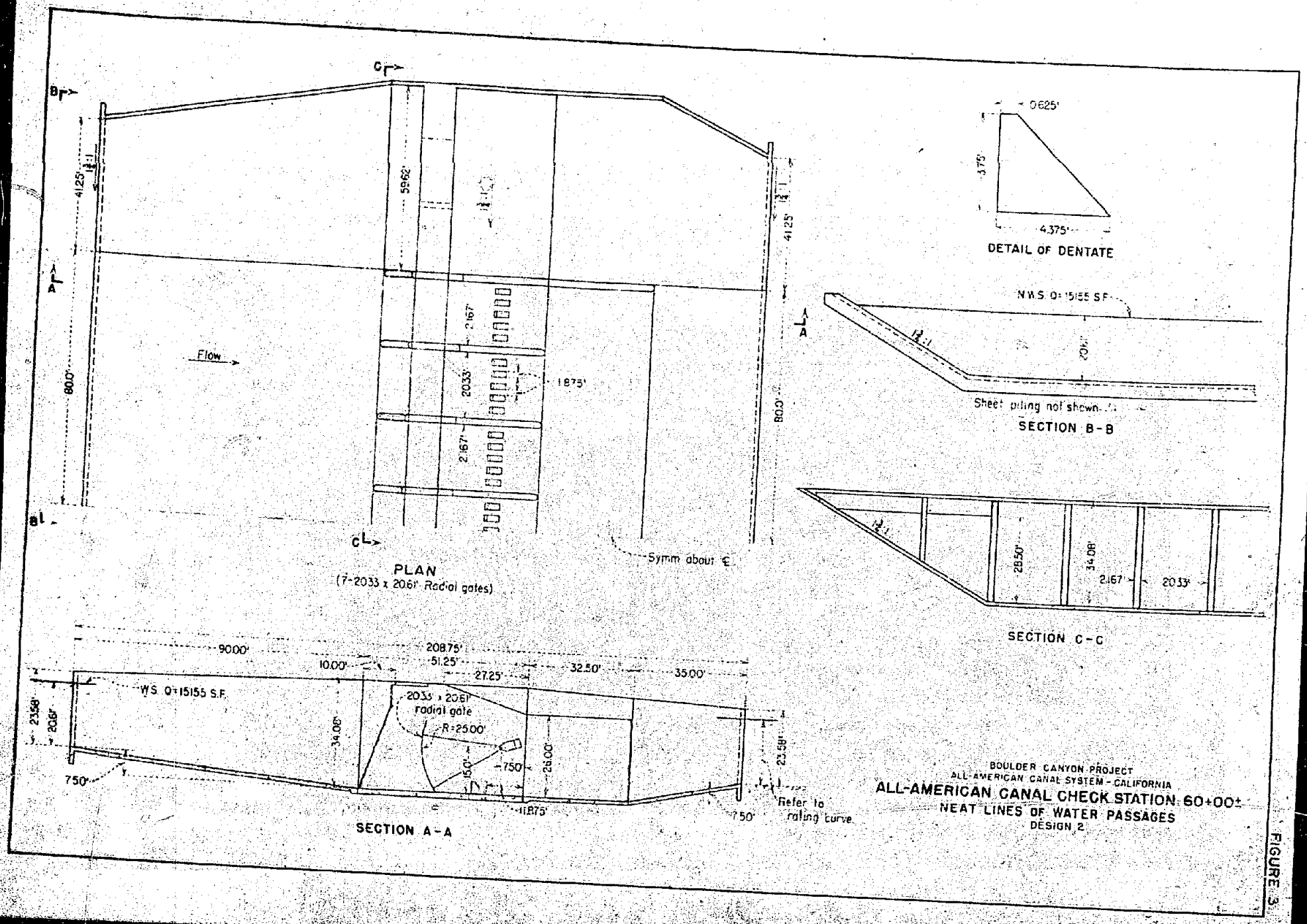
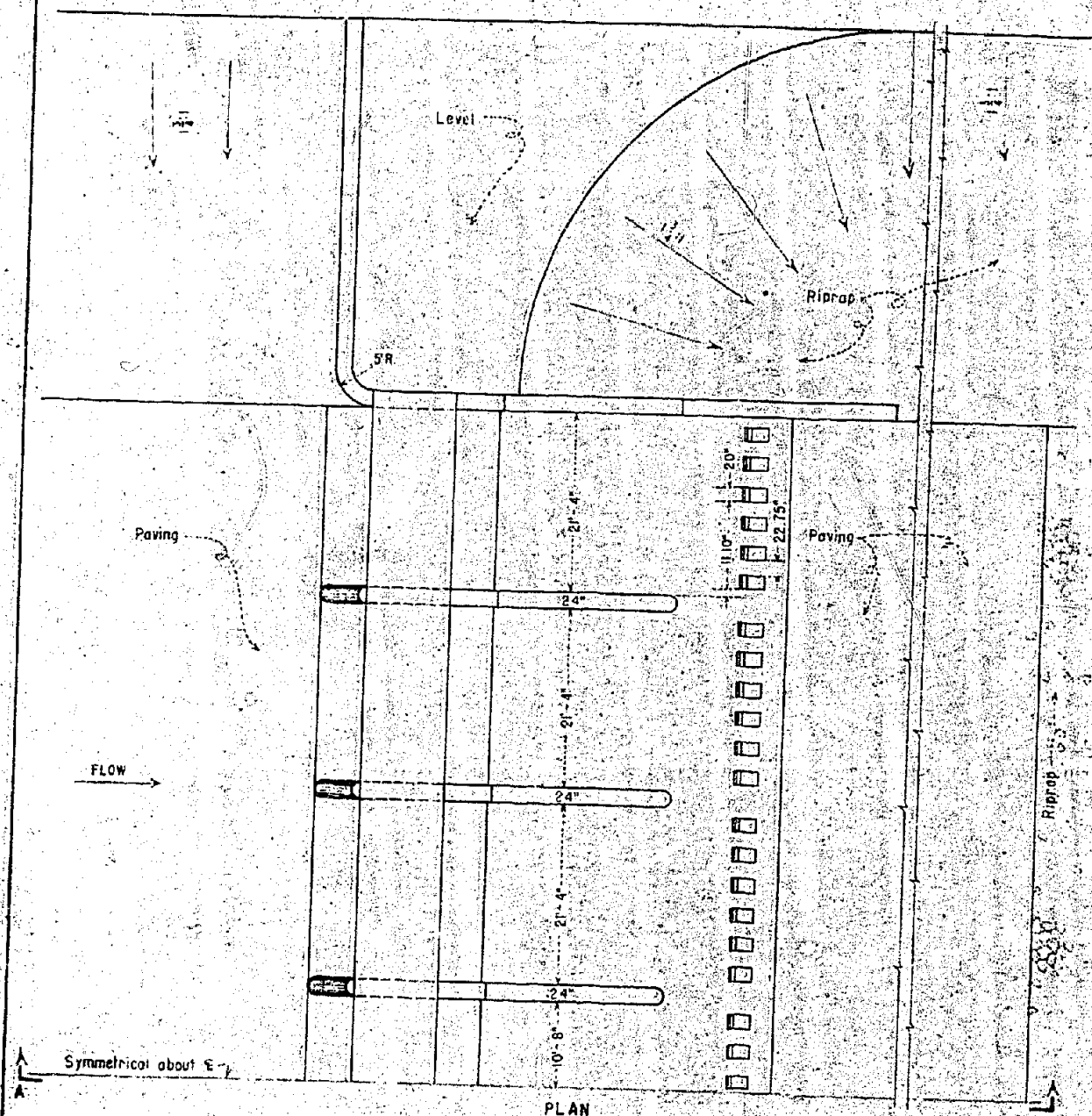
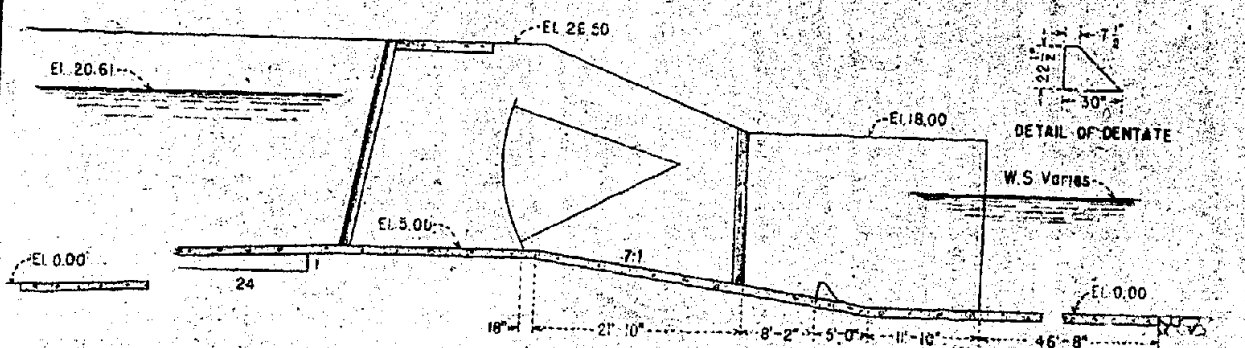

PLAN
(7-20.33' x 20.61' Radial gates)
Flow
Symm about ℄
DETAIL OF DENTATE
0.625'
3.75'
4.375'
N.W.S. Q=15155 S.F.
Sheet piling not shown
SECTION B-B
SECTION C-C
W.S. Q=15155 S.F.
20.33' x 20.61' radial gate
R=25.00'
Refer to rating curve
SECTION A-A
BOULDER CANYON PROJECT
ALL-AMERICAN CANAL SYSTEM - CALIFORNIA
ALL-AMERICAN CANAL CHECK STATION 60+00±
NEAT LINES OF WATER PASSAGES
DESIGN 2

FIGURE 3

FIGURE 4





SECTION A - A

ALL-AMERICAN CANAL

CHECK STATION 60+00

DESIGN III - NEAT LINES OF WATER PASSAGES