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UNITED STATES
DEPARTMENT OF THE INTERIOR
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Progress Report No. 2

HYDRAULIC MODEL STUDIES, RELATING TO THE DESIGN OF THE STILLING-BASIN FOR THE SPILLWAY AT DAVIS DAM

Hydraulic Laboratory Report No. 255

RESEARCH AND GEOLOGY DIVISION

Branch of Design and Construction
Denver, Colorado

January 4, 1949

UNITED STATES
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Laboratory Report No. 255
Hydraulic Laboratory
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Subject: Progress Report No. 2, relating to the design of the stilling-basin for the spillway at Davis Dam.

This report of progress on the testing of designs for the Davis Dam Spillway apron is furnished to summarize the results thus far obtained on tests of the hydraulic jump apron. From test results described herein, decisions can be made as to the length of horizontal paved apron and the amount of channel bank protection. Also, a testing schedule can be outlined so that tests on the final design may be started.

In January of 1948 the testing of the diversion plan for Davis Dam was completed. This testing was based upon a hydraulic jump apron, but only the upper portion of the apron was fully developed, as the remainder of the apron was to be built under a separate contract. The details of the horizontal portion of the apron were to be worked out in later tests--and these are the tests summarized here.

This testing program was divided into two phases:

I. Determination of the proper length of the horizontal apron

II. Study of various designs of end sills and right training-wall extensions

The first tests to determine the proper length for the stilling-pool were made with the downstream end of the pool at Station 44+06. The length was then reduced by 36 feet to Station 43+70. Finally, the length was reduced by another 30 feet to Station 43+40, making the length of the horizontal apron 100 feet. Tests of this phase of the work are summarized as follows:

Test 1. Test 1 was made with the end of the pool at Station 44+06. With a discharge of 1,7900 cfs and the tailwater at the predicted ultimate level, the maximum scour after 3 hours of model operation was to elevation 443, or 27 feet below the floor of the apron. The point of maximum scour was located approximately 50 feet downstream from the end of the apron, and to the right of its centerline.

Approximately 6 feet of the downstream face of the apron cutoff wall was exposed, as shown in Figure 3. This design was believed to be satisfactory, but the saving in cost that could be effected by a shorter apron design justified further model tests.

Accordingly, the next tests were run with the pool length reduced by 36 feet--the end of the pool being at Station 43+70. Two tests were run with this pool length--Tests 2A and 2B.

Test 2A. A prototype discharge of 175,000 cfs was allowed to flow for 4 hours with the tailwater at ultimate elevation. The scour pattern produced in this test was not very satisfactory, as the face of the apron cutoff wall and the end of the right training-wall were exposed to a depth of 22 feet, Figure 4. It was believed this was due to the rotating eddy which developed at the right of the main spillway flow, Figure 5.

Test 2B. In an attempt to reduce the effect of the eddy, a series of sills was introduced parallel to the main spillway flow and in line with the right training-wall. Sills of different heights and shapes were tested, and in all cases the scour pattern improved. The improvement was believed to be due to the upward deflection by the sill of the bottom currents in the eddy. In the interest of economy, it was decided that the contractor's cofferdam, now in existence, cut off below minimum tailwater elevation, would serve as a substitute for the sill, Figure 2. A model of the cofferdam was installed and the discharge of Test 2A was duplicated. Results of a 2-hour test indicated that the sill had substantially reduced the scour, Figure 6. The point of maximum scour was moved further downstream, and the end of the training-wall was exposed only to a depth of 11 feet.

Test 3A. The apron was reduced in length by an additional 30 feet, so that its downstream end was now at Station 43+40. The cofferdam was placed in position to the right of the spillway, Figure 2, with a flat top at elevation 490. A 4-hour test with a discharge of 175,000 cfs and ultimate tailwater conditions gave more severe scour than that with the 130-foot apron--particularly in the corner formed by the right training-wall and the cofferdam, where the end of the training-wall was exposed for a depth of 19 feet, Figure 7.

Test 3B. In Test 3B, an attempt was made to lessen the scour at the end of the right training-wall by installing a 45° wall to connect the downstream end of the training-wall with the inner face of the cofferdam. In a test similar to Test 3A, the scour in the corner was reduced approximately by 8 feet, Figure 8.

These tests indicated that a horizontal apron length of 100 feet was ample protection against dangerous erosion if the cofferdam cells are also used. However, it was believed that further improvement might be obtained with a more efficient type of end sill. Four sill designs were tested, all on the 100-foot apron with a discharge of 175,000 cfs and ultimate tailwater conditions. In each case, the model was run for 4 hours and the results photographed.

Sill A was a dentated sill--the same as used in all tests to determine apron length. The dentil was 14 feet high with a vertical upstream face and a downstream face sloping at 45°, Figure 1. Widths of spaces and dentils were the same. Tests of this sill, Test 3B, indicated that the maximum scour would be approximately 22 feet below the level of the stilling-basin and that the downstream face of the apron cutoff wall would be exposed to a depth of 11 feet, Figure 8.

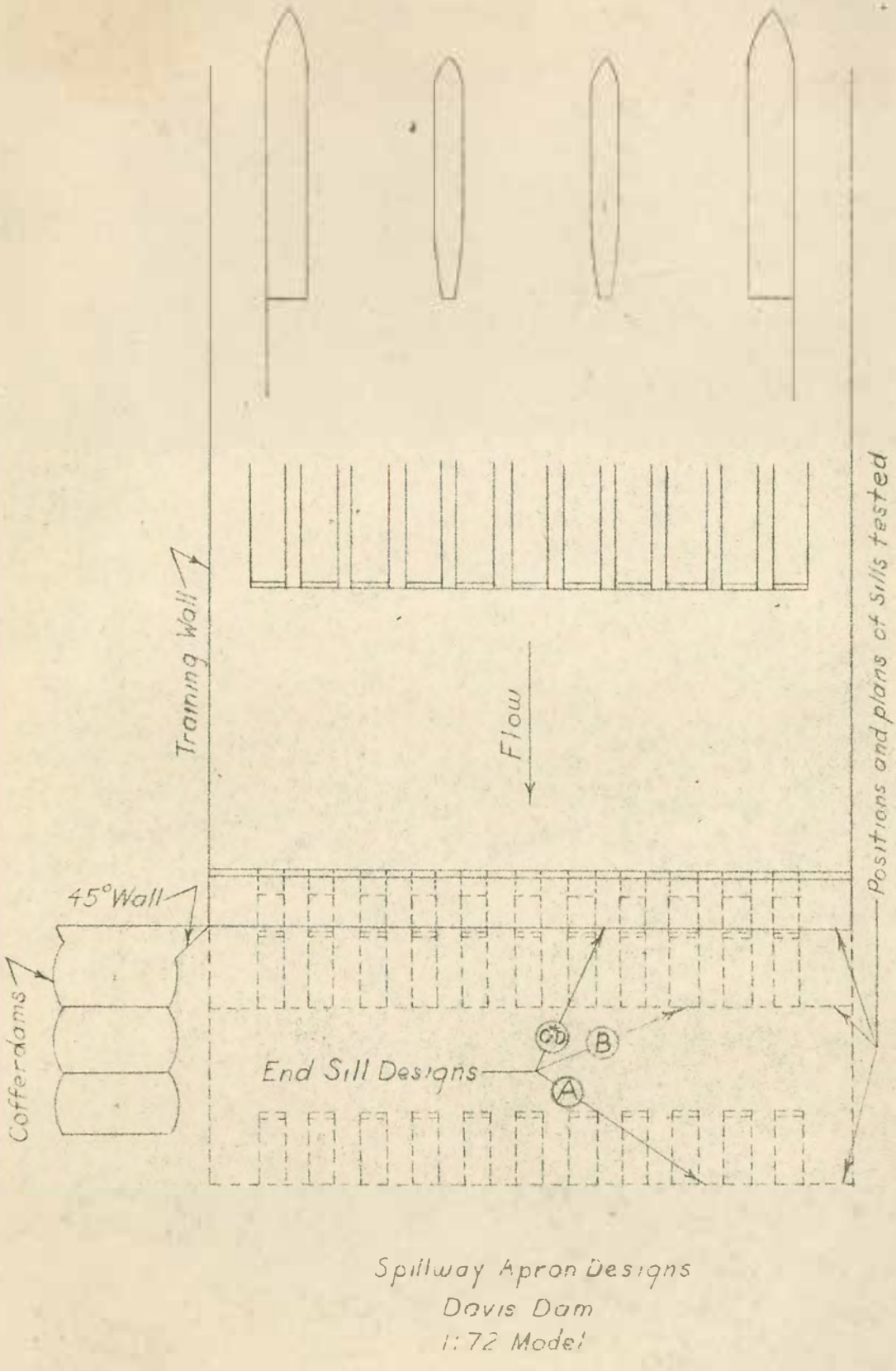
Sill B was similar to Sill A except that a 45° slope was substituted for the upstream vertical face of Sill A, Figure 1. After testing, the depth of scour at the end of the cofferdam was 3 feet less for this design than with Sill A, but 36 feet of the downstream end of the cofferdam was exposed, as compared with 27 feet for Sill A, Figure 9. Surface velocities at the end of the pool were noticeably higher than with Sill A.

Sill C was a solid sill, 20 feet high, with a vertical upstream face and a sloping downstream face, Figure 1. A test using this sill indicated a somewhat better scour pattern than previously tested designs produced. Very little of the downstream face of the cutoff wall was exposed. A hole, 7 feet below apron elevation, scoured in the corner between the cofferdam and right training-wall, Figure 10. The point of maximum scour was further downstream than with either Sills A or B. One objectionable feature of this design, however, was that it caused a high boil at the end of the apron, resulting in a rough wave pattern below the stilling-basin, Figure 11.

In an effort to obtain smoother surface flow and still keep the erosion as small as possible, Sill D was designed and tested. Sill D was also 20 feet high and similar to Sill C but was a dentated sill, Figure 1. Of all the designs tested, this produced the best scour pattern. There was no tendency to undermine the apron, and there was no scour at the base of the end sill. The maximum scour was 24 feet below apron level but was located approximately 70 feet downstream from the end of the apron, Figure 12. The water surface, Figure 13, below the stilling-basin was smoother than for Sill C and this, in combination with the scour pattern, made Sill D the best design tested.

The main erosion problem during these tests was in the vicinity of the cofferdam and right training-wall as already described. Very little consideration was given to the possible effects of erosion at the end of the left training-wall since it was believed by the designers that the material composing the left bank was of a more stable nature and would not be so easily eroded. While the tests were in progress, however, the question arose as to whether this left bank material was as stable as it was originally thought to be. Velocity measurements made in this area indicated a maximum velocity of 6.1 feet per second, and some erosion of the fine sand in the model left bank was evident. The depth and extent of the erosion varied with the type of sill and apron, but in any case the erosion was not considered extremely serious. However, when the tests on the final design for the apron and right training-wall are made, further tests can be made to determine the amount and type of protection necessary along the left bank.

FIGURE 2



Spillway Apron Designs
Davis Dam
1:72 Model

Figure 2. Location of cofferdam and water velocities with Sill D and 100-foot apron.

DAVIS 1:72
DD-225
454
450
443
497
483
H-643-213

Figure 3. Test 1--Apron length 166 feet. Scour after 3 hours' operation with a prototype discharge of 175,000 cfs. Ultimate tailwater conditions.

DAVIS 1:72
DD-239
500
475
38
450
51
H-643-227

Figure 4. Test 2A—Apron length 130 feet. Scour after 4 hours' operation, discharge of 175,000 cfs. Ultimate tailwater conditions.

Sta. 43 + 70
Flow
H-643-228A

Figure 5. Test 2A--Eddy at right of spillway. It is believed this eddy is responsible for most of the severe scour at the end of the apron shown in Figure 4.

DAVIS 1:72
DD-259
500
470
490
462
453
475
450
446
457
H-643-247

Figure 6. Test 2B--Apron length 130 feet with contractor's cofferdams in place. Scour after 2 hours, discharge 175,000 cfs, ultimate tailwater conditions.

6

DAVIS SP'Y
H-643-263
511
500
475
482
490
462
446
441
450
438

Figure 7. Test 3A--Apron length 100 feet. Scour after 4 hours, discharge 175,000 cfs, with ultimate tailwater conditions. Notice scour in corner formed by right training-wall and cofferdam.

DAVIS SPY
H-643-264
511
490
463
449
450
450
435
453

Figure 8. Test 3B, Sill A--Apron length 100 feet. Forty-five-degree wall installed to connect right training-wall and cofferdam. Scour after 4 hours, discharge 175,000 cfs, ultimate tailwater condition.

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DAVIS SP'Y
H-643-267
12
490
454
452
432

Figure 9. Sill B--Apron length 100 feet in place. Scour after 4 hours, discharge 175,000 cfs, ultimate tailwater condition.

515
500
475
450
DAVIS SP'Y
H-643-268
490
448
453
445
435
455

Figure 10. Sill C—Apron length 100 feet in place. Scour after 4 hours, discharge 175,000 cfs, ultimate tailwater condition.

DAVIS SPIY
H-643-270

Figure 11. Sill C--Apron length 100 feet. Operation with discharge of 175,000 cfs. Notice high boil at end of training-wall caused by high continuous sill.

516
500
475
490
452
460
452
450
436

Figure 12. Sill D--Apron length 100 feet. Scour after 4 hours, discharge 175,000 cfs, ultimate tailwater condition. Note absence of scour in front of 45° wall and along end of apron.

DAVIS SP'Y
H-643-273

Figure 13. Sill D--Apron length 100 feet. Operation with discharge of 175,000 cfs. Note relatively smooth flow leaving apron.