HYDRAULIC MODEL STUDIES ON THE
SPILLWAY FOR CASCADE DAM
BOISE PROJECT

Hydraulic Laboratory Report Hyd.-234

ENGINEERING AND GEOLOGICAL
CONTROL AND RESEARCH DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

NOVEMBER 7, 1947
List of Figures

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location Map--Cascade Dam</td>
</tr>
<tr>
<td>2</td>
<td>General Plan and Sections--Cascade Dam</td>
</tr>
<tr>
<td>3</td>
<td>Recommended Design--Cascade Dam</td>
</tr>
<tr>
<td>4</td>
<td>Original Design--Spillway</td>
</tr>
<tr>
<td>5</td>
<td>Recommended Design--1:30 Scale Model</td>
</tr>
<tr>
<td>6</td>
<td>Approach to Spillway--1:30 Model</td>
</tr>
<tr>
<td>7</td>
<td>Approach to Spillway--12,500 second-feet</td>
</tr>
<tr>
<td>8</td>
<td>Spillway Discharge Curves--Crest Elevation 4808</td>
</tr>
<tr>
<td>9</td>
<td>Spillway Discharge Curves--Crest Elevation 4823</td>
</tr>
<tr>
<td>10</td>
<td>Water Surface Profiles--Low Crest--Left Gate Open</td>
</tr>
<tr>
<td>11</td>
<td>Water Surface Profiles--Low Crest--Both Gates Open</td>
</tr>
<tr>
<td>12</td>
<td>Water Surface Profiles--Low Crest--Left Gate Open</td>
</tr>
<tr>
<td>13</td>
<td>Water Surface Profiles--Low Crest--Both Gates Open</td>
</tr>
<tr>
<td>14</td>
<td>Straight Chute Outlet--Discharge 12,500 second-feet</td>
</tr>
<tr>
<td>15</td>
<td>Straight Chute Outlet--Discharge 12,500 second-feet</td>
</tr>
<tr>
<td>16</td>
<td>Curved Chute Outlet--Discharge 12,500 second-feet</td>
</tr>
<tr>
<td>17</td>
<td>Diffuser Bucket Details</td>
</tr>
<tr>
<td>18</td>
<td>Operation of Original Diffuser Bucket--12,500 second-feet</td>
</tr>
<tr>
<td>19</td>
<td>Recommended Diffuser Bucket Trajectories</td>
</tr>
<tr>
<td>20</td>
<td>Recommended Bucket Operation--Low Discharge</td>
</tr>
<tr>
<td>21</td>
<td>Recommended Bucket Operation--2,500 second-feet</td>
</tr>
<tr>
<td>22</td>
<td>Recommended Bucket Operation--5,000 second-feet</td>
</tr>
<tr>
<td>23</td>
<td>Recommended Bucket Operation--7,500 second-feet</td>
</tr>
<tr>
<td>24</td>
<td>Recommended Bucket Operation--10,000 second-feet</td>
</tr>
<tr>
<td>25</td>
<td>Recommended Bucket Operation--12,500 second-feet</td>
</tr>
</tbody>
</table>
Subject: Hydraulic model studies on the spillway for Cascade Dam—Boise Project.

SUMMARY

Model studies of the Cascade Spillway were made to investigate flow conditions in the spillway approach, the gate section, the chute, and the stilling-pool, and to modify the structure where necessary to provide an economical and satisfactorily operating structure.

The hydraulic model studies indicated that the approach to the spillway gave satisfactory though somewhat unsymmetrical flow conditions. Both the high and the low crest designs will pass slightly more than the required discharges. Changes in the slope and width of the chute are recommended in order to improve flow conditions. A diffuser-type bucket energy dissipator was found to give the required protection to the Pacific Power Company's wood stave penstock.

DESCRIPTION OF THE PROJECT

The Cascade Dam, Boise Project, Idaho, is located on the North Fork of the Payette River near Cascade, Idaho, as shown on the location map, Figure 1. The earthfill dam will be approximately 800 feet long at the crest with a maximum height of 80 feet above the riverbed. The open channel spillway is to be located on the right abutment of the dam. The spillway flow, 12,500 second-feet maximum, will be controlled by two 21- by 20-foot radial gates. Flow through the low level outlets, 2,800 second-feet maximum, will be controlled by two 5-foot square high-pressure slide gates. The general plan of the project is shown in Figure 2.

DESCRIPTION OF THE MODEL

The Cascade Spillway model was constructed in the Hydraulic Laboratory at the Denver Federal Center to a scale of 1 to 30. The model layout, recommended design, is shown in Figure 3. The original model was designed and constructed according to the plan and sections
of the spillway shown in Figure 4. Photographs of the model, recommended design, are shown in Figure 5. In the original design the crest was at elevation 4808 with normal reservoir at elevation 4828. A proposed future addition to the project is a high crest at elevation 4823 which will raise the normal reservoir to elevation 4843. The same radial gates will be used on both the high and the low crest.

THE INVESTIGATION

The Spillway Approach

The approach to the spillway is slightly unsymmetrical as indicated in Figure 4. This results in somewhat unsymmetrical flow conditions in the chute. This condition is minor in nature and no change in the approach is recommended. The approach in the model for the high and low crests, is shown in Figure 6. Flow in the approach section, high and low crests, is shown in Figure 7 for the maximum discharge of 12,500 second-feet.

The Gate Section

The coefficient of discharge used for the design of the low crest was 3.33. Model calibration showed the coefficient to be 3.40. The coefficient of discharge for the high crest with the reservoir at elevation 4843 was found by model calibration to be 3.67. Both crests will therefore pass somewhat more than the required discharges. Discharge curves for the low crest are given in Figure 8 and for the high crest in Figure 9.

The Chute

Two chute designs were tested in the model. In the original design, Figure 4, the principal slope of the chute floor was 0.373. The chute width decreased from 45 feet at Station 3/19.81 to 20 feet at Station 4/75.00 with the 20-foot width continuing to the end of the chute, Station 5/55.00. In the revised design, Figure 3, the principal slope of the chute floor was increased to 0.463, and the convergence of the chute walls was decreased from that in the original design. The chute width decreased from 45 feet at Station 3/19.81 to 20 feet at the end of the chute, Station 5/55.00. Both the increased slope and the increased width in the central portion of the chute contributed to the smoother flow conditions observed in model operation of the revised design. Water surface profiles in the final chute design for both the high and low crests with one and two gates open are shown in Figures 10, 11, 12, and 13. Figures 11 and 13 show the slightly unsymmetrical flow in the chute resulting from the unsymmetrical approach to the spillway.

The Stilling-Pool

General. The primary consideration for satisfactory operation of the stilling-pool is the protection of the 72-inch wood stave penstock
of the Pacific Power Company located across the river from the spillway, Figures 2 and 5. Three types of chute outlets were tested in the model. Straight and curved chute outlets did not give adequate protection to the penstock. A diffuser bucket gave satisfactory results.

Straight chute outlet. Straight chute outlets at elevation 4745.0 and 4751.5 were tested in the model. Figure 4 shows the details of the outlet at elevation 4745.0. In both cases the jet from the spillway crossed the river and climbed the opposite riverbank with practically no dissipation of energy. Model operation is shown in Figures 14 and 15.

Curved chute outlets. In an attempt to keep the spillway jet away from the penstock, numerous curved chute outlets were tried. The curved outlets were successful in keeping the jet along the right bank but resulted in extremely rough surface conditions at the railroad bridge downstream, and a very damaging upstream eddy over the penstock. These unsatisfactory flow conditions are shown in Figure 16.

Attempts were made, using the curved chute outlet, to direct the flow down the center of the river, and thus avoid the damaging upstream eddies. The jet, directed to the center of the river, was unstable. It either swung across the river and climbed the bank over the penstock, or it followed the right bank causing an upstream eddy along the left bank and the penstock. Even for the brief periods that the jet stayed in the center of the river, flow conditions were very rough.

Diffuser bucket. A diffuser-type-bucket outlet gave satisfactory flow conditions. Disturbances in the vicinity of the penstock were at a minimum and flow downstream in the river was smooth. All diffuser buckets tests were made with the chute outlet at elevation 4745.0. The first diffuser bucket, Figure 17, extended 30 feet downstream to Station 5781.5 and was 10 feet high. Model operation is shown in Figure 18. Observation of this operation indicated that the jet should have a greater spread with a shorter trajectory in order to give maximum protection to the penstock.

To accomplish this result, the following items were changed as indicated:

1. The base width of the chute at the outlet was increased.
2. The length of the lip of the diffuser bucket was increased.
3. The height and steepness of the lip of the bucket was increased.
4. The length of the bucket from the end of the chute was decreased.
5. The side slopes were adjusted.

From a series of tests incorporating the above changes, the recommended design of diffuser bucket was evolved, Figure 17. The recommended bucket extended 20 feet downstream to Station 5771.5 and
was 12.5 feet high. This bucket spread the jet and shortened the trajectory giving satisfactory protection to the penstock. The trajectory of the jet for various discharges is shown in Figure 19. For small discharges, the bucket acts as a stilling-pool. The flow washes out of the bucket at a discharge of about 2,700 second-feet, Figure 20. As the flow is decreased, the stilling-pool action again starts at a discharge of about 1,300 second-feet. Model operation of the diffuser bucket, recommended design, is shown in Figure 5B, and 21 through 25.
CASCADE DAM
1:30 SCALE HYDRAULIC MODEL
RECOMMENDED DESIGN
A. Model - Ready for operation

B. One gate discharging 6,250 second-feet

CASCADE DAM 1:30 MODEL RECOMMENDED DESIGN
A. Low Crest - Elevation 4808
  Gates in lowered position

B. High Crest - Elevation 4823
  Gates in raised position

CASCADE DAM 1:30 MODEL
APPROACH TO THE SPILLWAY
A. Low Crest

B. High Crest

CASCADE DAM 1:30 MODEL
APPROACH TO THE SPILLWAY
12,500 SECOND-FEET THROUGH TWO GATES
CASCADE DAM
DISCHARGE CURVES
FROM CALIBRATION OF 1:30 SCALE MODEL
TWO GATES - UNIFORM OPENINGS
LOW CREST - ELEVATION 4808
CASCADE DAM
DISCHARGE CURVES
FROM CALIBRATION OF 1:30 SCALE MODEL
TWO GATES - UNIFORM OPENINGS
HIGH CREST - ELEVATION 4823
EXPLANATION

- Profile along left side of chute
- Profile along center line of chute
- Profile along right side of chute

SPILLWAY PROFILE

STATION 3+45

STATION 4+41

STATION 5+17

STATION 5+46

CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES
IN RECOMMENDED CHUTE DESIGN
HIGH CREST-BOTH GATES OPEN

NOTE
Transverse section taken normal to chute floor looking downstream.
EXPLANATION

Profile along left side of chute
Profile along center line of chute
Profile along right side of chute

SPILLWAY PROFILE

STATION 3+45

STATION 3+88

STATION 4+41

STATION 5+17

STATION 5+46

CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES
IN RECOMMENDED CHUTE DESIGN
LOW CREST—BOTH GATES OPEN
MODEL SCALE: 1:30; DISCHARGE: 12,500 S.F.

NOTE
Transverse section taken normal to chute 11.4 cm looking downstream.
EXPLANATION
- Profile along left side of chute
- Profile along center line of chute
- Profile along right side of chute

SPILLWAY PROFILE

STATION 3+45

STATION 4+41

STATION 5+17

STATION 5+46

GASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES
IN RECOMMENDED CHUTE DESIGN
HIGH CREST-LEFT GATE OPEN
MODEL SCALE 1:30- DISCHARGE 6,250 C.F.

NOTE
Transverse section taken normal to chute floor
looking downstream.
EXPLANATION
--- Profile along left side of chute
- Profile along center line of chute
- Profile along right side of chute

SPILLWAY PROFILE

STATION 3+45

STATION 3+88

STATION 4+41

STATION 5+17

STATION 5+46

CASCADE DAM SPILLWAY
EXPERIMENTAL WATER SURFACE PROFILES
IN RECOMMENDED CHUTE DESIGN
HIGH CREST-BOTH GATES OPEN
MODEL SCALE 1:30 - DISCHARGE 12,500 S.F.

NOTE
Transverse section taken normal to chute floor looking downstream.
A. Straight Chute Outlet - Elevation 4745.0

B. Straight Chute Outlet - Elevation 4751.5

CASCADE DAM 1:30 MODEL
12,500 SECOND-FEET
A. Straight Chute Outlet in Operation

B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
12,500 SECOND-FEET
A. Curved Chute Outlet in Operation

B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
12,500 SECOND-FEET
ELEVATION-ORIGINAL DESIGN

ELEVATION-RECOMMENDED DESIGN

PLAN-ORIGINAL DESIGN

PLAN-RECOMMENDED DESIGN

CASCADE DAM
1:30 SCALE HYDRAULIC MODEL
DIFFUSER BUCKET DETAILS

FIGURE 17
A. Discharge - 5,000 Second-feet

B. Discharge - 12,500 Second-feet

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - ORIGINAL DESIGN
A. Diffuser Bucket Discharging Approx. 2,500 Second-feet. The Jet is approaching the washout stage.

B. Diffuser Bucket Discharging 2,700 Second-feet. The Jet has just washed out of the bucket.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN
A. Diffuser Bucket Discharging 2,500 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge.
A. Diffuser Bucket Discharging 5,000 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN
A. Diffuser Bucket Discharging 7,500 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN
A. Diffuser Bucket Discharging 10,000 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge.

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN
Diffuser Bucket Discharging 12,500 Second-feet.

B. Resulting Flow Conditions at the R.R. Bridge

CASCADE DAM 1:30 MODEL
DIFFUSER BUCKET - RECOMMENDED DESIGN