Travel to Deer Creek Dam and Powerplant
Travel to Deer Creek Dam and Powerplant to discuss tube valve replacement and potential impacts to the existing tailrace

Date(s) of Travel: August 1 – 2, 2017
To: Manager, Hydraulic Investigations and Laboratory Services Group  
From: Josh Mortensen, Hydraulic Engineer  
Subject: Site visit to Deer Creek Dam and Powerplant to discuss tube valve replacement and potential impacts to the existing tailrace.

1. Travel period: 1 – 2 August 2017

2. Places or offices visited: Deer Creek Dam and Powerplant

3. Purpose of trip: Flow through the outlet works at Deer Creek Dam and Powerplant is regulated by two 52-inch tube valves that have been in service since the 1940’s. Given the age and O&M issues with these valves, preparations are being made to replace them with a modern valve design [1]. The main purpose of this site visit was to observe one of the valves and tailrace in operation and to discuss potential impacts to existing operations from valve design alternatives with personnel from the Provo Area Office and Provo River Water User’s Association (PRWUA). This Trip Report, which discusses the matter from a hydraulic perspective, will be submitted concurrently with a separate Trip Report from Wes Bower with a focus on the mechanical design of the replacement alternatives.

4. Synopsis of trip: On August 1st Josh Mortensen travelled with Wes Bower (86-68420) to Heber City, UT. On August 2nd they met with personnel from Reclamation’s Provo Area Office and PRWUA. The group toured various facilities, some owned and operated by Central Utah Water Conservancy District (CUWCD), to observe existing plunger valves in operation. While these observations were helpful, it should be noted that valves in these facilities were not in the same configuration planned for Deer Creek (in-line rather than free discharge) and that there is no more than six years of operating experience which makes it difficult to predict the longevity of this valve design. The final stop was a tour of the Deer Creek Powerplant to see the tube valves and tailrace (also referred to as plunge basin). Following the site visit and discussion with the Provo Area Office, PRWUA and their contractors, Josh and Wes returned to the Salt Lake International Airport and then flew back to Denver.

In replacing the tube valves with a different valve design, the main hydraulic question is “What impacts will a new valve design have on the existing plunge basin?” The three main design alternatives under consideration are plunger valves, jet-flow gates, and fixed cone valves [1]. The concern is that the discharge characteristics of the impinging jet from a different valve design,
such as a jet-flow gate with a smaller diameter and greater velocity for example, will increase scour in the downstream plunge basin that was not designed to dissipate energy from such a valve. The main question is addressed from both a historical and analytical approach in an attempt to draw relevant conclusions and recommendations.

First, there are no design or as-built drawings available of the outlet works and plunge basin so assumptions had to be made. Bathymetry data of the plunge basin are available from a survey performed in 2000 as part of the construction of the intake for the Salt Lake Aqueduct. A physical model study of the outlet works and plunge basin was conducted in 1937 prior to construction [2], which provided a drawing of the recommended design at model scale (Figure 1). It is assumed that the existing plunge basin was constructed according to the recommended design based on a comparison of the dimensions from the scaled up model drawing, the 2000 survey data, and Google Earth (Figures 1 and 2).

The 1937 model study was performed assuming 48-inch needle valves would be installed at Deer Creek and testing focused on velocity currents throughout the basin, wave action, as well as scour and riprap movement [2]. However, model valves corresponding to 56-inch needle valves were used in actual model testing due to their immediate availability at that time and results were assumed valid for the smaller 48-inch valves. This assumption, while likely valid, certainly provides results that are less conservative due to lower jet velocities with a 56-inch valve entering the plunge basin. The final recommended design for the plunge basin was considered satisfactory for all operating conditions of two 48-inch needle valves up to 796 ft³/s each. It should be noted that “satisfactory” from the model report does not mean “completely scour free” and that some scour would be expected.

In addition, Reclamation experience indicates that the discharge characteristics of a water jet exiting from a jet-flow gate are similar to those of a needle valve and the two could be used interchangeably when considering energy dissipation [3]. Assuming this similarity of jet-flow gates and needle valves to be true, and based on results from the 1937 model study, it is unlikely that discharge from a different valve design would have additional impacts to the plunge basin beyond that of the existing tube valves.

An attempt was made to estimate scour in the plunge basin for both a 52-inch tube valve and a 47-inch jet-flow gate [1]. Calculations were made based on a Reclamation Hydraulics Lab study of plunge basins in 1974 [4]. Table 1 compares jets from the two designs based on information from Figures 3 and 4. Actual scour quantities were not attainable as the dimensions and operation of Deer Creek were outside the study parameters. However, this effort resulted in two findings that suggest the existing plunge basin adequately limits scour for both existing and alternative valve designs. First, the ratio of the total energy head to the tailwater depth, \((Hv+Y)/T\), for both valves are in a range of 3.5 to 5 that typically results in minimal scour (Figure 4). This assumed a worst case of 750 ft³/s each at a minimum tailwater elevation of 5,273.4 ft. Second, the study found that shallow jet impingement angles (flatter than 25°, see Figure 3) did not cause scour but rather produced surface waves that could be significant. These findings are supported by data from the 2000 survey that shows a scour hole that is only about 4-ft deep (Figure 2). A new survey is needed to provide updated information.
For the Deer Creek plunge basin, surface waves may be more of a concern than scour, based on jet impingement angles less than 25° and recent observations of plunge basin operation. Although a concern, history has indicated that the plunge basin has performed well. The same report that documented the physical model study also included observations of prototype tests conducted in 1946 following construction. These tests showed the operation of the plunge basin to be “very satisfactory” and that the condition of the riprap was “considered to be good” (Figure 5). Testing was made with total flows up to 1,000 ft³/s (see photos in Figures 6 - 11). Neither the physical model nor prototype tests mentioned concerns with surface waves.

Results and observations from these prototype tests definitely add confidence to the design and operation of the existing plunge basin. However, it should be noted that prototype discharges never reached the design discharge of 1,500 ft³/s and that results from both prototype and model testing do not account for impacts to the downstream gate structure or intake to the Salt Lake Aqueduct. The generation and impact of surface waves are difficult to predict and would require a more intensive investigation such as a numerical or physical model study.

5. Conclusions and Recommendations:
   - It is unlikely that any of the alternative valve designs (plunger, jet-flow gate, or fixed cone) will have a greater impact on scour of the plunge basin compared to the existing tube valves. Any of the proposed valve designs are expected to be acceptable with regard to scour in the plunge basin based on a review of available information.

   - In general, the tailrace provides sufficient energy dissipation for a combined discharge of 1,500 ft³/s with acceptable scour limits in the main plunge basin.

   - A survey of the existing plunge basin is recommended to give an accurate assessment of scour. Updated information will help confirm the true performance of the plunge basin as well as provide a baseline for future operations of the new valve design. The survey could be conducted either in the dry or in the wet. TSC hydraulics group, as well as others, have capabilities for bathymetric surveys.

   - Surface waves generated by the shallow impingement angle of the valves are the greatest concern for the integrity of the plunge basin, which now includes the downstream gate structure and intake to the Salt Lake Aqueduct. It could not be determined if a different valve design would further influence the impacts from surface waves. A more intensive investigation, likely requiring numerical or physical modeling, would be needed to predict impacts from surface waves.

6. Action correspondence initiated or required: N/A

7. Client feedback received: N/A
8. REFERENCES


cc:

Gary Carlson (PRO-332)
Kent Kofford (PRO-105)
Wes Bower (86-68420)
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Travel to: Deer Creek Dam and Powerplant

Dates of Travel: 1 – 2 August 2017

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Figure 1 Drawing of recommended plunge basin design from 1937 physical model study. Dimensions are at model scale (1:20).
Figure 2  Survey from 2000 showing bathymetry data of plunge basin. Provided by Bowen, Collins & Associates.
Figure 3  Schematic of parameters used in calculations in Table 1 and Figure 4 from 1974 lab studies of scour in plunge basins.

Table 1  Calculations used to estimate scour hole dimensions from Figures 3 and 4. Values from Deer Creek were outside the test parameters of the study but calculations indicated scour would be minimal due to lower levels of total head and shallow impingement angles of the jet entering the tail water.

<table>
<thead>
<tr>
<th>Units</th>
<th>Description</th>
<th>52&quot; TUBE VALVE*</th>
<th>47&quot; JET-FLOW GATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL. Outlet = 5280</td>
<td>5280</td>
<td>ft</td>
<td>Center Line of discharge valve</td>
</tr>
<tr>
<td>EL. Tailrace = 5260</td>
<td>5260</td>
<td>ft</td>
<td>Invert of plunge basin</td>
</tr>
<tr>
<td>Djet = 52</td>
<td>47</td>
<td>inch</td>
<td>Diameter of water jet from valve</td>
</tr>
<tr>
<td>Ajet = 14.75</td>
<td>12.05</td>
<td>ft²</td>
<td>Area of water jet</td>
</tr>
<tr>
<td>Do = 3.84</td>
<td>3.47</td>
<td>ft</td>
<td>Equivalent jet dimension</td>
</tr>
<tr>
<td>Q = 750</td>
<td>750</td>
<td>ft³/s</td>
<td>Maximum discharge</td>
</tr>
<tr>
<td>V = 50.9</td>
<td>62.2</td>
<td>ft/s</td>
<td>Jet velocity</td>
</tr>
<tr>
<td>Z = 20</td>
<td>20</td>
<td>ft</td>
<td>Outlet to plunge basin invert</td>
</tr>
<tr>
<td>EL. T.W. = 5273.4</td>
<td>5273.4</td>
<td>ft</td>
<td>Min. plunge basin water surface elev.</td>
</tr>
<tr>
<td>Y = 6.6</td>
<td>6.6</td>
<td>ft</td>
<td>Drop from outlet to water surface</td>
</tr>
<tr>
<td>T = 13.4</td>
<td>13.4</td>
<td>ft</td>
<td>Plunge basin depth</td>
</tr>
<tr>
<td>Hv = 40.2</td>
<td>60.2</td>
<td>ft</td>
<td>Velocity head</td>
</tr>
<tr>
<td>(Hv+Y)/T = 3.49</td>
<td>4.98</td>
<td>-</td>
<td>Total Head to water depth ratio</td>
</tr>
<tr>
<td>Hv/Y = 6.08</td>
<td>9.12</td>
<td>-</td>
<td>Velocity head to drop ratio</td>
</tr>
<tr>
<td>θ = 22.07</td>
<td>18.32</td>
<td>deg</td>
<td>Jet impingement angle</td>
</tr>
</tbody>
</table>

*Assumed that discharge characteristics of plunge valve jets are similar to tube valves. Fixed-cone valve not included as it is assumed more conservative with a larger jet diameter.
Figure 4  Plot from 1974 lab study to estimate the scour depth (Ds) using dimensionless parameters of the total energy head from the jet. Y-axis is the ratio of total head to tailwater depth, (Hv+Y)/T, and the x-axis is the ratio of scour depth to equivalent jet diameter (Ds/Do). Curves indicate ratio of velocity head to vertical drop (Hv/Y).

Operating range of Deer Creek based on total head (y-axis). Scour depth (Ds) unable to be estimated as Hv/Y curves were outside the range considered in the study. This is due to small values of the drop (Y) which corresponds with shallow impingement angles.
PART II PROTOTYPE TESTS

Prototype Operations

On May 15, 1946, an opportunity was found to observe and photograph the operation of the tube valves and stilling-basin. Fifty-two-inch tube valves had been installed in the prototype instead of the 48-inch needle valves shown on the prototype drawings in this report. Reference is made to a letter from the Construction Engineer at Provo, Utah, to the Chief Engineer, Branch of Design and Construction, Denver, dated June 17, 1946, which states:

"The operation of the outlet works stilling-basin has proved to be very satisfactory. Under all conditions of operation the major part of turbulence of the water was found to occur in the stilling-basin, and the turbulence occurring in the channel which leads from the stilling-basin to the river was not considered to be excessive. It has been found from past operations that the operation of one tube valve at high rate of discharge causes a circular swirling motion of the downstream portion of the stilling-basin. Whenever possible all discharge into the stilling-basin is divided equally through the two tube valves.

"The present condition of the riprap in the stilling-basin and stilling-basin channel is considered to be good with the exception of one small area on the south bank of the basin. This area of riprap sloughed into the stilling-basin after a concentration of surface drainage water had eroded the bank upon which the riprap had been placed. The concentration of the drainage water resulted from a spring storm of short but intense duration which clogged a culvert underneath the highway on the side hill immediately above the stilling-basin. The necessity of discharging water into the stilling-basin through only one tube valve during the time that the storm occurred further aggravated this condition. Repair work to the area of riprap is being made at the present time."

Figures 23 to 26 illustrate the operation of the tube valves and the stilling-basin.

Figure 5 Quote from a letter describing the 1946 prototype tests of the outlet works and plunge basin. Notice the recommendation to operate both valves with equal discharge whenever possible to avoid swirling flows in the plunge basin.
Figure 6. Photo from 1946 test. Left tube valve discharging about 500 ft³/s.
Figure 7  Photo from 1946 test. Left tube valve discharging 700 ft\(^3\)/s and right tube valve discharging 50 ft\(^3\)/s.
Figure 8  Photo from 1946 test. Both tube valves discharging 500 ft³/s each.
Figure 9  Photograph from 1946 test. View is from the right bank near the end of the plunge basin looking downstream. Total discharge is 1,000 ft³/s.
Figure 10  Photograph from Aug. 2, 2017 site visit. View is approximately the same as Figure 9. Total discharge is about 605 ft³/s (500 ft³/s from powerplant and 105 ft³/s from left tube valve).

Figure 11  Photograph from Aug. 2, 2017 site visit. Left tube valve discharging 105 ft³/s.