Wheatland Irrigation District Tunnel
Dam Rehabilitation, Level II Study
Executive Summary of the Final Report

August 1, 2018

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This document is released under the authority of Skylor W. Wade, P.E. on August 1, 2018.

Skylor W. Wade, P.E. Associate
1.0 Introduction

In June 2017, the Wyoming Water Development Commission (WWDC) contracted with the team lead by Wenck Associates, Inc. (Wenck) to perform the Wheatland Irrigation District Tunnel Dam Rehabilitation, Level II Study. This study was performed at the request of the sponsor; the Wheatland Irrigation District, and under the direction of the Wyoming Water Development Office. Team members included: Deere & Ault Consultants, Inc., M.C. Schaff and Associates, Inc., and Panhandle Geotechnical & Environmental.

In April 2011, the Wheatland Irrigation District Master Plan, Level I Study was completed. This master plan developed a list of recommended improvements to Wheatland Irrigation District’s (WID) existing facilities and infrastructure. One recommendation from the master plan was to rehabilitate Tunnel Dam. This report presents the results of the rehabilitation study for Tunnel Dam. This feasibility study includes a review of existing information, and engineering and geotechnical evaluation of the diversion structure, rehabilitation plan, preliminary design, cost estimates, economic analysis, and environmental and permitting requirements associated with the rehabilitation of Tunnel Dam.

1.1 HISTORY AND DESCRIPTION OF WHEATLAND IRRIGATION DISTRICT

The WID spans three counties in southern Wyoming: Carbon, Albany, and Platte. Its history spans Wyoming statehood and its accomplishments represent several ‘firsts’ for the State. Initial surveys of the Wheatland Flats began in 1881 followed by the incorporation of the Wyoming Development Company in 1883: the first actual irrigation corporation within the Territory of Wyoming. By 1886 the Bluegrass Tunnel and portions of the canal system on the Wheatland Flats were completed. These construction efforts were soon followed by completion of Wheatland Reservoir No. 1 and its supply canal (1896), Wheatland Reservoir No. 2 and Tunnel Dam (1901). In 1932, The Wheatland Irrigation System was formed as a public entity in order to pursue public funding of Wheatland Reservoir No. 3. That reservoir was eventually completed in 1943 (Anderson Consulting Engineers, Inc., 2011).

In 1947 the Wheatland Irrigation System was incorporated as the Wheatland Irrigation District and organized under Wyoming State Statutes as a public entity. The WID incrementally grew to its current size and infrastructure. Today, the WID infrastructure includes eleven reservoirs with total storage rights of approximately 180,000 acre-feet and water rights on 10 streams. The general configuration of the WID’s primary delivery system is displayed on Figure 1-1. Water is initially stored in Sand Lake, located in the Medicine Bow Mountains within Carbon County. Water released from the lake is conveyed via Rock Creek to the Canon Canal headgate. This portion of the system represents the first legal trans-basin diversion in the State of Wyoming. Once in the Canon Canal, flows are conveyed to Dutton Creek, diverted again at the Dutton Canal headgate and ultimately delivered to the Laramie River and Wheatland Reservoirs No. 2 and 3. Storage released from the reservoirs into the Laramie River is diverted downstream at the Tunnel Dam into Bluegrass Tunnel. Flows are finally conveyed via Blue Grass Creek and Sybille Creek to the WID’s main canal headgates. Once in the main canal and conveyance system, water is ultimately delivered to the farm. WID provides irrigation water for approximately 54,100 acres, and the Tunnel Dam is absolutely critical to the delivery of water to much of the District (Anderson Consulting Engineers, Inc., 2011). The Tunnel Dam structure is located on land owned by the State of Wyoming, and the reservoir inundates portions of land owned by Bureau of Land Management, State of Wyoming, and the Wheatland Irrigation District.
Figure 1-1: Wheatland Irrigation District: Location Map

Figure Source: Wheatland Irrigation District Master Plan, Level I: Anderson Consulting, Inc., 2011
2.0 Diversion Structure Assessment

On November 9 and 10, 2017, the project team conducted an engineering and geotechnical evaluation of the structure. The evaluation included a survey of the site, geotechnical investigation, and structural condition assessment.

2.1 SITE SURVEY

A topographic survey of the Tunnel Dam, reservoir and surrounding area was conducted during the site visit and was used to help assess the current capacity of the reservoir and aided in the preliminary design and hydraulic analysis. The survey consisted of surveying all accessible features on the existing Tunnel Dam and tunnel inlet structure, and downstream flume. The boring locations were surveyed as well as several ground targets throughout the site. A drone took aerial photos of the entire site and used the ground targets for photogrammetry. The photogrammetry developed one-foot contour intervals of the entire site. Survey data is in Wyoming State Plane Coordinate System NAD 1983; East Zone.

The topographic survey was used to estimate sediment volume and compare the current reservoir capacity to the design capacity. Based on the topographic survey, the current capacity of the reservoir is 144 acre-feet. Further analysis suggests there is approximately 65,000 cubic yards of sediment deposited in the reservoir, resulting in 40 acre-feet of storage being lost to sediment. This suggests the design capacity of the reservoir is approximately 185 acre-feet. Possible sources of sediment include stream bank erosion during high flow events. There are several ponds and dikes in the Laramie River, below Wheatland Reservoir No. 2 that have breached causing significant bank erosion around the dikes.

2.2 GEOTECHNICAL INVESTIGATION

The geotechnical investigations included reconnaissance level geologic mapping of the site, geomorphic evaluation and feasibility level geotechnical drilling, including laboratory testing and geotechnical analysis. This investigation was performed to support development of three diversion dam alternatives. Alternative 1 would be to rehabilitate the existing diversion structure. Alternative 2 involves building a new diversion dam upstream of the existing dam across the valley near the tunnel. Alternative 3 would consist of a shorter diversion dam located well upstream of the existing structure and an armored levee leading to the tunnel.

2.2.1 Geotechnical Conditions

The geotechnical conditions at the site were investigated by conducting reconnaissance geologic mapping, drilling four exploratory borings and testing soil samples from the borings in the laboratory. To support the investigation, a topographic survey was conducted at the site. Geotechnical borings SB-1 and SB-2 were drilled in the existing embankment dam to provide information for Alternative 1. Boring SB-3 was drilled for Alternative 2 and boring SB-4 was drilled for Alternative 3. Select samples were tested in a laboratory for index and engineering properties. Laboratory test data is shown by depth on the summary logs in the appendix of the final report.
The geotechnical conditions of the site are characterized by reservoir sediment, alluvial deposits and colluvial deposits overlying amphibolite bedrock. The alluvial deposits include at least three levels of terraces and alluvium deposited by the Laramie River. The resulting morphology is a river valley bounded by steep bedrock outcrops. The character of the various soils observed at the site are discussed in more detail in the final report.

The embankment fill (ef) represents the embankment dam. Based on the Unified Soils Classification System, the soils classify as clayey sand (SC) and lean clay with sand (CL). These soils were sampled and tested in the laboratory for index and engineering properties to evaluate the character of the dam. The laboratory testing indicates that the soils have between 47 and 56 percent fines and up to about 3 percent gravel. The Atterberg limits show a liquid limit of about 30 percent and a plasticity index of about 17 percent. One Standard Proctor test performed on the dam fill suggest the optimum moisture content is about 13.5 percent and the maximum dry density is about 114.9 pcf. The natural moisture content of the fill ranges from 15 to 21 percent, the latter value representing the saturated material. The natural dry density ranges from 103 to 109 pcf. The moisture density relationships suggest that the embankment fill is a high-quality material for the embankment dam. Blow counts and moisture content results indicate the soils are saturated, loose and soft below about 15 feet.

2.3 STRUCTURAL CONDITIONS

The existing tunnel diversion dam provides a check across the Laramie River to supply water to the tunnel inlet structure. The diversion is composed of a concrete check structure and an earth embankment across the Laramie River channel.

The existing crest across the concrete dam section has been lowered since the original placement of the concrete. There is roughly a 2-foot drop from the original crest to the existing elevation where the river overtops the dam. The surface is rough in this area and has large aggregate exposed on the surface (Photo 1). There doesn’t appear to be much deterioration of the crest since the work was done to lower the elevation, generally the crest is rough but is in good condition.

Photo 1 –Concrete crest looking toward the concrete abutment walls
On the upstream face of the concrete dam there are noticeable cold joints from the construction of the dam as well as some expansion cracks that have formed over time. The cold joints most likely allow seepage through the dam that could result in water reaching the downstream face of the dam leading to freeze/thaw deterioration. The concrete surface has exposed aggregate that is typical for a structure of this age. There is some evidence of segregation of larger aggregate but generally the upstream face is in good condition.

The concrete surface on the downstream slope of the diversion dam is in poor condition. The downstream slope has a steep 1:1 (H:V) slope from the crest down to the river channel. The surface of the downstream face has been repaired in the past with a concrete overlay ranging from a few inches thick near the dam crest to 8 to 10 inches thick at the bottom near the river water line. It appears the overlay was placed to cover up and protect the existing deteriorated concrete surface. The overlay repair has no reinforcing steel or dowels to anchor the overlay to the existing concrete surface. Currently there are large sections of the concrete overlay that have broken off exposing the original deteriorated concrete surface and steel reinforcement (Photo 2).

The condition of the downstream surface is due to a combination of factors. Most of the damage appears to be from the effects of freeze/thaw deterioration. Additional damage is a result of when the river overtops the dam during high flows. Water discharges over the crest of the dam and drops down the face of the dam exposing the concrete surface to high velocity flow and abrasion from debris and sediment.

Despite the appearance of the surface of the downstream side of the dam the main dam section is stable. Based on the boring completed in the embankment dam crest the concrete dam is likely constructed on bedrock. There is no apparent settlement, sliding, or buckling of the mass concrete section.
It is our opinion that this concrete is more permeable than modern concrete due to the cold joints formed from mass placements that created seepage paths. Inconsistent construction methods would have also contributed to more permeable concrete placement.

It is our opinion that this structure can be rehabilitated even with the low concrete strength and permeable concrete conditions. Repairs to the concrete surface should include removal of deteriorating concrete to prepare to a sound concrete surface prior to placement of a concrete overlay. Repairs to the concrete surface should also include rebar dowels drilled and epoxied into place to physically bond the proposed concrete overlay to the existing surface.

### 2.3.1 Outlet Gate and Tunnel

The dam has a cast iron sluice gate with seating head installed on the upstream and left side of the concrete dam, the sluice gate is located roughly at the creek invert level (Photo 3). The sluice gate controls flow from the upstream side of the dam through a tunnel constructed in the concrete section of the dam and is currently non-functional. The tunnel is roughly 3-feet wide by 5-feet tall and is approximately 30-feet long and discharges to the downstream side of the dam adjacent to the downstream abutment wall. The sluice gate operator is anchored at the top of the tower and operates the sluice gate with a valve stem mounted to the upstream surface of the dam. The operator pedestal has sheared off and currently tied in place with cable and concrete anchors.

![Photo 3 – Control gate and access platform (upstream side of concrete dam)](image)
The accessible portions of the tunnel were inspected and appeared to be in good condition. Due to water releases, the downstream side of the slide gate and concrete section of the gate is mounted to could not be inspected. The condition of the tunnel below the slide gate is unknown. Based on the condition of the concrete in other areas, it is reasonable to assume this concrete section has been exposed to freeze/thaw conditions and needs repaired.

The sluice gate has a broken slide and operator and is also not functional. There is heavy sediment deposited on the upstream side of the dam for at least 13-feet to the top of the vault walls. Because the sluice gate is damaged water flows past the gate uncontrolled into the outlet tunnel and discharges to the river on the downstream side of the dam. Significant repairs are needed to the outlet gate structure before it is operational again, and depending on the basis for design described below, repairing the outlet gate structure may not be an option.

2.3.2 Concrete Abutment Walls

The abutment wall on the upstream side of the dam is roughly 35 feet tall at the dam crest. The upstream wall was constructed with a concrete buttress to provide strength for the wall to support the load from the earth embankment (Photo 1). The wall surface is deteriorated with exposed aggregate and cracking that suggest the earth load has compromised the wall. There is also a cold joint created between concrete placements during the construction of the wall (photo 3).

The downstream wall is in much worse condition than the upstream abutment wall. Like the upstream side, the wall is roughly 35 feet tall at the dam crest and transitions down to the toe of the dam near the river invert. The base of the wall is essentially at the point of failure. The bottom of the concrete wall at the foundation is eroded away leaving a void and exposed rebar between the bottom of the wall and the foundation slab connection (photo 4). There are large voids behind the wall most likely from the dam embankment sloughing off at the base due to the loss of the lower portion of the wall and erosion by the river during high flows. The wall also appears to have a buckle or bow towards the center of the wall that indicates the earth load from the dam embankment to the north exceeds the strength of the concrete and reinforcement steel of the wall. The downstream wall was not constructed with a buttress like the upstream wall resulting in less strength to support the wall height. The wall also has large sections of exposed steel reinforcement where the first couple inches of the concrete surface have spalled off.
This wall is at the end of its useful life and needs to be replaced. Designs for replacing this wall should include plans to replace the control gate and to address issues with the earth embankment.

2.4 FLOOD HYDROLOGY

2.4.1 Flood Frequency Analysis

A flood frequency analysis was performed to estimate frequency of floods for the Laramie River at U.S. Geological Survey (USGS) gage 06662000 (Laramie River near Lookout, WY) just upstream of Wheatland Reservoir #2. A Log-Pearson Type III Distribution analysis was conducted to evaluate flood frequency and estimate peak flow discharges for different return periods. The flood frequency resulting from the Log-Pearson Type III analysis is shown in Table 2-1. The results from the flood frequency analysis were imperative in the preliminary design of rehabilitation for the WID Tunnel Dam’s primary and appurtenant hydraulic structures to allow passage of the regulatory design flood as dictated by the dam’s hazard classification.
Table 2-1: Flood Frequency Analysis USGS Site No. 06662000

<table>
<thead>
<tr>
<th>Annual Exceedance Probability</th>
<th>Recurrence Interval</th>
<th>Q (cfs)</th>
<th>Q 95% Confidence Limit (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>2</td>
<td>1,097</td>
<td>1,275</td>
</tr>
<tr>
<td>0.2</td>
<td>5</td>
<td>2,066</td>
<td>2,487</td>
</tr>
<tr>
<td>0.1</td>
<td>10</td>
<td>2,723</td>
<td>3,359</td>
</tr>
<tr>
<td>0.04</td>
<td>25</td>
<td>3,519</td>
<td>4,453</td>
</tr>
<tr>
<td>0.02</td>
<td>50</td>
<td>4,071</td>
<td>5,234</td>
</tr>
<tr>
<td>0.01</td>
<td>100</td>
<td>4,584</td>
<td>5,971</td>
</tr>
<tr>
<td>0.005</td>
<td>200</td>
<td>5,060</td>
<td>6,665</td>
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<tr>
<td>0.002</td>
<td>500</td>
<td>5,634</td>
<td>7,515</td>
</tr>
<tr>
<td>0.001</td>
<td>1,000</td>
<td>6,031</td>
<td>8,108</td>
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<tr>
<td>0.0005</td>
<td>2,000</td>
<td>6,397</td>
<td>8,661</td>
</tr>
<tr>
<td>0.0002</td>
<td>5,000</td>
<td>6,947</td>
<td>9,499</td>
</tr>
<tr>
<td>0.0001</td>
<td>10,000</td>
<td>7,141</td>
<td>9,796</td>
</tr>
</tbody>
</table>

2.4.2 Estimated Hazard Classification

A dam breach inundation analysis was completed to confirm the hazard classification. The result of the analysis indicates no permanent habitable structures were identified in the inundation area that would be adversely affected and the hazard classification for Tunnel Dam is likely low hazard.

2.4.3 Regulatory Design Flood

The regulatory design flood for low hazard structures is the 100-yr recurrence interval flood. Based on the flood frequency analysis, the regulatory design flow for Tunnel Dam is 4,600 cfs.

2.5 HYDRAULIC ANALYSIS

A hydraulic analysis was performed to evaluate the Tunnel Dam’s existing outflow capacity for its three release structures: the outlet works, the principal concrete spillway, and the auxiliary earthen spillway. The rating curve developed from the hydraulic analysis shows that at the point of overtopping the existing dam elevation (6481.0 feet) the sluice gate will pass 430 cfs, the principal spillway will pass 6,290 cfs, and the auxiliary spillway will pass 3,800 cfs. It should be noted, there is strong concern about the erodibility of the auxiliary spillway and its ability to pass flood flows without breaching the dam. For this analysis, we assumed the embankment fill would support the maximum flows through the auxiliary spillway without breaching. In reality, this is likely not to be the case.

2.6 DIVERSION STRUCTURE ASSESSMENT CONCLUSIONS AND RECOMMENDATIONS

This feasibility-level investigation has resulted in the following conclusions:

1. Based on the Standard Proctor testing of the dam embankment fill, the material is good quality fill. For Alternative 1, any portion of the dam that is excavated should be recompacted back into the excavation at 95 percent of Proctor, resulting in a more stable dam.
2. The existing embankment fill below about 17 feet and the floodplain deposits are saturated and weak. This is potentially an instability concern for the existing dam. For Alternative 1, we recommend excavating the existing dam fill and the floodplain deposits from its foundation. Also excavate the alluvial deposits to bedrock below the upstream end of the dam to cut off seepage beneath the dam.

3. The alluvial deposits below the existing dam represent a suitable foundation material that can help drain the phreatic surface in the dam. The amphibolite bedrock also represents a strong dam foundation.

4. For any additional borrow that may be needed for embankment construction, the tributary alluvium in the vicinity of boring SB-4 can be targeted. Additionally, the colluvial and slopewash deposits may represent an additional source of borrow. The area just north of the left dam embankment may be a good area to target colluvial soils as borrow.

5. The left abutment wall is at the end of its useful life and needs to be replaced.

6. Significant repairs are needed to the outlet gate structure before it is operational again, and depending on the basis for design, repairing the outlet gate structure may not be an option.

7. Repairs to the concrete surface should include removal of deteriorating concrete to prepare to a sound concrete surface prior to placement of a concrete overlay. Repairs to the concrete surface should also include rebar dowels drilled and epoxied into place to physically bond the proposed concrete overlay to the existing surface.

8. Based on the engineering evaluation and geotechnical investigation, the existing diversion structure is suitable for rehabilitation.
3.0 Rehabilitation Plan Alternatives

An engineering and geotechnical evaluation of the existing Tunnel Dam structure was completed as described in the previous section. The findings and results of the evaluation led to the conclusion that the existing structure was suitable for rehabilitation. Alternatives to the rehabilitation of the existing structure were considered and presented below.

3.1 ALTERNATIVES

The following diversion alternative concepts were identified:

Alternative 1 – Repair and rehabilitate the existing structure to include a sluiceway.

Alternative 2 – Remove the existing structure and relocate it approximately 600 feet upstream.

Alternative 3 – Remove the existing structure and relocate a smaller check structure upstream of the Tunnel Inlet and construct a new canal to convey water to the tunnel inlet.

Contributing factors to the design of the alternatives included sediment deposition, water quality, hydraulic limitations, cost, operation and maintenance, needs of the District, environmental impacts, and permitting. An alternatives comparison matrix is presented in Table 3-1.
### Table 3-1: Alternatives Comparison Matrix

<table>
<thead>
<tr>
<th></th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>On channel, existing location</td>
<td>On channel, 600' upstream</td>
<td>On channel, 2,700' upstream</td>
</tr>
<tr>
<td><strong>Storage Capacity</strong></td>
<td>144 AF</td>
<td>100 AF approx.</td>
<td>0 AF</td>
</tr>
<tr>
<td><strong>Surface Area</strong></td>
<td>22 acres</td>
<td>16 acres</td>
<td>0 acres</td>
</tr>
<tr>
<td><strong>Dam Type</strong></td>
<td>Earth/Concrete</td>
<td>Earth/Concrete</td>
<td>Earth Dike/Concrete</td>
</tr>
<tr>
<td><strong>Gate Type/Outlet</strong></td>
<td>Slide/Sluiceway</td>
<td>Laydown</td>
<td>Laydown</td>
</tr>
<tr>
<td><strong>Dam Height</strong></td>
<td>36 ft</td>
<td>32 ft approx.</td>
<td>20 ft approx. (dike)</td>
</tr>
<tr>
<td><strong>Crest Elevation</strong></td>
<td>6471 ft</td>
<td>6471 ft</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Crest Length</strong></td>
<td>410 ft</td>
<td>600 ft</td>
<td>275 (gate)/1020 (dike)</td>
</tr>
<tr>
<td><strong>Borrow Material Availability</strong></td>
<td>Minimal amount required, available onsite</td>
<td>50,000 CY required, likely available onsite</td>
<td>70,000 CY required, potentially available onsite</td>
</tr>
<tr>
<td><strong>Cultural Impacts</strong></td>
<td>minimal</td>
<td>minimal, study required</td>
<td>minimal, study required</td>
</tr>
<tr>
<td><strong>Wetlands Impacts</strong></td>
<td>&lt;0.1 acres</td>
<td>minimal fringe wetlands downstream (&lt;1 acres)</td>
<td>minimal fringe wetlands downstream (&lt;1 acres)</td>
</tr>
<tr>
<td><strong>Water Quality Impacts</strong></td>
<td>Impacts during construction. Improvements during operation with incorporation of sluiceway</td>
<td>Impacts during construction. Approx. 35,000 CY of sediment needs to be removed to meet turbidity criteria.</td>
<td>Impacts during construction. Approx. 65,000 CY of sediment needs to be removed to meet turbidity criteria.</td>
</tr>
<tr>
<td><strong>Sediment Management</strong></td>
<td>More natural river flows, reduces sediment deposits</td>
<td>More natural river flows, reduces sediment deposits significantly</td>
<td>More natural river flows, eliminates sediment deposits</td>
</tr>
<tr>
<td><strong>Permitting Requirements</strong></td>
<td>Minimal: Ag exemption</td>
<td>Significant: USACE Section 404; EIS likely</td>
<td>Significant: USACE Section 404; EIS likely</td>
</tr>
<tr>
<td><strong>Project Costs</strong></td>
<td>$5M</td>
<td>$8M</td>
<td>$10M</td>
</tr>
</tbody>
</table>

**Favorable characteristics**

**Unfavorable characteristics**

**Probable fatal flaw or very unfavorable characteristics**

It is our opinion that the rehabilitation of the existing diversion dam provides the Wheatland Irrigation district with the best alternative (alternative 1) to move forward into final design. Alternative 1 has favorable characteristics with sediment management, environmental impacts, water quality impacts, permitting requirements, and is the most cost-effective alternative. Alternatives 2 and 3 would require extensive infrastructure be designed and constructed to provide a facility to meet the current capacity required by the district and relocating the point of diversion would cause significant permitting efforts. These characteristics drive up the costs of Alternatives 2 and 3 to the point where costs are prohibitive. These unfavorable characteristics of Alternatives 2 and 3 along with the
favorable characteristics of Alternative 1, are the reasons Alternative 1 was advanced to preliminary design.

### 3.2 STREAMFLOW MEASUREMENT ALTERNATIVES

The Wyoming State Engineer’s Office (SEO) operates and maintains a Parshall flume approximately 0.3 miles downstream of Tunnel Dam to measure streamflow in the Laramie River. The Parshall flume, with an 8-foot throat width and 3-foot wall height, has the capacity to measure up to 187 cubic feet per second (cfs). An overflow located on the left bank, upstream and adjacent to the flume is used to pass flows that exceed the flume's capacity. Measurement at the flume has been compromised as a result of bank erosion at the overflow. Currently, the invert of the eroded overflow sits less than one inch above the invert of the Parshall flume, resulting in inaccurate measurement of flow. The following alternatives were considered for the measurement of streamflow downstream of the diversion dam in the Laramie River:

- **Streamflow Alternative 1** – Rehabilitate the overflow at the existing flume.
- **Streamflow Alternative 2** – Rate the stream reach at Tunnel Road bridge.
- **Streamflow Alternative 3** – Rate the outlet structures at Tunnel Dam.

Contributing factors to the design of the streamflow measurement alternative included flow measurement, operation and maintenance and cost.

#### 3.2.1 Streamflow Measurement Recommendations

After discussion with the SEO, it is recommended to pursue streamflow measurement alternative 1. This would allow accurate measurement across the low flow range where accuracy is critical and less expensive than alternative 2 and 3 since there is already an existing gauging station at this location. Streamflow measurement accuracy during high flow is not as critical and installing a new gauging station at alternative 2 site is cost prohibitive. It is recommended to rate the new spillway section of Tunnel Dam, so the SEO can continue to use their water level instrumentation at the tunnel inlet structure.
4.0 Preliminary Design and Cost Estimate

The preferred alternative identified in the previous section (alternative 1) was advanced to preliminary design and cost estimates were developed of sufficient accuracy to support a legislative request for Level III Construction funding. The proposed rehabilitation of Tunnel Dam consists of concrete demolition and resurfacing, removing and replacing the left abutment wall, incorporating an Ogee crest, sluiceway and stilling basin into the principal spillway, removal and replacement of embankment fill, bedrock excavation, and installation of a blanket drain, toe drain, and slide gates, as show in Figure 4-1 through Figure 4-3.

4.1 BASIS FOR DESIGN

4.1.1 Diversion and Storage Capacities

The proposed Ogee crest elevation will be set at the existing crest elevation of 6471.4’ above sea level to ensure the diversion and storage capacities remain the same. Based on the survey completed during the site assessment phase, the current storage capacity of the reservoir is approximately 144 acre-feet. The Normal High Water Line (NHWL) is proposed to remain the same (6471.4’) and the rehabilitation will not affect diversions through the tunnel.

4.1.2 Construction Access

**Dredging**
Approximately thirteen feet of sediment has been deposited adjacent to the upstream face of the dam and requires removing and stockpiling approximately 4,000 cubic yards of sediment to gain access to the bottom of the dam. Sheet piling, shoring, or grading could be used to support excavated slopes from deposited sediment that hasn’t been dredged. Once construction is completed, the temporary shoring should be removed, and the sediment replaced back in the river channel to the elevation prior to removal.

**Earth Embankment**
As described above, the left abutment wall is essentially at a point of failure and should be replaced. The existing wall is approximately 35 feet tall and is founded on bedrock. In order to gain access to the bottom of the abutment wall, a significant portion of the earth embankment to the north should be removed to bedrock and stockpiled.

**Handling of Water**
Outside of the irrigation season baseflows range from 10 to 15 cubic feet per second (cfs). This flow in the Laramie River needs to bypass Tunnel Dam during construction. The contractor will be responsible for the design of the bypass and permitting requirements; however, a bypass plan could include a coffer dam and piping to convey water through Tunnel Dam during construction. There is potential for significant effort in handling bypassed flows and the costs associated with this bid item is reflective in the cost estimate.

4.1.3 Concrete Demolition

Once construction preparations are complete and access to the lower portions of the dam are available, the demolition phase can begin. Demolition of the abutment would likely consist of jackhammering, saw cutting and use of heavy ballast to knock the wall over.
tunnel access tower, gate operator, slide gate and handrail as well as the top four feet of the existing crest, including the higher original crest should be removed in preparation of the proposed Ogee crest. Widening the principal spillway creates a longer weir and increases the capacity of the crest. This rehabilitation plan does not utilize the existing outlet works, and the existing low-level outlet should be abandoned. The existing tunnel and tunnel access tower should be plugged with concrete.

4.1.4 Surface Preparation

All remaining concrete should be prepared to provide a solid and sound concrete surface for concrete and shotcrete to bond. Any loose and deteriorating concrete on the upstream and downstream face should be removed by sawcutting and bush hammering, followed by hydro-blasting in preparation of an overlay. A minimum 5,000 pound per square inch (psi) Hydro-blasting is required after areas have been prepared with bush hammers to remove cracked and loose concrete. All exposed steel should be cleaned to remove all flaking and loose steel. Any steel that has been corroded beyond repair should be removed and replaced. This will likely be the majority of the exposed steel at this location.

Any weathered bedrock that concrete will be founded on should be excavated to solid rock and rock anchors installed. Dowels should be epoxied into the existing concrete and the drain materials installed (if required).

4.1.5 Concrete Overlay

After the existing concrete has been prepared, an overlay of the upstream face, crest and downstream face can be placed. The overlay includes reinforced concrete and is designed to be a rehabilitation of the deteriorating concrete. The overlay encases the existing concrete and will help prevent water from seeping through the noticeable cold joints, expansion cracks and voids in the surface that have formed over time. Rebar dowels should also be installed by drilling and epoxying the bar to the existing concrete surface to provide a physical connection between the existing surface and the new concrete overlay.

Upstream Face
The cast-in-place overlay on the upstream face could be formed using a one-sided form and is proposed to be two feet thick. A shotcrete application for the upstream face should also be considered in the design process.

Ogee Crest
An ogee crest is proposed to replace the existing broad crest. There are several advantages to an ogee crest compared to a broad crest, primarily the hydraulic efficiency. A properly designed ogee crest can pass up to 40% more flow compared to a broad crest the same length. As described above, there is a concern about the erodibility of the existing auxiliary spillway during an overtopping event that could lead to a failure of the earth dam embankment. By incorporating an ogee crest, the existing auxiliary spillway could be removed eliminating a potential failure mode.

Downstream Face
The overlay on the downstream face consists of a stepped surface design. There are several advantages to a stepped spillway design compared to the existing chute spillway. The biggest advantage is constructability. The existing face is approximately 1:1 slope and forming and placing concrete at this slope is difficult and labor-intensive. The steps also provide better quality of concrete, since it is easier to vibrate and segregation is less since
concrete is not placed on a steep slope. Another advantage to a stepped spillway design is
energy dissipation. The steps are specifically designed to dissipate energy and velocity and
can extend the design life of the spillway. The high velocity flow from the existing chute
spillway causes abrasion from debris and sediment as well as creates significant uplift forces
at voids and cracks. The high velocity flow from the existing chute spillway is a contributing
factor to the degradation of surface concrete. A properly designed stepped spillway reduces
velocity and energy and extends the design life of the spillway.

4.1.6 Abutment Wall

The left abutment wall is a significant structure that needs to be replaced. The proposed
wall will be approximately 36 feet tall at the dam crest and transitions down matching the
slope of the earth embankment to where the wall intersects bedrock at the invert of the
Laramie River. The wall requires significant structural steel and concrete counterforts to
provide strength. The proposed wall will be approximately 250 feet long and two feet thick
and requires approximately 600 cubic yards of concrete. The wall should be founded on
bedrock, potentially with rock anchors and include a cantilever foundation design along the
entire length of the wall to prevent overturning. During construction care should be made at
the interface between the concrete wall and earth embankment to provide proper
compaction and prevent internal erosion of the embankment. The counterforts also act as a
cut-off wall and a properly designed filter and drain reduce the potential for piping and
internal erosion.

4.1.7 Gated Outlet Works, Sluiceway and Stilling Basin

The proposed rehabilitation plan includes abandoning the existing low-level outlet and
relocating it slightly north, adjacent to its current location. The proposed outlet works
includes a large 10 feet wide by 8 feet tall stainless steel fabricated slide gate and a smaller
4 feet wide by 8 feet tall stainless steel fabricated slide gate that discharges to an open
channel sluiceway and stilling basin. The proposed slide gates are not self-contained and
would mount directly to a concrete headwall with a pedestal and gate operator mounted at
the dam crest. The gate stems would operate in an oil filled casing pipe for protection from
ice and debris. The invert of the slide gate should be set at the current sediment level,
6,458 feet above sea level, to prevent the release of accumulated sediment. The sluiceway
consists of a concrete stepped section followed by a stilling basin before discharging back
into the Laramie River.

The basis for a sluiceway design is to improve sediment management in the reservoir and
sluice it downstream during high flows. Approximately 64,000 cubic yards of sediment have
accumulated in the reservoir indicating the current outlet works is undersized and cannot
effectively pass sediment. Peak sediment loading conditions come from bank erosion and
runoff during high flows and rain events. Sluicing during high flows allows the suspended
sediment to pass through the dam before it can settle in the reservoir which would reduce
storage capacity and has the potential to be released downstream when the reservoir is
drained in the fall. A sluiceway also passes sediment during naturally occurring turbid
conditions minimizing downstream sediment deposition. The proposed slide gates and
sluiceway provide increased capacity through the outlet works and mimics more natural
river flows. The increased capacity through the proposed outlet works also reduces times of
overtopping of the concrete crest and may extend the life of the principal spillway. While
there is a higher cost associated with incorporating a sluiceway into the design, the left
abutment wall needs to be replaced and it is less expensive to incorporate a sluiceway now
compared to the future, and a sluiceway would allow WID a more effective way to manage sediment in the reservoir and downstream of Tunnel Dam.

4.1.8 Earth Embankment

Based on the low strength of the saturated fill in embankment and the fact portions of the fill are not founded on bedrock, it is recommended to remove the entirety of the embankment fill and recompact it to 95 percent of optimum moisture content and density. Regardless, approximately one-third to one-half of the material needs to be excavated to gain access to the abutment wall of the diversion dam and to allow for river bypass. The presence of the weak floodplain soils in the existing foundation is concerning from a dam stability perspective. Any failure plane through the floodplain soils could compromise the stability of the existing embankment structure or a new embankment if they are not removed. We therefore recommend removing all floodplain deposits in the existing foundation.

The existing upstream slopes of the embankment range from 2.5-3:1 (H:V) and downstream slopes range from 2-3:1 (H:V). The proposed design slopes are 3:1 for both upstream and downstream slopes. A cut/fill balance completed during the preliminary design indicates that approximately 500 cubic yards of additional fill would be required for the new embankment. Because the existing embankment is not at maximum dry density, when the fill is recompacted, there will likely be some additional volume loss. It is anticipated that suitable borrow sources can be found onsite in the near vicinity of the project and there will not be a need to haul additional material from sources off site.

The embankment design includes a sand blanket drain and toe drain to control seepage through the embankment, enhance dam stability, and to prevent internal erosion. The upstream face of the embankment includes 2 feet of riprap and 12 inches of riprap bedding placed at the surface for erosion control from wave action.
4.1.9 Hydraulic Structures

A hydraulic analysis was performed to evaluate the Tunnel Dam’s outflow capacity for the proposed release structures: the sluiceway outlet works and the principal concrete spillway with an ogee crest. The total combined outlet capacity of the proposed ogee crest and gated sluiceway is 12,770 cfs, compared to the existing outlet capacity (3 ft x 5 ft gate, principal spillway, auxiliary spillway) of 10,520 cfs (21% increase). The proposed design can pass more flow than the existing conditions even by removing the existing auxiliary spillway and eliminating a potential failure mode.

Comparing the proposed outlet capacity to the flood frequency analysis indicates the proposed design of Tunnel Dam can pass greater than a 10,000-year flood event (7,141 cfs). Since this is a low hazard dam, Safety of Dam regulations require the dam to pass a 100-year flood event (4,584 cfs) in which the proposed design is more than adequate.

4.2 ALTERNATIVES TO DESIGN

Alternatives to the proposed design described above were investigated with consideration to cost, environmental impacts, operation and maintenance, capacity, and sediment deposition.

4.2.1 Repair and Replace Existing Outlet Works

This alternative to the proposed sluiceway design includes repairing and replacing the existing sluiceway and utilizing the existing outlet tunnel through the concrete dam for reservoir releases. All other required work at the dam described above, excluding a sluiceway, would still be required. While this may be a less expensive alternative than a sluiceway design, significant effort is still required to rehabilitate the existing outlet works, and it does not address sediment deposition in the reservoir nor environmental impacts downstream of the dam, to the same extent as the proposed new sluiceway design. As previously discussed, the left abutment wall is failing and needs replaced. It appears the abutment wall forms the side of the tunnel and demolition of the abutment wall may compromise and render the existing outlet works nonrepairable. In addition, the existing outlet works are undersized for proper sluicing; as a result, sediment is deposited in the reservoir reducing the storage capacity and has potential to be released downstream when the reservoir is drained in the fall. Since the abutment wall needs to be replaced, this presents an opportunity to WID to update the design of the diversion dam to modern design criteria by including a sluiceway at a relatively inexpensive cost. Incorporating a sluiceway now during the rehabilitation of the structure would be far less expensive than adding a sluiceway in the future and would allow WID a more effective way to manage sediment in the reservoir.

While repairing the existing outlet works may move some sediment through the reservoir, a sluiceway would give WID operational flexibility to manage sediment deposition in both the reservoir and downstream by sluicing during high flow. Without sluicing ability, flow over the spillway could flush downstream sediment; however, downstream sediment deposition could occur in the fall when the reservoir is drained. Sluicing allows sediment to pass during high flows and minimizes deposition in the reservoir that could later be released when the reservoir is drained in the fall. Another advantage of a sluiceway compared to repairing the existing outlet works is the sluiceway allows for bypassing high flows during runoff instead of over-topping the concrete structure, thus increasing the longevity of the structure. It also allows for much simpler access to the gates for future maintenance. Major
dewatering and rerouting the river is required to gain access to the existing sluicegate. It is very important to ensure long-term compliance with applicable surface water quality standards that prohibit excessive sedimentation, physical degradation or suspended solids that could impact the ability of the Laramie River to support designated uses such as fisheries and other aquatic life. A sluiceway is a more effective way to manage sediment deposits and turbidity than the current outlet works configuration at Tunnel Dam. It is not recommended to pursue this repair and replace alternative.

4.3  OPERATION PLAN

The operation of the Tunnel Dam facility post rehabilitation is recommended to change as follows. To promote the longevity of the Tunnel Dam and Reservoir, it is recommended to utilize the sluice gates to make future reservoir releases. Utilizing the sluice gates will help to move sediment through the system. When surplus water is available in the Laramie River (i.e. when Wheatland Reservoir #2 and #3 are full) and water is flowing past the Bluegrass Tunnel, the sluice gate(s) should be opened to pass sediment along the bottom of the reservoir and down the Laramie River. This operation best matches the natural sediment transport of the river. In years when sluicing of the reservoir occurs, the reservoir should be drawn down in the fall after the irrigation season. In years when there is no surplus water and sluicing does not occur, the reservoir could remain full over the winter to minimize release of sediment during low flow conditions. If the reservoir is to remain full over the winter, a current day storage water right should be obtained, and can be filled from Wheatland Reservoir #2 storage water right.

4.4  COST ESTIMATE

Three cost estimate components were developed for this project: the initial capital cost, operation and maintenance, and mechanical component end-of-life replacement. The present value capital cost of engineering design, permitting, and construction totals $5 million. Annual operation and maintenance costs total $10,500. To fund like kind replacement of mechanical components at the end of their design life, an annual investment of $2,700 is required.

4.5  CONSTRUCTION SEQUENCING

The construction to complete the rehabilitation of Tunnel Dam will likely have to occur during the non-irrigation season and will have to be completed in one season so the structure is ready for the beginning of the next irrigation season. This poses several challenges that the contractor will have to overcome. One challenge is the short duration for the amount of work that needs to occur. Another challenge is winter construction in a mountainous environment. Placement of fill during freezing conditions will require frost protection (e.g. sacrificial lifts or blankets or ground heaters). Placement of concrete during freezing conditions will also require frost protection (e.g. blankets or tenting and heating). Handling of water during construction is another challenge. Baseflows typically range from 10 to 15 cfs and must be maintained in the Laramie River. Wheatland Reservoir #2 may be able to minimize flooding at the construction site which could minimize the water handling capacity needed.
5.0 Permitting and Environmental

5.1 PERMITTING CONSIDERATIONS

Consultations with various agencies were held throughout this study to identify permitting requirements associated with the rehabilitation of Tunnel Dam. A copy of the draft report was sent to various agencies requesting comments outlining issues, permitting requirements and timeframes associated with the permit approval/review process.

5.1.1 U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) made a preliminary jurisdictional determination based on the proposed preliminary design. The USACE determined this rehabilitation project falls under the agricultural exemption (as proposed) pursuant to Section 404(f)(1) and therefore would not require coverage under a 404 Nationwide Permit.

5.1.2 Wyoming Department of Environmental Quality

There are several permitting requirements through the DEQ Water Quality Division (WQD) that primarily focus on the construction of a project and are typically obtained by the contractor. A temporary turbidity waiver, storm water construction general permit, and temporary discharge permit are required prior to construction.

5.1.3 Wyoming State Engineers Office

The Wyoming State Engineers Office Safety of Dams Program is responsible for ensuring the safety and structural integrity of water storage facilities in the state. A plan review will be required prior to the rehabilitation of Tunnel Dam. The review takes around 60 days and there is no fee.

5.1.4 Wyoming Office of State Lands and Investments

The dam and access road are on state property and a temporary use permit issued by the Wyoming Office of State Lands and Investments will be required for construction activities at Tunnel Dam.

5.1.5 County Planning and Development Office

Albany County does not have general zoning or building codes. A Flood Plain Development Permit may be necessary for the rehabilitation of Tunnel Dam and a simple maintenance agreement between the contractor and Albany County may be necessary to maintain Tunnel Road during construction.
6.0 Economic Analysis and Project Financing

6.1 FUNDING SOURCES

The preferred alternative (rehabilitation of Tunnel Dam) was advanced to economic analysis and evaluation of project financing. The likely funding source is the Wyoming Water Development Commission (WWDC). The WWDC may fund rehabilitation projects for eligible entities from their Rehabilitation Program Water Development Account II. The WID is an eligible entity. Funding consists of a 67 percent grant and 33 percent loan at four percent interest and a payment period of up to 50 years not to exceed the life of the project.

There are other sources that provide grants and funding, in which this project would be eligible, such as Wyoming Department of Environmental Quality Section 319 Grants and Natural Resource Conservation Service PL-566 Watershed and Flood Prevention Operations program; however, these programs are very competitive, and applicants are ranked based on potential improvement to resource concerns.

6.2 ECONOMIC ANALYSIS

Assuming a loan amount for $1,650,000 (33% of the total project cost), 50-year payment period and 4% interest rate, capital cost funding from this program would require a $76,808 annual loan payment.

WID members are currently assessed $15 per acre annually. There are approximately 54,100 assessed acres in the WID. The additional annual assessment needed to make the annual loan payment assuming 67 percent grant funding from the WWDC Rehabilitation Program is $1.42 per acre ($76,808 / 54,100 acres = $1.42 per acre). Operation and maintenance costs would require an annual assessment of $0.19 per acre ($10,500 / 54,100 acres = $0.19 per acre). End of life replacement sinking fund costs would require an annual assessment of $0.05 per acre ($2,700 / 54,100 acres = $0.05 per acre). Total additional annual assessment needed to retire debt and fund operation, maintenance, and replacement costs is $1.66 per acre.
7.0 Conclusions and Recommendations

Alternative 1 consisting of the rehabilitation of the existing Tunnel Dam structure was determined to be the most feasible option. The proposed rehabilitation of Tunnel Dam consists of concrete demolition and resurfacing, removing and replacing the left abutment wall, incorporating an ogee crest, sluiceway and stilling basin into the principal spillway, removal and replacement of embankment fill, bedrock excavation, and installation of a blanket drain, toe drain, and slide gates. The following recommendations and areas of further study are provided if WID chooses to progress the rehabilitation project to final design:

- It is recommended to rehabilitate the existing diversion dam by installing a new gate structure, sluiceway and stilling basin. The existing low-level outlet works, including the existing slide gate and tunnel should be plugged and abandoned.

- The concrete structure should be prepared to a sound concrete surface and placement of a concrete overlay along the upstream face, crest and downstream face should be incorporated.

- It is recommended to incorporate an ogee crest and stepped spillway into the design of the concrete overlay. It is also recommended to remove the tunnel access tower and widen the crest length to 75 feet for increased hydraulic capacity.

- The existing left abutment wall is failing, at the end of its useful life, and should be removed and replaced. It is recommended that designs for replacing this wall should include plans for a sluiceway to better manage sediment depositions in the reservoir.

- The existing embankment fill below approximately 17 feet and the floodplain deposits are saturated and weak. This is potentially a stability concern for the existing dam. It is recommended to excavate all of the existing dam fill and the floodplain deposits from its foundation to bedrock.

- It is also recommended to rebuild the dam at 3:1 upstream and downstream slopes using the excavated embankment fill recompacted to 95 percent of Proctor density, and install a blanket drain and a toe drain to facilitate drainage of the phreatic surface in the dam.

- It is recommended to remove the existing auxiliary spillway and utilize an ogee crest and larger slide gates to pass flood events.

- To promote the longevity of the Tunnel Dam and Reservoir, it is recommended to utilize the sluice gates to make future reservoir releases. Utilizing the sluice gates will help to move sediment through the system. When surplus water is available in the Laramie River (i.e. when Wheatland Reservoir #2 and #3 are full) and water is flowing past the Bluegrass Tunnel, the sluice gate(s) should be opened to pass sediment along the bottom of the reservoir and down the Laramie River. In years when sluicing of the reservoir occurs, the reservoir should be drawn down in the fall after the irrigation season. In years when there is no surplus water and sluicing
does not occur, the reservoir could remain full over the winter to minimize release of sediment during low flow conditions.

- Remote operation of the sluice gates as described in Section 5.2.3, is recommended and will increase the ability of the District to control irrigation deliveries to the Bluegrass Tunnel while performing sluicing operations during high flows. Automation of the gates should also be considered.

- It is recommended to pursue streamflow measurement alternative 1. This would allow accurate measurement during low flows when accurate measurement is critical and would be less expensive than alternative 2 and 3. If cost sharing between WID and SEO is an option, alternative 3 may be feasible.

- It is recommended to apply for a Level III project from the Wyoming Water Development Commission by the September 1, 2018 deadline and progress this project to final design.

- Final design investigations should include:
  
  o Geotechnical borings in and around the existing dam to understand the geometry of the alluvial deposits and bedrock foundation permeability.

  o For borrow sources, excavate test pits in the colluvial deposits on the left abutment of the dam and in the tributary alluvial deposits in the vicinity of SB-4. Additional test pits of the sediment deposits upstream of the existing concrete dam section should be excavated and lab testing completed to provide information for excavation and grading of these soils for access to the upstream side of the dam during construction.

The following steps and schedule are required for final implementation of the project:

1. WID seeks funding – WWDC Level III application deadline – September 1, 2018
2. Level III funding approved by Legislature – March 2019
3. Notice to Proceed for final design and permitting – April 2019
4. Final design, specifications and permitting completed – Spring 2020
5. Construction bidding – Summer 2020
6. Construction commencement – September 2020
7. Construction completion – April 2021

It is recommended for WID to start discussions on strict shutdown and startup dates for the 2020 and 2021 irrigation seasons, respectfully, to maximize the construction window.