EXECUTIVE SUMMARY
FOR
GREYBULL VALLEY REHABILITATION/
UPPER SUNSHINE DIVERSION, LEVEL II STUDY

Prepared For:
Wyoming Water Development Commission
6920 Yellowtail Road
Cheyenne, WY 82002

Prepared By:
Anderson Consulting Engineers, Inc.
375 E. Horsetooth Road, Bldg 5
Fort Collins, CO 80525

June 15, 2010
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(ACE Project No. WYWDC27)

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I. INTRODUCTION

On June 7, 2007 Anderson Consulting Engineers, Inc. (ACE) entered into a contract with the Wyoming Water Development Commission (WWDC) to provide professional services in support of the Greybull Valley Rehabilitation/Upper Sunshine Diversion, Level II Study. The Greybull Valley Irrigation District (GVID) requested the feasibility study to evaluate the rehabilitation/replacement needs associated with the existing diversion dam and headgate facilities that divert water into the supply canal and ultimately the Upper Sunshine Reservoir. In their application to the WWDC, the GVID specifically requested that the study address or evaluate the items indicated below:

- transport and accumulation of large cobbles in the vicinity of the supply canal headgates, and sands/gravels in the upper reaches of the supply canal; and
- condition and longevity of the existing diversion facilities, including the diversion dam, sluice gates, supply canal headgates, and gravel diversion berm.

In addition, the West Timber Creek Drop Structure and the supply canal extending from the canal headgate to the drop structure were included in the feasibility study.

This work included an inventory and assessment of existing structures and facilities, hydraulic and geomorphic evaluation of sediment transport and channel stability, identification and evaluation of structure improvement alternatives, development of conceptual design and costs associated with the structure improvements, and identification of permitting requirements. Design guidelines and recommendations to improve the hydraulic efficiency of the diversion and conveyance facilities, minimize the sediment transported to the canal headgates, and increase the longevity of the existing structures have been specifically developed and documented in this study.

II. GEOMORPHIC CONSIDERATIONS

The results of the geomorphic evaluation provided the considerations listed below.

- The existing channel within the study reach appears to be stable. There appear to be no indicators of systemic channel degradation or aggradation. Similarly, there were no indicators of significant bank erosion within the study reach. Consequently, any design alternatives must consider the potential impacts of modification of the current channel configuration (slope, width, etc.) upon this balance.
- Regardless of the location of the diversion facility, the Greybull River will continue to require training of flows to the south bank to facilitate diversion. The existing berm appears to be accomplishing this task. Because it is constructed with material dredged from the existing channel and floodplain, material will be remobilized during peak flows and consequently, will require frequent maintenance/reconstruction.
Alternatives involving potential relocation of the existing diversion structure will require consideration of potential effects on channel stability. The existing channel appears to have adjusted to the effects of dam construction. Removal of the existing structure/dam without mitigation of impacts upon channel slope would result in an over-steepened reach and subsequent channel degradation and headcutting.

No obvious advantages to relocating the structure from a geomorphic consideration can be determined. The river is a steep gravel/cobble bed channel transporting a considerable amount of bedload sediment. Regardless of the location of a structure, there will be similar quantities of bedload transported within the river.

The study reach of the Greybull River reflects a naturally migrating river system and is continually changing its planform as meander bends migrate within the limits of the existing streambanks and terraces. Consequently, regardless of where a diversion structure is located, there would be a long-term tendency for the channel to move laterally without some form of training structure to concentrate flows.

III. STRUCTURE CONDITIONS

During the inventory and evaluation of the existing structures, the following observations and conclusions were generated.

**Diversion Dam**

- Cracking, spalling and noticeable deterioration of the concrete was evident along the exposed surfaces of the structure. Seepage was evident along the face of the concrete spillway (see Figure 1).
- Sediment deposition, along with subsequent vegetation encroachment, has occurred along the entire extent of the diversion dam with the deposition exceeding the sill elevation of the dam crest in some locations.
- Rock revetment, previously indicated on the design drawings immediately downstream of the concrete spillway, is no longer present. The bed of the river has degraded along the interface of the concrete spillway and the channel. Based on the design plans, the concrete diversion dam is recessed into the bedrock approximately 5 feet.
River Sluiceway and Gates

- The concrete is considered in fair condition given the age of this structure. Minor cracking was noted and deterioration of the concrete floor was observed due to abrasion from the heavy sediment load (see Figure 2).
- The bed of the river has degraded along the interface of the concrete sluiceway floor and the channel. Riprap revetment at this location, noted on the original design plans has been removed.
- The sluice gates appear to be functional with no obvious structural deficiencies. Minor seepage was evident through the gates.

Forebay and Sediment Sluice Gate

- Significant deterioration of the forebay wall and floor (both concrete and steel) has occurred and it is dysfunctional with respect to precluding sediment deposition in the vicinity of the supply canal headgates (see Figure 3).
- The original river sluice gate, installed in the 1930s, is in need of replacement.

Diversion Structure and Headgates

- Portions of the concrete walls have experienced cracking and spalling, with heaving of the walls at some locations.
- The seals and guides associated with the two roller gates have experienced significant deterioration. In their present condition, the gates are difficult to operate and require significant effort to raise and lower during the diversion of flows into the supply canal.
- Given the heavy sediment load in the Greybull River and the condition of the forebay, sediment is transported through the headgates and is deposited in the floor of the diversion structure (see Figure 4).
Supply Canal

- The conveyance section has changed since originally constructed. The bottom width has increased and sideslopes have steepened.
- The reduction in velocity within the supply canal results in the deposition of the heavy sediment load transported to, and through, the supply canal headgates (see Figure 5).

West Timber Creek Drop Structure

- The concrete inlet box is in fair condition, but has been modified to increase the capacity to convey the irrigation diversions.
- The outlet structure is experiencing concrete deterioration and scour along the toe of the headwalls and wingwalls. Improvements and/or replacement is warranted.

IV. HYDRAULIC AND SEDIMENT TRANSPORT CONSIDERATIONS

The hydraulic and sediment transport conditions for the supply canal and the diversion facilities were evaluated. The results of these analyses are summarized below.

Supply Canal

- The conveyance capacity of the supply canal was originally designed to be as much as 750 cfs. Water measurements have reported the capacity to convey diversions of approximately 900 cfs.
- The hydraulic analyses indicated the capacity of the supply canal is limited to 630 cfs to 675 cfs due to backwater created by the capacity of the 72-inch pipe at the West Timber Creek Drop Structure. Improvements to the West Timber Creek Drop Structure will result in a canal capacity that exceeds 1,000 cfs.
- The material mobilized ranges from very fine to fine gravels (for diversions less than or equal to 400 cfs) to coarse sands to very fine gravels (for diversions greater than 400 cfs). This reduction in the size of the material transported by the flow reflects the reduction in velocity associated with the backwater created by the West Timber Creek Drop Structure. As the backwater is increased, the material transported by the flow tends to decrease thereby promoting sediment deposition in the canal.
- At the canal headgates, diversions can typically mobilize and transport fine gravel material. Within the first 500 feet to 1,000 feet of the supply canal, deposition occurs due to a reduction in the capacity to transport the sediment load.
Alternatives developed to resolve the apparent disparity in sediment transport within the upper reach of the supply canal will rely on limiting the sediment available for transport into the supply canal headgates on the Greybull River.

**Diversion Facilities**

When the river sluice gates are fully open and no diversions into the supply canal occur, the information below summarizes the hydraulic and sediment transport conditions for flows ranging from 200 cfs to 2,000 cfs.

- Very coarse gravels to small cobbles are moved within the Greybull River through the range of flows.
- The gravel berm tends to constrict the flows and increase the size of the material transported by the flow.
- Ponding of water at the river sluiceway tends to create a backwater and reduces the bed material transport rate, thereby depositing all material larger than coarse gravel immediately adjacent to the supply canal headgates.
- Depending on the flow, the hydraulic conditions within the river sluice gates can convey particles as large as small boulders. It should be noted that the same hydraulic conditions may exist should the supply canal headgates be opened; consequently, the material deposited adjacent to the headgates will be mobilized as the river sluice gates are opened.

For the same range of flows, the hydraulic and sediment transport conditions within the Greybull River assuming the supply canal headgates are fully open (and by-pass flows are limited) are listed below.

- Very coarse gravels to small cobbles continue to be mobilized within the Greybull River through the range of flows.
- The gravel berm tends to constrict the flows and increase the size of the material transported by the flow.
- Due to the headwater required to divert water into the supply canal headgates, the bed material transport rate is reduced and results in the deposition of all material larger than fine gravels immediately adjacent to the supply canal headgates.
- Depending on the flow, the hydraulic conditions within the supply canal headgates can mobilize and transport materials ranging from fine to medium gravels. Deposition of this gravel material occurs within 500 feet to 1,000 feet downstream of the headgates.
V. ALTERNATIVE DEVELOPMENT AND SCREENING

The development of alternatives focused on the mitigation of the problems presently encountered by the GVID and described above. Initial development of alternatives included:

Alternative 1: Relocation of the Existing Diversion Facilities
Alternative 2: Replacement of the Existing Diversion Facilities
Alternative 3: Rehabilitation of the Existing Diversion Facilities

Alternative 1 was removed from further consideration based on permitting requirements, potential increase in costs, and the fact that limited benefits would be generated by relocating the facilities. Consequently, the screening of the alternatives focused on either replacement (Alternative 2) or rehabilitation (Alternative 3) of the existing facilities at their present location. The results of the additional screening effort provided the following conclusions:

• Removal and replacement of the diversion dam will create additional costs associated with implementation of Alternative 2.
• Retention of the existing diversion dam creates the need for a training berm that is similar to that required for implementation of Alternative 3.
• Both Alternatives 2 and 3 require the replacement of the sluiceway and gates, sediment forebay, and canal headgate structure, as well as installation of measurement structures in the diversion facilities and supply canal.
• Permitting requirements appear to be similar for both of the remaining alternatives.
• The need for additional easements will be similar for both of the remaining alternatives.

Based on these conclusions, Alternative 3-Rehabilitation of the Existing Diversion Facilities was selected for conceptual design. Specific design guidelines were generated for the components associated with Alternative 3 and included in the following improvements:

• Retention and rehabilitation of the existing diversion dam. The rehabilitation includes removal of a portion of the dam to allow for the enlargement of the river sluiceway.
• Construction of a permanent training berm.
• Replacement and enlargement of the river sluiceway.
• Replacement of the sediment forebay.
• Replacement of the canal headgate structure.
• Installation of a measurement structure integrated into the river sluiceway improvements.
• Installation of a measurement structure in the supply canal.
• Automation of both the supply canal measurement structure (real-time flow recording/reporting) and the diversion facilities (flow measurement, gate operation, water level monitoring).
VI. MEASUREMENT DEVICES

The results of the identification and selection of appropriate measurement devices for the supply canal and the diversion facilities are presented below.

**Supply Canal**

- The West Timber Creek Drop Structure was selected as the location to measure flows within the supply canal. Installation of the measurement structure at this location will coincide with replacement/rehabilitation of the drop structure.
- Alternatives for measurement included installation of a cipolletti weir versus installation of a parshall flume. Both alternatives assumed replacement of the 72-inch pipe within the drop structure to preclude excessive tailwater on the measurement structure.
- Based on the results of the evaluation, installation of a parshall flume, or similar type of measurement structure, is recommended. Automation of the site is also recommended to facilitate remote access to the diversion measurement.
- To obtain measurement of the flows as high as 900 cfs, the parshall flume will need to incorporate a throat width of 90 feet, measurement head of slightly less than 5 feet, total length of approximately 75 feet, and maximum wall height of 9 feet. Installation of a parshall flume of this size will create a maximum backwater in the supply canal of 7 feet for a flow of 900 cfs. To minimize the tailwater on the parshall flume will require a pipe in the drop structure that is equivalent to a 6 ft x 8 ft RCB or an 8 ft RCP.

**Greybull River By-pass Flow Measurement**

- Alternatives for measurement of the by-pass flows included both overshot gates as well as undershot gates.
- Following the alternative evaluation, installation of an overshot gate was selected as the most viable option. With automation and gate controllers, these devices operate as adjustable weirs and provide water measurement capability while providing the capability to control water surface elevations in the river thereby facilitating diversions into the supply canal. The harsh river environment, along with the heavy sediment loads precluded selection of the undershot gates as a measurement device.
- To accommodate the measurement of by-pass flows as high as 800 cfs will require an overshot gate with a crest width of 20 feet.
VII. CONCEPTUAL COSTS AND ECONOMIC EVALUATION

Following a design review meeting with the GVID manager, board members and the WWDO project manager, modifications to project components associated with Alternative 3 were identified and discussed. Based on the information provided during the review meeting, two additional modifications to Alternative 3 were conceptually designed. These alternatives consisted of the following:

Alternative 3.1: All components were similar to Alternative 3 with the exception of the spillway in the proposed training berm and the forebay wall. The notched spillway was replaced with a series of Obermeyer spillway gates and half of the permanent concrete wall in the forebay was replaced by Obermeyer gates.

Alternative 3.2: All components were similar to Alternative 3 with the exception of the following: (a) the proposed training berm was reduced in height; and (b) a series of Obermeyer spillway gates was placed on the crest of the existing diversion dam.

To facilitate the selection of the preferred configuration, conceptual cost estimates were generated for Alternatives 3, 3.1 and 3.2, respectively. Based on the cost estimates generated for each configuration, an economic evaluation was conducted to determine the economic impact of construction of the alternatives on the existing assessment for lands to which the storage capacity of the upper Sunshine Reservoir Project has been apportioned. Presently, the existing assessment is $3.25 per acre-foot of water storage capacity. Assuming 50,166 acre-feet of storage capacity, the economic evaluation determined the increase in assessment for each alternative. The evaluation was based on a grant/loan from the WWDC with an interest rate of 4% and a term of 20 years. The results of the evaluation are summarized in Table 1.

Table 1. Economic Evaluation of Project Alternatives on Existing Assessment

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Alternative 3</th>
<th>Alternative 3.1</th>
<th>Alternative 3.2</th>
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<tr>
<td>Total Project Cost</td>
<td>$3,373,865</td>
<td>$4,284,984</td>
<td>$3,995,482</td>
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<td>67% Grant</td>
<td>$2,249,225</td>
<td>$2,856,670</td>
<td>$2,663,788</td>
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<td>33% Loan</td>
<td>$1,124,610</td>
<td>$1,428,314</td>
<td>$1,331,694</td>
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<tr>
<td>Annual Debt Retirement (@ 4%, 20 years)</td>
<td>$82,749</td>
<td>$105,095</td>
<td>$97,986</td>
</tr>
<tr>
<td>Assessment Increase ($/AF)</td>
<td>$1.65</td>
<td>$2.09</td>
<td>$1.95</td>
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</table>
VIII. IDENTIFICATION OF PERMITS

The GVID was issued a Department of the Army permit for Roach Gulch Dam (COE project file No. 1994-40297), which requires GVID to notify the COE before making any changes to the Upper and Lower Sunshine Reservoir diversion structures. The purpose of the “permit condition” was to allow the COE to make a determination as to whether activities associated with modification of those structures are exempt from regulation. The decision on exemption is based in part on maintenance of a 5 cfs upstream in the Greybull River above the confluence of the outlet channel of Lower Sunshine Reservoir.

Based on the permit condition noted above, coordination was conducted with Matt Bilodeau of the COE regional office located in Cheyenne, Wyoming. A meeting was conducted and a letter was formally submitted to specifically request information regarding the permitting requirements for the proposed improvements to the diversion facilities. Following coordination with the Wyoming Game and Fish Department (WGFD), Mr. Bilodeau determined that the proposed Upper Sunshine Reservoir diversion structure construction activities do not require Department of the Army authorization because Part 323.4(a)(3) of the regulations indicate that the construction activities were exempt.

While no additional permitting may be required with the COE, additional coordination should be conducted with the following agencies should this project proceed to final design and construction:

- Wyoming DEQ/Water Quality Division to determine the permitting requirements under the National Pollutant Discharge Elimination System (NPDES) for construction activities.
- The State Historic Preservation Office (SHPO) given the age of the existing diversion facilities.
- The State Engineer’s Office to provide specific information related to plans and specifications detailing the construction of the improvements to the diversion facilities.

IX. RECOMMENDATIONS

Given the information presented above, the following recommendations are provided.

1. The GVID should proceed with the Level III design of the improvements associated with Alternative 3. This alternative was selected in consideration of the following:

   - Alternative 3 provides the most cost-effective solution to mitigate the existing problems and deficiencies. The increase in assessment associated with this alternative was estimated to be $1.65/acre-foot.
   - Incorporation of adjustable weirs in the forebay wall, as indicated in Alternative 3.1, are not deemed necessary to facilitate sediment deposition near the canal headgates. A permanent forebay wall provides the optimum solution. Furthermore, limited maintenance is required for the permanent forebay wall compared to a wall that incorporates Obermeyer gates. Similar reasoning
applies to the Obermeyer gates identified for the training berm for Alternative 3.1. Implementation of this alternative also resulted in the highest cost per acre-foot of storage ($2.09).

- For Alternative 3.2, placement of Obermeyer gates along the crest of the existing diversion dam will continue to require construction of a training berm to divert low flows toward the canal headgates in a hydraulically efficient manner. Similar to Alternative 3.1, maintenance of Obermeyer gates will be higher than a permanent solution associated with the training berm in Alternative 3. Implementation costs were estimated to be $1.95/acre-foot.

2. Should Level III design effort be initiated, proceed with additional coordination to confirm the permitting requirements associated with the project.

3. As part of a Level III design effort, coordination with the landowners should be initiated to identify easements necessary for construction of the proposed improvements. Specifically, the easement associated with construction of the training berm should be prioritized to determine the final alignment of this project component.