STATE OF WYOMING
WATER DEVELOPMENT COMMISSION

Contract No. RV052688/F

CHEYENNE NORTH CROW REHABILITATION PROJECT
LEVEL II - PHASE II

Executive Summary

November, 1989

Prepared by:
ESA CONSULTANTS
Fort Collins, Colorado
STATE OF WYOMING
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I. INTRODUCTION AND BACKGROUND

The Cheyenne Board of Public Utilities (CBPU), with assistance from the Wyoming Water Development Commission (WWDC), is proposing to perform remediation construction on the dam at Upper North Crow Reservoir and the Old North Crow Diversion Dam. The remedial work will result in safer structures, with an estimated extended life of 50 years. Both dams are located along North Fork Crow Creek, approximately 20 to 30 miles west of the City of Cheyenne, (Figure 1, Site Location Map). Upper North Crow Reservoir is one of several municipal storage reservoirs owned by CBPU in the Laramie Mountains. The Old North Crow Diversion Dam intercepts releases from Upper North Crow and delivers them through a pipeline to a water treatment plant near Cheyenne. The location of these structures upstream of Cheyenne and outlying residential areas poses a potentially significant hazard in the event of a dam failure, particularly in the case of Upper North Crow Dam which impounds a reservoir of approximately 2700 acre-feet. In recognition of this potential hazard, and on the basis of earlier studies at Crystal Springs and Granite Dams, the CBPU has initiated a review of the safety and operational adequacy of Upper North Crow Dam and the associated Diversion Dam. The WWDC, functioning as overall project administrator as part of their agreement with the CBPU, will be the agent for state and federal construction-related permits and approvals. The CBPU will operate the project and will be the designated applicant for all operational permits and holder of all assets associated with the project.

The Cheyenne North Crow Rehabilitation Project Level II study was authorized by the 1988 session of the Wyoming Legislature. The WWDC entered into Contract No. RV052688/F with ESA Consultants on June 24, 1988 to perform the required studies. Phase I of the Level II study was completed by ESA in January, 1989. The Phase I North Crow study presented an evaluation of the overall hydrologic and structural condition of the two dams and their major appurtenances, and conceptual remediation alternatives to address hydrologic, structural, geotechnical, and dam safety deficiencies identified during the Phase I investigations. In Phase II, a more detailed evaluation of the condition of the structures was completed, and an optimum plan for the remediation of the structures was developed to adequately address concerns for static and seismic stability, flood protection, and operation.

Available records indicate that Upper North Crow Dam was built in the early 1930's, while the Diversion Dam appears to have been built around 1910. Figures 2 and 3 present the original design plans for the Upper North Crow Dam and Old North Crow Diversion Dam, respectively. (It should be noted that in both cases the actual configuration of the structures differs significantly from that shown on the plans.)

Studies completed during Phase I indicated that the existing Upper North Crow Dam would safely pass a flow equal to 1/4 of the Probable Maximum Flood (PMF), but would fail under larger PMF series floods (ie: 1/2 or full PMF). The studies also indicated that there is some question as to the stability of the existing Upper North Crow Dam under earthquake loading conditions, due primarily to an apparent weaker layer identified within the dam embankment during the geotechnical investigation.
During the Phase II study, ESA was directed to design for the Probable Maximum Flood event. The remediation design for Upper North Crow Dam consists of an eight-foot raise of the existing dam crest, and widening of the existing emergency spillway to allow safe passage of the PMF. The dam raise is required to provide sufficient head on the spillway to pass the PMF. The normal high water level in the reservoir will not be raised, since the dam raise is only to provide additional head on the spillway during emergency situations. Consequently, no additional water will be impounded by the proposed rehabilitation plan. The earthwork to be completed for the dam raise will include widening of the embankment section and flattening of the slopes such that the structure will have an adequate safety factor against failure during the design earthquake, as well as under static conditions.

Rehabilitation of the Old North Crow Diversion Dam will include the addition of one-foot thick facing concrete. The facing concrete will extend the life of the dam, mitigating further deterioration of the concrete and protecting the downstream face against erosive flows in the event of overtopping.

In addition to the dam safety rehabilitation measures, it is proposed to upgrade the outlet works and operational facilities at both dams to a 50-year extended life. Additionally, remedial work will be performed on the outlet works tunnel at Upper North Crow Dam to improve safety for the enclosed facilities and for personnel access. Each of the rehabilitation design components is summarized in the following sections.

II. REHABILITATION PLAN

The Phase II, Level II studies for the rehabilitation of Upper North Crow Dam and Old North Crow Diversion Dam included the development of a remediation plan and feasibility design, based on the evaluation of dam safety and operational considerations. The resulting plan and design addresses the geotechnical, structural, and flood protection concerns and deficiencies identified in both the Phase I and Phase II investigations, as well as providing an estimated 50-year extended life of the facilities.

A. Upper North Crow Dam

Figure 4 presents a plan view of the proposed configuration of the dam embankment and spillway. The proposed improvements to be made at Upper North Crow Dam are based on the following criteria:

1) Inflow design flood equal to full Probable Maximum Flood,

2) Design earthquake of magnitude 5.5, 0.27g acceleration.

Additional improvements are proposed for the outlet works, for stabilization of the outlet works tunnel, and operational rehabilitation measures.

1. Spillway

The existing spillway at Upper North Crow Reservoir is located at the north abutment of the dam. It is approximately 225 feet long, with a masonry overflow crest. A
30-foot long principal spillway is incorporated into the overflow crest, at an elevation approximately one foot lower than the remainder of the crest. This principal spillway discharges via a concrete chute over a steep rock slope and into the valley below. The vertical distance from the crest of the principal spillway, which determines the maximum normal reservoir level, to the existing dam crest is approximately 10 feet.

The proposed rehabilitation design includes widening of the existing spillway by approximately 155 feet. The new section of spillway will have a concrete overflow crest and will have an elevation one foot higher than the existing overflow crest. The new spillway cut will incorporate 1 horizontal:1 vertical side slopes along the north side of the spillway channel. This slope may be flattened by over excavation if additional borrow material is needed for embankment construction.

It is anticipated that all required borrow material can be obtained from the spillway excavation. If other sources are needed, several old borrow areas from construction of the original dam are available nearby.

2. Embankment

The existing dam at Upper North Crow Reservoir consists of an earthfill embankment approximately 650 feet long and 88 feet high at the centerline of the maximum section. The proposed embankment rehabilitation will increase the overall height of the dam by eight feet. The completed embankment will have 3:1 (horizontal to vertical) slopes on the upstream face, and 2:1 slopes on the downstream face.

The riprap and rock blanket will be removed from the existing dam and stockpiled for later re-use. Construction of the proposed embankment improvements will require placement of approximately 91,000 cubic yards of fill (general fill, drain material, and riprap), to be taken from the spillway excavation and rock material to be removed from the existing dam. The compacted fill to be added to the existing dam to accomplish the dam raise will also serve to isolate and strengthen the apparent weak layer identified during the geotechnical investigation.

3. Outlet Works Tunnel

The existing outlet works includes a rock tunnel through the right (south) abutment of the dam. A concrete bulkhead is located in the tunnel approximately 160 feet upstream from the downstream portal. A 20-inch pipe carries flow from the upstream side of the bulkhead, through the downstream portion of the tunnel, and to the outfall at a mortared-rock valve house. Control valves are located both at the bulkhead and in the valve house. Rockfall and slaking of the rock mass has occurred in a 70-foot-long unlined portion of the tunnel downstream of the bulkhead. The remaining approximate 90 feet of the downstream portion of the tunnel has a corrugated metal pipe (CMP) liner. The liner sections have separated by up to about one inch at the overlaps in several locations. Open space or loose rock material is often visible at the separations, and it appears that the space between the CMP and the tunnel wall was not backfilled.

Rehabilitation of the outlet works will include stabilization of the outlet tunnel excavation. At a minimum, this will include the addition of a liner to the exposed portion
of the tunnel downstream of the concrete bulkhead. The recommended treatment of this tunnel section includes the use of easily-installed liner plate with grout backfill, which would provide adequate, dependable protection for that portion of the tunnel which frequently requires access to personnel. In addition, it is recommended that the existing CMP liner also be replaced with the liner plate system. It is expected that the CMP liner would need replacing at some time during the 50-year design life of the protected facilities, and it would be preferable to do so at the same time the other section is installed. Immediate replacement would also mitigate further deterioration of the rock mass unsupported behind the CMP.

When the reservoir is drawn down for construction of the dam improvements the portion of the outlet works tunnel upstream of the plug will be examined, and a decision will be made as to what, if any, treatment is needed to stabilize the tunnel. It is anticipated that such treatment may include application of shotcrete to curb deterioration of the tunnel walls.

4. Outlet Works Operational Upgrades

Rehabilitation of the Upper North Crow outlet works will include replacement of pipes, valves, and operators, construction of a new control building, and installation of remote control and monitoring equipment. The outlet works piping will be entirely replaced from the existing concrete plug in the tunnel to the downstream end of the outlet tunnel, a distance of approximately 160 feet. The new control building will be insulated, heated, lighted, and ventilated. Remote control and instrumentation facilities to be installed in the control building will allow monitoring and control of reservoir operations both at the site and remotely in Cheyenne. Electric and phone service must be brought into the site, and comprises an estimated 50 percent of the total cost of the operational upgrade.

B. Old North Crow Diversion Dam

It is not proposed to perform any major rehabilitation on the Old North Crow Diversion Dam. A surficial examination of the concrete dam indicated that the existing structure can be expected to function safely over the short term for normal loading conditions.

1. Concrete Dam

The existing Old North Crow Diversion Dam is a small, single-curvature, concrete arch dam approximately 140 feet long and 35 feet high. About 20 radial cracks were observed crossing the crest of the dam, which are most probably thermal stress cracks typical of those found in older concrete dams. Minor, intermittent seepage is apparent at many of the lift joints, along with shallow spalling. The spalling of the concrete appears to be associated with freeze/thaw action, and is more frequent on the lower half of the downstream face.

In view of the intent to upgrade the Diversion Dam facilities to an extended life of 50 years, it is recommended that facing concrete be applied to the downstream face of the existing structure. The downstream face of the dam will be cleaned of loose or deteriorated
concrete and a one-foot thick concrete facing applied, doweled into the existing competent concrete. Construction of the facing will require placement of approximately 180 cubic yards of concrete. This facing will curb further deterioration of the existing structural concrete, and will protect the structure against erosion and possible damage in the event of overtopping.

2. Outlet Works Operational Upgrades

The outlet works at Old North Crow Diversion Dam will also be upgraded to allow remote control and monitoring in Cheyenne. The upgrading will include a new control building to house new control valves, metering, and control and indication equipment. Heating, lights, ventilation, and humidity control will be installed in the completed facility. The features and operation of the new control and monitoring facilities will be similar to those to be installed at Upper North Crow Dam. The cost of bringing phone and power service to the site is estimated to be 44 percent of the total facility construction cost.

C. Construction Schedule

Construction of the planned remediation and upgrading is expected to be completed within one construction season. It is anticipated that the reservoir will be drawn down and construction begun in late spring to early summer at Upper North Crow Reservoir. Unless highly unexpected and unusual weather conditions occur, all planned construction should be completed by mid-fall, so that the reservoir can begin refilling the following spring. Construction at Old North Crow Diversion Dam will be concurrent with that at Upper North Crow.

III. PERMITTING STATUS

The Phase II, Level II design studies included the preparation of an Army Corps of Engineers 404 Permit. The 404 Permit is required for the placement or discharge of material into a watercourse. During a site meeting with Corps of Engineers representatives, it was tentatively noted that the project would impact approximately one acre or less of wetlands, which under current law must be replaced by converting an equivalent area of other lands to wetland habitat. No requirements for other environmental permits are anticipated. The filing of the 404 Permit will trigger an Environmental Assessment (EA) by the Corps of Engineers. It will also be necessary to obtain a 401 certificate with the Wyoming Department of Environmental Quality prior to beginning construction.

IV. COST ESTIMATES AND ECONOMIC STUDIES

The total project cost for the Cheyenne North Crow Rehabilitation Project is estimated to be $2.94 million in 1989 dollars. This includes construction costs of $2.7 million, and a cost of $244,000 for final design, plans, and specifications. A breakdown of the estimated total project costs is presented in Table 1.

An Ability-to-Pay analysis and Benefit-Cost analysis was completed as part of the Phase II, Level II study. Considering the cost of replacement water for the North Crow
Reservoir supply, and ignoring the significant recreation benefits at the North Crow facility, a very conservative estimate of the benefit-cost ratio is 2.5:1.

If Cheyenne obtains a fifty percent grant for construction, then its remaining loan obligation will be $1.47 million (including 50 percent of the construction costs and 50 percent of the Level III costs). An annual payment of $68,430 will be needed to retire a $1.47 million, 4 percent loan over 50 years. To repay the design and construction loan, Cheyenne has several options for raising the additional revenue through increases in the existing water rate structure.

Cheyenne can implement an across-the-board increase in both the monthly minimum fee and water sales charge, or simply increase one of these charges. At present, Cheyenne uses a $3.25 minimum monthly fee and charges $1.46 per thousand gallons of water. Currently, there are 17,355 taps within the Cheyenne service area. In the past five years, water sales have averaged 3.781 billion gallons per year.

An increase of about one percent in both fees would raise monthly minimum fees to $3.28 and water sales charges to $1.48 per thousand gallons. This combined increase would generate $81,868 per year in added revenue. Raising just the water sales charge to 1.48 per thousand gallons would generate an additional $75,620 per year. Generating the additional revenue solely from the monthly minimum charges necessitates an increase to $3.59 (about 10 percent) to yield $70,808 per year.
TABLE 1

Project Cost Estimates

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. UPPER NORTH CROW DAM/SPILLWAY</strong></td>
<td></td>
</tr>
<tr>
<td>1. Mobilization, bonding, clean-up, etc.</td>
<td>$105,000.00</td>
</tr>
<tr>
<td>2. Clearing/Grubbing</td>
<td>10,000.00</td>
</tr>
<tr>
<td>3. Strip riprap from existing dam</td>
<td>105,000.00</td>
</tr>
<tr>
<td>4. Spillway excavation</td>
<td>372,000.00</td>
</tr>
<tr>
<td>5. Embankment Construction</td>
<td>653,500.00</td>
</tr>
<tr>
<td>6. Concrete spillway crest</td>
<td>50,000.00</td>
</tr>
<tr>
<td>7. Concrete training wall</td>
<td>37,500.00</td>
</tr>
<tr>
<td>8. Reclamation (seeding)</td>
<td>10,000.00</td>
</tr>
<tr>
<td>9. Wetlands Remediation</td>
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<tr>
<td><strong>SUB TOTAL</strong></td>
<td><strong>Upper North Crow Dam Rehabilitation</strong></td>
</tr>
<tr>
<td><strong>B. UPPER NORTH CROW OUTLET WORKS</strong></td>
<td></td>
</tr>
<tr>
<td>1. Stabilize downstream tunnel</td>
<td><strong>$50,000.00</strong></td>
</tr>
<tr>
<td>2. Stabilize upstream tunnel</td>
<td>90,000.00</td>
</tr>
<tr>
<td>3. Upgrading of outlet works</td>
<td>364,650.00</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td><strong>Upper North Crow Outlet Works</strong></td>
</tr>
<tr>
<td><strong>C. DIVERSION DAM</strong></td>
<td></td>
</tr>
<tr>
<td>1. Facing concrete, with steel</td>
<td><strong>$46,250.00</strong></td>
</tr>
<tr>
<td><strong>D. DIVERSION DAM OUTLET WORKS</strong></td>
<td></td>
</tr>
<tr>
<td>1. Upgrading of outlet works</td>
<td><strong>$226,000.00</strong></td>
</tr>
</tbody>
</table>

**ESTIMATED TOTAL CONSTRUCTION COST** | **$2,124,900.00**
15% Construction Contingency | **318,735.00**
Subtotal | **2,443,635.00**
10% Construction Management | **244,364.00**
Total Construction Cost | **2,687,999.00**
10% Final Design Engineering (10% of Construction Subtotal) | **244,364.00**
**ESTIMATED TOTAL PROJECT COST** | **$2,940,000.00**
SITE LOCATION MAP

FIGURE 1
FIGURE 2

ORIGINAL DESIGN DRAWING OF
UPPER NORTH CROW DAM AND APPURTENANCES
EXISTING OVERFLOW SPIILLWAY CREST

EXISTING PRINCIPAL SPIILLWAY CHUTE

CONCRETE TRAINING WALL

APPROXIMATE LOCATION OF NATURAL HEDGE ALONG EXISTING LEFT ORION - MAXIMUM ELEVATION APPROX. 7565 AT NORTH END

APPROXIMATE FOOTPRINT OF PROPOSED EMBANKMENT

TOE OF EXISTING DAM FILL

CREST NORTH

CREST SOUTH

OUTLET WORKS OUTFALL

EXISTING OVERFLOW SPIILLWAY CREST

APPROXIMATE LIMITS OF SPIILLWAY EXCAVATION

NEW CONCRETE OVERFLOW CREST 16-1, 1970

CREST NORTH

CREST SOUTH

OUTLET WORKS OUTFALL

FIGURE 4

ESA CONSULTANTS
Fort Collins, Colorado

REHABILITATION PLAN
FOR
UPPER NORTH CROW DAM

FIGURE 4