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Crow Creek Flood Control and Groundwater Recharge Project

Executive Summary
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Submitted to:
State of Wyoming
Water Development Commission

Prepared by:
States West Water Resources Corporation
Cheyenne, Wyoming

in association with
ESA Consultants

March, 1990
Crow Creek Flood Control and Groundwater Recharge Project:

Executive Summary

Introduction

Two major water resource problems have been identified for the lower Crow Creek valley area of southeastern Wyoming. Flooding occurs on an occasional basis, causing damages to roads, structures, and croplands. In addition, the lack of surface water and precipitation has forced farmers to rely on groundwater for irrigation, and the groundwater supply is rapidly diminishing. This investigation studied possible solutions to the flooding situation and to the decline in groundwater levels.

Of particular importance is the potential use of flood waters for artificial recharge of groundwater in the area. Storage and diversion of flood waters from Crow Creek to prepared recharge areas not only could reduce flood problems on Crow Creek, but may also reverse the decline of water levels in the area. Within this executive summary, we delineate these two distinct problems and describe our findings for reaching potential solutions to them.

The Crow Creek Watershed

Crow Creek drains an area of about 450 square miles in parts of Albany and Laramie counties in southeast Wyoming. The creek has its headwaters about 35 miles west of Cheyenne on the east slope of the Laramie Mountains. From its headwaters tributaries, Crow Creek flows east to Cheyenne and then flows east and southeast for some 30 miles until it leaves Wyoming near Carpenter (Figure 1). After crossing the state line, Crow Creek flows essentially southerly for 40 miles to drain an additional 900 square miles before joining the South Platte River.

Crow Creek flows year-round along most of its length, although in several locations it dries up where the groundwater table is low. Springtime peak flows from snowmelt and rains usually are limited to several hundred cubic feet per second (cfs); flows remain elevated for only a few days. During most of the year, Crow Creek has only a few cfs of streamflow through Cheyenne. However, return flows from Cheyenne's Crow Creek and Dry Creek sewage treatment plants increase the streamflow below the city by about 10 cfs.
The Flood Problem

Though Crow Creek generally is "mild-mannered", it has flooded in the past, wreaking destruction and causing death. Since the founding of Cheyenne when record keeping began, major flooding has occurred on Crow Creek about every other decade, and sometimes more frequently. Details about the first significant recorded flood on Crow Creek, which occurred in 1883, are sketchy. The earliest flood recorded on Crow Creek in this century occurred on May 20, 1904. Every bridge on Crow Creek, except for the Union Pacific mainline bridge, was destroyed. Two children lost their lives in the flood and many more had to be rescued from rising floodwaters. A large flood on Crow Creek in 1929 resulted in an estimated peak flow of 8,200 cfs at Cheyenne. Damages to bridges, dams, highways, crops, and railroads were reported. The Hereford Ranch Reservoir No. 1 dam may have failed during this flood.

Six years later in 1935, there was a flood on Crow Creek that was considered less extensive than the floods of 1929 and 1904. The flood spread out into the valley, destroying ditches, roads, and fields, and residents of the Hereford Ranch were forced to fill all cracks in the houses of the ranch village to keep out the water. The most noted storm in the Crow Creek basin was that which occurred on August 1, 1985. The storm was centered over downtown Cheyenne and the Dry Creek basin. Peak flows on Crow Creek were estimated at 7,470 cfs near the southeast city limit. Significant damage occurred both in Cheyenne and along Crow Creek.

The Groundwater Problem

Southeast Wyoming receives about 15 inches of precipitation a year, yielding a semiarid climate. The country is a natural grass rangeland, which can be maintained by the annual precipitation. During the past 50 years, well and irrigation technology has allowed groundwater use for the irrigation of fields. In areas such as southeast Wyoming, where the climate normally would restrict growth of high water-requirement crops, groundwater irrigation makes producing such crops possible. The development of the center-pivot sprinkler and the ease of obtaining waters from the local aquifers have allowed southeast Wyoming to produce higher value crops than could be grown naturally in a semiarid climate.

Although the use of groundwater has permitted farmers to grow crops of higher value, their use of groundwater is affecting the resource itself. When the rate of water use is greater than the rate of recharge to an aquifer, water levels in the aquifer decline. The decline causes greater pumping lifts and higher pumping costs. If the aquifer is too greatly stressed, it may essentially be drained, requiring hundreds or thousands of years to recharge. The high density of center-pivot irrigation near Carpenter has caused substantial groundwater declines. Because
of declining water levels in the area, the Wyoming State Engineer has made this part of southeastern Laramie County a "control area" and has limited the drilling of new wells in the area. At present, therefore, no new irrigation wells can be drilled; if the water level decline continues, older wells may be forced out of production. Both the farmers involved and southeastern Wyoming will experience economic loss in the conversion of irrigated crops to dryland crops.

Flood Control Project

Flood Analysis

The first stage in determining the flood control measures necessary to reduce damages on Crow Creek was a study of flooding and its effects. The evaluation method proceeded in several steps. A flood hydrology study was made for Crow Creek, with peak discharge estimates made for several flood frequencies up to the 100-year flood. Next, a flood plain conveyance analysis was conducted using the flood discharge estimates, and flood plains were mapped. In order to provide a baseline damage condition with no flood control program, we used the mapped flood plains to assess the damage potential from flooding. The key findings of the flood plain analysis were:

- The 100-year flood on Crow Creek ranges from 6,930 cfs at the confluence with Dry Creek to 7,260 cfs at the state line.
- Mapping indicates a fairly broad 100-year flood plain in the Crow Creek valley, but few damageable structures are located in the flood plain. The greater magnitude of flood damages occurs to creek crossings (culverts and bridges) rather than to buildings.
- Average annual flood damages in the Crow Creek flood study reach are estimated at $69 thousand. The present worth of these flood damages, evaluated over 50 years at a 6 percent interest rate, is $1.09 million.

Flood Control Alternatives

Three flood control plans using structural components were analyzed for their damage-reducing potential. A non-structural plan based upon flood plain management was also evaluated. A brief summary of each of these four alternative flood control plans is provided below.

Plan 1: Conveyance Improvement

Plan 1 directly reduces flood damage and hazards at the road crossings and through the Wyoming Hereford Ranch (WHR) by using structural improvements to better convey flood flows. Upgrading
or replacing road crossings and improving the channel through the WHR will require minimal land/easement acquisition; these recommended changes can be instituted when existing facilities are replaced due to age or flood damage. The plan calls for flood plain management in areas not affected by the structural improvements. Plan 1 cost estimates range from $630 thousand to $2.6 million, depending upon the level of flood protection provided (Table 1).

Plan 2: Detention Storage

This second plan uses a flood-water detention reservoir to reduce peak flood flows and decrease downstream damages. The best location for detention storage on Crow Creek is at the existing WHR Reservoir No. 1. Enlargement of this reservoir offers the most economical and effective means of reducing peak flows (and consequently damages and hazards) through the entire flood study area. Raising the dam by about six feet will increase storage by approximately 720 acre-feet and may enhance recreational and environmental values. Because the reservoir is privately owned, cooperation from the owner is necessary for this plan to be feasible. In addition, an easement or land acquisition will be necessary.

Implementation of this plan would cost about $635 thousand (Table 1). Although the plan reduces damages and hazards, it does not eliminate them. Damage/hazard reduction decreases as distance downstream from the reservoir increases.

Plan 3: Combined Detention Ponding and Conveyance Improvement

Plan 3 integrates structural elements from both plan 1 and plan 2; it increases detention storage and improves channels and crossings for better conveyance. Because the detention facility reduces peak flood flows, the conveyance improvements are smaller in size than those used for plan 1. Plan 3 reduces damages and diminishes or eliminates hazards throughout the entire study area. Further, the improvements can be built in phases.

Enlargement of the WHR Reservoir No. 1 may enhance recreational and environmental values, but will require the cooperation of the owner of the reservoir. Also, property or easement acquisition will be necessary. The cost of this plan ranges from $830 thousand to $2.7 million, depending upon the level of protection given (Table 1).

Plan 4: Flood Plain Management

A nonstructural alternative that minimizes the impacts of flooding is the use of flood plain management to regulate development of new construction in the flood plain. The plan has little effect on flood damages to existing structures. Other components of the plan are flood warning and public information/notification
Table 1: Estimated costs of flood control improvements.

<table>
<thead>
<tr>
<th>Level of Protection</th>
<th>Right of Way</th>
<th>Construction</th>
<th>Administrative/Engineering</th>
<th>Total</th>
<th>Benefit-Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year</td>
<td>20</td>
<td>2,357</td>
<td>236</td>
<td>2,613</td>
<td>0.40</td>
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<tr>
<td>50-year</td>
<td>18</td>
<td>1,903</td>
<td>191</td>
<td>2,112</td>
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<tr>
<td>25-year</td>
<td>17</td>
<td>1,432</td>
<td>141</td>
<td>1,590</td>
<td>0.57</td>
</tr>
<tr>
<td>5-year</td>
<td>16</td>
<td>557</td>
<td>55</td>
<td>628</td>
<td>0.84</td>
</tr>
<tr>
<td>Plan 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All levels</td>
<td>50</td>
<td>532</td>
<td>53</td>
<td>635</td>
<td>1.10</td>
</tr>
<tr>
<td>Plan 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year</td>
<td>69</td>
<td>2,379</td>
<td>240</td>
<td>2,688</td>
<td>0.39</td>
</tr>
<tr>
<td>50-year</td>
<td>66</td>
<td>2,017</td>
<td>204</td>
<td>2,287</td>
<td>0.44</td>
</tr>
<tr>
<td>25-year</td>
<td>65</td>
<td>1,582</td>
<td>159</td>
<td>1,806</td>
<td>0.53</td>
</tr>
<tr>
<td>5-year</td>
<td>48</td>
<td>711</td>
<td>71</td>
<td>830</td>
<td>0.68</td>
</tr>
</tbody>
</table>

programs. By alerting residents to danger, flood warning systems may somewhat moderate hazards. However, flood hazards at road crossings would remain. This plan has insignificant costs.

Comparison of Alternatives

Among the structural plans, the lowest cost and best benefit-cost ratio is derived from plan 2 (Table 1); however, this plan reduces flood damages and hazards the least. Plans 1 and 3 have similar costs and benefit-cost ratios for the 100-, 50-, and 25-year levels of protection and afford equal, high reductions of hazard and damage. At the lowest level of protection studied (5-year), plan 1 has a better benefit-cost ratio. Plan 2 is not cost-efficient at the 5-year level of protection.

A matrix analysis of non-dollar benefits ranks plan 3 at all levels of protection as the best alternative, followed by plan 2 and then by plan 1. Plans 2 and 3 receive these higher ratings because of the positive influence of the reservoir enlargement on ranking criteria. However, the viability of plans 2 and 3 depends upon the cooperation of the owner of WHR Reservoir No. 1.

Summary

Evaluation of the various plans favors no single alternative conclusively. However, the cost of plan implementation is de-
dependent upon the level of protection provided, with costs for the various alternatives ranging from about $630 thousand to $2.7 million. Benefit-cost ratios varied from 0.39 to 1.10 for the several alternatives and levels of protection. The detention storage alternative was the only alternative with a BC ratio greater than 1.0. A matrix analysis of non-dollar benefits indicated that the combined conveyance improvement and detention storage alternative (plan 3) provided the greatest intangible benefits. Thus, to finalize an alternative selection, the desired level of protection and the willingness to pay for that level of protection must be decided by the people of the Crow Creek valley.

Groundwater Recharge Project

Recharge Analysis

Several facts had to be ascertained prior to the development of the recharge project plan. This information included determination of water available for recharge, the location of areas where recharge would be most effective, and the method to be used for recharge. A summary of the findings on these topics is presented below.

- Existing surface water available for groundwater recharge in the Carpenter area, including flood flows, is limited to about 600 acre-feet per year. Utilizing Crow Creek flood flows and City of Cheyenne future return flows, up to 10,000 acre-feet per year may be available to enhance groundwater recharge in the Carpenter area.

- Two locations — one about two miles west of Carpenter and another area approximately one mile northeast of Carpenter — were identified as the most promising for groundwater recharge.

- The relatively flat topography of the Carpenter area and the high-permeability, alluvial terrace deposits that form the outwash plains east and west of Carpenter are favorable for water spreading. Use of unlined canals in the two areas would be the most practical recharge means.

Recharge Plan Alternatives

Conceptual plans were developed for each of three phases of the proposed recharge program. Because Phases II and III share several similar elements, they are discussed together.

Phase I: Natural Channel Water Spreading

The proposed Phase I recharge program utilizes natural channel water spreading along Crow Creek. Installation of several small — about five feet high — check dams across Crow Creek will
spread channel water by creating shallow flooding for as large an area as possible. For the greatest recharge benefit, the optimal location for the check dams is along a reach immediately below a narrowed section of Crow Creek west and northwest of Carpenter (Figure 2). The dams will be sufficiently far apart to maximize wetted area. Facilities will be necessary to pass water safely from the upstream check dams to the lower dams.

Estimates indicate that each dam structure will cost $25 thousand. The total cost for the entire Phase I system shown on Figure 2 will be about $150 thousand (Table 2). Operation and maintenance costs will be minimal due to the simplicity of the system. On a long-term basis, the structures will fill with sediment and require rehabilitation. Large flood flows could wash out portions of the embankments, necessitating repair.

Phases II and III: Diversion to Areas with Declining Water Tables

The overall concept for both phases uses diversion of surface water from Crow Creek with transmission to the recharge areas. Several facilities ranging in complexity from a small dam impounding only enough water to allow the diversion to a combination diversion/storage dam were investigated. A larger dam and reservoir could store flood flows for slow release to the recharge areas, settle sediment, and provide flat-water recreation. Three potential sites for a storage/diversion reservoir are shown in Figure 2.

To deliver as much water as possible, the transmission facilities conveying water from the dam to the recharge area must be watertight. Therefore, we considered two water-conserving conveyance methods. One such method utilizes lined canals, which have the advantages of being fully accessible and of being relatively inexpensive. Another water-conserving method that was investigated would be use of a pipeline. Buried pipelines are desirable for smaller flow rates, particularly in rough terrain; however, debris must be prevented from entering the pipeline.

Two locations near Carpenter have the greatest potential for groundwater recharge. One area is about two miles west of Carpenter and will be developed in Phase II. The other area is approximately one mile northeast of Carpenter and will be developed in Phase III. At these sites, we propose unlined canals as the principle recharge facilities for the Phase II and Phase III recharge locations.

To effectively recharge the groundwater, the canals must penetrate the topsoil layer, which is approximately two feet thick, into the terrace sands and gravels which will be recharged. The recharge canals should have a minimum two-foot bottom width and slopes limited to approximately 0.1% to control erosion and increase recharge efficiency. Drop structures will be required
Figure 2
Recharge facility location map.
Table 2: Estimated costs of recharge systems.

<table>
<thead>
<tr>
<th>Location and Component</th>
<th>System Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 cfs</td>
</tr>
<tr>
<td><strong>Phase I Recharge System</strong></td>
<td></td>
</tr>
<tr>
<td>Six (6) Check dams</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$150,000</td>
</tr>
<tr>
<td><strong>Phase II West Recharge System</strong></td>
<td></td>
</tr>
<tr>
<td>Alternate Site 1 Diversion dam</td>
<td>$157,000</td>
</tr>
<tr>
<td>West transmission and recharge system</td>
<td>522,000</td>
</tr>
<tr>
<td>Total</td>
<td>$679,000</td>
</tr>
<tr>
<td>Alternate Site 2 Diversion dam</td>
<td>$500,000</td>
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<tr>
<td>West transmission and recharge system</td>
<td>350,000</td>
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<tr>
<td>Total</td>
<td>$850,000</td>
</tr>
<tr>
<td>Alternate Site 3 Diversion dam</td>
<td>$125,000</td>
</tr>
<tr>
<td>West transmission and recharge system</td>
<td>394,000</td>
</tr>
<tr>
<td>Total</td>
<td>$519,000</td>
</tr>
<tr>
<td><strong>Phase III East Recharge System</strong></td>
<td></td>
</tr>
<tr>
<td>Alternate Site 1 East transmission and recharge system</td>
<td>$522,000</td>
</tr>
<tr>
<td>Alternate Site 2 East transmission and recharge system</td>
<td>$287,000</td>
</tr>
</tbody>
</table>

N/A: Not Applicable
Note: Costs include design, construction engineering, and contingencies.

because most of the recharge areas have slopes exceeding the optimum. Figure 2 illustrates the conceptual layout of Phases II and III.

Costs were estimated for the three dams, and for transmission and recharge facilities at each recharge area for three recharge rates (5, 10, and 20 cfs). These cost estimates assume that an RCC dam would be utilized at Site 1 and an earthfill dam would be
used at Site 2. Site 3 costs were based upon an earthfill dam and included only the Phase II recharge system. Costs for the Phase II system (Table 2) range from $519 thousand (site 3 dam and 5 cfs system capacity) to $1.225 million (site 2 dam with 20 cfs diversion capacity). Phase III system costs range from $287 thousand (site 2 dam and 5 cfs system capacity) to $956 thousand (site 1 dam with a 20 cfs system capacity).

Summary

To recapitulate, the groundwater recharge investigation found that, should the State of Wyoming or Carpenter area groundwater users decide to pursue a recharge program in the future, a phased approach of data collection and project development should be undertaken. Existing surface water available for groundwater recharge in the Carpenter area, including flood flows, is limited to about 600 acre-feet per year. In order to achieve and quantify recharge benefits from this water, the Phase I recharge system would have to be implemented at an estimated construction cost of $150 thousand.

With use of Crow Creek flood flows and City of Cheyenne future return flows, up to 10,000 acre-feet per year may be available to enhance groundwater recharge in the Carpenter area. If it can be assured through negotiations with the City of Cheyenne that this quantity of water will be available, the Phase II recharge and Phase III recharge systems may become feasible. However, it should be noted that it will be several years before Cheyenne's return flows will contribute this amount of water.

Conclusions and Recommendations

At the level of analysis conducted for this investigation, options for providing flood control and groundwater recharge in the lower Crow Creek valley appear to be technically feasible. However, some questions remain unanswered. For example, to fully assess the project's geotechnical feasibility and provide better information for developing project costs, a drilling program should be undertaken. Likewise, several matters relating to project sponsorship and funding should be resolved. Principle project conclusions and recommendations are as follows:

- Though jointly studied in this analysis to assess whether there would be significant benefits to combining the flood control and groundwater recharge aspects, it appears that each aspect could stand on its own. Some benefit might be derived for the groundwater project by having a flood control reservoir upstream, but an upstream reservoir is not necessary for recharge purposes. Therefore, each component could proceed on its own.

- Local project sponsor groups should be formed prior to the WWDC committing to continue with the project. A drainage control district or irrigation district could form as
project sponsors for the flood control and groundwater recharge projects, respectively. The information provided in this report should assist these groups in their formation.

- Federal assistance may be available to help finance either the groundwater recharge or the flood control project. The Soil Conservation Service or the U.S. Army Corps of Engineers appear the most likely agencies to assist in the flood control project. An experimental groundwater recharge program could receive assistance from one of several federal programs aimed at groundwater recharge research.

- Streamflow data on the lower Crow Creek is completely lacking because the creek has never been gaged. Therefore, all of the streamflow information in this report was statistically generated and subject to error. In order to provide an adequate database for future studies, the WWDC should install a streamflow gaging station on lower Crow Creek in the vicinity of Arcola.

- If the Wyoming Water Development Commission decides to pursue a Carpenter-area recharge program, a phased approach should be taken. Initially, a data collection phase should be undertaken to provide additional information on the feasibility of the program. If the findings of the data collection phase suggest that the project continue, a three-phase project program could be implemented — with advancement to higher phases occurring as the recharge water supply becomes available.