# CASE STUDY: MODERNIZATION OF THE GOVERNMENT HIGHLINE CANAL

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## ABSTRACT

The Government Highline Canal Modernization Study was completed to evaluate options for reducing the flow rate requirement of the Government Highline Canal during the late Summer and Fall water delivery months. The intent was to develop a design for which Colorado River diversions could be better matched to on-farm demands. The two primary challenges associated with reducing diversions are that (i) at low canal flows many turnouts do not have sufficient pressure, and (ii) it is difficult to schedule diversions to match deliveries.

The Government Highline Canal is part of the federal Grand Valley Project in the Colorado River Basin in west-central Colorado, USA. The project is located at the confluence of the Colorado and Gunnison Rivers at Grand Junction, Colorado. The elevation of Grand Junction is about 4600 feet (above sea level). The United States Bureau of Reclamation (USBR) built the Government Highline Canal in the 1910s in cooperation with the Grand Valley Water Users Association (GVWUA). Project facilities are owned by the USBR; the facilities are maintained and operated by the GVWUA.

The study provided an analysis of structural and operational options that will permit the reduction of operational spills, a series of alternate designs that could achieve this effect, and a computer model of the Government Highline Canal. This paper describes the process and results from the Government Highline Canal Modernization Study.

## INTRODUCTION

Modernization of the Government Highline Canal in Grand Junction, Colorado was initiated due to an environmental concern on the upper Colorado River. The Recovery Implementation Program for the Endangered Fish Species in the Upper

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Colorado River Basin (Recovery Program) identified a problem in a 15-Mile Reach of the Colorado River between Palisade, Colorado and the confluence of the Colorado and the Gunnison Rivers at Grand Junction, Colorado. The 15-Mile reach was identified as an area needing additional water supplies to maintain habitat conditions for several identified endangered fish species. The Recovery Program involves members from environmental and water user groups. Potential water savings from reductions in spill from the Government Highline Canal could provide a water supply alternative to the 15-Mile Reach. The Recovery Program determined that additional flows were needed during the late summer and fall months (August through October) to help maintain habitat conditions for the endangered Colorado squawfish and the rare razorback sucker. To protect and restore these endangered species, the US Fish and Wildlife Service (USFWS) released a final Recovery Program in 1987 (USBR 1998).

The first step in a modernization study is to identify the objectives. For the Government Highline Canal, they were:

**Objectives**

1) The primary objective of this study was to identify options to reduce late-season operational spill, while maintaining the current level of water delivery flexibility to the farmers.

2) A secondary objective was to ensure that changes or modifications resulting from this study did not inhibit future work for the GVWUA related to reducing day-to-day spill throughout the irrigation season.

This paper describes the specific course of action by a project team that was organized to explore options to fulfill these objectives. The project team was particularly interested in maintaining the level of water delivery service and project performance that currently exists in the GVWUA. The current operation provides very simple and flexible service to the farmers. The current system also requires minimal personnel to operate and maintain facilities. Water that is not delivered to farm turnouts crops is simply returned to the source (the Colorado River) with the same water quality as it had when it was diverted. This form of simple canal operation and flexible service was considered ideal by irrigation engineers prior to the recognition of the impact on endangered species that are impacted by in-stream flows.

The improvements discussed in this paper are a combination of management and hardware improvements to the system. It was stressed to all of the participants in this study that research has found that simple hardware improvements could improve the operation/management of the system (Burt and Styles, 1998).

## COOPERATORS IN THE STUDY

In 1988, the Governors of Colorado, Utah and Wyoming, the Administrator of the Western Area Power Administration (WAPA) and the Secretary of the Interior executed a cooperative agreement to carry out the activities of the Recovery Program. The water users provide funding for the Recovery Program. Proposals are submitted to the Recovery Program to evaluate potential projects that could enhance water supplies for the Colorado River. The modernization study began in 1994 with funds from the Recovery Program.

The following are the cooperators in the study:

- Colorado River Fish Recovery Program (Recovery Program)
- US Bureau of Reclamation - Grand Junction Area Office (GJAO)
- Grand Valley Water Users Association (GVWUA)
- Cal Poly - Irrigation Training and Research Center (ITRC)
- US Bureau of Reclamation - Engineering Center, Denver (EC)

The GJAO funded the Government Highline Canal Modernization Study through its participation in the Recovery Program and served as the overall project manager. The GJAO coordinated interactions between team members and allowed for rapid exchanges of ideas and responses. The GJAO has a close familiarity with project details and operations, and was able to provide team members with requested technical information. The GJAO also facilitated close coordination with the GVWUA and was active in the development of project strategies. The EC provided brainstorming during the initial phases of the project.

The role of ITRC was to analyze the potential for spill reduction, and to design several alternate series of checks, automated gates, and operational procedures that would maintain water levels in the canal and flexibility while minimizing operational spill. ITRC has a history of canal modernization research, education and implementation, and has developed a pragmatic approach to canal modernization that stresses the simplest functional design. ITRC has also developed and built a fully operational Water Delivery Facility that allows ITRC to test and demonstrate canal structures and operational techniques.

The role of the GVWUA was to assist with data collection, accept or decline submitted designs, provide input on design options, and implement selected operational changes. Negative or unforeseen consequences will primarily affect the GVWUA. The GVWUA raised concerns about different maintenance requirements, hydraulic mishaps and personnel training requirements. The GVWUA specified that any form of canal modernization must not affect water rights.

This study placed an emphasis on including the GVWUA in all discussions and decision making. The GVWUA manager and board members visited Cal Poly

ITRC early in the program to learn about options for water delivery modernization, impacts on farm irrigation, and the general nature of outside pressures being exerted on other irrigation districts in the Western U.S. At the ITRC Water Delivery Facility the GVWUA leadership was able to see a wide variety of control structures and learn about the benefits and negative aspects of various structures and control schemes. This early visit was very important in establishing a common vocabulary and understanding among all the participants.

Team members held frequent meetings with the GVWUA. Members of the study team visited the Government Highline Canal with GVWUA board members, soliciting board member and manager input about potential canal improvements. Although the primary goal of this study was to minimize operational spills, the team firmly believed that spill reduction should not take place at the expense of water delivery flexibility. Presently, farmers operate their own turnouts from a pipelined system (which is supplied by the Government Highline Canal) on a loosely arranged schedule that approximates a demand schedule.

The other focus of this study was to keep modernization alternatives simple. ITRC used comprehensive analysis procedures to develop robust and relatively simple operational procedures and hardware solutions. Although the design analysis and computations were not intended to be readily understandable to water users, the completed design and operational rules must be clearly understood for the modernization project to be successful.

Another aspect of this project was to include the Recovery Program in the discussions of the proposed changes and the new operational procedures of the system. The study team made a presentation to the Recovery Program's Implementation Committee. This meeting covered the critical issue of how much water could potentially be made available as a water supply alternative to the 15-Mile Reach. In 1994, the Grand Valley Water Management Project began. The construction of new structures is scheduled to begin in Winter 2000.

Table 1. Timeline of Project Completion.

| | |
|---|---|
| August 1996 | - Initial plan |
| October 1996 | - Right of way investigations |
| October 1996 | - FCC radio license |
| October 1996 | - Discussions with Affected Agencies |
| October 1996 | - Preliminary cost estimates |
| November 1996 | - Revised plan |
| January 1997 | - GVWUA, USBR, Recovery Program consensus/acceptance |
| June 1998 | - Construction drawings |
| August 1998 | - Approval of environmental assessment |
| August 1999 | - O&M agreement |
| Winter 2000 | - Construction of structures |

## CURRENT OPERATIONS

The Government Highline Canal diverts water from the Grand Valley diversion dam through 55 miles (88.5 km) of canals south and west to the Badger Wash Check. The diversion dam is located about 8 miles (12.9 km) northeast of the city of Palisade, Colorado. The main canal has a diversion capacity of about 1,675 cfs (47.4 cms), about half of which goes to the Orchard Mesa Power Canal (OMPC) and half continues to GVWUA and other water users. There are spillways after the OMPC that return spill from the Government Highline Canal to the Colorado River. Indian Wash Flume is the "start" of the GVWUA and is located near Grand Junction. The irrigated area of GVWUA is about 21,000 acres (8,500 ha). The spill at Badger Wash is the last spillway and is located at the terminus of the Government Highline Canal. Figure 1 shows the locations of the main components of the Government Highline Canal.

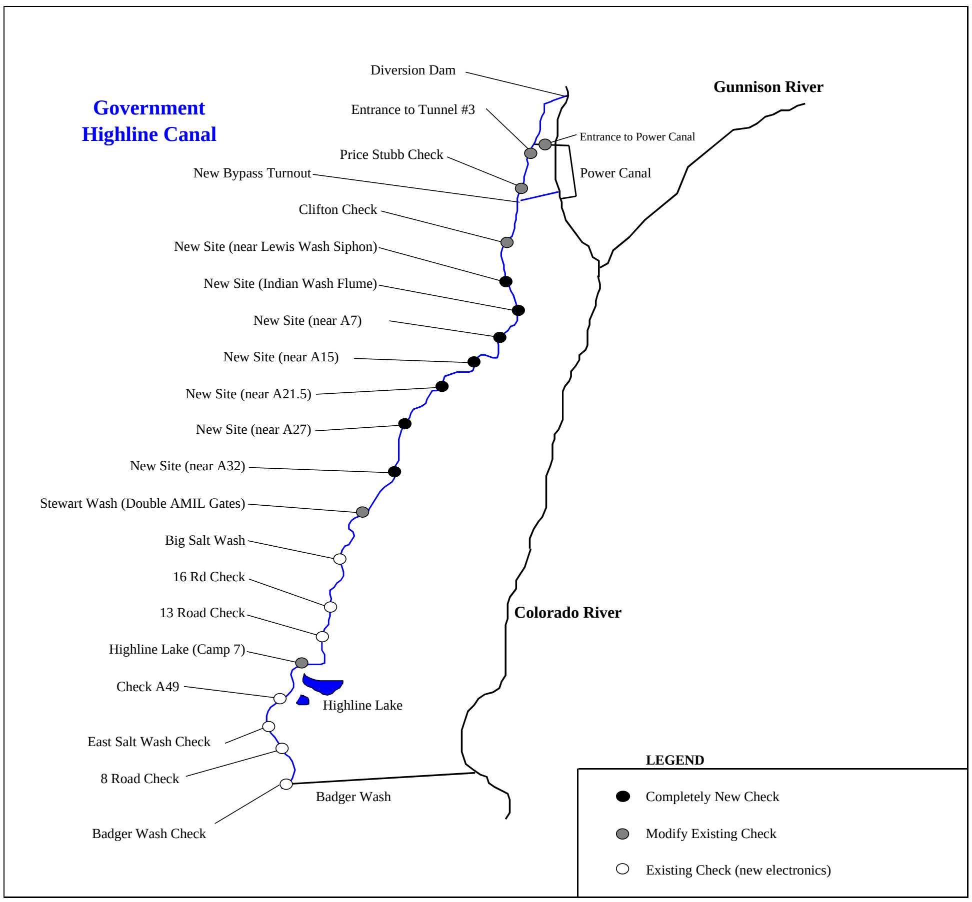


Figure 1. Government Highline Canal.

Farmers typically take deliveries from laterals that are supplied from the Government Highline Canal by gravity. A significant number of the laterals have been converted from open ditch to pipelines. The closed pipeline systems have caused additional spill water to occur on the Government Highline Canal since the pipeline passes fluctuations or mismatches in supply back to the main canal. Prior to pipelines, the open laterals would have individual spill occurring at the end of each lateral. More pipeline conversions are planned in the future.

The irrigation season starts between April and May; during this time there is water available in the Colorado River to meet diversion requirements. The first diversions are used to flush and ready the system for the irrigation season. Demand quickly reaches canal capacity, usually around early to mid June. The canal runs full almost the entire summer until irrigation demand starts to decrease around mid to late August.

There are time periods when the demands on the system exceed the capacity of the canal. During peak water use, it is sometimes required for the GVWUA to institute a pro-rate system where growers can only receive 1 cfs per 40 acres.

In September and October, the canal has fewer orders but it is still operated with at least two thirds the maximum flow rate. This high flow rate (much greater than the demand) keeps the water surface level high enough to meet delivery orders through laterals or turnouts on higher lands and also prevents potential damage to pipeline laterals. Pipelines can be damaged if air is allowed to enter the pipe. Maintaining high water surface levels results in water being passed through the canal and spilled into one of six outlet structures into existing washes. The spill water flows back to the Colorado River.

The current operation of the Government Highline Canal requires that farmers order water on request cards that are provided to the ditchriders by 6:00 a.m. the day before water is to be delivered (i.e., 24 hour advance notice). However, the ditchrider generally provides same day service for orders if water is available in the canal (if the request card is given to the ditchrider before 6:00 a.m.). By 10:00 a.m., each ditchrider contacts the manager and informs him of the changes in demand for his "ride". There are 5 rides or sub-areas in the GVWUA, plus water is delivered to the OMPC, and to two other irrigation districts (referred to as the “Carriage Contracts”).

The GVWUA manager sums up the changes in demand on the system and instructs the ditchriders to modify the operational spills along the Government Highline Canal to match the supply with the demand on the canal. This means that each ditchrider has a set amount of water that is spilling during the day. The spill may stay constant or fluctuate due to unannounced changes made by the growers. The manager may make changes to the canal flow rate at the Diversion Dam and/or the flow rate that supplies the OMPC turnout depending on the time of the year and the anticipation of large changes in demand for the water.

Due to the relatively long time it takes flow rate changes to travel down the Government Highline Canal, the GVWUA must operate with spill within their boundaries to provide flexibility in meeting the changes in demand on the system. The current system allows for excellent service to the growers in that flow rates can be changed during irrigations, the growers can shut off water, and on some laterals the growers can turn on water. This flexibility in the service provided to the growers translates into water savings for the grower.

To analyze the potential for spill reduction, the turnout demands during August through October were determined from water orders provided by the GVWUA. The assumed seepage for the Government Highline Canal was 20 cfs (0.57 cms) from Indian Wash to Badger Wash based on studies done by the USBR. Figure 2 shows a breakdown on the destinations of the diverted water within the GVWUA boundaries.

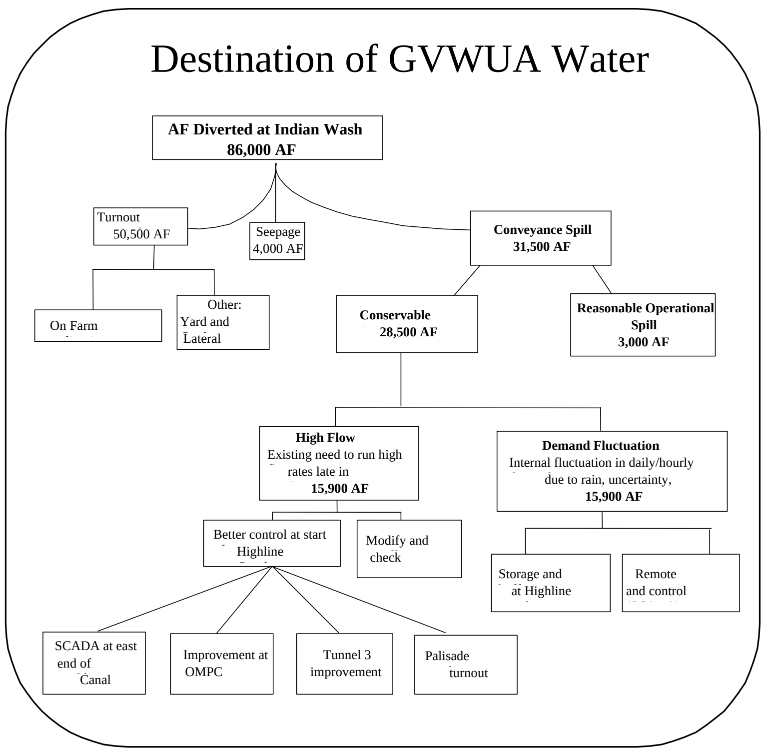


Figure 2. Water Destinations for GVWUA

The average amount of conveyance spill for August through October in 1992-1994 was about 31,500 AF. This included a reasonable operational spill of about 3,000 AF, which leaves about 28,500 AF as the excess spill that could be conserved by the implementation of the proposed project.

The conservable spill amount was found to have two components:

- High Flow Spill (15,900 AF)
- Demand Fluctuation Spill (12,600 AF)

These values were estimated by running multi-year simulations of canal operation with CanalCAD. CanalCAD is an unsteady flow computer simulation model and was used to evaluate the canal system. CanalCAD has been developed with funding provided by Imperial Irrigation District, Imperial, California; U.S. Water Conservation Lab, Phoenix, Arizona; USBR, Denver, Colorado; and ITRC, San Luis Obispo, California (Holley and Parrish 1992).

**Minimizing High Flow Spill**

During the months August through October the Government Highline Canal must be managed to maintain certain water levels to provide deliveries to some laterals that are on high lands. An analysis determined that the amount of spill caused by this situation was 15,900 AF in August through October 1992-1994.

There are several solutions proposed in this modernization study to minimize the spill due to keeping the water level high in the Government Highline Canal. They include the following items:

- The modification of existing check structures and installation of new check structures
- The implementation of a central Supervisory Control and Data Acquisition (SCADA) system
- A new water management plan

**Minimizing Demand Fluctuation Spill**

The demand fluctuation spill volume of 12,600 AF is due to internal fluctuations in daily/hourly demands on the system. The demand fluctuation spill was determined by comparing the canal flow necessary to meet turnout demands plus losses and a maximum water ordering rule. The maximum water ordering rule was established based on historical trends of the water orders. The difference in amounts was the spill due to fluctuations in demand on the system. The current system provides a level of flexibility to the grower. Growers can shut off deliveries, change the delivery flow rate during irrigation, and on some laterals turn the water on.

The modernization project proposes to minimize the spills due to fluctuations in demands by:

- Using Highline Lake as a buffer reservoir and installing a new pump station.
- The implementation of a supervisory control and data acquisition (SCADA) system to remotely monitor the canal.

# CANAL MODELING

Canal modeling was also conducted to make an evaluation of various alternatives to meet water deliveries at low canal flow rates. The evaluation included the locating of check structures, evaluation of reservoirs, and tuning of algorithms used for controlling the canal.

There is some minimum acceptable flow rate or pressure for farmer turnouts that had to be identified and evaluated with the software. It was a requirement of this project that service to the farm and lateral turnouts was not decreased.

A reservoir was identified as being a critical component of the modernization if a relatively simple control algorithm was to be used. Simplicity and robustness of implementation were two key requirements for this project; therefore complex downstream canal control algorithms for sloping canals were dismissed. Those options were also limited because of the lack of pool storage in the canal.

CanalCAD facilitated the evaluation of a reservoir and pumping plant on the lower portion of the Government Highline Canal. Several sites were investigated and the existing Highline Lake was selected as the final location. A critical part of the evaluation was to determine the amount of spill that would occur from the reservoir based on holding different setpoints.

The last step of the modeling was to develop a set of operations criteria for the modernization. This was done by using control algorithms for key points in the system. The computer simulation of the Highline Canal contains several user-defined algorithms that control both its operation and gate automation.

## Control Algorithms

Upper Section of Highline Canal: An algorithm was generated for controlling the operation of the upper end of the Highline Canal between the outlet to Tunnel #3 and Highline Lake. In the CanalCAD model, demand changes are scheduled to occur between 7:00 and 8:00 a.m. each day. Flow rate changes at the outlet to Tunnel #3 occur at 11:00 a.m. each day. In other words, it is assumed that by 11:00 each day, all the new turnout orders will have been completed and the new demand for that day can be determined and used for the control algorithm.

Because accurate advanced knowledge of daily turnout demands is unlikely, uncertainty routines were added to the head flow calculations. Each day at 11:00 a.m. when the new turnout flow rates are calculated, errors of ± 3, 5 and 7% were randomly assigned to the total daily demand value. This uncertainty was designed to simulate ordinary errors in flow rate measurement as well as discrepancies between the volume of water ordered and the volume of water actually taken. The uncertainty coefficient is applied to the turnout flow number only and not the total new head flow rate value.

Palisade Pipeline Turnout and Indian Wash Flume: The proposed location for the Palisade Pipeline Turnout is just below Tunnel #3. In general, the algorithm operation will be once per day, a flow rate target for the Indian Wash flume will be determined. This update will occur at the same time as the Diversion Dam update, or 11:00 a.m. The target setting will be based on that day's scheduled turnout demand downstream of the Palisade Pipeline Turnout taking into account seepage and spill. This will essentially bring the "start" of the canal to the Palisade Pipeline Turnout. A target flow rate of 50 cfs (1.42 cms) will be maintained at this point. This will allow plus and minus variations of the flow rate out of the turnout to handle the changes in the daily demands.

Reservoir Pumping Array Control: A pumping algorithm was developed for Highline Lake. Six pumps are modeled with flow rates of: 5 cfs, 10 cfs, 10 cfs, 10 cfs, 20 cfs and 20 cfs (0.14 cms, 0.28 cms, 0.28 cms, 0.28 cms, 0.57 cms, and 0.58 cms). These pumps are sequenced to turn on based on the water level in the pool downstream of the reservoir. The pumps will be controlled using a VFD on one of the 20 cfs (0.58 cms) pumps (the largest pump).

Operational Rule for West End: Flow regulation through the West End of the Highline Canal is controlled by adjustments made in proportion to an error signal derived from the flow rate through Badger Wash located at the end of the canal. Flow control through the Camp 7 check (start of the West End) will use Proportional-Integral (PI) process control techniques to maintain a desired water level at the Camp 7 flume located immediately downstream of the cross regulator. A water level set point associated with a particular flow rate through the flume will be monitored automatically on a one-minute time step. The Camp 7 gate will be adjusted as required to maintain water levels at the set point resulting in the desired flow rate through Camp 7.

Proportional-Integral Gate Control: Automatic upstream water level control is accomplished using gates automated with the velocity form of Proportional-Integral (PI) process control and the Universal Factor (UF) concept (Burt et al. 1998). For simplicity and robustness, long crested side weirs are designed into each new check gate structure.

## SUPERVISORY CONTROL AND DATA ACQUISTION (SCADA)

At the beginning of the study, it was recognized that real-time operational information available to the operators of the system would be a valuable component of the modernization. It is critical that the monitoring system be designed properly. This includes locating sensors, use of good SCADA software, and incorporation of reliable hardware. The suggested approach is to implement SCADA in 3 phases:

1) Minimum equipment at key control points (Indian Wash, Badger Wash, Camp 7 Spill)
2) Full monitoring implementation
3) Automatic control

With priorities established, the equipment will be selected to allow, or be expandable into, automatic control without replacing any components used in the earlier priorities. Secondly, the equipment will be standardized to reduce necessary spare parts and make maintenance easier.

## Communications

The communication in a water delivery system between sites and between the remote sites and the control station must have the most reliable form of communications. Radio was determined to be the best suited for this project.

Higher power FCC licensed radios in the 900Mhz range can be very reliable. A good radio path survey was done along with on-site field strength measurements to verify this would work for the system. The high power (900 Mhz) radio system is the recommended system for this SCADA system. The only drawback is that the FCC licensing requires approximately one year for a frequency to be assigned once the application is submitted.

## Distributed Control System

A Remote Telemetry Unit (RTU) is required at each remote monitoring or control point. The important things to consider in choosing an RTU controller are:

- Reliability and service. Major manufacturers provide very reliable units with good technical support. ITRC does not recommend small custom-built units that do not conform to standards.
- Communication protocol. Modbus is recommended; this has become the industry standard. Most SCADA software packages will have drivers that support this.
- Generally, the enclosure should be sturdy (NEMA 4) and provide the correct environment for the controller, temperature, humidity, etc. The wiring should be neat with wire numbers and full documentation. There needs to be proper surge and lighting protection. Wiring to sensors should be in shielded conduit or cable if possible.

## Software

Ease of use is the primary requirement for the SCADA software. For most small scale SCADA systems the Windows NT-based systems have been very reliable. Flexible software packages will allow for easy re-configuration as requirements change, without expensive programming.

## Implementation

Evaluation of the vendor (integrator) is critical and must be based on past performance. The implementation of the SCADA system must be "turn-key". In that way, one vendor is responsible for all phases of the project. This will eliminate much of the conflict normally associated with hiring individual contractors.

# PROPOSED MODERNIZATION PLAN

The proposed modernization project will add new structures and facilities to maintain the same level of flexibility and reliability of service to the GVWUA customers, yet have less spill. Implementation of the project is expected to cause a 28,500 AF reduction in the operational spill requirements of the GVWUA during the months of August through October. The daily operation by the ditchriders will remain largely unchanged, except they will need to shift their duties toward preventative maintenance and equipment surveillance, rather than check structure adjustment. The manager will have better access to information and will be able to make more frequent flow rate changes at the canal headworks. In addition, the manager will have new capabilities for flow rate control at Camp 7 and at the new Palisade Pipeline Turnout.

The main features of the proposed project are:

- Seven new check structures
- New pump station and buffer reservoir at Highline
- New Palisade Pipeline turnout to the Colorado River upstream of the 15-Mile Reach
- Implementation of SCADA
- Twenty-one new RTU sites connected by radio
- New central office control facilities
- Modification of thirteen existing check structures
- Modification of the OMPC turnout

Table 2 is a summary of the key control points for the project. Table 3 is a summary of the proposed changes in the operational strategy of the Government Highline Canal.

Table 2. Summary of Key Control Points for the Government Highline Canal.

| | |
|---|---|
| 1. Diversion Dam | Local automatic flow rate control based on water level measurement 500 feet downstream. Flow rate is monitored and the flow rate setpoint is manually adjusted remotely at the GVWUA office. |
| 2. Orchard Mesa Power Canal Turnout | Local automatic upstream water level control by gate at tunnel entrance. Gate to OMPC is manually operated, but can be changed remotely. Water level from OMPC is fed to GVWUA office via the RTU used for both gates. |
| 3. Palisade Pipeline Turnout | Local automatic flow rate control using signal from propeller meter in turnout pipeline. Flow rate setpoint changed manually from GVWUA office, based on desired flow through Indian Wash. |
| 4. Indian Wash Flume | Flow rate measurement site. Desired flow rate depends on the previous day demand, and changes in demand, Camp 7 spill, and reservoir storage. Flow rate controlled by changing bypass turnout, the OMPC turnout and diversion flows. |
| 5. Camp 7 Spill | Primary spill site. Will always attempt to have some spill; further ITRC/USBR work will define this. |
| 6. Highline Lake Pump Station | Pump station will automatically maintain the water level in Camp 7 reach if it drops below a pre-set depth. Capacity of 75 CFS |
| 7. Camp 7 Check | Automatic local flow rate control. Gate control based on new flow rate measurement station downstream. Flow rates changed manually at GVWUA office, based on the previous day demand, changes in demand, and spill at Badger Wash. |
| 8. Badger Wash Spill | Last spill site. Some spill is scheduled to always occur at this site. |

Table 3. Summary of Changes to Structures and Operations for the Government Highline Canal.

| Site | Proposed Structural Changes | Operation |
|---|---|---|
| Highline Canal Headworks | RTU, water level sensor, gate position sensor, gate control | Local automatic flow rate control. Target remotely adjusted at GVWUA office. Water level measured 500 feet downstream in rated section. |
| Orchard Mesa Power Canal Turnout | Motorize the existing gate operator, air vent, RTU, 2 water level sensors, gate position sensor, gate control | Remote manual flow rate control. Based on water level in the OMPC across the river; gate movements made from GVWUA office. |
| Tunnel 3 (Entrance) Check | New gate hoist, water level sensor, gate position sensor, gate control | Local automatic upstream water level control using RTU. |
| Price-Stubb Check | Insert new overshot gate, RTU, water level sensor, gate position sensor, gate control | Local automatic upstream water level control using RTU. |
| Palisade Pipeline Turnout | New structure, 1,000 feet of pipeline, 120 CFS capacity, large diameter, RTU, gate position sensor, gate control, flow meter | Local automatic flow rate control. Measured in pipe and adjusted remotely to fine tune Indian Wash Flume flow rate. |
| Clifton Check | Add manually operated sluice gates at 2 of the stop log bays, RTU, 2 water level sensors, gate position sensor | Local automatic upstream water level control using a single AMIL-450 gate. |
| Lewis Wash Siphon | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-40' long crested weirs | Local automatic upstream water level control using RTU. |
| Indian Wash Flume | Add an acoustical flow meter, water level sensor, RTU | Flow rate based on change in reservoir storage plus change in demand. Flow rate to be controlled by adjustments to the River By-Pass Turnout. |
| A1-1/4 Check | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-35' long crested weirs | Local automatic upstream water level control using RTU. |
| A7 Turnout | Remove and place 500 feet upstream | |
| A7 Check | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-33' long crested weirs | Local automatic upstream water level control using RTU. |
| A15 Check | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-31' long crested weirs | Local automatic upstream water level control using RTU. |
| A21-1/5 Check | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-28' long crested weirs | Local automatic upstream water level control using RTU. |
| A27 Check | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-25' long crested weirs | Local automatic upstream water level control using RTU. |
| A32 Check | New check structure, RTU, water level sensor, gate control, 2-12' gates, 2-23' long crested weirs | Local automatic upstream water level control using RTU. |
| Stewart Wash | Possibly modify the set point | Local automatic upstream water level control using an double AMIL-450 gates. |
| Big Salt Wash Check | RTU, 2 water level sensors, gate position sensor, gate control, modify entrance | Local automatic upstream water level control using RTU. |
| 16 Road Check | RTU, water level sensor, gate position sensor, gate control, abandon well | Local automatic upstream water level control using RTU. |
| 13 Road Check | RTU, water level sensor, gate position sensor, gate control, abandon well | Local automatic upstream water level control using RTU. |
| Camp 7 Spill | Add long crested weir 100 feet long, modify Replogle Flume, remove existing sluice gates, new sluice gate on weir | |
| Highline Lake Pump Station | New pump station, possibly 3 pumps- 40 CFS w/ VFD, 20 CFS, 15 CFS, 36-inch discharge piping, RTU, 2 water level sensors, pump control | Water level control based on reach upstream of Camp 7 Check. Pumps turn on if water level drops below weir. Operate in 6" band (2 AF) |
| Highline Lake | Storage - 250 AF | Operation rule to be determined. |
| Camp 7 Check | RTU, water level sensor, gate position sensor, gate control, flow measurement 500 feet downstream of check, abandon well | Local automatic flow rate control. Measured on new downstream flow measurement site and adjusted based on the change in demand and the spill at Badger Wash. |
| A49 Check | RTU, 1 water level sensor, gate position sensor, gate control, need to abandon existing stilling wells | Local automatic upstream water level control using RTU. |
| East Salt Wash | RTU, 1 water level sensor, gate position sensor, gate control, need to abandon existing stilling wells | Local automatic upstream water level control using RTU. |
| 8 Road Check | RTU, 1 water level sensor, gate position sensor, gate control, need to abandon existing stilling wells | Local automatic upstream water level control using RTU. |
| Badger Wash Check | RTU, 1 water level sensor, gate position sensor, gate control, need to abandon existing stilling wells | Local automatic upstream water level control using RTU. |
| Badger Wash Spill | RTU, 1 water level sensor, new Replogle Flume | Flow rate knowledge used to help control Camp 7 Check |

## SUMMARY

In summary, a detailed evaluation of the Government Highline Canal was performed. Recommendations for modernization were made based on using a computer simulation program (CanalCAD). The main purpose of the project was to recommend changes that would maintain the current level of "service" that is currently made available to the farmers in the GVWUA. The current system is characterized as having a simple and efficient operation. The modernization steps would emphasize simple solutions for the new control strategy.

The results of the study were that about 28,500 AF of water that currently spills from the Government Highline Canal could be used for the "15 Mile Reach" of the Colorado River (located above the confluence of the Gunnison River and Colorado River). These additional flows would aid in the restoration of habitat for the endangered Colorado squawfish and the rare razorback sucker.

The total cost of the modernization project is estimated at $8.4 million (about $400/acre or $988/ha) to plan, design, and construct the canal improvements and for the expected increase in operation and maintenance costs.

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