INTRODUCTION

Grand Valley Project

The Government Highline Canal is part of the Bureau of Reclamation, Grand Valley Project, located in Grand Junction, Colorado (figure 1). The canal construction was started in 1913 and completed during the Great Depression. The canal extends 52-miles from the diversion dam on the Colorado River flowing westward through the Grand Valley. Two Federal environmental programs spanning a 25-year period have had a dramatic impact on the modernization of the Highline Canal. This paper discusses the use of an operational pipeline spill near the canal head of the canal, in conjunction with a regulating reservoir and pump station near the canal end for reducing operational spills and improving canal water management.

The Colorado River Endangered Species Act funded the Highline Canal moderation program, with an objective of reducing canal diversions in the fall, to enhance Colorado River flows in a critical 15-mile reach, for the benefit of Colorado's endangered native fish population.

Historically canal flows ranged between 650 cfs to a minimum flow of 400 cfs. The minimum flow was necessary to maintain canal water surface levels for turnout deliveries. The addition of seven new check structures reduced the required minimum canal flow to 150 cfs.

Today the canal has 21 automated check structures in series, spanning 48 miles of the 52 mile canal. The check structures reduced the required minimum canal flows (figure 1). The combination of a controlled operational spill (Palisade Pipeline) near the start of the canal, and a reservoir pump-back station (Highline Lake) near the end, was envisioned to compensate for mismatches between water supplies from Colorado River diversion and irrigation water delivery demands.

HIGHLINE CANAL MODERNIZED FACILITIES

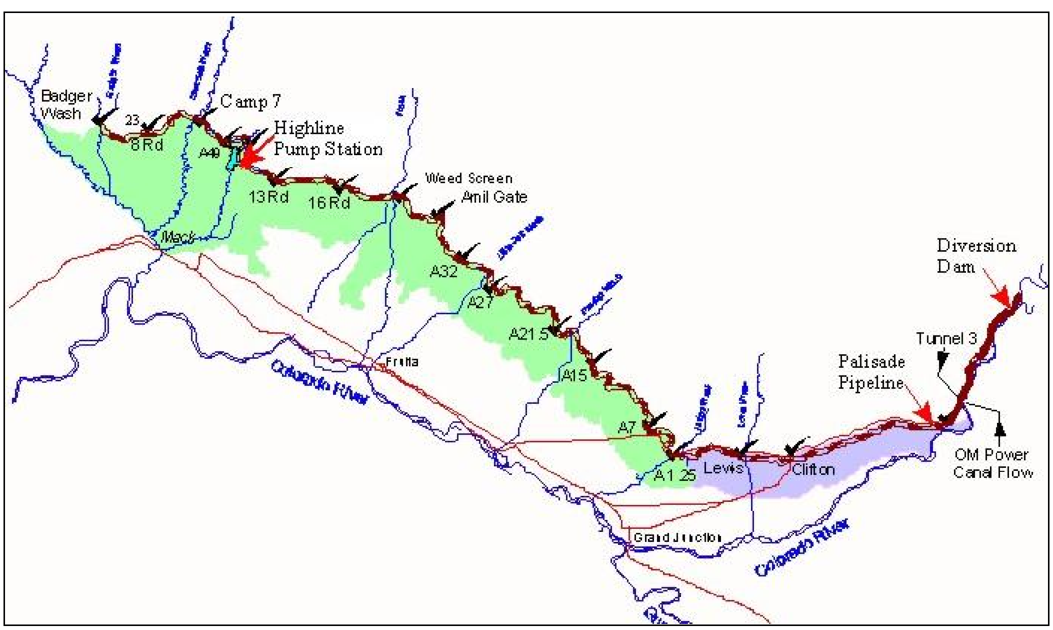

Figure 1: Grand Valley Project, Government Highline Canal

Palisade Pipeline Operation Spill

The Palisade Pipeline is designed to fine tune the flow in the Highline Canal. The pipeline (spill) is 6.5 canal miles downstream of the diversion dam, and is located below the four major turnouts that deliver water to three other irrigation districts and a power plant. The operational spill is a metered turnout structure from the Highline Canal, (figure 2), with a flow control gate and 1000 feet of 36-inch PVC pipe.

Figure 2: Palisade Pipeline Turnout from Highline Canal

The Palisade Pipeline spill discharges back into the Colorado River, (figure 3) above the critical 15-mile fish habitat reach of the river. The flow capacity in the pipeline is in excess of 100 CFS.

Figure 3: Pipeline Spill Returning 75 cfs to the Colorado River

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Highline Lake Regulating Reservoir and Pump Station

Highline Lake is a recreation reservoir, with a surface area of 140 acres when full. The primary water supply for the lake is the Camp 7 spill, (figure 4) from the Highline Canal. The Camp 7 spill is 44 canal miles downstream from the Colorado River diversion dam. The historic flexibility for canal operation was achieved by diverting more water than required for irrigation deliveries, and spilling the excess water into the natural washes that intersect the canal throughout the Grand Valley, (figure 1).

Figure 4: Camp 7 Spill into Highline Lake

As part of the canal modernization program, a pump-back station was constructed in Highline Lake (figure 5). The pump station has a 200-horsepower lead pump, controlled with a VFD, and two additional 150-horsepower pumps, which are staged to supply additional flow. The total pumping capacity of the Highline pump station is 70 cfs (figure 6).

Figure 5: Highline Lake Pump Station

Reducing the operational spills in the canal will sometimes create a situation where the water delivery demands exceed the available water a particular canal reach. The purpose of the pumping station is to supplement these shortages, while more water is moved from the Palisade Pipeline spill down the canal, to cover the delivery shortage.

Figure 6: The Pump Station Delivering 70 CFS into the Highline Canal

Pipeline Spills and Regulating Reservoir Operation from the Designer's Point of View

The Palisade Pipeline allows the operator to fine tune the flow in the Highline Canal without adjusting the river diversion at the dam. By maintaining base flow of 50 cfs in the pipeline spill, canal flows can be increased or decreased by 50 cfs at the spill turnout. The time required to see a change in canal low at Camp 7 from a change in the pipeline spill is 13 hours. In other words, decreasing the flow by 25 cfs at 6:00 AM in the Palisade Pipeline will be seen as a 25 cfs flow increase at Camp 7 by 7:00 PM on the same day.

If the operational spill into Highline Lake is managed around 15 cfs, and the operational spill at the end of the canal, (Badger Wash) 6-miles downstream of the Camp 7 spill, is managed at 20 cfs; In theory, there is a 35 cfs spill buffer between canal supply and delivery demand. Add the 70 cfs automatically available from the Highline Lake pump station, and there is in theory a 100+ cfs buffer between canal supply and delivery demand. The design envisioned that the 35 cfs spill buffer could accommodate moderate increases in demand. If a demand increase exceeded the spill buffer, the pumping plant would turn on. When the pump was turned on, the flow of water in the Palisade Pipeline would be reduced, leaving more water in the canal. Within 13 hours, the additional flow would reach Camp 7 and allow the pumps to turn off.

Canal operation is not as simple as it seems to the designer. The canal is 52 miles long, with 21 check structures in series along the canal, operating in upstream water level control mode. All the check gates are automated. This is a perfect setup for a big wave tank.

Pipeline Spills and Regulating Reservoir Operation from the Manager's Point of View

This part of the paper is based on an interview with Richard Proctor, Manager of the Grand Valley Water Users' Association. The Palisade Pipeline spill was the manager's idea during the modernization study in the late 1990's. The pipeline spill is used to fine tune the flow in the Highline Canal, and it has been operated for five years. This spill is used to match canal flows with water deliveries, and operational spills at the end of the canal, without changing the river diversion at the dam. The pipeline spill is operated during the spring to stay a head of increasing irrigation water demands. At peak demand, in July, the spill is off.

Then from August through the end of the irrigation season, the spill is used as a quick response to changes in water delivery demand. The indicators for a change in canal flow, are the amount of spill at Camp 7 and Badger Wash.

The manager's target spill, into Highline Lake at Camp 7, is about 90 cfs, and the target spill at Badger Wash is 40 cfs. Why is there such a large difference between the designer's spill targets and the manager's spill targets?

The water surface in the canal at the Camp 7 spill is controlled with a side-channel automated over-shot gate that spills into Highline Lake. The canal water surface is well controlled, but the spill into the lake fluctuates by about 60 cfs on a two hour cycle, (figure 7).

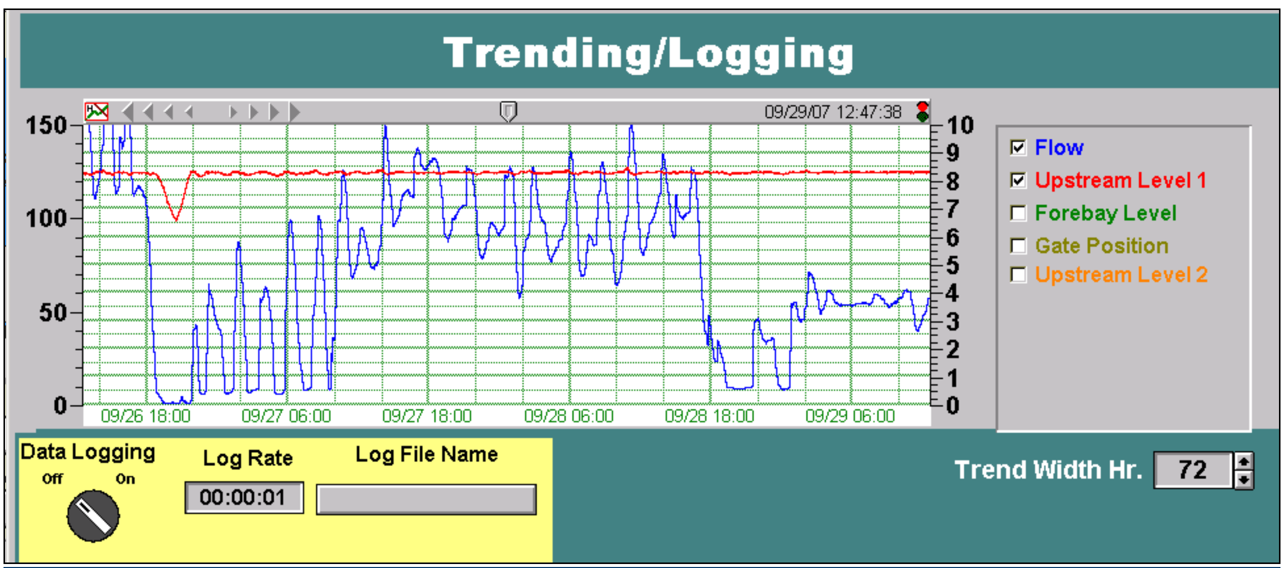

Figure 7: Log of the Camp 7 Spill into Highline Lake

When the Camp 7 spill target is at 90 cfs, the reliable buffer of extra water is about 30 cfs. The stable water surface level in the canal at Camp 7 produces a relative constant flow into the 6-mile end section of the canal. The trending log, (figure 8) is a three day log of the Badger Wash spill at the end of the canal.

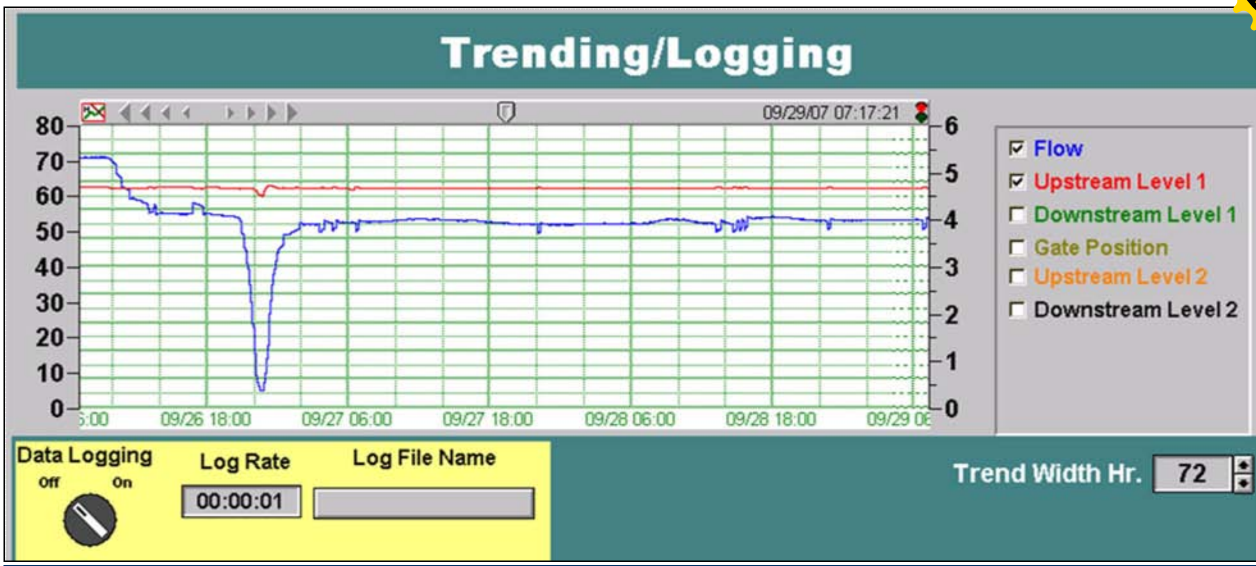

Figure 8: Log of Spills at the End of Highline Canal

The manager has had one full operating season with the automated pump-station, and is still on the learning curve. Currently the pump-station is used to compensate for operational malfunctions with canal equipment. The bumps, on the water surface trending lines (red), on the logs represent an accidental 50% (600 cfs) downward spike in canal flow at the diversion dam. At Camp 7, the spill dropped to zero and 45 cfs was pumped from Highline Lake into the canal. The regulating reservoir and pump-station respond well to large canal flow fluctuations, but why is the spill into the lake so unstable?

HIGHLINE CANAL AUTOMATION

Automated Canal Gates and Control Methods

Reclamation constructed the first motorized canal check structures in the Highline Canal as part of a canal lining, salinity control effort in 1979. The four new canal checks were automated as an afterthought in 1982, with surplus "Little-Man" controllers from a California Reclamation project.

Little-Man control logic uses an upstream canal water level as a target. If the water level moves a significant amount (up or down) from the target, the gate will automatically move in the appropriate direction to restore the water level to the target. Typically the gate move with Little-Man control is a fixed time length (5 seconds) and the control time step is also fixed (5 minutes). That means that if the water surface is off target, every five minutes the gate will move for five seconds to try to restore the water level to the target. The Little-Man controller will repeat the gate move process every five minutes until the target level is restored.

In 1986 the end of the Highline Canal was lined, under the salinity control program and four additional canal check structures were added. These checks were automated with an industrial ladder-logic controller, using Little-Man logic.

The Irrigation Training and Research Center (ITRC) and the Bureau of Reclamation partnered in a comprehensive canal modernization study starting in 1996. Construction of the canal structures from the studies recommendations began in 2000. The ITRC had developed a Proportional Integral Filtered (PIF) gate control algorithm. The ITRC modeled the Highline Canal system with the 14 existing and 7 proposed check structures on a hydrodynamic canal computer program.

The purpose of modeling all the gates in concert was to tune each PIF filter constants for overall canal stability, at various canal flow rates. If all of the gates are properly tuned, the gates should not induce waves in the canal.

When modernization construction was completed, the PIF logic was installed in the new check gates. Because of time and money constraints, the PIF logic for the older check gates was not implemented. These gates were already “automated”. Performance of the old gates appeared to be fine. The Little-Man logic did not seem to be inducing waves into the canal and seemed to be able to hold the canal at the desired water levels.

We were aware of the fluctuations in the Camp 7 spill but believed these fluctuations were caused by the control on the overshot gate. In the summer of 2007 the control was changed to a PIF algorithm. This algorithm did a much better job of maintaining the desired water surface level in the canal, but the spill fluctuations persisted. Our current theory on the cause of the Camp 7 spill fluctuations is that the Little-Man control in the three old upstream canal checks are causing the problem.

CONCLUTION

Lessons Learned

Just because the canal water surface looks stable and the automated gates are working, don’t assume the canal is under control.

The magnitude of the spill fluctuation was not believed by the designers until a SCADA system was implemented at the site, and data trending logs were examined.

It appears that Little-Man control can induce waves. Flow fluctuations are not observed in the canal in reaches with PIF control. One portion of the canal with Little-Man control appears to behave well, but in another portion Little-Man control appears to induce flow fluctuations.

The automated spill at Camp7 and the Highline pump station work very well, but the canal is not yet tamed.

The designer’s operational point of view and the manager’s operational point of view may merge, when the canal is brought under control