IRRIGATION CANAL IMPROVEMENTS IN NORTHERN UTAH FOR ENHANCING WATER RESOURCES MANAGEMENT

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ABSTRACT

A variety of improvements were made to the irrigation canals in two northern Utah counties during the past several years using state funding meant for enhancements in managing water resources. The improvements included operation and maintenance surveys and recommendations, calibrations of existing flow measurement structures, design and construction of flow measurement structures, measurement of seepage losses, and installation of water level recorders, data loggers, and telemetry systems for improved monitoring of flows. All of the work involved the participation of canal company management, and it was done at the request of the water users and or river commissioner, always in collaboration with state and local government agencies. Some of the results of this work include new flow measurement structures and recording/transmitting equipment, updated measurement structure calibrations, O&M recommendations, detailed GIS-based maps and photographs of the canals and structures, and maps and analysis of seepage losses in several canal reaches.

INTRODUCTION

Cache Valley, in Utah and Idaho, has several irrigation canals which take water from streams and rivers flowing into the valley from the surrounding Wasatch Mountains. Many of these canals were constructed early in the 20th century and most are still earthen, although plans are in place to line several miles of canals in the coming years. As the population of Cache Valley grows, the demand for high-quality water has increased, and the need for improved water management has become more important. Irrigation water users have been especially targeted for water management improvements because they use the largest quantities of water in the valley. The situation is particularly difficult because water measurement capability in the canals is limited, and the operation and maintenance (O&M) budgets of the canal companies have always been very low, often leading to significant deferred maintenance of the infrastructure, including the water measurement installations.

For these reasons, a series of steps were taken over the past seven years to assess the current state of water management in several Cache Valley canals, including surveys to develop improved (and expanded) maps of the canals, the state of the infrastructure, and the current management practices. New operation and maintenance plans were developed for each of the canals, some new flow measurement structures were designed and installed, telemetry and data-logging systems were installed, and seepage losses were quantified. In addition to these measures, calibration checks were performed for each of

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the existing flow measurement structures in the main canals, and those structures that could no longer function as flow measurement devices have been identified and documented.

All of the main irrigation canals receiving water from the Logan River which flow west and north through the valley were selected for inclusion in the improvement work which has been accomplished, including one canal to the south, and another which takes water from a different mountain stream. The Nibley-Blacksmith-Fork canal conveys water from the Blacksmith Fork River, and the remainder of those included in this work receive water from the Logan River through ten different canals. These are all important canals because the flow in them makes up more than half of the irrigation water used in the valley. In a typical year, the irrigation canals operate from April to early October. The improvement process which was followed comprised several related steps, including the following:

1. Detailed physical surveys of selected canals and related infrastructure;
2. Interviews with canal company personnel and state water officials;
3. Presentations at canal company board meetings;
4. Measurement of canal seepage losses and gains;
5. Preparation of O&M plans to assist canal company managers in achieving improved management of the available water resources;
6. Calibration of existing flow measurement structures in the main canals;
7. Design and construction of open-channel flow measurement structures; and,
8. Installation of telemetry systems and data-loggers to monitor and record water levels at key water measurement locations.

IRRIGATION SUPPLY SYSTEM SURVEYS

Surveys were conducted on most of the Cache Valley irrigation canals to determine the present condition and operability of these canals, including culverts, gates, flumes, and other structures along the main canals. Attention was paid to all the minute physical details by walking in and along the canals, also giving opportunities to meet and talk with some of the water users and canal operations personnel. This type of survey has been called a *Diagnostic Walk-Through* (Skogerboe and Merkley 1996). The diagnostic surveys were conducted on nine irrigation canals that carry water from the Logan River to the west and to the north, and in one case to the south. During the surveys, several hundred digital photographs of flow measurement and water delivery structures, among other significant locations, were taken, along with comments about operations and maintenance issues which were recorded in the field notes at the time each photo was taken. The coordinates of each location were taken with a GPS unit and were also registered in the field notes. One version of the new canal map is presented in Fig. 1.

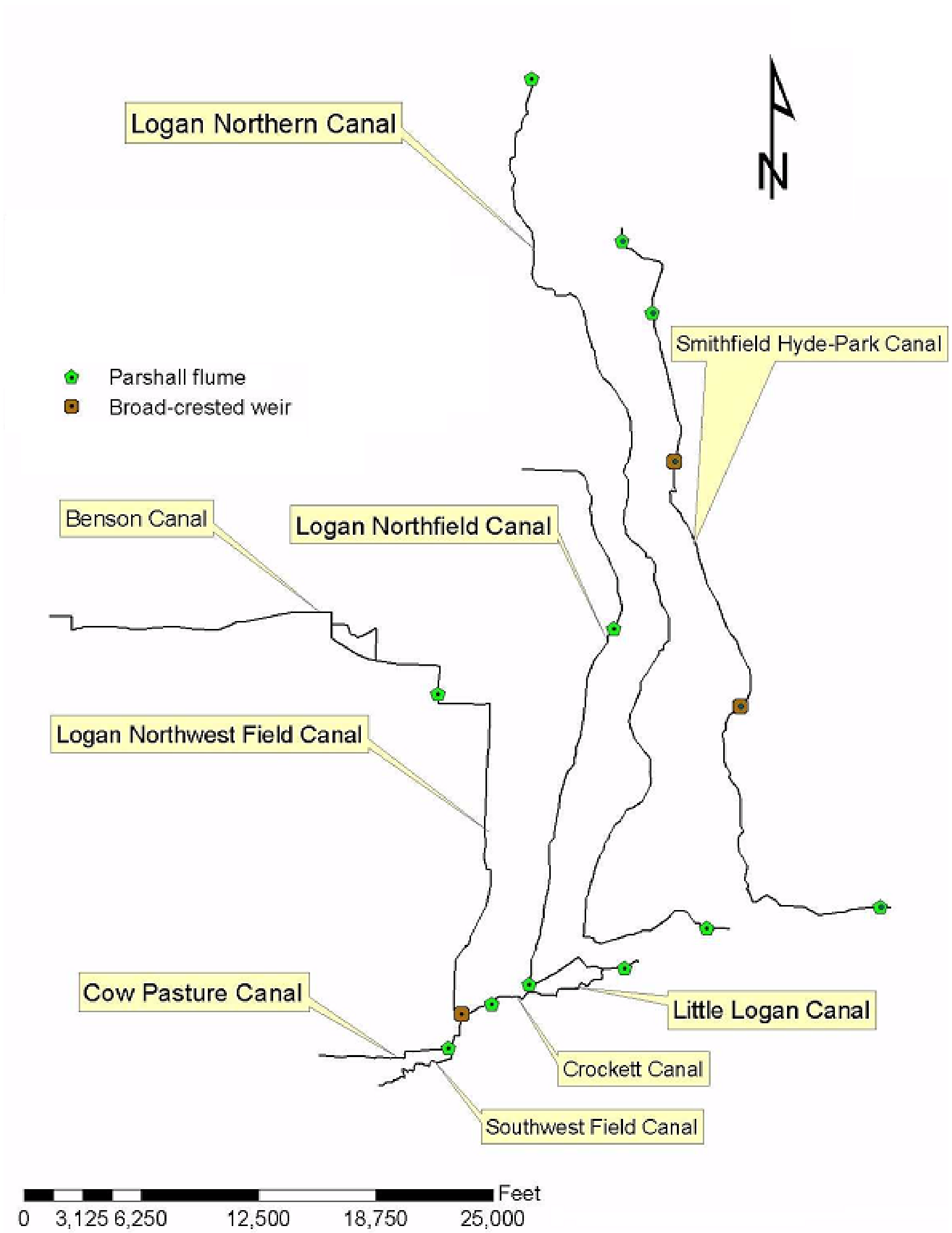

Figure 1. Plan view of selected Cache Valley irrigation canals

Interviews and Preparation of O&M Plans

Many of the people involved in the canal operations played an important role in the entire process of development of O&M plans for irrigation canals. In this process, efforts were made to communicate with canal management officials, learn their present methods, strategies, concerns, and problems in achieving the goal of meeting irrigation water requirements within existing budgetary constraints, and with minimum water losses. The observations of the diagnostic surveys were discussed in the interviews with the canal company management and operators, and photographs taken at the time of the survey were shown to them to more clearly discuss key locations in the canals and their importance.

One of the objectives of this study was to develop O&M plans for selected irrigation canals (Tammali 2005). In this plan, all the practical O&M problems identified during the diagnostic surveys were shown with proposed solution approaches. The individual plans also presented a set of guidelines for periodic maintenance of the canals with the active participation of all who are involved in their management. Some of the main maintenance tasks, as observed at the time of the diagnostic surveys, were:

- Periodical removal of weed growth;
- Removal of debris at trash screens;
- Lubrication of outlet gates and head gates;
- Removal of lawn trimmings from the canals;
- Repair of flow measurement structures (where necessary);
- Removal of sediment and tree leaves from the canals; and,
- Repair of side walls damaged by trees growing near the canals.

Calibration of Existing Flow Measurement Structures

The existing measurement structures were calibrated using a current meter to determine the flow rate, taking several measurements, such as upstream and downstream depths at the structure, water surface elevations, and the channel cross section downstream of the structure. The dimensions of all Parshall flumes were checked against the dimensions for standard flume sizes and any discrepancies were noted. Most of the Parshall flumes were found to have standard dimensions and the calibration checks agreed with the standard ratings by ±5% of the discharge.

Some non-functional flow measurement structures were found in the canals. For instance, the Logan Smithfield-Hyde Park canal has three Parshall flumes and two broad-crested weirs (BCWs). One of the three Parshall flumes was observed to be operating under submerged-flow conditions, but the measurement arrangements at the structure were made only for free-flow conditions. At this location there is no provision to measure downstream depth to determine the flow rate under submerged-flow conditions. Thus, the assumption of free-flow at this flume yields large errors in the measurement of flow rate at that location. Thus, it was also necessary to provide some training to the canal management and operators about the correct use of flumes and other measurement structures.

Stormwater Inflow

The most significant operational problem for the Cache Valley canals is storm water drainage into the canals. The development of many new commercial and residential buildings has including the construction of many parking lots which, by themselves, have very little capacity to retain rainwater. The collected storm water often flows directly into the irrigation canals which pass in the vicinity (or downhill) of the developed areas.

This problem is significant because the canals were designed and constructed to supply water, so the capacity reduces in the downstream direction, and they are unable to accept large inflows, especially in the downstream reaches. For example, the Logan Northfield canal in Logan City, which conveys water to the Benson canal, is one of the canals suffering from stormwater inflow problems. Because of stormwater drainage into the canal, the canal company does not have any control on the water flow in the canal when they have surplus water in the canal. There are many problems such as flooding of adjacent lands, sediment deposition, water quality degradation, and channel bed erosion in the canal due to stormwater drainage inflows.

A new broad-crested weir was designed and built by USU on the Southwest Field Canal at the request of the Logan River Commissioner. The structure was built using concrete in an earthen canal, and included an upstream stilling well with an enclosure for water-level recording instrumentation. The new location was equipped with a data logger and a float assembly to record water levels at 15-minute intervals during the irrigation season. The data logger is powered by a 12-volt deep-cycle marine battery, which does not require recharging during the irrigation season, thereby avoiding the need for a solar panel and ancillary equipment.

MEASUREMENT OF CANAL SEEPAGE

Seepage measurements were performed using the inflow-outflow method in several reaches of the canals (Fig. 2), including many repeat measurements at different times during the irrigation season. Discharge measurements were estimated using mini, electromagnetic, and acoustic current meters with rods and the wading method.

Field activities included the monitoring of water levels to observe if the water depth was fluctuating; measurements were only done while the water depth remained constant. Reaches were selected based on accessibility, uniformity of cross section, and predominance of inflow and outflow points at the canal banks. For convenience and accuracy, reaches with numerous water inflow and delivery (turnout) structures were avoided, but inflows and outflows were quantified to distinguish them from seepage loss or gain.

Canal seepage data from the included irrigation canals indicated both spatial and temporal variations. Monthly comparisons of seepage losses within the monitored reaches indicate a higher seepage loss during the late summer, as compared to the spring and early summer. Spatial variations show that most of the canals presented a decreasing average seepage loss in the downstream direction. Between canals it was observed that reaches located in the east part of Logan City presented higher seepage losses than reaches in the canals on the west side. Some canal reaches manifested net seepage losses, while others had net seepage inflow at the time of the measurements. Superposition of the seepage measurements and thematic maps showed a pattern between the estimated canal seepage and the surrounding type of soil, the saturated hydraulic conductivity, the presence of the shallow groundwater and the topography.

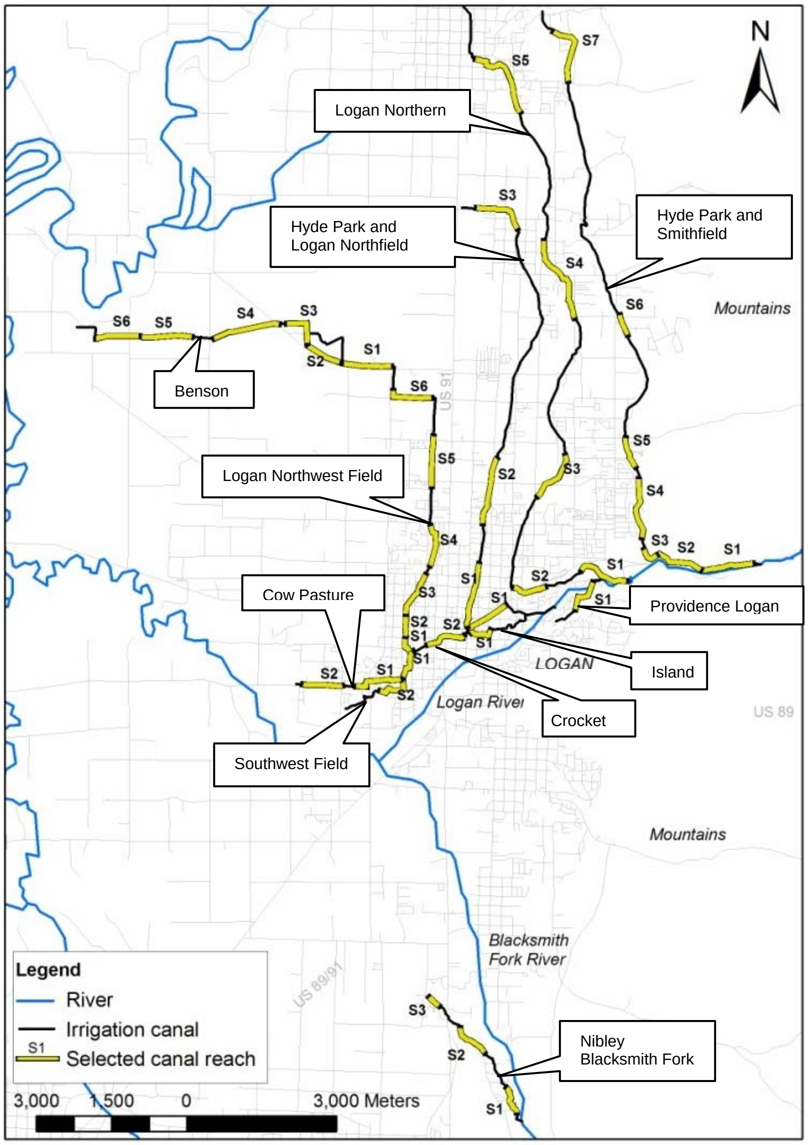

Figure 2. Map of the Cache Valley canal reaches in which most of the seepage measurements were made (after Napan et al. 2009)

TELEMETRY SYSTEMS AND DATA LOGGERS

The Utah Department of Water Resources (UDWR) designed and implemented a data acquisition and telemetry system to provide better and more frequent information for the monitoring and documentation of water withdrawals from the Bear River. This was prompted, in part, due to compliance problems with pumping and diversions of water from the river. Over one hundred stations have been set up at pump sites and open-channel measurement flumes along the lower Bear River in northern Utah. Each station is periodically polled, one-by-one, and transmits water depth or flow data to a UDWR station in Logan, Utah, via radio signal. The data are then sent to a UDWR computer in

Salt Lake City, are processed using calibration and other algorithms, and are made available with an approximately 20-minute delay to the public on the UDWR website.

The Utah Water Research Laboratory (UWRL) provided funding for the design and implementation of a data acquisition system at sites in nine of the Cache Valley irrigation canals. The list of sites was determined collaboratively with the Logan River Commissioner after a review of the existing mechanical water level recorders, many of which were found to be in a dilapidated condition. Some of the required SCADA equipment was purchased by the UWRL, and the rest was supplied by the UDWR, but both collaborated on the design and installation at the various canal sites. Canal company personnel and the Logan River Commissioner also assisted in the installations, providing some tools and labor to complete the process.

The design consisted of a data acquisition and telemetry system, along with a power supply, at nine existing Parshall flumes and broad-crested weirs, all of which operate exclusively under free-flow conditions. In locations where the radio signal was unavailable or too weak due to obstructions from trees or buildings, a data logger was used in place of the telemetry system to record, rather than transmit, flow measurement data. This was the case at two of the seven sites.

A wooden small shelter encloses most of the data acquisition system at each site, protecting it from the weather and vandalism. The shelter was placed over a stilling well and the depth of water in the well corresponds to the depth in the canal on the upstream side of the flume or broad-crested weir. A digital shaft encoder was installed in the shelter and was connected to a pulley with a float and counterweight which was placed inside the stilling well. After installation, the readings from the shaft encoder were calibrated to the actual water level, based on the elevation of the upstream flume floor (or the sill elevation, for BCWs), represented as a linear equation in the data logger.

A network of repeater towers was necessary to transmit flow data from various locations in Cache Valley to the UDWR base station, thereby providing line-of-sight coverage. One repeater tower was installed on the roof of the main engineering building at USU, permitting coverage in a previously “blind” region along the Logan River. A radio antenna and transmitter were mounted on a steel pole which was anchored into the ground next to each shelter, and at one site the antenna was mounted on the roof of a building adjacent to the canal. Water level data are transmitted to the UDWR base station at regular intervals (approximately every 20 minutes) during the irrigation season.

The data loggers are programmed to record date, time, battery voltage, water depth, and flow rate. To determine the flow rate, the appropriate free-flow calibration equation was programmed into the data logger using coefficients and exponents obtained from calibration measurements for the specific flume or weir at that site. Records and observations confirm that the flumes at each of the nine locations never operate under submerged-flow conditions during the irrigation season.

Once the UDWR system has called (or attempted to call) every station, it automatically cycles back to the first station and the process repeats. If the system runs through a complete cycle of all stations in under five minutes, a sleep mode is invoked until the five-minute period is reached, at which point the call cycle begins again. However, the cycle has never been completed in less than five minutes in this system, especially with the recent addition of several new stations.

Four of the stations do not have radio reception and are manually integrated into the system when the Logan River Commissioner gathers the data during the normal weekly monitoring routine. The data can either be downloaded by the use of a data card that inserts directly into the data logger or by hooking the data logger up to a PC for direct download. Two of these four stations have solar panels to trickle-charge the small battery which powers the data logger, and the other two have deep-cycle marine batteries without solar panels. The two stations without solar panels were experiments to determine whether a deep-cycle battery could power the data loggers for an entire irrigation season, avoiding the need for solar panels which might be shaded by trees at the site and which can be subject to vandalism and theft. Thus far, the deep-cycle batteries have lasted all season, and are recharged during the off-season.

RESULTS AND DISCUSSION

Administrators of the lower Bear River project have stated that the publicly available flow measurement data has solved a number of water disputes between farmers. And the director of the UWRL commented on how the system has improved management during years of drought and reduced water disputes (McKee and Khalil 2006). The addition of flow measurement data from the nine new sites has also improved monitoring and management, including the resolution of occasional disputes over water rights issues, flood damages to adjacent properties, and compliance with the canal operating plans.

The canal improvements implemented in Cache Valley have shown how public and private organizations can successfully cooperate to improve water management and conservation. The UDWR provided the technology and design of the telemetry system, the UWRL provided funds to complete the project, and local canal companies provided labor and tools to assist with the equipment installation. And the diagnostic surveys and O&M plans were developed in direct participation with the canal companies and Logan River Commissioner, also enjoying the support and assistance of some of the affected municipalities in the valley. As a result, the involved organizations have gained valuable experience in cooperating to improve water management, water monitoring, and documentation of management practices.

SUMMARY AND CONCLUSIONS

Through the combined efforts of the UDWR, UWRL, USU, and various canal companies, the lower Bear River SCADA system was expanded to include several canals which take water from the Logan River. Digital shaft encoders, radio transmitters, and data loggers were installed to provide accurate and timely data to water managers and water users through the UDWR webpage at some sites, and through data loggers at others. The implementation of this project has already resulted in improved water regulation throughout Cache Valley, helping to make a positive impact on the local water supply and water conservation in general. Indeed, the cooperation of public and private organizations and agencies is an excellent example of how to use all available resources collaboratively to enable enhanced water management.

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