Technical Evaluation for the Low Power Automatic Controls (LOPAC) Flow Monitor

Assessed in Current Irrigation Management Practices Study

2007 - 2009

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INTRODUCTION

The Low Power Automatic Controls (LOPAC) flow monitor was designed by *AquaSystems 2000 Inc.* (Lethbridge, Alberta), to determine annual volumes of water delivered through an irrigation district owned infrastructure. Originally, the monitor's design and intended use was to record the number of hours of water flow through an individual turnout. It is designed to sense and totalize the occurrence of flow time in one direction and is not capable of determining flow velocity or volumetric measurements. Several hundred of these original units were installed in the irrigation districts but no comprehensive performance evaluations had been completed on this newly designed device.

In 2007, a second generation of the LOPAC, the model LHE2 was developed with an additional housing containing a Hobo Model U11 3-State/1 Event Data Logger. The data logger is instrumented to the monitor to time/date stamp on and off cycles which was required to meet the needs of an irrigation management practices research project titled "Current Irrigation Management Practices 2" (CIMP2) conducted by Alberta Agriculture and Rural Development (Nitschelm et al, 2011). The CIMP2 study provided the opportunity to assess the reliability, accuracy and durability of the LOPAC LHE2 flow monitor over three growing seasons. For the CIMP2 study, the data logger was programmed to record the beginning and ending time and duration of each irrigation event (flow on/flow off) as a means to determine an accurate understanding of both the timing and volume of water delivered. A detailed list of component specifications can be obtained from AquaSystems 2000. A short description of the LOPAC units used to serve the CIMP2 project is as follows:

- The sensor housing is a one and one-half inch diameter stainless steel pipe coupler, approximately three and one-half inches in length. One threaded end provides the connection to the pipe where flow is to be monitored, and the opposite end connects to a standard two and one-half inch PVC threaded tee to provide the housing for the data logger and time counter (Figures 1 and 2).
- A non-resettable time counter powered by a five year battery is permanently sealed within the unit to guard against tampering and ingress of moisture.
- The flow vane is shaped to conform to the inside circumference of the pipe, thereby reducing the likelihood of debris buildup. Water velocity in the pipe moves the flow vane into the "on" position and when flow stops, the vane, with the aid of a small counter weight, returns to the "off" position.
- The sensor consists of a single pole double throw magnetic reed switch. A start or stop in water flow initiates travel of the flow vane which activates the switch, simultaneously closing or opening circuits to both the counter and data logger.

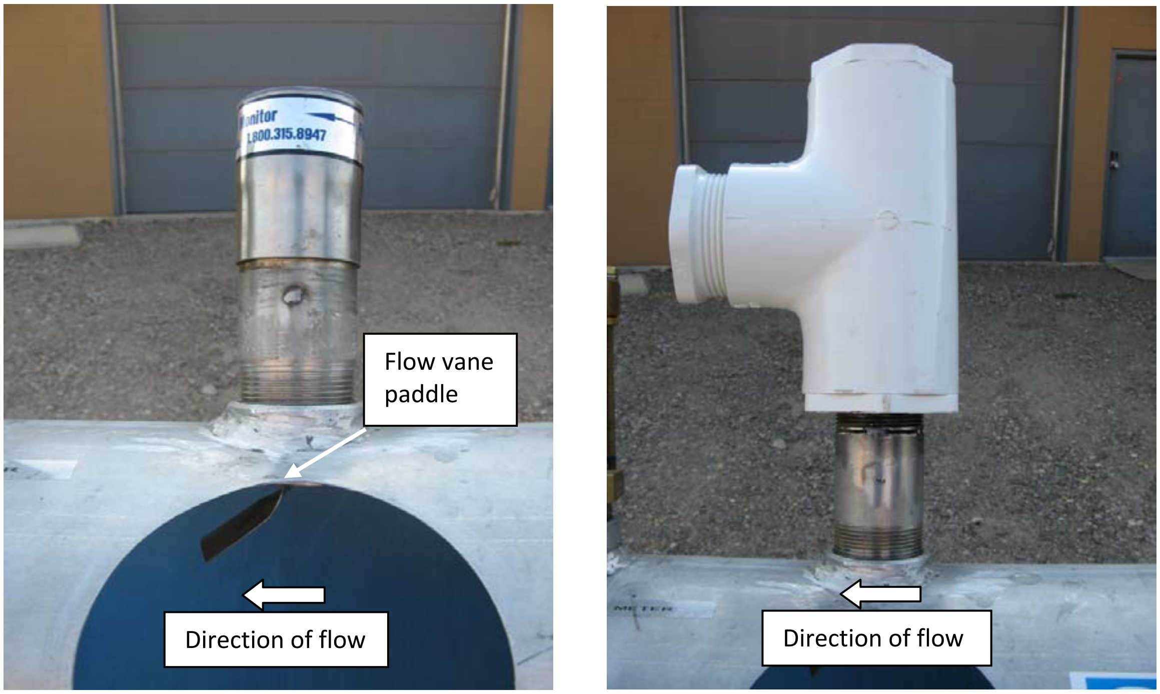

Figure 1. Originally designed LOPAC flow monitor equipped with non resettable counter only (at left) and Model LHE2 with additional PVC housing and data logger (at right).

Figure 2. Time counter installed in top of the PVC housing displays time of flow in hours and minutes (at left) and accessing data logger in horizontal portion of PVC housing (at right).

BACKGROUND

Management of irrigation water (from an Alberta perspective) may be considered in three broad categories: diversion and storage, conveyance and delivery, and application to meet the demands of plant uptake. In order to improve upon water conservation and conveyance efficiencies (water savings) Alberta's Irrigation Districts are continually maintaining and improving upon conveyance and delivery infrastructure to increase water savings. Quite possibly the most note worthy of improvements to conveyance and delivery systems has been the replacement of earthen canals with closed pipelines. From 2001 to 2009 the number of kilometres of closed pipelines conveying water in Alberta's thirteen Irrigation Districts has increased from approximately 25% of total water conveyance infrastructure to 40%.

From 1970 to 1995 the percentage of land being irrigated by sprinkler systems has increased from 30% to 80% (Chinn 1996). Observations from 1999 to 2009 reveal a shift towards the utilization of low pressure centre pivot systems. In 1999, 53% of total irrigated area was irrigated with centre pivots, compared to 72% in 2009 (ARD 2010).

In 2007 Alberta Agriculture and Rural Development, along with six irrigation districts in southern Alberta, implemented a study designed to monitor irrigation management practices as a means to better understand the on-farm component of irrigation management. As producers continue to shift towards the more efficient, low pressure centre pivot method of irrigation, there is an expectation for a corresponding increase in irrigation management practices as well. Current Irrigation Management Practices 2 (CIMP2) was introduced to update information learned from an original CIMP study conducted from 1996 to 2000. The desired outcomes of both studies were primarily to quantify on-farm irrigation applications and to evaluate the effectiveness of irrigation management in terms of meeting the crop demand for water in order to achieve optimum crop production. As irrigation is the largest consumptive user of water in the South Saskatchewan River Basin, it is critical to understand what the present level of irrigation water use is and what future demand may be expected.

The irrigated landscape in Alberta is shifting towards low pressure centre pivot sprinkler systems and water conveyance and delivery to the farm through closed pipelines. Therefore the methodology of CIMP2 was geared specifically to monitor fields based on criteria that water delivery was from a closed pipeline and low pressure centre pivots utilizing drop tube technology. In order to adapt to these criteria, an additional objective of the CIMP2 study was to implement and test the latest technology for measuring water applied through this combination of delivery and application method. Irrigation amounts and detection of the timing of applications was accomplished by installing a LOPAC Model LHE2 flow monitor, manufactured by *Aqua Systems 2000 Inc.* at the turn-out of each centre pivot field involved in the study (LOPAC LHE $480; installation $95 per unit). The Model LHE2 monitor was instrumented with a Hobo state/event data logger, supplied by *Onset Computer Corporation*, programmed to record the beginning and ending times and duration of each irrigation event. A measured flow rate to factor against the duration of irrigation events was obtained by periodically measuring flow rates with a portable, transit-time ultra sonic flow meter. As an additional small scale pilot project, three of the LOPAC monitors were instrumented with text messaging, telemetry alarm units, which operated on a SMS program and transmitted irrigation on/off times from the LOPAC flow monitor to a demonstration website.

LOPAC FLOW MONITOR

Installation Instructions

To install a LOPAC monitor, a hole is cut into the top of the turnout pipe and a threaded coupler is inserted and welded in place on a level plane. The coupler is used to connect the LOPAC flow monitor to the pipe being monitored. If possible, position the coupler downstream of a shutoff valve so that the monitor can be isolated from the water delivery system in the event that it needs to be removed or replaced. The threaded base of the monitor, being a one and one-half inch diameter by three and one-half inch long threaded nipple, must then be wrapped with thread sealant tape to ensure a proper seal. It is recommended not to use grease or pipe sealant compound, as it may interfere with the movement of the flow vane. The base of the monitor can then be inserted and tightened into the coupler with a pipe wrench. Be careful only to apply torque to the metal fitting and not the upper PVC housing, as it can easily be turned on the opposing end of the fitting (Figure 3). The LOPAC monitor has front and back sides and must be oriented, when tightened, so that the paddle of the flow vane angles in the direction which water flow will occur. Ensure that the two inch plug of the PVC housing is sealed with thread sealant tape as well to protect the Hobo data logger from moisture.

Figure 3. Installing the model LOPAC LHE2 monitor.

As learned from trouble shooting during the course of the CIMP2 study (discussed in greater detail later in this document) it is important to position the coupler so that it protrudes into the inside diameter of the pipe by approximately 5 mm. This helps to insure that the base of the monitor, and more importantly the flow vane, is adequately recessed into the pipe in order to allow for complete unobstructed travel of the flow vane.

Flow monitors for the CIMP2 study were installed in both steel and aluminum pipe. Recommendations for installation in pipe materials that cannot be welded are limited due to the absence of testing or experience incurred during the course of the CIMP2 study. However, it is believed to be possible to install a monitor in PVC or plastic pipe utilizing a manufactured clamp on saddle, with an existing threaded collar and gasket assembly to provide the necessary attachment to the pipe.

Site Suitability

The CIMP2 study sites were selected based on numerous criteria – with the key condition being that the irrigation system was directly connected to a district pipeline. A few of the selected sites were unusual in that the district infrastructure had very short sections of horizontal pipe, or none at all, following the district shut-off valve and before the connection to the producer's system. Therefore, the only alternative was to install the LOPAC on the vertical riser between ground level and the elbow to which the district's shut-off valve is attached. The monitors encountered problems if installed vertically in a section of pipe where turbulent flow existed. The turbulent flow would continuously toggle the monitor on and off, or chatter, and the data loggers would prematurely fill up with data and the counters displayed incorrect time duration of irrigation events. The best solution derived for this issue was to avoid installation on vertical sections.

Evaluations and assessments regarding site suitability did not include formal testing to determine a minimum installation distance from an elbow, to avoid problems caused from turbulent water flow. Water travelling through a pipe will become more turbulent depending on how abruptly the direction of flow has been altered. A general rule of thumb is that turbulent flow can exist in a region of pipe within a distance equal to approximately ten times the diameter of the pipe past the point where direction has been altered; and in a region equal to four times the diameter upstream from a point where the direction of flow has been altered.

Sites where flow monitors were installed for the study had varying lengths of straight horizontal pipe downstream of the elbow attached to the vertical riser. These distances ranged from a low of 30 cm to a high of 150 cm, with the majority falling in the range of 50 to 90 cm. Turbulent flow may have existed at numerous sites where monitors were installed in horizontal sections of pipe; however, problems interfering with data collection were experienced almost exclusively at sites where monitors were installed on the vertical section of turnouts or near sharp horizontal elbows. Based on the experiences incurred from the CIMP2 study, a minimum distance of 40 cm of horizontal pipe is recommended for trouble free installation and operation of the LOPAC monitor.

Maintenance

When properly installed, oriented and seated to the pipe, the LOPAC flow monitor requires minimal maintenance during the irrigation season. During the course of the CIMP2 study, weekly visits were performed every 2 to 3 weeks throughout the first two seasons of operation to verify proper operation of the monitors through visual observations of the irrigation activity in the field. The first year of the study exhibited the majority of performance issues and troubleshooting and redesign measures were implemented before the next season. Following the redesign efforts the unit's performance proved to be much more reliable and site visits were extended to bi-weekly.

A maintenance schedule for the monitor was broken into in pre season, in season activities and post season. Pre-season maintenance should be performed prior to the start of water run.

1. **Pre-season:**

   Proper functionality of the LOPAC monitor depends on the proper operations of one moving apparatus. This is the flow vane, which is attached inside the stainless nipple with a simple pin type hinge. All of the components of the hinge are either stainless steel or a hard white plastic material. During the four years in which the monitors were tested the hinge points were never lubricated and no incidences occurred of the hinge corroding or binding so as to impede its movement. Prior to each season the LOPAC can be tested by either removing the monitor and manually activating to test its components, or tested in place by following the procedure below.

- ➢ Check the tightness of the monitor's base to the installation coupler and tighten if needed to ensure leaks do not develop.
- ➢ Toggle the sensor to the on position by placing a relatively strong magnet on the stainless nipple which houses the sensor and flow vane. Ensure that the sensor is functioning properly by visually observing the counter is operating – the indicator bar in the view screen of the counter will flash on and off. Remove the magnet after ten or fifteen seconds has elapsed and again observe the indicator. This procedure verifies operation of the sensor and the counter and an on/off cycle will also appear in the data file once the Hobo logger is downloaded.
- ➢ Remove the two inch threaded plug from the PVC housing and check for moisture. If moisture is evident re-apply silicone to the clear lexan top face covering the counter.
- ➢ Connect the Hobo shuttle to the data logger and check for battery voltage as prompted. Data collection and management is discussed in a later section of this document. If the logger's battery voltage is lower than 2.8 volts it is recommended to replace it. When replacing the battery, power supply to the logger is interrupted and the logger must be restarted. Be sure to download the logger prior to replacing the battery, as any stored data will be erased upon restarting.
- ➢ As a precaution against moisture place dry desiccant packs with the logger in the PVC housing, apply new Teflon tape to the threaded PVC plug and tighten in place.

2. **In-season Activities:**

- Once pre-season maintenance has been performed, maintenance during the season is primarily based on verifying proper functioning which can be done in one or two visits during the early part of the season. When water flow is on, the stainless nipple is sometimes cooled to a considerably lower temperature than the air around it, creating a small amount of condensation. This is normal and should not be a concern. If moisture is observed inside the PVC housing, it is likely entering from the elements and prevention measures will need to be taken or the data logger will eventually be corrupted if moisture reaches the battery or circuit board.
- Check that the counter is not in the on mode, or counting, when irrigation is off – or vice versa. Download the data logger once irrigation has occurred and check that duration of irrigation time corresponds with time counted on the counter.
- Check the battery voltage when downloading the logger. It is recommended to start the season with a new battery. The batteries have a life expectancy of two to three years; however, this varies greatly depending on how the logger is programmed to operate.

3. **Post-season:**

- Download the logger and check for proper functionality by checking corresponding times on the counter and logger as previously mentioned. When recovering data the amount of storage used will be indicated as a percentage of memory used. Once data is off loaded it can be transferred and archived in computer based files utilizing Hobo Onset software which is required to initiate and support data logging and management.
- Recommend to check for moisture in PVC housing and replace desiccant packs. The battery in the counter is non replaceable and has a life expectancy of five years. When the battery expires the counter must be replaced.

Data Management and Recovery

Equipping the LOPAC flow monitors with the HOBO Model U11 3-State/1-Event data logger was required for the study so that each time status of flow at the irrigation turnout changed (whether on or off) the event was recorded and time/date stamped and stored in the loggers memory to be retrieved at a later time. Both the timings and volume of irrigation events were required so that actual irrigation practices could be compared to computer based modeled scenarios. The scenarios were generated so that irrigation timings and volumes corresponded with optimum crop growth. Modeling provides a benchmarked comparison as to how effectively actual irrigation management practices were at meeting crop water demand required for optimum growth.

Usage of the Hobo loggers requires the user to acquire Hobo onset software in order to program the loggers, view and manage the data generated. The loggers can be programmed and launched from a desktop machine or in the field using a laptop computer. More information about

Hobo Onset can be acquired by going to www.onsetcomp.com. Data was retrieved from the units in the field with either a handheld shuttle or a laptop computer loaded with the Hobo Onset software. The shuttle has memory capacity equivalent to downloading approximately 1000 of the event type files generated from the loggers used in the CIMP2 study. Once the shuttle is downloaded to a computer, the files are identified by the heading given to the logger during initial programming and the date of when each file was offloaded from the logger. If an identical file is offloaded more than once, it is automatically given a subscript identifier rather than being over written and can be discarded at a later time. Files are "windows" compatible and are easily categorized and archived as long as the computer system is loaded with the Hobo Onset software. Stored files can be exported into Microsoft Excel and data can be summarized for individual sites and managed according to user preference. An example of how the raw data was graphed with Onset software and summarized in a spreadsheet for the CIMP2 project is displayed in the Appendix.

CIMP2 data was retrieved every two to three weeks – providing the monitors were functioning properly. This is likely not necessary in the absence of the requirements of a research based project, as the loggers have memory capacity to record approximately 40,000 individual on/off events. During the study, the only instances when data logger memory became full was at sites where monitors were installed on vertical sections of pipe and the flow vane would continuously toggle on and off during irrigation events. When memory used reaches 100% the logger will no longer record additional state or event changes and must be downloaded and then restarted. It is important to note that the logger must be downloaded prior to restarting or recorded data will be lost. Logically, data retrieval and management can be integrated with pre or post season maintenance when batteries are replaced and loggers are stopped or restarted.

Performance Testing/Results

Prior to the CIMP2 study, the LOPAC flow monitor had received limited field testing or documented performance evaluations. The CIMP2 project was conducted over three consecutive irrigation seasons from 2007 thru 2009 with the majority of the monitors remaining installed to over-winter and continue operating through the 2010 season. This provided the opportunity to further evaluate and consider the performance and effects of winter weather to the reliability of approximately 50 to 75 LOPAC flow monitors used in the study.

During the three-year period in which the study was conducted, the flow monitors were removed from the field locations at the end of each irrigation season, stored indoors over winter and units experiencing any problems were returned to the manufacturer for repairs. In the fall and winter of 2009/10 the flow monitors were tested for over-wintering reliability and remained on site to operate for the 2010 season. The additional season was included to further evaluate the durability of the units and the efficacy of the batteries after being exposed to winter weather.

The LOPAC flow monitors experienced numerous performance issues during the first year (2007) of the project (Table 1). Problems encountered are grouped into general categories and discussed in greater detail below.

1. Installation – The first units to be installed in 2007 were installed with the coupler positioned on top of the outer surface of the pipe rather than sinking it slightly into the pipe. As a result, numerous flow monitors functioned properly early in the irrigation season, but over time the flow vanes rusted to the couplers or adhered to excess thread sealant and were not responsive to changes in water flow.

2. Flow vane – The flow vane was originally designed to conform as closely as possible to the inside circumference of the pipe to reduce the likelihood of debris buildup. As a result, the flow vane would come in contact with the LOPAC housing, the installation coupler or the inside wall of the pipe when flow triggered the flow vanes and in some cases the flow vanes rusted and remained in the "on" position. When the flow vane contacted any of the pre-mentioned components, the amount of travel or movement of the flow vane was reduced, and in some cases, resulted in incomplete activation of the reed switches.

3. Counter – A number of counters malfunctioned during the irrigation seasons of 2007 and 2008, by displaying hours of irrigation inconsistent with the data logger records, or the counter display no longer functioning, or was sliding down in the housing.

4. Reed Switch – In 2007 the counter and data logger operated on two independent switches, thereby requiring a certain amount of travel from the flow vane to activate both switches. Incomplete travel of the flow vane could switch one component on but leave the other off, making identification of the problem component difficult.

5. Electrical grounding – At one site in 2007, two sites in 2008 and one in 2009 (all different sites) the flow monitors exhibited erratic behavior, consequently overloading the reed switches rendering the monitors unresponsive. Eventually, after much testing for stray voltage the sites were suspected to have faulty grounding of the electrical equipment at the sites.

6. Site suitability – A few of the LOPAC monitors were installed on the vertical portion of pipeline turnouts as the horizontal portion was of insufficient length for installation. These sites also consisted of turnouts with 90 degree elbows immediately downstream of the flow monitor installation, and turbulent water flow caused the flow monitors to repeatedly turn on and off, or "chatter," eventually filling up the data logger file and causing data to be lost. It was also noted that when the time duration of irrigation events was calculated – from the data loggers experiencing periods of on/off chatter – the length of irrigation time was inconsistent with the length of time derived from the monitor's corresponding hour counter.

Table 1. Assessment of LOPAC flow monitor performance from 2007 to 2009. Some LOPAC flow monitors exhibited more than one performance issue.

Number of LOPAC flow monitors	2007	2008	2009
Originally installed units	*52*	*69*	*61*
Trouble free field performance	*24*	*44*	*56*
LOPAC malfunction resulting in lost data	19	4	1
Pivot off, LOPAC counter or data logger "on" (two reed switches in 2007, difficult to isolate problem)	16	-	-
Pivot off, counter "on" (changed to single reed switch for 2008)	-	9	4
Counter or data logger stopped working	13	0	0
Counter stopped working	10	18	5
Excess "on/off" activity recorded on data logger	4	4	3
Site unsuitable (elbow installation)	2	2	2
Site had faulty electrical ground	1	2	1

Trouble Shooting and Redesign

Based on the performance issues and field testing observations recorded by ARD staff, AquaSystems 2000 redesigned and made alterations to some of the monitor's components prior to the 2008 season (Table 2). Following the 2008 season it was evident that the redesign had resolved some of the performance issues, but did not resolve all issues. Particularly, numerous instances of the counters failing completely or flow times were inconsistent when compared to the data loggers. Although the counters were not essential to data collection for the CIMP2 study the failed counters were replaced for monitoring in 2009 and a different style of counter was selected and installed in ten of the monitors to be tested during the 2009 season. No failures occurred from these ten units/counters in 2009 and 2010.

The troubleshooting – following the first year of testing the LHE2 model and implementing some key design changes – proved to be fundamental in achieving improved success of the monitor's performance for the subsequent two years of the study. The rationale for the redesign and alterations to certain components of the monitors is explained in (Table 2) and discussed in greater detail below.

Table 2. Summary of improvements tested in the 2008 field season to address LOPAC flow monitor performance problems observed in the 2007 field season.

Issue in 2007 field season	Solution tested in 2008/2009 field seasons	Issue resolved
Flow vane sticking open, rust binding flow vane to coupler	Extend flow vane, make part of vane plastic, add weight to paddle	Yes
Flow vane not deep enough to toggle on both counter and data logger	Extend flow vane, one switch for both counter and data logger, sink coupler into pipe	Yes
Counter not robust, sliding down in housing and/or display readout malfunctions	Glue counter housing and silicon connector in place. Replace reed switch	No*
Pipe dope excessive inside coupler	Use silicon sealant or thread tape sealant, apply to flow monitor, not coupler	Yes
Excess on/ off "chatter" on elbow installs	Do not install on 90 degree elbows or on vertical sections of pipe	Yes

* A new counter style was tested in 10 units in 2009 with no performance issues encountered.

1. Installation – Problems related to the flow vane not returning to the "off" position were attributed to a combination of the installation procedure or the design of the flow vane itself. One solution to prevent the flow vane from contacting the installation coupler or the inside wall of the pipe when toggled on, was to adjust the installation procedure. The couplers, when welded to the pipe were inserted or sunken slightly into the pipe approximately 3 to 5 mm. This helped to ensure that, when the monitor is turned into the coupler, the flow vane protrudes far enough into the pipe to help ensure adequate travel of the flow vane to the "on" position and un-obstructed to return to the "off" position. It is also recommended to apply one to two layers of thread sealant tape to threads on the threaded nipple (monitor's base) rather than a pipe sealant compound. Proper seating of new installations in 2008 helped to improve performance of the flow vane.
2. Flow vane – A further remedy to the problem of the flow vane not returning to the "off" position and/or experiencing inadequate travel was to re-design and make alterations to the flow vane. Modifications for the 2008 season consisted of the flow vane being made longer, enabling it to travel on and off without making metal to metal contact, as the metal hinging portion of the vane was replaced with a hard plastic material. Also, a small counter weight was welded directly to the paddle portion of the vane. The redesigned flow vanes performed well throughout the 2008 to 2010 seasons.
3. Counter – The counters were more securely fastened in the housing for 2008 and a new style tested in ten of the monitors beginning in 2009, as performance issues continued to arise with the original versions commencing the 2008 season. The ten monitors equipped with the new version of counters (a Redington model 53) did not exhibit any problems in 2009 and 2010.

4. Reed Switch – For the 2008 season the reed switches were changed to a single pole, double throw switch, to have the counter and data logger operating on the same switch. Therefore, if one failed but the other was operating, the problem component was identified.

TELEMETRY INSTRUMENTED LOPAC FLOW MONITORS

In 2008, three of the turnouts equipped with LOPAC flow monitors for the CIMP2 study were instrumented with Omni Text SMS Alarm Units configured to transmit irrigation on/off times from the flow monitors to a demonstration website (Figure 4). The website displayed real time flow status and a record of irrigation on/off flow times. The reliability of the telemetry communication is dependent on the proper functioning of the flow monitor or metering device to which it is connected. The accuracy of the data reported to the website status of the irrigation systems was verified through visual observations, producer records and the use of Hobo motor loggers installed on the irrigation pump motors. All three of the test sites operated trouble free from 2008 to 2010, aside from one Omni Text unit requiring a new battery after two years of operation.

The communication system and website was designed and operated by a third party contractor, Genivar. The unit sends a text message to a SMS gateway when the flow status of the irrigation system changes. The SMS gateway then creates a record in a SQL server data base from which the web pages were created. The alarm units were programmed to report in every 24 hours via a text message to ensure they are still functioning. If a message has not relayed within the past 30 hours, the system sends an email to alert the user. Multiple users can be included in the messaging system. The same data logging system was used, as in all the other CIMP2 sites, providing the opportunity to compare the telemetry information to corresponding data logger recordings with only slight differences observed in irrigation durations due to small time delays within the communications network.

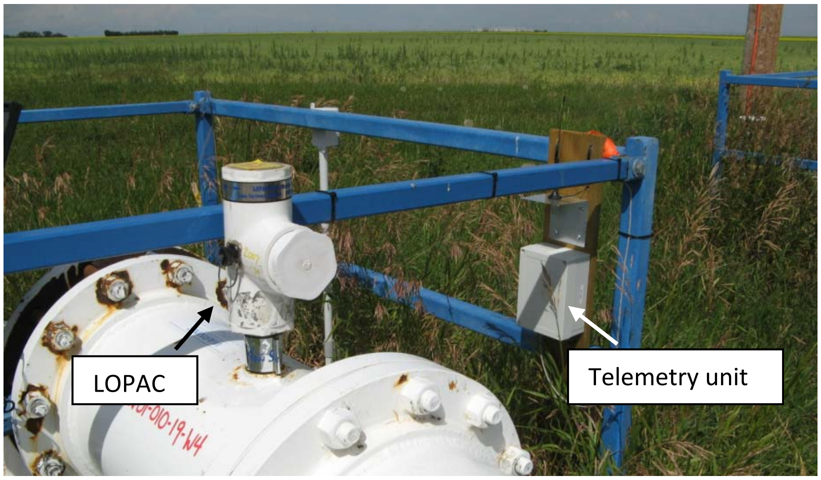

Figure 4. LOPAC flow monitor connected to Omni-Text telemetry unit – SMS text message monitoring and alarm system.

CONCLUSIONS AND RECOMMENDATIONS

During the first year of testing and evaluation of the LOPAC flow monitors, their reliability as a data acquisition device for the CIMP2 study was significantly inhibited. While 46% of the 52 units deployed in 2007 operated trouble free for the season, 36% of installed units incurred problems resulting in inaccurate or missing data for that year of the study. The majority of the problems encountered in the first year were due to flow vanes sticking in the “on” position when flow had ceased or malfunctioning counter. Redesigning the flow vane and changing the reed switch configuration greatly improved the ability of the monitor to sense changes in flow status providing reliable flow monitoring data for the subsequent two years of the study. Trouble free operation increased to 64% in 2008 and 92% in 2009. The majority of problems encountered during the 2008 season were related to the counters. The number of instances of counters malfunctioning was highest in 2008 and lowest in 2009, with 26% and 8% respectively experiencing counter related issues. It is important to note, although testing was not as extensive, that the ten counters replaced with the Redington Model 53 counter (used in 2009 and 2010) did not experience any performance issues. The Hobo State/Event data loggers proved to be very robust and operated year after year with only a few issues encountered due to moisture entering the outer PVC housings. The field testing and troubleshooting procedures during the course of the CIMP2 study (involving approximately 75 of the LOPAC flow monitors over a three-year time period) significantly contributed to the development of a dependable device capable of sensing changes in state of water flow from irrigation pipeline turnouts.

Recommendations

- The testing results for the LOPAC Model LHE2 flow monitor – with the redesigned flow vane, reed switch and new counter – indicate that the relatively low-cost LOPAC monitor is a reliable device capable of sensing water flow in closed pipelines and recording and storing the corresponding on/off times and durations of flow**.**
- The LOPAC flow monitor requires installation in a coupler welded in a horizontal section of pipe with non-turbulent water flow.
- The LOPAC flow monitor equipped with the Hobo data logger presents various possibilities for collecting useful information regarding water delivery and usage. Potential applications of the LOPAC flow monitor are likely best suited to smaller scale, specific data acquisition programs or research related projects requiring regular site visits.
- As with any flow meter or monitor, the LOPAC flow monitor requires proper installation and maintenance to ensure accurate and reliable performance.

A condensed version of this document is also available from Alberta Agriculture and Rural Development titled “**Technical Overview of the Low Power Automatic Controls LHE2 Flow Monitor.**”

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APPENDIX

Data Management Related to the CIMP2 Study

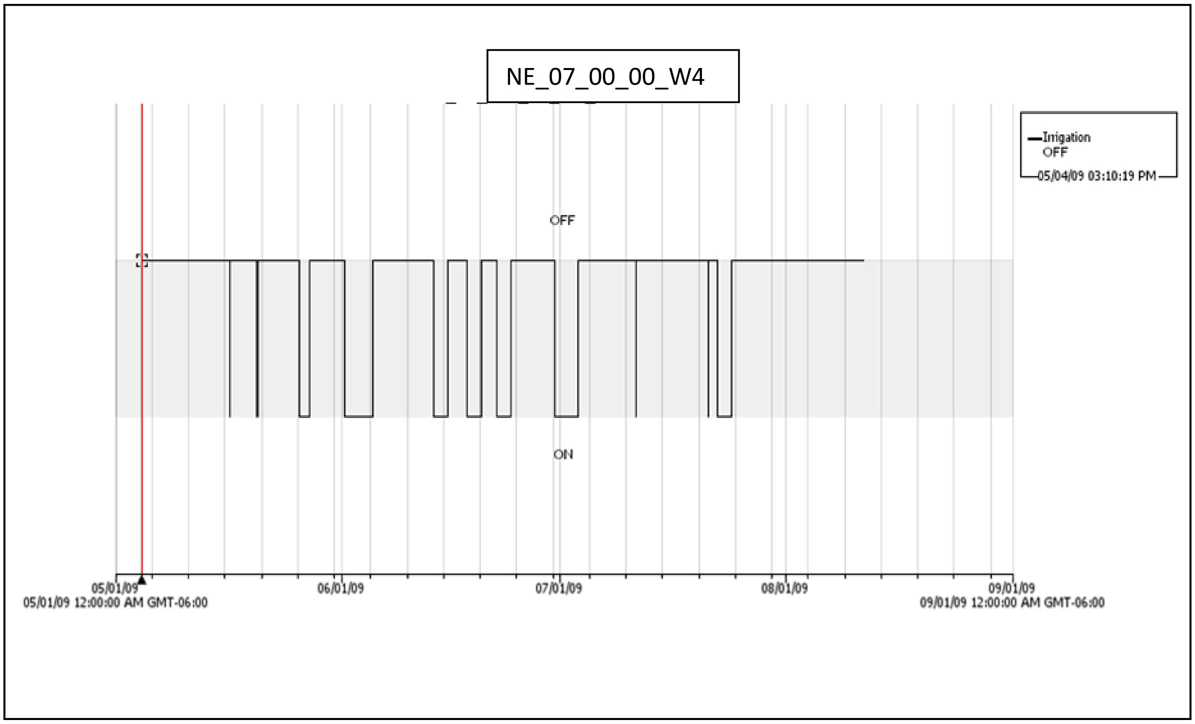

Figure A-1. Hobo logger raw data file displaying irrigation on and off time/dates.

Following data collection from the Hobo loggers, the appropriate files for individual fields were exported to an excel spreadsheet template (Figure A-2). The end gun on flow value in US gallons per minute (gpm) is determined from an average of periodic system flow measurements taken when each system was operating at full capacity with corner tower or end gun on, if applicable. Flow measurements were taken with a portable GE Panametrics transit-time ultrasonic flow meter.

Calculator results			**HOBO raw file >>**	Start date	4-May
				Finish date	11-Aug
NE_07_000_00_W4_FLOW_SMRID_11AUG				Hours	
Irrigation ON		Irrigation OFF			
20-May-09	11:27 AM	20-May-09	11:38 AM	0.2	
26-May-09	6:56 AM	26-May-09	7:10 AM	0.2	
26-May-09	7:15 AM	27-May-09	1:42 PM	30.5	
1-Jun-09	9:35 AM	5-Jun-09	6:37 AM	93.0	
13-Jun-09	3:43 PM	15-Jun-09	2:58 PM	47.3	
18-Jun-09	7:30 AM	20-Jun-09	2:33 AM	43.1	
22-Jun-09	8:29 AM	24-Jun-09	5:36 AM	45.1	
30-Jun-09	8:08 AM	3-Jul-09	10:31 AM	74.4	
22-Jul-09	2:17 PM	24-Jul-09	12:07 PM	45.8	
Irrigation applied				379.5	
Hours of irrigation					379.5
Acres irrigated					130.0
End gun on flow (gpm)					982.0
Irrigation applied ac-ft					0.53
Irrigation applied inches					6.33

Figure A-2. Summarized irrigation data and calculated irrigation values.