

**EVALUATION, INSTALLATION, AND DOCUMENTATION OF ADCON
TELEMETRY STATIONS CONNECTED AT CAL POLY**

By

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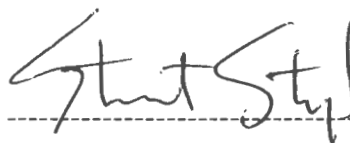
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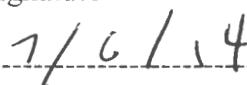
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Dr. Stuart Styles



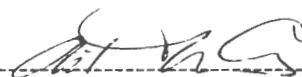
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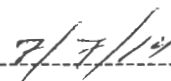
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ABSTRACT

This project will provide Cal Poly with a new fully functioning Adcon Telemetry station at the Nelson Reservoir. A new map will show all the existing Adcon Telemetry stations. All the stations will be visited and evaluated. Additionally a guide for updating the online graphs will be provided for future monitoring of the data. Overall the project will show the importance of the advancing technology of the Adcon Telemetry stations and their impact on Cal Poly's agriculture.

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INTRODUCTION

Irrigation, the largest use of water in the world, uses about 85% of the available water in developing countries (Plusquellec, 1994). Since water is a limited resource, it is becoming increasingly important to monitor the usage of such large quantities of water. Traditionally, water flow has been monitored manually by the use of flow measurement devices and daily readings. The growing SCADA technology has transformed the methods used to monitor water usage. SCADA, or supervisory control and data acquisition can be used in a variety of applications. SCADA systems were first introduced several decades ago, but have become more common over the past 10 years. Water districts are investing in SCADA for real-time information which results in a decrease in operation details performed by an individual, and puts the districts on the right path to conserve water (Rijo, 2008). SCADA systems have become more affordable and the hardware and software are increasing in efficiency and accuracy, creating a more desirable product (Rijo, 2008).

SCADA systems contain the following components including a sensor, some type of on-site apparatus that creates an electrical signal to be transmitted, a local power supply, a type of communication system, a receiving unit, and lastly a mechanism to display the information (Styles 2012). Overall there should be detailed procedures for every adjustment of the system so that the historical reports and trend displays stay as consistent and accurate as possible (McCrary, 2013).

The main goal of water monitoring using SCADA systems is to minimize water waste. Water is a precious resource that can be misused and wasted during water delivery between connected systems.

The objective of this project is to implement a new Adcon Telemetry station at the Nelson Reservoir and connect the site to the entire Cal Poly reservoir system. Following installation of the Nelson site, evaluation and documentation of the entire system will be conducted. The project will analyze how efficiently the system is operating, and provide guidelines for what currently works well in the system as well as improvements to be made.

LITERATURE REVIEW

Overview

Since SCADA, supervisory control and data acquisition, is the state of the art technology, a variety of different SCADA applications will be examined.

SCADA System

In one case study a SCADA system was used to monitor a micro irrigation system with four types of filtration units. The SCADA system activated the irrigation system as well as the backflushing of the filter. From data provided by the SCADA system, workers were able to monitor the pressure and flow at each filtration units. The components used in a particular SCADA system used to monitor the data for a micro irrigation system are shown in figure 1 below. This technology greatly increased response time to clogging problems in the irrigation laterals. Additionally the study proved that monitoring the measure of the consumed water in the filter backwashing units was useful for future water needs (Duran-Ros, 2008).

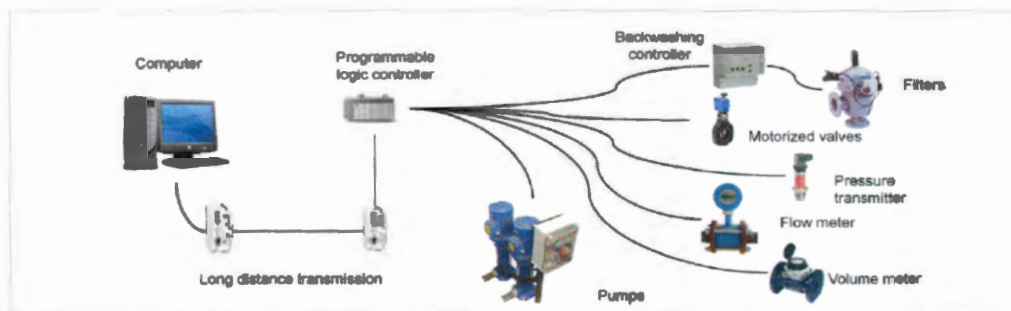


Figure 1: SCADA system components (Duran-Ros, 2008).

A paper produced by M. Rijo examines the design, implementation, and field tuning of a SCADA system for an irrigation canal network for the Sorraia Water District. The system is an upstream controlled network with AMIL gates and equipped with other automated devices. The SCADA system monitors the outflows at the main canals providing essential data. The flow equations were fine-tuned using collected data from a Doppler current meter. The overall system allows the water manager to continuously compare the hydraulic state of the system to the optimal state, thus allowing for modifications to be made (Rijo, 2008). With continuous data provided the system is easily modified to change water flow in order to optimize water resources of the canal network.

One application of a SCADA system for a wastewater treatment plant facility was documented for the change in software from an older SCADA system to a newer upgraded system. The City of Houston's Wastewater Operations branch used to have a SCADA system that had a text based operating system, therefore the control-center

operators had a tedious task of monitoring the pump stations across the city. The plant operators monitored the site 24 hours a day with shifts to check different plants every few hours of the night (Dieu 267). By upgrading the facility with a window based SCADA system the wastewater treatment facilities helped the Wastewater Operations Branch to monitor effectively the city's sewage collection and distribution systems. The SCADA trending tool helped the city optimize the wastewater plant's processes for savings in operations, chemical, energy, and maintenance expenditures (Dieu 281). Overall the SCADA system successfully transformed the plants operating systems and made monitoring water use easier and more accurate.

SCADA Intrusion Detection

As with anything that is accessed through the internet there are certain aspects that must be considered such as software security. With modern SCADA networks becoming more popular for monitoring data, the systems are becoming more vulnerable to cyber-attacks. These attacks are due to the common use of standard communication tools and increased connections from the corporate network concluded through the internet. A new approach to improving the security of SCADA networks is described using a flow whitelisting. This approach will legitimate traffic based on four properties of the specific network that are the client address, server address, sever-side port and transport protocol. The system is used to identify a whitelist and alarm the system (Barbosa, 2013).

McCrometer

McCrometer is one of the leading companies in producing monitoring products for agriculture and water industries. McCrometer offers a wide range of products including one device called *McCrometer Connect*. This device utilizes comprehensive choice in wireless remote monitoring for irrigation and crop management. The system offers robust SCADA software to monitor equipment from one's computer, smart phone or tablet. The system offers real-time data in order to make timely modifications to one's system. Convenience is becoming a more and more critical component to any product's success in the market (McCrometer, 2013).

Adcon

Adcon Telemetry is a company that was established in 2003 with headquarters located in Austria. The company produces a product called AddVANTAGE Professional that is a superior SCADA package. Their product offers tremendous management capabilities for large numbers of data points, great data providers, and easy access via the internet (Adcon 2014).

PROCEDURES AND METHODS

This section of the report will explain the process of evaluating the existing Adcon Telemetry stations, the installation of a station, and the process for configuring a new remote transmission unit. The first step to these processes was to learn the basic components of all Adcon Telemetry stations.

Adcon Telemetry Station Equipment

There are three main components that make up an Adcon Telemetry Station. Represented at every station are the remote transmission unit, a power source, and a sensor.

Remote Transmission Unit. The remote transmission unit is commonly referred to as the RTU (see figure 2 below). The RTU is responsible for transmitting the data via radio waves from the site back to the master station at the Water Resources Facility known as the Gateway. The RTU is designed for year round unsupervised operation in almost any environment. The unit is configured for a multitude of parameters from large scale networks.



Figure 2: Remote Transmission Unit

The Cal Poly stations use the A753 model type RTU. This 500mW remote transmission unit transmits the 70cm frequency band between 430 and 470MHZ. The Adcon addWAVE series 4 can submit transmissions up to twenty kilometers away. These high distance communications enable stations placed in remote locations or over difficult terrain to be successful. The RTU is enclosed in a compact aluminum enclosure that requires no additional enclosure or covering, therefore proving to be a very durable component in all weather conditions. Additionally the RTU supplies power to the

sensors that are attached to it. This model of RTU is 160 x 60 x 80 mm with a weight of two and a half pounds. The enclosure has a protection rating of IP-67. IP stands for ingress protection and 67 refers to the two rating standards of totally protected against dust and protected against the effects of immersion between 15cm and 1 meter. The RTU power supply is an internal 6.2V NiMH battery that can be charged by a solar panel or mains adaptor. This device can support 12 analog inputs and 4 counter inputs. As with most devices there are extensions that can be applied to accept more sensor values if the readings need to be more precise. The device is also capable of configuring 4 digital inputs or outputs. The RTU has memory storage of 32KB for up to 20,000 readings from most sensors (Adcon 2013). For a complete table of RTU's features see appendix D.

Power Source. All electronic components require some power source. For most systems the battery is built into the remote transmission unit that powers the data transmission. The battery is commonly charged by a solar panel (see figure 3 below). The use of renewable radiant energy reduces the maintenance required for the sites as well as lowering the cost for power.

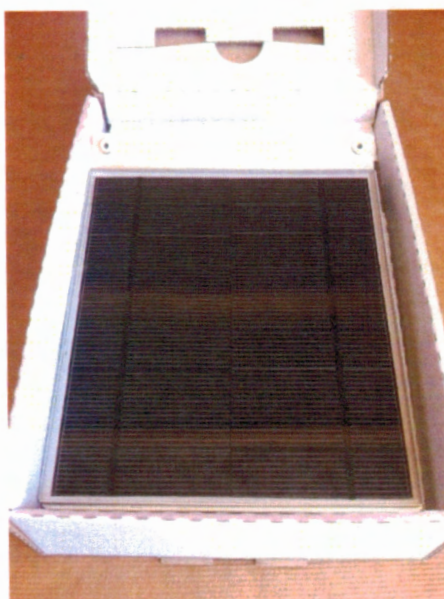


Figure 3: New solar panel to be used at the Nelson Reservoir Site

Sensor Data Collector. Every station must have some kind of sensor that is collecting data that needs to be transmitted back to the base station. Some common sensors used at the sites visited are water level sensors, pressure transducers, and flow meters. Although these few were used to help monitor the water flow through campus, there are many different types of sensors that could utilize an Adcon Telemetry station for collecting and recording real time data.

Site Visits

The first step to this project was the visitation to all existing Adcon Telemetry stations currently operating at Cal Poly. There are Adcon Telemetry stations located all across

campus in order to monitor water movement (see appendix B). There are currently six Adcon Telemetry stations collecting real time data that can be accessed online (not including the new site to be added at the Nelson Reservoir).

There are five main water reservoirs located on campus that act as water storage facilities that can be tapped into when water is needed. The five main reservoirs include Indonesian, Drumm, Shepard, Nelson, and Middlecamp. Although there are many different pipelines that transport water to their designated area of campus, the main water line is called the Ag contract line. The Ag contract line serves as a main waterway for most of the water movement across campus from reservoirs to fields.

Water Resources WS Open Flow Meter. The Water Resources Facility is located at the Drumm reservoir. There are currently two Adcon Telemetry stations at the Water Resources Facility that monitor flow rates. From the data collected using the RTU titled “Water Resources WS Open Flow Meter” three graphs are produced. The first graph titled “BPI vs Prob” displays the 18” flow meter and the McCrometer BPI flow meter (see figure 4 below). The second graph is titled “Open Channel Flow Meter” and displays two flow meters data (see figure 5 on the following page). The 12” flow meter is located on the VFD line and the 18” flow meter is located on the propeller main line. The final graph title “Service” displays the battery voltage, charging regulator, and the data delay of the Adcon RTU (see figure 6 on the following page). Every RTU has a “Service” graph that shows the information about the condition of that RTU.

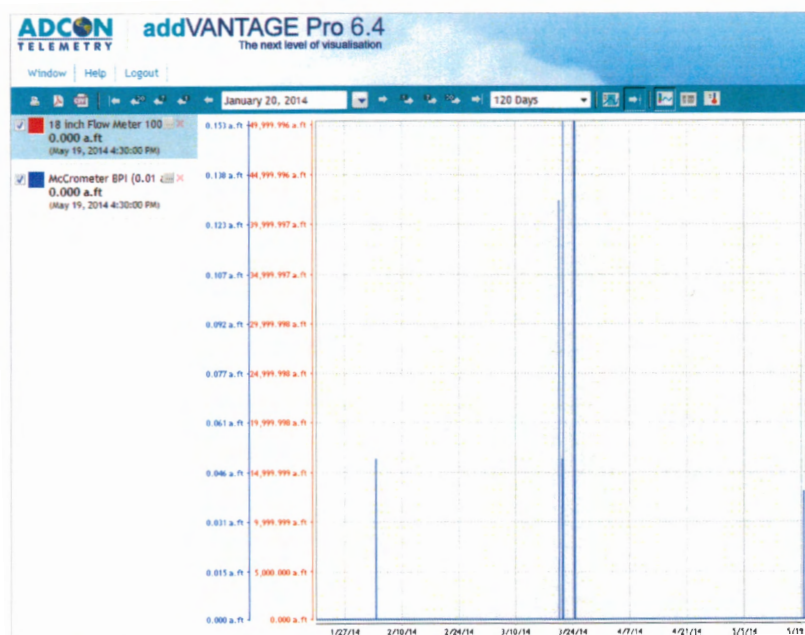


Figure 4: “BPI vs Prob” graph for Open Flow Meter RTU



Figure 5: "Open Channel Flow Meter" graph for Open Flow Meter RTU

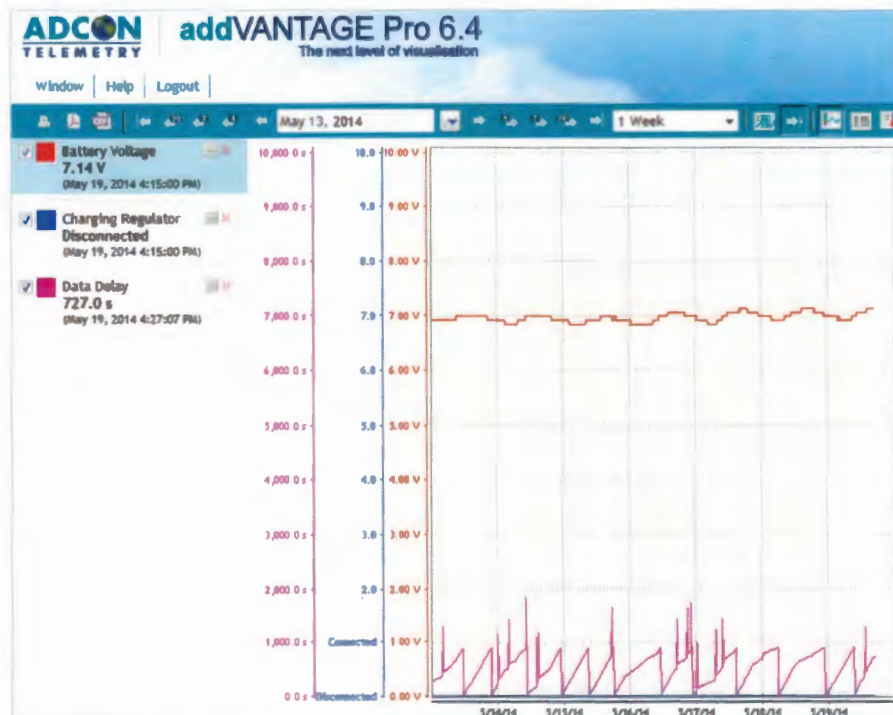


Figure 6: "Service" graph for open flow meter RTU

Field 25 Pump. Field 25 is located near a lemon orchard on campus. The field has a small pump house that has a pressure transducer attached to it. This pressure transducer can display data to show when the pump is running and when it is off. The Adcon Telemetry station is connected to the pressure transducer and the pole is mounted to the corner of the pump house (see figure 7 below). The graph displayed on the webpage is titled "Pressure" and shows one line recording the pressure in psi (see figure 8 below).



Figure 7: Field 25 RTU on pump house



Figure 8: "Pressure" graph for Field 25 RTU

Water Resources Pumps. The second RTU at the Water Resources Facility is titled the "Water Resources Pumps" RTU. This RTU retrieves data from both the 12" flow meter on the VFD line and the 18" propeller flow meter on the main line (see figure 9 below). The second graph for the Pumps RTU is titled "BPI flow vs McCrometer BPI" and evaluates the McCrometer flow meter with battery powered insertion. The graph has a split axis with the upper portion displaying the flow in gallons per minute and the lower portion displaying the total accumulated in acre-feet (see figure 10 below).

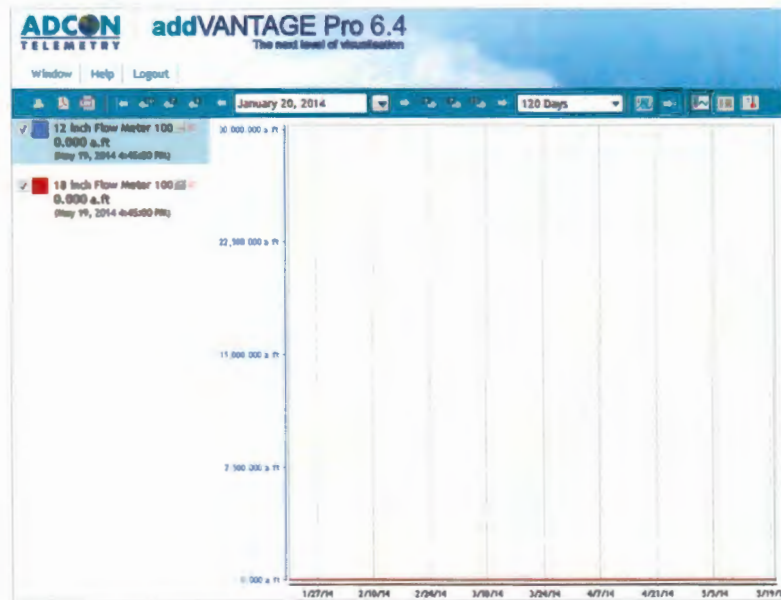


Figure 9: "Flow WR Pumps" graph for pumps RTU

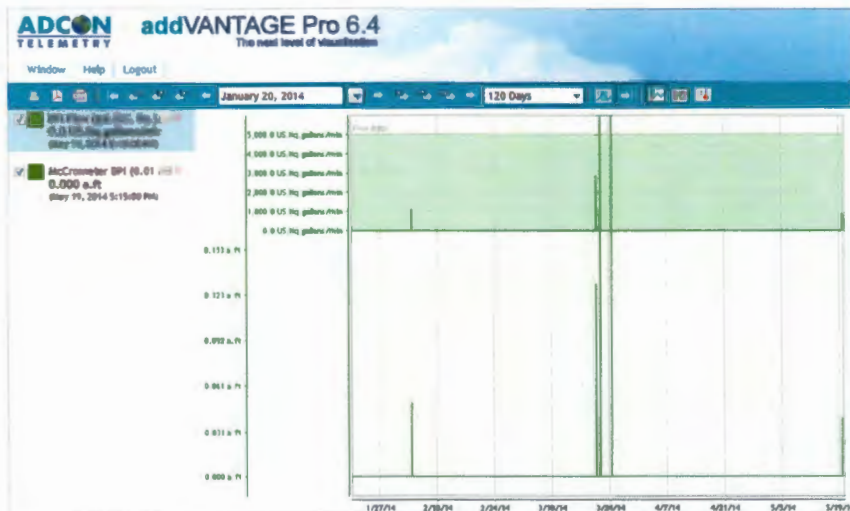


Figure 10: "BPI flow vs McCrometer BPI" graph for Pumps RTU

Sports Complex. The sports complex station is located near the Cal Poly Baseball stadium and the turf fields. The sports complex monitors the flow rate through the pipelines coming from the Shepard Reservoir (see figure 11 below). The graph titled "Flow Rates at Sports Complex" measures the flow through two meters as well as the pressure through one pipeline (see figure 12 below).



Figure 11: Shepard Reservoir

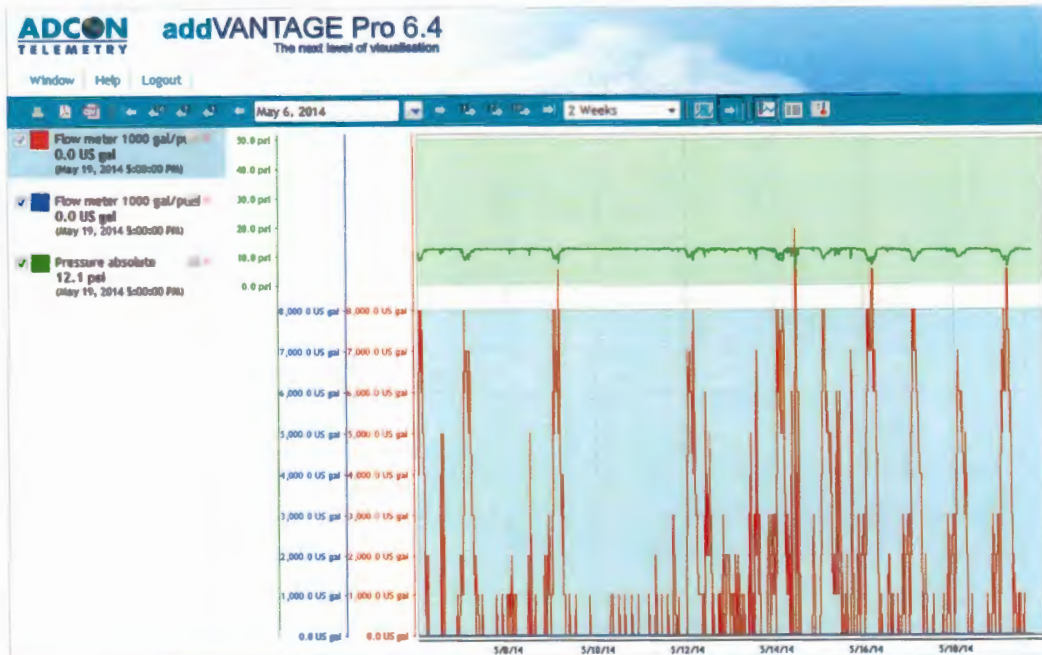


Figure 12: "Flow Rates at Sports Complex" graph for Sports Complex RTU

One pressure gauge on a line running from the Shepard Reservoir is shown in figure 13 below.



Figure 13: Pressure Gauge for Shepard Reservoir

One flow meter measuring the flow through the pipeline is shown in figure 14 below.



Figure 14: One flow meter at Sports Complex

Figure 15 on the following page shows the Adcon Telemetry station at the Sports Complex. There are three inputs (on the left under side of the RTU) for this station and one cord that connects the solar panel to power the RTU.



Figure 15: Adcon Telemetry Station at Sports Complex

ITRC Weather Station. The weather station RTU transmits a lot of important data for monitoring weather conditions. This RTU has the most sensors connected to it out of all the stations that the ITRC monitors (see figure 16 below). This unit is vital for providing quick data transmittal of values used to determine ETo, dew point, rainfall total, wind speed, temperature, precipitation, relative humidity, and wind direction.



Figure 16: Weather Station Adcon Telemetry Station

Indonesian Reservoir. This site served as a model for the installation of the Nelson Reservoir site. The Indonesian Reservoir is located above the equine unit at Cal Poly (see figure 17 below). This reservoir directly feeds into Drumm Reservoir. The water level sensor was installed in 2012 by the Irrigation Training and Research Center. This site measures the reservoir water level as well as the water temperature. Figure 18 below shows the set-up of the RTU (top) followed by the solar panel (middle) and the water level sensor transmitter box also known as a breather box (bottom).



Figure 17: Indonesian Reservoir



Figure 18: Adcon Telemetry Station at the Indonesian Reservoir

The graph titled “Raw Reservoir Data” shows the Indonesian water level, surface temperature, and water temperature (see figure 19 on the following page). The second graph titled “Water level only” shows the maximum water level of the reservoir and the current water level.

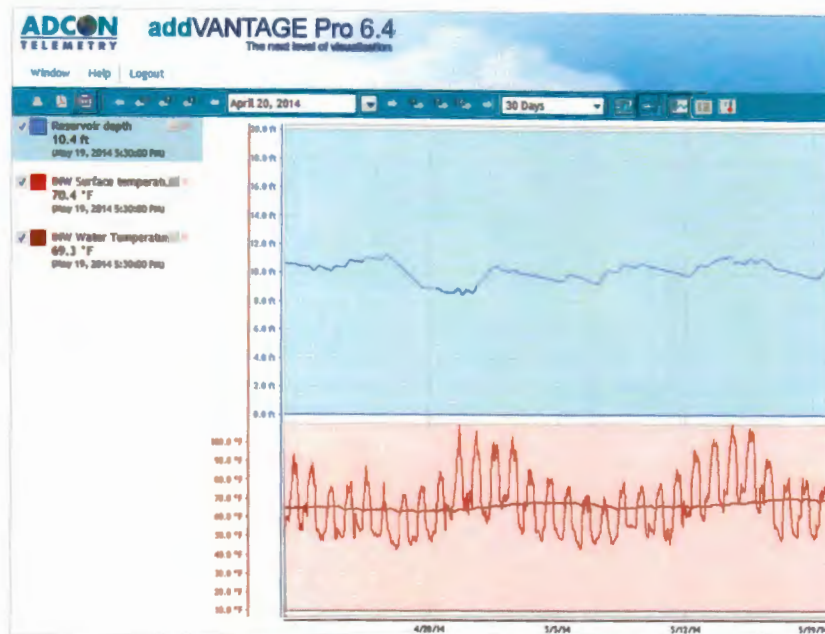


Figure 19: "Raw Reservoir Data" graph from Indonesian Reservoir RTU

ITRC A850. The ITRC A850 also known as the gateway is the core to the entire network of sensors (see figure 20 below). The A850 controls when and how to retrieve data from the RTUs in the fields. The A850 knows when and how often to retrieve data from each RTU as well as the route to each RTU. The network admin can assess many parameters of each RTU including battery voltage, internal temperature and firmware versions. With close monitoring of this data the A850 can quickly identify potential problems before trouble occurs. The A850's configurator can be used to directly open a trend panel where one can view any kind of data in tabular or graphical format. This technology can be particularly useful when SCADA software is present. With this key feature one can view effective trends of data for system diagnosis. The gateway has dimensions of 259 x 186 x 47 mm and is an ingress protection class of IP-50 meaning it is protected against dust with limited ingress. For a complete table of A850 features see appendix E.



Figure 20: A850 Gateway at the Water Resources Facility

Nelson Reservoir Adcon Telemetry Station Set Up

Another component of this project was the installation of a new Adcon Telemetry Station at the Nelson Reservoir. This station utilizes a water level sensor in the reservoir and has data uploaded onto the Cal Poly system. In order to prepare for the installation of the station, a float and a weight were built.

Float. The float was constructed out of 4" PVC pipe. The float was 1.5' long with a 4" PVC cap on each end (see figure 21 below). On one end of the float an eyelet was threaded into the pipe cap. The water level sensor cord could then be fed through the eyelet to bring to the top of the reservoir.



Figure 21: PVC Float for Nelson Reservoir water level sensor

Weight. In order to get accurate readings from the water level sensor, the sensor must be placed near the bottom of the reservoir to get the pressure difference. For this apparatus a 2 gallon bucket was filled with concrete (see figure 22 below). Additionally the same size eyelet as the float was set into the concrete in the bucket. Using the eyelet, the water level sensor cord was zip tied to the weight. Since the eyelet was placed in the top of the bucket the sensor is approximately 8 inches from the bottom of the reservoir.



Figure 22: Concrete Weight to sink water level sensor in Nelson Reservoir

Nelson Reservoir Adcon Telemetry Station Installation

On May 6, 2014, an Adcon Telemetry Station was installed at the Nelson Reservoir. A pump and filter station is currently being developed at the Nelson Reservoir and will utilize the Adcon Telemetry station in the future. The concrete pad for the pump and filter station has already been poured by a group of BRAE 433 students. The first step in installing the sensor was the assembly of the pole. The first element to add to the pole is the RTU placed at the top of the pole followed by the solar panel placed below the RTU (see figure 23 below).



Figure 23: RTU and Solar Panel Assembly

Before attaching the water level sensor breather box to the pole the water level sensor cord had to be fed through the eyelets of both the float and weight. In order to accomplish this, the wires had to be disconnected inside the breather box to fit the cord through the eyelets. Figure 24 below shows the inside configuration of the water level sensor breather box.



Figure 24: Breather Box Configuration for water level sensor

Once the cord was fed through both eyelets the breather box was reassembled. The water level sensor was then zip tied to the bucket handle in order to maintain a constant level (see figure 25 below).



Figure 25: Water level sensor secured to weight

Next the breather box was attached to the pole underneath the solar panel as shown in figure 26 below.

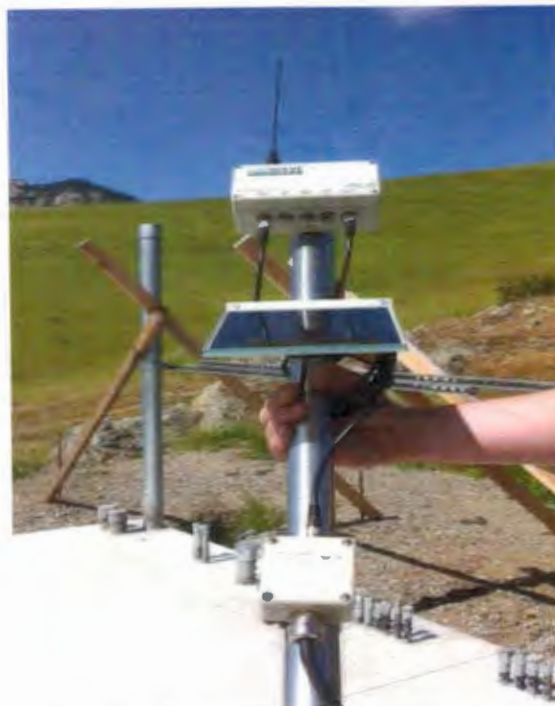


Figure 26: Full assembly of Adcon pole

The pole was mounted to an existing pole at the pump pad for the pump and filter station that will be installed at the Nelson Reservoir in the future (see figure 27 below). The pole was mounted to the closest pole to the reservoir in order to get the sensor as far into the reservoir as possible with the limited cord length.



Figure 27: Pump pad at Nelson Reservoir

The next step was to place the sensor in the reservoir. In order to accomplish this task the ITRC's boat was used (see figure 28 below). The boat was rowed out into the open water as far as was possible with the length of cord available. Next a rope was used to lower the concrete bucket weight to the bottom of the reservoir. The float was successfully held in place by the tension in the cord from the weight. While in the same location as the water level sensor a staff gauge was used to record the water level of the reservoir.



Figure 28: Boat used to lower weight and sensor into the Nelson Reservoir

RESULTS

Completed Nelson Reservoir Station

The installation of the Nelson Reservoir Adcon Telemetry Station was completed on May 6, 2014 (see figure 29). The water level sensor was placed in the reservoir and the float properly shows where the sensor is located (see figure 30). The solar panel was given a few days to ensure that the battery was fully charged and ready for transmitting water level sensor data to the gateway. The staff gauge measured the depth of the reservoir to be approximately 14.5 feet. The next step was to configure the RTU to transmit the data to the gateway.



Figure 29: Complete Nelson Reservoir Adcon Telemetry Station



Figure 30: Nelson Reservoir Float

Manual for Configuring New Adcon Telemetry Station

The first step to configuring a new Adcon Telemetry station is the initial setup of the RTU done by the company producing the product, in this case McCrometer. A new RTU unit is pulled off the shelf and is charged for 7 to 10 days. Next the company uses a terminal program on a PC and a programming cable to set up the frequency so that the RTU is on the same frequency as the rest of the network for that system. The ITRC network uses a frequency of 462.2625 MHz and a channel spacing of 12500 Hz.

Following the initial set up, the RTU must be programmed into the A850 gateway. The gateway is a server device that controls the communication between all systems in the network. The gateway can collect data from each station and change the data into a date, time, time zone, value, and engineering unit so that a software program can use it. The RTU type must be inserted followed by the RTI code or serial number. Then the sensors are attached through a graphical user interface so it is easy to visualize. After this setup one can communicate with the RTUs and after setting up the sensor drivers the A850 takes care of the rest. The A850 gateway can be accessed through the website <http://129.65.141.120>. Using the master user name and password the system can be accessed and settings can be changed. In order to change any of the settings the program must first be “locked”. While in the locked mode one can input new RTUs and configure them to the gateway.

Once the data is available in the A850 it can be accessed through the ITRC website under weather data and online databases. The SCADA-lite package is called addVANTAGE Professional. Through this system one can log into the network and view the trends and data from each RTU in the network.

The Nelson Adcon Station was fully configured and began collecting accurate data on May 15, 2014 (see figure 32 below).

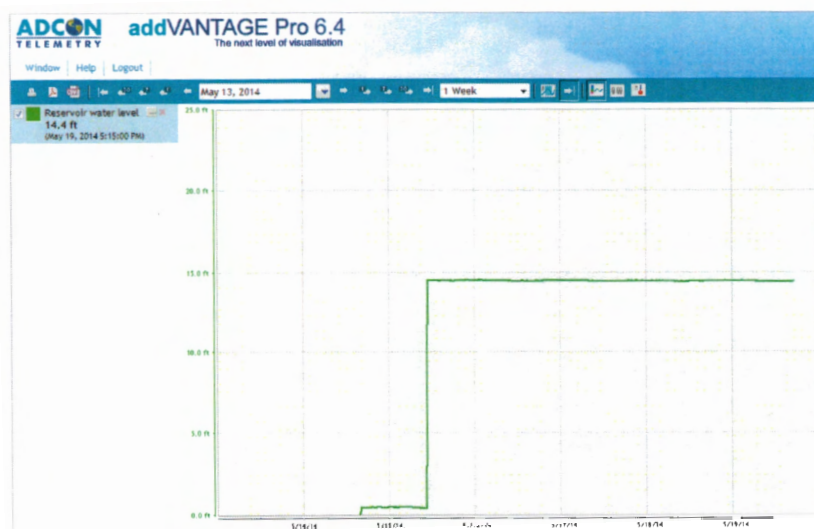


Figure 31: Nelson Reservoir Adcon Telemetry station trend

Guide for Editing Online Data Charts

The addVANTAGE Pro 6.4 is the system used by the ITRC for their RTUs. When the data is first transmitted to the system there are multiple settings that are automatically defaulted.

By logging onto the addVANTAGE Pro 6.4 with a master username and password the settings can be adjusted to better display the data.

There are four tabs at the top of the screen directly under the header titled Tools, Window, Help, and Logout. Most of these are not used for changing the graphs, but rather changing the overall program settings. For example, under Tools in the User Options one can change the password of the login by going to the Security tab on the right.

Under the four tabs are a row of buttons and a search bar (see figure 33 below). The first button on the left that looks like a RTU with a green plus sign is used for creating a new RTU. After one has configured the RTU with the A850 gateway the RTU can be uploaded to this program.



Figure 32: Initial Screen

The next button to the right is for the creation of a new panel. By clicking the mouse on the New Panel button there is a drop down menu with the four options of Event Viewer, Explorer, List, and Trend. Event viewer opens a window with a list of events that have been made. Explorer opens the exact same window in a new browser, so one can have a split screen focusing on different things. The List option provides a new window where one can add graphs to make a list. This could be useful for quick viewing of similar graphs by having them in a list right next to each other. The final option titled Trend opens up a new blank graph.

The third button from the left, shaped like a floppy disk, is a save button to save the new settings. The fourth button from the left is a save as button to save the new settings using a different name.

The fifth button from the left, shaped like a piece of paper with a checklist on it, is a Property of Selected Object button. If one has an RTU highlighted and then clicks on the

Properties button a window pops up with the general information about that RTU. Information in this window includes descriptions such as name, node identification, alarms, and events. By going to the second tab at the top titled Action one can create new events. There is a button on the right of the screen where one can add an event. Events have actions attached to them that can notify one if a certain time is reached. There is a maximum age of the event where one can tell the system how many days, hours, and minutes the event is to last. There are also multiple actions that can take place including sending an email, turning a switch on or off, or calling a landline.

The sixth button is the red “X” that is for deleting an RTU. This should only be pressed if a RTU is being taken out of the system.

As seen in the figure above there is a search bar option. The button that is shaped like a magnifying glass is an option for the search bar to be filtered by name, class, subclass, or ID.

Trend Settings. By clicking on the plus signs next to the names of a station, graph icons will appear (see figure 34 below). By double clicking on the graph icon a new window will pop up with the trend of that particular graph displayed. Within this window there are many options for optimizing the graphing display of the data collected at the RTU.

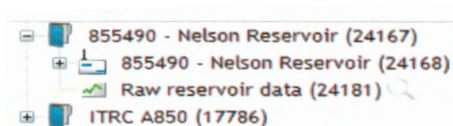


Figure 33: Opening an RTU graph

The setup of this window is similar to the home addVANTAGE screen with the additions of more buttons and axis setting options (see figure 35 below).

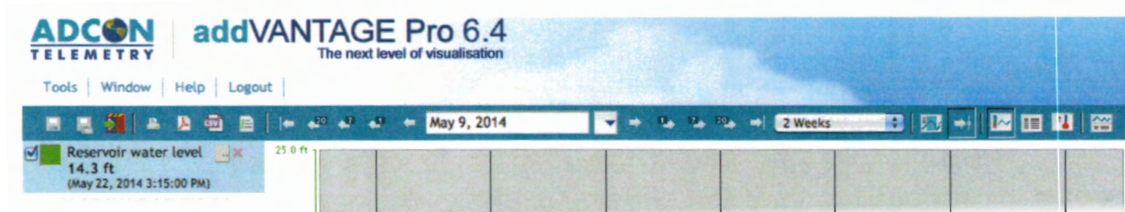


Figure 34: Trend Window Display

The first and second buttons on the left side of the toolbar are the save and save as buttons, respectively. The third button is to add to the node template, but the node templates are not needed for this application. The fourth button is for printing the screen. The fifth and sixth buttons are for exporting the values of the data to either a PDF or excel spreadsheet respectively.

The seventh button opens up the Trend Options window and is the most commonly used feature for editing the graph display (see figure 36 below). In this program the sensors

are called tags. There are options at the top right of the screen to add, delete, or change the order of the tags for graphs with multiple trends displayed. Next one will notice that under the tags window there are four tabs titled Y Axis, Plot, Thresholds, and Display. In the Y-axis tab one can change the y-axis scale with the high and low value appropriate for the data transmitted to the graph. Another good feature in this tab is the band option. The band refers to where the full scale of a sensor is located. For example, if one wanted to split a screen one could make one sensor's band from 0 to 50% and the other sensor's band from 50% to 100%. There is also an option to change the grid display. The number indicates how many breaks in the scale will occur. For example, if the scale is set from 0 to 25 and the grid is set to 5, then the y-axis will count up in increments of 5. Additionally the background grid color can be changed from grey to any color.

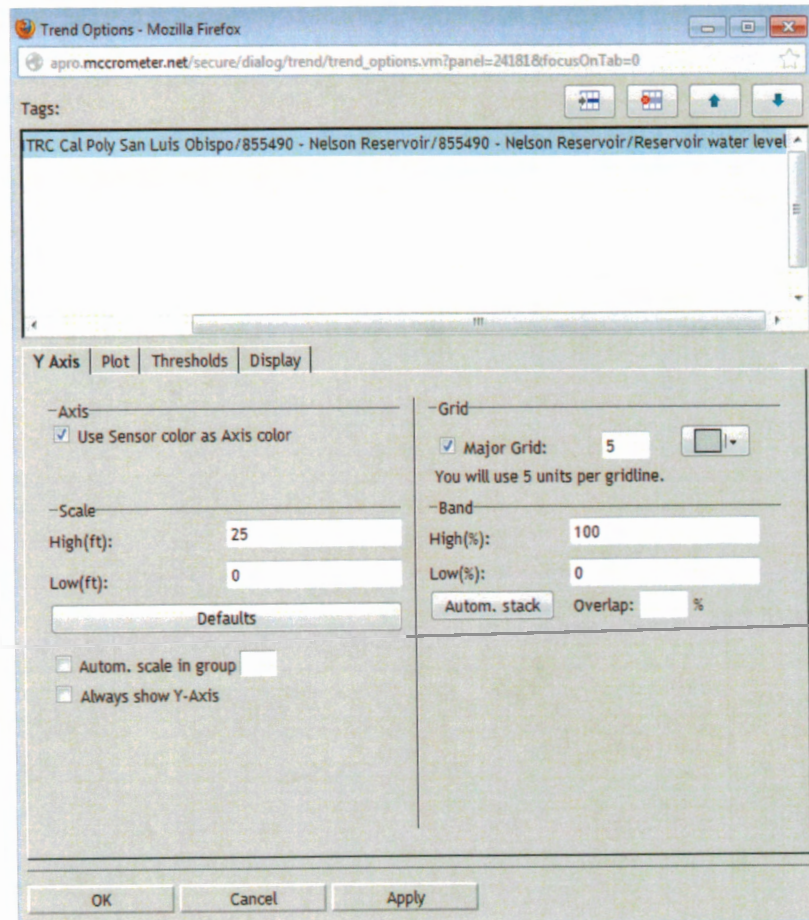


Figure 35: Trend Options Window

The next tab titled Plot is where one can change the color and weight of the line representing the data. There is also a Style option where one can change the graph from a line graph to a bar or area graph.

The neighboring tab titled Thresholds is where one can add a horizontal strip of color to the graph. This threshold could be used to easily determine if the sensor is out of its normal range. Use the top button to the right of the threshold name area to add a new

threshold. On the left under General in the value window one can set the maximum for the threshold. Under Fill there is a value window called Base where one can set the minimum for the threshold. Additionally, the Paint color is the color that the threshold will show up as on the graph.

The final tab titled Display is used to change some of the x-axis settings. Under Time Axis options one can change the major grid color and the time axis color. Under the Duration options one can change the duration of time for the axis as well as the gap at the end of the data. Although it can be altered here, the time axis is easier to change from the initial graph screen. The last options under the Display tab are under Graphic Options. In the Graphic Options one can change the graphic background color, the axis background color, the legend background color, and the legend color.

The next ten buttons are all used to format the timeframe of data displayed. The five buttons to the left of the first date are all used to go to past data. Each button has a different increment for how far to jump back in the data. The first one goes to the beginning, the next goes back 30 days, the next goes back 7 days, and the next goes back 1 day. The date represented in the middle is a start or end point for the arrows surrounding the window. In the second window there is a drop down menu for changing the length of time displayed on the x-axis. Based on that increment, the arrow to the left of the date will go back that distance while the arrow to the right of the date will jump forward that increment of time from the given data.

The first button to the right of the interval window can be useful for reading data off the graph. If the button is mostly white then by selecting a section of data one will get the sum, average, minimum, and maximum for that data and the date and time range of it. Additionally, one can export that specific data by right clicking the selected light blue section and going to Export All Values in Selected Time Range.

The next button that looks like a right arrow connected to a vertical line will jump the data to the last available data point.

The next three buttons will change how the data is displayed. The first button that looks like a graph is the graph mode button. This is the most common type of setup. The next button that looks like a list will change the data to a list format. The final button only displays the most recent data point in a picture mode.

Map of ITRC Adcon Telemetry Stations

To distinguish the placement of the ITRC Adcon Telemetry stations a google map image was used to show each of the stations (see Appendix B). The legend of the image shows what type of sensor each station is using. Additionally the map will increase awareness of where each station is located relative to one another.

Evaluation of Adcon Telemetry Stations

In order to evaluate each Adcon Telemetry station each site was visited and each online graph was viewed. From the initial site visits it was clear that all the stations were still in their correct location and properly connected. Next the online data was analyzed.

Most of the Adcon Telemetry stations are functioning correctly. Most stations are accurately collecting and transmitting data to the gateway. These stations are providing useful graphs in the addVANTAGE program.

Two stations are currently not operating correctly. Both the Adcon Telemetry stations at the Water Resources Facility are not functioning properly. The first station titled “Water Resources WS Open Flow Meter” is not properly transmitting data. This was determined by the lack of data although water has been flowing through the flow meters. After talking with a representative at the Water Resources Facility it was determined that there was a problem between the sensor and RTU interface. One of the sensors has been sent back to McCrometer to identify the problem.

The other Adcon Telemetry Station at the Water Resources Facility titled “Water Resources Pumps” is also not measuring any flow through either of the flow meters. These flow meters have been running recently and should have been logged by the online data.

It is important to check the system often so that a problem is caught early on to avoid other disasters. When sensors and RTUs are not recording or transmitting proper data, the best way to troubleshoot the problem is to check the online settings and look for warning signs. Next one should contact the company that produces the product and ask the company to check the product to try to identify the problem.

DISCUSSION

Communication with McCrometer Representative

As with any project communication is a key element to getting tasks accomplished with limited knowledge. One aspect of this project required outside help with an expert. In order to get the new RTU station configured to the A850, a representative from McCrometer, Steve Grove assisted in inputting the codes online to get the process started. Although this process was completed, it was extremely difficult to get the process going and to get the information needed to complete this project due to difficult communication.

Troubleshooting RTU Connection with the Sensor

One problem that occurred during the configuration of the sensor was the initial data collection from the sensor was not being transmitted from the RTU at the Nelson Reservoir station. This issue was solved by checking the connections at the Adcon Telemetry station. The connection between I/O A was checked for a secure connection and possible bent prongs in the connector. Seeing no problem with that connection and the power connection was working properly, the next connection to check was the wire connectors in the breather box. By reconnection one loose wire and reassembling the breather box, the system began to properly collect and record data.

RECOMMENDATIONS

Length of Sensor Connection Cable

When preparing for this project the ITRC already had the components needed to set up a station. Although the station is in place and running properly, a longer cable would have been preferred. If a longer cable was used the sensor could have been placed farther out into the middle of the reservoir creating more distance from the sides of the reservoir. This option would give a better average of the reservoir depth and potentially have less problems associated with being close to the edges of the reservoir.

Additional Sensors

One way to improve this station is to add multiple sensors to the station. The plan for the site is to install a pump and filter station. A flow meter could be added to the station and therefore provide data to show when the system is running. Another option is to add a pressure gauge to the pipeline. Any additional sensors that can be added to the Adcon Telemetry station will provide more data that can help monitor the water flow through the Ag Contract line at Cal Poly.

Trench Pipeline to Cover Sensor Cord

When setting up the Adcon Telemetry station at the Nelson Reservoir the cord was run from the pressure transducer to the pole with the RTU. This cord was left exposed on top of the ground from the water surface to the pole. One recommendation is to trench a pipeline to protect the cord from the pole to the water line. The cord is very sturdy and may not need covering, but the extra protection could be useful in some cases. As well as protection, trenching a pipeline will improve the aesthetics of the site.

Adcon Telemetry Station at the Middlecamp Reservoir

The Middlecamp Reservoir directly feeds into the Nelson Reservoir. Therefore once the pump station is installed at the Nelson Reservoir, it will be very important to monitor the water level of the Middlecamp Reservoir. Adding a similar Adcon Telemetry station as the Nelson Reservoir to the Middlecamp Reservoir will be easy and straightforward with the instructions provided in this report.

Mobile App

One way to improve the Adcon Telemetry system at Cal Poly is to create a mobile app for easy access to the graphs. Although the data is easy to access on a computer, a mobile app that gives a quick overview of the graphs would be very useful for workers in the fields. The mobile app doesn't need to have all the features as the online version, however just showing a small amount of data would be very useful.

REFERENCES

- Adcon. 2013. Adcon Telemetry. <www.adcon.com>, referenced November 18, 2013.
- Barbosa, R. R. R., R. Sadre, and A. Pras. 2013. Flwo whitelisting in SCADA networks. *International Journal of Critical Infrastructure Protection*. 6:150-158.
- Dieu, B. 2001. Application of the SCADA system in wastewater treatment plants. *ISA Transactions*. 40: 267-281.
- Duran-Ros, M., J.Puig-Bargues, G. Arbat, J. Barragan, and F.R. Cartagena. 2008. Definition of a SCADA system for a microirrigation network with effluents. *Computers and Electronics in Agriculture* 64(2):338-342.
- McCrady, S. G. 2013. *Designing SCADA Application Software*. Elsevier. Canada, pp 25-50.
- McCrometer. 2013. McCrometer the Flow Measurement Specialists. <www.mccrometer.com>, referenced November 19, 2013.
- Rijo, M. 2008. Design and Field Tuning of an Upstream Controlled Canal Network SCADA. *Irrigation and Drainage*. 57(2):123-137.
- Rossman, N.R., and V.A. Zlotnik. 2013. Review: Regional groundwater flow modeling in heavily irrigated basins of selected states in the western United States. *Hydrogeology Journal*. 21(621):1173-1192.
- Plusquellec H, Burt C, Wolter HW. 1994. *Modern water control in irrigation*. World Bank Technical Paper No 246 – Irrigation and Drainage Series, Washington, DC.
- Styles, S., S. Herman, M. Yasutake, and C. Keezer. 2012. *SCADA. Irrigation Training and Research Center*. San Luis Obispo, CA, 1-9 p.

APPENDIX A: HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

Major Design Experience

The BRAE senior project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes fundamental elements as outlined below. This project addresses these issues as follows.

Establishment of Objectives and Criteria. Project objectives and criteria are established to meet the needs and expectations of the Irrigation Training and Research Center. See *Design Parameters and Constraints* below for specific objectives and criteria for the project.

Synthesis and Analysis. The project incorporates the evaluation of several Adcon Telemetry stations at Cal Poly.

Construction, Testing and Evaluation. The Adcon Telemetry station at Nelson Reservoir was constructed, installed, and evaluated.

Incorporation of Applicable Engineering Standards. The project utilizes the national electrical codes (NEC) for installation of automated devices and the California Building Codes for solar installation.

Capstone Design Experience

The BRAE senior project is an engineering design project based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge and skills from these key courses:

BRAE129 LabSkills/Safety
 BRAE133 EngineeringGraphics
 BRAE151 AutoCAD
 BRAE 236 Irrigation Principles
 BRAE 328 Measurements and Computer Interfacing
 BRAE 433 Concrete Structures
 ENGL149 TechnicalWriting

Design Parameters and Constraints

This project addresses a significant number of the categories of constraints listed below.

Physical. The Adcon Telemetry Station was mounted to a pole at the Nelson Reservoir with a water level sensor dropped into the reservoir.

Economic. The project was funded by the Irrigation Training and Research Center and through McCrometers equipment.

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Economic. The project was funded by the Irrigation Training and Research Center and through McCrometers equipment.

Environmental. A benefit of the project is a reduction in water loss from the reservoirs. The Adcon Telemetry stations utilize a renewable energy supply from the small solar panel attachment to each pole.

Sustainability. The durability of the stations will enable long term use and the renewable energy supply will provide long term battery life.

Manufacturability. N/A

Health and Safety. N/A

Ethical. N/A

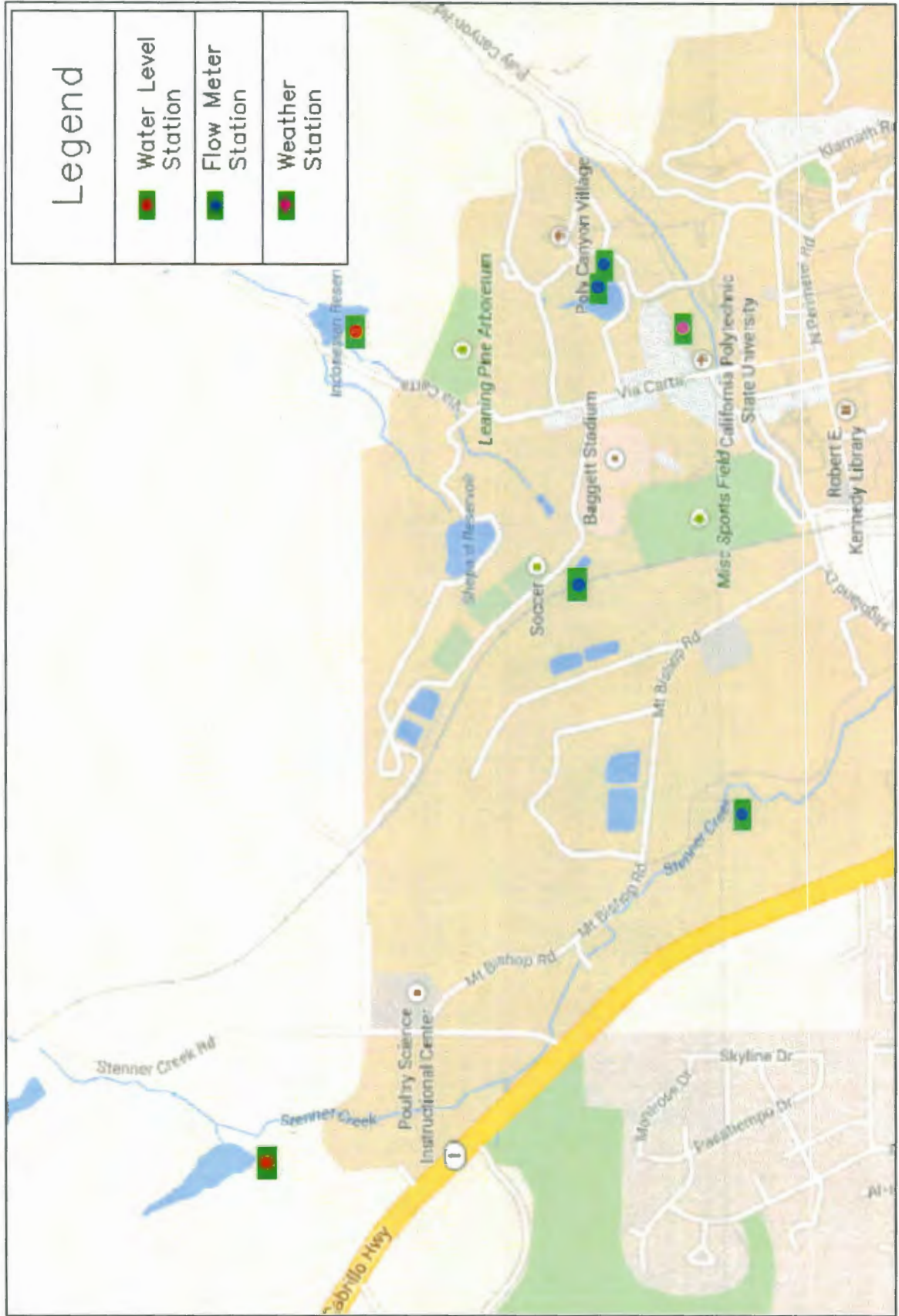
Social. N/A

Political. The project will reduce water losses at Cal Poly.

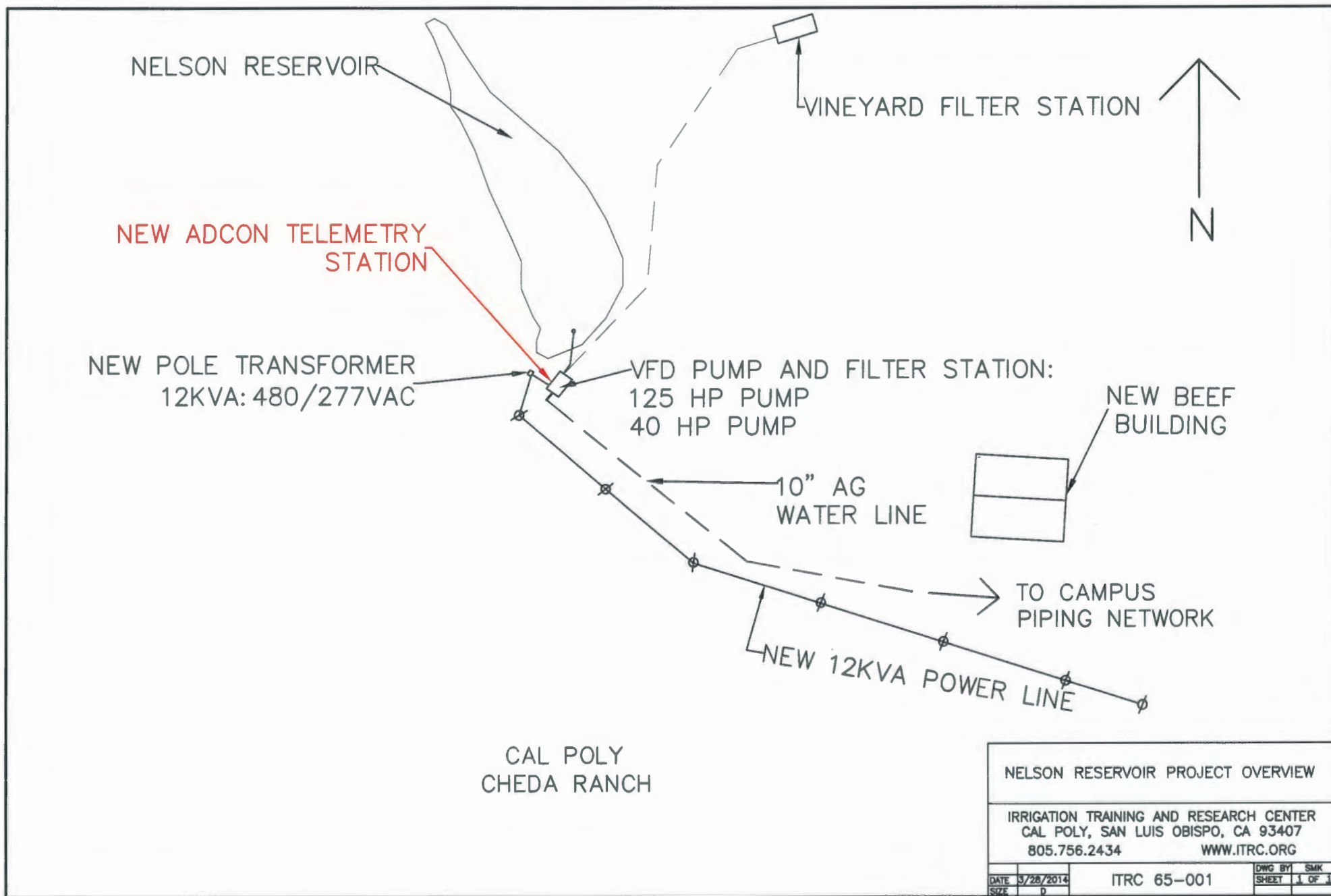
Aesthetic. The finished product is fully installed at the pump and filter station at the Nelson Reservoir. Wires are properly connected and neatly tied up and hidden.

Productivity. The Adcon Telemetry stations are designed to collect readings every 15 minutes.

APPENDIX B: ADCON TELEMETRY STATIONS AT CAL POLY MAP



APPENDIX C: NELSON RESERVOIR DRAWINGS



APPENDIX D: RTU DATA TABLE

RTU A753 addWAVE

Mechanics

Case	Aluminum, powder coated
Protection class	IP-67
Dimensions / weight	160 x 60 x 80 mm / 1.200 gr.
Connectors for sensors and power	4 x M9 female 7-pin to sensor 1 x M9 female 5-pin to power Made in Germany by Binder Sockets: brass, nickel plated, with gold plated socket contacts; IP-67 protection class 2 protective caps
Antenna connector	TNC with external seal, IP-67, Made in Germany
Mounting	Mast mounting bracket, integrated
Operating temp.	-30°C ... +75°C

Special Logger functionality

Wind gust monitoring	Port C + Adcon wind sensor: 4 samples per second, 4 times per second calculation of 3-second average; Date and time of gust stored
Wind vector monitoring	Port C + Adcon wind sensor: wind direction is measured simultaneously with speed, weighed depending on speed, and stored as a vector
Rain intensity monitoring	Port D + rain gauge with pulse output (max. resolution: 1 second). Date and time of each pulse are stored; in addition up to 3 analog signals and 2 counter inputs can be stored, e.g. wind speed and air temperature
Pressure hammer detection	Port C + Adcon manometer sensor: manometer is permanently excited, sampled 4 x per second, and a 3-second average is stored
Low Voltage amplifier	Port B: sensors with an analog output of 0-150mV can be connected directly; internal amplifier
Asynchronous sampling	To prevent sensors from influencing each others readings when read simultaneously ports can be sampled sequentially
Event-Monitor	To rapidly detect status changes on a digital input it can be sampled up to once per second; date and time of each status change are put in memory; attention: with frequent status changes this can generate a lot of data! Applications: error detection on equipment, access control, pump monitoring, etc.

Data transmission

Frequency ranges	Band 1: 430 ... 440 MHz Band 2: 440 ... 450 MHz Band 3: 450 ... 460 MHz Band 4: 460 ... 470 MHz
Modem	Made by Adcon Telemetry
Antenna	Omni directional, vertical, TNC jack, +2dBi

General

Power Supply	internal 6.2V battery, charged by solar panel or mains power supply
Battery	Panasonic Hi-temperature cell, industry grade, NiMH, 3300mAh
Type approvals	FCC, R&TTE, CE, Industry Canada, ACMA Australia

Logger

I/O channels	60
Analog inputs	12x0...1V/2.5VDC (3 channels on Port C can be programmed to a measuring range of 0 - 150mV DC low temp. drift with internal amplification)
Digital inputs	40 x SDI-12 Values
Counter inputs	Total of 4 inputs: 2 for standard reed switches, debounced, e.g for rain gauges; max. 30 pulses per second. Min. pulse length 17ms, min. break time 17ms 2 for fast puls generators, e.g. wind speed sensors or flow meters; max. 500 pulses per second. Min. pulse length 1ms, min. break time 1 ms.
TTL In- / Outputs	4 x TTL compatible status inputs or switching outputs, programmable; of which 1 x 5V (Port A) and 3 x 3.3V (all others)
Analog resolution	16-Bit
Sensor excitation voltage	Programmable: - Unregulated battery voltage from 5.5V ... 7.5V - Stabilized voltage, programmable from 3.3V ... 5.5V in 0,1V increments
Memory	2MB for up to 500.000 values, depending on types of sensors attached (SDI-12 typically needs more memory than analog). Example: 15-minute data of an ETo station can be stored for 6 months.

APPENDIX E: A850 DATA TABLE

A850 Telemetry Gateway

Dimensions	182 x 260x 52 mm
Weight	1.862g
Connectors	1 x 100Base-T Ethernet 1 x RS-232 (ext. modems) 1 x RS-232 (Console) 1 x RS-485 (Radio Modem) 2 x USB (ext. modems) 1 x Mains Power
Analog Modem	external via USB or RS-232
Micro Processor	Cirrus Logic 32-bit ARM
Memory	1GB Flash, 32MB RAM
Operating System	Linux OS 2.4 Kernel
Power Supply	90 ... 240 V AC; an integrated 8.4V NiMH battery with 4.500mAh serves as uninterruptible power supply
Operating Temperature	-10°C ... +55°C

A440 Wireless Modem

Dimensions	119 x 79x 60 mm
Weight	590g
Connector	1 x RS-485 to connect to A840 / A850
IP Protection	IP67
Power Supply	via the RS-485 connection to the A850 / A840 Telemetry Gateway
Mounting	Mast mounting bracket
Operating Temperature	-30°C ... +60°C
Tx Output power	500mW e.r.p.
Rx Sensitivity	-120dBm (10 dB S/N)
Channel spacing	12.5 / 25 kHz (factory preset)
Antenna	Omni-directional, 0dB
Antenna connector	TNC with external seal
Frequencies	430 ... 470MHz (in 4 bands of 10MHz each)
Approvals	R&TTE, CE, FCC, Ind.Canada, AUS

APPENDIX F: PARTS LIST

Adcon Telemetry Station – Nelson Reservoir Parts List

RTU – Remote Telemetry Unit

- Model: A753-46
- 100.753.004 B4
- SN:855490
- ID: 55490
- FCC ID: SHXA753-46
- IC: 3606A-A75346

addWAVE Series 4

Adcon Solar Set:

- 9VDC, 460mA,4,3W
- Item Number: 200.733.522
- Country of Origin: Austria

Keller druckmesstechnik (breather box)

- Type: Baromodul PAA-80748.99
- Range: Programmierbar
- Output: 0..2.5V
- Supply: +5.5..15VDC
- 1: GND
- 2: +OUT
- 3: +Vcc
- SN: 556
- Tel: +41/52/235 25 25 +49 /77 45/9214-0

Cord

- P-136-29-MSHA
- 18AWG
- 4/C SOOW
- 90C
- 600V
- Water Resistant

Keller druckmesstechnik (water sensor)

- Type: PA-36W/80748.9-10
- Range: 0 .. 10 bar
- Output: Digital RS 485
- Supply: + 5.5 .. 15 VDC
- 1/WH:GND 3/PK:RS 485A
- 2/BK: +Vcc 4/GN:RS 485B

- Tel: +41/52/235 25 25 +49/77 45/9214-0

Hose Clamps

- 2" and 4"

Zip Ties

- Large

Bucket

- 2 gallon

Eyelets with thread

- $\frac{3}{4}$ " – short thread
- $\frac{3}{4}$ " – long thread

PVC

- 4" Pipe
- 2 - 4" Caps

Small Bucket of Cement