Appendix B. Task 200 SCADA Reliability & Redundancy
FINAL

TASK 200 - SCADA RELIABILITY AND REDUNDANCY

B&V PROJECT NO. 401414

PREPARED FOR

Santa Rosa

21 OCTOBER 2019
REVISED 22 SEPTEMBER 2020
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1.0 Introduction and TM Organization

This technical memorandum (TM) summarizes the options for the City of Santa Rosa (City) Water Department to address supervisory control and data acquisition (SCADA) system reliability issues that were discovered during the Tubbs fire. Black & Veatch evaluated the Tubbs fire for the City and documented the findings in the “Evaluation of the Water System’s Response in Fountaingrove to the October 2017 Fire” report released in August 2018. That report recommended several areas for additional research. In 2019, the City issued the Water System Reliability Study to perform additional research. This TM is one of the TMs developed to meet the requirements of the Water System Reliability Study.

This TM addresses the requirements for Task 200. The TM is focused on understanding the existing SCADA system, existing reliability, and redundancy and documenting the alternatives to consider for increasing the reliability and redundancy of the SCADA system. The SCADA system evaluation was performed at the system level, not at the facility level, and included research on the following:

- Multiple SCADA communication methods.
- Programmable logic controller (PLC) enclosure insulation and protection.
- Standby power sizing for lengthy outages.

Black & Veatch evaluated and developed options for the City’s consideration utilizing the latest available technologies and market trends. Black & Veatch held meetings with several individuals to gather information in conjunction with the kickoff meeting. Several options were researched and are presented in this TM.

A draft version of this TM was used during a workshop that occurred on August 5, 2019, where the project team reviewed the options and planned a path forward.

This TM is organized into the following sections:

- Section 2.0, Project Background.
- Section 3.0, SCADA System Communications Findings.
- Section 4.0, SCADA System Reliability and Redundancy Options.

2.0 Project Background

Black & Veatch instrumentation and control (I&C) personnel met with City I&C personnel on May 6, 2019, to review the existing SCADA system. During this meeting, the technologies were reviewed at the utilities field office (UFO) building, and a tour of the SCADA server room was provided. Black & Veatch traveled into the field and visited several locations including Reservoir 17, Pump Station 18, Pump Station 4, Reservoir 3, and other locations.

The following strengths were discussed:

- The SCADA servers are in a climate-controlled data center at the UFO. The data center has key card controlled doors. There are redundant SCADA servers in the server room. The servers and network equipment appear to be recent models and are in excellent condition.
A backup SCADA server is located at Pump Station 4. Pump Station 4 is approximately 3.5 miles from the UFO. A high-speed network connection is available through the City's wide area network at this location. An existing server rack in a climate-controlled room is also available in Pump Station 4.

The three member I&C support team have the skills needed to support the current SCADA system.

Bandwidth on the SCADA system is not an issue.

The following SCADA system challenges were discussed or discovered:

- Poor communication exists between the reservoirs and the pump stations.
- The radio system is obsolete.
- Limited power is available at the reservoirs.
- There is limited redundancy in the serial radio system.

On August 5, 2019, a workshop was held that reviewed a draft version of this document, along with other topics. Information shared during the workshop included the following:

- The design basis power loss is 5 days (120 hours). Pacific Gas and Electric (PG&E) has announced that it is reviewing options for preventing events such as the Tubbs fire. The leading option is developing “high winds” criteria. If the criteria are exceeded, a high probability exists that the high voltage lines could get close enough to each other to create an electrical short, break the line, and drop the energized lines on the ground, causing a wildfire. During high wind conditions, the power would be turned off to large portions of the service area for up to 5 days.
- The leased copper lines lose connectivity approximately once every 2 months for generally a day or less.
- A project is approaching 40 percent design that is a “like-for-like” replacement of the current serial radio system. There is no effort to add the reservoirs to the existing project.
  - This project includes an effort to replace obsolete PLCs with currently supported versions of the City's standard PLC.
- A radio path study is needed for the reservoirs.
- There is a desire for a SCADA masterplan.
- The serial radio system polls every location about every 1 minute.
- Questions were asked about the bandwidth capability of the Mesh network. One vendor stated 600 megabits per second (Mbps). For comparison, the serial radios operates at 9,600 bits per second, so this technology can handle 60 million times as much data. A streaming security camera consumes approximately 1 million bits per second.
- A pilot study is desired for a Mesh network to verify its capabilities and connectivity.
Most pump stations have variable frequency drives (VFDs) and have a pressure control mode. When communications between the reservoir and the pump station are lost, either the pumps are operated in “remote manual” or the reservoir is isolated, and the pump station is placed in pressure control mode.

Although most pump stations have VFDs, there is effort to put VFDs at the remaining pump stations.

There are some pump stations that have fixed speed pumps with across-the-line starters.

Adding a level display to the SCADA screens that is based on pressure at the discharge of the pump could be considered. The level would be accurate only when no pumps are running.

Information could be added about portable power changes that would be needed at reservoirs and Mesh network repeaters.

There is no desire to add a third repeating station because of the significant licensing that would be needed. The serial radio system is very reliable.

There is no desire to research cellular data connectivity for the SCADA system because City employees know there are several locations with no coverage or poor coverage.

Additional research is needed to expand battery power at the reservoirs and add solar panels.

These topics have been incorporated into this TM, where appropriate.

3.0 SCADA System Communications Findings

3.1 RADIO SYSTEM

The current radio system is a licensed, 153 megahertz (MHz), point-to-point system utilizing 9600 baud, serial-based, DataRadio Integra radios. The remote radios located at the pump stations communicate with one of two relay radios located at Reservoir 7 or Reservoir 17. A master radio is located at the UFO, through one of two repeater radio sites.

Figure 1 shows the radio system for the City. The following information is provided on Figure 1:

- Green dots are wastewater lift stations.
- Blue dots are reservoirs.
- Pink dots are pump stations.
- The red lines are serial radio paths.
- The copper lines are not displayed.

At the UFO, the serial radio signal is converted to Ethernet by a MOXA NPort 5610 serial-to-Ethernet converter. Ethernet communication is used for the SCADA servers, historian servers, and the enterprise network.

The Integra radios are no longer manufactured as of February 2018. The City wastewater group researched and was favorable to the Trio QR150 radios from Schneider Electric. The drinking water group hired a designer to replace the existing serial radio system with a Trio QR150-based radio system.
There are copper line connections between the reservoirs and the pump stations. The reservoirs and associated pumps are between 500 feet and 5 miles apart. The installation utilizes copper wires and phone modems for communications between the reservoir and the pump station. There are instances of City-owned copper and instances of leased lines from AT&T. Some cables are direct buried; some cables are buried in conduit.

The ratio of reservoirs and circuits is not 1-to-1 because some reservoirs can be filled by multiple pump stations.

Connectivity of the 25 circuits detailed by the City include the following:

- 11 leased lines from AT&T (at approximately $50/month each) was the biggest communication issue during the Tubbs fire.
- 12 copper lines owned by the City did not have any failures during the Tubbs fire.
- 1 radio connection between Pump Station 11 and Reservoir 11.
- 1 fiber-optic link between Pump Station 5 and Reservoir 5.

The reservoirs generally have very few points of SCADA data, typically, reservoir level, chlorine residual, or other water quality sensor and a cabinet intrusion switch. These values change slowly, and the tanks are polled by the pump stations every 1 minute. This has met the City's needs for many years.

Figure 2 shows a typical diagram of pump station and reservoir communications.
3.3 PROGRAMMABLE LOGIC CONTROLLERS

The City has standardized on Tesco PLCs. The following observations were made:

- The PLCs that were visited on May 6 were using serial communications.
- Some newer PLCs have Ethernet capability. PLCs that do not have Ethernet capabilities generally have available expansion slots that could be used for an Ethernet card.
- No reliability issues were reported or observed to be caused by the PLCs.

3.4 RESERVOIRS AND PUMP STATIONS

Approximately 21 reservoirs have a matching pump station. The relationship is not 1-to-1 because some pump stations serve multiple reservoirs. The pump stations are typically located at a lower elevation than the reservoir. The pump stations have a PLC that controls the start and stop of the pumps according to reservoir level. The pump will start when reservoir levels get low and stop when the reservoir is full. In addition, hardwired interlocks, such as low suction pressure and motor overload, will stop the pump or prevent it from starting.

4.0 SCADA System Reliability and Redundancy Options

4.1 COMMUNICATION BETWEEN THE RESERVOIRS AND THE PUMP STATIONS

4.1.1 Communication Issues

The City has indicated that communication between the pump stations and the reservoirs has been unreliable. The facilities with direct buried cables lose communication about once every 2 months. Facilities with cables in conduit are more reliable. The primary cause is damage to the communication cable. When communication fails, the PLC for the pumps cannot receive the
reservoir level, and the pumps stop. Operators must manually run the pumps either from the SCADA system or locally to prevent the tank from overflowing and to maintain adequate storage in the tank. A damaged cable takes approximately 4 days for the City or the local communications company to repair.

4.1.2 Option 1 – Place the Copper Wires in Conduit
The copper lines that are in conduit are more resilient than the lines that are direct buried. The copper wires that are in conduit take less time to repair. The cost of putting conduit in the ground is estimated at $75 per linear foot. If this option is selected, consideration should be given to installing fiber-optic cable instead of, or in addition to, copper wires.

4.1.3 Option 2 – Replace Copper Wires with Serial Radios
In 2002, the City performed a radio path study showing that there was poor point-to-point radio links between these locations using 900 Mhz and 153 Mhz. To improve connectivity, obstacles would need to be removed, antenna heights would need to be increased, or additional repeaters would be needed to go around the obstacles. The radio broadcast power was not reviewed. A radio path study is recommended to reevaluate point-to-point radio link options.

The serial radio path study will provide a primary connection and a secondary connection if available. If a direct path is not available, the study should indicate the height of antenna poles or tower needed at each side to make the connection. If the parameters are not acceptable, a Mesh network connection should be studied for connectivity between tank and pump station.

4.1.4 Option 3 – Replace Copper Wires with Mesh Radios
Mesh radio technology is a multi-point to multi-point Ethernet network using WiFi technology. Frequencies are at 2.6 gigahertz (GHz) with a maximum bandwidth of 600 MBS. There are three types of radios in a Mesh system. Base stations connect to the wired network. Endpoints connect to the network at a pump station or reservoir. Repeaters are placed between the base stations and end points.

The repeaters look for nearby base stations, endpoints, and other repeaters. Adding more base stations or repeaters improves bandwidth and reliability. The repeaters and base stations are continuously scanning for other base stations, repeaters, or endpoints. When a repeater or base station moves in range and is discovered, it is automatically added to the network. This is particularly useful for employees with laptops in moving vehicles.

The Mesh network is self-healing and if a single repeater or base station loses power, traffic is automatically redirected through repeaters to base stations.

The Mesh network operates at different frequencies than the existing serial radio system and should be able to operate in parallel without interference.

Most Mesh radios will be able to be powered by 12-48 volts direct current (VDC), 110-240 volts alternating current (VAC), or power over Ethernet.
Some Mesh radios have power options to connect them to the “luminaire” street lights, which are equipped with a light sensor that is continuously powered. The power source from these luminaire street lights can be easily modified to power the Mesh radios without impacting the operation of the luminaire lights. Figures 3 and 4 show examples of Mesh radios powered by luminaire. Coordination and testing with the luminaire support group should be considered.

![Figure 3 Typical Street Signal and Luminaire with Mesh Repeater](image1)
![Figure 4 Mesh Repeater Powered by Luminaire](image2)

Mesh options to be considered may include the following:

**ABB - TropOS family of radios**
- Backhaul: Edge Node – TropOS 1420 / 2420
- Relay: Mesh Router – TropOS 6420
- End Point: Client Node – MicrOS 410 / 411

**Fluidmesh.com**
- Backhaul: FM3200 Base
- Relay: FM3200 Base
- End Point: FM1000GWY

### 4.1.5 Costs

ABB and Fluidmesh were contacted to provide cutsheets and manufacturer suggested retail prices for these devices. The cutsheets for these devices are in Appendix A of this document.

The Fluidmesh pricing model is based on bandwidth licensing. The hardware is the same for all available bandwidths. The pricing increases as desired bandwidth increases. For this effort, 1 Mbps was selected. This is enough bandwidth to support the SCADA system but is not enough to support the enterprise applications. Fluidmesh did not provide a price for the FM3200s because more than one will be needed. It wanted map coordinates of where they could potentially be installed. This information was not provided to Fluidmesh, and it did not provide pricing. Fluidmesh did indicate the minimum bandwidth for a FM3200 is 30 Mbps.
Table 1 provides the models and costs for the Mesh options.

### Table 1  Mesh Options

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>ABB MODEL</th>
<th>RETAIL COST</th>
<th>FLUID MESH MODEL</th>
<th>FLUID MESH COST</th>
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<td>FM 1200 Volo</td>
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<td>$999</td>
<td>Not Available</td>
<td>Not Available</td>
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</tbody>
</table>

4.1.6 Comparison of Options

Several other factors should be considered when adding a Mesh network to the serial network or potentially replacing the serial network with a Mesh network.

**Communication Protocol**

If Ethernet Mesh radios are used, the City would need to add Ethernet switches at the pump stations and reservoirs. Each location would need to do one of the following:

- Use the Ethernet capability of the PLCs.
- Add Ethernet to serial converters at PLC locations that do not have Ethernet capability.

Since Mesh radios operate at 2.6 GHz, they require line of sight connectivity. Mesh routers could be placed at intersections on street luminaries to allow them line of sight with each other along the streets. Base stations could be installed at any City building that has high speed data connectivity. Buildings could include police stations, fire stations, and other municipal buildings.

If serial radios are used to replace the copper lines, the protocol does not change.

With either Mesh or serial, a physical radio path study is recommended. Tabletop path studies are easier because the analyst uses available topographical information to check the radio path. A physical radio path study has an analyst in the field to verify the information. This is particularly important because large areas with large trees burned completely during the Tubbs fire. The trees are already returning, and their full growth potential needs to be taken into consideration for the radio path studies.

**Support Skills**

The City I&C support team of three individuals has limited, if any, experience with Mesh radios and Ethernet switches. The team has decades of experience with serial radios. Utilizing Mesh radios would require additional training or additional staff to support this communication technology. The City Information Technology Department may have an Ethernet network engineer that may be able to provide support or training.

Considering the amount of hardware to be added and supported, an additional I&C employee may need to be considered.
Redundancy

Having communications in the ground and in the air will provide redundant paths. There could be value in retaining the copper line connections.

Security

The Mesh radios are based on the Wi-Fi standard and have several security features including data encryption, passwords for configuration, and several others.

The Trio QR150 radios have several security features including data encryption, passwords for configuration, and several others.

For both radio systems, the security is typically turned off when it is shipped from the factory to facilitate installation and configuration. Security would need to be enabled.

Support for Enterprise Information Technology Applications

The bandwidth of the Mesh network can carry streaming video cameras, phone calls, work order system data, and geographic information system (GIS) data easily. This could allow City employees who work in the field to have laptops with connectivity nearly as good as what they have at their desks. The Mesh network can be used for connectivity for vehicles for utilities, police, fire, and others.

The Mesh radios may be capable of supporting multiple networks. The SCADA network and Enterprise network could use the same Mesh network hardware, and the networks would still be considered separate. This could be helpful for utility employees utilizing a mobile work order system and may be helpful for connectivity for police and fire departments and other mobile Wi-Fi users.

Sharing hardware across multiple departments may need detailed support and access agreements.

Support for a 5 Day Outage

The cutsheet for the ABB battery backup shows a device that bolts to a pole. The battery capacity is fixed, and the power uptime on battery is based on the power consumption of the radio. Uptime ranges between 2.5 and 7 hours. This clearly does not meet the 5 day (120 hour) requirement.

Fluidmesh does not provide a battery backup system. Battery backup or redundant power supply is left to the engineer, designer, or installer.

Solar panels for battery charging do not look like viable options for installations on luminaire poles.

4.1.7 Option 4 – Cellular Connectivity

Cellular connectivity for SCADA was briefly considered. Multiple City employees shared that there are several areas with poor cellular connectivity.

4.1.8 Option 5 – Control Pumps Based on Discharge Pressure

Black & Veatch knows of only a couple of instances where this option was implemented. It should only be considered for a backup method of tank level control at locations that have single speed pumps. The tanks/reservoirs occasionally overflowed.
A review of the data from the Tubbs fire confirmed that the discharge pressure of the pump stations was an indicator of reservoir level while the pumps were off.

Discharge pressure while the pumps are running is available but could not be consistently correlated to the downstream reservoir level with the data provided. This is because a reservoir under normal operation changes only by about 10 feet (or approximately 4.5 pounds per square inch [psi]). Pressure oscillations from the pumps running may make level measurements inaccurate.

Consideration could be given to developing a pump operational mode during a loss of communications with the reservoir level. A control description and PLC logic may be able to be developed that would start the pump with low discharge pressure.

The pumps could be stopped according to the total gallons that have passed through the flowmeter since that pump started. For example, the pumps could be started at 25 percent full and stopped when half of the capacity of the reservoir has passed through the flowmeter.

During the August 5, 2019, workshop, the City shared that reservoirs that have matching pump stations with VFDs have a “pressure mode.” The speed of the pumps is varied to maintain a constant pressure. The reservoir needs to be isolated for pressure mode.

Pump stations with single speed drives are being scheduled for upgrades to VFDs. Adding the above pressure control did not seem to provide a significant benefit to the workshop attendees.

4.1.9 Option 6 – Add Level Display Based on Pressure

The reservoirs have level sensors. The SCADA operator screens level indications are based on these sensors. When electrical power or signal wires are damaged between the pump and reservoir, the signal is lost to the SCADA system.

An additional display could be added to the operator screens indicating reservoir level on the basis of the discharge pressure of the pump when the pumps are not running. The indication on the operator screens could be suppressed when the pumps are running. This arrangement could be valuable if communications to the reservoir are disrupted for any reason.

4.1.10 Recommendations

Option 5 was not selected because of the ongoing effort to replace all the single speed pumps with variable speed pumps. Programming to start on low pressure and stop on totalizer flow would be wasted effort.

Option 6 is recommended to be completed as a lower priority and as part of the normal work for the I&C staff.

Connectivity Options 1 through 4 – During the August 19, 2019, conference call there was extended discussion on this topic. The discussion overlapped with the Section 4.2 discussion about the obsolete serial radio system. The recommendations for these options are included in the recommendations for the obsolete serial radio system.
4.2 OBSOLETE SERIAL RADIO SYSTEM

4.2.1 Problem Statement
The City drinking water group is using a radio system that is nearing obsolescence. The DataRadio Integra last available date to be ordered was February 23, 2018. The drinking water group is considering technology options to replace the existing serial point-to-point radio system.

4.2.2 Option 1 – Replace the DataRadio Integra with the Trio Family
The City wastewater group uses the Trio Family of radios from Schneider Electric. This is a reliable serial radio and should be close to a “like-for-like” replacement. It has the capability to continue using the 153 MHz at 9600 baud that is currently being used to carry serial data. It can be configured to carry Ethernet data.

The City has contracted with a consultant to perform the detailed design of a “like-for-like” replacement of the existing serial radio system with another serial radio system. During the August 5, 2019, workshop, the project was approaching 40 percent design. Potential additional radio paths for the reservoirs are not included with this project.

Serial radio connections to the reservoirs could be added to the scope of the existing radio system. There could be benefit for a single designer and installation contractor to be responsible for the functionality of the entire serial radio system.

4.2.3 Option 2 – Mesh Network
As previously stated, dedicated Mesh network links between reservoirs and pump stations can peacefully coexist with the existing serial radio system. Consideration should be given to replacing the entire water and wastewater radio system with a Mesh radio network. A radio path study would be needed to estimate the number and likely locations for repeaters and backhaul connections.

A report was shared outlining the replacement of the existing serial radios. The report includes the replacement of older Tesco PLCs. The recommended replacements are Ethernet capable and thus ready for Mesh network connectivity.

4.2.4 Option 3 – SCADA Masterplan
A SCADA Masterplan could be considered. Several aspects of the SCADA software and servers, radio networks, and PLCs are being addressed as they fail or become obsolete. A SCADA Masterplan could lay out a vision of the future, assess the current state, develop a gap assessment, prioritize projects, and lay out a multiphase implementation plan. Some example SCADA master plan assessment content could include the following:

- VFDs at pump stations.
- Standardization for human-machine interface (HMI) screens, PLC programming, naming conventions.
- SCADA server redundancy at different locations.
- SCADA cybersecurity program.
Data integration between the SCADA system, asset management, laboratory information management, advanced metering infrastructure (AMI), and GIS systems.

Skill set assessment and staffing levels.

### 4.2.5 Recommendation

During the August 5, 2019, workshop, the team came to the following conclusions and recommendations:

- The Mesh network is not capable of meeting the 5 day power outage requirement. Small independent Mesh networks between the pump stations and reservoirs may improve the connectivity issues of the direct buried cable. A Mesh network will not improve the reliability of the entire SCADA serial radio system.

- The Mesh network may be justifiable for utilities enterprise applications such as mobile work orders. Coordination and further justification could be considered with enterprise IT, police, fire, and other city organizations that may be able to improve operations with a Wi-Fi-based Mesh network. If a citywide Mesh network is created, a secure amount of bandwidth could be created to provide a redundant path for the SCADA serial radio system.

- The Mesh networking technology would likely need a pilot study to establish confidence in its performance capabilities. A test plan with agreed-upon success criteria may be necessary.

- The serial radio replacement project is approaching 40 percent design review. The project is a “like-for-like” replacement of the existing serial radios. Potential future connections to the reservoirs is not currently in scope. The City could consider expanding the scope of the radio design to include the reservoirs. It could be beneficial to have a single designer and contractor responsible for the performance of the entire serial radio system.

- Cellular data connectivity for the SCADA network should not be considered because there are known areas of the City with poor cellular connectivity.

Serial Radio and Mesh Network Options – The existing project for serial radios will move forward with no changes. A new serial radio path feasibility study will be commissioned to expand the radio network to make connections to the reservoirs. If serial links are prohibitive, Mesh network radios will be considered.

Option 3, SCADA Masterplan, was decided against in the short term. There was consensus that it is important and should planned for in the future after the projects dealing with more acute challenges are completed.

### 4.3 LIMITED POWER AT THE RESERVOIRS

#### 4.3.1 Problem Statement

A weakness noted during the Tubbs fire was a sustained loss of electrical power. Reservoirs and pump stations lost power from a few hours to several days. The pump stations have diesel or natural gas generators that provide power as the motive force for the pumps. They also provide power for the controls systems and the radio(s) for communication. The engine generators started promptly and powered the pump stations.
The root cause of the Tubbs fire is attributed to high winds that caused high voltage electrical transmission lines to break and fall energized to the ground, causing the fire. Electricity was out for days, and hundreds of buildings were burned to the ground.

The design basis loss of electricity is 5 days or 120 hours. This value was selected because PG&E announced that if wind conditions such as those leading up to the Tubbs fire occurred, it would power down the transmission lines until the weather condition passes and repairs can be made.

4.3.2 Option 1 – No Changes

The reservoirs have a low power demand and do not have engine generators. They do have batteries on-site that maintain the sensors and electronics during loss of electricity. The batteries last approximately 24 hours. There are spare batteries in inventory.

To respond to the Tubbs fire, the I&C support group pulled the charged batteries from inventory, took them to a site, swapped them out, charged the removed batteries, took them to a different location, swapped them out, charged the batteries, took them to a different location, and so on.

4.3.3 Option 2 – Add Engine Generators at Reservoirs

The team discussed purchasing small, perhaps 1,000 watt gasoline generators and keeping them in inventory so they could be taken to pump stations when needed. This was ruled out because the onboard gasoline storage only lasts approximately 6 to 8 hours.

Travel to the sites could be impaired, depending on the threat that occurs such as fire, flooding, or earthquake. Access to the sites was challenging during the Tubbs fire.

If the City decided to pursue adding generators, the changes to a local panel to allow the connection of a portable gasoline generator are relatively simple. There should already be a breaker for the entire panel to disconnect it from site power. An additional break can be connected in parallel. A mechanical interlock would be needed to allow only one breaker to be shut at a time. An extension cord can be fabricated that could be connected to the gasoline generator. The breakers would be changed to allow the panel to be powered by site power or by the gasoline generator via the extension cord.

4.3.4 Option 3 – Add Solar Panels and More Batteries

The team discussed adding solar panels to the reservoirs. The solar panels could be large enough to keep the station electronics powered and charge the batteries during the daylight hours. The batteries could keep the station powered during the nighttime hours. This arrangement could be effective during an earthquake and the design basis PG&E power outage. During a fire, the panels could be damaged. Battery monitoring could be added and battery status provided to the SCADA system. The existing battery system could be used and expanded. Consideration could be given to a commercially available off-the-shelf uninterruptable power system (UPS).

4.3.5 Recommendation

At the workshop held on August 5, 2019, the consensus was to further explore Option 3.

- Option 1 – Maintained until the results of the Option 3 study are evaluated.
- Option 2 – Decided against because it does not improve the reliability.
Option 3 is Recommended – A solar feasibility study is recommended for each of the reservoirs. A solar feasibility study estimates the amount of solar energy that is available at locations on the planet and considers topography and weather patterns. The solar panels capacity needs to be determined to power the site and charge the batteries.

The battery capacity could be engineered to keep the site powered from 24 to 120 hours on battery only. Factors for battery capacity should include available volume in the cabinet. Battery monitoring equipment can be added. Signals for remaining battery capacity and other parameters could be connected to the local PLC.

### 4.4 FIRE DAMAGE TO ELECTRONIC COMPONENTS

#### 4.4.1 Problem Statement

Many of the reservoirs have chain link fencing for perimeter security. The PLC, sensor, electrical service entry, communication service entry and other electronics cabinets are mounted on posts or boards near the site perimeter or reservoir. The cabinets appear to be National Electrical Manufacturers Association (NEMA) rated for outside use. During the fire, some of these cabinets were engulfed in flames, and the internal electronics were extensively damaged.

#### 4.4.2 Option 1 – Fire Rated Cabinets

Black & Veatch researched “fire insulated” or “fire rated cabinets.” Several were found for holding paint and other flammable liquids. None of the cabinets found were rated for outdoor use and would likely allow water and dust inside the cabinet. In addition, holes would need to be drilled in the cabinets to allow wires in and out. Drilling a hole in the cabinet voids the fire protection warrantee.

#### 4.4.3 Option 2 – Masonry Wall

A masonry wall may protect the electronics from fire. Several factors should be considered for design concepts. For example, what should be protected? Just the sensor cabinet, the electrical entrance, the entire facility, or other assets? Many of these locations are in residential neighborhoods, and the neighbor’s opinions should be taken into consideration.

#### 4.4.4 Option 3 – Removing Vegetation

Removing vegetation such as plants and bushes may remove enough fuel to prevent fire damage to the electronic assets. Physical security guidance recommends keeping the perimeter clean of vegetation for 15 feet outside of the fence line. This may not be able to be achieved at all locations because the fenceline is close to or on the property line. In several locations, private land owners are on the other side.

#### 4.4.5 Recommendation

At the workshop held on August 5, 2019, the consensus was to further explore Option 2.

- Option 1 – Decided against because a cabinet does not exist that meets the conditions.
- Option 2 – Supported. As changes or improvements are made to each reservoir, design considerations should be given to protecting the electronics at the site. This could include the electrical power coming into the site. Masonry walls can be placed around the individual cabinets, around the entire site, or some combination thereof.
- Option 3 – Decided against to prevent disruption to potential neighbors.
4.5 LIMITED REDUNDANCY IN THE SERIAL RADIO SYSTEM

Reservoirs 7 and 17 are relay stations. If the electronics or power at either one of these locations is lost, the UFO will lose indications for approximately 50 percent of the water and wastewater data. The equipment, for most locations, will continue to operate, but the UFO will not be able to see it. During facility casualty events, it is particularly important to keep the SCADA system fully functional to monitor changing events.

4.5.1 Option 1 – Maintain the Current System

The current system is reliable. Outages are primarily due to loss of electricity and not radio hardware failures. On-site generators and batteries at each location have provided enough power to keep reliability at acceptable levels.

4.5.2 Option 2 – Keep Spares at the Sites

Radios could fail, and finding spares and installing them takes time. Time could be saved if there are spares configured at Reservoir 7, Reservoir 17, and the UFO. Spares are already stored at Pump Station 4. A diagram or instructions could be maintained at each location so that an untrained person could disconnect the malfunctioning radio and connect the spare radio.

4.5.3 Option 3 – Additional Relay Locations

Consideration could be given to applying for additional licenses to create a third or fourth relay location. This would not improve resilience; it would only lower the number of lost field locations if a loss occurred at a relay location.

4.5.4 Recommendation

At the workshop held on August 5, 2019, the consensus was to further explore Option 1.

- Option 1 – Moving forward because a project that is approximately 40 percent is designed to replace the existing radio system that is a “like-for-like” system. This reinforces the desire for Option 1.
- Option 2 – Deemed not necessary because of the high reliability of the serial radio system.
- Option 3 – Deemed not necessary because of the high reliability of the serial radio system.

4.6 MESH NETWORK BACKHAUL REDUNDANCY

The success of a Mesh network is dependent on several factors, one of which is backhaul connections to the existing enterprise or SCADA network. Backhaul connection locations could be water facilities such as Pump Station 4 and the UFO. Coordination could be attempted with other municipal buildings such as police stations and fire stations.

If insufficient backhaul connections exist for the Mesh network, consideration could be given to studying high speed Ethernet radio connectivity between UFO and Reservoir 17 and the UFO and Reservoir 7. Reliability could be increased further by a radio between Reservoir 17 and Reservoir 7, making a triangle. A quick check using Google Earth shows that the hill holding Reservoir 16 may be obstructing the path between Reservoir 7 and Reservoir 17. Reservoir 16 may be able to relay between Reservoir 7 and Reservoir 17.

Ethernet-based backhaul will not improve the reliability of the serial radio network.