Jacobs

SCADA/IT Master Plan

May 13, 2022

Tahoe-Truckee Sanitation Agency

Document History and Status

Revision	Date	Description	By	Review	Approved
0	April 1, 2022	Draft SCADA/IT Master Plan	M. Johnson	J. Hardison	4/15/2022
1	June 3, 2022	Final SCADA/IT Master Plan	M. Johnson	M. Johnson	6/3/2022

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Acronyms and Abbreviations

AIMS	asset information mapping system
CMMS	computerized maintenance management software
DHS	Department of Homeland Security
DMZ	demilitarized zone
FMS	financial management system
GIS	geographic information system
HMI	human-machine interface
I&C	instruments and control devices
I/O	input/output
ISA	International Society for Automation
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
IT	information technology
KPI	key performance indicator
LIMS	laboratory information management system
OT	operational technology
PPE	personal protective equipment
PID	proportional-integral-derivative
PIS	plant information system
PLC	programmable logic controller
RFID	radio frequency identification
RTU	remote telemetry unit
SCADA	supervisory control and data acquisition
SQL	structured query language
SSL	secure sockets layer
T-TSA	Tahoe-Truckee Sanitation Agency
TRI	Truckee River Interceptor
UPS	uninterruptible power supply
VFD	variable frequency drive
VM	virtual machine
VPN	virtual private network
WIMS	water information management system
WRP	water reclamation plant
WQIS	water quality information system

1. Executive Summary

1.1 Introduction

The Tahoe-Truckee Sanitation Agency (T-TSA) provides regional wastewater conveyance and treatment to several North Lake Tahoe area communities through T-TSA's member sewage collection districts. T-TSA is governed by a Board of Directors comprised of an appointed Director from each of its member districts. The five member districts are as follows:

- Tahoe City Public Utility District
- North Tahoe Public Utility District
- Olympic Valley Public Service District
- Truckee Sanitary District (includes Northstar Community Services District)
- Alpine Springs County Water District

T-TSA owns, operates, and maintains the Truckee River Interceptor (TRI) and the 9.6-million-gallon-per-day (MGD) Water Reclamation Plant (WRP). The TRI conveys wastewater from Tahoe City to the WRP in Martis Valley, east of the town of Truckee, California. The TRI collects flows from the member districts, is approximately 17 miles in length, and varies in diameter from 18 inches to 42 inches. The six telemetry sites along the TRI that communicate flows to the WRP are as follows:

- Alpine Meadows
- Dollar Hill
- Granite Flat
- Olympic Valley
- Rampart
- Tahoe City North/West (includes two flow meters)

T-TSA uses a Supervisory Control and Data Acquisition (SCADA) system to monitor the six flow measurement sites and to monitor and control the WRP. The SCADA system and the data it collects are critical to supporting operations and regulatory reporting functions.

A typical SCADA system consists of multiple hardware and software components designed to work together to collect process and maintenance data to support equipment operation in real-time. Hardware components include programmable logic controllers (PLC), human-machine interfaces (HMI), network equipment, and servers. Software components include operating systems, PLC programming, HMI graphic development, alarm management, and data archiving.

T-TSA self-developed a Plant Information System (PIS) to combine maintenance, operations, lab, and water quality data. PIS is based on a PostgreSQL opensource structured query language (SQL) database and is no longer internally supported. Major information technology (IT) applications include a Computerized Maintenance Management System (CMMS), a Financial Management System (FMS), and back-office applications. Other IT applications are a Geographic Information System (GIS) and a Water Quality Information System (WQIS). The WQIS includes a Laboratory Information Management System (LIMS) and a Water Information Management System (WIMS). Current IT software products include the following:

- FMS Caselle
- CMMS Lucity, Inc.
- GIS Asset Information Management System (AIMS)
- Back Office Microsoft Office (Word, Excel, Access, PowerPoint, Outlook)
- WQIS LIMS (Autoscribe Informatics) and Hach WIMS

1.2 Master Planning Process

The SCADA/IT Master Plan focuses on upgrade and replacement needs for all technology components, except for Instrumentation and Control (I&C) devices. It also includes an organizational resource assessment to support the SCADA/IT technology. During development of the SCADA/IT Master Plan, improvements in standardization, development, and maintenance were identified. Such improvements are described as separate projects in the implementation plan.

The SCADA/IT Master Plan project consisted of a series of workshops. Each workshop produced a Technical Memorandum (TM) to form a section of the Master Plan. The TM topics are shown in Table 1-1.

Table 1-1. SCADA/IT System Master Plan Development

SCADA/IT System Master Plan Development		
TM Topic	**Workshop Conducted**	**Section/TM Delivered**
Section 2: System Assessment	October 19, 2021	October 29, 2021
Section 3: Industry Standards and Trends	November 16, 2021	December 17, 2021
Section 4: Needs Analysis	January 18, 2022	January 31, 2022
Section 5: Implementation Planning	February 15, 2022	February 25, 2022
Section 6: Organization Assessment	March 15, 2022	March 25, 2022
Draft SCADA/IT System Master Plan	N/A	April 15, 2022
Final SCADA/IT System Master Plan	N/A	June 3, 2022

T-TSA staff that participated in the workshops and reviewed the Technical Memos and Master Plan include:

Richard Pallante	Luke Swann	Michael Peak	LaRue Griffin
Paul Shouse	Kevin Woods	Tanner McGinnis	Jay Parker

1.2.1 Current State Summary

The assessment of the existing SCADA/IT system in Section 2 includes observations from the site visits, documentation reviews and results from the system assessment workshop. These observations are summarized below:

- Knowledge transfer of existing SCADA/IT functionality, capabilities, and development is severely hampered by a lack of documentation, particularly in the PIS and other IT applications.
- Limited resources and inconsistent naming systems are driving a need for well-organized and clearly communicated naming standards based on T-TSA assets.
- Symptomatic of the general lack of documentation and standards and growing threats from unauthorized access, cybersecurity is a high-priority concern.
- Compounding the cybersecurity concern is the aging and obsolescence of almost all SCADA/IT technology components, specifically:
  - The SCADA/IT network uses multi-mode fiber cables and copper with incomplete segregation of the SCADA/IT and security (video camera) networks.
  - Flow site communications rely on cellular modems and obsolete radio equipment.
  - Of the 31 PLCs at the WRP, 20 are already obsolete, and 9 will be phased out in 2 years, leaving only 2 PLCs at the WRP with a sustainable end-of-life status.

- An obsolete BACnet system controls the HVAC and some digestion processes. The digestion processes should be controlled by a PLC as part of the SCADA system.
- Of the 5 physical servers identified, 2 are already obsolete, and 2 more will be phased out in 5 months, leaving only 1 physical server actively supported.
- Incompatibilities between multiple servers and VM application versions create instabilities in application performance and backup and recovery procedures.

- Physical security at the WRP and flow sites needs to be upgraded to support cybersecurity improvements.

These observations define four driving factors for replacing/upgrading the SCADA/IT system, as follows:

- System sustainability dependent on limited resources
- Knowledge transfer of SCADA/IT functions, capabilities, and development
- Cybersecurity that enables data integration and remote access secured against unauthorized intrusion
- Technical obsolescence

1.2.2 Future State Summary

The development of goals and objectives to define the future state of the SCADA/IT system began with a presentation and discussion of industry trends and standards. These discussions developed T-TSA's goals and objectives for replacing/upgrading the SCADA/IT system. Section 3 describes the industry trends and standards and T-TSA preferences under seven topics:

- Section 3.2: SCADA/IT Servers
- Section 3.3: Security
- Section 3.4: Networks
- Section 3.5: PLC/HMI Control Objects
- Section 3.6: HMI Graphics
- Section 3.7: Alarm Management
- Section 3.8: IT Applications

T-TSA's preferences in each of these topics defined specific goals and objectives and generated a list of project concepts, as shown below.

- Develop sustainable knowledge transfer methods for current and future SCADA/IT functionality, capabilities, and development, particularly for the PIS to other IT applications.
- Develop well-organized and documented standard database naming systems that support application integration for asset management.
- Replace PIS functions with standard off-the-shelf software applications.
- Implement cybersecurity measures as a high-priority task.
- Provide standards for HMI graphics development based on Situational Awareness concepts.
- Develop project plans (budget and schedule) for technology upgrades for all SCADA/IT components, including:
  - Upgrade the physical servers to eliminate incompatibilities among multiple servers and VM application versions and minimize instabilities in application performance.
  - Establish robust backup and recovery systems and procedures.
  - Implement high-performance HMI graphics with PLC upgrade project(s).
  - Develop and implement alarm management process.
  - Provide secure interfaces among segregated networks for the SCADA, business/IT, and security (video camera) systems.
  - Upgrade physical security at the WRP and flow sites using card reader access for perimeters and buildings.

- Upgrade flow site communications, using the licensed radio frequency where feasible.
- Optimize current IT applications (such as Lucity, Inc, AIMS and Caselle) to improve asset management.

From a utility management perspective, the industry trend of improving Asset Management is notable for its broad impacts on practices, people, and technology to drive what is commonly experienced as a cultural change. The SCADA/IT Master Plan focuses on the application of asset management principles to the SCADA/IT system.

1.2.3 Planning Process Summary

Section 4 summarizes the current and future states and analyzes the technology needs to replace/upgrade the SCADA/IT system. It identifies performance criteria to measure successful achievement of SCADA/IT system goals and further defines project concepts.

Section 5 introduces Master Plan cost estimating characteristics, aligns the SCADA/IT Master Plan with the 2022 Master Sewer Plan, and develops project concepts into specific technology projects. It includes summary project descriptions and a summary of the SCADA/IT system replacement implementation plan.

Section 6 analyzes the practices and people needs to sustain the SCADA/IT system by reviewing the 2020 Organizational Assessment. It describes the SCADA/IT system maintenance workload and outlines a SCADA/IT system governance process.

1.3 Master Plan Summary

The SCADA/IT Master Plan is a 5-year plan that considers asset management principles as they apply to SCADA/IT technology, practices, and people. It includes 3 phases to set the foundation, replace the SCADA system, and optimize asset management. Once the foundation is set for a sustainable SCADA/IT system, the Master Plan allows for flexibility in scheduling and sequencing individual PLC replacement projects. The flexibility addresses resource limitations, construction project coordination, and emergency PLC replacements as needed. Current and projected resource limitations extend the schedule to 7 years; therefore, a second upgrade to the servers is planned, based on a 5-year life cycle for servers.

The Master Planning process developed eight technology projects, describes a maintenance workload analysis approach, and recommends a governance process to sustain the SCADA/IT system. The technology projects are grouped into three phases and summarized as shown in Table 1-2. The implementation plan is summarized in Section 5.4. The workload analysis for training and the governance process are described in Section 6. Detailed technology project descriptions are included in Appendix D. Detailed cost estimates for each technology project are included in Appendix E.

Table 1-2. SCADA/IT Master Plan Summary

Phase Name Duration, Phase Cost	Project Name	Duration (months)	Project Cost
1. Set the Foundation 24 months, $1,321,000	1. Upgrade Servers (FY22/23) Upgrade Servers (FY27/28)	12 15	$250,000 $500,000
	2. Upgrade Networks and Security	15	$330,000
	3. Develop Standards	6	$241,000
2. Replace SCADA System 60 months $3,021,000	4. Replace Pilot PLCs (4)	12	$663,000
	5. Replace WRP PLCs (13)	48	$1,777,000
	6. Replace RTUs (14)	12	$581,000
3. Optimize Asset Management 18 months $390,000	7. Upgrade Reports	6	$96,000
	8. Improve Physical Security	12	$294,000
Total Cost		**84**	**$4,732,000**

2. Existing System Assessment

Staff at T-TSA identified several issues and concerns that negatively affect the SCADA/IT system's short-term reliability and long-term usefulness. These concerns include the following:

- System sustainability dependent on limited resources
- Knowledge transfer of SCADA/IT functions, capabilities, and development
- Cybersecurity that enables data integration and remote access secured against unauthorized intrusion
- Technical obsolescence

Jacobs conducted a kickoff meeting and site visit on September 22, 2021. Jacobs and T-TSA toured the WRP and inspected representative PLC control panels and remote input/output (RIO) panels, the main control room, and the server locations.

Jacobs conducted an assessment workshop on October 19, 2021 and presented preliminary findings and questions for T-TSA comment and clarification. Jacobs and T-TSA toured representative flow measurement sites at Tahoe City and Granite Flats for Jacobs' investigation of flow site monitoring, telemetry, and security.

This assessment summarizes the findings from the kickoff meeting, site visit, documentation review, and assessment workshop.

2.1 SCADA/IT Network Overview

The current SCADA/IT architecture includes both IT and SCADA networks. Both networks are partially segregated local area networks (LAN) based on a multi-mode fiber optic and copper network installed in a star configuration. Remote access to the SCADA system is available through a virtual private network (VPN) and a jump server between the IT and SCADA networks. The VPN uses shared keys and does not include multifactor authentication; it also uses a weak cipher and hash. The WRP communicates with TRI flow measurement sites using cellular and radio communications.

Appendix A lists WRP and flow site network equipment including 25 switches, 5 cellular modems, 8 900-megahertz (MHz) modems, and 2 radios. The WRP radio is at end of life and used only for the Tahoe City North/West flow site. Only four switches and the Tahoe City North/West flow site radio are currently supported by their manufacturer. The remaining 21 switches reached their end of service life (EOSL), ranging from March 2012 to May 2019.

TRI flow sites (except for Tahoe City North/West) communicate with the WRP using cellular modems without VPN. Flow data are transmitted through internet connections to an on-site PostgreSQL database that resides on the IT network. The data is then transferred to the operational technology (OT) network via a VPN tunnel. The flow sites use a microcontroller and a cellular modem to communicate to the WRP.

The Tahoe City North/West flow site uses Motorola 450 MHz analog radios with a repeater at Northstar between Tahoe City and the WRP. The Northstar repeater relays information to the MOSCAD PLC in Operations and then communicates via MODBUS TCP to the Siemens I/O Server.

Figure 2-1 shows an overview of the fiberoptic and radio connections in the WRP network.

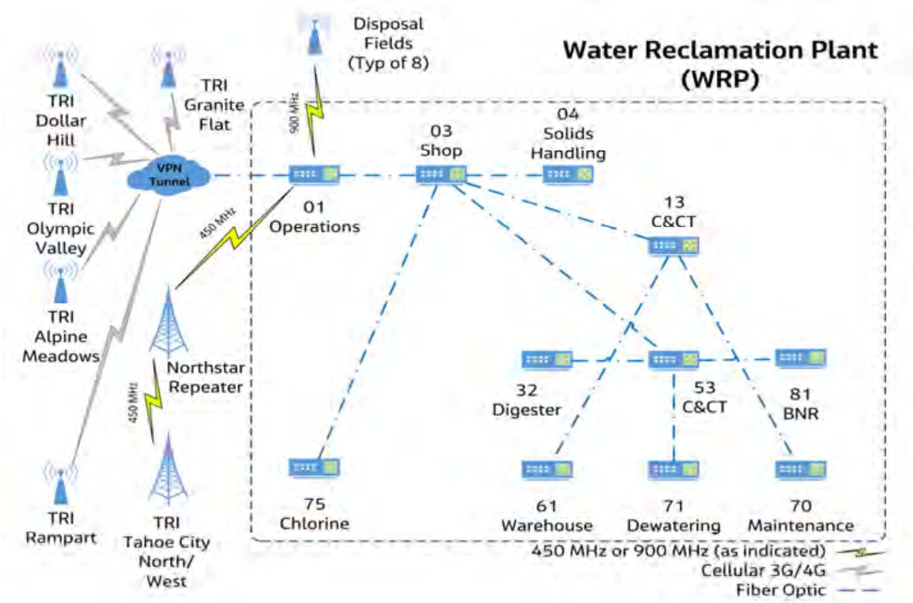


Figure 2-1. WRP Network Overview

2.2 SCADA Controllers

The SCADA control system consists of 31 PLCs (all Siemens except for one obsolete Motorola controller) that monitor and control local processes through hardwired and Profibus decentralized peripherals (DP) connections to instrumentation and control devices. Table 2-1 summarizes the controller model numbers and firmware versions with end-of-life status.

Table 2-1. PLC End-of-life Status Summary

# of PLCs	Siemens PLC Model	Firmware	End-of-life Status	Support Resources
1	Motorola ACE3600		Cancelled: Unknown	Available only as spare part.
2	6ES7 211-1BD30-0XB0 6ES7 212-1BD30-0XB0 (WRP)	V2.2	Cancelled: 09/18/2012	No known support resources.
4	6ES7 315-2AG10-0AB0 (WRP) 6ES7 317-2EK13-0AB0 (WRP)	V2.0 V2.6	Discontinued: 10/01/2020	E&M (3rd party)
1	6ES7 417-4XL00-0AB0 (WRP)	V3.1	Discontinued: 05/22/2018	E&M (3rd party)
9	6ES7 315-2EH14-0AB0 (WRP) 6ES7 315-2EH14-0AB0 (WRP) 6ES7 317-2EK14-0AB0 (WRP)	V3.1 V3.2 V3.1	Cancellation scheduled for: 10/01/2023	Siemens
6	6ES7 211-1BE40-0XB0 6ES7 212-1HE40-0XB0 (WRP) 6ES7 212-1BE40-0XB0 (WRP)	V4.0 V4.0 V4.2	Active support	Siemens
8	6ES7-216-2BD22-0XB0	N/A	Cancelled: 01/10/2017	No known support resources.

Note on Table 2-1:

Products at End-of-Life are considered Cancelled. Cancellation has 3 phases:

1. Available only as a spare part.
2. Spare part availability ends. Only warranty cases are processed.
3. Product discontinued.

Appendix B lists the WRP and flow site controllers and locates the 30 Siemens PLCs and a Motorola controller. The Motorola controller is past end of life and only at the Tahoe City North/West flow site. Ten PLCs (one at Alpine Meadows, one in conventional and chemical treatment [C&CT] and 8 in the disposal fields) are cancelled and no longer supported by Siemens. Five PLCs are discontinued, and nine PLCs are scheduled to be phased out by October 2023. Only six PLCs are still actively supported by Siemens, and only two of these are located at the WRP. Four of the actively supported PLCs are located at the TRI flow sites. An obsolete BACnet system controls building HVAC and some digestion processes. The digestion process controls controlled by a PLC as part of the SCADA system.

2.3 SCADA/IT Applications

The SCADA software application uses Aveva (formerly Wonderware) SCADA platform with InTouch HMI, Historian, and data acquisition server modules for operator interaction with real-time and historical process data. The Aveva software modules vary in version and use Microsoft SQL Server 2008 databases. The historian and real-time data servers each have redundant physical and virtual machines (VM) running Windows Server 2003 and 2008 operating systems. Twelve thin client HMI workstations are located at multiple control rooms throughout the WRP and use remote desktop protocol (RDP) to login into terminal server sessions on a dedicated remote desktop server for HMI access. The dedicated RDP server is either virtual or physical depending on which type of session the user launches. InTouch Security uses Active Directory for user authentication. Common control room location-based logins are used to grant permissions to perform functions. Table 2-2 summarizes WRP SCADA VMs, collectively referred to as the SCADA applications. Backup and recovery for the SCADA applications are conducted by T-TSA staff.

Table 2-2. SCADA Applications

Name	VM Host	Operating System	Function	Software Installed
SCADAMAIN2	None	Windows Server 2003	Historical data server	Wonderware Historian 2012 P01 Microsoft SQL Server 2008
SCADAMAIN3	SCADAMAIN5	Windows Server 2008	Historical data server	Wonderware Historian 2012 P01 Microsoft SQL Server 2008
SCADAMAIN4	None	Windows Server 2008	Real-time data server	DASMBTCP 2.0.0 DASSIDirect 1.5.0 Simatic 8.1.0.0
SCADAMAIN6	VMHOST3	Windows Server 2008	Real-time data server	DASMBTCP 2.0.0 DASSIDirect 1.5.0 Simatic 8.1.0.0
SCADAMAIN10	VMHOST1	Windows Server 2012	RDP Server for HMI workstations and Development Machine	InTouch 2014

2.3.1 Business Applications

T-TSA is currently transitioning away from a self-developed PIS for maintenance, operations, lab, and water quality data. PIS is based on a PostgreSQL opensource database and will be migrated into a new LIMS and WIMS as PIS development is no longer actively supported. T-TSA recently purchased a LIMS (Autoscribe Informatics) and Hach WIMS to replace the PIS.

The CMMS application provided by Lucity, Inc. went live in December 2021 and includes operational and maintenance information for assets. The AIMS (GIS) application includes location and maintenance data for geographics assets such as parcels and pipelines. Caselle financial software is used for general ledger, accounts payable, accounts receivable, billing, payroll, purchasing, and financial reporting.

All SCADA/IT applications run on redundant physical servers located in the maintenance offices. Table 2-3 summarizes WRP SCADA VM hosts and physical servers.

Table 2-3. WRP SCADA VM Hosts and Physical Servers

Name	Location	Dell Model	Life Cycle	Virtual Machines Hosted
SCADAMAIN2	03 Shop	PowerEdge 1800	EOSL: 04/01/2011	None
SCADAMAIN4	03 Shop	R515	EOSL: 03/26/2022	None
SCADAMAIN5	03 Shop	R515	EOSL: 03/26/2022	SCADAMAIN3
VMHOST1	03 Shop	R710	EOSL: 09/26/2020	TTSA-DESKTOP-SERVER-VM-1
VMHOST3	03 Shop	R730	Active product	SCADAMAIN6

2.4 Other Considerations

2.4.1 Standby Power Systems

Uninterruptible power supplies (UPS) are located at each server rack, control room workstation, and PLC control panel at the WRP. UPSs are standardized on APC brand and 120-volt alternating current. PLC control panel UPSs are monitored via SNMP and email notifications configured through a web interface. Tahoe City North/West uses a DC UPS style.

APC UPSs are located at each TRI flow site except for Tahoe City North/West. UPSs are monitored by the local PLC and transmitted to the WRP SCADA network. All equipment in flow site control panels require a 24-volt direct current power source. 24-volt direct current power is provided from two power supplies connected to a power redundancy module with output to control panel equipment. T-TSA is considering replacing flow site alternative current UPS with a direct current UPS and batteries in a separate enclosure to extend operating time on standby power.

All UPSs (WRP and flow sites) are regularly serviced with battery replacement dates logged by location.

2.4.2 Security

The WRP video cameras have been installed at numerous locations for plant-wide surveillance. The main gate controller has been updated, and the RFID gate card reader allows general entrance to the WRP but does not provide access to buildings. Buildings at the WRP are accessed using master keys to lock and unlock doors. T-TSA is investigating access control systems with key card access for each building. Not all PLC panels are locked, and server rooms are equipped with a combination door lock and are locked except for maintenance activities.

Site security is an issue for some of the TRI flow sites because the manholes, control panels, and appurtenances are generally accessible to unauthorized access from roads and highways. Jacobs observed Tahoe City North/West and Granite Flats locations following the assessment workshop. Tahoe City North/West is located inside the fencing for the California Department of Transportation yard. Granite Flat is easily accessible off Highway 89 without any fencing around the control panel. Transient camps have been witnessed near the flow site, and unauthorized power use is a concern at the Granite Flat service meter. None of the TRI sites include panel intrusion alarms or video surveillance.

Cybersecurity is a concern despite the security measures described in the SCADA/IT network overview. Remote access to the SCADA system is available through a VPN and a jump server between the IT and SCADA networks. The VPN does not require username and password, nor does it require multifactor authentication. The WRP communicates with TRI flow measurement sites using cellular and radio communications.

2.4.3 Weather Protection and Temperature Monitoring

TRI flow site control panels are exposed to direct sunlight, rain, wind, and snow. All sites **except** North and West Tahoe provide temperature data or alarm signals to the WRP SCADA network. TRI flow site control panels include thermostats, fans, and heaters for heating and cooling. SCADA monitors the PLC output for the fan or heater, it does not receive feedback if either are running. T-TSA noted that Olympic Valley has sun and high-temperature issues, and all TRI flow sites should be considered candidates for weather shielding. T-TSA noted that wasp nests are a common occurrence and will need to be considered in weather protection designs. External battery enclosures would extend maintenance intervals and provide better protection from the elements.

2.5 Summary of Observations

Based on documentation provided, site visits, and workshop discussions, Jacobs observed the following:

- Knowledge transfer of existing SCADA/IT functionality, capabilities, and development is severely hampered by a lack of documentation, particularly in the PIS and other IT applications.
- Limited resources and inconsistent naming systems are driving a need for well-organized and clearly communicated naming standards based on T-TSA assets.
- T-TSA has purchased off-the-shelf software applications to replace PIS functions.
- Symptomatic of the general lack of documentation and standards, cybersecurity is a high-priority concern.
- Compounding the cybersecurity concern is the aging and obsolescence of almost all SCADA/IT technology components, specifically:
  - The SCADA/IT network uses multi-mode fiber cables and copper with incomplete segregation of the SCADA/IT and security (video camera) networks.
  - Flow site communications rely on cellular modems and obsolete radio equipment.
  - The licensed radio frequency needs to show beneficial use for license renewal.
  - Of the 31 PLCs at the WRP, 20 are already obsolete, and 9 will be phased out in 2 years, leaving only 2 PLCs at the WRP with a sustainable end-of-life status.
  - An obsolete BACnet system controls the HVAC and some digestion processes. The digestion processes should be controlled by a PLC as part of the SCADA system.
  - Of the 5 physical servers identified, 2 are already obsolete, and 2 more will be phased out in 5 months, leaving only 1 physical server actively supported.
  - Incompatibilities between multiple servers and VM application versions can create instabilities in application performance and backup and recovery procedures.
- Physical security at the WRP and flow sites needs to be upgraded to support cybersecurity improvements.
- Overall, the attention, awareness, and commitment to identifying and resolving SCADA/IT concerns reflects a cultural shift concurrent with industry trends.

3. Industry Trends

3.1 Stakeholder Goals

T-TSA desires to upgrade or replace SCADA/IT system components to achieve substantial improvements in performance, reliability, and sustainability through applying effective asset management practices. These improvements are defined by stakeholders (users of the SCADA/IT system or SCADA/IT data), including operations, maintenance, IT, engineering, and management. Although all stakeholders desire improvement in all areas, they can be grouped by their primary improvement interest. These primary interests and improvement goals are as follows:

- Operations (Performance)
  - To maximize regulatory compliance
  - To maximize reliability and responsiveness
  - To optimize operating procedures
  - To improve ease of use
  - To provide a secure and resilient system
- Maintenance/IT (Reliability)
  - To be consistent in design, components, configuration, and documentation
  - To be flexible in modifications, additions, reporting, and analysis
  - To monitor process, equipment, and system performance
  - To implement a more reliable and efficient system
  - To provide robust backup/recovery procedures
  - To maintain or improve SCADA/IT system security (cyber and physical)
  - To identify system and component end-of-life status and failures
  - To provide a plan for component or system replacement
- Engineering/Management (Sustainability)
  - To provide SCADA/IT data for reporting, life-cycle analysis, and capital improvements
  - To develop internal resource capability with training and knowledge
  - To enhance external resource capacity with prequalified contractors
  - To implement long-term asset management practices for capital improvements

Achieving these goals requires thoughtful consideration of how others in the water/wastewater industry are achieving similar goals and applying those approaches to each component of the T-TSA's SCADA/IT system. This technical memorandum identifies and reviews industry trends and standards in seven sections. Each section covers a major component of the SCADA/IT system in place at T-TSA. Each section briefly describes the industry trends and standards organizations for each component and identifies trend and standard preferences at T-TSA to achieve these goals. The last section summarizes the preferences expressed. The discussion sections are as follows:

- Section 3.2: SCADA/IT Servers
- Section 3.3: Security
- Section 3.4: Networks
- Section 3.5: PLC/HMI Control Objects
- Section 3.6: HMI Graphics
- Section 3.7: Alarm Management
- Section 3.8: IT Applications
- Section 3.9: Summary of Preferences

3.2 SCADA/IT Servers

Server technology continues to evolve with hyperconverged computer systems currently being implemented across the industry. These systems provide highly reliable platforms for data communications, storage, and processing. The server platform must meet or exceed the same requirements for redundancy, reliability, security, and standardization, as required for other SCADA system components.

Of all the components in a SCADA system, the servers, workstations, and operating system software evolve much faster and become obsolete much sooner than any other component. Figure 3-1 compares the life-cycle durations of all SCADA system components.

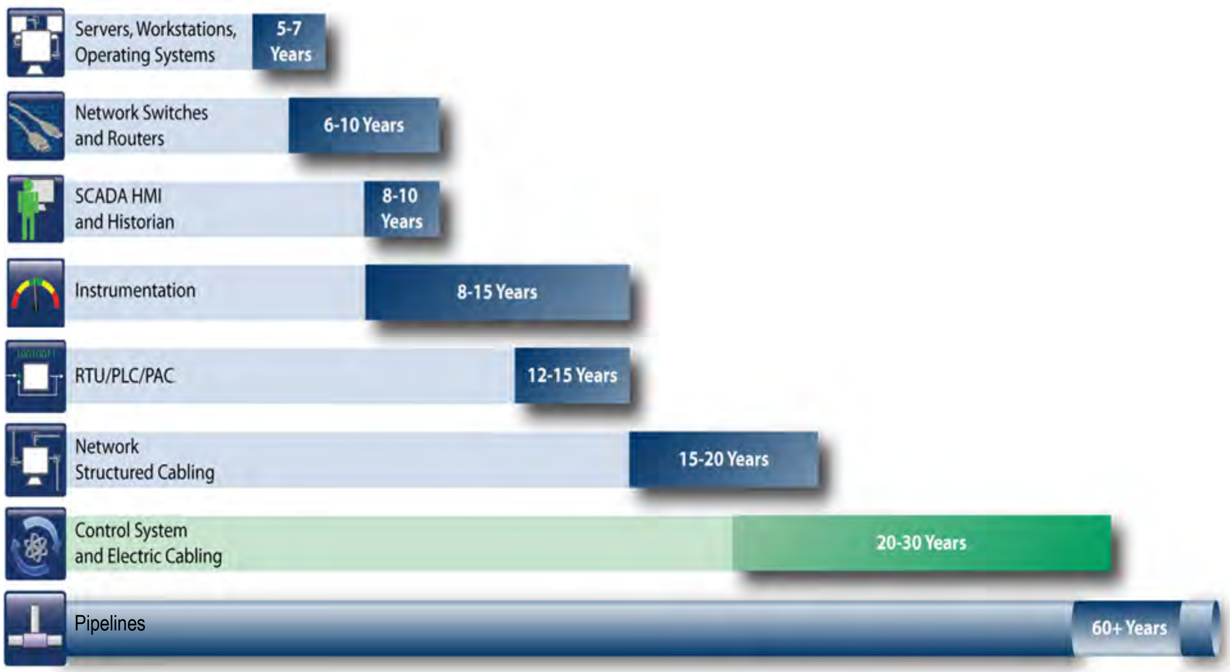


Figure 3-1. SCADA Component Life-cycle Comparison

Because of this continuous development in technology and software upgrades, the industry trends are to plan for physical server replacement every 5 years and to use virtual machines (VM) to establish a redundant and resilient server with backup and recovery options built in. The SCADA platform hardware and software (servers, operating systems, and VMs) must be based on current products (up to 5 years).

An alternative to hyperconverged servers onsite is cloud-hosted systems, where the server functions (processing, storage, and communications) are leased instead of purchased. Cloud-hosted systems can provide emergency operations and backup and a platform for back-office and IT applications. Although technically feasible to provide a platform for SCADA applications, the risks of dependence on communications links generally outweigh the cost benefits of cloud-hosted systems.

Another industry trend for water/wastewater utilities is to leverage a reliable SCADA platform to run IT applications so that SCADA information can be readily shared with IT applications. A commonly used industry model is where the SCADA system is a source of asset (processes, equipment, and systems) performance information that supports asset maintenance and financial management functions and IT applications.

3.2.1 Preferences

- Design and configure a hardware and software operating system and SCADA data delivery system, based on a 5-year life cycle.
- Use virtualization and separate locations to maximize resiliency of the SCADA/IT servers.
- Create a separate and secure SCADA data platform so that engineers and managers can access SCADA data and reports on an ad-hoc basis without direct access to SCADA displays.
- Evaluate the benefits of linking standard operating procedures to SCADA displays and using the SCADA system to train future operators.
- Develop a change management procedure for the PLC and SCADA programs.

3.3 Security

Since the terrorist attack on September 11, 2001, security has been an increasing concern. Initially, security measures focused on deterring or preventing physical access, but as unauthorized access methods became more sophisticated, the focus shifted to develop better cybersecurity methods. As a result, government and trade organizations developed and established security guidelines. These organizations include the following:

- Department of Homeland Security (DHS)
- North American Electric Reliability Corporation (NERC)
- American National Standards Institute (ANSI)

The main premise of the DHS standards is that security standards should be established with a Defense in Depth philosophy. Using the Cybersecurity Maturity Model shown on Figure 3-2, T-TSA will focus on the “Secure” and “Defend” steps by using appropriate physical security technologies, applying security best practices, and implementing appropriate cybersecurity methods.

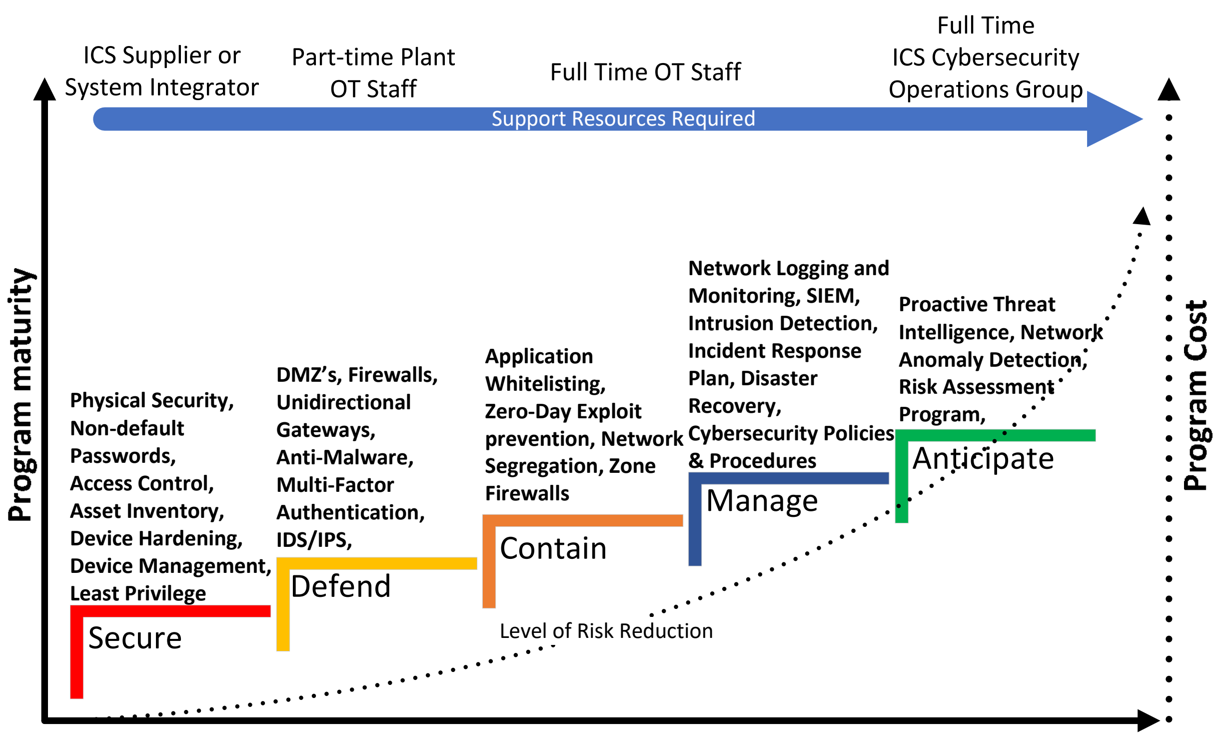


Figure 3-2. Cybersecurity Maturity Model

3.3.1 Physical Security

The WRP video cameras have been installed at numerous locations for plant-wide surveillance. The main gate controller has been updated, and the RFID gate card reader allows general entrance to the WRP but does not provide access to buildings. Buildings at the WRP are accessed using master keys to lock and unlock doors. T-TSA is investigating access control systems with key card access for each building. Not all PLC panels are locked, and server rooms are equipped with a combination door lock and are locked except for maintenance activities.

Site security is an issue for some of the TRI flow sites because the manholes, control panels, and appurtenances are generally accessible to unauthorized access from roads and highways. The Tahoe City North/West site is located inside the fencing for the California Department of Transportation yard. The Granite Flat site is easily accessible off Highway 89 without any fencing around the control panel. Transient camps have been witnessed near the flow site.

3.3.2 Cybersecurity

Currently, the SCADA system at the WRP is logically, not physically, segregated from the business/IT network. This reflects a long history of network isolation as the most effective security measure. However, the industry trend is to provide access to SCADA data and remote access to authorized operators. Water and wastewater utilities need to lay a framework to minimize unauthorized intrusions from external networks. DHS standards recommend the Perdue Model of Process Control for Cybersecurity, as shown on Figure 3-3, as a basis for a secure network with industrial controls.

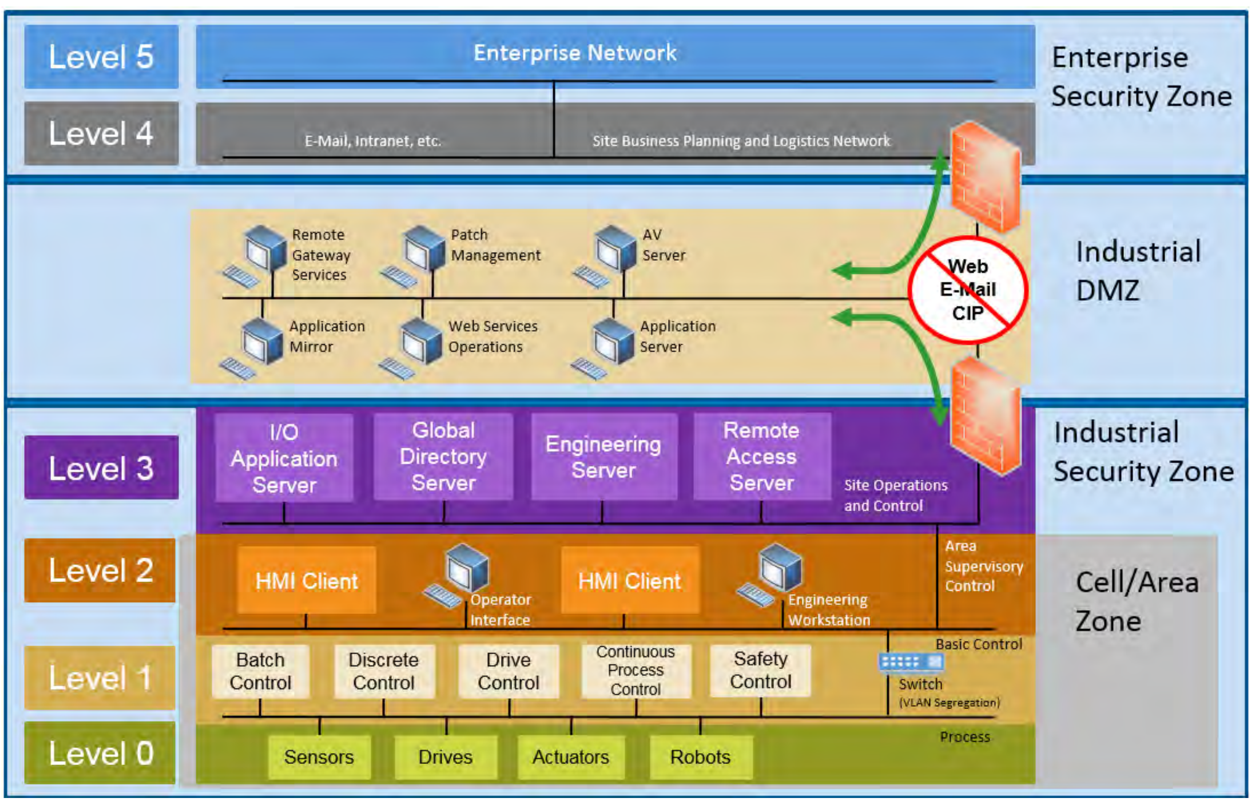


Figure 3-3. Perdue Model of Process Control for Cybersecurity

3.3.3 Preferences

- Extend radio frequency identification (RFID) authentication to include perimeter (fencing) and building access.
- Integrate physical security authentication with control system network authentication, e.g., RFID.
- Adopt a video surveillance storage retention standard of 360 days.
- Use a firewall for SCADA system isolation (Secure step) and firewalls for demilitarized zone (DMZ) and internet security (Defend step).
- Design DMZ layer to include secure sockets layer (SSL) certificate secured gateways and individual user permissions for SCADA access (zero trust approach).
- Physically segregate SCADA and business/IT networks.
- Logically segregate video and business networks with dedicated virtual private networks (VPNs).
- Include a robust backup and recovery system for the SCADA/IT servers.

3.4 Networks

Currently, the WRP plantwide network is based on a multimode fiber optic and copper network installed in a star configuration. It is a flat architecture that requires manual intervention to reroute data communications in the event of failure. The plantwide network supports SCADA, business/IT, and video security communications.

3.4.1 Plantwide Network Architecture

With trends of declining costs of single-mode fiber transceivers and increasing bandwidth requirements, single-mode fiber is now the industry standard for any distances over 100 meters. Most current designs use multi-mode fiber communication within buildings and single-mode fiber between buildings.

To keep current with communications technology and provide a self-healing plantwide network, T-TSA should evaluate an upgrade to single-mode fiber. The fiber upgrade analysis should consider a dual loop architecture that provides each PLC panel with two paths to the SCADA servers and the cost/benefits of redundant network switches in each process area PLC panel. Figure 3-4 shows an example of a dual-loop network architecture. The analysis should include sufficient fiber to support segregated business/IT and video security networking.

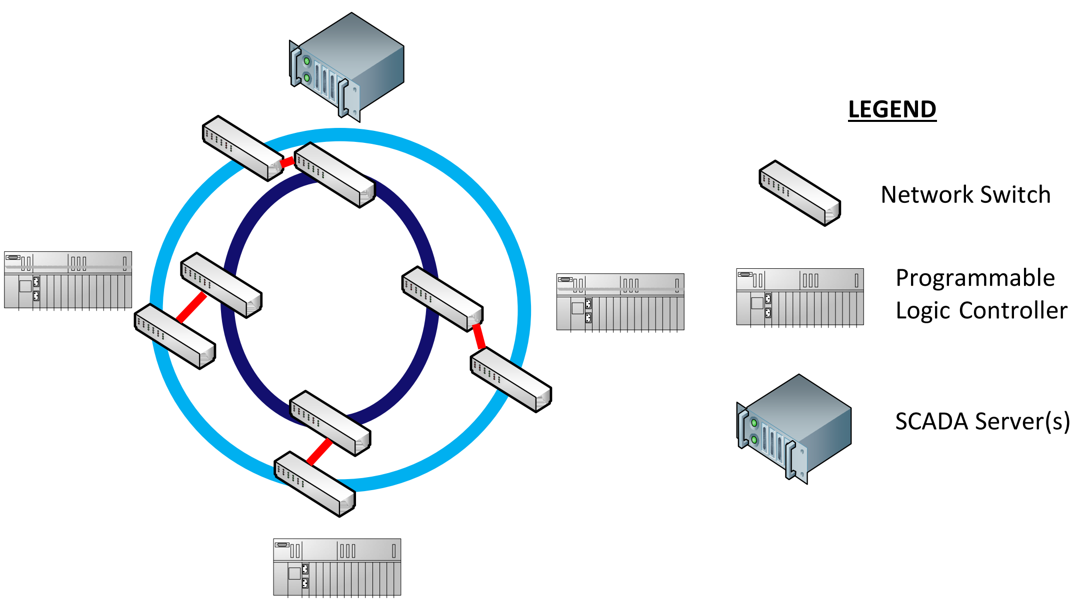


Figure 3-4. Dual Loop Network Architecture Concept

3.4.2 Instrumentation Networks

Currently, some instruments and field devices are hardwired (2-wire, 4-20 mA) to the plant PLCs, and some are connected via PROFIBUS. The industry trend is to collect more information on the health and status of instruments and control devices (I&C), which requires network protocols that support digital communication. The following four I&C network protocols are leading the industry in digitizing instruments and control devices, such as actuators, MCCs, and variable-frequency drives (VFD):

- HART – An open protocol that was originally developed by Rosemount
- Foundation Fieldbus (FF) – Currently administered by the FieldComm Group
- PROFIBUS – Governed by PROFIBUS and PROFINET International
- Ethernet/IP – Currently managed by Open DeviceNet Vendor Association (ODVA) Incorporated

Table 3-1 compares the technical aspects of these four protocols.

Table 3-1. I&C Network Protocol Technical Comparison

Criterion	HART	FF	PROFIBUS (PA or DP)	Ethernet
Remote Scaling	Yes	Yes	Yes	Yes
Additional Variables	Yes	Yes	Yes	Yes
Diagnostics	Yes	Yes	Yes	Yes
Configuration	Remote	Remote	Remote	Remote
Time Stamp	No	Periodical	No	Yes
Field Control	No	Yes	No	Yes
Necessary Technical Skills (1 = most available)	1	4	3	2
Integral Data Security	No	No	No	Yes
Base Standards	None	IEC 61158, ISA SP50 (H1): IEC 8802 (HSE)	IEC 61158	IEEE 802.3
Communication Relationship	None	Master/Slave	Client/Server	Client/Server Broadcast
Instruments/Field Devices Connectivity	Instruments and some actuators	Both	Both (PA and DP)	Limited Availability
Maximum Distance	3.0 km	1.9 km/9.5 km (H1): 100 m (HSE)	1.9 km/9.5 km (PA) 1,512 m (DP):	Based on media
Maximum # of Devices	Typically, 1 per segment	32 per segment (H1): unlimited (HSE)	32 per seg (PA) 247 per seg (DP)	1 per segment
Needs Linking Device	No	No	Yes	Yes
Adding Devices Online	Yes	Yes	No	Yes
Compatible with 4-20 mA	Yes	No	No	No

Table 3-1. I&C Network Protocol Technical Comparison

Criterion	HART	FF	PROFIBUS (PA or DP)	Ethernet

Notes:

DP = decentralized peripherals
HSE = high-speed ethernet
IEC = International Electrotechnical Commission
IEEE = Institute of Electrical and Electronics Engineers
ISA = International Society for Automation
ISO = International Organization for Standardization
km = kilometer
m = meter
PA = process automation

Instrumentation protocol development and deployment is ongoing, and the trend seems to be toward ethernet. Although the benefits of digitizing instrumentation are numerous, the cost of implementation can be high. Implementation of the HART protocol is the most cost effective (based on using existing wiring) but does not include all control devices. Currently, HART, Foundation Fieldbus and PROFIBUS support valve actuators, and only Endress Hauser, Auma, and Hach offer control devices that are truly compatible with ethernet communication. Most of the remaining instrument and actuator suppliers offer products compatible with FF and PROFIBUS, and almost all are looking to migrate to ethernet in the future. Advance Physical Layer (APL) for ethernet was approved in 2021 and device manufacturers are beginning to offer control devices compatible with this protocol.

3.4.3 Preferences

- Design and install a redundant fiber loop at the WRP with redundant network cards in the PLC chassis at each control panel.
- Design a multilayer network that isolates segments of the network to improve security and reduce failure vulnerabilities.
- Replace the existing multi-mode fiber cables with single-mode fiber cables.
- Upgrade network hardware as needed for warranty coverage and ease of replacement.
- Upgrade radio equipment as necessary and maintain clear paths.
- Evaluate costs and benefits of instrumentation network protocols based on current networked instruments and devices and recommend an action.

3.5 PLC/HMI Control Objects

Control programming is the heart of the SCADA system and resides in PLCs. PLCs perform the initial data processing to provide reliable performance trends and use this information to control processes and equipment. Since most instrumentation consists of flows, levels, and pressures, and many control devices are pumps or valves, most control programming is repetitive. The industry trend is to adopt control objects (PLC function blocks paired with popup graphics) for PLC programs. Linking well-documented control objects with the HMI display icons leads to efficiencies in programming, documentation, maintenance, and training activities. Additional efficiency can be gained by adopting standardized tagging and documentation processes to work with the PLC and HMI control objects.

Based on the observation that the 31 PLCs at the WRP include 20 discontinued or cancelled PLCs and 9 PLCs to be phased out within 2 years (leaving only 2 PLCs in active support), an evaluation should be conducted to select a new PLC model to replace the current PLC model. A key consideration in selecting the PLC replacement model is its ability to support standard control objects. Many PLC manufacturers offer a mature library of control objects. These control objects should include functional capabilities that meet or exceed typical wastewater control applications; provide consistency in programming, configuration, and testing of the SCADA system; and enable easier knowledge transfer between system integrators and T-TSA staff as projects are completed. T-TSA should develop or use control objects for each item shown in the preliminary list below:

1. I/O Handling
   a. Analog Input Scaling
   b. Analog Output Scaling
   c. Analog Alarm
   d. Compliance Alarm
   e. Discrete Alarm
2. Equipment Handling
   a. Modulating Valve
   b. Open-Close Valve
   c. Open-Stop-Close Valve
   d. Solenoid Valve (single output maintained)
   e. Fixed-speed Motor
   f. Adjustable-speed Motor
   g. Pump Lead-Lag Sequence
   h. Pump Lead-Standby Sequence
3. Process Handling
   a. Chemical Dosage
   b. Proportional Integral Derivative (PID) Control

3.5.1 Preferences

- Engage plant operators as stakeholders in control philosophy and database naming discussions to develop T-TSA's tagging standard, so that consistent naming and labelling can be used across the input/output (I/O) database, PLC programming, and HMI graphic displays.
- Engage plant operators as stakeholders in control object development to define the T-TSA PLC control object needs in coordination with HMI display standards.

3.6 HMI Graphic Displays

HMI graphic displays are the most visible component of SCADA systems. They are the windows into SCADA information and the interface to control processes and equipment. The current trends in HMI graphic display development are called "High-Performance Graphics" or "Situational Awareness." The standards for Situational Awareness and how this concept affect operator displays are addressed and developed by numerous trade organizations and government entities, including the following:

- International Society for Automation (ISA)
- International Organization for Standardization (ISO)
- Occupational Safety and Health Administration (OSHA)
- International Electrotechnical Commission (IEC)
- Engineering Equipment and Materials Users Association (EEMUA)

The research done by these organizations shows the amount of information that can be processed by human beings without sacrificing accurate understanding is limited. These studies identified the following factors and behavior patterns that affect a user's ability to process information and make accurate interpretations:

- Introduction of external factors
- Too many distractions
- Incomplete and irrelevant information
- Lack of communication between shifts
- Failure to document or include all necessary stakeholders in communications

The same studies summarized the benefits of adopting standard Situational Awareness practices as follows:

- Helps the operators focus control within the normal ranges
- Manages abnormal situations more efficiently
- Reduces operator fatigue
- Improves operator confidence
- Increases reliability and availability
- Efficiently transfers knowledge among personnel

The primary goals of good Situational Awareness practices are to recognize the correct information, understand the process, and predict abnormal situations in advance of them occurring.

The three most applied industry standards for water and wastewater are as follows:

- ISA 101.01 – HMIs
- ISA 18.2 – Alarm management
- ISO 11064: Control rooms design

The purpose of the ISA 101.01 (Human Machine Interfaces for Process Automation Systems) standard is to address the philosophy, design, implementation, operation, and maintenance of HMIs for process automation systems. The standard defines the terminology and models to develop an HMI and the work processes recommended to maintain the HMIs. The standard has nine parts. Parts 1 through 3 are introductory in nature. Parts 4 through 9 describe the life-cycle model and how to support the life cycle. The standard describes mandatory and nonmandatory requirements. The concept of High-Performance Graphics was derived from these standards.

Some of the principles driving the guidelines of High-Performance Graphics are as follows:

- Navigation between the graphic displays should be streamlined. Each graphic display should be accessible with three mouse-clicks.
- The colors used for alarms should not be used for any other purpose.
- Static information should be simplified, and only essential dynamic process values should be displayed.
- The displays should be created with an awareness of the sensory and cognitive boundaries.

The purpose of ISA 18.2 is focused on alarm management, based on the same principles of High-Performance Graphics. Alarm management is discussed in the next section.

The ISO 11064 (Ergonomic Design of Control Centers) standard includes six parts: principles for the design of control centers, principles for the arrangement of control suites; control room layout; layout, and dimensions of workstations; displays and controls; environmental requirements for control centers; and principles for the evaluation of control center.

The industry trend is to adopt the standards of High-Performance Graphics to create a hybrid version to match each client's operational needs. The figures shown in Appendix C illustrate some examples of a hybrid approach. Preliminary preferences expressed by the T-TSA team follow.

3.6.1 Preferences

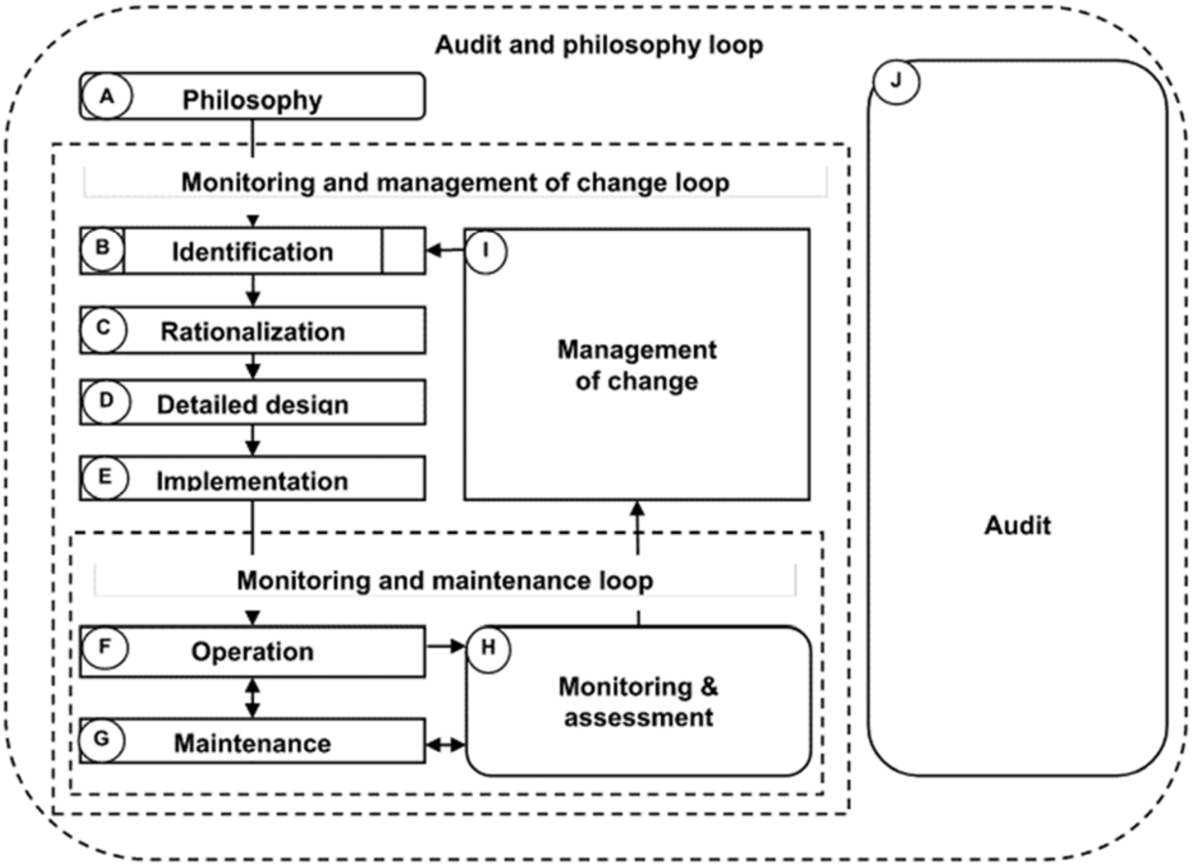
- Engage plant operators as stakeholders in HMI graphic standards discussions to develop T-TSA's HMI graphic display standards.
- Based on current conventions, the color RED should be used for equipment that is ON and valves that are OPENED. All equipment that is OFF and valves that are CLOSED should be shown in the background color. This would allow operators to focus on operating equipment, and equipment that is OFF would be merged into the background.
- Mini-trends should be shown with each analog value. This would allow operators to see the recent trends of the process and how close the process was to alarm levels.
- Navigation should be performed using a Windows Explorer-type file structure and hyperlinks. Folder structures and website-type hyperlinks are more intuitive for the current generation of operators.
- Develop pop-up graphics that allow the operators and maintenance staff to access more detailed information (such as alarm set points, alarm delay timers, maintenance mode).

3.7 Alarm Management

A critical aspect of Situational Awareness standards is alerting operators to abnormal conditions. A SCADA system can generate many alarms to indicate imminent or occurring abnormal conditions. Unmanaged, this ability can overwhelm operators with too many alarms. The current trend among utilities is to adapt the alarm management practices as outlined in the ISA 18.2 standard. This standard describes the development, design, installation, and management of alarming systems in the process industries. The standard was developed as an extension of other ISA standards (i.e., ISA 101.01).

The current standard has sections on alarm system models, alarm philosophy, alarm system requirement specifications, identification and rationalization, detailed design, implementation, operation, maintenance, and management of change and audit processes.

The alarm management life cycle is illustrated on Figure 3-5 (from the ISA 18.2 standard).



NOTE 1 The box used for stage B represents a process defined outside of this standard per 5.2.2.3.
NOTE 2 The independent stage J represents a process that connects to all other stages per 5.2.2.11
NOTE 3 The rounded shapes of stages A, H, and J represent entry points to the lifecycle per 5.2.3.
NOTE 4 The dotted lines represent the loops in the lifecycle per 5.2.5.

Figure 3-5. Alarm Management Life Cycle from ISA 18.2 2016

Some rule-of-thumb guidelines for effective alarm management at an operating facility are as follows:

- Under normal conditions, there should be no active alarms.
- Under any conditions, there should be fewer than 10 active alarms.
- Critical alarms criteria should be documented.
- Alarming system should be audited and reviewed annually.

Table 3-2 shows examples of alarm priority definitions.

Table 3-2. Alarm Priority Definition

Criteria / Priorities	Level 1 / Urgent	Level 2 / High	Level 3 / Medium	Level 4 / Low
Cost /Financial Loss /Downtime/ Permits	▪ Cost greater than $100K ▪ Requires senior management reporting	▪ Cost between $10K and $100K ▪ Requires reporting ▪ Short duration of outage	▪ Cost less than $10K ▪ Requires internal reporting	No loss

Table 3-2. Alarm Priority Definition

Criteria / Priorities	Level 1 / Urgent	Level 2 / High	Level 3 / Medium	Level 4 / Low
	▪ Shutdown of treatment		▪ No outage	
Environmental Damage /Public Perception	▪ Involves community and complaints ▪ Uncontained release of hazardous materials ▪ Extensive cleanup	▪ Contamination causes non-permanent damage ▪ Single or few complaints	▪ Contained release ▪ Internal report	No effect
Response Time	▪ Less than 5 minutes	▪ Between 5 and 15 minutes	▪ Between 15 minutes and 1 hour	Over 1 hour
Health and Safety	▪ Extremely hazardous	▪ Dangerous conditions		

3.7.1 Preferences

- Flashing symbols should be used for active and unacknowledged alarms only. This allows the operator to focus on the important, active alarms and not be distracted with inactive information.
- Engage plant operators as stakeholders in alarms and reporting discussions to develop the T-TSA alarm management, so that alarm prioritization, criteria, and presentation are documented and understood by all SCADA system users.
- Audit the existing alarms per the new alarm management standard.

3.8 IT Applications/Integration

From a utility management perspective, the industry trend is to integrate all technology applications and data under the overarching objective of improving Asset Management. This trend is notable for its broad impacts on utility management, practices, people, and technology to drive what is commonly experienced as a cultural change. For the purposes of planning, this SCADA/IT Master Plan focuses on the application of asset management principles to the SCADA/IT system and how those applications can support utility-wide asset management.

At its core, asset management encompasses life-cycle optimization of all assets within an organization. Most organizations readily apply asset management principles and practices to large assets with a long life cycle. The cultural change is applying those same principles and practices to all assets regardless of life-cycle duration, which drives utilities to refine their definition of an asset. This redefinition typically develops a detailed asset hierarchy (in Asset Maintenance), supplemented by performance monitoring (in Asset Operations), that are then rolled up into financially managed assets (in Asset Administration). Figure 3-6 shows a simple model of asset management business functions and technology applications.

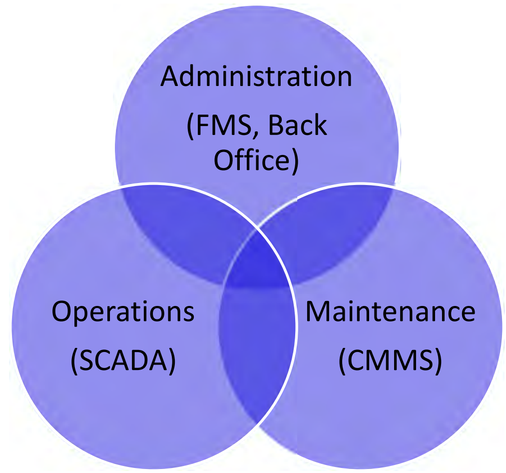


Figure 3-6. Asset Management Model

Each business function contributes to effective asset management on an annual basis. Most organizations include an engineering function to focus on long life-cycle assets. As a point of reference, the engineering function typically focuses on asset management plans and activities on a multi-year basis (5 years or more).

Depending on the characteristics of all assets owned by a utility, the three main technology applications (FMS, CMMS, SCADA) can be supplemented by other technology applications, such as GIS or LIMS. Each application is based on a dataset that supports the business function. These datasets are integrated using key indexes that correlate data about each asset among the applications. Table 3-3 summarizes the attributes of the major technology applications at T-TSA.

Table 3-3. T-TSA Major Technology Applications

Application	Vendor	Dataset	Key Index
FMS	Caselle	Accounts	Chart of Accounts
CMMS	Lucity, Inc.	Assets	Asset Hierarchy
SCADA	Aveva/Siemens	Performance	I/O List
GIS	AIMS [a]	Assets, Locations	TRI and Parcel IDs
LIMS/WIMS	Autoscribe Informatics/Hach	Water Quality and Dataset	Sample IDs

[a] AIMS (Asset Information Management System) is a custom developed GIS technology application for horizontal assets, including parcels and the TRI.

3.8.1 Preferences

- CMMS: Build on Lucity, Inc. application, integrating with asset hierarchy and using active modules on work management, warehouse/inventory, fleet, and key performance indicators (KPIs).
- GIS: Integrate work management for AIMS horizontal assets (including parcels and TRI) with CMMS vertical assets (WRP).
- Recognize three classes of assets in inventory, parts for work orders, consumables (mostly safety and personal protective equipment [PPE] supplies), and chemicals.

- Use the work order priority system and develop a criticality assessment .
- FMS: Develop complete asset inventory information, including fixed assets, mobile assets, and warehouse assets.
- FMS: Improve flexibility of asset management accounting.
- Caselle and Lucity, Inc. are recent acquisitions; AIMS is a custom developed and supportable application; therefore, T-TSA will plan to optimize these solutions.

3.9 Summary of Preferences

The vision for the SCADA system, based on interviews and discoveries from the assessment task, discussions in the System Assessment and Industry Trend workshops, and comments received in the System Assessment Technical Memo, is described by summarizing all the preferences for each component of the SCADA/IT system. Overall, T-TSA envisions a culture of continuous improvement by using SCADA/IT technology to enable more efficient workflows in effective asset management.

3.9.1 SCADA/IT Server Preferences

- Design and configure a hardware and software operating system and SCADA data delivery system, based on a 5-year life cycle.
- Use virtualization and separate locations to maximize resiliency of the SCADA/IT servers.
- Create a separate and secure SCADA data platform so that engineers and managers can access SCADA data and reports on an ad-hoc basis without direct access to SCADA displays.
- Evaluate the benefits of linking standard operating procedures to SCADA displays and using the SCADA system to train future operators.
- Develop a change management procedure for the PLC and SCADA programs.

3.9.2 Security Preferences

- Extend RFID authentication to include perimeter (fencing) and building access.
- Integrate physical security authentication with control system network authentication, e.g., RFID.
- Adopt a video surveillance storage retention standard of 360 days.
- Use a firewall for SCADA system isolation (Secure step) and firewalls for DMZ and internet security (Defend step).
- Design DMZ layer to include SSL certificate secured gateways and individual user permissions for SCADA access (zero trust approach).
- Segregate SCADA, business/IT, and video networks.
- Include a robust backup and recovery system for the SCADA/IT servers.

3.9.3 Network Preferences

- Design and install a redundant fiber loop at the WRP with redundant network cards in the PLC chassis at each control panel.
- Design a multilayer network that isolates segments of the network to improve security and reduce failure vulnerabilities.
- Replace the existing multi-mode fiber cables with single-mode cables.
- Upgrade network hardware as needed for warranty coverage and ease of replacement.
- Upgrade radio equipment as necessary and maintain clear paths.
- Evaluate costs and benefits of instrumentation network protocols based on current networked instruments and devices and recommend an action.

3.9.4 PLC/HMI Control Object Preferences

- Engage plant operators as stakeholders in control philosophy and database naming discussions to develop T-TSA's tagging standard so that consistent naming and labelling can be used across the I/O database, PLC programming, and HMI graphic displays.
- Engage plant operators as stakeholders in control object development to define the T-TSA PLC control object needs in coordination with HMI display standards.

3.9.5 HMI Graphic Display Preferences

- Engage plant operators as stakeholders in HMI graphic standards discussions to develop T-TSA's HMI graphic display standards.
- Based on current conventions, the color RED should be used for equipment that is ON and valves that are OPENED. All equipment that is OFF and valves that are CLOSED should be shown in the background color. This would allow operators to focus on operating equipment, and equipment that is OFF would be merged into the background.
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- Navigation should be performed using a Windows Explorer-type file structure and hyperlinks. Folder structures and website-type hyperlinks are more intuitive for the current generation of operators.
- Develop pop-up graphics that allow the operators and maintenance staff to access more detailed information (such as alarm set points, alarm delay timers, and maintenance mode).

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- Flashing symbols should be used for active and unacknowledged alarms only. This allows the operator to focus on the important, active alarms and not be distracted with inactive information.
- Engage plant operators as stakeholders in alarms and reporting discussions to develop the T-TSA alarm management so that alarm prioritization, criteria, and presentation are documented and understood by all SCADA system users.
- Audit the existing alarms per the new alarm management standard.

3.9.7 IT Application Preferences

- CMMS: Build on Lucity Inc, application, beginning with asset hierarchy and adding modules on work management, warehouse/inventory, fleet, and KPIs.
- GIS: Integrate work management for AIMS horizontal assets (including parcels and TRI) with CMMS vertical assets (WRP).
- Recognize three classes of assets in inventory, parts for work orders, consumables (mostly safety and PPE supplies), and chemicals.
- Will need a criticality assessment and a work order priority system.
- FMS: Develop complete asset inventory information, including fixed assets, mobile assets, and warehouse assets.
- FMS: Improve flexibility of asset management accounting.
- Caselle and Lucity, Inc. are recent acquisitions; AIMS is a custom developed and supportable application; therefore, T-TSA will plan to optimize these solutions.

3.9.8 Summary of Future State Goals and Objectives

Based on the documentation provided, site visits, and workshop discussions, the following goals are identified:

- Develop sustainable knowledge transfer methods for current and future SCADA/IT functionality, capabilities, and development, particularly for the PIS to other IT applications.

- Develop well-organized and documented standard database naming systems that support application integration for asset management.
- Replace PIS functions with standard off-the-shelf software applications.
- Implement cybersecurity measures as a high-priority task.
- Provide standards for HMI graphics development based on Situational Awareness concepts.
- Develop project plans (budget and schedule) for technology upgrades for all SCADA/IT components, including:
  - Upgrade the physical servers to eliminate incompatibilities among multiple servers and VM application versions and minimize instabilities in application performance.
  - Establish robust backup and recovery systems and procedures.
  - Upgrade physical security at the WRP and flow sites using RFID card reader access for perimeters and buildings.
  - Provide secure interfaces among segregated networks for the SCADA, business/IT, and security (video camera) systems.
  - Upgrade flow site communications, using the licensed radio frequency where feasible.
  - Evaluate PLC alternatives to replace Siemens PLCs, based on PLC/HMI control object capabilities.
  - Implement high-performance HMI graphics with PLC upgrade project(s).
  - Develop and implement alarm management process.
  - Optimize current IT applications (such as Lucity, Inc., AIMS and Caselle) to improve asset management.

4. Needs Analysis

A Needs Analysis examines the gap between current and future states, identifies the needs to bridge that gap, and considers alternatives to develop a conceptual plan to reach the desired future state. The current state of the T-TSA SCADA/IT system is organized into five technology components, including servers, networks, WRP PLCs, Remote Site PLCs and IT Applications. Drivers for each technology component are listed in one or more driver groups described in the System Assessment. A fourth driver group, System Sustainability, focuses on internal and external resource components designed to support the new SCADA System and is discussed in the Organizational Assessment section. Table 4-1 cross references the SCADA/IT system technology components and their drivers.

Table 4-1. Current State Summary

	SCADA/IT Technology Replacement Drivers		
System Component	**Knowledge Transfer**	**Security (physical/cyber)**	**Technical Obsolescence**
Servers			
Hardware/OS	Lack of documentation in server configurations, and event response plans.	Using RDP for 12 thin clients.	4 of 5 VM hosts at EOSL by 3/26/22 Multiple versions of OS and VM software
HMI (Aveva)	Lack of database tagging, graphics and alarm management standards	Using common control room location logins for permissions.	Using SQL Server 2008 and Windows 2003 and 2008.
Networks			
WRP Fiber	Lack of network documentation, i.e. diagrams and configurations.	Network segregation may be compromised. Remote access security is vulnerable.	21 of 25 switches at EOSL. Multi-mode fiber is aging, and needs to be tested for degradation.
Remote Sites	Lack of network documentation.	5 sites use cellular modems but only 3 use a VPN 1 site uses licensed radio	Radio and repeater at WRP are at EOSL
WRP PLCs			
25 PLCs (Siemens) 1 BACnet system for Digestion processes	No Process Control Narratives Program Logic developed without standard Database Tagging or Control Objects. Record Drawings, such as Panel Documentation, Loop Diagrams, etc. may need updates.	Perimeter is fenced with gate access only Building access is keyed and generally locked Panel access is keyed and generally locked	6 Siemens Models with 7 firmware versions: 9 PLCs Cancelled 5 PLCs Discontinued 9 PLCs Discontinued by 10/2023 2 PLCs in Active Support 1 Obsolete BACnet system

Table 4-1. Current State Summary

System Component	SCADA/IT Technology Replacement Drivers		
	Knowledge Transfer	**Security (physical/cyber)**	**Technical Obsolescence**
Remote Site PLCs			
6 PLCs (Siemens, Motorola)	Record Drawings, such as Panel Documentation, Loop Diagrams, etc. may need updates.	Panels are locked but exposed to weather and generally accessible (no fencing). Temperature monitoring in all panels except Tahoe City North/West. No video surveillance.	2 Siemens Models 1 Motorola PLC Motorola and Alpine PLCs are Cancelled 4 Siemens PLCs in Active Support
IT Applications			
a) CMMS (Lucity, Inc.) b) FMS (Caselle) c) MS Office d) GIS (AIMS) e) WQIS (LIMS, WIMS)	Recent implementations imply new knowledge based is being developed. To be determined by system integration development.	Using Active Directory with individual passwords.	a) Implemented 2021 b) Implemented 2020 c) Current licensing d) Implemented 2018 e) Expected implementation 2022

Based on the Stakeholder Goals and Industry Trend preferences, Table 4-2 summarizes the future state of the SCADA system at the WRP. The approaches to address each technology driver are based on developing standards and documentation and replacing obsolete equipment. SCADA convention standards include control philosophy, database naming, control objects, graphics, and alarm management. SCADA component standards include instrumentation, control panels, control equipment (including PLCs), and network equipment. IT convention standards include data mapping and key index alignments.

Table 4-2. Future State Summary

System Component	Approaches to Address Technology Replacement Drivers		
	Standards To Be Developed	**Documentation To Be Developed**	**Future Technical Description**
Servers			
Hardware/OS	One server model, one VM version, one OS version.	Self-generated configuration reports.	Planned replacement every 5 years
HMI (Aveva)	Control object, HMI graphics, and alarm management standards.	Self-generated configuration reports.	Single current version Active Directory Security Change management policy in place

Table 4-2. Future State Summary

System Component	Approaches to Address Technology Replacement Drivers		
	Standards To Be Developed	**Documentation To Be Developed**	**Future Technical Description**
Networks			
WRP Fiber	Network component standards and DHS, NERC, NIST standards for ICS	As-built Drawings Self-generated network configuration.	Single mode fiber Dual Ring Architecture Segmented with managed switches (network health monitored) DMZ security allowing remote access
Remote Sites	Network component standards	As-built Drawings	To be determined by radio/cellular cost/benefit analysis.
PLCs (Siemens)			
All PLCs	Evaluate alternative PLC models/manufacturers to develop component standards.	Self-generated program reports	One PLC manufacturer, Consistent PLC models and firmware versions.
WRP PLCs Remote PLCs	Control philosophy, database tagging, and control object standards	Process Control Narratives (WRP only) As-built Drawings	One PLC manufacturer with scalable models depending on process application. One programming language.
IT Applications			
FMS, CMMS, etc.	IT convention standards.	Developed as part of implementation.	Data sets for all SCADA/IT applications integrated to support effective asset management practices.

Achieving this future state depends on effective development and deployment of convention and component standards to successfully meet all stakeholder goals. Defining and measuring success criteria is described in the next section.

4.1 Criteria/Approaches

The future state of the T-TSA SCADA/IT system is achieved by selecting and applying the industry trends and best practices that best fit T-TSA's needs. These selections are based on their potential to achieve the strategic goals identified in the Industry Trends section. Performance-based criteria are developed from the strategic goals to measure progress and improvement. These criteria are grouped around reliability (where improvements are measured by reductions in downtime) and responsiveness (where improvements are measured by faster response times). Both sets of criteria are listed in order of increasing time measurement objectives.

4.1.1 Performance Criteria:

1. Reliability:
    1.1. Secure, self-healing network
    1.2. Self-healing servers
    1.3. Consistent control logic and graphic presentation (situational awareness)
    1.4. Monitor system health and performance (condition awareness)
2. Responsiveness:
    2.1. High speed network, 1 second response within WRP, 15 second response to remote sites
    2.2. Effective alarm management
    2.3. Automatic backup and quick recovery
    2.4. Consistent control program development
    2.5. Trained and experienced technical resources

The above criteria provide the tools to measure the success of SCADA/IT projects towards achieving the future state. The projects are defined by applying selected industry trends and best practices and designing the approach with the greatest potential to improve performance. Alternatives for each component are described in the Industry Trends section. Table 4-3 summarizes the planned approaches, and their respective criteria focus.

Table 4-3. Industry Trends and Planned Approaches Summary

System Component	Selected Industry Trend	Planned Approach Description	Criteria Focus
Servers			
Hardware/OS	Virtualization, Outsource Support	2 redundant and physically separate virtual servers, current version of Windows Server, dedicated to SCADA applications (such as Aveva), with hardened security, backup/recovery system, and UPS power	1.2, 2.3 2.5
HMI Software (currently Aveva)	Thin Clients Control Objects, High Performance Graphics, Alarm Management	High Performance Graphics compliant with ISO 101, current versions of HMI software, supports tablets and workstations, Active Directory security, compliant with all convention standards	1.3
Networks			
WRP Fiber	Single mode, Remote access	Single Mode Fiber, with Dual-Ring network segmentation for resiliency, managed network switches, and DMZ Security for remote access	1.1, 1.4 2.1, 2.2
Remote Sites	Ethernet	All remote sites on radio with cellular backup	2.1
WRP PLCs Remote Site PLCs	Single PLC manufacturer	One programming language, compliant with all convention standards, two standard PLCs (one for WRP PLCs, one for remote site PLCs).	1.3, 2.4
PLC Program	Control Objects	Define in convention standards	1.3, 2.2, 2.4
PLC/HMI Program	Alarm Management	Define in Alarm Management Philosophy (convention standard)	1.3, 2.2, 2.4
IT Applications	Asset Management	Establish integrated data sets by mapping data to key indexes.	1.4, 2.4

Other factors affecting the needs analysis and approach selection for the SCADA/IT system upgrade projects are financial and non-technical. Resource limitations may extend the transition period from the current state to the future state. New construction projects may set precedence for some component replacements over others. Contractual restrictions may extend procurement processes. Staffing and skill availability may also extend project schedules.

For master planning purposes, consideration of these factors will assume the following:

- A balanced distribution of annual resource requirements over 5 years.
- Average lead time for procuring most hardware and software products is 4-6 months.
- All labor to deliver all SCADA replacement/upgrade projects will be contracted services.

The System Sustainability group of drivers focus on the development of internal and external resources to support and sustain the SCADA system replacement. Development of these resources includes documentation, contracting procedures, training of internal staff, and maintaining a list of pre-qualified contractors. The stakeholder goals for sustainability are focused on self-sufficiency and will measure responsiveness (see Performance Criteria 2.5) to show improvements toward self-sufficiency.

4.2 Project Concepts

The Project Concept discussion in the Needs Analysis workshop revealed some prioritization and schedule considerations. Major component replacements are prioritized based on life-cycle obsolescence and criticality to the SCADA/IT system, as follows:

- Servers
- Networks
- SCADA/IT Application Integration
- WRP and Remote Site PLCs.

4.2.1 Replace Servers

The server replacement project includes two concepts: replacing the servers and developing the HMI and alarm system upgrade. The server replacement concept assumes two server locations using virtual designs with self-healing resiliency, and thin clients for user interfaces. The server replacement project concept includes the HMI software and alarm system software upgrades and establishes login security using Active Directory for authorized users of the HMI software.

The HMI and alarm system software upgrade concept will develop SCADA system convention standards based on using control objects, high-performance graphics, and integrated alarm management. Control object development will be based on the PLC manufacturer. This project concept establishes the convention standards to prepare for programming each PLC with control objects and develops a transition plan. The transition plan will cover the time between the first PLC to be interfaced into the new HMI system and the last PLC. The transition period could last 3 or more years.

4.2.2 Upgrade Networks

The network upgrade includes two concepts: the WRP SCADA network and the remote site (radio) network. The SCADA network upgrade project concept assumes new single mode fiber, new network switches from a single manufacturer, self-healing dual ring architecture, and segmentation designed for security and resiliency. The network upgrades also establish remote access and data access using current cybersecurity techniques such as a firewall and DMZ.

The WRP SCADA network upgrade concept will develop a detailed upgrade plan. The upgrade plan assumes existing PLCs can be connected to the existing HMI system through the new network, so that the WRP network upgrade project can be decoupled from the server upgrade project. The upgrade plan will identify instrumentation network needs, such as the BACnet system for the boilers, and develop a cutover plan for all PLCs. The network cutover schedule could last several weeks.

The remote site network upgrade concept evaluates the feasibility of expanding the licensed 450 MHz radio or the 5G cellular system to include all six remote sites. The cost-benefit analysis would consider the merits and security of a single communication system.

The WRP network includes 25 switches, of which 20 switches are beyond EOSL, leaving only 5 WRP switches/routers as active products. The 9 Phoenix Contact radios in the disposal fields are obsolete. All remote site network equipment is in active support except for the Motorola MCS 2000 radio located at the WRP. Table 4-4 summarizes the technical obsolescence of the network equipment.

Table 4-4. Network Switch Obsolescence Summary

WRP			Remote Sites
EOSL: 2010-2015	**EOSL: 2016-2020**	**Active Support**	**(Support Status)**
3 HP1400-24G (2012)	2 Juniper SRX240 (2019)	Ciena 3930	1 MCS 2000 (EOSL: 2005)
3 HP2910-24G (2014)	1 Netgear JFX524 (2018)	HP 2530	1 XPR 5350 (EOSL: 2022)
1 HP2920-48G (2014)		Netgear XS708E	5 Cellular 3G/4G (Active)
1 N-Tron 900B (2014)		Aruba 2520	
6 HP1801G-24G (2015)		N-Tron 317FX	
3 HP 2615 (2015)	9 Phoenix Contact 2867131 (Disposal Fields)		

4.2.3 Optimize IT Applications

The IT Application Optimization includes two concepts: establishing convention standards for an integrated IT database and implementing a Water Quality Information System (WQIS) that integrates lab analysis information and treatment process performance information. The IT convention standards can be developed concurrently with SCADA convention standards. IT convention standards would define the data map to build data integration interfaces between SCADA and IT applications.

The WQIS project implements the WIMS and LIMS software to provide a reliable source of water quality data for regulatory reporting and treatment process analysis and optimization. Water quality data is a combination of process performance data from the SCADA system and lab test results from water samples.

4.2.4 Upgrade/Replace PLCs

The WRP PLC upgrade project concept assumes replacement of all 31 PLCs over a multi-year period. The project begins with an evaluation of PLC manufacturer alternatives to select a standard PLC for T-TSA applications. The objective of the PLC selection is to standardize on one common programming language for all PLCs and consider cost-effective models for scalability to complex or simple applications. At T-TSA, complex PLC applications all reside at the WRP.

Programming these PLCs will be based on the convention standards and control objects developed in the HMI upgrade project. Prioritization and sequencing of specific PLC replacements will be defined in the transition plan and based on process criticality and obsolescence urgency.

WRP PLCs are assumed to be more complex than remote site and disposal field PLCs. Some WRP PLCs are already cancelled or discontinued, while other WRP PLCs are scheduled to be phased out in 2023. PLCs in 53 C&CT and 32 Digester are generally older than PLCs in other WRP processes. PLCs in active support can be scheduled toward the end of the PLC replacement project. Table 4-5 summarizes T-TSA's PLCs by process complexity and technical obsolescence.

Table 4-5. PLC Obsolescence Summary

WRP PLCs (Complex Applications)		Simple Application PLCs	
Discontinued	**Phasing Out (10/2023)**	**Cancelled**	**Active Support**
PLC65: 53 C&CT	PLC10: 53 C&CT	Disposal Field 1	PLC71: Dollar Hill TRI
PLC04: 53 C&CT	PLC03: 04 SHS	Disposal Field 2	PLC73: Rampart TRI
PLC08: 53 C&CT	PLC08: 04 Thickening	Disposal Field 3	PLC75: Olympic Valley TRI
PLC60: 53 C&CT	PLC63: 32 Digester (Active)	Disposal Field 4	PLC76: Granite Flat TRI
PLC05: 32 Digester	PLC06: 71 Dewatering	Disposal Field 5	
PLC40: 81 BNR	PLC21: 71 Dewatering	Disposal Field 6	
BACnet: 32 Digester	PLC22: 71 Dewatering	Disposal Field 7	
	PLC50: 52 Oxygenation Basins	Disposal Field 8	
	PLC62: 02 AWT	PLC74: Alpine Meadows TRI	
	PLC07: 02 AWT	Motorola: Tahoe City TRI	
	PLC09: 75 Chlorine (Active)		

Note on Table 4-5:
Both PLC09 and PLC63 are PLCs in active support and do not require replacement based on technology obsolescence. PLC63 is grouped with the other Digester PLCs (PLC05, PLC08) to replace these 3 PLCs and the BACnet system collectively for a consistent PLC design and installation within the Digester process.

For the purposes of planning and estimating, the simple application PLCs are referred to as Remote Telemetry Units (RTU). RTUs have the same capabilities as PLCs with a smaller capacity, RTUs are scaled to applications such as the disposal fields (one or two controlled valves) and TRI remote sites (one or two flow monitors). RTUs and PLCs will be produced by the same manufacturer. Ideally, both RTUs and PLCs are programmable by one programming software.

4.3 SCADA/IT Needs Summary

Based on the project concept descriptions, the SCADA/IT technology needs are summarized as follows:

1. **Upgrade SCADA/IT Servers (Establish VM Platform)**
   a. Two separate locations for backup and recovery and to support reliability needs.
   b. Hyperconverged physical servers to run all VM platforms for SCADA and IT applications.

2. **Upgrade Networks and Security Systems**
   a. Conduct fiber optic testing to determine upgrade options to single mode fiber.
   b. Robust network design based on Perdue ICS model with new switches, firewalls, and DMZ to allow remote access and address cybersecurity concerns.
   c. Describe instrumentation network upgrade needs, such as the BACnet system for the boilers.
   d. Enhance physical security with RFID cards for perimeter and building access.
   e. Evaluate 5G cellular to licensed frequency communications to remote sites.
3. **Optimize SCADA/IT Applications for Effective Asset Management**
   a. Leverage recent implementations (Caselle, Lucity, Inc., AIMS) by developing IT convention standards based on key indexes and data map to support future integrations.
   b. Implement WQIS by integrating LIMS, WIMS, and SCADA systems using IT convention standards.
4. **Develop SCADA Application Platform**
   a. Establish SCADA convention standards based on database naming, control objects, high performance graphics, alarm management, and reporting.
   b. Update HMI software to current version to establish platform for PLCs to transition to.
   c. Develop PLC upgrade transition plan to describe priorities and sequencing.
5. **Upgrade PLCs Sequentially**
   a. Establish SCADA component standards based on an analysis and selection of a single PLC manufacturer that can provide scalable products to WRP and simple applications.
   b. Develop PLC programming documentation, including process control narratives and P&IDs.
   c. Design and Implement PLC Replacement Projects based on a sequential transition plan (the transition period is assumed to be 3 or more years).

4.4 Project Concept Matrix

The Project Concept Matrix shown in Table 4-6 organizes the project concepts into three phases. Phase 1 sets the foundations for a hardware platform, network security, and software conventions. Phase 2 builds a new SCADA system on the foundations set in Phase 1 and includes replacing all obsolete PLCs. Phase 3 optimizes asset management by implementing data integration and developing organizational resources and may be executed concurrently with Phase 2. Key assumptions are included in the project descriptions.

Table 4-6. Project Concept Matrix

Project Name	Project Concepts
Phase 1	Set the Foundation
1. Upgrade Servers	▪ Establishes computing platform for all SCADA/IT applications ▪ Detailed cutover planning will minimize downtime ▪ Development and testing should occur offline before each cutover ▪ SCADA systems must function in parallel during transition
2. Upgrade Networks and Security	▪ Establishes communications platform for SCADA, IT, video security and instrumentation ▪ Network designed for secure remote access, segmentation, DMZ, etc. ▪ Detailed planning with other upgrade projects will minimize rework ▪ Must function in parallel with existing network during transition ▪ Network upgrades can be decoupled from server and SCADA upgrades
3. Develop Standards	▪ Establishes convention and component standards for all SCADA/IT applications ▪ Establishes data map and key index interface for SCADA/IT applications ▪ Establishes control philosophy, database naming, control objects, graphics, and alarm management philosophy for SCADA programming ▪ Evaluates and establishes a PLC/RTU product line to replace obsolete models ▪ Develops transition plan to replace PLC/RTUs over a multi-year (3 or more) period
Phase 2	Replace SCADA System
4. Replace Controls and Graphics	▪ PLC/RTU programming will be based on standard control objects ▪ HMI graphics will be based on situational awareness principles ▪ A Pilot project would provide proof-of-concept for SCADA standards ▪ Assume 5 PLCs/RTUs replaced per year (6 years), dependent on resource limits
Phase 3	Optimize Asset Management
5. Upgrade Reports	▪ Implement WQIS (WIMS, LIMS, or others) ▪ Interface SCADA with WQIS to automate reporting ▪ Complete application upgrades to replace PIS ▪ WQIS implementation can be decoupled, integration follows initial SCADA replacement
6. Integrate Business Applications	▪ Can be concurrent with SCADA replacement projects ▪ Financial and Work Management can be optimized sequentially or concurrently ▪ Dependent on resource limits
7. Develop Resources	▪ Can be concurrent with SCADA/IT projects, depending on workload ▪ Training should occur as close as possible to application
8. Improve Physical Security	▪ Is independent of all other SCADA/IT projects ▪ Establishes secure system for perimeter and building access ▪ Improves video surveillance

5. Implementation Planning

The first step in implementation planning is to refine the project concepts into specific projects and describe general characteristics of each project. Project characteristics include name, purpose, dependencies, durations, primary tasks, major deliverables, and estimated schedules and costs. Summary project descriptions are included in this section. Detailed project descriptions are in Appendix D. Project descriptions include:

Summary Project Descriptions	Detailed Project Descriptions
▪ Project Name	▪ Project Name
▪ Project Purpose	▪ Primary Tasks
▪ Dependencies	▪ Major Deliverables
▪ Duration	▪ Estimated Schedule
▪ Estimated Cost (Class 5)	▪ Estimated Cost (Class 4)

5.1 Master Plan Cost Estimating

Implementation planning introduces cost estimates to the project concept descriptions. Cost estimates for the Implementation Planning TM are based on Class 5 characteristics as published by the Association for Advancement of Cost Estimating (AACE) in the 2005 Cost Estimate Classification System (AACE International Recommended Practice No. 18R-97). Cost estimates for the SCADA/IT Master Plan are based on Class 4 characteristics. AACE estimating characteristics are shown in Table 5-1.

Table 5-1. AACE Cost Estimating Characteristics

Characteristic	Class 5	Class 4
Level of Project Definition	0% - 2%	1% - 15%
End Usage	Concept Screening	Study or Feasibility
Methodology	Judgment or Analogy	Equipment Factored
Expected Accuracy Range	Low: -20% - -50% High: +30% - +100%	Low: -15% - -30% High: +20% - +50%
Preparation Effort	1 (1 = least effort)	2 to 4

All cost estimates assume that all services will be performed by contracted labor. This provides a consistent hourly rate for skill levels and further supports a conservative cost estimate. Class 4 detailed cost estimates include the following items:

- **Labor:**
  - Design: Based on estimated hours for each staff category (Staff, Engineer, Technician)
  - Development: Based on estimated hours for programming, configuration, and factory testing
  - Implementation: Based on estimated hours for field installation, field testing, and training
  - Project Management: Includes the following three items.
    - Project Management: Based on 10% of project labor hours
    - Administrative Support and QA/QC: 50% of Project Management costs
    - Other direct costs: 6% of design, development, and implementation labor costs

- **Materials:**
  - Hardware: includes servers, network switches, thin clients, PLCs, panels, and miscellaneous
  - Software: based on software licensing costs
  - Miscellaneous: includes mobilization, test equipment and other materials
- **Contingency:** assumed to be 20% of labor and material costs.
- **Total Cost:** includes labor, materials, and contingency.

Class 4 cost estimates (Excel Worksheets) are provided in Appendix E.

Financial and non-technical factors considered in the gap analysis include resource limitations, new construction projects, procurement restrictions, and staffing and skill availability. For implementation planning purposes, financial and non-technical factors are assumed to be the following:

- A balanced distribution of resource workloads over 5 years.
- Technology performance costs will continue to decrease at a rate sufficient to offset inflation.
- Average lead time for procuring most hardware and software products is 6 months.
- All labor to deliver SCADA replacement/upgrade projects will be professional services.
- New construction projects, such as the Digestion Improvements project, may modify the sequencing of PLC replacements.

5.2 Master Sewer Plan Alignment

The February 2022 Master Sewer Plan assessed all TRI and WRP infrastructure and recommended a Capital Improvement Plan (CIP) for the next 25 years, consisting of 5 consecutive five-year phases. It identified primary goals and developed Levels of Service (LOS) goals and strategies that were adopted by the Board in May 2019.

Based on these goals, the Master Sewer Plan recommended a series of projects, including costs and schedules, to repair and replace TRI and WRP infrastructure, construct new WRP facilities to meet existing and future regulations, improve TRI wet weather capacity, and improve WRP processes. The Master Sewer Plan investigated civil, structural, mechanical, and electrical systems but did not investigate financing strategies, rate impacts, or control system needs.

The SCADA/IT Master Plan investigates control system needs to support successful achievement of the same goals and strategies described in the Master Sewer Plan. While IT generally supports all goals and strategies, a reliable SCADA system is required to enable the primary goal of operating and maintaining the WRP and related facilities in a sound, efficient, and effective manner. The SCADA/IT Master Plan matches well with Phase 1 of the Master Sewer Plan. Both are 5-year plans that focus on rehabilitating and replacing assets. Phase 1 projects, excluding SCADA/IT, are estimated at:

Master Sewer Plan Phase 1 (FY 22/23 to 26/27)	Estimated Costs
Collection System (TRI)	$2,905,000
Wastewater Reclamation Plant (WRP)	$37,084,000
Total for Phase 1	**$39,989,000**

A review of Phase 1 projects confirmed a focus on civil, structural, mechanical, and electrical system rehabilitations or replacements. The projects assume controls as needed but do not investigate the control system itself. This review identified two projects with significant control system elements:
CIP-14 – Communications Network Replacement, and WRP-10 – Digestion Improvements.

1. **CIP-14 – Communications Network Replacement:** This CIP project identifies replacement of communications equipment and cabling only. The SCADA/IT Master Plan describes the network replacement in more detail and upgrades the network by adding cybersecurity measures that allow secure remote access. The network replacement and security upgrade should be one project.
2. **WRP-10 – Digestion Improvements:** This CIP project replaces the boilers, heat exchangers, hot water circulation system, waste gas flare, PLCs, and steam lines. The SCADA/IT Master Plan identifies three Digester PLCs and a BACnet control system to be replaced using SCADA convention and component standards. The purpose and scheduling of the Digestion Improvements project creates an ideal opportunity for a pilot PLC replacement project.

A successful Pilot PLC project depends on the establishment of SCADA standards (conventions and components) and the SCADA hardware platform (SCADA servers). If the Digestion Improvements project includes the Pilot PLC project, then the SCADA standards must be developed prior to 60% design and the SCADA servers must be upgraded prior to construction.

5.3 Summary Project Descriptions

Three project concepts listed in Table 4-6. Project Concept Matrix, changed significantly as the planning process developed project descriptions. The concepts that changed are as follows:

- **Concept 4. Replace Controls and Graphics** evolved into three projects; Replace Pilot PLCs, Replace WRP PLCs, and Replace RTUs. All three projects develop new PLC controls and HMI graphics. The Pilot PLC replacement project applies the SCADA standards developed in Concept 3 and builds a mature library of PLC/HMI control objects. The SCADA standards and control object library are used in the WRP PLC and RTU replacement projects.
- **Concept 6. Integrate Business Applications** is postponed indefinitely. The recent installations of Lucity, Inc. (CMMS) and Caselle (FMS) are still in the process of developing new workflows, business practices, and analytical tools. As the CMMS and FMS become more established, integration opportunities may then define business application integration concepts and projects.
- **Concept 7. Develop Resources** is reframed as an ongoing effort, instead of a project. While the technology projects establish a modern SCADA/IT system, system sustainability includes two ongoing practices: training and governance. Both practices are described in Section 6.

Based on the updated project concepts and in alignment with Master Sewer Plan projects, summary SCADA/IT project descriptions are developed and listed in Table 5-2. Project summary descriptions include project name, duration, cost, purposes, and dependencies. Detailed project descriptions are provided in Appendix D. Detailed cost estimates are provided in Appendix E.

Table 5-2. Summary Project Descriptions

Project Name Duration Cost	Project Purposes	Dependencies
1. Replace Servers 12 months, $430,000	▪ Replace obsolete server hardware and software to provide a current, reliable platform for SCADA/IT applications. ▪ Implement reliable backup/recovery systems and practices. ▪ Develop Server Cutover Plan.	▪ Completion of this project will establish the hardware platform for all subsequent SCADA/IT projects.
2. Upgrade Networks and Security 15 months $330,000	▪ Replace obsolete multi-mode fiber optic with single mode. ▪ Replace obsolete non-managed switches and flat architecture with robust, self-healing ring network.	▪ Can be scheduled independently, but cutover planning must coordinate with other projects.

Table 5-2. Summary Project Descriptions

Project Name Duration Cost	Project Purposes	Dependencies
	▪ Evaluate costs and benefits of upgrading serial radios to use 5G cellular service as backup. ▪ Develop Network Cutover Plan.	
3. Develop Standards 6 months $241,000	▪ Develop Convention Standards for control philosophy, database naming, data mapping, control objects, HMI graphics, and alarm management. ▪ Develop Component standards for field instruments, control panels, and PLCs (single manufacturer). ▪ Develop PLC Transition Plan based on obsolescence (covers 3 or more years).	▪ Completion of this project will establish Convention and Component Standards for SCADA/IT software applications.
4. Replace Pilot PLCs (4) and HMI Graphics 12 months $ 663,000	▪ Include Pilot PLC Replacement in Digestion Improvements project. ▪ Apply all Convention and Component standards to field instruments, control panels, and PLC hardware. ▪ Replace Digester PLCs with appropriately sized PLC models. ▪ Install new control panels with new PLCs. ▪ Develop PLC Startup Plan that includes all field instruments and control devices in the Digester Improvements project. ▪ Provide operator training and as-built documentation.	▪ Requires fully developed Convention and Component Standards. ▪ Follows PLC Transition Plan.
5. Replace WRP PLCs (13) and HMI Graphics 48 months $1,777,000	▪ Modify Transition Plan sequencing of PLC/RTU replacements as necessary. ▪ Apply all Convention and Component standards to field instruments, control panels, and PLC hardware. ▪ Replace all obsolete PLCs with appropriately sized PLC model. ▪ Install new control panels with new PLCs. ▪ Develop individual PLC Cutover Plans that include all field instruments and control devices for each PLC. ▪ Provide operator training and as-built documentation.	▪ Requires library of control objects developed in Pilot PLC and HMI Graphics. ▪ Follows PLC Transition Plan. ▪ Sequencing of PLCs can be modified based on process needs and/or construction opportunities.
6. Replace RTUs (14) at TRI Sites and Disposal Fields 12 months $581,000	▪ Modify Transition Plan sequencing of PLC/RTU replacements as necessary. ▪ Apply all Convention and Component standards to field instruments, control panels, and RTU hardware. ▪ Replace all obsolete PLCs with appropriately sized PLC model at TRI remote sites and disposal fields. ▪ Install new control panels with new RTUs. ▪ Develop individual Cutover Plans that include all field instruments and control devices for each RTU. ▪ Provide operator training and as-built documentation.	▪ Requires library of control objects developed in Pilot PLC and HMI Graphics. ▪ Follows PLC Transition Plan. ▪ Sequencing of PLCs can be modified based on process needs and/or construction opportunities.
7. Upgrade Reports 6 months $96,000	▪ Integrate SCADA data with LIMS and WIMS data to automate operations reports for water quality.	▪ Based on database naming and data mapping standards.

Table 5-2. Summary Project Descriptions

Project Name Duration Cost	Project Purposes	Dependencies
8. Improve Physical Security 12 months $294,000	▪ Implement employee ID cards with controlled access to WRP perimeters and critical building entrances.	▪ Assumes the Network upgrades establish a segregated infrastructure for security system communications.

Based on the dependencies shown in the summary project descriptions, a phased approach to implementing the SCADA replacement/upgrade projects is recommended.

1. Phase 1 establishes the new SCADA/IT platform (hardware, networks, and standards) and includes projects 1, 2, and 3.
2. Phase 2 replaces the SCADA system over a transition period of 6 or more years and includes projects 4, 5, and 6.
3. Phase 3 integrates SCADA and IT data, improves physical security, and includes projects 7 and 8.

Phase 1 can start in July 2022. Phase 2 can start in January 2023, assuming the Convention and Component Standards are developed. Phase 2 begins with identifying the Pilot PLC Replacement domain and continues replacing PLCs over 4 or more years. This phasing schedule is shown in Figure 5-1. Phase 3 can start when the database naming and data mapping conventions are established.

5.4 Implementation Plan Summary

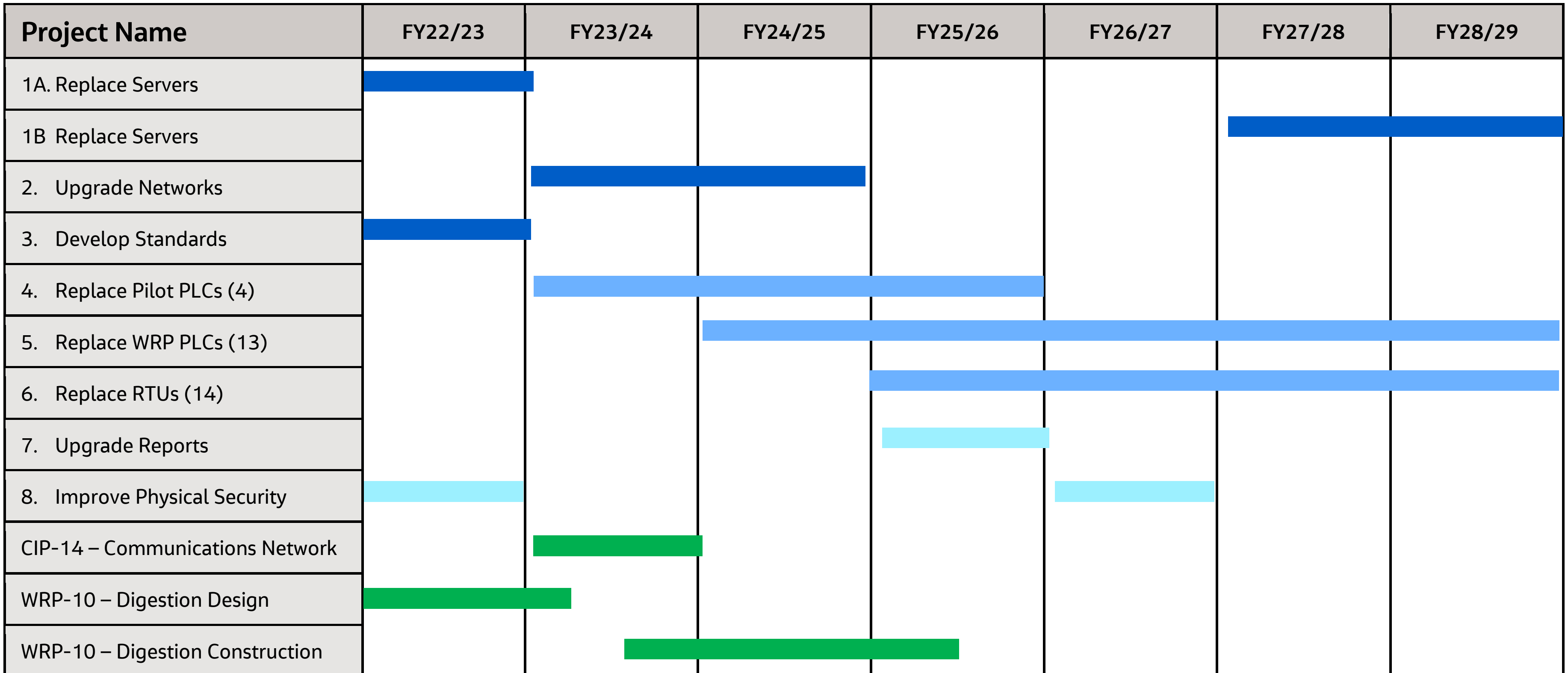
The Implementation Plan summary includes the following information:

1. Summary table of implementation plan costs (Table 5-3)
2. Gannt chart summarizing the estimated project schedule (Figure 5-1)
3. Phased cost schedule (Table 5-4)

Table 5-3. Implementation Plan Summary

Phase Name Duration, Phase Cost	Project Name	Duration (months)	Project Cost
1. Set the Foundation 24 months, $1,321,000	1. Replace Servers (FY22/23) Replace Servers (FY27/28)	12 15	$250,000 $500,000
	2. Upgrade Networks and Security	15	$330,000
	3. Develop Standards	6	$241,000
2. Replace SCADA System 60 months $3,021,000	4. Replace Pilot PLCs (4) and HMI Graphics	12	$663,000
	5. Replace WRP PLCs (13)	48	$1,777,000
	6. Replace RTUs (14)	12	$581,000
3. Optimize Asset Management 18 months $390,000	7. Upgrade Reports	6	$96,000
	8. Improve Physical Security	12	$294,000
Total Cost		**84**	**$4,732,000**

Combining the summarized project costs and schedules and using the phased approach to balance resource workloads produces an estimated phased cost schedule, as shown in Table 5-4.



Notes on Figure 5-1:

The CIP-14 – Communications Network project is superceded by the network upgrade (Project 2).

SCADA standards (Project 3) should be developed prior to 60% design in WRP-10 and the upgraded servers (Project 1A) should be operational prior to start of digestion construction (WRP-10).

The Pilot PLC replacement (Project 4) should coordinate closely with WRP-10.

LEGEND	
SCADA/IT MP Phase 1	
SCADA/IT MP Phase 2	
SCADA/IT MP Phase 3	
Master Sewer Plan	

Figure 5-1. Phased Project Schedule (Gannt Chart)

Table 5-4. Phased Cost Schedule

Project Name	FY22/23	FY23/24	FY24/25	FY25/26	FY26/27	FY27/28	FY28/29	Total Cost
1. Replace Servers	$ 250,000	$ -	$ -	$ -	$ -	$ 250,000	$ 250,000	$ 750,000
2. Upgrade Networks	$ -	$ 165,000	$ 165,000	$ -	$ -	$ -	$ -	$ 330,000
3. Develop Standards	$ 241,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 241,000
4. Replace Pilot PLCs (4)	$ -	$ 198,900	$ 265,200	$ 198,900	$ -	$ -	$ -	$ 663,000
5. Replace WRP PLCs (13)	$ -	$ -	$ 355,400	$ 355,400	$ 355,400	$ 355,400	$ 355,400	$1,777,000
6. Replace RTUs (14)	$ -	$ -	$ -	$ 145,250	$ 145,250	$ 145,250	$ 145,250	$ 581,000
7. Upgrade Reports	$ -	$ -	$ -	$ 96,000	$ -	$ -	$ -	$ 96,000
8. Improve Physical Security	$ 147,000	$ -	$ -	$ -	$ 147,000	$ -	$ -	$ 294,000
Totals	**$638,000**	**$363,900**	**$785,600**	**$795,550**	**$647,650**	**$750,650**	**$750,650**	**$4,732,000**

6. Organizational Assessment Review

In November 2020, an Organizational Assessment reviewed T-TSA's organizational structure, business practices, and performance metrics to prepare for impending capital improvement projects. The assessment compared T-TSA to similar organizations and wastewater agencies and provided recommendations for staffing, programmatic development, and contracted services. It considered the entire T-TSA organization and interviewed 94% of T-TSA staff. The results of the interviews provided a solid comparison to industry best practices and financial performance and a basis for staffing and programmatic recommendations in all departments (Operations/Laboratory, Maintenance, IT, Engineering/Safety, and Administration).

6.1 Organizational Progress

Jacobs' review of the of the 2020 Organizational Assessment focused specifically on SCADA/IT recommendations and options and describes status and progress made since November 2020. The 2020 Organizational Assessment grouped recommendations in staffing, programmatic, or contracted services groups. Table 6-1 lists each SCADA/IT recommendation or option with a progress description for each item. Checkmarks (✓) indicate recommendations that are considered complete.

Table 6-1. 2020 Organizational Assessment SCADA/IT Recommendation Progress

Recommendation	Status
Staffing	
✓ New CMMS/GIS Position	Completed. Position created and filled.
✓ Add 1 SCADA/IT Analyst	Completed. Position filled. Currently, two SCADA/IT Analysts are on staff.
✓ New Planner/Scheduler Position	Completed. The Planner/Scheduler role is distributed among the maintenance supervisors and the CMMS/GIS position. This is a common adaptation and best practice for comparable agencies.
▪ Use CMMS (Lucity) to analyze workload and needs	In progress. Lucity went live in December 2021 and is starting to collect workload data. A framework for analyzing SCADA/IT workload and resource needs is described in Section 5.2 – Workload Analysis.
Programmatic	
✓ Develop SCADA/IT Master Plan	Completed. Contracted with Jacobs Engineering in September 2021 to develop and deliver SCADA/IT Master Plan.
✓ Conduct Cybersecurity Evaluation	Completed. The SCADA/IT Master Plan evaluated current cybersecurity measures and network configuration. Cybersecurity improvements will be implemented with the network upgrade project described in the SCADA/IT Master Plan.
✓ Evaluate Physical Site Security	Completed. The SCADA/IT Master Plan evaluated physical site security and includes a site security improvement project description to install card readers for all employees and authorized visitors at perimeter and critical building access points.
▪ Establish SCADA comprehensiveness (Standards)	Defined. The SCADA/IT Master Plan defines a comprehensive set of SCADA/IT standards, including SCADA conventions, SCADA components and IT conventions. The Master Plan includes a standards development project description.

Table 6-1. 2020 Organizational Assessment SCADA/IT Recommendation Progress

Recommendation	Status
▪ Establish standard workflows and procedures	In progress. Lucity went live in December 2021 and standard workflows and procedures are being developed. The SCADA/IT workload analysis framework assumes general SCADA/IT work categories. See Section 5.2 – Workload Analysis.
▪ Integrate CMMS (Lucity) into daily use	In progress. Lucity will include the warehouse and inventory assets to streamline daily work order development and execution.
Contracted Services	
▪ Systems administration and integration	Started. Contracted Logically to provide technical support for IT servers, network, and cybersecurity from outside intruders. Other technical support services for SCADA technology may be contracted as necessary.
▪ Engineering support	Started. The development of comprehensive SCADA/IT standards will provide a guide for capital projects with a SCADA component to be developed consistently with documented T-TSA SCADA conventions and standard SCADA equipment.

6.1.1 Assessment Review Summary

The Assessment review recommends three development efforts to further implement SCADA/IT recommendations and sustain the SCADA/IT system. These development efforts are:

1. SCADA/IT Standards: Develop SCADA Conventions, SCADA Components, IT Conventions as described in the Implementation Plan Summary, Project 3 – Develop Standards.
2. Standard Workflows and Procedures: Standard SCADA/IT workflows and procedures are the basis for effective workload analysis. Section 6.2 – Workload Analysis outlines general SCADA/IT maintenance work categories in Table 6-2. T-TSA staff is currently developing standard work procedures in house and may procure contracted services to assist.
3. SCADA/IT Governance: Governance is the process to manage system integrations, technical support, and engineering support, and to maintain compliance with SCADA/IT standards. A general governance process is described in Section 6.3 – SCADA/IT Governance.

6.2 Workload Analysis

The purpose of workload analysis is to optimize resources that maintain and develop the SCADA/IT system. Resources include both T-TSA staff and contracted services, so this section classifies SCADA/IT maintenance by work best performed by T-TSA staff, contracted services, or a blend of both resources. For planning purposes, this section assumes all SCADA development work in CIP projects is performed by contracted services through Contracted Services Agreements (CSA) and reviewed by T-TSA staff. Note that the IT system is included in the network and server components. Staff development needs are therefore based on the maintenance work categories listed in Table 6-2.

6.2.1 Development Needs

T-TSA staff perform a wide variety of work to maintain and develop the SCADA system. In addition, T-TSA staff maintains the site security system on its own network within the SCADA network cabling. The site security system is separate from the SCADA system and adds a significant workload to T-TSA staff. Each

SCADA component and the site security system requires its own skill set and experience to perform maintenance work efficiently.

Table 6-2 cross references maintenance work categories with SCADA components to identify training needs. Maintenance work categories are listed from top to bottom by increasing experience requirements and SCADA components are listed from left to right by increasing skill requirements. SCADA component work is performed by T-TSA staff, CSAs, or a blend of T-TSA staff and CSAs as shown in Table 6-2.

Table 6-2. Staff Development Needs Matrix

	SCADA/IT System Components						
Maintenance Work	**Security**	**I&C**	**Panels**	**PLCs**	**HMI**	**Network [1]**	**Servers [1]**
Routine Maintenance	OJT	OJT	OJT	Siemens	Thin Clients		
Diagnostics/Analytics	OJT	OJT	OJT	Siemens	Siemens	SNMP	
Program Modifications	OJT	N/A	N/A	Siemens	Siemens		
Backup and Recovery	OJT	N/A	N/A	Siemens	In Servers		
Documentation [2]	OJT	OJT	OJT	OJT	OJT		
Planned Projects [2]	OJT	OJT	OJT	OJT	OJT		

Legend	
T-TSA	(blue hatching)
T-TSA/CSA	(green hatching)
CSA	(grey hatching)

Notes:

1. SCADA network and servers are managed and backed up by T-TSA staff. Enterprise network and servers are managed and backed up with CSA assistance.
2. Documentation and Planned Project work generally requires more experienced or senior level staff. Planned Projects are not CIP Projects.

OJT = on-the-job training

SNMP = Simple Network Management Protocol

6.2.2 Observations on Staff Development

Table 6-2 shows that most SCADA maintenance work is performed by T-TSA staff and supplemented by contracted services for specialized support as needed for network and server components. General observations include:

1. Planned projects for networks and servers, such as replacing the SCADA servers every 5 years, require contracted services to perform.
2. Enterprise IT server maintenance work and external cybersecurity is provided under a CSA (Logically).
3. Skill sets for most SCADA maintenance work are developed by on-the-job training (OJT), specifically, experience gained by familiarity with T-TSA standards, practices, facilities, and equipment.
4. The fundamental skill set for SCADA system development is knowledge and familiarity with the standards and products for the T-TSA SCADA system, including Siemens PLCs and Aveva HMI.
5. PLC and HMI maintenance work requires skill development by specialized training in Siemens PLCs and Aveva. Minimum training requirements include:
   a) Siemens TIA (Totally Integrated Automation) Portal Software Development Part 1
   b) Siemens TIA Portal Software Development Part 2
   c) Siemens Step 7
   d) Aveva InTouch HMI 2020 R2

    e) Aveva Application Server 2020 R2
6. Routine maintenance for HMI assumes thin clients for each HMI workstation. Thin clients are designed to be easily replaced by T-TSA staff without the need to modify HMI programming.
7. Backup and Recovery procedures assume the HMI application is included in the SCADA server backup and recovery system supported by T-TSA staff. Enterprise server backup and recovery is semi-automatic and supported by contracted services (Logically).
8. Training on Simple Network Management Protocol (SNMP) enables T-TSA staff to diagnose network faults and health.

These minimum knowledge requirements for the fundamental skill set establishes the workforce qualifications necessary to perform the workload outlined in Table 6-2. Additional training courses may be considered based on workload requirements and specific maintenance needs.

6.2.3 Staffing Levels

Based on the existing WRP SCADA system described in the SCADA/IT Master Plan (17 WRP PLCs, 14 remote sites (including 8 disposal fields), 5 servers, fiber and radio networks, and site security systems), a relative workload analysis is shown in Table 6-3. All values shown are full time equivalent (FTE) staff assigned to SCADA/IT system maintenance activities and does not include management or supervision.

Table 6-3. Workload Analysis

Maintenance Work	SCADA/IT Components (1 FTE = 2000 hrs/year)						
	Security	I&C	Panels	PLCs	HMI	Network	Servers
Routine Maintenance	0.1	0.2	-	0.1	-	0.1	-
Diagnostics/Analytics	-	0.2	0.1	0.1	-	0.1	-
Program Modifications	-	N/A	N/A	0.3	0.3	-	-
Backup and Recovery	-	N/A	N/A	0.2	0.2	-	0.1
Documentation	-	0.1	-	-	-	0.1	-
Planned Projects	-	0.2	0.2	0.1	0.1	-	-
Totals	**0.1**	**0.7**	**0.3**	**0.8**	**0.7**	**0.3**	**0.1**

Note:

Component workloads with no value shown are assumed to consume less than 200 hours per year.

6.2.4 Observations on Workload Analysis

The workload analysis estimates a total of 3.0 FTEs is needed to perform all SCADA/IT system maintenance work. An additional 0.3 FTE (20%) is assumed to allow T-TSA SCADA/IT staff to participate in workshops and reviews for CIP Projects.

A more quantitative workload analysis should be performed in the future to determine actual FTEs using workload data from Lucity, Inc. in the Maintenance Work categories shown in Table 6-3.

6.3 SCADA/IT Governance

Governance is the general process of how people in authority are held accountable by their stakeholders. Governance models include policy boards, management teams, cooperative agreements, and advisory panels or committees. The advisory panel is most appropriate model for SCADA/IT-related governance and development. This panel is called the **SCADA/IT Committee** and it is responsible for advising and communicating SCADA/IT-related concerns and plans to all stakeholders and T-TSA management.

6.3.1 SCADA/IT Committee

Membership and participation in the SCADA/IT Committee meetings represents all stakeholders. Because the SCADA system is primarily an Operations tool supported by Maintenance staff, both Operations and Maintenance representatives are standing members of the committee. Other stakeholder groups (Engineering, Management, Laboratory, etc.) are represented as needed, particularly when IT-related topics are discussed. Table 6-4 shows the stakeholder membership in the SCADA/IT Committee.

Table 6-4. SCADA/IT Committee Membership

Standing Membership	As-Needed Representation	
Maintenance Manager (Chair)	Engineering	Laboratory
Operations Manager	SCADA/IT Specialist	CMMS/GIS Technician
Electrical & Instrumentation Supervisor	Management	

Objectives and goals of the SCADA/IT Committee are based on the Objectives and Goals described for the SCADA/IT Master Plan. The committee can modify, update, and prioritize objectives and goals as evolving requirements place new demands on the SCADA system. The objectives and goals for the SCADA system are summarized here:

Objectives:

1. Consistent and sustainable SCADA system components, with all CIP Projects compliant with convention and component Standards.
2. Self-sufficiency in maintaining SCADA system assets and implementing minor upgrades, with appropriate staffing levels and training.

Goals:

1. Provide a highly reliable Operations tool that can optimize process monitoring and automation.
2. Provide a flexible platform that can adopt industry standards while adapting new technology.
3. Comply with SCADA-related cybersecurity standards while allowing secure remote access.
4. Provide useful information to external databases that can satisfy the data needs of T-TSA stakeholders.

6.3.2 SCADA/IT Governance Processes

The process of SCADA/IT governance consists primarily of scheduling and conducting meetings. SCADA/IT governance uses two meeting types, scheduled and ad-hoc. The purposes of these meetings are to identify, discuss, and document SCADA/IT-related concerns and to develop recommendations and action items to resolve those concerns. The standing agenda for regularly scheduled (annual, quarterly, or monthly) SCADA/IT Committee meetings is:

1. Call to Order (Take attendance)
2. SCADA/IT Budget (Review expenditures and projections).
3. Old Business (Review existing action items and recommendations)
4. New Business (Identify, discuss, and document new SCADA/IT-related concerns)
5. Wrap-up (Summarize action items and schedule next meeting)

Ad-hoc meetings are typically focused on one or two urgent topics and occur between regularly scheduled meetings. The standing agenda for ad-hoc SCADA/IT Committee meetings is:

1. Call to Order
2. Discuss Ad-hoc Topic
3. Next Steps

Processes that support SCADA/IT governance include:

- **Identification:** The most common form of SCADA/IT-related concern identification is a written (generally email) request or inquiry on a SCADA/IT-related issue. Some concerns may be generated from the observations captured in a work order. A verbal request should generate a written request. Any stakeholder can submit a request or inquiry.
- **Discussion:** All SCADA/IT-related inquiries and requests should be brought to the attention of the SCADA/IT Committee Chair. The Chair may respond to the request directly, place the item in a regularly scheduled meeting agenda, or schedule an ad-hoc meeting.
- **Documentation:** When a SCADA/IT Committee meeting is held, the Chair is responsible for taking notes and documenting the meeting. The Chair may delegate this responsibility and assign meeting notes to a committee member or a meeting participant.
- **Recommendation:** The results of SCADA/IT Committee meetings are recommendations or action items. Recommendations are typically captured in a memorandum or report, which may be written by others. Memorandums and reports accepted by the Chair may be used for communicating meeting results to all stakeholders.
- **Action Item:** Action items may generate a work order, a PO, or a CSA. Action items remain on the regularly scheduled meeting agenda until formally closed out by the committee.
- **Closeout:** Action items are typically closed out when the SCADA/IT system documentation (as-builts) of the SCADA/IT-related concern is updated or completed.

The sustainability and continuing development of the T-TSA SCADA/IT system is measured by the performance criteria listed in Section 4.1. Performance criteria are based on the strategic goals adopted by the SCADA/IT Committee. Performance criteria are grouped around reliability (where improvements are measured by reductions in downtime) and responsiveness (where improvements are measured by faster response times).

Every SCADA/IT Committee meeting should include a reminder to all participants of their responsibility to communicate the meeting's results to their respective stakeholder groups.

Appendix A
WRP and Flow Site Network Equipment

Appendix A. WRP and Flow Site Network Equipment

Location	Type	Model	Life Cycle	Tag Name or Location
WRP Network				
01 Operations	ISP Switch	Ciena 3930	Active product	
01 Operations	Router	Juniper SRX240	EOSL: 05/10/2019	
01 Operations	Router	Juniper SRX240	EOSL: 05/10/2019	
01 Operations	Switch	HP 2910al-24G-PoE	EOSL: 09/30/2014	01-27-1CSW1
01 Operations	Switch	HP 1801G-24G	EOSL: 04/01/2015	01-1A-1CSW1
01 Operations	Switch	HP 1801G-24G	EOSL: 04/01/2015	01-1A-1CSW2
01 Operations	Switch	HP 1801G-24G	EOSL: 04/01/2015	01-1A-1CSW3
01 Operations	Switch	HP 2920-48G	EOSL: 09/30/2014	01-1A-1CSW4
01 Operations	Switch	HP 2910al-24G-PoE	EOSL: 09/30/2014	01-1A-1CSW5
01 Operations	Switch	HP 1400-24G	EOSL: 03/01/2012	01-1A-1CSW6
02 AWT	Switch	HP 1801G-24G	EOSL: 04/01/2015	02-CP02A1-WCSW1
02 AWT	Analog 450MHz	Motorola MCS 2000	Discontinued: 09/01/2005	Tahoe City North/West
03 Shop	Switch	HP 1400-24G	EOSL: 03/01/2012	MAINT
03 Shop	Switch	HP 1400-24G	EOSL: 03/01/2012	03-1A-1CSW3
03 Shop	Switch	HP 2910al-24G-PoE	EOSL: 09/30/2014	03-1A-1CSW4
03 Shop	Switch	HP 2530	Active product	03-1A-1CSW5
03 Shop	Switch	HP 1801G-24G	EOSL: 04/01/2015	03-1A-3CSW1
03 Shop	Switch	Netgear XS708E	Active product	03-1A-3CSW2
03 Shop	Switch	Aruba 2520-8G w/POE	Active product	03-1A-3CSW3
53 C&CT	Switch	HP 1801G-24G	EOSL: 04/01/2015	53-1A-2CSW2
71 Dewatering	Switch	HP 2615	EOSL: 02/15/2015	
71 Dewatering	Switch	Netgear JFS524	EOSL: 01/23/2018	
75 Chlorine	Switch	HP 2615	EOSL: 02/15/2015	75-CP75C-WCSW1
81 BNR	Switch	HP 2615	EOSL: 02/15/2015	81-CP81B-WCSW2
81 BNR	Switch	N-Tron 317FX-SC	Active product	
81 BNR	Switch	N-Tron 900B	EOSL: 09/30/2014	
Disposal Fields 1	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 1
Disposal Fields 2	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 2
Disposal Fields 3	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 3

Appendix A. WRP and Flow Site Network Equipment

Location	Type	Model	Life Cycle	Tag Name or Location
Disposal Fields 4	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 4
Disposal Fields 5	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 5
Disposal Fields 6	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 6
Disposal Fields 7	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 7
Disposal Fields 8	900MHz	Phoenix Contact 2867131	Obsolete	Disposal Field Cabinet 8
Disposal Fields 9	900MHz	Phoenix Contact 2867131	Obsolete	02 AWT PLC07
Flow Sites				
Dollar Hill	Cellular 3G/4G	Cradlepoint IBR600	EOSL: 03/31/2020	
Rampart	Cellular 3G/4G	Cradlepoint IBR600	EOSL: 03/31/2020	
Alpine Meadows	Cellular 3G/4G	Cradlepoint IBR600	EOSL: 03/31/2020	
Olympic Valley	Cellular 3G/4G	Cradlepoint IBR600	EOSL: 03/31/2020	
Granite Flat	Cellular 3G/4G	Cradlepoint IBR600	EOSL: 03/31/2020	
Tahoe City North/West	Analog 450MHz	Motorola XPR 5350	EOSL: Unknown	

Note:

EOSL = end of service life

Appendix B
WRP and Flow Site PLC Equipment

Appendix B. WRP and Flow Site PLC Equipment

PLC ID	Location	Siemens Model	Firmware	Lifecycle Status	PLC Name
WRP PLCs					
PLC65	53 C&CT	6ES7 212-1BD30-0XB0	V2.2	Cancelled: 09/18/2012	CCT_WATER_DETECTOR
PLC04	53 C&CT	6ES7 315-2AG10-0AB0	V2.0	Discontinued: 10/01/2020	BNR_OAF
PLC05	32 Digester	6ES7 315-2AG10-0AB0	V2.0	Discontinued: 10/01/2020	DIGESTER
PLC08	53 C&CT	6ES7 315-2AG10-0AB0	V2.0	Discontinued: 10/01/2020	CCT_DIG
PLC40	81 BNR	6ES7 417-4XL00-0AB0	V3.1	Discontinued: 05/22/2018	BNR
PLC60	53 AWT	6ES7 317-2EK13-0AB0	V2.6	Discontinued: 10/01/2020	DATA_COL_PSA
PLC03	04 SHS	6ES7 315-2EH14-0AB0	V3.1	Phase-out: 10/01/2023	04 SHS/HYDRATED LIME
PLC06	71 Dewatering	6ES7 315-2EH14-0AB0	V3.1	Phase-out: 10/01/2023	DEWATERING
PLC07	02 AWT	6ES7 315-2EH14-0AB0	V3.1	Phase-out: 10/01/2023	DISP_CAUSTIC
PLC10	53 C&CT	6ES7 315-2EH14-0AB0	V3.1	Phase-out: 10/01/2023	CCT_NEW
PLC21	71 Dewatering	6ES7 315-2EH14-0AB0	V3.2	Phase-out: 10/01/2023	M71151
PLC22	71 Dewatering	6ES7 315-2EH14-0AB0	V3.2	Phase-out: 10/01/2023	M71152_NEW_MAIN_DRIVE
PLC30	04 Thickening	6ES7 315-2EH14-0AB0	V3.2	Phase-out: 10/01/2023	THICKENING_NEW
PLC50	52 Oxygenation Basins	6ES7 315-2EH14-0AB0	V3.2	Phase-out: 10/01/2023	O2_BASIN
PLC62	02 AWT	6ES7 317-2EK14-0AB0	V3.1	Phase-out: 10/01/2023	AWT_FILTER_NEW
PLC09	75 Chlorine	6ES7 212-1BE40-0XB0	V4.2	Active support	CHLORINE_BUILDING
PLC63	32 Digester	6ES7 212-1HE40-0XB0	V4.0	Active support	PLC-63-DIG-LEL
BACnet	32 Digester	N/A	N/A	Obsolete (Date N/A)	BACnet control system
	Disposal Field 1	6ES7 216-2BD22-0XB0	Unknown	Cancelled: 01/10/2017	

Appendix B. WRP and Flow Site PLC Equipment

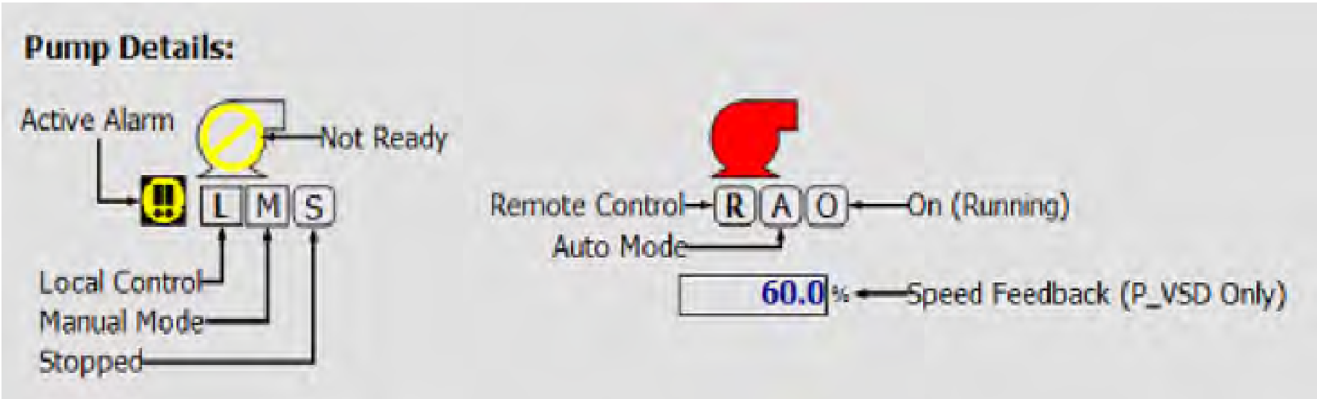
PLC ID	Location	Siemens Model	Firmware	Lifecycle Status	PLC Name
	Disposal Field 2	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
	Disposal Field 3	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
	Disposal Field 4	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
	Disposal Field 5	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
	Disposal Field 6	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
	Disposal Field 7	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
	Disposal Field 8	6ES7 216-2BD22-0XB0	?	Cancelled: 01/10/2017	
TRI Flow Sites					
PLC71	Dollar Hill TRI	6ES7 211-1BE40-0XB0	V4.0	Active support	
PLC73	Rampart TRI	6ES7 211-1BE40-0XB0	V4.0	Active support	
PLC74	Alpine Meadows TRI	6ES7 211-1BD30-0XB0	V2.2	Cancelled: 09/18/2012	
PLC75	Olympic Valley TRI	6ES7 211-1BE40-0XB0	V4.0	Active support	
PLC76	Granite Flat TRI	6ES7 211-1BE40-0XB0	V4.0	Active support	
N/A	Tahoe City North/ West TRI	Motorola ACE3600		Cancelled: Unknown	

Notes:

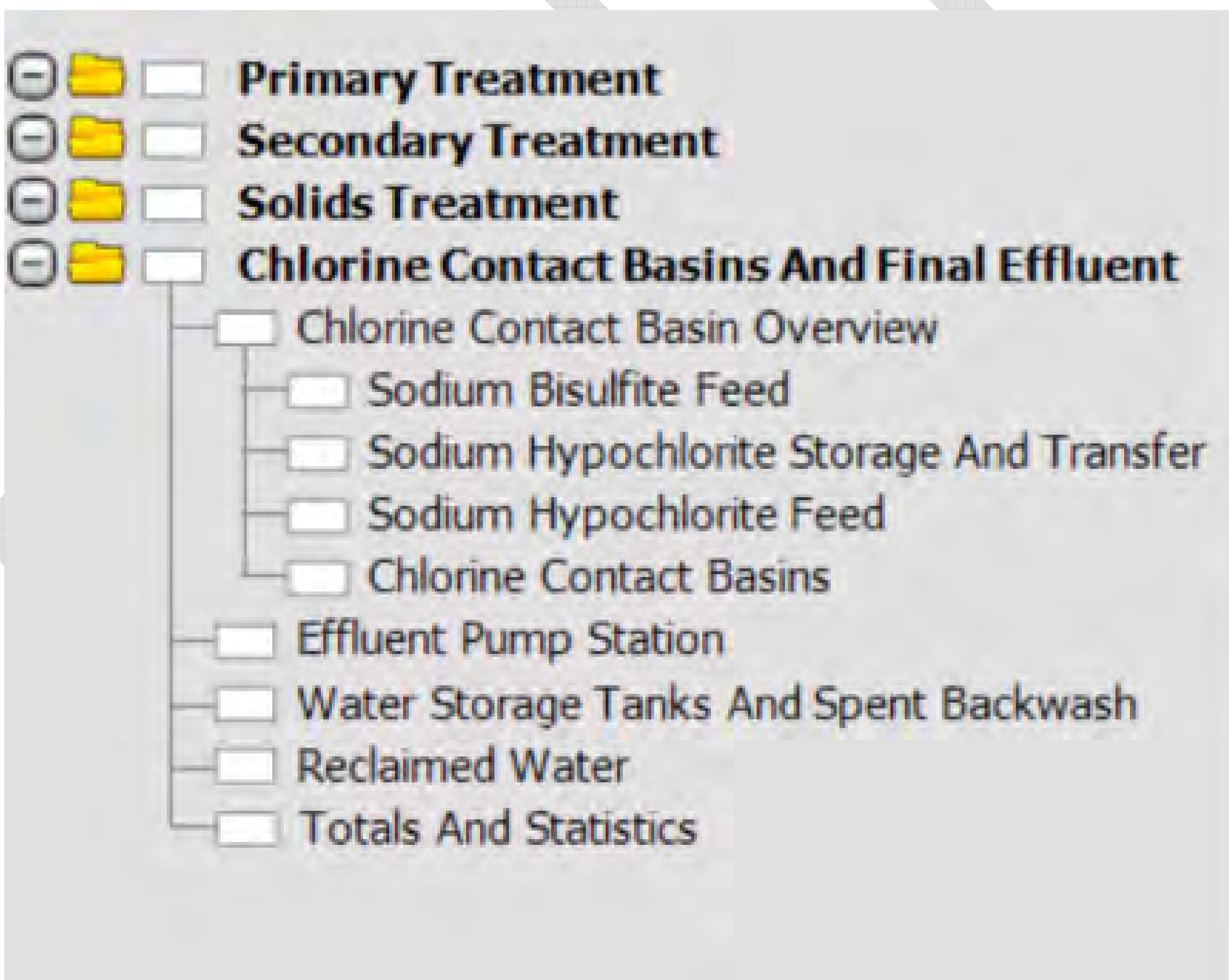
AWT = Advanced Water Treatment
PLC = programmable logic controller
TRI = Truckee River Interceptor
WRP = Water Reclamation Plant

Appendix C
High-Performance Graphics Examples

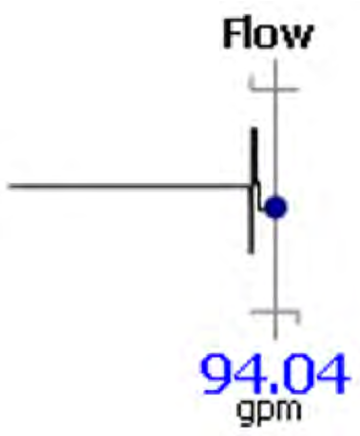
Pump Symbol Examples:



✓ Navigation Tree Example:



Analog Point Example, with Mini Trend:



Pop-up Display Examples for an Analog Display:

Appendix D
Detailed Project Descriptions

Detailed project descriptions are provided in the following tables for:

Project 1. Replace Servers
Project 2. Upgrade Networks and Security
Project 3. Develop Standards
Project 4. Replace Pilot PLC and HMI Graphics
Project 5. Replace PLCs and HMI Graphics
Project 6. Replace RTUs (TRI sites and Disposal Fields)
Project 7. Upgrade Reports
Project 8. Improve Physical Security

Project No. 1 – Replace Servers	
Project Purposes	▪ Replace obsolete server hardware and software to provide a current, reliable platform for SCADA applications. ▪ Develop new SCADA platform to run in parallel with old system to minimize operational disruptions. ▪ Implement reliable backup/recovery systems and practices. ▪ Upgrade Aveva SCADA InTouch to System Platform current version. ▪ Upgrade Aveva Historian to latest version. ▪ Develop Server Cutover Plan.
Primary Tasks	▪ Design for Servers, Bridge PLC, and Server Network. ▪ Develop design packages (50%, Final) and conduct design workshops for T-TSA review. ▪ Programming and Configuration of Servers ▪ Develop cutover and testing plans. ▪ Conduct Factory Test of Servers (including historians, domain controllers, backup and recovery systems, alarming software). ▪ Perform installation, field testing and commissioning. ▪ Conduct training.
Major Deliverables	▪ Configured, tested, and commissioned SCADA servers and workstations. ▪ Configured, tested, and commissioned Historian, Alarm software and backup and recovery packages. ▪ Completed Training Material and O&M Manuals.
Schedule and Dependencies	▪ Minimal demands (review and assistance only) on T-TSA resources. ▪ Can be completed under a Contracted Services Agreement (CSA). ▪ Requires fully developed Convention Standards. ▪ Establishes the SCADA platform for all subsequent SCADA projects. ▪ Estimated completion in 15 months.
Class 4 Cost Estimate	$250,000 (estimated costs of in-house server upgrade in FY22/23) $430,000 (assuming contracted services for FY22/23 and FY 23/24, see Appendix E for details) $500,000 (assuming contracted services for FY27/28 and FY 28/29)

Project No. 2 – Upgrade Networks and Security	
Project Purposes	▪ Upgrade the WRP SCADA network. ▪ Upgrade the remote site radio network. ▪ Replace obsolete multi-mode fiber-optic with single mode. ▪ Replace obsolete non-managed switches and flat architecture with robust, self-healing dual-ring network. ▪ Develop Network Cutover Plan.
Primary Tasks	▪ Design physical and logical network. The design shall adhere to the Department of Homeland Security and NIST network standards. ▪ Coordinate remote access and security requirements with the T-TSA IT department. ▪ Develop design packages (50%, Final) and conduct design workshops for T-TSA review. ▪ Programming and Configuration of network switches. ▪ Conduct Factory Test of network switches and remote access firewalls. ▪ Perform installation, field testing and commissioning. ▪ Conduct training.
Project Deliverables	▪ Configured, tested, and commissioned physical and logical network (fiber and network switches) ▪ Configured, tested, and commissioned Remote Access hardware and software ▪ Completed Training Material and O&M Manuals
Schedule and Dependencies	▪ Minimal demands (review and assistance only) on T-TSA resources. ▪ Should supercede CIP-14 – Communications Network Replacement. ▪ Can be completed under a CSA. ▪ Can be scheduled independently, but cutover planning must coordinate with other projects. ▪ Estimated duration 15 months
Class 4 Cost Estimate	$315,000

Project No. 3 – Develop Standards	
Project Purposes	▪ Establish design guide for all SCADA programming and interfaces to IT applications.
Primary Tasks	▪ Develop T-TSA SCADA convention standards, including control philosophy, database naming, PLC/HMI control objects for Siemens PLCs, HMI graphics, and alarm management. ▪ Develop T-TSA SCADA component standards, including field instruments, wiring, PLC hardware and software, and control panels. ▪ Develop T-TSA IT convention standards, including data map and key indexes to FMS, CMMS, SCADA, WQIS, and GIS. ▪ Develop PLC/RTU Transition Plan that includes 17 WRP PLCs and 14 RTUs (TRI sites and disposal fields).
Project Deliverables	▪ SCADA/IT Design Guide (including SCADA/IT conventions and SCADA components) ▪ PLC/RTU Transition Plan (covers 5 years)
Schedule and Dependencies	▪ Urgency to establish SCADA standards to guide PLC design in WRP-14 – Digestion Improvements Project. The PLC replacement in WRP-14 will establish a library of PLC/HMI control objects to use in all subsequent PLC replacements. ▪ Design can be completed under a CSA. ▪ Estimate duration of 6 months
Class 4 Cost Estimate	$241,000

Project No. 4 – Replace Pilot PLCs (4) and HMI Graphics	
Project Purposes	▪ Replace Siemens PLCs identified for Pilot PLC Replacement with new PLCs. ▪ Program new PLCs to use new PLC/HMI control objects. ▪ Install new control panels with new PLCs. ▪ Apply all Convention and Component standards to field instruments, wiring and PLC hardware. ▪ Develop Cutover Plans. ▪ Provide operator training and as-built documentation.
Primary Tasks	▪ Develop Process Control Narratives and I/O lists for each process area. ▪ Design control panel and PLC hardware, including remote I/O panels. ▪ Develop packages (30%, 60%, and Final) and conduct design workshops for T-TSA review. ▪ Develop individual cutover plans for 5 PLCs that includes all field instruments and control devices for each PLC. ▪ Conduct Factory Tests of PLC and HMI software. ▪ Perform Startup, field testing and commissioning work for the PLC and SCADA control programs and the Historian and Alarming software. ▪ Conduct training.
Project Deliverables	▪ Configured, tested, and commissioned PLC panels (including PLC programs). ▪ Updated Control Narratives ▪ Updated SCADA database (including Historian and Alarming software) ▪ New configuration files for all DeviceNet converted devices. ▪ Final Training and O&M documentation.
Schedule and Dependencies	▪ Coordinated with WRP-14 – Digestion Improvements Project design and construction schedule. ▪ Elevated demands (review, shared program development, field assistance, startup coordination, and training participation) on T-TSA resources ▪ Requires Convention and Component Standards developed in Project 3. ▪ Estimated duration of 15 months
Class 4 Cost Estimate	$663,000

Project No. 5 – Replace WRP PLCs (13) and HMI Graphics	
Project Purposes	▪ Replace all remaining Siemens PLCs (after Pilot Project) with new PLCs. ▪ Apply all Convention and Component standards to field instruments, wiring and PLC hardware. ▪ Program new PLCs to use new PLC/HMI control objects. ▪ Install new control panels with new PLCs. ▪ Develop Cutover Plans. ▪ Provide operator training and as-built documentation.
Primary Tasks	▪ Develop Process Control Narratives and I/O lists for each process area. ▪ Design control panel and PLC hardware, including remote I/O panels. ▪ Develop packages (30%, 60%, and Final) and conduct design workshops for T-TSA review. ▪ Develop individual cutover plans for 13 PLCs that includes all field instruments and control devices for each PLC. ▪ Conduct Factory Tests of PLC and HMI software. ▪ Perform Startup, field testing and commissioning work for the PLC and SCADA control programs and the Historian and Alarming software. ▪ Conduct training.
Project Deliverables	▪ Configured, tested, and commissioned PLC panels (including PLC programs). ▪ Updated Control Narratives ▪ Updated SCADA database (including Historian and Alarming software) ▪ New configuration files for all DeviceNet converted devices. ▪ Final Training and O&M documentation
Schedule and Dependencies	▪ Elevated demands (review, shared program development, field assistance, startup coordination, and training participation) on T-TSA resources ▪ Requires Convention and Component Standards developed in Project 3. ▪ Estimated duration of 48 months.
Class 4 Cost Estimate	$1,777,000

Project No. 6 – Replace RTUs (TRI Sites and Disposal Fields)	
Project Purposes	▪ Replace all TRI sites and disposal field PLCs with new RTUs. ▪ Apply all Convention and Component standards to field instruments, wiring and RTU hardware. ▪ Program new RTU to use new PLC/HMI control objects. ▪ Install new control panels with new PLCs. ▪ Develop Cutover Plans. ▪ Provide operator training and as-built documentation.
Primary Tasks	▪ Design control panel and RTU hardware. ▪ Develop packages (30%, 60%, and Final) and conduct design workshops for T-TSA review. ▪ Develop cutover plans for 14 RTUs that includes all field instruments and control devices. ▪ Conduct Factory Tests of PLC and HMI software. ▪ Perform Startup, field testing and commissioning work for the PLC and SCADA control programs and the Historian and Alarming software. ▪ Conduct training.
Project Deliverables	▪ Configured, tested, and commissioned PLC panels (including PLC programs). ▪ Updated SCADA database (including Historian and Alarming software) ▪ New configuration files for all DeviceNet converted devices. ▪ Final Training and O&M documentation
Dependencies	▪ Elevated demands (review, shared program development, field assistance, startup coordination, and training participation) on T-TSA resources ▪ Requires Convention and Component Standards developed in Project 3. ▪ Estimated duration of 48 months.
Class 4 Cost Estimate	$581,000

Project No. 7 – Upgrade Reports	
Project Purpose	▪ Integrate SCADA data with LIMS and WIMS data to automate operations reports for water quality.
Primary Tasks	▪ Implement Water Quality System (WIMS, LIMS, or other) ▪ Interface SCADA with WQIS to automate reporting ▪ Complete application upgrades to replace PIS ▪ WQIS implementation can be decoupled, integration follows pilot PLC replacement.
Project Deliverables	▪ Development of report format. ▪ Completed and tested WQIS automated report generation.
Schedule and Dependencies	▪ Based on database naming and data mapping standards. ▪ Estimated duration of 6 months.
Class 4 Cost Estimate	$96,000

Project No. 8 – Improve Physical Security	
Project Purpose	▪ Produce design documents and provide construction management assistance to procure and install employee ID card readers for secure access at WRP perimeters and critical building entrances.
Primary Tasks	▪ Design perimeter and building access security system. ▪ Develop security bid packages (60%, and Final) and conduct design workshops for T-TSA review. ▪ Develop startup and testing plan. ▪ Assist in startup, testing and commissioning work for the perimeter and building security access system. ▪ Assist in vendor-provided training on new security system.
Project Deliverables	▪ Design packages (60% and Final); includes security specifications, drawings (site plans, building plans), power over Ethernet (PoE) load calculations, bandwidth and storage calculations, bill of materials. ▪ Final Acceptance Report (documenting startup and testing process)
Schedule and Assumptions	▪ 12-month duration (design and construction). ▪ 50 employees (ID cards individually assigned) ▪ 2 perimeter gates (1 outer and 1 inner perimeter) ▪ 30 building entrances (critical buildings only, non-critical buildings will continue to be keyed) ▪ Door hardware and electronic lock sets included in Architectural specifications and drawings. ▪ Perimeter fencing and perimeter barriers included in Civil drawings. ▪ Fiber optic network infrastructure will be available. ▪ No additional video surveillance or intrusion detection.
Class 4 Cost Estimate	$310,000

Appendix E
Detailed Cost Estimates

	Projects Cost Summary	**FY 1**	**FY 2**	**FY 3**	**FY 4**	**FY 5**	**FY 6**	**FY 7**	
	SCADA/IT Master Plan Projects								
1	Upgrade Servers	$ 250,000	$ -	$ -	$ -	$ -	$ 250,000	$ 250,000	$ 750,000
2	Upgrade Networks and Security	$ -	$ 165,000	$ 165,000	$ -	$ -	$ -	$ -	$ 330,000
3	Develop Standards	$ 241,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 241,000
4	Replace Pilot PLCs (4) and HMI Graphics	$ -	$ 198,900	$ 265,200	$ 198,900	$ -	$ -	$ -	$ 663,000
5	Replace WRP PLCs (13) and HMI Graphics	$ -	$ -	$ 355,400	$ 355,400	$ 355,400	$ 355,400	$ 355,400	$ 1,777,000
6	Replace RTUs (14) at TRI Sites and Disposal Fields	$ -	$ -	$ -	$ 145,250	$ 145,250	$ 145,250	$ 145,250	$ 581,000
7	Upgrade Reports	$ -	$ -	$ -	$ 96,000	$ -	$ -	$ -	$ 96,000
8	Improve Physical Security	$ 147,000	$ -	$ -	$ -	$ 147,000	$ -	$ -	$ 294,000
	TOTAL	***$638,000***	***$363,900***	***$785,600***	***$795,550***	***$647,650***	***$750,650***	***$750,650***	***$4,732,000***

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	Track	Project Cost	Design Labor	Implementation Labor	Construction Management	Project Management	Hardware Costs	Software Costs	Misc. Costs	TTSA Support	Contingency
	SCADA/IT Master Plan Projects										
1	Upgrade Servers	$ 430,000	$ 82,000	$ 40,000	$ 33,000	$ 43,000	$ 78,000	$ 15,000	$ 40,000	$ -	$ 99,000
2	Upgrade Networks and Security	$ 330,000	$ 72,000	$ 24,000	$ 25,000	$ 28,000	$ 54,000	$ 20,000	$ 31,000	$ -	$ 76,000
3	Develop Standards	$ 241,000	$ 150,000	$ -	$ -	$ 35,000	$ -	$ -	$ -	$ -	$ 56,000
4	Replace Pilot PLCs (4) and HMI Graphics	$ 663,000	$ 52,000	$ 149,000	$ 43,000	$ 70,000	$ 196,000	$ -	$ -	$ -	$ 153,000
5	Replace WRP PLCs (13) and HMI Graphics	$ 1,777,000	$ 104,000	$ 377,000	$ 69,000	$ 160,000	$ 637,000	$ -	$ 20,000	$ -	$ 410,000
6	Replace RTUs (14) at TRI Sites and Disposal Fields	$ 581,000	$ 40,000	$ 36,000	$ 33,000	$ 30,000	$ 280,000	$ -	$ 28,000	$ -	$ 134,000
7	Upgrade Reports	$ 96,000	$ -	$ 54,000	$ 3,000	$ 17,000	$ -	$ -	$ -	$ -	$ 22,000
8	Improve Physical Security	$ 294,000	$ 26,000	$ 15,000	$ -	$ 12,000	$ 60,000	$ -	$ 113,000	$ -	$ 68,000
	Totals	***$ 4,412,000***	***$ 526,000***	***$ 695,000***	***$ 206,000***	***$ 395,000***	***$ 1,305,000***	***$ 35,000***	***$ 232,000***	***$ -***	***$ 1,018,000***

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1	Upgrade Servers						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			400	$ 81,520	$ 82,000	
	Develop Detailed Design for Server Architecture	Eng	$ 235	160	$ 37,600		
	Develop Design Drawings	Tech	$ 166	120	$ 19,920		
	Develop Develop Server Cutover Plan	Stf	$ 200	120	$ 24,000		
	Implementation Labor			240	$ 39,840	$ 40,000	
	Programming and Configuration	Tech	$ 166	160	$ 26,560		
	Factory Test	Tech	$ 166	80	$ 13,280		
	Construction Management			184	$ 33,264	$ 33,000	
	Field Installation and Testing	Stf	$ 200	80	$ 16,000		
	Field Installation and Testing	Tech	$ 166	80	$ 13,280		
	Provide Training	Tech	$ 166	24	$ 3,984		
	Project Management			164	$ 42,961	$ 43,000	
	Project Management	PM	$ 268	82	$ 21,976		
	Admin Support	Adm	$ 95	41	$ 3,895		
	QA/QC	QC	$ 190	41	$ 7,790		
	Other Direct Costs		6%		$ 9,300		percentage of labor fees, except for PM
	Hardware Costs				$ 78,000	$ 78,000	
	Server Hardware		$ 10,000	2	$ 20,000		
	Server Switches		$ 5,000	2	$ 10,000		
	UPS		$ 2,000	1	$ 2,000		
	Thin Clients (Workstations)		$ 3,000	12	$ 36,000		
	Alarm Notification Switches / Modems		$ 5,000	2	$ 10,000		
	Software Costs				$ 15,000	$ 15,000	
	SQL Server		$ 15,000	1	$ 15,000		
	VMWare				$ -		
	Misc. Costs				$ 40,000	$ 40,000	
	Control Room Improvements		$ 40,000	1	$ 40,000		Server racks, furniture
	Contingency				$ 99,300	$ 99,000	
	30% of Total Fees		30%		$ 99,300		percentage of total fees
	Project Cost					**$ 430,000**	

Assumptions and Notes:
The Upgrade Server cost estimate is for one project. This estimate does not include a second Upgrade Server project in 5 years, and assumes contracted labor for all replacement services.

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2	Upgrade Networks and Security						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			340	$ 71,620	$ 72,000	
	Design FO network - Construction Drawings	Eng	$ 235	180	$ 42,300		
	Design the WAN / LAN for the WRP	Eng	$ 235	40	$ 9,400		
	Develop Design documents	Tech	$ 166	120	$ 19,920		
	Bid Phase Support	Eng	$ 235	0	$ -		
	Develop Network Cutover Plan				$ -		
	Evaluate radio/5G upgrades				$ -		
	Implementation Labor			144	$ 23,904	$ 24,000	
	Programming and Configuration	Tech	$ 166	120	$ 19,920		
	Factory Test	Tech	$ 166	24	$ 3,984		
	Construction Management			144	$ 25,264	$ 25,000	
	Field Installation and Testing	Stf	$ 200	40	$ 8,000		
	Field Installation and Testing	Tech	$ 166	80	$ 13,280		
	Conduct training	Tech	$ 166	24	$ 3,984		
	Project Management			126	$ 27,924	$ 28,000	
	Project Management	PM	$ 197	63	$ 12,411		
	Admin Support	Adm	$ 87	31.5	$ 2,741		
	QA/QC	QC	$ 175	31.5	$ 5,513		
	Other Direct Costs		6%		$ 7,260		percentage of labor fees, except for PM
	Hardware Costs				$ 54,000	$ 54,000	
	Firewalls / Network Switches		$ 5,000	4	$ 20,000		
	Fiber Optic Cabling (See assumptions and notes below)		$ 4.00	6000	$ 24,000		
	Fiber Patch Panels		$ 1,000	10	$ 10,000		
	Software Costs				$ 20,000	$ 20,000	
	Firewall Software		$ 20,000	1	$ 20,000		
	Misc. Costs				$ 31,000	$ 31,000	
	Contractor to install fiber (see assumptions and notes)		$ 2.50	6000	$ 15,000		
	Contractor testing of terminations and OTDR tests		$ 200	80	$ 16,000		
	Contingency				$ 76,200	$ 76,000	
	30% of Total Fees		30%		$ 76,200		
	Project Cost					$ 330,000	

Assumptions and Notes:
Single Mode fiber assumed to be $4 per linear foot
Assumed 6000 feet of single mode fiber to be pulled
Assumed 10 new patch panels to be installed
25 hours of Contactor labor per 1000 feet at $100 / hour = $2.50/foot
Assume 2 Contractors at $100/hour for 80 hours to test terminations

3	Develop Standards						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			640	$ 150,400	$ 150,000	
	Convention Standards	Eng	$ 235	280	$ 65,800		
	Component Standards	Eng	$ 235	240	$ 56,400		
	Develop PLC Transition Plan	Eng	$ 235	120	$ 28,200		
	Project Management			128	$ 35,272	$ 35,000	
	Project Management	PM	$ 268	64	$ 17,152		
	Admin Support	Adm	$ 95	32	$ 3,040		
	QA/QC	QC	$ 190	32	$ 6,080		
	Other Direct Costs		6%		$ 9,000		percentage of labor fees, except for PM
	Contingency				$ 55,500	$ 56,000	
	30% of Total Fees		30%		$ 55,500		percentage of total fees
	Project Cost			**768**		**$ 241,000**	

Assumptions and Notes:

4	Replace Pilot PLCs (4) and HMI Graphics						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			240	$ 52,200	$ 52,000	
	Detailed Design				$ -		
	Develop PCN, I/O lists, PLC parts list	Eng	$ 235	80	$ 18,800		
	Bid Support	Eng	$ 235	0	$ -		
	Develop PCN, I/O lists, PLC parts list	Stf	$ 200	80	$ 16,000		
	Cutover Plan	Eng	$ 235	40	$ 9,400		
	Cutover Plan	Stf	$ 200	40	$ 8,000		
	Implementation Labor			880	$ 148,840	$ 149,000	
	Programming and Configuration of PLC and HMI	Tech	$ 166	800	$ 132,800		
	Factory Test	Eng	$ 235	40	$ 9,400		
	Factory Test	Tech	$ 166	40	$ 6,640		
	Construction Management			240	$ 42,560	$ 43,000	
	Field Installation and Testing	Stf	$ 200	80	$ 16,000		
	Field Installation and Testing	Tech	$ 166	80	$ 13,280		
	Training	Tech	$ 166	80	$ 13,280		Includes development of training materials
	Project Management			272	$ 70,468	$ 70,000	
	Project Management	PM	$ 268	136	$ 36,448		
	Admin Support	Adm	$ 95	68	$ 6,460		
	QA/QC	QC	$ 190	68	$ 12,920		
	Other Direct Costs		6%		$ 14,640		percentage of labor fees, except for PM
	Hardware Costs				$ 196,000	$ 196,000	
	New PLC Panels and Wiring-Fabrication		$ 40,000	4	$ 160,000		
	New PLCs		$ 4,000	4	$ 16,000		
	Network Switches		$ 5,000	4	$ 20,000		
	Contingency				$ 153,000	$ 153,000	
	30% of Total Fees		30%		$ 153,000		percentage of total fees
	Project Cost					**$ 663,000**	

Assumptions and Notes:

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5	Replace WRP PLCs (13) and HMI Graphics						
	ITEM	**Rate**	**Unit Cost**	**Qty**	**Cost**	**Master Plan Cost**	**Notes**
	Design Labor			480	$ 104,400	$ 104,000	
	Detailed Design				$ -		
	Develop PCN, I/O lists, PLC parts list	Eng	$ 235	160	$ 37,600		
	Bid Support	Eng	$ 235	0	$ -		
	Develop PCN, I/O lists, PLC parts list	Stf	$ 200	160	$ 32,000		
	Cutover Plan	Eng	$ 235	80	$ 18,800		
	Cutover Plan	Stf	$ 200	80	$ 16,000		
	Implementation Labor			2240	$ 377,360	$ 377,000	
	Programming and Configuration of PLC and HMI	Tech	$ 166	2080	$ 345,280		
	Factory Test	Eng	$ 235	80	$ 18,800		
	Factory Test	Tech	$ 166	80	$ 13,280		
	Configuration of DeviceNet devices	Tech	$ 166	0	$ -		
	Construction Management			380	$ 68,520	$ 69,000	
	Field Installation and Testing	Stf	$ 200	160	$ 32,000		
	Field Installation and Testing	Tech	$ 166	160	$ 26,560		
	Training	Tech	$ 166	60	$ 9,960		Includes development of training materials
	Project Management			620	$ 160,255	$ 160,000	
	Project Management	PM	$ 268	310	$ 83,080		
	Admin Support	Adm	$ 95	155	$ 14,725		
	QA/QC	QC	$ 190	155	$ 29,450		
	Other Direct Costs		6%		$ 33,000		percentage of labor fees, except for PM
	Hardware Costs				$ 637,000	$ 637,000	
	New PLC Panels and Wiring-Fabrication		$ 40,000	13	$ 520,000		
	New PLCs		$ 4,000	13	$ 52,000		
	Network Switches		$ 5,000	13	$ 65,000		
	Misc. Costs				$ 19,920	$ 20,000	
	DeviceNet Upgrades	Tech	$ 166	120	$ 19,920		
	Contingency				$ 410,100	$ 410,000	
	30% of Total Fees		30%		$ 410,100		percentage of total fees
	Project Cost					**$ 1,777,000**	

Assumptions and Notes:

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6	Replace RTUs (14) at TRI Sites and Disposal Fields						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			188	$ 40,260	$ 40,000	
	Conduct Network and Path Analysis	Eng	$ 235	0	$ -		
	Conduct Network and Path Analysis	Stf	$ 200	0	$ -		
	Develop Report	Eng	$ 235	60	$ 14,100		
	Develop PCN, I/O lists, PLC parts list	Eng	$ 235	0	$ -		
	Bid Support	Eng	$ 235	0	$ -		
	Develop PCN, I/O lists, PLC parts list	Stf	$ 200	112	$ 22,400		
	Cutover Plan	Eng	$ 235	16	$ 3,760		
	Implementation Labor			200	$ 35,960	$ 36,000	
	Programming and Configuration of RTU	Tech	$ 166	120	$ 19,920		
	Factory Test	Eng	$ 235	40	$ 9,400		
	Factory Test	Tech	$ 166	40	$ 6,640		
	Configuration of DeviceNet devices	Tech	$ 166	0	$ -		
	Construction Management			184	$ 33,264	$ 33,000	
	Field Installation and Testing	Stf	$ 200	80	$ 16,000		
	Field Installation and Testing	Tech	$ 166	80	$ 13,280		
	Training	Tech	$ 166	24	$ 3,984		
	Project Management			114	$ 29,939	$ 30,000	
	Project Management	PM	$ 268	57	$ 15,276		
	Admin Support	Adm	$ 95	28.5	$ 2,708		
	QA/QC	QC	$ 190	28.5	$ 5,415		
	Other Direct Costs		6%		$ 6,540		percentage of labor fees, except for PM
	Hardware Costs				$ 280,000	$ 280,000	
	New PLC Panels and Wiring-Fabrication		$ 15,000	14	$ 210,000		
	New PLCs		$ 2,000	14	$ 28,000		
	Radios		$ 2,000	14	$ 28,000		
	Switches		$ 1,000	14	$ 14,000		
	Misc. Costs				$ 28,000	$ 28,000	
	Antenna poles and wiring		$ 2,000	14	$ 28,000		
	Contingency				$ 134,100	$ 134,000	
	30% of Total Fees		30%		$ 134,100		percentage of total fees
	Project Cost					**$ 581,000**	

Assumptions and Notes:

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7	Upgrade Reports						
	ITEM	**Rate**	**Unit Cost**	**Qty**	**Cost**	**Master Plan Cost**	**Notes**
	Design Labor			0	$ -	$ -	
	Develop PCN, I/O lists, PLC parts list	Eng	$ 235	0	$ -		
	Bid Support	Eng	$ 235	0	$ -		
	Develop PCN, I/O lists, PLC parts list	Tech	$ 166	0	$ -		
	Site Investigation	Eng	$ 235	0	$ -		
	Site Investigation	Stf	$ 200	0	$ -		
	Implementation Labor			320	$ 54,480	$ 54,000	
	Programming and Configuration (LIMS and WIMS)	Tech	$ 166	240	$ 39,840		
	Factory Test	Tech	$ 166	40	$ 6,640		
	Factory Test	Stf	$ 200	40	$ 8,000		
	Construction Management			16	$ 2,656	$ 3,000	
	Field Installation and Testing	Stf	$ 200	0	$ -		
	Field Installation and Testing	Tech	$ 166	0	$ -		
	Provide Training	Tech	$ 166	16	$ 2,656		
	Project Management			68	$ 17,377	$ 17,000	
	Project Management	PM	$ 268	34	$ 9,112		
	Admin Support	Adm	$ 95	17	$ 1,615		
	QA/QC	QC	$ 190	17	$ 3,230		
	Other Direct Costs		6%		$ 3,420		percentage of labor fees, except for PM
	Hardware Costs				$ -	$ -	
	Radios		$ 2,000	0	$ -		
	Switches		$ 1,000	0	$ -		
	Misc. Costs				$ -	$ -	
	Antenna poles and wiring		$ 2,000	0	$ -		
	Contingency				$ 22,200	$ 22,000	
	30% of Total Fees		30%		$ 22,200		percentage of total fees
	Project Cost			**404**		**$ 96,000**	

Assumptions and Notes:

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8	**Improve Physical Security**						
	ITEM	**Rate**	**Unit Cost**	**Qty**	**Cost**	**Master Plan Cost**	**Notes**
	Design Labor			112	$ 26,320	$ 26,000	
	Detailed Design for 30 card readers, 6 reader panels	Eng	$ 235	96	$ 22,560		
	Bid Support	Eng	$ 235	16	$ 3,760		
	Implementation Labor			120	$ 15,000	$ 15,000	
	Programming and Configuration	Sec	$ 125	120	$ 15,000		Assume 4 hours x 30 card readers
	Project Management			46	$ 11,902	$ 12,000	
	Project Management	PM	$ 268	23	$ 6,164		
	Admin Support	Adm	$ 95	11.5	$ 1,093		
	QA/QC	QC	$ 190	11.5	$ 2,185		
	Other Direct Costs		6%		$ 2,460		percentage of labor fees, except for PM
	Hardware Costs				$ 60,000	$ 60,000	
	Card Reader Panels (includes wiring connections)		$ 10,000	6	$ 60,000		Each Reader Panel includes software
	Misc. Costs				$ 112,500	$ 113,000	
	Wiring and Conduit per Card Reader (50' from panel)		$ 750	30	$ 22,500		
	Door locking hardware mounting and installation		$ 3,000	30	$ 90,000		
	Contingency				$ 67,800	$ 68,000	
	30% of Total Fees		30%		$ 67,800		percentage of total fees
	Project Cost					**$ 294,000**	

Assumptions and Notes: