Jacobs

SCADA Master Plan

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City of Livermore

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Project Manager: Michael Johnson
Author: Dhumal Aturaliye

Jacobs Engineering Group Inc.

2485 Natomas Park Drive, Suite 600
Sacramento, California 95833-2937
United States
O +
F +1.916.920.8463
www.jacobs.com

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2	11/12/21	Add Convention and Component Standards (Chapters 2 and 3 (Draft)	MDJ	JH	MDJ
3	12/14/21	SCADA Master Plan (Final)	MDJ	DNA	MDJ

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Acronyms and Abbreviations

%	percent
AACE	Association for Advancement of Cost Estimating
AI	analog input
ANSI	American National Standards Institute
AOI	Add On Instructions
AR	Administrative Regulations
ASTM	ASTM International (American Society for Testing and Materials)
CPU	Central Processing Unit
CSI	Construction Specification Institute
DHS	Department of Homeland Security
DIN	Deutsche Industrie-Norm
DLR	Device Level Ring
DMZ	demilitarized zone
DO	dissolved oxygen
FB	function block
FTE	full time equivalent
GBT	gravity belt thickener
GHz	gigahertz
HIM	Human Interface Module (MCC / VFD keypad)
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISA	International Society for Automation
ISO	International Organization for Standardization
IT	information technology
I/O	input/output
KPI	Key Process Indicator
LD	ladder diagram
LOR	Local Off Remote
LS	lift station
MCC	motor control center
MHz	Megahertz
N/A	not applicable
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NIST	National Institute of Standards and Technology
O&M	operation and maintenance

OIP	Operator Interface Panel
OJT	on-the-job training
ORP	oxygen-reduction potential
OSHA	Occupational Safety and Health Administration
OT	Operations Technology
P&ID	process and instrumentation diagram
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PO	purchase order
PS	pump station
PSA	Professional Services Agreement
RAS	return activated sludge
RIO	Remote Input / Output
SCADA	Supervisory Control And Data Acquisition
SFC	sequential function chart
SNMP	Simple Network Management Protocol
SOP	Standard Operating Procedure
SQL	structured query language
ST	structured text
TM	technical memorandum
TSS	total suspended solids
UDT	User-Defined Data Type
UL	Underwriters Laboratory, Inc.
UPS	uninterruptible power supply
UV	ultraviolet
UVT	ultraviolet transmissivity
VAC	volt(s) alternating current
VBA	Visual Basic for Applications
VDC	volt(s) direct current
VFD	variable-frequency drive
WAS	waste activated sludge
WRD	Water Resources Division
WRP	Water Reclamation Plant

Implementation Plan

1.1 Introduction

The City of Livermore (Livermore) Public Works Department Water Resources Division (WRD) receives treated water from Zone 7 Water Agency, and is responsible for water distribution, wastewater collection, wastewater treatment, and stormwater management. The WRD uses a supervisory control and data acquisition (SCADA) system to monitor and control the Water Reclamation Plant (WRP), four wastewater lift stations, three stormwater lift stations, and the water distribution system (including five pump stations and three reservoir sites). The SCADA system monitors all controllable water, wastewater, and stormwater facilities owned by Livermore. The data the SCADA system collects is critical to supporting operations and regulatory reporting functions.

The SCADA Master Plan focuses on upgrade and replacement needs for all hardware and software components, except for instrumentation and control (I&C) devices. During development of the SCADA Master Plan, improvements in I&C procurement, standardization, installation, or maintenance may be identified. Such improvements may be developed as separate projects in the implementation plan.

The SCADA Master Plan project consists of a series of workshops designed to develop three main chapters: Implementation Plan, Conventions Standards, and Component Standards. Each workshop produced a technical memorandum (TM) that forms a section in each chapter. The TMs and Master Plan chapters are shown in Table 1-1.

Table 1-1. SCADA System Master Plan Outline

SCADA System Master Plan Outline		
Chapter Title/TM Topic	**Workshop Conducted**	**Chapter/TM Delivered**
System Assessment	September 11,2020	October 9, 2020
Industry Standards and Trends	October 15, 2020	November 13, 2020
Gap and Alternatives Analysis	November 12,2020	December 24, 2020
Implementation Planning	December 17, 2020	February 26, 2021
Implementation Plan	**Draft March 12, 2021**	**Final April 30, 2021**
Control Philosophy [a]	January 21, 2021	March 5, 2021
Database Standards [a]	February 18, 2021	March 19, 2021
Control Objects [a]	March 18, 2021	April 14, 2021
Graphics Presentation [a]	April 15, 2021	May 11, 2021
Alarms and Reporting [a]	May 13, 2021	June 9, 2021
Convention Standards	**Draft June 11, 2021**	**Final July 23, 2021**
Instrumentation and Control Panels	June 10, 2021	August 9, 2021
Servers and Networks [b]	August 5, 2021	October 8, 2021
Documentation and Contracting	September 2, 2021	October 22, 2021
Governance and Staff Development	October 6, 2021	November 3, 2021
Component Standards	**Draft November 12, 2021**	**Final December 14, 2021**

[a] Includes Operations participants [b] Includes Cybersecurity participant

The WRD staff who participated in workshops and reviewed TMs and Master Plan chapters were:

SCADA System Master Planning Team		Operations	Cybersecurity
Yanming Zhang	Andy Hall	Jimmie Truesdell	Donald Hester
Rick Teczon	Kevin Kolte	Kevin Kepler	
Brian Zumwalt	Arup Paul	Russell Smith	
Josh Adams			

1.2 System Assessment

1.2.1 Existing WRP SCADA System Assessment

The original architecture of the WRP communication system was built in 1992. A multimode fiber network provides infrastructure links between the Programmable Logic Controller (PLC) panels in each facility. Currently, the control system is based on a Rockwell Automation FactoryTalk SE (Site Addition) SCADA platform. The PLCs at each facility are different models, all from Rockwell Automation. Local Operator Interface Panels (OIP) are PanelViews, also from Rockwell. Figure 1-1 shows an overview of the PLCs at the WRP. Table 1-2 provides a summary of the PLC panels at each location.

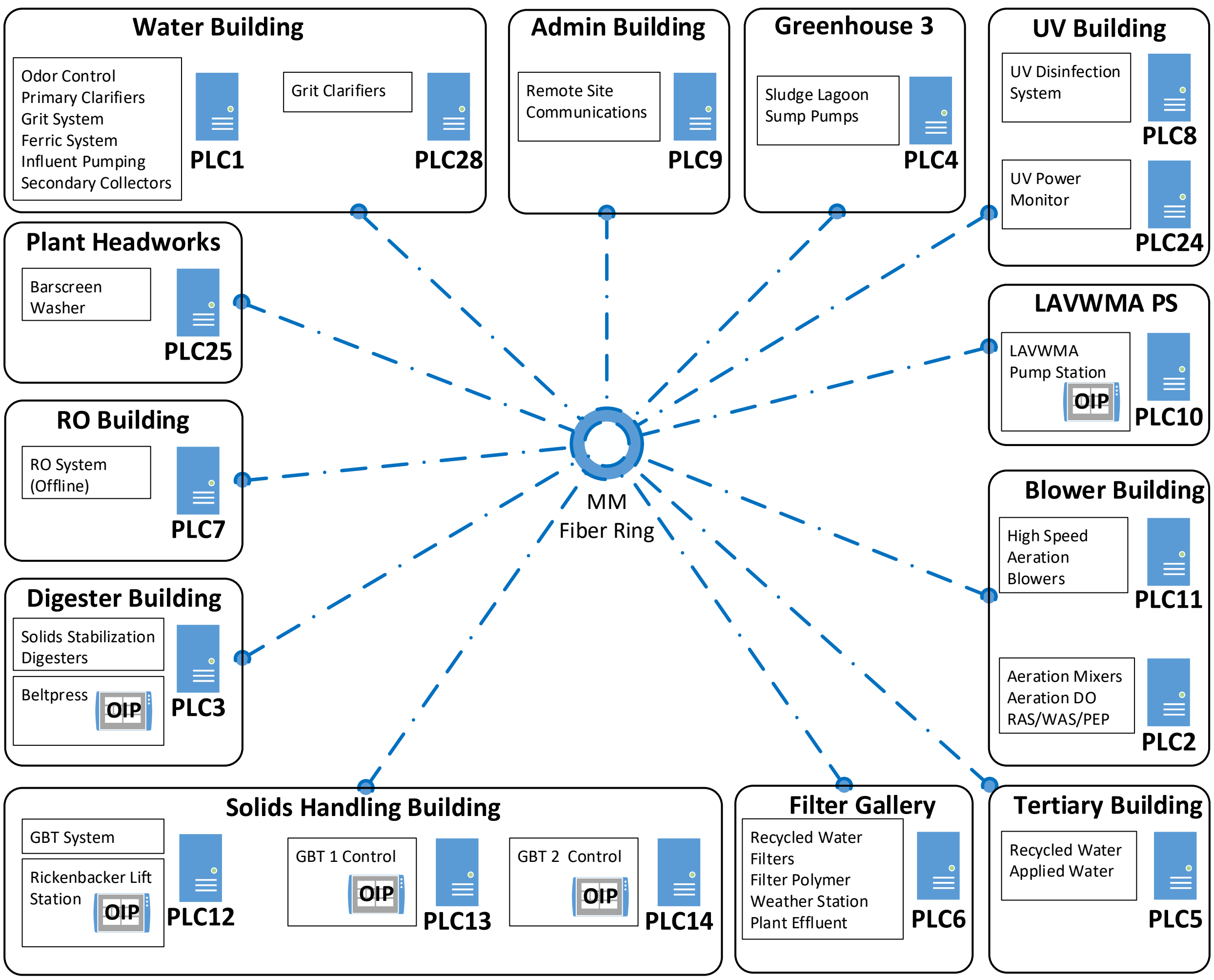


Figure 1-1. WRP PLC Overview

Most of the network switches are from Rockwell Automation (Stratix), Moxa, or Cisco. Figure 1-2 shows a diagram of the backbone Ethernet network for the WRP and remote sites. The system has two servers in physically separate buildings. The primary server is located in the Reverse Osmosis building and the backup server is located in the tertiary building. Table 1A-1 in Appendix 1-A provides a list of the computers (workstations and servers) at the plant.

Table 1-2. WRP PLC Panel Summary

PLC ID	Location	PLC Model	Comments
PLC1	Water Building	PLC5/40E Series E	Linked to the Headworks, Bar Screens, and Primaries processes
PLC28	Water Building	ControlLogix	Grit Classifiers
PLC25	Headworks	MicroLogix	Bar Screen Washer
PLC2	Blower Building	PLC5/40E Series D-CE	Current project is moving all DeviceNet drives to Ethernet The older PLC will be moved to a Remote IO at another building Includes Aeration Mixers, DO Monitoring, RAS, WAS
PLC11	Blower Building	ControlLogix 5572	High Speed Aeration Blowers
PLC3	Digester Building	PLC5/40E Series D-CE	Has one RIO (3B) linked to this PLC External IT (Comcast) links to the plant network here Includes PanelView for the Belt Press
PLC4	Greenhouse	PLC5/40E Series D-CE	Communicates to PLC8 Has a fiber link to PLC10
PLC5	Tertiary	ControlLogix 5570	All DeviceNet drives in this facility are migrated to Ethernet The backup server is located adjacent to this PLC (next room)
PLC6	Filter	ControlLogix 5563	This PLC is in a small, air-conditioned hut on the filter deck. The Ethernet antenna to El Charro is located on top of this hut.
PLC7	Reverse Osmosis	PLC5/40E Series D-CE	This PLC is decommissioned and will be removed soon. This room currently houses the primary servers which will be moved to the Laboratory building for the remodeling.
PLC8	UV Building	SLC 1747	UV Disinfection System includes a packaged unit from the vendor. The WRD has no access to sections of the PLC program. The communication hardware is obsolete.
PLC24	UV Building	MicroLogix 1100	UV Power Monitor
PLC9	Administration Building	CompactLogix 5335E	This panel serves as the communication hub for the plant.
PLC10	LAVWMA Pump Station	CompactLogix 5335E	This panel is for the Effluent Pumps used occasionally for maintenance (includes PanelView)
PLC12	Solids Handling Building	ControlLogix 5562	GBT System, Rickenbacker Lift Station (Includes PanelView)
PLC13	GBT1	ControlLogix 5562	Packaged PLC from the GBT vendor, includes PanelView
PLC14	GBT2	ControlLogix 5562	Packaged PLC from the GBT vendor, includes PanelView

Note:
DO = dissolved oxygen
GBT = gravity belt thickener
IT = information technology
I/O = input/output
RAS = return activated sludge
RIO = Remote Input / Output
UV = ultraviolet
WAS = waste activated sludge

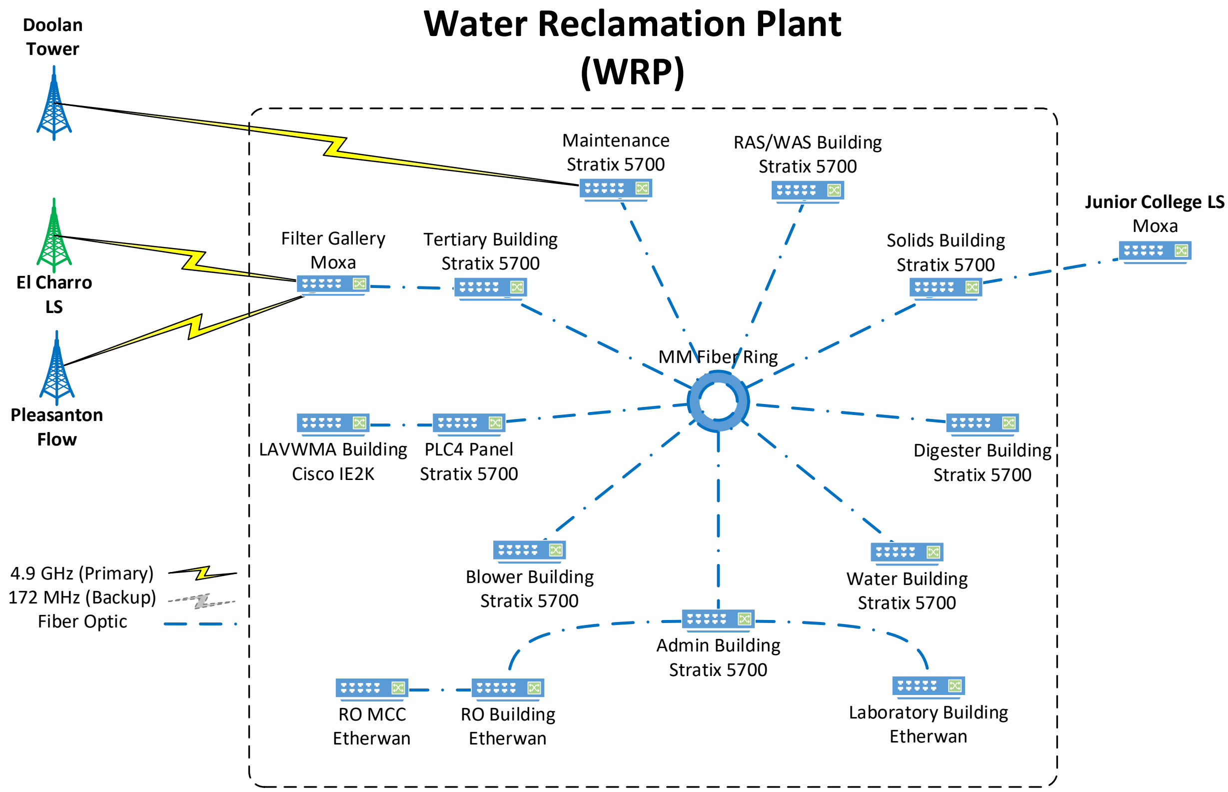


Figure 1-2. WRP Ethernet Overview

Observations

The main control system is based on Allen-Bradley PLCs with preprogrammed manual and automatic controls distributed throughout the WRP. Communications among the PLCs and to the human machine interfaces (HMI) is based on a fiber-optic ring. The control system network is isolated from the internet. The only outside connection is a paging modem that does not allow any incoming links. The HMIs are based on an Allen-Bradley's FactoryTalk SE, which also provides historical data to the Historian. Alarm paging notification is managed by WIN911, an add-on software package.

1) Allen-Bradley Observations

   a) Some of the older PLC models at the plant (PLC5/40) are no longer supported by Allen-Bradley. Plant PLCs range from 28 years old to less than 1 year and include seven different Allen-Bradley models.

   b) The WRP includes three packaged systems (bar screens, gravity belt thickeners and ultraviolet [UV]). All other control logic is programmed in the PLCs of the main control system.

   c) The existing version of FactoryTalk SE client runs on Windows (multiple versions ranging from XP to Windows 10) and needs to be upgraded.

   d) The WRD has a service agreement with Rockwell Automation for technical support. There are no agreements for the instrument suppliers, network switches or (Dell) servers.

   e) The WRP includes three versions of PanelViews (OIP), each with its own configuration software.

2) Network Observations
   a) The plant network architecture is 15 years old and based on a multi-mode fiber-optic ring.
   b) Many control devices (variable-frequency drive [VFD], motor control centers [MCCs]) use DeviceNet to connect to a PLC. Some have been upgraded to Ethernet, and remaining DeviceNet connections are planned for upgrade.
   c) Many instruments are installed with HART capabilities, but HART has not yet been implemented.
   d) The plant network is segregated from the business information technology (IT) network. The existing plant network is flat with no segmentation, includes multiple single points of failure, and is therefore prone to failure.
   e) The plant security cameras share the same fiber cables and paths as the main control system but are on separate fibers within the fiber cables.
   f) The communication dialout modems at the plant are not supported by the manufacturer.
3) Control Room Observations
   a) The main control room is monitored 24 hours on all days. All the remote sites are monitored (no remote control) from the main control room.
   b) The main control room has four SCADA workstations. One workstation is dedicated to WIN911 and another workstation is dedicated to the security cameras.
   c) The plant uses WIN911 for alarm paging and it needs to be upgraded.
4) Historian Observations
   a) The control system data is archived on a structured query language (SQL) database Historian, located at the plant. All the analog values are saved on the Historian. The SQL database and related software packages were configured in-house and are no longer supported.
   b) The SCADA and Historian servers are 10+ years old and should be replaced.
   c) Currently backup data and data configurations use a RAID 5 configuration and single external hard drive.
   d) Currently, the primary SCADA server takes multiple ‘reboots’ to startup correctly.
   e) A monthly report is generated (in Microsoft Excel) using Report Builder. The report consists of data pulled from the Historian and some operator-entered data.
5) SCADA Client Workstation Observations
   a) The plant has fifteen SCADA clients located in different buildings.
   b) The remote sites do not have installed SCADA clients.

1.2.2 Existing Remote Site SCADA System Assessment

All the remote sites are monitored in the main control room at the WRP. All control logic for the remote sites is performed in the remote site PLC. In addition, most of the remote sites have their own security camera systems. The data from the security cameras is stored locally at each site. A list of remote sites is shown in Table 1-3.

Table 1-3. Summary of Remote Site PLCs

Water Sites	PLC Model	Wastewater Sites	PLC Model
Doolan Tower and Reservoir	CompactLogix 5335E	El Charro Lift Station	CompactLogix 5335E
Airway Pump Station	CompactLogix 5335E	Airport Lift Station	Micrologix 1500
Pleasanton Flow	CompactLogix 5335E	Junior College (JC) Lift Station[a]	CompactLogix 5335E
Dalton Reservoir	CompactLogix 5335E		
Trevarno Pump Station	CompactLogix 5335E	**Stormwater Sites**	**PLC Model**
Altamont Tanks	Micrologix 1500	N. Livermore Pump Station	Micrologix 1200
Altamont Pump Station	CompactLogix 5370	North P Street Pump Station	Micrologix 1200
Vasco Pump Station	ControlLogix 5570	Murrieta Pump Station	Micrologix 1200
Oakville Pump Station	CompactLogix 5335E		

[a.] JC Lift Station has a direct Fiber-optic Link to the WRP

Four WRD staff conducted remote site visits with the Jacobs team on September 28, 2020. Remote sites visited included:

- Doolan Tower
- Junior College (JC) Lift Station
- Airway Pump Station
- Vasco Pump Station
- Dalton Pump Station
- P Street Stormwater Pump Station
- Murrieta Pump Station

Network Assessment

Two licensed radio systems communicate with the remote sites. Both licenses belong to Livermore. The radio systems are designed to be redundant. When communication fails on the primary radio, the link moves to the backup radio. Some sites have only serial communications.

1) Primary system is a 4.9 gigahertz (GHz) Ethernet radio from Esteem.
2) Backup system is a 172 megahertz (MHz) serial radio from Teledesign.

The Doolan tower serves as the serial radio master site and includes a data concentrator PLC. The PLC at the Doolan tower switches between the serial and Ethernet radios when one system fails. The Doolan tower communicates to the radios and PLC at the WRP Administration Building.

A remote site network drawing is shown on Figure 1-3. The lift station (LS) sites shown in green are wastewater or stormwater locations, while the pump station (PS) sites shown in blue are water locations. All the sites with serial radios communicate with the master radio at the Doolan tower.

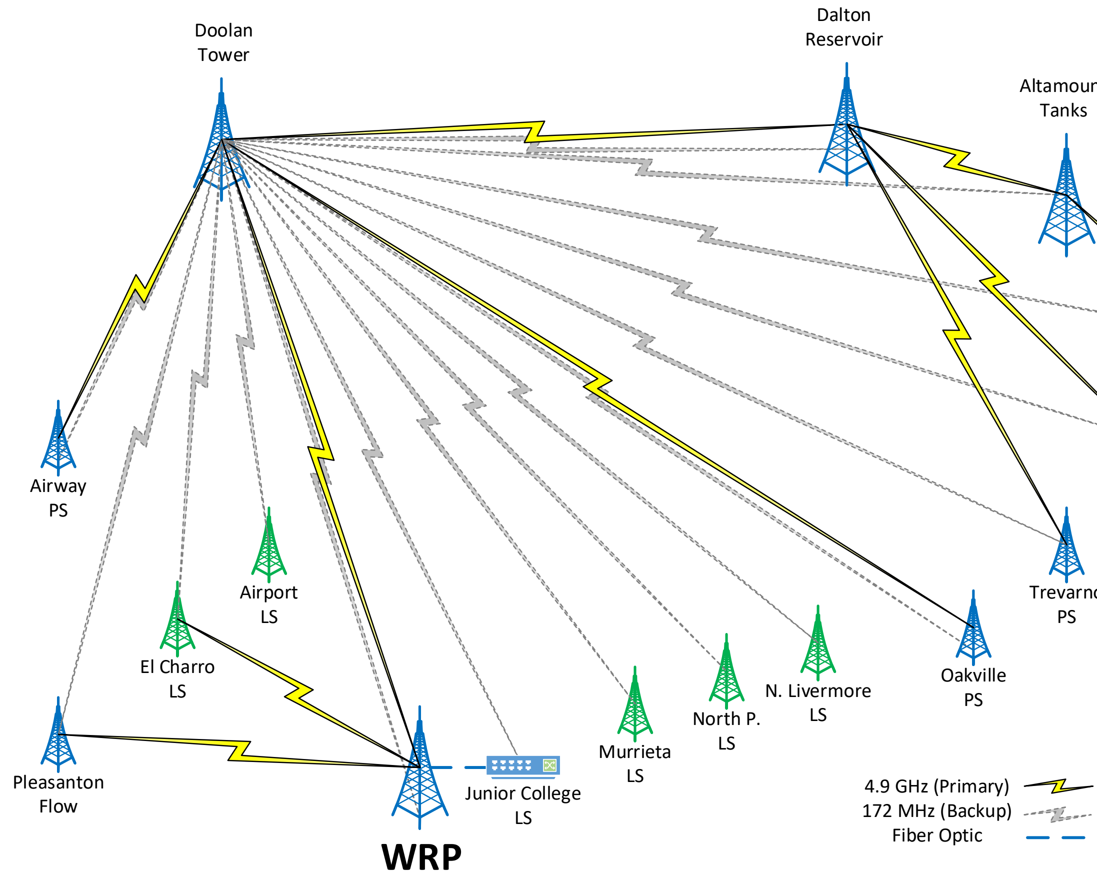


Figure 1-3. Remote Site Network

Observations

1) Remote Site Network:

Both the primary and backup radio systems fail intermittently due to pathway obstructions. New construction has introduced obstructions that required re-routing of Ethernet radios. Serial radio antennas have been moved by other City departments (i.e., P-Street pump station), and not all antennas are mounted on proper poles. A fiber link exists between the El Charro PS and the Airport LS, but the Airport LS has an older PLC that needs to be upgraded to complete the link.

2) Site-specific Notes:

a) At Doolan, the master PLC communicates with Remote input/output (I/O) cabinets at each tank (one for potable water and two for recycle water). While the police own the building that houses the PLC panel, the WRD is responsible for the seismic and structural requirements for the tower.

b) The Junior College Lift Station site has DeviceNet links to the MCCs. There are IT fibers that run parallel to the control system fiber between this lift station and the WRP.

c) The Ethernet radio signal at Airway PS is partially blocked by tall trees adjacent to the station.

d) The PLC at Vasco station was upgraded in 2015 and has a Prosoft module to convert the serial links to the PLC.

e) The panel at Dalton PS was completed in 2019-2020. The new Ethernet radios and antennas were installed and commissioned with that upgrade.

3) Notes on control logic:

   a) All the remote sites are controlled by the local PLCs. The WRP only monitors these sites.

   b) The potable water pumps all operate based on the discharge tank level (Doolan or Dalton). The pumps start when the tank level is below a low-level set point and stop at a high-level set point. If the signal from the remote level transmitter fails, the pumps stop operation.

   c) The stormwater pumps all operate based on a local level sensor and pump when there is water in the sump. The P-Street pumps typically only operate during storms, while the Murrieta pumps, because of their proximity to the creek, operate much more frequently.

1.2.3 SCADA Replacement Drivers

Based on the issues and concerns identified in the proposal process, the Jacobs team and WRD staff refined and expanded these issues into the main drivers for the replacement (or upgrade) of the existing SCADA system. The original issues are highlighted in **bold**.

- **Technical obsolescence**
  - PLC5/40s are no longer supported by Allen-Bradley, and WRD has already replaced some. The most recent replacements are PLC7 (decommissioned) and PLC2 (in process). There are three more PLC5/40s that need to be replaced.
  - DeviceNet (connecting control devices to PLCs) is obsolete and WRD has already upgraded some MCCs. The most recent are the Tertiary Building (PLC5 – complete) and the Blower Building (PLC2 – in process).
  - Multi-mode fiber is still serviceable, but single mode fiber has become the industry trend. The 15-year-old ring architecture should be revisited to strategize replacement options.
  - Some FactoryTalk workstations run on Windows XP, which lost support from Microsoft in 2014. Workstation life cycle is around 3 to 5 years, and the industry trend is moving toward thin clients, which don’t require individual software licenses. A FactoryTalk upgrade must be concurrent with hardware and operating system upgrades.
  - FactoryTalk servers are 10+ years old, while the average server life cycle is 5 years. The backup server already requires multiple reboots to restart, placing backup and recovery processes at risk. Backup and recovery software need to be upgraded.
- **Lack of Documentation and Standards:**
  - WRD staff knows where the existing multi-mode fiber has been pulled, but record drawings may not show these routes on site plans
  - The lack of documented tagging and programming standards has already created inconsistencies between processes constructed in different projects. These inconsistencies result in difficulties maintaining instrumentation, control hardware, control strategies, and documentation.
  - The WRP includes 7+ different models of Allen-Bradley PLCs and the remote sites include 5 different models. Some models overlap between the WRP and remote sites. These models require 3 different PLC programming packages to maintain. Current Allen-Bradley products can reduce these numbers to 2 models for all locations and 1 common programming package.
  - The WRP includes 3 different versions of the Panelview displays and these can also be consolidated into one version.

- **Self-Sufficiency:**
  - Defined as the ability to self-perform all routine maintenance work as an 80 percent (%) base workload, including hardware and software diagnostics, system health analytics, backup and recovery, minor repairs, part replacements, control logic adjustments, and graphic modifications.
  - Supplemented by contract resources to perform major replacements and upgrades, new construction projects, and technical support requiring product expertise.
  - Supported by **system maintainability**, defined as conformance to standards in product selection and installation, consistency in programming and documentation, and accountability for all SCADA system resources, internal or external
  - Achieved by **development of SCADA technician skills and responsibilities** based on projected workload and skill requirements, includes training and skill evaluations

Objectives and Goals

The team identified some objectives to define successful replacement of the SCADA system. Following is a summary of these objectives, which are further developed in the Industry Trends section.

1) The WRD would like to define more consistent and sustainable system components, by consolidating PLC models, programming software versions, operating systems, network and radio equipment, workstations, servers, and operator interface panels.
2) The WRD would like to be self-sufficient to maintain existing assets or for minor upgrades. The WRD would like new projects to be completed by Contractors, based on new programming standards.
3) The SCADA Master Plan should perform a workload analysis and identify additional personnel needs. Currently, there are two open requisitions for technicians.

The WRD should embark on a SCADA system replacement or upgrade so that the new system will satisfy the following goals:

- Will be designed, configured, and implemented with new programming and configuration standards.
- Will provide a framework to adopt industry standards while leaving room for adapting to upcoming trends.
- Can communicate and exchange the necessary information with Historians, Computerized Maintenance Management System (CMMS) and other external databases, to satisfy the needs of all stakeholders (from operations to maintenance to executive management).
- Lay the framework to enhance the development of SCADA technician skills and responsibilities .
- Will be designed and implemented to comply with the latest cyber security standards.
- Will be designed and implemented with redundancy to minimize risks, while maintaining the quality of the effluent.
- Will institute the technology and practices that will provide a reliable platform for operations with the ability to optimize with changing instrumentation and automation procedures.

1.3 Industry Trends

1.3.1 SCADA System Vision

Stakeholder Goals

The WRD desires to upgrade or replace SCADA system components to achieve substantial improvements in performance, reliability, and sustainability. These improvements are defined by stakeholders (users of the SCADA system or SCADA 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:

- Operations (Performance)
  - To ensure regulatory compliance
  - To maximize reliability and responsiveness
  - To optimize operating procedures
- Maintenance/IT (Reliability)
  - To be consistent in design, components, configuration, and documentation
  - To be flexible in modifications, additions, reporting, and analysis
  - To monitor system and process equipment performance
  - To provide robust backup/recovery procedures
  - To maintain or improve SCADA system security
  - 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 data for reporting, life cycle analysis, and capital improvements
  - To develop internal resource capability with training and knowledge
  - To enhance external resource capacity with pre-qualified and standard contracts

Achieving these goals requires a thoughtful consideration of how others in the water/wastewater industry are achieving similar goals and applying those approaches to each component of the WRD's SCADA system. This section identifies and reviews industry trends and standards in six sections. Each section covers a major component of the SCADA system in place at the WRD. Each section briefly describes the industry trends and standards organizations for each component and identifies trend and standard preferences at the WRD to achieve these goals. The last section summarizes the preferences expressed. The discussion sections are:

- Section 1.3.2: SCADA Servers/Other Platforms
- Section 1.3.3: Networks
- Section 1.3.4: Security
- Section 1.3.5: PLC/HMI Graphic Objects
- Section 1.3.6: HMI Graphic Displays
- Section 1.3.7: Alarm Management
- Section 1.3.8: Summary of Preferences

1.3.2 SCADA Servers/Other Platforms

SCADA system component life cycles vary considerably as shown on Figure 1-4. The WRD SCADA system servers and operating systems are obsolete. For example, support for Windows XP ended more than 5 years ago. The industry trends are to plan for replacement after a 5-year life cycle and use virtualization software to establish a redundant and resilient server with backup and recovery options built-in.

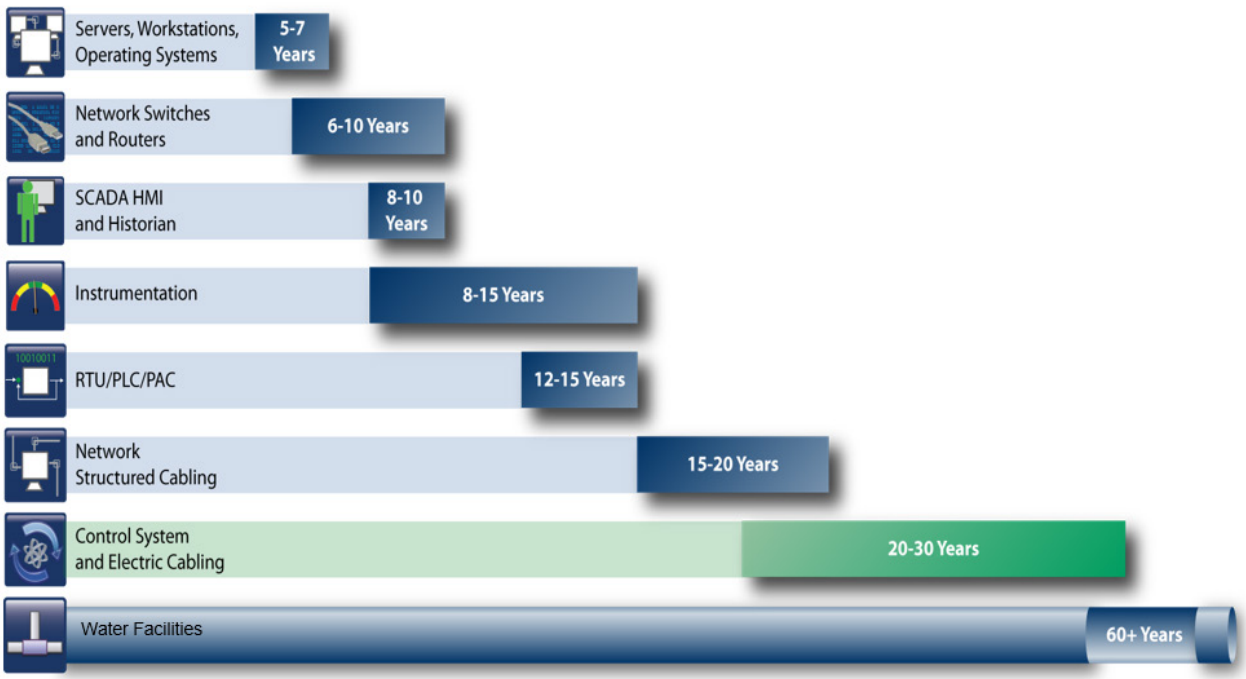


Figure 1-4. SCADA Component Life-Cycle Comparison

The SCADA platform hardware and software (servers, operating system, virtualization, etc.) must be based on current products (less than 5 years old). This platform must meet or exceed all the requirements, such as redundancy, reliability, security, standardization, etc., as other SCADA system components. Because WRD has already established two server locations for the purpose of redundancy, the upgrade will include both locations.

The industry trends for water/wastewater utilities is to leverage a reliable SCADA platform to link to other platforms so that SCADA information can be shared, and more stakeholders can benefit. The industry is moving towards a model, where a control system is seen as a source of information which can be utilized by different stakeholders to their benefit. Following are some examples of how a control system can be linked to other platforms.

- Use the SCADA system to link to a process or hydraulic model so that operators can be trained on a simulation model (digital twin).
- Embed links in the SCADA displays to Standard Operating Procedures or Maintenance Information.
- Use tablets to link to a secure, remote desktop-type SCADA client so that operators can view the SCADA system from a tablet in any location at the plant.
- Leverage Rockwell Automation's AssetCentre software to audit and manage the PLC and SCADA programming changes and support disaster recovery.

- Use the smart instrument networks with a maintenance software such as Endress+Hauser's Fieldcare to configure and manage the smart (HART compatible) field instruments.
- Leverage a third-party software such as CyberX to monitor network traffic and provide any alarms in advance to network switches developing any issues or crashing.
- Linking the SCADA system to CMMS to create automatic workorders based upon field conditions.

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.
- Create a separate and secure SCADA data platform so that engineers and managers do not need direct access to SCADA displays and can still access reports and data on an ad-hoc basis.
- 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 and investigate the value of using Rockwell Automation's AssetCentre software.

1.3.3 Networks

The data communications network is the backbone of the SCADA system. The SCADA system at WRD includes three major components:

- A plant-wide fiber-optic ring at the WRP connecting the PLCs to the SCADA servers
- Multiple protocols connecting instrumentation and field devices to the PLCs, and
- A licensed radio network connecting the remote site PLCs to the SCADA server.

The plant-wide, instrumentation and remote site networks are all described in this section.

Plant-Wide Networks

Currently, the WRP plant-wide network is based on a multi-mode fiber cable loop run through the entire plant and installed more than 15 years ago. It is a flat architecture that requires manual intervention to reroute data communications in the event of failure.

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.

Keeping current with communications technology and providing a self-healing plant-wide network require that the WRD needs to consider an upgrade to single mode fiber. The fiber upgrade analysis should evaluate 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 1-5 shows an example of a dual-loop network architecture.

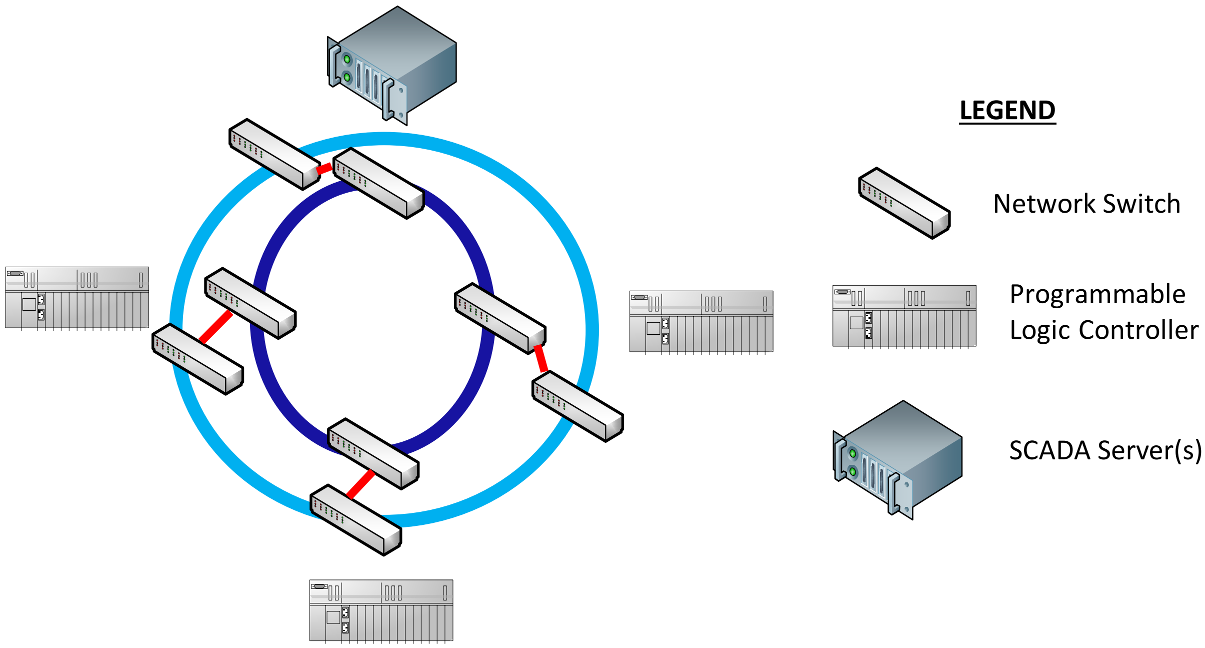


Figure 1-5. Dual Loop Network Architecture Example

Instrumentation Networks

Currently, instruments and field devices are generally hardwired (2 wire 4-20 mA) to the plant PLCs. New field instruments are specified to be HART compatible. Some of the MCCs and VFDs communicate over DeviceNet to the plant PLCs. DeviceNet is being phased out to Ethernet as MCCs and VFDs are upgraded. Rockwell Automation recommends Ethernet communications between MCCs and VFDs and the PLCs.

The current industry trend is to collect more information on the health and status of instruments and field devices, which requires network protocols that support digital communication. Currently, four instrumentation network protocols are leading the industry in digitizing instrumentation and field devices, such as actuators, MCCs, and VFDs:

- 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.

WRD has installed HART-ready instruments, wiring, and HART ready analog input (AI) modules by Rockwell. The feasibility of implementing HART depends on development of PLC and HMI configuration to process, present, and analyze the HART data. Typical HART data provides several fault codes from the instrument. These codes can be interpreted and presented as descriptive faults with appropriate configuration of the PLC and HMI. However, the cost/benefit ratio is usually too high to be cost-effective. WRD shall consider implementing HART where feasible (i.e., cost-effective).

Table 1-4 provides a technical comparison of the four protocols:

Table 1-4. Instrumentation Network Protocol Technical Comparison

Criterion	HART	FF	Profibus	Ethernet/IP
Remote Scaling	Y	Y	Y	Y
Additional Variables	Y	Y	Y	Y
Diagnostics	Y	Y	Y	Y
Configuration	Remote	Remote	Remote	Remote
Time Stamp	N	Periodical	N	Y
Field Control	N	Y	N	Y
Necessary Instrument Technical Skills (1 = most available)	1	4	3	2
Integral Data Security	N	N	N	Y
Base Standards	None	IEC 61158, ISA SP50 (H1) IEC 8802 (HSE)	IEC 61158	IEEE 802.3
Baud Rate (bps)	1200	31.25k (H1) 100/1M (HSE)	12M	10M/100M/1G
Communication Relationship	None	Master/Slave	Client/Server	Client/Server Broadcast
Instruments/Field Devices Connectivity	Instruments Only	Both	Both (PA and DP)	Limited Availability
Maximum Distance	3.0 km	1.9 km or 9.5 km (H1) 100 m (HSE)	1512 m (DP) 1.9 km, 9.5 km (PA)	Based on media
Maximum # of Devices	Typically, 1 per segment	32 per segment (H1): unlimited (HSE)	247 per seg (DP): 32 per seg (PA)	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

Notes:

PA = Process Automation

DP = Decentralized Peripherals

HSE = High Speed Ethernet

IEC = International Electrotechnical Commission

IEEE = Institute of Electrical and Electronics Engineers

ISA = International Society for Automation

Instrumentation protocol development and deployment is ongoing, and the trend seems to be toward Ethernet based protocols. While 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 instead of CAT5/6 Ethernet cable) but would not include control devices. Currently, only Foundation Fieldbus and Profibus support valve actuators and only Endress Hauser and Hach offer 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.

Remote Site Network

Currently, Livermore owns two licensed frequencies for their radio communication; a 4.9 GHz channel for Ethernet communications, and a 173.### MHz channel for serial communications. The Ethernet radio links are the primary communications mode and serial link are the backup. The Ethernet links are more prone to interference than the serial links. The WRD does not need to add long-term local historian at any of the remote sites. If communication is lost on both radio links, the operators can drive out to any of the sites within a few hours.

The industry trends are driven by the lack of availability of licensed frequencies. Many utilities are forced to lease microwave frequencies through cellular providers, or lease fiber-optic lines through telecommunications providers. The ownership of licensed frequencies is a coveted option unavailable to many utilities. The best option for the WRD is to maintain the licensed frequencies for as long as possible. The 4.9 GHz license was recently renewed to 2035.

Preferences

- Design a multilayer network which isolates segments of the network to improve security and reduce failure vulnerabilities.
- Design and install a redundant fiber ring at the WRP with redundant network cards in the PLC chassis at each control panel.
- Replace the existing multi-mode fiber cables with single-mode cables.
- Upgrade all the remaining drives on DeviceNet communication links to Ethernet links.
- Evaluate costs and benefits of instrumentation network protocols based on current networked instruments and devices and recommend an action.
- Upgrade radio equipment as necessary and maintain clear paths.

1.3.4 Security

Currently, the SCADA system at the WRP is isolated 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 the framework to keep the control system secure, while minimizing intrusions from external networks as much as possible. As a result, the following government and trade organizations have established guidelines regarding security:

- Department of Homeland Security (DHS)
- North American Electric Reliability Corporation (NERC) – typically water and wastewater agencies follow the examples and standards set by NERC
- American National Standards Institute (ANSI)

The main premise of the DHS standards, which follows the Perdue Model of Process Control as shown on Figure 1-6, is that security standards should be established with a Defense in Depth philosophy.

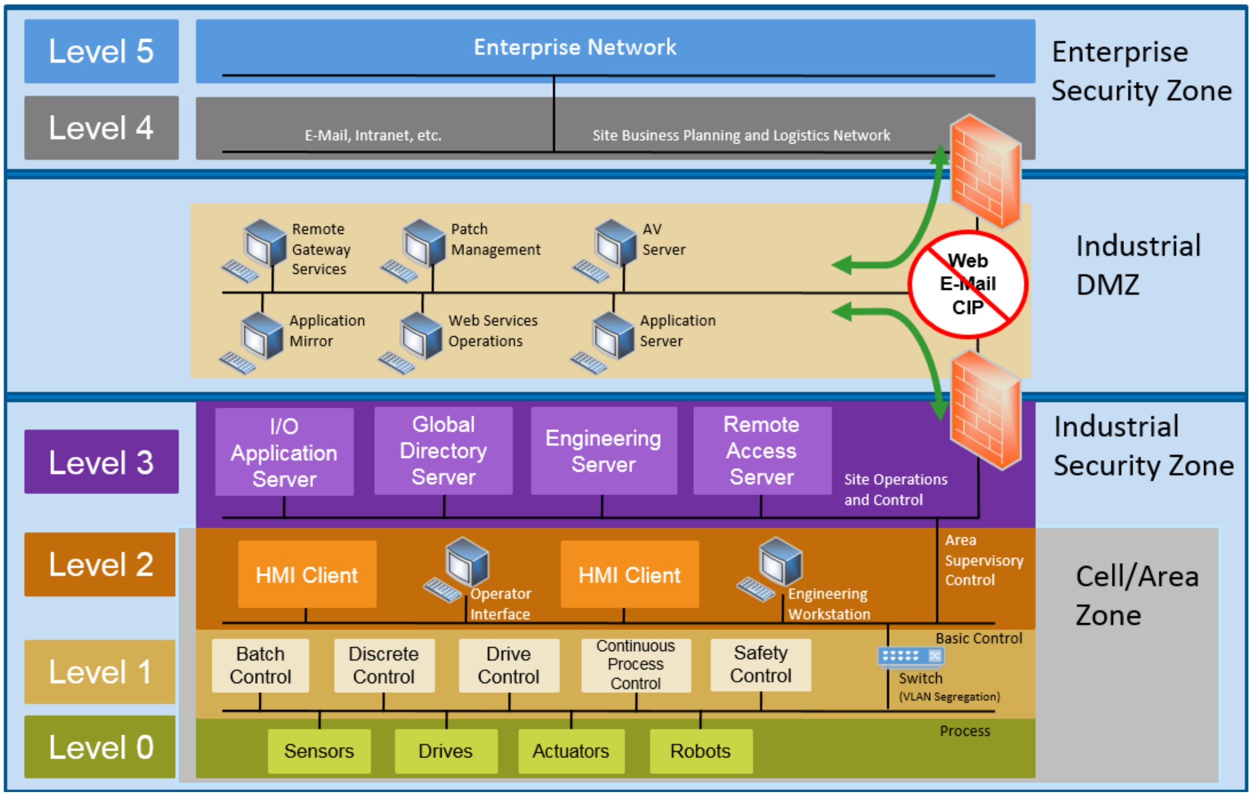


Figure 1-6. The Perdue Model of Process Control for Cyber Security

Some of the important elements from the DHS Defense in Depth Strategy are to establish policies and procedures in the following fields:

- Risk Management
- Cybersecurity architecture
- Physical security
- ICS network architecture and perimeter security
- Security monitoring
- Vendor management
- Host security

Developing security policies and procedures should be performed with collaboration with Livermore's Cybersecurity Division and WRD management.

Preferences

- Build a proactive security model, which strictly governs remote and external access.
- Adopt standardized countermeasures for Industrial Control Systems (using National Institute of Standards and Technology [NIST] 800-82 and 800-53).
- Keep abreast of current security standards (NERC, NIST etc.).
- Use the industry available tools and services for security training and maintenance.
  - DHS ICS-CERT, CSET, DAR
  - AWWA Cybersecurity Guidance and Tool
- Design and configure a Disaster Recovery Center (DRC)
- Design and regularly schedule a Backup and Recovery Procedure

1.3.5 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 (also known as function blocks) 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.

The WRD has standardized on Rockwell Automation's Allen Bradley PLC platform. Standard control objects for Allen Bradley PLCs can be developed by WRD or adapted from other sources. Rockwell Automation has a published a vast library of control objects that can be adapted for a variety of industries. Once the WRD has adopted a set of standard control objects, the programming, configuration and testing of any new project can be consistent. Standard control objects streamline knowledge transfer between system integrators and WRD staff once a project is complete.

Control Objects are available from Rockwell Automation as Add-On Instructions (AOI) with standard HMI faceplates in FactoryTalk. A Control Object example (for an Adjustable Speed Drive) is shown in Appendix 1-B. The WRD uses control objects for each item shown in the following preliminary list:

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 (single output maintained) Valve
   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

Preferences

- Consolidate PLC programming languages to Studio 5000 and PLC models to ControlLogix.
- Engage plant operators as stakeholders in the Database Standards Workshop to develop the WRD'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 the Control Objects Workshop to define the WRD's PLC control object needs, based on the preliminary list shown above and to be coordinated with the HMI display standards.

1.3.6 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:

- 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 which 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:

- 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 industry standards most applied for water and wastewater are:

- ISA 101.01 – Human Machine Interfaces
- ISA 18.2 – Alarm Management
- ISO 11064 – Applied to the design of control rooms

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 lifecycle model and how to support the lifecycle. The standard describes mandatory and non-mandatory requirements. The concept of 'High-Performance Graphics' was derived from these standards.

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

- 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 the same principles of High-Performance Graphics. Alarm management is discussed in Section 2.6.

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, principles for the evaluation of control center. Currently, the WRD has no plans to modify the WRP control room.

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 1-C illustrate some examples of a hybrid approach. Preliminary preferences expressed by the core team include:

Preferences

- 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 while 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.
- Flashing symbols should be used for active and unacknowledged alarms only. This would allow the operators to focus on the important, active alarms and not be distracted with other, older information.
- 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 access to the more detailed information (such as alarm set points, alarm delay timers, maintenance mode).
- Engage plant operators as stakeholders in the Graphics Presentation Workshop to develop the WRD’s HMI graphic display standards.

1.3.7 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 lifecycle is illustrated on Figure 1-7 (from the ISA 18.2 standard).

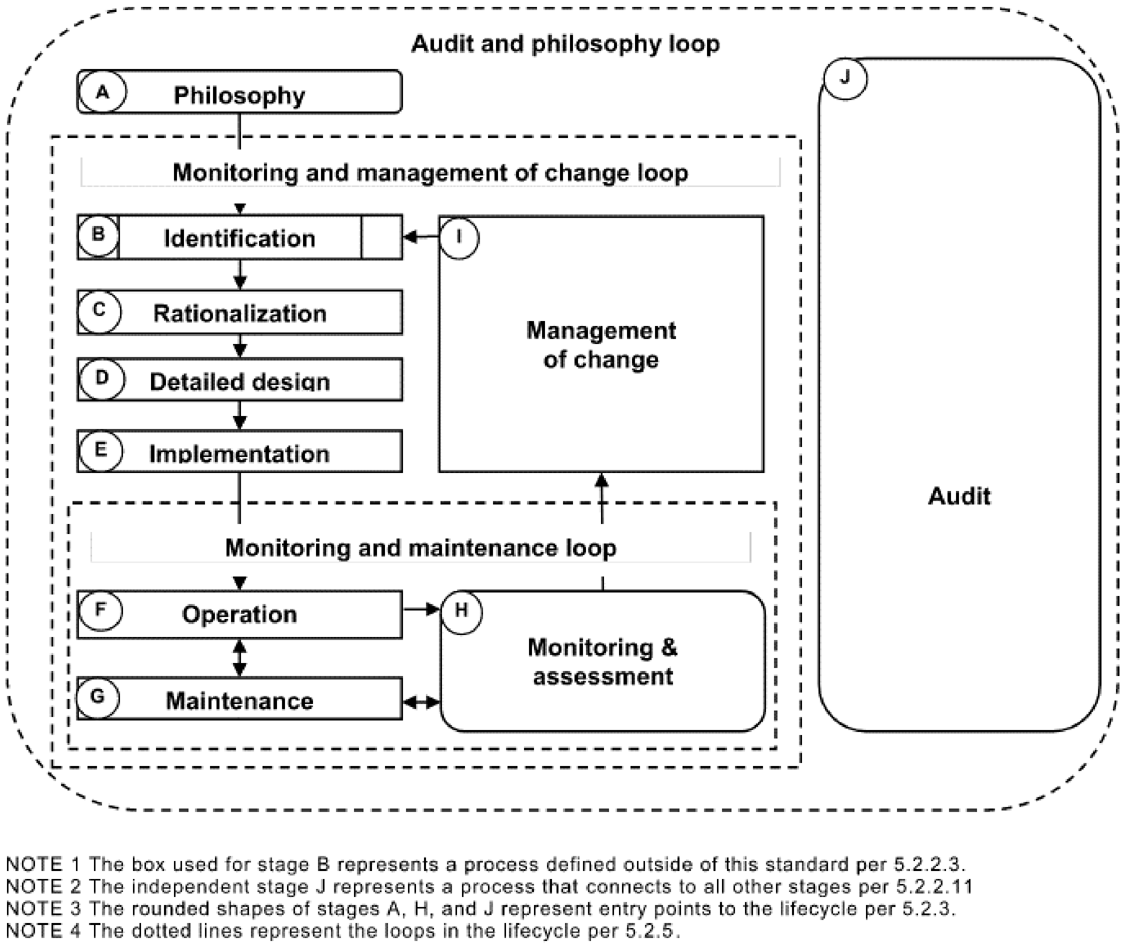


Figure 1-7. Alarm Management Life Cycle from ISA 18.2 2016

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

- Review the definition of an alarm (clearly delineate notifications from alarms)
- Under normal conditions, there should be no active alarms
- Under any conditions, there should be less than 10 active alarms
- Critical alarms criteria should be documented
- Alarming system should be audited and reviewed annually

Alarm prioritization enables operators to quickly identify critical conditions that require immediate response from less serious conditions. This helps operators prioritize and execute appropriate responses to abnormal conditions. Alarm prioritization is based on condition consequences. Table 1-5 shows an example of an alarm priority definition.

Table 1-5. 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 Snr Management Reporting ▪ Shutdown of Treatment	▪ Cost between $10K and $100K ▪ Requires Reporting ▪ Short duration of outage	▪ Cost less than $10K ▪ Requires internal reporting ▪ No outage	▪ No loss
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	▪ More than 1 hour
Health and Safety	▪ Extremely Hazardous	▪ Dangerous conditions		

Preferences

- Flashing symbols should be used for active and unacknowledged alarms only. This would allow the operators to focus on the important, active alarms and not be distracted with other, older information.
- Engage plant operators as stakeholders in the Alarms and Reporting Workshop to develop the WRD's alarm management, so that alarm prioritization, criteria, and presentation (including colors, graphics, and alerts) are documented and understood by all SCADA system users.
- Following the workshop, the WRD should audit the existing alarms per the alarm management standard.

1.3.8 Summary of Preferences

The preferences expressed in the Industrial Trends workshop and at the end of each component discussion all contribute to improvements in performance, reliability, and sustainability. Some preferences will show immediate improvements, while others will take time to develop and demonstrate long-term improvements. The next step (Gap Analysis) in the Master Plan will compare the current situation described in the System Assessment to the goals and objectives established by these preferences. The Gap Analysis will establish priorities, identify alternatives, and discuss evaluation criteria. Table 1-6 lists a summary of preferences expressed the section for each SCADA component.

Table 1-6. Summary of Preferences and Relevant Stakeholders

Preferences	OPS	I&C	IT	ENG	Mgt
SCADA Platform					
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.	✓	✓	✓	✓	✓
Create a separate and secure SCADA data platform so that engineers and managers do not need direct access to SCADA displays and can still access reports and data on an ad-hoc basis	✓	✓	✓	✓	✓
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 and investigate the value of using Rockwell Automation's Asset Manager software.		✓			
Networks					
Design and install a redundant fiber loop at the WRP with redundant network switches at each control panel.		✓			
Replace the existing multi-mode fiber cables with single mode cables.		✓		✓	
Upgrade all the remaining drives on DeviceNet communication links to Ethernet links		✓		✓	
Evaluate costs and benefits of instrumentation network protocols based on current networked instruments and control devices and recommend an action.		✓		✓	
Upgrade radio equipment as necessary and maintain clear paths.		✓			
Security					
Build a proactive security model, which includes developing the appropriate policies and procedures.		✓	✓	✓	
Adopt standardized countermeasures for Industrial Control Systems (using NIST 800-82 and 800-53).		✓	✓		
Keep abreast of current security standards (NERC, NIST etc.)		✓	✓		
Use the industry available tools and services for security training and maintenance.		✓	✓	✓	
Design and configure a Disaster Recovery Center (DRC).		✓		✓	✓
Design and create a Backup and Recovery Procedure.		✓		✓	✓

Table 1-6. Summary of Preferences and Relevant Stakeholders

Preferences	OPS	I&C	IT	ENG	Mgt
HMI Graphics					
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.	✓	✓			
Mini-trends could be shown with each analog value.	✓	✓			
Flashing symbols should be used for active and unacknowledged alarms only.	✓	✓			
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 access to more detailed information (such as alarm set points, alarm delay timers, maintenance mode).	✓	✓			
Develop the WRD's HMI graphic display standards in the Graphics Presentation Workshop to be coordinated with the Control Objects standards.	✓	✓			
PLC/HMI Control Objects					
Consolidate PLC programming languages to Studio 5000 and PLC models to ControlLogix.	✓	✓			
Develop the WRD's tagging standard in the Database Standards Workshop, so that consistent naming and labelling can be used across the I/O database, PLC programming and HMI graphic displays.	✓	✓			
Develop the WRD's PLC control objects in the Control Objects Workshop, based on the preliminary list shown above and to be coordinated with the HMI display standards.	✓	✓			
Alarm Management					
Flashing symbols should be used for active and unacknowledged alarms only.	✓	✓			
Develop the WRD's alarm management philosophy in the Alarms and Reporting Workshop, so that alarm prioritization, criteria, and presentation are documented and understood by all SCADA system users.	✓	✓			
Following the workshop, the WRD should audit the existing alarms per the alarm management standards developed.	✓	✓			

1.4 Gap Analysis and Implementation Planning

1.4.1 Current/Future States

The Gap Analysis examines the current and future states, identifies the differences, and considers alternatives to develop a conceptual plan to reach the desired state. The current state of the WRD SCADA system is organized into four major components, including servers, networks, WRP PLCs, and Remote Site PLCs. Drivers for each component are listed in one or more driver groups described in the System Assessment section. A fourth group of drivers, Self-Sufficiency, focuses on internal and external resource development designed to support the new SCADA System. Table 1-7 cross references the SCADA system components and its drivers.

Table 1-7. Current State Summary

System Component	SCADA Replacement Drivers		
	Technical Obsolescence	**Lack of Standards**	**Lack of Documentation**
Servers			
Hardware/OS	10+ years old No backup/recovery policies	Limited skill set to support	N/A
HMI (FactoryTalk)	Windows XP Standalone clients No security policies No change management policies	Multiple Versions on clients No Database Tagging, Control Object, or Graphics Standards	N/A
WIN911	Standalone desktop with dialup modem	No Alarm Management Standards	N/A
Networks			
WRP Fiber	Multi-mode fiber Unmanaged devices, No segmentation No security policies Flat Ring, No remote access	N/A	No Record Drawings High Level Network Diagram is current, but no detailed configuration drawings
WRP Instrumentation	4-20 mA (Instruments) DeviceNet (MCC Controls)	N/A	No detailed configuration drawings
Remote Sites	4 PLCs have serial only.	N/A	No detailed configuration drawings

Table 1-7. Current State Summary

System Component	SCADA Replacement Drivers		
	Technical Obsolescence	**Lack of Standards**	**Lack of Documentation**
WRP PLCs			
PLC1 (Headworks)	PLC5/40E	7 PLC Models 3 RS5XXX Versions Program Logic developed without Database Tagging or Control Object standards. 3 models of Panelviews, each with its own configuration software and communication mode.	No Process Control Narratives No Record Drawings, such as Panel Documentation, Loop Diagrams, etc.
PLC3 (Digesters)	PLC5/40E		
PLC2 (Aeration)	PLC5/40E		
PLC4 (Greenhouse)	PLC5/40E		
PLC8 (UV)	SLC 1747		
PLC9 (Admin)	CompactLogix		
PLC10 (LAVWMA)	CompactLogix		
Remote Site PLCs			
9 Water Sites	7 CompactLogix PLCs	3 PLC Models	N/A
3 Wastewater Sites	Airport LS Serial only	2 PLC Models	N/A
3 Stormwater Sites	Serial Only	N/A	N/A

Note:

N/A = not applicable

Based on the Stakeholder Goals and Industry Trend preferences, Table 1-8 summarizes the future state of the SCADA system at the WRD. The planned resolutions for each component are based on the Convention Standards and Component Standards defined in other chapters of the SCADA Master Plan. Convention Standards include Control Philosophy, Database Naming, Control Objects, Graphics, and Alarms. Component Standards include Instrumentation, Control Panels, Control Equipment (including PLCs), and Network Equipment.

Table 1-8. Future State Summary

System Component	Planned Resolutions to SCADA Replacement Drivers		
	Future Technical Description	Standard Compliance	Documentation Available
Servers/HMI			
Hardware/OS	Planned replacement every 5 years	Contracted Support (As needed)	Self-generated configuration reports.
HMI (FactoryTalk)	Single current version All HMI on thin clients Active Directory Security Change management policy	All Convention Standards	Self-generated configuration reports.
WIN911	Compatible seamlessly with FactoryTalk, providing voice and text message alerts via cell phones. Runs on same servers	Alarm Management outlined in ISA 18.2	Self-generated configuration reports.
Networks			
WRP Fiber	Single mode fiber Dual Ring Architecture Segmented with managed switches (network health monitored) DMZ security allowing remote access	Network Component Standards and DHS, NERC, NIST Standards for ICS	Record Drawings As-built Drawings Self-generated network configuration.
WRP Instrumentation	4-20/HART (Instruments) Ethernet (Control Devices)	HART IEEE 802.3	As-built Drawings
Remote Sites	All remote sites include both Primary and Secondary radios	Network Component Standards	As-built Drawings
PLCs			
All PLCs	1 programming package, 1 program tracking package,	Studio5000, AssetCentre	Self-generated program reports
WRP PLCs	ControlLogix for each process area, vendor package, and small applications, thin clients for OIPs (currently PanelViews)	Control Philosophy, Database Tagging, and Control Object Standards	Process Control Narratives As-built Drawings
Remote Site PLCs	ControlLogix for all remote sites	Control Philosophy, Database Tagging, and Control Object Standards	As-built Drawings

Note:

DMZ = Demilitarized Zone

Achieving this future state depends on effective deployment of the Convention and Component Standards defined in this SCADA Master Plan to successfully achieve all stakeholder goals. Defining and measuring success is discussed in the next section.

1.4.2 Criteria/Approaches

The future state of the SCADA system for the WRD is achieved by applying the industry trends and best practices that best fit the SCADA system needs. These selections were 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.

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)
    - 1.5 No single point of failure
2) Responsiveness:
    - 2.1 High speed network, 1 second response within WRP, 15 second response with all 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 replacement/upgrade projects towards achieving the future state. The projects are defined by considering industry trends and best practices and selecting which approach best fits the WRD's needs. Alternatives for each component are described in the Industry Trends section. Table 1-9 summarizes the planned approaches, and their respective criteria focus.

Table 1-9. Industry Trends and Planned Approaches Summary

System Component	Industry Trend	Planned Approach Description	Criteria Focus
Servers/HMI			
Hardware/OS	Virtualization, Outsource Support	2 redundant and physically separate virtual servers, current version of Windows Server, dedicated to SCADA applications (FactoryTalk, WIN911), with hardened security, backup/recovery system, and UPS power	1.2, 2.3 2.5
HMI (FactoryTalk)	Thin Clients Control Objects, High Performance Graphics	High Performance Graphics compliant with ISA 101, current Versions of FactoryTalk, supports tablets and workstations, Active Directory security, compliant with all Convention Standards	1.3
WIN911	Alarm Management	Current Version integrated with FactoryTalk, compliant with alarm management philosophy and 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, 2.1 1.1, 2.1 2.1, 2.2
WRP Instrumentation	Ethernet	Upgrade all DeviceNet MCC control devices to Ethernet, Implement HART where feasible.	1.4
Remote Sites	Ethernet	all remote sites with both Ethernet (Primary) and Serial (Secondary) radios.	2.1
PLCs			
WRP PLCs	Consolidation (5 PLC models reduced to 1)	One programming language, Compliant with all Convention and Component Standards, two standard PLCs, ControlLogix for large applications, small applications, and vendor packages.	1.3, 2.4
PLC 5/40s	Upgrade to current version	Requires new I/O wiring and new control panels, include in new construction where possible or standalone projects. Compliant with database tagging and control object standards.	1.3, 2.4
Control Objects	Standardize	Defined in Convention Standards	1.3, 2.2, 2.4
PLC/HMI Programs	Standardize	Compliant with all Convention Standards	1.3, 2.2, 2.4
Remote Site PLCs	Consolidation (3 PLC models reduced to 1)	One programming language, Compliant with all Convention and Component Standards, one standard PLC, ControlLogix for all remote sites.	1.3,2.4

Note:

UPS = uninterruptible power supply

Other factors affecting the gap analysis and approach selection for the SCADA system upgrade projects are financial and non-technical. Examples are:

- 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.

The Self-sufficiency 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 self-sufficiency are focused on sustainability and will measure responsiveness (see Performance Criteria 2.5) to show improvements toward self-sufficiency.

A cost saving consideration is to upgrade CompactLogix PLCs instead of replacing them. This consideration retains the objective of consolidating PLC programming software to Studio 5000 only, and still achieves consolidating the number of PLC models to 2 (ControlLogix, CompactLogix) while eliminating 3 PLC models (PLC5/40E, SLC1747, and MicroLogix).

1.4.3 Project Concepts/Priorities

Project concepts were developed based on considerations of industry trend approaches with the greatest potential to achieve the stakeholder goals. The project concept discussion identified some prioritization and schedule considerations. Major component replacements are prioritized based on life-cycle obsolescence and criticality to the SCADA system, as follows:

- Servers, including HMI software
- Networks
- WRP PLCs, and
- Remote Site PLCs.

Replace Servers

The server replacement project 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 will develop high-performance graphics and control objects and integrate alarm management based on the Convention Standards. This project concept establishes the Convention Standards in preparation for each PLC to be reprogrammed with Control Objects and requires a well-planned transition period. The transition period is the time between the first PLC to be interfaced into the new HMI system and the last PLC to be interfaced into the new HMI system. The transition period could last 2 or more years.

Upgrade Networks

The network upgrade projects include three concepts: the WRP SCADA network, the WRP instrumentation network, and the remote site (radio) network. The SCADA network upgrade project concept assumes new single mode fiber, self-healing dual ring architecture, segmentation designed for security and resiliency, and establishes remote access and data access using a firewall and Demilitarized Zone (DMZ). This project concept requires a well-planned cutover schedule. The cutover schedule assumes existing PLCs can be connected to the existing HMI system through the new network, so that the network upgrade project can be decoupled from the server upgrade project. The network cutover schedule could last several months.

The instrumentation network upgrade concept assumes field instrumentation (4-20 ma) networks will be upgraded to HART as needs and abilities to use HART develop, and control device (DeviceNet) networks will continue to be replaced by Ethernet as projects and opportunities allow. The instrumentation network upgrades will be conducted in each PLC upgrade/replacement project.

The remote site network upgrade concept adds Ethernet (Primary) radios to the 4 remote sites that currently only have Serial (Secondary) radios and considers replacing the Serial radios with 5G cellular radios. The remote site network upgrade can be consolidated with the remote site PLC upgrades. A cost-benefit analysis is recommended before proceeding with the 5G concept.

Upgrade/Replace WRP PLCs

The WRP PLC upgrade project includes two concepts. One concept upgrades ControlLogix PLC programs to the new Convention standards. The other concept replaces PLC5/40, CompactLogix, MicroLogix, and SLC models with ControlLogix and upgrades the programming to the new Convention standards. These projects program the PLCs using the PLC/HMI control objects described in the Convention Standards and developed in the HMI upgrade project. Both concepts assume the same software package for PLC programming development.

The WRP ControlLogix upgrade concept applies Convention Standards to current ControlLogix PLCs and assumes minimal field or component modifications. This concept assumes one project will include all ControlLogix PLCs and one cutover schedule. This project finalizes, tests, and implements the PLC/HMI control objects developed in the HMI upgrade project. This project includes upgrading any DeviceNet devices to Ethernet and PanelViews to thin clients. The ControlLogix PLCs, listed in numerical order, are:

- PLC6 (Filters)
- PLC11 (Blowers)
- PLC12 (Solids Handling)
- PLC13 (GBT1)
- PLC14 (GBT2)
- PLC28 (Grit Classifiers)

The WRP PLC5/40 replacement concept includes control panel design and I/O wiring based on Component Standards, and program development based on Convention Standards. This concept assumes a separate project and separate cutover schedule for each PLC5/40, CompactLogix, MicroLogix, or SLC. This project includes upgrading any DeviceNet devices to Ethernet and PanelViews to thin clients. The prioritization sequence for PLC5/40 replacement is based on current construction schedule and process criticality, as follows:

- PLC1 (Headworks Upgrade Project, design completed by December 2021)
- PLC3 (Digesters)
- PLC8 (UV) - SLC
- PLC2 (Aeration)
- PLC4 (Greenhouse)
- PLC9 (Admin) – CompactLogix
- PLC10 (LAVWMA) - CompactLogix
- PLC24 (UV Power) – MicroLogix
- PLC25 (Bar Screen Washer) - MicroLogix
- PLC5 (Tertiary) – This panel (with a ControLogix PLC but old wiring will need to be replaced)

Upgrade/Replace Remote Site PLCs

The remote site PLC upgrade project assumes ControlLogix at all remote sites as the standard PLC. Of the 15 remote sites, 5 sites have MicroLogix PLCs installed, 9 sites have CompactLogix PLCs, and one site has a ControlLogix PLC. MicroLogix PLCs include both Ethernet and Serial communication ports and can support both Primary and Secondary communications.

One project concept will upgrade the programming in 1 ControlLogix PLC as one project. The second project concept will replace the 9 CompactLogix and 5 MicroLogix PLCs on a project-by-project basis.

The discussion on the remote site PLC upgrade project concept revealed other factors to consider when defining the replacement schedule. These factors include a potential 5G network upgrade to replace Serial communications, new construction, or process criticality. Table 1-10 lists the remote site PLCs by PLC model. No prioritization criteria for remote site PLC upgrades/replacements were identified at this time.

Table 1-10. Remote Site PLCs

MicroLogix	CompactLogix	ControlLogix
Altamont Tanks (W)	Doolan Tower and Reservoir (W)	Vasco Pump Station (W)
Airport Lift Station (WW)	Airway Pump Station (W)	
N. Livermore Pump Station (SW)	Pleasanton Flow (W)	
North P Street Pump Station (SW)	Dalton Reservoir (W)	
Murrieta Pump Station (SW)	Trevarno Pump Station (W)	
	Altamont Pump Station (W)	
	Oakville Pump Station (W)	
	El Charro Lift Station (WW)	
	Junior College Lift Station (WW)	

Notes:
(W) = Water
(WW) = Wastewater
(SW) = Stormwater

Project Concept Matrix

The project concepts developed in the Gap Analysis Workshop are based on consideration of industry trend preferences with the greatest potential to achieve the stakeholder goals. All project concepts assume the following:

- Fully developed Convention and Component Standards will be available in time to support the Headworks Upgrade Project.
- The WRP will continue to use two server locations for redundancy, backup and recovery purposes, and will be upgraded to the latest version of virtualization software.
- All new PLCs will be ControlLogix.
- All new HMIs and OIPs will be thin clients.
- All future PLC programming and documentation will use the most current version of Studio 5000.

The Project Concept Matrix shown in Table 1-11 organizes all the system components into seven (7) project concepts that will close the gap and achieve all stakeholder goals. These project concepts are listed in decreasing order of priority.

Table 1-11. Project Concept Matrix

Project Name	Project Concepts
1. Replace SCADA Servers a) Hardware/OS b) HMI (FactoryTalk) c) WIN911	2 locations, virtual servers with RAID, Planned Transition Period, Applies all Convention Standards, including Alarm Management Assumes thin clients for user interfaces
2. Upgrade WRP Network a) Upgrade WRP Fiber b) Upgrade DeviceNet/ HART c) Upgrade Remote Network	2.a: Network designed for self-healing resiliency, replace multi-mode with single mode fiber. Planned Cutover, can be independent of server replacement project. Secure firewall and DMZ for remote access and SCADA data requests. Multimode fiber segments can be replaced with a temporary link or a phased shutdown of each PLC. 2.b: See Projects 3 – 4 2.c: See Projects 5 – 7
3. Upgrade 6 ControlLogix PLCs at the WRP	Applies all Convention and Component Standards. Includes upgrading all DeviceNet devices to Ethernet, any PanelView to thin client, and selected 4-20mA instruments to HART. One project to upgrade programs in ControlLogix PLCs, with minimal field modifications, only card replacements. Converts most of the WRP to new SCADA system, with Planned Cutover.
4. Replace 1 ControlLogix (PLC5), 5 PLC 5/40Es, 2 CompactLogix PLCs, 2 MicroLogix PLCs, and 1 SLC at the WRP	Applies all Convention and Component Standards. Includes a new control panel for each new PLC, upgrading all DeviceNet devices to Ethernet, any PanelView to thin client, and selected 4-20mA instruments to HART. Each PLC replacement may be its own project with its own cutover plan or included in a capital improvement project for its process area.
5. Evaluate Serial Radios	Conducts a cost-benefit analysis of 5G cellular services to replace Serial backup communications.
6. Upgrade 1 Remote Site ControlLogix PLC	Applies all Convention and Component Standards. One project to upgrade programs in 1 ControlLogix PLC, with minimal field modifications, only card replacements.
7. Replace 9 CompactLogix PLCs and 5 MicroLogix PLCs	Applies all Convention and Component Standards, including remote site network upgrades. Includes a new control panel for the new PLC and each PLC replacement may be its own project.

1.4.4 Implementation Planning Process

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 include the topics shown in Table 1-12. Detailed project descriptions add the topics listed in Table 1-12 and are shown in Appendix 1-D. Project description topics include:

Table 1-12. Project Description Topics

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

Estimated costs are based on 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). Summary project descriptions include Class 5 estimated costs. Detailed project descriptions include Class 4 estimated costs. AACE estimating characteristics for Classes 5 and 4 are listed in Table 1-13.

Table 1-13. AACE Cost Estimate Classification Summary

AACE 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

The Class 4 detailed cost estimates provided in Appendix 1-E 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 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

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 3 years.
- The Headworks Upgrade Project (which includes PLC1) will complete design by December 2021.

- Average lead time for procuring most hardware and software products is 2 months.
- All labor to deliver SCADA replacement/upgrade projects will be professional services.

1.4.5 Implementation Plan Summary

The Implementation Plan summary includes the following information:

1) Summary project descriptions (Table 1-14)
2) Summary table of estimated project costs (Table 1-15)
3) Phased cost schedule (Table 1-16)
4) Gannt chart summarizing the estimated project schedule (Figure 1-8)

Table 1-14. Summary Project Descriptions

Project Name Duration Cost	Project Purposes	Dependencies
1. Replace Servers 14 months, $538,000	▪ Replace obsolete server hardware and software to provide a current, reliable platform for SCADA applications. ▪ Implement reliable backup/recovery systems and practices. ▪ Upgrade FactoryTalk HMI to current version. ▪ Develop PLC/HMI control objects compliant with all Convention Standards. ▪ Implement Alarm Management standards. ▪ Implement Historian. ▪ Develop Transition Plan (covers 2 or more years).	▪ Requires fully developed Convention Standards. ▪ The completion of the project will establish the SCADA platform for all subsequent SCADA projects.
2. Upgrade WRP Network 16 months $473,000	▪ Replace obsolete multi-mode fiber-optic with single mode. ▪ Replace obsolete non-managed switches and flat architecture with robust, self-healing ring network. ▪ Develop Network Cutover Plan.	▪ Can be scheduled independently, but cutover planning must coordinate with other projects.
3. Upgrade WRP PLCs 13 months $693,000	▪ Upgrade all ControlLogix PLCs to use new PLC/HMI control objects. ▪ Upgrade any PanelViews to thin clients. ▪ Upgrade all DeviceNet devices to Ethernet and any appropriate instruments to HART protocol. ▪ Apply all Convention and Component standards to field instruments and wiring and PLC hardware. ▪ Develop PLC Upgrade Cutover Plan that includes 7 ControlLogix PLCs. ▪ Provide operator training and as-built documentation.	▪ Requires fully developed Convention and Component Standards. ▪ Requires PLC/HMI control objects developed in Project 1.
4. Replace WRP PLCs 24 months $1,067,000	▪ Replace all PLC 5/40, CompactLogix, MicroLogix, and SLC with new ControlLogix PLCs (and PLC5). ▪ Program new PLCs to use new PLC/HMI control objects. ▪ Install new control panels with new PLCs. ▪ Upgrade any PanelViews to thin clients.	▪ Requires fully developed Convention and Component Standards. ▪ Requires PLC/HMI control objects developed in Project 1.

Table 1-14. Summary Project Descriptions

Project Name Duration Cost	Project Purposes	Dependencies
	▪ Upgrade all DeviceNet devices to Ethernet and any appropriate instruments to HART protocol. ▪ Apply all Convention and Component standards to field instruments and wiring and PLC hardware. ▪ Develop individual PLC Cutover Plans (4 PLC5/40Es, 2 CompactLogix, 2 MicroLogix, 1 SLC, PLC5) that includes all field instruments and control devices for each PLC. ▪ Provide operator training and as-built documentation.	
5. Evaluate Serial Radios 2 months $52,000	Evaluate costs and benefits of upgrading serial radios to 5G cellular service as backup communications to Ethernet.	N/A
6. Upgrade Remote PLCs 9 months $156,000	Upgrade 1 ControlLogix PLC to use new PLC/HMI control objects. Apply all Convention and Component standards to field instruments and wiring and PLC hardware. Develop PLC Upgrade Cutover Plan that includes 1 ControlLogix PLC. Provide operator training and as-built documentation.	Requires fully developed Convention and Component Standards. Requires PLC/HMI control objects developed in Project 1.
7. Replace Remote PLCs 24 months $902,000	Replace all CompactLogix and MicroLogix PLCs with new ControlLogix 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 and wiring and PLC hardware. Develop individual PLC Cutover Plans (9 CompactLogix, 5 MicroLogix) that includes all field instruments and control devices for each PLC Provide operator training and as-built documentation.	Requires fully developed Convention and Component Standards. Requires PLC/HMI control objects developed in Project 1.

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 platform and includes projects 1 and 2.
2) Phase 2 focuses on the WRP controls and includes projects 3 and 4.
3) Phase 3 completes the SCADA system and includes projects 5, 6, and 7.

Table 1-15. Project Cost Summary

Phase Name Duration, Phase Cost	Project Name	Duration (months)	Project Cost
1. Establish SCADA Platform 17 months, $1,011,000	1. Replace Servers	14	$538,000
	2. Upgrade WRP Network	16	$473,000
2. Integrate WRP Controls 36 months $1,760,000	3. Upgrade WRP PLCs	13	$693,000
	4. Replace WRP PLCs	24	$1,067,000
3. Integrate Remote Sites 30 months $1,110,000	5. Evaluate Serial Radios	2	$52,000
	6. Upgrade Remote Site PLCs	9	$156,000
	7. Replace Remote Site PLCs	24	$902,000
Total Cost			**$3,881,000**

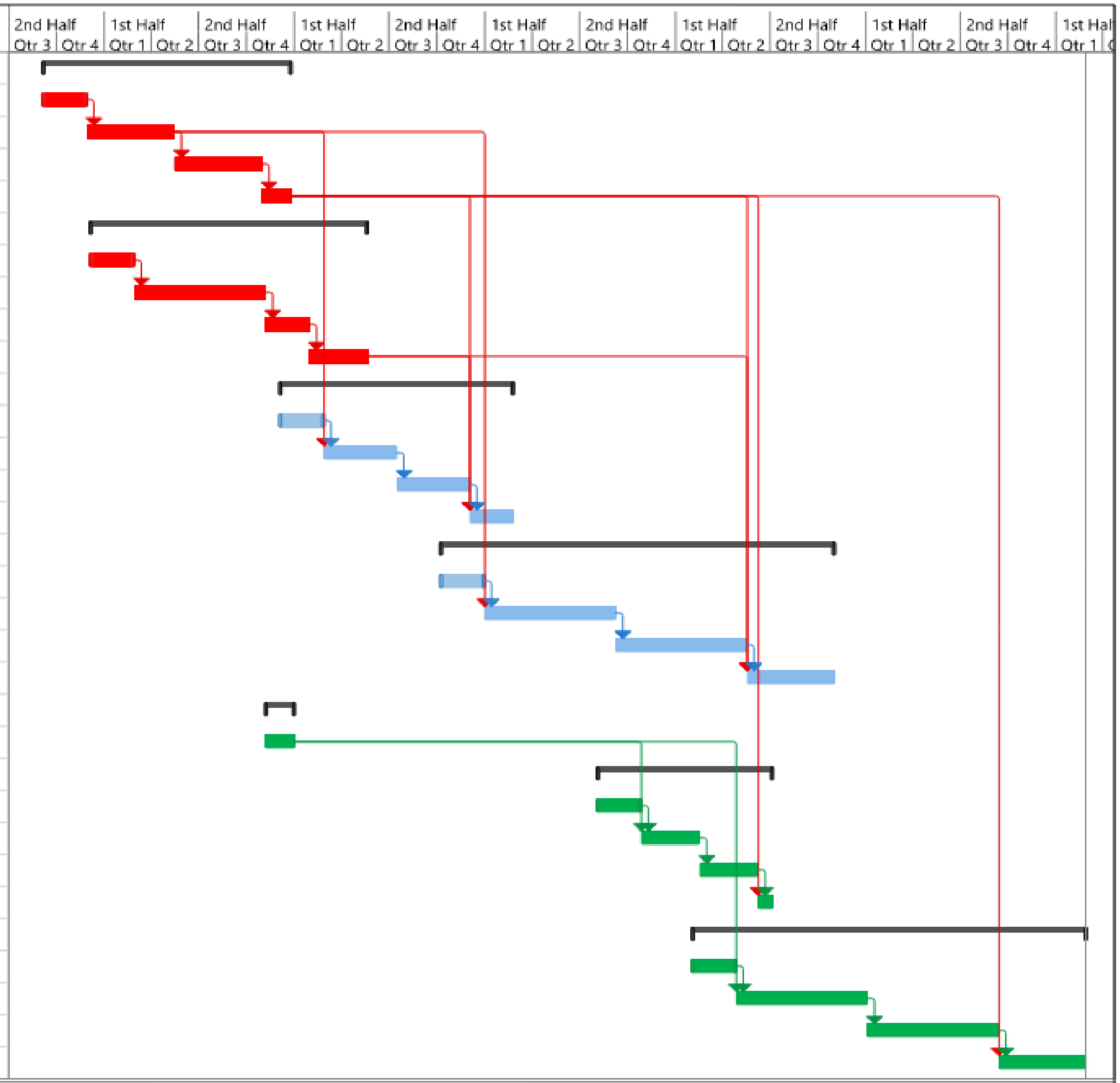
Combining the summarized project costs and durations and using the phased approach to balance resource workloads produces an estimated phased cost schedule, as shown in Table 1-15.

Table 1-16. Phased Cost Schedule

Project Name	Year 1	Year 2	Year 3	Year 4	Year 5	Total Cost
1. Replace Servers	$53,800	$107,600	$376,600	$ -	$ -	$538,000
2. Upgrade WRP Network	$47,300	$189,200	$236,500	$ -	$ -	$473,000
3. Upgrade WRP PLCs	$ -	$207,900	$207,900	$277,200	$ -	$693,000
4. Replace WRP PLCs	$ -	$320,100	$320,100	$426,800	$ -	$1,067,000
5. Evaluate Serial Radios	$ -	$52,000	$ 0	$ 0	$ 0	$52,000
6. Upgrade Remote Site PLCs	$ -	$31,200	$124,800	$ 0	$ 0	$156,000
7. Replace Remote Site PLCs	$ -	$ 0	$ 0	$451,000	$451,000	$902,000
Totals	**$101,100**	**$908,000**	**$1,265,900**	**$1,155,000**	**$451,000**	**$3,881,000**

Phase 1 can start in July 2021, assuming the Convention Standards are fully developed by June. Phase 2 can start in January 2022, assuming the development of PLC/HMI Control Objects in Project 1 by December 2021. The overall estimated schedule is shown on Figure 1-8.

ID	Task Name	Duration
1	**1. Replace SCADA Servers**	**340 days**
2	Proj 1 Consultant scope and agreem	3 mons
3	Proj 1 Design	6 mons
4	Proj 1 Prog & FAT	6 mons
5	Proj 1 Field to Completion	2 mons
6	**2. Upgrade WRP Network**	**380 days**
7	Proj 2 Consultant scope and agreem	3 mons
8	Proj 2 Design	9 mons
9	Proj 2 Prog & FAT	3 mons
10	Proj 2 Field to Completion	4 mons
11	**3. Upgrade PLCs at the WRP**	**320 days**
12	Proj 3 Consultant scope and agreem	3 mons
13	Proj 3 Design	5 mons
14	Proj 3 Prog & FAT	5 mons
15	Proj 3 Field to Completion	3 mons
16	**4. Replace end of life PLCs at the WRP**	**540 days**
17	Proj 4 Consultant scope and agreem	3 mons
18	Proj 4 Design	9 mons
19	Proj 4 Prog & FAT	9 mons
20	Proj 4 Field to Completion	6 mons
21	**5. Evaluate Serial Radios at Remote Si**	**40 days**
22	Proj 7 Study and Report	2 mons
23	**6. Upgrade Remote Site PLCs**	**240 days**
24	Proj 6 Consultant scope and agreem	3 mons
25	Proj 6 Design	4 mons
26	Proj 6 Prog & FAT	4 mons
27	Proj 6 Field to Completion	1 mon
28	**7. Replace Remote Site PLCs**	**540 days**
29	Proj 7 Consultant scope and agreem	3 mons
30	Proj 7 Design	9 mons
31	Proj 7 Prog & FAT	9 mons
32	Proj 7 Field to Completion	6 mons



Page 1

Figure 1-8. Phased Project Schedule (Gannt Chart)

Convention Standards

2.1 Introduction

A well-designed and implemented SCADA system performs two functions. First, the SCADA system monitors process and equipment performance in real-time and collects data for historical and analytical purposes. The data collection function performs best when it is based on reliable instrumentation, reliable data communications, and consistent database standards.

Second, the SCADA system controls equipment remotely. Remote control enables more efficient manual operation and more effective automatic operation. With the advantages of advanced data analytics, remote control can optimize operations. The control function performs best when it is based on a control philosophy that establishes a consistent approach to remote control through local PLCs.

The window into the SCADA system is the Human Machine Interface (HMI). The HMI graphically presents pertinent information for operators to make timely and responsive decisions. A well-designed and consistent HMI enables operators to quickly understand current operating conditions, alerts the operator of unusual operating developments, supports subsequent investigations, projects operating scenarios, and can even suggest operating alternatives for consideration.

The development of such a high-performance SCADA system is governed by the Convention Standards. Each Convention Standard introduces and describes a detailed framework for implementing the SCADA system at the WRD. Each section builds on the previous section in the following order:

1) Control Philosophy
2) Database Tagging
3) PLC Programming
4) HMI Graphics
5) Alarm Management
6) Historical Data

The purposes of these Convention Standards are twofold; first, to establish a framework of standards specific to the WRD, and second, to introduce future resources to those same standards. For these purposes, it is written in a narrative style. It is not intended to be a technical manual for programmers or technicians.

The Convention Standards are to be applied to all the projects described in the Implementation Plan, as well as to any other projects designed, implemented, and constructed by WRD staff or any contracted consultants, engineers, and programmers.

2.2 Control Philosophy

The control philosophy establishes the basis for all convention standards and some component standards. The control philosophy will guide development of the following standards:

- Convention Standards
  - Tagging and Database Standards
  - PLC/HMI Control Objects
  - HMI Graphics
  - Alarm Management
  - Historian Reports and Trends
- Component Standards
  - Control Strategy Descriptions
  - Control System Input / Output lists
  - Control Schematics
  - Control Panel Designs

The Control Philosophy includes the following topics:

1) Equipment Control Modes
2) Equipment Monitoring
3) Process Monitoring
4) Automatic Controls

2.2.1 Equipment Control Modes

Controlled equipment in a water utility includes pumps, valves, and other powered devices. Controlled equipment falls into one of three categories; non-SCADA controlled, SCADA controlled equipment, and SCADA controlled package systems.

- **Non-SCADA controlled:** This equipment may be monitored by SCADA, and operation of this equipment only occurs locally,
- **SCADA controlled:** This equipment is monitored by SCADA, and normally operated through SCADA.
- **Packaged:** This equipment is monitored by SCADA and controlled through a Human Interface Module (HIM) at the MCC / VFD keypad. The SCADA system may issue commands and setpoints to the packaged system.

SCADA control will be the default mode of operation for most controlled equipment. All the interlocks that protect personnel and equipment as well as the critical safety alarms, will be hardwired at the local control panels. The E-stop selector or pushbutton will always be located at the equipment with the interlock hardwired. SCADA will monitor all these alarms and will only apply selected software interlocks.

All SCADA-controlled equipment will include a LOCAL / OFF / REMOTE (LOR) or LOCAL / REMOTE (L/R) selector switch at the field. In LOCAL, the control of the equipment will be based on the local pushbuttons and hardwired control logic. The hardwired interlocks will be active irrespective of the position of the L/R selector switch. The REMOTE status (of the LOR or L/R selector switch) will be monitored at SCADA.

Some pumps may include another level of control at the MCC / VFD HIM (typically located in an electrical room). The field L/R selector must be in the REMOTE position and the HIM must be in LOCAL mode for control through the HIM. The pump can now be operated from the HIM. Control from the local pushbuttons at the field panel will be disabled in this option. SCADA will also monitor the LOCAL / REMOTE status of the HIM module.

When the device is in REMOTE in the field and in REMOTE at the HIM, control will be transferred to the SCADA. The operator may select MANUAL or AUTO control modes at the SCADA display for each device in REMOTE mode. In the MANUAL mode of operation, the operator can manually operate each device from the SCADA displays. In the AUTO mode of operation, the equipment is controlled by the automatic control strategy for each device. Software interlocks will be active for this mode of control. A diagram of these equipment control modes is shown on Figure 2-1.

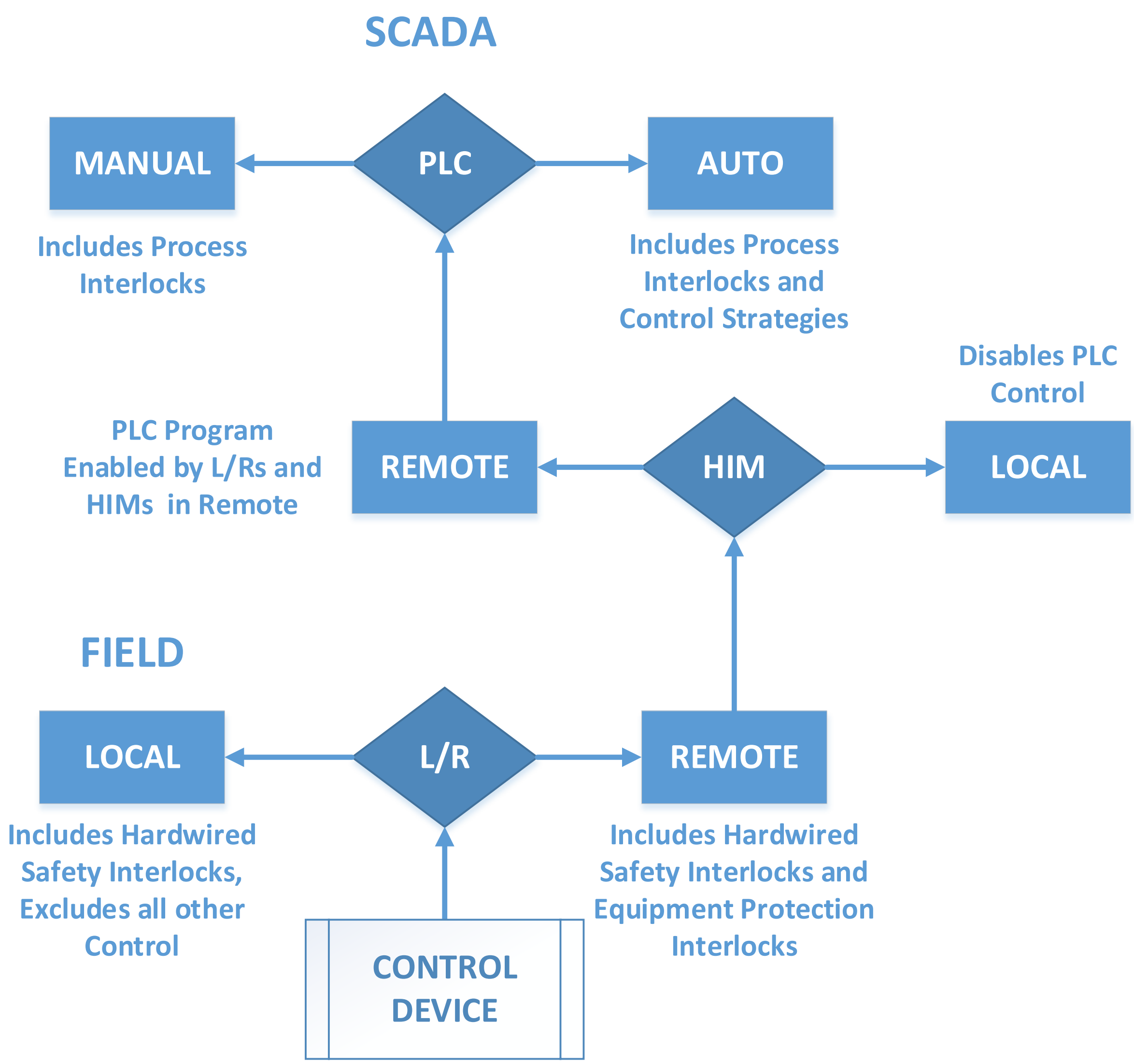


Figure 2-1. Control Modes for Equipment with MCC/VFD HIM

A summary of control mode selection based on selector switch status is shown in Table 2-1.

Table 2-1. Control Modes when using a HIM

Selection Point	Selection Point Status		
Field L/R Selector Switch	L	R	R
HIM Selector Switch	N/A	L	R
PLC M/A Selector Point	N/A	N/A	Manual/Auto
Control Mode Result	Local Control Panel	HIM	SCADA

2.2.2 Equipment Monitoring

This section describes general monitoring functions applicable to broad classifications of equipment, such as motors, valves, and other equipment. These functions may be applied as desired to any equipment monitored by SCADA. These functions are assumed in the individual control strategies.

1) Field Selection of Control Mode

Every device directly controllable by SCADA includes a L/R or LOR switch to select the device's control mode. SCADA monitors the device's L/R switch state to determine when the device is being locally controlled, or the PLC has control of the associated equipment. Current L/R status is displayed in SCADA. Existing device switches may have some variation of HAND/LOCAL, OFF, or AUTO/REMOTE. As new switches are added or replaced, the labels should be replaced with LOCAL and/or REMOTE.

2) Hard-wired Interlocks

Safety related and equipment protective alarms will be hardwired and not programmed within the PLC. Latched interlocks (i.e., E-Stop, High Discharge Pressure, Motor Overload) will require the operator to reset the interlock at the local control panel or at the face of the MCC. Unlatched interlocks (i.e., Low Suction Level, Moisture Alarm) do not require an operator reset. Once the process condition returns to its normal operating range, the equipment will return to available status for REMOTE control. Activated interlocks will not impact the LOCAL / REMOTE status into the PLC. Certain system related and SCADA generated alarms (i.e., 'No Pumps available for Remote Control' alarm, PLC to PLC communication Fail alarm) will be reset from the SCADA displays.

3) Runtime Calculation

The PLC will maintain an elapsed run time for any equipment that provides a RUN status. The total elapsed time will be displayed on SCADA in units of hours, with a resolution of 0.1 hour. A Supervisor or Administrator will be able to reset the total run time. An alarm is generated if the runtime exceeds its register capacity.

4) Equipment Faults

If the PLC issues a command to a motor and if the correct motor feedback status is not registered within a specific time, the PLC will issue an alarm and place the device in a 'Failed' state. The PLC will also generate an 'Unsolicited Change' alarm and put the device in a 'Failed' state, if a running device (in REMOTE) stops without a command from the PLC. These alarms must be reset at SCADA to re-establish control of this device (from a failed state).

5) Energy Information

Energy data will be collected for equipment greater than 50 horsepower and the data will be typically collected via an Ethernet link. The energy information monitored by the SCADA system includes the following:

- Power in kilowatts
- Power in kilovolt-amperes reactive
- Power in kilovolt-amperes
- Power Factor
- Volts (each phase)
- Amperes (each phase)

2.2.3 Process Monitoring

1) Analog Input Filtering

Analog signal quality (over/under range.) will be monitored and flagged by SCADA. Points with unacceptable quality will not be used for control or calculation purposes.

2) Digital Input Filtering

When required, the PLC will use an adjustable time delay function for the purpose of de-bouncing discrete input variables. De-bounce timers will be used on all discrete alarm inputs. The time delays are adjustable only by qualified technicians familiar with PLC programming. By default, discrete inputs are configured with de-bounce timers set to zero (0) seconds.

3) Position/Speed Indication

For modulating valves/gates and for VFDs, the PLC will generate a discrepancy alarm if the position or speed feedback is not within an adjustable percentage (initial setting is 3 %) of the output command within an adjustable time (initial setting 60 seconds). Both parameters will be adjustable (in the PLC control objects) for each controlled device.

4) Flow Totalizers

Every liquid flow rate transmitted to the SCADA will have a flow total calculated as follows:

- The current day's total flow (midnight to midnight) is calculated in the PLC and displayed at SCADA.
- The previous day's total flow (as of midnight) is calculated in the PLC and displayed at SCADA.
- A running total flow is calculated at the PLC and displayed at SCADA. This total may be reset by the supervisor at SCADA. When this total is reset, the PLC creates a timestamp of the reset action and SCADA displays this time and date next to the running total.

5) Communication Statistics

The SCADA system will track all communication errors for remote and in-plant PLCs. Any in-plant communication fault, which results in three or more (user adjustable) consecutive failed retries, will generate an appropriate communication alarm describing the problem. A SCADA communication summary will display the status of each SCADA node on the network.

2.2.4 Automatic Controls

1) Pump Call Order

Where two pumps are available in a unit process and no more than one pump may run at a time, the PLC program will use a lead/standby strategy. Where both pumps may be required to run simultaneously, the PLC program provides lead/lag logic. Where 3 or more pumps are available, and more than one pump may be required to run simultaneously, the PLC program will provide lead/lag/standby logic. The operator will select which pump is lead, lag, etc. at the SCADA display. The PLC will change the lag and standby selection after the lag pump has run and stopped. The lead pump will be changed based on an operator-input at SCADA.

2) Equipment Runtime Balancing

Where two or more controlled devices operate in an alternating sequence and are available, the PLC program will alternate the lead unit selection upon shutdown of the unit process with the goal of balancing the runtime between all units. The equipment with the least runtime hours will be initially set to be the lead unit, allowing the auto alternation of equipment to balance the runtimes. The PLC program will not automatically alternate the lead unit based on runtime.

3) PID Control

Automatic process control will require PID control loops to achieve stability over a range of process conditions. PID control loops will adjust pump speed or valve position in response to the difference between the process variable and a setpoint.

PID control modes will be selected at the SCADA displays. Tuning parameters will be adjusted only by qualified maintenance technicians familiar with process control. All adjustable parameters will be changed through the PLC program (as opposed to the SCADA displays), provided the user has valid permission privileges.

4) Chemical Dosing

Chemical dosing will be controlled with a direct flow setpoint, a pump speed setpoint, or a flow pacing with trim option. Flow pacing with trim is the preferred strategy for chemical dosing. The trim will automatically adjust the chemical dosage setpoint based on feedback from an on-line water quality analyzer. Flow pacing through the SCADA system will require reliable on-line water quality analyzers to execute the flow pacing algorithms. This strategy is also known as cascade PID control since the output of one PID loop sets the setpoint of another PID loop.

5) Restart after a Power Outage

Most pieces of equipment will be re-started manually after a power outage. However, some process areas (i.e., hypochlorite pumps) may be automatically re-started after a power outage. These process areas will be identified during design and programming activities.

2.3 Database Tagging Standards

2.3.1 Database Tagging Objectives

The SCADA Database Tagging standard establishes the identification system of all field-generated data points, including both process instrumentation and equipment control/feedback. The data collected by the SCADA system enables and enhances both performance and operations. Properly processed SCADA data provides critical information to operators, maintenance technicians, engineers, and management, that helps optimize operations, accelerate diagnostic processes, and analyze process and equipment performance. Therefore, the primary purpose of database tagging is to identify SCADA data quickly and easily.

A database tagging system consistently applied is critical to maintaining easy identification and access. This is achieved by rigid enforcement of clear and well-organized rules and guidelines. Database tagging rules provide predetermined formats and field entries and do not allow for deviations without an approved formal change to the rule. Database tagging guidelines provide a general framework and allow for flexibility within predetermined boundaries. Deviations within the boundaries of the guideline may be approved without a formal change to the rules or guidelines.

These rules and guidelines must be strictly followed by every SCADA system designer or programmer authorized to develop, maintain, document, or modify SCADA system programming, instrumentation, and control devices.

This section describes the database tagging rules for tagging format and tag field codes and the guidelines for loop numbers and elements.

2.3.2 Database Tagging Format Rules

1) Tagging Formats

Database tagging formats consist of a series of increasingly specific tag fields that uniquely identify the data point. The WRD defines these fields as follows.

Tag Field	Governance	Application
1. Facility (FFFF)	Rule	All Sites
2. Controller (CCS)	Rule	WRP Only
3. Process Area (PP)	Rule	WRP Only
4. Equipment (EEEE)	Rule	All Sites
5. Loop (LLLSS)	Guideline	All Sites
6. Element (.x)	Guideline	All Sites

Base tag names at the WRP include tag fields 1 through 5. Base tag names at remote sites include tag fields 1, 4, and 5. Tag field 6 (elements) provide an array of attributes associated with a base tag. The tagging format for the WRP is shown on Figure 2-2. The tagging format for remote sites is shown on Figure 2-3.

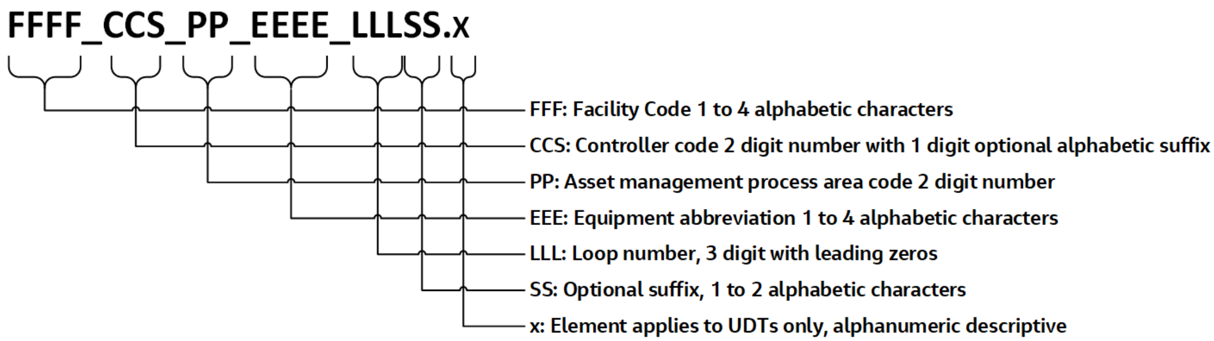


Figure 2-2. WRP Tagging Format

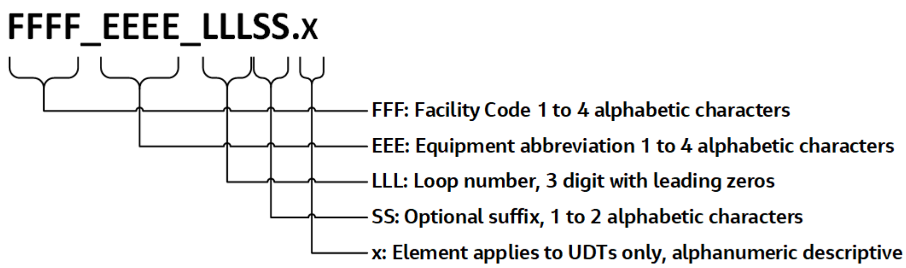


Figure 2-3. Remote Site Tagging Format

2) Tag Name Rules

Based on the rules defined by Allen-Bradley Studio 5000® programming manuals, tag naming must adhere to the following rules.

- Tag name must be unique
- Tag cannot be more than 31 characters long, including elements
- Tag can consist of any combination of letters, numbers, and underscores
- A tag name cannot begin with a number
- Case is not significant in tag names (upper and lowercase characters are equal)

The WRD further requires tag naming to adhere to the following rules:

- Underscores (_)separate tag name fields
- All letters are UPPER case, no lower-case letters in tag names
- Dots (.) delineate elements for User-Defined Data Types (UDT) and AOIs.
  - Element naming will use title case (Proper Case) without spaces. Examples are: .iOutOfService, .iAlarmDelaySP, .pAlarmSeverity, etc.

3) Tag Description Rules

All tag names include an associated description. The description uses descriptive words organized by increasingly specific details about the data point. Therefore, the tag description is intended to accurately reflect the tag name. The following examples show desirable and undesirable descriptions.

i. Desirable Descriptions:

a) Primary Effluent Pump Station Discharge Flow
b) Primary Effluent Pump 1 Discharge Pressure Alarm High
c) Aeration Basin 1 Mixer 1 Fault

ii. Undesirable Descriptions:

a) Flow Primary Effluent Pump Station Discharge
b) High Alarm Pressure Primary Effluent Pump 1
c) Mixer 1 Fault Aeration Basin 1

Tag descriptions are tested by sorting the tag list on description only**. If the tag descriptions are clear and consistent, all related equipment will group together in a database sort. If not, the tag descriptions must be revised**.

2.3.3 Database Tagging Field Entry Rules

The first four fields in the database tagging format are populated by selecting predetermined entries. As previously noted, only the Facility (FFFF) and Equipment (EEEE) fields are populated for data points at remote sites.

1) Facility (FFFF) Codes

All tags begin with 3 to 4 alphabetic characters, selected from the codes identified in Table 2-2.

Table 2-2. Facility Codes

FFFF	Description	Type
WRP	Water Reclamation Plant	Plant
DOT	Doolan Tower and Reservoir	Water
AWPS	Airway Pump Station	Water
PFS	Pleasanton Flow	Water
DAT	Dalton Reservoir	Water
TRP	Trevarno Pump Station	Water
APS	Altamont Pump Station	Water
ATS	Altamont Reservoirs	Water
VPS	Vasco Pump Station	Water
OVPS	Oakville Pump Station	Water
MPS	Murrieta Storm Lift Station	Storm
NLPS	North Livermore Storm Lift Station	Storm
PSPS	North P Storm Lift Station	Storm
ECLS	El Charro Lift Station	Sewer
ALS	Airport Lift Station	Sewer
JCLS	Junior College Lift Station	Sewer

2) Controller (CCS) Codes

The controller code field applies only to data points physically located at the WRP. Data points that are hardwired or digitally connected to a PLC will use a two-digit PLC number without a suffix. Data points that are hardwired or digitally connected to a Remote Input / Output (RIO) in a separate enclosure will use a two-digit PLC number and an alphabetic suffix, unique to each separate RIO enclosure.

Note: PLCs and RIO racks located in the same enclosure are assigned a PLC number without a suffix. Similarly, multiple RIO racks located in the same enclosure are assigned the same PLC number with a suffix. RIOs in separate enclosures are assigned a PLC number with unique suffixes for each enclosure. Controller codes are selected from the entries listed in Table 2-3.

Table 2-3. PLC Controller (CCS) Codes

PLC ID	CCS	Location	Related Processes
PLC1	01	Water Building, Rack 2,3,4	Headworks and Primaries
RIO1A	01A	Pump & Blower Room	
RIO1C	01C	Odor Control	Odor Control
RIO1D	01D	Bar Screen	Bar Screens
PLC2	02	RAS/WAS Building	RAS, WAS
PLC3	03	Digester Building	Digesters
PLC4	04	Greenhouse	
PLC5	05	Tertiary Building	
RIO5C	05C	Recycle Pump Station	
PLC6	06	Filter Gallery (2nd Floor)	
RIO6B	06B	Weather Station	
RIO6C	06C	Old Caustic Tank	
RIO6D	06D	Hypo Bulk Tanks	Hypochlorite Storage
PLC7	07	Reverse Osmosis	(Will be discarded after new WIN911 installation)
PLC8	08	UV Building	UV Disinfection System
PLC9	09	Admin Building	
PLC10	10	LAVWMA	Effluent Pumps
PLC11	11	Blower Building	Aeration Blowers, Aeration Mixers, DO Monitoring,
PLC12	12	Solids Handling Building	GBT System, Rickenbacker Lift Station
PLC13	13	GBT1	Packaged PLC from the GBT vendor
PLC14	14	GBT2	Packaged PLC from the GBT vendor
PLC24	24	UV Building	UV Power Monitor
PLC25	25	Headworks	Bar Screen Washer
PLC28	28	Water Building	Grit Classifiers

3) Process Area (PP) Codes

The process area code applies only to data points physically located at the WRP and consists of a two-digit numeric value. The first digit corresponds to a WRP Process Area Code Map shown in Appendix 2-A. For any CIP project, the two-digit numbers are the same as those from the equipment numbers (asset numbers) in the drawings which are given by the WRD. The second digit is based on the elevation of the device and will be one of the following.

- 0 designates devices located below grade in a vault, basement, or other area below grade.
- 1 designates devices located at grade, on the first floor, etc.
- 2 designates devices located above grade, on floors higher than the first, etc.

4) Equipment (EEEE) Codes

All database tags consist of a 1 to 4-character alphabetic code to identify the type of equipment monitored by the PLC. Equipment codes for process instrumentation, equipment control, and equipment feedback are derived from the ISA 5.1 standard. Equipment codes apply to data points monitored or controlled in the PLC. Equipment codes may also be used on process and instrumentation diagram (P&ID) or physical tags of equipment not connected to the SCADA system.

Field equipment connections to the SCADA system include three protocols: hardwired (4-20 mA, 24 volts direct current [VDC], or 120 volts alternating current [VAC]), HART (process instruments), or Ethernet (control devices). Equipment that can transmit multiple data points through HART or Ethernet protocols are grouped together as intelligent devices.

5) Hardwired Data Points

Equipment codes for hardwired data points are shown in Table 2-4. Table 2B-1 in Appendix 2-B includes an extensive list of examples of hardwired tag names for process instrumentation and equipment feedback and control.

Table 2-4. Hardwired I/O (EEEE) Codes

	1st Letter	2nd Letter	3rd Letter
Process Instrumentation			
A	Analytical	Alarm	
D	Density		
E	Voltage		
F	Flow		
H			High
I	Current	Indicate (Local only)	
J	Power		
L	Level		Low
M	Moisture		
P	Pressure		
PD	Pressure Differential		
S		Switch	
T	Temperature	Transmit	
V	Vibration		
W	Weight		
Equipment Control/Feedback			
C		Control/Command	Close/Closed
H	Remote Status (Hand)		
O			Open/Opened
S	Speed	Switch	
T		Transmit	
U	Common (Multi Variable)		
Y	Status (Running)		
Z	Position		

6) Intelligent Devices

Process instruments that use HART protocol transmit more than one data point from a single instrument. The equipment code for HART instruments will use a 2-character code. The first character will use one of the **bold** letters shown in Table 2-5. The second character will use “**T**” for Transmit. Data points transmitted through this base tag name will be distinguished by elements (.x). Table 2B-2 in Appendix 2-B includes a list of tag name examples for HART instruments.

Some equipment may produce a mix of both hardwired and Ethernet data points. All hardwired data points will use a hardwired equipment (EEE) code like the examples shown in Table 2B-1. Equipment using Ethernet to connect multiple data points to the PLC include feedback data points and control signals. The code for equipment using Ethernet is based on the equipment description and selected from the entries listed in Table 2-5. Feedback data points and control signals communicated through this base tag name will be distinguished by elements (.x). Table 2B-3 in Appendix 2-B includes a list of tag name examples for Ethernet connected equipment.

Table 2-5. Ethernet Equipment (EEE) Codes

Code	Description	Code	Description
AC	HVAC, Air conditioner	~~GT~~	~~Gravity Belt Thickener~~
AH	HVAC, Air Handler, package units	~~GW~~	~~Gritwasher~~
AV	Control Valve or Gate Actuator (Modulating)	~~HX~~	~~Heat Exchanger~~
AV	Valve or Gate Actuator (Open/Close Only)	IN	Instrument
~~AV~~	~~Valve, Auto~~	IN	Power Data Monitor
BA	Battery	IN	Variable Frequency Drive
BC	Battery Charger	~~LP~~	~~Light Pole~~
BL	Blower	~~MCC~~	~~Motor Control Center~~
BL	Blower with VFD	ME	Motor
BL	Compressor	MX	Mixer
~~BP~~	~~Filter Press~~	MX	Mixer with VFD
~~BS~~	~~Bar Screen~~	PB	Breaker
~~BT~~	~~Odor Scrubber~~	~~PC~~	~~Computer~~
~~CL~~	~~Clarifier~~	PLC	Programmable Logic Controller
CM	Camera	PP	Chemical Feeder
~~CO~~	~~Crane~~	PP	Pump
~~CV~~	~~Valve, Check~~	PP	Pump with VFD
~~CY~~	~~Conveyor~~	RA	Radio
DR	Drives	~~SE~~	~~Substation~~
ED	Power Supply (24 VDC or 12 VDC)	SS	Soft Start
ED	Protective Relay	~~TK~~	~~Tank~~
ET	Transformer	UP	Uninterruptible Power Supply
~~FC~~	~~Flocculator~~	~~UV~~	~~UVChamber~~
~~FL~~	~~Filter~~	~~VF~~	~~Fan~~
~~GB~~	~~Burner, Waste Gas~~	~~VF~~	~~Fan with VFD~~
~~GE~~	~~Generator~~	~~VM~~	~~Valve, Manual~~
~~GR~~	~~Grinder~~	~~WG~~	~~Water Gate~~

2.3.4 Database Tagging Loop Numbering Guidelines

1) Loop Numbers and Suffixes (LLLSS)

Loop numbers (LLL) will be three-digit numeric values. Loop number ranges are assigned to specific projects through a formal governance procedure. Loop number ranges will be assigned within two main guidelines.

i. Remote Facilities: loop numbers should not overlap with loop numbers already in use at the site.

ii. WRP: loop numbers should not overlap with loop numbers already in use within the Controller (CCS) and Process Area (PP) codes.

Example:

a) A project in the Aeration Facility (Process Areas 30, 31, and 32) adds new equipment above, below, and at grade level. If a new PLC or RIO is required, any loop number range can be assigned. If the new equipment is connected to the existing PLC (i.e., PLC11), the loop number range assigned should start above the highest existing loop number as shown below.

PP	Highest Existing Loop #	Assigned Range
30	032	100 to 199
31	316	400 to 499
32	104	200 to 249

Loop numbers within the assigned range may be designated at the designer's discretion. Grouping numbers together logically is encouraged wherever possible.

Suffixes (SS) may be used in the event of closely related data points. Examples are.

iii. Both remote and local hand switch statuses are monitored by the SCADA system. Assuming a common loop number (121) for the hand switch and its related equipment, the EEE_LLLSS tag names would be HS_121A for Remote Status and HS_121B for Local status.

iv. Both suction header pressure and the discharge header pressure on a pump are monitored by the SCADA system. Assuming a common loop number (150) for the pressure instruments and their related pump, the EEE_LLLSS tag names would be PIT_150A for Suction Pressure and PIT_150B for Discharge Pressure.

2) Elements (.x)

Elements are reserved specifically for UDTs and AOIs and are delineated by a dot (".") at the end of the base tag name. Base tags consist of FFF_CCS_PP_LLLSS or FFF_EEE_LLLSS, while elements are an array of attributes associated with a base tag. Element naming starts with a lower case leading alphabetic character indicating general functionality and ends with descriptors using title case without spaces. The following is a list of typical leading alphabetic characters.

io: Indicates a hardwired or digitally communicated data point (i.e., Flow, Remote Status, etc.)
c: Indicates the value is constant (i.e., pi, alarm severity, etc.)
pi: Indicates the value is an input from another program
po: Indicate the value is an output to another program
i: Indicates the value is an input to the PLC from the HMI
o: Indicates the value is an output from the PLC to the HMI

Element descriptors are designated at the programmer's discretion within the tag name rules defined by Allen-Bradley Studio 5000. Elements and their use in UDTs and AOIs are described in more detail in the PLC Programming and PLC Control Objects sections.

2.4 PLC Programming

2.4.1 Programming Overview

The purpose of this section is to establish control object programming standards as applied to Allen-Bradley (A-B) ControlLogix and CompactLogix PLC processors. Programming standards provide uniformity across multiple control system projects which can use multiple programmers. Specific goals include:

- Simplify control strategy development by using standard control objects.
- Reduce development, installation and maintenance costs of PLC and HMI programs.

PLCs are the foundation of a solid SCADA system. Properly programmed, they collect all critical process information and perform all critical process functions. This includes scaling process variables, alarm acknowledgement and suppression, critical control logic, and math functions. PLCs provide continuous control of equipment even when the HMI servers are down.

Inputs and Outputs (I/O), equipment control, and process control should be handled as consistently as possible. Consistency reduces confusion around equipment operation, increases operator awareness of improper response of the equipment or process, and aids in faster troubleshooting for maintenance staff.

A-B ControlLogix and CompactLogix PLCs use Rockwell Automation's Studio 5000® for programming. Studio 5000 provides user customization with UDT and Add On Instructions (AOI). AOIs are reusable programming instructions that provide consistent control of similar equipment, process functions, handling of I/O and monitoring of PLC diagnostics. The AOI is accompanied by a UDT that provides a consistent software tag naming structure for each AOI. Each UDT includes all software tags required in the AOI logic. Consistency of PLC code and tag naming enables consistency in HMI graphic creation. Each AOI is paired with an HMI popup graphic for a complete control object.

ControlLogix and CompactLogix PLC programs include four components, which work together to form the overall PLC program. The components of the PLC program are:

- I/O configuration
- PLC tag database
- PLC control program
- PLC control objects

2.4.2 I/O Configuration

The Input/Output (I/O) configuration includes signal addressing, processing, and I/O communication to and from the PLC. Addressing defines I/O module selection, location, naming, and parameter selection. Signal processing defines calibration, alarm limits, type, etc. I/O communication configuration sets the data transfer rates to and from the Central Processing Unit (CPU). I/O configuration will be based on the Convention Standards provided to designer/programmers to develop design documents such as the following:

- P&IDs
- Control Strategy Descriptions
- Control panel layout drawings
- Loop diagrams
- I/O list
- Hardware operation and maintenance (O&M) manuals

2.4.3 PLC Tag Database

The PLC tag database names all PLC data points used in control code processing. Tag names can be created from the I/O configuration and the I/O list. Tag naming rules and guidelines are described in the Database Tagging section. The I/O configuration creates default database tags based on the I/O modules. These default tag names must then be associated with the field instrument or control device. The alias name is based on the field device's data identifier.

1) Base Tags and Alias Tags

Studio 5000 uses two types of data tags: base tags and alias tags. A base tag identifies a data point and defines an area of CPU memory for storage. Base tag configuration assigns a data type, such as integer, real, bool, timer, counter, etc. Base tags can be configured as a single point, as an array, or as a UDT.

An alias tag references the CPU memory location defined by another tag. An alias tag may refer to a base tag or to another alias tag. An alias tag may also refer to a specific point within a larger structured tag. Examples would be a reference to a single bit within an integer, or a specific integer within an integer array, or an element within a UDT. Alias tags allow more descriptive tag names without consuming more memory in the CPU.

As a rule, the alias tag (and not the base tag) is used for all control programs in the PLC. This rule reduces the risk of writing conflicting commands to registers. Where alias tags are used, tag descriptions are linked to the alias tag. Alias tags are used to associate WRD's data identifiers with I/O configuration base tags.

2) Controller Scoped and Program Scoped Tags

All PLC Tags are either controller scoped, or program scoped. Controller-scoped tags are accessible by all parts of the PLC control program as well as applications outside of the PLC, such as SCADA/HMI systems.

Program-scoped tags are configured within a separate data memory area associated with a program. Within the PLC program, they are only accessible by the program in which they are configured. This allows for the ability to use a common tag name multiple times across several programs. This is used when applying standardized control code across multiple programs.

For data transferred to/from an external application, such as the SCADA/HMI systems, individual tags, AOI data types, or UDT controller scoped tags may be used. If a UDT tag is used, it should only contain data that is normally used by the external application.

3) Produced Tags and Consumed Tags

When a control strategy requires a PLC to communicate directly to another PLC (peer-to-peer) or multiple PLCs (broadcast), Studio 5000 uses produced and consumed tags. A produced tag uses one network connection at a CPU. Where non-cached messages are used, only *read* messages shall be used. To avoid overwriting local control commands in a receiving PLC, *write* messages shall not be used.

A produced tag is typically configured as a PLC2PLC UDT data type. This allows the status of the data along with 64 INT and 64 REAL values to be available to PLCs requiring the information.

A consumed tag is typically configured as a Multicast connection over Ethernet/IP (Unicast not checked), with an RPI of 500 milliseconds. This allows the same data word to be read by multiple PLCs if required but restricts the data tag to the same subnet. Data is then mapped in/out of the arrays as required by each PLC.

2.4.4 PLC Control Program

The PLC control program relies on both the I/O configuration and the tag database for execution. In Studio 5000, each PLC control program is organized into tasks, programs, and routines, as shown on Figure 2-4.

1) Tasks

Tasks occupy the highest level of organization in the program structure and can be continuous, periodic, or event-driven. All tasks, except for the single continuous task, can be assigned a priority level from 1 to 15, with 1 being the highest priority level. Periodic or event-driven tasks, when triggered, will pause the main continuous task to execute the logic of the given periodic or event-driven task, then resume execution of the continuous task where it was paused. If two tasks are triggered at the same time, the task with the higher priority will execute first. If two tasks with the same priority are triggered at the same time, the controller switches between the two tasks every millisecond. The continuous task runs at a fixed priority lower than all other tasks in the controller.

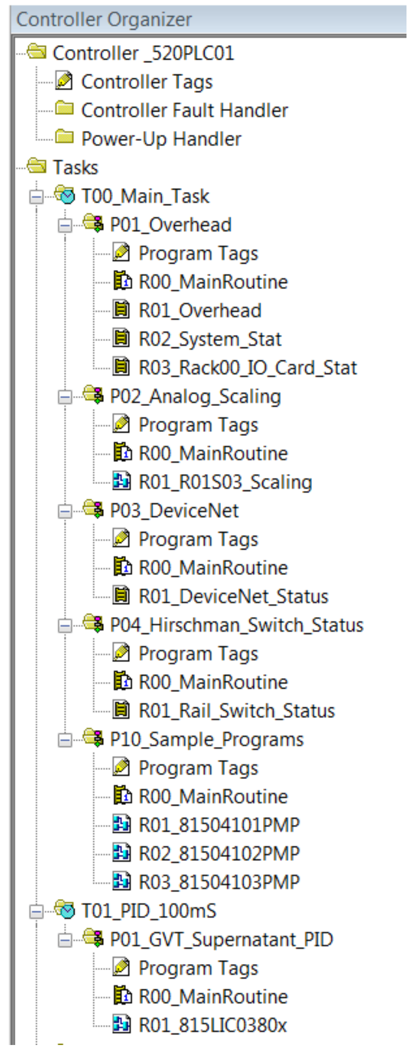


Figure 2-4. Sample Program Configuration

The continuous task runs continuously (i.e., in the background) through all its assigned programs, unless interrupted by another task. All CPU time not allocated to other operations (such as communications, periodic, or event-driven tasks) is used to execute the programs within the continuous task. Once the continuous task completes a full execution scan, an update of outputs is triggered, and the scan immediately starts over. A continuous task is created automatically upon creation of a new control program.

Periodic tasks run at preset time intervals ranging from 0.1 milliseconds to 2 seconds. Periodic tasks perform a function at a specific rate. The task is triggered at the end of a specified time. When triggered, the task interrupts any lower priority task (continuous, periodic, or event-driven), and all programs assigned to the task are executed or scanned once, from top to bottom. After this single scan, an output update is triggered, and control is returned to the interrupted task at the point at which it was interrupted. Multiple periodic tasks may exist on a controller, where each task is configured to operate at independent rates.

Periodic task time intervals are used for consistent flow totalizing and PID control. Periodic tasks also update PLC outputs faster than the continuous task. For these reasons, all control programs at WRD use periodic tasks only.

An event-driven task is a task that performs a specific function when triggered by a specified event. An event-driven task can be triggered by any of the following:

- Change of state of a digital input
- A new sample of analog data
- A consumed tag
- An event instruction
- Various motion control operations

When the event-driven task is triggered, it interrupts any lower priority tasks, executes one time, and returns control to the task that was interrupted at the point at which it was interrupted. A common application of event-driven tasks is in high speed assembly lines that require instantaneous response to shutdown triggering events. These circumstances do not apply to water/wastewater processes. For this reason, event-driven tasks are not used at WRD.

2) Programs

Programs execute within a task. Each program contains its own program-scoped tag database (local data table), a main executable routine, and optionally several subroutines. It is also possible to specify an optional fault routine for each program. The program-specific fault routine is executed if the controller encounters an instruction-execution fault within any of the routines in the associated program.

To execute the routines within a program when a program is triggered, at least one routine must be configured as the main routine. At WRD, each PLC program will include a routine with a common name of *R00_MainRoutine*. This routine calls all other routines within that program using the Jump to Subroutine (JSR) command.

3) Routines

Routines are the building blocks of the control strategy and include the actual programming code. Each program within a task includes one or more routines organized for input signal processing, equipment control, process control, and output signal processing.

The Studio 5000 software offers routines in one of four IEC-61131 standard languages, including ladder diagram (LD), function block (FB), sequential function chart (SFC), and structured text (ST). Due to the difficulties inherent in troubleshooting ST, this language is not used at WRD except within AOIs. SFC is most useful in machine control where a defined repetitive sequence is required. The applicability of SFC is limited for process-intensive applications such as those found in water/wastewater facilities.

The two programming languages used in WRD control programs are LD and FB. LD is used for most Discrete (or Boolean) control. FB is used for most Analog (or Variable) control. Both types of control are common at WRD.

4) User-Defined Data Types and Add On Instructions

The ControlLogix and CompactLogix PLCs include two user-definable building blocks for routines: UDT and AOI. Both blocks enable the programmer to organize programs more efficiently and consistently. The UDT is a custom data type that collects tags of other data types into a single entity.

UDTs are configurable groups of data elements organized into a standard structure related to a task or device. Element names start with a base tag followed by a dot then the element (i.e., [base tag].[element]). Element naming guidelines are described in the Database Tagging section. UDTs are used for CPU date and time information, HART devices, equipment, etc. UDTs are used to handle all PLC internal data about equipment. Separate UDTs for internal data and HMI data simplify creating HMI applications and eliminate unnecessary data sent to the HMI.

An AOI is the building block for a control object and includes standardized program logic. AOIs are applied as standard programming elements during PLC program development. AOIs are best used to program tasks requiring repetitive standardized code such as analog input scaling or motor control.

An AOI can be created using LD or FB. LD provides faster AOI execution times. Once created, AOIs may be selected from the Add-On tab drop down list during programming.

The following section describes AOIs commonly used in water or wastewater PLC programs. These AOIs are provided to the PLC programmer and used as needed in all WRD PLC programs to maintain consistency across PLCs and the HMI graphics. The features described below are based on the general functionality described in the control philosophy.

2.4.5 PLC Control Objects

Control objects are designed to provided consistency in programming repetitive functions. Control objects are not used for unique logic and control scenarios or very specific applications. AOIs are paired with HMI popups to create a complete control object. Control objects are grouped into three categories: I/O Handling, Equipment Handling, and Process Handling. The categories and control objects are organized as follows:

i. I/O Handling
   a) Analog Input Scaling
   b) Analog Output Scaling
   c) Discrete Alarm
   d) Totalizers

ii. Equipment Handling
   a) Motor Control Fixed Speed
   b) Motor Control Adjustable Speed
   c) Motor Interlocks
   d) Valve Control Modulating
   e) Valve Control Open Stop Close
   f) Valve Control Solenoid

iii. Process Handling
   a) Lead Standby Sequence
   b) Lead Lag Sequence
   c) Sequential Start
   d) PID Controller
   e) Chemical Dosing
   f) Auto Alternate

The following paragraphs describe the AOIs to be used at WRD. These AOIs are the basic building blocks for implementing control objects in the PLC and HMI. Alarm handling is included in the AOIs. Examples of HMI popup graphics are included with some AOI descriptions.

1) I/O Handling AOIs

Analog Input Scaling

The Analog Input Scaling AOI scales the raw input signal to engineering units. It provides logic for calibration mode (hold at last state), test mode (manually set engineering value), individually adjustable setpoints to generate a series of alarms including High-High, High, Low, Low-Low, Rate of Change, and monitors the signal input for failure. Additional functions include out of service mode and alarm reset dead band input. Alarm processing provides alarm time delays, priority assignment, shelving, suppression and disable logic.

Analog Output Scaling

The Analog Output Scaling AOI accepts a scaled input value, rescales it, and makes it available for the output device.

Discrete Alarm

The Discrete Alarm AOI is for digital inputs unassociated with other devices. It provides signal debounce timer, alarm disable, alarm priority, shelve, disable, and test mode. Additional functions include out of service mode and logic inversion allowing the instruction to work for both normally open and normally closed inputs by selecting the invert setting.

Totalizer

The Totalizer AOI integrates the input flow signal and provides a revolving totalization for today, yesterday, current week, current month, current year, and a service total. It provides two resets: one for interval totals, and one for the grand total. It provides inputs for the flow rate, totalization units, and the PLC routine scan time.

2) Equipment Handling AOIs

Motor Fixed Speed

The Motor Fixed Speed AOI provides motor control logic for local / remote, start / stop, motor fault handling, emergency stop, failed to start / stop, process interlock, ready status, motor and pump runtimes, and cycle start counters. It provides auto/manual start/stop logic, individual notification alarms and the ability to pass through the motor current, power, and voltage to the HMI. Additional functions include out of service mode, alarm time delays, priority, shelving, suppression and disable logic.

Motor Variable Speed

The Motor Variable Speed AOI provides drive control logic for local / remote status, start / stop, motor fault handling, emergency stop, failed to start / stop, failed to reach commanded speed, process interlock, ready status, motor and pump runtimes, and cycle start counters. It provides individual notification alarms and the ability to pass through the motor current, power and voltage to the HMI. Additional functions include scaling of the drive speed feedback, out of service mode, alarm time delays, priority, shelving, suppression and disable logic (see Figure 2-5).

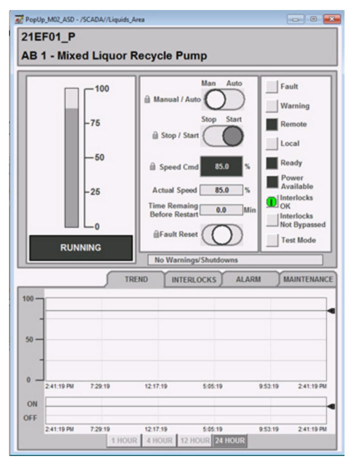


Figure 2-5. Motor Control Variable Speed

Motor Interlocks

The Motor Interlock AOI provides optional supervisor bypass of up to eight separate motor software interlocks. It provides text string logic to house descriptions of all eight interlocks.

Valve Control Open-Stop-Close

The Valve Open Stop Close AOI adjusts the valve position upon receiving an open /close command until a stop command is received, or a full opened / closed limit is reached. It provides inputs for local / remote status, auto and manual open and closed commands, full open / full closed limit switches, max travel time for failed to open / close alarming. Additional functions include out of service mode, cycle count, ready status, alarm time delays, priority, shelving, suppression and disable logic (see Figure 2-6).

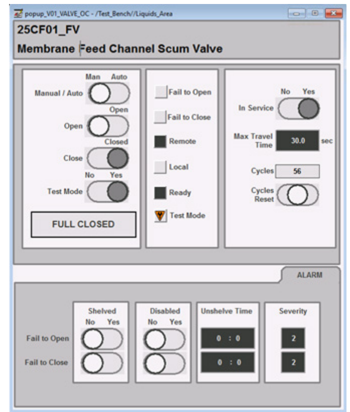


Figure 2-6. Valve Control Open-Stop-Close

Valve Control Solenoid

The Valve Solenoid AOI opens the valve upon receiving an open command until the open command ceases. It provides inputs for optional full open / closed limits. It provides inputs for local / remote status, auto and manual open commands, full open / full closed limit switches, and max travel time for failed to open / close alarming. Additional functions include out of service mode, cycle count, ready status, alarm time delays, priority, shelving, suppression and disable logic.

Valve Control Modulating

The Valve Modulating AOI scales the valve position feedback and adjusts valve position output when the new position setpoint is greater than the dead band around the current position. It monitors and alarms if the valve position feedback fails. It provides inputs for local / remote status, auto and manual position setpoints, position feedback, full opened / full closed limit switches (if available), max travel time and position dead band for failed to position alarming. Additional functions include out of service mode, cycle count, ready status alarm time delays, priority, shelving, suppression and disable logic (see Figure 2-7).

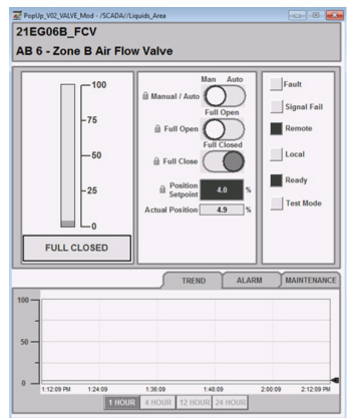


Figure 2-7. Valve Control Modulating

3) Process Handling AOIs

Lead Lag

The Lead Lag AOI calls the lead unit to run and calls for the lag unit to run if a second unit is needed, or the lead unit fails, or becomes unavailable. It provides logic to select the lead unit from PLC program code or from the HMI (see Figure 2-8).

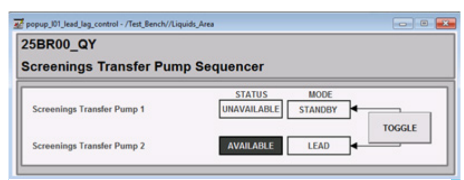


Figure 2-8. Lead Lag

Lead Standby

The Lead Standby AOI calls the lead unit to run and calls for the standby unit to run if the lead unit fails or becomes unavailable. It provides logic to select the lead unit either from PLC program code or from the HMI.

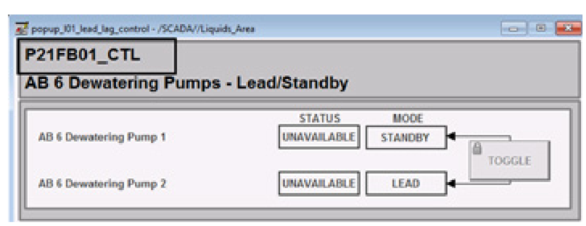


Figure 2-9. Lead Standby

Sequential Start

The Sequential Start AOI selects the order of starting and stopping up to 8 devices. If the number of units running in automatic control is greater or less than the required number, the logic starts or stops the next available unit in the sequence. If a unit fails, the logic starts the next unit in sequence. It provides inputs for the number of units required to run, the total number of units in the lineup, the minimum number of units required to run, and failed and available status for each unit. Additional logic monitors the start order for a duplicate unit selection, provides an alarm, and reverts selection back to the previous valid selection (see Figure 2-10).

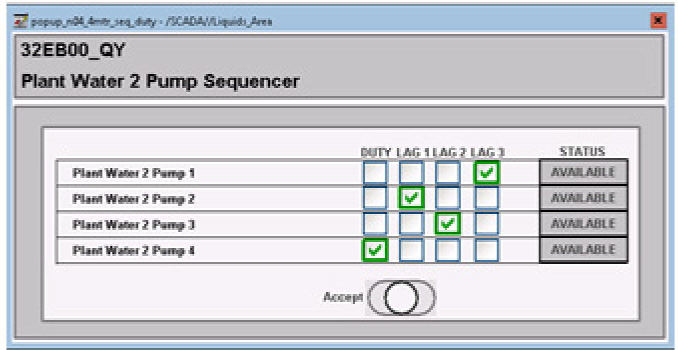


Figure 2-10. Sequential Start

Chemical Dosage

The Chemical Dosage AOI calculates chemical injection setpoints based upon a pacing flow, chemical properties (concentration and specific gravity) and a desired injection rate. It monitors the injection setpoint against the chemical pump(s) max capacity and alarms if the capacity is exceeded. It provides inputs for a dosage setpoint, flow setpoint, pump capacity, chemical concentration, and specific gravity. It provides outputs for a flow pace setpoint used for the remote setpoint on a flow control loop, and a pump speed to be used when the feed pump has no flow control mode. Additional functions include out of service mode, alarm time delays, priority, shelving, suppression and disable logic.

PID Control

The PID Control AOI provides PID control with built in override logic, bumpless transfer and alarming for high deviation, low deviation and PID fault. Additional functions include alarm, priority, shelving, suppression and disable logic.

Auto Alternate

Auto Alternate AOI adjusts the call order of up to eight devices including pumps in a pump station. The call order is updated when the lead device stops. The lead device will not alternate unless the lead device has achieved a minimum run time (see Figure 2-11).

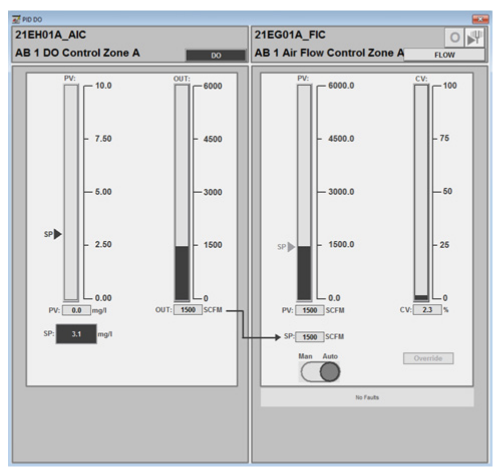


Figure 2-11. PID Control

2.5 HMI Graphics

2.5.1 Graphics Overview

This section establishes graphic display standards based on Rockwell Software FactoryTalk View Site Edition HMI. Graphic standards provide uniformity within WRD to enable rapid analysis by operations staff for system status and events, to reduce development time by programmers for system implementations, and optimize support response by technicians for maintenance and modifications.

1) Screen Layout

The default HMI screen resolution is 1920x1080 pixels. Graphic displays are sized to maximize the default resolution. FactoryTalk View Site Edition uses Scalable Vector Graphics (SVG) that does not require rework for display on mobile devices. SVG format is used for global object creation and graphic displays. Graphic objects with user input animations are enlarged to provide user-friendly interfaces, regardless of the size of the device used to display the HMI graphics.

At a minimum, the default HMI screen layouts include status and control of the items listed below. Navigation to other displays does not affect access to the items listed below.

- Date/Time in long format.
- Alarm Banner with active alarms sorted by:
  - i. Priority (Critical, Urgent, Warning, Caution)
  - ii. Status (Unacknowledged, Acknowledged)
  - iii. Alarm Event Time
- Display history with forward and back buttons and navigation list for minimum of last 10 screens.
- Navigation tab or button with access to flyout or popup graphics, including the entire hierarchy of displays for the HMI project.
- User login/logout with textual graphic object indicating current username.
- Replaceable process displays on navigation event.

2) Display Navigation

The graphic navigation rule is a maximum of 3 clicks to access desired status and control graphics. Navigation events are triggered using the methods listed below as a minimum.

- Display history with forward and back buttons and navigation list for minimum of last 10 screens.
- Flyout or popup graphic including the entire hierarchy of displays for the WRD facilities.
- Off-page connectors on flow streams with object key display navigation animations.
- Equipment or site location Key Process Indicator (KPI) graphics with object key display navigation animations to equipment faceplate popups or process displays.

2.5.2 Graphic Elements

1) Graphic Styles and Symbology

Any symbol used more than once is based on a global object graphic component. Global objects are templates that use parameters for indirect referencing to PLC tags in runtime. Edits to global objects are propagated throughout the HMI application to reduce development effort and provide consistency.

High performance graphics based on ISA 101 are the default graphic style. High performance graphics are proven to reduce operations response times by using color to indicate abnormal status and grayscale graphics to indicate normal operation. Unique symbols and textual graphics are used to annunciate alarm conditions to accommodate colorblindness. Normal conditions include running and stopped states where running states are shown in dark gray and stopped states are shown in light gray. The HMI background color is the lightest shade of gray so that normal conditions are clearly visible. Red and yellow colors are reserved for alarm conditions and are not to be used for equipment status.

2) KPI Graphics

Key Process Indicators (KPIs) are used for critical analog values (level indicators, analyzers, etc.) and alarm limits (HIHI, HI, LO, LOLO) are configured to allow easy interpretation of current process conditions. KPIs are typically displayed as a vertical bar with an arrow showing current process variable value within the engineering unit minimum and maximum values. Alarm limits are shown on the KPI bar as bands between the limit values and change from grayscale to color once the process variable enters an alarm limit band. The color varies with alarm limit severity. A sparkline is provided with the KPI wherever possible to display historical data along with the current value. The sparkline includes an operator configurable time span with the end time set to the current time. The default sparkline time span is 2 hours. See KPI graphic example on Figure 2-12.

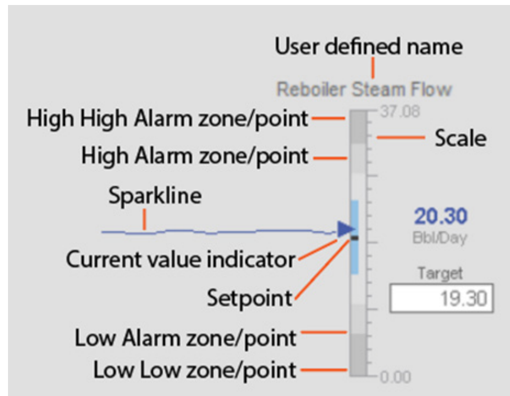


Figure 2-12. KPI Graphic Example

KPI-based displays are used in overview displays where multiple similar sites, processes, or equipment types are displayed. KPI-based overview displays provide operations a systemwide status at glance with animations on each graphic indicating alarm conditions for the site, process, or equipment represented. An example of a KPI-based display is a service map with tank sites, pump/lift stations, or wells.

3) Schematic Process Displays

Schematic process displays are provided where graphic representation of the physical process layout is desirable. Schematic process displays include lines for process flow streams, flow stream abbreviations, and off-page connectors with arrows pointing in or out of the display with descriptions for the off-page process area. See off-page connector example on Figure 2-13. Object display animations are provided at off-page connectors for navigation to associated process areas with an HMI display. Process flow streams are shown in grayscale with a noticeable shade difference between equipment stopped and equipment running. Process flow streams are not animated to show flow as these animations require scripting in development and may inaccurately reflect actual operating conditions. Hybrid type displays include KPIs in schematic displays for critical process values.

Figure 2-13. Off-Page Connector Example

4) Equipment Graphics

Equipment graphics include fill color animations to display running/stopped or opened/closed status. Alarm graphics outline the equipment graphic and blink or flash if unacknowledged. An alarm symbol is displayed in the upper corner of the alarm graphic outline to accommodate colorblindness. Alarm graphic colors and symbols vary by alarm severity. Symbols are also used to indicate alarm disabled and shelved statuses. See examples on Figure 2-14.

Equipment graphic global objects include object display animations and navigation to equipment faceplates for the associated object. The object tag name on the equipment graphic is also shown on the equipment faceplate to dynamically display the popup with current values and setpoints for the associated object.

Textbox graphics with animations are provided along with equipment graphics and animations to further annunciate equipment operation status. Textbox graphics with Boolean animations are provided for the following:

- Remote (R)/Local (L)
- Auto (A)/Manual (M), (Not applicable in Local)
- Running (O) /Stopped (S)

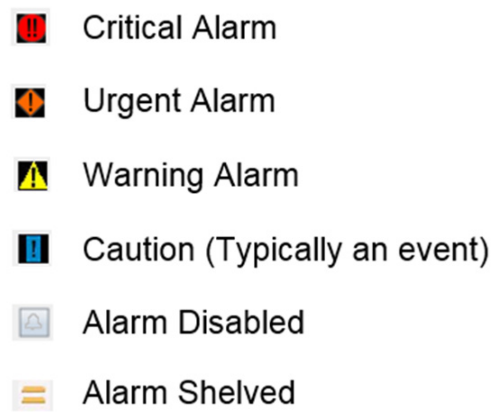
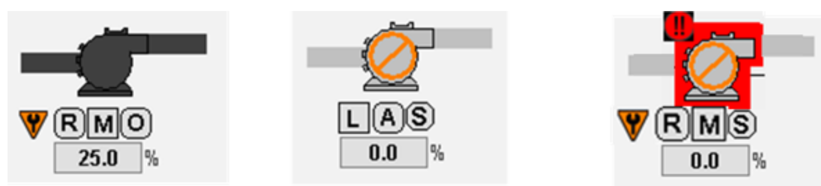


Figure 2-14. Alarm Symbol Examples

Textbox graphics with analog value animations are provided for modulating valves and variable speed drives. Textbox graphics with analog valve animations include engineering unit abbreviations. Figure 2-15 shows examples of equipment graphics showing various statuses.



Remote / Manual Running Forward / Test

Local / Auto Stopped / Out of Service

Remote / Auto Stopped / Faulted / Test

Figure 2-15. Equipment Graphic Examples

Equipment and textbox global objects are combined in a unique global object for each object type to minimize development of unique object instances on process displays. Low profile textboxes and equipment graphics are used to reduce multiple global object orientations for each object type.

Legend displays are accessed from the navigation menu for operator reference. Legend displays include graphic and animation examples for each graphic object used in the SCADA system. Abbreviations for equipment operation states, engineering units, and flow streams are defined on legend displays. See Appendix 2-C for a sample legend display.

5) Alarm Graphics

Appendix 2-D lists common alarm terminology and is also referenced in the Alarm Management section. Four alarm severities are defined in Appendix 2-E. Alarm severities are assigned by operations. The four alarm severities are:

- Critical
- Urgent
- Warning
- Caution

Multiple alarm annunciation methods are designed to establish consistent alarm notification to operations, and consistent response requirements to abnormal process conditions. Alarm information is displayed using the following methods:

- Equipment Graphic Animations
  - Outline graphic with unique symbol and textual graphic. Color varies by severity.
  - Blink or flash animation for unacknowledged alarms.

- Equipment Faceplates
  - Textbox graphic with fill color animation.
  - Blink or flash animation for unacknowledged alarms.
  - Controls for severity setpoint, disable, and shelving.
  - Historical trend of alarm point with operator configurable time span and trend end time set to current time.
- Process Overview Navigation Button Animations
  - Pushbutton graphic with fill color animation.
  - Blink or flash animation for unacknowledged alarms.
  - Textual display graphic with animation displaying active acknowledged and unacknowledged alarms.
- Alarm Summary and History
  - Tabular display with connection to real-time and historical alarm databases including the following columns as a minimum:
    - Alarm Tag Name, Description, Group, State, Severity
    - Alarm Acknowledgement User, Computer, and Comment
    - Times for Alarm, Acknowledgement, and Return to Normal Events
  - Filtering tools for the following as a minimum:
    - Date/Time
    - Alarm Group
    - Alarm Tag Name
- High-Priority Popup Notification
  - Popup window displays critical and high priority alarms.
  - Option to access alarm resolution instructions.
  - Requirement to close dialog box at operations console to continue SCADA system navigation.
  - Used sparingly and includes logic to avoid cascade of popup alarms on system failure or malfunction.
  - Option to shelve or disable alarm from popup window. Shelve option includes operator entered setpoint for shelve duration. Shelve or disable feature will be used as a measure to avoid nuisance alarm popups.

6) Trend Graphics

Trends display historical information for process values and provide insights for diagnosing process conditions. Trend values include Boolean or analog values. At a minimum, the following values are historized:

- Boolean Values:
  - Running/Stopped
  - Opened/Closed
  - Critical Alarms

- Analog Values:
  - Input/Output Process Variables (Flow, Level, Speed, Power, etc.)
  - Analog Alarm Limits (HIHI, HI, LO, LOLO)
  - Equipment Runtime
  - Equipment Call Order
  - Chemical Dosing Setpoints
  - PID Tuning Setpoints
  - Operator Setpoints

Multiple trend display methods are provided to display and interact with recent and historical process conditions. Historical information is displayed using the following methods:

- KPIs and Process Display Trend Animations
  - Object display animation for navigation to equipment faceplate popup.
  - Sparkline with operator configurable time span for critical process values.
- Equipment Faceplates
  - Embedded trend with push buttons for changing the trend time span. Push buttons are provided for the following:
    - 1 hour
    - 2 hours
    - 4 hours
    - 24 hours
    - Custom (includes operator configurable setpoints for time span value and units)
  - Navigation button to display a customizable trend screen that replaces the default process display. Includes object instance tag name on customizable trend screen to automatically display tag pen on trend upon trend screen display.
- Customizable Trend Screen
  - HMI project tag browser with tag filtering options
  - Simultaneous display of multiple tag pens with individual tag pen display options
  - Customizable trend date/time start, end, and span
  - Trend template import/export

7) Diagnostic Graphics

Graphic displays are provided for the following:

- Network Communications
  - Schematic diagrams showing the logical layout of SCADA network equipment
  - HMI application server status and operation mode
  - Object display animations for navigation to web browser for web enabled equipment
- PLC Status
  - PLC current date/time, operating mode, and network addresses
  - PLC module and channel status available from PLC equipment faceplate popup.

2.5.3 Control Object Faceplates

Control objects provide consistency in repetitive programming functions. Control objects are not used for unique logic and control scenarios or very specific applications. AOIs are paired with HMI popups to create a complete control object. Each HMI control popup is a specific display with parameters mapped to the specific equipment tag of the AOI control object. Control objects are grouped into three categories: I/O Handling, Equipment Handling, and Process Handling.

The categories and control objects are organized as follows:

i. I/O Handling

- a) Analog Input Scaling
- b) Analog Output Scaling
- c) Discrete Alarm
- d) Totalizers

ii. Equipment Handling

- e) Motor Control Fixed Speed
- f) Motor Control Adjustable Speed
- g) Motor Interlocks
- h) Valve Control Modulating
- i) Valve Control Open Stop Close
- j) Valve Control Solenoid

iii. Process Handling

- k) Lead Standby Sequence
- l) Lead Lag Sequence
- m) Sequential Start
- n) PID Controller
- o) Chemical Dosing
- p) Auto Alternate

Refer to the PLC Programming section for individual AOI control object descriptions.

1) Popup Faceplates

HMI control popup faceplates include equipment tag name and description along with tabs for equipment operations, trending, alarming, configuration, and operator notes. See Figure 2-16 for an example of a control object popup faceplate. See Table 2-6 for a description of popup tab navigation icons.

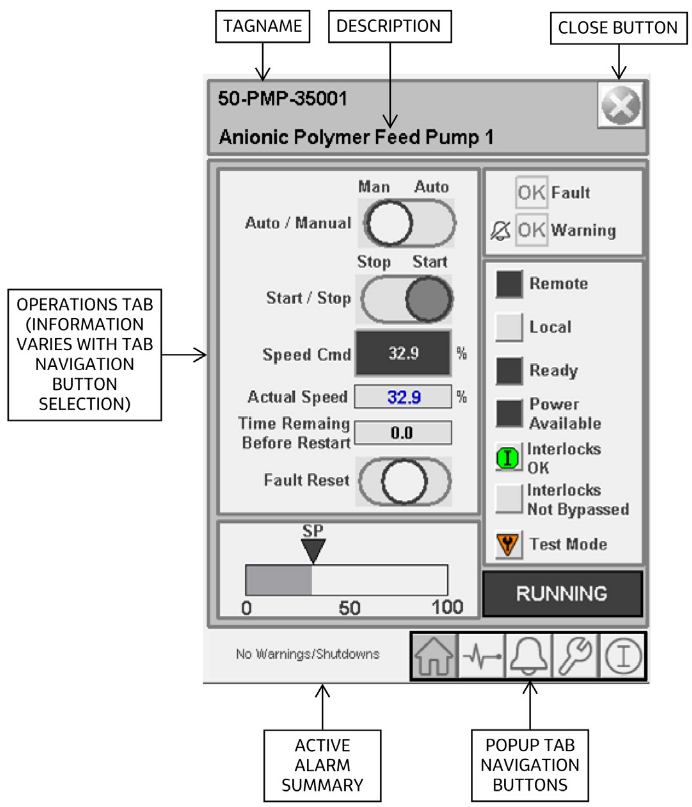
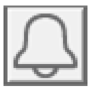
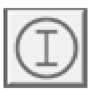


Figure 2-16. Control Object Popup Example

Table 2-6. Control Object Popup Tab Navigation Buttons

Symbol Icon	Symbol Name	Popup Tab Function
	Home	Control object operations status and control features.
	Trend	Control object trend showing recent historical data with operator configurable time span.
	Alarms	Control object alarm status and controls.
	Configure	Control object configuration setpoints.
	Information	Control object operator notes.

2.5.4 Application Organization

1) Application Files and Folders

FactoryTalk View Site Edition HMI project files are stored by default upon project creation at C:\Users\Public\Documents\RSView Enterprise\SE\HMI Projects\. The Microsoft Windows project folder structure is a direct correlation of the HMI Project Explorer in FactoryTalk View Studio Site Edition with Windows folders created for each HMI project object group. See Table 2-7 for HMI project object groups and corresponding Microsoft Windows folders.

Table 2-7. HMI Project Object Structure

Windows Folder Name	HMI Object Group	Windows Folder Name	HMI Object Group
DLGLOG	Data Log Models	Mcr	Macros
DTS	Derived Tags	PAR	Parameters
EDS	Events	RCP	Legacy Recipes
Gfx	Displays	RecipePro	RecipePro+ Editor
Global Objects	Global Objects	Startup	HMI Project Properties Startup Components
Images	Images	TAG	Tags
KEY	Client Keys	TREND	Trend Templates Trend Snapshots
Local	Local Messages	TRENDPRO	TrendPro Templates

HMI projects backup and restore functions are performed using FactoryTalk View SE Application Manager. HMI project backups are saved with a ".APB" file extension and stored in the default archive directory at C:\Users\Public\Documents\RSView Enterprise\SE\Archives\. HMI project backup filenames include the project name, version, and backup date. HMI project backup must be performed prior to any modifications to the current application.

2) Display Names and Descriptions

Displays are named using the database tagging standards and the applicable fields shown in Table 2-8. All HMI display graphics are prefaced with the “FFFF” facility code. Display graphic names include a short description for the display. The display tag prefix and description are delineated with a hyphen. A version number suffix is included for displays with multiple versions in the HMI project folder.

Table 2-8. Display Name Fields

Field	Application	Display Type
Facility (FFF)	All Sites	Process Display
Controller (CCS)	WRP Only	Process Display
Process Area (PP)	WRP Only	Process Display
Equipment (EEE)	All Sites	Equipment Faceplate Popup
Loop (LLLSS)	All Sites	Equipment Faceplate Popup

A global object process display template is created with a background color conforming with graphic display standards and includes a textual graphic with a string animation to display the filename for the current process display during runtime.

Each HMI control object popup faceplate is created for each AOI control object. The HMI control object popup faceplate display name begins with “AOI,” followed by a hyphen, then the name of the AOI control object in the PLC.

Graphic templates for process displays are created on a global object display and named by the type of component. The name includes any variants of the component in the same global object display.

A textual graphic object description is displayed for each object shown on process displays. The textual graphic object description includes specific information for the equipment and loop as applicable. The textual graphic includes a tooltip to display object tag names when the cursor hovers over the graphic object.

3) Animations and Scripts

Animations and scripts are developed using Animation and Command Wizards whenever possible to maintain consistency and minimize development and modification efforts. Commands and expressions in these wizards are documented in the FactoryTalk View Studio User Guide.

Visual Basic for Applications (VBA) Integrated Development Environment (IDE) may be accessed from any display by right-clicking on the display background and clicking VBA Code. VBA provides a platform for complex programming when a function is unavailable from Animation and Command Wizards. VBA code is used sparingly as VBA code can be difficult to troubleshoot.

2.5.5 Permissions Model

The WRD SCADA system uses Microsoft Windows Active Directory Domain Services to define user group permissions in the HMI application. Permissions are based on the Windows linked users and groups within a FactoryTalk View application.

Permissions user groups include:

- Administrators
  - Full access to development and runtime application functions.
- Managers
  - No access to development functions.
  - Full access to runtime application functions.
- Supervisors
  - No access to development functions.
  - No access to PID tuning parameters.
  - Access to equipment operation, mode selection, and process control setpoints.
- Operators
  - No access to process control setpoints.
  - Access to equipment operation and mode selection.
- View Only
  - No access to operator controls and equipment setpoints.
  - Read-Only display navigation access to runtime application.

The FactoryTalk View permissions model uses permission codes labeled A through P to identify write permissions to alarms, tags, and graphic objects. This provides up to 16 unique permission codes. The WRD SCADA system uses 4 permission codes as shown in Table 2-9. Alarm Acknowledgement and Table 2-10. Tag Write Permissions. These codes group write permissions as follows:

- **B** – Alarm Handling Permissions
- **E** – Operating Permissions
- **G** – Supervising Permissions
- **I** – Administrating Permissions (reserved for SCADA system administrators)

The permission codes are assigned to user groups as shown in Table 2-11. User Groups. Other permission codes and user groups may be defined as required for other functions.

Table 2-9. FactoryTalk View Permission Codes – Alarm Acknowledgement

Command Permission	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Acknowledge Alarms		X														
Acknowledge All Alarms		X														

Table 2-10. FactoryTalk View Permission Codes – Tag Write Permissions

Tag Based Permission	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Close Valve or Gate					X											
Open Valve or Gate					X											
Start Motor					X											
Stop Motor					X											
Mode Toggle (Auto/Manual)					X											
Lead/Lag/Standby Mode Change					X											
Reset (Failed / Alarms)					X											
Disable (Alarm Disables)					X											
Operating Setpoints							X									
Alarming Setpoints							X									
Equipment Out Of Service							X									
Run Time Reset							X									
Cycles Reset							X									
Calibrate Mode (Instruments)									X							
Loop Tuning Parameters									X							
EU Limits									X							
Test Mode									X							

Table 2-11. FactoryTalk View – User Group Assignments

USER GROUP	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
View Only																
Operator		X			X											
Supervisor		X			X		X									
Managers							X									
Administrators							X		X							

2.6 Alarm Management

This section describes an alarm system management framework derived from ISA 18.2. The purposes of alarm management are to ensure regulatory compliance, increase safety; improve reliability, and enable more proactive operations. These purposes can be achieved by the implementation of, and adherence to, an effective alarm philosophy in the design and execution of the alarm system. Alarm management terminology is listed in Appendix 2-D.

2.6.1 Alarm Management Overview

ISA 18.2 describes alarm management as a multifaceted process (comprised of 10 steps lettered A through J) within three iterative reviews (identified as audit, development, and usage). The audit review defines the alarm philosophy and an annual audit process. The development review describes the design process (including identification, rationalization, detailed design, and implementation) and change management steps for an event-driven review process. The usage review defines the operation, maintenance, monitoring and assessment steps in a continuous review process. These process steps and reviews are illustrated on Figure 2-17.

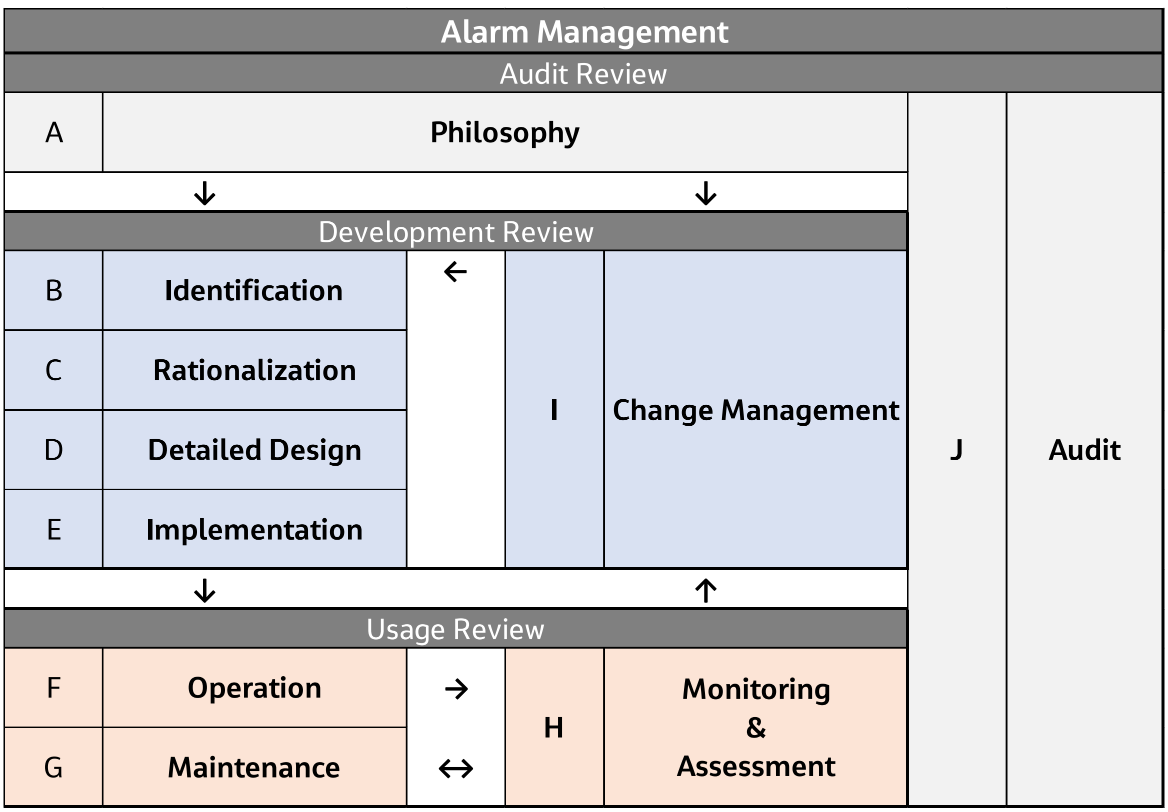


Figure 2-17. Alarm Management Overview

ISA 18.2 includes definitions to key terms used in the alarm management. These definitions are listed in Appendix 2-D. Table 2-12 summarizes the three review cycles, showing the frequency, topic collection method, results, and documentation for each cycle.

Table 2-12. Alarm Review Cycle Summary

Review Cycle	Frequency	Topic Collection Method	Results and Documentation
Audit	Annual	Broad-based deficiencies, Operations interviews	Recommendations Report
Development	Event-Driven	New additions, discovered deficiencies, audit recommendations	Alarm Configuration, Alarm Master Database
Usage	Continuous	Performance Metric Monitoring	Performance Assessment (once per month or as needed)

The following sections describe each step within each review.

2.6.2 Audit Review

1) Step A - Philosophy

The purpose of an alarm philosophy is to serve as the guideline for the design, implementation and modification of alarms used in WRD facilities. Alarms are generated to alert operations of equipment malfunctions, process deviations, or abnormal conditions that indicate a potential public health or personnel safety hazard, an exceedance of regulatory compliance, a process instability or potential property damage that would require immediate action by the operator. An alarm is more than a notification to the operator of a change of condition. The alarm philosophy for the WRD is summarized by:

- Under normal conditions, there are no alarms; therefore, all alarms are maintained, managed, and audited.
- Every alarm requires a response; therefore, operators are trained on standard response procedures for every alarm they encounter.
- Alarm priorities are pre-defined; therefore, alarms will assist the operator to determine appropriate operating procedures and response.

Alarm management applies this philosophy to an alarm system that:

- Effectively manages alarms for clear and easy comprehension of current conditions.
- Effectively handles alarms to prevent alarm floods.
- Consistently configures alarms in accordance with industry best practices.
- Identifies, resolves, and/or removes nuisance alarms.
- Notifies operations of the source and priority of the alarm.
- Aids operations in root cause analysis of process upsets.
- Aids maintenance in root cause analysis of equipment failures.

2) Step J - Audit

The purpose of auditing the alarm system is to review ongoing and recurrent issues that may require a broad-based solution, such as a new software functionality or a revised standard. The findings of an alarm system audit may result in modifications to the alarm philosophy. Audits are conducted on an annual basis. An effective alarm audit uses the following tools, materials, and team members:

- Audit Tools:
  - A checklist of topics to be covered during the audit (may be collected during the year).
  - Interviews with operations to identify alarm system issues and describe performance improvements.

- Audit Materials:
  - Alarm Philosophy
  - Master Alarm Database
  - Alarm History (specific to audit topics)
  - Monitoring Reports (specific to audit topics)
  - Training Records (specifically who received what training on alarm responses and operating procedures and when)
- Audit Team Members:
  - Alarm system administrator
  - Operations
  - Maintenance

2.6.3 Development Review

The purposes of the development review are to identify, rationalize, design, implement, and confirm alarm effectiveness in supporting the alarm philosophy. Development reviews are triggered by three types of events: new additions, discovered deficiencies, and audit recommendations. New alarms may be needed when new processes or equipment are added to WRD facilities, or regulatory requirements are added to operations procedures. Deficiencies may be discovered in usage reviews, and audit recommendations may include alarm modifications or improvements.

1) Step B - Identification

The identification step identifies all potential alarms, describes the abnormal condition(s) to consider in the rationalization step, and adds the potential alarm to the alarm database. It provides the first layer of filtering for alarm candidates to test conformance with the alarm philosophy. The identification step defines the alarm data kept in the alarm database, including:

- Alarm Name
- Description
- Priority
- Class
- Setpoint Value.
- Debounce Time Delay
- Is Escalation Required Y/N
- Consequence of Inaction
- Operator Action (Reference to standard operating procedure [SOP])
- Test Frequency
- Test Procedure Location
- Revision Date
- Revision Comment

The retention period, user access, and document control procedures are defined by the system administrator.

2) Step C - Rationalization

The rationalization step ensures an alarm conforms with alarm philosophy requirements by checking the prioritization, classification, and setpoint determination values in the master alarm database. Alarm priorities are assigned by using the pre-defined priority matrixes shown in Appendix 2-E. These matrices provide standard priority descriptions based on the alarm philosophy to promote clear understanding of alarm situations and appropriate operator actions. Alarm classifications, such as life safety and regulatory reported, help track alarm requirements for maintenance purposes.

An effective rationalization step uses the following tools, materials, and team members:

- Rationalization Tools:
  - A list of identified alarms to be rationalized.
- Rationalization Materials:
  - Alarm Philosophy
  - Master Alarm Database
  - Reference Documentation
    - P&IDs, Control Narratives (processes and equipment)
    - Permits (regulatory requirements)
  - Alarm History (specifically on discovered deficiencies and audit recommendations)
- Rationalization Team Members:
  - Alarm system administrator
  - Operations
    - Plant
    - Collections
    - Distribution
  - Maintenance
  - Management
  - Engineering
  - Safety

3) Step D - Alarm Design

The purpose of each alarm is to enable operations to detect, diagnose and respond to an abnormal process condition. Therefore, the principal design features of an alarm are to be relevant, understandable, timely, actionable, and prioritized. These design features are achieved in two areas: alarm logic and alarm display.

The alarm design step includes packaged systems to bring those alarms into conformity with alarm system management. Using HMI alarm display features typically achieves the most conformity with the least amount of risk. The alarm design step develops packaged system requirements for alarm design features to be included during design and procurement.

Alarm Logic

Alarms are commonly generated from analog and discrete signals, which are processed by PLC control objects. See section 2.4.5 for more details. Alarm logic is built into control objects whenever possible. It is commonly used to reduce nuisance alarms.

Alarm logic to reduce nuisance alarms from analog signals includes:

- Time delay (on) before alarming
- Use of a deadband for return to normal.
- Suppression by design (use of an alarm condition to suppress other alarms)

Alarm logic to reduce nuisance alarms from discrete signals includes:

- Time delay (on) before alarming
- Time delay (off) for return to normal.
- Alarm latching with operator resets, as needed.

Alarm logic to reduce nuisance alarms in general includes:

- Out of service
- Test mode
- Acknowledgement status

Alarm Display

Alarms are displayed in the HMI graphics. Consistent HMI graphics aid in the detection, diagnoses, and response to alarm conditions. For more detail on the display of alarms, see section 2.5.2. The alarm philosophy guides alarm display development by:

- Displaying alarm priority (see Appendix 2-E) with multiple methods to ensure universal recognition, including.
  - Color
  - Symbols
  - Text
- Providing alarm banner features such as:
  - A clear alarm banner message
  - Including the process value in the message at the time of the alarm.
  - Allowing navigation to the graphic where the alarm controls reside.
  - Filtering of the alarm banner
- Providing access to the SOP from the HMI graphic.

4) Step E - Implementation

Implementation is the step between design and operation during which the alarm is put into service. Implementing a new alarm or changing an existing alarm includes:

- Planning
- Training operations on the response to the new or modified alarm
- Testing and validation of the new or modified alarm
- Documentation of training and testing

5) Step I - Change Management

The change management step identifies alarm issues that may occur when changing or adding alarms to the system. This step highlights deficiencies that may require an audit review or start a new development review. Changes subject to formal review include:

- Alarm Setpoint
- Alarm Priority
- Alarm Addition or Deletion

2.6.4 Usage Review

The purpose of the usage review is to measure and monitor alarm system performance and includes three steps. The first step ensures operators are trained on alarm system updates. The second step tests alarms according to their classification requirements. The third step monitors and assesses alarm system performance using metrics based on the alarm philosophy. Alarm system performance is typically reviewed monthly.

1) Step F - Operation

The Operation step is the day-to-day usage of the alarm system, including the alarm responses and the SOPs defined in Step C - Rationalization.

Training is the primary activity of the operation step and critical to effective usage of the alarm system, Refresher training on the alarm system features and functions is conducted periodically in addition to normal operational training developed in Step E - Implementation. Features included in the training are:

- Alarm filtering.
- Alarm shelving.
- Removing alarms from service.
- Returning alarms to service.
- Flagging nuisance alarms for maintenance.

2) Step G - Maintenance

The Maintenance step takes an alarm out of service for alarm logic failure (not to be confused with physical failure of sensors or equipment). Out of service documentation includes:

- Cause (Why was the alarm placed out of service?)
- Backup (What alternate protection was implemented?)
- Resolution (How and when was the alarm returned to service?)

Testing is the primary activity of the maintenance step. Testing requirements are based on alarm classes assigned in Step B - Identification and Step C - Rationalization. An alarm maintenance plan determines testing procedures and frequencies.

3) Step H – Monitoring and Assessment

The monitoring and assessment step measures the alarm system performance. The alarm philosophy guides the process and metrics to assess the system. Automated alarm reports provide continuous alarm system performance monitoring. An example of alarm system performance metrics is included in Appendix 2-F.

Assessments of the alarm system performance metrics are conducted periodically or as needed to validate conformance with the alarm philosophy. Assessments are typically conducted monthly. Alarm system performance metrics generate alerts to the alarm system administrator to assess the system or initiate a development review.

2.7 Historical Data

This section describes the historical data system. The purposes of historical data are to provide long-term trends in both process and equipment performance, support forensic and comparative analysis of past and current events and scenarios, enable life-cycle analysis and asset management, and provide a single source of facility performance data for advanced data analytics. These purposes are achieved by consistent capture, compression, archival, and retrieval of SCADA data. The repository for this data is Rockwell Software's FactoryTalk Historian.

Rockwell Software FactoryTalk Historian integrates well with the Rockwell Software FactoryTalk View Site Edition HMI, allowing operations to simultaneously view both present values and past trends. Historical data is generated by the PLC control objects and the HMI graphics.

2.7.1 Historical Data Defaults

The analog values discussed in sections 2.4.5 and 2.5.2 are captured initially in the HMI. The HMI displays short-term historical data simultaneously with real-time values. The default short-term data capture period is 5 years. This allows historical values to be available for troubleshooting and comparison with current values. Additional values identified during startup and operations are added to the historian as needed.

The control objects with default historical data include:

i. I/O Handling
   a) Analog Input Scaling
   b) Discrete Alarm
   c) Totalizers

ii. Equipment Handling
   a) Motor Control Fixed Speed
   b) Motor Control Adjustable Speed
   c) Valve Control Modulating
   d) Valve Control Open Stop Close
   e) Valve Control Solenoid

iii. Process Handling
   a) PID Controller

See Appendix 2-G for a description of the default historical data names.

1) Default Data Compression

Long-term historical data is archived separately from short-term data in the FactoryTalk Historian. Data compression techniques are applied to short-term historical values to minimize storage requirements for data archives. These compression techniques are applied to historical value types as shown in Table 2-13. Long-term historical data archive files can be unregistered from the historian and stored externally. If access to long-term historical data is needed, it can be re-registered to the historian.

The Historian uses two methods, Exception and Compression, for data archiving. Each of these methods uses a maximum interval to ensure that data is still collected. The Exception method specifies how much a point's value must change before the data collector considers it a significant value and sends it to the

Historian. The Exception interval specifies a time limit on how long the data collector will go without reporting a value to the Historian server.

The Compression method specifies how much a value may differ from the previous value before the data collector considers it to be a significant value. The Compression interval specifies a time limit on how long the data collector will go if the point value has not changed more than the compression deviation.

Table 2-13. Historical Data Compression Techniques

Value Type	Exception	Exception Interval	Compression	Compression Interval	Scan Class
Analog Tags (Reporting)	0.5% of Span	1 minutes	1% of Span	Off	5 secs
Standard Analog Tags	1% of Span	5 minutes	1% of Span	8 Hours	5 secs
Totalizers	10x Max Range	10 minutes	10× Max Range	8 Hours	5 secs
Motor Speed	1% of Span	5 minutes	1% of Span	8 Hours	5 secs
Motor Current	0.1	5 minutes	0.1	8 Hours	5 secs
Motor Run Time Hours	0.1	10 minutes	0.1	8 Hours	1 Hour
Discrete Alarm / Status	N/A	10 minutes	N/A	8 Hours	5 secs

2.7.2 Data Reporting

The SCADA system logs data into two separate databases for historical proposes, Alarm & Events database and Historian database. These two databases provide data on the alarm system performance, the HMI graphic system effectiveness, and the operational performance of processes and equipment. Rockwell's FactoryTalk VantagePoint is used to query the Alarm & Events database to track the alarm system performance using the metrics defined in Appendix 2-F. Since operator actions are logged as events, the review of the alarm and event logs can aid in the alarm system audit process. Helping to determine the effectiveness of the HMI and operator training, FactoryTalk VantagePoint can also be used to provide dashboard graphics to show key metrics for plant staff.

Excel based reports are used for several tasks. Additional reports or updates to these reports use the OSI PI Datalink Excel plugin.

- Permit Report: provides data needed for the monthly regulatory report.
- Operations Report: provides data on the status of daily operations, such as minimum, maximum, and average flows and analytical values, and daily chemical consumption values.

Note: WRD desires network queries on device configurations and statuses of networked radios, switches, and firewalls to aid in the troubleshooting and recovery from network issues along and to monitor the network for security issues. This may be a SCADA application or a separate network management system yet to be determined.

1) Data Analysis

Currently there are no plans to procure data normalization, data analysis software or use third-party web-based data analysis software. The use of Rockwell Automation's HMI and historian software are sufficient for currently identified data analytical needs.

Component Standards

3.1 Introduction

In conjunction with the Convention Standards, the Component Standards define the WRP Design Guidelines for the SCADA system. The purpose of the Component Standards is to document functional requirements, preferred products, and best practices for SCADA system development and management. These standards are intended to supplement the WRD's WRP Design Standards for design projects with the common goal of providing consistency and efficiency at WRD's WRP.

The Component Standards chapter describes the product and practice components necessary to achieve a reliable and sustainable SCADA system. Collectively, these components supersede Chapter 7 – Instrumentation of the WRP Design Guidelines. Product components are WRD's preferred products to perform required functions within the SCADA system. Preferred products include I&C equipment, hardware and software products, and networking equipment. Practice components are the best practices necessary to develop and maintain a sustainable SCADA system in a landscape of constant change.

Each Component Standard section introduces the purpose of each component. Product preferences are identified, and practice procedures are outlined. Each section builds on the previous section in the following order:

Products:

1) Instrumentation
2) Control Panels
3) Servers
4) Networks

Practices:

5) Documentation
6) System Development
7) Staff Development
8) Governance

All product components and the documentation practice are intended to work with WRP Design Guidelines and project specifications. Product components often include construction elements for installation, so these component sections include references to the appropriate WRP Design Guideline chapter and CSI MasterFormat 17 Division. Documentation is developed in planned projects using the WRP Design Guidelines and maintained by WRD staff.

All practice components are intended to work with Livermore Administrative Regulations (AR) policies. Practice components include procurement procedures, training requirements, and advisory processes, so these component sections include references to the appropriate AR sections.

3.2 Instrumentation

The purpose of the Instrumentation component is to acquire process and equipment performance data and convert that data into usable digital formats for processing, displaying, and analyzing by the SCADA system. Instrumentation components are classified as either discrete (two state, i.e., ON/OFF) or analog (a range of values, i.e., 0-100%). Discrete instruments produce a digital format, while analog instruments convert a field variable (flow, level, pressure, etc.) to an electrical signal that can be converted into a digital format. Discrete instruments are hardwired using either 24VDC or 120VAC dry contacts.

Analog instruments are hardwired with 4-20 mA signals. Analog instruments are either loop powered (2-wire, powered from signal wiring) or field powered (4-wire, powered from PLC panel via a separate circuit). The instrument power voltage requirements are specified in bid/construction documents.

3.2.1 Instrumentation Design Standards

All projects shall be designed to comply with the latest instrumentation design codes and standards in effect at the start of design, which include but are not limited to those listed in Table 3-1.

Table 3-1. Applicable Instrumentation Design Codes and Standards

Reference	Title
ANSI	American National Standards Institute
ASTM	ASTM International
CBC	California Building Code
CFC	California Fire Code
EIA	Electronics Industries Alliance
IEC	International Electrotechnical Commission
ISA	Instrumentation Systems and Automation
TIA	Telecommunications Industry Association
UL	Underwriters Laboratory

3.2.2 Environmental Considerations

Construction materials shall be compatible with process fluids and suitable for anticipated hostile environmental conditions. Type stainless steel tubing shall be used for all new instrument process connections, except where process conditions require other material. Verify the material compatibility with the process fluids/gases and note any deviations on the drawings and specifications.

Instruments with digital (LCD/LED) displays shall not be exposed to direct sunlight. Whenever feasible, outdoor instruments with digital displays shall be oriented to face north. Where it is not feasible to orient north include manufacturer covers or design a sunshield by adding appropriate notes and details on the applicable drawings and schedules.

Identify the explosion proof areas on the electrical plan drawings and verify the instruments in those areas are compatible with the area’s environment. To the extent possible locate instruments in areas that are not classified and provide intrinsically safe barriers where required.

3.2.3 Flow Measurement

Instrument selection for flow measurement requires evaluation of the total cost, flow velocity, flow profile, process, Reynolds number, density, turndown, mechanical installation constraints and accuracy requirements. Turndown shall be selected so that the flowmeter can cover the range of flow rates within specified accuracy limits. The Reynolds number shall be calculated for the minimum and maximum flow rates. The minimum Reynolds number is calculated by using the minimum expected fluid flow and density and the maximum expected viscosity. The maximum Reynolds number is calculated using the maximum expected fluid flow and density and the minimum expected viscosity. Moody's charts shall be used to compensate for pipe or channel roughness and select piping or channel size to accommodate the required flow profile over the entire operating range.

Flowmeters shall be located to suit the specific technology requirements and manufacturer's minimum installation requirements. Magnetic flowmeters are the preferred type for fluids transmitted in a full pipe.

Magnetic Flow Transmitters

For difficult conditions, flow conditioners are considered as necessary to isolate the liquid flow disturbances from the flowmeter while minimizing the pressure drop across the conditioner. The flow conditioner removes swirls from the fluid stream and allows the profile velocity to achieve fully developed turbulent flow, or at least a stable acceptable geometry. Meter installation requirements shall be coordinated with mechanical designs for pipelines and structural designs for channels. The preferred magnetic flowmeter manufacturer is Endress Hauser or Rosemount.

Thermal Mass Flow Transmitters

Thermal mass flow meters shall be used for gas flow applications. The preferred thermal mass flow meter manufacturer is FCI (with flow conditioner).

3.2.4 Level Measurement

Level Transmitters

The preferred level measurement for process fluids shall be non-contact type whenever possible and includes ultrasonic and microwave types applied within their operational capabilities. The preferred ultrasonic and microwave radar manufacturer is Vega.

Level Switches

The preferred level switch for sump and point level applications is ITT Flygt ENM-10.

3.2.5 Pressure Measurement

Pressure Transmitters

Pressure transmitters (including differential pressure) shall be capacitance type. Ranges shall be selected such that the normal operating pressures will be within 25 to 75 percent of the calibrated range. Protective diaphragm seals shall be provided when process contains slurries, highly viscous, or corrosive fluids. The preferred pressure transmitter manufacturer is Emerson Rosemount 3051 Series.

3.2.6 Temperature Instruments

Temperature measuring elements will be filled system, bimetallic, thermocouple or three-wire platinum RTD bulb elements to suit the application. In general, Type 316 stainless steel protective wells are required. High temperature environments shall require Inconel thermal wells. The preferred temperature transmitter manufacturer is Emerson Rosemount.

3.2.7 Analytical Instrumentation

Analytical instrumentation measures water quality parameters, including dissolved oxygen (DO), total suspended solids (TSS) and/or turbidity, pH / oxygen-reduction potential (ORP), ultraviolet transmissivity (UVT), and chlorine residual. The preferred analytical instrumentation manufacturer is Hach as follows:

- DO Analyzer — Hach LDO with SC1000 controller
- TSS or Turbidity Analyzer — Hach SOLITAX with SC1000 controller
- pH / ORP Analyzer — Hach with SC1000 controller
- UVT% Analyzer — Hach UVAS with SC200 or SC1000 controller

The preferred chlorine residual analyzer manufacturer is Endress Hauser.

3.2.8 Control Devices

The purpose of the Control Device component is to control equipment based on output signals sent from the SCADA system. Control Device components are also classified as either discrete (two state, i.e., ON/OFF) or analog (a range of values, i.e., 0 to 100%). Discrete control devices include motors and valves controlled by contacts. Analog Control Devices include VFD motors and variable position valves with actuators. These devices convert a 4-20 mA signal sent from the SCADA system to a motor speed or a valve position.

Design guidelines for most control devices are described in the WRP Design Guidelines. Control Device references to the Design Guidelines and CSI MasterFormat 17 Divisions are shown in Table 3-2.

Table 3-2. Control Device Cross References

Control Device	WRP Design Guidelines Chapter	CSI Division
Equipment (Pumps, Blowers, etc.)	Chapter 5 – Mechanical 5.3 – Design Calculations 5.4 – Equipment Selection	15 – Mechanical
Valves	5.5.3 – Valves	15 – Mechanical
Motors	5.9 – Motor Design	15 – Mechanical
Power Distribution MCC VFD	Chapter 6 – Electrical Design 6.3.2 – MCCs 6.3.4 – VFDs	16 – Electrical

Actuators for variable position valves or gates shall be sized to meet the requirements of the project and the mechanical feature of the valve or gate. Interface the actuators to the PLC with hardwired signals. The preferred actuator manufacturers are Rotork or Auma.

Table 3-3 summarizes the preferred manufacturer(s) for all Instrumentation and control device components.

Table 3-3. Instrumentation Preferred Manufacturers

Instrumentation Component	Preferred Manufacturer(s)
Magnetic Flow	Endress Hauser, Rosemount
Thermal Mass Flow	FCI (with flow conditioner)
Level (Ultrasound or Radar)	Vega
Level Switch	ITT Flygt ENM-10
Pressure	Emerson Rosemount 3051 Series
Temperature	Emerson Rosemount
DO Analyzer	Hach LDO with SC1000 controller
TSS or Turbidity Analyzer	Hach SOLITAX with SC1000 controller
pH / ORP Analyzer	Hach with SC1000 controller
UVT% Analyzer	Hach UVAS with SC200 or SC1000 controller
Chlorine Residual Analyzer	Endress Hauser
Valve Actuator	Rotork, Auma

3.3 Control Panels

3.3.1 General

The purposes of the Control Panel component are to protect and support control and network equipment. SCADA control panels include PLC panels that house PLCs and related equipment and network panels that house network and communications equipment. Refer to WRP Design Guidelines, Chapter 6 – Electrical, Section 6.5 NEMA Enclosure Ratings & Materials by Area for panel material standards. The Control Panel designer shall confirm all panel classification and material selections with WRD's latest applicable standards. This section describes design, construction, and documentation requirements for control panels included in the SCADA system.

3.3.2 Control Panels

Standards and Codes

The following are general standards requirements.

- American National Standards Institute (ANSI).
- ASTM (American Society for Testing and Materials) International
- Deutsche Industrie-Norm (DIN): VDE 0611, Specification for modular terminal blocks for connection of copper conductors up to 1,000V ac and up to 1,200V dc.
- Institute of Electrical and Electronics Engineers, Inc. (IEEE): C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
- International Society of Automation (ISA):
  - RP12.06.01, Recommended Practice for Wiring Methods for Hazardous (Classified) Locations Instrumentation Part 1: Intrinsic Safety.
  - S5.1, Instrumentation Symbols and Identification.
  - S5.4, Instrument Loop Diagrams.
  - S50.1, Compatibility of Analog Signals for Electronic Industrial Process Instruments.
  - TR20.00.01, Specification Forms for Process Measurement and Control Instruments, Part 1: General.
- International Conference on Energy Conversion and Application (ICECA).
- National Electrical Code (NEC).
- National Electrical Manufacturers Association (NEMA):
  - 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
  - ICS 1, Industrial Control and Systems General Requirements.
- National Fire Protection Association (NFPA): 820, Standard for Fire Protection in Wastewater Treatment and Collection Facilities.
- National Fire Protection Association (NFPA): 79, Electrical Standard for Industrial Machinery
- NSF International (NSF):
  - NSF/ANSI 61, Drinking Water System Components - Health Effects.
  - NSF/ANSI 372, Drinking Water System Components - Lead Content.
- Telecommunication Industry Association (TIA)
- Underwriters Laboratory, Inc. (UL): 508A, Standard for Safety, Industrial Control Panels.

Panel Sizing and Layout

The preferred PLC panel size is approximately 84 inches high, 72 inches wide, and 20 inches deep. The control panel designer must ensure the enclosure will fit in the proposed space. The panel layout must fit all components within the enclosure and mounted on the back panel only. Side panels are not used.

PLC enclosures shall be Nvent, Saginaw, Rittal or equal. All PLC enclosures should be provided with single handle to operate a 3-point latching mechanism. The 3-point latching mechanism is the only approved method of holding the door shut and maintaining its NEMA rating. No clips, clasps, or other devices located around the outside of the door are allowed.

The PLC rack, remote I/O racks, and power supplies will be located in the upper part of the PLC control panel. All I&C device wiring will be located in the lower part of the panel.

Over size wireways shall be used for easier access during maintenance activities and future expansion. Wireways for I/O entry on the top and bottom of the enclosure shall be included. Unused space between wireways shall be minimized by locating the same size terminal blocks with similarly sized equipment.

All 120VAC circuit breakers shall be grouped together. Power supplies and DC circuit breakers shall be grouped together. AC and DC circuits shall be located in separate areas of the panel. Routing AC and DC wiring in parallel shall be avoided. All 4-wire instrumentation (magnetic flow meter, analytical instrumentation, etc.) will be powered from ground fault interrupt circuit breakers located within the PLC.

For field I/O terminal block space requirements refer to the PLC Panel Components requirements below. For each type of hardwired I/O provide a minimum of 20% wired spares. Provide a minimum of 20% spare DIN rail space for future hardwired I/O.

See Appendix 3-A for a typical PLC control panel layout diagram.

PLC Panel Components

PLC equipment will be limited to the following models to simplify spare parts.

- ControlLogix Chassis (Size as needed, include a minimum of 2 spare slots)
- ControlLogix L8x series PLCs (Verify Firmware Version with WRD)
- 1756-IA16 (16 DIs 120VAC)
- 1756-IA32 (32 DIs 120VAC)
- 1756-OB16D (16 DOs 24VDC, with individual isolation relays)
- 1756-OB32 (32 DOs 24VDC, with individual isolation relays)
- 1756-IF8I (8 AIs, 2-wire or 4-wire isolated interface)
- 1756-OF8 (8 AOs)
- 1756-EN2T (Standard Network Interface)
- 1756-EN2TR (Networks with Device Level Rings [DLRs])
- Rockwell Automation panel mounted touchscreen (size dependent on panel)
- Others with WRD approval

Each PLC panel will be powered externally with a dedicated circuit. The following equipment will be powered from circuit breakers not on uninterruptible power supply (UPS) power.

- LED Panel Lighting
- Convenience Receptacle
- Other loads not critical to panel functionality during a power failure.

Each PLC panel and associated network panels will be powered by a single UPS. Refer to WRP Design Guidelines, Chapter 6 – Electrical, Section 6.9 Instrument and UPS Selection for UPS sizing standards. A power relay will be provided and powered by the output of the UPS. When the UPS is plugged in and providing power the power relay coil will be energized directing UPS power to all equipment intended to be powered by the UPS. If the UPS is unplugged or fails, the power relay coil will be de-energized directing non-UPS power to all equipment intended to be powered by the UPS. UPS power failure monitoring relay modules shall be provided for each UPS and the PLC shall monitor the UPS common alarm. Any UPS larger than 5KVA shall be provided with an external bypass switch. UPSs will be sized to maintain power for 90 minutes at full load assuming full capacity of power supplies and other loads. WRD prefers Eaton or APC as UPS manufacturers.

- PLC Power Supplies
- Nearby Network Panels if applicable
- Networking Equipment if applicable
- Panel Mounted Computer and Touchscreen if applicable
- DC Power Supplies
- All 4-wire instruments powered from the panel
- All I/O loads
- Other equipment critical to PLC functionality

Panel mounted computers or thin client architecture with touchscreens is preferred over Allen-Bradley Panelviews or other OIPs. OIPs are acceptable for some vendor packaged systems for specialty processes like UV Treatment Systems. In general, package system controls should be discouraged whenever possible. The designer shall coordinate with WRD when a design includes packaged systems.

PLC enclosures that use networking switches with POE+ (power over Ethernet) must include DC power supplies capable of producing up to 52 VDC.

In general, WRD has no specific preferred manufacturers or specific model numbers for components used in PLC panel. WRD prefers that all components used in panels be rated for industrial use. The following equipment should be provided with every control panel.

- Redundant Power Supplies: Monitor failure at the PLC of each power supply modules and redundancy modules.
- Panel Lights: Provide LED panel light for every 3 feet of panel space with door activated switch
- Panel Door Open Limit Switch: Provide one or more limit switches to monitor whether a panel door is open.
- Temperature Monitoring: Provide a temperature transmitter for monitoring PLC panel temperature at the PLC.
- Provide a door mounted laptop table.

For panels located outside a heating, ventilation, and air conditioning (HVAC) system must be provided. Require the contractor to perform heat load calculations for sizing the HVAC and heater systems to handle extreme conditions. If the UPS is located within the panel the UPS heat load must also be accounted in the calculations. All HVAC systems shall be powered by a separate and dedicated external circuit breaker. The PLC panel and the HVAC for the panel will be considered separate loads.

Field I/O terminal blocks will be provided with the following features:

- All field terminals shall be spring type. Screw terminal blocks are not acceptable.
- Discrete Inputs: Provide two terminals adjacent to each other. Provide fused disconnect for wetting voltage.
- Discrete Outputs: Provide space optimized relays for each discrete output. For every four relays provide two 120VAC power terminal blocks with fused disconnects sourcing power to solenoids or other devices that need to be powered directly.
- Analog Inputs: Provide five terminal blocks per analog input. Two terminals will be dedicated to loop power whether instrument is loop powered or not. The loop power positive terminal block will be equipped with a fuse disconnect. Provide two disconnect terminal blocks for interfacing the point to the analog input module. Provide a grounding terminal block for the analog signal drain wire. In general, all signal wires for analog inputs shall be grounded at the PLC panel and not grounded in the field. All grounding terminal blocks will be bonded to an isolated ground.
- Analog Outputs: Provide three terminal blocks per analog output. Provide two disconnect terminal blocks for interfacing the point to the analog output module. Provide a grounding terminal block for the analog signal drain wire. In general, all signal wires for analog outputs shall be grounded at the PLC panel and not grounded in the field. All grounding terminal blocks will be bonded to an isolated ground.

Control Stations

Use 30.5-millimeter construction with a NEMA rating appropriate to the installation conditions for all pushbuttons, selector switches, pilot lights, E-stop buttons, etc. Field control stations and local interface controls will be determined on a project-by-project basis and located in separate field mounted enclosures or on MCCs and VFD dependent on the project needs as discussed with the WRD staff.

Construction

All control panels will be constructed by a UL 508A certified panel shop and constructed to UL 508A standards. UL certification is unnecessary for the panel.

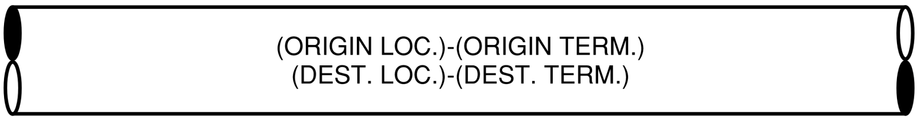
At a minimum PLC panels will be tested in the factory to validate the following

- Panel was constructed to all standards and requirements
- All equipment associate with the panel is new and functioning properly.
- All required panel drawings are accurate and reflect as constructed conditions.
- If required, the PLC software functionality and interface with the HMI is operating properly.

Panel documentation will consist of panel layouts, power distribution, and connection drawings. Detailed panel layout drawings showing full detail of all product installed in the panels. Power distribution diagrams will be provided to show AC and DC power distribution throughout the drawing. Connection drawings will be provided for all wired and spare input/output points. Connection drawings shall show terminals at the field device for signal interface and power if the instrument is powered from the panel.

Field Wire Tagging Standards

Provide the following wire numbering scheme for all field wiring.



Where,

- Origin Loc. = Designation for originating panel or device
- Origin Term. = Terminal designation at originating panel or device
- Dest. Loc. = Designation for destination panel or device
- Dest. Term. = Terminal designation at destination panel, device, or PLC I/O Address at s destination panel.

Field instruments are always identified as the origin. PLC equipment is always identified as the destination. Location is the panel designation. For connections to MCCs, location is the specific starter tag and loop number. Location is the tag and loop number for motor starters, field instruments and equipment. Any hyphen in the panel designation or tag and loop number shall be omitted. Terminal designation is the actual number on the terminal block where the conductor terminates at field devices and vendor control panels. For multi-conductor cables, all terminal numbers shall be shown, separated by commas. Terminal designations at motor leads shall be the motor manufacturer's standard terminal designation (e.g., T1, T2, T3, etc.). Terminal designations at PLCs where the field conductor connects to field terminal blocks for a PLC input or output shall be the PLC address (Note: the following PLC I/O numbering scheme is typical for Allen-Bradley):

Discrete Point: W:X:Y/Z.
Analog Point: W:X:Y.Z.

Where:

W = I for input, O for output
X = PLC number (1, 2, 3…)
Y = Slot number (01, 02, 03…)
Z = Terminal number (00, 01, 02…) for a discrete point or a word number for an analog point (1, 2, 3…)

Terminal designations at PLCs where the conductor does not connect to a PLC I/O point shall be the terminal number with a "C" prefix (e.g., C0010). For common power after a fuse or neutrals after a switch, the subsequent points shall have a capital letter suffix starting with "A" (e.g., C0010A).

Field Wire Tagging Examples

Case 1: Vendor control panel (VCP) to PLC control Panel:

Field wire number/label: A-B/C-D

A = Vendor control panel number without hyphen (VCP#)

B = Terminal number within VCP (manufacturer's or vendor's standard terminal number)

C = Process control module number without hyphen (PLC#)

D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a "C" prefix if not connected directly to a PLC I/O point (C0010)

Examples: VCP#-10/PLC#-I:1:01/01
CP#-10/PLC#-O:1:10/07
VCP#-10/PLC#-C0100

Case 2: Field instrument to PLC module:

Field wire number/label: E-F/C-D

C = Process control module number without hyphen (PLC#)

D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a "C" prefix if not connected directly to a PLC I/O point (C0010)

E = Field mounted instrument tag and loop numbers without hyphen (EDV#)

F = Manufacturer's standard terminal number within instrument. Use both terminal numbers for analog points separated by a comma

Examples: TIT#-2,3/PLC#-I:1:01.1
TSH#-1/PLC#-I:2:01/00

Case 3: MCC to process control module (PCM):

Field wire number/label: G-B/C-D

B = Terminal number within MCC (manufacturer's or vendor's standard terminal number)

C = Process control module without hyphen (PLC#)

D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a "C" prefix if not connected directly to a PLC I/O point (C0010)

G = Actual starter designation in the MCC without hyphen (MMS#)

Examples: MMS#-10/PLC#-I:1:01/01
MMS#-10/PLC#-O:1:10/07
MMS#-10/PLC#-C0100

Case 4: MCC to vendor control panel (VCP):

Field wire number/label: G-B/A-B

A = Vendor control panel number without hyphen (VCP#)
B = Terminal number within VCP (manufacturer's or vendor's standard terminal number)
G = Actual starter designation in the MCC without hyphen (MMS#)

Examples: MMS#-X2/VCP#-10

Case 5: Motor leads to a MCC:

Field wire number/label: H-I/G-B

B = Terminal number within MCC (manufacturer's or vendor's standard terminal number)

G = Actual starter designation in the MCC without hyphen (MMS#)

H = Equipment tag and loop number without hyphen (PMP#)

I = Motor manufacturer's standard motor lead identification (e.g. T1, T2, T3, etc.)

Examples: PMP-#-T3/MMS#-T3

Case 6: Remote or separately mounted starter or VFD to PLC Module:

Field wire number/label: J-B/C-D

B = Terminal number within MCC (manufacturer's or vendor's standard terminal number)

C = Process control module without hyphen (PLC#)

D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a "C" prefix if not connected directly to a PLC I/O point (C0010)

J = Starter or VFD tag and loop number without hyphen (MMS#)

Examples: MMS#-10/PLC#-I:1:01/01
MMS#-10/PLC#-O:2:10/07
MMS#-10/PLC#-C0010

Case 7: CAT 6 or Fiber from one network panel to a fiber-optic panel (FOP) or network switch:

Network number/label: K-L/M-N

K = Fiber-optic patch panel or network switch)
L = FOP termination slot or network switch port
M = Destination FOP or network switch
N = FOP termination slot or network switch port

Examples: FOP10-01/FOP20-02

3.4 SCADA Servers

The purpose of the SCADA server component is to establish a reliable, self-healing computing platform to run the SCADA system applications, such as HMI, alarm management, Historian, security, etc. Server technology is based on virtualization to maximize reliability and performance. In a virtual environment, a physical server runs multiple virtual servers. A virtual server is dedicated to each SCADA application. By design, the virtual environment enables server or application upgrades to occur without stopping operations. A virtual environment minimizes downtime and maintenance costs.

3.4.1 Virtual Environments

Virtual server environments can be converged or hyperconverged. Both environments provide a packaged system of computing, storage, and networking components. A converged environment is a preconfigured package of software and hardware in a single system with discrete components that can be separated. Figure 3-1 shows a single SCADA server configuration with redundant network switches, two application servers and a storage server in a traditional converged environment running multiple applications on virtual servers.

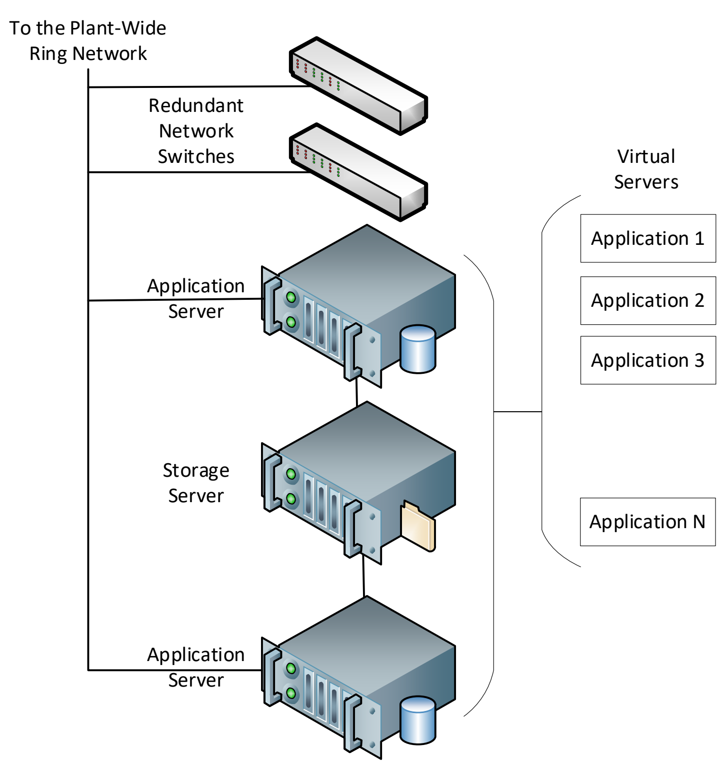


Figure 3-1. SCADA Server in a Traditional Converged Virtual Environment

In a hyperconverged environment, these discrete components are software-defined elements that are implemented virtually, with seamless integration managed by a hypervisor. This allows flexibility during design by adding computing, storage, or networking modules as needed. The use of commodity hardware yields a virtual environment that's easier to support than traditional converged environments.

Hyperconverged environments typically include a cluster of three physical servers, often referred to as nodes. Two nodes are designated as active nodes, with all the computing, storage, and networking modules needed for all virtual applications. The third node (Management Node) is designated as the hypervisor, which synchronizes, coordinates, and manages the two active nodes.

WRD SCADA servers will establish a virtual environment for all SCADA applications. Because server technology continues to develop rapidly and a typical server life cycle is 5 years, a cost-benefit analysis will be conducted at the beginning of each server replacement cycle. At a minimum, the cost benefit analysis will consider the following factors:

- SCADA application sizing requirements (in computing, storage, and networking capacities)
- Backup and recovery requirements
- Product costs
- Support services availability
- Comparable alternatives

This analysis will determine the sizing needed, the virtual environment configuration, and the specific hardware and software components or modules needed to host all virtual applications.

3.4.2 SCADA Applications

To further simplify SCADA system management and reduce maintenance costs, thin clients are used instead of SCADA workstations. All thin clients can access all virtual applications, depending on the user's privileges. Based on the number of I/O points in the current system (approximately 7,500 tags) and Rockwell Automation SCADA software application requirements, the HMI application, data application and alarm / event applications are designed to accommodate up to 10,000 tags. Table 3-4 lists the minimum virtual servers and applications for the WRD SCADA system.

Table 3-4. SCADA Virtual Applications

Server Name:	Virtual Application Description	Vendor
DC01:	Domain Controller 1	TBD
DC02:	Domain Controller 2	TBD
RDS01:	Remote Desktop Server (10 thin clients)	TBD
RDS02:	Remote Desktop Server (10 thin clients)	TBD
BUP01:	Backup and Recovery Server	TBD
NMS01:	Network Management	TBD
EP01:	Endpoint Protection Server (Antivirus)	TBD
FTD01:	FactoryTalk Directory (PhoneBook of Rockwell Computers)	Rockwell
HMI01:	Primary HMI Server and Alarm Server for Operator Workstations	Rockwell
HMI02:	Secondary HMI Server and Alarm Server for Operator Workstations	Rockwell
DATA01:	Data Server (Polls PLCs) Historian Live Data Collector	Rockwell
DATA02:	Data Server (Polls PLCs) Historian Live Data Collector	Rockwell
ENG01:	AssetCentre Server with Full MS SQL License	Rockwell
ENG02:	FactoryTalk View Studio and Studio5000 (RSLogix)	Rockwell
HIST01:	Tier 1 Historian (Historical Data for use by SCADA system)	Rockwell
ALERT01:	Alarm Management Server (SMS/Voice/Both)	WIN911
HIST02:	Tier 2 Historian (Historical Data for use by others, located in the DMZ)	Rockwell
DMZMOB:	Alarm Management Mobile (Cloud Communication, located in the DMZ)	WIN911

3.4.3 Backup and Recovery

Although the major processing components (PLCs, servers) are designed for high reliability, the loss of data, configuration, and programming from a single failure of any of these components can be disastrous. Therefore, backup and recovery systems are included in the design of each component. WRD currently uses a secondary SCADA server located separately from the primary SCADA server as its backup server. Backup and recovery system design approaches are shown in Table 3-5.

Table 3-5. Backup and Recovery System Design Approaches

PLCs (AB ControlLogix, CompactLogix)	SCADA Servers
Data: Real-time process data is continuously transmitted to the SCADA servers. In the event of a SCADA server or communication failure, the PLC retains 48 hours of real-time process data to download when the SCADA server or communication functions are restored.	Data: Real-time process data is historized by the SCADA server into short-term and long-term historical databases. Both databases are backed up by disaster recovery software to the backup SCADA server and to an offsite location, typically in cloud storage.
Configuration: PLC configurations are stored on the SCADA server using disaster recovery software. Because WRD PLCs are all AB products, WRD uses FactoryTalk AssetCentre.	Configuration: SCADA server configurations are stored on the backup SCADA server and offsite location by disaster recovery software. Selection of this software is included in the 5-year cost benefit analysis.
Programming: PLC programs are stored on the SCADA server using disaster recovery software. Because WRD PLCs are all AB products, WRD uses FactoryTalk AssetCentre.	Programming: Virtual application programs are stored on the backup SCADA server and offsite location by disaster recovery software. Selection of this software is included in the 5-year cost benefit analysis.

Note:
SCADA server disaster recovery and backup software options include VEEAM and Acronis.

The backup and recovery portion of the cost benefit analysis will consider:

1) Data, configuration, and programming backup requirements for all virtual applications
2) Recovery Point Objectives (RPO) and Recovery Time Objectives (RTO)
3) Redundancy requirements for disaster recovery resources onsite and offsite
4) Disaster recovery performance factors, including storage media and communication means

3.5 Networks

The purpose of the SCADA network component is to establish a reliable, self-healing, and high-speed communication system that seamless connects all SCADA servers, workstations (thin clients), and PLCs. Network technology is standardized on Ethernet (IEEE 802.3) protocols with backbone connections based on fiber-optic media. The fiber-optic or radio (4.9GHz or 172 MHz) media is the physical layer of the SCADA network. The protocol is the logical layer of the network. Both layers are described in the first part of this section.

Security (both physical and cyber) is critical to the ability of the SCADA network to achieve its purpose as a reliable high-speed communication system. Security systems will be designed to detect any unauthorized access and prevent any unauthorized action. The second part of this section discusses security and defense in depth.

3.5.1 Network Cabling and Switches

Currently, the WRP has a fiber ring network connecting each of the major facilities throughout the plant. The existing fiber is a 6-strand multimode fiber cable based on an early IEC 11801 standard OM1 62.5/125-micron fiber. This supports 1GB network connections of 902 feet or 10GB network connections of 108 feet. Single mode fiber based on IEC 11801 standard OS1 offers 10GB connectivity up to 6561 feet. Since the distances between most WRP facilities are greater than 108 feet, the high-speed network requirements can only be achieved using single mode fiber. WRD uses some OM3 fiber that supports 10GB network connections up to 984 feet.

In addition to the SCADA network, two more networks also require a fiber-optic upgrade to support higher data speeds. All three networks will maintain separation by using dedicated fiber pairs and switches for each network. Therefore, the fiber-optic upgrade will install a minimum of 12 strands of single mode fiber. The three networks at the WRD WRP are:

1) Control / SCADA network: currently maintained by the WRD’s Operations Technology (OT) team
2) Access / PA network: currently maintained by the WRD’s OT team
3) Business / Enterprise network: currently maintained by Livermore’s IT team

All fiber strands for the three networks will be terminated in each facility’s communication panel. Each strand will be tagged so that the separate fiber will be clearly demarcated between each network / purpose. Each facility will have a separate communication panel, with its own Uninterruptible Power Supply (UPS).

Physical Layer (SCADA, Access, and Business networks)

The existing physical backbone ring will be retained with the key differences listed below.

1) The fiber cabling will support three physically separate networks, specifically the SCADA system network, access network, and business network. The SCADA system network will include equipment related to SCADA servers, PLCs, OIPs, and other related SCADA system components. PLC communications will include physically separate subnetworks dedicated to communication with smart devices like VFDs, MCCs, and intelligent instruments over DLRs where possible. The access network will include equipment related to access control (card keys, electric door locks, etc.), public address system, and security related closed-circuit television. The business network will include enterprise related systems including email, file management, financial systems, Internet access, etc.

2) Fiber-optic network patch panels, Ethernet switches, and other related network equipment will be housed in physical separate communication panels. Currently the communication equipment is housed in PLC and control panels. As the networks are physically separated to serve three different purposes, the PLC panels will be dedicated to PLC and control equipment and communication panels will be dedicated to the new communication equipment. Separating the communication equipment from the PLC enclosures simplifies maintenance on both components.

Logical Layer (SCADA Network only)

The logical layer defines how a network is connected for self-healing in the event of a fiber cable break. Figure 3-2 shows three buildings connected in a physical ring topology and a logical redundant star topology. In the event of a fiber-optic break (physical fault), each network component includes an alternate path to maintain communications.

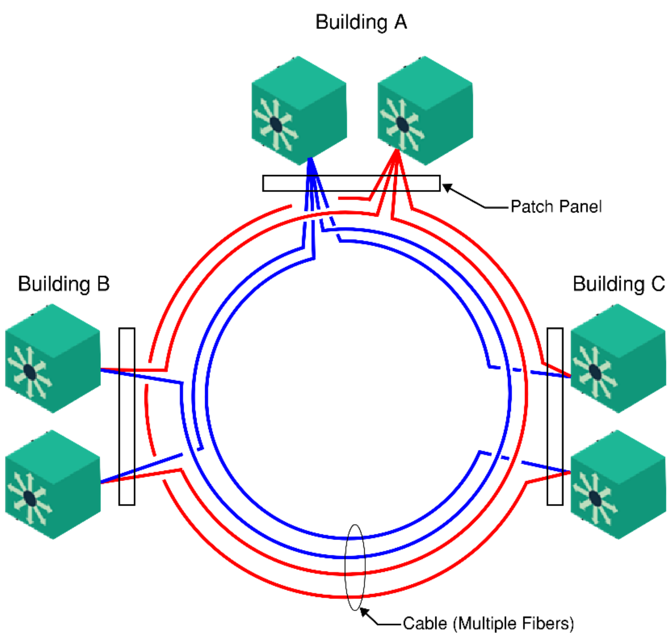


Figure 3-2. Self-healing Logical Ring

Device Level Rings (SCADA Network Only)

Within each facility, one or more DLR networks will be installed within each PLC to Ethernet connected devices. This design approach isolates traffic specifically between the PLC and smart devices. For example, smart MCCs, power monitors and other intelligent devices within each facility will be on a DLR network to the local PLC. Figure 3-3 shows an example of several intelligent devices connected to a local PLC (patch panels and the self-healing backbone ring are not shown).

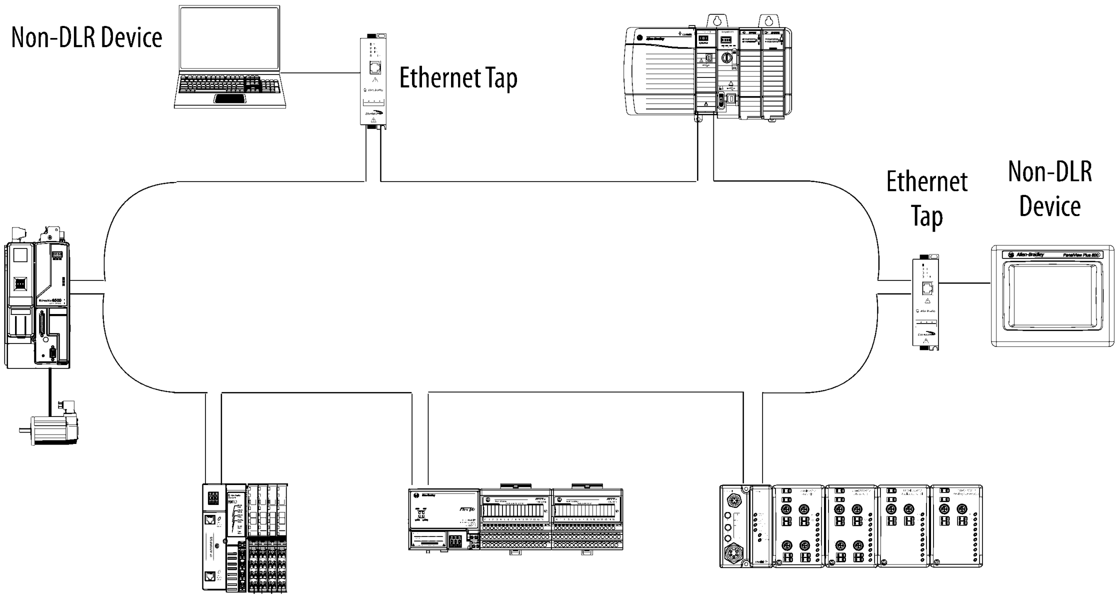


Figure 3-3. Example of DLR

Network Switches (SCADA Network only)

Currently, the WRP is standardized on Stratix model switches (from Rockwell Automation). A comparison analysis between Stratix, Cisco and Moxa switches recommended keeping Stratix as the standard. The analysis also recommended all switches to have the same number of ports to simplify spare parts inventory.

3.5.2 SCADA Network Security

Cybersecurity Model

The existing SCADA network at WRD uses an 'air-gap' between the SCADA and external networks to restrict all remote access. While providing some security, it also prevents authorized users, including operations, maintenance, product support, and service providers from remote access. Establishing secure remote access to the control system is an objective for the SCADA system upgrade. This includes routing remote site radio communications through the remote access firewall to the SCADA network. A cybersecurity model is shown on Figure 3-4 and WRD has adopted the following goals for this model:

1) Design and maintain controlled and secure remote access to all SCADA resources.
2) Maintain physical network segregation between the SCADA, Access, and IT networks.
3) Harden all SCADA system devices.
4) Actively engage in network monitoring and software patching.

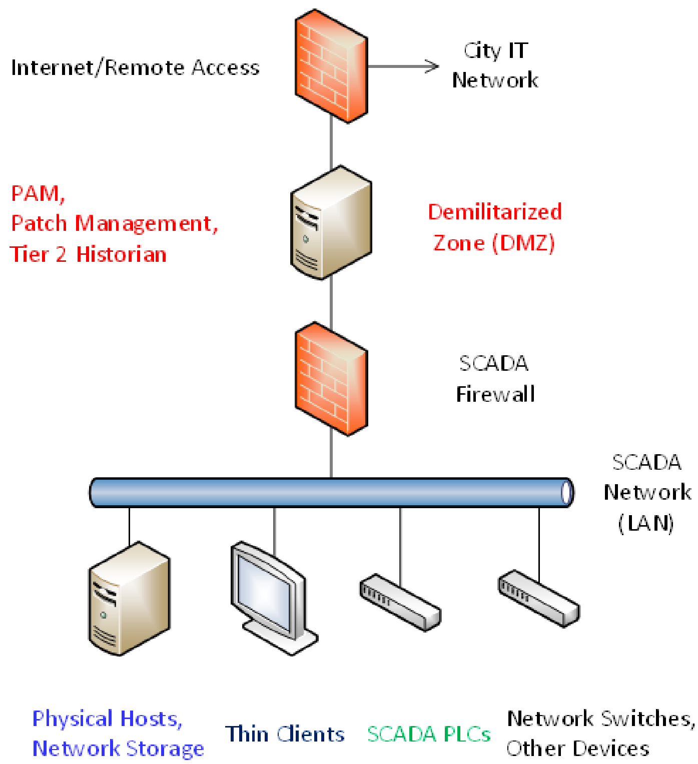


Figure 3-4. Cybersecurity Model

This cybersecurity model includes two firewalls and a DMZ in compliance with the industry standard of providing 'defense in depth' from a security perspective. Defense in depth security includes:

1) Physical security: all servers and primary network switches are installed in lockable panels in lockable rooms. This could also include biometrics and data-centric security.
2) Network security: including firewalls, DMZs, and Virtual Private Networks (VPNs).
3) Application security: including passwords, multi-factor authentication, encryption, antivirus software, and intrusion detection systems.
4) Administrative security: WRD's cybersecurity policies and procedures, including hiring practices, security requirements, and data handling procedures. Operations will work with the Livermore Cybersecurity department to ensure a shared understanding of cybersecurity policies and procedures.

Demilitarized Zone

A DMZ is a physical and logical subnetwork that contains the SCADA network's external-facing services to an untrusted larger network. This protects the SCADA network from untrusted traffic. It sits between the City IT firewall and the SCADA firewall, using both to filter traffic. The WRD DMZ includes the four components shown in Table 3-6.

Table 3-6. DMZ Components

Control Device	Purpose and Description	Potential Vendor
Privileged Access Management (PAM)	▪ To provide secure and authenticated remote access ▪ Scalable and can be integrated with Active Directory ▪ Provided encrypted communication for authenticated users ▪ Pricing is based on a perpetual and subscription-based license	BeyondTrust (Bomgar)
Patch Management	▪ To monitor and manage all Microsoft patches	Microsoft Intune
Tier 2 Historian	▪ To provide a data repository outside of the plant's Local Area Network. This Historian will store any I/O points that will need to be accessed externally through the SCADA firewall (i.e., external dashboards)	Rockwell
DMZMOB	▪ To provide external alarm notification to mobile devices.	WIN911

Firewalls

The WRD cybersecurity model uses two firewalls (as shown on the diagram above). Livermore's Cybersecurity Division is conducting a study to determine a new vendor provider for their standard firewalls. The final installation / selection of the firewalls for the SCADA cybersecurity model depends on resulting Citywide Cybersecurity Strategic Plan. Three commonly used firewalls in SCADA environments are:

1) Cisco
2) PaloAlto
3) Fortinet

Threat Detection and Response (Network Monitoring)

Livermore's Cybersecurity Division is in the process of creating a Citywide Cybersecurity Strategic Plan. The resulting plan will include a strategy for advanced threat detection and response. The ICS network monitoring solution will be needed to provide continuous ICS security monitoring and report or alert Livermore's Security Operations Center (SOC). Three common solutions are:

1) Darktrace Industrial Immune System
2) Tenable.OT
3) Nozomi Networks SCADAguarding

3.6 Documentation

The purpose of the documentation component is to accurately represent the SCADA system. Accurate representation of the current (as-built) SCADA system and its components reduces engineering and maintenance costs substantially by minimizing pre-design field verification and streamlining diagnostics. The SCADA system documentation consists of five (5) sets including I&C, control panels, control programs, networks, and servers. The following describes each documentation set and includes references to applicable City design standards.

Some SCADA system documentation must comply with City Design Standards, such as the WRP Design Guidelines. WRP Design Guidelines were created to provide consistency and efficiency for design projects at the WRP. These Standards document requirements, issues, decisions, products, and procedures preferred by the City and plant operations staff.

The Convention and Component Standards in the SCADA System Master Plan were created to provide consistency and efficiency for the WRD SCADA system development. SCADA development work includes a variety of ongoing, short-term, and long-term projects, and a wide range of complexity. SCADA development work can be performed by WRD staff or contracted professional services.

3.6.1 Instrumentation and Control Devices

Instrumentation and control devices are the interface between the WRP facilities and the SCADA system. Product preferences for I&C devices are described in Section 3.2 of the SCADA Master Plan. The tagging format for instruments, auto valves, and VFDs is provided in Section 2.3 of the SCADA Master Plan. Adherence to these SCADA system Standards is mandatory for SCADA system consistency and efficiency.

Design and construction requirements, issues, decisions, and procedures for I&C devices are described in the WRP Design Guidelines. A cross reference table for instrumentation and control devices to the WRP Design Guidelines and CSI Division is provided in Section 3.2. Adherence to these City Design Standards is mandatory for consistency at the WRP facilities.

3.6.2 PLC Control Panels

Control panels house the PLC and supporting equipment. Section 3.3 of the SCADA Master Plan provides a list of general standards and codes, an example of panel sizing and layout, and detailed descriptions of panel components and documentation. Section 3.3 also includes field wire tagging standards and examples. Control panel design and construction documentation includes:

- Control Panel Layout (Example provided in Appendix 3-A of SCADA Master Plan)
- Power Distribution
- Connection Drawings (Termination/Loop Diagrams)

Other control panel design and construction documentation includes:

- PLC Panel Elevation Diagrams (PLC rack details)
- Control equipment schematics and control enclosure schematics
- PLC Parts Inventory
- I/O List (per panel, listed by Database tagging format described in Section 2.3)

Refer to Chapter 6 of the WRP Design Guidelines for panel materials, grounding, lighting, receptacles, UPS, conduit, and cabling requirements.

3.6.3 Control Programs

Control programs perform the monitoring and control functions of the SCADA system on the WRD facilities. They are based on the Convention Standards described in Chapter 2 of the SCADA Master Plan. The program logic is developed from I/O lists, Process Flow Diagrams (based on P&IDs), Process Control Narratives (based on control strategy descriptions), and packaged system specifications.

P&IDs and control strategy descriptions are generated from the design project and included in the 50% design, 90% design, and 100% design submittals. The Design Project SCADA engineer develops Process Flow Diagrams and Process Control Narratives to develop and document the control program. Control program development documentation includes:

- Process Flow Diagrams (based on P&IDs)
- Process Control Narratives (based on control strategy descriptions):
  - Equipment, I/O List (all instruments and control devices)
  - Control Modes (Local, Manual, Auto, etc.)
  - Strategies (narrative descriptions of control mode functions and selection criteria)
  - Alarms (see Section 2.6 of the SCADA Master Plan for Alarm Management standards)

Control program acceptance documentation includes as-built Process Flow Diagrams and as-built Process Control Narratives generated by the SCADA system programmer.

3.6.4 Network

The network is the communication backbone of the SCADA system. The network designer must comply with City CAD Standards and Standard Drawings for a physical overview of the network panels, backbone cabling, and conduit system. Design projects must show panel, cabling, and conduit modifications to the network in the 50% design, 90% design, and 100% design submittals.

The fiber-optic network is designed to carry multiple independent networks, including the SCADA system, Access/PA, and Business (IT) networks. DLR are local, SCADA system only, and typically carried on Ethernet cable. Other network drawings and documentation are provided in draft (90% design) and final (100% design) by the network designer. Network documentation includes:

- Plan Diagram (Physical overview of the fiber-optic cable layout)
- Block Diagrams (Logical overview of the fiber pair assignments for each network [SCADA, Access, IT, DLRs])
- Network Panel Layout
- Fiber Termination Diagrams (network patch panel connections)
- Network Inventory (switches, routers, stand-alone/modules)
- Port Configuration (network assignment, security measures, port assignments, etc.)
- IP Addressing (developed, but not published in any public documentation for security reasons)

Refer to Chapter 6 of the WRP Design Guidelines for panel materials, conduit, and fiber-optic cabling requirements.

3.6.5 Servers

The servers provide the computing platform that performs all the centralized data processing and storage functions of the SCADA system. Two server locations (primary and backup) provide redundancy and enable backup and recovery systems to minimize down time of the SCADA servers. Server locations may change due to facility modifications or remodeling. Server designs are developed at the beginning of each 5-year replacement cycle with a cost-benefit analysis. The cost-benefit analysis produces a draft design (90% submittal), a final design (100% submittal), and an as-built submittal. Server design documentation includes:

- Server Architecture (diagram showing hardware and software components and connections)
- Server Rack Diagrams
- Server Inventory (hardware and software)
- Server Configuration

3.7 System Development

System development is the general process of modifying or enhancing SCADA functionality to existing facilities, or of adding new facilities or functions to the existing SCADA system. System development includes all work performed by WRD staff and contracted professional services. Work performed for SCADA development is organized into two categories, SCADA System Maintenance and Design Projects. This section outlines general procedures for equipment procurement, configuration, programming, testing, commissioning, decommissioning, training, and documentation for each category.

All work performed for SCADA development assumes a material (SCADA hardware, software, supplies) and a labor (WRD staff, professional services) component. Both work categories assume a blend of labor resources, depending on work requirements and resource skills and availability. SCADA development work described in this section assumes non-Federal funding on non-public projects, although SCADA development work can be included in a public project (Federal or non-Federal funded). See City of Livermore Administrative Regulations (AR) 6.0 for definitions of Federal funding and public/non-public projects. All SCADA development work must be compliant with all SCADA Master Plan Convention and Component Standards and WRP Design Guidelines.

Table 3-10 summarizes procurement requirements defined in AR 6.0 for materials and labor. Material procurement requires at least three (3) quotes, whenever possible, for approval of a purchase order (PO). Labor, i.e., Professional Services, procurement requires the service provider be selected from a pre-qualified list. Professional Services do not require competitive bids. WRD can negotiate a Professional Services Agreement (PSA) for approval by the appropriate authority shown in Table 3-7.

Table 3-7. Material and Labor Purchasing Thresholds

Threshold	Material Bid/Quote Requirement.	PO Approval Authority (Materials)	PSA Approval Authority (Labor)
$5,000	None	Department Head	N/A
$15,000	Informal (Verbal or Written Quote)	Admin. Serv. Director	N/A
$25,000	Informal (Written Quote)	Admin. Serv. Director	Department Head
$50,000	Informal (Written Quote)	City Manager	N/A
$100,000	Formal (Bid)	City Manager	City Manager
> $100,000	Formal (Bid)	City Council	City Council

Refer to AR 6.0 for complete procurement policies and procedures.

3.7.1 System Maintenance

SCADA system maintenance consists of the daily work activities that continuously maintain and develop the SCADA system's functionality. Typical maintenance activities include:

- Routine Work Orders, including cleaning, calibration, repairs, and replacements of instrumentation, control devices, PLCs, etc.
- Diagnostics/Analytics; covering a wide range of alarms, faults, system malfunctions, and system failures in the SCADA system. Network and server alarms and faults may require professional services to assist.

- Program Modifications; including PLC control logic, HMI graphics, alarm management, historian configuration, etc. Most program modifications are performed by WRD staff. PLC program version control uses Rockwell's AssetCentre. Network and server modifications typically require professional services to assist.
- Backup and Recovery; PLC program backup and recovery uses Rockwell's AssetCentre to manage PLC programming files. Server backup and recovery is semi-automated and may require professional services to assist.
- Documentation; the critical component of SCADA system development, is typically generated by professional services in design projects that provide conformed as-builts and maintained by WRD maintenance staff.
- Planned Work Orders; includes significant repair and replacement of SCADA system components within the capability of WRD staff. WRD staff workloads and availability may require professional services to supplement.

SCADA System Maintenance Procedures

The general procedure for performing SCADA system maintenance activities starts with a User Service Request. As outlined in Table 3-8, the maintenance procedure begins with a Work Order that first identifies materials and labor needed. Work orders are further developed by obtaining the required bids/quotes, identifying the resources, and scheduling the work. Work orders can include a wide range of activities and complexities. All resources performing this work must be familiar with the SCADA System Convention and Component Standards and how these standards specifically apply to the work order.

Table 3-8. SCADA System Maintenance Procedures

Procedure	Materials	Labor
User Service Request		
Work Order	Identify Equipment, Parts, and Supplies Needed. Obtain Bids/Quotes as Required	Identify Skills and Estimate Hours Needed. Identify and Schedule Resources.
PO/PSA	Generate PO and Receive Materials (Refer to AR 6.0 for requirements)	Negotiate PSA as necessary. (Refer to AR 6.0 for requirements)
Execution	Install and Test Materials	Perform Work in Conformance with SCADA System Standards. Depending on work request, work may include configuration, programming, testing, commissioning, decommissioning, and training.
Closeout	Update Documentation	Update Documentation

SCADA system development through maintenance activities focus primarily on compliance with the Convention and Component Standards in the SCADA System Master Plan. Depending on the work performed, the WRP Design Guidelines may also be applicable.

3.7.2 Design Projects

Design projects consist of the CIP projects planned, designed, and built by the WRD Engineering Division. These projects upgrade facilities that include a SCADA system component or add new facilities with a SCADA system component. The Engineering Division solicits input and feedback from Operations and

Maintenance staff for these projects and uses the WRP Design Guidelines for all facility designs, except for the SCADA system component. The WRD developed the SCADA System Convention and Component Standards to provide SCADA design guidelines complementary to the WRP Design Guidelines.

Design projects are developed in phases as outlined in Table 3-9. The WRP Design Guidelines define specific design submittals in the design phase. Table 3-9 shows a list of SCADA-specific information to be provided with each design submittal. SCADA-specific information must be provided by a SCADA designer collaborating with the project designer. The 50% Design Submittal assumes:

- the WRD Tagging Format is applied to facility equipment, and
- the Database Tagging Standard is applied to SCADA I&C devices.

Table 3-9. Design Project Procedures (SCADA System Specific)

Procedure	Materials	Labor
Plan	Identify SCADA Equipment Needed for Class 4 Material Cost Estimate.	Identify General Activities for Ballpark Class 4 Labor Cost Estimate.
Design	s	
50% Design Submittal	▪ Instrument Tagging compliant with Database Tagging (Section 2.3) ▪ Network Plan Diagram ▪ Equipment Descriptions for Class 3 Material Cost Estimate	▪ P&IDs compliant with Control Philosophy (Section 2.2) ▪ Control Strategy Descriptions ▪ Identify Resources for Class 3 Labor Cost Estimate
90% Design Submittal	▪ Draft Network Design ▪ Draft Bill of Materials ▪ Draft Class 2 Material Cost Estimate	▪ Draft Process Flow Diagrams ▪ Draft Process Control Narratives ▪ Draft Class 2 Labor Cost Estimate
100% Design Submittal	▪ Final Network Design ▪ Final Bill of Materials ▪ Final Class 2 Material Cost Estimate	▪ Final Process Flow Diagrams ▪ Final Process Control Narratives ▪ Final Class 2 Labor Cost Estimate
Bid (Procurement)	PO for SCADA Equipment	PSA for SCADA Services
Build	SCADA equipment may be installed under the General Contractor or a separate PSA.	SCADA Services includes configuration, programming, testing, commissioning, and training.
Final Acceptance	As-Built Documentation	As-built Documentation

The WRP Design Guidelines provide detailed descriptions of construction design, including site preparation, concrete, masonry, metals, wood, plastics, doors and windows, finishes, and furnishings. The WRP Design Guidelines also provide detailed descriptions of equipment, conveying systems, mechanical systems, and electrical systems. The Design Project develops specifications and drawings for these facility elements.

The SCADA Convention Standards provide detailed descriptions of control philosophy, database tagging, PLC programming, HMI graphics, and alarm management. The SCADA Component Standards provide detailed descriptions of SCADA system equipment, including instrumentation, control panels, servers, and networks. The Component Standards reference specific chapters in the WRP Design Guidelines with design details for instrumentation, control panels and networks.

All Component Standards are intended to work with WRP Design Guidelines and design project specifications. Product components often include construction elements for installation, so these component sections include references to the appropriate WRP Design Guideline chapter and CSI MasterFormat 17 Division as shown in Table 3-10. Practice components must comply with all Livermore policies and procedures, so these component sections also include references to the appropriate City of Livermore AR.

Table 3-10. Component Standard Cross References

Component Standard	WRP Design Guidelines Chapter	CSI Division	Livermore Admin Regulations
3.2 Instrumentation	~~Chapter 7~~ (Superseded)	17 - Instrumentation	
3.3 Control Panels	Chapter 6 – Electrical 6.5 – NEMA Panel Materials 6.6 – Grounding System 6.7 – Lighting System 6.8 – Receptacle System 6.9 – UPS Selection 6.11 – Conduit and Cable System	16 - Electrical	
3.4 Servers	~~Chapter 7~~ (Superseded)	N/A	
3.5 Networks	Chapter 6 – Electrical 6.11 – Conduit and Cable System	16 – Electrical	
3.6 Documentation	Chapter 2 – General 2.5 – Design Submittals	1 – General Requirements	
3.7 System Development	N/A	N/A	6.0, Purchasing Policy and Procedures

3.8 Staff Development

The purpose of the staff development component is to optimize resources to maintain and develop the SCADA system. SCADA resources include both WRD staff and professional services, so this section classifies SCADA development by work best performed by WRD staff, professional services, or a blend of both resources. For planning purposes, this section assumes all SCADA development work in Design Projects is performed by professional services and reviewed by WRD staff. Staff development needs are therefore based on the maintenance work described in System Development.

3.8.1 Development Needs

WRD staff perform a wide variety of work in maintaining and developing the SCADA system. In addition, WRD staff maintain the security system on its own network within the SCADA network. The security system is separate from the SCADA system and includes components comparable to SCADA components (i.e., intrusion switches and security cameras are comparable to I&C, the security server is comparable to the SCADA server, etc.). The security system adds a significant workload to WRD staff. Each SCADA component and the security system requires its own skill set and experience to perform maintenance work efficiently.

Table 3-11 cross references maintenance work with SCADA components. Maintenance work is listed from top to bottom by increasing experience requirements and SCADA components are listed from left to right by increasing skill requirements. Component work is performed by WRD staff, professional services via a PSA, or a blend of WRD staff and professional services as shown in Table 3-11.

Table 3-11. Staff Development Needs Matrix

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

Notes:

Network and Server maintenance work is often performed on a quarterly or annual basis and generally require more specialized skills.

Documentation and Planned Project work generally requires more experienced or senior level staff. Planned Projects are not Design Projects.

OJT = on-the-job training

SNMP = Simple Network Management Protocol

Legend	
WRD	
WRD/PSA	
PSA	

Observations on Staff Development

Table 3-11 – Staff Development Needs Matrix shows SCADA maintenance work is generally performed by WRD staff and supplemented by professional 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 servers every 5 years, require professional services to perform.
2) Skill sets for most SCADA maintenance work are developed by on-the-job training (OJT), specifically, experience gained by familiarity with WRD standards, practices, facilities, and equipment.

The fundamental skill set for SCADA system development is knowledge and familiarity with the Rockwell products that are standard components for the WRD SCADA system. These products include ControlLogix PLCs, FactoryTalk HMI, and AssetCentre (for PLC program management, version control, backup, and recovery). Specific observations include:

1) PLC and HMI maintenance work requires skill development by specialized training in ControlLogix PLCs, FactoryTalk, and AssetCentre. Minimum knowledge requirements include:
   a) ControlLogix Fundamentals and Troubleshooting (Studio 5000 Level 1)
   b) ControlLogix Function Block Programming (Studio 5000 Level 2)
   c) FactoryTalk View SE Programming
   d) FactoryTalk AssetCentre System Design and Implementation
2) Routine maintenance for HMI assumes thin clients for each HMI workstation. Thin clients are designed to be easily replaced by WRD staff without the need to modify HMI programming.
3) Backup and Recovery work for the HMI assumes the HMI application is included in the server backup and recovery system. Server backup and recovery is semi-automatic and generally supported by professional services.
4) Training on Simple Network Management Protocol (SNMP) enables WRD 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 3-11. Additional training courses may be considered based on workload requirements and specific maintenance needs.

3.8.2 Staffing Levels

Based on the existing WRP SCADA system assessment described in the SCADA Master Plan (17 WRP PLCs, 15 remote sites, 15 workstations, 2 servers, fiber and radio networks) and including the security system, a relative workload analysis is shown in Table 3-12. All values shown are full time equivalent (FTE) staff dedicated to SCADA system maintenance activities and does not include management or supervision.

Table 3-12. Workload Analysis

Maintenance Work	SCADA Components (1 FTE = 2000 hrs/year)					
	I&C	**Panels**	**PLCs**	**HMI**	**Network**	**Servers**
Security System	0.2	-	N/A	N/A	-	0.1
Routine Maintenance	0.4	0.1	0.1	-	0.1	-
Diagnostics/Analytics	0.4	0.1	0.2	-	0.1	-
Program Modifications	N/A	N/A	0.5	0.5	-	-
Backup and Recovery	N/A	N/A	0.3	0.3	-	-
Documentation	0.3	0.1	-	-	0.1	-
Planned Projects	0.2	0.2	0.1	0.1	0.1	0.1
Totals	1.5	0.5	1.2	0.9	0.4	0.2

Note:

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

Observations on Workload Analysis

The workload analysis estimates a total of 4.7 FTEs is needed to perform all SCADA system maintenance work. An additional 0.5 FTE (20%) is planned to allow WRD SCADA staff to participate in workshops and reviews for Design Projects.

A more quantitative workload analysis can be performed based on work orders in the Computerized Maintenance Management System (CMMS).

3.9 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-related governance and development. This panel is called the **SCADA Committee** and it is responsible for advising and communicating SCADA-related concerns and plans to all stakeholders and WRD management.

3.9.1 SCADA Governance Advisory Panel

The purpose of the SCADA Committee is to:

> *Develop a reliable, secure, and flexible SCADA system that enables WRD Operations to meet or exceed effluent quality requirements, supports proactive maintenance, and provides useful process information to all WRD stakeholders.*

Membership and participation in the SCADA Committee meetings represents all stakeholders. Because the SCADA system is primarily an Operations tool supported by Maintenance staff, both Operations and SCADA maintenance representatives are standing members of the committee. Other stakeholder groups (Engineering, Management, Cybersecurity, etc.) are represented as needed. Table 3-13 shows the stakeholder membership in the SCADA Committee.

Table 3-13. SCADA Committee Membership

Standing Membership	As-Needed Representation	
Technical Programs Manager (Chair)	Engineering	Laboratory
Asset Management Specialist (Co-chair)	Cybersecurity	Water
Operations Manager	SCADA Technicians	Collections
Maintenance Supervisor	Management	
Electrical & Instrumentation Lead		

Objectives and goals of the SCADA Committee are based on the Objectives and Goals described for the SCADA 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 Design 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 cyber security standards while allowing secure remote access.
4) Provide useful information to external databases that can satisfy the data needs of WRD stakeholders.

3.9.2 SCADA Governance Processes

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

1) Call to Order (Take attendance)
2) SCADA Budget (Review expenditures and projections).
3) Old Business (Review existing Action Items and Recommendations)
4) New Business (Identify, discuss, and document new SCADA-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 typically occur between regularly scheduled meetings. The standing agenda for ad-hoc SCADA Committee meetings is:

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

Processes that support SCADA governance include:

- **Identification:** The most common form of SCADA-related concern identification is a written (generally email) request or inquiry on a SCADA-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-related inquiries and requests should be brought to the attention of the SCADA 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 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 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 communication of meeting results to all stakeholders.
- **Action Item:** Action items may generate a work order, a PO, or a PSA. 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 system documentation (as-builts) of the SCADA-related concern is updated or completed.

Notes:

- Every SCADA Committee meeting should include a reminder to all participants of their responsibility to communicate the meeting’s results to their respective stakeholder groups.
- The Alarm Management audit and usage reviews should be part of SCADA Committee meetings.

Appendix 1-A
SCADA Computer List for the WRP

Table 1A-1. SCADA Computer List

Name	Location	Use	Software/Model
Workstations			
OP1	Taj	FactoryTalk client	
Taj-PC	Taj	FactoryTalk client	
Solids-PC	Taj	FactoryTalk client	
UV-PC	Taj	FactoryTalk client	
Laboratory	Lab (ops)	FactoryTalk client	Excel, Reportbuilder, access
Watersuper	Water (super)	FactoryTalk client	
testpc	Water (Common)	FactoryTalk client	
FT-UV	Solids	FactoryTalk client	
LAVWMA	Tertiary	FactoryTalk client	
Spare-PC	UV	FactoryTalk client	
Blowerbuilding	Blower	FactoryTalk client	
Opsuper	Ops Super	FactoryTalk client	Excel
EngineeringPC	Engineering	FactoryTalk client	ReportBuilder
Raj-PC	Maint	PLC development	All PLC programs
ElCoordinator	Maint	PLC Development	All PLC programs
	Lab (common)		Excel
	Lab (Super)		Excel
Servers			
DC1	RO MCC	Domain Controller	
Scada1	RO MCC	FactoryTalk SE Server	FactoryTalk SE server
ROServer 1	RO MCC	Backup	
ROServer 2	RO MCC	Historian	MySQL, FactorySQL, FactoryTalk Linx
DBServer	RO MCC	Historian (backup)	MSSQL, FactorySQL, FactoryTalk Linx
DC2	Tertiary	Domain Controller	
Scada2	Tertiary	FactoryTalk Server	FactoryTalk SE server
ScadaDev2	Maint	Development	FactoryTalk studio

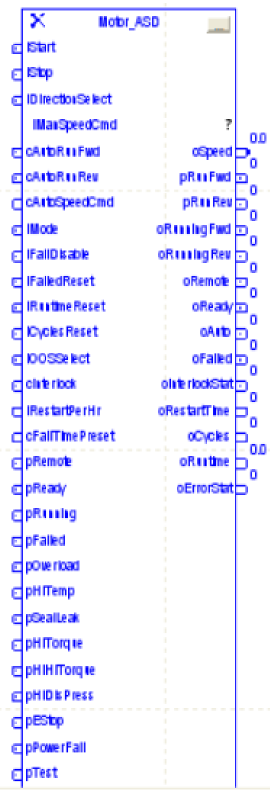
Table 1A-1. SCADA Computer List

Name	Location	Use	Software/Model
Panelview Displays			
	Belt press	Operator Interface	Panelview Plus 1250
	LAVWMA	Operator Interface	Panelview Plus 1500
	GBT #1	Operator Interface	Panelview Plus 1500
	GBT #2	Operator Interface	Panelview Plus 1500
	Rickenbacker LS	Operator Interface	Panelview CE 700

Appendix 1-B
Example of Rockwell Automation Add On Instructions – For Adjustable Speed Drive

RSLOGIX5000 VARIABLE SPEED MOTOR CONTROL BLOCK

Normal View



Expanded View

Version:

1.1 – Initial Release

General

- This block is used for control of an ASD motor.
- Controls are provided for Non-Reversing or Reversing control
    - Reverse commands are not visible as a standard block setting.
    - Reverse output is not visible as a standard block setting.
    - Non visible control functions can be selected as visible from the block settings accessed using the "selection ellipses" located in the top right corner of the AOI.
- Standard code includes VSD Run Time Hours, VSD Number of Starts (Cycles) and VSD Ready control.
- The AOI is programmed in relay ladder logic.
- Scaling and Pre-sets:
    - Fail timer setting: 15 seconds
    - Maximum number of starts per hour = 0 (infinite starts)
    - Maximum Run Time Hours: 99,999 hours

AOI Inputs

AOI INPUTS		
INSTANCE NAME	DATATYPE	DESCRIPTION
pReady	BOOL	Motor Disconnect switch is engaged status input
pRemote	BOOL	Remote/Local status input
pRunning	BOOL	Running Status Input
pFailed	BOOL	Failed/Fault Status Input
pOverload	BOOL	Motor Overload Status Input
pHiTemp	BOOL	Motor Hi Temperature Status Input
pSealLeak	BOOL	Motor Seal Leak Warning Status Input
pHiTorque	BOOL	Motor Hi Torque Status Input
pHiHiTorque	BOOL	Motor Hi-Hi Torque Status Input
pHiDisPress	BOOL	Motor Hi Discharge Pressure Status Input

RSLOGIX5000 VARIABLE SPEED MOTOR CONTROL BLOCK

AOI INPUTS		
pEStop	BOOL	Motor Starter E-Stop Button Status Input
pPowerFail	BOOL	Power Fail Status Input
pTest	BOOL	Test Mode Select
iManSpeedCmd	BOOL	HMI manual speed reference command
iStart	BOOL	HMI Manual Start command
iStop	BOOL	HMI Manual Stop command
iDirectionSelect	BOOL	HMI Manual Mode Direction select
iMode	BOOL	HMI Auto/Manual Mode Select
iFailedReset	BOOL	HMI Reset Latched Failed condition
iFailDisable	BOOL	HMI Disable Fail Alarm
iRunTimeReset	BOOL	HMI Runtime Reset
iCyclesReset	BOOL	HMI Cycles counter reset
iOOSSelect	BOOL	HMI Out Of Service Select
iRestartPerHr	INT	HMI Number of Restarts Per Hour
cAutoRunFwd	BOOL	Auto mode run request (Forward direction)
cAutoRunRev	BOOL	Auto mode run request (Reverse direction)
cAutoSpeedCmd	REAL	Auto mode speed reference command
cInterlock	BOOL	Motor Process Interlock Input
cFailTimePreset	REAL	Fail to start/stop timer setpoint

HMI Control Inputs:

- *iManSpeedCmd*, Speed reference setpoint from HMI when in Manual Mode (0.0% - 100.0%)
- *iStop*, Manual STOP control from push button on HMI. Active when motor is in Manual mode.
- *iStart*, Manual START control from push button on HMI. Active when motor is in Manual mode. Forward or Reverse direction is dependent on *iDirectionSelect* (Default direction is forward).

- *iDirectionSelect,* Activated from matching push buttons on HMI. Used to select between FORWARD and REVERSE directions when in Manual mode. 0 = Forward, 1 = Reverse.
- *iMode,* Activated from matching push buttons on HMI. Used to select between AUTO and MANUAL mode. 0 = Manual, 1 = Auto
- *iFailedReset,* Activated from push button on HMI. Motor Fault is latching fault and requires a manual reset.
- *iFailDisable,* Activated from push button on HMI. Disables the motor failed alarm.
- *iRunTimeReset,* Activated from push button on HMI. Used to reset the TOTAL run time hours. RTH will also reset automatically at 99,999 hours.
- *iCyclesReset,* Activated from push button on HMI. Used to reset the total number of starts. Cycles will also reset automatically at 99,999 starts.
- *iOOSSelect,* Activated from matching push buttons on HMI. Used to select between IN SERVICE and OUT OF SERVICE. 0 = In Service, 1 = Out Of Service
- *iRestartPerHr,* Numeric input from HMI. Used to set the maximum allowed motor starts per hour. A default value of zero will allow an unlimited number of starts per hour.

Internal Control Inputs:

- *cAutoSpeedCmd*, Auto mode speed reference command generated by custom code elsewhere in the PLC program.
- *cAutoRunFwd*, This input is mapped from the overall automatic RUN in Forward direction control and is used to start the motor when the motor is set to AUTO mode.
- *cAutoRunRev*, This input is mapped from the overall automatic RUN in Reverse direction control and is used to start the motor when the motor is set to AUTO mode.
- *cFailTimePreset,* This is the timer setpoint for the Fail To Start timer. This timer detects when the motor is commanded to run and there is no running feedback detected.
    - Default Setting: 15 Seconds
- *cInterlock*, This input is for any process interlocks, such as no seal water flow, and shuts down the run output to the motor. There is no time delay for stopping the motor if the input transitions from On to Off.

Physical Inputs:

- *pReady,* Motor Starter is Ready (not locked out remotely) input.
- *pRemote*, Motor Starter is in Remote mode input. If not in Remote, the motor starter is assumed to be in Local mode.
- *pRunning,* Motor is running input. The running direction is assumed to be the same as the *iDirectionSelect* mode input. The default direction is forward.
- *pFailed*, Motor Starter is failed (or faulted) input.

- *pOverload*, Motor Starter Overload Trip status input. 0 = OK (Not Tripped), 1 = Overload Tripped.
- *pHiTemp*, Motor High Temperature alarm status input. 0 = Normal, 1 = High Temperature.
- *pSealLeak*, Motor Seal Leak warning status input. 0 = Normal, 1 = Leak Detected.
- *pHiTorque*, Motor High Torque alarm status input. 0 = Normal, 1 = High Torque alarm.
- *pHiHiTorque*, Motor High High Torque alarm status input. 0 = Normal, 1 = High-High Torque Alarm
- *pHiDisPress*, Pump High Discharge Pressure alarm status input. 0 = Normal, 1 = High Discharge Pressure
- *pEStop*, Emergency Stop pushbutton status input. 0 = Normal, 1 = Emergency Stop
- *pPowerFail*, Power Failure status input. During a Power Failure, the control remembers the operation state of the motor and once power has been restored, the drive is returned to its prior state. During the power failure, all alarms are suppressed. 0 = Power OK (run as required), 1 = Power Failure detected.
- *pTest*, Activated to place the motor control into test mode. This input should only be used for software testing as it forces inputs and outputs for testing only.

AOI Outputs

AOI OUTPUTS		
INSTANCE NAME	DATATYPE	DESCRIPTION
pRunFwd	BOOL	Run (Forward Direction) command to Motor
pRunRev	BOOL	Run (Reverse Direction) command to Motor
oSpeed	REAL	Speed reference command to the ASD (0 – 100%)
oRunningFwd	BOOL	Motor is Running (in forward direction) status to HMI
oRunningRev	BOOL	Motor is Running (in Reverse direction) status to HMI
oRemote	BOOL	Motor is in Remote mode status to HMI
oReady	BOOL	Motor is in Ready mode status to the HMI
oAuto	BOOL	Motor is in Auto mode status to HMI
oFailed	BOOL	Motor is Failed alarm status to HMI
oInterlockStat	BOOL	Process control interlock status
oRestartTime	REAL	Time (minutes) till next allowed restart
oCycles	REAL	Number of motor starts to HMI
oRunTime	REAL	Runtime hours to HMI

AOI OUTPUTS		
oErrorStat	INT	Integer format for motor error code

HMI Status Outputs:

- *oRunningFwd*, Discrete status to indicate the motor is ON (in the Forward Direction).
- *oRunningRev*, Discrete status to indicate the motor is ON (in the Reverse Direction).
- *oRemote*, Motor Remote status based on Remote/Local indication from motor starter. (0 = Local, 1 = Remote)
- *oReady*, Motor Ready status based on Ready indication from motor starter. (0 = Not Ready, 1 = Ready)
- *oAuto*, Auto/Manual mode feedback indication. (0 = Manual, 1 = Auto)
- *oInterlockStat*, Motor process interlock status for display on HMI
- *oErrorStat*, Motor Fail status in integer format. Used to animate message display on HMI Motor Pop-Up.
    - 0 = No Faults
    - 1 = Out Of Service (Disables all alarms from block)
    - 2 = Restart Limit Reached
    - 3 = Interlock Not Enabled
    - 4 = Fail to Start/Stop
    - 5 = Motor Fail (from MCC/Drive)
    - 6 = Overload Tripped
    - 7 = Hi Temp
    - 8 = Seal Leak (Warning Only - does not shut down the drive)
    - 9 = Hi Torque
    - 10 = Hi-Hi Torque
    - 11 = Hi Discharge Pressure
    - 12 = E-Stop
- *oRestartTime*, Time (minutes) till next allowed restart. This is used in conjunction with the maximum number of restarts per hour setting.
- *oRunTime*, Total Run Time Hours
- *oCycles*, Total motor starts

HMI Alarms:

- *oFailed*, Motor Failed/FAULT alarm indication. Fault generated by "fail to start/fail to stop" or FAULT input from motor starter.

Physical Outputs:

- *pRunFwd*, Motor Forward RUN command to VSD
- *pRunRev*, Motor Reverse RUN command to VSD
- *oSpeed*, Speed reference signal to ASD in the range 0.0% to 100.0%. This is rescaled elsewhere in the PLC before moving to the analog output module.

Control:

- If the motor is in auto mode (*oAuto* = 1) and the Auto Start Forward is active (*cAutoRunFwd* = 1) then Forward RUN output will activate (pRunFwd = 1) and Auto Speed Reference setpoint (*cAutoSpeedCmd*) will be passed to the Speed output (*oSpeed*)
  - Auto Start is controlled from detail code created elsewhere in the PLC program based on functional design narratives.
  - Auto speed reference setpoint is controlled from detail code created elsewhere in the PLC program based on functional design narratives.
- If the motor is in auto mode (*oAuto = 1*) then Forward RUN output will deactivate (oRunFwd = 0) if Auto Start Forward is inactive (*cAutoRunFwd* = 0).
- If the motor is in auto mode (*oAuto = 1*) and the Auto Start Reverse is active (*cAutoRunRev* = 1) then Reverse RUN output will activate (oRunRev = 1) and Auto Speed Reference setpoint (*cAutoSpeedCmd*) will be passed to the Speed output (*oSpeed*)
  - Rev Auto Start is controlled from detailed code created elsewhere in the PLC program based on functional design narratives.
  - Auto speed reference setpoint is controlled from detail code created elsewhere in the PLC program based on functional design narratives.
  - Not all motors require the use of the reverse input. The function block default is for the FWD/REV select input to be invisible and reverse to not be visible (default to forward only).
  - Visibility can be enabled via the block selection ellipsis located in the upper right corner of the AOI.
- If the motor is in auto mode (*oAuto = 1*) then Reverse RUN output will deactivate (pRunRev = 1) if Rev Auto Start is not active (*cAutoRunRev* = 01)
- If the motor is in manual mode (*oAuto = 0*) then one RUN output will activate (pRunFwd or pRunRev = 1) if Manual Start toggles active (*iStart* goes to 1). Manual speed reference setpoint (*iManSpeedCmd*) will be passed to the Speed Output (*oSpeed*)
  - Actual direction is dependent on the *iDirectionSelect* input. If *iDirectionSelect* = 0 then direction = Forward. If *iDirectionSelect* = 1 then direction = Reverse.

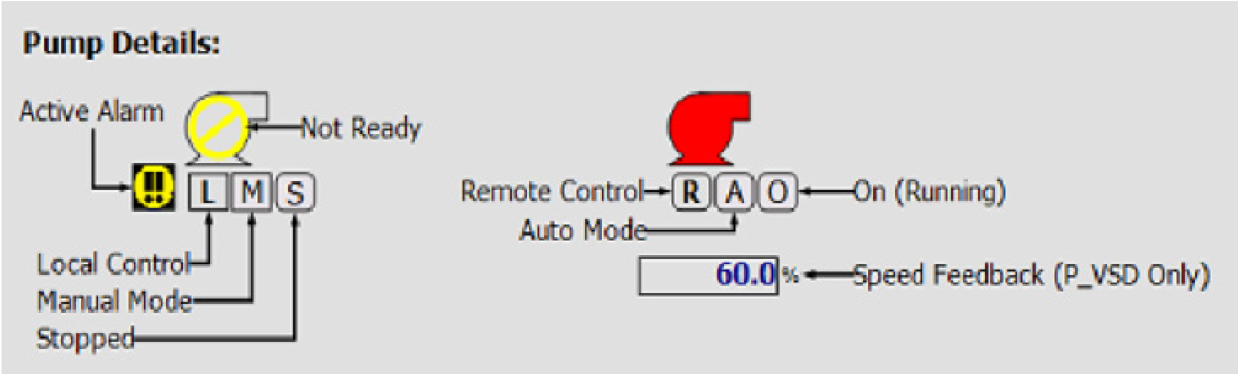
- While in auto mode, the *iManSpeedCmd* value is updated with the current *oSpeed* output value for bumpless transfer from Auto to Manual mode.
- If the motor control is in manual mode (*oAuto = 0*) then RUN outputs will deactivate (pRunFwd and pRunRev = 0) if Manual Stop toggles to active (*iStop goes to 1*)
- If in Auto or Manual mode motor will not start (or will stop if running) if:
  - Motor Ready input = 0 (From Motor Starter Status, Bit 0)
  - Motor Fail Output = 1
  - Motor Interlocks = 0
- The control code allows for a maximum number of restarts per hour. This is generally used on larger motors to prevent damage due to excessive starting. If the default value of zero is used the logic will allow for an unlimited number of restarts per hour. If any other number is used, the code will monitor the number of starts in a one hour period using an internal timer and counter. If a motor has been started the maximum number of times in less than one hour, the code will prevent any further restarts and indicate the number of minutes till another restart is allowed.

Runtime and Number of Starts:

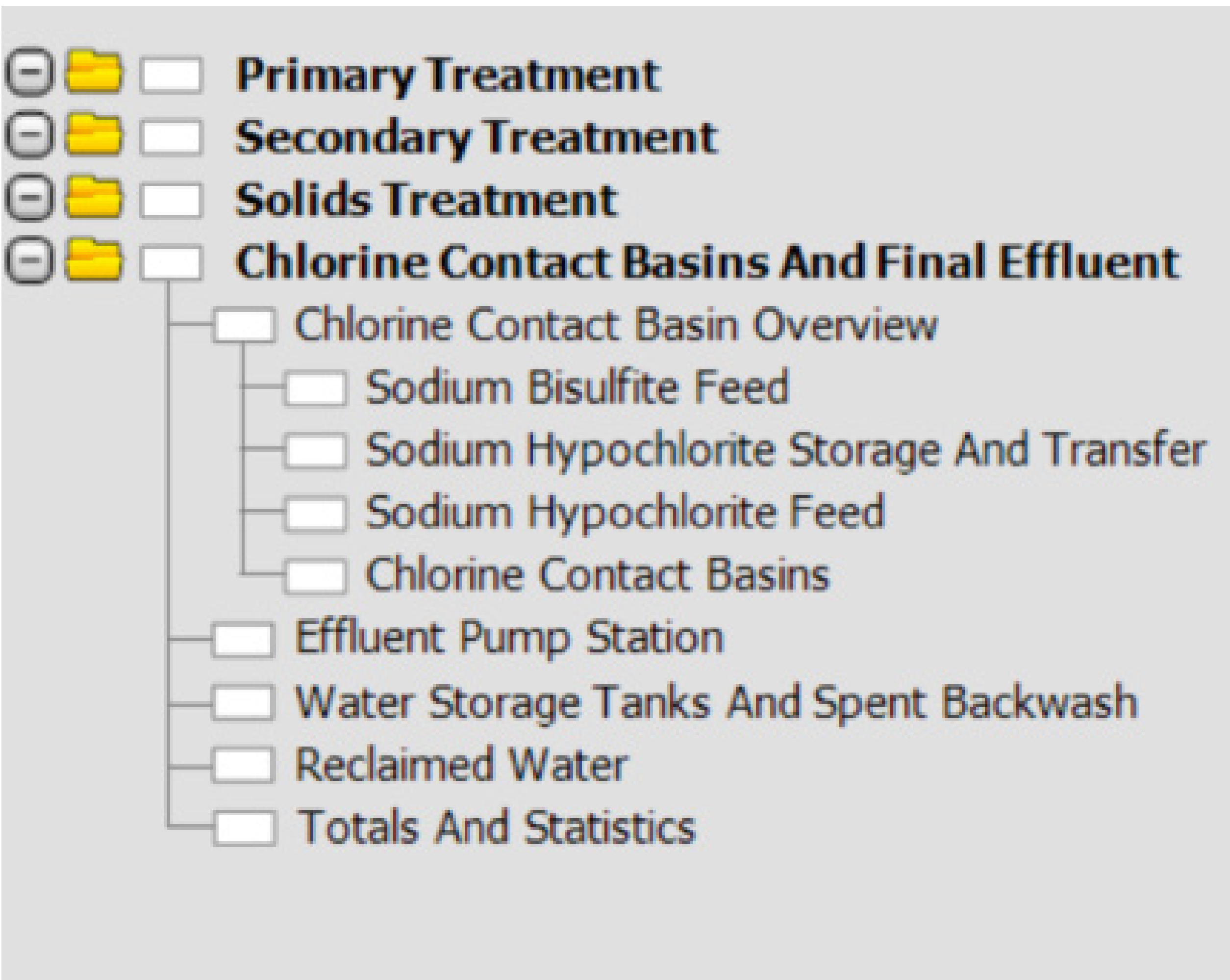
- Run Time Hours (*oRunTime*) are calculated as a total cumulative interval.
  - Total Cumulative hours accumulate to a maximum of 99,999 hours continuous operation.
  - Total cumulative hours can be reset from the HMI.
- The number of starts (*oCycles*) is incremented each time the motor starts.
  - Number of Starts can be reset from the HMI using the *iCyclesReset* command input.

Appendix 1-C
Examples of a Hybrid High-Performance Graphic Display Application

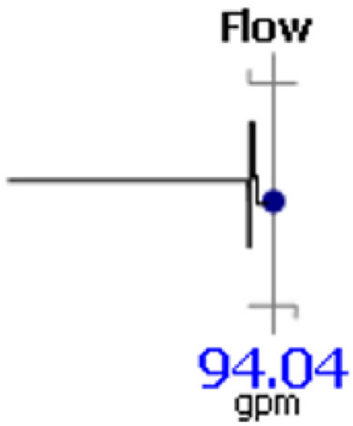
Sample Pump Symbols:



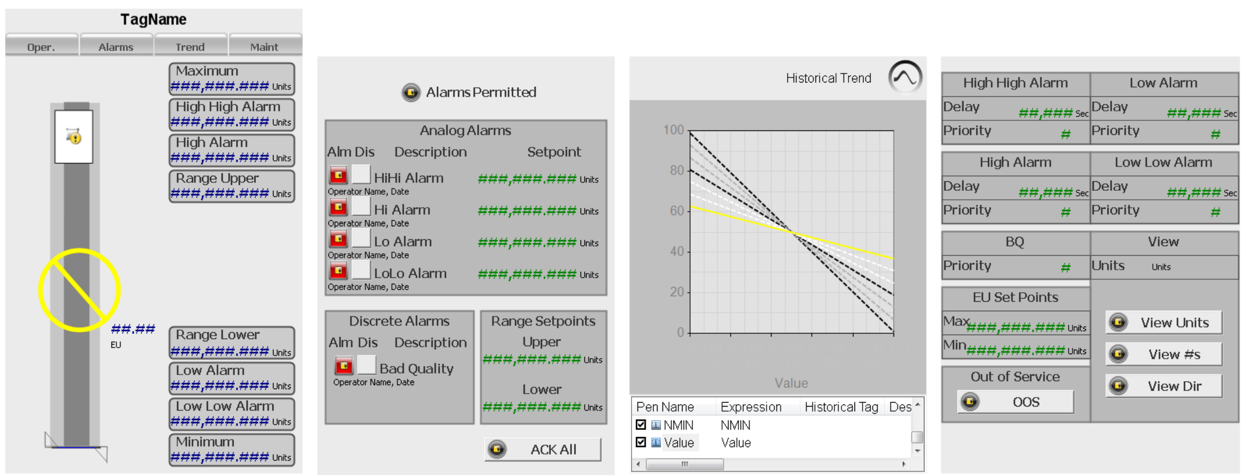
Sample Navigation Tree:



Sample Analog Point, with mini trend:



Sample Pop-up displays for an Analog Display:



Appendix 1-D
Detailed Project Descriptions

Detailed project descriptions are provided in the following tables for:

- Project 1. Replace Servers
- Project 2. Upgrade WRP Network
- Project 3. Upgrade WRP PLCs
- Project 4. Replace WRP PLCs
- Project 5. Evaluate Serial Radios
- Project 6. Upgrade Remote Site PLCs
- Project 7. Replace Remote Site PLCs

Project No. 1 – Replace SCADA Servers	
Project Purposes	▪ Replace obsolete server hardware and software to provide a current, reliable platform for SCADA applications. ▪ Implement reliable backup/recovery systems and practices. ▪ Upgrade FactoryTalk HMI to current version. ▪ Develop PLC/HMI control objects compliant with all Convention Standards. ▪ Implement Alarm Management standards. ▪ Implement Historian. ▪ Develop Transition Plan (covers 2 or more years).
Primary Tasks	▪ Design for Servers, Bridge PLC, and Server Network. ▪ Develop design packages (50%, Final) and conduct design workshops for City review. ▪ Programming and Configuration of Servers and Bridge PLC. ▪ Develop cutover and testing plans. Cutover plan shall include the phased programming of the Bridge PLC. ▪ 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, thin clients and Bridge PLC. ▪ Configured, tested, and commissioned Historian, Alarm software and backup and recovery packages. ▪ Updated Convention Standards (HMI Graphics). ▪ Completed Training Material and O&M Manuals.
Schedule and Dependencies	▪ Minimal demands (review and assistance only) on COL resources. ▪ Can be completed under a Professional Services Agreement (PSA). ▪ Requires fully developed Convention Standards. ▪ Establishes the SCADA platform for all subsequent SCADA projects. ▪ Estimated completion in 14 months.
Class 4 Cost Estimate	▪ $538,000

Project No. 2 – Upgrade WRP Network	
Project Purposes	▪ Replace obsolete multi-mode fiber-optic with single mode. ▪ Replace obsolete non-managed switches and flat architecture with robust, self-healing ring network. ▪ Develop Network Cutover Plan.
Primary Tasks	▪ Design for physical and logical network. The design shall adhere to the Department of Homeland Security and NIST network standards. ▪ Coordinate the remote access and security requirements with the City IT department. ▪ Develop design packages (50%, Final) and conduct design workshops for City 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 network (fiber and network switches) ▪ Configured, tested, and commissioned Remote Access hardware and software ▪ Completed Training Material ▪ O&M Manuals
Schedule and Dependencies	▪ Minimal demands (review and assistance only) on COL resources. ▪ Could be combined with Project 1. ▪ Can be completed under a PSA. ▪ Can be scheduled independently, but cutover planning must coordinate with other projects. ▪ Estimated duration 16 months
Class 4 Cost Estimate	▪ $473,000

Project No. 3 – Upgrade PLCs at the WRP	
Project Purposes	▪ Upgrade all ControlLogix PLCs to use new PLC/HMI control objects. ▪ Upgrade current FactoryTalk clients and Panelviews with thin clients ▪ Upgrade all DeviceNet devices to Ethernet and any appropriate instruments to HART protocol. ▪ Apply all Convention and Component standards to field instruments, wiring, and PLC hardware. ▪ Develop PLC Upgrade Cutover Plan that includes 7 ControlLogix PLCs. ▪ Provide operator training and as-built documentation.
Primary Tasks	▪ Develop Process Control Narratives and I/O lists for each process area. ▪ Develop plans for the PLCs to be upgraded. ▪ Develop overall cutover plan for 7 ControlLogix PLCs. ▪ 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 PLCs (including PLC programs). ▪ Updated Control Narratives ▪ Updated SCADA database (including Historian and Alarming software) ▪ Updated Convention Standards (PLC/HMI Control Objects). ▪ 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 COL resources ▪ Projects 1 and 2 must be completed. ▪ Design can be completed under a PSA. ▪ Estimate duration of 13 months
Class 4 Cost Estimate	▪ $693,000 ▪ The cost estimate is for all ControlLogix PLCs and assumes an equivalent level of effort for each individual ControlLogix PLC. A more detailed estimate should be provided with the scope of work for this project.

Project No. 4 – Replace end of life PLCs at the WRP	
Project Purposes	▪ Replace all PLC 5/40, CompactLogix, MicroLogix, and SLC with new ControlLogix PLCs. ▪ Program new PLCs to use new PLC/HMI control objects. ▪ Install new control panels with new PLCs. ▪ Upgrade all DeviceNet devices to Ethernet and any appropriate instruments to HART protocol. ▪ 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 City review. ▪ Develop individual cutover plans for 7 PLCs (4 PLC5/40Es, 2 CompactLogix, 2 MicroLogix, 1 SLC) 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 COL resources ▪ Requires fully developed Convention and Component Standards. ▪ Requires PLC/HMI control objects updated in Project 3. ▪ Design can be completed under a PSA. ▪ Estimated duration of 24 months
Class 4 Cost Estimate	▪ $1,067,000 ▪ The cost estimate assumes an equivalent level of effort for each PLC5/40E and a half equivalent level of effort for each CompactLogix, MicroLogix and SLC PLCs. A more detailed estimate should be provided with the scope of work for each replacement project.

Project No. 5 – Evaluate 5G Cellular Radios at Remote Sites	
Project Purposes	▪ Evaluate costs and benefits of upgrading serial radios to 5G cellular service as backup communications to Ethernet.
Primary Tasks	▪ Conduct network and path analysis to identify improvements necessary to convert to an Ethernet-based network. ▪ Produce a conceptual design report with a cost estimate weighing the pros and cons of upgrading the serial radios to a 5G network.
Project Deliverables	▪ Report for evaluation of 5G radios as backup communications at the remote sites
Dependencies	▪ Minimal demands (review and assistance only) on COL resources. ▪ Study can be performed under PSA. ▪ Estimated duration of 2 months.
Class 4 Cost Estimate	▪ $52,000

Project No. 6 – Upgrade Remote site PLCs	
Project Purpose	▪ Upgrade all ControlLogix PLCs to use new PLC/HMI control objects (1 remote site). ▪ 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. ▪ Develop plans for the control panels to be upgraded. ▪ Develop design packages (30%, 60%, and Final) and conduct design workshops for City review. ▪ Develop PLC Upgrade Cutover Plan that includes 1 ControlLogix PLC. ▪ Conduct Factory Test 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 PLCs (including PLC programs and network configuration files). ▪ Updated Control Narratives ▪ Updated SCADA database (including Historian and Alarming software) ▪ Final Training and O&M documentation.
Schedule and Dependencies	▪ Variable demands (minimum review and assistance, optional shared program development, field assistance, startup coordination, and training participation) on COL resources. ▪ Could be combined with Project 7. ▪ Design can be completed under a PSA. ▪ Requires fully developed Convention and Component Standards. ▪ Requires PLC/HMI control objects developed in Project 3. ▪ Includes design recommendations from Project 5. ▪ Estimated duration of 14 months.
Class 4 Cost Estimate	▪ $156,000 ▪ The cost estimate assumes an equivalent level of effort for each remote site PLC. A more detailed estimate should be provided with the scope of work for this project.

Project No. 7 – Replace Remote site PLCs	
Project Purpose	▪ Replace all CompactLogix and MicroLogix with new ControlLogix PLCs (14 remote sites). ▪ Program new PLCs to use new PLC/HMI control objects. ▪ Install new control panels with new PLCs (use thin clients for any local OIP). ▪ 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. ▪ Develop plans for the control panels to be replaced. ▪ Develop design packages (30%, 60%, and Final) and conduct design workshops for City review. ▪ Conduct Factory Tests of PLC and HMI software. ▪ Develop individual PLC Cutover Plans (9 CompactLogix, 5 MicroLogix) that includes all field instruments and control devices for each PLC. ▪ 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 and network configuration files). ▪ Updated Control Narratives ▪ Updated SCADA database (including Historian and Alarming software) ▪ Final Training and O&M documentation
Schedule and Dependencies	▪ Variable demands (minimum review and assistance, optional shared program development, field assistance, startup coordination, and training participation) on COL resources. ▪ Could be combined with Project 6. ▪ Design can be completed under a PSA. ▪ Requires fully developed Convention and Component Standards. ▪ Requires PLC/HMI control objects developed in Project 3. ▪ Includes design recommendations from Project 5. ▪ Estimated duration of 17 months.
Class 4 Cost Estimate	▪ $902,000 ▪ The cost estimate assumes an equivalent level of effort for each remote site PLC. A more detailed estimate should be provided with the scope of work for this project.

Appendix 1-E
Detailed Cost Estimates

Sonoma County Water Agency
SCADA Master Plan
Project Costing Sheets

	Projects Cost Summary	Total	FY 1	FY 2	FY 3	FY 4	FY 5		FY 1	FY 2	FY 3	FY 4	FY 5	FY 6	FY 7
	SCADA Master Plan Projects														
1	Replace SCADA Servers	$ 538,000	$ 53,800	$ 107,600	$ 376,600	$ -	$ -	$ 538,000	10%	20%	70%	0%	0%	0%	0%
2	Upgrade WRP Network	$ 473,000	$ 47,300	$ 189,200	$ 236,500	$ -	$ -	$ 473,000	10%	40%	50%	0%	0%	0%	0%
3	Upgrade PLCs at the WRP	$ 693,000	$ -	$ 207,900	$ 207,900	$ 277,200	$ -	$ 693,000	0%	30%	30%	40%	0%	0%	0%
4	Replace end of life PLCs at the WRP	$ 1,067,000	$ -	$ 320,100	$ 320,100	$ 426,800	$ -	$ 1,067,000	0%	30%	30%	40%	0%	0%	0%
5	Evaluate Serial Radios	$ 52,000	$ -	$ 52,000	$ -	$ -	$ -	$ 52,000	0%	100%	0%	0%	0%	0%	0%
6	Upgrade Remote Site PLCs	$ 156,000	$ -	$ 31,200	$ 124,800	$ -	$ -	$ 156,000	0%	20%	80%	0%	0%	0%	0%
7	Replace Remote Site PLCs	$ 902,000	$ -	$ -	$ -	$ 451,000	$ 451,000	$ 902,000	0%	0%	0%	50%	50%	0%	0%
8	0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	0%	0%	0%	0%	0%	0%	0%
	TOTAL	***$3,881,000***	***$101,100***	***$908,000***	***$1,265,900***	***$1,155,000***	***$451,000***	***$3,881,000***							

	Track	Project Cost	Design Labor	Implementation Labor	Construction Management	Project Management	Hardware Costs	Software Costs	Misc. Costs	COL Support	Contingency
	SCADA Master Plan Projects										
1	Replace SCADA Servers	$ 538,000	$ 92,000	$ 72,000	$ 36,000	$ 55,000	$ 104,000	$ 15,000	$ 40,000	$ -	$ 124,000
2	Upgrade WRP Network	$ 473,000	$ 122,000	$ 40,000	$ 28,000	$ 43,000	$ 70,000	$ 20,000	$ 41,000	$ -	$ 109,000
3	Upgrade PLCs at the WRP	$ 693,000	$ 89,000	$ 132,000	$ 109,000	$ 92,000	$ 91,000	$ -	$ 20,000	$ -	$ 160,000
4	Replace end of life PLCs at the WRP	$ 1,067,000	$ 160,000	$ 138,000	$ 116,000	$ 114,000	$ 280,000	$ -	$ 13,000	$ -	$ 246,000
5	Evaluate Serial Radios	$ 52,000	$ 32,000	$ -	$ -	$ 8,000	$ -	$ -	$ -	$ -	$ 12,000
6	Upgrade Remote Site PLCs	$ 156,000	$ 38,000	$ 35,000	$ 17,000	$ 25,000	$ 3,000	$ -	$ 2,000	$ -	$ 36,000
7	Replace Remote Site PLCs	$ 902,000	$ 142,000	$ 96,000	$ 124,000	$ 101,000	$ 210,000	$ -	$ 21,000	$ -	$ 208,000
8		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Totals	***$ 3,881,000***	***$ 675,000***	***$ 513,000***	***$ 430,000***	***$ 438,000***	***$ 758,000***	***$ 35,000***	***$ 137,000***	***$ -***	***$ 895,000***

City of Livermore
SCADA Master Plan
Project Costing Sheets

1	SCADA Server Upgrade						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			440	$ 92,320	$ 92,000	
	Develop Detailed Design for Servers and Network Architecture	Eng	$ 235	240	$ 56,400		
	Develop Transition Plans	Stf	$ 200	80	$ 16,000		
	Develop Design Drawings	Tech	$ 166	120	$ 19,920		
					$ -		
	Implementation Labor			400	$ 71,920	$ 72,000	
	Programming and Configuration	Tech	$ 166	200	$ 33,200		
	Factory Test	Tech	$ 166	120	$ 19,920		
	Update Convention Standards	Eng	$ 235	80	$ 18,800		
					$ -		
					$ -		
	Construction Management			200	$ 35,920	$ 36,000	
	Field Installation and Testing	Stf	$ 200	80	$ 16,000		
	Field Installation and Testing	Tech	$ 166	80	$ 13,280		
	Provide Training	Tech	$ 166	40	$ 6,640		
					$ -		
					$ -		
	Project Management			208	$ 54,692	$ 55,000	
	Project Management	PM	$ 268	104	$ 27,872		
	Admin Support	Adm	$ 95	52	$ 4,940		
	QA/QC	QC	$ 190	52	$ 9,880		
	Other Direct Costs		6%		$ 12,000		percentage of labor fees
	Hardware Costs				$ 104,000	$ 104,000	
	Server Hardware		$ 10,000	6	$ 60,000		
	Network Switches		$ 5,000	4	$ 20,000		
	UPS		$ 2,000	1	$ 2,000		
	Thin Clients (Workstations)		$ 3,000	4	$ 12,000		
	Alarm Notification Switches / Modems		$ 5,000	2	$ 10,000		
	Software Costs				$ 15,000	$ 15,000	
	Alarming Software		$ 15,000	1	$ 15,000		
					$ -		
					$ -		
					$ -		
					$ -		
	Misc. Costs				$ 40,000	$ 40,000	
	Control Room Improvements		$ 40,000	1	$ 40,000		

City of Livermore
SCADA Master Plan
Project Costing Sheets

1	SCADA Server Upgrade						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
					$ -		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		percentage of labor fees
	Contingency				$ 124,200	$ 124,000	
	30% of Total Fees		30%		$ 124,200		percentage of total fees
	Project Cost					$ 538,000	

Assumptions and Notes:

City of Livermore
SCADA Master Plan
Project Costing Sheets

2	WRP Network Upgrade						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			560	$ 122,200	$ 122,000	
	Design FO network - Construction Drawings	Eng	$ 235	320	$ 75,200		
	Design the WAN / LAN for the WRP	Eng	$ 235	80	$ 18,800		
	Develop Design documents	Tech	$ 166	120	$ 18,800		
	Bid Phase Support	Eng	$ 235	40	$ 9,400		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Implementation Labor			240	$ 39,840	$ 40,000	
	Programming and Configuration	Tech	$ 166	200	$ 33,200		
	Factory Test	Tech	$ 166	40	$ 6,640		
					$ -		
					$ -		
					$ -		
	Construction Management			160	$ 27,920	$ 28,000	
	Field Installation and Testing	Stf	$ 200	40	$ 8,000		
	Field Installation and Testing	Tech	$ 166	80	$ 13,280		
	Conduct training	Tech	$ 166	40	$ 6,640		
					$ -		
					$ -		
	Project Management			192	$ 42,888	$ 43,000	
	Project Management	PM	$ 197	96	$ 18,912		
	Admin Support	Adm	$ 87	48	$ 4,176		
	QA/QC	QC	$ 175	48	$ 8,400		
	Other Direct Costs		6%		$ 11,400		
	Hardware Costs				$ 70,000	$ 70,000	
	Firewalls / Network Switches		$ 5,000	4	$ 20,000		
	Fiber Optic Cabling (See assumptions and notes below)		$4	10000	$ 40,000		
	Fiber Patch Panels		$ 1,000	10	$ 10,000		
					$ -		
					$ -		

2	WRP Network Upgrade						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Software Costs				$ 20,000	$ 20,000	
	Firewall Software		$ 20,000	1	$ 20,000		
					$ -		
					$ -		
					$ -		
					$ -		
	Misc. Costs				$ 41,000	$ 41,000	
	Contractor to install fiber (see assumptions and notes)		$ 3	10000	$ 25,000		
	Contractor testing of terminations and OTDR tests		$ 200	80	$ 16,000		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		
	Contingency				$ 109,200	$ 109,000	
	30% of Total Fees		30%		$ 109,200		
	Project Cost					$ 473,000	

Assumptions and Notes:
Single Mode fiber assumed to be $4 per linear foot
Assumed 10000 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
Assume 2 Contractors at $100/hour for 80 hours to test terminations

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Project Costing Sheets

3	Upgrade PLCs at the WRP						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			400	$ 89,100	$ 89,000	
	Detailed Design				$ -		
	Develop PCN, I/O lists, PLC parts list	Eng	$ 235	240	$ 56,400		
	Bid Support	Eng	$ 235	0	$ -		
	Develop PCN, I/O lists, PLC parts list	Stf	$ 200	120	$ 24,000		
	Cutover Plan	Eng	$ 235	20	$ 4,700		
	Cutover Plan	Stf	$ 200	20	$ 4,000		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Implementation Labor			760	$ 131,680	$ 132,000	
	Programming and Configuration of PLC and HMI	Tech	$ 166	480	$ 79,680		
	Factory Test	Eng	$ 235	80	$ 18,800		
	Factory Test	Tech	$ 166	80	$ 13,280		
	Configuration of DeviceNet devices	Tech	$ 166	120	$ 19,920		
					$ -		
	Construction Management			600	$ 109,120	$ 109,000	
	Field Installation and Testing	Stf	$ 200	280	$ 56,000		
	Field Installation and Testing	Tech	$ 166	280	$ 46,480		
	Training	Tech	$ 166	40	$ 6,640		
					$ -		
					$ -		
	Project Management			352	$ 92,048	$ 92,000	
	Project Management	PM	$ 268	176	$ 47,168		
	Admin Support	Adm	$ 95	88	$ 8,360		
	QA/QC	QC	$ 190	88	$ 16,720		
	Other Direct Costs		6%		$ 19,800		percentage of labor fees

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Project Costing Sheets

3	Upgrade PLCs at the WRP						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Hardware Costs				$ 91,000	$ 91,000	
	PLC Modifications & OIPs		$ 5,000	7	$ 35,000		
	New PLCs		$ 3,000	7	$ 21,000		
	Network Switches		$ 5,000	7	$ 35,000		
					$ -		
					$ -		
	Software Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Misc. Costs				$ 19,920	$ 20,000	
	DeviceNet Upgrades	Tech	$ 166	120	$ 19,920		
					$ -		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		percentage of labor fees
	Contingency				$ 159,900	$ 160,000	
	30% of Total Fees		30%		$ 159,900		percentage of total fees
	Project Cost					$ 693,000	

Assumptions and Notes:
8 Equivalent PLC Upgrades (7 ControlLogix, 2 MicroLogix)
3 PanelView Upgrades (GBT1, GBT2, Rickenbacker LS)

City of Livermore
SCADA Master Plan
Project Costing Sheets

4	Replace end of life PLCs at the WRP						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			720	$ 159,520	$ 160,000	
	Detailed Design (30%, 60%, 100%)				$ -		
	Drawings and Specifications	Eng	$ 235	480	$ 112,800		
	Bid Support	Eng	$ 235	40	$ 9,400		
	Develop Design documents	Tech	$ 166	120	$ 19,920		
	Site Investigation	Eng	$ 235	40	$ 9,400		
	Site Investigation	Stf	$ 200	40	$ 8,000		
	Implementation Labor			800	$ 138,320	$ 138,000	
	Programming and Configuration of PLC and HMI	Tech	$ 166	480	$ 79,680		
	Factory Test	Eng	$ 235	80	$ 18,800		
	Factory Test	Tech	$ 166	80	$ 13,280		
	Configuration of DeviceNet replacement devices	Tech	$ 166	160	$ 26,560		
					$ -		
	Construction Management			640	$ 115,760	$ 116,000	
	Field Installation and Testing	Stf	$ 200	280	$ 56,000		
	Field Installation and Testing	Tech	$ 166	280	$ 46,480		
	Training	Tech	$ 166	80	$ 13,280		
					$ -		
					$ -		
	Project Management			432	$ 113,508	$ 114,000	
	Project Management	PM	$ 268	216	$ 57,888		
	Admin Support	Adm	$ 95	108	$ 10,260		
	QA/QC	QC	$ 190	108	$ 20,520		
	Other Direct Costs		6%		$ 24,840		percentage of labor fees
	Hardware Costs				$ 280,000	$ 280,000	
	Control Panel Modifications & OIPs		$ 15,000	10	$ 150,000		
	New PLCs		$ 8,000	10	$ 80,000		
	Network Switches		$ 5,000	10	$ 50,000		
					$ -		
					$ -		
	Software Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		

4	Replace end of life PLCs at the WRP						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Misc. Costs				$ 13,280	$ 13,000	
	DeviceNet Upgrades	Tech	$ 166	80	$ 13,280		
					$ -		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		percentage of labor fees
	Contingency				$ 246,300	$ 246,000	
	30% of Total Fees		30%		$ 246,300		percentage of total fees
	Project Cost			2592		$ 1,067,000	

Assumptions and Notes:
6 Equivalent PLC Replacements (4 PLC/5/40, 2 CompactLogix, 1 SLC)
2 PanelView Replacements (Belt Press, LAVWMA)

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SCADA Master Plan
Project Costing Sheets

5	Evaluate Serial Radios at Remote Sites						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			140	$ 31,500	$ 32,000	
	Conduct Network and Path Analysis	Eng	$ 235	40	$ 9,400		
	Conduct Network and Path Analysis	Stf	$ 200	40	$ 8,000		
	Develop Report	Eng	$ 235	60	$ 14,100		
					$ -		
					$ -		
	Implementation Labor			0	$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Construction Management			0	$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Project Management			28	$ 7,667	$ 8,000	
	Project Management	PM	$ 268	14	$ 3,752		
	Admin Support	Adm	$ 95	7	$ 665		
	QA/QC	QC	$ 190	7	$ 1,330		
	Other Direct Costs		6%		$ 1,920		percentage of labor fees
	Hardware Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Software Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		

5	Evaluate Serial Radios at Remote Sites						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Misc. Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		percentage of labor fees
	Contingency				$ 12,000	$ 12,000	
	30% of Total Fees		30%		$ 12,000		percentage of total fees
	Project Cost					$ 52,000	

Assumptions and Notes:

City of Livermore
SCADA Master Plan
Project Costing Sheets

6	Upgrade Remote Site PLCs						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			176	$ 38,320	$ 38,000	
	Develop PCN, I/O lists, PLC parts list	Eng	$ 235	80	$ 18,800		
	Bid Support	Eng	$ 235	40	$ 9,400		
	Develop PCN, I/O lists, PLC parts list	Tech	$ 166	40	$ 6,640		
	Site Investigation	Eng	$ 235	8	$ 1,880		
	Site Investigation	Stf	$ 200	8	$ 1,600		
	Implementation Labor			200	$ 34,560	$ 35,000	
	Programming and Configuration	Tech	$ 166	120	$ 19,920		
	Factory Test	Tech	$ 166	40	$ 6,640		
	Factory Test	Stf	$ 200	40	$ 8,000		
					$ -		
					$ -		
	Construction Management			96	$ 17,296	$ 17,000	
	Field Installation and Testing	Stf	$ 200	40	$ 8,000		
	Field Installation and Testing	Tech	$ 166	40	$ 6,640		
	Provide Training	Tech	$ 166	16	$ 2,656		
					$ -		
					$ -		
	Project Management			94	$ 24,694	$ 25,000	
	Project Management	PM	$ 268	47	$ 12,596		
	Admin Support	Adm	$ 95	23.5	$ 2,233		
	QA/QC	QC	$ 190	23.5	$ 4,465		
	Other Direct Costs		6%		$ 5,400		percentage of labor fees
	Hardware Costs				$ 3,000	$ 3,000	
	Radios		$ 2,000	1	$ 2,000		
	Switches		$ 1,000	1	$ 1,000		
					$ -		
					$ -		
					$ -		
	Software Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Misc. Costs				$ 2,000	$ 2,000	

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SCADA Master Plan
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6	Upgrade Remote Site PLCs						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Antenna poles and wiring		$ 2,000	1	$ 2,000		
					$ -		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		percentage of labor fees
	Contingency				$ 36,000	$ 36,000	
	30% of Total Fees		30%		$ 36,000		percentage of total fees
	Project Cost			566		$ 156,000	
	Assumptions and Notes:						

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SCADA Master Plan
Project Costing Sheets

	Replace Remote Site PLCs						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			680	$ 141,840	$ 142,000	
	Detailed Design for 14 PLC Panels	Eng	$ 235	320	$ 75,200		
	Bid Support	Eng	$ 235	40	$ 9,400		
	Detailed Design for 14 PLC Panels	Tech	$ 166	240	$ 39,840		
	Site Investigation	Eng	$ 235	40	$ 9,400		
	Site Investigation	Stf	$ 200	40	$ 8,000		
	Implementation Labor			560	$ 95,680	$ 96,000	
	Programming and Configuration	Tech	$ 166	400	$ 66,400		
	Factory Test	Tech	$ 166	80	$ 13,280		
	Factory Test	Stf	$ 200	80	$ 16,000		
					$ -		
					$ -		
	Construction Management			680	$ 123,760	$ 124,000	
	Field Installation and Testing	Stf	$ 200	320	$ 64,000		
	Field Installation and Testing	Tech	$ 166	320	$ 53,120		
	Provide Training	Tech	$ 166	40	$ 6,640		
					$ -		
					$ -		
	Project Management			384	$ 100,536	$ 101,000	
	Project Management	PM	$ 268	192	$ 51,456		
	Admin Support	Adm	$ 95	96	$ 9,120		
	QA/QC	QC	$ 190	96	$ 18,240		
	Other Direct Costs		6%		$ 21,720		percentage of labor fees
	Hardware Costs				$ 210,000	$ 210,000	
	New PLCs		$ 8,000	14	$ 112,000		
	Network Switches		$ 5,000	14	$ 70,000		
	Radios		$ 2,000	14	$ 28,000		
					$ -		
					$ -		
					$ -		
	Software Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		

	Replace Remote Site PLCs						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Misc. Costs				$ 21,000	$ 21,000	
	Antenna poles and wiring		$ 2,000	9	$ 18,000		
	Additional panels where necessary		$ 1,000	3	$ 3,000		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
			0%		$ -		percentage of labor fees
	Contingency				$ 208,200	$ 208,000	
	30% of Total Fees		30%		$ 208,200		percentage of total fees
	Project Cost					$ 902,000	

Assumptions and Notes:

City of Livermore
SCADA Master Plan
Project Costing Sheets

8	Template						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Design Labor			0	$ -	$ -	
	Preliminary Design	Eng	$ 235	0	$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
		Eng	$ 235	0	$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Implementation Labor			0	$ -	$ -	
	Software Development	Eng	$ 235	0	$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Construction Management			0	$ -	$ -	
		Stf	$ 200	0	$ -		
		Eng	$ 235	0	$ -		
					$ -		
					$ -		
					$ -		
	Project Management			0	$ -	$ -	
		PM	$ 268	0	$ -		
		Adm	$ 95	0	$ -		
		QC	$ 190	0	$ -		
			6%		$ -		percentage of labor fees

City of Livermore
SCADA Master Plan
Project Costing Sheets

8	Template						
	ITEM	Rate	Unit Cost	Qty	Cost	Master Plan Cost	Notes
	Hardware Costs				$ -	$ -	
			$ 40,000	0	$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Software Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	Misc. Costs				$ -	$ -	
					$ -		
					$ -		
					$ -		
					$ -		
					$ -		
	COL Support				$ -	$ -	
	10% of External Fees		10%		$ -		percentage of labor fees
	Contingency				$ -	$ -	
	20% of Total Fees		20%		$ -		percentage of total fees
	Project Cost			0		$ -	

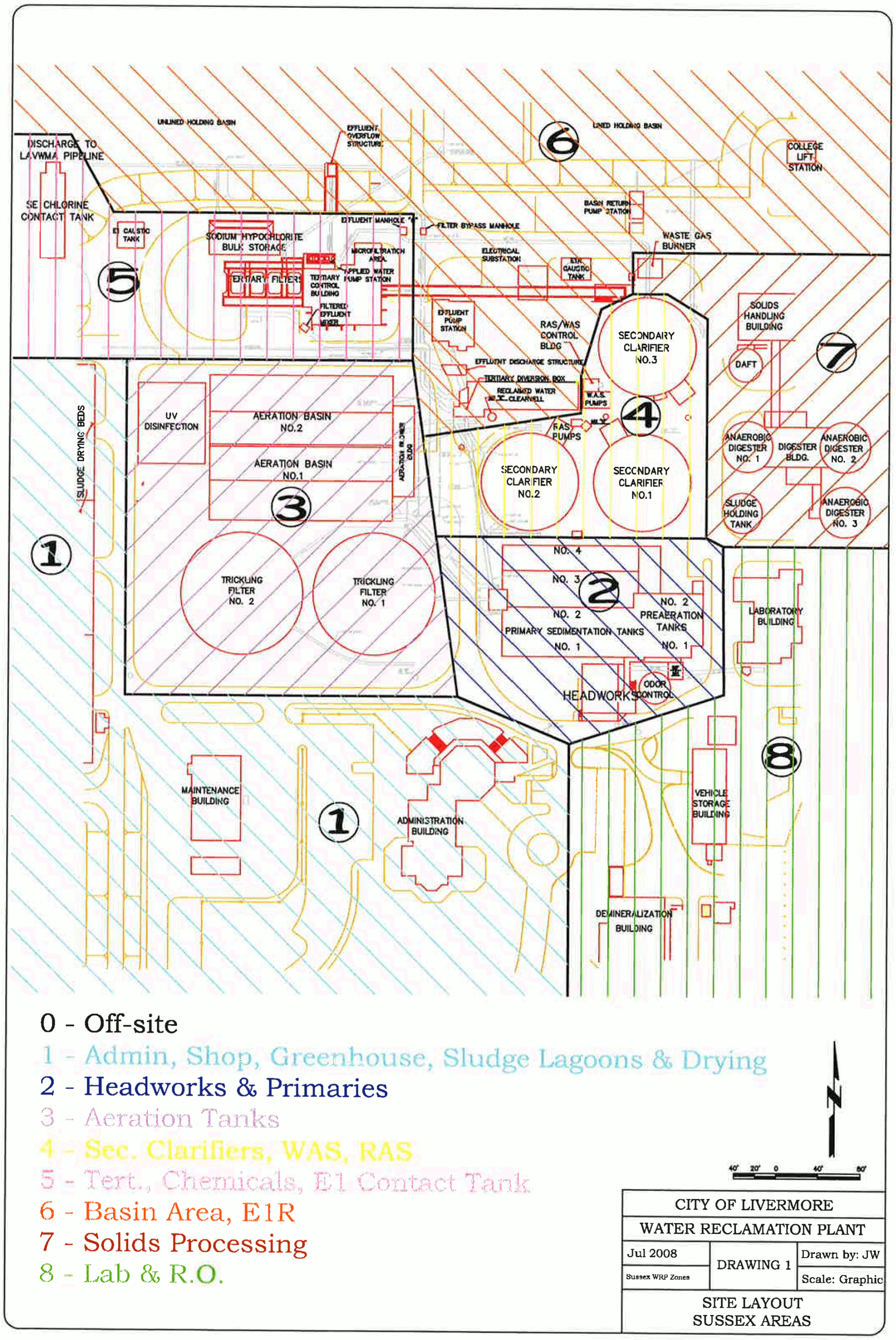
Assumptions and Notes:

Sonoma County Water Agency
SCADA Master Plan
Project Costing Sheets

Engineering

Principal Engineer	PM	$ 268.00
Senior Engineer	Eng	$ 235.00
Staff Engineer	Stf	$ 200.00
Technician	Tech	$ 166.00
Admin	Adm	$ 95.00
Quality Control	QC	$ 190.00
Client	Clt	$ 95.00

Appendix 2-A
WRP Process Area Code Map


DISCHARGE TO LAVWMA PIPELINE
SE CHLORINE CONTACT TANK
UNLINED HOLDING BASIN
EFFLUENT OVERFLOW STRUCTURE
LINED HOLDING BASIN
COLLEGE LIFT STATION
BASIN RETURN PUMP STATION
WASTE GAS BURNER
SODIUM HYPOCHLORITE BULK STORAGE
TERTIARY FILTERS
MICROFILTRATION AREA
APPLIED WATER PUMP STATION
TERTIARY CONTROL BUILDING
FILTERED EFFLUENT MIXER
EFFLUENT MANHOLE
FILTER BYPASS MANHOLE
ELECTRICAL SUBSTATION
EFFLUENT PUMP STATION
RAS/WAS CONTROL BLDG
EFFLUENT DISCHARGE STRUCTURE
TERTIARY DIVERSION BOX
RECLAIMED WATER CLEARWELL
W.A.S. PUMPS
RAS PUMPS
SECONDARY CLARIFIER NO.3
SECONDARY CLARIFIER NO.2
SECONDARY CLARIFIER NO.1
SOLIDS HANDLING BUILDING
DAFT
ANAEROBIC DIGESTER NO. 1
DIGESTER BLDG.
ANAEROBIC DIGESTER NO. 2
SLUDGE HOLDING TANK
ANAEROBIC DIGESTER NO. 3
UV DISINFECTION
AERATION BASIN NO.2
AERATION BASIN NO.1
SLUDGE DRYING BEDS
TRICKLING FILTER NO. 2
TRICKLING FILTER NO. 1
NO. 4
NO. 3
NO. 2
PRIMARY SEDIMENTATION TANKS
NO. 1
NO. 2 PREAERATION TANKS NO. 1
HEADWORKS
ODOR CONTROL
LABORATORY BUILDING
MAINTENANCE BUILDING
ADMINISTRATION BUILDING
VEHICLE STORAGE BUILDING
DEMINERALIZATION BUILDING
1
2
3
4
5
6
7
8
0 - Off-site
1 - Admin, Shop, Greenhouse, Sludge Lagoons & Drying
2 - Headworks & Primaries
3 - Aeration Tanks
4 - Sec. Clarifiers, WAS, RAS
5 - Tert., Chemicals, E1 Contact Tank
6 - Basin Area, E1R
7 - Solids Processing
8 - Lab & R.O.
N
40' 20' 0 40' 80'
CITY OF LIVERMORE
WATER RECLAMATION PLANT
Jul 2008
Sussex WRP Zones
DRAWING 1
Drawn by: JW
Scale: Graphic
SITE LAYOUT
SUSSEX AREAS

Appendix 2-B
Tag Name Examples

Table 2B-1. Hardwired I/O (EEEE) Examples

EEE	Description	Comments
Process Instrumentation		
AIT	Analytical Indicating Transmitter	
DIT	Density Indicating Transmitter	
EAL	Voltage Alarm Low	Battery Low Alarm
ESL	Voltage Switch Low (Status)	Battery Low Status
ET	Voltage Transmitter (Indication)	Power Meter Voltage Values
FIT	Flow Indicating Transmitter	
FT	Flow Transmitter	Flow meter without local indication
FAH	Flow Alarm High	
FAL	Flow Alarm Low	
FSH	Flow Switch High (Status)	
FSL	Flow Switch Low (Status)	
IAH	Current Alarm High	Power Meter Current High Alarm
IAL	Current Alarm Low	Power Meter Current Low Alarm
ISH	Current Switch High (Status)	Power Meter Current High Status
ISL	Current Switch Low (Status)	Power Meter Current Low Status
IT	Current Transmitter (Indication)	Power Meter Current Values
JAL	Power Switch Low (Status)	Power Supply Low
JT	Power Transmitter (Indication)	Power Meter Power Values
LIT	Level Indicating Transmitter	
LT	Level Transmitter	Level Instrument without local indication
LAH	Level Alarm High	
LAHH	Level Alarm High High	
LAL	Level Alarm Low	
LALL	Level Alarm Low Low	
LSH	Level Switch High (Status)	
LSHH	Level Switch High High (Status)	
LSL	Level Switch Low (Status)	
LSLL	Level Switch Low Low (Status)	
MAH	Moisture Alarm High	

Table 2B-1. Hardwired I/O (EEEE) Examples

EEE	Description	Comments
MAL	Moisture Alarm Low	
MSH	Moisture Switch High (Status)	
MSL	Moisture Switch Low (Status)	
PDIT	Pressure Differential Indicating Transmitter	
PDT	Pressure Differential Transmitter	
PDAH	Pressure Differential Alarm High	
PDAL	Pressure Differential Alarm Low	
PDSH	Pressure Differential Switch High (Status)	
PDSL	Pressure Differential Switch Low (Status)	
PIT	Pressure Indicating Transmitter	
PT	Pressure Transmitter	Pressure Transmitter without local indication
PAH	Pressure Alarm High	
PAL	Pressure Alarm Low	
PSH	Pressure Switch High (Status)	
PSL	Pressure Switch Low (Status)	
TT	Temperature Transmitter	
TAH	Temperature Alarm High	
TAL	Temperature Alarm Low	
TSH	Temperature Switch High (Status)	
TSL	Temperature Switch Low (Status)	
VAH	Vibration Alarm High	
VAL	Vibration Alarm Low	
VIT	Vibration Indicating Transmitter	
VSH	Vibration Switch High (Status)	
VSL	Vibration Switch Low (Status)	
WT	Weight Transmitter	Use for scales or chemical tote weight, etc.
WAH	Weight Alarm High	
WAHH	Weight Alarm High High	
WAL	Weight Alarm Low	
WALL	Weight Alarm Low Low	

Table 2B-1. Hardwired I/O (EEEE) Examples

EEE	Description	Comments
WSH	Weight Switch High (Status)	
WSL	Weight Switch Low (Status)	
Motor Control & Monitoring Examples		
HS	Remote Status	Multi-use Local Status, Off Status, etc.
IAH	Fault Alarm, Motor Overload Alarm	
UA	Common Alarm	VFD Fault Code, Valve Actuators, Soft starters
SC	Speed Control	
ST	Speed Transmitter (Indication)	
YC	Run Command/Start Command	Control signal to start equipment
YL	Running Status, Alternate	Multi-use On, Running Slow, Running Fast, etc.
Valve Actuator Examples		
ZIT	Position Indicating Transmitter	
ZT	Position Transmitter	
ZC	Position Control	
ZSC	Position Switch Closed	
ZSO	Position Switch Open	
ZCO	Position Command Open	
ZCC	Position Command Close	

Table 2B-2. HART Instrument Tag Name Examples

Base Tag Name	Element	Description
WRP_11_60_FT_110	.ioFlow	RAS Pump 1 Flow
	.ioFlowHigh	RAS Pump 1 Flow Alarm High
	.ioFlowLow	RAS Pump 1 Flow Alarm Low
	.pInstrumentFault	RAS Pump 1 Instrument Fault
WRP_24_30_AT_200	.ioDissolvedO2	UV Dissolved Oxygen
	.pAnalyzerFault	UV DO Analyzer Fault
	.ioResidualO2High	UV Oxygen Demand High
DAT_LT_110	.ioLevel	Dalton Reservoir Level
	.ioLevelHigh	Dalton Reservoir Level High
	.ioLevelHiHi	Dalton Reservoir Level High High
VPS_PT_110	.ioPressure	Vasco Pump Station Pressure
	.ioPressureHigh	Vasco Pump Station Pressure High
	.ioPressureLow	Vasco Pump Station Pressure Low

Note:

RAS = return activated sludge

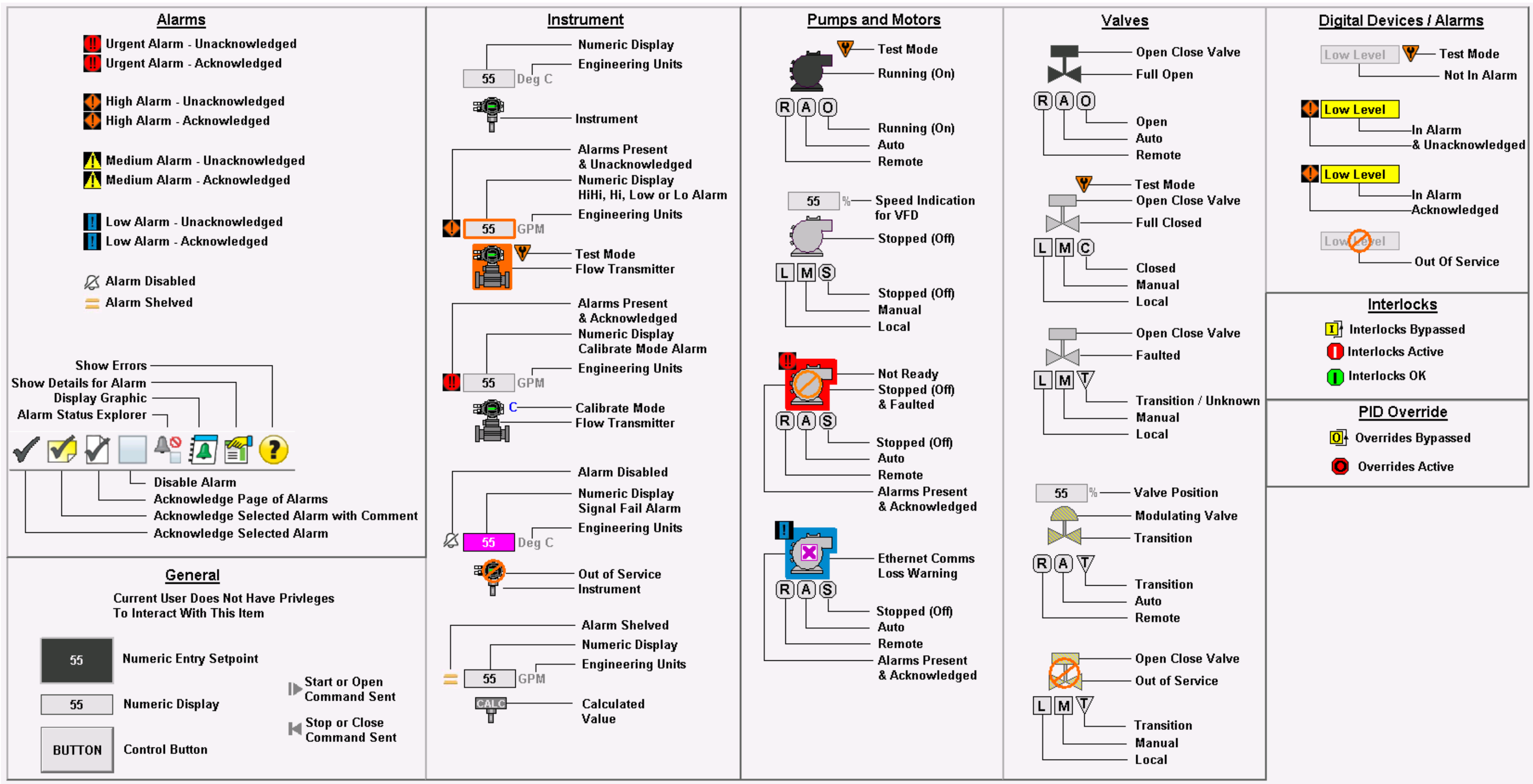
Table 2B-3. Ethernet Connected Equipment Tag Name Examples

Base Tag Name	Element	Description
VPS_P_110	.ioRemote	Vasco Pump 1 Remote Status
	.ioOverload	Vasco Pump 1 Motor Overload
	.iStartCommand	Vasco Pump 1 Run/Start Command
	.ioRunning	Vasco Pump 1 Running Status
WRP_11_31_BV_110	.ioRemote	Blower 1 Remote Status
	.ioVFDFault	Blower 1 VFD Fault Alarm
	.ioCommonAlarm	Blower 1 Common Alarm
	.iSpeedControl	Blower 1 Speed Control
	.ioSpeed	Blower 1 Speed
	.iStartCommand	Blower 1 Run/Start Command
	.ioRunning	Blower 1 Running Status
DAT_V_110	.ioValveClosed	Dalton Tank Valve Closed
	.ioValveOpened	Dalton Tank Valve Opened
	.iOpenCommand	Dalton Tank Valve Open Command
	.iCloseCommand	Dalton Tank Valve Close Command
WRP_02_40_CV_120	.ioValvePosition	WAS Valve Position
	.iPositionControl	WAS Valve Control
	.ioValveClosed	WAS Valve Closed
	.ioValveOpened	WAS Valve Opened
	.iOpenCommand	WAS Valve Open Command
	.iCloseCommand	WAS Valve Close Command

Note:

WAS = waste activated sludge

Appendix 2-C
Legend Display Example


Alarms
Urgent Alarm - Unacknowledged
Urgent Alarm - Acknowledged
High Alarm - Unacknowledged
High Alarm - Acknowledged
Medium Alarm - Unacknowledged
Medium Alarm - Acknowledged
Low Alarm - Unacknowledged
Low Alarm - Acknowledged
Alarm Disabled
Alarm Shelved
Show Errors
Show Details for Alarm
Display Graphic
Alarm Status Explorer
Disable Alarm
Acknowledge Page of Alarms
Acknowledge Selected Alarm with Comment
Acknowledge Selected Alarm
General
Current User Does Not Have Privleges
To Interact With This Item
55
Numeric Entry Setpoint
55
Numeric Display
BUTTON
Control Button
Start or Open
Command Sent
Stop or Close
Command Sent
Instrument
Numeric Display
Engineering Units
55
Deg C
Instrument
Alarms Present
& Unacknowledged
Numeric Display
HiHi, Hi, Low or Lo Alarm
Engineering Units
55
GPM
Test Mode
Flow Transmitter
Alarms Present
& Acknowledged
Numeric Display
Calibrate Mode Alarm
Engineering Units
55
GPM
C
Calibrate Mode
Flow Transmitter
Alarm Disabled
Numeric Display
Signal Fail Alarm
Engineering Units
55
Deg C
Out of Service
Instrument
Alarm Shelved
Numeric Display
Engineering Units
55
GPM
CALC
Calculated
Value
Pumps and Motors
Test Mode
Running (On)
R A O
Running (On)
Auto
Remote
55
%
Speed Indication
for VFD
Stopped (Off)
L M S
Stopped (Off)
Manual
Local
Not Ready
Stopped (Off)
& Faulted
R A S
Stopped (Off)
Auto
Remote
Alarms Present
& Acknowledged
Ethernet Comms
Loss Warning
R A S
Stopped (Off)
Auto
Remote
Alarms Present
& Acknowledged
Valves
Open Close Valve
Full Open
R A O
Open
Auto
Remote
Test Mode
Open Close Valve
Full Closed
L M C
Closed
Manual
Local
Open Close Valve
Faulted
L M T
Transition / Unknown
Manual
Local
55
%
Valve Position
Modulating Valve
Transition
R A T
Transition
Auto
Remote
Open Close Valve
Out of Service
L M T
Transition
Manual
Local
Digital Devices / Alarms
Low Level
Test Mode
Not In Alarm
Low Level
In Alarm
& Unacknowledged
Low Level
In Alarm
Acknowledged
Low Level
Out Of Service
Interlocks
Interlocks Bypassed
Interlocks Active
Interlocks OK
PID Override
Overrides Bypassed
Overrides Active

Appendix 2-D
Alarm System Terminology

Term	Definition
Absolute alarm	An alarm generated when the setpoint is exceeded
Acknowledge	The operator action that confirms recognition of an alarm
Activate	The process of enabling an alarm function within the alarm system
Adjustable alarm (operator-set alarm)	An alarm for which the setpoint can be changed manually by the operator
Alarm	An audible and/or visible means of indicating to the operator an equipment malfunction, process deviation, or abnormal condition requiring a response.
Alarm attributes (alarm parameters)	The settings for an alarm within the process control system (e.g. alarm setpoint, alarm priority).
Alarm class	A group of alarms with common alarm management requirements (e.g. testing, training, monitoring, and audit requirements).
Alarm deadband	The change in signal from the alarm setpoint necessary to clear the alarm.
Alarm delay (Debounce)	The time a process measurement remains in the alarm state before the alarm is annunciated or the time a process measurement remains in the normal state before the alarm is cleared.
Alarm flood	A condition during which the alarm rate is greater than the operator can effectively manage (e.g., more than 10 alarms per 10 minutes).
Alarm group	A set of alarms with common association (e.g., process unit, process area, equipment set, or service).
Alarm log	The repository for alarm records
Alarm (system) management	The processes and practices for determining, documenting, designing, operating, monitoring, and maintaining alarm systems.
Alarm message	A text string displayed with the alarm indication that provides additional information to the operator (e.g., operator action).
Alarm overview indicator	The composite indicator of alarm status for a process unit or area.
Alarm philosophy	A document that establishes the basic definitions, principles, and processes to design, implement, and maintain an alarm system. (This document.)
Alarm priority	The relative importance assigned to an alarm within the alarm system to indicate the urgency of response (e.g., seriousness of consequences and allowable response time).
Alarm setpoint	The threshold value of a process variable or discrete state that triggers the alarm indication.
Alarm summary	A display that lists alarms with selected information (e.g., date, time, priority, and alarm type).
Alarm type (alarm condition)	A specific alarm on a process measurement (e.g., low process variable alarm, high process variable alarm, or discrepancy alarm).
Alert	An audible and/or visible means of indicating to the operator an equipment or process condition that requires awareness, that is indicated separately from alarm indications, and which does not meet the criteria for an alarm.
Allowable response time	The maximum time between the annunciation of the alarm and the time the operator must take corrective action to avoid the consequence.

Term	Definition
Calculated alarm	An alarm generated from a calculated value instead of a direct process measurement.
Call-out alarm	An alarm that notifies and informs an operator by means other than or in addition to, a console display (e.g., pager or telephone).
Chattering alarm	An alarm that repeatedly transitions between the alarm state and the normal state in a short period of time.
Classification	The process of separating alarms into classes based on common requirements (e.g., testing, training, monitoring, and auditing requirements).
Decommission	The change process to remove an alarm from the alarm system.
Deviation alarm	An alarm generated when the difference between two analog values exceeds a limit (e.g., deviation between primary and redundant instruments or a deviation between process variable and setpoint).
Discrepancy alarm (mismatch alarm)	An alarm generated by error between the comparison of an expected plant or device state to its actual state (e.g., when a motor fails to start after it is commanded to the on state).
Dynamic alarming	The automatic modification of alarms based on process state or conditions.
Enforcement	An enhanced alarming technique that can verify and restore alarm attributes in the control system to the values in the master alarm database.
First-out alarm (first-up alarm)	An alarm determined (i.e., by first-out logic) to be the first, in a multiple-alarm scenario.
Highly managed alarm	An alarm belonging to a class with more requirements than general alarms (e.g., a safety alarm).
Implementation	The transition stage between design and operation during which the alarm is put into service.
Instrument diagnostic alarm	An alarm generated by a field device to indicate a fault (e.g., sensor failure).
Interim alarm	An alarm used on a temporary basis (e.g., in place of an out-of-service alarm) without completing the management of change process.
Latching alarm	An alarm that remains in alarm state after the process has returned to normal and requires an operator reset before it clears.
Master alarm database	The authorized list of rationalized alarms and associated attributes.
Nuisance alarm	An alarm that annunciates excessively, unnecessarily, or does not return to normal after the correct response is taken (e.g., chattering, fleeting, or stale alarms).
Out-of-service	The state of an alarm during which the alarm indication is suppressed, typically manually, for reasons such as maintenance.
Prioritization	The process of assigning a level of operational importance to an alarm.
Rate-of-change alarm	An alarm generated when the change in process variable per unit time, (dPV/dt), exceeds a defined limit.
Rationalization	The process to review potential alarms using the principles of the alarm philosophy, to select alarms for design, and to document the rationale for each alarm.

Term	Definition
Re-alarming alarm (re-triggering alarm)	An alarm that is automatically re-annunciated to the operator under certain conditions.
Reset	The operator action that unlatches a latched alarm.
Return to normal	The indication an alarm condition has transitioned to the normal state
Safety alarm	An alarm that is classified as critical to process safety or the protection of human life.
Shelve	A mechanism, typically initiated by the operator, to temporarily suppress an alarm.
Signal fail alarm	An alarm generated when the signal for a process measurement is outside the expected range (e.g., 3.8mA for a 4-20mA signal).
Silence	The operator action that terminates the audible alarm indication
Stale alarm	An alarm that remains in the alarm state for an extended period of time (e.g., 24 hours).
Standing alarm	An alarm in an active alarm state (e.g., unack alarm, ack alarm)
State-based alarm (mode-based alarms)	An alarm that is automatically modified or suppressed based on process state or conditions.
Suppress	Any mechanism to prevent the indication of the alarm to the operator when the base alarm condition is present (i.e., shelving, suppressed by design, out-of-service).
Suppressed by design	A mechanism implemented within the alarm system that prevents the transmission of the alarm indication to the operator based on plant state or other conditions.
System diagnostic alarm	An alarm generated by the control system to indicate a fault within the system hardware, software or components (e.g., communication error).
System integrator	A person or group that is either contracted or internally staffed who is tasked with creating, updating, commissioning, or maintaining the connection and display of field equipment or sensors to the SCADA system.
Tag (point)	The unique identifier assigned to a process measurement, calculation, or device within the control system.
Unacknowledged	The unique identifier assigned to a process measurement, calculation, or device within the control system.

Appendix 2-E
Alarm Priority Matrices

Table 2E-1. Consequence Ratings

Criteria/ Consequence	Critical	Urgent	Warning	Caution
Cost/Financial Loss/ Downtime/Permits	▪ Cost Greater than $100K ▪ Requires Snr Management Reporting ▪ Shutdown of Treatment	▪ Cost between $10K and $100K ▪ Requires Reporting ▪ Short duration of outage	▪ Cost less than $10K ▪ Requires internal reporting ▪ No outage	▪ No loss
Environmental Damage/Public Perception	▪ Involves community and complaints ▪ Uncontained release of hazardous materials ▪ Extensive cleanup	▪ Contamination causes non-permanent damagse ▪ Single of few complaints	▪ Contained release ▪ Internal report	▪ No effect
Health and Safety	▪ Extremely Hazardous	▪ Dangerous conditions		

Table 2E-2. Urgency Ratings

Urgency	Allowed Response Time
Immediate Action	Less than 5 minutes
Action	Between 5 and 15 minutes
Attention	Between 15 minutes and 1 hour
Notification	Greater than 1 hour

Table 2E-3. Alarm Priority Matrix

<table>
<tr><th colspan="3" rowspan="2">Escalation Strategy
* consider configuring a higher priority alarm to trigger if the alarm condition persists or worsens.
** configure a higher priority alarm to trigger if the alarm condition persists or worsens.</th><th colspan="4">Consequence Rating</th></tr>
<tr><th>Critical</th><th>Urgent</th><th>Warning</th><th>Caution</th></tr>
<tr><td rowspan="4">Urgency Rating Allowed Response Time</td><td>Immediate Action</td><td>Less Than 5 minutes</td><td>1</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>Action</td><td>5-15 minutes</td><td>1</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td>Attention</td><td>15 minutes to 1 hour</td><td>2</td><td>3**</td><td>3</td><td>4</td></tr>
<tr><td>Notification</td><td>Greater than 1 hour</td><td>3**</td><td>3*</td><td>4</td><td>4</td></tr>
</table>

Appendix 2-F
Alarm Performance Metrics

Table 2F-1. Alarm System Performance Metrics

Metrics Guidelines		
Metric	**Target (Acceptable) Value**	**Maximum Manageable Value**
Alarms Per 10 Minutes	~1 alarm per 10 minutes (average)	~2 alarms per 10 minutes (average)
Alarms Per Hour	~6 alarms per hour (average)	~12 alarms per hour (average)
Alarms Per Day	~150 alarms per day (average)	~300 alarms per day (average)
Metric		**Target**
Percentage of hours containing more than 30 alarms		~<1 percent
Maximum number of alarms in a 10 minute period of time		< 10 Alarms
Number of chattering alarms		0 Alarms
Stale Alarms		<5 present on any day
Annunciated Priority Distribution *		P1 - ~ 5 percent P2 - ~ 15 percent P3 - ~ 80 percent P4 – No set percentage
Unauthorized Alarm Suppression		0 Alarms
Unauthorized Alarm Attribute Changes		0 Alarms

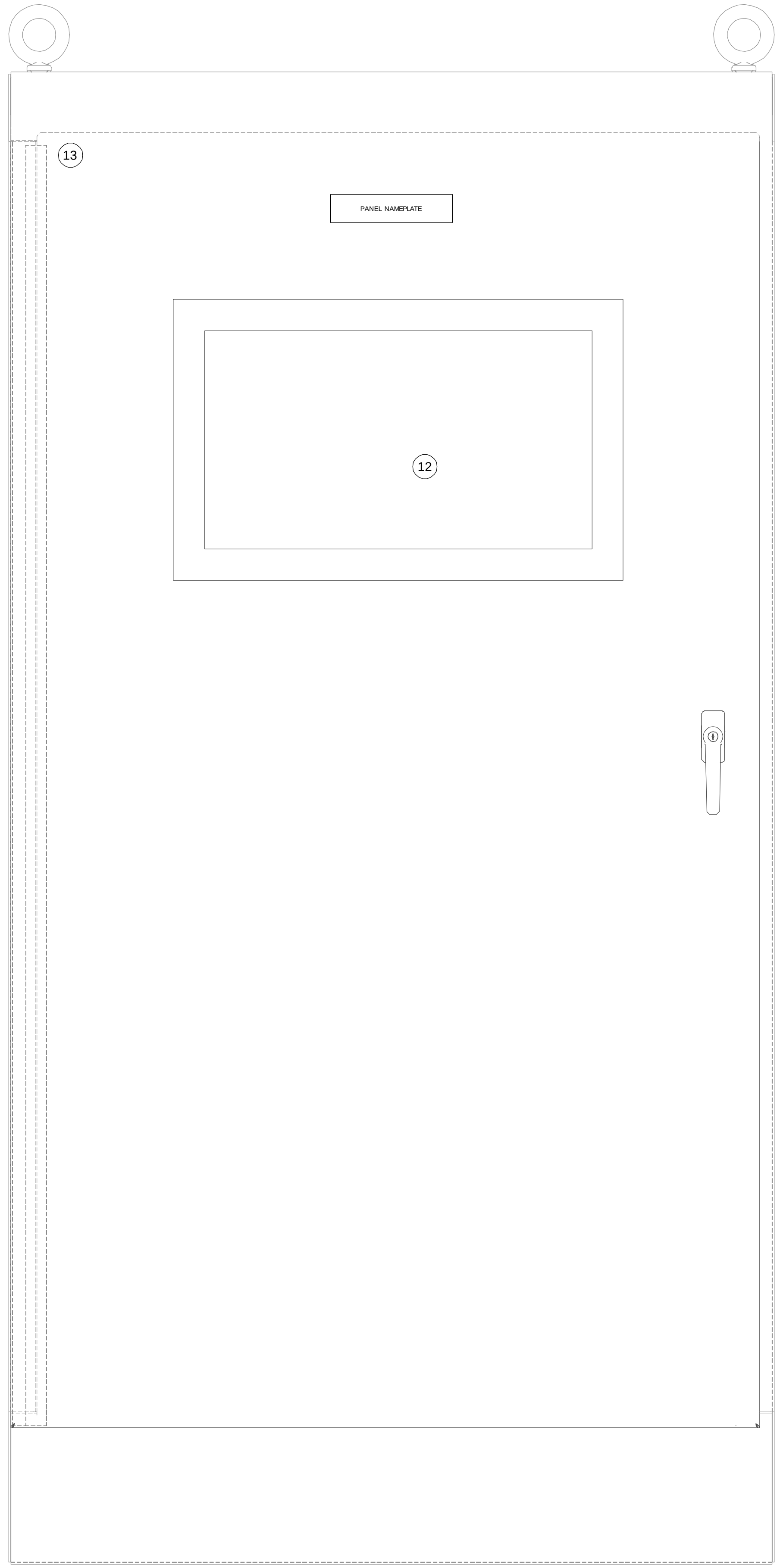
Appendix 2-G
Default Historian Data

Table 2G-1. Default Historian Data

Control Object Data Point	Name	Description
Motor Control Fixed Speed	Running	Running Feedback Signal from Motor
Motor Control Fixed Speed	Runtime	Runtime Hours from Motor
Motor Control Fixed Speed	Failed	Fault signal of any kind associated with Motor
Motor Control Fixed Speed	Remote	Local / Remote Feedback
Motor Control Adjustable Speed	Running	Running Feedback Signal from Motor
Motor Control Adjustable Speed	Runtime	Runtime Hours from Motor
Motor Control Adjustable Speed	Failed	Fault signal of any kind associated with Motor
Motor Control Adjustable Speed	Speed	Speed Feedback
Motor Control Adjustable Speed	Remote	Local / Remote Feedback
Motor Control Adjustable Speed	Current	Current / Amps
Valve Control Open Stop Close	Full Opened	Opened Feedback
Valve Control Open Stop Close	Full Closed	Closed Feedback
Valve Control Open Stop Close	Remote	Local / Remote Feedback
Valve Control Solenoid	Full Opened	Opened Status (No Feedback)
Valve Control Modulating	Full Opened	Opened Feedback
Valve Control Modulating	Full Closed	Closed Feedback
Valve Control Modulating	Remote	Local / Remote Feedback
Valve Control Modulating	Position	Position Feedback on Valves
Totalizer	Total	Totalized Flow
Analog Input Scaling	PV	Scaled Process Variable
Analog Input Scaling	Signal Fail	Signal Failure from Instrument
Digital Alarm	Alarm	Alarm Active
PID Controller	PV	PID Process Variable
PID Controller	CTRLOut	Control Output
PID Controller	CTRLSP	Control Setpoint

Appendix 3-A
Typical PLC Control Panel Layout

GENERAL SHEET NOTES



1
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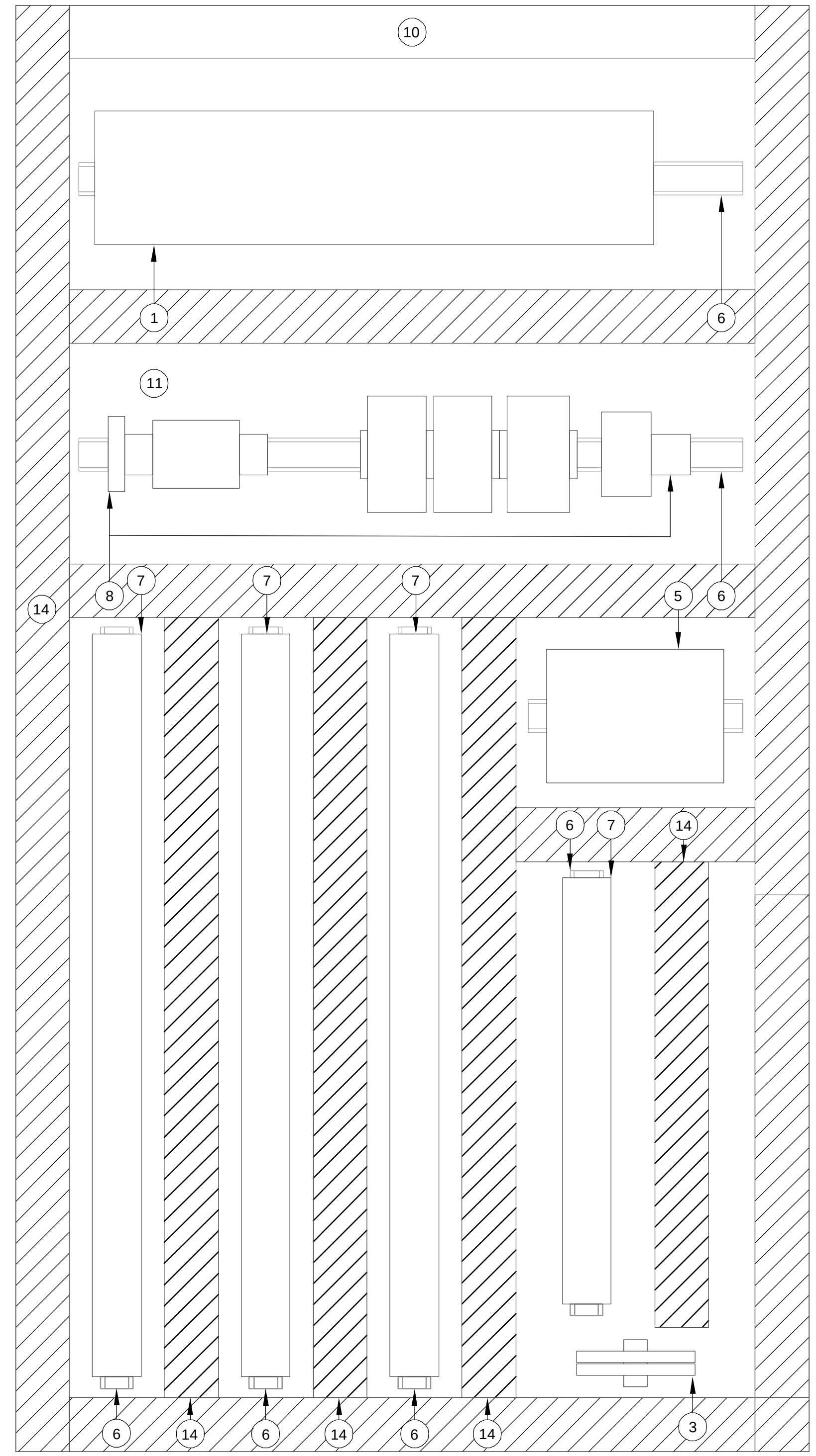
EXTERIOR PANEL ELEVATION
SCALE:



2
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INTERIOR PANEL ELEVATION
SCALE:

ITEM	DESCRIPTION
1	PLC RACK
2	CONVENIENCE RECEPTACLE
3	GROUND BAR
4	REMOTE IO RACK
5	20-PORT ETHERNET SWITCH
6	DIN RAIL
7	IO TERMINAL STRIPS (TERMINAL BLOCKS)
8	PANEL POWER SUPPLIES AND DISTRIBUTION (TERMINAL BLOCKS, FUSES, CIRCUIT BREAKERS)
9	CONTROL RELAYS
10	PANEL LIGHT
11	BACK PANEL
12	21.5" PANEL MOUNT COMPUTER WITH TOUCHSCREEN
13	ENCLOSURE
14	WIRE DUCT

PANEL

TYPICAL PANEL LAYOUT - PLC PANEL

CHECKED/APPROVED	DRAWN		
SECTION MANAGER	DESIGNED		
O&M MANAGER	SCALE AS SHOWN		DATE
APPROVED	APPROVED		
PLAN NO.	DRAWING/FILE NO.		REVISION NO.

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