Section 11 – SCADA Standards

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11.0 SCADA Standards

SCADA standards appear on the following pages, arranged according to the following sections:

1. SCADA System Standards Overview
2. General SCADA System Standards
3. Electrical Design Standards
4. Hardware Design Standards
5. Control System Software Standards
6. Appendices

Wayne County Department of Public Services
SCADA System Improvements Project

WCDPS SCADA Standards

Rev. 1.1

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1. SCADA SYSTEM STANDARDS OVERVIEW

1.1. INTRODUCTION

This document, the SCADA System Standards, is a record of the Wayne County Department of Public Services (WCDPS) design standards for Supervisory Control and Data Acquisition (SCADA) systems and adopted for WCDPS's Downriver Wastewater Treatment Facility (DWTF) and remote facility automation projects.

SCADA systems are installed in WCDPS facilities to support the operator's ability to control the process by presenting information that is complete and accurate and for other users to obtain process information essential to elements of the work they perform. Data and functionality provided by the SCADA system shall be standardized between processes and systems as much as possible to provide a consistent and uniform presentation of the system facility operations.

1.1.1. Purpose

The purpose of this document is to provide SCADA System Standards for WCDPS, designers, consultants and contractors to ensure uniformity and consistency of automation control projects in WCDPS facilities.

This approach, when used by consultants and WCDPS staff, will unify and standardize the control system equipment, software and design in contract specifications and serve as the guide for future upgrades.

For any standard to be successful, it must be constantly and consistently applied to all projects that deal either directly or indirectly with process control. The SCADA System Standards is not just a list of product standards but an entire approach for designing, specifying, implementing, and testing. The SCADA System Standards define installation and equipment standards such as wiring methods, interface connections, operator interfaces, and other technical information. The SCADA System Standards provide a source of technical information to promote the use of standard project methodologies, instruments, equipment, software and control philosophies within WCDPS. The SCADA System Standards furnish acceptable design practices and design standards that are in accordance with applicable codes. However, all users are expected to exercise good judgment and independent thought when applying the standards.

1.1.2. New or Upgraded Facilities

When new automation is incorporated into WCDPS's facilities, or existing automation is upgraded, the work shall be designed in accordance with the design standards set out in this document. This is to ensure that automation becomes an integral part of the County-wide automation control program. Not only must the design be consistent, but data must be coordinated with WCDPS's system-wide database.

1.1.3. Existing Facilities

Existing facilities will not be upgraded merely to comply with these SCADA System Standards. Where appropriate, these standards provide a policy and methods by which existing facilities should be migrated towards these Standards.

1.1.4. Benefits

The cost benefits realized through the use of standardized procedures for design, equipment procurement, operation and maintenance are self evident. In addition, the use of proven techniques, approved equipment, and common hardware and software will result in overall benefits from the uniformity of control strategies, reports and logs, process optimization, and improvement in overall business efficiency.

1.1.5. Dissemination

For the SCADA System Standards to be useful they must be properly distributed to project participants. Since the SCADA System Standards cover technical as well as contractual standards the dissemination of the information must be controlled carefully.

Section 1.2, Document Organization, explains how the SCADA System Standards are structured.

Section 1.3, Revisions and Updating, explains the revision process and the documentation standards to be used when further developing the SCADA System Standards.

Section 1.4, Glossary and Definition, provides terms found in this document or normally found within the industry and pertaining to SCADA systems.

1.2. DOCUMENT ORGANIZATION

1.2.1. Document Structure

The SCADA System Standards are divided into six parts for quick access to information and for ease of maintenance. Each part has its own numbering sequence and is divided into sections as necessary. The Index, List of Figures, and List of Tables (where applicable) precedes each part of the Standard.

The six sections are defined as follows:

Section 1 – SCADA System Standards Overview
Section 2 – General SCADA System Standards
Section 3 – Electrical Design Standards
Section 4 – Control System Hardware Design Standards
Section 5 – Control System Software Programming Standards
Section 6 – Appendices

1.2.2. Index Organization

There are two types of indices used in the organization of this manual and its sections/documents. The first is the Master Index for the entire document. This index provides an overview of the manual, and lists the breakdown of each section. The Master Index is located at the front of this manual, and is intended as a starting point for users seeking specific topics.

The second index is the Section Index. This index is at the beginning of each Section, and provides further detail regarding the organization of the standards.

1.2.3. General SCADA System Standards

Section 2 of the SCADA System Standards consists of general sections used to support the standards in Parts 3 – 5. These standards apply to all sections and are intended to provide background information and document deliverable formats.

Topics covered include:

a) Basic Design Requirements
b) SCADA System Philosophy and Concepts
c) Naming Standards
d) Documentation Standards
e) Drawing Standards
f) Quality Assurance
g) Testing Standards
h) Spare Parts
i) Training Standards.

1.2.4. Electrical Design Standards

Section 3 of the SCADA System Standards consists of standards that are used to describe the design and component makeup of a control system.

Topics covered include:

a) Basic Design Requirements
b) Wiring and Cable Standards
c) Grounding Standards
d) Equipment Panel Design Standards
e) Electrical Device Standards.

1.2.5. SCADA System Hardware Design Standards

Section 4 of the SCADA System Standards consists of the hardware components required for process measurement and monitoring, data transmittal, processing, and local display.

Topics covered include:

a) System Architecture
b) Network Design Standards
c) Programmable Logic Controllers (PLC)
d) Local Operator Interface Panels
e) Control Device I/O Interfaces
f) Instrumentation.

1.2.6. SCADA System Software Programming Standards

Section 5 of the SCADA System Standards consists of the software components required for system development, PLC and Human Machine Interface (HMI) programming.

Topics covered include:

a) General SCADA Software Development Standards
b) PC-based (Graphical User Interface) GUI Development Standards
c) PLC Programming Standards.

1.2.7. Appendices

Section 6 of the SCADA System Standards is reserved for Appendices. Appendix contents are industry standards, WCDPS reference standards including a list of preferred vendors, and examples of key Standard components.

1.3. REVISIONS AND UPDATING

1.3.1. Enforcement

Use of the SCADA System Standards is not optional. The standards are to be continuously and consistently applied to all control system projects. WCDPS will enforce applicable standards to the design, implementation, and ongoing support of all automation projects.

WCDPS must designate an Owner (group) and enforcer of the SCADA Standards documents. This group will be responsible for the revision procedures and review process for design projects. The group issues copies of the SCADA System Standards to individuals responsible for I&C activities and projects. Sections of the standard will be issued, as required, upon request.

The group invites new or improved practices that should be integrated into applicable sections so that the SCADA System Standards may continue to represent current acceptable practices at WCDPS.

Revisions to the SCADA System Standards will be sent to individuals or otherwise disseminated to persons that have been issued controlled copies of the SCADA System Standards.

1.3.2. Revision and Updating

This Section defines the formats to be followed when developing or revising the SCADA System Standards documents. These documents have been prepared using Microsoft Word 2003.

1.3.2.1 Indices

The Master Index lists all of the sections within the Manual, organized by sections, down to the second sub-level (e.g. 4.2.1). Each section includes revision level for document control.

1.3.2.2 Header and Footer

Each Section shall have a header containing the following:

a) A text portion containing the words "SCADA System Standards" in Arial font, 9 point, italic.
b) A horizontal line the full width of the page.

The footer shall contain the following:

a) A horizontal line the full width of the page.
b) Left - Revision number of the Section (Arial font, italic, 8 point).
c) Center - Page number showing the section number and page number (Arial font, 10 point).
d) Right - Date of current revision (Arial font, italic, 8 point).

1.3.2.3 Styles

The body of the text will use the following font attributes, with indents or tabs as indicated:

1. SECTION HEADINGS WILL BE ARIAL FONT, BOLD, 14 POINT, ALL CAPS.

1.1 THE SECOND LEVEL HEADING WILL BE ARIAL FONT, BOLD, 11 POINT, ALL CAPS.

1.1.1 The Third Level Heading will be Arial Font, Normal, 11 Point.

1.1.1.1 The Fourth Level Heading will be Arial Font, Normal, 11 Point, increased indentation.

The body of the text will be normal. The normal font shall be Arial 11 point. Text shall start at the left margin, and will be full justified. Left and right margins shall each be 1". Top and bottom margins shall each be 0.5". Line spacing shall be single.

1.3.2.4 Revision Record

The last page of each section shall have a subsection titled "Revision Record" to provide a mechanism for tracking revisions. This listing, in table format, shall have a column for the dates followed by revision number and the reason for the revision, as follows:

Revision Record

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0	August 2008	Updated Section to change fonts

The revision reason comment shall be fully detailed rather than cryptic.

1.3.2.5 Authorization and Revision Procedure

The authorized Owner (group) will prepare an authorization and revision procedure for the Standards, to be inserted at this point in the documents.

1.3.2.6 Figure Identification

Figure names shall correspond to the section number where the figure is used. The number of the figure is first, followed by the figure name. For example, if the figure is the third such figure in Section 2.3.1, then the figure would be labeled as Figure 2.3.1-3: Pump Gallery Layout.

1.4. GLOSSARY AND DEFINITIONS

Term	Definition
Backbone	The primary communications path on a LAN and on which segments or network devices attach. A backbone is typically fiber optic and can support bandwidth capacities higher then the devices can communicate. A typical example of a network with a ring topology backbone is the segments that create the ring itself.
Control Circuit	Any circuit which principal purpose is the conveyance of information and not the conveyance of energy for the operation of an electrically powered device.
Control Loop	A combination of one or more interconnected instruments arranged to measure or control a process variable, or both. (Source *ISA Standards and Practices for Instrumentation*)
Control Room	An environmentally controlled room intended for housing digital control equipment, computers, large control panels, etc., and generally intended to be regularly occupied by operators.
Data Sheets	Data sheets as used in this specification shall comply with the requirements of ISA S20.
Electrical Isolation	Pertaining to an electrical node having no direct current path to another electrical node. As used in this specification, electrical isolation refers to a device with electrical inputs and/or outputs which are galvanically or optically isolated from ground, the device case, the process fluid, and any separate power supply terminals, but such inputs and/or outputs are capable of being externally grounded without affecting the characteristics of the device or providing a path for circulation of ground currents.
Fail	Hardwired shut down mode or virtual condition that prevents the equipment from operating in a normal state.
Fast Ethernet	Common name for the LAN specified by IEEE 802.3 and CCITT 8802.3. A base band, local area network that operates at 100 million bits per second and can be extended up to 1.5 kilometers of cable. It uses a carrier sense multiple access/collision detection protocol.
Four-Wire Transmitter	A transmitter which derives its operating power supply separate from the signal transmission circuit and therefore requires separate power supply connections. As used in this specification, four-wire transmitter refers to a transmitter that provides a 4 to 20 milliampere current regulation of signal with a maximum external circuit resistance of 600 ohms separate from an external power source.
HMI	Human Machine Interface. The graphical interface in the main control room between the user and the SCADA system. Normally used by an Operator to monitor and control the process.

Term	Definition
LAN	Local Area Network. A system of physical cables and associated procedures to allow the exchange of information between two or more personal computers, host computing system and computer terminals. The most common LANs are Ethernet (IEEE 802.3 and CCITT 8802.3).
LOCAL	Local-Off-Remote Switch is set in the LOCAL position and commands to the field device are initiated through the local hardwired buttons. Commands from the PLC are disabled.
L-O-R	A Local-Off-Remote switch, located at the associated field device, a local panel, or the MCC.
Multimode Fiber	Glass fibers, with a common diameter in the 50-to-100 micron range for the light carry component (the most common sizes are 50 and 62.5). Multimode fiber provides high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths or modes through the cable's core typically 850 or 1300nm. Typical multimode fiber core diameters are 50, 62.5, and 100 micrometers. However, in long cable runs (greater than 3000 feet [914.4 m), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.
OFF	Local-Off-Remote Switch is set in the OFF position and commands to the field device from the local hardwired controls or buttons are disabled. Commands from the PLC are disabled.
OIT	Operator Interface Terminal. The graphical interface at a PLC control panel between the user and the SCADA system.
Operator	The person responsible for running the process operations. Typically interacts with the process through use of an HMI or OIT.
Panel	An instrument support system that may be a flat surface, a partial enclosure, or a complete enclosure for instruments and other devices used in process control systems. Unless otherwise specified or clearly indicated by the context, the term "panel" in these SCADA System Standards shall be interpreted as a general term that includes flat panels, enclosures, cabinets and consoles.
PCS System	The top-end control system located for treatment facilities that is comprised of redundant hosts, multiple workstations, peripherals, front-end processors, and is the user interface for monitoring and control, trending, report generation, and other functions commonly provided in a human-machine interface for plant processes and SCADA.
PLC	Programmable Logic Controller
PLC Panel	Generic name of a panel that contains a PLC and the necessary support devices for operation of the PLC.
Power Circuit	Any circuit which principal purpose is the conveyance of energy for the operation of an electrically powered device.
Ready	Ready is defined as all hardwired conditions, including power, satisfied to permit remote control of the equipment.
Real Time	Pertaining to a system or mode of operations in which computation is performed during the actual time that an external process occurs, in order that the computation results can be used to control, monitor, or respond in a timely manner to the external process.
REMOTE	Local-Off-Remote Switch is set in the REMOTE position and commands to the field device are initiated through the PLC. Commands from the PLC may be initiated by operator command or a control strategy.
SCADA	Supervisory Control and Data Acquisition. The top-end control system for remote monitored sites comprised of hosts, multiple workstations, peripherals, front-end processors, and is the user interface for monitoring and control, trending, report generation, and other functions commonly provided in a human-machine interface for SCADA
Signal Circuit	Any circuit operating at less than 120 volts AC or DC.

Term	Definition
TCP/IP	Transaction Control Protocol/Internet Protocol. A communication protocol that allows multi vendor systems to participate on a network.
Two-Wire Transmitter	A transmitter that derives its operating power supply from the signal transmission circuit and therefore requires no separate power supply connections. As used in this specification, two-wire transmitter refers to a transmitter that provides a 4 to 20 milliampere current regulation of signal in a series circuit with an external 24-volt direct current driving potential and a maximum external circuit resistance of 600 ohms.
UPS	Uninterruptible Power Supply.
WAN	Wide Area Network.
Workstation, Engineer	A PC-based user interface similar to an Operator Workstation, but with additional capabilities to modify system database, graphics, reports, control strategies, and other programming functions.
Workstation, Operator	A PC-based user interface located in the control room.
Workstation, Supervisor	A PC-based user interface similar to an Operator Workstation, but usually allowed to perform a higher level of system control, such as changing alarm limits. May also be provided with additional capabilities to modify system database, graphics, reports, control strategies, and other programming functions.

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0	August 2008	Initial Release
Rev 1.0	March 2009	Updated for Submission, date changes in footer
Rev 1.1	June 2010	Updated for As-Built conditions, date changes in footer

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2. GENERAL SCADA SYSTEM STANDARDS

2.1. BASIC DESIGN REQUIREMENTS

The overall goal of the SCADA system is to enable WCDPS to provide wastewater collection and treatment, and related services in an efficient and reliable manner consistent with compliance of regulatory agencies. To achieve this, the SCADA system must support the Operator's ability to control the process by presenting information to Operations that is complete and accurate. Initial considerations in designing the SCADA system are to understand the process, analyze possible disturbances or variations imposed on the process system, and define the strategies or goals for reliably controlling the process.

All SCADA systems rely on instrumentation and sensors to provide monitoring and control capabilities. Therefore, it is imperative that these devices be given careful consideration as an essential part of any SCADA system. In addition, standardization of hardware, software, and functionality allows WCDPS the ability to benefit from cost effective, uniform, and consistent SCADA Systems.

Functions provided by SCADA systems used in WCDPS facilities shall be standardized between systems where possible. The following functions should be available in every SCADA system at a WCDPS facility.

2.1.1. Process Monitoring

All equipment involved with a process or in support of a process should be instrumented as necessary to provide flows, levels, speeds, pressures, temperatures, positions, and equipment status.

2.1.2. Equipment Fault Monitoring

Any time field equipment fails to respond to commands, changes status without Operator or strategy intervention or switches states, the SCADA system shall notify Operations via an alarm.

2.1.3. Process Controls

2.1.3.1 Local Control

All equipment shall be provided with the means to operate the equipment locally in LOCAL mode. Such control may be at the device itself or at the associated MCC or local panel. Local control shall be fully independent of PLC control, and is activated by placing the Local-Off-Remote switch in the LOCAL position. Indication of the position of all LOR switches shall be provided on the SCADA System HMI and OIT.

2.1.3.2 User Interface Control

The Operator should have control of all major equipment and process setpoints from the HMI or OIT. The Operator must be able to respond to process changes or alarms by operating valves, turning on pumps and motors, and changing the setpoints on control loops. Control should be executed primarily through the HMI in the area control rooms, and as a backup, through the OITs at the PLC control panels.

2.1.4. Process Variable Monitoring (HMI Trending)

Variables such as flow, level, temperature, speed, and measurements from analytical instruments shall be able to be trended both in real-time and historically. An Operator should have the ability to call up real-time or historical trends that display interdependencies between process variables.

A historical data storage and retrieval system capable of holding a minimum of 5 years of data on-line without requiring installation of archived media should be provided.

2.1.5. Constraint or Interlocks

The SCADA system should provide an Operator with reasons why the command issued failed. Equipment interlocks that inhibit the commanded action need to be included on a HMI/OIT display and in as-built record documentation.

2.1.6. Instrumentation Faults

The SCADA system should have the ability to identify and react to malfunctioning instrumentation. Input signals that are abnormal or out of range should be alarmed. In addition, the SCADA system must be capable of modifying or inhibiting control when signals assume abnormal or out of range values. Equipment control must be automatically placed in a fail safe mode upon instrument failure.

2.1.7. Loop Tuning

An authorized system user should be able to change tuning parameters of control loops through PLC programming software. This function must be password protected (administrator security level) and may be made available through the workstations. PID loops should be contained only in the PLC.

2.1.8. Report Generation

A wide variety of logs and reports are required to aid the Operator's interpretation of events and assist in controlling the process. Reports shall be produced on a fixed schedule and the system shall support ad-hoc reporting to suit Operator needs. The information content of the reports may contain real-time or historical data.

The report generating software is XLReporter and is independent of the SCADA system and HMI iFIX software.

2.2. SCADA SYSTEM PHILOSOPHY AND CONCEPTS

This section defines the general control and monitoring philosophy for WCDPS facilities. SCADA Systems are used within WCDPS facilities to provide real-time monitoring and control of the process operations, and to provide Operators a meaningful interface to process equipment.

2.2.1. Facilities Control System Philosophy

WCDPS facilities shall be automated to the greatest extent possible, relieving Operators of time consuming and repetitive operations, allowing them to focus on other activities. To achieve these objectives, the SCADA system shall be designed such that:

- The process shall be instrumented to that extent required to allow automated, unmanned operation.
- Process operations shall be automated, controlled by process control strategies executing in PLCs.
- A level of redundancy is provided that failure of any PLC will not affect more than one process area, allowing for continuous operation of the facility.
- In the event of PLC failure, all equipment can be operated locally by the use of manual controls.
- Remotely located PLC control panels shall be provided with a networked local OIT (Thin Client) using a touchscreen interface or keypad, so that any process area can be controlled from the remotely located control panel OIT.
- In the event of a process network failure (e.g., Ethernet LAN), the PLC will continue to control equipment. The OIT interface is temporarily provided with notebook thick client PCs.
- The PLC shall be powered from a UPS that is capable of providing power to the PLC and the PLC powered instrumentation.

2.2.2. Critical Process Areas

Control systems for critical processes shall be designed with a level of redundancy such that the continuous operation of the facility is maintained following key equipment failures. Each SCADA project shall include an analysis of the effects of PLC failure on the operation of the facility, and critical processes identified. For such critical systems, the following additional requirements shall apply:

- A backup control system shall be provided that will assume control of the process following PLC failure.
- A backup PLC shall be provided that will assume control of the process following primary PLC failure.

2.2.3. Remote Site Control System Philosophy (CSO Basins and Pump Stations)

- Remote sites, where feasible, shall be instrumented to that extent required to allow automated, unmanned operation.
- Primary control shall be by a local PLC.
- A backup means of control shall be provided that will assume control of the process following PLC failure.
- The site should be capable of being controlled from a central control facility.
- A local OIT shall be provided to provide local PLC control and facility monitoring.
- The PLC shall be powered from a UPS that is capable of providing power to the PLC and the PLC powered instrumentation.
- In the event of PLC failure, all equipment can be operated by the use of manual local controls.

2.2.4. Control Modes

When process equipment is provided with local and automatic control capability, coordination between local control and control provided through PLCs is extremely important. Control Modes are coordinated through the use of LOCAL-OFF-REMOTE switches. Different terminology and nameplate engravings are in use at WCDPS facilities for these switches, such as HAND-OFF-AUTO. It is a requirement of this Standard that as equipment is replaced or upgraded, nameplate engravings be changed to match the terminology defined by this Section.

The following control modes are defined for use in WCDPS facilities:

- LOCAL: Changes to process equipment are initiated from the L-O-R switch. A pump in the LOCAL position shall be controlled through the local START and STOP buttons. A valve may be opened and closed through the local OPEN and CLOSE buttons or a switch.

- OFF: All local commands to the device are disabled. A running pump will stop when switched to the OFF position.

- REMOTE: Changes to process equipment are initiated from the PLC, or backup control system. The REMOTE control mode has two states, which may be changed from the HMI or OIT. For critical processes having a backup control system, an AUX mode may be available.

- SCADA-MANUAL: Changes to process equipment are initiated by an Operator. This may be from the OIT or the HMI.

- SCADA-AUTO: Changes to process equipment are initiated by a control strategy resident within the PLC logic.

A dedicated OIT or HMI faceplate graphic must be used to switch from SCADA-MANUAL to SCADA-AUTO. Switching from SCADA-MANUAL to SCADA-AUTO changes the current condition of the equipment (e.g., RUNNING or OPEN) to that required by the control strategy. Switching from SCADA-AUTO to SCADA-MANUAL does not change the current condition.

Switching a device from OFF to REMOTE mode will always place the device in SCADA-MANUAL. Note that changing the position of the L-O-R switch from the LOCAL position will always first STOP a motor. EMERGENCY STOP buttons and important safety interlocks shall be operable independent of the position of any other switches or control modes.

2.2.5. Process Monitoring

All process parameters such as flows, pressures, levels, etc. are to be displayed as required on the local panels and transmitted through the SCADA system to the HMI. The status of major process equipment shall be indicated locally and transmitted to the SCADA system. Once the information is in the SCADA system it can be displayed at any HMI workstation.

The status of auxiliary systems, such as HVAC, Electrical Power Distribution etc. should be monitored as required by the facility operating procedures and requirements.

All process and equipment faults and abnormal situations shall be indicated and alarmed at the OITs and on the HMI workstations. All alarms are generated within the PLCs and transmitted to the HMI.

Interfaces must provide not only process information but also status information. All pumps, valves, gates, blowers, mixers, and like process equipment shall have signals to the SCADA system which define the equipment's state of readiness, operation status, and control mode.

The following are general guidelines for selection of points to be monitored by the SCADA system:

a) Analog values for all major process variables such as flow, level, and pressure

b) The status of all major process equipment such as pumps, blowers, compressors, etc.

c) The status of all process variables or equipment monitored or controlled by a PLC.

d) The status of all Hand/Off/Remote switches.

e) Limit switches on all computer controlled, two-state valves (both open and closed).

f) Limit switches on all valves and gates used for flow routing, sluice gates and other critical equipment.

g) Motor speed for all variable speed devices that are to be monitored or controlled by the SCADA system.

h) Valve and gate position for all gates and valves which position is adjusted by the SCADA system

i) All safety indicators (e.g., combustible gas detection, fire detection, etc.).

j) Valves used strictly for maintenance such as isolation valves on pump suction and discharge will generally not be monitored.

2.2.6. Alarm Monitoring Guidelines

The following are general guidelines for selection of alarms to be monitored by the SCADA system:

a) The PLCs will generate alarm signals for all process equipment and process values, equipment status changes, extreme signal levels (value out of range), excessive rates of change, controlled device failure to respond, and system diagnostic signals. The PLCs will generate all analog point limit value alarms.

b) All emergency or alarm conditions shall be reported to the OIT and HMI for Operator acknowledgement and response as determined by the alarm priority.

c) Each alarm will be assigned a priority reflecting its severity and importance. Priority 1 alarms are designated as CRITICAL and are considered to be conditions requiring

immediate action, such as effluent quality, safety conditions, hazardous chemical leaks, fire, over torque, temperature overloading of motor driven equipment, and critical levels. These alarms will always generate a specific alarm annunciation at the HMI, with an audible alarm, and requiring acknowledgement by an Operator.

d) Priority 2 alarms are designated as GENERAL, and are considered conditions of potential problems unless corrective action is asserted on an "as soon as possible" basis. These alarms will always generate a specific alarm annunciation at the HMI, but can be distinguished from CRITICAL by alarm name, listing, color, and audible alarm tone. These alarms require Operator acknowledgement.

e) Priority 3 alarms are designated as ALERTS. These are signals that do not require immediate Operator attention or Operator acknowledgement, and will not generate an audible alarm.

2.2.7. SCADA System Domains

SCADA System is divided into two distinct domains:

1. A DWTF SCADA domain for monitoring and controlling the WCDPS Downriver Wastewater Treatment Facility.
2. A CS SCADA domain for collection system facilities.

The WWTF SCADA domain includes a combination of PLCs linked together into a local area network (LAN) to provide DWTF control and monitoring. Control shall be distributed throughout the facility, with each PLC assigned a specific process area. All facility process areas shall be monitored and controlled by the SCADA system, with HMI workstations located at control rooms and local operator interface terminals distributed around the facility as necessary.

The CS SCADA domain monitors and controls equipment that is installed at remote sites using PLCs and other field processing equipment connected to the SCADA Head End via HDSL and Cellular Services. The remote sites associated with the wastewater collection system shall be monitored and include supervisory control from the DWTF.

2.2.8. Process Control Narratives

2.2.8.1 General

Process Control Narratives shall be used to describe how each process is to be controlled. These narratives are important for PLC programming, HMI and OIT development, and facility operation. These narratives should be divided on a process by process basis. Each process narrative identifies all associated equipment within the control scheme for each individual process.

The Process Control Narrative describes how the SCADA system interfaces with the facility and its process system and equipment. It gives details on the process indicators that need to be monitored to ensure that the process is operating correctly. This includes complete listings of all device names, I/O points, control loops, tag names, and control modes.

The Process Control Narrative shall follow the format described as follows:

2.2.8.2 Narrative Structure

Each narrative follows a standard format. Items in the standard format that are not relevant or not used for control shall be indicated as such.

The following outlines the basic structure to be followed.

PART 1 – GENERAL

1.1 Introduction
1.2 Common Functions.

PART 2 – PROCESS A (Repeated for each Process)

2.1 Equipment Summary
2.2 System Control Strategy
2.3 Equipment Control Strategy (for each device within process)

PART 3 – CONTROL SYSTEM INTERACTION

3.1 Input Validation
3.2 Alarms
3.3 Signal Conditioning.

a) PART 1 – General

The following describes the information to be included in the applicable sections.

- Introduction – An overview of the process control area and how it fits into the overall SCADA system. Shall include interfaces to other process control narratives as required. Shall reference drawings and auxiliary information required to interact with the control narrative.

b) PART 2 – Process Sections

The following describes the information to be included in the applicable sections.

- Equipment Summary – A description of all equipment within the associated process and integral to the overall control philosophy of the process. Include device tag names.

- System Control Strategy – Describes how the process is to be controlled. Includes descriptions of all field selector switches, including all I/O that is part of the process.

- Equipment Control Strategy – A detailed description of all I/O associated with each individual device including any calculations that are to be associated with the device (runtime, number of starts, etc.) Describes any hardwired interlocks that may alter equipment operation and all control modes associated with the device. Includes step-by-step descriptions to how they function in all control modes. This section contains all programmed interlocks and setpoints that are required to drive the process.

c) PART 3 – Control System Interaction

- Input Validation – Addresses all values and I/O that are required to be displayed at the HMI and OIT. Tag names are to be included for labeling these values.

- Alarms – Provides specific details for all points that have alarming parameters. Alarm classification (level), display requirements, and alarm messaging are to be included.

- Signal Conditioning – If any signal conditioning is required, it will be included under this section.

2.3. NAMING STANDARDS

Each piece of equipment in WCDPS facilities requires a unique identification number. These numbers will be permanently attached to the associated equipment and used on all documentation including process flow diagrams, O&M manuals, and the SCADA system database. The format of the identification numbers must be carefully followed by all projects dealing with SCADA systems or related instrumentation.

Failing to follow the numbering standards may lead to database configuration problems which will make interfacing, documenting, and troubleshooting SCADA systems, operational data, and report generation extremely difficult.

2.3.1. Instrument and Equipment Naming Standard

Instrument and equipment numbers are a combination of ten (10) alphanumeric characters derived from the WCDPS equipment maintenance management system. The ten characters are a combination of the process/facility area (first two digits) and unique equipment identification (last eight digits). Any contractor performing work shall be required to coordinate the addition of any new instrument and equipment numbers with WCDPS when required. An example of an instrument and equipment tag number is shown here: 03-SGD01-000

2.3.2. Loop Assignment Procedure

Loop names consists of three main components: the three (3) letter ISA prefix identifier, a ten (10) digit equipment number, and single (1) letter ISA suffix identifier. Based on this format, different types of assets will share similar loop (equipment) numbers when related to the same equipment. A sample loop number is shown here: AAH-03-SGD01-000-A and represents one of two LEL monitors on an Aeration Train.

1. Determining the Area Process Code

The first two digits of the ten digit equipment number relates to the process code. Each WCDPS SCADA asset falls into a process category. The SCADA Process Code is determined by the Maintenance Management System.

To determine the Process Code, locate the associated process/facility and corresponding two (2) character number in the table below.

Code	Location	Code	Location
01	DWTF Preliminary Treatment	50	Dearborn Heights Basin
02	DWTF Primary Treatment	51	Inkster Basin

Code	Location	Code	Location
03	DWTF Secondary Treatment	52	Redford Basin
04	DWTF Solids Handling	53	Rouge River Basin
05	DWTF DAF (Not Used)	54	Dearborn Heights Lift Station 1A
06	DWTF Skimmings	55	Livonia Basin
07	Disinfection	56	Taylor Basin
08	Pump Station No. 5	57	LeBlanc Station
09	Pine Street	58	Goddard Basin
10	Tunnel Pump Station	59	Monroe Basin
11	Buildings and Grounds	60	ECPAD #3
12	Administration Building	61	Lateral 94
13	Maintenance Building	62	Northeast Pumping Station
14	Service Building	63	Milk River Pumping Station
15	Laboratory	64	Kerby Road Pumping Station
16	General Safety	65	Henry Ruff Field Office
17	SCADA	66	Rouge Valley
18	Vehicles	67	Harper Woods
		68	Milk River Recirculation Station

Meters and Sewers			
Code	**Location**	**Code**	**Location**
80	Regulators	84	Junction Chambers
81	Rain Gauges	85	Restriction Manholes
82	Slide Gates	86	Flow Meters
83	Siphons		

2. Determining the Equipment Number

After assigning the two digit process code, the next eight digits sub divide each process into segments or control loops typically allocated to major pieces of equipment. Contact the WCDPS maintenance management supervisor for assigning new equipment numbers.

2.3.3. SCADA I/O List

The SCADA I/O list identifies equipment, the inputs and outputs associated with signals into the SCADA system, individually hardwired or data-linked and the operating characteristics of each signal. Each SCADA project shall produce a SCADA PLC Field I/O List using a standard format, defined in Section 5.1.3.

2.3.4 I/O Point Identification System

The I/O point identification uses up to a sixteen-character alphanumeric point identifier and a forty-eight character description, composed as shown in the following example:

N XX-XXXXX-XXX S

N Prefix (N=Equipment Command)

XX	The first two characters represent the process area.
XXXXX	The next five characters represent the main item.
XXX	The next three characters represent the main item's support equipment.
S	Suffix (S = Start).

The identifier prefix defines the point type and the suffix defines the point function.
The ten digit main characters (XX-XXXXX-XXX) represent the equipment tag number, presently used in WCDPS CMMS equipment numbering. This standard should be followed closely coordinated with WCDPS maintenance management to prevent the duplication of I/O points in WCDPS facilities.

2.4. DOCUMENTATION STANDARDS

This section defines the general content and format for the documentation required for all SCADA system projects.

SCADA system documentation should include the following major parts:

- Functional Design Documentation
- Detail Design Documentation
- Operations and Maintenance (O&M) Manuals
- System Engineer's Manuals
- Site Configuration Inventory
- Record Documentation.

2.4.1. Functional Design Documentation

Functional Design Documentation shall include the following:

a) Product Information

Product information shall include, but not be limited to: catalog cuts, data sheets, performance surveys, test reports, equipment lists, material list, diagrams, pictures, and descriptive material. The product information shall cover all items including mechanical devices, mounting components, wiring, terminal strips, connectors, accessories, and spare parts. The submittal information shall show the standard and optional product features, as well as all performance data and specifications.

b) Equipment Location Plan

Drawings showing the location of all equipment being installed for the project shall be prepared. Drawings shall show, as a minimum, the location of PLC control panels, junction boxes, instruments, conduit or raceway routes, communications patch panels.

c) Panel Fabrication and Layout Drawings

Panel fabrication drawings are scaled drawings that shall show the physical dimensions, materials, and construction of panels, cabinets, terminal boards, or other electrical or mechanical equipment enclosures. These drawings show the physical arrangement and mounting of all components in or on a panel, terminal board, cabinet, or enclosure. These

drawings show the physical dimensions, and the space and mounting requirements of mechanical, electrical, control and instrumentation devices or pieces of equipment. Other information provided may include ventilation requirements, locations of connections, weight, and paint color, material and dry film thickness.

As a minimum, panel fabrication and layout drawings shall include a bill of materials: front, back, and section views; the locations of all components to be mounted in or on the panel, cabinet, console, enclosure or assembly; drawing scale; nameplate engraving schedule; and structural materials and supports. All drawings shall be scaled. Overall dimensions and minimum clearances shall be shown. Sufficient detail shall be included to demonstrate material choices, outward appearance, construction methods, and other specific requirements.

2.4.2. Detail Design Documentation

Detail Design Documentation shall include the following:

a) Panel Connection Diagrams

Panel connection diagrams shall show all connections internal to each panel, and specifically power wiring connections, wiring not shown on Instrument Loop Diagrams, network connections, and connections to the OIT.

b) Instrument Loop Diagrams

Instrument loop diagrams shall be provided for each loop, and shall conform to ISA S5.4 and these SCADA Standards. Each loop shall be documented such that there are no more than four loops per sheet with each connection point shown.

c) Installation Drawings

Installation drawings shall show installation arrangements for all provided equipment, mounting and anchoring details, conduit entries into cabinets, and SCADA System electrical power supply distribution conduit and wiring. Data sheets and/or catalog cuts for mounting devices, anchors, wire and other incidental installation materials shall be included.

d) Interface Cables

Interface cables diagrams depicting cable pin-out/cable makeup shall be provided as part of the documentation package. This includes all network cables, radio to PLC cables and computer to PLC cables. All cables shall either be standard cables from the manufacturer or custom made without the use of gender changers, 9-25 pin converters, or null modem adapters.

e) Equipment Lists

Additional documentation that shall be furnished, and described elsewhere in these Standards in more detail includes: Wiring Schedules, Cable Schedules, Conduit Schedules, and I/O Lists.

f) Software

The software documentation shall provide a comprehensive description of all software necessary for the operation and maintenance of all components of the SCADA system. It shall include a description of any engineered or custom software required.

Documentation shall be furnished for the PLC programming software, OIT/HMI programming software, and any PLC loadable modules or other custom software. This document shall include, as a minimum:

- A list of the installed characteristics of the PLC programming program, including priority, and access privileges and computer system requirements (Processor, Operating System i.e., Windows XP, Windows 7, etc.) needed to run the program.
- A list, with descriptions, of any PLC loadable modules used for configuration.
- A list, with descriptions, of any other custom software used.
- Cut sheets or product data sheets for the software provided.

2.4.3. Operations and Maintenance (O&M) Manuals

O&M Manual Documentation typically includes the following:

a) Instruction Manual

The instruction manual shall be illustrated in detail to the component level, including assemblies, subassemblies, and components. It shall contain a detailed analysis of each major component so that maintenance personnel can effectively service, inspect, maintain, adjust, troubleshoot, and repair the equipment.

Each manual shall include a Table of Contents, arranged in systematic order, and shall be divided into the following sections:

- Introduction: The purpose of the manual, special tools and equipment, and safety precautions.
- General Information and Specifications: A general description of the equipment item, and specifications of its major components.
- Listings: Supplier's name, address, web site information, and telephone number. Each product shall include name, address, web site information, and telephone number of subcontractor, or installer, recommended maintenance contractor, and local source for replacement parts.
- Theory of Operation: The relationship of assemblies, subassemblies, components and interchangeability of components, and explanation and analysis of their functions to the lowest replaceable components.
- Software: Listing and explanatory text for any software or firmware. This includes loadable modules used in the PLC at each site.

- Operation Procedures: The locations and functional descriptions of all controller indicators, or displays installed at each process area or remote site.

- Troubleshooting: A list in tabular format of symptoms, probable causes of malfunction or improper operation, and probable remedies to the lowest replaceable components.

b) Preventive Maintenance Instructions

These instructions shall include all applicable visual examinations, hardware testing, and diagnostic hardware/software routines. Instructions on how to load and use any test and diagnostic programs and any special or standard test equipment shall be an integral part of these procedures.

c) Corrective Maintenance Instructions

These instructions shall include guides for locating malfunctions down to the PLC module-replacement level for PLC failures and device replacement level for other PLC panel components such as relays and power supplies. These guides shall include adequate details to quickly and efficiently locating the cause of common equipment malfunctions and shall state the probable source(s) of trouble, the symptoms, probable cause, and instructions for remedying the malfunction. These guides shall explain how to use on-line test and diagnostic programs for all devices and any special test equipment, if applicable.

The corrective maintenance instructions shall include:

- Explanations for the repair, adjustment, or replacement of major items. Schematic diagrams and parts location, illustrations, photographs, and sectional views giving details of mechanical assemblies shall be provided as necessary to repair or replace equipment. Information on the loading and use of special off-line diagnostic programs, tools, and test equipment as well as any cautions or warnings that must be observed to protect personnel and equipment shall be included.

- A list of test equipment and special tools required.

- A list of all abbreviations and circuit symbols used.

- Warranties, bonds and maintenance records, including proper procedures in the event of failures and instances that might affect the validity of warranties, bonds, or contracts.

- A parts catalog enumerating each part to the module level for PLCs and to the component/device level for other PLC panel components. The description shall include component symbol, description, ratings, accuracy, manufacturer's name and address, manufacturer's part number, commercial equivalents, and quantity per assembly or subassembly. The parts catalog shall identify the appropriate locations of the parts and shall group each component by assemblies or subassemblies within each subsystem so that each component can be identified as being part of the next larger assembly.

- A list of recommended spare parts that includes all parts necessary to maintain and repair components installed at the facility and remote sites. The list shall identify the specific part or model number, description, manufacturer’s name and address, current

unit price, and recommended quantity. The spare parts list shall indicate which components (by model and serial number) have been provided with the delivered system as part of the spare inventory.

2.4.4. System Engineer's Manuals

System Engineer's Manuals shall include the following (as appropriate):

a) System Software Engineer's Guide

The Software Engineer's Guide shall be a user's manual for the PLC and OIT/HMI software programs. It shall include the step-by-step procedures required to obtain communications between the programming computers, PLCs, and OIT/HMI used in the project. It shall include a list of all cables and other hardware required for system programming.

b) Software Support Materials

Software support materials shall include copies of all software programs supplied by the PLC and OIT/HMI manufacturers. In addition, complete PLC program softcopies shall be provided. Programmer manuals shall be included and enable SCADA system personnel to maintain, modify, and expand the capacity and functionality of the SCADA System. These manuals shall comprise:

- The complete set of the manufacturer's standard manuals for the PLC programming software provided.
- All hardware manuals for each of the PLC modules provided.
- All networking and communications equipment manuals.
- All manuals accompanied with the OIT/HMI software packages.

2.4.5. Configuration Inventory Documentation

Configuration Inventory Documentation typically refers to an inventory list for all equipment, software, spare parts, and test equipment comprising the SCADA system. Hardware identification of each unique module by serial number and each software unique module shall be included on the list. The inventory list shall include, but not be limited to, the following information:

- Manufacturer's name, part number, and serial number
- Quantity of units supplied for System/subsystem
- Software Licenses which shall be assigned to WCDPS
- Software modules supplied
- System documentation supplied
- Site, cabinet, rack number or slot, and cables.

2.4.6. Record Documentation

Record Documentation refers to final as-built documentation following final acceptance and prior to project closeout.

Prior to project closeout, the Contractor shall provide all “as-built” documentation. The documentation shall be assembled in 3-ring binder(s) and shall be clearly labeled and include the project name, project number, and date submitted. Each section shall be identified by tabs with a corresponding index to allow for quick access.

The sections shall be divided and include the following information:

1. Index with reference to color-coded sections
2. Contractor and manufacturer’s contact names, addresses, phone #s, and website addresses
3. Network System Diagram and installation details including cable labeling
4. Equipment Matrix to include list of make and models, serial numbers, and IP addresses
5. Project specific configuration and programming instructions
6. Project specific troubleshooting and support guidelines
7. Diagnostic Tool User Guides and Instruction Manuals
8. Device Manufacturer’s Manuals, cut-sheets, and installation guidelines
9. Product Warranties
10. Software Licenses with renewal and update instructions

* All extraneous information including advertising and marketing information not specific to the products shall be removed from manufacturer documentation.

Two (2) hardcopies and one (1) electronic copy on CDs of all Record Documentation shall be delivered and approved by WCDPS prior to project close-out, final payment, and release of retainage (if applicable). All available electronic documents for the manufacturers’ equipment shall be provided in Adobe PDF or Microsoft Word, with drawings in AutoCAD if available. All electronic documents of Contractor’s documents shall be provided in Microsoft Word and drawings in AutoCAD.

2.5. DRAWING STANDARDS

This section defines the general content and format for the drawings that are a requirement for all SCADA system projects.

2.5.1. Drawings Categories

General categories of drawings as defined by WCDPS include:

a) Architectural
b) Civil
c) Electrical
d) General
e) HVAC
f) Instrumentation
g) Mechanical
h) Process Flow Diagrams (PFD)
i) Process and Instrument (P&ID)

j) Structural
k) Network: Computer / Telemetry / SCADA
l) Shop Drawings.

2.5.2. Drawing Preparation

All new drawings shall be prepared utilizing the version of AutoCAD supported by WCDPS.

Prior to issue of the final drawings, letters or numbers (e.g., Revision A, Revision B, etc.) shall identify revisions. Revision of drawings shall be indicated as follows:

a) Change revision letters and provide date of revision in the title block
b) Enter the new revision letter and specify revisions in the revision column.

Symbols used in documents and drawings shall conform to the list of standard symbols as specified below:

- WCDPS Standard Symbols (request from WCDPS).
- Institute of Electrical and Electronics Engineers,
- National Electrical Manufacturers Association,
- ISA-S5.1 Instrumentation Symbols and Identifications, as defined in WCDPS's Standard Symbols drawing
- ISA-S5.3 Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic and Computer Systems,
- ISA-S5.5 Graphic Symbols for Process Displays,
- ISA-S5.4 Instrument Loop Diagrams.

Each drawing shall use symbols from only one standard reference source. The contractor shall follow the WCDPS Standard Symbols drawing and submit all non-standard symbols for approval.

The Contractor shall submit five hard copies of all final drawings and one electronic copy on CD.

Lettering shall be minimum .125-inch height. All lettering shall be Helvetica regular 12 point for general notes and dimensions, 18 points for subtitles and 24 point for general titles and Helvetica slant 12 point shall be used for all general revisions and as-builts.

Drawings shall be 11 x 17 inches unless explicitly directed by WCDPS.

Each drawing prepared by a contractor and submitted for review shall have, in the lower right hand corner just above the title, a 3 x 4 inch blank space in which WCDPS can indicate the action taken. Each drawing shall indicate the following information in the title block:

a) Project, Drawing number, date, title, and revision number;
b) Contractor's name; and
c) Subcontractor/Manufacturer name (if applicable).

Drawings must be arranged for ease of reading. Drawings must not be crowded or cluttered. Notes shall be located as far toward the right-hand border of the drawing as possible. Circuitry

shall be presented on the drawing with a minimum of crossed or offset lines. Electrical connection drawings for panels shall be drawn to reflect the actual physical wiring of the panels.

The contractor is required to use the following line work when preparing drawings:

a) Minimum 0.01 inch for the use of Dim Lines, Leader Lines, and background
b) Minimum 0.03 inch for the use in the primary object of the drawing
c) Maximum 0.07 inches for the use of diagrammatic drafting and reinforcing.

2.5.3. Process Flow Diagram (PFD) Drawings

Process flow diagrams are considered as the master document from which all other process and instrumentation drawings and equipment lists are developed. They are typically encompassing of an entire treatment facility or SCADA network. They are overview representations of major processes and their interactions within the entire process.

2.5.3.1 Purpose and Scope

Process flow diagrams are typically used to show the entire process of the facility. Common processes are typically shown as rectangles and only one pump is shown where required. Directional lines are shown denoting process flow from the beginning or head works of the facility, and how wastewater is routed throughout the facility to the outfall. Non-detailed drawings provide a general description to how the facility operates. It is common that these drawings contain information concerning loop identification numbering from process to process.

2.5.4. Process and Instrumentation Diagram (P&ID) Drawings

Process and Instrumentation Diagrams (P&IDs) convey process, instrument and control equipment information. Understanding these diagrams allows individuals to understand the means of measurement and control of the process within a given treatment process. P&IDs are accurate representations of the physical process or system and shall show equipment in the proper functional relation.

2.5.4.1 Purpose and Scope

A set of P&IDs for a process or sub-process shall include all aspects of the process or sub-process. All piping, equipment, and instrumentation and controls related to that process must be included.

WCDPS P&IDs shall show the following:

- Current project additions, deletions, and modifications
- All automated and non-automated systems
- All instruments and equipment providing inputs to the PLC
- All instruments and equipment receiving outputs from the PLC
- All hardwired interlocks (symbol only)
- Instrument naming with asset name derivation information included.

2.5.4.2 Single Layer Drawings

A single layer shall be used for all WCDPS P&IDs. Instrumentation and equipment located in the field are grouped within a single layer with PLC signal information. It is the intent for WCDPS to use these drawings for depicting process and related instrumentation and equipment, and for process control engineers as a reference tool for relating the instrumentation and equipment to the SCADA System. PLC I/O address information shall be obtained from the PLC files and not depicted on the P&IDs to minimize drawing change management requirements.

2.5.4.3 Interlocks

Process interlocks are control connections wired between two separate equipment items. There are two types of interlocks used within the industry; hardwired and software. WCDPS's standard is to show both hardwired and software interlocks. The usage of electrical signal lines between instruments and equipment denote the interlock. For all software interlocks, the usage of the interlock symbol (request list from WCDPS) shall be shown to denote that an interlock is present; however, details of this interlock will not be shown. The Control Strategy documentation and PLC program will define and describe these interlocks.

2.5.4.4 PLC I/O

All instrumentation terminated at a PLC shall have signal lines connected to a PLC I/O symbol. These lines denote that the instrumentation is controlled or monitored by the PLC based on the signal type.

2.5.4.5 Typifying

The method of typifying relates to showing only one instance for multiple pieces of equipment and is allowed. For example, if there are 3 pumps all connected to and from the same processes, P&ID typifying would only indicate one, and relate information that the other two are represented the same way.

2.5.4.6 Standard Symbols

WCDPS has developed a standard set of symbols and abbreviations that shall be used for all P&IDs including equipment representation, title block, piping and process abbreviations, and WCDPS's custom equipment naming convention. Request the standards symbols and abbreviations from WCDPS prior to starting work.

2.6. QUALITY ASSURANCE

2.6.1. Quality Assurance and Control

SCADA system providers shall maintain quality control over suppliers, manufacturers, products, equipment, software, services, site conditions, and workmanship, to produce Work of specified quality. The SCADA system provider shall maintain adequate records to provide evidence of quality and accountability. These records shall include results of inspections, tests, certification of processes and personnel, discrepant material (including records of disposition) and other quality requirements defined in the project requirements. These records shall be maintained and made available to WCDPS at all times during the performance of the project and for the retention period as specified in the project. Inspection and testing records shall, as a minimum, indicate the nature of the observations, the number of observations made, and the number and types of deficiencies found. Records for monitoring work performance, inspection, and testing

shall indicate the acceptability of work or products and the action taken to correct deficiencies. The records shall be retrievable and traceable from a component failure to demonstrate its original acceptance by test, inspection, and the criteria used.

2.6.1.1 QC Program

The SCADA system provider shall establish and maintain written procedures defining a Quality Control (QC) Program. The procedures shall include, but not be limited to, functional testing, discrepancy control, measuring and test equipment calibration/certification, drawing control, quality assurance records, shipping inspection, software design, installation techniques, and installation inspection. The procedures shall be made available to the WCDPS upon request.

The Quality Control Program shall provide for adequate inspection, instructions for handling, storing, preserving, packaging, marking, and shipping to protect the quality of products and to prevent damage, loss, deterioration, degradation, or substitution thereof. The Quality Control Program shall require and monitor the use of procedures to prevent handling damage to products. Handling procedures shall include the use of special crates, boxes, containers, transportation vehicles, and facilities for material handling. Means shall be provided for protection against deterioration or damage to products in storage. Periodic inspection for the prevention and correction of such deterioration or damage shall be provided.

2.6.1.2 Product and Support Services

The SCADA system provider shall ensure that calibration services from equipment vendors or others utilize an effective time or usage-cycled calibration/certification program. SCADA system supplier shall ensure validity of measurements and tests through the use of suitable inspection, measuring, and test equipment of the range and type necessary to determine conformance of items with the Specification requirements. Measuring devices shall be verified or calibrated against certified standards that have a known traceable relationship to the National Institute of Testing and Standards (NIST). Furthermore, every device so verified or calibrated shall bear an indication attesting to the current status and showing the date (or other basis) on which inspection or recalibration is next required.

The SCADA system provider shall be responsible for ensuring that all supplies and engineering services procured conform to the project requirements. WCDPS has the right to inspect and reject at the source or project site, any supplies furnished or services rendered under the project requirements.

The SCADA system provider shall inspect and physically or functionally acceptance-test all equipment and software delivered under the Contract. Inspection shall occur at appropriate points in the project to ensure quality consideration for compliance with drawings, test specifications, process specifications, and quality standards. Testing shall provide a measure of the overall quality of the completed product and shall be performed so that the testing simulates, to a sufficient degree, end product use and function. When modifications, repairs, or replacements are required, there shall be re-inspection or retest of characteristics affected. Inspection and testing shall provide for reporting to WCDPS any unusual difficulties, deficiencies, or questionable condition.

2.7. TESTING

The testing requirements shall require that the contractor demonstrate that the system was fully tested during development and installation and is a functioning, integrated, and reliable SCADA system before final payments are released. The testing requirements shall require a comprehensive and progressive series of contractor conducted tests, contractor certifications, and WCDPS witnessed demonstrations. For projects that involve reuse of major portions of existing WCDPS SCADA components, i.e. PLCs, the contractor shall provide a test plan and perform the FAT for only the new SCADA components.

The basic testing requirements shall require the contractor to provide tests for all equipment and software. All software and all equipment including mechanical, instrumentation, electrical, and all other equipment related to the SCADA system shall be tested both individually and together as a system.

2.7.1. Factory Acceptance Testing (FAT)

The requirements of this section shall be applied to all major SCADA system projects. If the amount of equipment and software to be provided under a particular project does not warrant a Factory Test, these requirements may be waived at the discretion of the WCDPS Project Manager.

A Factory Acceptance Test and verification for all deliverable equipment, software, and associated documentation shall be performed prior to shipment of subsystems or major components. The equipment factory tests shall be performed to verify that the equipment is manufactured and assembled correctly, is operating as designed, and is in compliance with the contractual requirements for the deliverables. The factory test shall be performed to verify that the software and hardware will meet the functional and performance requirements of the SCADA system project.

The contractor should submit a FAT test plan to WCDPS for approval prior to start of the FAT. The FAT shall include the test and verification activities specified in this section.

2.7.1.1 System Configuration and Serialization Verification

Prior to beginning the Factory Acceptance Testing, the elements shall be subjected to system deliverable configuration and serialization verification. A copy of the Configuration Inventory Documentation for each site shall be annotated to reflect this verification and shall be included with the Factory Acceptance Test Report. No equipment replacement or substitutions shall be permitted without WCDPS's approval.

2.7.1.2 Equipment Test and Verification

Hardware Tests

The Factory Acceptance Test for the equipment (hardware) shall include individual end-item verification and integrated testing of all components. These tests shall include visual inspection verification and running the hardware diagnostic programs, plus all special diagnostic programs used by the SCADA system supplier to demonstrate that the hardware integration task has been completed.

Inspections

The following inspection checks shall be performed on all deliverable hardware items, as applicable:

a) I/O Subsystem physical layout
b) Power supply mounting
c) Power cable routing
d) Data cable routing
e) Wiring runs properly installed
f) Fans and blowers are unobstructed
g) Power supply and power conditioning equipment correctly installed
h) Wire numbering and color coding
i) Device labeling
j) Enclosure integrity
k) Paint work.

2.7.1.3 I/O Point Checkout

The SCADA system supplier shall perform a complete, end-to-end checkout for every I/O point from the field wiring terminal strip to a SCADA workstation and the local OIT. The I/O Point Checkout shall be witnessed by WCDPS or WCDPS's Representative and shall be conducted on each PLC on a site-by-site basis. The SCADA system contractor shall test every input and output point including spares for proper operation. Test signals shall be injected to verify the operation of each Analog Input (AI) and Discrete Input (DI). Each Analog Output (AO) and Discrete Output (DO) shall be also tested for proper operation.

The SCADA system contractor shall develop a complete I/O Point Checkout Test Procedure. The test procedure shall identify the method to be used by the SCADA system supplier for injecting test signals for each input point type and the method to be used for verifying the appropriate output signals for each output point type. The SCADA system supplier shall program the PLCs to demonstrate that signals reporting under 4 mA and over 20 mA do not report negative or out of range values.

The SCADA system contractor shall develop a point checkout form for each I/O point. The point checkout form shall include the point ID, description, all checks performed for the point, date and time of the check, and a signoff block for the SCADA system contractor's representative, and the WCDPS representative. For each item checked, the form shall include both the expected value/result and the actual value/result witnessed.

The following items shall be checked for each I/O point as applicable:

a) For each analog input point, the following values shall be checked:
   - Value at -1% of full scale (ramped in both directions)
   - Value at 0% of full scale (ramped in both directions)
   - Value at 25% of full scale (ramped in both directions)
   - Value at 50% of full scale (ramped in both directions)
   - Value at 75% of full scale (ramped in both directions)
   - Value at 100% of full scale (ramped in both directions)
   - Value at 101% of full scale (ramped in both directions)

- High Alarm Limit
- HiHi Alarm Limit (if entered in database)
- Low Alarm Limit
- LoLo Alarm Limit (if entered in database)
- Alarm Deadband.

b) For each analog output point, the following values shall be checked:
- Milliamp reading at 0% of full scale (ramped in both directions)
- Milliamp reading at 25% of full scale (ramped in both directions)
- Milliamp reading at 50% of full scale (ramped in both directions)
- Milliamp reading at 75% of full scale (ramped in both directions)
- Milliamp reading at 100% of full scale (ramped in both directions).

c) For each discrete input point, the following items shall be checked:
- For status points, proper indication
- For alarm points, proper alarm notification.

d) For each discrete output point, the following items shall be checked:
- Proper operation
- Actuation time-out alarm (if value is entered in database).

The completed I/O Checkout forms for all points shall be included as part of the I/O Checkout Test Report to be prepared and submitted at the conclusion of all I/O checkout activities.

2.7.1.4 FAT System Configuration

The SCADA system contractor shall stage at its facility the PLCs, control panels, OIT/HMI, controllers, signal simulators, etc. for an integrated Factory Acceptance Test.

2.7.1.5 System Functional Test

Test Facets

The functional test shall exercise specified system function and shall include, but not be limited to, the following. For projects that involve reuse of major portions of existing WCDPS SCADA components, i.e., PLCs, the contractor shall provide a test plan and perform the Functional Test for only the newly added SCADA functionality:

a) Rigorous exercising of all devices both individually and collectively
b) Verification of proper scanning and data acquisition of all status and data points
c) Verification of proper Control Strategy up/down loading to the PLCs
d) Verification of all Control Strategies to ensure that they result in the correct sequence of operation for each site
e) Demonstration of all required device control functions
f) Demonstration of analog input, pulse input, and analog output accuracy
g) Demonstration of the functionality of the spare I/O of each panel. This verification will be to the panel demarcation point
h) Testing the user interface functions for all PLCs that have local operator interfaces
i) Create and process device failure conditions
j) Demonstration of all functions and components

k) Demonstration of recovery from power loss
l) Demonstration of UPS and battery backup functionality.

Support Software Tests

The Factory Acceptance Test for the support software shall include the following, as a minimum:

a) Demonstration of connecting the programmer's laptop to each type of PLC and establishing communications and running diagnostics.
b) Demonstration of editing capabilities including the addition and deletion of points in a PLC, the addition, deletion, and modification of control strategies, and the modification of the PLC database.

Test Thoroughness

The FAT shall demonstrate compliance to the requirement of the specification. The SCADA system supplier shall use a database such as Microsoft Access to build a FAT cross-reference table that lists each specification paragraph that imposes a uniquely identifiable technical requirement. The SCADA system supplier shall add to the format a data field for the FAT test number of the test that is going to demonstrate compliance with the requirement. A second version of the table, sorted by test number, shall also be printed. This will make it possible to select any specification paragraph and identify the FAT test that should demonstrate the feature. The version ordered by test number can be used to verify the completeness of each test and shall be used during the FAT to check off the features demonstrated.

72-Hour Continuous Test

After the successful completion of the functional testing specified above, a 72-hour continuous run of each PLC provided shall be performed. For projects that involve reuse of major portions of existing WCDPS SCADA components, i.e., PLCs, the contractor shall provide a test plan and perform the 72-Hour Continuous Test for only the new SCADA components. The test shall be passed if no function is lost, no hardware or software failure occurs, and no module automatic failover occurs. Hardware failure is defined for this test as the loss of a major piece of hardware, such as a PLC processor, I/O board, power supply, UPS, other panel equipment, or improper operation by the controller.

During this test, the PLC shall be exercised (with simulated inputs, events, and conditions) in a manner that approximates an operational environment.

No programming changes will be allowed to bypass failed modules during this test. Any software and/or hardware correction made to the PLC shall result in the mandatory rerun of the entire 72-hour test for that PLC.

During the 72-hour period, at least 24 hours of unstructured testing shall be included in which WCDPS or WCDPS's representatives shall be allowed to operate the equipment without the SCADA system supplier's supervision. WCDPS personnel will exercise the PLCs by randomly selecting functions to perform, including starting and stopping pumps. The PLC shall perform as specified. Any deviations shall be corrected and demonstrated to WCDPS or WCDPS's representative.

2.7.2. Site Acceptance Testing (SAT)

A Site Acceptance Test of the functions, software, and performance shall be conducted individually at each site (or facility process) after all elements have been installed and the I/O Point Checkout has been completed at each site.

The system Site Acceptance Tests shall be performed to verify complete operation of the system, requiring a repeat of much of the factory acceptance tests but with the equipment installed at the permanent sites, and shall include additional tests required to verify field-installed equipment which was not available at the factory. For projects that involve reuse of major portions of existing WCDPS SCADA components, i.e., PLCs, the contractor shall provide a test plan and perform the Site Acceptance Test for the SCADA system including portions that could not be tested prior to equipment installation. WCDPS must approve all testing on installed equipment.

The SCADA system contractor shall:

a) Verify the facility installation.
b) Demonstrate each functional requirement identified by the specification. This demonstration shall repeat the tests used during FAT, but using real rather than simulated conditions.
c) Demonstrate all equipment control functions, including the operation of automatic control strategies. Actuation of field devices shall be closely coordinated with WCDPS's staff.
d) Verify system performance parameters and system responses under field operational conditions.
e) Verify accuracy of documentation, especially operator's manuals, software documentation, and site operating instructions.

As each Site Acceptance Test is completed, the SCADA system contractor shall repeat steps a-e above for the next site until all sites have been successfully transferred and tested. During this test phase, the SCADA system contractor shall provide technical representatives for the execution of the Site Acceptance Tests.

The SCADA system contractor's test support personnel shall be qualified to resolve and correct problems encountered with the system during the tests. In addition to test support personnel, the SCADA system contractor shall provide all test instruments and equipment necessary to troubleshoot any of the PLC problems encountered.

2.7.3. Site Availability Demonstration (SAD)

At the completion of system Site Acceptance Tests, WCDPS will conduct a System Availability Demonstration (SAD) test utilizing all equipment, software, and services provided under the project in the normal day-to-day operation of the system. During the test, the system shall meet the availability criteria as defined below.

The System Availability Demonstration shall be performed under field operating conditions. All functional and performance requirements specified in this document shall be met during the SAD.

The system shall be subjected to System Availability Demonstration evaluation for 30 days (720 hours). If at the end of the 30 days, the system availability is determined to be less than that required, the test shall continue on a day-by-day basis, dropping off the oldest day's test results. This sliding window concept shall continue until the system passes the test or until 45 days time has passed, at which time WCDPS shall have the right to pursue other alternatives as specified under the project contract.

2.8. SUPPLIES AND SPARE PARTS

The SCADA system contractor shall furnish all spare parts, maintenance items, tools, and special test equipment needed to maintain all elements of the system. Quantities of spare parts shall be determined and specified for each project. In general, spare part will include:

1. One (1) of each PLC
2. One (1) PLC communications adapters
3. One (1) each type of PLC I/O base
4. 25% spare I/O capacity in each PLC configuration
5. Minimum of one (1) or 10% of network components such as routers, switches, hubs, splice kits, 100 base-FX connectors
6. Minimum of two (2) or 10% of all other control panel and instrumentation equipment.

The requirements of this section shall be applied to all major SCADA system projects. If the amount of equipment and software to be provided under a particular project does not warrant such a spare parts list, these requirements may be waived at the discretion of the WCDPS Project Manager.

Spare parts shall be identical to the installed components. Any modifications required of the installed components shall be provided on the spare parts at no extra cost. The spare parts must be as listed in the spare parts section of the O&M manual.

Spare parts shall be provided in the manufacturer’s original packaging to prevent accidental damage or degradation during storage and the package shall be clearly marked as to model, type, part number, etc.

2.9. WARRANTY

The Warranty period for the SCADA system, usually two years, shall commence at the time of Final Acceptance of the complete system. Final Acceptance as defined in the contract documents shall be used as the milestone that verifies completion of the project and allows the warranty period to commence.

Final Acceptance shall be specifically defined in the project contract documents, and shall include, as a minimum, the following technical requirements:

1. Satisfactory completion of the Site Acceptance Test
2. Satisfactory completion of the Site Availability Demonstration
3. Submittal and approval of Record Documentation
4. Delivery and acceptance of all supplies and spare parts

The SCADA system contractor shall provide two (2) notarized copies of warranties and bonds required for products identified in each individual section of the contract specifications.

The SCADA system contractor shall ensure that all guarantees or warranties, issued by manufacturers of machinery, equipment and all other materials supplied by SCADA system supplier or by SCADA contractor's subcontractors or vendors, covering the performance of the material and equipment supplied by them, be issued in the joint name of the SCADA contractor and WCDPS such that WCDPS receives the same benefits and protection provided by any such guarantees or warranties as the SCADA system contractor. The issuance or existence of any such guarantees or warranties shall however in no way relieve the SCADA system contractor of his obligations under the project contract.

2.10. TRAINING STANDARDS

Training for applicable management, engineering, operations and maintenance personnel should be included for all SCADA projects. It is important that WCDPS personnel be adequately trained in the installation, operation, maintenance, and expansion procedures and techniques of the SCADA system. Each SCADA system project shall include as applicable a combination of standard product vendor-training and custom SCADA system contractor training.

2.10.1. General Requirements

Experienced personnel should conduct training and the contractor should provide all necessary training material. Each trainee should receive individual copies of the technical manuals and pertinent documents. All courses should include approximately 50% lecture and 50% hands-on training with the system. All training courses (or key portions of multiple-day sessions) should be videotaped and copies should be provided to WCDPS for review and reference.

The performance of each of the personnel being trained should be determined through testing. As a result of this testing, each of the personnel should be classified as either satisfactory (demonstrates basic knowledge and performance of the subjects presented in the course) or unsatisfactory (requires more training on the subjects).

The following subjects should be covered in the training:

1. PLC Programs for Instrumentation Staff
2. Functional description review
3. Control narrative review
4. Non standard instrumentation O&M review
5. HMI Operations review for Operation Staff

2.10.2. Provided Materials

Comprehensive training manuals should be provided for all training courses and present the course material in a format that is easy to comprehend. The manuals shall serve as teaching aids during presentation of the training classes and as reference material after the training has been completed. It is not recommended that the Contractor use system technical documentation solely as the training manuals since system documentation is generally not written in an instructional format. Portions of system documentation may be incorporated into training manuals provided that the overall manual achieves an instructional format.

2.10.3. Types of Courses

The WCDPS personnel training requirements will depend upon the SCADA system project. The duration of each training course should depend upon the complexity of the system. In general the following types of training should be available to personnel as required:

1. Management/Supervisor Training - It is paramount that management and supervisors have a general understanding of the system. Therefore, the contractor should provide a course of one to two days duration to include an overview of system operation.

2. Instrument Engineer Software Training - The contractor should provide sufficient training to enable the creation, modification, integration, testing and documentation of any software utilized by the system.

3. Instrument Engineer Hardware Training - The contractor should provide sufficient training to enable the addition, deletion, modification, integration, testing and documentation of any hardware utilized by the system.

4. System Operator Training - Operations personnel should be provided with training to enable and encourage effective and straightforward operation of the WCDPS facilities. The training duration will vary according to the system.

2.10.4. Training Plan

The Contractor is required to submit a Training Plan not less than 60 days prior to the scheduled start of training. The Training Plan should address:

- Syllabus for all classes
- Instructor names and qualifications
- Schedule of classes
- Pre-requisites for classes, if any
- Sample training materials.

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0		Initial Release
Rev 1.0	March 2009	Revised equipment tagging procedure
Rev 1.1	June 2010	Updated footer and WCDOE references

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3. ELECTRICAL DESIGN STANDARDS

3.1. BASIC DESIGN REQUIREMENTS

3.1.1. Introduction

The electric power serving a control computer system must be "clean," stable, and reliable. This means the electrical distribution system must be protected against power outages, voltage fluctuations, distortions, transients, surges, and spikes.

In addition, all electrically powered equipment, from computers to instrumentation, must be properly grounded to reduce noise and interference, protect personnel and equipment, and provide a "quiet" environment for electronic instrumentation.

This section of the SCADA System Standards describes what is required to provide a proper power source and system ground to minimize electrical problems.

3.1.2. Power Requirements

Providing clean power for the SCADA system is critical. Voltage fluctuations and outages can cause output errors, loss of data, equipment damage, and other problems. High-speed transients can damage memory devices, power supplies, and semiconductor components. Transients can cause data errors in instrumentation, communication, and computing devices.

Problems can occur in a process plant regardless of whether power is supplied by the utility or by an on-site generator. Typical utility problems include load switching, load shedding, accidents, and brownouts. Normal power net switching by a local utility can cause several hundred outages per year, each lasting one second or more. The inability of utilities to meet power demands in peak periods forces them to schedule "brownouts" (i.e., a planned 3, 5, or 8% voltage reduction at the generating point). Such a major reduction could take the computer's voltage below its lower operating limit. On-site power generation has many of the above problems, plus capacity limitations and frequency stability difficulties. Therefore, it is necessary to provide electrical power to SCADA system cabinets and equipment from an uninterruptible power supply (UPS).

3.1.3. Uninterruptible Power Supply

Uninterruptible power supplies shall be provided to support the SCADA system for the following equipment to provide back-up power for the period of time specified in the contract documents:

- The SCADA system equipment in control rooms
- At each PLC control panel

3.1.3.1 Control Room UPS

The control room UPS shall be designed to support all SCADA system equipment, including computers, monitors, printers, and network components.

A. UPS

1. The UPS shall be a true online system having Normal, Backup, Recharge, Automatic Restart, Bypass (Automatic and Manual)
2. Modular, scalable, multibay frame design consisting of the appropriate number of modules to produce no less than 125% times initial continuous full critical load capacity and N+1 redundancy.
3. System Continuous Rating: Minimum output voltage of 110 VAC, 60 Hz over entire battery voltage range at specified power factor. Maintain output voltage within specified limits at any load from full load to no-load.
4. Battery Capacity: Capable of operating at full rated load for 60 minutes.
5. Input Voltage Limits: +/- 10 percent.
6. UPS Power Factor over full range of loads and input voltages: 0.7 lagging power factor
7. Output Voltage Regulation: +/- 3 percent full range of DC input and no load to full load variations.
8. Ambient Temperature for Operation: 0^{o}C to + 40^{o}C at 95% RH.
9. Output Free Running Frequency: 60 Hz +/- 0.5 percent.
10. Output Harmonic Distortion: Maximum 5 percent RMS total harmonic distortion (THD) and maximum 3 percent any single harmonic, at rated frequency and voltage, from 10 percent load to full load and over battery voltage range, measured into a linear load.
11. Output Current Limit: 150 percent of rated output current surge and 125 percent for 10 minutes with utility power on. 150 percent surge and 110 percent for 10 minutes on inverter power.
12. Efficiency: 90 percent at full load with utility power on, 87 percent on inverter at full load.
13. Voltage spike attenuation from utility power line: 2000:1.
14. Common Mode Noise Rejection from load: Better than 120 dB.
15. Transverse Mode Noise Rejection from Load: Better than 60 dB.
16. Isolation of Load from Power Line: Complete isolation, with less than 2 pF of effective capacitance between line and load.
17. UPS System Reliability: 50,000 hours MTBF, minimum.
18. UL Listing: UPS system shall be UL listed.
19. System shall have front panel LEDs for AC line, inverter (with audible tone) UPS ready and not ready, and alarm with additional coded alarm tone for low battery, high battery, low runtime left, low AC out, high AC out, output overload, charger trouble, shutdown pending, low DC, alarm test, inverter malfunction, system malfunction.
20. It shall provide liquid crystal display of power parameters and alarm condition messages, AC volts in and out, AC current in and out, battery current and voltage, AC frequency, battery runtime to go.
21. Provide four dry contacts, one which opens on general trouble, one which opens on failure of primary voltage, one which opens on batteries not OK, and one which opens on low battery voltage condition approximately 10 minutes before UPS will shut down on low battery at full load. These alarms shall be wired to the PLC I/O.
22. Provide a bypass circuit as an integral part of the UPS and automatic transfer logic.

B. Battery:

1. Storage Battery: Sealed, maintenance free, flame-retardant, valve-regulated, gas recombination, lead acid with expected service life 5 years.

3.1.3.2 PLC Control Panel UPS

The PLC control panel UPS shall be designed to support all control system equipment in the panel, including the PLC, the OIT, network components, and instrument power supplies The UPS shall conform to the same specification as the control room UPS, with the exception that the UPS and battery may be in the same housing.

3.1.4. Codes and Standards

The contract documents should require that all work by the contractor conform to the applicable requirements of the current National Electrical Code and the local Electrical Code, together with the code and regulations of public utilities and all others having jurisdiction.

The contract documents should require that all equipment be designed, constructed, installed and tested and is in conformity with all requirements, and as a minimum the following applicable standards:

a) Institute of Electrical and Electronics Engineers (IEEE)

b) Underwriters Laboratories, Inc. (UL)

c) National Electrical Manufacturers Association (NEMA)

d) National Electrical Code (NEC)

e) American Society for Testing and Materials (ASTM)

f) American National Standards Institute (ANSI)

g) National Board of Fire Underwriters (NBFU)

h) National Fire Protection Association (NFPA)

i) National Electrical Contractors Association "Standard of Installation" (NECA)

j) Joint Industrial Council (JIC)

k) Insulated Cable Engineers Association (ICEA)

l) Instrument Society of America (ISA)

m) Occupational Safety and Health Administration (OSHA).

In addition, all materials and equipment shall be listed by Underwriters Laboratories Inc., except for classes of materials and equipment not available with such listing.

3.1.5. Shop Drawings Requirements

The shop drawings provide the WCDPS Engineer a way to monitor the contractor’s compliance with the contract requirements. This section covers what should be included in an electrical

submittal in order to maintain project control. Quantities of drawings and submittal requirements are defined in Section 2.5.

The following electrical shop drawings should be provided and defined in the contract documents as a minimum submittal list for all WCDPS SCADA projects:

a) Overall site plans. Show exterior conduits and wiring to radio antennas, telephone poles, yard valves and meters, and all other related components.

b) Interior power plans. Show interior conduits, wiring, junction boxes, all control system equipment, control panels, instruments, and all other related components.

c) Interior and exterior wall elevations. Show mounting of PLCs, disconnect switches, power distribution panels, conduit connections to existing power distribution panels, light switches, emergency pull switches in control centers, antenna feed line routing, and locations of all other electrical devices and conduit systems.

d) Detail drawings for backup panel, interposing relay panel, relay control cabinet, PLC assembly and installation. Include conduit entry, exterior panel elevations, interior panel elevations, device and nameplate schedules, wire way and terminal block placement, electronic module and power supply placement, fans, heaters, thermostats, filters, and all other devices.

e) Elementary control and wiring diagrams for all control panels, PLC control panels and remote I/O panels (if required).

f) Elementary control diagrams for all switchgear, motor starters, and process equipment control circuits having interfaces with the project.

g) Instrument loop diagrams per ISA S5.4 for all instruments, pump controls, valve and gate controls, solenoid valve controls, status contacts, and all other devices connected to PLC I/O systems. Include terminal designations for all wiring, including shields of instrumentation cables. Include wire and cable numbers.

h) Control room power distribution panel schedules.

i) Point-to-point conduit, wire, and cable lists for all conduit, wiring and cabling from field devices to and from I/O cabinet or shall be developed using the latest version of Microsoft Excel or Microsoft Access supported by WCDPS. Include conduit, wiring, and cabling for all intermediate conduit runs to junction boxes, manholes, pull boxes, termination cabinets, interposing relay panels, backup panels, and all other points of access or termination for wiring and cabling.

Include as a minimum, the following database fields for each run of conduit/raceway:

1. Conduit tag number
2. Conduit/raceway source
3. Conduit/raceway destination
4. Conduit/raceway length
5. Conduit/raceway intersections
6. Conduit/raceway size

7. Wire sizes and types for all wires
8. Cable type and conductor sizes for all wires
9. Wire tag numbers for all wires
10. Cable tag number for all cables
11. Instrument loop numbers for all wires and cables.

Catalog cuts from manufacturers' data sheets for conduit, wire, cable, enclosures, disconnect switches, circuit breakers, lighting equipment, indicator lights, pushbuttons, selector switches, relays, sockets, terminal blocks, fuse blocks, wireways, control panels, termination cabinets, pull boxes, power line conditioners, UPS systems, heat tracing systems, and all other electrical equipment described in the contract documents.

Where catalog cuts describe more than one model or option, circle the item that applies, or stamp the item with a bold arrow pointing to it. Draw a bold line through all text and pictorial information that does not apply to the item.

Information submitted for approval shall be according to the requirements of the submittal section of the contract specification and shall include:

a) Specification section and paragraph number.

b) Manufacturer's name and product designation or catalog number.

c) Electrical ratings.

d) Standards or specifications of ANSI, ASTM, ICEA, IEEE, ISA, NEMA, NFPA, OSHA, UL, or other organizations, including the type, size, or other designation.

e) Assembly drawings in sufficient detail to identify every part of the specified equipment.

f) Dimensioned plan, sections, and elevations showing means for mounting, conduit connections, and grounding, and showing layout of components.

g) Materials and finish specifications, including paints.

h) List of components including manufacturers' names and catalog numbers.

i) Wiring diagrams including single-line, elementary connection and interconnection diagrams.

Elementary control diagrams shall use the ladder diagram format incorporating line number, operation function statement, contact location line number with an underline for a normally closed contact and a description of operation of each device. Label each contact with its function, as well as its number, e.g.: "FIT 101, Discharge Flow ". Format and symbols should be subject to approval by WCDPS. Show terminals for field wiring. Show field wiring as dashed lines.

Instruction booklets, operating manuals and parts list, with all necessary information required for the installation and maintenance of the equipment and for ordering replacement parts.

Manufacturer's recommended list of spare parts.

Detailed drawings, descriptive data and other data sheets showing design information that verifies the equipment meets the technical requirements of the Specifications.

Instrumentation cable schedule detailing each cable routing shall be developed using the latest version of Microsoft Excel or Microsoft Access supported by WCDPS. The schedule shall include, as a minimum, the following data for each cable:

- Cable number
- Cable type and conductor size
- Conductor insulation color each cable conductor
- Instrument loop number served by each conductor group
- Terminating instrument numbers (source and destination)
- Conductor numbers
- Conduit number through which cable is routed.

3.1.6. Cable Ways Requirements

The building may require extensive internal cabling initially and should be provided with features that permit easy modification and addition of cable and conduit in future years. Cable troughs should be sized to accommodate cables anticipated for each area and for future expansion.

Vertical cable shafts are recommended for routing cables and conduits between floors of any two-story sections of a building. Conduits and cables should be arranged to avoid immediately adjacent routing of heavy current carrying circuits and low-level data circuits. Steel conduit should always be used to minimize inductive coupling between parallel wiring.

3.1.7. Conduit and Wire Way Fill Requirements

The National Electrical Code (NEC) prescribes fill factors, or the maximum percentage of the internal cross-sectional area of conduit and tubing that it is permissible to fill with electrical conductors. The NEC also calls attention to the fact that the length of a conduit run, number of bends, and other factors might result in less fill than the maximum. Tables in the NEC indicate the maximum number of conductors of a given size and type that are permitted to occupy a given trade size of conduit.

3.1.8. Clearances

Maintain clearances from electrical panels and other electrical installations the NEC. Maintain working clearances around electrical equipment required for proper maintenance, operation and accessibility.

3.2. WIRING AND CABLE STANDARDS

This section defines general guidelines for wiring and cable for monitoring and control signal wiring between field-mounted transmitters, control devices, local panels, device panels, and PLC control panels. This standard is also applicable to power wiring between the power distribution panel, motor control center, and field mounted transmitter.

3.2.1. Guidelines

All wiring and cable shall be installed in conduit as described in Section 3.2.4. The type of conduit used shall be suitable for the purpose intended.

Each wire and cable shall use an identification or number code to facilitate wiring and troubleshooting. Wire and corresponding terminals on each end shall be identified.

Wiring shall be continuous and without splices. The contract documents should state the Engineer must approve any exceptions. If splices are necessary, all splicing shall occur at a junction, pull box, or termination cabinet. Continuity of all conductors and shields shall be maintained at a splice. Connections shall be made by compressing the two wires to be joined with a compression device for power wiring and by terminal strip for control wiring.

3.2.1.1 Power and Control Signal Wiring and Cable Types

All power wire insulation shall be rated 600 volt RHW or XHHW. Conductors shall be copper. No wire smaller than number 12 AWG shall be used for power wiring.

3.2.1.2 Signal Wiring and Cable Types

Single conductors shall be 14 AWG or larger. Multiconductor cables shall be 16 AWG. Signal wiring insulation shall have a minimum dielectric strength of 600 volts. Insulation temperature range shall extend to at least 80 degrees C and the insulation shall be suitable for wet or dry locations. Multiconductor cable overall jacket material shall be moisture resistant, abrasion resistant, flame retardant and compatible with the environment in which it is installed.

Multiconductor cables shall be Belden 8627, 9623, 8628, 8629 or current catalog number, or approved equal.

3.2.1.3 Twisted Pair Instrumentation Cables

Twisted pair instrumentation cables shall be 18 AWG, with each pair individually shielded, and an overall shield. Signal wiring insulation shall have a minimum dielectric strength of 300 volts.

All twisted pair cables shall be uniformly twisted with a minimum of six twists per foot. All pairs shall be twisted in the same direction. Shields shall be continuous foil or metalized plastic providing 100% coverage. A drain wire in continuous contact with the shield shall be included.

Twisted pair instrumentation cables shall be Belden 147xA series or current catalog number,, or approved equal.

3.2.2. Color Coding

All single conductor wire must be color-coded including wires in pull boxes or junction boxes, even if not terminated in the boxes. All single conductor wires shall be color-coded as defined in this standard.

No. 10 AWG and smaller wires shall have colored insulation. No. 8 AWG and larger wires may be identified by using color coded non-conducting, self-adhesive vinyl tape, attached at each end of the cable including junctions. The tape shall be Brady Perma-sleeve or equal.

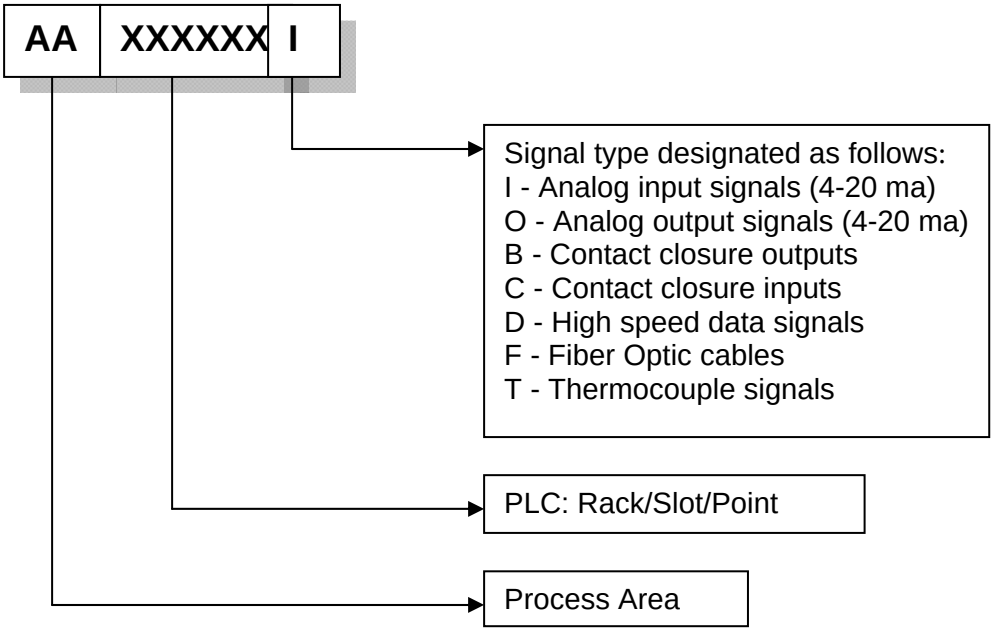
Wire and cable shall be identified using the following schedule:

DESCRIPTION AND/OR FUNCTION	VOLTAGE	NUMBER OF PHASES	COLORS
Lighting and Power	120	1	Black White (Neutral) Green (Ground)
Lighting and Power	120/240	1	Black Red White (Neutral) Green (Ground)
Lighting and Power	120/208	3	Black Red Blue White (Neutral) Green/Bare (Ground)
Lighting and Power	480	3	Brown Orange Yellow Green/Bare (Ground)
Multi-Conductor	-----	--	In accordance ICEA S-61402, Part 5 Method 1
Control	120	1	Red
DC Control	24 VDC +	--	Purple
DC Control	24 VDC common	--	Light Blue
4-20 mA	--	--	Blue
Motor Control	120	--	Red
Relay Circuits	120	--	Red
Automatic Control or Foreign Power	120	--	Yellow

DESCRIPTION AND/OR FUNCTION	VOLTAGE	NUMBER OF PHASES	COLORS
Alarm	120	--	Orange
Instrumentation	120	--	Orange
Telemetering	120	--	Orange

3.2.3. Cable Identification Numbering

This section defines the cable identification requirements. A block of numbers to be used for control cable identification will be assigned for each new project or contract. Cable numbering shall use a multiple character alphanumeric numbering scheme composed in the following manner.



Each single conductor wire shall be numbered with an abbreviated number of the terminal to which the wire is to be connected. Tags or wire markers shall be Brady Perma-sleeve or equal. The wires shall be identified near the connecting terminal with the number of the terminal it is to be connected to one inch back from the first tag. The tag number of the terminal on the opposite end of the wire shall be applied.

Multiple conductor (unshielded) cable assemblies shall all be marked with its designated cable number where it enters the panel. The identification number tag shall be round plastic with the identification number engraved on the plastic tag. Groups of wires shall be separated and marked with #19 insulated twisted wire of the same color as group tracer. Individual wires shall be tagged as described above.

Large multiple conductor (shielded) cable assemblies and cable groups shall be marked as described above. Small cable assemblies shall be marked with the designated cable number using Brady cable markers.

Individual wires shall be marked near the terminal with an abbreviated form of the terminal number to which it is connected. One inch back from the first tags, on marked sleeves, the number of the cable from which it was taken shall be marked.

Cables that have intermediate termination points in junction boxes, pull boxes, or feed through points in manholes shall be identified by engraved 1" x 3" plastic tags. The tags shall be white laminated plastic with engraved black 5/32" high characters. The tags shall be attached to cables with plastic tie wraps.

3.2.4. Signal Wiring and Grounding

Modern control systems use low voltage or current signals for the information transfer between the field-mounted equipment and the process control computer. These signals can get "lost" in unwanted background signals, commonly called noise, if proper design and installation techniques are not applied.

The accuracy of the SCADA system is dependent on the signals being clear of noise. A high signal-to-noise ratio is necessary to ensure the SCADA system is not compromised in terms of accuracy and sensitivity by high noise levels.

Proper I/O wiring and grounding will ensure a high signal-to-noise ratio and a working control system.

3.2.4.1 Noise Definitions

Measurements of the noise in the wiring arriving at either the computer or the field control device through the wiring are measured two different ways:

a) Normal Mode Noise
b) Common Mode Noise.

Many different types of problems may have created the noise but these are the two ways which the noise is defined and measured.

Normal mode noise is measured as the differential voltage between two signal wires. Normal mode noise is commonly the result of RFI (radio frequency interference) or EMI (electromagnetic interference). RFI is created by radio frequency energy coupled into signal wires. EMI is created by either high currents running in conductors or by large motors. A magnetic field is produced by these sources, which radiates through air. If signal wires are in the proximity of the magnetic field, voltage is generated in the signal wire by transformer coupling.

Common mode noise is measured between each signal wire and ground. Common mode noise is the result of an electrostatic field rather than an electromagnetic field. This field is capacitively coupled into the signal wire. Different ground potentials in a plant are the most common source. If there are two grounds used in a system the potential between the grounds will cause current to flow through the signal wire and create noise.

3.2.4.2 Noise Reduction Practices

Only shielded twisted pair wire shall be used for all 4-20 mA instrumentation wiring. Refer to Section 3.2.1.3. Each twisted pair in a multi-pair cable shall have its own shield. The multi-pair cable shall also have an overall shield that provides extra protection for each shielded twisted pair. The mechanical strength of the cable must meet the pulling requirements for installation in conduit.

Separation of wires that contain different levels of voltage will also reduce noise problems. Signal levels can be divided into three categories:

a) High level signals, 50 volts and above
b) Medium level signals, 1 to 24 volts
c) Low level signals, millivolt range.

High voltage signals, 480 volts and above, shall be separated from signal wiring by a minimum distance of 12 inches and be run in different metallic conduit. In addition, the signal wires should be in metallic conduit and not in a cable tray anytime the path must parallel high voltage. Runs that cross should be at a ninety degree angle to reduce the EMI from the magnetic field generated by the high voltage cables.

Select a route for the signal wires which is free from noise sources. Large motors or SCR drives are a major source of noise.

Intermittent noise sources should also be identified and taken into account in the design. Welding equipment used for maintenance and radio transmitters which produce RFI can cause noise problems which are intermittent in nature and very difficult to track down. Survey the location where cabinets or boxes are going to be installed for RFI sources, both in the facility and outside of the facility (radio or TV transmitter nearby). Cabinets designed to eliminate RFI interference can be obtained for areas with high RFI interference.

All cables shall be installed in raceway. Conduit is the preferred raceway. Conduit, cable tray and wireway provide physical protection for signal cables. Metallic conduit provides the best protection from physical damage and noise.

The shielding on a twisted pair cable must be connected to ground at one end only. Best grounding practices and conditions are achieved through grounding at the PLC control panel. The shield at the ungrounded end of the cable must be bent back, away from the conductors, and covered with insulating tape. Installation requirements must call for installing an insulated sleeve over each of the drain wires and removing the shield material back to the point where the cable assembly is split to allow the individual conductors to be separated from the cable. The cable assembly shall be taped at the point where it is split to assure that the loose pieces of shield material do not contact the enclosure that the cable assembly enters.

The shield wires may be connected to a dedicated instrument ground. If this type of connection is made, special attention to the shield in relationship to other conductors must be taken. Neither the shield drain wire nor the aluminized Mylar or braided copper shield material may touch anything connected to another grounding system.

The drain wire shall terminate on an insulated copper ground bus contained within the enclosure. At intermediate connection points such as field junction boxes the shield wires shall be connected to terminal blocks to maintain continuity of the shield across the entire signal path. No splicing of shields is allowed at any location.

Where there is a possibility of lightning striking the I/O wiring, surge arrestors shall be provided for the individual I/O points.

3.3. GROUNDING STANDARDS

3.3.1. Shielding

Article 250 of the NEC covers the general requirements for grounding and bonding of electrical installations. The NEC emphasizes safety as related to power circuits. Additionally, the problems of crosstalk and injection of unwanted signals into low-level data circuits and equipment must be considered.

In order to minimize interference between various equipment groups, the single point ground concept is recommended. The following definitions apply with the single point ground concept.

Earth Ground - A high quality earth ground of as low an impedance as practical.

Site Reference Ground - A central ground tie point which serves as a single reference ground point for all parts of the system and the building.

Grounding Circuits - With the single point ground concept, several independent insulated ground circuits are established by functional usage and all are terminated at the Site Reference Ground point. Except for structure ground, the individual ground circuits must be insulated from each other except at the Site Reference termination point. Computer cabinet and signal grounds must never share electric power ground circuits. Typically ground system circuits are established for:

a) Electric AC neutrals
b) Electrical equipment cabinet/conduit grounds
c) Computer/peripheral cabinet grounds
d) Signal ground
e) Facility/structure ground.

Site specific ground circuits can be established in different parts of the building. For example, all computer equipment type cabinets in a computer room may be connected by insulated cable to an insulated ground bar. This bar, in turn, is then terminated to the Site Reference Ground. Similar arrangements can be made in other areas.

3.3.2. Guidelines

In most cases, an isolated single point ground (SPG) system shall be used with electronic instrumentation and process control computers. This means that the system's ground connects to earth at only one point. This point may be a facility ground or a dedicated ground rod. If the process control system uses fiber optics as a data highway a single point ground does not have to be distributed to each distributed PLC. The fiber optic cable eliminates facility ground loops

and isolation problems related to using copper conductors. With fiber optics each PLC will require a SPG local to only the equipment mounted in the PLC panel or located nearby.

A SPG system has grounding branches that serve various parts of the computer and instrumentation system. Major branches connect to the system ground, while minor branches connect to analog, digital, or rack ground buses. Each ground branch must be connected at one end only; the far ends of each ground branch must be disconnected from ground.

Do not allow the design or the contractor to use conduit, cable raceways, or building steel to distribute the SPG from point to point. Distribution should be through a well-insulated, dedicated wire of appropriate size.

The earth ground for a SPG system should conform to the National Electrical Code, Section 250-50 through 250-70. The buried ground should:

a) Be made of good electrical conductors;
b) Withstand mechanical abrasion;
c) Provide sufficient contact area with the soil to minimize grounding resistance.

Ground resistance to earth is measured using methods outlined in Standard Handbooks for Electrical Engineers, or by following procedures recommended by vendors of ground-measuring equipment. Although the NEC requires that ground resistance not exceed 25 ohms, electronic control systems ground should be as low as practicable, but not more than 5 ohms.

The conductor connecting the earth ground to the system ground should be insulated and stranded copper wire, #2/0 AWG. This conductor should follow the most direct path between the ground points. Sharp turns decrease the conductor's ability to carry high currents, such as those encountered when lightning strikes nearby, and should be avoided.

3.3.3. I/O Racks

Guidelines for designing grounds for I/O racks containing analog and digital signals are:

a) Each I/O rack shall have an isolated signal ground bus, 1-inch wide by 1/4-inch thick, running from top to bottom in the rack. The bus shall have tapped holes to accommodate ground connections from various devices in the rack. The signal ground bus shall connect to the system ground plate at only one point, via a stranded, insulated copper wire of #8 AWG or larger. If the rack contains analog and digital signals, a separate bus shall be provided for each signal type.

b) The I/O rack frame shall be connected to the system ground, via a connection that is kept isolated from the signal ground bus

c) Each chassis or panel in a rack shall have internal grounding lines that connect to the signal ground bus. Connections shall be via ring tongue connectors that bolt to the bus. If the chassis has several types of signals that need to be grounded, such as low level sensor signals, high-level output modules, or noisy switching circuits, each shall have a separate line to the signal ground bus. Only circuits of the same voltage level shall share the same ground return line.

3.3.4. PLCs

Grounding requirements for the PLCs containing analog and digital signals are similar to those for the I/O racks:

a) Each PLC shall have a stranded, insulated, copper wire # 8 AWG or larger connecting the PLC ground terminal to a ground lug attached to the interior of the PLC cabinet.

3.3.5. Computer Components

Grounding requirements for the computer equipment and peripheral devices are similar to those for the I/O racks:

a) The cabinets of all computer equipment shall be connected to the system ground via a separate conductor.

b) Rack frames for all computer peripherals shall be connected to the system ground via a separate conductor.

c) The computer ground bus (supplied by the vendor, and usually located in the CPU cabinet) shall be connected to the system ground plate using an insulated #2/0 AWG (or larger) wire. The ground conductor shall run in conduit, using the shortest possible path to the ground plate. This line shall be separate from the cabinet frame ground. Follow the guidelines for the I/O signal bus ground.

d) In all cases the computer ground bus shall connect to the building ground. Electrical codes and safety require all grounds be bonded together. The computer ground shall be connected to the building ground at only one place. The location of the connection should be as close to the computer system ground rod as possible

3.3.6. Radio Antennas

A single point ground shall be used to mount radio surge protectors and to provide a ground for all of the equipment chassis. This interior single point ground shall be connected to an external ground system with a low impedance copper strap. The tower ground system and the single point ground system must be interconnected. This interconnection should be below grade and with a bare low inductance conductor. The coax cable shield must not be the only interconnection between ground systems.

To provide a single point ground, a plate where the radio surge protectors will be mounted shall be located near the ground to keep the inductance of the ground conductor low. However, if this is not possible the plate shall not be far from the radio equipment panel.

Radio surge protectors shall be Polyphase IS-50UX-C1 or current catalog number, or approved equal.

3.4. EQUIPMENT PANEL DESIGN STANDARDS

This section describes the types of control panels used by WCDPS as well as general requirements, materials of construction, and construction guidelines.

3.4.1. Panel Types

Panel types shall be specified to be compatible with and suitable for the environment of the installation location, and shall protect enclosed instruments and equipment. The choice of location for panels should attempt to minimize exposure to ambient temperature extremes, moisture, dirt and gaseous contaminants. Panels shall be specified to be designed, manufactured and tested in accordance with the latest applicable standards of NEMA, IEEE, NEC, UL and ANSI. The following is a list of typical NEMA enclosures for SCADA system components:

a) NEMA Type 1 - General purpose - Indoor enclosures are intended primarily to prevent accidental contact of personnel with the enclosed equipment in indoor applications wherever oil, dust or water is not a problem.

b) NEMA Type 2 - Drip proof - Indoor enclosures are intended for use indoors to protect the enclosed equipment against falling non-corrosive liquids and falling dirt.

c) NEMA Type 3 - Dust tight, Rain tight and Sleet (Ice) Resistant -Outdoor enclosures are intended for use outdoors to protect the enclosed equipment against windblown dust and water.

d) NEMA Type 3R - Rainproof and Sleet (Ice) Resistant - Outdoor enclosures are intended for use outdoors to protect the enclosed equipment against rain and are constructed so the accumulation and melting of sleet (ice) will not damage the enclosure and its external mechanisms.

e) NEMA Type 3S - Dust tight, Rain tight and Sleet (Ice) Proof - Outdoor enclosures are intended for use outdoors to protect the enclosed equipment against windblown dust and water and to provide for its operation when the enclosure is covered by external ice or sleet.

f) NEMA Type 4 - Watertight and Dust tight - Indoor and Outdoor enclosures are intended for use indoors or outdoors to protect the enclosed equipment against splashing water, seepage of water, falling of hose-directed water, and severe external condensation.

g) NEMA Type 4X - Watertight, Dust tight and Corrosion Resistant -Indoor or outdoor enclosures have the same provisions as Type 4 enclosures and, in addition, are corrosion-resistant.

h) NEMA Type 9 - Class II, Group E, F or G - Indoor Hazardous Locations - Air-break equipment enclosures are intended for use indoors, in atmospheres defined as Class II, and Group E, F or G in the "National Electrical Code", to prevent the entrance of explosive amounts of hazardous dust.

i) NEMA Type 12 - Industrial Use - Dust tight and drip tight - Indoor enclosures are intended for use indoors to protect the enclosed equipment against fibers, filings, lint, dust and dirt, and light splashing, seepage, dripping and external condensation of non-corrosive liquids.

j) NEMA Type 13 - Oil tight and Dust tight - Indoor enclosures are intended for use indoors primarily to house pilot devices such as limit switches, foot switches, pushbuttons, selector switches, pilot lights, etc. and to protect these devices against lint and dust, seepage, external condensation, and spraying of water, oil or coolant.

The above enclosure descriptions are not intended to be a complete representation of the National Electrical Manufacturers Association (NEMA) standards for enclosures but to indicate various types of enclosures that may be specified.

Only the following NEMA types are approved for installation in WCDPS facilities:

- NEMA Type 12
- NEMA Type 4
- NEMA Type 4X (stainless steel)
- NEMA Type 4X (fiberglass)
- NEMA Type 9

Use of other NEMA types must be approved by WCDPS.

Local Panels shall never be located in hazardous locations. Local Control Stations consisting of lockout or limited start/stop control may be located in a hazardous area only if all controls and the panel are rated for hazardous locations.

3.4.2. Panel Construction

Panels shall be designed to accommodate all necessary accessories such as instrument air, power supplies, mounting hardware, terminal blocks and any signal conditioning or conversion equipment that may be necessary to make operational all monitored and controlled equipment to be mounted in the panel. Panels shall be designed with sufficient spare space to provide for future expansion of 25% of initial capacity.

Panel layout and equipment spacing should be designed to allow for device removal, calibration and maintenance without disassembly of adjacent devices.

Removable eyebolts must be provided to facilitate sling handling of large enclosures. Eyebolt mounting should be a part of the structural support bracing to distribute stresses and enclosure weight during installation.

All panels shall have sufficient structural reinforcements to ensure a plane surface, limit vibration and to provide rigidity during shipment, installation and operation without distortion or damage to the panel or injury to any mounted instruments. All enclosure seams must be continuously welded and ground smooth to be undetectable after painting.

There are two basic mounting configurations that may be specified for WCDPS facilities; either wall-mounted or free-standing:

3.4.2.1 Wall-Mounted Panels

Single door, wall-mounted enclosures shall be specified up to a maximum of 48 inches high x 10 inches deep. These panels shall be constructed of a minimum of 14-gauge steel. All two-door panels shall be constructed of a minimum of 12-gauge steel.

3.4.2.2 Free-Standing Panels

All freestanding Panels shall be specified to be constructed of a minimum of 12-gauge steel.

All panels shall be specified to be primed and finished with two coats of a factory finished ANSI #61 light gray lacquer finish on all exterior surfaces. The panel interior shall be white.

Suitable strip heaters (heat reflector assemblies) shall be specified with thermostat control for condensation and freezing protection in all outdoor enclosures.

An interior incandescent light fixture and a duplex G.F.I. convenience outlet with on/off G.F.I. circuit breaker for maintenance purposes shall be specified for all panel enclosures.

All enclosures shall be specified to be provided with flush hinges and vault-type latch capable of accepting a 3/8-inch shackle padlock. Enclosure doors 36" high and larger shall also require three point latch assemblies.

3.4.3. Panel Cooling

3.4.3.1 Maximum Temperature

All panels should have ample cooling to prevent high temperatures from shortening the life of the equipment mounted inside. The specification should prohibit any location within the panel or interior of the equipment mounted inside to reach temperatures higher than 15 degrees F. above the temperature of the location in which the panel is located.

3.4.3.2 Intake Air Filters

If panels require air exchange for cooling, fans drawing air into the panel must be filtered. The filter surface area should be sized three times larger than the fan intake area for each fan.

3.4.3.3 Cooling Without Air Exchange

Panels in areas of heavy particulate contamination shall be cooled without air exchange between the interior and the exterior of the panel. Either solid-state cooling equipment or refrigeration must be used to cool the panel. The heat dissipation portion of the cooling unit shall be designed for use in areas with heavy particulate contamination and shall be capable of running extended periods without cleaning.

3.4.4. Panel Wiring and Terminations

All internal panel wiring and terminations shall be designed in accordance with the latest applicable standards of the NEC as well as applicable state and local electrical codes.

Signal wiring shall be segregated from control power wiring, grouped functionally and arranged neatly to facilitate circuit tracing. Low level analog signals of 100 millivolts or less shall not be

combined with digital input or control output wiring nor shall they be intermixed within the same bundle, duct, or Panduit within a panel.

Plastic wiring wraps shall be used to bundle wires, except within wiring ducts. The bundles shall be securely fastened to the steel structure at suitable intervals, not exceeding 12 inches.

Where shielding is required, shields shall be continuous foil or metalized plastic providing 100% coverage. A drain wire in continuous contact with the shield shall be included. The drain wire shall not be used as a control signal conductor.

All DC signal wiring shall be segregated from wire conducting AC signals.

Power wiring insulation shall be rated at 600 volts at 90^{o} C and be type MTW. No wire smaller than 12 AWG shall be used for power wiring.

Wiring shall not be spliced. Wire shall be run in continuous lengths from screw terminal to screw terminal. Wire service loops shall be provided to permit device removal.

Design of the terminal layout shall include a grounded barrier to segregate those terminals devoted to current type signals from others. The terminal blocks are to be factory assembled on a mounting channel and the channel bolted to the inside of the panel. Terminals shall accept wire size 12 AWG and smaller.

Terminal blocks shall be rated at least 300 volts for NEMA general industrial control devices; 600 volts NEMA limited power circuits. The terminals shall have a continuous marking strip.

Field wiring terminal blocks shall be provided for interconnections with field instruments and other termination cabinets. It shall not be permitted to connect field wiring directly to PLC I/O module wiring terminals. Field wiring terminal strip shall use Wago (or equal) spring type terminal blocks, as listed below, and Wago ferrules for multi-strand wires.

Application	**WAGO terminal**	**WAGO end/sep (orange)**	**WAGO stops**	**Color**
Analog Input	280-874	280-373	249-116	Grey
Analog Output	280-874	280-373	249-116	Grey
Discrete Input	281-619	281-341	249-116	Grey
Discrete Output	281-619	281-341	249-116	Grey
Line AC Power	281-629	281-341	249-116	Blue
24 VDC Power	281-663	281-335	249-116	Red
DC Common	281-664	281-335	249-116	Black
System Ground	281-657	281-335	249-116	Yellow-green
Intrinsic Safe Analogs	281-695	209-191	249-116	Light grey
Intrinsic Safe Discretes	281-695	209-191	249-116	Light grey
Intrinsic Safe System Ground	281-657	281-335	249-116	Yellow-green

All wiring terminating on Wago (or equal) terminal strips shall be fitted with ferrules, as listed below.

Application	WAGO #	Color
12 AWG	216-207	Grey
14 AWG	216-205	Yellow
16 AWG	216-204	Black
18 AWG	216-203	Red
20 AWG	216-202	Grey
22 AWG	216-201	White

Control panel wiring shall be identified at each termination by marking with a number to correspond with the diagrams and shall be color-coded as follows:

TYPE OF WIRING	WIRE COLOR
Line and load circuits, AC or DC	Black
AC control circuits	Red
DC control circuits	Blue
Interlock control circuits on the panel energized from external source	Yellow
Equipment grounding conductors	Green
Current carrying grounded conductor (Neutral)	White

All wires and cable terminated within control panels, instrumentation panels and termination cabinets shall be provided with identification tags to identify cables according to Section 3.2.

3.4.5. Panel Display Devices

Instruments or devices furnished for front of panel mounting shall be suitable for panel mounting and selected to match each other and present a coordinated aesthetically pleasing functional arrangement. The arrangement of devices on the panel shall be as symmetrical as possible and shall functionally group devices to enable operators to easily locate groups of devices or individual devices to control the process. Panel indication or display devices shall be mounted between 48 and 60 inches above the floor to be easily readable by the operator.

Display devices shall consist of rectangular panel meters, edgewise panel indicators, recorders, annunciators and graphic displays.

All display devices shall have scales that indicate the actual process value with the measured variable reading in engineering units (i.e., 0 to 3000 GPM). It is unacceptable for display devices to indicate the measured value as a percent of maximum (i.e., 0 to 100% full scale) except for those devices displaying position (i.e., percent valve open, percent valve closed).

3.4.5.1 Analog Controllers

Analog controllers shall be self-contained, stand-alone, microprocessor-based, and completely configurable through the use of internal software. The controller shall be configurable for all analog control applications. The internal programming shall have a minimum of 70 function blocks stored in ROM. The controller shall be designed for interfacing to distributed control systems. Controllers shall also be capable of being tied together through the use of a local instrument link allowing communication between multiple controllers.

The controllers shall be able to be programmed by selection and interconnection of function blocks in order to establish the station type and control strategy. Configuration data shall be stored in non-volatile memory to prevent loss of data during an electrical power interruption. Programming shall be either through the use of controls on the front of the controller or by using a personal computer to download the software configuration to the controller. The software in the PC shall also be capable of uploading programs from the controllers to archive, modify and verify these programs.

3.4.5.2 Switches, Pushbuttons and Lights

Selector switches and pushbuttons shall be the type that are supplied with the add-on operator mechanisms so that the appropriate number of contact blocks and block type can be attached to the switch. Contact block terminals shall be labeled for identification purposes and contain not less than one single pole, double throw contact.

Contacts shall be specified as heavy-duty type, rated 10 amperes at 120 VAC breaking current.

In the case where the contact blocks are handling low level signal currents, the contacts shall be rated for electronic duty and provide mechanical self-cleaning action for reliable operation on electronic loads where thermal cleaning action is not present. The contacts should be rated at 1 amp at 28 Vdc and be constructed of gold or gold flashing over silver.

All selector switches, pushbuttons and indicating lights shall be oil tight NEMA Type 13. All pushbuttons and indicating lights shall be supplied by one manufacturer, shall be of the same series or model, and shall be heavy duty oil tight, Square D, Allen Bradley, or approved equal. All selector switches shall be Honeywell Microswitch ‘CMC’ type, or approved equal..

All indicating lights shall be oil tight type operating from either 24 VDC or 120 VAC, 60 Hz power source. Indicating lights operating on 120 VAC shall be transformer type with the indicating lamps operating on 6 to 8 VAC. Indicating lights operating on 24 VDC shall have lamps rated for 28 VDC for longer life. The use of light emitting diodes (LED) is preferred. Removal and replacement shall be accessible through the front of the panel. A push-to-test-feature shall be employed on indicating lights to provide a positive test of light condition. The indicating lights shall be Square D, Allen Bradley, or approved equal.

Indicating lights shall be color-coded as followed:

LEGEND NOMENCLATURE	LENS COLOR
TROUBLE/MALFUNCTION	AMBER
STATUS	WHITE
RUNNING	RED
CONDITION OF DANGER, ACTIVE STATE	RED

LEGEND NOMENCLATURE	LENS COLOR
CONDITION OF SAFETY, INACTIVE STATE	GREEN
STAND-BY/ENERGIZED ON/RUN	GREEN RED
OPEN CLOSED NEITHER OPEN NOR CLOSED (TRAVELING)	RED GREEN RED AND GREEN LAMPS LIT

3.4.6. Relays and Timers for Instrumentation and Control Panels

WCDPS's standard for control logic relays are heavy duty, machine tool industrial type with contacts rated not less than 10 amperes at 240 volts AC, 5 amperes at 24 VDC. Relay coils shall be molded construction and operate on 24 VDC or 115 VAC 60 Hz +10% as required. If space constraints dictate, miniature relays can be used. However, the electrical ratings of the miniature relay coils and contacts must be carefully matched to the supply voltages and loads. All relays shall be UL recognized. Operating temperature range shall be compatible with the environment in which the relay will be installed.

All relays shall be an eleven-pin base plug-in type furnished with appropriate sockets complete with retention spring.

All auxiliary interposing relays shall be supplied by the same manufacturer to assure similar appearance and uniform operating characteristics. All relays shall have a clear polycarbonate dust cover and internal light indication to show if the relay is energized. Contact material shall be gold or gold flashing over silver and rated 1.0 amperes at 24 VDC in instances where low level signal currents are being switched. Relays shall be Potter & Brumfield or approved equal.

All electrical timing relays, (timers) shall be supplied by the same manufacturer to assure similar appearance and time setting procedures. Timing ranges shall be as required with a range of 10 to 1, minimum. Operating voltage shall be 115 VAC 60 Hz +10%. Contact rating shall be 10 amperes at 115 VAC and a minimum mechanical life of one million operations. On-delay and/or off-delay shall be supplied as required. Repeat accuracy shall be +5% or better. Reset and recycle time shall be 200 milliseconds maximum. All time delays shall be adjustable via a graduated knob on the timer body. Timing relays shall be DIN-rail mounted, Allen-Bradley or approved equal.

3.4.7. Nameplates and Identification Tags

All equipment in WCDPS facilities must be identified as to the function each piece of control equipment provides, its name, and other information as outlined in this section of the SCADA System Control Standards. The equipment nameplate should also conform to the standards as defined in this section.

3.4.7.1 Equipment Nameplates

Nameplates must identify the function, position, and/or condition indicated for each pushbutton, switch, indicating light, or other control device. Nameplates for pushbuttons, switches, indicating lights, and similar control devices shall be the standard type furnished with the device.

Nameplates should be provided for each receptacle, designating the panel board and circuit number that supplies power to that receptacle.

Nameplates should be secured to equipment fronts using screws. Rivets or adhesive may be used for securing nameplates to the inside face of recessed panel board doors in finished locations or other type equipment that is enclosed in panels.

Nameplates made of embossed tape should not be permitted for any application, even temporary.

Equipment nameplates shall be made of laminated plastic approximately three thirty-seconds of an inch thick (3/32 inch), beveled edge, white with black engraved lettering, attached with corrosion-resistant machine screws with castellated nuts. Nameplates shall be a minimum size of one and one quarter (1-1/4) inches high by three and one-half (3-1/2) inches wide.

Nameplates for pushbuttons, switches, indicating lights, and similar control devices shall be the standard type furnished with the device.

Nameplates must be provided for the following equipment:

a) All electrical distribution and control equipment and loads served

b) Panel boards, Switchboards and Motor Control Centers with identification of voltage rating and source.

c) Individual Circuit Breakers, Switches, and Motor Starters in Panel boards, Switchboards, and Motor Control Centers, with identification of circuit and load served, including location

d) Individual Circuit Breakers, Enclosed Switches, and Motor Starters, with identification of load served

e) Transformers, identify equipment designation, with identification of primary and secondary voltages, primary source, and secondary load and location

f) Receptacles, with identification of panel board and circuit number.

3.4.7.2 Instrument Identification

All instrumentation should be identified with equipment and tag numbers in the same way as for equipment described above. However, in many field locations the use of nameplates would be impractical. Equipment tags made of stainless steel ribbon tape is a more practical approach. The stainless steel ribbon tape is embossed with the instrument name. The ribbon has a hole for attaching it with stainless steel wire to the instrument. This type of stainless steel ribbon provides the most indestructible and long lasting nameplate.

3.5. ELECTRICAL DEVICE STANDARDS

This section describes the requirements for electrical devices, which may be mounted in panels depending upon scope of the project. These requirements apply to all devices, irrespective as to whether they are provided separately or as part of a complete assembly or process package.

The Control System supplier shall assume that equipment supplied shall be installed in an environment which is classified as harsh, possibly prone to chemicals, and condensing humidity, and low levels of free chlorine. As such, equipment shall be rated for installation in such environment or the system supplier shall provide the suitable protective enclosures.

Devices shall be rail mounted, rack mounted, panel door mounted. The total number of manufacturers shall be kept to a minimum by purchasing as types of devices as possible from the selected Manufacturers.

Electric style relays shall be used for control signals (analog and discrete).

The following electrical component shall be reviewed and approved by WCDPS prior to selection and commencing work:

3.5.1. DC Loop Power Supplies
3.5.2. Controller Circuit Transformers
3.5.3. Circuit Breakers
3.5.4. Transient Protection – Power Line
3.5.5. Transient Protection – Signal Line
3.5.6. Safety Barriers
3.5.7. Selector – Switches
3.5.8. Selector – Pushbuttons
3.5.9. Disconnect
3.5.10. Contactors
3.5.11. Lamps – Indicator
3.5.12. Lamps – Strobe
3.5.13. Relays – Light Duty
3.5.14. Relays – Heavy Duty
3.5.15. Relays – Electronic
3.5.16. Relays – Time Delay
3.5.17. Relays – Light Duty
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3.5.19. Power Switches (120 V)
3.5.20. Receptacles
3.5.21. Utility Box Covers

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0	September 28, 2007	Draft Version for internal review
Rev. 1.0	March 2009	Draft submittal
Rev. 1.1	June 2010	Removed highlights and updated WCDOE references

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4. HARDWARE DESIGN STANDARDS

4.1. SYSTEM ARCHITECTURE

WCDPS's SCADA Systems shall conform to the four-level architecture shown functionally in Figure 4.1-1. The drawing does not show all required components, but defines the required hierarchy.

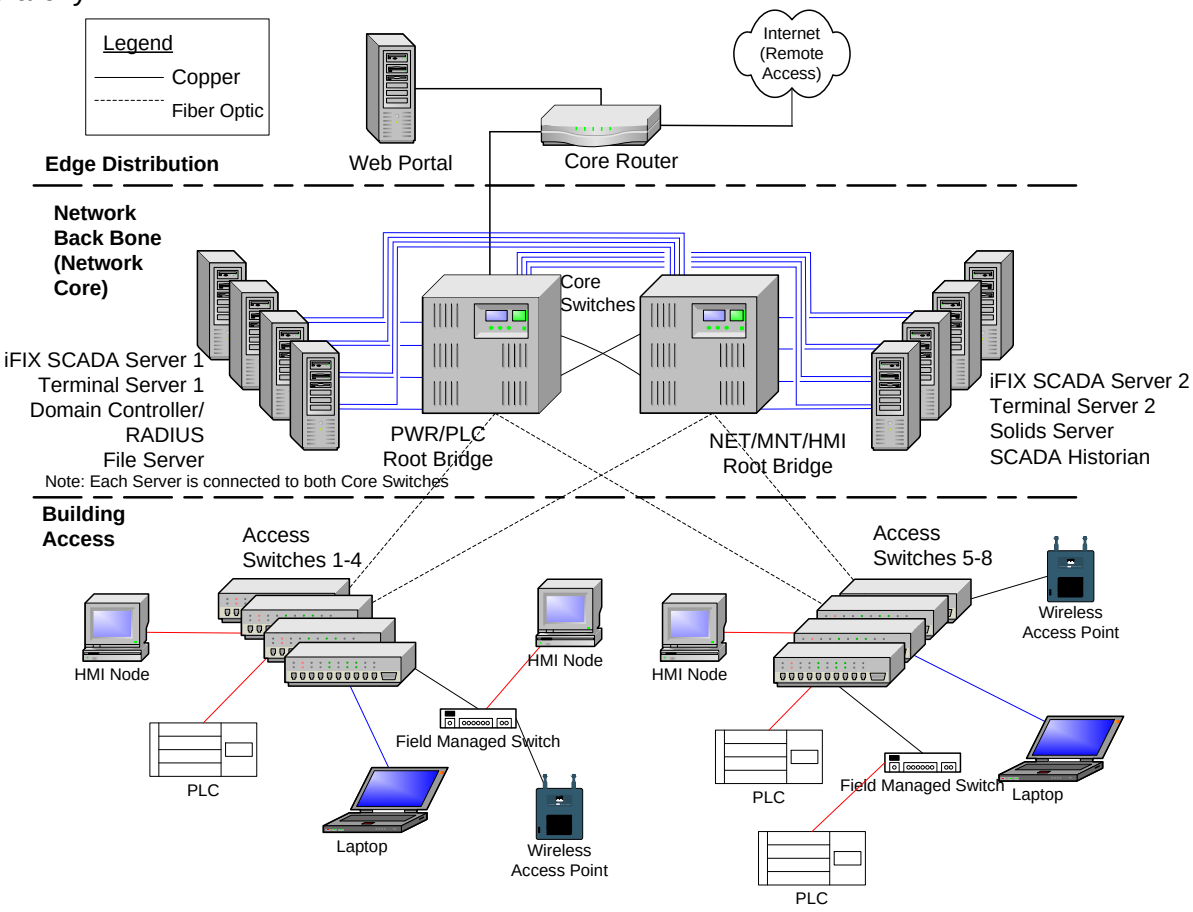


Figure 4.1-1 System Architecture

The DWTF SCADA system architecture provides reliability, redundancy and meets WCDPS's current and anticipated future requirements.

A GE-Fanuc Intellution iFIX Proficy client/server architecture is provided with redundant SCADA servers, to provide fail over in the event of a failure of one (1) of the servers. Multiple server pairs can be implemented – a WWTF server pair and a future Collection System server pair. The iFIX architecture also includes two Terminal Servers, an Historian Server, a Domain/Radius Server, and a remote Network Attached Storage Device. Operator interface with the SCADA System is through a combination of thin client workstations and thick client workstations located in control areas.

CSO Basin and Pump Stations require individual Servers class machines with iFIX Development Licenses for standalone operation in the event of a network failure with the DWTF. This network is not depicted in Figure 4.1-1

4.1.1. Server Level

The SCADA servers are dedicated exclusively for the function of interfacing with the process control network. The SCADA servers are equipped with an iFIX development license to allow for maintenance and configuration changes to the SCADA system. These servers are not utilized for plant visualization purposes. Terminal Servers provide visualization (graphics) to the multiple Thin Clients distributed throughout the DWTF.

The use of network VLANs is provided to enable separate PLC and HMI networks to share the same network infrastructure. This allows for prioritizing network traffic based on the VLAN and QoS. The PLC process control network traffic is typically given the highest priority and HMI network traffic is given second priority. This prioritization ensures that Operations will always have the ability to view and interact with the SCADA system.

4.1.2. HMI Level

HMIs are provided through the DWTF. The HMI workstations are classified as Thick Clients and Thin Clients. Thick Clients include iFIX software and resident system graphics and are installed in key operating locations. Thin Clients receive graphics and process information directly from the Terminal Servers. Thin Client workstations are utilized due to their lower cost. Notebook workstations are also provided for remote access to the SCADA System both in house via wireless access points or off site via standard phone or cellular connections.

Recognizing the requirement for non-DWTF personnel to view the SCADA system HMI, an iFIX Web Portal is used for instances of non critical applications for personnel requiring a view only interface into the SCADA system with no control capabilities. XLReporter is used in conjunction with the SCADA Historian for producing regulatory and adhoc reports. WIN911 is used for remote alarm notification to pagers and cell phones.

4.2. NETWORK DESIGN STANDARDS

The following network standards shall be followed when new SCADA networks are being designed and installed or when existing networks are being upgraded.

SCADA systems transfer real-time critical data and require robust, reliable communications for PLC to PLC, server to PLC, and server to workstation data exchanges. Therefore, SCADA system network installations require reliable, high-speed communications with consideration of utilization and capacity for future growth. Communications media to convey signals between network devices shall be fiber optic cables and copper cables. Fiber-optic cabling shall be installed for all backbone network segments that run between process areas of the DWTF and between buildings. Copper cabling may be used for network segments that are completely within a single room, such as a control room, and between fiber optic network nodes and devices such as PLCs, subject to the maximum allowed distance for CAT6 cable.

T1 or business-class HDSL shall be used for communications between the DWTF and the CSO Basins and Pump Stations. Cellular communications shall be used for communications between the DWTF and the smaller collection system facilities.

4.2.1. Fiber Optic Media

All PLC network installation and improvements shall use fiber optic media for backbone segments to support Ethernet communications for process monitoring and control, and other possible applications as indicated below. The backbone shall be installed using multimode fiber optic cable consisting of a minimum of 24 fiber strands. The fiber within each facility shall be configured to support connectivity as follows:

Number of Fibers Strands	Network Application
2	PLC Ethernet network communications
2	Redundant PLC Ethernet network
2	Security (CCTV)
2	WCDPS WAN connectivity
2	Multimedia, A/V training, or other future needs
14	Spare for future network upgrade

4.2.1.1. Fiber Cable Characteristics

Low-loss, glass type, fiber-optic multimode graded-index cables with the following operational and construction features shall be used:

1. Number of fiber strands: 24
2. Maximum attenuation: 3.00 dB/km at 850 nm.
3. Minimum bandwidth: 800 MHz-km at 850 nm.
4. Fiber type (core/cladding): 50/125 microns
5. Numerical aperture: 0.20 ± 0.015.
6. Buffer Type: Gel Filled Loose buffer.
7. Maximum tensile load: 2700 N short term, 600 N long term.
8. Minimum bend radius (unloaded, under residual installed load): 15.25 cm and 22.5 cm under maximum tensile load.
9. Maximum vertical rise capability shall not be less than 247 meters.
10. Outer Strength Member: Kevlar Yarn Fibers.
11. Inner Jacket: Black PVC - .022” Nominal Wall.
12. Outer Jacket: UV & Moisture Resistant Polyethylene meeting the requirements of IEEE-383 Flame Test UL 1581 - .045” Nominal Wall.
13. Fibers within the cable shall be color-coded so that each fiber may be individually identified.
14. Ripcords shall be provided to simplify sheath removal.
15. Operating characteristics: -40 to 80 degrees C, relative humidity 100% for outdoor installation.
16. Cable shall be rated as a minimum at 1 Gbps transmission speed.

4.2.1.2. Terminations

Refer to Figures 4.2.1-1 and 4.2.1-2 Typical Fiber Optic Node for the following discussion.

1. A fiber termination panel shall be installed at each fiber-to-copper interface location. Fiber termination panels shall include splice trays and patch panels.
2. Fiber optic pigtails shall be installed between each patch panel and the splice trays. One end of each pigtail shall be preconnectorized at the factory with a Type ST connector. Field installed fiber connectors on the pigtails are not allowed.
3. Fibers shall be spliced using the fusion method. Mechanical splices are not allowed. Splices shall have a loss of 0.2 dB or lower. All spare fibers from cables entering each patch panel shall be spliced and terminated at the patch panel.
4. Preconnectorized fiber optic jumper cables shall be installed between each patch panel and optical communication devices. Optical communication device connectors shall be Type ST, unless Type ST connectors are not manufactured for the device. Connections shall have a typical loss of 0.2 dB or better and shall provide stable optical performance after re-mating. Field terminations shall use a simple procedure requiring minimal training.
5. Single, unjacketed fibers shall not be used for terminations to optical communication devices. All fibers entering a patch panel shall be terminated and tested by a certified technician.

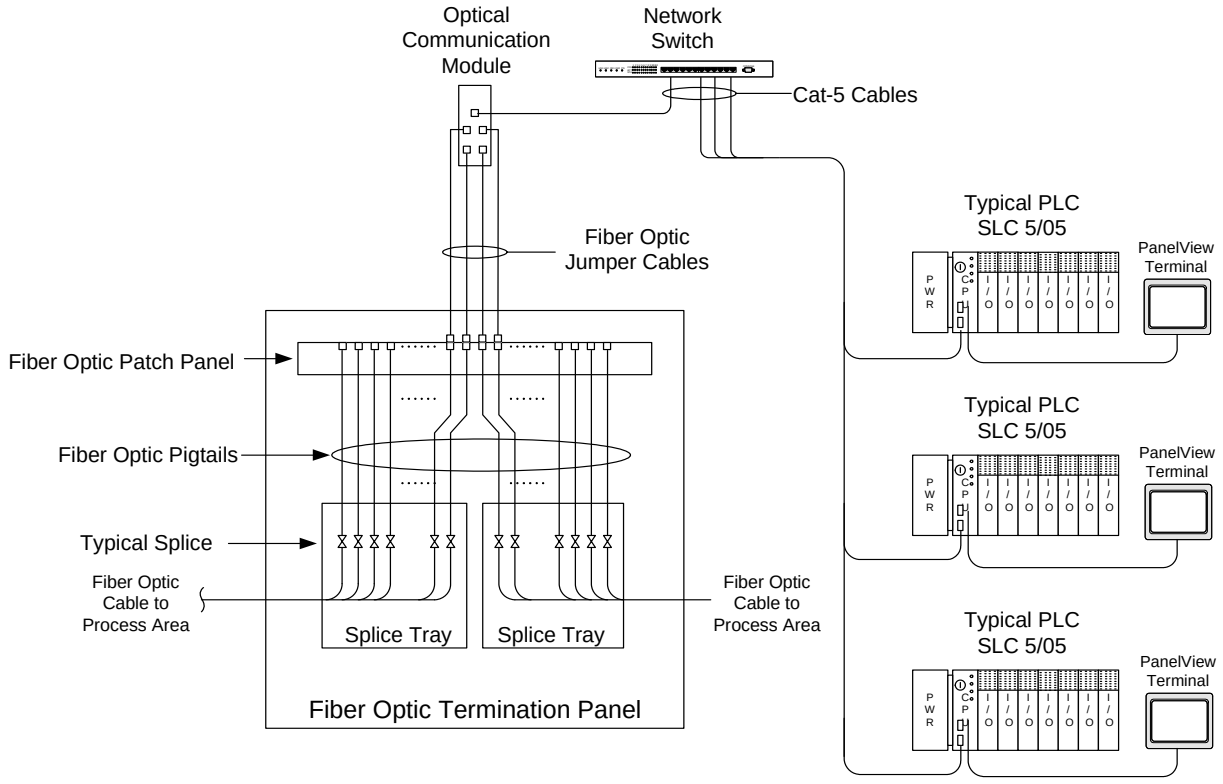


Figure 4.2.1-1 Typical Fiber-Optic Node (multiple PLCs)

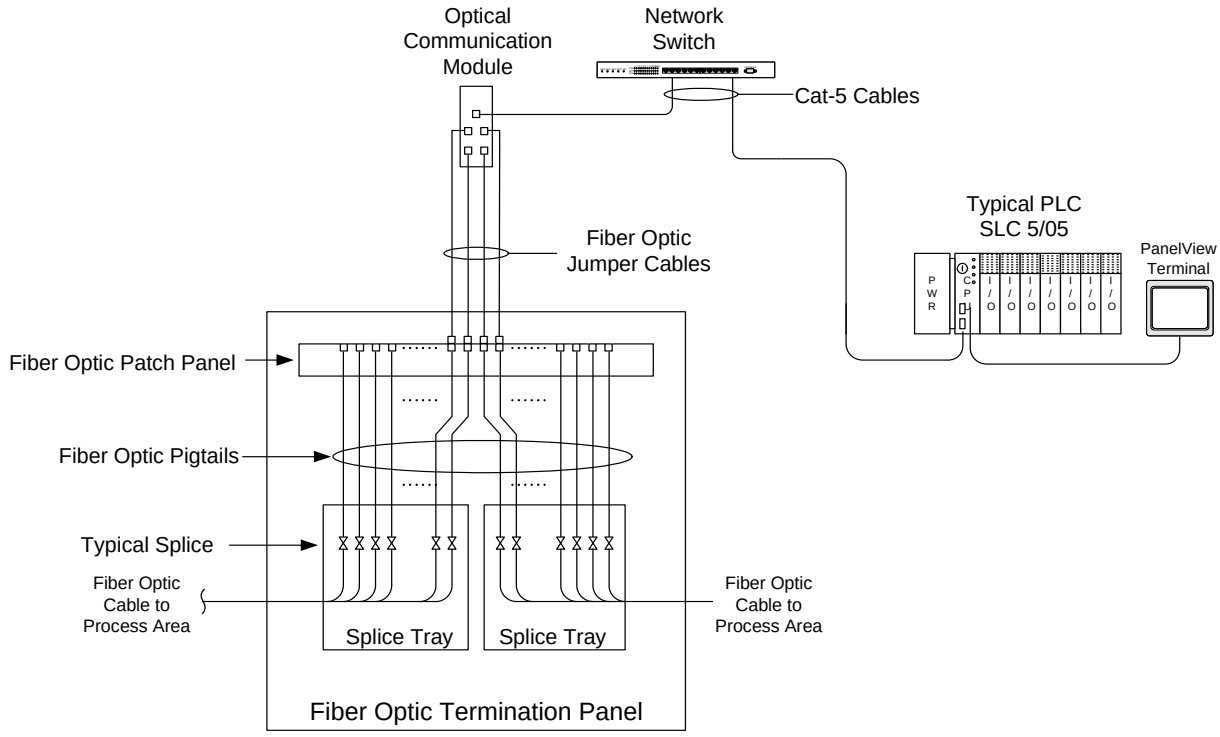


Figure 4.2.1-2 Typical Fiber-Optic Node (single PLC)

4.2.1.3. Manufacturers

Fiber optic cable shall be the FREEDM Fiber Optic One Plenum Cable as manufactured by Corning, or approved equal.

4.2.1.4. Testing

Once the installation is complete, the fiber shall be tested and the results shall be documented. The test data must be provided to WCDPS for review and acceptance prior to connecting SCADA system equipment. The test results must provide adequate information to determine that the installation was successful and include the manufacturer's maximum allowable dB loss.

4.2.2. Copper Network Cable

Copper cabling for network applications shall meet or exceed the specifications for Category 6 cables based on the Commercial Building Telecommunications Wiring Standard. All network devices including jacks, connectors, patch panels and jumper cables shall be rated for Category 6 use, or better.

4.2.3. In-Facility Installation Requirements

All fiber optic cables shall be mounted or supported as required by the NEC and local codes. The installation location shall not interfere with the maintenance or operation of plant equipment and shall not create a safety hazard. If installation is in a hazardous environment, the fiber

cable, conduit, pipe hangers, raceway, and fittings must be approved for the environment as certified by the manufacturer. At no time shall the fiber cable or conduit come in direct contact with high voltage current.

A minimum of four (4) feet excess cable shall be provided at each termination point to prevent tension on either end of the termination points. All conduits shall be installed with break-out boxes following local codes and compliances and shall not exceed the minimum bend radius specified by the manufacturer. At no time shall tension exceed the cable manufacturer's rating and all cable lengths exceeding 25 feet shall be kept spooled with care not to twist, knot, or bend in a manner that will prohibit performance.

Appropriate wire management hardware shall be used to organize cross-connection routing and to ensure maintenance of vendor specified bend ratios. All cables and connectors shall be labeled. The connector on the cable end and the device into which the cable fits shall be labeled in a way that clearly identifies the proper cable and device connection. In-plant fiber optic cables shall be installed using one of the following four methods:

1. Within innerduct laid in cable trays
2. Indoors within conduit
3. Underground in innerduct within conduit.

Where installed in cable trays, innerduct shall be orange and corrugated.

Where indoor conduit is required, conduit shall be Schedule 40 steel.

4.2.4. Underground Installation Requirements

Where outdoor cable is required, 4-inch conduit shall be buried underground. Each conduit shall be installed with three innerducts. Each innerduct shall have a distinct color and one innerduct shall be orange. The fiber optic cable shall be installed in the orange innerduct. The other innerducts will be available for future cables.

A metalized leader or marker tape shall be placed directly above the cable or casing so it can later be detected. Above ground, industry standard fiber communications markers shall be placed directly above the cable route within line of sight from each other, at the intersection of changes in direction, and be clearly labeled as follows:

CAUTION: COMMUNICATIONS CABLE BURIED BELOW

Property of: Wayne County Department of Public Services

Contact: WCDPS prior to digging or excavation

The label shall be installed within one (1) foot from the top of the marker, made of a water proof material, made to withstand extreme cold and heat, and have lettering large enough to be read from a distance of five (5) feet.

All underground fiber installations shall not exceed the minimum bend radius specified by the manufacturer. At no time shall tension exceed the cable manufacturer's rating and all cable lengths exceeding 25 feet shall be kept spooled with care not to twist, knot, or bend in a manner that will prohibit performance.

At all locations where installation is planned, all underground utilities must be marked prior to digging and all fibers must be tested and approved prior to breaking ground. In all cases following installation, the above ground surface conditions must be restored to their original condition.

4.2.5. Network Topology

The SCADA System includes PLCs, SCADA nodes, View nodes, historian nodes, a programming terminal and printers. In order to ensure performance of critical data communications between PLCs and the other nodes, the SCADA System will be implemented with two Ethernet networks:

1. SCADA Network
2. PLC Network.

4.2.5.1. General

For each new network installation or improvement, the topology should be evaluated as part of the design. The topology for the SCADA Network shall be a star configuration. For the PLC Network, the preferred topology shall be a star configuration; however a ring configuration or hybrid star-ring configuration may be used if facility layout makes a star topology impractical or too expensive. The configurations described in Figure 4.2.5-2 are to be evaluated for each project and the best design identified. In each case, due attention shall be paid to achieving a level of redundancy that ensures system reliability. For each SCADA project, a Preliminary Design shall identify the benefits of the selected topology.

Devices on the network shall communication over Ethernet using TCP/IP. The use of TCP/IP over Ethernet is justified due to:

- The dominance of Ethernet as a communications technology, and the continuing pursuit of "open" standards. Most SCADA software manufacturers, have leveraged this approach in their new SCADA Human Machine Interfaces (HMIs) with the goal of adding features and lowering the cost of ownership.
- The reduced costs being achieved through simpler connectivity and therefore easier integration
- A move towards the use of "smart" field devices (including instruments) and digital communications; these devices may be used at WCDPS in the future
- Adoption of "open" standards to improve connectivity with other applications. These standards include ODBC, XML, OPC, web services, Ethernet, ".Net" (Microsoft platform), and the IEC-61131 PLC software standards
- Increased integration of SCADA with other plant applications in a typical utility, such as Computer Maintenance Management Systems (CMMS), Asset Management, Geographic Information Systems (GIS), and Laboratory Information Management Systems (LIMS)

- Ethernet has become the de facto standard for communications in an industrial control environment. Implementing an Ethernet backbone will provide the necessary LAN infrastructure and connectivity for future projects.
- An Ethernet backbone will be a solid basis for future changes and upgrades. The objective is to have in place a modern communications infrastructure which can confidently be built on over the longer term.

4.2.5.2. SCADA Network Topology

The SCADA Network will include GE-Fanuc Intellution SCADA nodes, Intellution View nodes, historian nodes, a programming terminal and printers in conjunction with a network switch, a router and firewall to the Internet. The network will be configured in a star topology operating at 100 Mbps. See Figure 4.2.5-1.

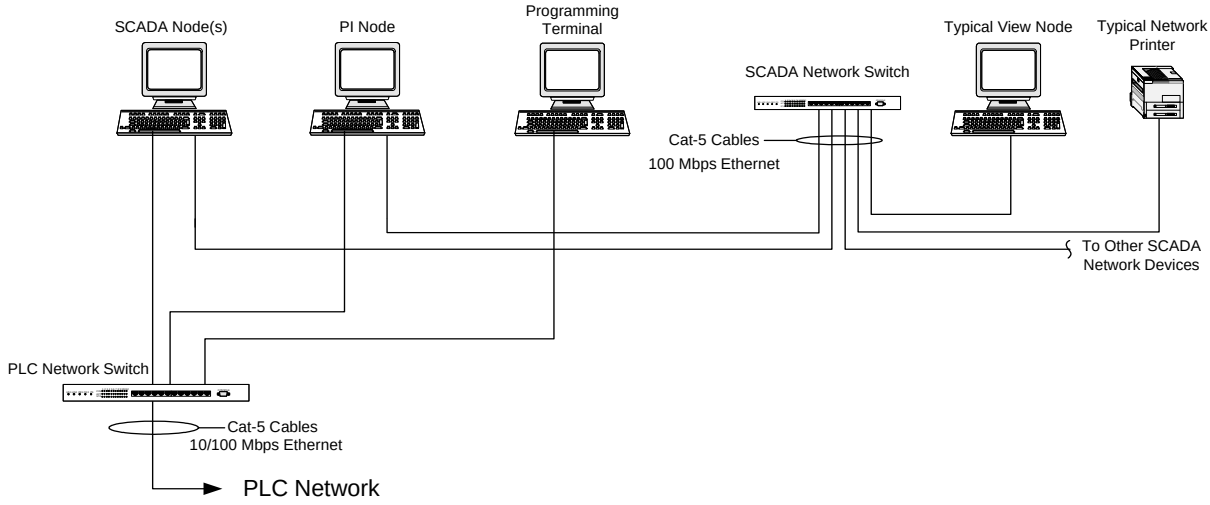


Figure 4.2.5-1 SCADA Network Topology

4.2.5.3. PLC Network Topology

The PLC Network shall provide 10 Mbps Ethernet communications between Allen-Bradley PLCs, Intellution SCADA nodes and the programming terminal. The topology will be a star topology. Fiber optic cables will extend from the PLC Network Ethernet switch to selected locations within the facility, as shown in Figure 4.2.5-2.

For isolated PLCs that are on dedicated extensions, simple copper-to-fiber media converters shall be used.

For the DWTF PLCs, a dual channel fiber optic ring will connect the PLCs. The two channels, operating over separate fibers, will communicate in opposite directions around the ring. Optical Communication Modules (OCM) will provide continuous on-line diagnostic monitoring of the optical signals of the primary and standby rings. If a fault is detected on the primary ring, the

system will automatically switch to the standby ring. Therefore, self-healing recovery is provided for a failure within any segment of the ring.

The optical communication devices will also provide media conversion between the optical fiber and the copper 10BaseT RJ45 port on the Ethernet switch at each PLC control panel.

Category 6 cables will extend from the PLC's Ethernet switch to the SLC5/05 Ethernet port. As of Rev.1 of these Standards, the SLC5/05 is capable of 10 Mbps communication only. The switches and optic modules will be configured to run at up to 100 Mbps.

At control panels at which more than one PLC is housed, PLCs will be connected to the Ethernet switch. This option may also be exercised at locations where PLCs are installed in separate cabinets that are in very close proximity. The use of hubs rather than switches at these and similar locations is discouraged.

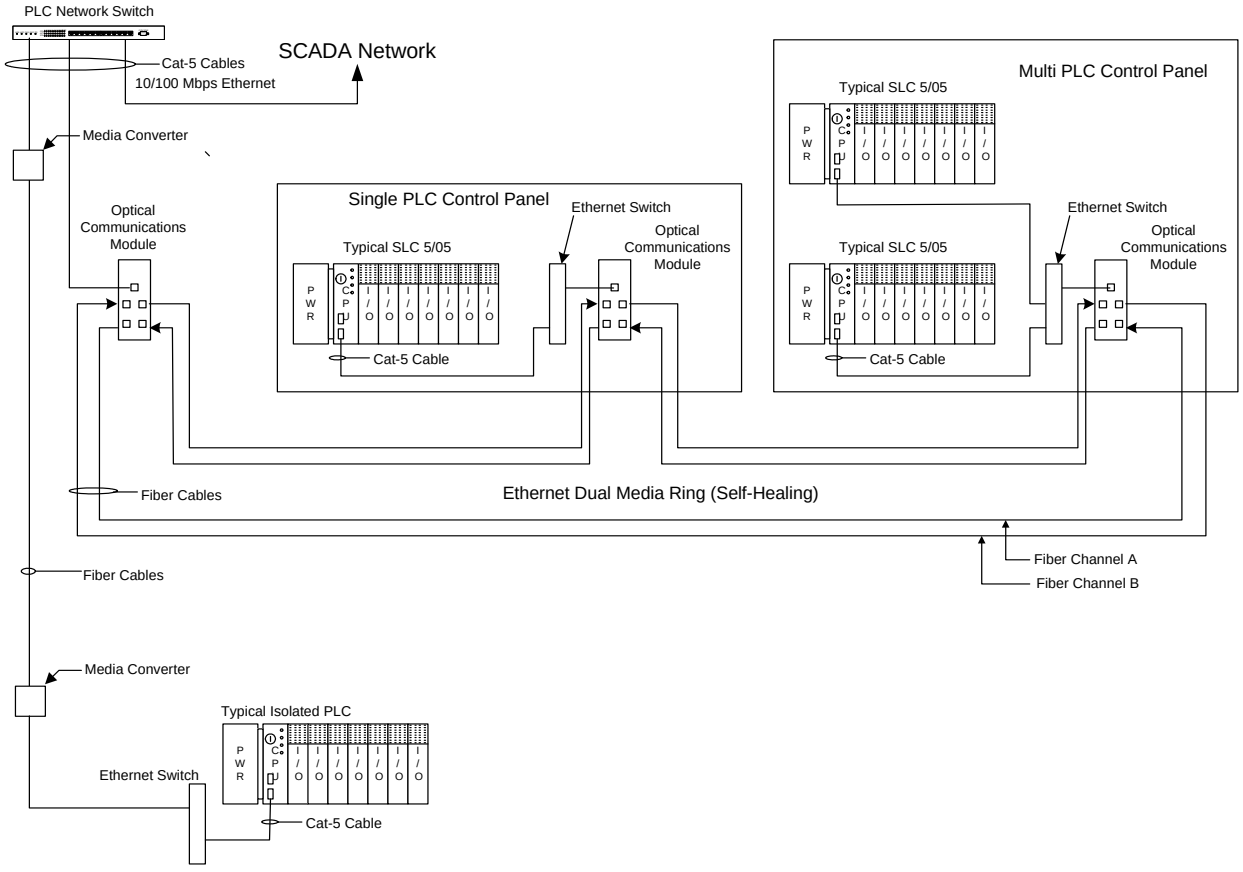


Figure 4.2.5-2 PLC Network Topology

4.2.6. Network Performance and Protocol

All new installations and network improvements shall be standard Ethernet TCP/IP network protocol. Every network switch and router must at a minimum be capable of providing 10/100 Mbps auto-switching communications rates. Where multiple paths exist, the network devices shall be attached to at least two paths to provide redundancy.

At locations where multiple LAN connections exists and involve direct connectivity to the SCADA Network, a router shall be installed with the capability to support virtual local area networks (VLANs) to segregate traffic and not impede the control system network performance.

4.2.7. Network Hardware

4.2.7.1. SCADA Network Ethernet Switches

Ethernet switches connected to the SCADA network shall be as defined here: Core switches shall be Cisco Catalyst 4506 or approved equal. The switches shall be installed in a secure environment where access can be limited to authorized personnel. Switches shall be 19" rack mounted and powered from the SCADA system UPS.

4.2.7.2. PLC Control Panel Ethernet Switches

Ethernet switches in the PLC control panels shall be GarrettCom Magnum CS14H, or approved equal. Switches shall be DIN-rail mounted with CAT6 modules to support connections to the PLCs. All switches shall contain a minimum of 3 ports. One port shall be assigned to a portable programming terminal.

4.2.7.3. Computer Network Interface Cards

The SCADA Nodes, Terminal Server nodes, Historian Node SLC programming terminal and View Nodes will be equipped with two Ethernet port. One port will be connected to the SCADA Network the second Ethernet port will be required for connection to the PLC Network. Network Interface Cards (NICs) shall be provided for this purpose. NICs shall meet the following specifications:

Link negotiation	Auto-negotiation between 10 and 100 Mbps networks
Media	100BaseT
Connectors	RJ45
IEEE compliance	802.3, 802.3x, 802.3u
Drivers	Windows XP, Vista, Windows 7

4.2.7.4. PLC Network Optical Interface Devices

PLC optical network interface devices shall be designed for use in a dual media ring configuration carrying Ethernet traffic. The optical network interface devices shall automatically switch to the standby fiber ring if the primary ring fails.

Optical Communication Modules (OCMs) shall be designed for standalone operation. OCMs shall provide media conversion between copper and fiber optic cable, and support Ethernet communication between PLCs and Intellution SCADA nodes. In addition, they shall support fault tolerant communications over a dual fiber ring.

OCMs shall provide on-line continuous diagnostics of the optical signals, detecting weak signals and channel faults. Discrete relay outputs shall be energized when a weak signal or a fault is detected on either channel in either direction. The OCMs shall be Cisco 2955C-12, or approved equal.

4.2.7.5. PLC Network Optical Media Converters

Optical Media Converters shall be GarrettCom Magnum Model 14E, Moxa IMC-101 Series, or approved equal, DIN-rail mounted devices.

4.2.8. PLC Communications

4.2.8.1. PLC-to-PLC Communication

PLCs shall be Allen-Bradley PLC5 (when reused) and Allen-Bradley ControlLogix PAC when new; PLCs and/or PACs will communicate with each other via 10 Mbps Ethernet. Each PLC shall be assigned a unique TCP/IP address. PLC-to-PLC communication shall be via Message instructions incorporated into ladder logic programs. Ladder logic programs shall be designed to optimize communication between PLCs by minimizing the number of messages and by arranging data tables within the PLC memory map to facilitate messaging.

The requirements for data transfer between PLCs shall be analyzed with respect to the need to initiate messages based on events (such as activation of an alarm condition) or on a regular timed interval. The 10 Mbps Ethernet speed will enable individual message transactions to be completed in sub-second durations. Nevertheless, the ladder logic shall be designed to not exceed the response time of the process requirements, except by some nominal factor.

The data files shall be organized to easily add new data values to Message instructions.

4.2.8.2. SCADA Node Communication to PLCs

GE-Fanuc Intellution SCADA nodes will communicate with PLCs via the PLC Ethernet Network. Rockwell Automation RSLinx communications software will be installed and configured on each SCADA and programming computer. Poll records will be configured on Intellution SCADA nodes to meet SCADA requirements.

The following guidelines shall be used to implement SCADA communications:

- Dedicated SCADA polling files shall be assigned in each PLC.
- The poll files shall be in floating point, integer and status data files as required.
- Bit files shall not be used; discrete data shall be transferred to integer files.
- The data shall be compacted into contiguous memory locations to minimize the size of poll records.
- The data files shall be organized to easily add new data values to poll records.
- The frequency of polling shall not exceed the update rate required by the SCADA system, except by a nominal factor.

4.2.9. Security on the SCADA Network

All default accounts and passwords shall be changed on all routers and network devices requiring configuration. Patches and software updates shall be maintained on each network device. If equipment is furnished by a Contractor the patches and updates shall be provided for a period of one year following project closeout.

At all locations where another LAN or WAN is connected to the SCADA network, a firewall shall be installed to prevent unauthorized access to the network, introduction of a virus, or to create a denial of service (DoS) attack.

The range of IP addresses shall be provided by WCDPS for the configuring the network devices. The Contractor shall secure all copies of all network IP addresses, network configurations, and project documentation.

All project related network documentation used by the Contractor for execution of the Work, shall be handled as "Confidential" and provided to employees on a "need to know" basis only. Prior to releasing any project related information a nondisclosure agreement must be signed and the Contractor must request, in writing, permission from WCDPS before providing project documentation to anyone not directly associated with the project.

4.2.10. Diagnostic Tools

The Contractor shall provide or integrate with existing network diagnostic software. The Network Management software shall be IntraVUE WNMS-064 to monitor data communications traffic and analyze data communications faults.

Protocol analyzers shall be provided that decode and display data communication bit streams (including control codes) for viewing and analysis by a technician. The analyzer shall count data blocks, transmission errors, etc. and calculate utilization of the communications channel. Test equipment shall be provided that determines fiber optic splice quality and can determine where on a segment, a break in the fiber occurred.

4.3. PROGRAMMABLE LOGIC CONTROLLERS

The WCDPS has chosen to maximize the service life of their existing Allen-Bradley's PLC-5 family of controllers, including processors, I/O modules, I/O chassis, and power supplies. When new or PLC replacement is required, Allen-Bradley ControlLogix PAC shall be provided as appropriate for the controls project. The PLC models used, the I/O quantities defined, and the I/O configurations are based on the following control requirements:

- Redundant PLC CPUs are not required except if deemed a critical application
- Redundant power supplies are not required except if deemed a critical application
- Whenever possible, removal of any single I/O card should not affect more than two major equipment items.
- Whenever possible, failure of any one I/O card shall not affect more than two major equipment items
- Each remote PLC shall be equipped with an operator interface terminal.

4.3.1. PLCs for Process Control Areas in the DWTF

Existing PLCs connected to the Ethernet data highway within the DWTF are PLC-5 40E with built-in 64K words of memory and 80E processor with built-in 128K words of memory. The PLC-5E provides built-in Ethernet connectivity.

4.3.2. PLCs for Independent Systems in the DWTF

Such PLCs may be provided by a Contractor for control of a packaged unit, part of a MCC providing unit drive control, or similar small process area. In each case the PLC is to be connected to a process area PLC that is on the PLC Network.

Communications between a packaged unit PLCs and the network-based PLC shall be Allen-Bradley DH+ or other compatible communications protocol.

4.3.3. RTUs for Remote Sites

RTUs located at a remote site (flow meter or gate position, precipitation gauge, etc.) and connected to the DWTF SCADA Server over a cellular network shall be a Telog RS-33 Remote Teloger Unit (RTU). Communications between the remote site and DWTF shall be coordinated through WCDPS's cellular service provider.

4.3.4. Module Arrangement

The first I/O rack, Rack 1, shall be configured as follows:

- Power supply shall be installed in slot 1
- CPU module shall be installed in slot 2
- Ethernet/fiber communications module shall be installed in slot 3, if required
- If required, I/O interface module shall be installed in the next available slot, otherwise left blank

Second and subsequent I/O racks shall be configured as follows:

- Power supply shall be installed in slot 1
- I/O interface module shall be installed in slot 2
- Slot 3 shall be left empty for future expansion
- I/O modules

I/O modules shall be placed in slots in Rack 1 and subsequent racks in the following order:

- Analog input module(s)
- Analog output module(s)
- Digital input modules(s)
- Digital output module(s)

4.3.5. I/O Modules

WCDPS preferences for I/O cards are as listed below. Exceptions can be made on a case by case basis, with the approval of the WCDPS Project Manager.

4.3.5.1. Digital Input Modules

The preferred digital input module is the 1771-IAN 120 VAC 32-Bit module. Modules shall be limited to 16 inputs to limit the effect of module failure.

4.3.5.2. Analog Input Modules

Analog inputs shall use 1771-IFE modules. All analog inputs shall be configured to operate on 4-20 mA.

4.3.5.3. Digital Output Modules

Digital outputs shall use 1771-OAN 32 point discrete output modules. This module has 16 form A contacts.

4.3.5.4. Analog Output Modules

Analog outputs shall use 1771-OFE modules, configured to drive 4-20 mA into a 750 ohm load.

4.3.6. Chassis Sizing

In-plant PLC configurations shall use a 16-slot I/O backplane assembly. PLC configurations requiring more than one backplane shall use multiple 16-slot backplane assemblies as required.

Remote site PLC configurations shall use a 7-slot I/O backplane assembly or as required.

4.3.7. I/O Wiring Requirements

Each I/O point, whether used or spare, shall be wired from the module terminal strip to the field wiring terminal strip at the panel demarcation.

4.3.8. PLC Power Supplies

PLC configurations shall use power supplies, A-B model 1771- P7. The power supplies shall be configured for 115 VAC input (102-132 VAC, 47-63 Hz), and shall be fed from the facility's UPS.

4.3.9. Software Requirements

RSLogix 5, 500 or 5000 software shall be used to program the PLCs as required for the PLC product. Refer to Section 5.3 for more details.

4.4. LOCAL OPERATOR INTERFACE TERMINALS

WCDPS has chosen GE-Fanuc PanelClient operator interface terminals to provide touch screen interfacing capabilities local to a PLC control panel.

4.4.1. Introduction

The Quick Panel thin client graphic terminals are rugged electronic interfaces designed to provide operations the ability to monitor the entire control system data and graphics locally at the remotely located control panels. They replace traditional pushbuttons, switches, and gauges as the input and output mechanisms for operator interaction with a PLC and the process. All process data, setpoints, and commands available in the PLC should be provided at the local operator panel. The displays on the local operator panel are shared from the Terminal Server.

4.4.2. Model Sizing

WCDPS has chosen the PanelClient 15 inch Color touchscreen for use in all future installations.

4.4.3. Communication Requirements

PanelClients used throughout WCDPS's facilities shall include Windows CE.net 4.1 or later operating system, and licensing for operation as a client of the SCADA system HMI software. The units shall have 128 MB of DRAM, no mechanical drives, and have communication ports for RS232 serial communication, two 10/100Base-T Ethernet; and two USBv1.1 ports and Type 2 compact flash slot.

4.4.4. Software Requirements

iFIX software shall be used to program the PanelClient terminals. Refer to Section 5.3 for more details.

4.5. CONTROL DEVICE I/O INTERFACES

4.5.1. General

In addition to the specific monitoring requirements detailed in this section, all controllable devices shall have the following status points monitored by the SCADA System:

- Run or Position Status (provided by auxiliary run contacts at starter)
- Auxiliary contact on disconnect switches and breakers (open contact when disconnect open)
- Local lockouts and interlocks (where applicable)
- Hand / Off / Remote Selector Switch Position (where applicable)
- Local Power-disconnect
- Emergency Stop Switch (where applicable).

The following minimum alarm status information shall be provided for all motors sized 25 HP and larger:

- General Failure
- Excessive Temperature
- Excessive Vibration.

4.6. INSTRUMENTATION

To achieve a high level of performance and reliability from control systems, WCDPS intends to ensure that instrumentation equipment provided for operating facilities will:

- Meet the County's performance requirements
- Enable implementation of changes and expansions over the next 15 years.

4.6.1. General Requirements

Instrumentation provided should be evaluated against the following assessment categories:

Performance Considerations

a) Applicability to the County's service/process areas
b) Record of successful performance in the wastewater industry
c) Verification of published performance figures
d) Evaluations from independent testing authorities such as the Instrument Testing Association (ITA)
e) Product development history
f) Reliability evidenced through MTBF and MTTR data
g) Quality assurance and control procedures
h) Warranty terms.

Installation Considerations

a) Ease of installation
b) Accessibility of servicing adjustments
c) Compliance with industry standards
d) Maintainability and availability of full servicing manuals
e) Servicing and maintenance support provided in the County's operating area.

Manufacturing Considerations

a) There will be a preference priority for equipment manufactured in the United States of America.

Economic Considerations - Whole life cost, consisting of:

a) Purchase price
b) Installation cost
c) Operating cost
d) Calibration cost
e) Cost of spare parts
f) Training/maintenance costs
g) Life expectancy.

WCDPS has identified certain instrument types that are suitable for its operating facilities to standardize equipment procurement. These approved instrument types should be selected for the appropriate application to ensure that WCDPS realizes the benefits of standardization.

The major benefits of standardization are:

- Reduced spare parts inventory
- Reduced training costs for O&M staff
- Reduced design and procurement costs
- Assurance of compatibility with existing systems.

Personnel responsible for design/specification of instrumentation for WCDPS projects will first consider the criteria contained in this section. If the recommended instruments are considered inappropriate for a specific application or superior instrumentation becomes available, then the alternative instrument should be submitted to WCDPS for approval.

It is the intent that the standard selections and recommendations for instrumentation contained herein be revised as new information and products become available. Alternative manufacturers or products should not be specified unless they have prior approval of WCDPS.

4.6.2. WCDPS Preferred Instrument List

SERVICE	TYPE	MANUFACTUER	MODEL
Analyzer Chlorine Residual	Amperometric	Capital Controls	TBD BY WCDPS
Analyzer Dissolved Oxygen	Galvanic	Hach	TBD BY WCDPS
Analyzer pH	Potentiometric	Hach	TBD BY WCDPS
Analyzer *Gas Leak Detector*	Electrochemical Multi Point	MSA	TBD BY WCDPS
Analyzer *Turbidimeter*	Light scatter	Hach	TBD BY WCDPS
Analyzer *Sludge Density*	Optical	Royce	TBD BY WCDPS
Analyzer *Combustible/Toxic Gas detection*	Galvanic	MSA	TBD BY WCDPS
Flow *Air*	Averaging Pitot	TBD BY WCDPS	TBD BY WCDPS
Flow/Level *Open Channel*	Ultrasonic	Accusonic	TBD BY WCDPS
Flow/Level *General*	Differential Pressure	Accusonic	TBD BY WCDPS
Flow *General*	Magmeter Wafer 0.1" to 8"	Krohne	TBD BY WCDPS
Flow *Open Channel*	H Type Flume	TBD BY WCDPS	TBD BY WCDPS
Flow Switch *Seal Water*	Variable Area	Anderson	TBD BY WCDPS
Level Switch *Wet Wells*	Float	Flyght	TBD BY WCDPS
Panel Device *Single Loop Controller (CMAT)*	Microprocessor	Allen-Bradley	TBD BY WCDPS
Panel Device *Recorder*	Microprocessor	GE-Fanuc	TBD BY WCDPS
Panel Device *Selector Switch*	Coordinated Manual Control	Allen-Bradley	TBD BY WCDPS
Pressure Switch *General*	Differential/ Gage Vacuum	Rosemount	TBD BY WCDPS
Temperature *General*	Transmitters T/C or RTD	Foxboro	TBD BY WCDPS
Temperature *General*	T/C or RTD Assembly	Foxboro	TBD BY WCDPS

4.6.3. Standards for Instrument Lists

The Instrument List shall be developed in a standard format to provide WCDPS with information that is uniform from project to project.

With information in a common format, management of the information will be possible using personal computers and database management software. This database can serve as an information base for accounting, maintenance, inventory, spare parts requirements, existing equipment listing, and other related requirements.

These lists are intended to be "live" documents suitable for use by the contractor, system supplier, WCDPS or others. The flexibility of the program allows the insertion of additional fields to aid procurement, installation, loop calibration, loop testing, maintenance management, and other activities.

The contract documents shall require the contractor to supply the instruments described in the lists and as referenced in the specification paragraph.

Drawing numbers in the list define location or installation diagrams. Within a given loop, each instrument is listed by equipment/tag number and should be referenced to an appropriate specification in the contract document that defines its overall quality. Additionally, a panel reference or drawing reference locates each instrument.

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0		Initial Release for internal review
Rev 1.0	March 2009	Updated for Submission
Rev 1.1	June 2010	Revised footer, added network graphic and updated WCDPS references

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5. CONTROL SYSTEM SOFTWARE STANDARDS

5.1. GENERAL SCADA SOFTWARE DEVELOPMENT STANDARDS

5.1.1. General Requirements

For any programming project involving the SCADA system, there are a number of items required to perform the work. For any PLC programming, HMI or OIT configuration, these three items are important to the overall understanding and knowledge of the work to be performed.

- P&ID / PFD Drawings –These drawings are used to help the programmers layout process and overview screens. Information on these drawings help programmers understand how much information is needed to be displayed, and whether multiple screens are required to show all of the information.

- SCADA PLC FIELD I/O LIST Database – This is a list of all field I/O that is being monitored with the SCADA system. This database is mandatory for PLC, HMI and OIT development.

- Process Control Narratives – Describes the process and how normal operation is to be performed. These are necessary for PLC programming to clarify to the programmer what instruments and signals are related to the control parameters and control strategies that are to be programmed.

5.1.2. HMI Software Requirements

WCDPS has chosen GE-Fanuc Intellution iFIX Proficy V5.0 process visualization, data collection, and supervisory control software for HMI SCADA system functions.

5.1.3. SCADA PLC Field I/O List Database

The following procedures shall be implemented at a minimum when developing the SCADA PLC Field I/O database list for SCADA projects:

a) The database shall be created in the latest WCDPS-supported version of Microsoft Excel.

b) The database shall be structured for quick sorting and filtering of any data field.

c) Any data field that has the same value for each point shall not be included within the database.

d) A separate tab or worksheet shall be included for statistics. The following statistics shall be included:

   - Total point count
   - Total point count by PLC
   - PLC breakdown by point type.

e) The following fields shall be included in the database:

- Tag name – I/O point name
- Point Type – AI, AO, DI, DO
- Tag name description
- Tagname subfields
- Equipment ID
- Equipment Description
- Signal Function
- PLC
- Rack
- Slot
- Point
- I/O Register
- SCADA Register
- Reference Drawing
- Instrument Range Low
- Instrument Range High
- Instrument Units – Engineering Units of the point
- ON Text – Signal status when High
- OFF Text – Signal status when Low.
- Totalize
- Accumulate Run Time
- Count Starts
- Trend
- Archive
- Alarm LoLo
- Alarm Lo
- Alarm High
- Alarm HiHi
- Alarm Priority
- Inverted

f) The tag name shall be created / calculated through the CONCATENATION function with an individual field for each part of the tag name.

g) The equipment description shall have the site name before the signal description for consistency and sorting abilities.

h) WCDPS has prepared a standard template file for preparation of the SCADA PLC Field I/O list, as defined in Section 6. All SCADA projects shall use the standard template file.

5.1.4. Graphic Screen Development Process

As a general guideline, the following development process should be followed on each SCADA project for the development of process graphic screens.

- WCDPS will provide the contractor / developer a drawing package comprised of the SCADA Standards, P&IDs, hand sketches, and existing screens, as available, as a baseline for how each screen should be presented.
- The contractor / developer should develop a minimum of two graphics and provide a submittal package to WCDPS for review and comment. Graphics shall be developed using the iFIX graphics development software.
- If necessary, the contractor / developer should hold a workshop to present the graphics design and finalize design details.
- Following WCDPS review and comment of the submitted graphics, the contractor / developer shall finalize the remaining graphics to the 90% level, and submit to WCDPS for review.
- Following WCDPS review and comment, the contractor / developer shall fully develop all the graphics.

5.2. USER INTERFACE DEVELOPMENT STANDARDS

This section defines the standards implemented in the creation and modification of the HMI graphics displays for the SCADA system. The standards are structured to keep the conventions as simple as possible. In an effort to minimize the learning curve on a system, it is imperative that a minimal amount of colors are chosen to signify elements and that those remain consistent throughout the system. All graphics will be developed and submitted for approval to WCDPS prior to implementation. Symbols will be developed in accordance with ISA standards for representation and layout. The symbols shall represent the different states by changing color and/or orientation due to the nature of the state.

5.2.1. General Requirements

5.2.1.1 Hierarchical Structure

The graphic displays are built in a hierarchical structure, which allows for viewing a process area or facility through a main menu. The navigation of these displays is accomplished by using the mouse to “click” on a process area graphic button and pull down menu. For example, the primary settling tank #7 graphic is selected from the primary treatment area menu button and by clicking on PST#7 on the primary treatment area pull down menu. Control action is only allowed through individual popup displays; the popup display is reached by clicking on the equipment graphic symbols (pumps, valves, etc.) on the process area graphic display.

5.2.1.2 Process Visualization

Process screens shall be based closely on Process and Instrumentation Drawings (P&IDs) in order that the system processes are accurately depicted in a consistent format and there is a minimal learning curve for the operators as the new graphics are brought online. Graphic layout should be as representative of the physical plant process as practical. Process displays include 2-D and 3-D-like symbols; shown from an isometric top view or side view perspective. Flow is directed from left to right and top to bottom on the screens whenever possible, unless there is a compelling reason for a different flow direction for the particular process. In the event of a large process in which there is more information that can reasonably fit onto one screen, the graphics shall be divided over multiple screens at logical places.

5.2.1.3 Operator Interface

The interaction of the operator with the HMI is intended to be user-friendly and mouse-intensive. When clicking on an object, the associated action is executed upon the mouse button being released.

5.2.1.4 Control Verification Actions

When issuing a critical command to a device, the operator must confirm the control action before the action is issued to the PLC. The purpose of this function is to avoid an unintended command. A pop-up display will request the operator confirm (yes/no) the command.

5.2.1.5 Display File Name Convention

The display file name is assigned based on the type of display (process, system, control, etc.) and the process area monitored. As discussed above, the system users will navigate to screens using the hierarchical or process flow methods, and as such, it is not necessary for the user to know the file names.

The general naming convention for the process area screens are as follows:

- Process Overview Screen: “DWTF_” + {Process Area Abbreviation} + “_00X”
- Process Detail Screens: “DWTF _” + {Process Area Abbreviation} + “_10X”
- Process Setpoint Screens: “DWTF _” + {Process Area Abbreviation} + “_20X”
- Process Trend Screens: “DWTF _” + {Process Area Abbreviation} + “_30X”

5.2.1.6 Screen Resolution

All HMI graphics shall be configured with a screen resolution of 1024 x 768 pixels.

5.2.2. Screen Layout

The current view for any screen shall consist of three parts; the Title Bar, the Display Area, and the Alarm Banner.

5.2.2.1 Title Bar

The title bar is located at the top of each screen to display the current user, date / time, and the name of the current screen. Below is the process area buttons. Functions performed here include security login and access to the global navigation toolbox, and navigation to individual process graphics.

5.2.2.2 Display Area

The area below the title bar is reserved for the display of overview and process screens, system displays (alarming and trending screens), and popup displays used to convey information and control process equipment.

5.2.2.3 Alarm Banner

The area below the display area is reserved for the alarm banner. This area is used to display the last three active alarms within the SCADA system.

5.2.3. Display Types

5.2.3.1 Overview Screens

Overview screens are at the top of the display hierarchy. The highest level is a campus layout representation of the facility. The next lower level consists of sub-overviews, which represent a process area. The hierarchy can continue through multiple levels, until an individual process is reached.

The overview screens allow quick visualization of key process data. Navigation to process screens is provided through the process area buttons in the Title Bar.

5.2.3.2 Process Screens

Process screens are at the second level and third level in the display hierarchy. They are P&ID-like representations of specific process areas. Screens shall be defined in accordance with WCDPS process and sub-process groups. These screens provide overviews of a treatment process (primary, secondary, etc.) at the second level and individual process tanks and components at the third level. The graphics shall contain only information specific to that process or required from another process to completely monitor and controls aspects of that process.

5.2.3.3 Pop-up Screens

Complex Equipment Pop-ups

All screens are designed to convey as much information as is practical, without overcrowding the screen or confusing the operator. The complex control pop-ups are provided when it is necessary to provide setpoint inputs on multiple pieces of equipment, i.e. master clarifier control or RAS ratio control. The pop-up allows the operator to input all required setpoint information on one graphic.

Control Pop-ups

More conventional use of pop-ups relates to the control parameters of controlled equipment. Control pop-ups are accessed from the process screens by clicking on the equipment icon. Field operation such as equipment control (start/stop or open/close), automatic pump sequencing, and setpoint adjustments are among the functions available through these screens.

5.2.3.4 System Screens

System screens are displays that provide information on the SCADA system as a whole. These screens include the Alarm Summary, Trend Overview, and other application specific screens. Much of the functionality is included within the HMI software package, but some features may be custom.

5.2.4. Text and Data Representation

5.2.4.1 Analog Feedback Display

Analog inputs from field instruments or calculated within the PLC shall be displayed as recessed boxes with the analog value and units (or engineering unit abbreviations). The data and the engineering units are displayed as black text. During alarm conditions, border around the box will turn the color red to show that the current value is in an alarm state. The box is located near the equipment, or location of where the transmitter originates on the screen layout.

5.2.4.2 Analog Setpoint Display

Analog values that are operator enterable, such as setpoints, are displayed on recessed buttons. The button is gray with the functional description displayed as black. A gray box displays the current value of the setpoint. Clicking the button will display an operator entered pop-up in which the operator will enter the new value to change the setpoint.

5.2.4.4 Text

Black text is used to identify equipment or label a process. Inactive equipment alarm information is shown as light gray.

5.2.4.5 Discrete State Text

Digital point values with only two states (no alarm state) are always displayed as black text and are located near the equipment, or location of where the transmitter originates on the screen layout.

5.2.4.6 Alarm Display

Specific textual alarms or equipment failure conditions are displayed when the alarms conditions occur. The alarming color sequence is as follows:

- Normal — Not Visible or White (case by case)
- Unacknowledged — Flashing Red
- Acknowledged — Static Red
- Unacknowledged, Return to Normal — Flashing Black.

5.2.4.7 Structures

Buildings, channels, and other physical structures shall be displayed to assist in the conveyance of the process. These structures shall be closely depicted to show actual relative size and placement within a process. Process piping is provided when flow paths are key to understanding or controlling the process.

5.2.4.8 Equipment

Pumps, valves, or any monitored or controlled devices are displayed on the screen and animated based on field I/O feedback. This allows the operator to fully monitor the current

status of the equipment and consequently the process itself. The description of the device will be placed below the device and analog feedback values above the device. Due to the complexity of some screens, it is not possible for all of the descriptions and values to be placed in the same location due to piping and any other graphics, but equipment layouts need to be consistent on a page-by-page basis.

5.2.5. Color Conventions

Color will be used in operator displays to denote processes and equipment conditions on the operator displays. The color standards are as follows:

5.2.5.1 General Color Schemes

- Screen Backgrounds — Blue-green
- Non Active Text — Dark Gray
- Informational Text — Black
- Discrete State Text — Black

5.2.5.2 Analog Feedback Boxes

- Recessed Box — Gray
- Analog Text — Black
- Engineering Units — Black

5.2.5.3 Analog Setpoint Boxes

- Recessed Button — Gray
- Functional Text — Black
- Feedback Text — Black
- Engineering Units — Black

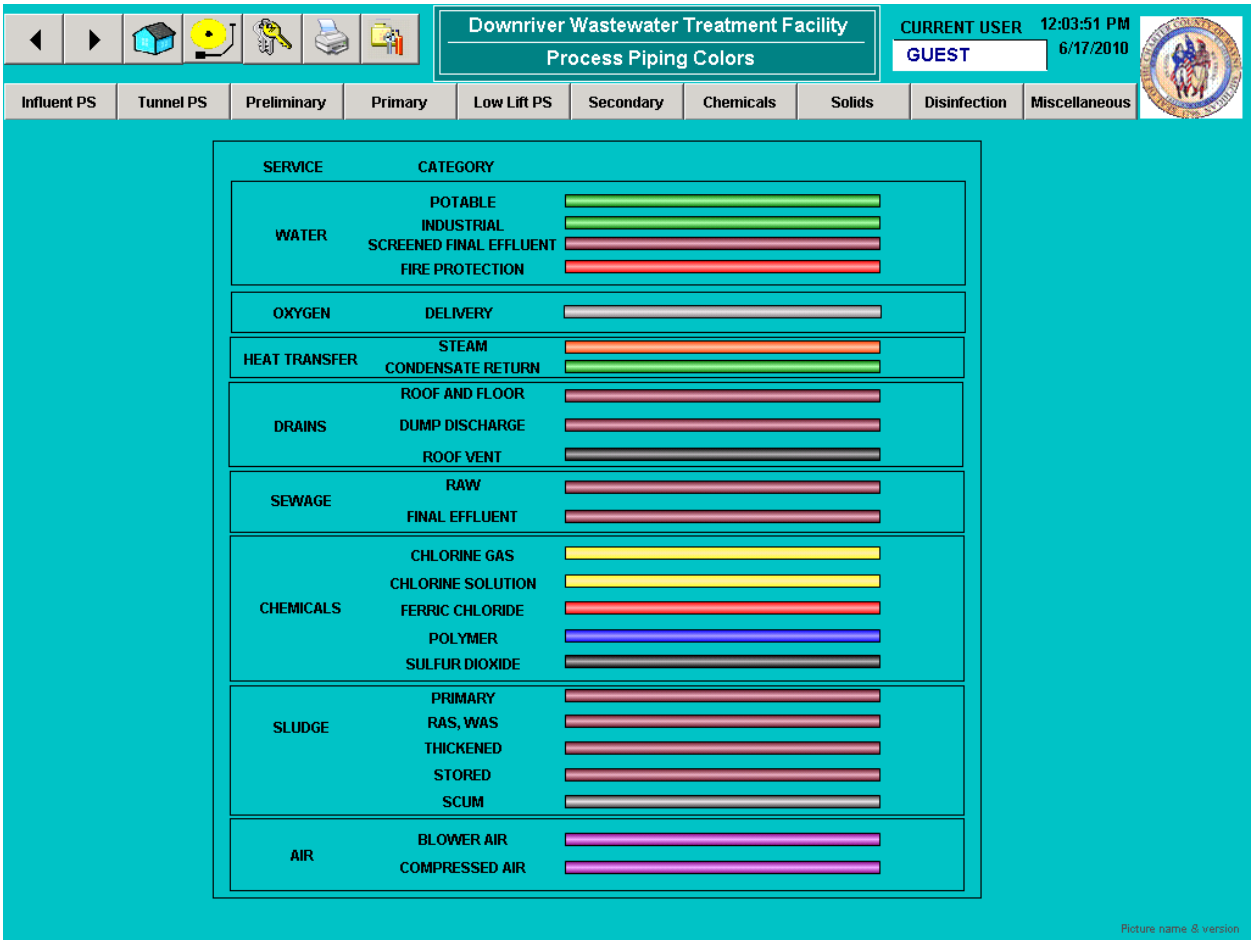
5.2.5.4 Equipment Device Color Schemes

- On / Open — Red
- Off / Closed — Green
- Alarm — Red Flashing
- No Feedback — Light Gray.

5.2.5.5 Process Piping Colors

A Process Piping Colors Screen provides the color format to be used for implementation of all HMI screens. Note that any deviation from these standards, or the use of additional colors not identified below must be approved by WCDPS prior to proceeding with development of the HMI graphics.

Figure 5.2.5.5-1 DWTF Color Standard Graphic Display



Note that to meet Federal ADA (Americans with Disabilities Act) requirements, color cannot be used solely for monitoring purposes. Equipment shown as “On” or “Open” shall be shown as solid symbols with “Off” / “Closed” shown as hollow. Alarmed states shall be shown as flashing and normal states are static.

5.2.6. Alarming

Each point in the system database shall be configured independently for alarming. Discrete and analog points alarm when the point value goes above or below pre-defined limits. Alarms are generated within the PLC. Alarms shall also be assigned an alarm priority. Alarms with a lower priority number are of higher importance (priority 1 – highest priority), and alarms with a higher priority number are of lower importance.

5.2.6.1 Alarm Groups

All I/O tags in the system shall be assigned to an alarm group. The alarm group assignment is based on the level of the alarm and the process area that the tag is associated with. Three alarm levels will be used; Critical, General and Warnings.

5.2.6.2 Alarm Groups

Alarm Groups are structured similar to WCDPS naming conventions for process identification. The groups are organized by a primary process group and secondary process group.

5.2.7. Historical Data and Trending

5.2.7.1 Historical Data Processing

The System Historian shall capture and store data for analysis and report generation at frequencies required for system reporting and trending and in consideration of the affect on data storage.

5.2.7.2 HMI Trending

The HMI shall be configured for trending any point within the SCADA system. The trends displayed shall be analogous to an XY strip chart plot, where the x-axis is time and the y-axis is the point value. Trends shall be made ad-hoc or pre-configured based on WCDPS operational requirements.

Operations shall have the ability to track up to eight tags per trend display. Each data track shall be configured as a different color. I/O points shall be configured to trend values in both real-time and from historical files and utilize the full features of the iFIX trending capabilities.

5.2.8. User Control

5.2.8.1 Peripheral Devices

The HMI interface shall utilize the mouse (single click only) for all navigational requirements of the SCADA system environment. There shall not be cases where special keyboard key combinations are required to navigate / operate the system; however, the keyboard shall be used for common tasks such as entering setpoints, security login procedures etc. A box appears around objects with functional attributes when the cursor rolls over the object denoting that actions are taken upon clicking the object.

5.2.8.2 Equipment Control

Controlling equipment in the field or changing parameters within the HMI are performed in a standard method requiring confirmation. These types of actions shall be performed from a control pop-up screen. Under no circumstances shall any field manipulation be performed from an overview, process, or system screen. For example, an operator needs to start RAS Pump #2. The user shall navigate to the Clarifier process screen and single-click Pump #2. A pop-up screen containing pertinent pump information shall be display with start and stop control buttons. The user may select the “start” command and the command is executed.

5.2.8.3 Confirmation of Action

All commands to field equipment are executed without secondary confirmation (yes/no) by the operator. After clicking the start or stop button from a pop-up display the command is issued to the device. Confirmation of action may be added for critical control actions when required.

5.2.9. HMI Database Naming Convention

The HMI database names shall use the ten (10) digit WCDPS equipment number as part of the overall structure. The ISA prefix, Equipment # and ISA suffix comprise the PLC Point database as described in Section 2 of this Standard.

5.2.10. Application Security

Security features of the HMI software allow classes of users to be defined, with specific privileges and restrictions placed on each class of user. Each user is assigned a unique username and password. The username will be linked to a group account set to the proper access properties.

As a default, the system will boot-up in a guest mode, so that process overview screens can be viewed without requiring an operator login. Once the user is logged in, an inactivity log-out timer (screen saver) will be enabled. After a programmed period of time, if no actions are taken by the operator (such as acknowledging alarms, setting control actions, changing screens, etc.) the screen saver activates and the user is logged off and the system reset to guest mode. The WCDPS default for the screen saver (inactivity) logoff is variable.

5.2.10.1 User Classes

The following user classes, in order of increasing access privileges, are defined below for use at all HMI workstations. Each user will be provided with a username and password linked to one of these user classes.

- **Guest Mode** - A console in the guest mode shall not accept commands to actual field devices nor accept input data affecting the real-time or historical databases.
- **Operator Mode** - All displays shall be accessible, commands may be sent to system devices, all programs applicable to real-time operations may be run, setpoint and popup screens active, and all hardcopy reports can be selected.
- **Administrator Mode** - When operating in this mode, a programmer may use the database edit and display generation and edit functions, or may perform program source edit, batch processing, and background CPU functions. Additionally, the programmer may enter data into the database via the programmer's data displays. This mode also provides for overall maintenance and management of the system, and includes all the other modes.

5.3. PLC PROGRAMMING STANDARDS

This section is a guideline for programming and configuring PLCs. It is intended to be a flexible standard that allows programmers to utilize custom techniques and methods that are reasonable simple to understand by personnel with basic to intermediate programming experience. The standards that follow layout general guidelines and minimal requirements that are to be included throughout the PLC code.

5.3.1. Software Requirements

Allen Bradley's RSLogix shall be utilized to program and configure all WCDPS PLCs. The latest version of RSLogix supported by WCDPS shall be used to encompass the most current libraries and newest features.

5.3.2. Program Language

WCDPS's preferred PLC programming language is Ladder Logic (LL). Written approval from WCDPS is required before another program language is used.

5.3.3. Program Structure

The following requirements are required for all PLC programming.

- Initial Setup / First Scan – This includes all blocks and functions that need to be executed when the PLC is placed into RUN. The most common usage of this section is for initialization of registers.

- Communication – This section is for locating all blocks and functions required for managing communications to and from other peer-to-peer devices and remote I/O. In many cases, discrete bit packing is an efficiency concept that packs bits into words for transmittal. This section may be used for the packing and unpacking of discrete bits.

- Input Buffer – This section is typically reserved for handling the raw input data and moving it to internal registers for manipulation. Scaling the analog inputs is typically performed here for using "real" values within logic blocks.

- Alarms – All logic used to generate alarms is included here. Many cases these alarms are used internally within logic blocks, triggers for audible alarms, and includes acknowledgment actions.

- Stats – This is a section used for calculations that are required at the HMI level. Industry best practices promote the method of performing no calculation at the SCADA Master level due to communications failure, PC failure, etc. Common functions include equipment runtime, numbers of starts / stops, and other totals.

- Control – These sections are for all logic required for determining control actions for the field equipment. In many cases, sub sections are required on an equipment-by-equipment basis. Common functions such as flow splitting will be included here, however, the logic used to determine a common flow setpoint, might reside in the stats section.

- Output Buffer – This section is typically reserved for handling the output data from the internal values. Scaling the analog values back to raw value is a common function here.

5.3.4. Programming Guidelines

The following are general techniques and guidelines to follow through the program.

- All programming is to be performed as positive logic. (power flow indicates action)

- Predefined control functions that are part of the programming language are preferred over custom programmed blocks.

- Every logical process shall be programmed as a separate program block. As a precursor to each program block, a detailed comment shall be provided which describes in detail the control philosophy achieved by the programming within the block.

- Where more than one line of logic is required in order to perform a required function continuation contacts shall be used. Continuation logic, which uses the continuation contact, will immediately follow the line ending with the associated continuation coil.

- Where it is necessary to maintain a coil, control logic will use set & reset coils. All lines of logic associated with the control of a common coil (i.e. set/reset coils) will immediately follow each other logic within the program and shall always reside within the same program block. Self-sealing control logic shall not be used.

- Outputs are to be used only once within the program. The only exceptions are those outputs controlled by set/reset logic which function in pairs, and values which are initiated in the “run first” program block. Even under these unique circumstances, references within the program are not to exceed two (2).

- Output rung enabling conditions shall be grouped at the beginning of each rung followed by conditions that inhibit the output at the end.

5.3.5. Standard PLC Program Modules

WCDPS has prepared standard program modules for use in all PLC programs. These standard modules shall be used when designing and assembling PLC programs. The actual ladder logic used in each module is available from WCDPS. The available program modules are:

1. Start / Stop for motor controls
2. Analog / signal conditioning
3. Lead/Lag control
4. VFD speed control
5. PID loop control
6. Open/Close for valve control
7. Signal conditioning blocks
8. Process Variable selection

5.3.6. Program Documentation

All PLC programs shall be fully documented to explain and describe the logic within the program. Each section shall be documented to explain all functionality associated within the section.

For each PLC programmed and configured, the documentation provided shall include:

a) Soft copies of all project files required by the PLC with rung annotations.
b) Complete soft copies of entire program including process narrative descriptions on a rung to rung basis.
c) Identification of all acronyms used through program.

d) Complete listing of all registers and data tables (logic components) associated with the PLC programming environment in spreadsheet format.

5.3.7. File Management

PLC Program files shall be named as follows:

PLC Control Panel Name.rss e.g., STACP.rss

where **.rss** is the standard RSLogix display extension.

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0		Initial Release for internal review
Rev 1.0	March 2009	Updated for Submission
Rev 1.1	June 2010	Updated graphics, footer and WCDPS references

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6. APPENDICES

6.1. INDUSTRY REFERENCES

This section references the latest revisions of applicable industry standards. These shall govern, as applicable, the electrical terminology, the design, the materials, the construction, and the testing methods for all equipment.

Standard	Title
ANSI C63.12-2000	Recommended Practice for Electromagnetic Compatibility Limits.
ANSI T1.102	North American Digital Hierarchy - Electrical Interfaces.
ANSI/IEEE Std. 100	IEEE Standard, Dictionary of General and Electronic Terms.
Bellcore GR-1089-CORE	Electromagnetic Compatibility and Safety.
Bellcore TR-332	Reliability Prediction Procedure for Electronic Equipment.
EIA/TIA-568	Performance Standards for Data Communication Wiring Systems.
EIA-RS-210-C	Racks, Panels and Associated Equipment.
FCC Rules	Part 2 - All applicable sections
FCC Rules	Part 21 - All applicable sections
IEEE 802.3	Information Technology - Telecommunication & Information Exchange Between Systems - LAN/MAN - Specific Requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications
ISO 2593	Interface Standard for High Speed Data Transmission Equipment.
NEC	National Electric Code (NFPA 70)
NESC	National Electrical Safety Code
TIA/EIA-455	Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices and Other Fiber Optic Components.
TIA/EIA-606	Administration Standard for the Telecommunications Infrastructure of Communications Building.
UBC	Uniform Building Code
Underwriters Laboratories, Incorporated	Unless otherwise specified, all electrical equipment and material shall be listed and labeled for the purpose for which it is used by the Underwriters Laboratories, Incorporated (UL). This requirement may be waived only if a UL listing is not available for the type of product.

6.2. LISTINGS OF STANDARDS AGENCIES

ANSI American National Standards Institute
1430 Broadway
New York, NY 10018

ASHRAE American Society of Heating, Refrigerating and Air Conditioning Engineers
1791 Tullie Circle, N.E.
Atlanta, GA 30329

ASME American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

ASTM American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

AWWA American Water Works Association
666 West Quincy Avenue
Denver, CO 80235

AWS American Welding Society
550 N.W. 42nd Avenue
Miami, FL 33126

FCC Federal Communication Commission
P. O. Box 36085M
Pittsburgh, PA 15251

FM Factory Mutual System
1151 Boston-Providence Turnpike
Norwood, MA 02062

FS Federal Specification
General Services Administration
Specifications and Consumer Information Distribution Section (WFSIS)
Washington Navy Yard, Bldg. 197
Washington, D.C. 20407

IEC International Electrotechnical Commission
P.O. Box 131
1211 Geneva 20, Switzerland

IEEE Institute of Electrical and Electronics Engineers
345 East 47th Street
New York, NY 10017

ISA Instrumentation, Systems, and Automation Society
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709

NEC National Electric Code
National Fire Protection Association
Battery March Park
Quincy, MA 02269

NEMA National Electrical Manufacturers Association
2101 L Street, N.W.

Washington, D.C. 20037

NFPA National Fire Protection Association
Battery March Park
Quincy, MA 02269

TAS Technical Aid Series
Construction Specifications Institute
601 North Madison Street
Alexandria, VA 22314

UL Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

6.3. WCDOE APPROVED VENDORS AND PRODUCTS

WCDOE has standardized on a limited number of vendors and products in order to reduce spare parts, maintenance, and support costs. Products may be added or removed from the approved list as required.

6.3.1. Approved Vendors

GE-Fanuc
Rockwell Automation

6.3.2. Approved Products

Approved Electrical devices are listed in Section 3. Approved instruments are listed in Section 4.

6.4. WCDOE STANDARD DRAWINGS

The following standard drawings form part of the SCADA System Standards:

1. WCDOE Standard Symbols for P&IDs: Contact WCDPS for a copy

6.5. I/O LIST FILE FORMAT

WCDPS has developed a standard SCADA PLC Field I/O list in Excel format to be use on all SCADA projects. Contact WCDPS for a copy.

Revision Record		
Revision Number	Revision Issue Date	Reason for Revision
Rev 0		Initial internal release
Rev 1.0	March 2009	Updated for Submission
Rev 1.1	June 2010	Updated footer, instruction for obtaining standard I/O list and symbols, updated ANSI C63.12-2000 version, and updated WCDPS references