PUBLIC NOTICE

The City of Kingsport is requesting sealed Expression of Interest/Request for Qualifications from firms with the expertise to perform work related to the Water and Wastewater Systems SCADA Master Plan Implementation Project

The Contractors must have experience in projects of this nature as specified in the invitation.

Sealed requests will be received by the Procurement Manager, City of Kingsport, until 4:00 P.M., Eastern Time, December 5, 2018 and at that time will be publicly opened and the names of the submitters read aloud in the Council Room, City Hall, 225 W. Center St., Kingsport, TN.

By submission of a signed Expression of Interest/Request for Qualifications, the contractor certifies total compliance with Title VI and Title VII of the Civil Rights Act of 1964, as amended, and all regulations promulgated thereunder.

Documents for the above referenced request are available online at https://www.kingsporttn.gov/city-services/purchasing/ .Interested parties may also contact the Procurement Department, City of Kingsport – Phone (423) 229-9419.

PUB1T: 11/14/18

Tilden J. Fleming
City Manager

SCADA MASTER PLAN IMPLEMENTATION SUMMARY OF WORK
REQUEST FOR CONTRACTOR QUALIFICATIONS

November 14, 2018

PROJECT: Request for Qualifications (RFQ) – City of Kingsport Water and Wastewater Systems SCADA Master Plan Implementation Project

Dear Representative:

The City of Kingsport is currently receiving qualifications from contractors / integrators that are interested in qualifying to bid on the above referenced project.

Contractors desiring to be considered must submit six (6) copies of the qualifications to:

Procurement Manager
City of Kingsport
225 West Center Street
Kingsport, TN 37660

REPLIES MUST BE RECEIVED BY 4:00 P.M., E.T., DECEMBER 5, 2018. THE RFQ OPENING WILL BE HELD IN THE COUNCIL ROOM, CITY HALL, 225 W. CENTER STREET, KINGSPORT, TN 37660. MARK THE OUTSIDE OF THE ENVELOPE REQUEST FOR QUALIFICATIONS – RAW WATER TRANSMISSION AND INTAKE IMPROVEMENTS

All Requests for Qualifications received by the Procurement Manager shall be publicly opened and examined at the in the Council Room, City Hall, 225 W. Center Street, Kingsport, TN at 4:00 P.M., E.T., 2018. Once all proposals have been opened, the Procurement Manager will announce only the names of the submitters.

Any additional information concerning this request may be obtained from the Procurement Department at (423) 229-9419.

Sincerely,

Brent Morelock, CPPO, CPPB
Procurement Manager

Request for Qualifications

Contractor / Integrator
City of Kingsport
Water and Wastewater Systems SCADA Master Plan Implementation Project

The City of Kingsport is currently receiving qualifications from contractors / integrators that are that are interested in qualifying to bid on the above referenced project.

History

The City of Kingsport manages a regional water system that provides potable water to approximately 36,000 customers over a 120 square mile service area. The water system consists of 28 MGD conventional water treatment plant, 750 miles of water lines, 22 water tanks, 15 major pumping stations and numerous small neighborhood booster pumps.

The City's wastewater collection system currently serves approximately 22,000 customers in the corporate limits of the City of Kingsport and in portions of Sullivan County. The sanitary sewer system consists of 12.4 MGD wastewater treatment plant, 577 miles of sewer lines, 96 lift stations and 268 residential lift stations.

A SCADA Master Plan was completed by CDM Smith to provide a coordinated path forward for future water and wastewater system improvements that will focus on reliable long term service and future needs for system monitoring and control. The purpose of Master Plan is to migrate the City of Kingsport's Water Treatment Plant (WTP), Wastewater Treatment Plant (WWTP) and all remote distribution and collection sites from the current RTU and radio communications hardware as well as a universal Supervisory Control and Data Acquisition (SCADA) software platform to replace the multiple SCADA software packages currently being used. The WWTP and the remote collection system sites will be the first project implemented. The second project will include the WTP and remote distribution sites. This RFQ will be used to pre-qualify contractor/integrators for both projects.

1.01 LOCATION OF WORK

A. The work of this Contract is located at the City of Kingsport Water Treatment Plant, the City of Kingsport Wastewater Treatment Plant, and all remote distribution and collection sites.

1.02 SCOPE OF WORK

A. Furnish all labor, materials, equipment and incidentals required to provide the City with standardized SCADA system across the water treatment and distribution system and the wastewater treatment and collection system sites in their entirety as described in the City of Kingsport Water and Wastewater Treatment Facilities SCADA Master Plan, as shown in the Contract Documents that will be made available to the list of pre-qualified contractors, selected by the City, based on this RFQ process. The SCADA Master Plan will be made available to those wishing to pre-qualify. Contract Drawings and

Specifications will only be made available to those contractors that were selected by the City to bid on the projects.

B. As an initial part of the bidding process, contractors will be required to submit qualifications to be considered "pre-qualified" for the bidding process.

C. The work will be divided into two bidding packages and two contracts.

D. The work of this Contract is estimated to begin in 2018. Estimated project completion time is one year for each contract.

E. The Work includes, but is not necessarily limited to, the following:

1. Update the PLC system hardware and software to a standardized platform.

2. Update the HMI software to a standardized platform.
   a. HMI graphics screens shall be developed and standardized through meetings with the PICS (Process Instrumentation and Control System) Supplier and the City during the design process.

3. Upgrade operator workstations. Workstation hardware shall support the HMI/SCADA software that was selected during the SCADA Master Planning process.

4. Provide a long term historical data storage system using the historical data. Contractor shall utilize the historian software from the HMI/SCADA vendor selected in the Master Planning process.

5. Provide remote terminal units (RTUs) for the Collection remote site Lift Stations, utilizing cellular modems for communications. Provide cellular modems for the RTUs based on information in the SCADA Master Plan.

6. Provide RTUs for the Distribution remote site Pump Stations and Tanks, utilizing Ethernet radios for communications. Provide Ethernet radios for the RTUs based on information in the SCADA Master Plan.

7. Provide layers of redundancy in the HMI/SCADA system software including the provision of redundancy local to each plant at the I/O server level for high availability of the system.

8. Review the security of the City's HMI/SCADA system, in collaboration with the City's IT department, using the Cybersecurity guidance that is available from resources such as AWWA and NIST and incorporate security improvements into the SCADA upgrades project.

9. Procurement and maintenance of the workstations, laptops, and networking equipment.

10. Scheduling coordination as required to convey and clarify Engineer's control design intent

11. Scheduling Standards discussion and documentation meetings to ensure the City of Kingsport has a standard guide for any future expansion or upgrades

12. Coordinating overall project delivery including field testing and startup

13. Document management of all the systems and software that are installed for the City of Kingsport that include, but are not limited to, the following: software versions, backups of programs/applications, operating systems, firmware version, etc.

14. The PICS Supplier will be responsible for the following:
    a. Programming application software for PLCs
    b. Programming plant OWS Workstations and HMI

1.03 WORK BY OTHERS

A. The following work will be performed by others concurrently with the Work of this Contract.

1. The Engineer will be responsible for the following:
    a. Developing detailed control descriptions for review and use by the PICS Supplier (NOTE: the existing control narratives have been requested for the WTP and WWTP PLCs for modification by the Engineer but the City does not have this documentation; therefore, the specifications will require the PICS Supplier to develop these control narratives as part of the testing procedure submittals for the factory acceptance testing and they will be reviewed by the Owner and the Engineer for approval).
    b. Witnessing tests of application software for compliance with Engineer's control strategy descriptions or the PICS Supplier's control strategy descriptions that were developed based on the converted PLC applications and approved by the Engineer/Owner.

2. The City will be responsible for the following:
    a. Witnessing software tests at the PICS Supplier testing site
    b. Accepting software in coordination with PICS Supplier plant testing and substantial completion

1.04 CONTRACTOR QUALIFICATION

A. Proposed contractors / integrators will be required to provide evidence of the following qualifications, certifications, or training to be considered for the subject project.

B. Minimum Experience

1. The minimum experience requirements for prequalification are:
    a. Successful completion of the Process Control Integration for at least five water or wastewater treatment plant upgrade or expansion projects where the applicant served as the primary Process Control Integrator or served as a subcontracted Process Control Integrator with each referenced project having contract or subcontract total of at least $5 million and the project was completed in the last ten years.
    b. Project work shall have included a project that required existing systems to be kept online/operational.
    c. Project work shall have included a minimum of one water and/or wastewater treatment plant upgrade or expansion completed after January 1, 2005 with a minimum of 10 MGD permitted capacity.

d. Project work shall include and contractor shall provide evidence of the installation and programming of the following:
    1) Installation and programing of Allen Bradley 1769 L3x Series with 1769 Compact I/O.
    2) ProSoft DNP3 Communications Module Model MVI69-DNPSNET for DNP3 communications with the HMI/SCADA software.
    3) Work including Programmable Logic Controller (PLC) programming, testing of PLC logic, Human Machine Interface (HMI) and Operator Interface Terminal (OIT) graphics development, HMI and OIT software configuration, database development, report development, and startup/training activities associated with the configured portions of the PLC/HMI/OIT system.
    4) Work including HMI/SCADA programming services including, but not limited to, the following:
        a) Upgrade of the existing SCADA software at each treatment plant to Trihedral's VT SCADA (latest supported version).
        b) Creation of new P&ID style graphics for operations and monitoring processes.
        c) Creation of reports utilizing SyTech's XL Reporter software and data from the VT SCADA historian database.

2. Applicants must provide evidence of financial and work force availability to perform the work including, at a minimum:
    a. Identification of key project managers and work force.
    b. Workload projections for the key workers through 2018 and 2019.
    c. Current bonding capacity.

C. Personnel Qualifications/Experience

The Integrator's designated project manager and lead and back-up PLC and HMI programmer must have experience on projects of similar size and scope. Applicant must dedicate the proposed personnel to the project and may not make changes without written approval from the City. The following qualifications will also be considered in this evaluation:

1. A lead and back-up PLC and HMI programmer shall be assigned to this project and shall have programmed wastewater treatment plant upgrades or water treatment plant upgrades to plants with a minimum of 10 MGD permitted capacity. Reference to be for services completed after January 1, 2005.

2. The lead and back-up PLC and HMI programmer shall also have, and be able to document, the following experience:
    a. VT SCADA Level 1 and Level 2 Operation and Configuration training or equivalent HMI programming software experience
    b. Allen Bradley / Rockwell Automation SLC500 and RSLogix 500 or above PLC programming software experience as well as RSLogix 5000 programming software experience, specifically with CompactLogix hardware.
    c. Experience converting Allen-Bradley SLC500 applications to RSLogix5000 applications as part of a PLC hardware upgrade.
    d. SyTech's XL Reporter software reporting software experience
    e. SQL Server 2000 or above database experience, including the ability to modify an existing database configuration to collect/receive additional historical data points
    f. Experience programming PLCs and HMI/SCADA software to perform the following:

1) Standard Motor Control logic including Lead/Lag/Standby sequencing with alternation for motor starters and variable frequency drives
2) Tuning PID controllers for pump speed control and valve position control
3) Chemical Flow Pacing
4) Calculations for equipment runtimes and flow totalization
5) Converting vendor supplied PLC logic for processes being utilized by the City (i.e. centrifuges for dewatering, UV for disinfection, filter backwash logic, etc.)

1.05 SELECTION CRITERIA

A. All proposals will be reviewed and rated by a selection committee representing the City of Kingsport. The selection criteria will include, among other items, and evaluation of: previous experience, past performance, overall capabilities to handle projects competently and on schedule and integrity. After the committee has completed their evaluations, the committee will meet and make a selection. The City reserves the right to interview firms.

B. Proposals will be subjected to the selection process outlined below.

1. All proposals will be reviewed in accordance with the requirements outlined herein.

2. A shortlist of applicants will be developed from proposals meeting the requirements outlined herein.

3. The City will interview shortlisted applicants as needed.

4. Final list of successful applicants will be made public.

5. Design documents and drawings, including bidding requirements, will be provided to those applicants.

The City of Kingsport Water and Wastewater Treatment Facilities

SCADA Master Plan

90% Implementation Update

Prepared for

City of Kingsport, TN

SCADA Master Plan Project

Prepared by

CDM Smith

Original: March 2017

Updated: November 2018

CDM Smith

Table of Contents

Summary of Master Plan Updates – November 2018

Water and Wastewater Systems SCADA Master Plan Implementation Project – 90% Design

Project Background

In March 2017, CDM Smith developed a SCADA Master Plan which detailed a comprehensive SCADA system upgrade to the City of Kingsport water and wastewater systems. Based on the Master Plan, CDM Smith was authorized to proceed with the design and implementation of the Master Plan. The design work plan is to utilize the information from the completed Master Plan document as the base starting point for this project and develop plans and specifications on this information and any new information provided by the City staff or Engineer during design. The Master Plan will be modified and updated in accordance with the design milestones and design progresses and will be finalized at the end of construction to align it with the newly installed systems. The current update corresponds to the 90% design milestone. The purpose of this summary is to highlight the modifications at this milestone.

In August 2018, 60% design documents were completed and reviewed. The documents included P&ID and system architecture drawings for the water treatment plant and the wastewater collection system assets. After completion and review of the previously mentioned 60% design documents, the City of Kingsport decided to make the wastewater treatment plant and the collection system assets a priority. In October 2018, 90% design documents were completed and reviewed. CDM Smith made a site visit to the City of Kingsport during the week of October 24-26, 2018 and used the 90% design documents as a basis of gathering final information to advance the design to 100%.

Control Narratives for the various sites and plant processes will remain unchanged unless new process controls and/or monitoring is added to a site or process during the detailed design. The existing control narratives were received from the City and CDM Smith has progressed the design to 90%, updating the control narratives where applicable. Where existing control narratives do not exist, the Contractor will be required to create detailed control narratives based on the existing PLC applications and submit them for review by the City and the Engineer. The Contractor will be responsible, as part of the development of testing documentation, to provide a complete set of control narratives for use in performing the witnessed factory testing and functional demonstration testing.

Water Treatment Plant (WTP)

The 90% WTP drawings are a combination of P&IDs from recently completed projects and new P&IDs based on site visits and HMI/PLC database information.

- System Architecture – general layout has been maintained from the Master Plan document

- New control panel for the Plant Process PLC and Filter PLCs in the Old High Service Pump Room will be designed and included in the 90% submittal.
- A typical Distribution site RTU panel is included to show a complete architecture of the systems and communications included at the Water Treatment Plant.
- Master radio is shown at the WTP with no repeater; this will be updated accordingly after the physical radio path study has been completed. The radio communications will utilize Cal Amp Viper SC+ Ethernet Radios.
- Raw Water Intake PLC – A new CompactLogix PLC with Modbus communication module will be provided to communicate Modbus RTU Serial communications over the existing RS-485 twisted shielded pair cabling. Existing cabling shall be reconfigured to use 2-conductors and a shield for the Modbus RTU serial communications.

- Raw Water Pump Station and Electrical System Monitoring – P&IDs were included from the Record Drawings completed in 2017.
- All other P&IDs were developed from site visit and HMI/PLC database information, including the following:
  - Filters No. 1 through No. 6
  - Filters No. 7 through No. 10
  - Filters No. 11A/11B & 12A/12B
  - Residuals Pump Station
  - Residual Thickeners and Truck Loading Pump Station
  - High Service Pump Station
  - GC Chemical System
  - Pre- and Post-Chlorine Chemical System

Water Distribution Sites

The 90% Water Distribution Site drawings were created as typical representations with each typical P&ID including a table that indicates what instrumentation and controls are installed at each specific site. This will provide the contractor with the general scope of work required for the RTU replacements at each site.

Distribution Sites are grouped into three types:

- Ground Storage Tank and Booster Pump Station
- In-Line Booster Pump Station (Pump House and Generator)
- Elevated Storage Tank

Wastewater Treatment Plant (WWTP)

The 90% WWTP drawings are the P&IDs from the WWTP Improvements project, completed in 2011, that have been updated based on site visits and HMI/PLC database information.

- System Architecture – general layout has been maintained from the Master Plan document
  - A typical Collection site RTU panel is included to show a complete architecture of the systems and communications included at the Wastewater Treatment Plant.
  - The cellular communications will be routed over a Verizon Wireless Private Network (VPN) from a cellular modem included in each Collection Site RTU panel to the Wastewater Treatment Plant Maintenance Building Network Panel via an Edge router device (either supplied by the City or Verizon Wireless; to be determined during implementation of the Verizon Wireless Private Network) through the firewall on the City's Intranet.
- Waste Pump Station – P&ID was developed to show replacement of existing Motor Starters and including pump control based on a submersible level transducer and monitoring of equipment status and station level.

Wastewater Collection Sites

Similar to the Water Distribution Sites, the 90% Wastewater Collection Sites drawings were created as typical representations with each typical P&ID including a table that indicates what instrumentation and controls are installed at each specific site. This will provide the contractor with the general scope of work required for the RTU replacement at each site. The existing Collection sites that are not currently equipped with RTUs/Telemetry are indicated in the table on each P&ID and in the Cellular Communications Overview drawing.

Collection Sites are grouped into seven types:

- Two Vacuum Prime Pumps Lift Station with Dry Prime Flooded Suction Backup Pump
- Two Submersible Pumps Lift Station
- Dry Pit Flooded Suction (Two or Three Pumps) Lift Station
- Two Submersible Pumps and Two Dry Pit Flooded Suction Pumps Lift Station (Station 315)
- Three Submersible Pumps Lift Station
- Two Submersible Pumps and Two Dry Pit Flooded Suction Pumps w/Dry Prime Flooded Suction Backup Pump Lift Station
  - This is a dual set of in-series pumps, meaning one submersible pump and one dry pit flooded suction pump always run together as a pair.
- Four Submersible Pumps and Four Dry Pit Flooded Suction Pumps Lift Station (Station 212)
  - Primary Station: Four submersible pumps are configured as two sets of in-series pumps that always run together as a paired set.

- Secondary Station: Four dry pit flooded suction pumps are configured as two sets of in-series pumps that always run together as a paired set.

Master Plan Updates

The Master Plan has been revised to include the updated information from the 90% design as described above. The Master Plan document text below has also been updated to reflect the design decisions that have been made throughout the course of design and meetings with the City.

In addition to the design updates, two software path studies have been completed and are in the process of being reviewed and finalized for design and physical path studies. The information provided in these studies will determine signal strength at each remote site and will dictate the design of the communication equipment and systems. The two path studies included the following:

- Cellular software path study for Wastewater Collection sites – this study has been completed and the RTUs will communicate as shown and specified in the design documentation.
- Radio path study for Water Distribution sites – the preliminary software study has been completed. Physical path study will be performed after Engineer provides direction to the Radio Path Study Contractor on the paths to investigate as part of the physical study. Information from the path study will be used to finalize the communications design for the Distribution Sites.

Section 1

Introduction

1.1 Introduction

The City of Kingsport currently uses several Supervisory Control and Data Acquisition (SCADA) systems for monitoring and controlling their Water Treatment Plant (WTP), Wastewater Treatment Plant (WWTP), remote Distribution sites, and remote Collection sites. These SCADA systems operate independently with the servers for all Water related SCADA systems located at the WTP and all Wastewater related SCADA systems located at the WWTP. This report focuses on upgrading the current SCADA, hardware, and software systems that monitor and control the remote RTU sites, as well as the in-plant SCADA equipment at the WTP and WWTP facilities as shown and specified in the design documentation. The SCADA, hardware, and software system upgrades consist of the following subsystems:

- **Supervisory Control and Data Acquisition** (SCADA), presents process data to the operator, which the operator uses to monitor and control the remote sites and plant processes.
- **Remote Telemetry Units** (RTUs) and **Programmable Logic Controllers** (PLCs) connecting to I/O at the in-plant and remote locations, converting signals to digital data, and sending data to the supervisory system.
- **Communications infrastructure**, connecting the supervisory system to the RTUs and PLCs. The upgraded communication system is comprised of CalAmp Viper SC+ Ethernet radios for Distribution sites, and Sierra Wireless AirLink RV50 Industrial LTE Gateway Modems for cellar communication to the Collection sites.
- **Reporting software**, a database management system which presents specific, formatted data from multiple sources of the processes and functions.

The purpose of this report is to summarize the recommendation plan to migrate the City of Kingsport Water Treatment Plant (WTP), Wastewater Treatment Plant (WWTP), and all remote distribution and collection sites from the current RTU and radio communications hardware as well as a recommendation for a single universal SCADA software platform to replace the multiple SCADA software packages currently being used. In addition, it will provide guidance on how to implement the new systems considering budgeting for phasing of the migration and prioritization of the required tasks. This document is not intended to be used as a final design document.

This SCADA Master plan was developed based on what was observed during the facility inspection of the City's current systems, including the WWTP, WTP, and a representative list of the City's lift stations, pump stations, and storage tanks as well as the existing HMI software and operator workstations. Based on the findings of this inspection, along with several focused workshops, CDM Smith has identified the hardware and software to recommend to the City for

system improvements and laid out a general implementation and prioritization plan for how the City of Kingsport should approach the recommended upgrades.

1.2 Standardization

One of the main design objectives for this project is Standardization. It is important to the City of Kingsport that during the design of the system upgrades, as well as throughout the process of the implementation, that standards are discussed and agreed upon prior to any work being completed. The City of Kingsport currently does not have hardware, software or programming standards. Therefore, the implementation of the SCADA Improvements shall also result in standards being discussed, documented, and applied to achieve a reliable, universal, and maintainable system. Some of the hardware and software standards to be considered and discussed are as follows:

- PLC Hardware – Allen-Bradley 1769 CompactLogix 5370 L3 controller with 1769 compact I/O modules.
- PLC/RTU programming – Ladder Logic.
  - Collection sites and Distribution sites will be programmed with standard logic to be able to easily add more stations in the future.
  - Create a standard for naming conventions for both the PLC/RTU.
- Telemetry – Ethernet radio for Distribution remote sites and cellular communication through a VPN for Collection remote sites.
- Servers – Dual Redundant Back-up Servers.
- Networking – most of the in-plant managed and unmanaged Ethernet Switches are manufactured by N-Tron; this will be developed into a standard networking hardware requirement for the SCADA Master Plant Implementation Project.
- Supervisory Control and Data Acquisition (SCADA) Software – VTScada.
  - Same Menu across all screens.
  - Collection and Distribution sites will be programmed with graphics and database standards and conventions to be able to easily add more stations in the future.
  - Create a standard for naming conventions for both plant HMIs.
- Reporting Software – XLReporter.
- Operator Interface Terminal (OIT) – Automation Direct C-More EA9.

1.3 Instruction to Users

Users of this SCADA Master Plan must keep in mind the City of Kingsport's intended purpose: to provide a common approach to the design of the system upgrades project(s) and to ensure uniformity and compatibility of systems, processes, and hardware across the remote sites and in-plant facilities.

Deviations from this design are permissible subject to the City of Kingsport's approval. Approval for deviations can be obtained by submitting a written request to the City's Project Manager for the specific project, specifying the standard from which deviation is requested, the requested change, and a brief explanation of the reason for the change and the benefit to be gained. The Project Manager, in consultation with the appropriate City of Kingsport staff and the Engineer, will determine if the change is acceptable.

1.4 Terminology

The following is a list of acronyms and technical words used throughout this report along with their definitions:

Term or Acronym	Meaning
APPLICATION SOFTWARE	Software to provide functions unique to this project and that are not provided by standard software alone. Configuring databases, tables, displays, reports, parameter lists, ladder logic, and control strategies required to implement functions unique to this project.
STANDARD SOFTWARE	Commercial software packages that are independent of the project on which they are used. Standard software includes system software and process monitoring and control software.
SYSTEM SOFTWARE	Application independent software developed by digital equipment manufacturers and software companies. Includes but is not limited to operating systems, programming languages such as C++, assemblers, file management utilities, text editors, debugging aides and diagnostics.
PMCS	Process Monitoring and Control Software. Standard software packages, independent of the specific process control project on which they are used, that provide process monitoring, control, and data collection capability.
CONTRACTOR	Firm responsible for electrical and I&C improvements. The Contractor is responsible for both the Electrical Supplier and the PICS Supplier scope of services.
ENGINEER	Design Engineer responsible for the design.
HMI	Human Machine Interface refers to the local facility operator workstations located on process equipment panels within facilities.
I&C	Instrumentation and Control System - generally refers to individual plant instrumentation and controls.
IT	Information Technology
OIT	Operator Interface Terminal refers to a panel mounted screen.
OPCC	Opinion of Probable Construction Cost
OWNER	The City of Kingsport Water and Wastewater Facilities
OWS	Operator Workstation refers to the operator workstations located at each WTP, WWTP, and central operation facility. This is the primary device used by operation staff to monitor and control the treatment process.
PICS	Process and Instrumentation Control System
PICS SUPPLIER	Refers to the firm responsible for implementation of the PICS system.
PLC	Programmable Logic Controller. Provides logic and sequencing for specific process areas within the facility. Examples include separate PLCs for each process areas such as chemical system or a switchgear PLC.
RTU	Remote Telemetry Unit refers to the monitoring and/or control device at each station responsible for communicating data to/from the central location.
SCADA	Supervisory Control and Data Acquisition System-generally used in reference to system-wide control and data acquisition system
TELEMETRY	Communication modes - VHF, UHF and spread spectrum radio, leased telephone line, auto dialers, etc. - used for communication between the plant, the Operations Center and off-site equipment such as remote pump stations, elevated storage tanks, and lift stations.
VPN	Virtual Private Network
WORKSTATION	Personal Computer Operator Machine Interface, printers, and ancillary components
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Section 2

Executive Summary

2.1 Objectives

The purpose of this SCADA Master Plan is to make recommendations for the system improvements that are maintainable, easy to use, upgradable, universal, and reliable. The current Kingsport Water and Wastewater SCADA systems serve the WTP, Distribution remote sites, WWTP, and Collection remote sites using several different hardware and software platforms. This non-standardized system makes it difficult to maintain as well as challenging to expand in the future due the pending obsolescence of some of the existing hardware. This SCADA Master Plan will provide the guidance necessary to provide the City with a standardized system across all hardware and software options as well as ensuring availability for local support and ultimately result in a reliable I&C system. Therefore, the overall objectives of the recommended system shall be:

- Update the PLC system hardware and software to a standardized platform.
- Update the HMI software to a standardized platform.
    - SCADA graphics and screens shall be developed and standardized through meetings with the PICS and the Client.
- Upgrade operator workstations.
- Provide a long-term historical data storage system implementing store and forward functionality.
- Provide an automated reporting system using the historical data.
- Provide cellular modems for the Collection sites and Ethernet radios for the Distribution sites.
- Provide layers of redundancy in the HMI/SCADA system software including the provision of redundancy local to each plant at the I/O server level for high availability of the system.
- Review the security of the City's HMI/SCADA system, in collaboration with the City's IT department, using the Cybersecurity guidance that is available from resources such as AWWA and NIST and incorporate security improvements into the SCADA Master Plan Implementation Project.

The equipment recommended in this Master Plan is universal for all the water and wastewater systems, both in-plant and remote sites. The City of Kingsport's IT department is responsible for the procurement and maintenance of the workstations, laptops, and networking equipment that connects to the City's Intranet. Networking hardware that is installed for the local area networks at the treatment plants is maintained by the City's maintenance staff. The recommendations of

this SCADA Master Plan will support the City's business objectives including safety, providing quality water, operations of facilities, reliability, regulatory reporting and maintenance.

2.2 Summary

The summary below provides the recommendations for migrating the City of Kingsport Water Treatment Plant (WTP), Wastewater Treatment Plant (WWTP), and all remote distribution and collection sites from the current RTU and radio communications hardware and provides recommendation for a single universal Supervisory Control and Data Acquisition (SCADA) software platform to replace the multiple software packages currently being used.

The metrics used to determine the best solution for the various components of the SCADA Master Plan Implementation Project are product application, cost, reliability, maintainability (supportability), constructability, operability, and flexibility. Using these metrics (detailed review of the products is in Section 4 of this Master Plan), it is CDM Smith's recommendation to design a new system with the following major components:

- The recommendation for the remote site RTUs would be the sole use of the CompactLogix PLC platform. The benefits for the sole use of the CompactLogix PLC include hardware/software commonality between utilities, the simplicity of integration into the existing SCADA system (communication protocol would be common and standardized), and hardware that is supportable and maintainable by City personnel.
- The recommendation for the HMI software would be VTScada. Due to the capabilities and ease of use of the trending, especially the configuration and end-user access to trending with the ability to create ad-hoc trends and being able to save the trend for future retrieval, the ability to create high performance or high impact graphics, and being an overall user-friendly and easily upgradable/maintainable environment; we think this is the best option for the features that the City currently uses and relies on as well as the platform that can expand and grow with the needs of the City.
- The recommendation for the Distribution Sites communications network would be a wireless Ethernet radio network utilizing the CalAmp Viper SC+ Series radios. This radio is an industrially rated, long range licensed narrowband Ethernet radio, which is ideal for monitoring the vast range of sites. The radio can support various communications protocols including Ethernet/IP and the DNP3 protocol, which are the main protocols that will be utilized during the project. Pending the physical radio path survey, the radio frequency, antenna height, and other design constraints will be determined.
- The recommendation for the Collection sites communications network would be a cellular network utilizing the Sierra Wireless AirLink RV50 series modem. This cellular modem is a low cost, low energy wireless communications option that would give the City the cellular coverage across all their remote sites as well as offer a management system for remote access and maintenance. The RV50 accepts all major carriers and only requires an SD card from the cellular provider; the RV50 will be pre-configured to operate on the provider's cellular network. Implementing a cellular modem at these sites, using the State of Tennessee contract with Verizon Wireless "Machine to Machine" data share plan and

utilizing a Verizon Wireless Private Network will ensure reliable data communication from the remote sites.

- The recommendation for the reporting software would be XLReporter. An overall lower cost of approximately $2,500 with similar functionality and flexibility compared to its higher cost competition, this software provides a reliable, easy to operate and cost-efficient option that has been used and implemented in many Water and Wastewater applications.
- The recommendation for the migration and implementation of the system upgrades is to perform them in a phased, prioritized approach, based on the City's budget. This includes performing a radio path study, conducting a standards and conventions workshop, installing the new communications infrastructure, programming the PLCs and HMIs based on logical priorities and migrating all sites, one at a time, as budgetary constraints allow.
- The recommendation for the training, staffing and maintenance needs includes the participation of the City staff in off-site training at manufacturer/vendor facilities as well as on-site training provided by the PICS. The recommendations also include the hiring of two I&C/SCADA technicians to provide additional resources and flexibility to the City staff for handling the maintenance and troubleshooting of the new system.
- It is recommended that each plant location will have a main server as well as a local backup server to ensure both local and plant-wide redundancy and reliability. Each plant will also be equipped with redundant I/O servers.

The goals for this project will be accomplished by following this document with the recommended upgrades for the system and implementation plan. Utilizing this document with assistance from the City of Kingsport will achieve a standardized, easily to use, maintainable, reliable system.

2.3 Approach

2.3.1 In-Plant PLCs

The Rockwell Automation Allen-Bradley SLC 5/05 series PLCs are labeled on the Rockwell Automation Product Lifecycle Status website as "Active Mature", meaning the product is still fully supported however a newer product exists. For the other SLC 500 Series PLCs in their product line, Rockwell Automation announced they will be discontinued and will no longer be supported, sold or manufactured. Since these controllers are an essential part of the in-plant control system, a replacement and migration plan to an open architecture system is urgently needed to stay ahead of the lifecycle curve.

2.3.2 Field RTUs

The City currently uses Motorola ACE3600 series and SCADAPack RTUs at approximately 79 remote sites including 44 lift stations and 35 pump stations/tanks. There are also 50 lift stations in the City's system that are currently without any telemetry installed. These are grouped by water and wastewater processes. The lift stations previously communicated through the City of Kingsport Trunking system, although the Collection Department's access has since been terminated. The Distribution Sites communicate back to the water treatment plant via 453 MHz CalAmp radios. The SCADA software (NI Lookout) accesses data from each remote using an

Ethernet connection to the Master Polling PLC's database. Each SCADA system is on a different version of HMI software, for both the remote sites and in-plant functions. The RTUs hardware and software not being on a uniform, standardized control system makes maintenance, upkeep, and reliability an issue.

These controllers are an essential part of the SCADA system because they control and/or monitor critical remote locations such as lift stations, pump stations, and tower sites. Because of their criticality, the City has asked CDM Smith to provide recommendations to migrate from the existing RTUs to open architecture controllers. This plan defines the migration path of the current hardware and software platform and makes recommendations regarding the upgrade of the existing SCADA system components to a new open architecture system.

2.3.3 Overall SCADA System Framework

As a result of the Master Planning process (details found in Sections 3 through 5), it is recommended that the overall system architecture should be revised to create a universal standard across the remote sites and in-plant monitoring and control systems. The control room locations will remain the same, with their workstations upgraded to current hardware standards and implemented with new HMI/SCADA software that utilizes radio communications for distribution sites and cellular communications for remote sites.

For the remote sites in the distribution system, a radio path study will be performed to determine the type of radio and necessary appurtenances for the most efficient communications pathway. The radio configuration could potentially be set up with repeaters on the tallest Water Tanks to create a backbone for the Ethernet radio communications, using sub-masters to communicate with the cluster of remote sites surrounding each node on the radio backbone. For the remote sites in the collection system, cellular modems are recommended for all Collection sites because of the potential difficulty of establishing radio communications due to the locations of the lift stations and the ubiquity of cellular service in all those locations. The City also felt comfortable utilizing cellular at the lift station sites due to the fact that the telemetry didn't require real-time control and is only going to be used to monitor the stations.

To provide more robust system operation and potentially reduce operating costs, it is recommended that the remote site locations be programmed with standard programs, where possible, for a small subset of RTU types, based on the quantity of I/O and/or the process controls at the site (i.e. tank only site, 2-pump lift station, etc.). The program for each RTU type would be configured specifically for each site so that the base program of the various RTU types would be consistent from site to site. This will help reduce the potential for errors in operations, maintenance, and troubleshooting. Having these template programs will create a more dependable system that provides consistent, reliable operations and, in the case of a failure, will be easier to troubleshoot and maintain.

2.3.4 SCADA RTU/PLC Architecture and Vendor

A SCADA migration plan requires a detailed system architecture and preliminary selection of equipment vendor(s) since many decisions are based on these variables. Several factors go into the selection of a system architecture and equipment vendor(s) for a large municipality such as the City of Kingsport.

First, the Remote Telemetry Units (RTUs) and Programmable Logic Controllers (PLCs) should be open architecture and made up of commonly used equipment for the industry. This allows the City the flexibility to solicit components and contract services from multiple vendors, which provides competitive bidding and reduced costs. Because the technical skills to implement and maintain open architecture systems are commonly found in the systems integration market, it gives the City the opportunity to contract services from a larger pool of potential firms. This ultimately makes the system more cost effective in terms of support and hardware availability.

Second, a "Top Tier" vendor should be used. CDM Smith considers common "Top Tier" open-architecture RTU/PLC products used in the water and wastewater markets in this region to be those manufactured by Allen-Bradley, Schneider-Electric, and Siemens. These vendors offer good communication options and solid track records for industrial applications and overall product quality. Each controller has features that are unique to the product, which makes controller selection easier since each one is different and allows selection of a product for an application. These products also have excellent support records, and generally, conform to industry-wide standards. They are produced by companies that are established in the market and will likely remain competitive when providing parts, service, and support.

Third, as the life-cycle operating cost of a SCADA system primarily consists of maintenance services (repair and modifications, including programming), and the mission-critical nature of SCADA at the remote water and wastewater sites often requires immediate service, the cost and availability of service is a primary consideration.

These and other factors were considered when evaluating alternatives.

Based on local support, standardization, cost, and communication options, CDM Smith recommends the Allen-Bradley CompactLogix series of PLCs and Trihedral VTScada HMI software for this project.

2.4 Standard Design Guidelines and Criteria

The Process and Instrumentation Control System (PICS) Supplier will be responsible for the following:

- Programming application software for PLCs.
- Programming plant OWS Workstations and HMI.

The Engineer will be responsible for the following:

- Developing detailed control descriptions for review and use by the PICS Supplier.
- Witnessing tests of application software for compliance with Engineer's control strategy descriptions.

The Contractor will be responsible for the following:

- Scheduling coordination as required to convey and clarify Engineer's control design intent.
- Scheduling Standards discussion and documentation meetings to ensure the City of Kingsport has a standard guide for any future expansion or upgrades.

- Coordinating overall project delivery including field testing and startup.
- Document management of all the systems and software that are installed for the City of Kingsport that include, but are not limited to, the following: software versions, backups of programs/applications, operating systems, firmware version, etc.

The City will be responsible for the following:

- Witnessing software tests at the PICS Supplier testing site.
- Accepting software in coordination with PICS Supplier plant testing and substantial completion.

This section describes general design requirements and guidelines for the PLC, HMI, Networking, and reporting.

2.4.1 Owner Provided Equipment

The owner may elect to provide selected equipment as determined and specified for each design project. The City of Kingsport IT Department shall provide the PCs and OWS with the City's standardized Dell Workstations and laptops.

2.4.2 PLC and HMI Guidelines and Criteria

This section describes general requirements for organizing and programming Programmable Logic Controllers (PLCs). All new PLCs will be programmed using the latest version of Studio 5000 software and CPU firmware.

PLC program development software shall be provided by the same manufacturer as the PLC process controllers.

All PLC programming shall utilize Ladder logic style/language only. Each program shall be broken down using subroutines for specific applications to create a structured "standard" to be applied across all remote Collection and Distribution sites. This will assist in future growth and understanding of the program for more efficient maintenance and upkeep.

PLC data files shall be structured in a manner associated with the PLC logical functions. This requirement is intended to facilitate the addition of future data registers and provide ease of programming maintenance.

General guidelines for data file organization are provided below.

Discrete data may be defined as a single point of data that corresponds to a single digital I/O point. The data point may be a hardwired I/O point or an internal bit in the PLC data memory file. Discrete data points are used to monitor equipment status and trigger process control events (i.e. start and stop a pump).

Analog values are registered in PLC memory in a binary data format. Analog data can be represented as a floating-point register or an integer register. Process flows, levels, and set points are a few examples of analog data.

The intentions of this section are not to define the various types of data available to a PLC programmer, but to recognize the numerous options and provide guidelines to data file organization.

Discrete field I/O points shall be mapped to unique internal PLC data tables. One file for discrete inputs and one file for discrete outputs. These internal data files shall be used exclusively for the field I/O points.

Analog field I/O values shall be mapped to unique internal PLC data registry files. One file for analog inputs and one file for analog outputs. These internal data files shall be used exclusively for field I/O points.

Analog Data shall be mapped to a unique data file allocated specifically to perform scaling of the raw data signals obtained from the field to engineering units. All raw analog scaling into or out of the PLC will be set to 4000-20,000 unless the analog value is used in the PLC for internal calculations such as flow totalization, PID Loop Control, and equipment set point control. In these cases, the analog will be scaled to the instrument's calibrated range and will remain an IEEE 32-bit floating point number. The subsequent totalized or integrated number will also remain an IEEE 32-bit floating point number and will be read into the HMI as a real number as well.

Each analog signal used in an automatic control loop shall be evaluated to determine control action to occur upon detection of an out-of-range signal alarm. Normally this would be to switch the loop to MANUAL and generate an alarm; however, a specific evaluation shall be performed for each loop.

PLC program files shall be organized by treatment process area to facilitate troubleshooting and maintenance.

2.4.2.1 PLC Program Documentation

PLC programmers shall provide clear and concise program documentation for both online and offline program troubleshooting.

All PLC registers shall be identified with an appropriate address symbol that corresponds to the adopted tagging and naming conventions. All PLC logic and subroutines shall include ladder-rung descriptions/comments that explain the control logic and identifies its purpose in an English descriptive format. Rung comments will be provided for each set of controls. At the beginning of each processing routine, a process description explaining the entire process will be provided. At each rung that performs crucial code, a rung description will be provided to explain the PLC code.

Provide a backup of all programming application files on a DVD. The DVD should also have PDF printouts of all programs.

2.4.2.2 OIT Graphic Displays

The Automation Direct C-More EA9 OIT is intended for local control and monitoring close to the unit process. These panels are typically mounted on the front of panel enclosures. The scope of work includes graphic development and deployment of graphics and database.

For existing facilities, many of the PLC control panels are equipped with VersaView OIT workstations that are executing the same HMI/SCADA software that is running on the Operator

Workstations in the Control Room or they are equipped with PanelView OITs with graphics that were developed specifically for the local process. It is intended to develop graphics for the OITs similar to the existing graphics with changes to allow monitoring, and control of new equipment, instrumentation, and support of new narratives. A unified graphic display convention for OIT graphics will be used for changes to existing graphics and for new graphics that need to be developed.

Coordination is required with the City of Kingsport to verify the correct revision level for graphic development prior to beginning OIT programming.

Guidelines for graphic development for VTScada HMI graphics and database also apply to the OIT graphics and database.

2.4.2.3 Servers and OWS Application System Architecture

The Process Monitoring and Control System (PMCS) SCADA Software at the treatment plant facilities shall be designed with two servers. Redundancy will be configured between the two servers at each plant. The PICS will be responsible for installing the license on new operator workstations.

- All communication will be over Ethernet. All OWS require minimum two Ethernet cards.
- All new OWS will utilize the new SCADA Software.
- All new OWS will utilize store and forward communications.
- All new OWS will have the minimum required hardware for the new SCADA Software.

The software shall also be set up to support wireless hotspots for monitoring and/or control the SCADA system via an iPad or Laptop at each facility. Users and accounts for secure access via the wireless hotspots will be determined during design implementation of the system upgrades.

2.4.2.4 SCADA Objects and Graphic Templates

The graphics shall be based on the current SCADA graphics the City is using, to assist with an easier transition to the new system. The standard object templates will be used for all new applications. Coordination is required with the City of Kingsport to verify the correct objects that are being used from the standard template. In cases where there is no standard object for a process in the City of Kingsport standard templates, the objects will be developed with the SCADA development tools and submitted to the City of Kingsport for their review and approval. All comments made by the City shall be incorporated into the custom process objects.

The structure of the SCADA is divided into individual WTP, WWTP, Distribution sites, and Collection sites. Also, within the plant objects, there are specific process objects. Inside the process areas objects are the equipment objects with all the required attributes. All objects and tag names created within the OIT and SCADA system software will follow the naming conventions that are developed as part of the Standards Workshop that will take place during implementation of the system upgrades. The Standards and Conventions Workshop will assist the City with the development of standards for their OIT and SCADA system and will cover the following areas, at a minimum:

- PLC & HMI/OIT Tag Names

- PLC & HMI/OIT Database Structure
- HMI/OIT Graphics including colors, symbols, layout, high performance/situational awareness, etc.
- Alarm Management including prioritization of alarms and definition of alarm events
- PLC Standard Logic Routines – motor control, pump alternation, equipment runtimes, flow totalization, etc.
- PLC Program Structure including subroutines to organize logic based on process areas
- Historical Data Management
- Report Templates

2.4.3 SCADA System Security Guidelines and Criteria

The SCADA system security shall utilize Microsoft Windows authentication. The SCADA software, internal to the application, should also provide a multi-level, multi-area password protection system. The SCADA software should provide a minimum of nine levels of security. The SCADA software should follow the following security levels:

- None – User cannot bypass security.
- Restricted – User can view some of the screens.
- View Only – User can access all screens but can't control. This will be the security level for Thin Clients or remote connections.
- Operators:
    - WTP operators – User has access to level one (1) set points [Level one (1) set points is the operator control level] control and monitoring for WTP. Also, can only view the WWTP, Distribution sites, and Collection sites.
    - WWTP operators – User has access to level one (1) set points control and monitoring for WWTP. Also, can only view the WTP, Distribution sites, and Collection sites.
    - Collection sites operators – User has access to level one (1) set points control and monitoring for the Collection sites. Also, can only view the WTP, WWTP, and Distribution sites.
    - Distribution sites operators – User has access to level one (1) set points control and monitoring for the Distribution sites. Also, can only view the WTP, WWTP, and Collection sites.
- Supervisor – User has access to level two (2) set points [Level 2 is tuning/control configuration] control and monitoring.
- Maintenance – User has access to SCADA troubleshooting and deployment capability of some objects/graphics.

- Super Maintenance – User has full SCADA configurations rights.
- Integrator – User has full administrator rights during development. This security level definition may be modified after the project has been deployed and completed in order to limit the integrator's ability to define new users or to lock down their access to specific areas of the SCADA system (in the event that another integrator is performing application engineering services for the City)
- Administrator – Full rights.

Software security will be configured for all applications, graphics screens, and objects. The system should also provide Auto Log OFF after a duration of time with no activity with a warning before initiating Auto Log OFF (adjustable, determined by the Client during the Standards and Conventions Workshop). The system should be flexible enough to allow for the assignment of capabilities, access, and functionality for each security level in each area.

2.4.4 Network Guidelines and Criteria

The IP address scheme that the City currently uses shall be followed by all integrators and can be requested/obtained from the City during the implementation of the SCADA Master Plan Implementation Project.

The Collection and Distribution sites equipment, as well as the SCADA system, shall utilize IP addresses allocated by the City of Kingsport IT staff.

- All communication shall be Ethernet. The network communication speed shall be 100 Mbps.
- Each plant will have a gateway connection.
- Managed and Unmanaged Ethernet switches shall be considered for use on the SCADA Master Plan Implementation Project. The implications of both shall be as specified and shown in the detailed design documents. Examples of items that require managed switches includes the configuration of rapid spanning tree protocol (RSTP) for fault-tolerant, self-healing fiber optic rings, secure configuration of ports by disabling the ones that are currently not in use, etc.
- IP addressing scheme will be specified by the City of Kingsport.
- Communication security will be specified by the City of Kingsport.

2.4.5 Reporting Guidelines and Criteria

Reporting configuration and programming shall be performed using a 3rd party software package that is compatible with VT SCADA. The reporting software shall be XLReporter by SyTech. All new analog data shall be incorporated into the report package with input from the City of Kingsport staff. Report templates, requirements shall be developed in conjunction with the City of Kingsport during the Standards and Conventions Workshop, with reporting software training being performed throughout the project, including on-site implementation and startup.

Section 3

Description of Existing Systems

3.1 Existing Systems

This section provides a description of the existing SCADA system software and hardware at the Distribution sites, Collection sites, WTP, and WWTP including control equipment and communication installations.

3.1.1 Existing Remote Sites – Water Distribution Sites

The City of Kingsport (City) is currently monitoring approximately 35 remote sites, using Control Microsystems SCADAPack, most of them Model 5203 series, Remote Terminal Units (RTUs) with 453MHz CalAmp Radios. The Distribution sites have three different typical configurations:

- Ground Storage Tank and Booster Pump Station
- In-Line Booster Pump Station (Pump House and Generator)
- Elevated Storage Tank

Each of the RTUs is equipped with backup power, either an uninterruptible power supply (UPS) or a sealed, lead-acid battery, so that the RTU will continue to function on a loss of control power. Overall, the current SCADA software for the WTP Remote Sites is used for monitoring and trending real time tank levels, system pressures, and statuses of the Booster Pumps.

The WTP Telemetry system uses NI Lookout Version 3.8 (Build 7) SCADA software which interfaces to the system RTUs for data gathering and storage. There is a Main Overview graphic which shows all the pumps and tanks sites with the real-time tank levels displayed. Clicking on each site from the Overview opens a separate screen showing the specific information pertaining to each site location including tank levels, pump statuses, and valve positions, depending on the configuration of equipment at the remote site.

3.1.2 Existing Remote Sites – Wastewater Collection Sites

For monitoring the Collection sites, the City currently uses Motorola ACE3600 series Remote Terminal Units (RTUs) with 800MHz Trunking Radios at approximately 44 of the 94 Lift Stations in the City. These RTUs are also equipped with backup power, in the form of a Motorola sealed, lead acid battery, either 6.5Ah or 10.0Ah which keeps the CPU and radio functional to allow the RTU to communicate a loss of power back to the central site. The Utilities Department had decided to use the trunking system for their Collection sites telemetry to take advantage of the coverage that a trunking system provides and had installed 44 of the new RTUs prior to City Management removing the telemetry from the trunking system to free up channel bandwidth on the system, leaving the Collection sites telemetry system inoperable. The Collection sites have seven different typical configurations:

- Two Vacuum Prime Pumps Lift Station with Dry Prime Flooded Suction Backup Pump

- Two Submersible Pumps Lift Station
- Dry Pit Flooded Suction (Two or Three Pumps) Lift Station
- Two Submersible Pumps and Two Dry Pit Flooded Suction Pumps Lift Station (Station 315)
- Three Submersible Pumps Lift Station
- Two Submersible Pumps and Two Dry Pit Flooded Suction Pumps w/Dry Prime Flooded Suction Backup Pump Lift Station
- Four Submersible Pumps and Four Dry Pit Flooded Suction Pumps Lift Station (Station 212)

Before it was removed from the trunking system, the Collection sites system was used for monitoring and trending real time wet well levels, pump statuses, pump runtimes, and flows. Each Collection site RTU communicated its information to the database tables in the Master Field Interface Unit (FIU), which essentially served as the Central Communications Controller of the telemetry system, and the data was then displayed on the WWTP Lift Station SCADA Workstation. Data is communicated via the Motorola XTL2500 radios in each RTU and FIU using Motorola's proprietary MDLC protocol which allows the remotes to communicate in a Report-by-Exception format, meaning that the remote only transmits data when there is a change of state of a tag in the data tables. The workstation uses Wonderware InTouch Version 10.0.300 SCADA software, utilizing a Modbus TCP I/O Server for communications over CAT6 Ethernet cabling, to collect data from the RTUs via the FIU's database. The main overview graphic shows all the Collection sites that are tied into the Telemetry system with the lift station name and number plus real-time pump statuses of each pump associated with the site. Clicking on each site from the Overview opens a separate screen showing the specific information pertaining to each lift station including wet well levels, pump statuses and equipment runtimes, depending on the configuration of equipment at each remote site.

3.1.3 Existing Plant Systems – Water Treatment Plant

The current system is comprised of several non-redundant SCADA computers. The Distribution Sites Telemetry PC is in the WTP Operator Control Room using the National Instruments HMI software NI Lookout Version 3.8 (Build 7). The SCADA computer is connected serially to the master radio unit manufactured by CalAmp and communicates to all the Pump Station and Tank remote sites via Modbus polling using a licensed 453 MHz radio frequency. In addition, the WTP has two other SCADA PCs, one for the WTP Plant Processes and one for the WTP Filters, both are in the WTP Operator Control Room. These SCADA PCs use the same NI Lookout software as the Telemetry PC but are utilizing Version 4.5.1 (Build 18) of the software. These computers are communicated over an unmanaged Ethernet Switch to each of the filter consoles and process control panels. There are also seven industrial PCs, one in each filter console, that are connected to the same unmanaged switch via CAT5 cabling and are running Version 4.5.1 (Build 18) of the NI Lookout software. The filter console nodes operate in the same manner as the main filter PC in the control room with the control functionality of the filter consoles limited to the local filters while still being able to monitor all 12 filters at any of the locations.

3.1.4 Existing Plant Systems – Wastewater Treatment Plant

The WWTP has three SCADA PCs, two of the PCs are duplicates of the overall WWTP processes; one is located in the WWTP Administration Building Operator Control Room using the SCADA software RSView32 V 7.20.00 (CPR7); the other is in the Old Control Building Operator Room running on VMWare Player to replicate the SCADA located in the Administration Building. The third PC is for monitoring the Dewatering Building PLC and it is in the Old Control Building Operator Room, using the runtime version of A-B Factory Talk View for Machine Edition (ME) V 5.10.00 (CPR9 SR2). The computers communicate over a Fiber Optic Network. However, the loop is not a redundant, self-healing Fiber Optic Ring, therefore if one of the fiber optic Ethernet Switches loses power, you lose everything that is downstream of that location.

3.1.5 Existing Plant Systems – Asset Management Software

The City of Kingsport is currently using Cartegraph OMS (Operations Management System) software for asset management. This system allows the user to manage the facility enterprise assets in conjunction with the work, resources needed, and requests required for running the municipality. Its primary use is for operations and maintenance, to ensure that the condition and cost of repairs are monitored and documented so assets won't be overlooked. It does this by evaluating the performance of the system and what assets you have with the resources and operations entirely, to find ways to improve your facility performance.

Section 4

Recommendations and Improvements

4.1 Recommended Improvements Plan

The City currently uses the following systems to communicate, control, and monitor in-plant equipment and instrumentation at the following facilities:

- Water Treatment Facility (SLC 5/05, VersaView 1700M, NI Lookout version 4.5.1)
- Wastewater Treatment Facility (SLC 5/05, PanelView Plus 1000, RSView32 version 7.20.00, FactoryTalk View for Machine Edition (ME) version 5.10.00)
- Distribution sites (Control Microsystems SCADAPack Model 5203 CPU, PanelView C600, 453 MHz CalAmp radio, NI Lookout version 3.8)
- Collection sites (Motorola ACE3600, 800 MHz Trunking Radio, Wonderware InTouch version 10.0.300)

Due to the non-uniformity of the existing systems being utilized, the following system components will be recommended and used as part of the forward migration plan for the City. The design is based on an open architecture philosophy and ensures the City a high level of assurance regarding product support and ongoing maintenance. The following approaches were explored and are explained in detail:

- Replace all PLCs/RTUs with the Allen-Bradley CompactLogix PLC at all in-plant and remote site locations.
- Replace existing corroded or damaged panels with stainless steel NEMA 4X panels or appropriately rated panels for the environmental conditions where the panels are installed. Re-use enclosures where possible and only install new subpanels with the new PLC hardware.
- Use Trihedral's VTScada software with dual (redundant) servers and unlimited thin clients for all monitoring and control for the WTP, WWTP, Distribution Sites, and Collection sites systems.
- Utilize the CalAmp Viper SC+ Licensed Narrowband Ethernet/IP Router for Ethernet Radio communication to all Distribution remote site RTUs, and the Sierra Wireless AirLink RV50 Industrial LTE Gateway for cellular communication through a Verizon Wireless VPN to all Collection remote site RTUs.
- Incorporate XLReporter software to generate scheduled reports from the data collected in the SCADA Historian for improved operation of the facilities and processes.

4.1.1 PLC Recommendation

The CompactLogix PLC is a modular PLC product used in many small to mid-size application projects. This is a moderate cost RTU for the functionality and capability it provides, which would be ideal for standardization across all sites. This series controller comes with the capability to add expansion I/O modules that would protect the investment in the controller by allowing for future improvements. It also has many different configurable components, such as flexible user memory options, to achieve the needs for each specific installation, while keeping everything on the same CompactLogix standard. These PLCs include a built-in Ethernet/IP protocol for the ability to communicate through Ethernet radio or over a private Cellular network, but in order to utilize the DNP3 protocol to achieve store-and-forward functionality, the CompactLogix series requires the use of a 3rd Party Communications Module. The CompactLogix PLC utilizes RSLogix Studio 5000 for the software programming environment. In addition, Rockwell Automation provides a migration path from existing Allen-Bradley PLCs that use RSLogix 500 for their programming software (SLC 5/05, MicroLogix, etc.) by converting to the latest Studio 5000 versions of the applications using the built-in translation tool. With the modular controller design, keeping the I/O cards and CPU separate allows for built-in reliability and ease of maintenance when repairing a failed I/O point, requiring only the replacement of the affected component or card rather than the entire controller.

Rockwell Automation has support channels through Allen-Bradley distributors. Kendall Electric Inc. is the local distributor for the City of Kingsport. The CompactLogix hardware platform is not the most expensive of the Rockwell Automation product offerings, but it is more costly when compared to other small to medium size application PLCs. This PLC offers a tag based and subroutine programming structure, with Ethernet and motor control capability.

Allen-Bradley Support Contact Information:

- Contact: Mark Cloyd
  - 1241 Jan Way
  - Kingsport, TN 37660
  - Phone: 423-246-8151
  - Fax: 423-247-4770

The 1769 CompactLogix 5370 L3x series controllers would replace all existing remote RTUs and plant PLCs. By doing this, a common product platform can be used for multiple systems within the City, with support readily available from the local A-B Distributor in Kingsport. There is also an interactive migration tool conversion program that Rockwell Automation advertises for use to convert the existing SLC 5/05 process programs from the RSLogix 500 environment to RSLogix 5000/Studio 5000, the environment that CompactLogix uses. This would assist in the PLC hardware and software migration process, reducing the labor time and costs that would be associated with this transition. This may help to offset some of the higher cost associated with the hardware.

4.1.2 HMI Recommendation

VTScada is an intuitive SCADA/HMI software that was created for in-plant, telemetry, or hosted systems of any size. Its unique architecture allows a system to be configured with a few hundred tags up to several million tags on a distributed network containing synchronized servers and client nodes. The scalability of the software also provides for future growth and expansion into other means of visualization such as remote access via laptops, tablets, and smartphones. In addition, Trihedral prides itself on their training course offerings for development and operator usage and their reliable customer support.

Each application server in a VTScada system contains all components integrated into the software such that the server can be configured as a standalone node. With the addition of another application server and a simple configuration change, both servers become synchronized, redundant nodes, able to continue operation of the system when one of the servers is out of service (due to maintenance, power outage, loss of communications, etc.). Another feature of VTScada is the deployment of smaller tag count servers that can function as the primary I/O communications at a local PLC while the main redundant application servers operate as the backup I/O communications for those PLCs. If the local VTScada node were to fail, the main redundant servers would continue to collect real-time data to maintain functionality for operations. Conversely, if the main servers were to fail, the local VTScada node would continue to poll its PLC's I/O and continue to function without the need for communications with the primary SCADA servers.

VTScada is a non-proprietary SCADA software with open connectivity to support all major PLCs or RTUs with the ability to provide polling of Master PLCs and collection of data from power monitors which typically use Modbus RTU or Modbus TCP for their protocols. VTScada has one of the most extensive communications driver libraries, due to their commitment to interfacing with any PLC/RTU hardware by developing drivers in-house to meet their clients' needs. The driver libraries also include connectivity to data loggers (Campbell Scientific), proprietary hardware (Data Flow Systems) and protocols for specific applications such as DNP3 and BSAP.

VTScada utilizes their Idea Studio for the creation of high performance or high impact graphics by employing images and symbols from the included graphic library as well as the ability to import JPG, BMP, PNG files from the desktop. In addition, the software also includes an updated set of "widgets", such as meters, switches, and other animations, providing a more photo-realistic look to the graphics. The software is also designed for multiple monitor resolutions and includes the ability to produce full screen as well as pop-up displays. Another unique graphic layout configuration included with VTScada is the ability to create tabbed displays, which allows the designer of the graphics to split the display into a set of upper tabs and lower tabs and then using those tabbed areas to make the operator controls and set points visible while still being able to monitor the main process equipment. VTScada also has a built-in page menu that is auto-generated as the programmer creates displays. It allows navigation from the current display to any other display without any user programming – it is pre-configured and appears in the toolbar as a pull-up menu similar to the functionality of the "Start" button in Windows operating systems.

The trending capabilities and ease of use, especially the configuration and end-user access to trending with the ability to create ad-hoc trends and being able to save the trend for future retrieval, is probably the best feature of VTScada. The historical data is collected to the integrated

historian but VTScada also supports the use of an external, 3rd party historian. Both methods of setting up historical data collection can be configured with redundancy to ensure long-term storage and retrieval of data. The historical data viewer (HDV) is the standard trend object employed by the application. Any data value on the graphic can be configured for trending (clicking a simple check box) and when in runtime, the operator can click the data value and it will be added immediately to an HDV pop-up with the most recently used time range. Additional pens can be added by clicking on other data values on the graphic. The time range can be selected easily from the pull-down menu of choices built into the HDV. If the operator likes the ad-hoc trend that was created, it can be saved from the menu of the HDV for future viewing. An unlimited number of pens can be added to the HDV and the min, max and average values of the configured pens can be viewed as well. The values that are displayed in the trend window can be switched from a graphical view to a data view, which appears as a spreadsheet in the HDV display. The data can be exported from this view to an Excel spreadsheet or CSV file.

Updating your SCADA screens and rolling out changes to the application can be done quickly and immediately through the ChangeSet file capability. You can also access the screens securely from anywhere with VTScada's thin client technology options for computers, phones, or tablets. They also provide scheduled reporting capabilities that can be sent by email or text message. Overall, this HMI software is user-friendly in both the operations and development standpoints, as well as highly capable of advanced trending and reporting.

To deploy SCADA access to laptop, tablets, and smartphones, Trihedral includes VTScada Anywhere Clients and VTScada Internet Clients. These mobile, thin client options are licensed in a similar manner to other HMI/SCADA manufacturers, but the options are easier to deploy. Since the VTScada software has a fully integrated internet server built-in, it eliminates the need for a 3rd party web server software such as Apache or Microsoft IIS (Internet Information Server). In addition, the mobile client graphics are configured in seconds with no requirement to rebuild or convert the current displays, providing a consistent workstation experience from a mobile device using any HTML5 compliant browser.

VTScada is supported on Windows 7, Windows 8, Windows 8.1 and Windows 10 (32-bit and 64-bit) as well as Server 2008 R2 and 2012 R2 (64-bit) with the following hardware requirements:

- Any dual core processor, Intel Core i3, i5 or i7 (i7 recommended), with a 2.0GHz clock speed (minimum).
- 8GB RAM (minimum).

VTScada provides a solution containing all the functional components in a single package with the ability to create redundant servers that synchronize with each other for reliability. Each server collects historical data and if the servers are configured for redundancy, the historian components are also synchronized and provide a backfill of data once a lost connection to the other server has been restored. The largest benefit that would come from using VTScada is maintaining the capabilities of standalone servers that is familiar to the City while providing an upgraded layer of redundancy for continued uptime of the SCADA system. In addition, the ease of configuration and user interface for the trending component of VTScada will be a significant upgrade from what was being used at the WWTP and the Collection sites applications and will be familiar to the WTP operations due to the similarity to the NI Lookout trending currently being

used. VTScada's most recent version upgrade focused mainly on historical and data trending as well as integrated reporting capabilities. This software provides the ability to create ad-hoc trends for up to 12 data points per trend by clicking on the analog values that are displayed on the SCADA graphics, allowing the Operator to see what they need to see to complete their daily reports or run the plant. VTScada offers 90 days of free SupportPlus Software © included in any software license which enables the Customer to next business day response times for issues with the VTScada software, not including issues with the customers' applications. Technical support can be purchased for an additional fee of 15% of the original purchase price of the SCADA software which can be renewed for the same price each year. Support is available Monday through Friday. VTScada also offers 24/7 emergency support for 5% annual of license value on top of the 15% for SupportPlus. As well as Ad-hoc support for hourly support at $137 per hour plus expenses. They also offer operations and configurations level 1 and level 2 classes in either Orlando Florida, Bedford Nova Scotia, Morrisville NC, Jupiter Florida, and Houston Texas.

VTScada SupportPlus Contact Information:

- Orlando Office – Monday-Friday (excluding statutory holidays), 9AM-5PM Eastern Standard Time (EST)
  - Phone: 407-888-8203
  - Fax: 407-888-8213
  - Email: support@trihedral.com

Based on this information, CDM Smith recommends VTScada HMI. The City of Kingsport is currently implementing several different SCADA software platforms that all run off different computers with very different development and operator environments. With the high usage of trending and graphics across all current applications, VTScada would be able to provide an overall user-friendly and easily upgradable/maintainable environment. VTScada's most recent version updates focused on improved trending and reporting, which are two of the City's main uses of their current SCADA software systems. They provide a very knowledgeable support team which is of tremendous value. VTScada meets the current needs of the City, but also provides room for growth and process improvement with their easy to understand and edit interface.

4.1.3 Communication Recommendation

The City of Kingsport is currently using CalAmp Guardian licensed Serial radio modems for Distribution System RTU communications and Motorola ACE3600 trunking radios for Collection System RTU communications. The CalAmp Guardian radios have performed well for the Distribution sites after switching to them due to the narrow banding of their FCC licensed radio frequency and channel width. For the Collection sites, the Motorola radio telemetry system had some communications issues to begin with, and then the City was removed from the Motorola Trunking system due to other needs within the City requiring the talk group that was assigned to the Collection system. Due to this and through discussions, the City will be switching their Collection sites communications and monitoring from radio to cellular communications.

The City has indicated a preference to utilize Ethernet communications throughout the design as a component of the SCADA Master Plan Implementation Project. There are several options for switching the Distribution sites SCADA monitoring from serial to Ethernet radio communications.

The CalAmp Viper SC+ is an intelligent IP router for licensed radio spectrum that supports long range, licensed narrowband communications. The Viper SC+ allows for multiple RTUs/PLCs to connect to a single polling master radio or, alternatively, communicating to a single access point as a repeater to transmit and receive data to/from the single polling master radio at the main control center. It also has the capability of communicating with serial or Ethernet enabled devices. Depending on the channel bandwidth allocated to an end user with their licensed frequency, the Viper SC+ can communicate at data rates that range from 4kbps (6.25 kHz channel spacing) up to 256 kbps (100 kHz channel spacing). The Viper SC+ radios can be equipped with CalAmp's DeviceOutlook asset management software that has the ability to perform remote device firmware and configuration updates over the air as well as providing a centralized method of monitoring radio diagnostics. This secure radio network is password protected and includes AES data encryption . The radio is compatible with Ethernet/IP and DNP3 communication protocols.

Due to the City's familiarity with the Guardian serial radios and the higher speed capability of the Viper SC+ IP radios, CDM Smith recommends the CalAmp Viper SC+ Series Radio for the Distribution system communications to the remote site RTUs. The CalAmp Viper SC+ is a simple and reliable solution that would provide implementation of a single radio device across the Distribution sites for ease of standardization purposes. CDM Smith recommends that, pending the results of a radio path survey, the City of Kingsport should utilize a repeater / access point in the system, located at the existing radio tower on Bays Mountain. By installing a repeater in the network, it should provide a strong signal to all RTUs (i.e. minimum of -20dB fade margin) to provide a more reliable telemetry system for the City. This recommendation is based on the preliminary engineering of the radio network and the parameters of the City's existing radio license. The recommended design for the radio system may be revised after final review of the software radio path study.

CDM Smith recommends the Sierra Wireless AirLink RV50 series cellular modem for the collection system remote site RTUs. The Sierra Wireless AirLink RV50 Gateway is a low power cellular LTE gateway providing real-time remote communications for metering and controls. This industrially rated, Class 1 Division 2 device is designed for harsh conditions. The 4G LTE communications provides coverage and services on any major global network. This device also comes with the option for the AirLink management system software which allows real time remote management of all the radios. It allows the operator or IT staff to manage, monitor, and troubleshoot any issues as well as create an over the air link to update and upgrade the firmware for each device. Secure signing and authentication of firmware images offers end-to-end protection of the software upgrade process, protecting the RV50 against unwanted malware. Port filtering and trusted IP configuration settings protect the devices connected to RV50s from unwanted access. Sierra Wireless offers technical support via their AirLink Support packages with web, phone and email support included in their Essential/Classic support package and emergency support from a dedicated, named support engineer included in their Preferred support package. Network engineering support is included in both packages as well as a three-year hardware warranty (upgradable to five years with the Preferred support package).

In addition to the Sierra Wireless modem/gateway, a private cellular network plan would be required for the cellular communication option. As stated previously, with any contract with a cellular provider, a cellular private network provides a safe, secure method for connecting remote sites to the plant SCADA system, similar to a point-to-point virtual private network (VPN). This type of mobile VPN (mVPN) provides additional security options such as enforced authentication of the user/device as well as encryption of the data traffic. The mVPN also provides a level of application compatibility that allows software that runs in an "always-connected" wired LAN environment to seamlessly run over the mVPN without modification. The private network allows for instant access to your data which can be setup as report by exception or polling. All unsolicited internet traffic and cyber-attacks, including viruses, malware, hackers or phishing are blocked. The State of Tennessee has a contract with Verizon Wireless which includes a "Machine to Machine" data share plan. This coverage includes the Verizon Wireless 4G, 3G, and 3G Extended networks data coverage. The Verizon Wireless Private Network provides protection from cyber threats since the data packets from the remote locations are not routed over the public internet. This is accomplished by changing the access point name (APN) to direct the remote communication devices at each of the remote sites to the private network. Therefore, the data transmitted from the remote sites is never combined with the public Internet traffic. This contract option also includes "Machine-To-Machine" Management Center which allows for gateway management of the Private Network Configuration. This includes configuration of the initial setup of a new cellular modem, the ability to activate or deactivate a modem if there is a communication issue, set data usage alarms (i.e. if a typical site is supposed to average around 5MB per month and it exceeds 5MB in the first three days of the month; set an alarm to indicate something is wrong with the site). As an added security measure, the cellular network has multiple frequencies that can be used and can be adjusted relatively quickly if a frequency interference or a problem with the communication arises.

4.1.4 Reporting Recommendation

XLReporter is an entry-level data management software created by SyTech Inc. used for creating and customizing reports for use by the operations, maintenance and engineering staff. This software is easy to use and user-friendly with its direct connection to Microsoft Excel– a spreadsheet software with which most people are familiar. XL Reporter includes built-in report templates that, if they meet the end-user's needs, allow the use of the software without needing Microsoft Excel installed on the computer. It is also very widely used in the Water and Wastewater industry. XLReporter allows the user to create their own templates for reporting with the information they require, and is very easy to configure. The software runs automatically in the background creating reports on a set schedule that the user can define, or it can be used on demand by direct user interaction to create specific reports. The team edition of XLReporter allows users to interact with the reporting software across the organization, meaning that users can produce their own automated or interactive reports through their own secure server-side log in. VTScada and XLReporter have been partnered since 2014. This allows for seamless data source connectivity and support. This software not only allows for flexibility of report creation but also has no limitation on the number of tags that are supported in any of the reporting packages SyTech offers. The reports can also be shared by various means of distribution capabilities such as web pages, printed on network connected printers, PDF files, email, and even can be seen on a mobile device via a web page. XLReporter is an overall intuitive, user-friendly,

customizable software that anyone can learn quickly without any SQL programming, while still delivering value for utilization, documentation, and ease of service. XLReporter is compatible with Windows operating systems and both 32 and 64-bit versions of Microsoft Excel.

XLReporter is a very reasonably priced third-party reporting software that has very powerful but simple features. Since the software is an Excel based program, it is very intuitive and easy to learn. There are no tag constraints on any of the software editions or price per licenses, it is only one set price per edition plus the Historical Data Access (HDA) option for the editions where it is not included in the base price. The Suite Edition with HDA is $1595, the Professional Edition with HDA is $1995 and the Team Edition with 3 clients is $2,595. The Professional and Team Editions also include 1 year of technical support and software upgrades and also includes Engineering Solution Support which assists the end user with intensive one-on-one phone tutorials and engineering sessions for application specific report creation. The partnership between SyTech and VTScada also provides a smooth path for integration into the new recommended system. With the combination of VTScada's historical data collection system and XLReporter's configurable reporting capabilities, users will be able to create templates for automated report generation or unique, on-demand informative reports.

Based on this information, CDM Smith recommends XLReporter as the reporting software for all upgraded systems . With the low cost and partnership with VTScada, XLReporter would be a user-friendly, customizable, intuitive environment that is data driven and provides an upgrade to the trend style reports currently being utilized by the City staff. This software would be able to provide an easy transition to the new reporting environment. With the multiple interfaces and customizable options, the City can create exactly what they want as well as create situational based reporting.

4.2 Implementation and Prioritization Plan

Due to budget constraints, if the city's Capital Improvements Plan (CIP) does not allow for the entire project (i.e. SCADA/OWS software and equipment, remote site hardware and in-plant hardware) to be completed in a single fiscal year, then it can be broken out into phases. The replacement plan shall be designed in phases lasting no more than 4 years.

It is recommended that when replacing any computer hardware at a site, that the City should replace all computers, servers, and workstations, located at the site. This will prevent any OS and HMI version incompatibility and minimize potential network communication interruptions caused by these and other associated incompatibilities.

Due to the components of the current hardware systems becoming obsolete as well as manufacturer support becoming less available, the recommended options discussed previously will assist in addressing these issues before it becomes a problem for the City. These upgrades will also assist in improving the overall performance, functionality, and reliability of the plants and remote sites.

Based on the large number of items that require upgrading or replacement, an implementation plan for migrating the current system to the recommended upgrades is necessary. CDM Smith recommends that the tasks be organized in a logical approach. However, the tasks should also be completed and implemented as budget allows. The tasks listed below are an example of the

recommended prioritization and path for completing the migration as smoothly as possible. The assumption of this recommendation is to work through each system in its entirety, including testing and confirmation of functionality, prior to moving onto the next to ensure minimal errors occur. As the tasks of the migration plan are implemented, additional meetings and discussions shall be held with the City and the City's staff and design Engineer(s), if requested by the City, to develop and further refine the standards conventions and documentation required for all aspects of the system upgrades as discussed in Section 2. A suggested example of task prioritizations, in order, are as follows:

- Radio Path Study.
- Standards and Conventions Workshop.
- Program the remote site PLCs.
- Program the HMI/SCADA servers for the remote site PLCs.
- Install the communications infrastructure.
- Install the redundant HMI servers at the plant locations.
- Begin to upgrade of the remote site PLCs.
- Convert the SLC 5/05 PLC programs.
- Program the HMI/SCADA servers for the in-plant PLCs.
- Begin upgrade of the in-plant PLCs.
- Test each site as they are upgraded to ensure communications with the polling master and the HMI/SCADA graphics.

4.2.1 Implementation Considerations

During a project of this nature, critical communication systems will be modified. In addition, hardware and software that is relied upon by operations for their daily job will be in the process of being upgraded or replaced. The order in which items are migrated from the old system to the new system will be extremely important. CDM Smith recommends that the construction sequence of this project be phased to enable efficient usage of the CIP money available and keep the overall system functioning while the migration and upgrades are installed. There are also varying degrees of current functionality in the four main areas of the City's system – Collection sites (Lift Stations), Distribution sites (Pump Stations and Tanks), WTP and WWTP – from non-functional to operationally critical, which will impact the sequence of construction as well. In general, construction activities should be performed as follows:

- Perform radio path survey for the WTP Distribution remote sites.
- Conduct a Standards and Conventions Workshop to develop the standardization desired by the City.

- Program the remote site PLCs, creating "templates" for common types of remote sites, to keep the programming relatively standard for ease of future expansion across all site types and locations.
- Program the polling master PLC for each plant with communication routines to transmit and receive data to/from the remote sites.
- Program the HMI/SCADA software including real-time database, HMI graphics, historical database, trending, alarming, etc. for the remote sites.
- Install and configure the new communications infrastructures (both radio and cellular), verifying that communication is successful between the master site, repeaters and remote site locations or any other communication points, based on the results of the path study. NOTE: the new infrastructure will be installed in parallel with the existing infrastructure so both systems will function during the migration/transition.
- Install and configure the new redundant HMI system at each plant location. Verify Ethernet communications between the HMI database and the polling master PLCs. NOTE: the new redundant HMI system will be installed in parallel with the existing HMI system so both systems will function during the migration/transition. For example, at the WWTP, the Old Control Building could serve as the initial deployment location for the new servers while the existing servers continue to operate in the Admin Building.
- Begin the migration of remote sites to the new system by replacing the existing PLCs and control panels with the new panels (or new subpanels mounted within the existing enclosures) which will incorporate the new hardware standards into each site. The number of remote sites that can be upgraded to the new system each year will depend on the City's budget.
- Each site should be fully tested for local control logic and communications with the HMI graphics before moving on to the next site.
- While the remote sites are being migrated, convert the existing Allen-Bradley PLC programs for both the WWTP and WTP using the Rockwell Automation Conversion software to the new RSLogix Studio 5000 platform. This step can be completed later in the project after the remote site migration has begun and when an adequate budget has been obtained. Since the SLC 5/05 PLCs have not been given an end of life date, there is some time left for this migration.
- After the conversion, incorporate all logic standardizations based on the Standards and Conventions workshop and any other minor modifications to the standards that have been made during the upgrades.
- Replace the existing PLCs with a CompactLogix PLC, either a new PLC control panel or a sub panel installed within an existing enclosure, complete with all necessary appurtenances.
- Program the HMI/SCADA software including real-time database, HMI graphics, historical database, trending, alarming, etc. for all in-plant PLCs, both the WWTP and WTP.

- Again, each in-plant PLC should be fully tested for local control logic and communications with the HMI graphics before moving on to the next PLC for both the WWTP and WTP.
- Develop reports using XLReporter software and test with VTScada Historical Data that has been collected during the initial site migrations. NOTE: report development can occur anywhere throughout the process to ensure that the City can make beneficial use of their historical data, when needed, for operations.

4.2.2 Additional Functionality

The City has expressed interest in adding features to their existing system during migration. The following items are things the City would like to incorporate during construction:

- Include Level Transducers in all wet wells.
- Install Power Monitoring, including Utility Power and Generator Power (kW, kVA, kVAR), Generator Statuses, and the ability to perform a remote generator test.
- Receive alarms/statuses from the soft starters and variable frequency drives to SCADA.
- Include run statuses for the Smith & Loveless Vacuum pumps that prime the lift station pumps; provide an alarm if the vacuum priming pump is running for a period without receiving the run status of the lift station pump.
- Include status information for the Godwin/Pioneer Dry Prime Pumps for monitoring at SCADA.
- Include flow totalizer and Sensidyne gas detector signals to SCADA at Lift Station 212.
- Include MCC-1A and MCC-1B Eaton Power Monitors parameters to SCADA at the WWTP via Modbus TCP driver to provide more information than is currently provided by the hardwired, 4-20mA signals.
- Configure the new functionality items (i.e. rain gauge, power monitoring, chemical usage, flows, runtimes, calculated flows from runtimes for lift stations, etc. to be accessible in SCADA.
- Improve Historical trending.
    - *Be able to monitor power trends and flow values on the same trend to get some valuable insight into the plant operation.*
- Improve reporting through user-friendly software that is either integrated into Microsoft Excel or that includes a feature that can export the reports to an Excel or PDF format.

Include alarm management that not only prioritizes alarms but incorporates standards that define what items in the database are alarms and what items really should be defined as statuses or notifications, since alarms should only be events that require operator intervention to resolve.

Section 5

Training, Staffing, and Maintenance

During the construction activities, and as part of the operations and maintenance plan, the City should consider requirements and needs for training, staffing, and maintenance programs.

5.1 Training

Training is an extremely important function for the ongoing and future success of any control system and should be provided for maintenance and operations staff for all new PLC hardware/software, and HMI software. Recommended training includes, as a minimum, troubleshooting and maintenance, and basic programming. The training should also come from two sources – the PICS and the Manufacturer/Vendor. Depending on the City's budget, sending appropriate staff to off-site training on the Allen-Bradley PLC hardware & software and the VTScada HMI/SCADA software would be beneficial in assisting the City with taking ownership in the new system and equipping their maintenance staff with valuable knowledge that they will use in their daily activities of troubleshooting and make programming improvements to the system. To further increase the City's knowledge base of the upgraded system, the training program provided by the PICS will include on-site training of the installed system, Whereas the off-site training provides the general understanding of the hardware and software being supplied by the contract, the on-site training will provide specifics about the way the system was programmed and the tools available to troubleshoot the actual applications that were deployed. The City should consider having staff from other business units attend the various on-site classes provided by the PICS (i.e. water operators attend wastewater operators training and vice versa). Cross-training of staff could provide efficiencies and cost savings to the City.

5.2 Staffing

As indicated above, the existing staff will need to be trained on new hardware and software to properly maintain and operate the new system. The City currently has one maintenance supervisor for Water (i.e. the WTP and Distribution Remote Sites) and one for Wastewater (i.e. the WWTP and Collections Remote Sites). CDM Smith recommends that at least two additional staff should be hired who will be able to assist the existing supervisors with the calibration of the instrumentation that provides the values monitored by the SCADA system as well as supporting the efforts of the supervisors to maintain and troubleshoot the PLC hardware. Having the additional I&C/SCADA Technicians will also provide flexibility when it comes to scheduling since there will be adequate staff available to troubleshoot an issue that occurs at either plant or at the remote site locations. It is also recommended that the City consider experience with the technologies recommended in the SCADA Master Plan for the system upgrades when interviewing candidates to fill these new I&C positions. It is recommended that the new staff be on board and participate in the SCADA improvements project to garner invaluable hands-on experience as the system is being installed and implemented.

5.3 Maintenance

After construction has been completed, the contractor will be required to provide updated and accurate operation and maintenance manuals for the new system components including an update of the control narratives, screen shots of the latest version of the HMI graphics, troubleshooting procedures, maintenance of the computer system (i.e. computer backups, historical data backups, application software backups, etc.), and documented printouts of the latest version of the PLC applications. These O&M manuals shall be delivered in an electronic format for ease of incorporation into the City's existing electronic O&M library. In addition, the design engineer can work with the PICS to ensure that a document management system is developed for the City to use so they know what versions of programming software, operating system software and application software that they have. As part of the design of the new system, proper testing and troubleshooting equipment can be purchased to support maintenance and calibration of the instrumentation and control system including digital multimeters, 4-20 mA loop simulators, HART communicators for HART-compatible instruments, and programming terminals/laptops for use in troubleshooting PLC code and for making edits to the PLC and/or HMI/SCADA system software applications.

Section 6

Considered Additional Improvements to Enhance the Performance of the System

Throughout the Master Planning process, including the initial site visit and meetings with the City of Kingsport, several items outside of the scope of the SCADA Master Plan have been mentioned as ways to enhance the current efficiency of the facilities. During this Master Planning process, CDM Smith has also developed some suggestions for the City to consider to improve the overall performance. Below is a list of those items to be considered for inclusion as part of the upgrades:

- It was mentioned that an area near the staircase at the WTP (where some of the old MCC equipment is located) could be a location to construct a room that could house all the PLCs for the filters. The wires from the PLCs and consoles could be extended to this room and only have the Industrial PCs at the filter consoles. This has since been revised to a standalone, air-conditioned control panel to reduce the cost of the project.
- Converting the EIM actuators for the valves in the filter pipe gallery at the WTP from RS-485 Modbus to Ethernet, to eliminate the need for ProSoft modules in the CompactLogix PLC chassis at the WTP.
- Establish a Fiber Optic ring at the WWTP. The current set up is not a loop, therefore if one of the links loses power, you lose everything that is downstream of the location where power was lost. The Fiber network layout could be improved by making it a redundant ring by installing fiber optic Ethernet Switches at all locations and then using the additional fibers in the cables to "loop back" from one end of the plant back to the other. Ethernet switches may need to be added in locations where there is not a way to ensure that the signal can be repeated the entire length of the network from the Raw Water Pump Station back to the Administration Building. By creating a fiber optic ring at the WWTP, if a fiber is cut or damaged, the communications could travel in the other direction around the ring to reach its destination, providing no loss in communications while the damaged fiber optic cable is repaired or replaced.
- Currently, the MCC-1 is set up as two sections (MCC-1A and MCC-1B). There is not automatic alternation between the two, so it was mentioned it would be nice to have separate PLCs. There is one each main feed so only 3 of the 6 pumps are used instead of all of them. A UPS was installed in the PLC cabinet to maintain power long enough to send an alarm to SCADA so that the operator knows to go over to the MCCs in the Pump Station and manually switch the feeds for the PLC.
    - Add a redundant radar transmitter for wet well level monitoring; put one on each MCC section to control each group of 3 pumps (only lose 3 pumps instead of 6 when one side of the MCC goes down).

- Perform an energy evaluation on the plants. Using the additional information and power statuses to make operational decisions.
  - Add power monitoring to the Dewatering Building gear.
  - Replace or fix the power monitors at the 4160V Switchgear House; only 1 of 6 power monitors are currently functional. NOTE: the 5KV Switchgear Project will replace the existing gear and will be equipped with power monitors that communicate to the new SCADA system.
- Investigate and fix the issue of analog cards being damaged on a consistent basis in multiple locations; this could be a surge protection issue.
- Investigate and fix the "new" pumps in Lift Station 212 and why these pumps trip the soft starter on a different condition each time the pumps try to run.
- The WTP is having issues with the raw pumps level control. For example, two pumps are running at 41 Hz, where one pump could handle the load; if the operator intervenes in the automatic strategy and shuts off the lag pump, the lead pump jumps up to 55 Hz. Most of the level control logic was in place prior to the WWTP Improvements project and was not modified, per the Owner's request. This could probably be corrected by using a PID block and level control set point.
- The existing Cartegraph asset management software has the ability to interface with several 3rd party software packages due to several built-in technologies – an API (application programming interface) tool that is available to allow software to interact with the Cartegraph software via custom integration and/or interfaces, ODBC links to its database and OLE (object linking and embedding). During the SCADA Master Plant Implementation Project, the design engineer could investigate the ability of VTScada to push equipment runtime information to the Cartegraph software system.

APPENDIX A

Summary of Existing Remote and In-Plant Facilities PLCs/RTUs

This appendix identifies all remote and in-plant facilities included as part of this SCADA Master Plan Upgrade report. It identifies current PLC manufacturer and model number, along with the type of communication that is being used.

Table A-1: Water Treatment Plant

PLC Name	PLC Type	Communication
Raw Water Pump Station	CompactLogix PLC	Ethernet
Clarifiers	Allen-Bradley SLC 5/05	Ethernet
Polling Master	Allen-Bradley SLC 5/05	Ethernet
Plant Process	Allen-Bradley SLC 5/05	Ethernet
Raw Water Intake	Allen-Bradley SLC 5/05	12-Pair Shielded Cable
High Service Building	Allen-Bradley SLC 5/05	Twisted Shielded Pair
Filter Console No. 1	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 2	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 3	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 4	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 5	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 6	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 7	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 8	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 9	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 10	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 11	Allen-Bradley SLC 5/05	Ethernet
Filter Console No. 12	Allen-Bradley SLC 5/05	Ethernet

Table A-2: Wastewater Treatment Plant

PLC Name	PLC Type	Communication
Raw Water Pump Station	Allen-Bradley SLC 5/05	Fiber Optic Cable
Bar Screen Control Panel	Allen-Bradley SLC 5/05	Fiber Optic Cable
Digesters No. 1 & No. 2	Allen-Bradley SLC 5/05	Fiber Optic Cable
Blower	Allen-Bradley SLC 5/05	Fiber Optic Cable
Intermediate Settling	Allen-Bradley SLC 5/05	Fiber Optic Cable
Chlorine Building	Allen-Bradley SLC 5/05	Fiber Optic Cable
Septage Control Panel	Allen-Bradley SLC 5/05	Fiber Optic Cable
Dewatering Building	Allen-Bradley SLC 5/05	Fiber Optic Cable
Digester No. 3	Allen-Bradley SLC 5/05	Fiber Optic Cable
RAS/WAS Pump Station	Allen-Bradley SLC 5/05	Fiber Optic Cable
UV System	Allen-Bradley SLC 5/05	Fiber Optic Cable
~~**Chlorine Contact Basin**~~	~~Allen-Bradley SLC 5/05~~	~~Fiber Optic Cable~~

Table A-3: Distribution Sites (Water Remote Sites)

Pump Station Name	PLC Type	Communication
Allandale	SCADAPack Model 5203	453 MHz CalAmp Radio
Colonial View	SCADAPack Model 5203	453 MHz CalAmp Radio
Double Springs	SCADAPack Model 5203	453 MHz CalAmp Radio
Eastern Star	SCADAPack Model 5203	453 MHz CalAmp Radio
Hillcrest (Edens View)	SCADAPack Model 5203	453 MHz CalAmp Radio
Huntington Hills	SCADAPack Model 5203	453 MHz CalAmp Radio
Raw Water Intake (Old)	SCADAPack Model 5203	453 MHz CalAmp Radio
Sam's	SCADAPack Model 5203	453 MHz CalAmp Radio
Shipp Springs	SCADAPack Model 5203	453 MHz CalAmp Radio
Skyland Drive	SCADAPack Model 5203	453 MHz CalAmp Radio
Tri - County	SCADAPack Model 5203	453 MHz CalAmp Radio
Walnut Lane	SCADAPack Model 5203	453 MHz CalAmp Radio
Westview	SCADAPack Model 5203	453 MHz CalAmp Radio
Woodsway	SCADAPack Model 5203	453 MHz CalAmp Radio

Tank Name	PLC Type	Communication
Allandale	SCADAPack Model 5203	453 MHz CalAmp Radio
Bays Mountain	SCADAPack Model 5203	453 MHz CalAmp Radio
Cemetery Hill	SCADAPack Model 5203	453 MHz CalAmp Radio
Central	SCADAPack Model 5203	453 MHz CalAmp Radio
Colonial View	SCADAPack Model 5203	453 MHz CalAmp Radio
Double Spring	SCADAPack Model 5203	453 MHz CalAmp Radio
Eastern Star	SCADAPack Model 5203	453 MHz CalAmp Radio
Easley	SCADAPack Model 5203	453 MHz CalAmp Radio
Edens Ridge	SCADAPack Model 5203	453 MHz CalAmp Radio
Fordtown	SCADAPack Model 5203	453 MHz CalAmp Radio
Eden's View	SCADAPack Model 5203	453 MHz CalAmp Radio
Hiara Heights	SCADAPack Model 5203	453 MHz CalAmp Radio
Highpoint	SCADAPack Model 5203	453 MHz CalAmp Radio
Hillcrest	SCADAPack Model 5203	453 MHz CalAmp Radio
Hunnington Hills	SCADAPack Model 5203	453 MHz CalAmp Radio
~~**Raw Water Intake (Old)**~~	~~SCADAPack Model 5203~~	~~453 MHz CalAmp Radio~~
Ridgecrest (Shipp Springs)	SCADAPack Model 5203	453 MHz CalAmp Radio
Sam's	SCADAPack Model 5203	453 MHz CalAmp Radio
Skyland Drive	SCADAPack Model 5203	453 MHz CalAmp Radio
University	SCADAPack Model 5203	453 MHz CalAmp Radio
Tri-County	SCADAPack Model 5203	453 MHz CalAmp Radio
Walnut Lane	SCADAPack Model 5203	453 MHz CalAmp Radio
Westview	SCADAPack Model 5203	453 MHz CalAmp Radio

Table A-4: Collection Sites (Wastewater Lift Station Remote Sites)

Station Number	Station Name	PLC Type	Communication
Station 101	Millye Street	Motorola ACE3600	XTL 2500 800MHz Radio
Station 102	E. Sullivan Court	N/A	N/A
~~**Station 103**~~	~~Lovedale~~	~~N/A~~	~~N/A~~
Station 104	Kinsler	N/A	N/A
Station 105	Adams Avenue	Motorola ACE3600	XTL 2500 800MHz Radio
Station 106	Kyle Hill	Motorola ACE3600	XTL 2500 800MHz Radio
Station 107	Goal Street	N/A	N/A
Station 108	Oak Glen	N/A	N/A
Station 109	Fairview Avenue	N/A	N/A
Station 110	Clouds Ford	Motorola ACE3600	XTL 2500 800MHz Radio
Station 111	Parker Lane	N/A	N/A
Station 112	Lewis Lane	Motorola ACE3600	XTL 2500 800MHz Radio
Station 113	Netherland Lane	N/A	N/A
Station 114	Bays Cove	Motorola ACE3600	XTL 2500 800MHz Radio
Station 115	Bays Cove Trail	Motorola ACE3600	XTL 2500 800MHz Radio
Station 116	Lochwood	Motorola ACE3600	XTL 2500 800MHz Radio
Station 117	Parham Place (Jacks)	Motorola ACE3600	XTL 2500 800MHz Radio
Station 118	Riverwoods	Motorola ACE3600	XTL 2500 800MHz Radio
Station 119	West Kingsport	Motorola ACE3600	XTL 2500 800MHz Radio
~~**Station 120**~~	~~Ridgefields~~	~~Motorola ACE3600~~	~~XTL 2500 800MHz Radio~~
Station 121	Longreen	Motorola ACE3600	XTL 2500 800MHz Radio
Station 123	Riverport Road (AEP)	N/A	N/A
Station 124	Riverport	Motorola ACE3600	XTL 2500 800MHz Radio
Station 125	Tenneva	N/A	N/A
Station 126	Carters Valley Bridge	Motorola ACE3600	XTL 2500 800MHz Radio
Station 127	Bells Ridge	Motorola ACE3600	XTL 2500 800MHz Radio
Station 128	Mackenzie	Motorola ACE3600	XTL 2500 800MHz Radio
Station 130	Bayberry	Motorola ACE3600	XTL 2500 800MHz Radio
Station 201	Central High school	Motorola ACE3600	XTL 2500 800MHz Radio
Station 202	Rocky Branch	Motorola ACE3600	XTL 2500 800MHz Radio
Station 203	Old Mill	Motorola ACE3600	XTL 2500 800MHz Radio
Station 204	Old Mill Court	N/A	N/A

Station 206	Chestnut Hill	N/A	N/A
Station 208	Norfolk Place	Motorola ACE3600	XTL 2500 800MHz Radio
Station 210	Cross Creek	N/A	N/A
Station 211	Whites	N/A	N/A
Station 212	Cooks Landing Road	Motorola ACE3600	XTL 2500 800MHz Radio
Station 213	Memorial Blvd	N/A	N/A
Station 214	Lacys	N/A	N/A
Station 216	Lakota	N/A	N/A
Station 217	Rose Trace	N/A	N/A
Station 218	Warrior Falls	Motorola ACE3600	XTL 2500 800MHz Radio
Station 219	Carolina Pottery (McDonald)	N/A	N/A
Station 301	Airport	Motorola ACE3600	XTL 2500 800MHz Radio
Station 302	Centenary	Motorola ACE3600	XTL 2500 800MHz Radio
Station 303	Cracker Barrel	Motorola ACE3600	XTL 2500 800MHz Radio
Station 304	Sam's	Motorola ACE3600	XTL 2500 800MHz Radio
Station 305	Shekinah Church	N/A	N/A
Station 306	Buttermilk	N/A	N/A
Station 307	Cooks Valley Boat Ramp	N/A	N/A
Station 308	528 Lakeside Drive	N/A	N/A
Station 309	430 Lakeside Drive	N/A	N/A
Station 310	385 Lakeside Drive	N/A	N/A
Station 311	Cooks Inlet	N/A	N/A
Station 312	Lakeland	Motorola ACE3600	XTL 2500 800MHz Radio
Station 315	Abilene	Motorola ACE3600	XTL 2500 800MHz Radio
Station 316	Chase Landing	Motorola ACE3600	XTL 2500 800MHz Radio
Station 317	Shoals	Motorola ACE3600	XTL 2500 800MHz Radio
Station 318	Hemlock on Bank	Motorola ACE3600	XTL 2500 800MHz Radio
Station 319	Road to Warriors	N/A	N/A
Station 320	Wendover	N/A	N/A
Station 321	Greenwood	N/A	N/A
Station 322	Hillandale	Motorola ACE3600	XTL 2500 800MHz Radio
Station 323	Lakecrest	Motorola ACE3600	XTL 2500 800MHz Radio
Station 324	Perkins	N/A	N/A
Station 325	Singles Club	N/A	N/A

Station 326	Regency	N/A	N/A
~~**Station 327**~~	~~Lebanon Road~~	~~N/A~~	~~N/A~~
Station 328	Conway	N/A	N/A
Station 331	Ava	N/A	N/A
Station 332	Warrior Drive	N/A	N/A
Station 333	Woodhaven	Motorola ACE3600	XTL 2500 800MHz Radio
Station 334	DeLee	N/A	N/A
Station 401	Cliffside	Motorola ACE3600	XTL 2500 800MHz Radio
Station 402	Thornton	Motorola ACE3600	XTL 2500 800MHz Radio
Station 403	Big Wesley	Motorola ACE3600	XTL 2500 800MHz Radio
Station 404	Little Wesley	N/A	N/A
Station 405	Kendrick Creek	Motorola ACE3600	XTL 2500 800MHz Radio
Station 406	Spring Leaf (Gary Wade)	N/A	N/A
Station 408	Moreland Drive	Motorola ACE3600	XTL 2500 800MHz Radio
Station 409	South High School	Motorola ACE3600	XTL 2500 800MHz Radio
Station 410	Anco Apartments	N/A	N/A
Station 411	Anco Trailer Park	N/A	N/A
Station 413	Barnett Drive	N/A	N/A
Station 414	Horse Creek	Motorola ACE3600	XTL 2500 800MHz Radio
Station 417	Willowbrook	N/A	N/A
Station 418	Aston Court	N/A	N/A
Station 419	Summerville	N/A	N/A
Station 420	Tri Cities Crossing	Motorola ACE3600	XTL 2500 800MHz Radio
Station 421	Wilcox	N/A	N/A
Station 422	Hilton Street	Motorola ACE3600	XTL 2500 800MHz Radio
Station 423	Double Springs	N/A	N/A
Station 424	Domtar Park	N/A	N/A
Station 425	Westfield	N/A	N/A
Station 426	Hidden Acres	N/A	N/A
Station 427	Brightwood	N/A	N/A
Station 428	Droke Farm	N/A	N/A

Summary of Existing In-Plant Computer Hardware and Software

This appendix identifies the in-plant facilities computer hardware and software currently in use.

WWTP SCADA PC – Administration Building Operator Control Room

- PC: Dell Optiplex GX745
- Processor: Intel Core 2 Duo CPU E4400 @ 2.00 GHz
- Memory: 2.00 GB RAM
- Operating System: Windows XP Professional SP2
- SCADA Software: RSView32 V 7.20.00 (CPR7)

WWTP Lift Station PC - Administration Building Operator Control Room

- PC: Dell Optiplex 580
- Processor: AMD Phenom II X2 B55 CPU @ 3.00 GHz
- Memory: 4.00 GB RAM
- Operating System: 64-bit Windows 7 Professional SP1
- SCADA Software: Wonderware InTouch V 10.0.300

WWTP SCADA PC – Old Control Building Operator Room

- PC: Dell Optiplex 9020
- Processor: Intel Core i5 – 4570 CCCPU @ 3.20 GHz
- Memory: 8.00 GB RAM
- Operating System: 64-bit Windows 7 Professional SP1
    - Running on VMWare Player – Windows XP Professional SP2
- SCADA Software: RSView32 V 7.20.00 (CPR7)

WWTP Dewatering Building Machine Edition PC – Old Control Building Operator Room

- **PC:** Dell Dimension 4700
- **Processor:** Intel Pentium 4 CPU @ 2.80 GHz
- **Memory:** 1.00 GB RAM
- **Operating System:** Windows XP Professional SP3
- **SCADA Software:** Touch Screen Software (Runtime) – A-B FactoryTalk View for Machine Edition (ME) V 5.10.00 (CPR9 SR2) --> S/N: 2523012016

WTP Plant Process PC – Operator Control Room

- PC: Generic PC
- Processor: Intel Core 2 Duo CPU E7500 @ 2.93 GHz
- Memory: 1.00 GB RAM
- Operating System: Windows XP Professional SP3
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271

WTP Telemetry PC – Operator Control Room

- PC: Custom Built PC
- Processor: Pentium Dual Core CPU E5200 @ 2.5 GHz
- Memory: 2.00 GB RAM
- Operating System: Windows XP Professional SP2
- SCADA Software: NI Lookout V 3.8 (Build 7) --> S/N: J10X94736

WTP Filters PC – Operator Control Room

- PC: Custom Built PC
- Processor: AMD Athalon XP 2400+ CPU @ 2.00 GHz
- Memory: 1.00 GB RAM
- Operating System: Windows XP Professional SP2
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271

Filters 1 & 2 Console

- PC: Allen-Bradley Industrial Computer – VersaView 1700M
- Processor: Celeron CPU @ 1.70 GHz with 256 MB RAM
- Operating System: Windows XP Professional SP1
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271
- Filter Overview screen is the same as Filters PC; Operators can drill down to the individual Filters 1 & 2 graphics, but not to the other individual filter graphics.

Filters 3 & 4 Console

- PC: Allen-Bradley Industrial Computer – VersaView 1700M
- Processor: Celeron CPU @ 1.70 GHz with 256 MB RAM
- Operating System: Windows XP Professional SP1
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271

- Filter Overview screen is the same as Filters PC; Operators can drill down to the individual Filters 3 & 4 graphics, but not to the other individual filter graphics.

Filters 5 & 6 Console

- PC: Allen-Bradley Industrial Computer – VersaView 1700P
- Processor: Intel Core Duo CPU U2500 @ 1.20 GHz with 3.0 GB RAM
- Operating System: Windows XP Professional SP2
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271
- Operators can drill down to the individual Filters 5 & 6 graphics, but not to the other individual filter graphics.

Filters 7 & 8 Console

- PC: Allen-Bradley Industrial Computer – VersaView 1700M
- Processor: Celeron CPU @ 1.70 GHz with 256 MB RAM
- Operating System: Windows XP Professional SP1
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271
- Filter Overview screen is the same as Filters PC; Operators can drill down to the individual Filters 7 & 8 graphics, but not to the other individual filter graphics.

Filters 9 & 10 Console

- PC: Allen-Bradley Industrial Computer – VersaView 1700P
- Processor: Intel Core Duo CPU U2500 @ 1.20 GHz with 3.0 GB RAM
- Operating System: Windows XP Professional SP3
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271
- Filter Overview screen is the same as Filters PC; Operators can drill down to the individual Filters 9 & 10 graphics, but not to the other individual filter graphics.

Filters 11A & 11B Console

- PC: Allen-Bradley Industrial Computer – VersaView 1700P
- Processor: Intel Core Duo CPU U2500 @ 1.20 GHz with 3.0 GB RAM
- Operating System: Windows XP Professional SP3
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271
- Filter Overview screen is the same as Filters PC; Operators can drill down to the individual Filters 11A & 11B graphics, but not to the other individual filter graphics.

Filters 12A & 12B Console

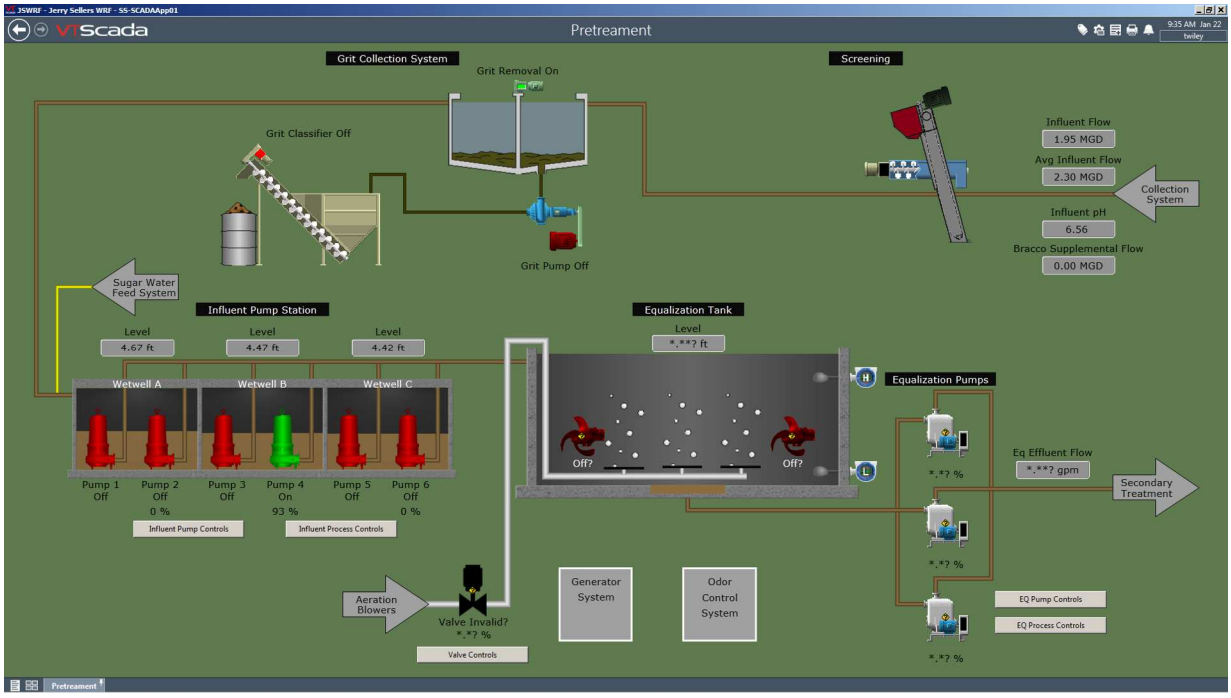
- PC: Allen-Bradley Industrial Computer – VersaView 1700P
- Processor: Intel Core Duo CPU U2500 @ 1.20 GHz with 3.0 GB RAM
- Operating System: Windows XP Professional SP3
- SCADA Software: NI Lookout V 4.5.1 (Build 18) --> S/N: J12X42271
- Filter Overview screen is the same as Filters PC; Operators can drill down to the individual Filters 12A & 12B graphics, but not to the other individual filter graphics.

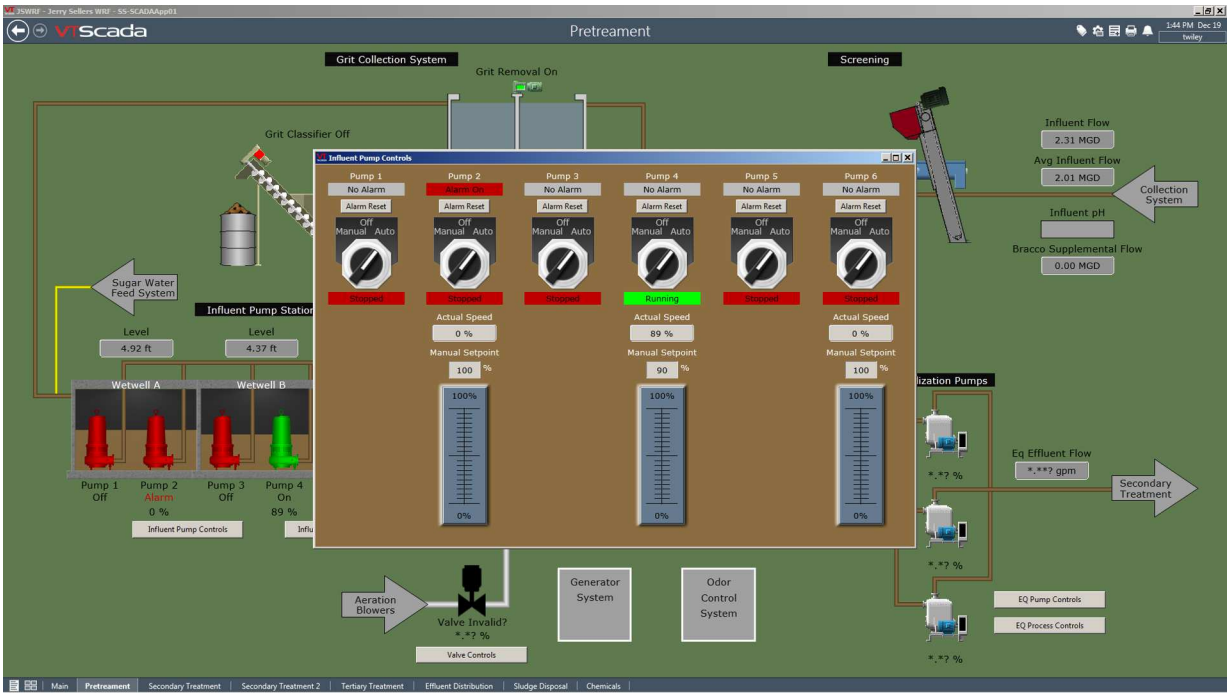
APPENDIX B

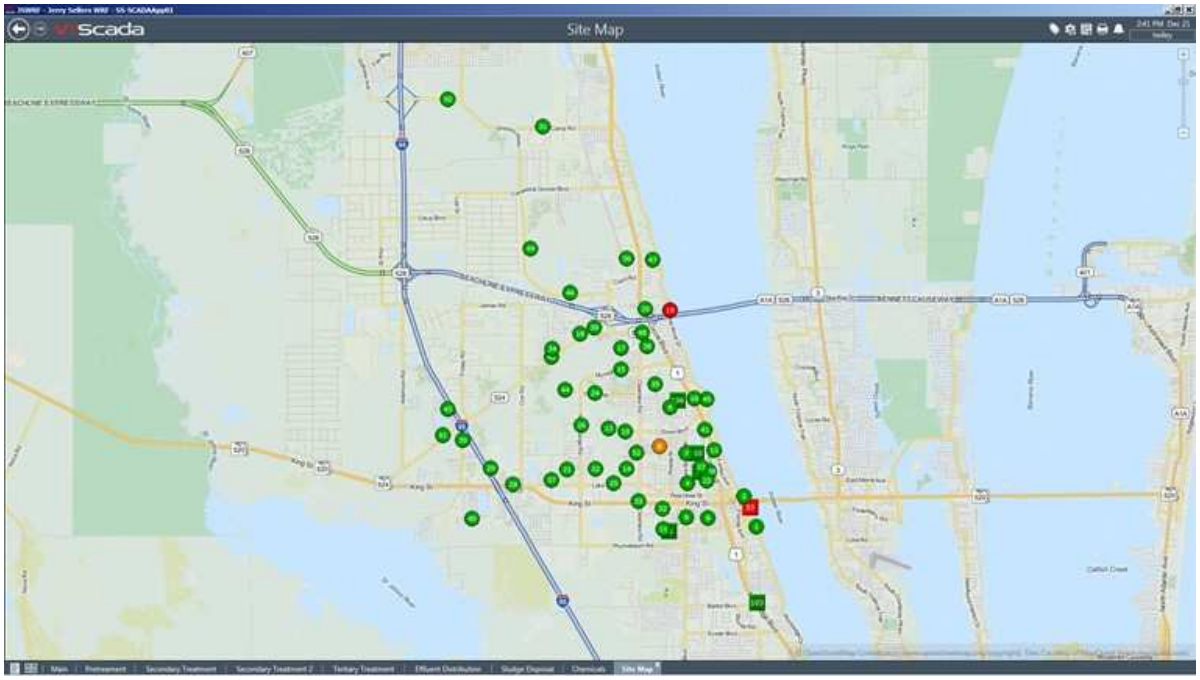
Vendor Comparison Charts

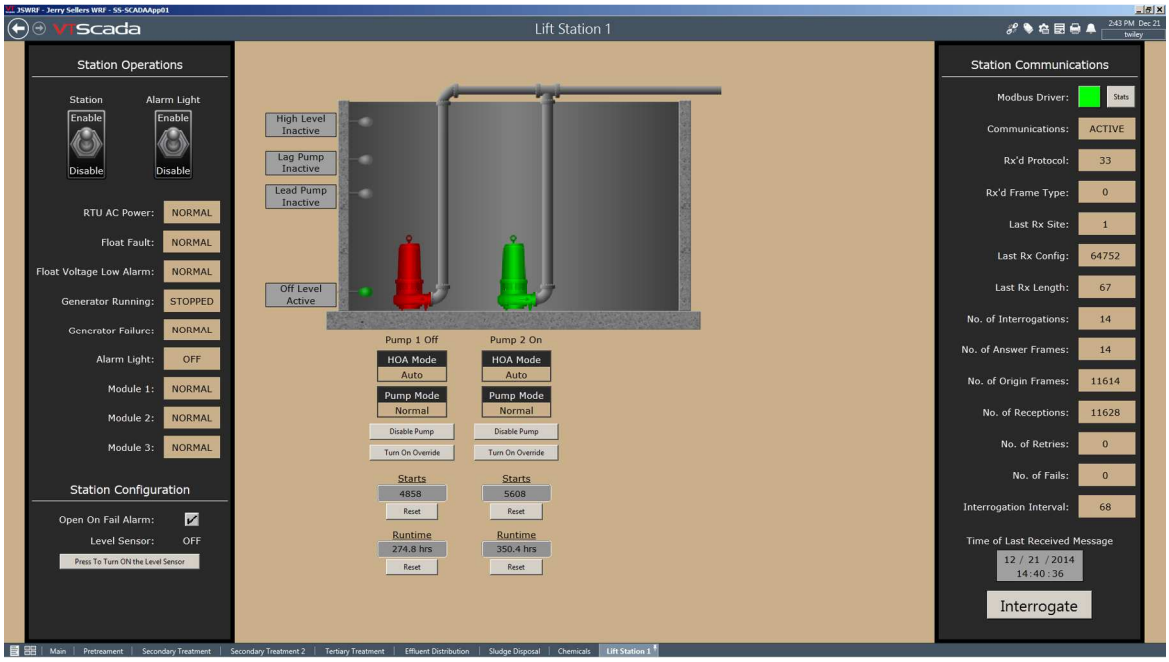
Below are the vendor comparison charts from the vendors discussed previously in the alternatives and recommendations memo.

Trihedral VTScada Screen Shot Comparison

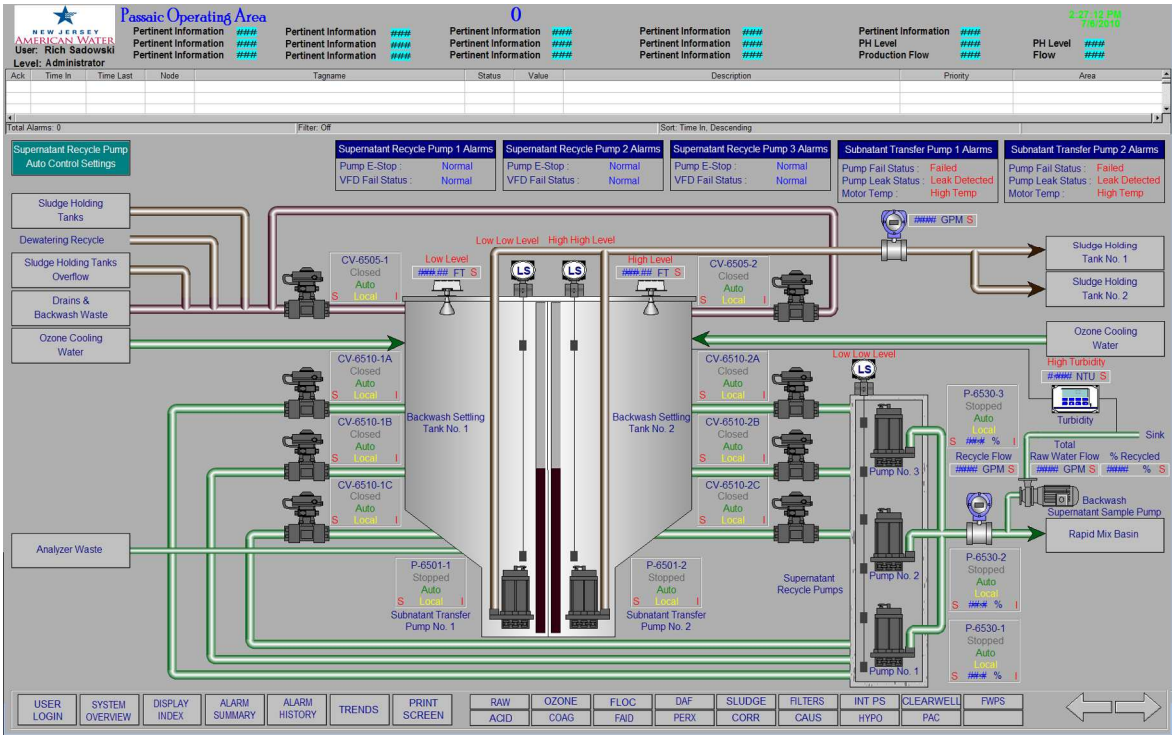



VTScada
Pretreament
Grit Collection System
Grit Removal On
Screening
Grit Classifier Off
Influent Flow
2.31 MGD
Avg Influent Flow
2.01 MGD
Collection System
Influent pH
Bracco Supplemental Flow
0.00 MGD
Sugar Water Feed System
Influent Pump Controls
Pump 1
Pump 2
Pump 3
Pump 4
Pump 5
Pump 6
No Alarm
Alarm Reset
Off Manual Auto
Stopped
Running
Actual Speed
0 %
89 %
Manual Setpoint
100 %
90 %
100%
0%
Level
4.92 ft
4.37 ft
Wetwell A
Wetwell B
Pump 1 Off
Pump 2 Alarm
Pump 3 Off
Pump 4 On
0 %
89 %
Influent Pump Controls
Eq Effluent Flow
*.**? gpm
Secondary Treatment
.? %
Aeration Blowers
Valve Invalid?
Valve Controls
Generator System
Odor Control System
EQ Pump Controls
EQ Process Controls
Main
Pretreament
Secondary Treatment
Secondary Treatment 2
Tertiary Treatment
Effluent Distribution
Sludge Disposal
Chemicals

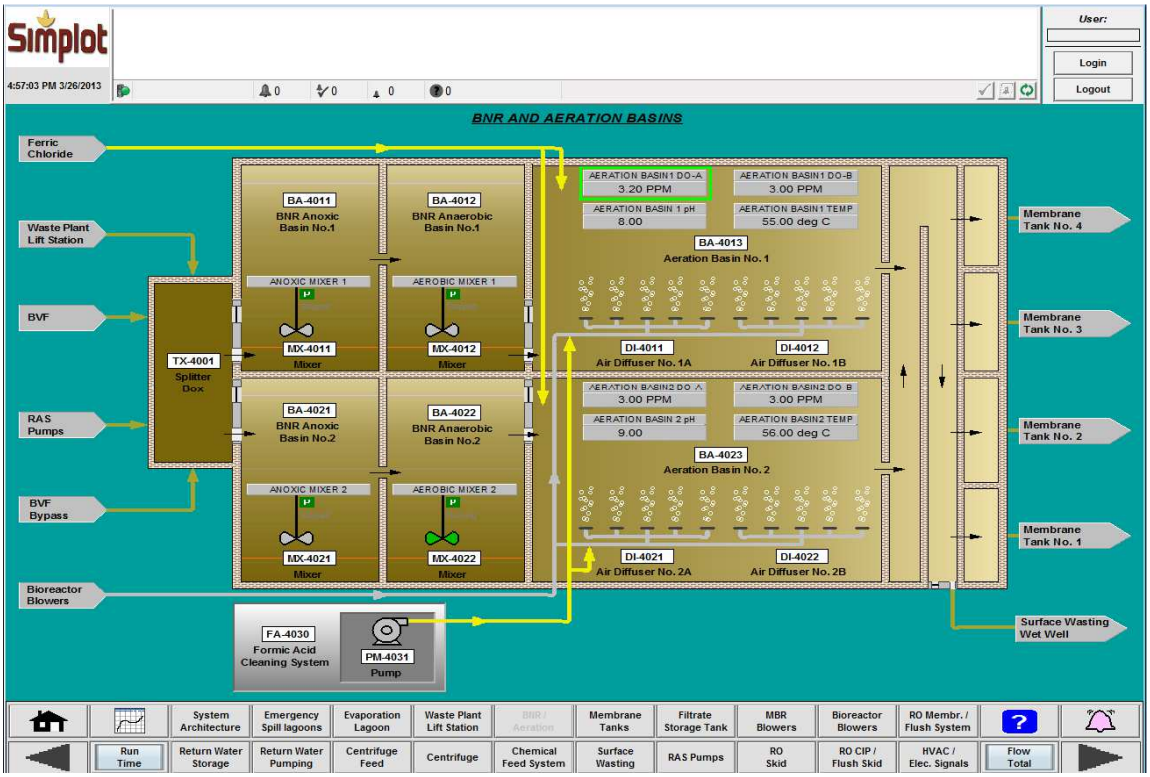

VTScada
Site Map


VTScada
Lift Station 1
Station Operations
Station
Alarm Light
Enable
Disable
RTU AC Power: NORMAL
Float Fault: NORMAL
Float Voltage Low Alarm: NORMAL
Generator Running: STOPPED
Generator Failure: NORMAL
Alarm Light: OFF
Module 1: NORMAL
Module 2: NORMAL
Module 3: NORMAL
Station Configuration
Open On Fail Alarm:
Level Sensor: OFF
Press To Turn ON the Level Sensor
High Level Inactive
Lag Pump Inactive
Lead Pump Inactive
Off Level Active
Pump 1 Off
Pump 2 On
HOA Mode
Auto
Pump Mode
Normal
Disable Pump
Turn On Override
Starts
4858
5608
Reset
Runtime
274.8 hrs
350.4 hrs
Station Communications
Modbus Driver:
Stats
Communications: ACTIVE
Rx'd Protocol: 33
Rx'd Frame Type: 0
Last Rx Site: 1
Last Rx Config: 64752
Last Rx Length: 67
No. of Interrogations: 14
No. of Answer Frames: 14
No. of Origin Frames: 11614
No. of Receptions: 11628
No. of Retries: 0
No. of Fails: 0
Interrogation Interval: 68
Time of Last Received Message
12 / 21 /2014
14:40:36
Interrogate
Main
Pretreatment
Secondary Treatment
Secondary Treatment 2
Tertiary Treatment
Effluent Distribution
Sludge Disposal
Chemicals
Lift Station 1

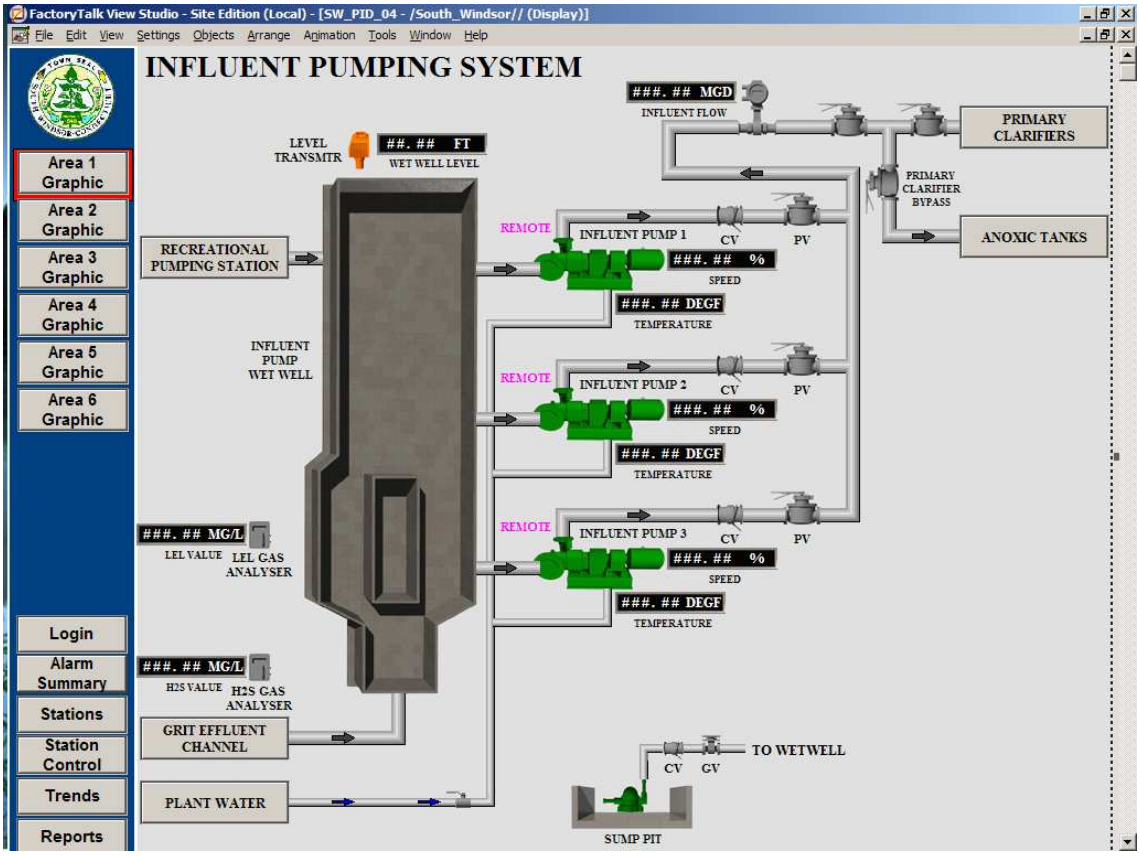
GE Proficy iFix Screen Shot Comparison



Allen-Bradley FactoryTalk View SE (PlantPAx Graphics) Screen Shot Comparison



Allen-Bradley FactoryTalk View SE (Image Graphics) Screen Shot Comparison



APPENDIX C

Radio Path Survey – required During Design orConstruction

This has not been conducted. This is part of the Engineering Design and Integrator cost responsibility.

APPENDIX D

Can Cellular Compete with Private Radio Memo

See attachments at the end of this document.

Can Cellular Compete with Private Radio?

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[1]Camp Dresser and McKee

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ABSTRACT

This paper explores wireless technologies available, the design steps required and analyzes the difference in costs between radio and cellular technologies over a 10 year life span for a typical telemetry system using an equivalent annual cost analysis. It will include the initial capital costs as well as the monthly service fees and maintenance of the telemetry equipment.

KEYWORDS: Cellular, Radio, SCADA, Telemetry, Wireless, Data Acquisition

INTRODUCTION

Water and wastewater utilities use telemetry equipment to send field data to a central location. This has historically consisted of telephone and radio technologies. Until recently, the costs of using a phone service or installing a radio network were very similar. With the advent of cellular data networks, the cost of moving data has dropped significantly, while the cost of other technologies has remained relatively unchanged. Unfortunately, recent changes in technology costs have not always been factored into the decision making process of which technology to use.

In a Data Acquisition system or a Supervisory Control and Data Acquisition (SCADA) system, telemetry provides a data path to connect far-flung remote sites back to a central location. These systems need to carry a limited amount of information on a cyclic basis with little or no time delays. Radio or cellular are the main wireless choices to move data to and from the field sites.

Beside installation and operational costs, a common concern is the difference between the security of radio compared to cellular systems. The types of security risks and procedures to address them are very similar between radio and cellular based systems. The main security difference between cellular and private radio is that cellular data passes over the telephone network while radio data is passed over public airwaves.

When selecting a telemetry system, there are more options available today, and several more factors that need to be considered before making a final decision. It used to be that, when selecting a means of communications, the only affordable choice for most municipalities was the local phone company and a serial modem. Now, because the cost of technology has come down,

not only are other hardware alternatives available, but alternatives are also available within each type of communication platform selected.

Cellular Equipment

Two main cellular technologies are most appropriate for SCADA telemetry systems: GPRS (General Packet Radio Service) and CDMA (Code Division Multiple Access) 1xRTT (Single Carrier Radio Transmission Technology). Because SCADA systems generally use a limited amount of data, higher bandwidth systems, like EVDO (originally stood for "EVolution, Data-Only", but now is also referred to as "EVolution, Data-Optimized), do not significantly improve speed unless other services (like video) are needed at the remote site. This technology provides data rates 10 times faster than the older 1xRTT technology, but for most remote SCADA sites, the amount of data is so little that an increase of the data rate does not make much of an impact overall. For either of these data services, cellular modems that support them are required at each site. These technologies are quickly changing to accommodate more data at faster data rates.

When using packet data protocol over a cellular network data is passed back and forth from a master station to a remote station over an IP connection similar to a DSL connection where the data path is always available. Charges are only based on the amount of data passed across the network. Because this is an IP network, there is a significant amount of overhead added to the packetized data as part of the header protocol. Therefore, use of a system like this one is optimized when communications is not constant but is limited to several packets of data transmitted each day. Cellular network companies usually have special packages based on amount of projected usage to accommodate data users, and the costs are fairly reasonable. However, when going over on data usage, similar to exceeding your allotted minutes used on your cell phone during a billing period, additional charges are accumulated.

There are also small Remote Telemetry Units (RTUs) that are sold as packaged cellular systems. These systems use cellular technology as the means of communications and provide limited monitoring and control functionality, including a web site where all of the data will be displayed. These systems are simplistic and designed to provide access to a limited number of I/O as well as ease of installation and configuration. There are even systems that can control the operation of equipment by the use of text messages from another cell phone, or just send text messages as alarms.

Another technology that has been used for years is the auto-dialer. This technology is used primarily for alarm monitoring and indication, although some manufacturers have now incorporated limited control functionality. In the past, these units were restricted to communication by standard dial-up phone lines. Today, with cellular modem technology, these auto-dialers can now be installed quickly and easily without waiting for the phone company to install phone lines in remote areas.

Cellular data communications is becoming more popular today for several reasons. The dramatic decrease in the cost of hardware and equipment has helped this technology increase in popularity. The cost of cellular technology used to be so expensive, only a few people could afford to use it. Today it almost seems strange if someone does not have a cell phone. The technology has also improved and the infrastructure has expanded because cell companies need

to provide a service to so many customers not to mention the competition driving the demand for quality services to be available at all times. A typical cell tower has large backup up generators to maintain services during power outages as well as redundant systems in case damage occurs to critical hardware components. As a result, these systems have become extremely reliable and very reasonably priced for many different applications

Radio Equipment

Spread spectrum radios in the 902 – 928 MHz band are popular because of their ease of use and license-free status. They operate in a data-only band, but since they operate on non-exclusive frequencies, some interference must be expected and considered normal. Therefore, radios are designed to manage the effects of interference by avoiding frequency bands, changing hopping sequences, and sending small data packets with auto retries.

Spread spectrum radios have a shorter effective range than licensed systems, primarily because they operate using only 1 watt. If repeaters are needed to extend coverage, they are easy to implement. Spread spectrum radios are also manufactured for the 2.4 GHz band. Due to the higher frequency, more signal attenuation from trees should be expected. They are widely available from a number of manufacturers and require no monthly licensing fees. Using directional antennas can reduce interference.

Licensed data-only frequency pairs exist in the 928/952 and 932/941 MHz bands. From a cost standpoint, except for the license fee, there is no significant difference between licensed and license-free 900 MHz radios.MAS systems are configured in a point-to-multipoint arrangement only. Transmission can be used for two-way (interrogate/response) communications between a master station and its remote sites. This is a data only frequency band that uses 5-watt transmitters. Data transmission speeds are available up to 9.6K bps and increase SCADA system response to alarms.

The FCC (Federal Communication Commission) licenses grant exclusive use of a designated frequency within a 70-mile radius to reduce interference. When a prospective user applies for a new radio frequency, the FCC considers the proposed use and whether the frequency is already in use by a nearby user to avoid interference. Licensed frequency congestion is a significant problem in metropolitan areas. The FCC has opened new frequencies between channels and is encouraging narrower bandwidths to permit more users to operate in a given area.

Ethernet radio modems have increased in popularity and offer another alternative in certain situations. Many manufacturers offer protocol options for programming and data communications using an Ethernet based network. Industrialized Ethernet applications have become more popular because of the wide-spread use and popularity of Ethernet. Wireless

Ethernet modems have a fast data transmission rate and offer acceptable levels of security. Most PLC manufacturers now offer Ethernet as a protocol option for data communications and programming access. With Ethernet radios installed a field technician would no longer need to travel to a remote site several miles away to change or modify a program. Instead, direct communication across the wireless Ethernet network could be utilized for all modifications.

There are also radio systems which incorporate I/O as an integral part of the radio, referred to as wireless I/O. These systems initially were very limited on I/O and functionality, and are primarily used to bring in I/O points from obscure locations within a couple hundred feet eliminating the need to run conduit. Just like any other technology, these systems quickly expanded their capabilities and are now able to do simple control functions using proprietary programming software and commands. They have also expanded hardware offerings including expansion I/O capability which includes analog and digital points. These systems generally do not require expensive antenna installations, support multiple protocols including Modbus, Profibus, DeviceNet, Ethernet IP, support Spread Spectrum technology including 900 MHz and 2.4 GHz, and support several security encryption methodologies.

Security

When selecting a method of communication, security must be considered as part of the selection process. With the creation of the Department of Homeland Security, concerns over cyber security are much greater than they have been in the past. There are significant differences between data security when using cellular or radio technology, however both technologies are specifically identified as a potential security risk in the Water Environment Federation's (WEF's) "Interim Voluntary Security Guidance for Wastewater/Stormwater Utilities."

The best form of security is to have local hard-wired networks which do not connect to an outside network such as the internet or other Wide Area Networks (WAN). In the past, this was not so difficult because SCADA technologies and Information Technology (IT) systems were not very complex. Most data was handled locally at a plant or pump station on a stand-alone computer, and reports were done on a local printer or just hand written. Today this has totally changed because of the improvements in technology (instrumentation and communications) and access to better, more accurate data. With greater access to this data a municipality now has the ability to improve control strategies, incorporate historical experiences into running processes, and store data for later analysis and detailed reporting.

With the improvements of data quality, quantity, and accessibility comes the opportunity of outside vandalism, and steps need to be taken to protect data and control systems, as well as entire SCADA networks. Steps should also be taken to protect data from internal sabotage as well such as disgruntled employees or even accidental breaches. The best way to approach this issue is to first determine how valuable the information is, and what the repercussions are to a breach of this data.

With private radio networks, the passing of data is limited to the localized area of each transmitter and receiver which makes radio systems a little less susceptible to cyber attacks than cellular networks. However, this does not make them immune to outside hackers. These systems can be "jammed" by an outside frequency, if the system is setup using a single fixed frequency

(licensed radios) and a hacker finds the frequency. “Jamming” is a way of stopping data from going from one point to another. It is not a means of capturing or stealing data, it is just done to cause disruption in a system. Finding SCADA system’s communication frequencies are not that difficult with the correct equipment. This equipment is generally expensive to purchase, but most people or companies that do radio work on a regular basis will have access to this type of hardware.

An alternative to using licensed or fixed frequency radios would be the Spread Spectrum radio. This radio will use a hopping frequency and only use the frequencies that are available when ready to transmit. This helps to keep hackers from trying to “jam” the airwaves to block data throughput.

Using a good communication protocol that has data encryption as part of the message packaging is also an excellent way to make it more difficult for hackers to steal or corrupt data. A protocol is the language used to communicate information between systems. Some protocols don’t have any data encryption and are widely used in SCADA systems today. Many of these systems are considered “open architecture” systems, which means they are commonly used systems that make their protocol structures available for public use. In other words, anyone can learn how they work, and use that to steal or corrupt a system which uses that protocol. A good solution for these systems which use open architecture protocols is to use the hardware, or radio modems, to encrypt the data before it is transmitted over the airwaves.

With Cellular technology, data is more accessible because it is broadcast over a phone system with multiple users. These systems are stretched across a much larger area than radio systems because they use a public domain with many other users who have access to the same network. It is very important when using this technology to also include data encryption techniques or even proprietary protocols to protect data.

With monitoring systems, security may not be an issue at all. These “monitor only” systems are referred to as Data Acquisition systems (DAQ) and are used solely for gathering data from remote sites. If a remote site is transmitting flow data back to a central computer, and someone hacks into the network and steals this data, it would not be considered a problem. It could be a problem, however, if a hacker were able to somehow break into the system and corrupt the data. This is much less likely to occur, therefore these systems do not require the same amount of security considerations as other systems that actually provide control or transmit private information.

Costs

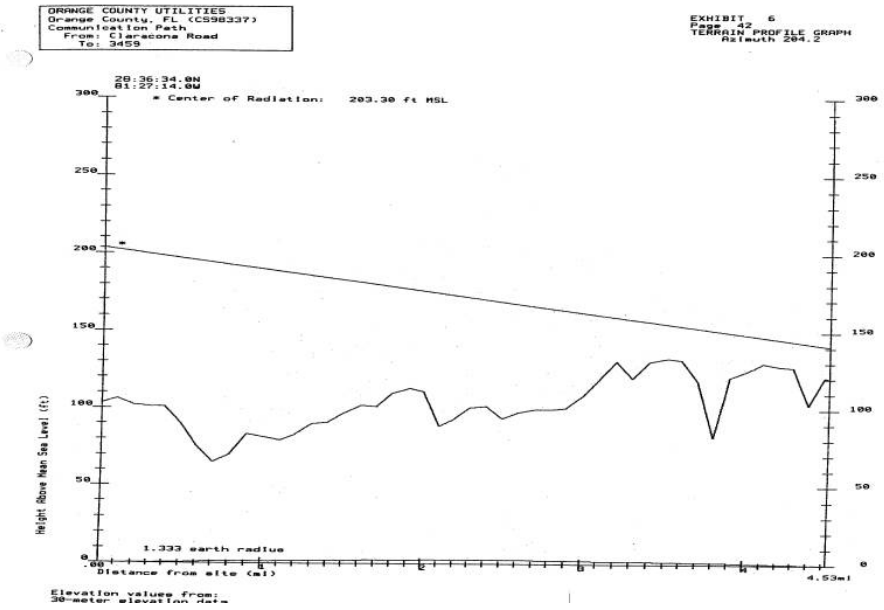
Until recently, the costs of using a phone service or installing a radio network were very similar. With the advent of cellular data networks, the cost of moving data has dropped significantly, while the cost of other technologies has remained relatively unchanged. Several factors play into the choice of technology. The overall cost can be broken down into three groups: design cost, installation cost, and operation & maintenance cost.

Design Cost

Cellular systems and radio systems both require similar steps to design. Coverage for each site must be verified first by consulting cellular provider coverage maps or performing a path study for radio. These are followed up with field visits to measure the signal strength. Both of these steps are easier to accomplish with a cellular system than with a radio system.

The first step of the design process for the cellular communication is to review an area coverage map from the service provider of choice to verify in general that cell coverage is available in the area of interest. Since multiple cellular companies are often present in the same area, each of their coverage maps should be reviewed. Using more than one service provider may provide better coverage. Once this is completed, a field survey should be performed.

For radio systems, a path study determines likely communication paths and highlights sites that may have no ability to connect to other radios. Path studies are planning tools and provide valuable information for system planning but they only determine approximate radio performance. If a site does not have a viable radio path, a repeater may be able to provide a suitable path.



The location of the remote site and the master station are used to produce a terrain profile along the path of interest. Line of sight paths between master radio towers and the remote sites are drawn on maps and terrain profiles are developed from the elevation changes along the radio path. In the past, terrain profiles were calculated by hand using topographical maps. Now that terrain data is available in computer format, software can quickly generate the terrain profile between two sites. Tools are appearing on the Internet that can produce similar results to a lower level of precision.

If the radio path says above the terrain and other know obstructions (such as trees), there is a good chance that a viable radio path exists. It may be possible to raise either the remote antenna or the Master antenna to obtain a good radio path. Community buy-in must be considered for pole heights required. Few residents appreciate a 90-foot pole in their back yard.

Radio studies can factor in many variables that affect the system, including site location, terrain, antenna height, antenna gain, transmission line loss, transmitter power, receiver sensitivity, fade margin, and vegetation (i.e. land use). One disadvantage of license free radios is that they are

limited to 1-watt of output power which limits their effective communications distance. A repeater may be able to be placed to extend the reach of these low power radios.

Path studies are not infallible. They are only a rough determination that a radio path may exist between two points. A field survey is needed to truly measure the effects of terrain, man-made obstructions, and foliage.

The field survey should be done early, preferably during the initial system design. For cell equipment, a small whip antenna and a portable cellular modem is used to measure the cellular signal strength and the data reliability. A signal should available at most sites show in the coverage map. If one of the cellular company signals is too weak, it is possible that that a different company may have a usable signal. At sites that have a weak cell signal, a test pole with a high gain external antenna can be used check if an adequate signal can be achieved by raising the antenna. This measurement confirms the viability of using cellular at each site.

Radio system field testing requires some additional equipment. Unlike cellular, a Master radio may need to be temporarily installed to produce a test signal to measure at the remote sites. Radios and antennas with known gains are temporarily installed at each master tower. A radio technician at each remote site uses a test pole to rotate a directional test antenna to maximize the intensity of the received signal and ensure reception is through the main antenna lobe. The data is then adjusted mathematically for any differences between the field test hardware and the proposed operational system hardware. A fade margin (20-30 dB) is added to the sensitivity of the radio to produce a minimum Received Signal Strength Indication (RSSI) target.

If the received signal is too weak for reliable operation, antennas can be raised or a repeater system may be needed to extend the coverage area. If repeaters are necessary for the system to work a potential repeater site is located and a path study is performed. This will be followed by a field survey. If the path is unsatisfactory, a new site is picked another round of survey are done. Potential repeater sites must be chosen carefully to reduce the number of paths studied. Evaluating multiple radio paths can become very expensive and time consuming.

Installation Cost

Cellular modems are widely available, but for best results, the equipment purchased should be the same equipment in use by the service provider used for that site. After the initial activation fee is paid, cellular service is available as soon as the unit is powered. At most locations, a simple whip antenna is all that will be needed to establish a cellular data connection. In areas that have weak cellular signals, a tower and antenna may be required to establish a connection. An additional benefit is that the units do not have to be at their final location to be tested. They can be powered on and tested anywhere the cellular signal is available.

Radio systems generally have a higher initial cost than cellular because they require significant hardware (e.g., tower, feedline, grounding, and antenna). The radio equipment and accessories are generally available. Since a pole or tower is usually needed to elevate the antenna above surrounding trees, construction is complicated somewhat by the need for a tower, grounding system for lightning, and feedline installation. These components are not familiar to most electrical contractors and the quality of installation varies widely unless a radio contractor is used. If the tower is high, concrete may be needed for the tower base and a crane may be required for tower installation. Poles and towers are available in a number of different materials including galvanized steel, fiberglass, aluminum, 316 stainless steel, and concrete poles. Some are designed to be foundation free. Camouflaged poles are also available in a number of designs, such as fake trees, light poles, church signs, and large flagpoles. A structural engineer should certify that all pole and tower systems are structurally sound and will handle the maximum expected wind loads where they are installed.

Operating & Maintenance Cost

Cellular data plans are available at different monthly rates depending on the number of megabytes used. The volume of data sent from the remote sites is generally very small, often less than 5 megabytes per month. If access to a negotiated government rate through the GSA is available, the cost per month could be as low as $20. Otherwise, data plans for $40 to $60 per month are widely available, though they generally offer much more data capacity than is needed.

The cellular monthly service cost for each site pays for the service provider's internal maintenance and operation - little to no maintenance is required for the remote site equipment. If an external high gain antenna is installed on a pole, then some site maintenance may be needed.

Cellular service during serve weather events is often a concern. The reliability of the cellular system has improved substantially in the last 10 years, and the cellular system is now on par with the hard-wired phone network, even during severe weather. The cellular network is maintained by the fulltime technicians. Since the cellular network also supports regular cell phone service, they have significant financial incentive to keep their

network operating, even if it requires the deployment of temporary cellular systems like Verizon's Cellular on Light Trucks (COLT) portable cell systems.

One of the main appeals to license free radio is that there are no monthly service fees. However, maintenance of radio components is a recurring need. The owner will need to maintain the radio infrastructure, including antenna towers and repeater sites. Lightning, surges, adjusting antenna direction, and other maintenance activities will require trained staff that are either in house or are obtained from a trusted radio firm.

COST COMPARISON METHODOLOGY

The cellular and radio systems are analyzed as mutually exclusive alternatives, since it is preferable to only implement either the radio or the cellular system. The best alternative is the one with the smallest Equivalent Annual Cost (EAC), which is calculated separately for the cellular and radio scenarios. Inflation is ignored since it will apply equally to both alternatives and the interest rate for capital is set at 7 percent annually. The problem horizon (or period of study) is 15 years after which both systems are assumed to have no salvage value. Not installing a telemetry system is not an option that is considered.

The costs of a telemetry link are broken down into design, installation, and operating & maintenance costs. The first costs (design and installation) are spread over the expected life of equipment. Maintenance costs include replacing 2 percent of the telemetry equipment each year for each system.

Licensed radios are only slightly more expensive than license free radios, primarily because of licensing fees. Over 15 years, the difference is not significant so only license free radios are considered. The remote radio sites include a 50 foot pole. The estimate does not include a master tower for the radio system. If needed, this should be priced separately and added to the costs for a more accurate estimate. This may have a major effect on the evaluation of small (less than 100 remotes site) systems. Establishing radio paths without using repeaters is assumed. This could be typical for fairly flat terrain but not mountainous or other environments without line of sight paths for radio. Using repeaters will also add to the radio system costs.

The EAC is calculated year by year using the first costs and the annual costs. These are calculated based on the equation:

EAC = (First cost) x (A/P, 7%, Year) + Annual costs

This translates to the Excel formula:

=-PMT(7%,Year,First Cost)+ Annual costs

Table 1

One time and Annual Costs

	Design	Installation	Operation
Radio	$ 220	$ 4,925	$ 32
Cellular 20	$ 25	$ 550	$ 260
Cellular 40	$ 25	$ 550	$ 980
Cellular 60	$ 25	$ 550	$ 1,460

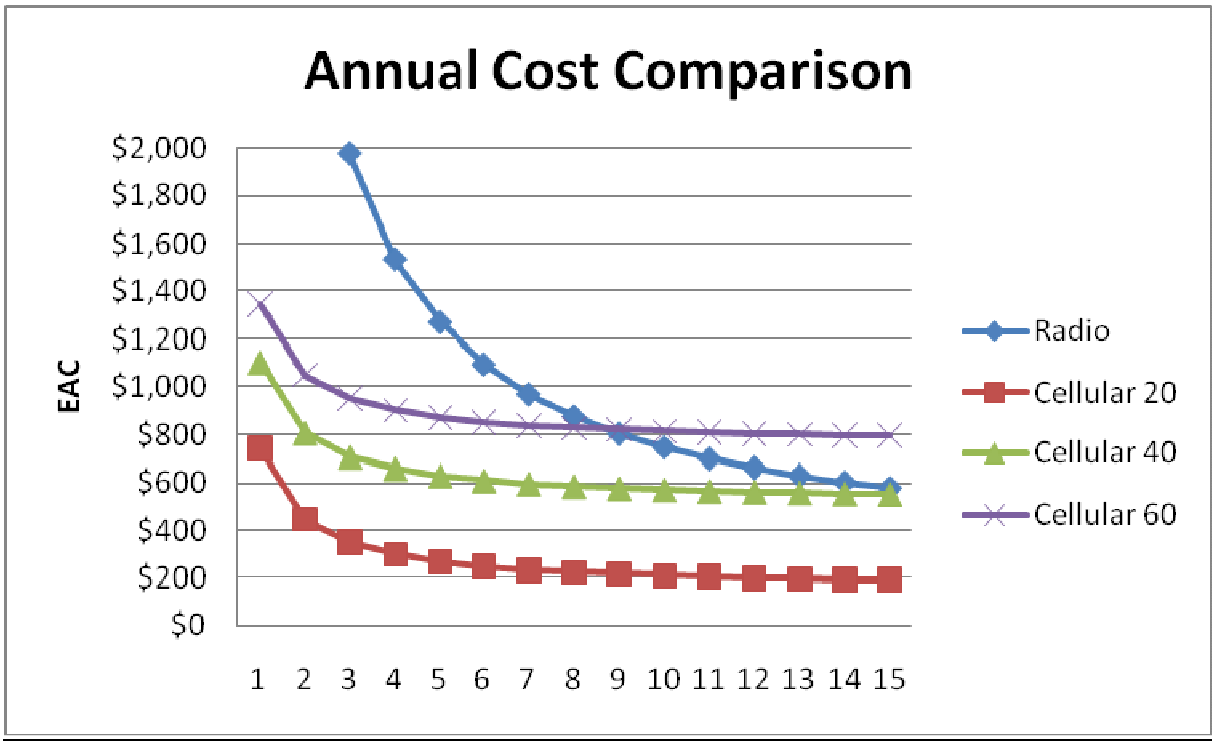


Figure 2

When these values are graphed (Figure 2), several trends become apparent. The cellular equipment rather quickly approaches the annual service fee and changes very little year to year after 3 years. The radio system EAC on the other hand changes dramatically for the first 12 years. It takes a long time to recoup the large first costs that were incurred. If our timeframe is around 9 years, then paying up to $60 per month for cellular service makes sense. If our time

frame is 15 years, then paying up to $40 per month for cellular service makes sense. The equipment will likely become obsolete after 15 years.

RESULTS

Once all the design, installation, and operation & maintenance costs are accounted for, cellular is shown as the less expensive system. This is true up to the 9 year mark for even the $60 per month data plan. The $20 or the $40 per month cellular service rate should be widely available and should be used if data needs allow the smaller bandwidth.

The first costs that occur for radio systems, including software and field surveys are almost non-existent for cellular systems. The surveys can take a long time to perform, and may require locating property that can serve as repeater sites. Because no radio surveys are needed, cellular systems can be installed rapidly.

The lower EAC for cellular systems make sense since the costs to build the cellular network is spread across all cellular users where as the radio network cost is borne solely by the end user. Cellular provider towers are high, strategically located over a wide service area, and powerful, they provide a much more reliable system than can be economically obtained in a private radio system. The cost of the tower is the major cost of a radio system. The height is required to get the antenna above surrounding trees and buildings. For cellular systems, a small whip antenna is generally all that is required for good reception from powerful service provider sites. The installation costs for a radio tower are not required most of the time for cellular systems. Because of this, a cellular ready panel can be delivered to a site and be sending data within hours instead of days or weeks.

The equipment maintenance costs are estimated at 2 percent of the purchase price per year. Even at these low levels, paying a monthly service fee is more economical than having radio technicians on staff. The difference in security between radio and cellular is negligible. Security is not a significant reason to use one over the other.

Cellular has the desirable characteristics of virtually no installation costs beyond ordering the service. In reality, the cost of cellular data has been dropping significantly for the last few years. It will likely be much less expensive 10 years from now. Radios generally have high design, installation, and maintenance costs that make them less attractive. If cellular technology is locally available, it is a good foundation for economical telemetry system.

APPENDIX E

Radio vs. Cellular Memoranda

See attachments at the end of this document.

Memorandum

To: *Niki Ensor*

From: *Greg Czerniejewski and Nicole Mellin*

Date: *January 5, 2017*

Subject: *Kingsport SCADA Master Plan – Capital Costs of Radio vs. Cellular*

Per the discussion during the Draft SCADA Master Plan Workshop and to assist the City in making the final decision between radio and cellular, this technical memorandum was developed based on items that were researched and compiled for comparison. It is the intent of this memo to summarize the capital costs of radio versus cellular for a single remote site, typical data packet size, and monthly data or upfront cost associated with each of these options.

Radio Capital Costs

The Radio recommended by CDM Smith is the GE MDS SD series radio. The cost of the radio is around $3,000 and approximately $5,000 - $15,000 for associated radio tower or poles and assemblies, which can range from a 20' freestanding tower or a 100' guyed tower with 10' mast, a Yagi or Omni Directional antenna, coaxial cable, connectors, grounding kits and surge protectors. Pricing may also fluctuate pending the radio path survey for the necessary pole heights and bracing to meet code for wind loading and for achieving optimal communication. In addition, there may be radio infrastructure required to install one or more repeater sites, including additional radios, towers, larger diameter coaxial cable, etc. The pricing proposal from Revere Controls for the Radio path study is attached at the end of this memo. As stated, the software path study and report pricing is $5,700 and the physical field path study and report pricing is $39,000.

Cellular Capital Costs

The Cellular modem recommended by CDM Smith is the Sierra Wireless AirLink Raven RV50 Industrial LTE Gateway. The cost of the modem is around $700 with very minimal installation or associated costs other than the monthly Verizon Wireless data plan contract. **Table 1** provides a summary of the Custom Machine to Machine SharePlans pricing breakdown per the State of Tennessee Contract with Verizon Wireless. The State of Tennessee has a contract with Verizon Wireless includes a "Machine to Machine" data share plan. This coverage includes the Verizon Wireless 4G, 3G, and 3G Extended networks data coverage. The Verizon Wireless Private Network provides cyber security since the data packets from the remote locations are not routed over the public internet. This is accomplished by changing the access point name (APN) to direct the remote communication devices at each of the remote sites to the private network. Therefore, the data

transmitted from the remote sites is never combined with the public Internet traffic. This contract option also includes "Machine-To-Machine" Management Center which allows for gateway management of the Private Network Configuration. This includes initial configuration of a new cellular modem, the ability to activate or deactivate a modem if there is a communication issue, set data usage alarms (i.e. if a typical site is supposed to average around 5MB per month and it exceeds 5MB in the first three days of the month; set an alarm to indicate something is wrong with the site), etc. As an added security measure, the cellular network has multiple frequencies that can be used and can be adjusted relatively quickly if a frequency interference or a problem with the communication arises. There is also less infrastructure required for a cellular network, essentially only requiring an antenna on top of the RTU enclosure instead of a Yagi antenna on a 20 or 30-foot pole for radio communication.

Table 1. Verizon Wireless State of Tennessee Contract Summary

Custom Machine to machine SharePlans			
These Custom Machine to Machine SharePlans with monthly access fees of $34.99 or higher are eligible for Monthly Access Fee Discounts			
Monthly Access	**Data Allowance**	**Overage Rate per MB**	**Share Option Included***
$5.00	1MB	$1.00 per MB	Group 1: Lines on 1MB through 150MB plans may share data
$7.00	5MB		
$10.00	25MB		
$15.00	50MB		
$18.00	150 MB		
$20.00	250MB	$0.015 per MB	Group 2: Lines on 250MB through 10GB plans may share data
$25.00	1 GB		
$50.00	5GB		
$80.00	10 GB		

Note: Machine to Machine coverage includes the Verizon Wireless 4G, 3G and 3G Extended networks. Current data **coverage** details and additional plan information can be found at www.verizonwireless.com. 4G service requires 4G Equipment and 4G coverage. Customer must provide its own equipment when activating service on Machine to Machine plans, or may purchase Equipment at full retail price. All usage (measured in KB) will be aggregated at the end of the bill cycle across all lines and then rounded to the next MB.

Data Sharing: Sharing among M2M Lines is available only among M2M Lines active on this Plan. At the end of each bill cycle, any unused data allowances for lines sharing across multiple accounts unused data allowances will be applied proportionally to all lines with overages and bills overage as KB. Plan changes may not take effect until the billing cycle following the change request. Lines provisioned on price plans within Group 1 cannot share with lines provisioned on price plans within Group 2.

The monthly access fees are per device that connects to the network. The data allowances for each device are added together for a total data pool that is shared among all sites in the group. An example is shown in **Table 2** below, using the 96 lift station sites:

Table 2. Verizon Wireless Monthly Cellular Fee Example – Group 1 Sites

Monthly Access Fee	Data Allowance	# of Sites	Total Data in "Pool"	Total Monthly Fee
$5.00	1MB	83	83 MB	$415
$18.00	150MB	13	1950 MB	$234
Totals			2033 MB	$649/mo.

We can adjust the monthly pricing to meet our data needs. Paul and Warren, with Verizon Wireless, also indicated that when we are deploying this and think we have the data plan set up correctly but we overshoot by 500MB, they would work with us to re-adjust the plan prior to the bill being sent out. So that instead of paying the $500 overage fee, they would add 3 or 4 "150MB" sites to the plan so that the increase in cost would only be $54 (3 additional 150MB sites) or $72 (4 additional 150MB sites). NOTE: when looking at the table that summarizes the State of Tennessee Contract for Verizon Wireless, the bold line in the middle separates the pricing into two groups. When doing a group share plan, all of the sites either need to be in Group 1 or in Group 2. An example using the Group 2 pricing is shown in **Table 3**.

Table 3. Verizon Wireless Monthly Cellular Fee Example – Group 2 Sites

Monthly Access Fee	Data Allowance	# of Sites	Total Data in "Pool"	Total Monthly Fee
$20.00	250MB	83	20.75 GB	$1660
$25.00	1000MB (1GB)	13	13 GB	$325
Totals			33.75 GB	$1985/mo.

Data Packet Sizing

Based on the current I/O modules being used in the existing Motorola RTUs and making assumptions based on discussions with the City on additional items that would likely be monitored on the SCADA system. **Table 4** provides an estimated data packet size for normal communications updates using the DNP3 protocol.

Table 4. Data Packet Example

Card	I/O	Description	Words	Bits
1	DI	Wet Well Level High-High		1
1	DI	Pump No. 1 In Auto		1
1	DI	Pump No. 1 Fault		1
1	DI	Pump No. 1 Running		1
1	DI	Pump No. 2 In Auto		1
1	DI	Pump No. 2 Fault		1
1	DI	Pump No. 2 Running		1
1	DI	Pump No. 3 In Auto		1
1	DI	Pump No. 3 Fault		1
1	DI	Pump No. 3 Running		1
1	DI	Pump No. 4 In Auto		1
1	DI	Pump No. 4 Fault		1
1	DI	Pump No. 4 Running		1
1	DI	Communication		1
1	DI	AC power		1
1	DI	Commercial Power		1
2	DI	Lead Pump Start Float		1
2	DI	Lag Pump Start Float		1
2	DI	Lag2 Pump Start Float		1
2	DI	Pumps Off Float		1
2	DI	Wet Well Level Low-Low		1
2	DI	Generator Running		1
2	DI	Generator Fault		1
2	DI	ATS Trouble		1
2	DI	Generator Battery Trouble		1
2	DI	Generator Fuel Tank Low		1
2	DI	Generator Fuel Tank Leak		1
2	DI	Spare		1
2	DI	Spare		1
2	DI	Spare		1
2	DI	Spare		1
2	DI	Spare		1
1	AI	Wet Well Level	2	32

Card	I/O	Description	Words	Bits
1	AI	Discharge Flow	2	32
1	AI	Combustible Gas Level	2	32
1	AI	Pump No. 1 Amps	2	32
2	AI	Pump No. 2 Amps	2	32
2	AI	Pump No. 3 Amps	2	32
2	AI	Pump No. 4 Amps	2	32
2	AI	Spare	2	32
	SAI	Pump No. 1 Runtime	2	32
	SAI	Pump No. 1 Starts	2	32
	SAI	Pump No. 2 Runtime	2	32
	SAI	Pump No. 2 Starts	2	32
	SAI	Pump No. 3 Runtime	2	32
	SAI	Pump No. 3 Starts	2	32
	SAI	Pump No. 4 Runtime	2	32
	SAI	Pump No. 4 Starts	2	32
	SAI	Discharge Flow Total	2	32
	SAI	Generator Runtime	2	32
	SAI	Generator Starts	2	32
	SAI	3-Phase Average Voltage	2	32
	SAI	3-Phase Average Current	2	32
	SAI	3-Phase Real Power (kW)	2	32
	SAI	3-Phase Apparent Power (kVA)	2	32
	SAI	Spare	2	32
		Total bits for 1 Site:		800
		Convert bits to bytes:		100
		Total bytes for all sites: (*96)		9600
		GB for all sites:		0.0000096
		Continuous Polling (once/sec for 1 month):		24.8832
		Continuous Polling (once/10 sec for 1 month):		2.4883
		Polling Interval to limit data to 2.0 GB/month:		12.44

DI: Digital Input, AI: Analog Input, SAI: Software Analog Input

Additional data requirements include DNP3 protocol overhead (10 bytes/message) and data transactions to back fill the SCADA database on a loss of communications, which will vary depending on the number of sites that lose communications and the length of the outage. The amount of data that is buffered in the local RTU until the communications link has been restored can be adjusted at the polling master (which in our case will be VT SCADA). Some examples of adjustments that can be made are event deviation percentage (i.e. percentage of the span of the analog value that must change before logging an event to the buffer), events based on engineering limits which are similar to alarm limits, rate of change events (i.e. over a period of 10 seconds, the analog value has a rate of increase of 5% or a rate of decrease of 8%, a rate of change event is logged to the buffer; all values are adjustable), and a no change event (i.e. over a period of 10 seconds, the data has not changed by at least 1%, a no change event is logged, indicating the potential of a failed sensor/transmitter). By making these and other adjustments to the polling master, the size of the buffer can be modified to limit the amount of data being communicated while still logging important parameters and not losing changes of state in the data. This is due to the rich feature set of the DNP3 protocol and the reason why the Allen-Bradley ControlLogix with the ProSoft DNP3 Communications Module was selected as the City's new PLC hardware. This type of PLC provides the universal PLC platform that the City requested and uses a protocol with report-by-exception and poll-on-demand that buffers data at the local RTU on loss of communication and backfills that buffered data to the polling master on restoration of the communications link.

Memorandum

To: *Tiffany Rank and Rodney Chervus*

From: *David Ubert*

Date: *June 16th, 2010, updated July 7th, 2010*

Subject: *Lexington Fayette Urban County Government*
Pump Stations Cost Comparison of Radio versus Cellular Technology

Introduction

Lexington Fayette Urban County Government (LFUCG) owns, operates, and maintains approximately 80 pump stations throughout the Lexington and Fayette county area. CDM has been contracted to provide design and upgrade services to the Supervisory Control and Data Acquisition (SCADA) systems at two wastewater treatment facilities and the pump stations. The pump station monitoring system is very old and LFUCG is concerned about the long term maintenance of it.

CDM has performed a cursory review of the system. It is comprised of the following components:

- Two computers running the Human-Machine Interface (HMI) software (cold backup, non-redundant) including:
  - iFix HMI software
  - Win911 alarm dialer software
- Radio Repeater
- Motorola Moscad or Intrac Remote Telemetry Units (RTUs) with radios

As part of the Process and Control Improvements design at Town Branch WWTP, West Hickman WWTP and pump stations, the HMI and controllers at the plants will be upgraded. As part of the upgrade, LFUCG would like to standardize on HMI software and controllers in both plants and the pump stations. As a result, careful consideration should be given as the pump station hardware and software upgrades are initiated. Several options using current technologies will be outlined to assist LFUCG to make a decision based on knowledge of the latest technologies.

Current Communication Concerns

The communication infrastructure is one of the most critical pieces in any SCADA system. It must be reliable, dependable, and robust for the system to operate successfully. The weak links in the pump station system are the radio repeater and obsolete RTUs and radios at each site. Each one of these items will impact the decision making process when choosing a new SCADA technology.

Repeater

The current system is set up using a single repeater to communicate to all radios in the system. This equipment is very old and in need of replacement. It is also a single point of system failure. If the repeater fails the entire pump station SCADA system (i.e. all 80 remote sites) will no longer pass data and alarming information.

RTUs and Radios

The Motorola RTUs installed throughout the SCADA system are used to gather I/O locally at each station and communicate that information back to the HMI for alarming and display. These units are critical to the overall reliability of the system, and have also exceeded their expected lifetime. All RTUs are obsolete and no longer supported by Motorola. The existing Motorola radios have also surpassed their expected lifetime and are in need of replacement.

PLC-Radio Solution

One possible solution would be to replace the current radio SCADA system with new PLCs and radios using the same frequency. The benefits of this include:

- Infrastructure is already in place (antennas, towers, and cables)
- The system communicates now using radio, so a radio study is not needed as long as the existing frequencies and output power are used
- Current staff has a knowledge of the system that is installed
- LFUCG maintains ownership and control of the telemetry system

- Adding a redundant repeater provides a more robust system

Some negative points associated with a radio solution include:

- LFUCG must maintain the telemetry system if it breaks or has problems
- There may be a change in repeater location to a new building. This would require a new radio survey to be done, as well as the coordination of a new location
- Existing radios for the entire pump station system (i.e. 80 pump stations) will need to be turned off while the new radios are being installed. This may require additional staff visits to the stations awaiting new radios.

Cellular Solution

If a cellular solution is selected, the existing infrastructure will need to be removed or abandon in place (antenna poles, antennas, radios, cables, repeater, etc.). The following are considered benefits of a cellular system solution:

- The initial costs are lower than a radio system
- Each RTU is portable and could be used at any location
- The cost of installation is relatively low
- Installation is easy and fast, and could be done in phases because the existing radio system can operate in parallel with the new cellular system
- The communication backbone maintenance is the service provider's responsibility; LFUCG has no cost to maintain that portion of the system
- No programming required for the HMI. This is hosted by the manufacturer
- A repeater is not required for the cellular system

Some negative points associated with a cellular solution would be:

- Each RTU has a monthly service fee
- You don't own the communication backbone, so you depend on a service provider for repair of that part of the system
- The HMI interface customization is limited

Proposed System Details

There are potential associated costs for each solution that should be considered. This is not intended to be a detailed design solution, so these costs should only be used to get an idea of what to expect when selecting a system.

HMI programming costs have NOT been included since it is anticipated that the new Town Branch WWTP SCADA system will be used for the pump station system. If the pump station system is replaced before the new Town Branch SCADA system is in place, costs to provide and configure a separate HMI would need to be added in.

Repeater

The system radio repeater is located in a small steel structured shelter on the top of the police departmentbuilding. The shelter is climate-controlled to support the radio equipment inside. This equipment may be moved, so costs associated with this should be included in the final decision. The new equipment needs to be located in a climate-controlled facility with local backup power. Also, this system should be upgraded to a redundant repeater to eliminate the existing single point of failure. The cost estimate associated with a single (non redundant) repeater for this site is $18,000. For a redundant repeater, the cost estimated is $40,000.

PLC RTU w/Radio

It is anticipated that all the obsolete RTUs will be replaced. A typical RTU replacement that would be considered is the Allen-Bradley MicroLogix 1100. The cost to replace the existing RTU with a Micrologix 1100 PLC is estimated to be $3,900 per unit. The typical costs for maintenance and life cycle are provided in the attached document. The cost for initial equipment and installation is shown in the table below. Installing new radios, antennas, and PLCs will cost significantly more than a typical cellular RTU, which is compared in the table below.

The existing site radios should be replaced because of their age. The current radio use licensed radio frequencies. A similar radio configuration should be used to minimize additional costs. The average cost for a radio is $800. The average cost for a Yagi antenna is $150.

Cellular System

There are two main cellular configurations. The first is a cellular modem with a PLC. The second option is a packaged cellular system such as a cellular dialer or cellular RTU. These work well only if control is not required. If control at the pump stations is desired in the future, then a cellular modem with a PLC would be the preferred arrangement.

Cellular Modem and PLC

It is anticipated that new RTUs will be required for the upgrade of the pump stations. Typically, an RTU consists of a controller, I/O modules, terminals, power supply, back up batteries, an enclosure, and a communication device (e.g. a cellular modem). The estimated cost for a typical cellular RTU (including a cellular modem and MicroLogix PLC) for the Pump stations would be $4,500. See the attached document for typical life cycle cost analysis.

Cellular RTU

The cellular RTU packaged system is a complete system, including the RTU and cellular communication equipment, as well as the manufacturer supplied HMI web portal. All required RTU equipment is included in the initial cost (i.e. batteries, terminals, modem, enclosure, etc.). These units are typically priced at approximately $2,200 each and then have a monthly service fee associated with them. Generally, they are not expandable like the MicroLogic type of RTU, and have very limited control features. These systems post all information to a web portal for viewing, and provide alarming features with options such as alarms sent via text message, email, or voice and web access capabilities. Installation costs are low and the HMI does not require any maintenance since it is supported by the vendor. A product brochure is attached to this memo. There are many manufacturers of this equipment; RACO and OmniSite are typical. If this path is selected, CDM recommends having the manufactures provide more information regarding system capabilities and pricing. , as these products are becoming more competitive every day, and are attempting to make their money in the monthly service fee rather than the equipment costs.

Cost Comparison

The following table provides a rough cost estimate comparison to purchase and install equipment at 80 pump stations:

	PLC RTU w/Radio	**Cellular RTU Package**
Controller/RTU	$3,900 x 80 stations = $312,000	$2,200 x 80 stations = $176,000
Communications (Radio or Cell modem)	$800 x 80 stations = $64,000	Included above
Antenna	$150 x 80 stations = $12,000	Whip antenna included above
Repeater (dual, redundant)	$40,000	N/A
Monthly Fees	N/A	$27 x 80 stations = $2,160 per month or $25,920 annually
Installation labor	$382,000	$118,000
Total Costs	**$810,000**	**$294,000 plus monthly fees**