

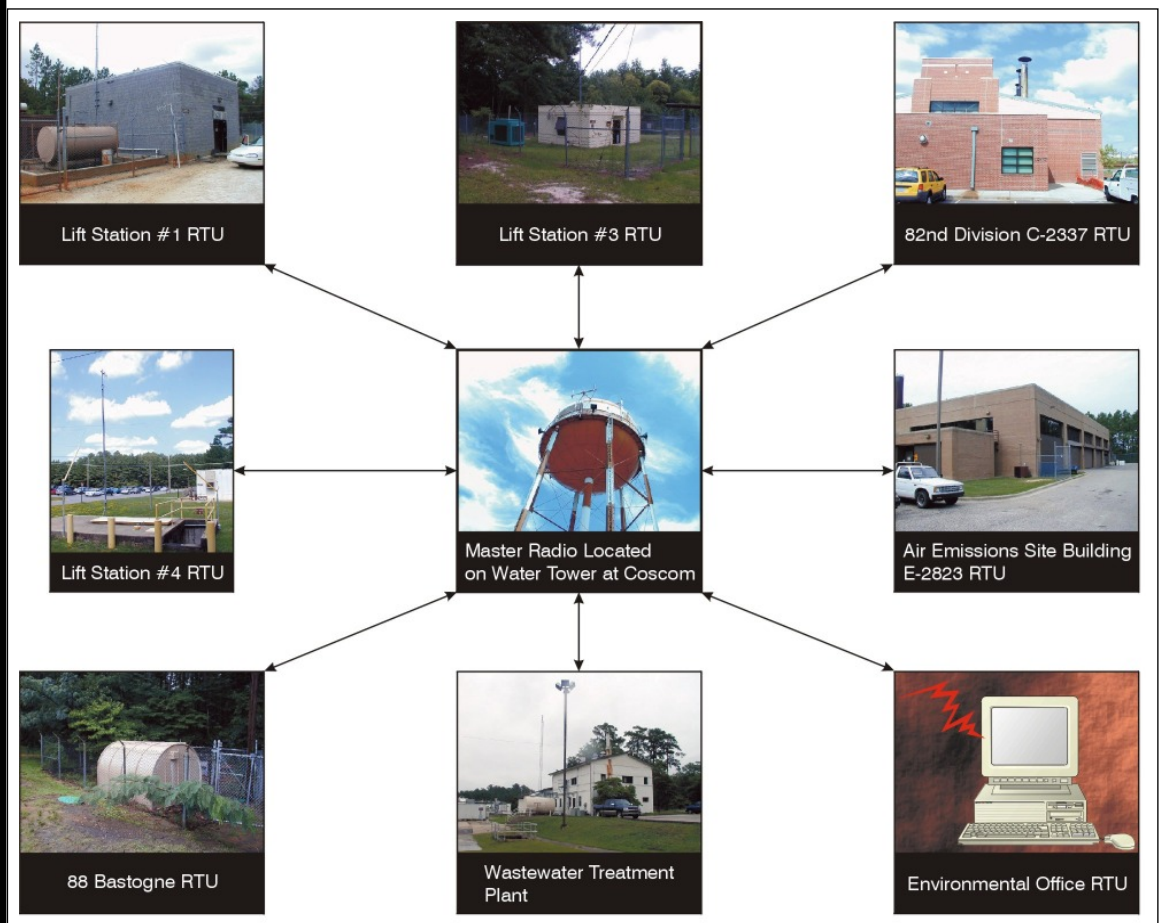


**US Army Corps
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Engineer Research and
Development Center

Installation of a Wastewater SCADA Monitoring System at Fort Bragg, NC

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Final report

Approved for public release; distribution is unlimited

Abstract: Fort Bragg has had several Notices of Violations (NOVs) because of collection system failures, primarily lift station overflows. A current shortage of personnel to operate and maintain the Fort Bragg Wastewater Treatment Plant (WWTP) and the collection system has prompted the decision to install a state-of-the-art Supervisory Control and Data Acquisition (SCADA) system. This report describes the system that was installed at Fort Bragg, the selection of the hardware and software components needed for the system, and the successful startup of that system.

The Wastewater SCADA Monitoring System was installed to monitor 26 remote sites. A detailed radio study of the area verified the feasibility of using radio equipment to transfer of data from these sites to a computer at the WWTP. Of these 26 sites, 9 had existing radio equipment that was upgraded. A master repeater for polling (with programmable logic controller) was set up at Corps Support Command using the existing sites with upgraded equipment. The existing frequency was used for the new SCADA system. The central host would reside at the WWTP. Lookout software was chosen for the human-machine interface at this site and another was set up at the Environmental Sustainment Division and resides on the Fort Bragg server with client software allowing two people viewing access at a time. Entirely new remote terminal unit panels were installed at the remaining 17 sites and these sites were integrated into the system. The new SCADA system now allows an operator to monitor and control lift stations at all remote sites on Fort Bragg.

Because of the remote sensing capability, the SCADA system eliminates the need for a full-time person to visually inspect each site. It is estimated that labor needed to monitor the wastewater collection system will be reduced by 60 percent. Considering only the savings in labor, the return on investment for the installation of this system is 6.6 years. There is also a cost avoidance by eliminating NOVs due to pump station failures. Fort Bragg averages three NOVs per year, at a cost of \$25,000 per NOV. Considering a cost avoidance of \$75,000/yr, the return on investment becomes 2.2 years. Within the first few months of operation, this system has prevented three overflow spills at Fort Bragg, preventing three NOVs.

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Preface

The work was performed for the Environmental Process Branch (CN-E) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Gary L. Gerdes. The work was done by MSE Technology Applications, Inc. (MSE-TA), Butte, MT. Joe Mullaney was Principal Investigator and Project Manager for MSE-TA. This research was funded under 622720960, “Congressional – Environmental Quality Technology,” typically referred to as the Western Environmental Technology Office (WETO) Program (WETO is a branch of the Department of Energy). Michelle Hanson is the WETO Program Manager for CN-E. The technical editor was Linda L. Wheatley, Information Technology Laboratory — Champaign. Dr. Kirankumar V. Topudurti is Chief, CN-E, and Dr. John T. Bandy is Chief, CN. The associated Technical Director was Gary W. Schanche. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, EN, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

The Public Works Business Center (PWBC) at Fort Bragg, NC, operates a domestic wastewater treatment plant (WWTP), including a collection system for domestic and industrial wastewater generated on the post cantonment area. The collection system includes several miles of sanitary sewer and several lift stations. Several years ago, a Supervisory Control and Data Acquisition (SCADA) system was installed to monitor a few of the lift stations. That system became nonfunctional and required major updates.

A shortage of personnel to operate the WWTP and the collection system has prompted the need for a state-of-the-art Supervisory Control and Data Acquisition (SCADA) system. To date, Fort Bragg has had several Notices of Violations (NOVs) because pump failures caused raw sewage to overflow in nearby storm water drainages. As of 2002, PWBC is required to submit an application for permitting their collection system under the North Carolina Administration Code (15A NACA 2H.0227). Once the collection system is permitted, Fort Bragg will have to show documentation that PWBC is either physically inspecting every pump station or has in place an automated data collection and alarming (SCADA) system.

The Fort Bragg PWBC chose to install a SCADA system, which will allow an operator to monitor and control lift stations at various remote sites. Systems such as the one installed by Fort Bragg allow remote sites to communicate with a central control facility and provide the necessary data for documentation. For many of its uses, SCADA provides an economic advantage as both the distance to lift stations and the difficulty in accessing these sites increase. SCADA is the better alternative to an operator visiting the site for inspections. A remote monitoring system also allows operators and compliance managers to correct problems before they become serious. The implementation of a single, flexible SCADA system at Fort Bragg ensures that future lift stations can easily be incorporated into the SCADA design.

Objective

The objective of this project was to install and test a large-scale prototype of a SCADA system that would be both cost-effective and meet North Carolina regulations requiring an automated data collection and alarming system.

Approach

The following steps were taken during the installation and testing of the Fort Bragg SCADA system:

- Field assessments of proposed control sites were conducted. Information and photographs were collected from each site in addition to the exact site location (by Global Positioning System, GPS).
- A data radio survey was conducted. Information on site locations was gathered during the site investigation.
- Specifications for the instrumentation and monitoring equipment required for Fort Bragg to have effective remote monitoring capabilities were determined.
- Radio communication hardware and SCADA software were purchased, installed, and tested.
- A limited cost analysis was performed.

Mode of Technology Transfer

This report will be made accessible through the World Wide Web (WWW) at <http://www.cec.er.army.mil>

2 General Description of System

A SCADA system allows a centralized facility to monitor and control processes that are distributed among diverse remote sites. The SCADA system has three major elements: the field software, the field hardware, and the central master host. The operator exercises control through information that is depicted on a monitor via a human-machine interface (HMI). Input to the system is normally initiated from the operator at the central host computer's keyboard. The central host monitors information from remote sites and displays information for the operator. Depending on the sophistication of the central host, the system may use algorithms embedded in its programming that allow it to make modifications to optimize the distribution system without operator intervention. Figure 1 depicts the basic idea of the communications topology for SCADA for Fort Bragg. (Not all remote sites are shown. Note: RTU = remote terminal unit; Coscom = Corps Support Command.)

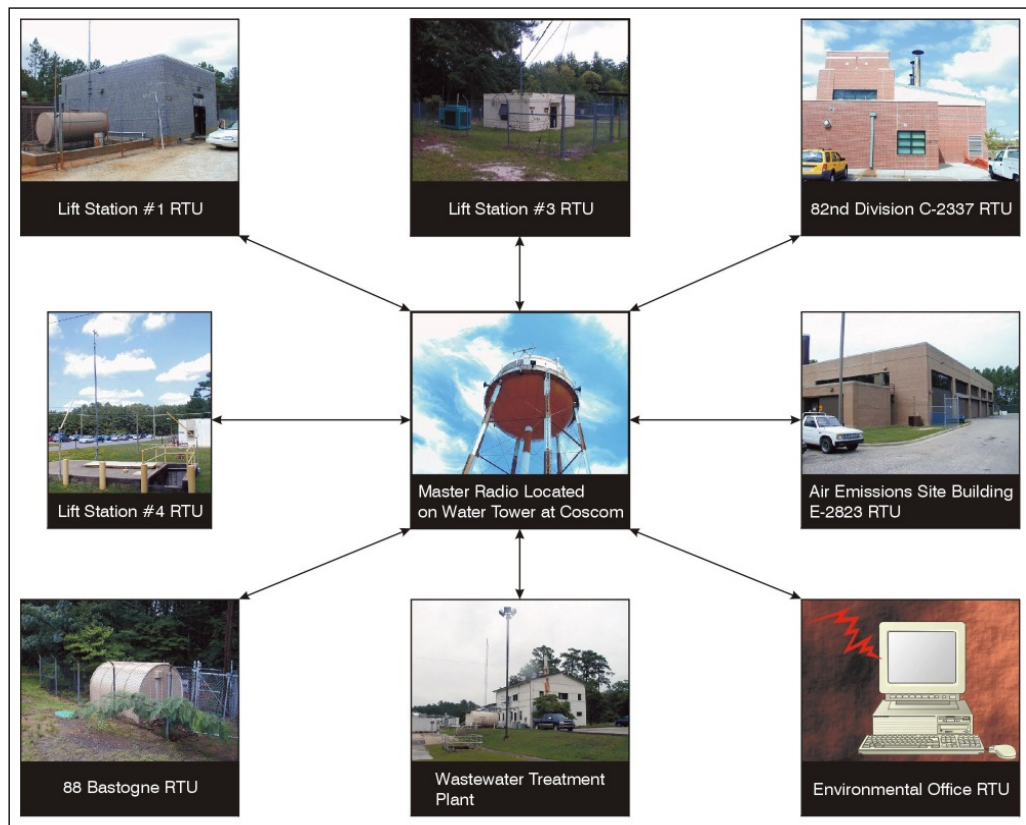


Figure 1. Fort Bragg-SCADA communications topology.

Field Software

As described above, remote field devices communicate with the central host to relay information regarding the state of the systems at the remote site. Because of the nature of the Fort Bragg project and plans to expand it in the future, MSE-TA designed the entire system to use an open architecture wherever possible. With this in mind, the wastewater SCADA system uses the Modbus® protocol (Modbus Org., Hopkinton, MA) for all communications between the remote sites and the central hosts. Modbus® is nonproprietary control protocol that is used by a majority of control vendors. By using this protocol, the entire SCADA system will be able to adapt and expand in the future without regard to a proprietary architecture, but rather with regard to what is best for the system.

Field Hardware

Field hardware used for the master site to communicate with the remote facilities is as follows:

- programmable logic controllers (PLCs)
- radios/communications
- field instruments and equipment.

Each of the listed items will be discussed in more detail in the following subsections.

Programmable Logic Controllers

PLCs are smart industrial electronic devices that can be programmed to control and monitor a process. For the Fort Bragg system, PLCs are used to monitor pump status. They also monitor vital process information. The points monitored at remote sites are:

- pump status (i.e., ON or OFF)
- alarms (i.e., pump failure, high level indication in wet wells, and communications failures).

PLCs can be programmed to provide control as well as an interface to poll data from the remote site. Generally, a master site will poll all the remote PLCs. For the Fort Bragg-SCADA System, Building N-6002 (Corps Support Command, COSCOM) will be the master site (Central Host) and all the other facilities will be remote or slave sites.

Fort Bragg's existing lift stations that had obsolete PLCs were replaced with Modi-

con Momentum PLCs that have Modbus® communications protocol capabilities. These PLCs are connected to the SCADA System via a wireless radio network. Future remote terminal units will feature PLC platforms using industry standard Modbus® communications protocol.

Communications/Radios

There are only three practical ways for a SCADA system to communicate: dial up, continuous cable installations (leased or company-owned), or radio. Radio was the design chosen because of its advantages over the other two options. Since Fort Bragg already had a frequency for the existing Fort Bragg SCADA system, MSE-TA used that frequency to incorporate each additional new site.

Instruments and Equipment

Field instruments and other equipment were selected utilizing the expertise of senior instrumentation and control engineers at MSE-TA. Industry standards, practices, and methods also used in the selection process included:

- Instrument Society of America (ISA)
- American National Standards Institute (ANSI)
- National Electric Code (NEC)
- American Water Works Association (AWWA).

Central Master Host

The central master host is a facility in which most SCADA systems house the main electronic equipment. This equipment is used to display and data warehouse pertinent remote site operating information. The site selected for the central master host is at the Fort Bragg WWTP (as shown in Figure 2). This site serves as the monitoring site for the SCADA system, operating 24 hours per day, 7 days per week. The Environmental Office also has a remote host slave PLC for remote viewing capabilities serving Compliance and Public Works/Sewage Collection maintenance personnel.

Master Repeater

The master repeater at the water tower (COSCOM) polls all remote sites. The repeater, in turn, broadcasts the polled data to the remote terminal unit (RTU) at the WWTP and to an RTU at the Environmental Office. HMI software, loaded on the desktop computers, poll these RTUs via an Ethernet Modicon PLC. This allows the information from the remote sites to be stored on an existing hard drive system.

Human-Machine Interface Software

Graphical HMI software is installed on the central host and remote host computers. This software allows users (operators, managers, and other personnel) easy access to remote data. The software also enables online process information. Appendix A shows HMI Screen examples.



Figure 2. Fort Bragg WWTP and Central Host site.

3 System Design

The following sections discuss each major item necessary to implement the Fort Bragg SCADA system.

FCC Licensing

The communications scheme for this system uses the existing frequency for Fort Bragg radio communications. Communications of this type allow the master radio and slave sites to receive data on one frequency.

There are three major frequency bands commonly used by SCADA systems. Two require licensing by the Federal Communications Commission (FCC). The three groups of radio bands are as follow:

- Very High Frequency (VHF): radios operate at frequencies starting at 150 megahertz (MHz) and require an FCC license to operate
- Ultra High Frequency (UHF): radios operate at frequencies starting at 450 MHz and require an FCC license to operate
- Spread Spectrum bands: radios operate at 920 MHz and 2.4 gigahertz (GHz), are license free and do not require registration with the FCC.

Fort Bragg has an FCC radio license in place for 413.475 MHz in the VHF band to operate data radios. MSE-TA utilized the existing permitted frequency for the SCADA system.

Master Repeater

The master repeater consists of an antenna and associated hardware that link the central host and remote monitoring stations. The community of Fort Bragg currently uses a repeater mounted on a water tower located at COSCOM. The SCADA system now also uses this repeater location (Figure 3). PLC code has been programmed to poll all remote sites and update the hosts with current data and alarms.

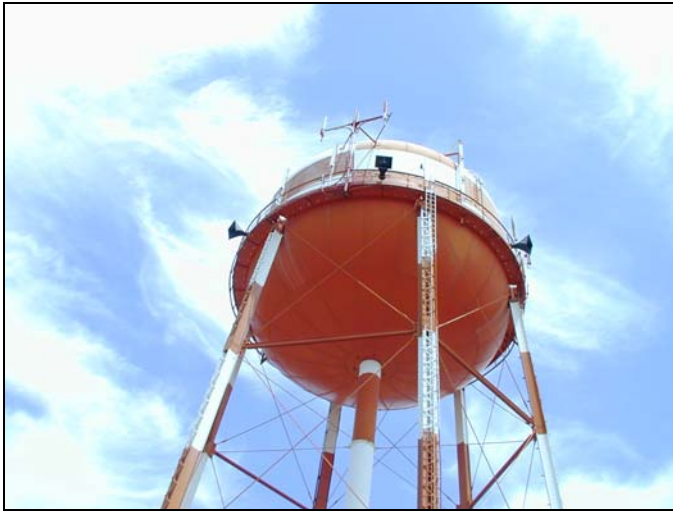


Figure 3. Fort Bragg Master Radio/PLC at the water tower next to COSCOM.

SCADA Central Host (Master Radio)

The WWTP houses the master SCADA operator workstation. Fort Bragg personnel may use the operator workstation to monitor and control the system. Software and hardware for the central host are discussed in greater detail in the following subsections.

Software

The HMI software used for the Fort Bragg SCADA system is National Instrument's *Lookout Enterprise* software running under Microsoft® Windows® 2000 operating system. *Lookout* is a powerful, user-friendly HMI and SCADA software package used for industrial automation. It communicates with field input/output (I/O) modules through PLCs, RTUs, and other devices.

The Enterprise edition of *Lookout* includes licenses for one server site and one client site. The server site is the only site that communicates directly with the field instrumentation. The clients can be configured to run the software locally or remotely through a web browser using ActiveX. ActiveX is a set of technologies that enable software components to interact with one another in a networked environment, regardless of the language in which the components were created. An ActiveX control is a user interface element created using ActiveX technology. ActiveX controls are small, fast, and powerful, and make it easy to integrate and reuse software components. Web browsing enables the SCADA system to be viewed from any PC that has the proper software installed. *Lookout* has extensive security built into the

software to prevent unauthorized access to the SCADA system. Although this capability is possible, no offsite monitoring is allowed because of network security at Fort Bragg.

Object-oriented and event-driven, *Lookout* is a configurable package that requires no programming or scripting. Instead, *Lookout* creates on a computer screen the graphical representations of real-world devices such as switches, dial gauges, chart recorders, pushbuttons, knobs, sliders, and meters. It then links the images to the field instruments using PLCs, RTUs, data acquisition boards, or other I/O devices.

Lookout has many diverse capabilities such as Statistical Process Control (SPC), recipe management, Structured Query Language (SQL), built-in security, flexible data logging, multiple processing on one computer, sophisticated animation, complex alarming, radio and dial-up telemetry support, audit trails of events and set-point adjustments, multimedia support, touch screen compatibility, networking (including multiple client and server processes running on one or many computers), and Dynamic Data Exchange (DDE and NetDDE).

Hardware

Computer hardware runs the HMI/SCADA server and one HMI/SCADA client. That hardware includes:

- Pentium III Class computers running at 800 MHz with a minimum of 8 gigabytes (GB) of disk storage
- the main system display (a 19-inch monitor) for the SCADA server located in the WWTP
- a laser printer.

SCADA Remote Host (Fort Bragg Environmental Sustainment Division)

The remote host at the Fort Bragg Environmental Sustainment Division is similar to the setup found at the central host. Fort Bragg environmental and wastewater maintenance personnel can use the operator workstation to monitor and troubleshoot the system. Environmental and maintenance reports can be generated at this site.

Upgrade to Communication Equipment at Fort Bragg Lift Stations

Lift Stations with Existing SCADA Hardware

Several lift stations had existing hardware that was in need of updating. That hardware was updated in a uniform manner so that all lift stations have the same configuration with the same hardware. This eliminates future troubleshooting problems should they arise. Upgraded sites were:

- Lift Station #1 (Bldg J-1824)
- Lift Station #2 (Bldg G-6849)
- Lift Station #3 (Bldg 5-4039)
- Lift Station #4 (Bldg 1-6421)
- Lift Station #5 (Bldg 4-2444)
- Lift Station #6 (Bldg P-4532)
- Lift Station #7 (Bldg C-9229)
- Lift Station #8 (Bldg E-1532)
- Lift Station #9 (Bldg Y-2920)

Updating these sites involved removing the existing Sixnet I/O Modules and replacing them with the Modicon modules; removing the analog radios and replacing them with the Integra-TR model (Dataradio, Waseca, MN). The existing uninterruptible power supplies (UPS), the 110- and 12-volt power sources, and the power failure relays were kept and re-used. Each panel was wired according to each lift station's reporting requirements.

The concept for each panel and hardware is for them to send the required data to both the master central host and the remote host. Inputs to and from the lift station instruments are wired into the Modicon PLC. The data from the instruments are transferred via the Integra-TR radio. Upon polling for information, the master repeater receives the data at the water tower at COSCOM and transfers those data to the central and remote hosts, where the data are stored and computed. Figures 4 and 5 are two of the sites that were upgraded.



Figure 4. Fort Bragg upgrade—Lift Station #1.



Figure 5. Fort Bragg upgrade—Lift Station #4.

Lift Stations without Existing SCADA Hardware

Other lift stations had no existing radio communications or PLCs. These sites were equipped with the necessary SCADA hardware. Equipment at these sites was installed in a uniform manner so all Fort Bragg lift stations have the same configuration with the same hardware, making it much simpler to troubleshoot problems should they arise. The following sites required new hardware:

- Lift Station #10 (New Womack Hospital)
- Lift Station #11 (88 Bastogne) (Figure 6)
- Lift Station #12 (3-4533)
- Lift Station #13 (P-1551)
- Lift Station #14 (Bldg A-2205)
- Lift Station #15 (Bldg C-3509)
- Lift Station #16 (Bldg D-1457)
- Lift Station #17 (D-1727)
- Lift Station #18 (Bldg G-4858)
- Lift Station #19 (N-7101)
- Lift Station #20 (Bldg P-7937)
- Lift Station #21 (Bldg P-2455)
- Lift Station #22 (Bldg P-1559)
- Lift Station #23 (Bldg P-1551)
- Lift Station #24 (Z-3252) (Figure 7)
- Lift Station #25 (Bldg 1-3571)
- Lift Station #26 (3-2533)
- Environmental Office (Remote Host) RTU #70 (Bldg 3-1333)
- Wastewater Treatment Plant (Central Host) RTU #71

Equipping these sites involved building new control panels with Modicon Modules, Dataradio's Integra-TR model radios, UPS, 110- and 12-volt power sources, and the

power failure relays. Each panel was wired according to each lift station's reporting requirements.

The concept of design and function for each panel and hardware is to send the required data reporting requirements to the master central host and the remote host, the same as for the upgrade to the existing panels at the other lift stations. Figure 6 is one of the sites.



Figure 6. Fort Bragg—new Lift Station #11 (88 Bastogne).



Figure 7. Fort Bragg— Lift Station #24 (Bldg. Z-3252).

All Fort Bragg Lift Station I/O Points

The following input/output (I/O) points are monitored and reported depending on each lift station configuration:

- Dry Well High Alarm
- Wet Well A High Alarm
- Wet Well B High Alarm
- Power Failure
- Generator On
- Pump #1 Alarm
- Pump #2 Alarm
- Grinder #1 Fault
- Grinder #2 Fault
- Seal Failure
- Pump #1 On
- Pump #2 On
- Pump #3 On
- Pump #4 On
- Grinder #1 On
- Grinder #2 On.

Installation at Individual Sites

Hardware and software at 10 major, 16 minor lift stations and two operator workstations were installed during 3 site visits over a 5-month period. Each lift station that had radio equipment was updated to replace obsolete hardware. For those not equipped with this kind of radio hardware setup, a new panel was designed and fabricated at MSE-TA in Butte, MT, and sent to each individual location at Fort Bragg to be installed. This panel generally included the Dataradio® units, the UPS, the power supply, the Modicon Momentum PLCs, and various terminations and wiring. Radio antennas were also installed at each site. These were positioned for optimum transmission to and from the master repeater at COSCOM. Software was installed at the WWTP and at the Environmental Office. Since the WWTP does not have access to the Fort Bragg network, it has its own setup. At the Environmental Office, however, the HMI software was set up on the PWBC server. Both the WWTP and Environmental Office may simultaneously view the status of the lift stations. Copies of Operations and Maintenance Manuals for these sites may be found at the Fort Bragg PWBC Maintenance Shop and WWTP, and at MSE-TA.

4 Communications

Prior to installation of the SCADA system, radio communication hardware was selected and studies were performed to verify that the strength of the radio signal to and from that hardware would be adequate. The following paragraphs describe the results of those studies.

Radio Selection

The radio chosen for the SCADA system is the Dataradio® Integra-TR model. This radio was chosen because it has the following features:

- *User-friendly.* The Integra-TR is a simple radio modem that provides advanced features without complicated system set up. With up to 5 watts output in UHF, VHF, and 900 MHz, the Integra-TR offers the most popular features required for telemetry and SCADA systems.
- *Speed.* The radio has a programmable, transparent modem that transmits data real-time without delays. Designed for speed, the Integra-TR delivers 19,200 bauds per second (bps) over the air in a 25 kilohertz (kHz) channel, and 9,600 bps in a 12.5 kHz channel.
- *No dribble bits.* The Integra-TR prevents transmission of any extraneous data bits to the terminal device. Generating no dribble bits makes the Integra-TR a perfect choice when working with protocols that cannot tolerate any extra data.
- *Online monitoring.* The diagnostic feature of the Integra-TR provides all the information required to monitor and maintain a communications link. Information such as power, temperature, voltage, signal strength, antenna/feedline condition, and data decode performance is transmitted online with no application interruption.
- *Automatic activation.* This radio has a data-activated transmit mode and automatically activates the transmitter in the presence of data, without needing a request to send (RTS) signal from the terminal equipment.
- *Flow control.* Integra-TR also supports CTS flow control for cases where the terminal rate exceeds the network rate.
- *Low power consumption modes.* The Integra-TR offers three ways to reduce power consumption for solar- or battery-powered remote sites: Variable Out-

put Power is programmable from 1 to 5 watts. Sleep Mode typically draws less than 12 milliamperes (mA) until the remote terminal unit turns on the RTS, which wakes the Integra-TR in less than 1/10th of a second, so it will not miss a poll. In Suspend Mode, the Integra-TR wakes periodically to check for channel activity.

- *Easy to use.* The Integra-TR provides light-emitting diodes (LEDs) on the front panel to give the user a visual indication of the radio modem activity. The two ports on the Integra-TR provide easy access to set up and test without having to unplug the application terminal device.
- *Rugged design.* The Integra-TR is optimized specifically for data transmission and is built to withstand virtually any remote environment.

Repeater Propagation Study

A computer-generated communication study was performed by MSE-TA to predict the accuracy and reliability of the proposed radio communication backbone of the SCADA system. The study generated a map showing predicted signal strength around the master radio repeater. The water tower next to COSCOM (Bldg. N-6002) was selected as the site for the master radio repeater. This propagation study confirmed the reliability of radio communications surrounding the repeater site.

The following assumptions were made in performing the propagation study:

- The antenna will be 90 feet (ft) above ground. The water tower is adequate for the Fort Bragg SCADA repeater.
- Fort Bragg is licensed for VHF for their existing wastewater facilities; that frequency is 413.475 MHz. The output power on the license is 10 watts and the effective radiated power (ERP) is 5 watts.
- Decibel (dB) loss for cable: Cable will be 7/8-inch heliax (LDF5-50A) with a loss of 0.5 dB per 100 ft of cable. This equates to $(260 + 50)\text{ft} \times (0.5 \text{ dB}/100 \text{ ft}) = 1.55 \text{ dB}$ loss due to cable run.
- Use of four connections totaling 0.5 dB loss due to connectors.
- A duplexer 1 dB loss; total decibel loss at repeater equates to approximately 3.05 dB loss.
- Use of a 5 dB gain antenna at top of tower. This will give an overall dB gain of about 2.0 dB system gain.
- Output of the transmitter will be 5 watts.
- Receiver lowest threshold level: -1.04 dBm = +1.4 micro volt. A 20 dB fade margin should also be designed.

Propagation Study Results

The results of the communications propagation study on the master repeater site can be viewed in Figure 8.

A propagation study is essentially the same as that of a point-to-point study, except it has the capability of superimposing receiver input signal strength over a geographic map in 360 degrees. The different colors on the map in Figure 8 represent the signal strength received in that area from the master transmitter. The levels are stated in the map's legend. The lowest signal strength at which a location can expect to receive a reliable signal from the master is depicted by red. If an area is deficient of adequate signal strength to meet the stated reliable receiver specification, it is considered to be below the threshold and is shown in light blue. Generally, the signal strength increases as the receiver is closer to the transmitter. This is especially true over flat areas, such as bodies of water, where threshold color bands are almost symmetrical. Conversely, in rough terrain, they are very complex. Valleys are usually very pronounced on a propagation map. They will frequently show signal dropouts (light blue) or lower signal levels. (This is the same way a cellular telephone may drop out in the valleys and work best on the hilltops.) The county boundary lines are plotted in black.

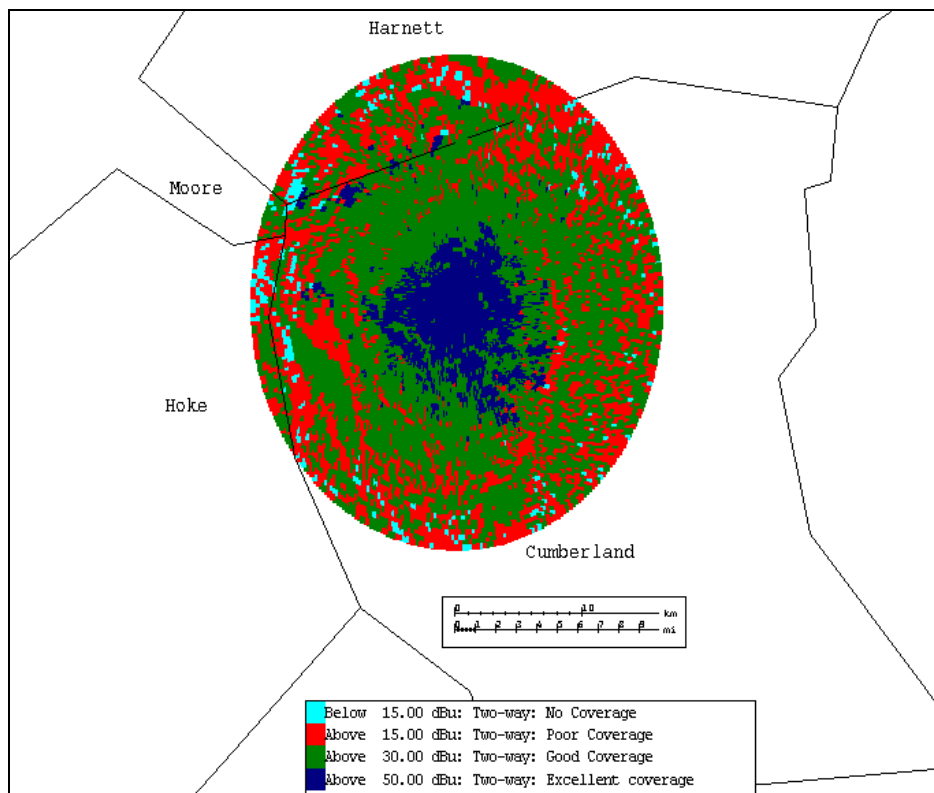


Figure 8. Communications propagation study results.

In general, the study indicates that radio communication surrounding the master repeater extends to all of the Fort Bragg remote sites. The point-to-point studies provide much greater detail of accuracy between individual sites and the master at COSCOM.

Point-to-Point Radio Study

Twenty-six point-to-point path studies were conducted to verify adequate communications between each of the lift station sites and the master repeater. The SCADA system would not be successful unless each of the sites can relay data to the master site through the repeater. Point-to-point studies are also generated using a computer model, though signal strengths are manually verified using radio equipment at sites where the signal may be questionable. Remote site assumptions used were:

- use of VHF radios with 5 watts power output
- antenna height of 25 ft
- additional cable needed is about 25 ft
- cable type is Belden 9913
- use of a Yagi antenna of approximately 9-12 dB gain.

Four factors basically determine whether a signal may be transmitted and received over any given distance:

- path obstructions, including manmade and foliage
- distance
- ERP of transmitter
- signal strength at input of receiver and specifications of the receiver.

There were no known manmade obstructions blocking transmission between any two particular sites when the studies were conducted. The study also does not account for foliage (trees, bushes, etc). Appendix B includes the individual point-to-point studies. Summarized findings of the point-to-point study are as follows:

Lift Station #1 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #2 No communication problems.

Lift Station #3 No communication problems.

Lift Station #4 No communication problems.

Lift Station #5 No communication problems.

Lift Station #6 No communication problems.

Lift Station #7 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #8 No communication problems.

Lift Station #9 No communication problems.

Lift Station #10 No communication problems.

Lift Station #11 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #12 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #13 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #14 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #15 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

Lift Station #16 No communication problems.

Lift Station #17 No communication problems.

Lift Station #18 No communication problems.

Lift Station #19 No communication problems.

Lift Station #20 No communication problems.

Lift Station #21 No communication problems.

Lift Station #22 No communication problems.

Lift Station #23 No communication problems.

Lift Station #24 No communication problems.

Lift Station #25 No communication problems.

Lift Station #26 No communication problems.

Lift Station #70 No communication problems.

Lift Station #71 Not quite within line-of-sight, though adequate signal strength was verified using a portable radio/RTU setup. Antenna height can be raised if problems with weak signal occur.

5 Cost Comparison

A simple cost analysis was completed to compare two alternatives that would meet the State-imposed monitoring requirements for the Fort Bragg Wastewater Treatment Plant collection system. The alternatives were: increasing manual inspections of the lift stations; and implementation of the proposed SCADA system. Installation and startup cost for the proposed SCADA system is estimated at approximately \$246,000. This expense includes: installation and testing of computer hardware and software and installation and testing of communications equipment (see Table 1). The expected operational life of the SCADA system is at least 20 years.

There will be some minor costs for electricity, replacement parts, and software upgrades, but these are considered to be negligible on a per year basis. The primary cost of operation and maintenance of the SCADA system is labor. It will require one person to check each of the sites twice a week and do calibrations. This labor expense has been estimated to be nearly \$25,000 per year (40% of one man-year) and includes direct pay and benefits. Without the SCADA system, monitoring at Fort Bragg would require one full-time employee to check each of the sites for potential problems daily, at an estimated loaded labor cost of over \$62,000 per year. Therefore, the proposed SCADA system is assumed to reduce the labor required by 60 percent, resulting in an annual cost savings of approximately \$37,000. Based on this projected annual cost savings, this project is expected to have a payback period of 6.6 years (see Table 1).

Improved monitoring of the wastewater collection system will also lead to cost avoidance due to improved environmental compliance. For each NOV received for a lift station overflow, Fort Bragg is levied a fine that must be paid into an account set up to remedy the problem associated with the spill. Fort Bragg averages approximately three spills per year with fines of \$25,000 per incident, for a total cost of \$75,000 per year. In this cost analysis, these penalties for spills were considered as a cost avoidance. Assuming the SCADA system will prevent three spills per year, the payback period for installing the SCADA system is reduced from 6.6 to 2.2 years (see Table 1). Figure 9 shows how the project payback period will change, depending on the number of spills occurring during a year.

Installation and upgrading of the wastewater SCADA system is financially viable due to the cost savings associated with labor reduction and prevention of fines for environmental violations. A similar SCADA system has been proven at Fort Bragg's Simmons Army Airfield where two wastewater spills were prevented, resulting in a potential cost avoidance of \$50,000. In addition to being economically feasible, this SCADA system will increase the process efficiency, result in better control of the pumps, and alert operators to potential problems.

Table 1. Summary of cost analysis for the wastewater SCADA system.

Capital/Startup	\$246,155
Annual Cost	\$24,960
Based on Reduced Labor:	
Annual Cost Savings	\$37,000
Payback Period, years	6.6
Based on Reduced Labor & Spill Elimination:	
Number of NOVs Per Year	3
Annual Cost Savings and Cost Avoidance	\$112,400
Payback Period, years	2.2

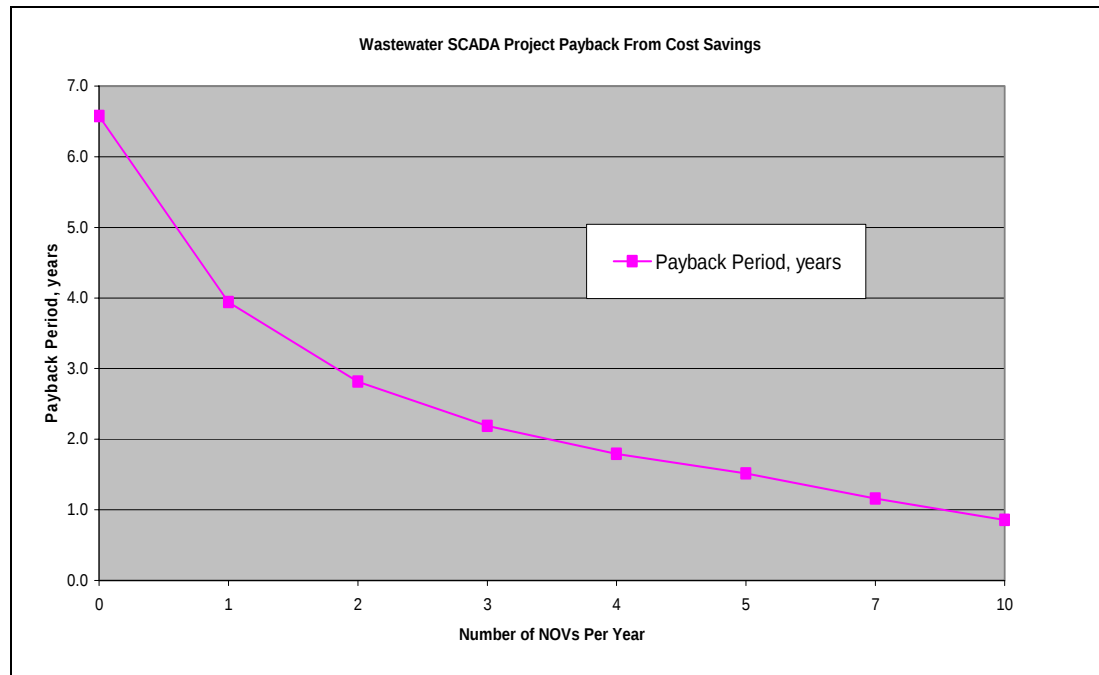


Figure 9. Project payback period based on cost savings from NOV prevention.

6 Summary and Conclusions

A SCADA wastewater monitoring system was installed at Fort Bragg, NC, to monitor 26 lift stations. Of these 26 sites, 9 had existing radio equipment that was upgraded and 17 sites received new equipment. A master repeater for polling the remote sites was set up at COSCOM, and hardware for the central host was set up at the WWTP. Lookout Enterprise software was chosen for the central host site. Another workstation was set up at the Environmental Office allowing that office independent access to SCADA information. MSE-TA conducted a detailed radio study of the area to verify the effectiveness of the radio equipment selected for the transfer of data from the 26 remote sites. It was found that the strength of the radio transmission was very high, indicating good equipment choices.

The SCADA system eliminates the need for a full-time person to visually inspect each lift station. It is estimated that labor needed to monitor the wastewater collection system will be reduced by 60 percent. Considering only the savings in labor, the return on investment for the installation of this system is 6.6 years. Costs will also be avoided by eliminating NOVs due to pump station failures. Fort Bragg averages three NOVs annually, at a cost of \$25,000 per NOV. Considering a cost avoidance of \$75,000/ year, the return on investment becomes 2.2 years.

Within the first few months of operation, this system has prevented three overflows, thus avoiding three potential NOVs. Clearly the SCADA system was an immediate success at Fort Bragg. Other Army installations that do not have SCADA systems may also benefit by installing them.

Appendix A: HMI Screens

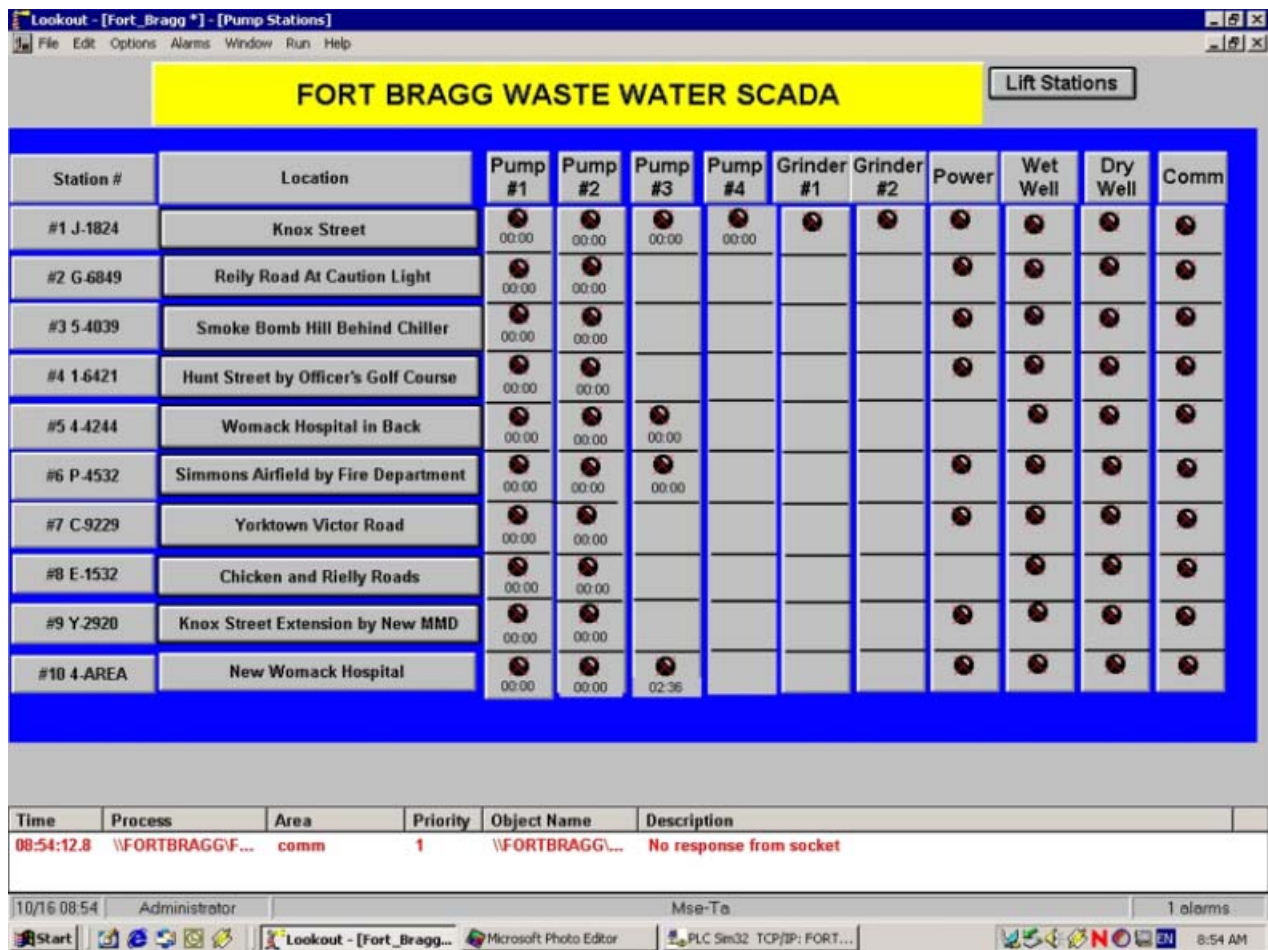


Figure A1. Lookout HMI screen for Fort Bragg major lift stations.

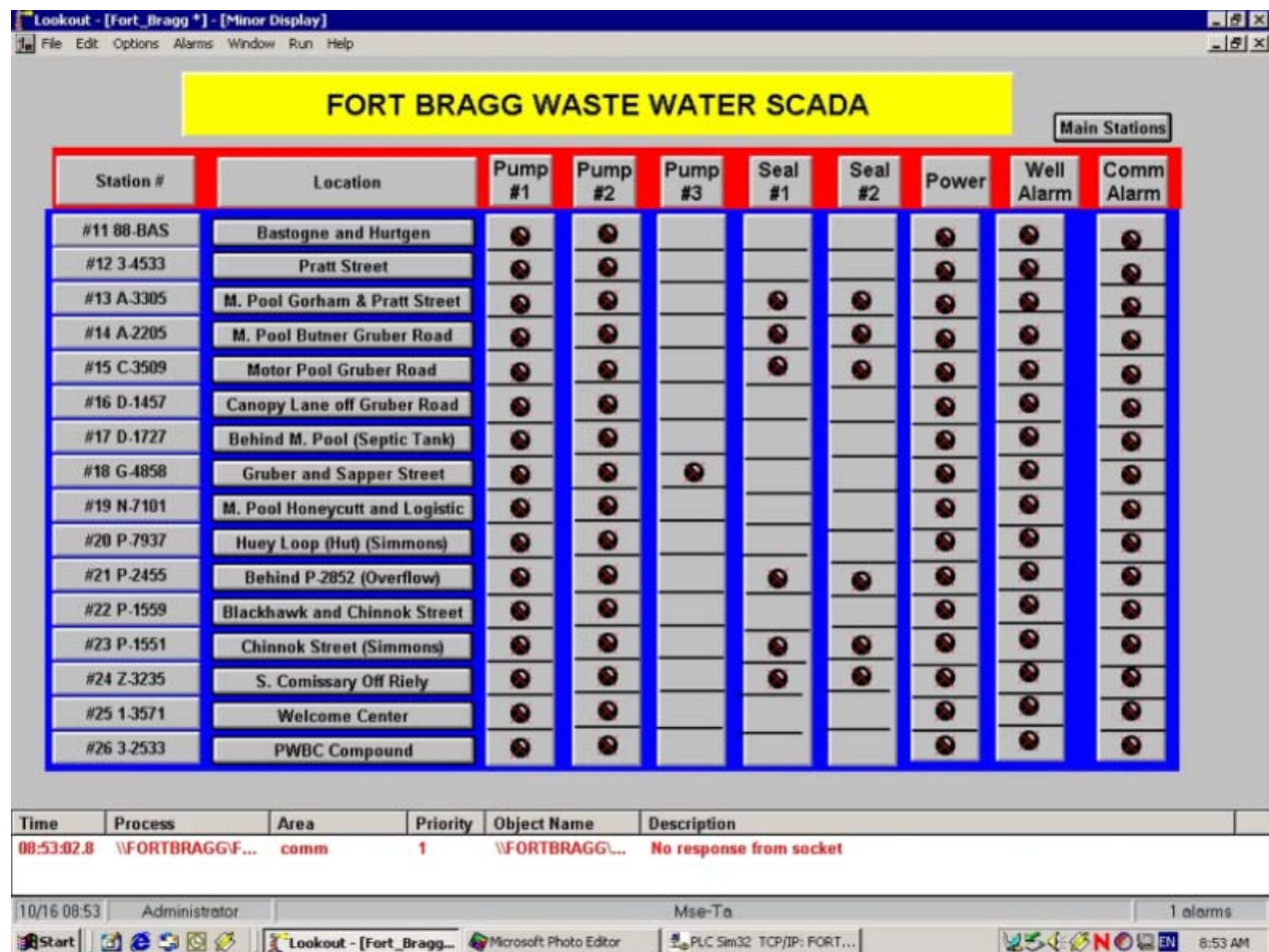


Figure A2. Lookout HMI screen for Fort Bragg minor lift stations.

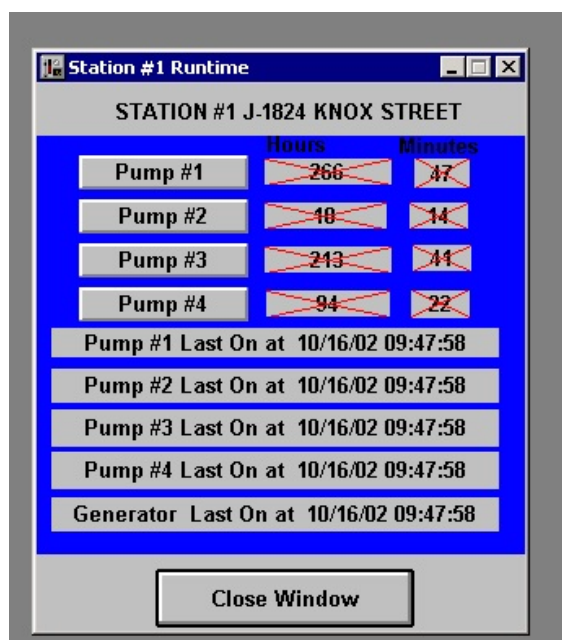


Figure A3. Lookout HMI screen for pump run times at major Lift Station #1.

Appendix B: Point-to-Point Radio Communications Studies

The figures in this appendix show the results of the point-to-point study for each of the 26 lift station sites. The information presented in these figures is as follows. The vertical right and left side axes are elevation above mean sea level (AMSL). The bottom horizontal is the distance in miles between the two sites. The lower irregular line (dark yellow) is the plot of the ground terrain level AMSL. The top, straight red line is the line-of-sight between the two points (site 1 to site 2). Site elevation is determined from the height of the center of radiation of each antenna AMSL, from one to the other. The slightly curved green line below the straight red line is called the “lower half Fresnel zone” or 0.5 Fresnel. The top half of the Fresnel zone, which is not shown, is a symmetrical or mirror image of the bottom zone. The line-of-sight forms the common axis for the mirror image. The zone between these two lines is the envelope in which two points can theoretically communicate reliably.

Master Repeater to Lift Station #1 (Bldg. J-1824)

Although these two facilities are not quite within line-of-sight, at 1.49 miles apart, they appear to be within the upper Fresnel zone of the recommended frequency 413.475 MHz. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If problems exist, antenna height at the remote location can be elevated to eliminate communication problems.

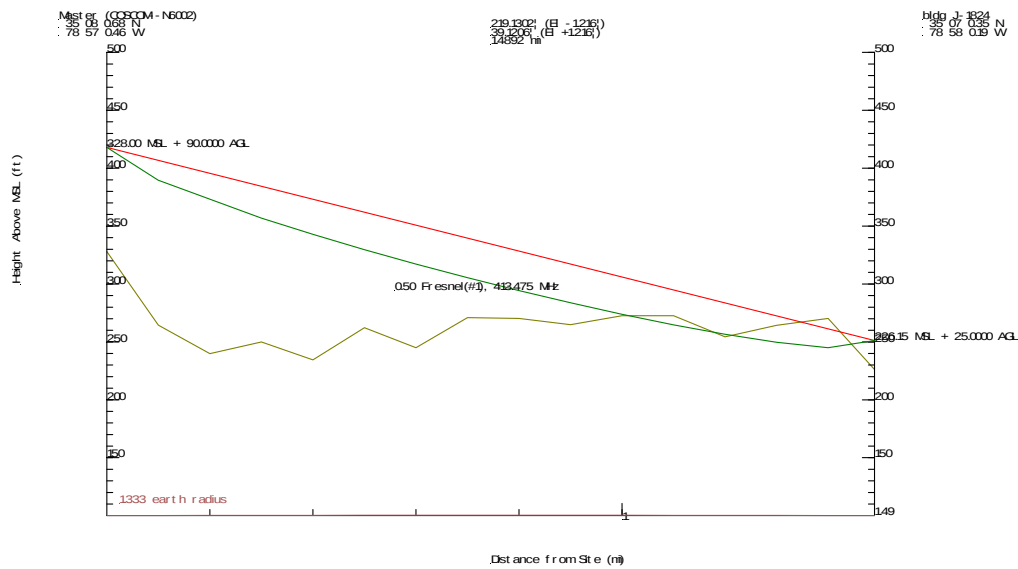


Figure B1. Point-to-point radio communications study for Master Repeater to Lift Station #1.

Master Repeater to Lift Station #2 (Bldg. G-6849)

These two facilities are within line-of-sight of each other at 2.22 miles apart, and there appear to be no communications problems between the two sites.

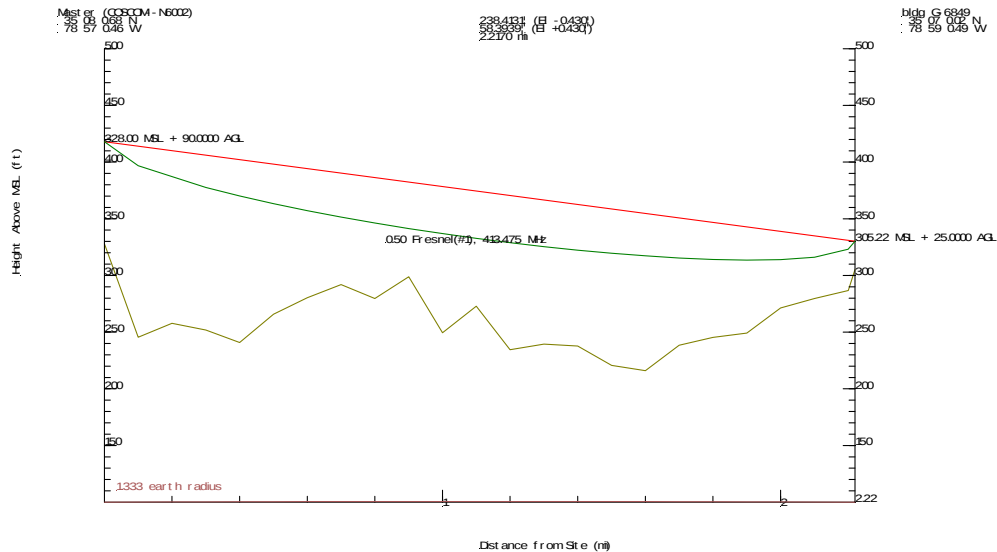


Figure B2. Point-to-point radio communications study for Master Repeater to Lift Station #2.

Master Repeater to Lift Station #3 (Bldg. 5-4039)

These two facilities are within line-of-sight of each other at 2.21 miles apart, and there appear to be no communications problems between the two sites.

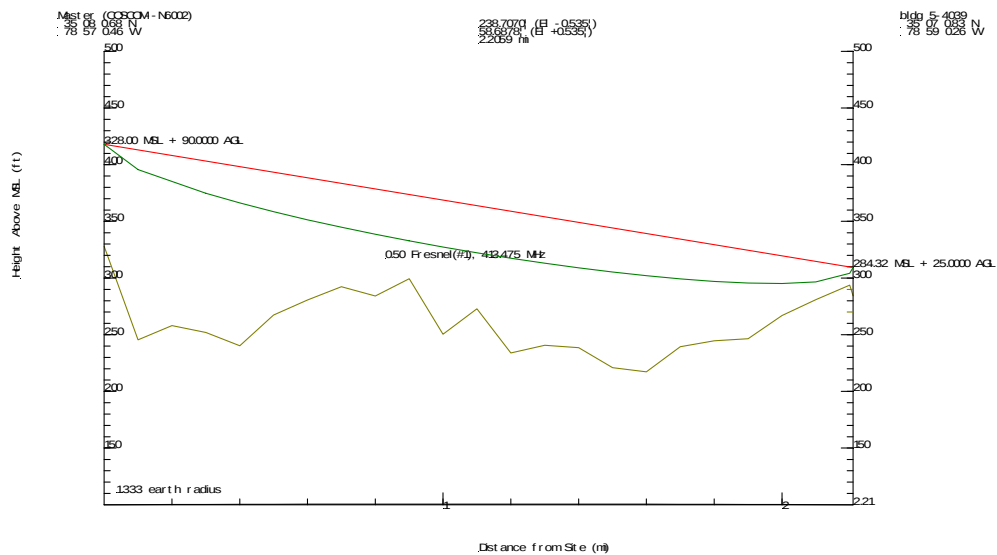


Figure B3. Point-to-point radio communications study for Master Repeater to Lift Station #3.

Master Repeater to Lift Station #4 (Bldg. 6421)

These two facilities are within line-of-sight of each other at 1.89 miles apart, and there appear to be no communications problems between the two sites.

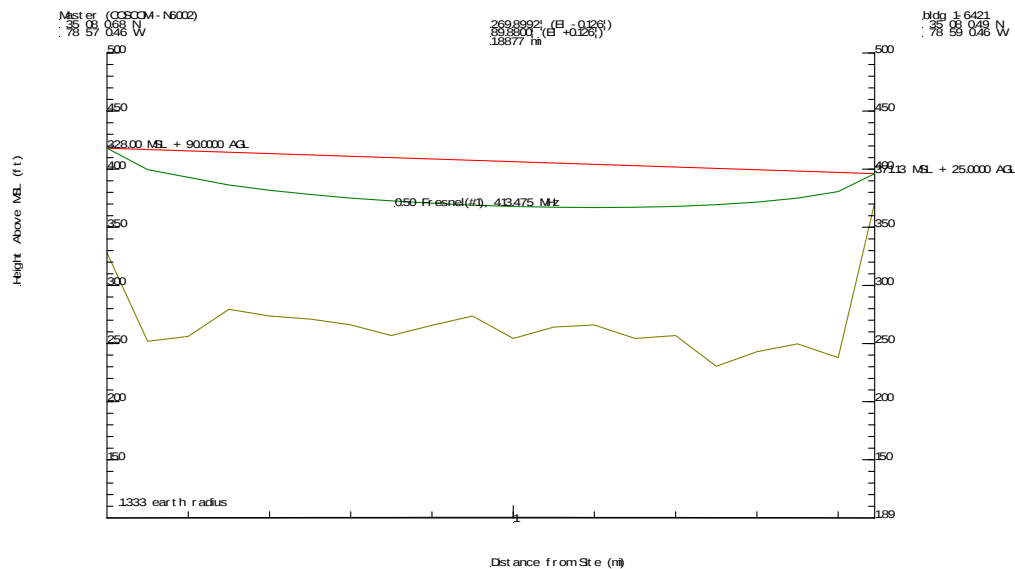


Figure B4. Point-to-point radio communications study for Master Repeater to Lift Station #4.

Master Repeater to Lift Station #5 (Bldg. 4-2444)

Within line-of-sight, 1.9 miles apart, and there appear to be no communications problems between the two sites.

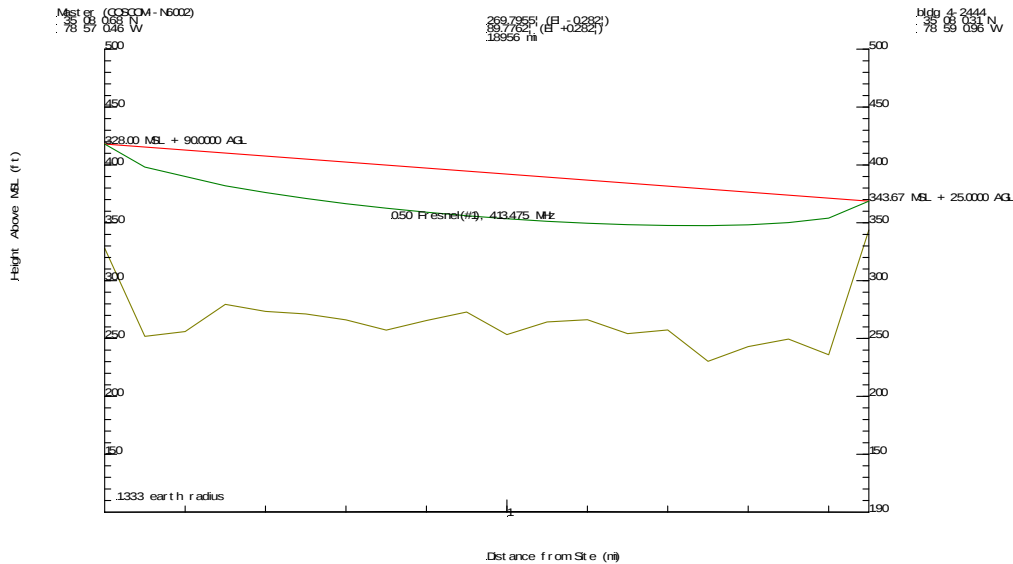


Figure B5. Point-to-point radio communications study for Master Repeater to Lift Station #5.

Master Repeater to Lift Station #6 (Bldg. P-4532)

These two facilities are within line-of-sight of each other at 0.94 miles apart, and there appear to be no communications problems between the two sites.

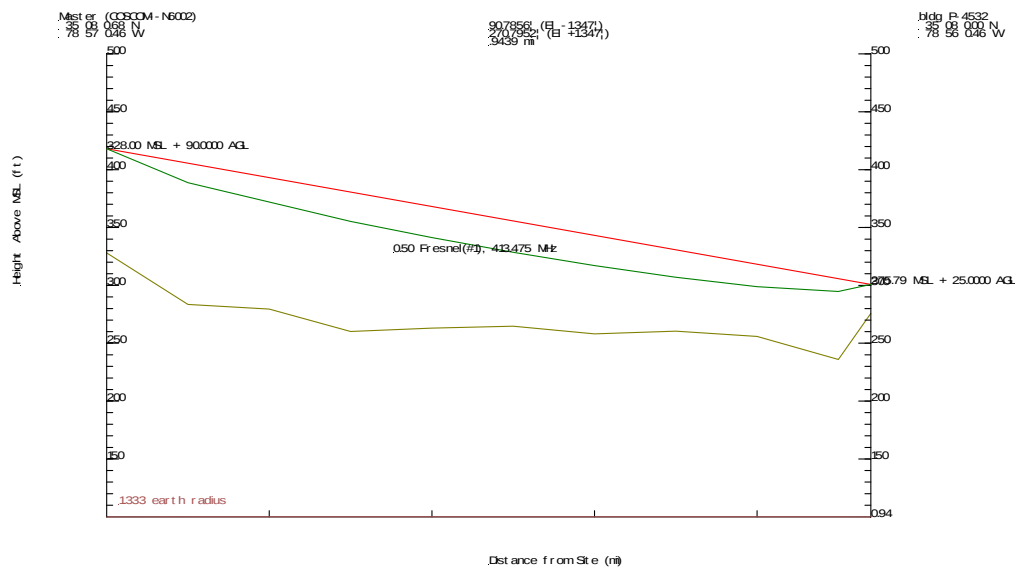


Figure B6. Point-to-point radio communications study for Master Repeater to Lift Station #6.

Master Repeater to Lift Station #7 (Bldg. 9229)

These two facilities are not quite within line-of-sight at 3.95 miles apart. Although they are not within line-of-sight, they appear to be within the upper Fresnel zone of the recommended frequency 413.475 MHz. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location can be elevated to eliminate the problems.

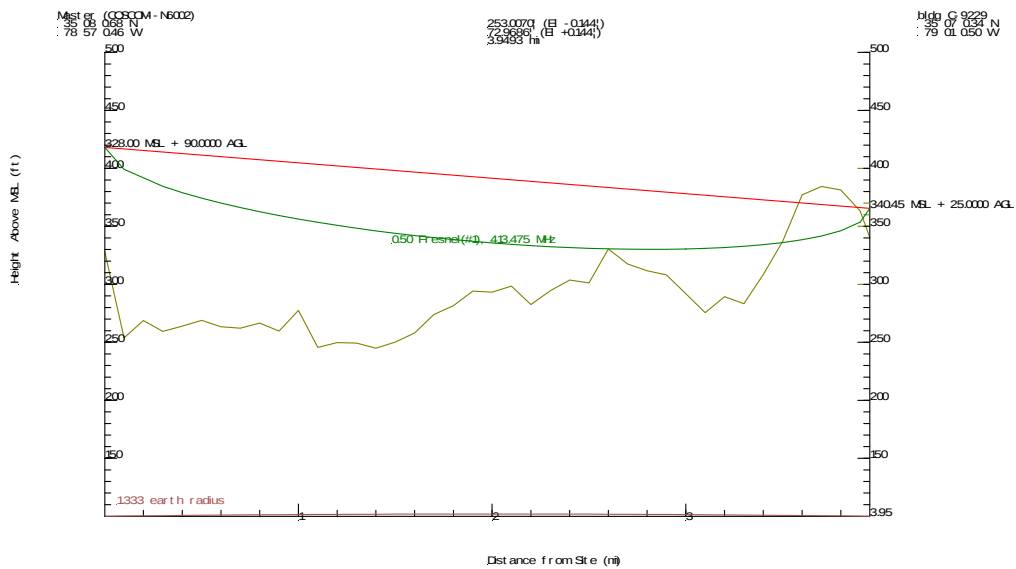


Figure B7. Point-to-point radio communications study for Master Repeater to Lift Station #7.

Master Repeater to Lift Station #8 (Bldg. E-1532)

These two facilities are within line-of-sight of each other at 3.65 miles apart, and there appear to be no communications problems between the two sites.

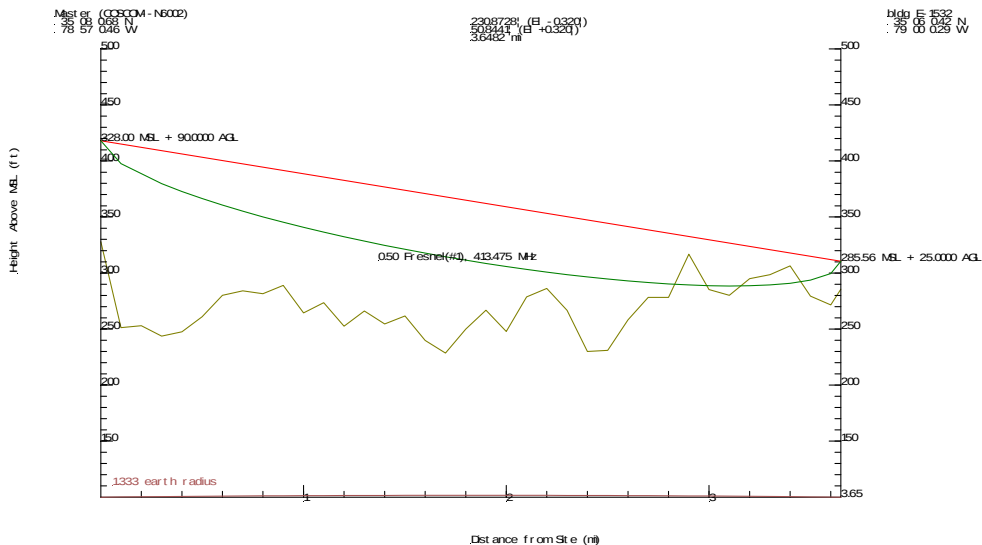


Figure B8. Point-to-point radio communications study for Master Repeater to Lift Station #8.

Master Repeater to Lift Station #9 (Bldg. Y-2920)

These two facilities are within line-of-sight of each other at 1.16 miles apart, and there appear to be no communications problems between the two.

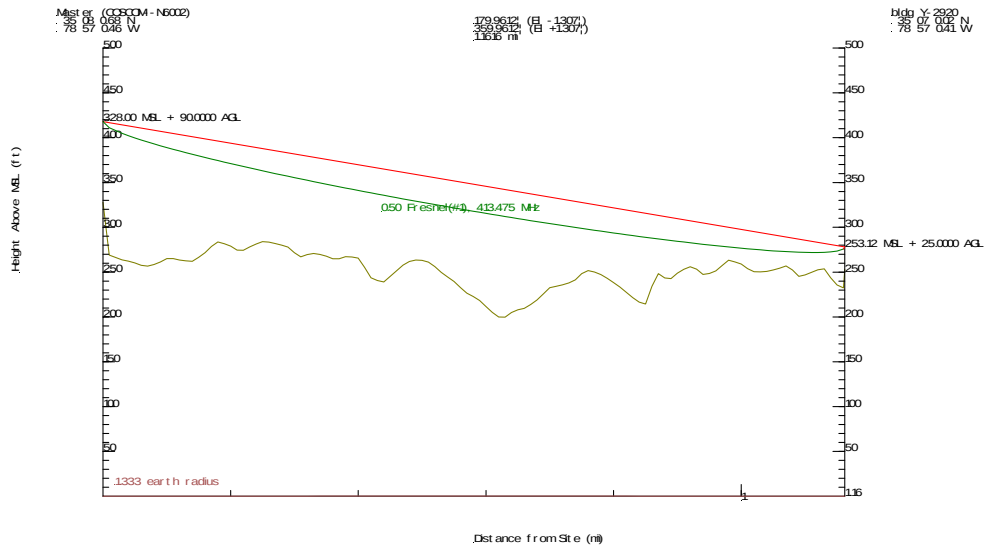


Figure B9. Point-to-point radio communications study for Master Repeater to Lift Station #9.

Master Repeater to Lift Station #10 (Bldg. 4-Area—New Womack Hospital)

These two facilities are within line-of-sight of each other at 2.83 miles apart, and there appear to be no communications problems between the two.

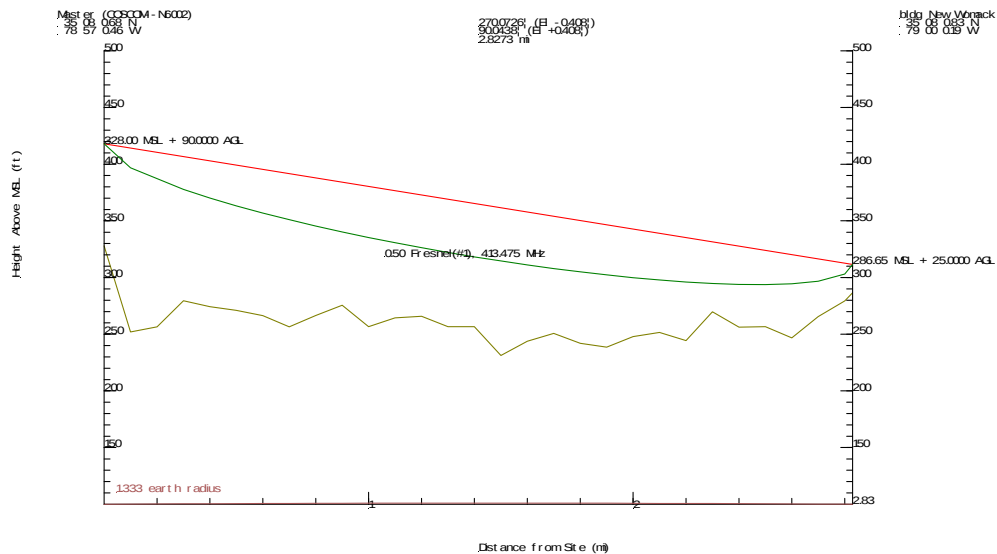


Figure B10. Point-to-point radio communications study for Master Repeater to Lift Station #10.

Master Repeater to Lift Station #11 (Bldg. 88 Bastogne)

These two facilities are not quite within line-of-sight at 3.95 miles apart. Although they are not within line-of-sight, they appear to be within the upper Fresnel ~~zone~~ zone of the recommended frequency 413.475 MHz. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location can be elevated to eliminate the problems.

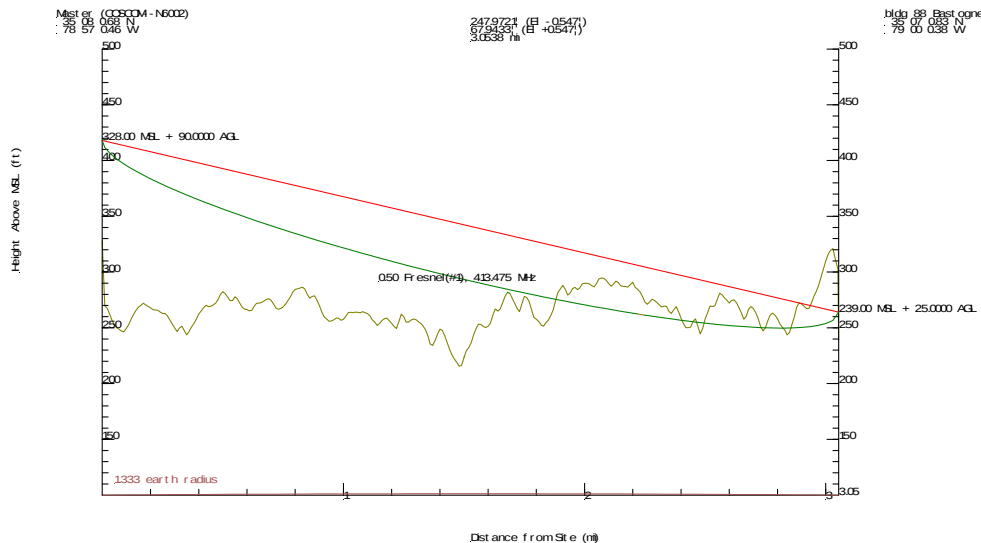


Figure B11. Point-to-point radio communications study for Master Repeater to Lift Station #11.

Master Repeater to Lift Station #12 (Bldg. 3-4533)

These two facilities are not quite within line-of-sight at 3.06 miles apart. Although they are not within line-of-sight, they appear to be within the upper Fresnel zone of the recommended frequency 413.475 MHz. Upon detail design of SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location can be elevated to eliminate the problems.

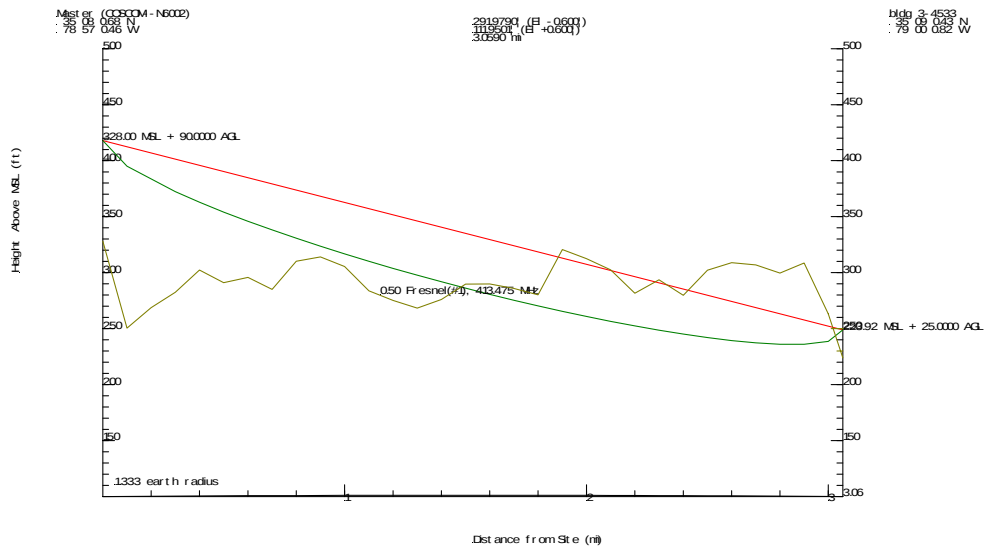


Figure B12. Point-to-point radio communications study for Master Repeater to Lift Station #12.

Master Repeater to Lift Station #13 (Bldg. A-3305)

These two facilities are not quite within line-of-sight at 4.72 miles apart. This remote site will probably need a tower taller than 25 ft. The upper Fresnel zone near site location is lower than elevation of local terrain. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location will be elevated to eliminate the problems.

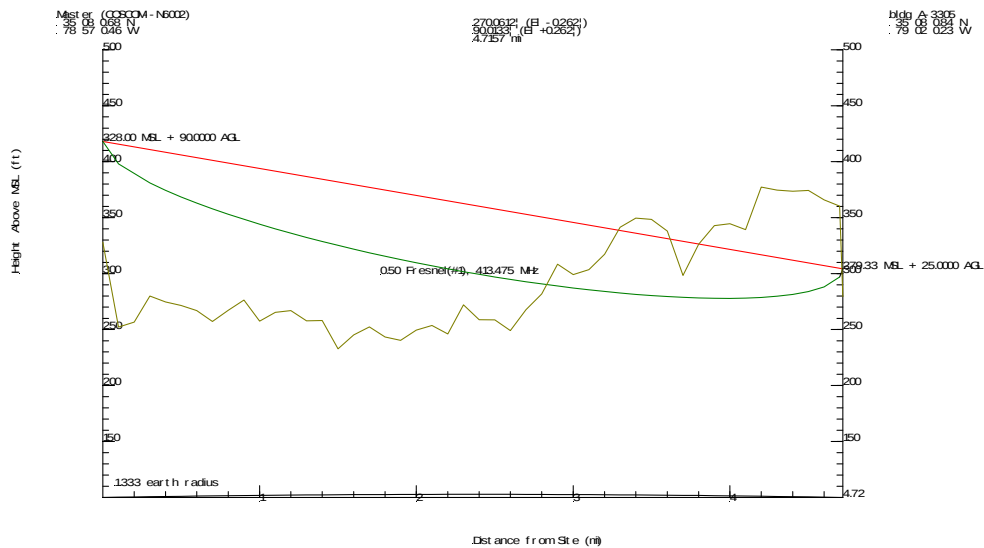


Figure B13. Point-to-point radio communications study for Master Repeater to Lift Station #13.

Master Repeater to Lift Station #14 (Bldg. A-2205)

These two facilities are not quite within line-of-sight at 4.72 miles apart. This remote site will probably need a tower taller than 25 ft. The upper Fresnel zone near site location is lower than elevation of local terrain. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location will be elevated to eliminate the problems.

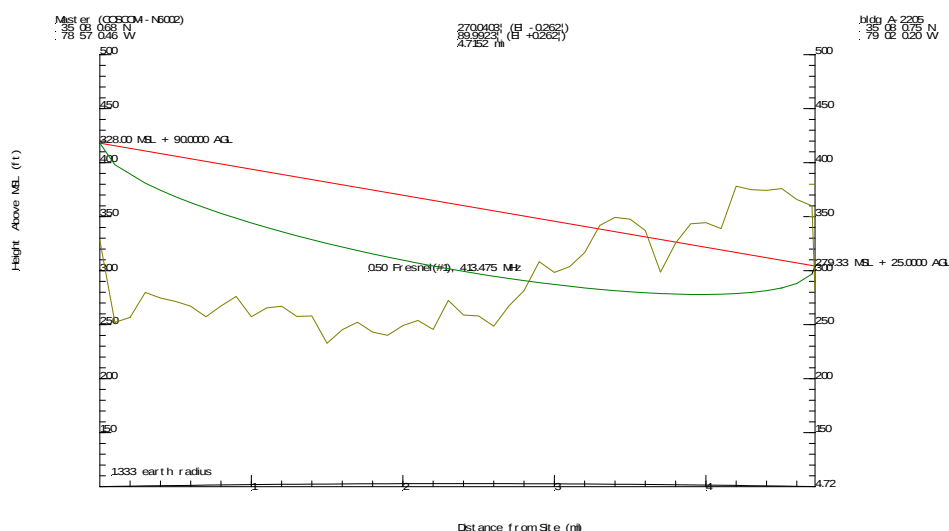


Figure B14. Point-to-point radio communications study for Master Repeater to Lift Station #14.

Master Repeater to Lift Station #15 (Bldg. C-3509)

These two facilities are not quite within line-of-sight at 4.71 miles apart. Although they are not within line-of-sight, they appear to be within the upper Fresnel zone of the recommended frequency 413.475 MHz. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location can be elevated to eliminate the problems.

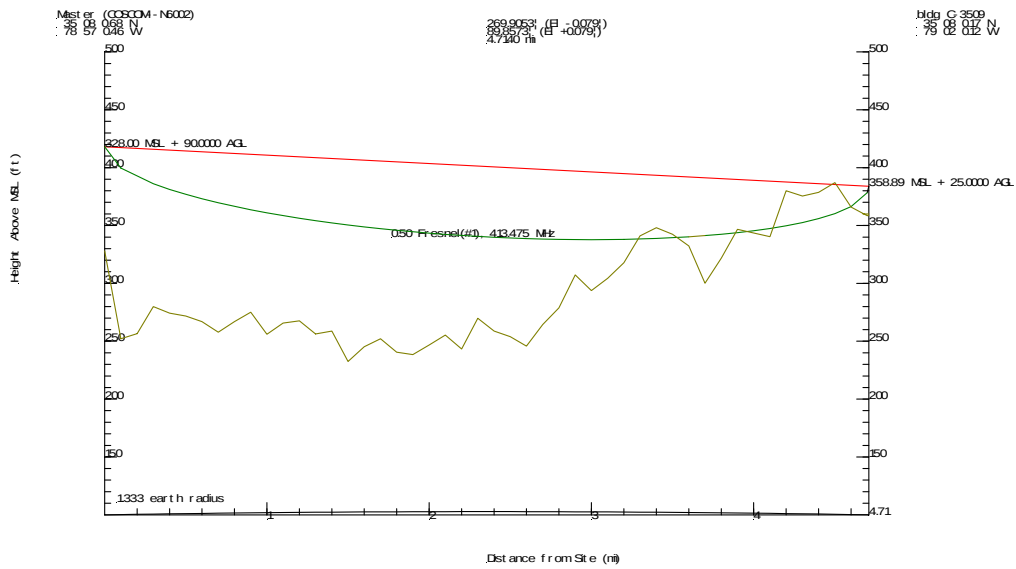


Figure B15. Point-to-point radio communications study for Master Repeater to Lift Station #15.

Master Repeater to Lift Station #16 (Bldg. D-1457)

Line-of-sight, 3.06 miles apart, and there appear to be no communications problems between the two sites.

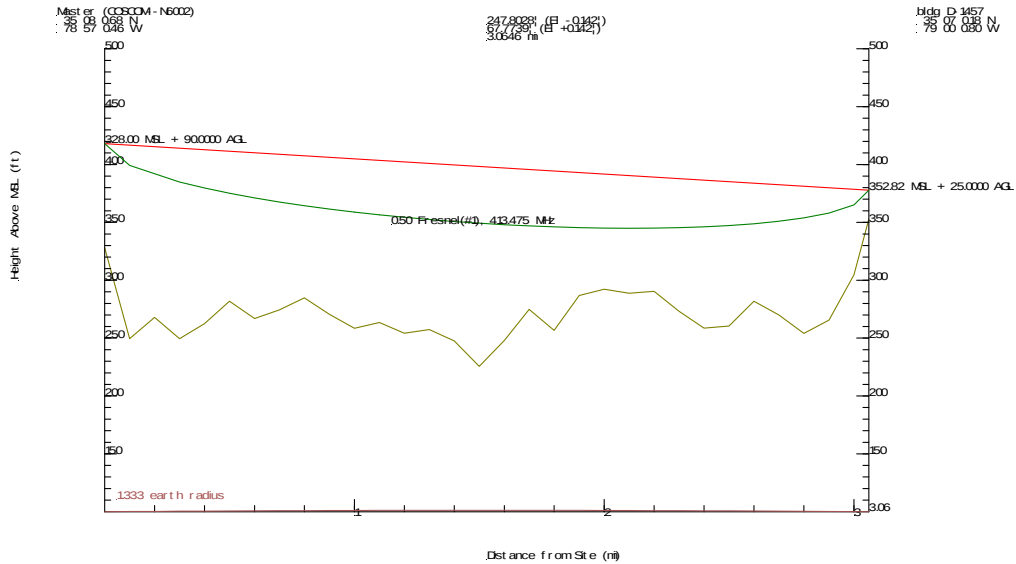


Figure B16. Point-to-point radio communications study for Master Repeater to Lift Station #16.

Master Repeater to Lift Station #17 (Bldg. D-1727)

These two facilities are within line-of-sight of each other at 3.06 miles apart, and there appear to be no communications problems between the two sites.

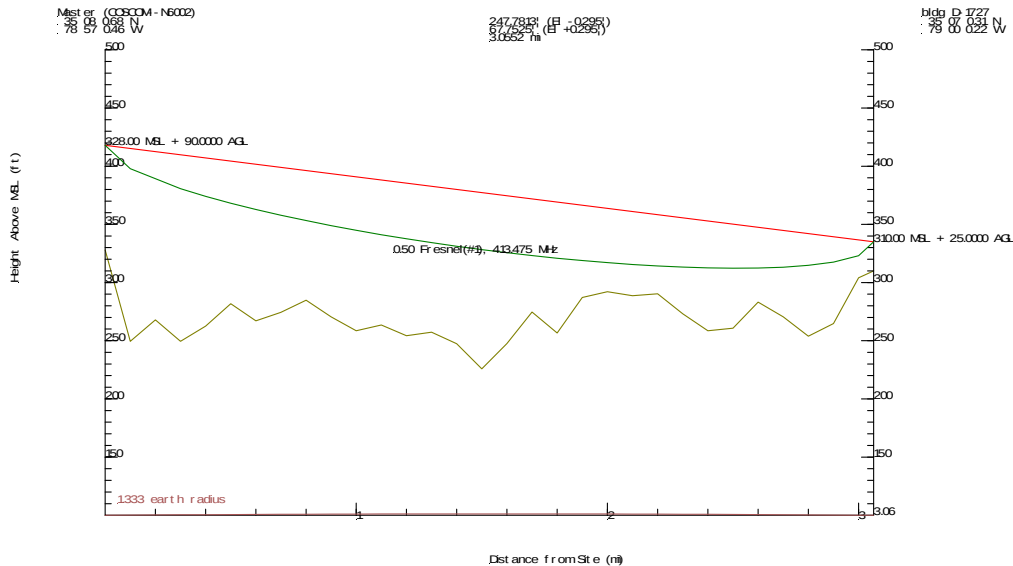


Figure B17. Point-to-point radio communications study for Master Repeater to Lift Station #17.

Master Repeater to Lift Station #18 (Bldg. G-4858)

These two facilities are within line-of-sight of each other at 1.50 miles apart, and there appear to be no communications problems between the two sites.



Figure B18. Point-to-point radio communications study for Master Repeater to Lift Station #18.

Master Repeater to Lift Station #19 (Bldg. N-7101)

These two facilities are within line-of-sight of each other at 0.0009 miles apart, and there appear to be no communications problems between the two sites.

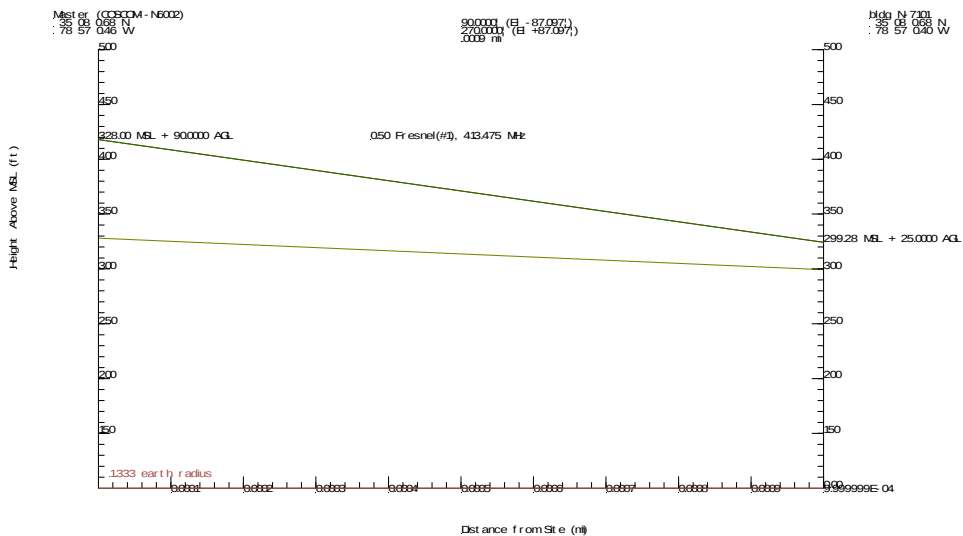


Figure B19. Point-to-point radio communications study for Master Repeater to Lift Station #19.

Master Repeater to Lift Station #20 (Bldg. P-7937)

These two facilities are within line-of-sight of each other at 1.49 miles apart, and there appear to be no communications problems between the two sites.

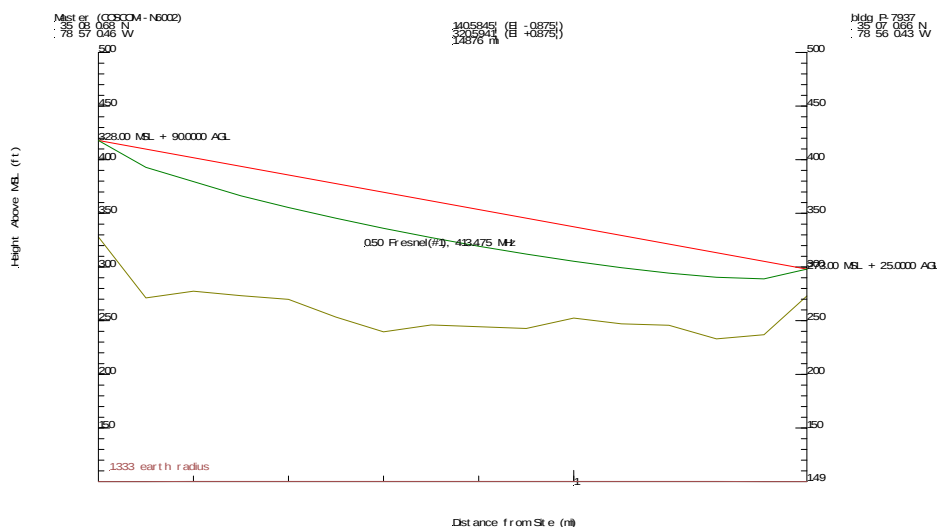


Figure B20. Point-to-point radio communications study for Master Repeater to Lift Station #20.

Master Repeater to Lift Station # 21 (Bldg. P-2455)

These two facilities are within line-of-sight of each other at 1.95 miles apart, and there appear to be no communications problems between the two sites.

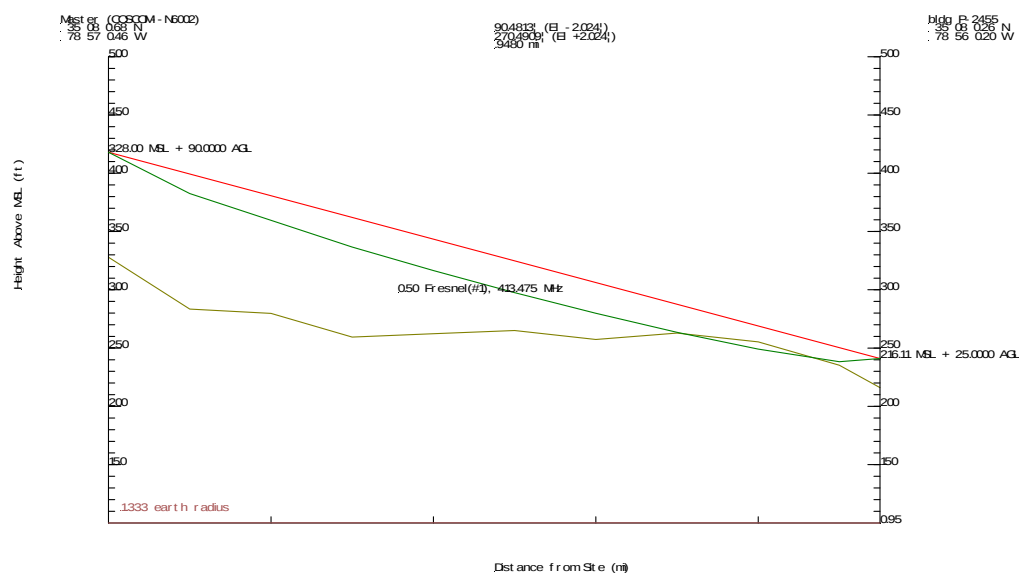


Figure B21. Point-to-point radio communications study for Master Repeater to Lift Station # 21.

Master Repeater to Lift Station #22 (Bldg. P-1559)

These two facilities are within line-of-sight of each other at 1.95 miles apart, and there appear to be no communications problems between the two sites.

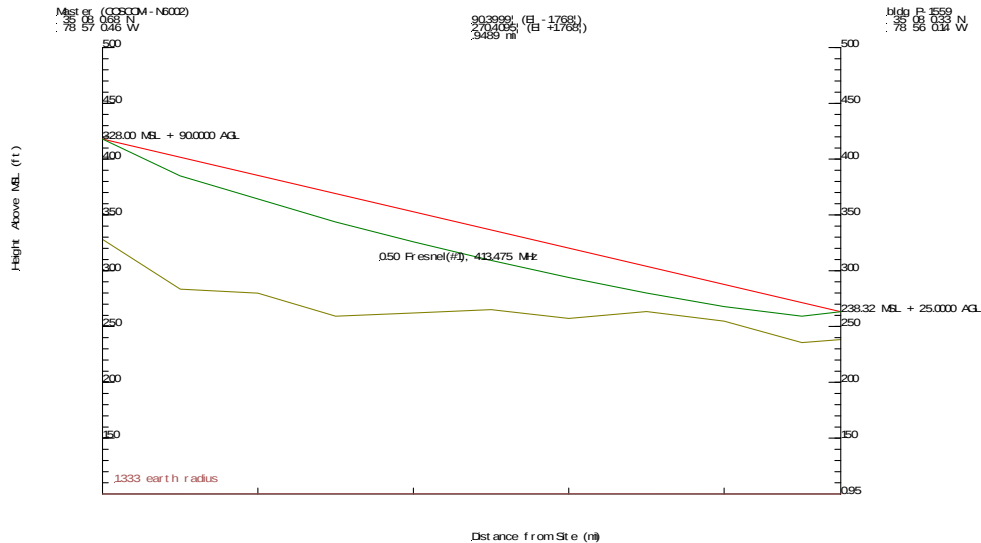


Figure B22. Point-to-point radio communications study for Master Repeater to Lift Station # 22.

Master Repeater to Lift Station #23 (Bldg. P-1551)

These two facilities are within line-of-sight of each other at 1.95 miles apart, and there appear to be no communications problems between the two sites.

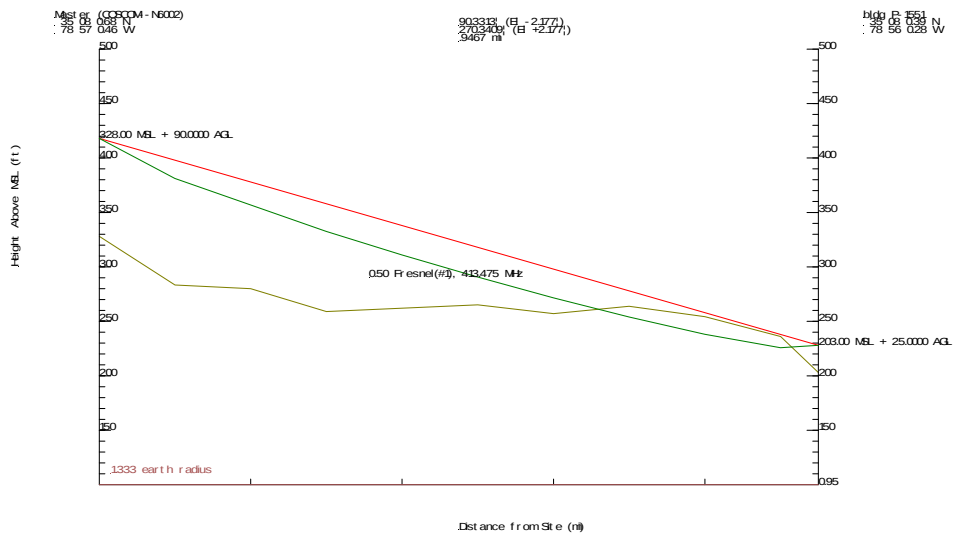


Figure B23. Point-to-point radio communications study for Master Repeater to Lift Station #23.

Master Repeater to Lift Station #24 (Bldg. Z-3252)

These two facilities are within line-of-sight of each other at 3.66 miles apart, and there appears to be no communications problems between the two sites.

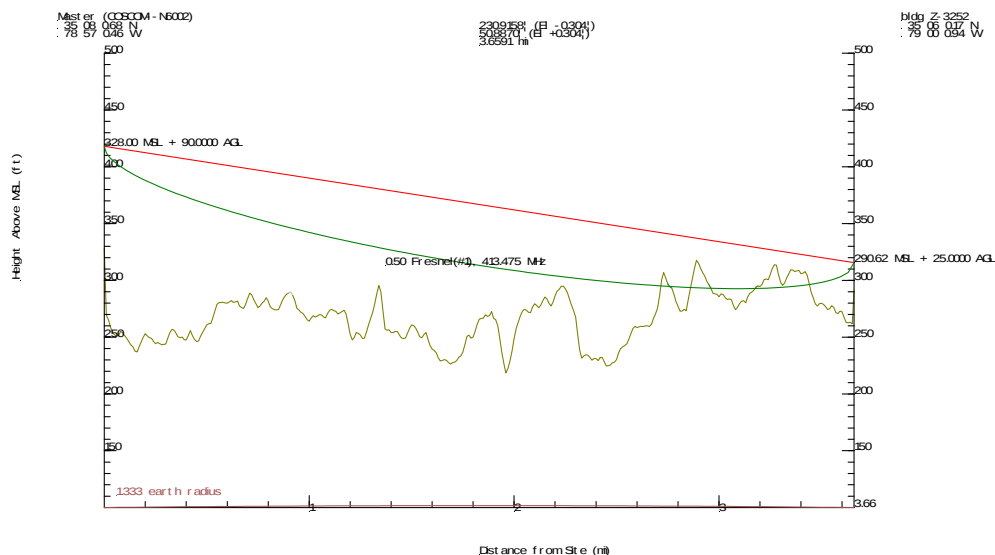


Figure B24. Point-to-point radio communications study for Master Repeater to Lift Station #24.

Master Repeater to Lift Station #25 (Bldg. 1-3571)

These two facilities are within line-of-sight of each other at 1.88 miles apart, and there appear to be no communications problems between the two sites.

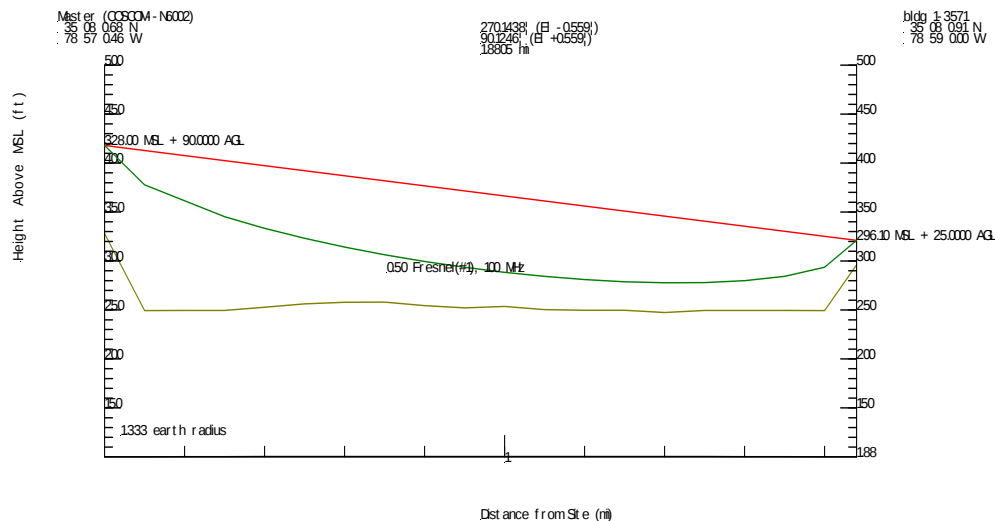


Figure B25. Point-to-point radio communications study for Master Repeater to Lift Station #25.

Master Repeater to Lift Station #26 (Bldg. 3-2533)

These two facilities are within line-of-sight of each other at 3.05 miles apart, and there appear to be no communications problems between the two sites.

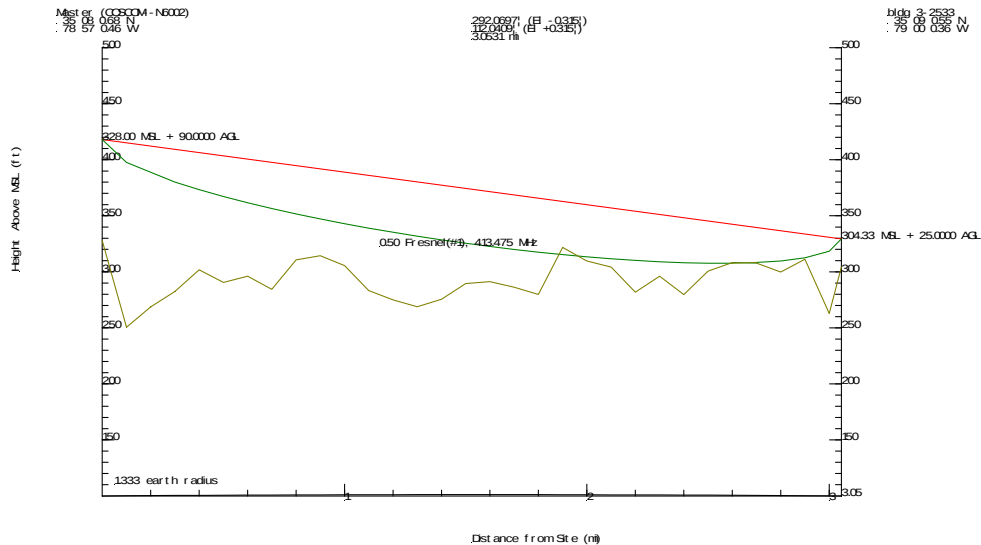


Figure B26. Point-to-point radio communications study for Master Repeater to Lift Station #26.

Master Repeater to Lift Station #70 (Bldg. 3-1333)

These two facilities are within line-of-sight of each other at 3.05 miles apart, and there appear to be no communications problems between the two sites.

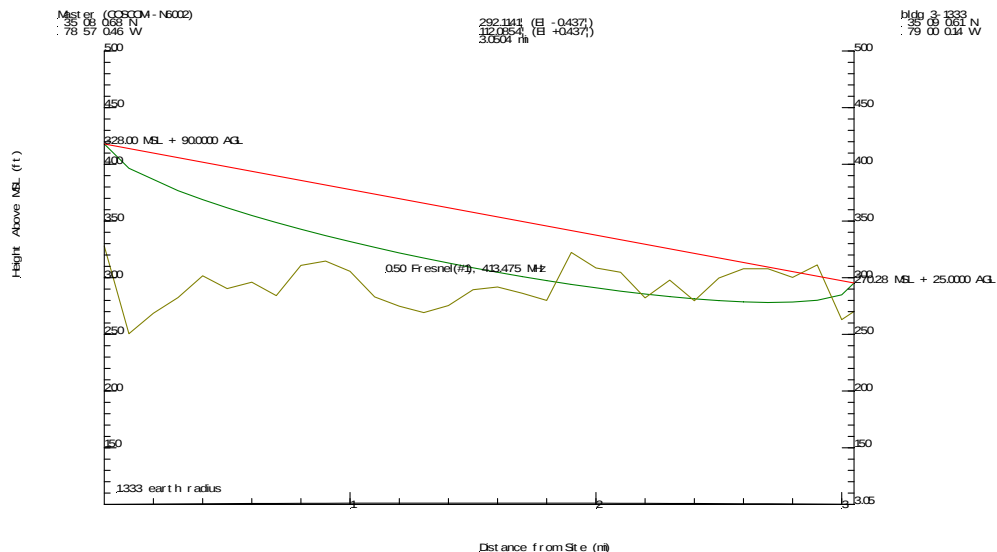


Figure B27. Point-to-point radio communications study for Master Repeater to Lift Station #70.

Master Repeater to Lift Station #71 (Bldg. Waste Water Treatment Plant)

These two facilities are not quite within line-of-sight at 4.45 miles apart. Although they are not within line-of-sight, they appear to be within the upper Fresnel zone of the recommended frequency 413.475 MHz. Upon detail design of the SCADA system, MSE-TA checked this site with a portable radio/RTU setup. If communications problems exist, antenna height at the remote location can be elevated to eliminate the problems.

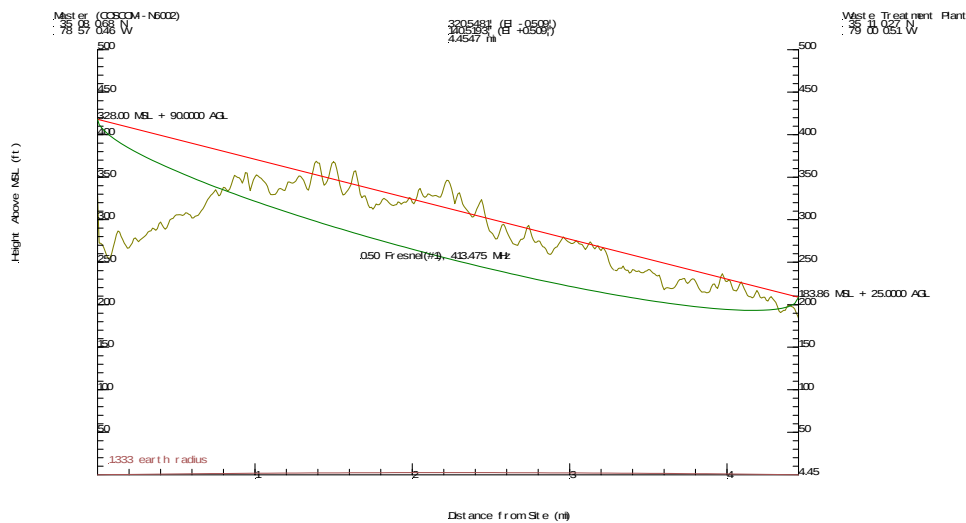


Figure B28. Point-to-point radio communications study for Master Repeater to Lift Station #71.

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14. ABSTRACT Fort Bragg has had several Notices of Violations because of collection system failures, primarily lift station overflows. A current shortage of personnel to operate and maintain the Fort Bragg Wastewater Treatment Plant and the collection system has prompted the decision to install a state-of-the-art Supervisory Control and Data Acquisition (SCADA) system. This report describes the system that was installed at Fort Bragg, the selection of the hardware and software components needed for the system, and the successful startup of that system.					
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