SPIRIT LAKE WTP AUTOMATION AND CONTROL UPGRADES, PHASE 1
Spirit Lake, Iowa
2023

CONTRACTOR'S BID DATE: Thursday, October 5, 2023 at 11:00 AM CT

PLACE TO FILE FOR CONTRACTOR'S BIDS:
City of Spirit Lake
City Hall
1803 Hill Avenue
Spirit Lake, IA 51360

ADDENDUM NO. 1
September 19, 2023

TO ALL PLANHOLDERS:

The following changes, clarifications, additions, and/or deletions are hereby made a part of the contract documents for the above-referenced project, as fully and completely as if the same were fully set forth therein. This addendum takes precedence over any items that may conflict.

SPECIFICATION

1. Refer to Table of Contents

   Added APPENDIX to Table of Contents

   Replace Table of Contents in it's entirety

2. Refer to Specification Section 00110 – NOTICE TO BIDDERS:

   Replace the time and date for filing sealed bids with the following:

   "11:00 AM, on October 5, 2023"

   Replace the date for the Notice to Proceed with the following:

   "October 20, 2023"

   Replace the specification section in its entirety

3. Refer to Specification Section 00120 – NOTICE OF PUBLIC HEARING:

   Replace the time and date for public hearing with the following:

   "5:30 PM, on October 10, 2023"

   Replace the specification section in its entirety

4. Refer to Specification Section 00430 – BID BOND:

   Replace the date for the letting with the following:

   "October 5, 2023"

   Replace the specification section in its entirety

5. Refer to Specification Section 00520 – AGREEMENT:

Replace the date for the notice to proceed no later than with the following:

"October 20, 2023"

Replace the specification section in its entirety

6. Create an Appendix, the creation of the Appendix has included the following:

   City of Spirit Lake Industrial Wireless Network Analysis

7. Refer to Specification Section 25 9100 – CENTRAL CONTROL:

   Replace paragraph 2.09.A.6. with the following:

   "6. Approved manufacturers:
   a. Allen-Bradley. Model: Micro870, with options specified.
   b. Allen Bradley. Model: 1769-L24, with options specified.
   c. No Substitutes."

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly registered Professional Engineer under the laws of the State of South Dakota.

Date: **09/19/2023**

MATTHEW JAMES PAJL, P.E.

License No. **11935**

My renewal date is **December 31, 2023**

Pages or sheets covered by this seal:

Entire document

SPECIFICATIONS
SPIRIT LAKE WTP AUTOMATION AND CONTROL UPGRADES, PHASE 1
CITY OF SPIRIT LAKE, IA

TABLE OF CONTENTS

TECHNICAL SPECIFICATIONS

SECTION 00110

NOTICE TO BIDDERS

FILING OF SEALED BIDS

Sealed Bids will be received by the City of Spirit Lake, Iowa of the City of Spirit Lake ("Owner"), at City Hall, 1803 Hill Avenue, Spirit Lake, IA 51360 until 11:00 AM, on October 5, 2023, for the construction of the proposed Spirit Lake WTP Automation and Control Upgrades, Phase 1 for said Owner, as described in the Specifications and drawings therefore on file in the office of the City Adminstator of the City of Spirit Lake. Bids will be publicly opened, read, and tabulated on the day and hour specified above, and will be acted upon by the Owner at that time or at such later time and place as the Owner may then determine.

GENERAL PROJECT DESCRIPTION

All Work, materials, and equipment are to be in accordance with the Contract Documents on file in the office of the City of Spirit Lake, Iowa, and at the office of HR Green, Inc. ("Engineer"), 431 North Phillips Ave Suite 400, Sioux Falls, SD 57104, by this reference made a part hereof as though fully set out and incorporated herein.

The Work for the said improvement, as required by the Contract Documents, is generally described as follows:

> Furnish all labor, materials, and equipment necessary to replace multiple turbidity, pH, chlorine analyzer sensors and transmitters, insert mag meters (multiple sizes), SCADA radios, improvements to the existing SCADA system, new SCADA server, and added monitoring of five (5) standby generators, together with related subsidiary and incidental work in accordance with the plans and specifications.

The City of Spirit Lake, in accordance with Title VI of the Civil Rights Act of 1964, 78 Stat. 252, 42U.S.C. 2000d to 2000d-4 and Title 49, Code of Federal Regulations, Department of Transportation, Subtitle A, Office of the Secretary, Part 21, Nondiscrimination in Federally-assisted programs of the Department of Transportation issued pursuant to such Act, hereby notifies all bidders that it will affirmatively ensure that in any contract entered into pursuant to this advertisement, minority business enterprises will be afforded full opportunity to submit bids in response to this invitation and will not be discriminated against on the grounds of race, color, or national origin in consideration for an award.

Work under the proposed Contract Documents shall be commenced upon written Notice to Proceed to be issued on or before October 20, 2023 and shall be completed and ready for operation on or before April 25, 2025, subject to any extension of time, which may be granted by the Owner.

PRE-BID CONFERENCE

Prospective bidders are encouraged to attend a pre-bid walk through of the proposed Work site which will be conducted jointly by the Owner and Engineer at 10:30 AM on September 8, 2023 at Water Treatment Plant. The objective of the walk through is to acquaint bidders with the site conditions.

OTHER PERTINENT INFORMATION

Each Bid shall be made on the Bid Form prepared for this purpose, which may be obtained from the Engineer. Any alteration in the official Bid Form will entitle the Owner, at its option, to reject the Bid from consideration. Each Bid shall be accompanied by a Bid Bond or a certified cashier's check, drawn on a solvent state or national bank, or a certified share draft drawn on a credit union in Iowa or chartered under the laws of the United States, and filed in a sealed envelope separate from the one containing the Bid. The Bid Bond shall be substantially in the form set forth in the Contract Documents. The Contractor's certified check or Bid Bond shall be in an amount equal to five (5) percent of the amount of the Bid, made payable to the Owner. The check may be cashed for the full amount by the Owner or the Bid Bond forfeited in the full amount to the Owner as liquidated damages in the event the successful Bidder fails to enter into contract and file acceptable bonds satisfactory to the Owner assuring the faithful fulfillment of the contract and maintenance of said improvements as required by law within ten (10) days after the acceptance of the Bid.

The Owner reserves the right to reject any or all Bids, to readvertise for Bids or to defer action on the Bids received for a period not to exceed 30 days from and after the date and time specified in this Notice to Bidders for receiving said Bids, and to waive irregularities and informalities.

The successful Bidder will be required to furnish a Performance and Warranty Bond and a Payment Bond, each in an amount equal to one hundred (100) percent of the contract price. Said bonds to be issued by a responsible Surety approved by the Owner and shall guarantee that the Principal shall promptly make payment to all persons, firms, Subcontractors, and corporations furnishing materials for or performing labor in the performance of the Work stated and the faithful performance of the contract and the terms and conditions therein contained and the guarantee and maintenance of said facilities in good repair and working conditions for not less than two (2) year(s) from the Notice of Acceptability of such improvements by the Owner.

Payment of the cost of said project will be made from cash on hand and/or received, payable from any fund or funds of Owner which may be legally used for such purpose, including, but not limited to, any of the following sources, or any combination thereof, at the sole discretion of Owner: (1) past and/or future earnings of Owner's utility; (2) proceeds of the sale and issuance of General Obligation Bonds and/or revenue bonds (or project notes anticipating the sale of such bonds); (3) federal, State or local grants or loans; and (4) proceeds from the sale of warrants, as authorized by Section 384.57 of the Code of Iowa. Payments will be made to the Contractor in accordance with the Contract Documents.

Construction items and materials included in the Project are exempt from State of Iowa and Local Option Sales and Use Taxes. Contractor is responsible for obtaining the exemption on items included, as provided by law or for applying for reimbursement for such taxes paid. Contractor shall pay all other taxes required to be paid by Contractor in accordance with the laws and regulations of the place of the Project that are applicable during the performance of the Work. Contractor shall NOT include Sales and Use Tax in Contractor's bid. For more information on this exemption, please check the State of Iowa's website: **www.state.ia.us/tax/business/Contr-ExEnt-Index.html**

By virtue of statutory authority, preference will be given to products and provisions grown and coal produced within the State of Iowa, and to Iowa domestic labor, to the extent lawfully required under Iowa statutes provided that the award of contract will be made to the lowest responsible bidder submitting the lowest responsive bid, which shall be determined without regard to state or local laws whereby preference is given on factors other than the amount of the Bid.

Electronic copies of said Contract Documents and the Bid Form may be secured by contacting HR Green, Inc., at 605-221-2691 and asking for Brooke Colby or by sending an email to **bcolby@hrgreen.com**. There is no charge for the plans and specifications. **Electronic plans and specifications are in Portable Document Format (PDF) and are available to download from our FTP site. Please contact for download instructions.**

This public improvement is being constructed pursuant to the provisions of Chapters 26 and 573 of the latest edition of the Iowa Code, including revisions.

Published upon order of the City of Spirit Lake, Spirit Lake, IA.

City of Spirit Lake

/s/_____
Bruce Keenan, Mayor

ATTEST:

/s/_____
Gregg Owens, City Adminstator

END OF SECTION 00110

SECTION 00120
NOTICE OF PUBLIC HEARING

NOTICE OF PUBLIC HEARING ON PROPOSED PLANS, SPECIFICATIONS, PROPOSED FORM OF CONTRACT AND ESTIMATED COSTS FOR THE CONSTRUCTION OF PROJECT Spirit Lake WTP Automation and Control Upgrades, Phase 1 IN AND FOR THE City of Spirit Lake, Spirit Lake, IA 51360.

Notice is hereby given that there are on file with the Clerk, City of Spirit Lake of the City of Spirit Lake, Spirit Lake, IA 51360, proposed drawings, project manual, proposed Form of Contract ("Contract Documents"), and opinion of probable cost for the construction of said improvement, for said Owner.

A hearing will be conducted thereon at a meeting of the City of Spirit Lake to be held at 1803 Hill Avenue, Spirit Lake, IA 51360 at 5:30 PM, on October 10, 2023, at which time and place any person may appear and file objections to the proposed drawings, project manual, proposed Form of Contract ("Contract Documents"), and opinion of probable cost for the construction of said improvement.

Published upon order of the City of Spirit Lake, Spirit Lake, IA.

/s/_____
Bruce Keenan, Mayor

ATTEST:

/s/_____
Gregg Owens, City Adminstator

END OF SECTION 00120

SECTION 00430
BID BOND

KNOW ALL MEN BY THESE PRESENTS; That we _____,
of _____ as Principal, and _____,
of _____, as Surety, are held and firmly bound unto the City of Spirit Lake hereinafter referred to as the Obligee, in the penal sum of _____, ($_____)
for which payment said Principal and Surety bind themselves, their heirs, executors, administrators, successors, and assigns jointly and severally, firmly by these presents.

WHEREAS, the Principal is herewith submitting their sealed proposal for constructing the Spirit Lake WTP Automation and Control Upgrades, Phase 1 as described in Section 00110 Notice to Bidders.

Date of Letting: October 5, 2023

NOW THEREFORE, if the said proposal bid by said Principal is accepted, and the Principal shall enter into a contract with the Obligee in accordance with the terms of such bid, and shall post the Performance Bond, Payment Bond, and Warranty Bond required by the contract documents with good and sufficient surety for the faithful performance of such contract, for the prompt payment for all labor and material furnished in the prosecution thereof and for the maintenance of the improvements in good repair and specified working conditions for two (2) year(s) after substantial completion of the project by the Obligee, then this obligation shall become null and void, or in the event of the failure of the Principal to enter such contract and give such Performance Bond, Payment Bond, and Warranty Bond, the Principal and Surety on these bonds hereby agree to pay to the Obligee the full amount of this Bid Bond, together with court costs, attorney's fees, and any other expense of recovery.

IN WITNESS WHEREOF, the Principal and Surety have caused these presents to be signed this day of_____, 2023.

_____
Principal
By _____
Contractor's Signature

_____
_____
Surety

END OF SECTION 00430

SECTION 00520
AGREEMENT

THIS AGREEMENT is dated as of the _____ day of _____, 2023, by and between the City of Spirit Lake (hereafter called Owner) and Contractor (hereafter called Contractor).

Owner and Contractor, in consideration of the mutual covenants hereinafter set forth, agree as follows:

ARTICLE 1. WORK.

Contractor shall complete all Work as specified or indicated under the Contract Documents entitled Spirit Lake WTP Automation and Control Upgrades, Phase 1 generally described as follows:

> Furnish all labor, materials, and equipment necessary to replace multiple turbidity, pH, chlorine analyzer sensors and transmitters, insert mag meters (multiple sizes), SCADA radios, improvements to the existing SCADA system, new SCADA server, and added monitoring of five (5) standby generators, together with related subsidiary and incidental work in accordance with the plans and specifications.

ARTICLE 2. CONTRACT TIMES.

With Notice to Proceed no later than October 20, 2023, all portions of the Work shall be completed and operational on or before April 25, 2025, subject to any extension of time, which may be granted by the Owner.

ARTICLE 3. LIQUIDATED DAMAGES.

Owner and the Contractor recognize that time is of the essence of this Agreement and that the Owner will suffer financial and other losses if the Work is not completed within the time specified in Article 2 herein, plus any extensions thereof allowed in accordance with Article 15 of the General Conditions. The parties also recognize the delays, expense, and difficulties involved in proving in a legal proceeding the actual loss suffered by the Owner if the Work is not completed on time. Accordingly, instead of requiring any such proof, the Owner and the Contractor agree that as liquidated damages for delay (but not as a penalty) the Contractor shall pay the Owner $750 PER DAY dollars for each day that expires after the time specified in Article 2 herein.

ARTICLE 4. CONTRACT PRICE.

Owner shall pay Contractor for completion of the Work pursuant to the Contractor's Bid Form and in accordance with the Contract Documents in current funds as follows: _____ dollars, ($ _____).

ARTICLE 5. PAYMENT PROCEDURES.

Contractor shall submit Applications for Payment in accordance with Article 15 of the General Conditions. Applications for Payment will be processed by Engineer as provided in the General Conditions. The Owner shall retain from each monthly payment five (5) percent of the amount which is determined to be due according to the recommendation of the Engineer. The retainage shall constitute a fund for the payment of claims for materials furnished and labor performed on the project and will be held and disposed of by the Owner as provided by current statute [in Chapters 26 and 573 of the latest edition of the Iowa Code, including revisions]
All amounts not paid when due shall bear the maximum interest percent allowed by law.

ARTICLE 6. ASSIGNMENT.

No assignment by a party hereto of any rights under or interests in the Contract Documents will be binding on another party hereto without the written consent of the party sought to be bound; and specifically but without limitation monies that may become due and monies that are due may not be assigned without such consent (except to the extent that the effect of this restriction may be limited by law), and unless specifically stated to the contrary in any written consent to an assignment, no assignment will release or discharge the assignor from any duty or responsibility under the Contract Documents.

Owner and Contractor each binds itself, its partners, successors, assigns and legal representatives to the other party hereto, its partners, successors, assigns and legal representatives in respect of all covenants, agreements and obligations contained in the Contract Documents.

ARTICLE 7. CONTRACT DOCUMENTS.

The Contract Documents, which comprise the entire contract between Owner and Contractor concerning the Work, consist of this Agreement; Performance and Warranty Bond and Payment Bond; Notice to Proceed; General Conditions; Supplementary Conditions; and Drawings and Technical Specifications, Contractor’s Bid Form, and all written amendments and other documents amending, modifying or supplementing the Contract Documents pursuant to paragraph 3.04 of the General Conditions, which may be fully executed after the effective date of the Agreement, for the said project.

IN WITNESS WHEREOF, Owner and contractor have caused this Agreement to be executed the day and year first above written.

City of Spirit Lake	Contractor
By:	By:
Bruce Keenan, Mayor	CAuthorizedSignature, CAuthorizedTitle
	CORPORATE SEAL
Attest:	Attest:
Gregg Owens, City Adminstator	Cattest, CAttestTitle
Address for giving notices	Address for giving notices
City of Spirit Lake 1803 Hill Avenue Spirit Lake, IA 51360	_____ _____ _____

END OF SECTION 00520

APPENDIX

CITY OF SPIRIT LAKE INDUSTRIAL WIRELESS NETWORK ANALYSIS

LARSON DATA COMMUNICATIONS
INDUSTRIAL WIRELESS & NETWORKED DATA SYSTEMS

Total Solutions Provider of Industrial Wireless Data Communications Systems.

No Drama, No Excuses, Just Performance.

SCADA • *Backhaul* • Smart Grid & AMI Communications Systems •
Guyed/Self Supporting Towers, Poles, & Structural Components

Industrial Wireless Network Analysis

City of Spirit Lake SCADA Radio System

Performed For:
HR Green
8710 Earhart Lane SW
Cedar Rapids, IA 52404-8947

[Report Date: 5 August 2023]

Analysis By:

Larson Data Communications
GE MDS Full Service Partner
for IA, MN, MT, ND, NE, SD & WY

Report Abstract

Larson Data Communications, Inc. was commissioned by HR Green Inc. to conduct an industrial data communications network analysis of the City of Spirit Lake, Iowa SCADA radio system.

The on-site portion of this analysis was performed June 21st. All of the on-site test and evaluation objectives were accomplished with no significant issues encountered. Other off-site preparatory work and follow-on analysis tasks were performed before and after that date.

The ultimate goal of this type of analysis is to assist utility operations & management staff and those contracted professional services providers a particular utility may utilize and rely on for subject matter expertise in making informed decisions as to the establishment, restoration, maintenance, and/or upgrade & optimization of an industrial data communications system. The desired outcome of such decisions is highly reliable, highly capable, highly flexible, highly expandable, easily maintainable, cost efficient, wireless data communications system fully capable of supporting the ongoing and evolving defined operational and control systems functionality requirements of that utility.

The purpose of this report is to present the results and findings of this analysis for use in the planned evolvement of this critical infrastructure asset into a more highly capable, functional, reliable, and optimally performing data communications network that will serve the City of Spirit Lake well into the future.

Report Contents

Section I.

Description of Sub-Consultant's Services

DESCRIPTION OF SUB-CONSULTANT'S SERVICES

Wireless Data Communications Systems Analysis

Included services:

- System-wide Analysis of existing GE MDS wireless data communications network by GE MDS Certified On-Site Engineer(s)/Technician(s).
- GE MDS radio hardware, site, & installation inspection; existing system performance logging.
- Recommended further actions to be taken based on analysis results and findings.
- Recommendations for system/network optimization and/or equipment upgrade options.
- Compilation and delivery of System Analysis Report.

Deliverables:

- System Analysis Report

Section II.

Report Summary

Wireless Network On-Site Analysis Report Summary

A. Background & Purpose

Larson Data Communications, Inc. was commissioned by HR Green to conduct a network analysis and design review for an industrial wireless data communications system capable of supporting an updated and expanded Supervisory Control and Data Acquisition (SCADA)/instrumentation & controls system for the City of Spirit Lake, Iowa Department of Utilities. An engineering study of this type is conducted to develop the detailed design parameters for a wireless network system capable of reliably providing the specified levels of continuous wireless data communications connectivity between and among the various current, and anticipated future, suite of SCADA/instrumentation & control system sensors, transducers, actuators, logic controllers, human-machine-interface terminals, etcetera typically comprising such a critical utility infrastructure system.

The purpose of this report is to present the results of this system analysis.

B. Network Performance Requirements

One of the critical variables that must be considered in a network evaluation process is the amount of payload data throughput capacity & speed is required; as well what levels of data security; routing, filtering, compression, manageability, etc. the network under evaluation must be capable of supporting.

Generally stated, there is a direct relationship between higher operating frequency wireless systems and higher data throughput capabilities. Therefore, if a minimum data throughput value is known, one or more radio systems capable of supporting at least that level of data throughput can be evaluated against the geospatial terrain model to determine what antenna positions, heights, azimuths, directivity gain parameters, etc. would be required to support the operating frequency and data throughput parameters of a given radio platform considering its unique signal transmission & reception performance parameters as well as its network & data processing capabilities.

Further information provided by HR Green as to the City's forward-looking operational needs estimate applicable to the requested analysis included the following:

"As for what we are looking for out of the radio network improvements, these are the key items:

1. *Move radio system to a currently manufactured and support* (sic) *radio system that is not at or near the end of its life.*
2. *Move to radios that support Ethernet communication to be compatible* (with) *today's PLC's.*
3. *Radio communication is for remote PLC*(s) *to communicate to* (the) *Master PLC at the WTP. Communication will be repeated where needed to reach the WTP as it currently does. No intention of using the radio system for security/access control, cameras, or remote SCADA PC's is envisioned."*

[Note: (Excerpted from Matt Pajl E-mail of 6/22/2023 2:25 PM)]

From a wireless network design perspective, the key parameters identified above for the City of Spirt Lake system are that any future system: a) must be capable of robustly supporting an Ethernet data communications rate compatible with current generation PLCs – as well as all necessary network switches, routers, remote I/O equipment, and all prudently associated network monitoring & management software; and, b) that wireless network "Repeater" topologies are acceptable as pragmatically required.

C. Analysis Methodology

In performing a network analysis appropriate to the needs of the City of Spirit Lake Water Utility SCADA system, consideration must be given to the data connectivity requirements between the individual network sites, the relative physical location of these sites, the nature of the various obstacles within the City of Spirit Lake's area of operation, and any impediments to efficient radiation & reception of electromagnetic energy these obstacles may represent.

Phase I of this process consists of gathering existing SCADA communications network system data such as control site location; radio configuration, and antenna system information; as well as other available communications system information. For this evaluation, this information was largely available from previous consultation work done for the City of Spirit Lake in 2007 after the currently installed SCADA radio network was installed.

The currently existing network topology is a (2) wireless network segment consisting of (13) GE MDS TransNET radios controlled by a single radio network Master Station. This network's topology consists of a TransNET "Master" radio located at the City's Water Treatment Plant (WTP) which communicates directly to (5) TransNET "Remote" sites and indirectly - via a TransNET configured in "Store-&-Forward" (Repeater) mode at the 1.5 M Gallon Tank - to the 1.5 M Gallon Tank itself and another (6) further outlying TransNET Remote equipped SCADA system sites.

Use of the earlier collected data and more recent details gathered along with the Owner's/Engineer's forward looking network performance requirements and estimates were used to perform and Electromagnetic Propagation Study – a PC based predictive performance analysis process used to evaluate iterative electromagnetic connectivity schemes overlaid onto geospatially correct project area terrain & obstruction models with the goal of developing an optimal network design and, ultimately, the creation of an optimally performing industrial/critical infrastructure wireless data communications network.

Phase II of this process typically involves on-site inspection & evaluation of each radio equipped control system site, the identification of any irregular site-specific antenna placement or electromagnetic propagation obstructions or impediments, and actual testing of each existing and/or proposed control site radio link. Optionally included in this phase is the inspection and/or evaluation of any other available utility owned communications equipment, structures, etc. as may be available for beneficial consideration.
On-site inspection, test and evaluation findings, results, and recommendations for each site were recorded and are documented within this report on "Radio System Site Evaluation Worksheets." Upon conclusion of on-site testing, the on-site test results contained in these worksheets were used to adjust

and calibrate the path profile models generated in the initial PC/software analysis. The over-the-air test results, along with various other physical site parameters identified while on-site were weighted and entered in place of earlier assumed initial values in the PC/software network model. The design parameters adjusted at that point in the process included antenna support-structure types and heights; specific antenna models, mounting techniques & positions; transmission line types & lengths; and obstacle proximity, height, and type.

While the Larson Data Communications staff was on-site, considerable radio network and TransNET radio specific information & training was provided to the City staff that will improve the performance, functionality, maintainability, and user confidence in the existing radio network

Of particular note, the radio configuration of the Center Lake LS radio link was corrected to best accommodate the site parameters existing there relative to the locations of both the TransNET network's Master radio at the Plant and the available network Repeater atop the 1.5 MG tank. A further optional action for this site would involve elimination of the significant self-interference being created there due to an inadequate clearance between that site's existing antenna system relative to the position of the new control panel. This was discussed with the City staff and they will be able to effect this improvement in-house should the now functioning radio link performance levels require it.

Also, diagnosis was made of the contents of a literal "BOX" of (8) TransNET radios the City had on-hand. Of the (8) TransNET radios, (2) were found to be inoperable and in need of repair; the remaining (6) were found to be fully functional – but, incorrectly programmed to be of any use in the City of Spirit Lake's SCADA system. Reprogramming of (3) of these radios was accomplished such that the City now has preprogrammed "Designated Spares" for the Plant/Master, Repeater, and any one of the Remote sites.

D. Findings & Test Results

The site-specific results of the on-site inspection & evaluations, and over-the-air radio link testing results for the City of Spirit Lake analysis as recorded on this project's Radio System Site Evaluation Worksheets are provided within **Appendix A** of this report.

The Phase I Electromagnetic Propagation Path Study - as further refined, adjusted, & calibrated based on the Phase II on-site analysis and link testing results - is contained in **Appendix B** of this report.

E. Conclusions, Options, & Recommendations

1. Though the existing TransNET RS-232 Serial radio network is currently communicating reasonably well, it is important to note that this TransNET radio network was installed some 19 years ago, back in 2004 as we understand. The TransNET radio - workhorse though it has been - has now been out of production and has not been factory repairable for a number of years now.

   The unlicensed 900 MHz TransNET radio operates at a relatively low over-the-air data-throughput rate of (115 kbps). This lower data throughput speed allowed this radio to occupy an also relatively narrow occupied frequency bandwidth when transmitting. This allowed the TransNET's receiver to operate VERY selectively which, in turn, allowed it to perform well even when receiving VERY weak received signal levels.

   The TransNET's extraordinary capability to receive such weak signals is the only think keeping the City of Spirit Lake's SCADA system functional as several of this system's radio links have experienced such degradation that they have all but failed entirely. Multiple antenna systems have severely degraded through oxidation and corrosion. Other site's antenna systems have become heavily obstructed with vegetation.

2. Over the intervening years this systems has been operating, the automation, instrumentation, and controls industry has largely evolved away from use of the RS-232 data communications protocol in favor of the MUCH more flexible and richly featured Ethernet data communications protocol. In fact, some Programmable Logic Controller (PLC) manufacturers have stopped producing RS-232 capable devices altogether. The clear trend is toward Ethernet based control systems.

   With respect to current technology radio platforms, the latest generation GE MDS Unlicensed radio platform, the Orbit Series NX915, has a payload data-throughput of 1.25 Mbps (over 1000% percent faster). This faster data throughput supports the Ethernet protocol particularly well. However, this comes at the cost of requiring significantly stronger & clearer received signals - so that the same extremely weak signal levels the City's existing TransNET radio network can successfully process will not in several cases be at all sufficient for the new, faster, and much more richly featured Orbit radios to do the same.

3. Of specific concern - given the signal strengths we have recorded in our on-site link testing records - would be the radio links to the 1.5 MG East Water Tower, the Million Gallon Tank West, and the Sludge Pit, 12th Street, KUOO, and Center Lake Lift Station sites.

While other sites' issues are relatively minor and can be easily corrected, the above listed sites require more significant antenna system upgrades as indicated in the On-site Path Test Results & Site Evaluation Worksheets and Electromagnetic Propagation Path Study sections of this report and as noted within the Radio Network Testing & Analysis Results Summary Table below.

4. The more significant issues in Item 3 preceding noted, the results of this analysis show that with otherwise only modest coaxial cabling & antenna system improvements effected as detailed in the Electromagnetic Propagation Path Study section of this report, the City of Spirit Lake SCADA radio network can, while continuing to operate in the 900 MHz unlicensed frequency band, be upgraded to a highly robust & reliable radio network capable of supporting virtually any desired current technology Ethernet capable PLC control system well into, and likely beyond, the foreseeable future.

City of Spirit Lake
SCADA Radio Network Testing & Analysis Results Summary Table

Wireless Network Segment	AP/MS Segment	Associated Remote Sites	2007 Projected Optimal Signal Strength (dBm)	2023 Projected Optimal Signal Strength (dBm)	2023 Reported Signal Strength (dBm) [See NOTES: (*)]	2023 Optimal vs 2023 Actual Δ	Identified Factors Affecting Deviation From 2023 Optimal [See Notes: (**)]	MS/AP Segment Signal Strengths With Known WTP Antenna System Issues Corrected	Rptr Segment Signal Strengths With Known 1.5 MGT Antenna System Issues Corrected	Estimated Signal Strengths With Known MS/AP/Rptr & Individual Site Issues Corrected
Access Point (Master Station) Segment	**WTP**						1 (~-1 dB) 3 (-8 dB)	+ ~9 dB		
		Sludge Pit Lift Station	-53	-58	-87	-29	3 (5 dB) 4 (15 dB)	-78		-59
		Raw Water Pump Station	-	-59	-68	-9	-	-59		-59
		North Hill Lift St	-60	-58	-68	-10	3 (1 dB)	-59		-58
		Gilbert Park Lift St	-46	-49	-59	-10	3 (1 dB)	-50		-49
		1.5 Million Gallon Tank	-67	-80	-94	-14	3 (3 dB)	-85	-82	-82
Repeater (Store & Fwd) Segment	**1.5 MG Tank**						3 (3 dB)		+ 3 dB (+?)	
		12th Street Lift Station	-66	-74	**-108**	-44	2 3 (7 dB) 5 (~21 dB)		**-105**	-77
		Southern Glen Lift Station	-57	-52	-100	-48	1 (5 dB) 2 3 (40 dB?)		-97	-52
		Deerland Lift Station	-61	-56	-67	-11	3 (2 dB)		-64	-62
		Business Park Lift Station	-72	-76	-83	-7	3 (1 dB) 5 (~5 dB)		-80	-74
		Center Lake Lift Station	-79	-75	-99	-24	2 (10 dB) 5 (~11 dB)		-96	-75
		KUOO Lift St	-69	-72	-91	-19	2 (~7 dB) 3 (1 dB) 5 (~6 dB)		-88	-74
		1.0 Million Gallon Tank	-	-62	-74	-12	1 (5 dB) 2 (3 dB) 3 (1 dB) 6		-71	-62

NOTES:

(*) Communications Protocols Reliably Supportable By These Signal Strength Levels In This Application:

Blue/Red: RS-232 Serial

Blue: Ethernet

xxxx None

(**) Observed Factors Causal and/or Contributing to Optimal/Actual Performance Discrepancy:

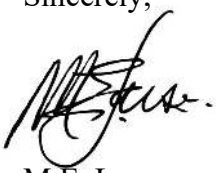
1) Antenna System Degraded/Failed
2) Inadequate Antenna System, Mounting Method, and/or Position Relative To Obstructions.
3) RG-8 Coaxial Cable (11 dB loss/100 ft) Installed Inadequate For 900 MHz Frequency And/Or Cable Length Installed. Value shown is versus recommended cable option(s).
4) Incorrect Antenna Polarization.
5) Significant Natural/Vegetative or Man-made Obstruction(S)
6) Suspected or Known Radiation Pattern Distortion and/or Self-interference

F. Administrative Notes

Every effort has been made to ensure the accuracy and completeness of this report. However, should any technical or administrative error be identified within this report, please bring the discrepancy to our attention – we would very much appreciate the opportunity to correct it.

Larson Data Communications very much appreciates the opportunity to work with HR Green in support of your service to the City of Spirit Lake. We greatly value your trust in our company & our staff, and we appreciate & thank you for your business. Please let us know how we can be of further service or assistance.

Sincerely,



M.E. Larson
Senior Wireless Systems Engineer

Appendix A.

On-Site Path Test Results & Site Installation Parameter Worksheets

a. **Water Treatment Plant Radio Network Segment**

b. **Repeater (1.5 MG Tank) Radio Network Segment**

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Water Plant

Site Location, Structure, & Environment Information

Antenna Support Structure(s):	30' mast on silo on roof of water plant
Building / Site Information:	Brick Water Treatment Plant
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	
Latitude: 43 26 03.66 N	Longitude: 095 06 16.20 W

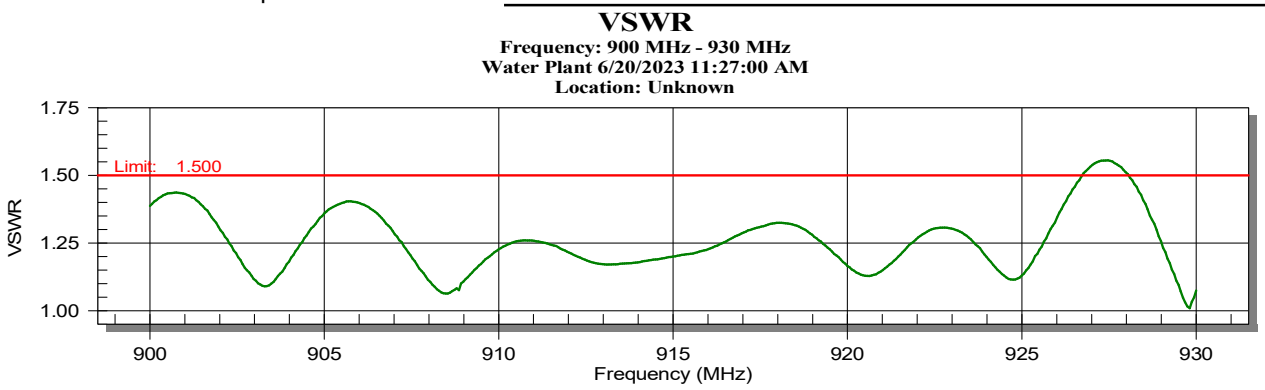
Radio Equipment Information

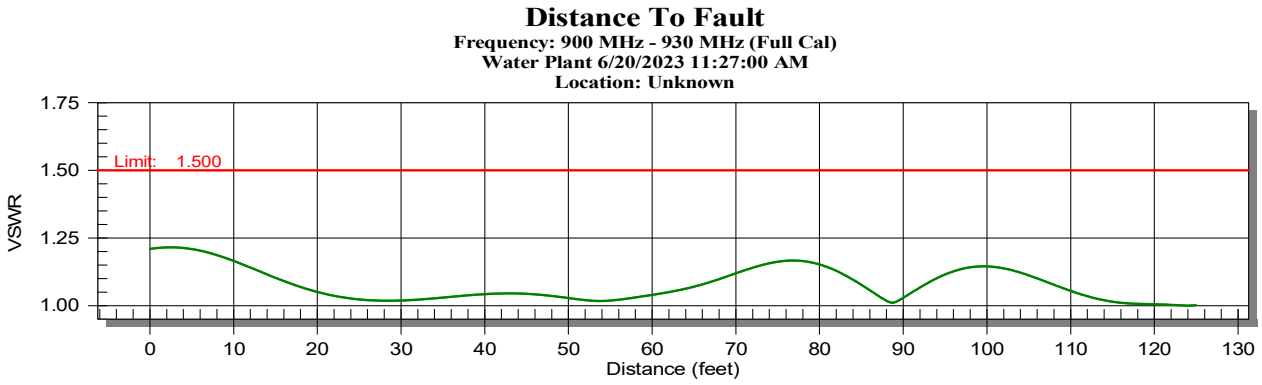
Radio Type:	TransNET	Serial Number:	1254417
Estimated EIRP:	37 dBm	IP Address:	N/A
Antenna Type:	Omni	Firmware Version:	3.2.3
Antenna Gain:	7 dBd	Cable Type:	RG8
Antenna Height:	70'	Cable Length:	100'

Radio System Performance Test Results

RSSI: N/A SNR: N/A

Cable & Antenna Sweep Results: Fail





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:	X	Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Antenna is on top of a 30' Mast that appears to sway in moderate winds. Recommend a more structurally sound antenna mounting structure be installed.

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Lime Sludge Lagoons

Site Location, Structure, & Environment Information

Antenna Support Structure(s): Mast attached to wood pole near panel

Building / Site Information: Freestanding panel

Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:

Latitude: 43 26 15.67 N Longitude: 095 06 22.00 W

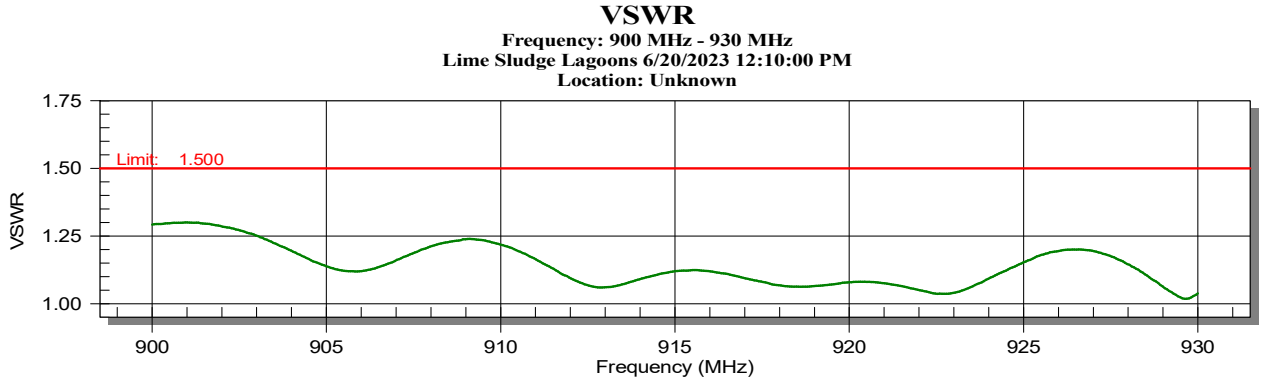
Radio Equipment Information

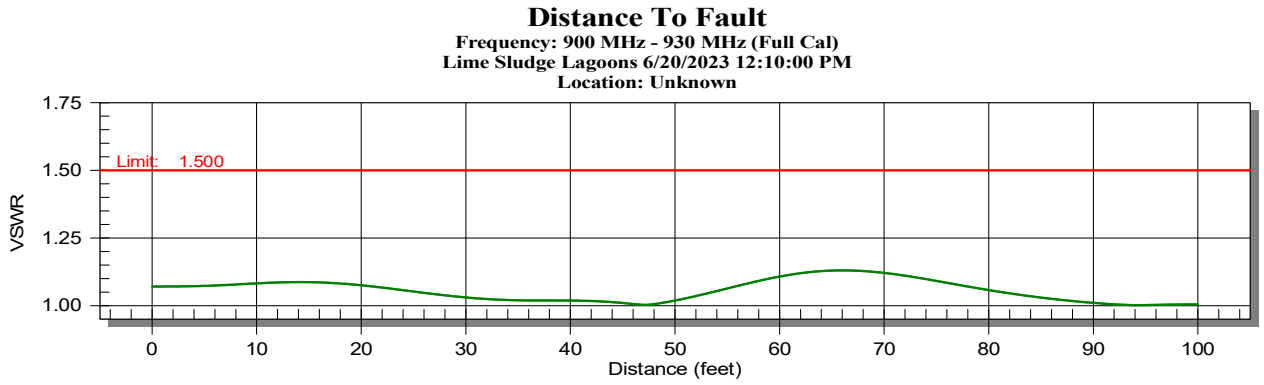
Radio Type:	TransNET	Serial Number:	1254418
Estimated EIRP:	40 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	25'	Cable Length:	60'

Radio System Performance Test Results

RSSI: -87 dBm SNR: 25 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Site Inspection & Test Worksheet

Site Name: Raw Water Pump Station
Latitude: 43 26 43.25 N
Longitude: 095 06 07.72 W
Misc. Site Info:

Radio Tests

Test 1	Antenna Height:	10	RSSI:	-68	S/N	25
Test 2	Antenna Height:	15	RSSI:	-67	S/N	25
Test 3	Anetenna Height	10	RSSI:	-69	S/N	25

Network Tests

1000 fping (32 Bytes) Min N/A Max N/A Ave N/A
Lost %: N/A

1000 fping (500 Bytes) Min N/A Max N/A Ave N/A
Lost %: N/A

Iperf Test:

Spectrum Analysis & Transmissions Components

In-band interference?: None detected
Noise Floor Readings:

Notes

Optimal location is the Southeast corner of the building, closest to the control panels.
1st and 2nd tests conducted from SE corner. 3rd test conducted at SW corner.

Site Hazards / Concerns

Immediately adjacent to a main road.

☐ Picture(s) of Site

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: North Hill LS

Site Location, Structure, & Environment Information

Antenna Support Structure(s):	Mast attached to panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	
Latitude: 43 26 26.63 N	Longitude: 095 06 08.43 W

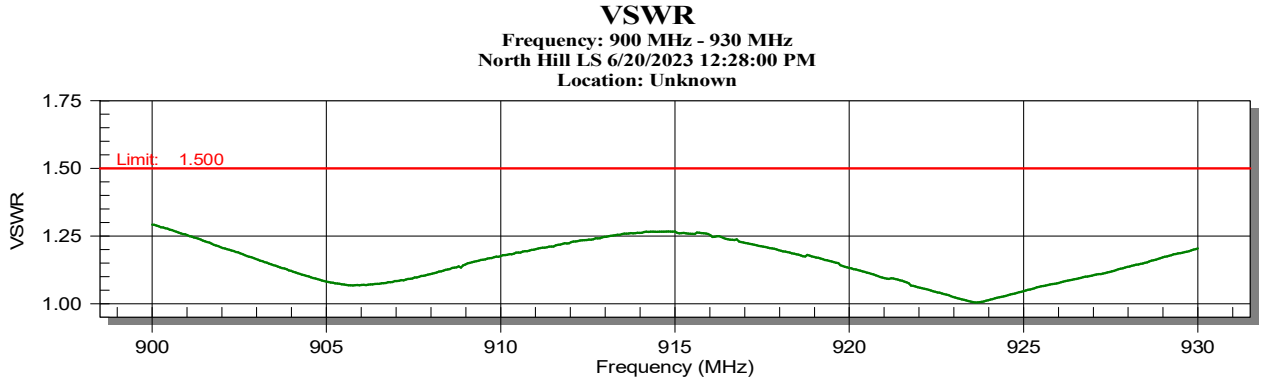
Radio Equipment Information

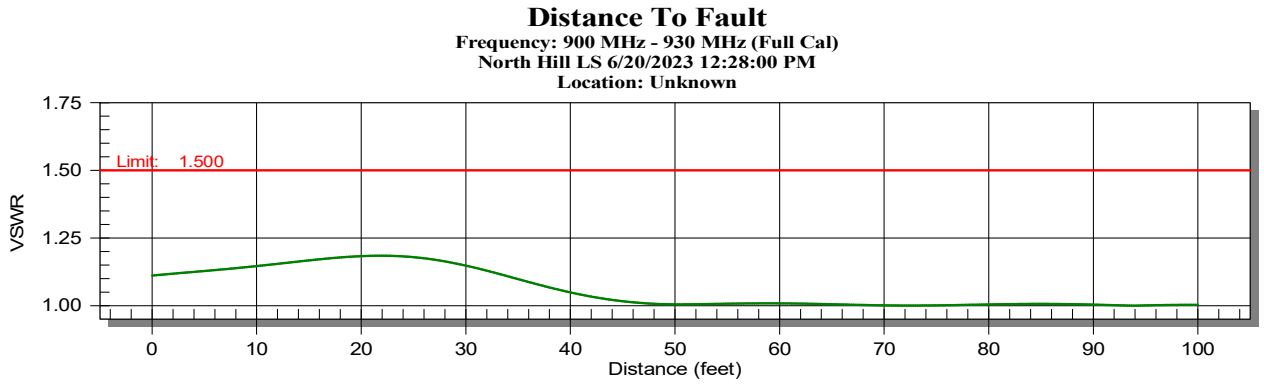
Radio Type:	TransNET	Serial Number:	1254423
Estimated EIRP:	37 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	12'	Cable Length:	15'

Radio System Performance Test Results

RSSI: -68 dBm SNR: 25 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Gilbert Park LS

Site Location, Structure, & Environment Information

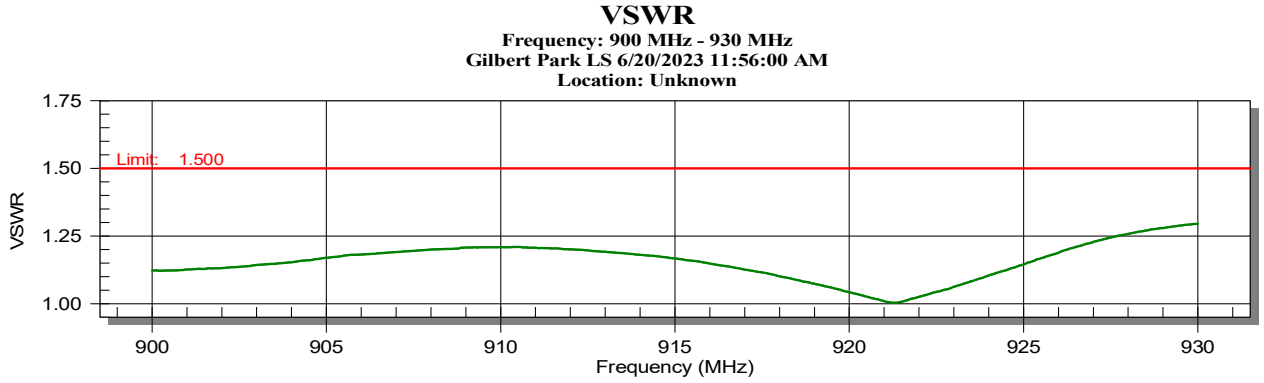
Antenna Support Structure(s):	Mast attached to panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	
Latitude:	43 26 06.98 N
Longitude:	095 06 11.39 W

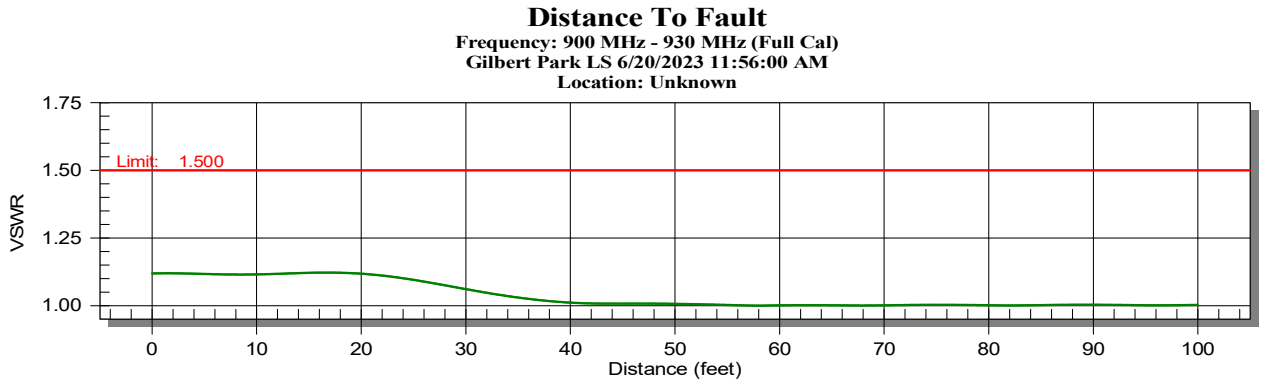
Radio Equipment Information

Radio Type:	TransNET	Serial Number:	1254420
Estimated EIRP:	40 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	12'	Cable Length:	15'

Radio System Performance Test Results

RSSI:	-59 dBm	SNR:	27 dB
Cable & Antenna Sweep Results:	Pass		





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: 1.5 Million Gallon Tank

Site Location, Structure, & Environment Information

Antenna Support Structure(s): Mast on railling on top of tower

Building / Site Information: Composite Water Tower

Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:

Latitude: 43 24 28.29 N Longitude: 095 06 17.43 W

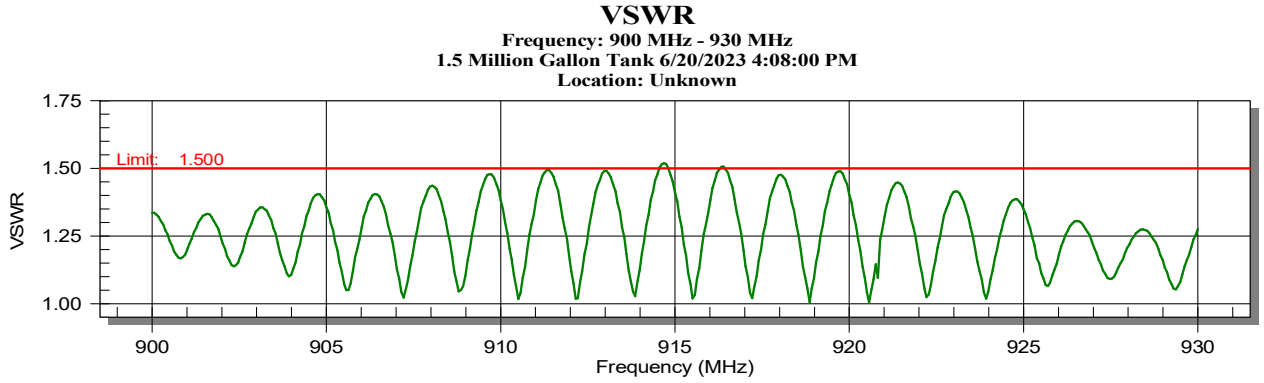
Radio Equipment Information

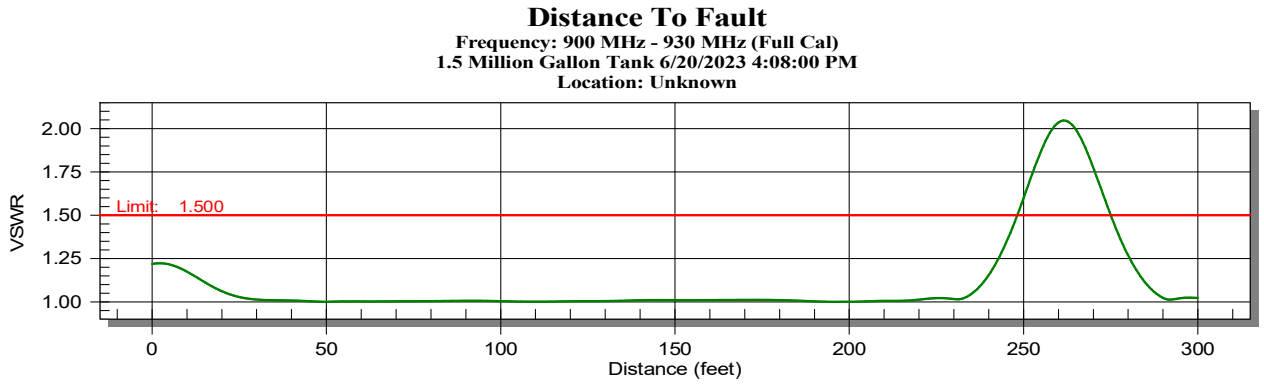
Radio Type:	TransNET	Serial Number:	2737764
Estimated EIRP:	37 dBm	IP Address:	N/A
Antenna Type:	Omni	Firmware Version:	4.1.2
Antenna Gain:	7 dBd	Cable Type:	LDF4-50A
Antenna Height:	140'	Cable Length:	250'

Radio System Performance Test Results

RSSI: -94 dBm SNR: 23 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: 12th St. LS

Site Location, Structure, & Environment Information

Antenna Support Structure(s): Mast on light pole near panel

Building / Site Information: Freestanding panel

Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:

Latitude: 43 25 43.09 N Longitude: 095 05 54.39 W

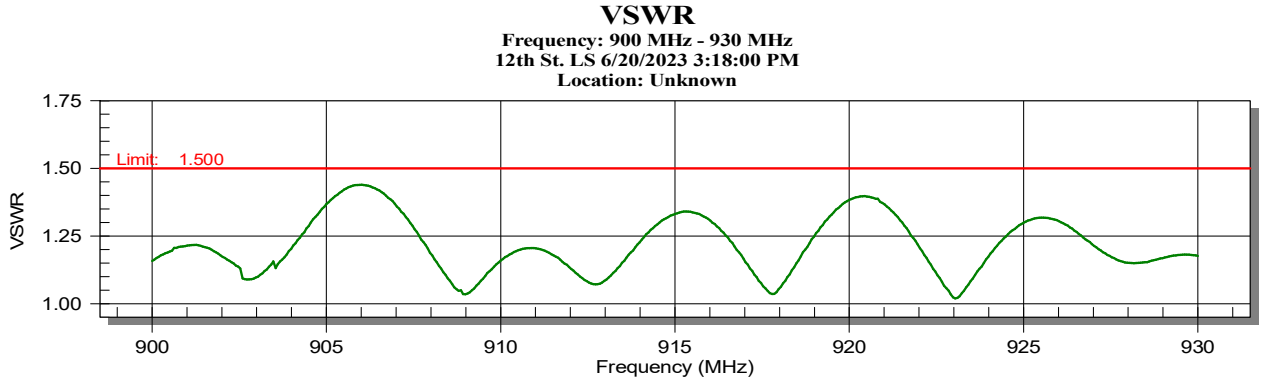
Radio Equipment Information

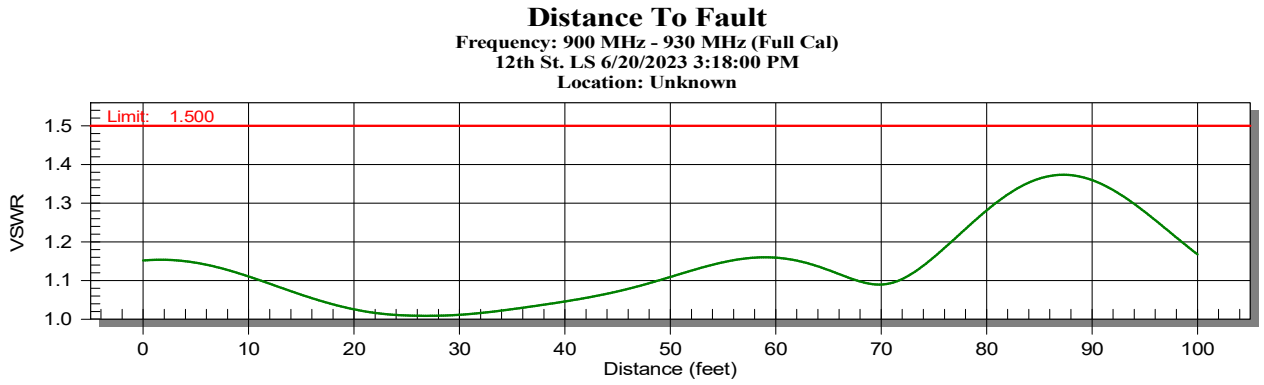
Radio Type:	TransNET	Serial Number:	2046581
Estimated EIRP:	40 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.6.1
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	40'	Cable Length:	80'

Radio System Performance Test Results

RSSI: -108 dBm SNR: 23 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Southern Glen LS

Site Location, Structure, & Environment Information

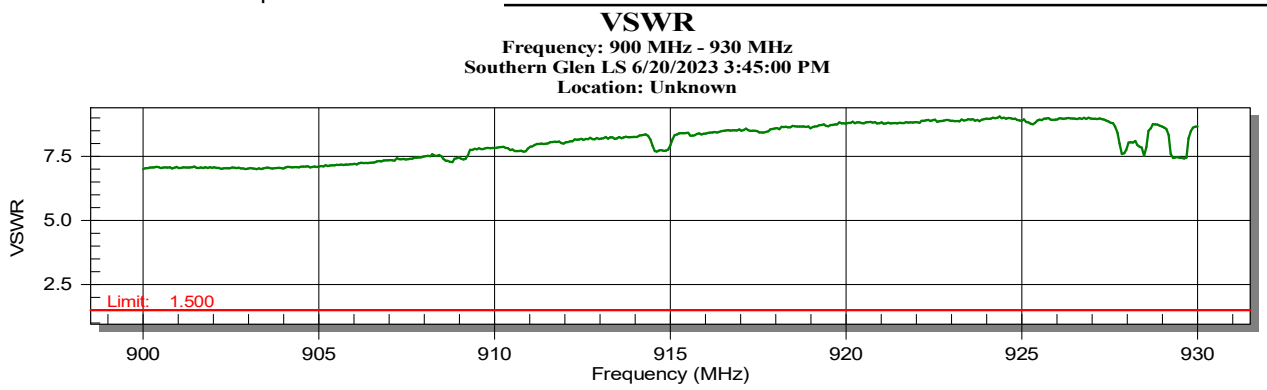
Antenna Support Structure(s):	Panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	
Latitude: 43 24 07.49 N	Longitude: 095 05 55.42 W

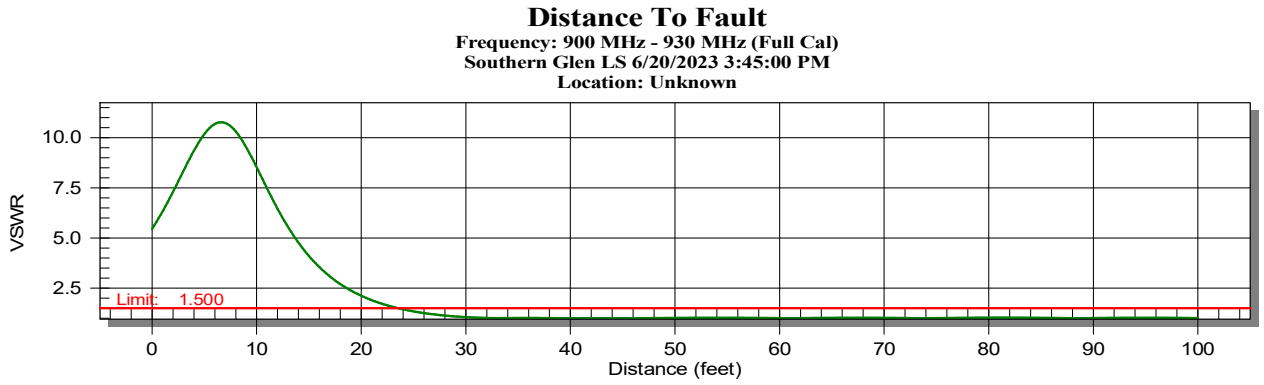
Radio Equipment Information

Radio Type:	TransNET	Serial Number:	1424882
Estimated EIRP:	31 dBm	IP Address:	N/A
Antenna Type:	Mobile	Firmware Version:	3.2.3
Antenna Gain:	1 dBd	Cable Type:	RG8
Antenna Height:	6'	Cable Length:	5'

Radio System Performance Test Results

RSSI:	-100 dBm	SNR:	23 dB
Cable & Antenna Sweep Results:	Fail		





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:	X	Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Current antenna requires an external ground plane but is mounted to non-conductive panel.

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Deerland LS

Site Location, Structure, & Environment Information

Antenna Support Structure(s):	Mast attached to panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	
Latitude: 43 24 01.26 N	Longitude: 095 07 41.00 W

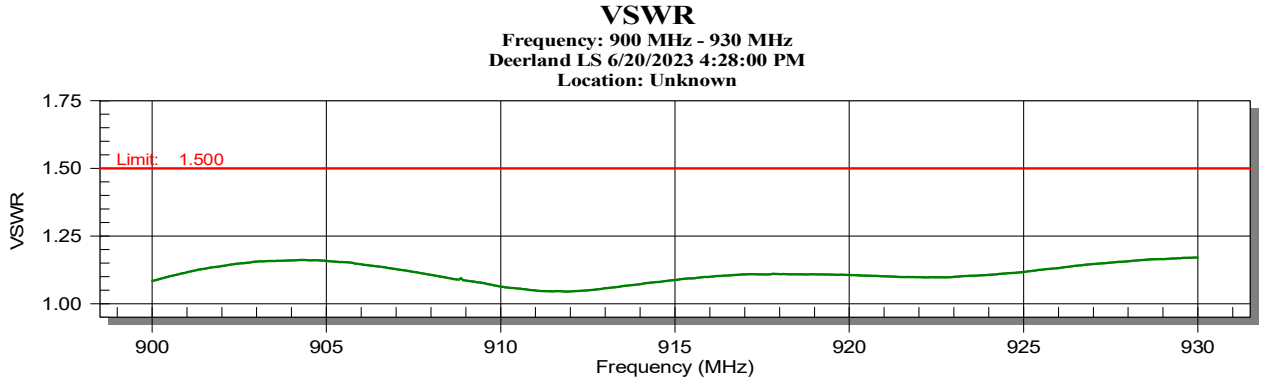
Radio Equipment Information

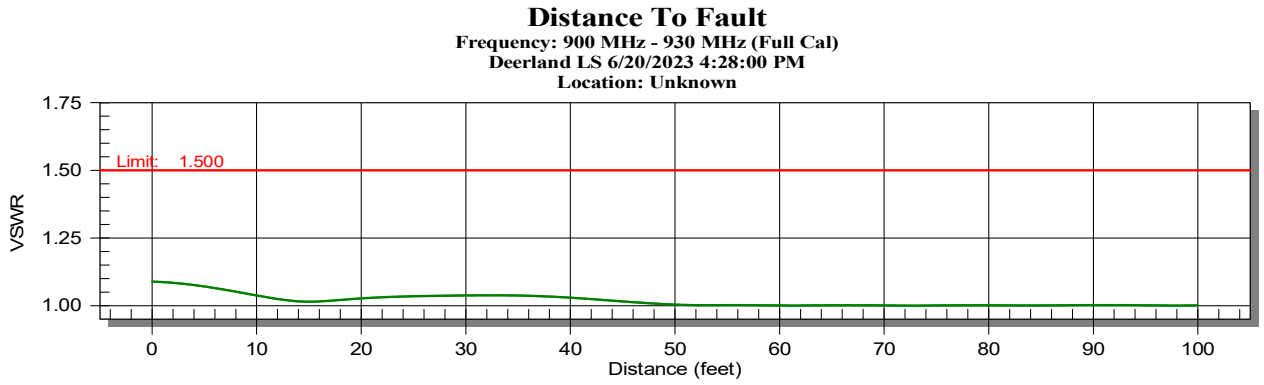
Radio Type:	TransNET	Serial Number:	1254433
Estimated EIRP:	30 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	12'	Cable Length:	20'

Radio System Performance Test Results

RSSI: -67 dBm SNR: 26 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Business Park LS

Site Location, Structure, & Environment Information

Antenna Support Structure(s):	Mast attached to panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	Trees
Latitude: 43 25 19.56 N	Longitude: 095 08 31.62 W

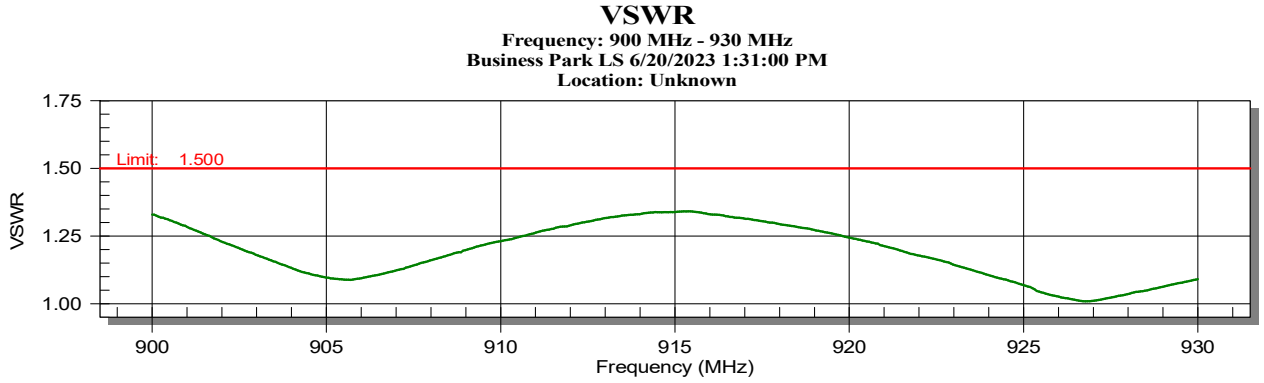
Radio Equipment Information

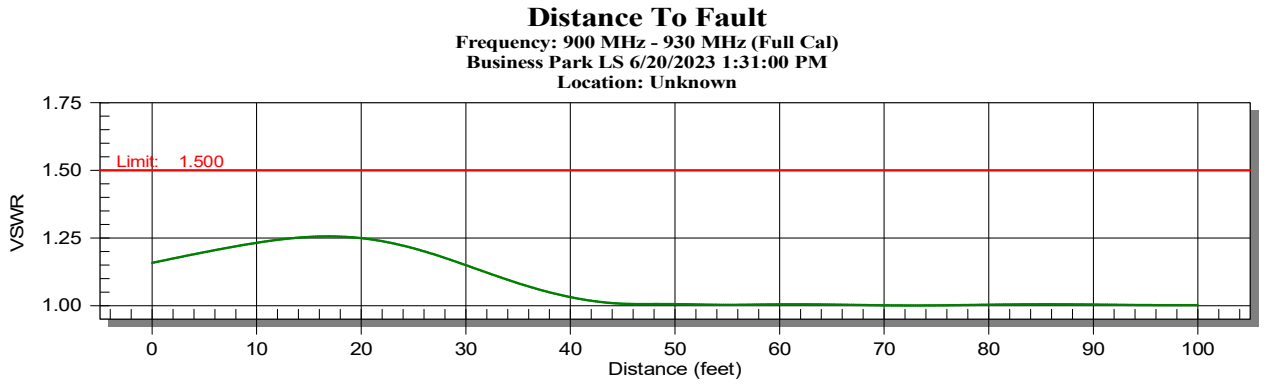
Radio Type:	TransNET	Serial Number:	1254435
Estimated EIRP:	30 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	12'	Cable Length:	15'

Radio System Performance Test Results

RSSI: -83 dBm SNR: 25 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: Center Lake LS

Site Location, Structure, & Environment Information

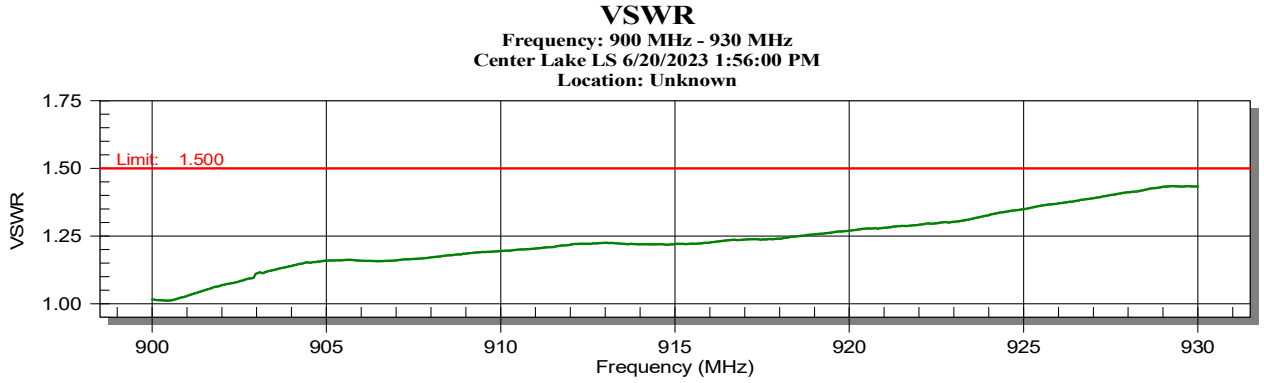
Antenna Support Structure(s):	Mast attached to panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	
Latitude:	43 25 05.68 N
Longitude:	095 07 46.20 W

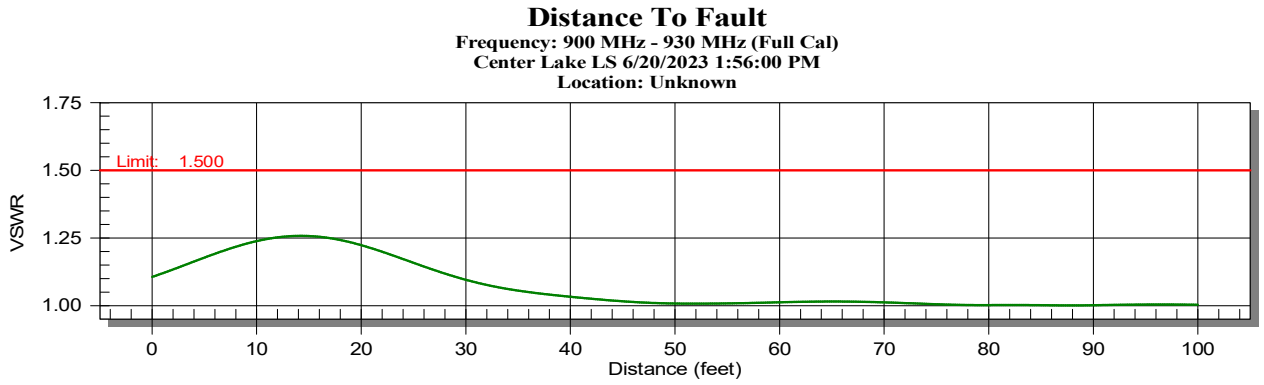
Radio Equipment Information

Radio Type:	TransNET	Serial Number:	1254423
Estimated EIRP:	37 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	7'	Cable Length:	15'

Radio System Performance Test Results

RSSI:	-99 dBm	SNR:	23 dB
Cable & Antenna Sweep Results:	Pass		





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Antenna is currently only a few inches over the panel. Mast extension needed to increase signal strength.

Signal test at -89 dBm at 15' AGL.

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: KUOO LS

Site Location, Structure, & Environment Information

Antenna Support Structure(s):	Mast attached to panel
Building / Site Information:	Freestanding panel
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	Trees and Metal Building
Latitude: 43 25 25.48 N	Longitude: 095 08 14.99 W

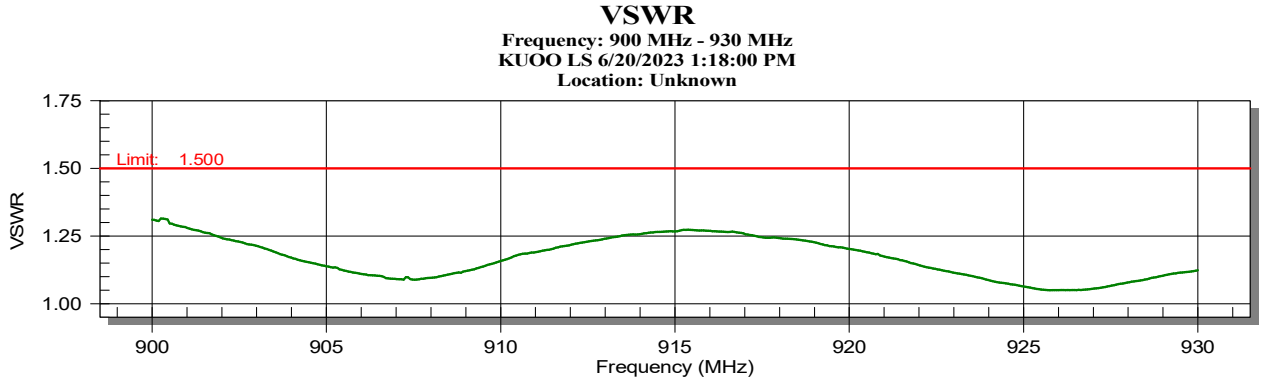
Radio Equipment Information

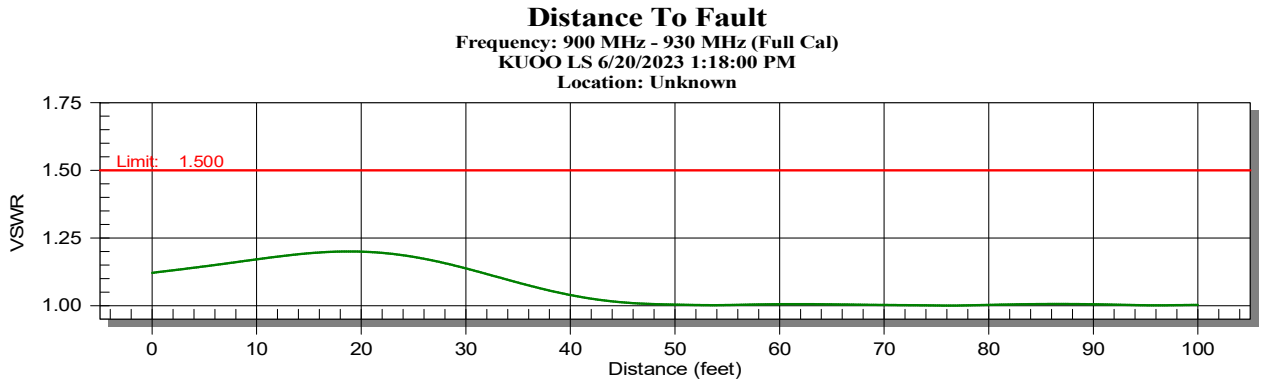
Radio Type:	TransNET	Serial Number:	2531050
Estimated EIRP:	30 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	4.1.2
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	12'	Cable Length:	15'

Radio System Performance Test Results

RSSI: -91 dBm SNR: 23 dB

Cable & Antenna Sweep Results: Pass





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

Antenna is aimed directly at a metal building. Additional height will be required if stronger signal needed.

Minimum of #6 stranded copper recommended for grounding purposes.

Larson Data Communications
Radio System Site Evaluation Worksheet

Site Evaluated: 1.0 Million Gallon Tank

Site Location, Structure, & Environment Information

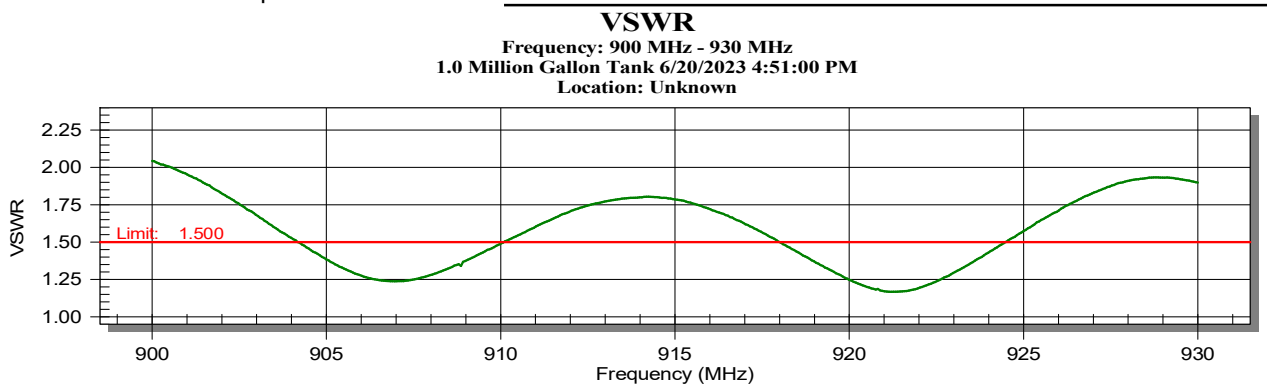
Antenna Support Structure(s):	Mast in ground at base of tower
Building / Site Information:	Spider-leg water tower
Co-Located or Nearby Structures, Facilities, EMI Sources, etc.:	Tower Legs
Latitude:	43 25 14.73 N
Longitude:	095 07 19.06 W

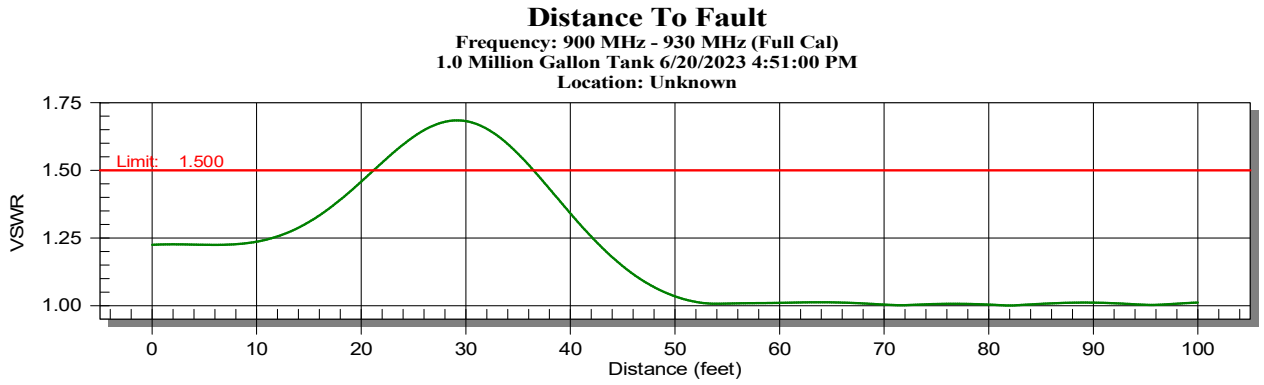
Radio Equipment Information

Radio Type:	TransNET	Serial Number:	1254419
Estimated EIRP:	30 dBm	IP Address:	N/A
Antenna Type:	Directional	Firmware Version:	3.2.3
Antenna Gain:	10 dBd	Cable Type:	RG8
Antenna Height:	12'	Cable Length:	20'

Radio System Performance Test Results

RSSI:	-74 dBm	SNR:	24 dB
Cable & Antenna Sweep Results:	Fail		





Recommended Corrective Actions:

Replace/Upgrade Cable:		Replace/Upgrade Lightning Arrestor:	X
Replace/Upgrade Antenna:		Provide Ground Connection to Radio:	
Improve Mounting Structure:		Ground Cabling/Antenna System:	X

Site Notes, Comments, & Recommendations

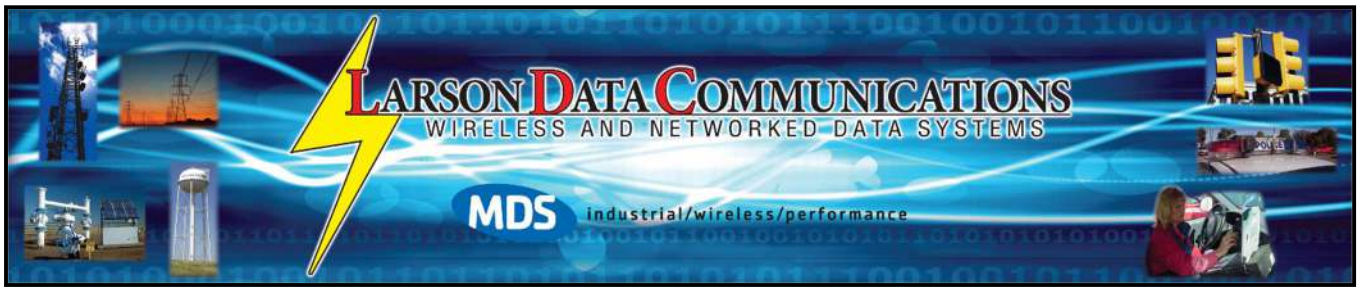
Minimum of #6 stranded copper recommended for grounding purposes.

Appendix B.

Electromagnetic Propagation Path Study Results

a. **Water Treatment Plant Radio Network Segment**

b. **Repeater (1.5 MG Tank) Radio Network Segment**



Wireless Network Propagation/Path Profile Analysis

Spirit Lake, IA Profiles – Ethernet Capable

Performed For:

HR Green
431 N. Phillips Ave, Suite 400
Sioux Falls, SD 57104

Analysis By:

Larson Data Communications
GE MDS Full Service Partner
for IA, MN, MT, ND, NE, SD & WY

Note

I. In-band Interference

Please be aware that this analysis cannot/does not take into account possible existing 902-928 MHz Industry, Scientific, or Medical (ISM) "License Free" frequency band electromagnetic activity in the proposed system area which may adversely affect the performance of the wireless network being considered.

We highly recommend that those involved in the decision making process for this project attempt to verify the presence of any existing co-located or nearby 900 MHz ISM Band/License Free system(s) that may need to be accommodated in some way, or with whose owners frequency coordination will be required in order to ensure a successful and well performing wireless data communications network installation.

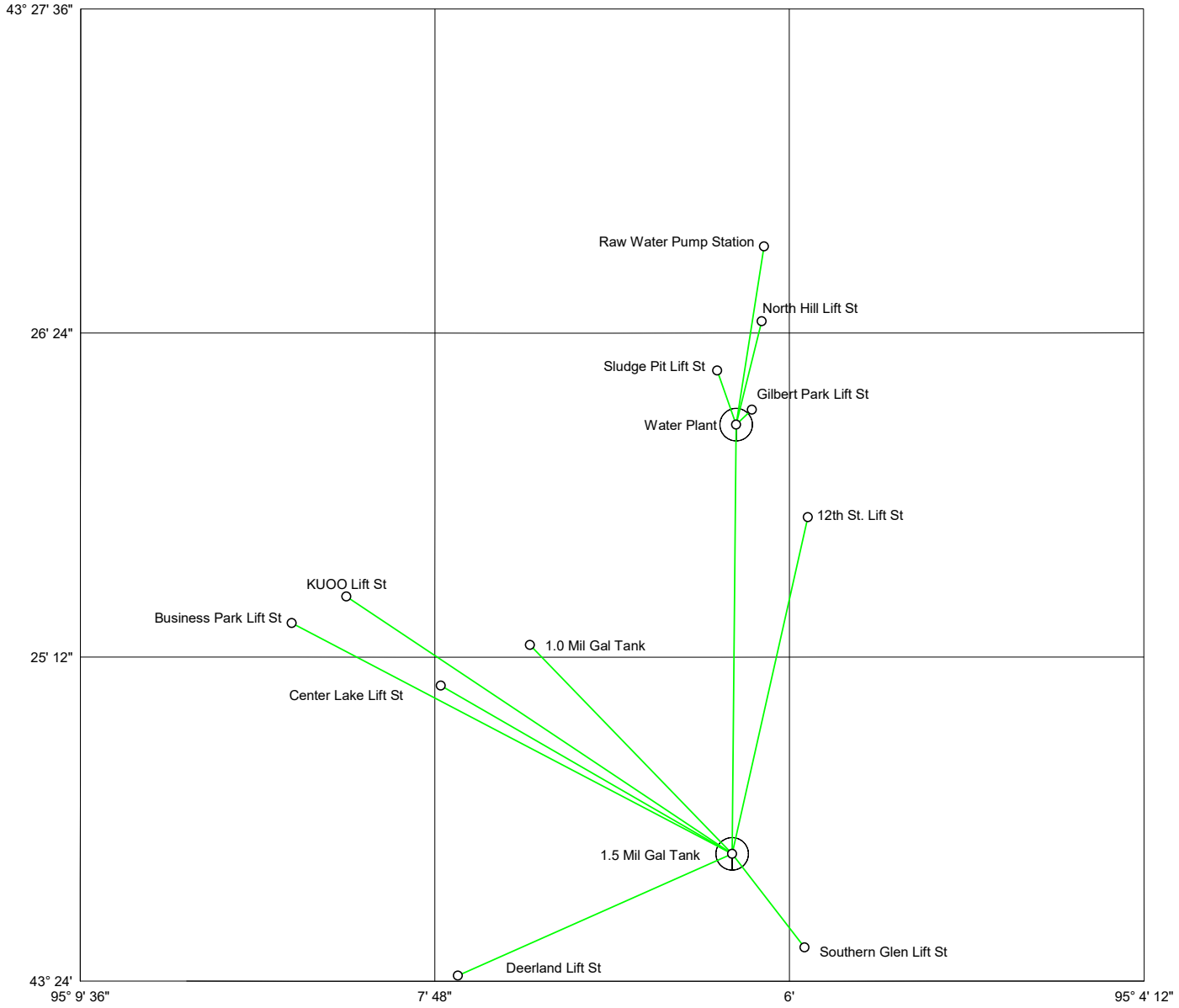
In addition to Public and Private Electric, Water, & Gas utility SCADA systems; other common users of this frequency spectrum are Wireless Internet Service Providers (WISPs) and other Rural Broadband Service Providers; Automatic Meter Reading (AMI/AMR) systems; Municipal, State, & Federal DOT Intelligent Transportation Systems; Local, State, & Federal Park Systems, Precision Agricultural & Road Construction ("RTK") operations, as well as other users. If such systems are/would be co-located on or nearby any communications towers or other antenna support structures, these systems CAN cause significant signal interference and system performance degradation if this "in-band" electromagnetic activity is not accounted for as part of any radio system planning process.

For more information or to receive assistance in evaluating or mitigating an electromagnetic interference issue, please contact Larson Data Communications, Inc. at 1 (866) 996-5521, or via e-mail at contact@larsondata.com.

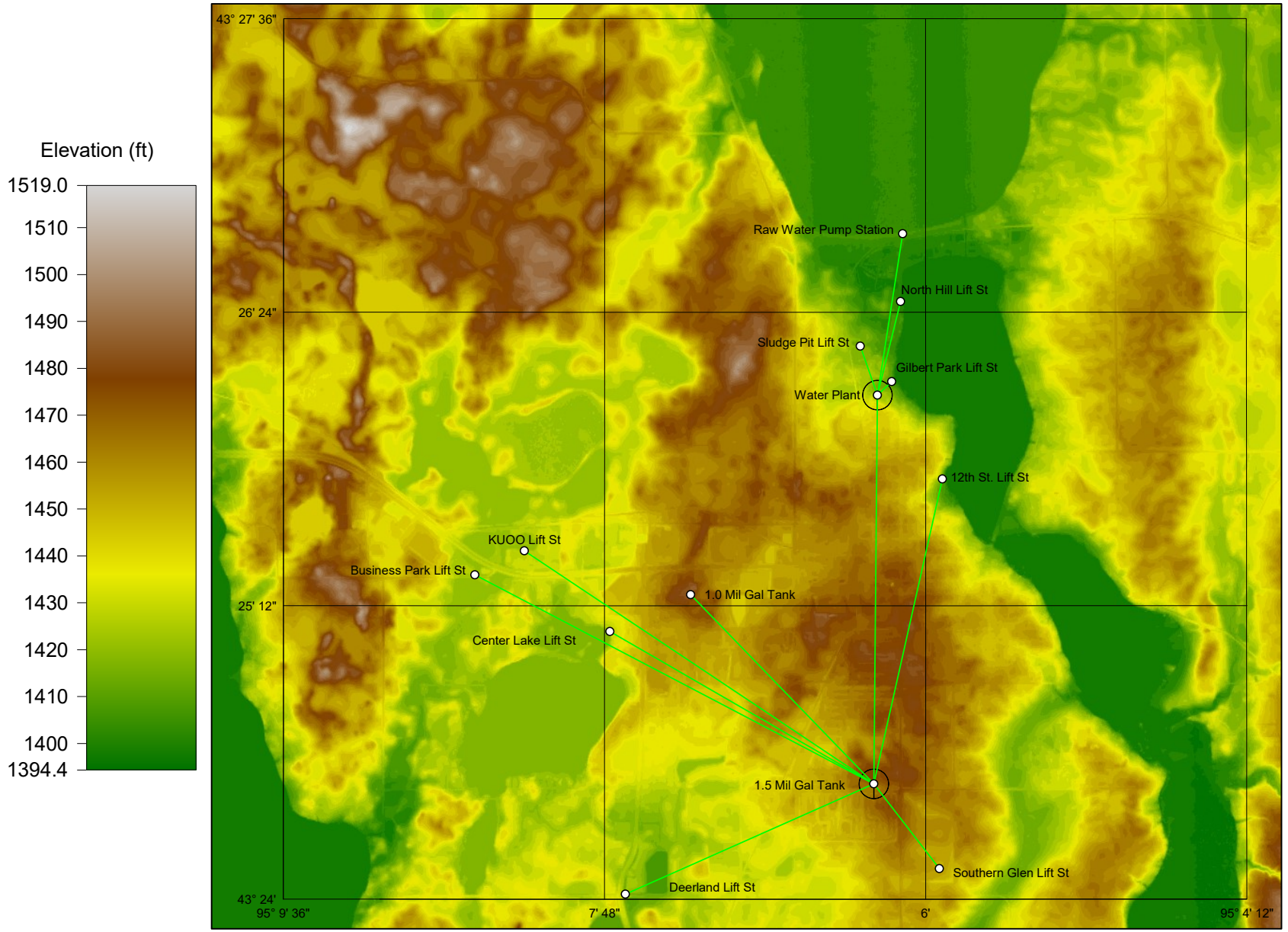
II. Disclaimer

The analysis results and calculated performance predictions contained herein assume - and are valid only to the extent that - each of the modeled antenna systems has been optimally installed with regard to height, orientation azimuth, polarization, and physical stability. Further, this analysis and any calculated performance predictions contained herein assumes and requires - relative to any other electromagnetically reflective or reactive part, appurtenance, fixture, or bracket of the intended support structure, or any other co-located antenna system - that each antenna has been positioned with adequate unencroached & unobstructed electromagnetic field generation space above, below, adjacent to, and forward of the proposed antenna system. To the extent that any of these required antenna system installation parameters are violated or otherwise compromised, distortion of the intended electromagnetic radiation pattern will occur and will, to varying degrees, adversely affect/degrade system performance - often resulting in the partial or total loss of usable wireless link connectivity and/or reliability.

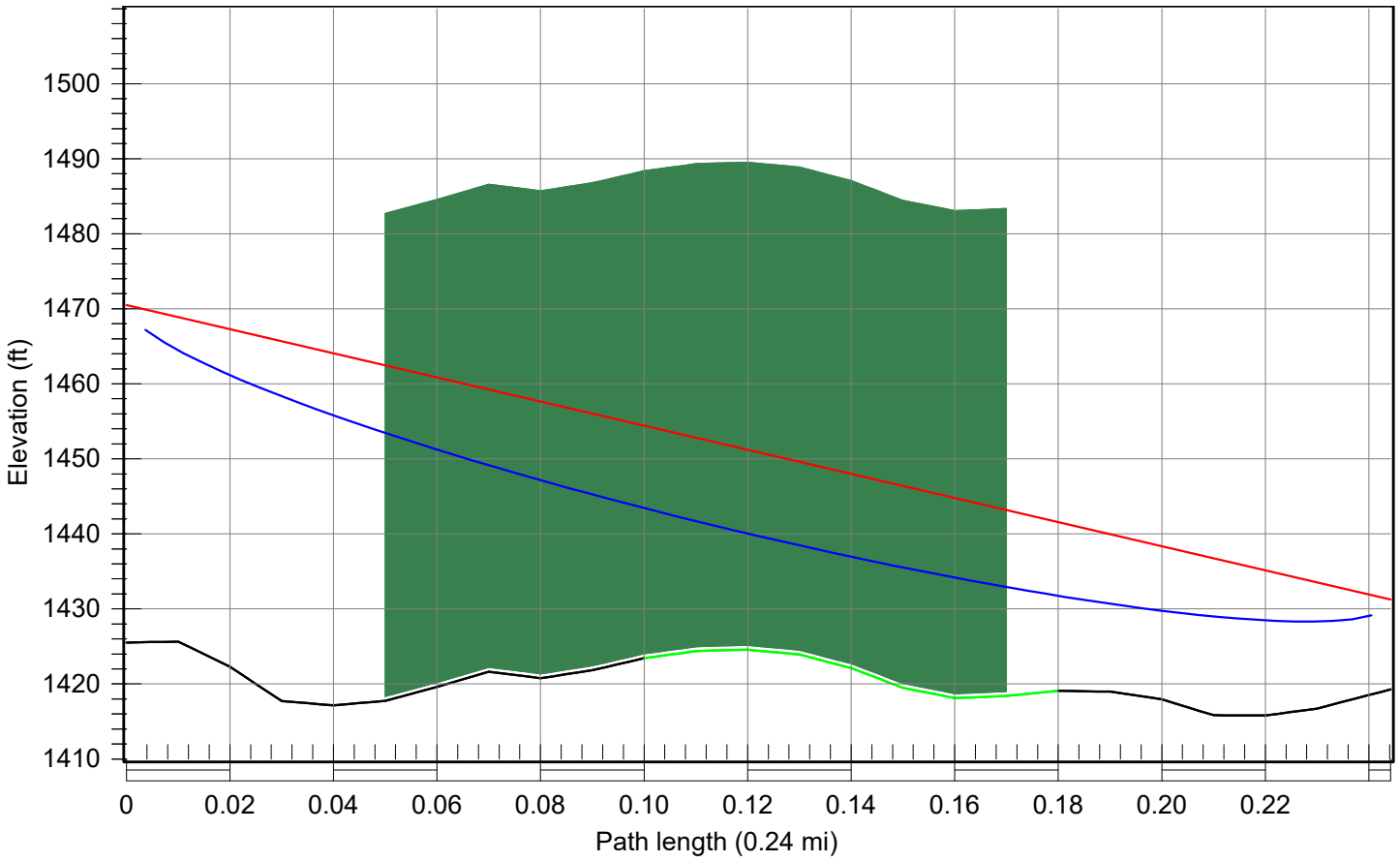
Spirit Lake, IA Network Overview
GE MDS Orbit NX915 @ 1.25 Mbps



Spirit Lake, IA Network Overview with Terrain Data
GE MDS Orbit NX915 @ 1.25 Mbps



Water Plant to Sludge Pit Lift St Terrain Profile



Water Plant	
Latitude	43 26 03.66 N
Longitude	095 06 16.20 W
Azimuth	340.61°
Elevation	1426 ft ASL
Antenna CL	45.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

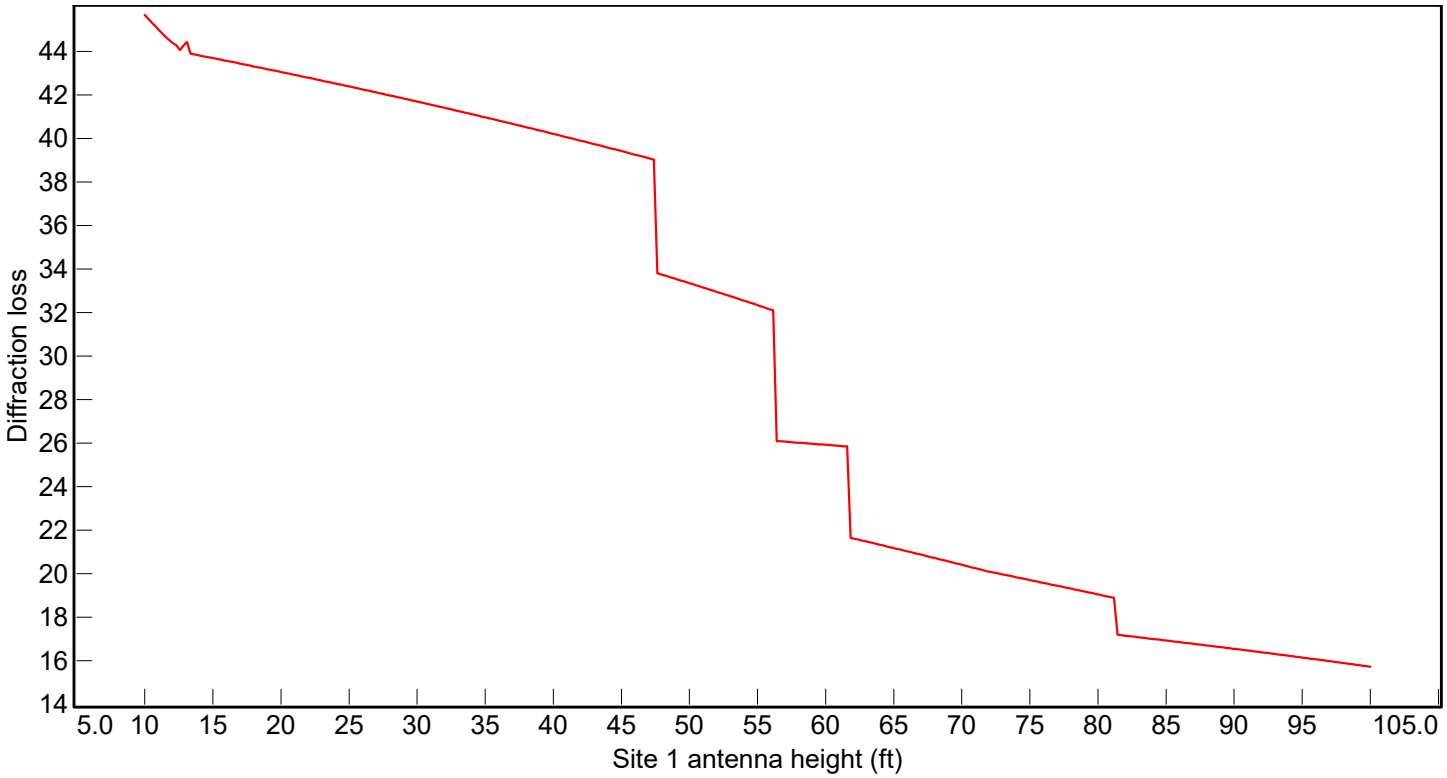
Sludge Pit Lift St	
Latitude	43 26 15.67 N
Longitude	095 06 22.00 W
Azimuth	160.61°
Elevation	1419 ft ASL
Antenna CL	12.0 ft AGL

Water Plant to Sludge Pit Lift St Link Summary

	Water Plant	Sludge Pit Lift St
Latitude	43 26 03.66 N	43 26 15.67 N
Longitude	095 06 16.20 W	095 06 22.00 W
True azimuth (°)	340.61	160.61
Elevation (ft)	1425.50	1419.27
Antenna model	BCD-87010 (TR)	RY-900B (TR)
Antenna gain (dBi)	12.15	12.15
Antenna height (ft)	45.00	12.00
Antenna azimuth (°)	0.00	
TX line model	LDF4-50A	LMR400
TX line length (ft)	90.00	25.00
TX line loss (dB)	2.01	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	0.24	
Free space loss (dB)	83.59	
Diffraction loss	21.43	
Net path loss (dB)	102.90	102.90
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	26.00
EIRP (dBm)	36.54	36.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-58.90	-57.90
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.01	0.01

Water Plant to Sludge Pit Lift St Obstruction Loss vs. Antenna Height Analysis

Sludge Pit Lift St @ 12’ / Water Plant @ 15’-100’

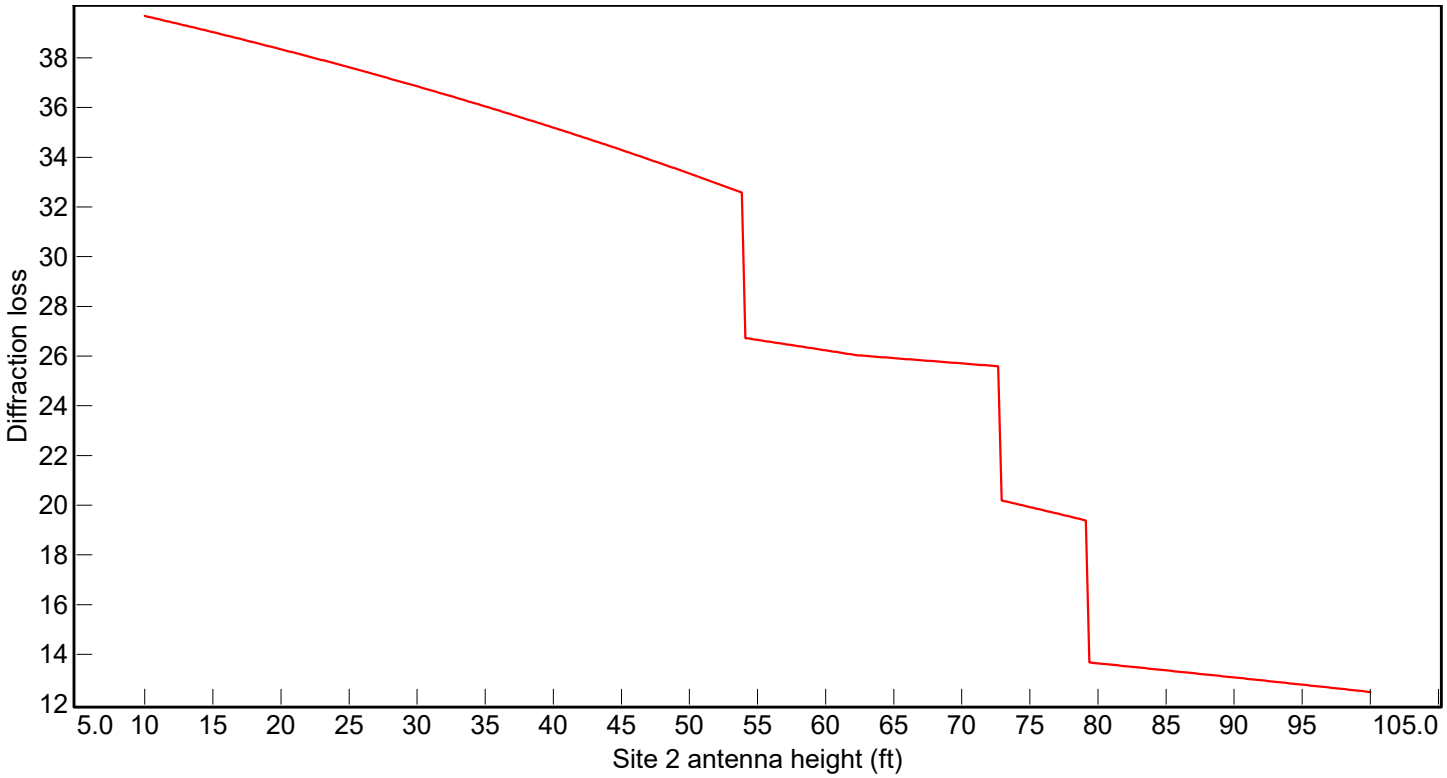


Variable parameter - Site 1 antenna height

Site 1 start antenna height (ft)	15
Site 1 end antenna height (ft)	100
Site 2 antenna height (ft)	12
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Sludge Pit Lift St to Water Plant Obstruction Loss vs. Antenna Height Analysis

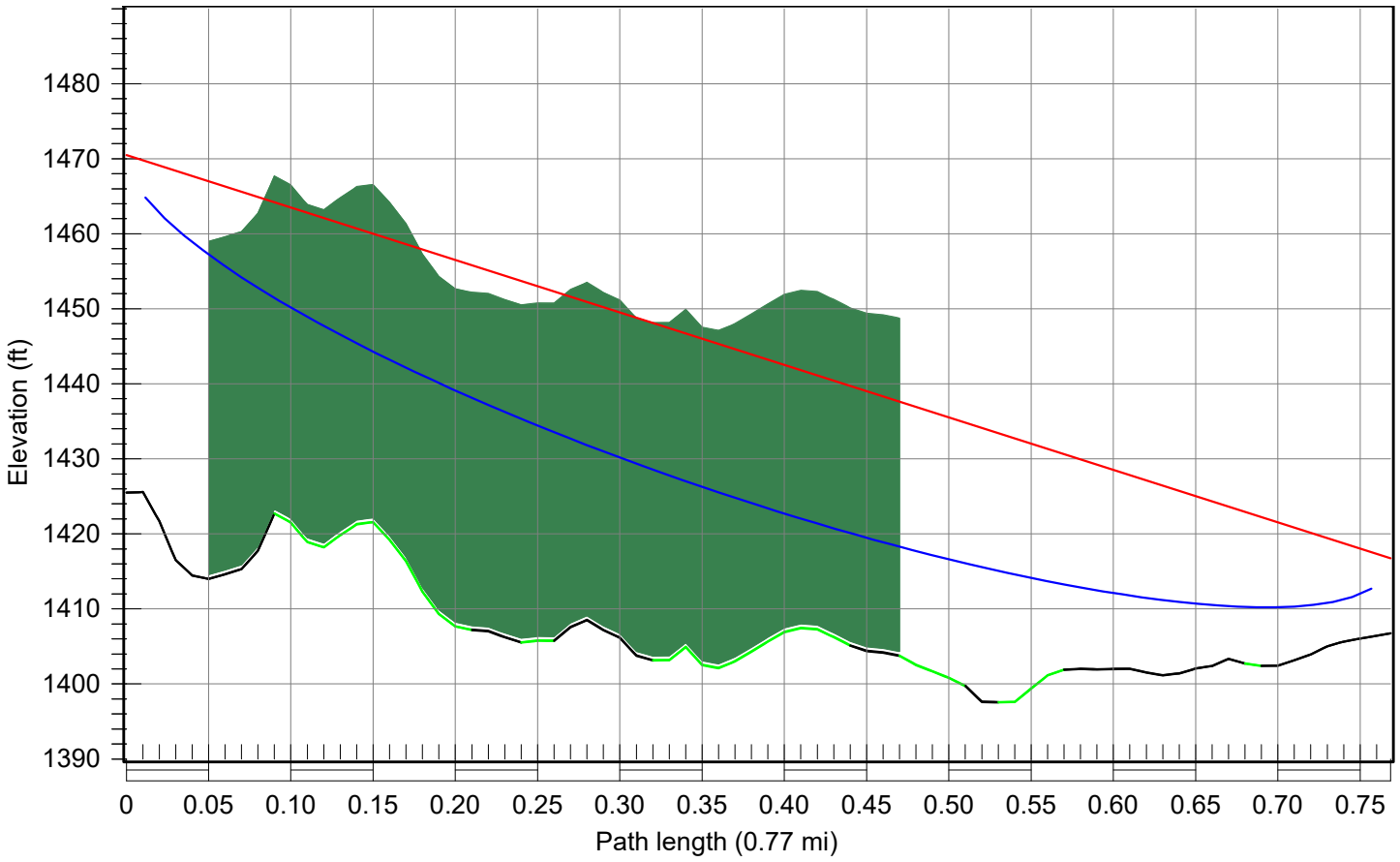
Water Plant @ 45’ / Sludge Pit Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	45
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Water Plant to Raw Water Pump Station Terrain Profile



Water Plant	
Latitude	43 26 03.66 N
Longitude	095 06 16.20 W
Azimuth	8.87°
Elevation	1426 ft ASL
Antenna CL	45.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

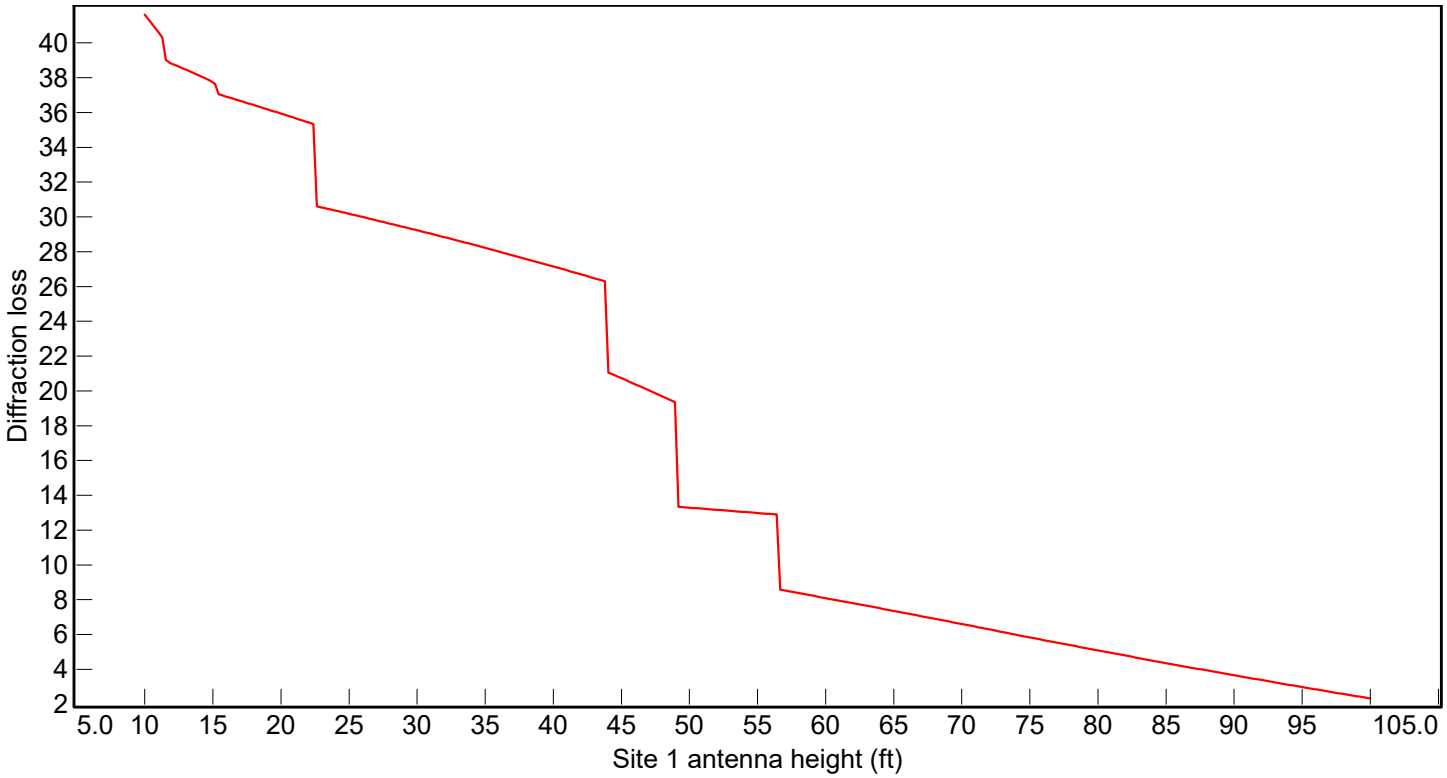
Raw Water Pump Station	
Latitude	43 26 43.25 N
Longitude	095 06 07.72 W
Azimuth	188.87°
Elevation	1407 ft ASL
Antenna CL	10.0 ft AGL

Water Plant to Raw Water Pump Station Link Summary

	Water Plant	Raw Water Pump Station
Latitude	43 26 03.66 N	43 26 43.25 N
Longitude	095 06 16.20 W	095 06 07.72 W
True azimuth (°)	8.87	188.87
Elevation (ft)	1425.50	1406.74
Antenna model	BCD-87010 (TR)	SP440-SF2SNF (TR)
Antenna gain (dBi)	12.15	7.15
Antenna height (ft)	45.00	10.00
Antenna azimuth (°)	0.00	
TX line model	LDF4-50A	LMR400
TX line length (ft)	90.00	25.00
TX line loss (dB)	2.01	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	0.77	
Free space loss (dB)	93.54	
Diffraction loss	7.57	
Net path loss (dB)	99.01	99.01
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	30.00
EIRP (dBm)	36.54	35.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-56.01	-59.01
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.06	0.12

Water Plant to Raw Water Pump Station Obstruction Loss vs. Antenna Height Analysis

Raw Water Pump Station @ 12’ / Water Plant @ 15’-100’

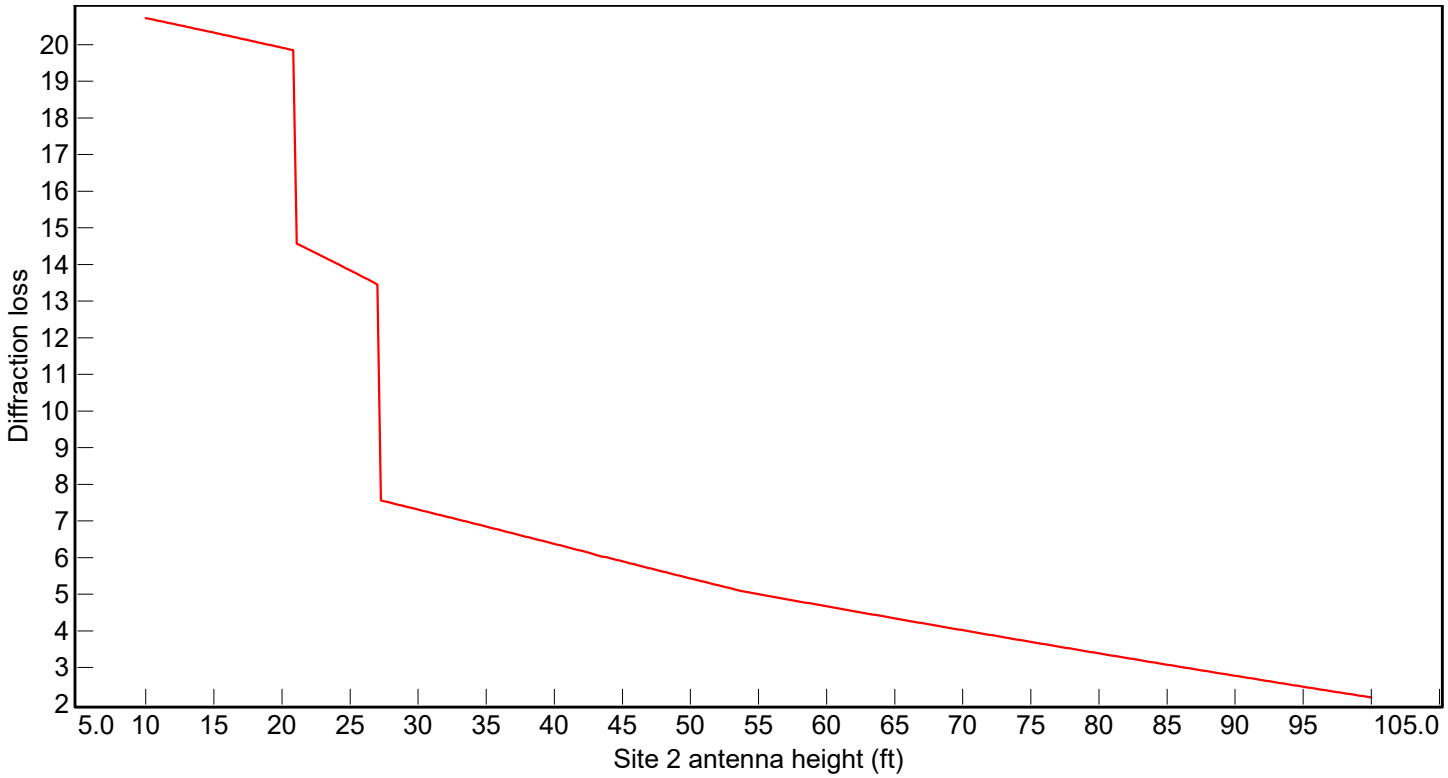


Variable parameter - Site 1 antenna height

Site 1 start antenna height (ft)	15
Site 1 end antenna height (ft)	100
Site 2 antenna height (ft)	12
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Raw Water Pump Station to Water Plant Obstruction Loss vs. Antenna Height Analysis

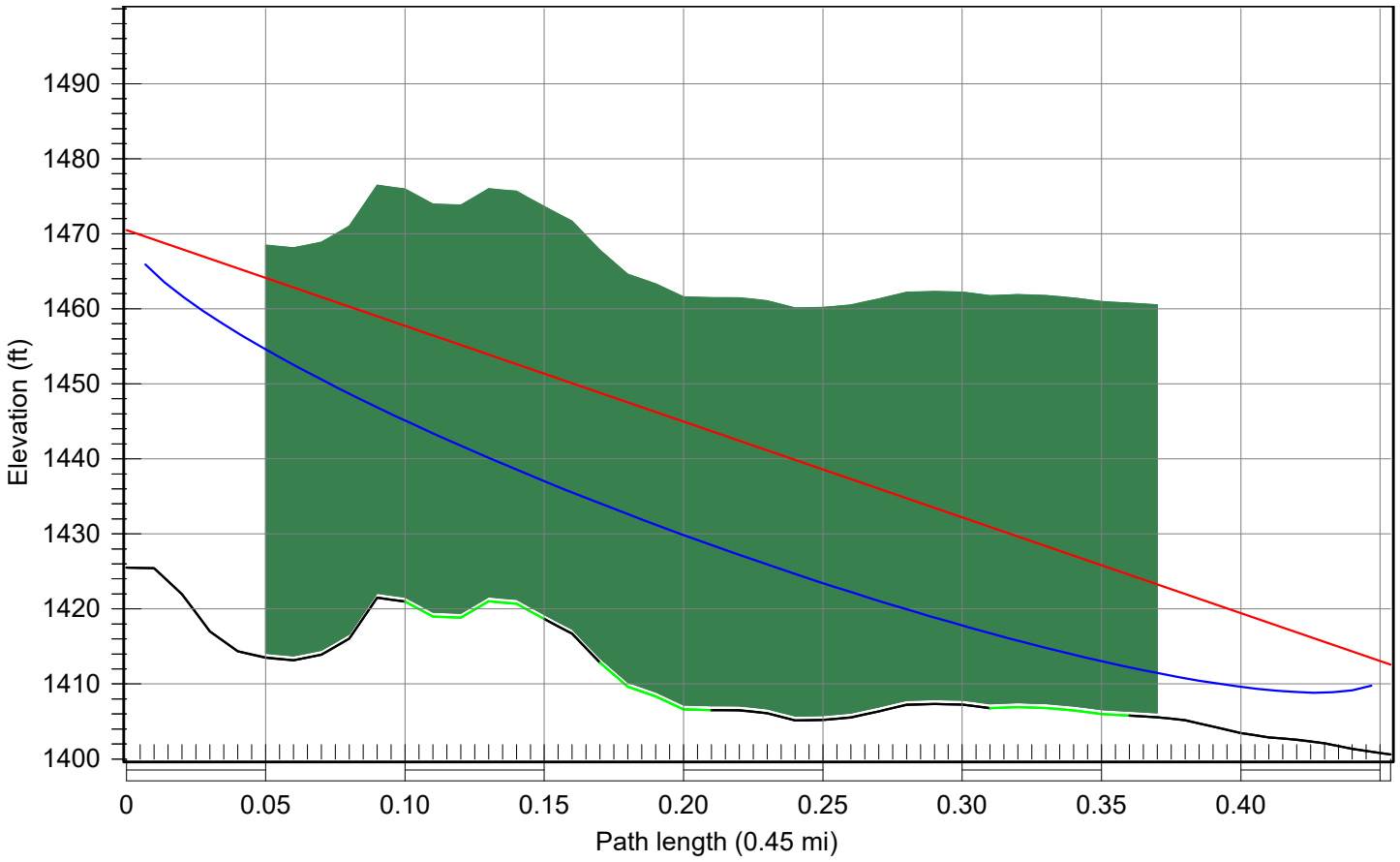
Water Plant @ 45’ / Raw Water Pump Station @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	45
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Water Plant to North Hill Lift St Terrain Profile



Water Plant	
Latitude	43 26 03.66 N
Longitude	095 06 16.20 W
Azimuth	13.85°
Elevation	1426 ft ASL
Antenna CL	45.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

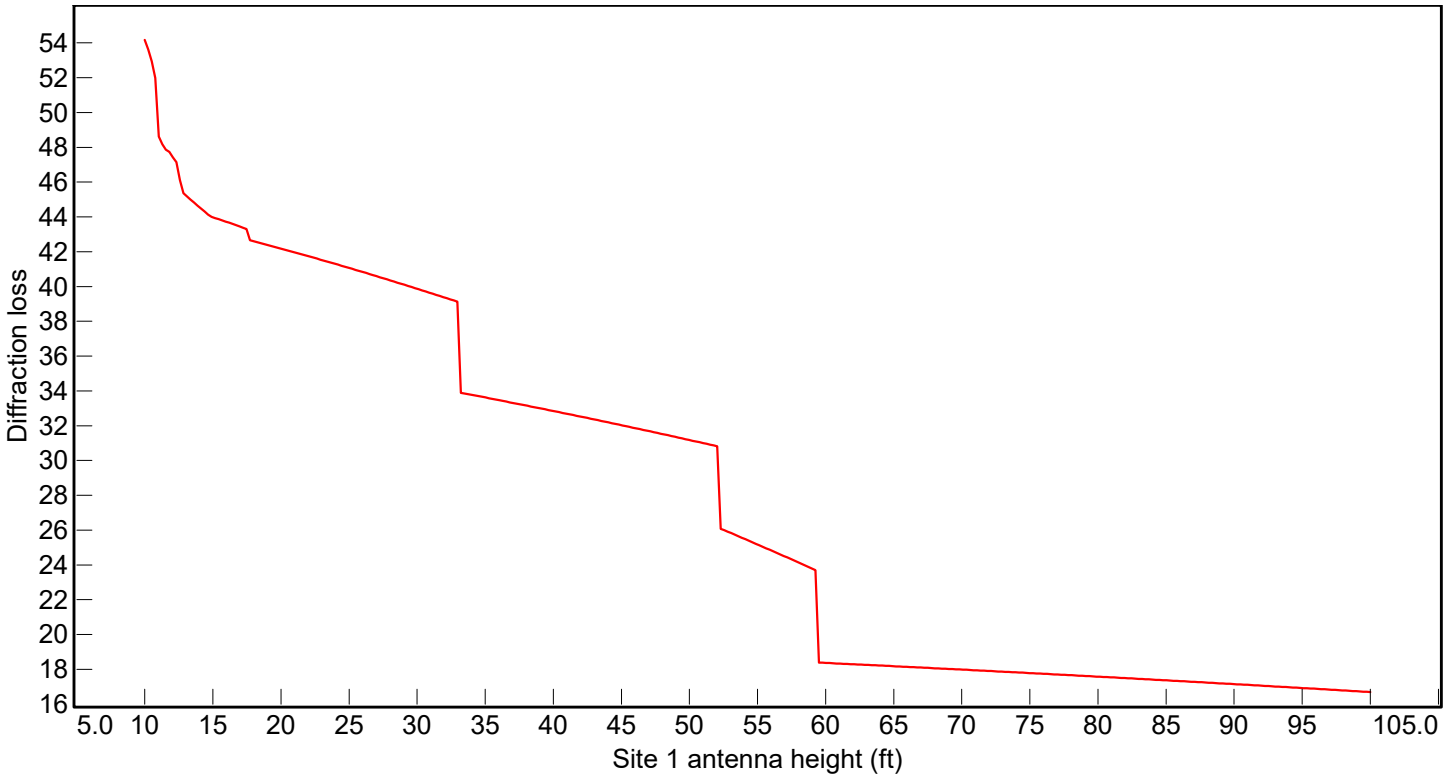
North Hill Lift St	
Latitude	43 26 26.63 N
Longitude	095 06 08.43 W
Azimuth	193.85°
Elevation	1401 ft ASL
Antenna CL	12.0 ft AGL

Water Plant to North Hill Lift St Link Summary

	Water Plant	North Hill Lift St
Latitude	43 26 03.66 N	43 26 26.63 N
Longitude	095 06 16.20 W	095 06 08.43 W
True azimuth (°)	13.85	193.85
Elevation (ft)	1425.50	1400.60
Antenna model	BCD-87010 (TR)	RY-900B (TR)
Antenna gain (dBi)	12.15	12.15
Antenna height (ft)	45.00	12.00
Antenna azimuth (°)	0.00	
TX line model	LDF4-50A	LMR400
TX line length (ft)	90.00	25.00
TX line loss (dB)	2.01	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	0.45	
Free space loss (dB)	88.97	
Diffraction loss	16.03	
Net path loss (dB)	100.89	100.89
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	26.00
EIRP (dBm)	36.54	36.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-58.89	-57.89
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.05	0.04

Water Plant to North Hill Lift St Obstruction Loss vs. Antenna Height Analysis

North Hill Lift St @ 12’ / Water Plant @ 15’-100’

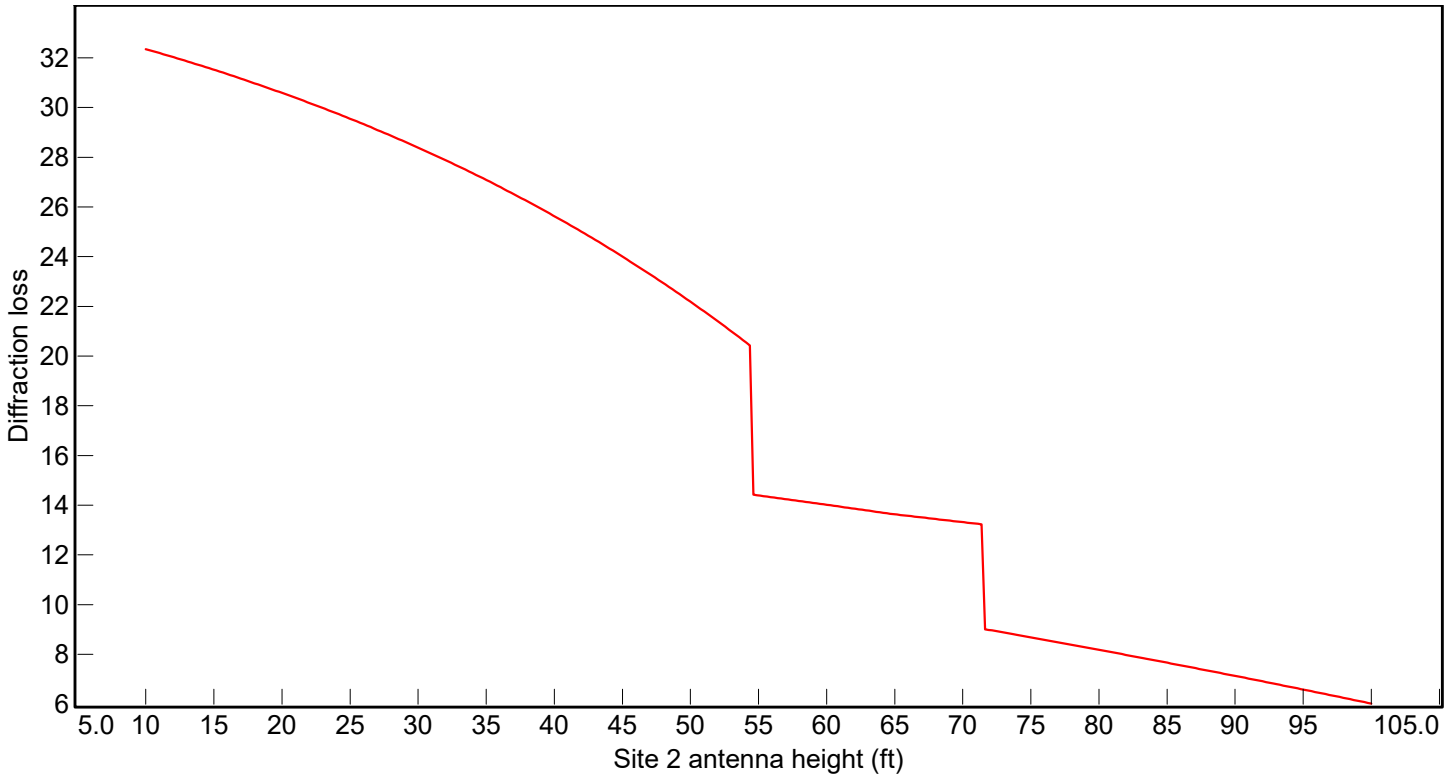


Variable parameter - Site 1 antenna height

Site 1 start antenna height (ft)	15
Site 1 end antenna height (ft)	100
Site 2 antenna height (ft)	12
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

North Hill Lift St to Water Plant Obstruction Loss vs. Antenna Height Analysis

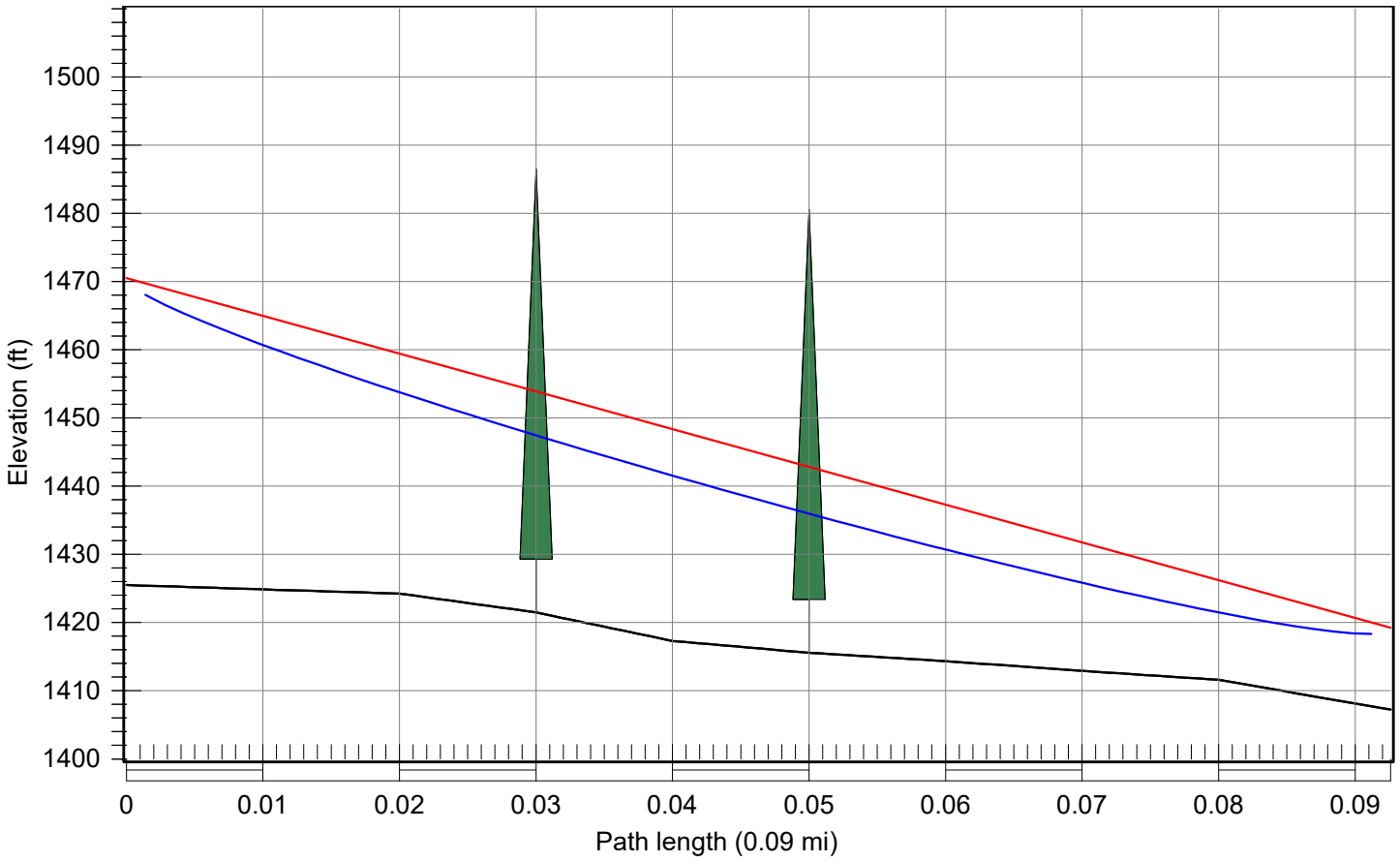
Water Plant @ 45’ / North Hill Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	45
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Water Plant to Gilbert Park Lift St Terrain Profile



Water Plant	
Latitude	43 26 03.66 N
Longitude	095 06 16.20 W
Azimuth	46.55°
Elevation	1426 ft ASL
Antenna CL	45.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

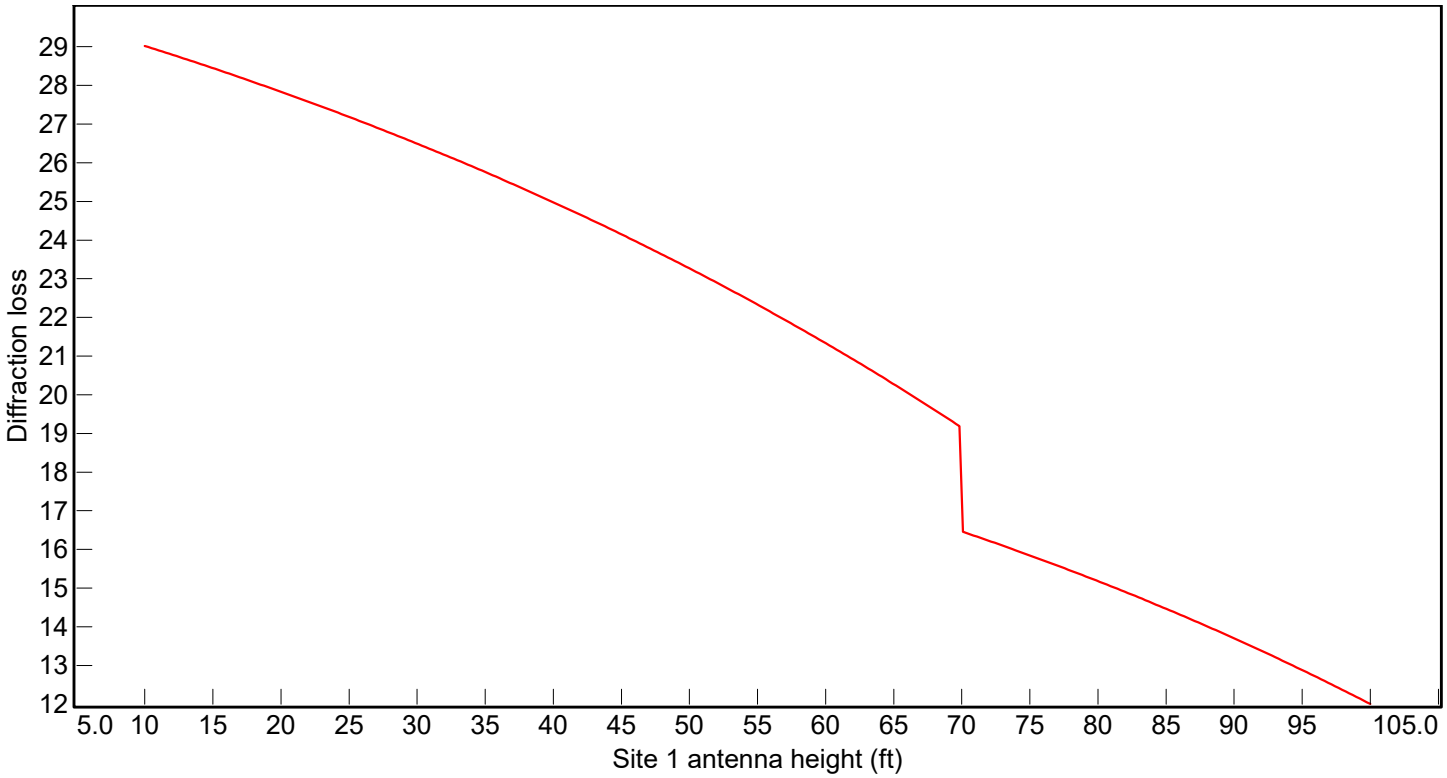
Gilbert Park Lift St	
Latitude	43 26 06.98 N
Longitude	095 06 11.39 W
Azimuth	226.55°
Elevation	1407 ft ASL
Antenna CL	12.0 ft AGL

Water Plant to Gilbert Park Lift St Link Summary

	Water Plant	Gilbert Park Lift St
Latitude	43 26 03.66 N	43 26 06.98 N
Longitude	095 06 16.20 W	095 06 11.39 W
True azimuth (°)	46.55	226.55
Elevation (ft)	1425.50	1407.24
Antenna model	BCD-87010 (TR)	SP440-SF2SNF (TR)
Antenna gain (dBi)	12.15	7.15
Antenna height (ft)	45.00	12.00
Antenna azimuth (°)	0.00	
TX line model	LDF4-50A	LMR400
TX line length (ft)	90.00	25.00
TX line loss (dB)	2.01	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	0.09	
Free space loss (dB)	75.21	
Diffraction loss	16.15	
Net path loss (dB)	84.25	84.25
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	30.00
EIRP (dBm)	36.54	35.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-46.25	-49.25
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.00	0.00

Water Plant to Gilbert Park Lift St Obstruction Loss vs. Antenna Height Analysis

Gilbert Park Lift St @ 12’ / Water Plant @ 15’-100’

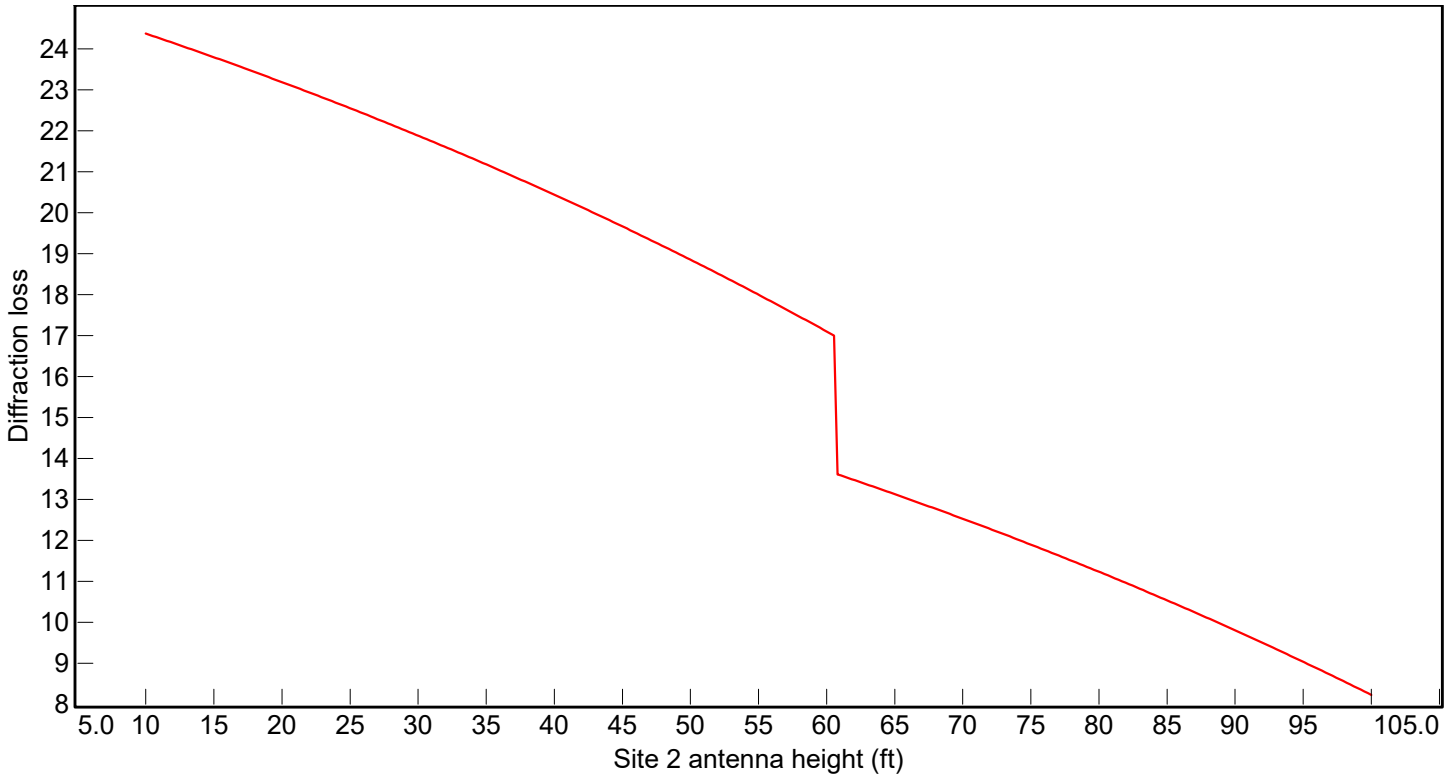


Variable parameter - Site 1 antenna height

Site 1 start antenna height (ft)	15
Site 1 end antenna height (ft)	100
Site 2 antenna height (ft)	12
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Gilbert Park Lift St to Water Plant Obstruction Loss vs. Antenna Height Analysis

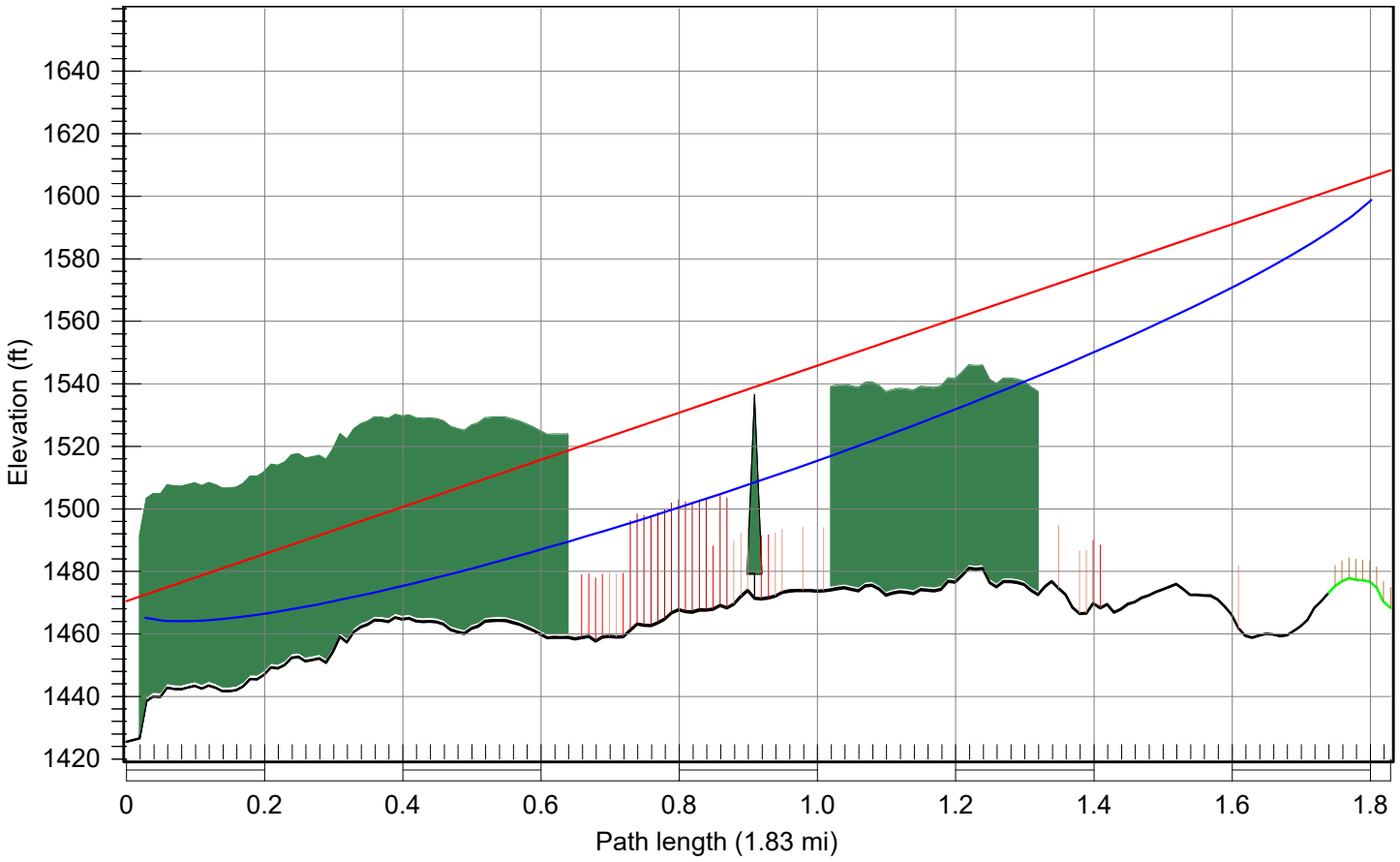
Water Plant @ 45’ / Gilbert Park Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	45
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Water Plant to 1.5 Mil Gal Tank Terrain Profile



Water Plant	
Latitude	43 26 03.66 N
Longitude	095 06 16.20 W
Azimuth	180.54°
Elevation	1426 ft ASL
Antenna CL	45.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

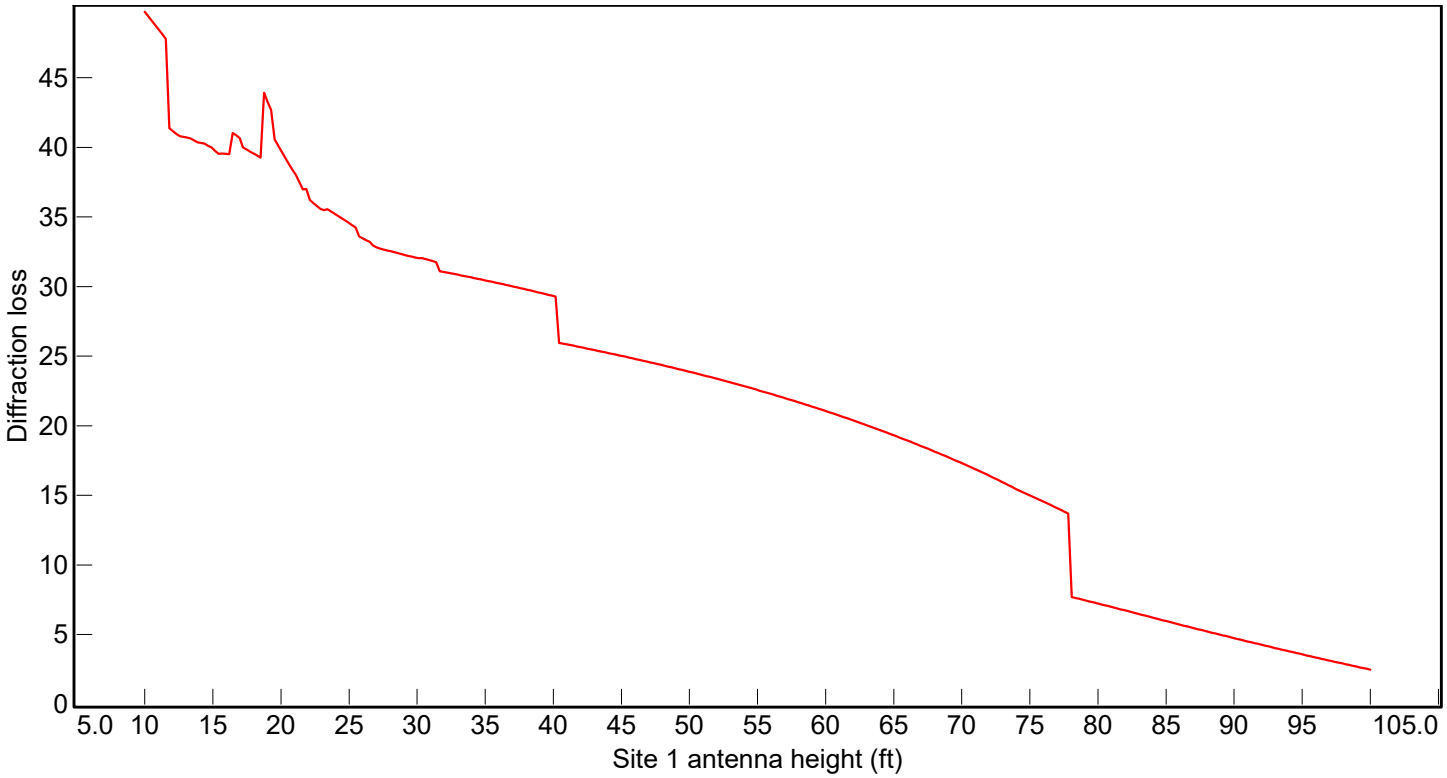
1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	0.54°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Water Plant to 1.5 Mil Gal Tank Link Summary

	Water Plant	1.5 Mil Gal Tank
Latitude	43 26 03.66 N	43 24 28.29 N
Longitude	095 06 16.20 W	095 06 17.43 W
True azimuth (°)	180.54	0.54
Elevation (ft)	1425.50	1468.33
Antenna model	BCD-87010 (TR)	RY-900B (TR)
Antenna gain (dBi)	12.15	12.15
Antenna height (ft)	45.00	140.00
Antenna azimuth (°)		0.00
TX line model	LDF4-50A	AVA5-50
TX line length (ft)	90.00	250.00
TX line loss (dB)	2.01	2.72
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	1.83	
Free space loss (dB)	101.07	
Diffraction loss	25.01	
Net path loss (dB)	107.73	107.73
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	28.00	29.00
EIRP (dBm)	37.54	37.83
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-78.73	-79.73
Annual multipath availability (%)	99.99998	99.99997
Annual multipath unavailability (sec)	7.74	9.75

Water Plant to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

1.5 Mil Gal Tank @ 140’ / Water Plant @ 15’-100’

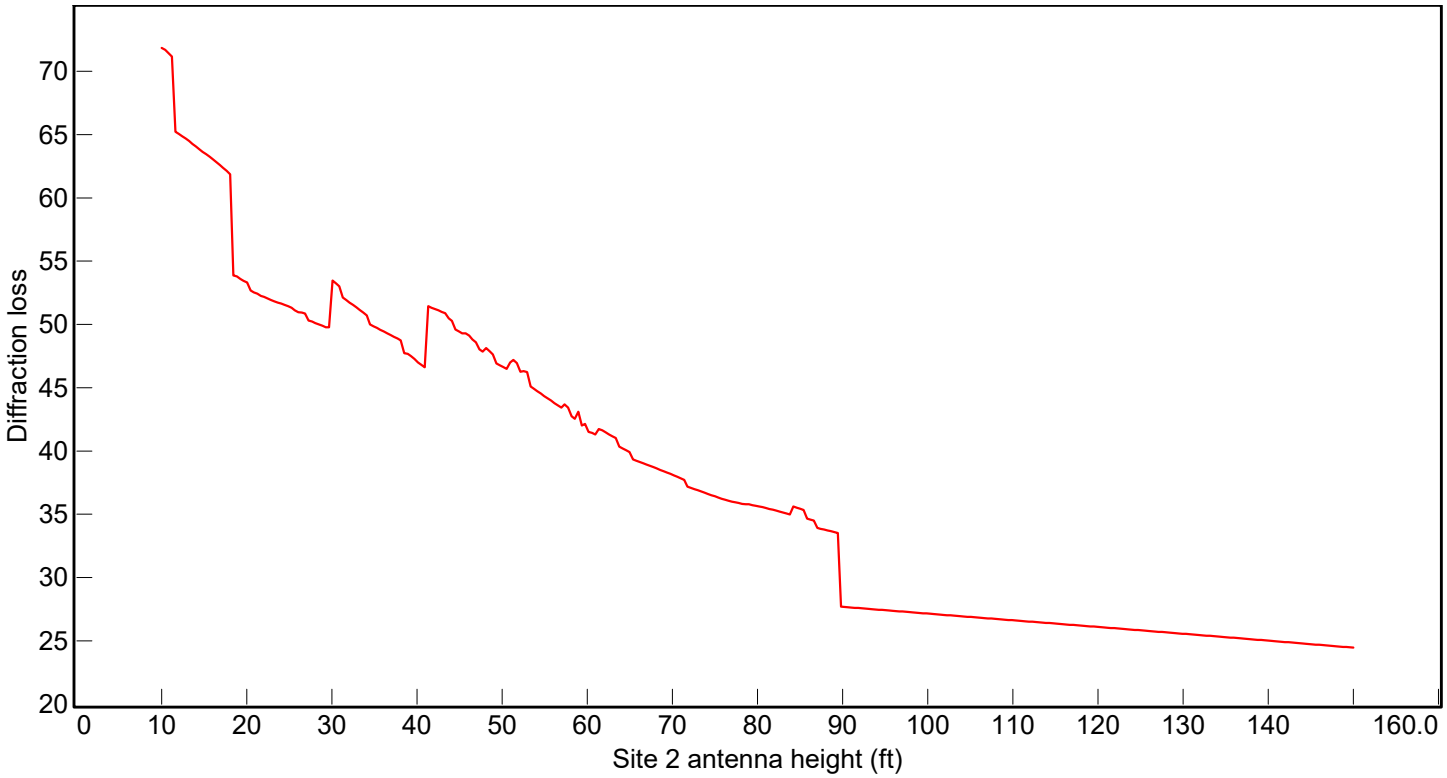


Variable parameter - Site 1 antenna height

Site 1 start antenna height (ft)	15
Site 1 end antenna height (ft)	100
Site 2 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to Water Plant Obstruction Loss vs. Antenna Height Analysis

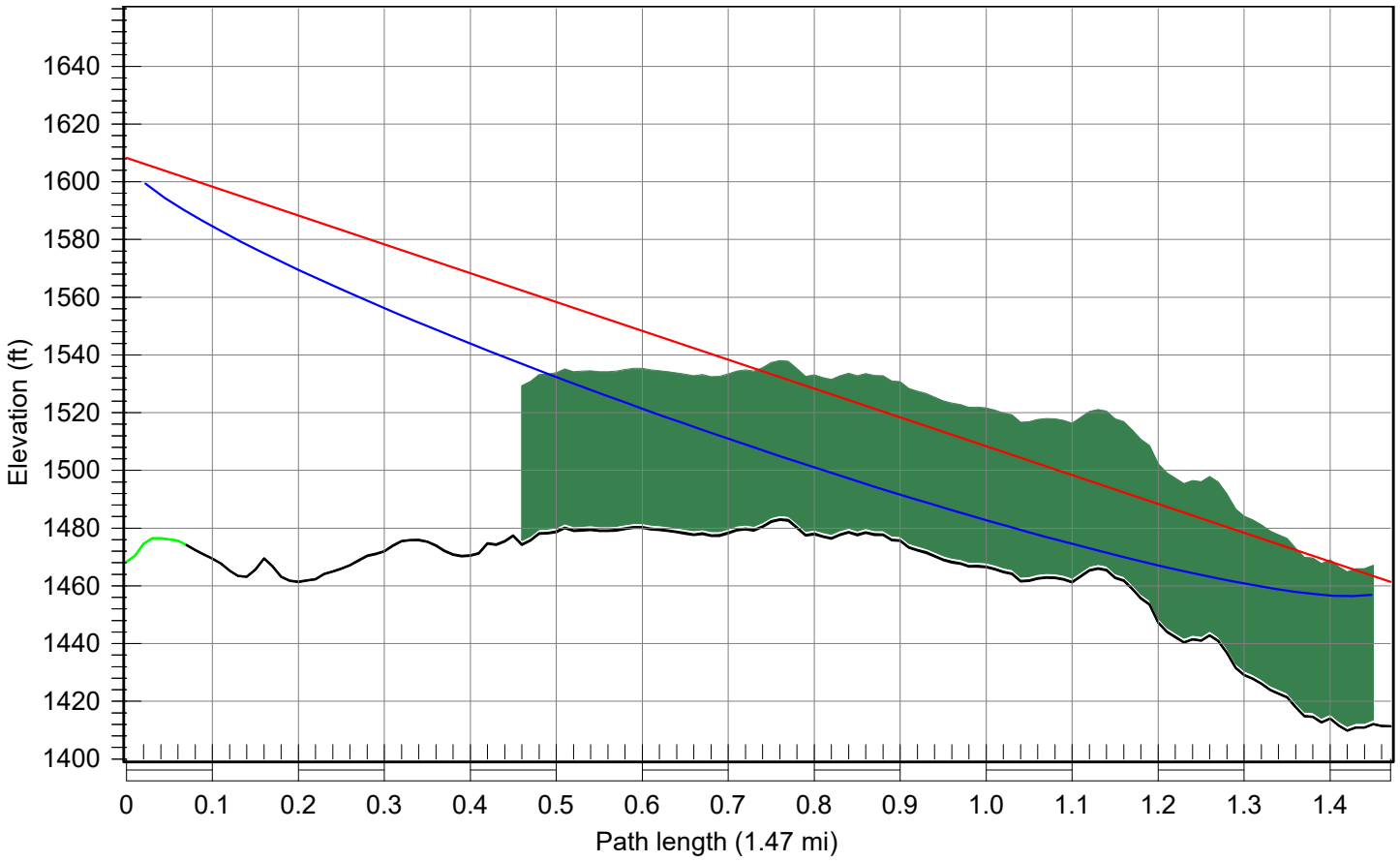
Water Plant @ 45’ / 1.5 Mil Gal Tank @ 15’-150’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	150
Site 1 antenna height (ft)	45
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to 12th St. Lift St Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	12.65°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

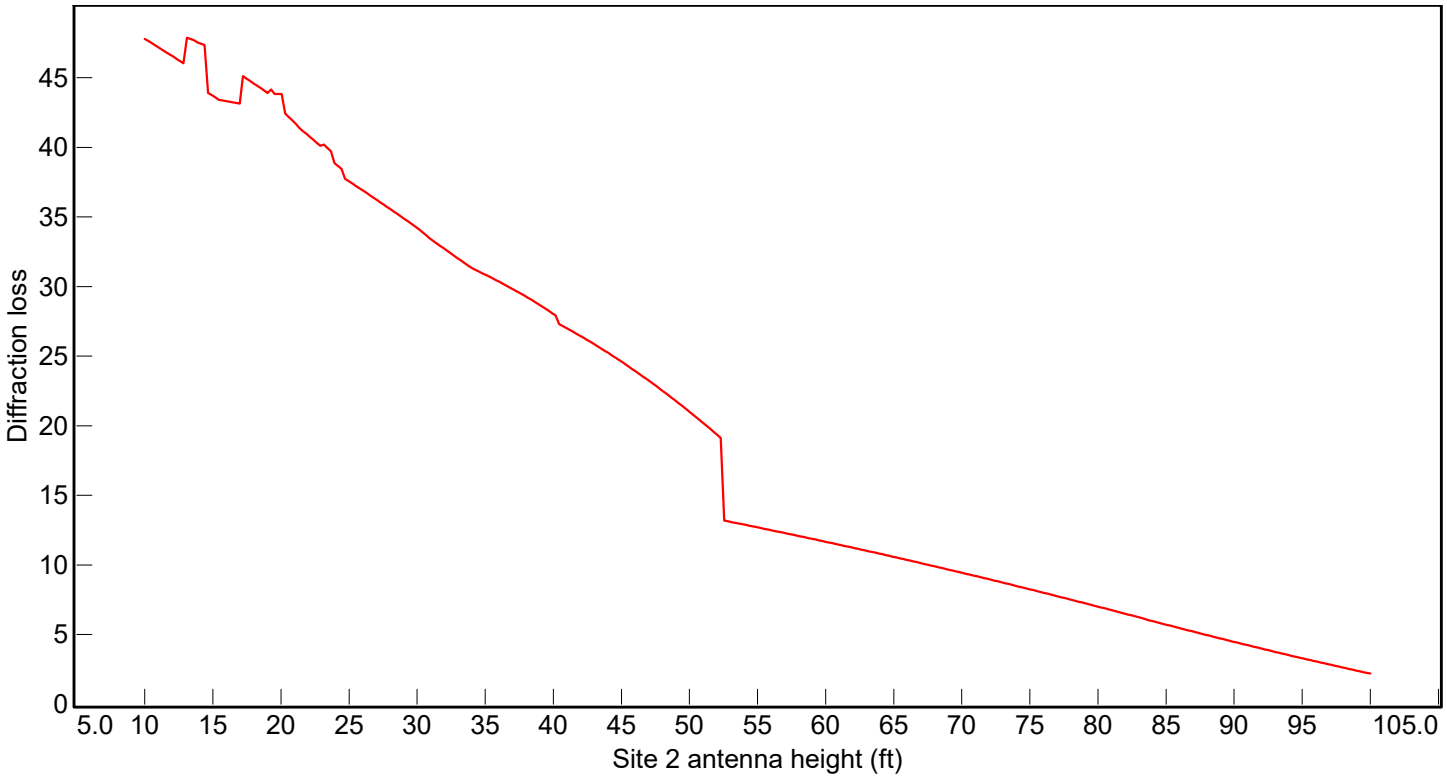
12th St. Lift St	
Latitude	43 25 43.09 N
Longitude	095 05 54.39 W
Azimuth	192.66°
Elevation	1411 ft ASL
Antenna CL	50.0 ft AGL

1.5 Mil Gal Tank to 12th St. Lift St Link Summary

	1.5 Mil Gal Tank	12th St. Lift St
Latitude	43 24 28.29 N	43 25 43.09 N
Longitude	095 06 17.43 W	095 05 54.39 W
True azimuth (°)	12.65	192.66
Elevation (ft)	1468.33	1411.33
Antenna model	ANT940F10 (TR)	RY-900B (TR)
Antenna gain (dBi)	12.15	12.15
Antenna height (ft)	140.00	50.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LDF4-50A
TX line length (ft)	175.00	75.00
TX line loss (dB)	1.91	1.67
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	1.47	
Free space loss (dB)	99.18	
Diffraction loss	21.01	
Net path loss (dB)	100.67	100.67
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	27.00
EIRP (dBm)	36.64	36.88
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-73.67	-73.67
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	1.25	1.25

12th St. Lift St to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

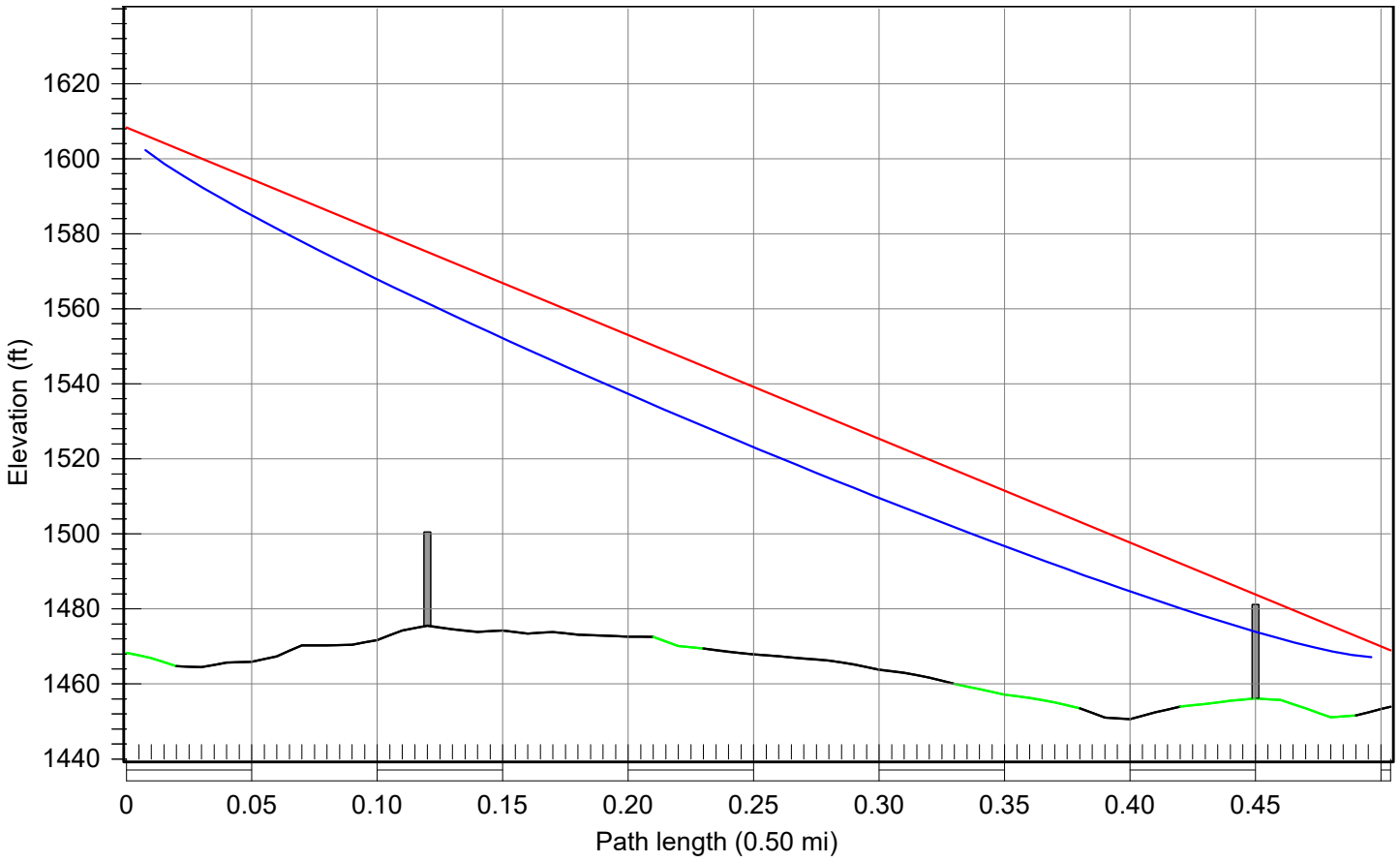
1.5 Mil Gal Tank @ 140’ / 12th St. Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to Southern Glen Lift St Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	142.35°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

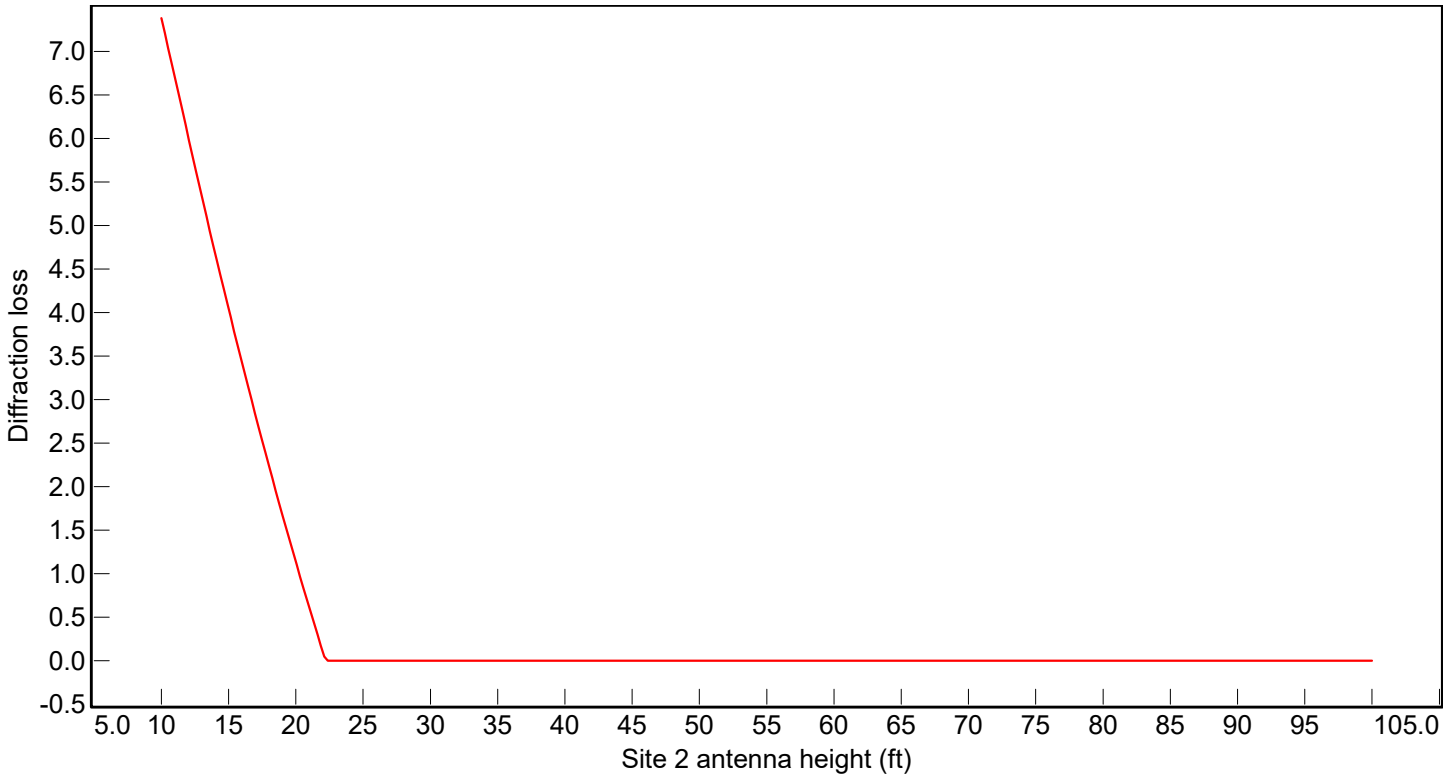
Southern Glen Lift St	
Latitude	43 24 07.49 N
Longitude	095 05 55.42 W
Azimuth	322.35°
Elevation	1454 ft ASL
Antenna CL	15.0 ft AGL

1.5 Mil Gal Tank to Southern Glen Lift St Link Summary

	1.5 Mil Gal Tank	Southern Glen Lift St
Latitude	43 24 28.29 N	43 24 07.49 N
Longitude	095 06 17.43 W	095 05 55.42 W
True azimuth (°)	142.35	322.35
Elevation (ft)	1468.33	1453.95
Antenna model	ANT940F10 (TR)	SP440-SF2SNF (TR)
Antenna gain (dBi)	12.15	7.15
Antenna height (ft)	140.00	15.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LMR400
TX line length (ft)	175.00	25.00
TX line loss (dB)	1.91	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	0.50	
Free space loss (dB)	89.89	
Diffraction loss	4.04	
Net path loss (dB)	78.72	78.72
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	30.00
EIRP (dBm)	36.64	35.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-48.72	-51.72
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.00	0.00

Southern Glen Lift St to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

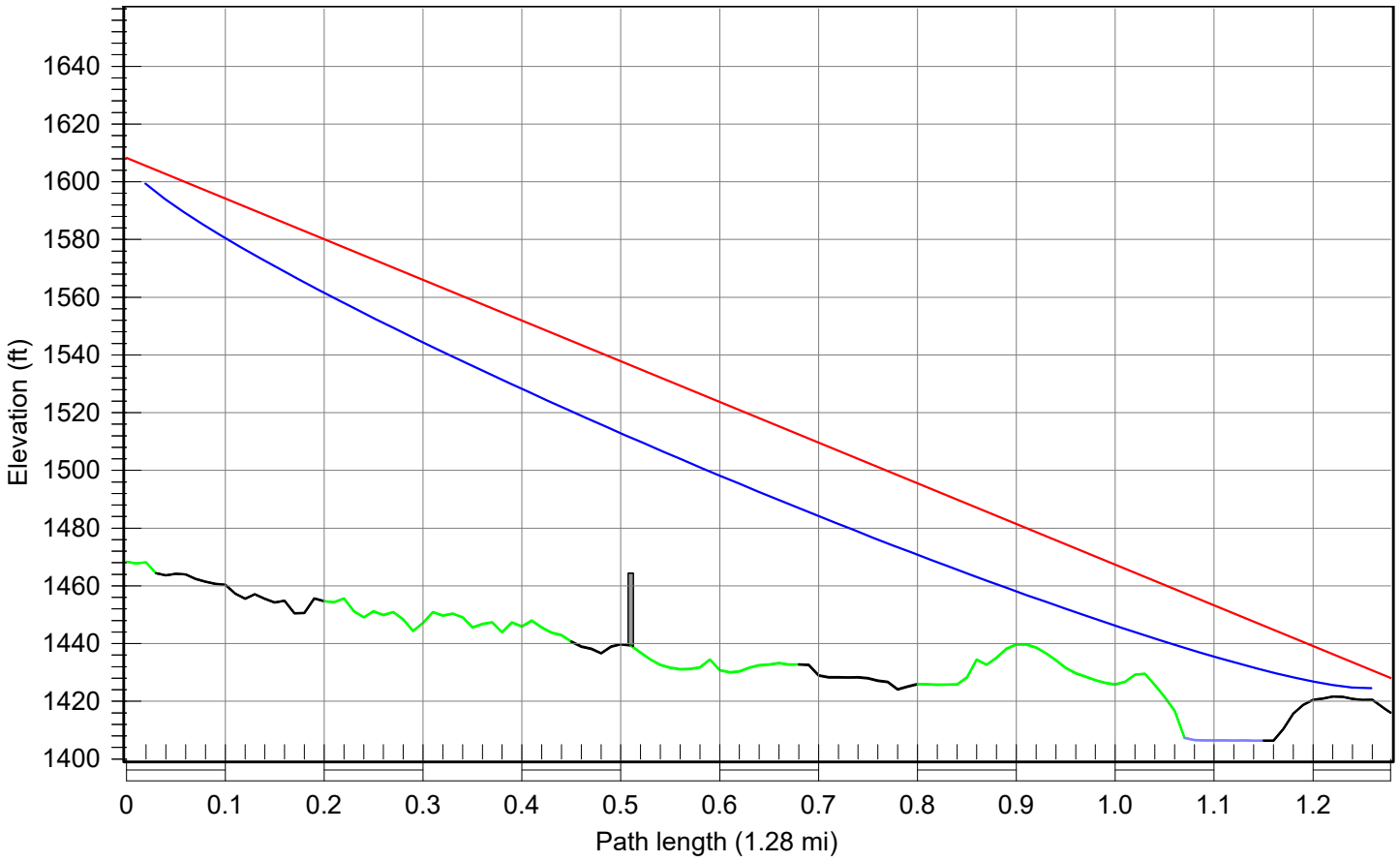
1.5 Mil Gal Tank @ 140’ / Southern Glen Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to Deerland Lift St Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	246.09°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

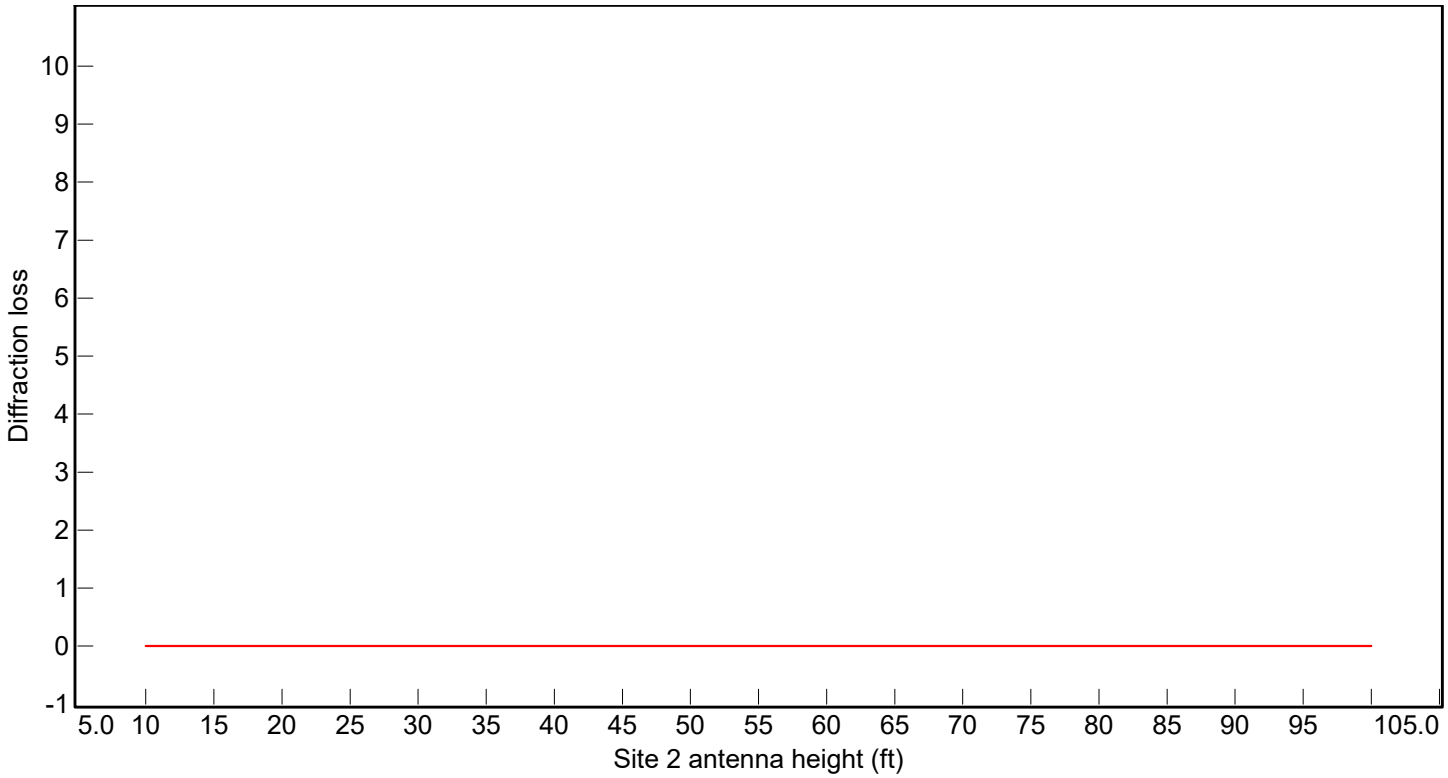
Deerland Lift St	
Latitude	43 24 01.26 N
Longitude	095 07 41.00 W
Azimuth	66.07°
Elevation	1416 ft ASL
Antenna CL	12.0 ft AGL

1.5 Mil Gal Tank to Deerland Lift St Link Summary

	1.5 Mil Gal Tank	Deerland Lift St
Latitude	43 24 28.29 N	43 24 01.26 N
Longitude	095 06 17.43 W	095 07 41.00 W
True azimuth (°)	246.09	66.07
Elevation (ft)	1468.33	1416.06
Antenna model	ANT940F10 (TR)	SP440-SF2SNF (TR)
Antenna gain (dBi)	12.15	7.15
Antenna height (ft)	140.00	12.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LMR400
TX line length (ft)	175.00	25.00
TX line loss (dB)	1.91	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	1.28	
Free space loss (dB)	97.96	
Net path loss (dB)	82.76	82.76
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	30.00
EIRP (dBm)	36.64	35.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-52.76	-55.76
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.01	0.01

Deerland Lift St to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

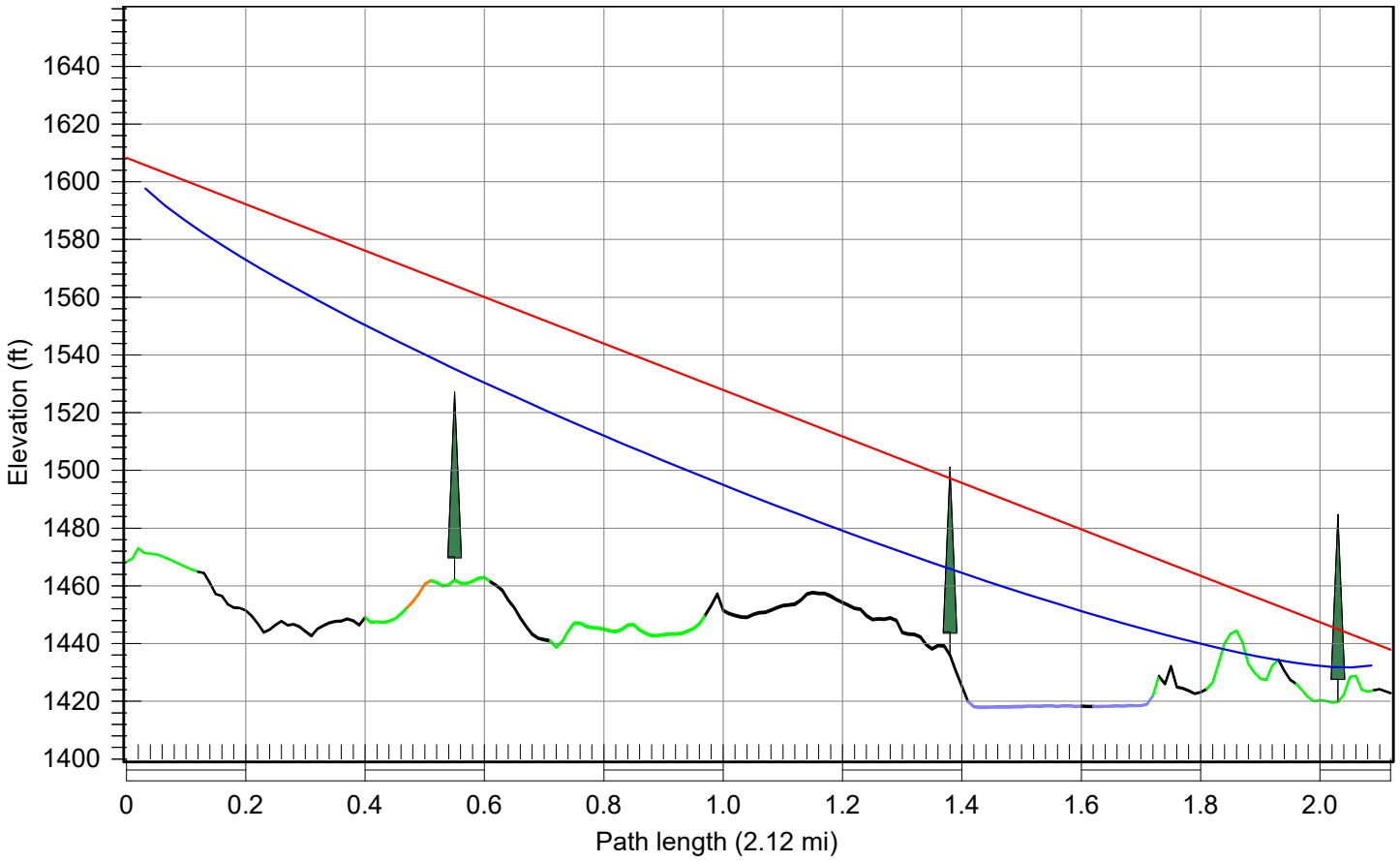
1.5 Mil Gal Tank @ 140’ / Deerland Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to Business Park Lift St Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	297.67°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

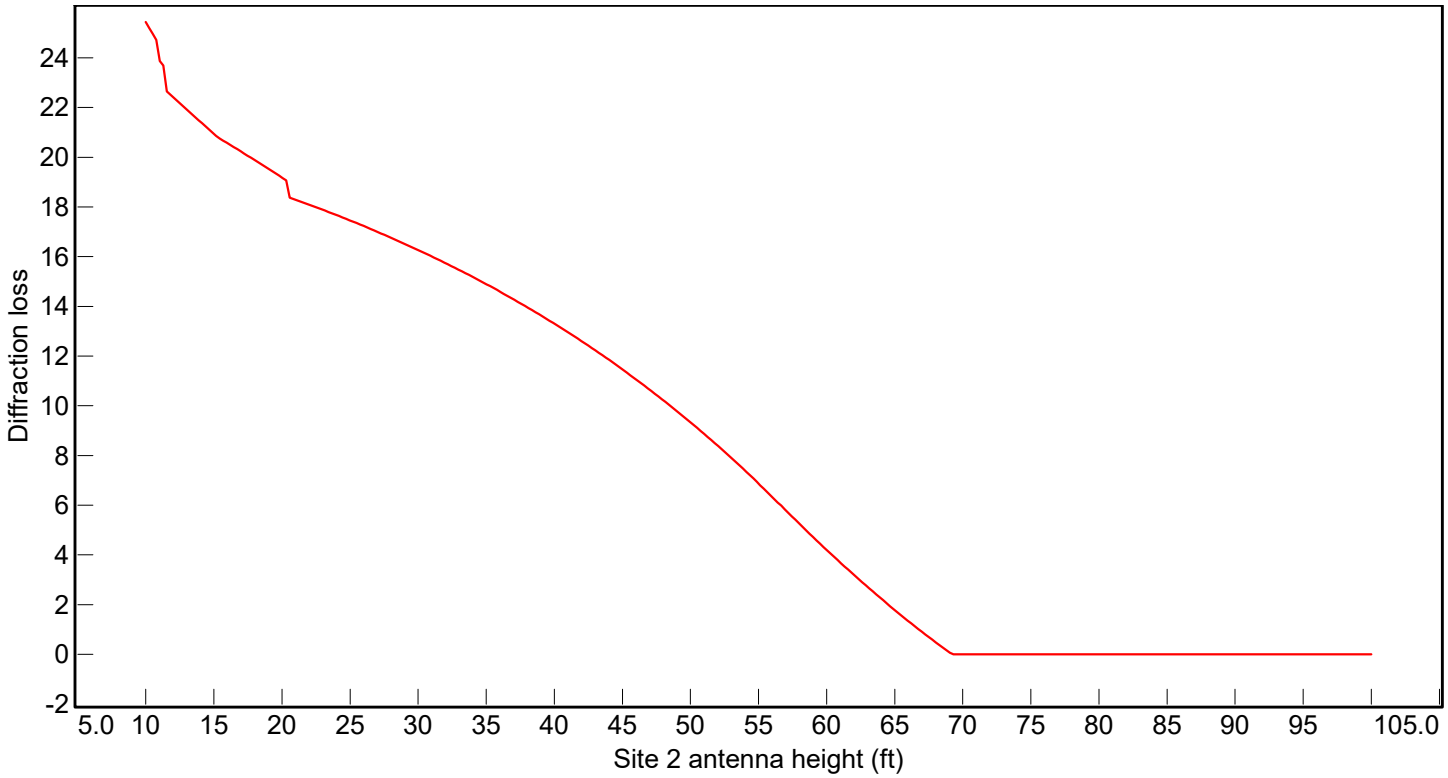
Business Park Lift St	
Latitude	43 25 19.56 N
Longitude	095 08 31.62 W
Azimuth	117.65°
Elevation	1423 ft ASL
Antenna CL	15.0 ft AGL

1.5 Mil Gal Tank to Business Park Lift St Link Summary

	1.5 Mil Gal Tank	Business Park Lift St
Latitude	43 24 28.29 N	43 25 19.56 N
Longitude	095 06 17.43 W	095 08 31.62 W
True azimuth (°)	297.67	117.65
Elevation (ft)	1468.33	1422.83
Antenna model	ANT940F10 (TR)	RY-900B (TR)
Antenna gain (dBi)	12.15	12.15
Antenna height (ft)	140.00	15.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LMR400
TX line length (ft)	175.00	25.00
TX line loss (dB)	1.91	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	2.12	
Free space loss (dB)	102.35	
Diffraction loss	20.93	
Net path loss (dB)	103.09	103.09
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	26.00
EIRP (dBm)	36.64	36.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-77.09	-76.09
Annual multipath availability (%)	99.99997	99.99998
Annual multipath unavailability (sec)	8.24	6.54

Business Park Lift St to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

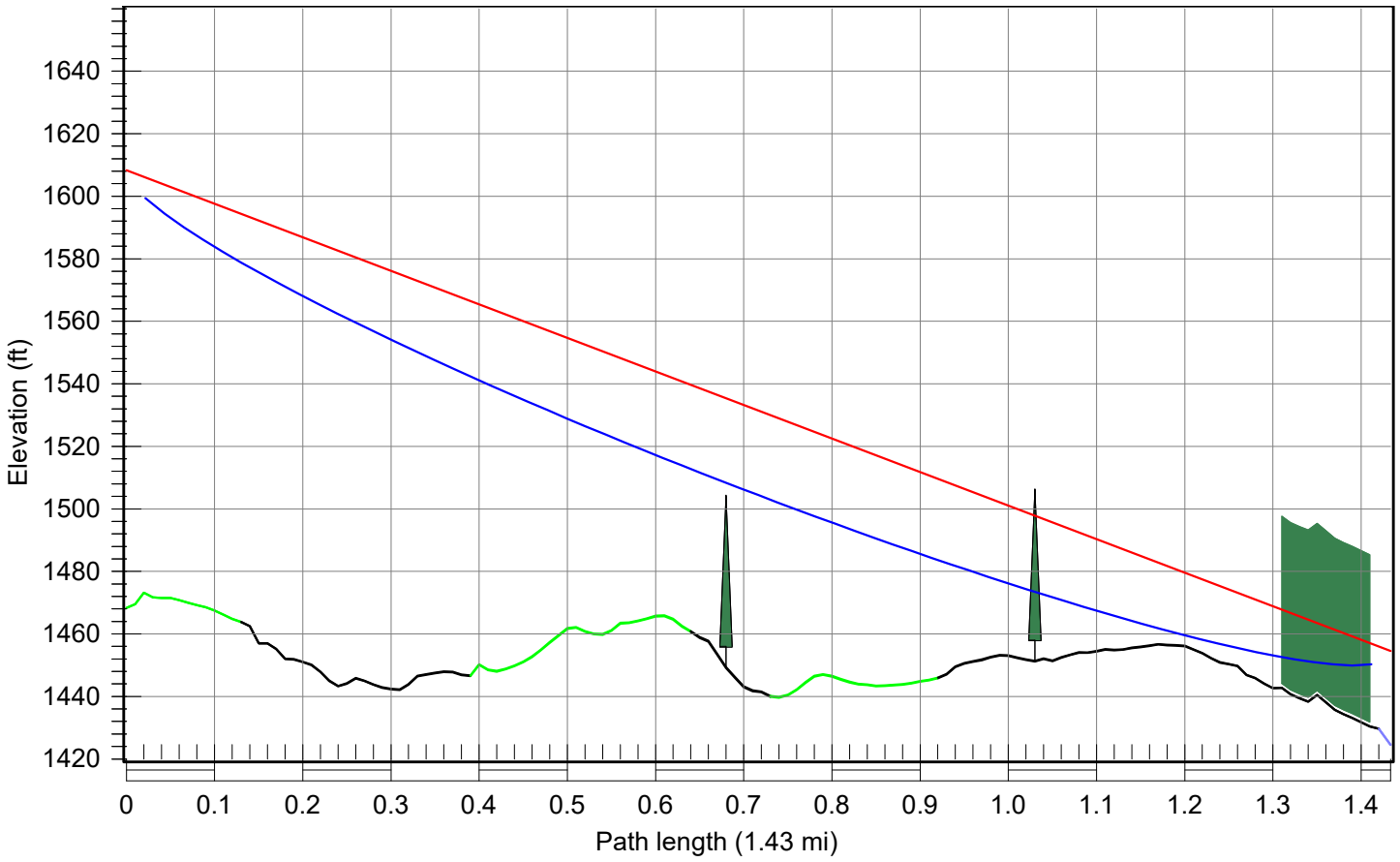
1.5 Mil Gal Tank @ 140’ / Business Park Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to Center Lake Lift St Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	300.03°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

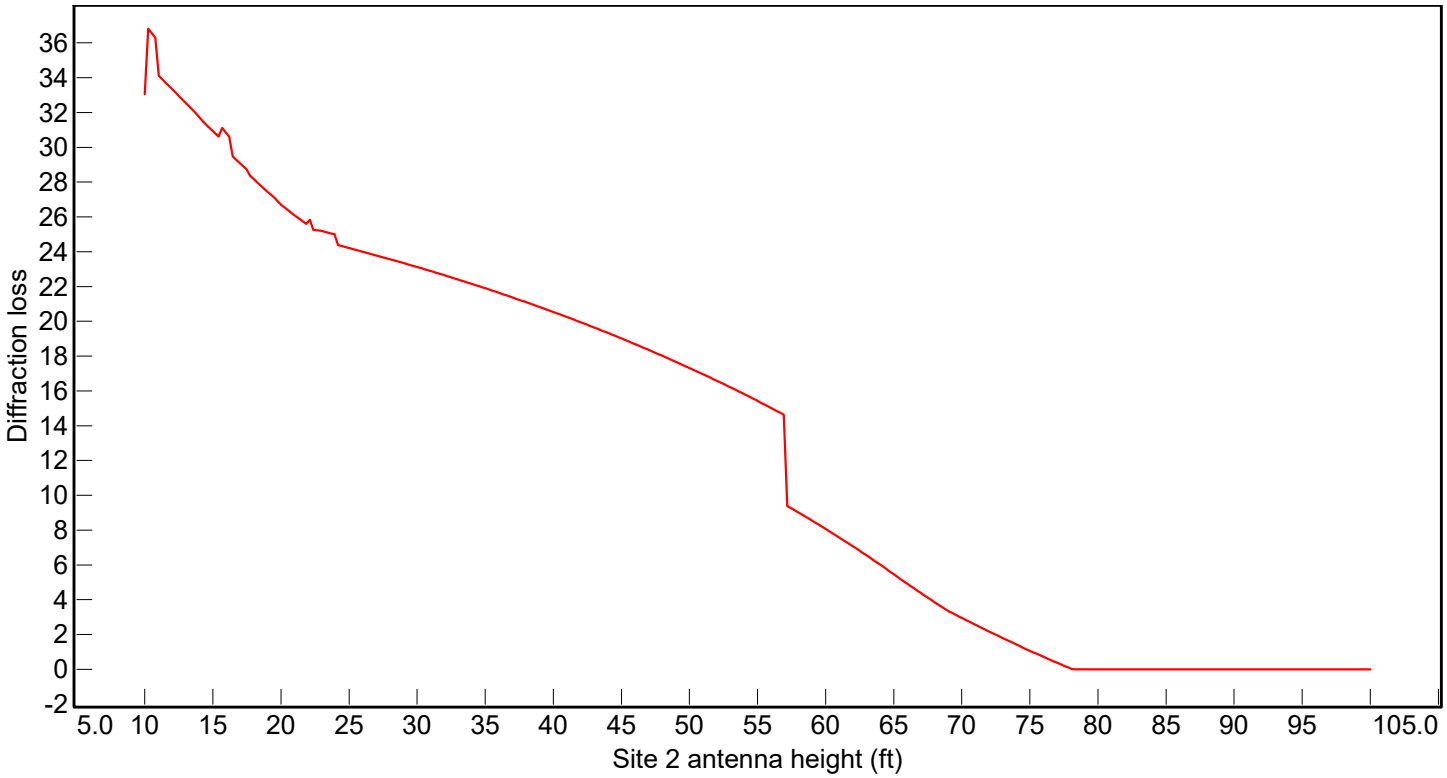
Center Lake Lift St	
Latitude	43 25 05.68 N
Longitude	095 07 46.20 W
Azimuth	120.01°
Elevation	1425 ft ASL
Antenna CL	30.0 ft AGL

1.5 Mil Gal Tank to Center Lake Lift St Link Summary

	1.5 Mil Gal Tank	Center Lake Lift St
Latitude	43 24 28.29 N	43 25 05.68 N
Longitude	095 06 17.43 W	095 07 46.20 W
True azimuth (°)	300.03	120.01
Elevation (ft)	1468.33	1424.56
Antenna model	ANT940F10 (TR)	RY-900B (TR)
Antenna gain (dBi)	12.15	12.15
Antenna height (ft)	140.00	30.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LDF4-50A
TX line length (ft)	175.00	50.00
TX line loss (dB)	1.91	1.11
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	1.43	
Free space loss (dB)	98.96	
Diffraction loss	23.12	
Net path loss (dB)	102.01	102.01
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	26.00
EIRP (dBm)	36.64	36.44
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-76.01	-75.01
Annual multipath availability (%)	99.99999	99.99999
Annual multipath unavailability (sec)	1.99	1.58

Center Lake Lift St to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

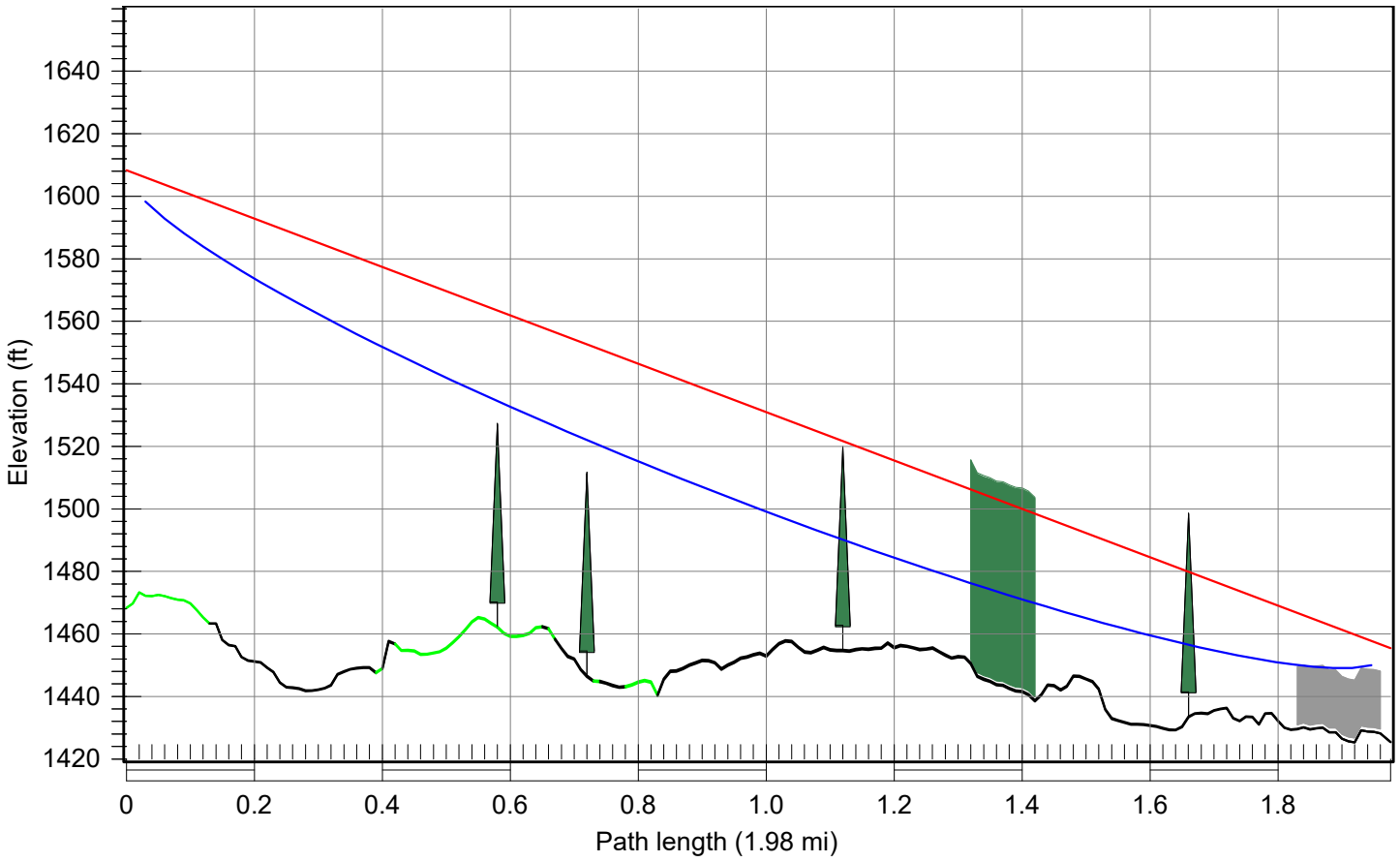
1.5 Mil Gal Tank @ 140’ / Center Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to KUOO Lift St Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	303.73°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

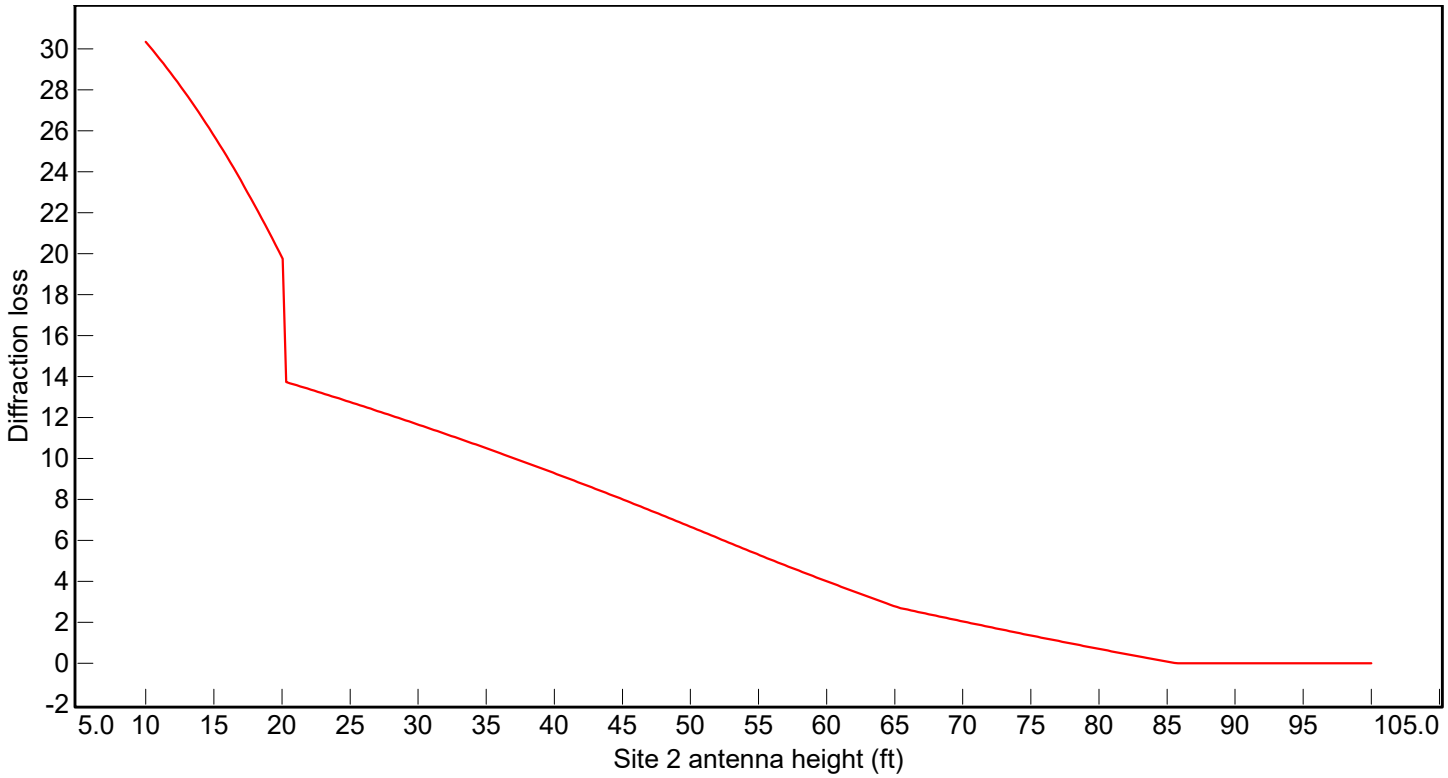
KUOO Lift St	
Latitude	43 25 25.48 N
Longitude	095 08 14.99 W
Azimuth	123.71°
Elevation	1425 ft ASL
Antenna CL	30.0 ft AGL

1.5 Mil Gal Tank to KUOO Lift St Link Summary

	1.5 Mil Gal Tank	KUOO Lift St
Latitude	43 24 28.29 N	43 25 25.48 N
Longitude	095 06 17.43 W	095 08 14.99 W
True azimuth (°)	303.73	123.71
Elevation (ft)	1468.33	1425.39
Antenna model	ANT940F10 (TR)	SP440-SF2SNF (TR)
Antenna gain (dBi)	12.15	7.15
Antenna height (ft)	140.00	30.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LMR400
TX line length (ft)	175.00	50.00
TX line loss (dB)	1.91	1.97
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	1.98	
Free space loss (dB)	101.74	
Diffraction loss	11.66	
Net path loss (dB)	99.19	99.19
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	30.00
EIRP (dBm)	36.64	34.58
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-69.19	-72.19
Annual multipath availability (%)	100.00000	99.99999
Annual multipath unavailability (sec)	1.08	2.16

KUOO Lift St to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

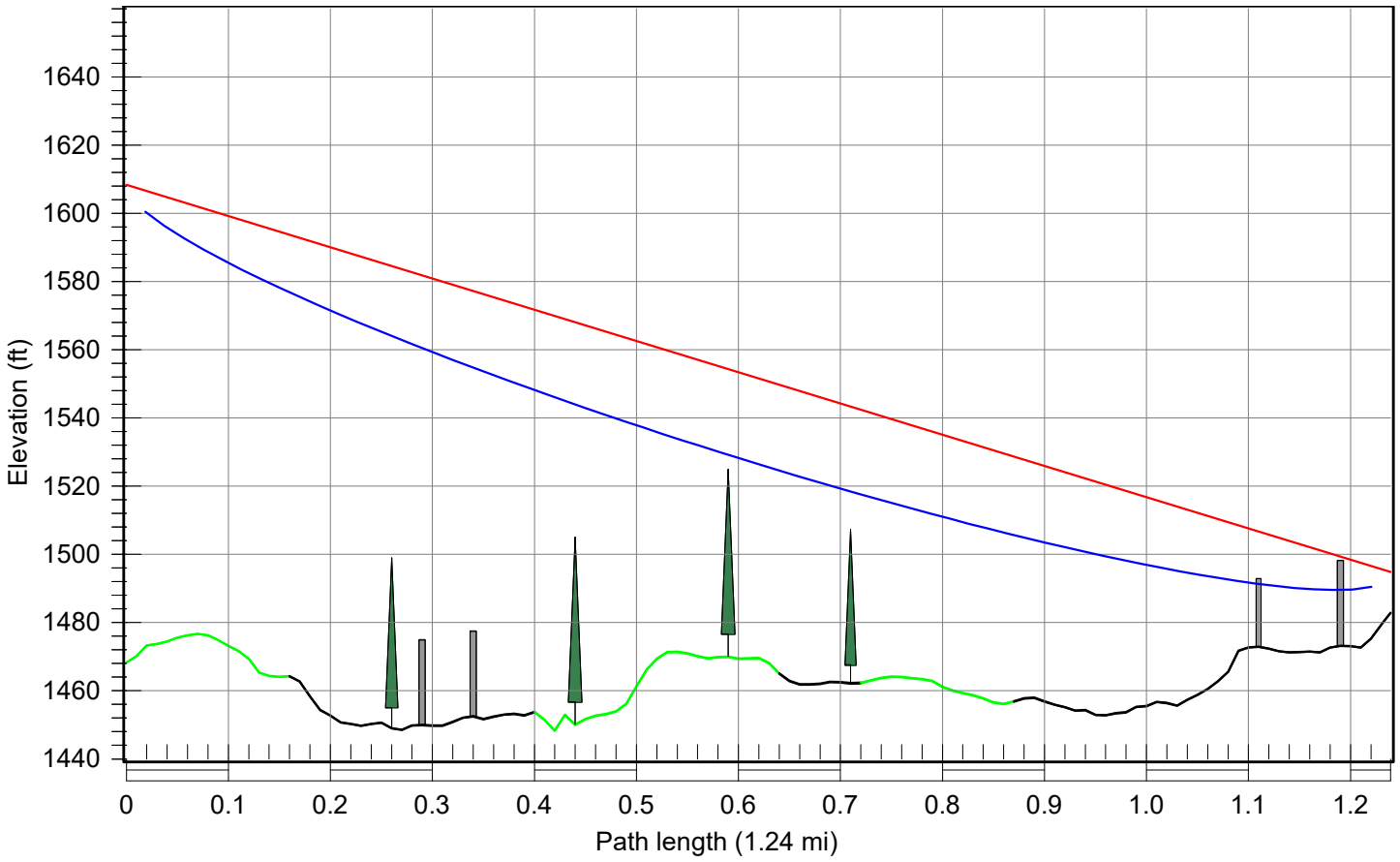
1.5 Mil Gal Tank @ 140’ / KUOO Lift St @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

1.5 Mil Gal Tank to 1.0 Mil Gal Tank Terrain Profile



1.5 Mil Gal Tank	
Latitude	43 24 28.29 N
Longitude	095 06 17.43 W
Azimuth	315.95°
Elevation	1468 ft ASL
Antenna CL	140.0 ft AGL

Frequency (MHz) = 915.0
K = 1.33
%F1 = 60.00

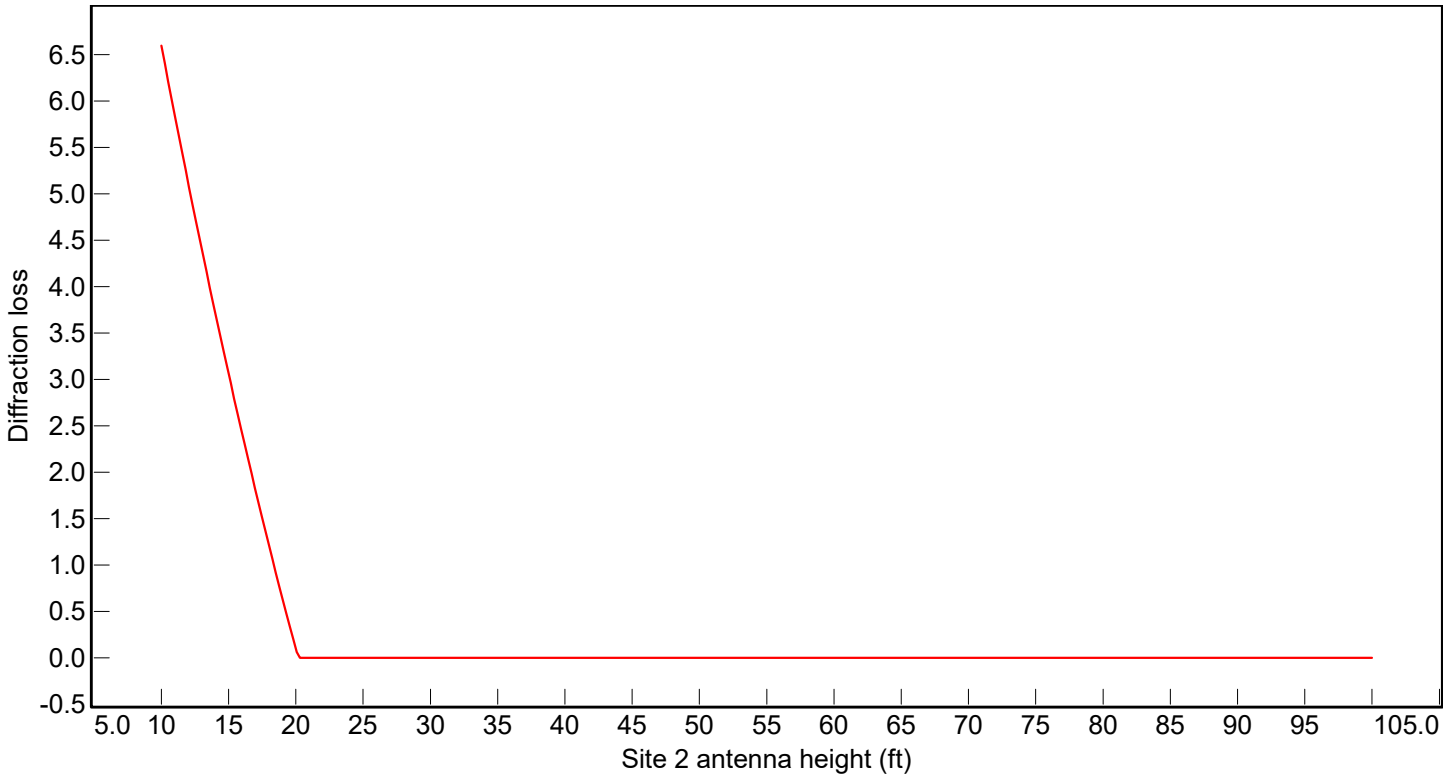
1.0 Mil Gal Tank	
Latitude	43 25 14.73 N
Longitude	095 07 19.06 W
Azimuth	135.94°
Elevation	1483 ft ASL
Antenna CL	12.0 ft AGL

1.5 Mil Gal Tank to 1.0 Mil Gal Tank Link Summary

	1.5 Mil Gal Tank	1.0 Mil Gal Tank
Latitude	43 24 28.29 N	43 25 14.73 N
Longitude	095 06 17.43 W	095 07 19.06 W
True azimuth (°)	315.95	135.94
Elevation (ft)	1468.33	1482.88
Antenna model	ANT940F10 (TR)	SP440-SF2SNF (TR)
Antenna gain (dBi)	12.15	7.15
Antenna height (ft)	140.00	12.00
Antenna azimuth (°)	0.00	
TX line model	AVA5-50	LMR400
TX line length (ft)	250.00	25.00
TX line loss (dB)	2.72	0.98
Connector loss (dB)	0.20	0.20
Miscellaneous loss (dB)	0.40	0.40
Frequency (MHz)	915.00	
Polarization	Vertical	
Path length (mi)	1.24	
Free space loss (dB)	97.69	
Diffraction loss	5.12	
Net path loss (dB)	88.42	88.42
Radio model	Orbit NX915	Orbit NX915
TX power (dBm)	27.00	30.00
EIRP (dBm)	35.83	35.57
RX threshold criteria	1x10^-6 BER	1x10^-6 BER
RX threshold level (dBm)	-95.00	-95.00
Receive signal (dBm)	-58.42	-61.42
Annual multipath availability (%)	100.00000	100.00000
Annual multipath unavailability (sec)	0.02	0.04

1.0 Mil Gal Tank to 1.5 Mil Gal Tank Obstruction Loss vs. Antenna Height Analysis

1.5 Mil Gal Tank @ 140’ / 1.0 Mil Gal Tank @ 10’-100’



Variable parameter - Site 2 antenna height

Site 2 start antenna height (ft)	10
Site 2 end antenna height (ft)	100
Site 1 antenna height (ft)	140
Earth radius factor K	1.33
Frequency (MHz)	915
Number of points	350

Appendix C.

Manufacturer's Specification & Product Information Brochures

a. GE MDS MPRU Master Station

b. Orbit NX915 Radio Platform

GE
Grid Solutions

MDS Master Station

Exceptional Reliability for Protected Licensed or Unlicensed Communications

Narrowband communication networks are deployed to monitor, control and maintain critical industrial processes and distributed assets. Such applications require high reliability and availability especially at the access point, thus driving demand for high duty cycle solutions with built-in redundancy that are capable of continuous operation. The MDS Master Station is built to meet these demanding requirements.

The MDS Master Station offers two transceivers in a 1+1 redundancy, and dual power supplies to maximize network availability. In the event of a failure the controlling logic switches to the standby transceiver unit. Switchover can occur based upon transceiver error codes, loss of communication over a configurable time period or loss of power.

The MDS Master Station supports two types of transceiver modules.

- Orbit licensed or unlicensed transceiver modules enable the latest generation performance, networking, and security offered in the MDS Orbit platform.
- SD licensed transceiver modules enable the deployment of MDS SD Series networks. Additionally, they allow for backward compatibility with x710/x790 legacy networks.

Key Benefits

- Maximize network availability with 1+1 transceiver protection and hot-swappable components
- Range of backward compatibility and migration options to extend or evolve legacy networks and provide project budget flexibility
- Simple migration options with field upgradability from SD to Orbit radio modules
- The most comprehensive set of cybersecurity and networking capabilities offered by the Orbit platform provides protection from threats and ease of integration into modern networks
- Integration with the MDS PulseNET network management system

Applications

Oil & Gas

- SCADA communication for flow/metering devices, controllers and RTUs
- Data acquisition for well head production data and pipeline status

Energy

- SCADA communication for IEDs, controllers and RTUs at distribution substations
- Data acquisition for pole-top transformers and capacitor banks

Water & Wastewater

- SCADA communication for lift station controllers and monitoring devices
- Data acquisition for tank and reservoir levels, flow rates and pipeline valve status

Reliability and Modularity

- Support for Orbit Unlicensed 900 MHz, Licensed 135-155MHz, and SD 350-400 MHz
- 1+1 transceiver redundancy with warm standby and fast radio switchover
- Various AC/DC power supply options with redundant operation
- Modular, in-service, hot-swappable components
- Operation from -30 to +60 °C
- Rated for continuous operation
- No moving parts or fans
- Battery backup option

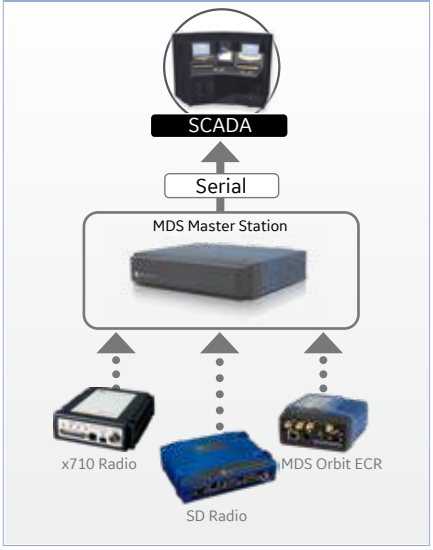
Flexibility

- Support for GE MDS SD Series radio technology covering the 300-512 MHz and 880-960 MHz bands with backward compatibility to legacy X710/X790 systems
- Support for GE MDS Orbit unlicensed 900MHz[1] or licensed technology with QAM covering the 100, 200, 400, 500, 700, and 900 MHz bands
- MDS Orbit supports up to 50kHz bandwidth in most of 100, 200, 400, 700 and 900 MHz bands
- Optional internal duplexer, GPS, and WiFi
- Connectivity for additional notched filter

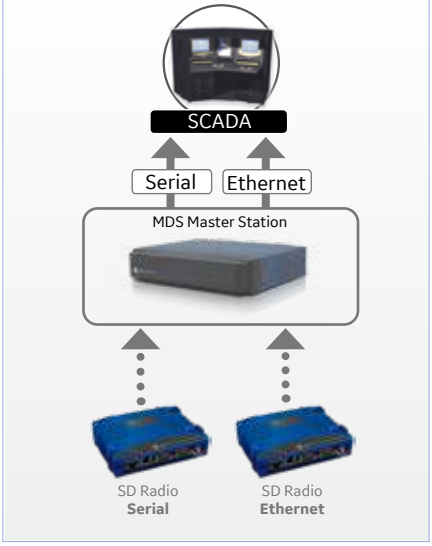
Advanced Networking & Security

- Orbit Network Operating System with advanced routing, switching, Quality of Service and network management capabilities
- Cutting edge cyber security suite including firewalling, RF Encryption, end-to-end IPSec VPNs, X.509 certificates with key rotation, secure boot and firmware

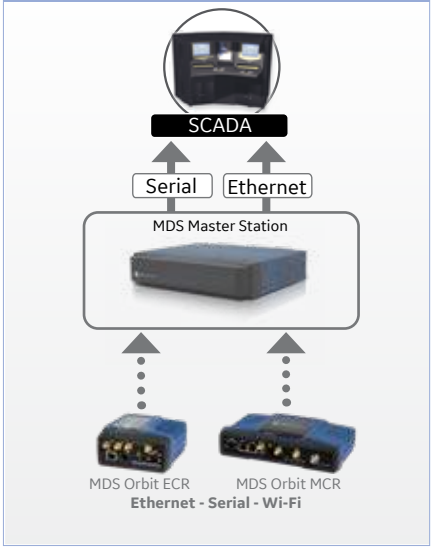
MDS Master Station Configured with SD Transceivers for Backward Compatible Serial Operation



MDS Master Station Configured with SD Transceivers for IP and Serial Operation



MDS Master Station Configured with Orbit Transceivers for Higher Speed QAM



MDS Master Station Overview

The MDS Master Station is built on a cutting edge hardware framework to offer exceptional reliability for critical communications. It can be configured as a 1+1 system with redundant power supplies and transceivers that are hot-swappable to ensure always-on operation and maximize network availability. Other components such as duplexers and alarm cards are also modular and can be field replaceable for ease of maintenance.

The Master Station utilizes a variant of the GE MDS Orbit network Operating System (Orbit OS) offering future-ready security, networking and quality of service capabilities.

Enterprise-Class Security

The MDS Orbit OS offers a comprehensive cyber security framework to facilitate the deployment of highly secure networks. Orbit's firewall ensures protection at Layer 2 to 4 to permit only valid traffic through the network. Its RF encryption secures communication between remote and AP while its IPSec VPN and DMVPN capabilities enable end-to-end encryption between remotes and control center. RADIUS enforces a centralized authentication process where users are granted access based on pre-authorized roles and access level.

Flexible Networking and Quality of Service

MDS Orbit OS enables the Master Station to offer dynamic and static routing services as well as full managed switch capability for maximum flexibility in network design. In addition to 1+1 transceiver protection, Orbit OS offers other High Availability mechanisms when used with MDS Orbit remotes such as interface bonding, Spanning Tree, Layer 3 failover, VRRP as well as latency and packet-loss based failover. Quality of Service enables the granular classification and prioritization of traffic as well as the dedication of uplink throughput on a per-application basis to minimize latency and maximize bandwidth for critical applications.

MDS Master Station with SD Radio Modules

The MDS Master Station may be configured with SD transceiver modules in a non-redundant or redundant mode of operation. SD transceiver modules utilize a similar radio technology as the industry-leading MDS SD Series radios to enable communication with MDS SD remotes, as well as MDS x710 and 2310/4310 remotes. The MDS Master Station has been designed to replace MDS 2100 and x790B masters and to provide a seamless evolution path to an all SD network. This backward compatibility allows the seamless co-existence of legacy and SD based networks.

Furthermore, when operating in the CPFSK A modem, the Master Station with SD radio modules can communicate with MDS Orbit remotes operating in a legacy backward compatible mode to facilitate the migration of legacy networks to Orbit-based technology. Once all of the legacy remotes have been replaced with Orbit, a field conversion is possible utilizing the same firmware already on the master station along with swapping out the SD radio modules for Orbit radio modules.

This can allow for more flexibility and control over cost and schedule compared to alternative forklift or higher cost full master station migration options.

MDS Master Station with Orbit Licensed Modules

The MDS Master Station may be configured with the latest generation MDS Orbit licensed radio modules covering the 100, 200, 400, 700, or 900 MHz bands. Orbit radio modules enable communication with the MDS Orbit MCR/ECR remotes using its high-performance radio technology with up to 64-QAM of modulation and up to 50kHz of bandwidth. Its bi-directional adaptive modulation as well as IP header and payload compression maximize upstream and downstream throughput. Dynamic Forward Error Correction (FEC) boosts link sensitivity to maximize distance and operation in tough terrains.

Network Management and User Interface

The MDS Master Station with its Orbit OS supports standards-based SNMP and Netconf network and device management protocols for easy integration into MDS PulseNet and 3rd party NMS software. It can be configured and managed using Command-Line Interface (CLI) or an intuitive Graphical User Interface (GUI).

Evolve Your Legacy Network to Orbit Technology

The MDS Master Station provides a solution for customers expanding existing MDS x710 and SD networks but also considering migrating that network to newer technology by replacing aging equipment with new Orbit remotes. This solution allows continued operation of the legacy network with new Orbit remotes operating in backward compatible transparent or packet-with-MAC mode. Customers may choose to replace a legacy x790 Master Station with a latest generation MDS Master Station installed with SD radio modules to support backward compatibility with legacy remotes in addition to new Orbit remotes operating in a backward compatible mode. For customers looking to evolve their networks to the faster, more secure communications offered by Orbit, they may migrate all their legacy remotes to Orbit. After an entire field is updated with Orbits, the modular platform of the Master Station allows for SD radio modules to swapped out for Orbit radio modules, providing a straight forward path to field upgrades with very little downtime.

Versatile Serial Server

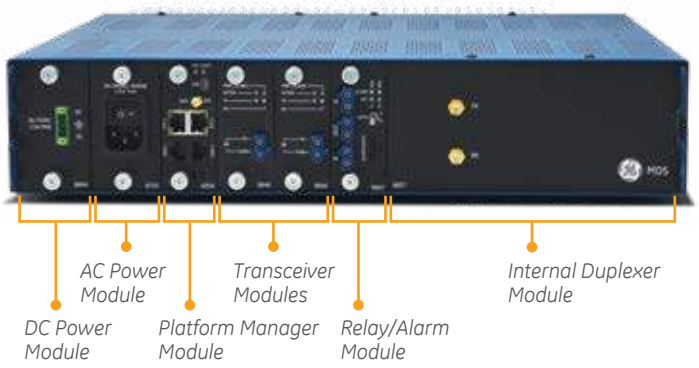
Serial traffic from SCADA and telemetry data can be encapsulated in TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) for point-to-point or point-to-multipoint transport across wired and wireless networks. Serial protocols, such as Modbus and DNPv3 are fully supported to connect legacy PLCs, RTUs etc...

Modular Communication Platform

Ease of maintenance and serviceability are benefits of the modular communications platform of the MDS Master Station. All components are easily accessed from the front panel for simplified maintenance. Redundant transceivers and power supply modules are hot swappable to ensure continuous operation during service periods after a failover. The Relay and Alarm module provides connectivity for two sets of alarm contacts to externally signal radio switchover and alarm events.

The Master Station's Platform Manager is the main processor/brain of the system. It can be factory-configured with optional WiFi to simplify local management. It also supports 2 Ethernet and 2 Serial interfaces, and allows for single or multiple SCADA host systems.

Exterior View – Front Panel



Graphical User Interface (GUI)

The MDS Master Station utilizes an intuitive Device Manager GUI based on the Orbit Network Operating System. The Device Manager allows for easy configuration and maintenance of radios, networking, security and management functions with specialized wizards that speed up complex configuration tasks. The Master Station can also be managed using a CLI.

MDS Master Station Configuration Options

The MDS Master Station can be factory-configured as a system with the following radio technology types: SD, Orbit Licensed, or Orbit Unlicensed. The system can be configured with single or dual redundant radio modules of the same type. Components such as chassis, power supplies, platform manager (processor), alarm modules and duplexers are common between the types of systems to enable flexibility in field upgrades, maintenance and inventory stocking. Most of the hardware components listed above can be ordered as spares, please check the online store or with a GE Sales representative for more information.

MDS Master Station loaded with	Compatible with	Modulations	Max Raw Data Rate in 25KHz	Duplex Modes
SD RADIO MODULES	• MDS SD Series remotes • MDS x710/x790 remotes • MDS Orbit Licensed Narrowband remotes operating in 3FSK modulation	• CPFSK, Digital	38.4 Kbps in 25 kHz	Half Duplex Full Duplex
ORBIT LICENSED NARROWBAND RADIO MODULES	• MDS Orbit Licensed Narrowband Remotes	• QPSK, 16QAM, 64QAM • Bi-directional Adaptive Modulation	120 Kbps in 25 kHz 240 Kbps in 50 kHz	Half Duplex
ORBIT UNLICENSED 900MHZ RADIO MODULES[1]	• MDS Orbit Unlicensed 900MHz Remotes	• 2, 4-level GFSK	1.25 Mbps	Half Duplex

MDS Master Station

ORBIT LICENSED NARROWBAND RADIO MODULES

Modulation	QPSK, 16QAM, 64QAM
Adaptive Modulation	Per-packet, per-remote, bi-directional
Dynamic FEC:	Convolutional, Reed Solomon
Compression	IP Header and Payload with up to 30% efficiency improvement
Media Access Control	High performance MAC

ORBIT MODULE BANDS

L1C: 135-155 MHz	L4C: 450-520 MHz
L1B: 150-174 MHz	L4E: 406.1-470 MHz
L2X: 216-235 MHz	L7A: 757-758 and 787-788 MHz
L4A: 330-406 MHz	L9A: 800-870 MHz
	L9C: 896-960 MHz

RAW DATA RATES

Channel	QPSK	16QAM	64QAM
6.25 KHz	9.6 Kbps	19.2 Kbps	28.8 Kbps
12.5 KHz	20 Kbps	40 Kbps	60 Kbps
25 KHz	40 Kbps	80 Kbps	120 Kbps
50 KHz[2]	80 Kbps	160 Kbps	240 Kbps

TRANSMITTER CHARACTERISTICS

Frequency Stability	+/- 0.5ppm	
Peak Power*	**330-470MHz**	**896-960MHz**
- Radio Module	39.28	38.8
- Non-Redundant, no duplexer	38.93	38.05
- Non-Redundant, with duplexer[3]	37.73	35.95
Power Range	+20dBm to +40dBm	
Output Impedance	50 Ohms	

RECEIVER CHARACTERISTICS

Type	Direct Conversion
Adjacent Channel Rejection	60 dB nominal

Receiver Sensitivity[5] — Frequency Bands

	L1B	L2X	L4E	L7A	L7A
Redundant, no duplexer	-114.7	-113.6	-112.4	-110.7	-110.7
Redundant, with duplexer	N/A	N/A	-111.2	-109.2	-109.2

ORBIT UNLICENSED 900MHZ RADIO MODULES

Frequency	902-928 MHz
Modulation	2, 4-level GFSK, Dwell Time 10-300 msec
Spreading method	FHSS, DTS
Occupied Bandwidth	152 to 1320 kHz, up to 80 channels
Data Rates/Sensitivity	

- 125 Kbps/-104 dBm
- 250 Kbps/-102 dBm
- 500 Kbps/-98 dBm
- 1.0 Mbps/-94 dBm
- 1.25 Mbps/-94 dBm

Peak Power	29dBm +/-0.5dB
Latency	tunable to <5 msec one-way
Output Impedance	50 Ohms

SD RADIO MODULES

Module	Digital, CPFSK
Radio Mode	Packet-with-MAC, Transparent
Compatibility	MDS X710 Series MDS SD Series MDS Orbit in CPFSK A Modem

SD MODULE BANDS

SDM4 D	300-360 MHz
SDM4 A	350-400 MHz
SDM4 B	400-450 MHz
SDM4 C	450-512 MHz
SDM9 C	928-960 MHz
SDM9 K	TX 926-960 MHz RX 880-915 MHz

RAW DATA RATES

Channel	300-512 MHz	880-960 MHz
6.25 KHz	4.8 Kbps	-
12.5 KHz	19.2 Kbps	19.2 Kbps
25 KHz	38.4 Kbps	38.4 Kbps
50 KHz	-	-

TRANSMITTER CHARACTERISTICS

Frequency Stability	+/- 0.5ppm	
Peak Power	**300-512MHz** (dBm +/- 0.5dB)	**928-960MHz** (dBm +/- 0.85dB)
- Radio Module	40.5	40.25
- Redundant, no duplexer	39.4	38.7
- Redundant, with duplexer[3]	38.2	36.6
Power Range	+30dBm to +40dBm	
Duty Cycle	Continuous	
Output Impedance	50 Ohms	

RECEIVER CHARACTERISTICS

Type	Double Conversion Superheterodyne	
Adjacent Channel	60 dB Nominal Rejection	
Receiver Sensitivity @1x10-6BER, Modem 9600	**400-512MHz**	**928-960MHz**
Redundant, no duplexer	-110.9	-112.5
Redundant, with duplexer	-109.7	-110.4

ELECTRICAL

Power Required	< 80 Watts (based on redundancy)
DC Power	+/- 12-36V, +/- 36-75V, +/- 75-140V
AC Power	100-240V, 50/60 Hz

MECHANICAL

Dimensions	3.5 H x 17.2 W x 16 D in 8.9 H x 43.8 W x 40.6 D cm
Weight	24 lbs., 10.9 kg

ENVIRONMENTAL

Temperature	-30° to +60°C (-22° to 140°F)
Humidity	95% at 40°C (104°F) non-condensing
Cooling	Heat sinks, no fans, no moving parts

WI-FI OPTION

- Frequency 2.4GHz with IEEE 802.11 b/g/n
- Operating Modes: Access Point, Station
- Scalability Up to 2 SSIDs, up to 7 clients/stations
- SSID hiding Yes | VLAN mapping Yes
- Carrier Power 20dBm adjustable

POWER SUPPLY OPTIONS

- 110/220 VAC
- 12-36 VDC
- 90-260 VAC
- +/- 36-72 VDC
- 75-140 VDC

INTERNAL DUPLEXER OPTIONS

- 9 MHz (932.0-932.5) / (941.0-941.5) MHz
- 24 MHz (928.0-929.0) / (952.0-953.0) MHz
- 31 MHz (928.0-929.0) / (959.0-960.0 MHz
- 39 MHz (896.0 - 898.0) / (935.0 -937.0) MHz
- 350-512MHz / 5-10MHz SP (INT)
- TX high or low duplexer options available for each band
- No Internal Duplexer

NETWORKING

- IPv4 Routing OSPF, EBGP, RIPv2 with performance-based route failover, IPv6 Routing[1]
- Full managed switch capability, IEEE 802.3, 802.1Q/VLANs, 64 VLANs, STP
- Concurrent Bridging & Routing
- GRE Tunneling with Layer 2 (Ethernet) and Layer 3 support
- Route/path failover between any two wireless/Ethernet interfaces based on link loss, latency degradation or packet loss thresholds
- Quality of Service 16 egress queues, Priority Queuing, Fair Queuing, Traffic Shaping, Classification based on DSCP, 802.1p and Layer 2-4 classifiers
- IP Protocols TCP, UDP, ARP, DHCP, ICMP, NTP, FTP, SFTP, TFTP, DNS, configurable HTTP and HTTPS, SSH
- Serial TCP server, Modbus/TCP, Modbus RTU, TCP client, UDP Unicast and Multicast, BSAP, and DNP3
- VRF, Open VPN

SECURITY

- IPSec VPN Server (responder) and Client (initiator) with DMVPN
- Authentication Public Key, EAPTLS, Pre-Shared, Ike 1-2
- Encryption : 3DES, AES 128/192/256, CBC, CTR, CCM, GCM, SHA 256/384/512 HMAC, WiFi WPA/WPA2 PSK
- Firewalling: Stateful Layer 3-4 Firewall with MAC Filtering, NAT, Source NAT (Masquerading), Static NAT, Port Forwarding
- Device Security : Secure Boot, Secure Firmware, Digitally Signed Hardware and Software, Magnetometer Tamper Detection
- Certificate Management: X.509, SCEP, PEM, DER, RSA
- User Authentication: Local RBAC, AAA/RADIUS, 802.1x
- FIPS 140-2 (Level 2) certification in progress

MANAGEMENT

- GE MDS PulseNET NMS support with device management and auto-configuration
- GUI configuration wizards to simplify operation
- Secure device management via a web-based GUI and/or CLI
- Event logging, Syslog-over-TSL, SSH, Console
- Iperf throughput diagnostic, NETCONF
- SNMPv1/v2c/v3, MIB-II, Enterprise MIB

INTERFACES

Serial COM1	RS232, RJ45
Serial COM2	RS232/485, RJ45
USB	2
Ethernet 1	10/100 BaseT, RJ45
Ethernet 2	10/100 BaseT, RJ45
Wi-Fi	RP-SMA connector
GPS	SMA Female
Antenna	N Female

AGENCY APPROVALS

Master Station with SD Radio Modules

- Industry Canada and ENTELA
- FCC Part 101: 820 to 960 MHz
- FCC Part 90: 928 to 960 MHz
- FCC Part 24: 820 to 960 MHz
- FCC Part 90: 300 to 512 MHz
- CE, ETSI: 300 to 512 MHz
- UL 60950-1 Safety approval

Master Station with Orbit Licensed Narrowband Radio Modules

- Industry Canada, Anatel
- FCC Part 90: 896-960 MHz
- FCC Part 90: 406-470 MHz
- FCC Part 27: 757-758 & 787-788 MHz
- CE, ETSI: 330-406 MHz, 406-470 MHz
- CSA General Safety approval

Master Station with Orbit Unlicensed Radio Modules

- FCC Part 15, ICRSS-210
- CSA General Safety approval

WARRANTY

Standard 2-year manufacturer warranty applies to all MDS Master Station models

1. Check with local sales representative for availability.
2. L1C, L2X, L4A, L4C, L7A, L9A and L9C Orbit band options support 12.5, 25, and 50 kHz. L1B and L4E 6.25, 12.5, and 25 kHz. L2B supports 5 kHz only.
3. With GE MDS standard 400MHz notch or 900MHz bandpass duplexers. Internal duplexers are not available for 100 and 200MHz versions.
4. dBm +/-0.5dB, QPSK Average Power is 5dB less than Peak, QAM Average Power is 7dB less than Peak. Power may vary for other frequency bands. Please consult GE for specs on your exact configuration.
5. Shown @ 1x10-6 BER, QPSK, 12.5kHz, No FEC. FEC enabled improves sensitivity between 3-6dB. Sensitivity reduced by -6dB in 16QAM and -13dB in 64QAM.

GEGridSolutions.com/Communications

Direct: +1-844-379-9630
Email: INDC.MDSInsideSales@ge.com

GEA-12790C(E)
English
210512

GE
Grid Solutions

MDS Orbit Platform

The Next-Generation Industrial Wireless Networks

As industrial SCADA and automation applications have evolved, corresponding requirements for security, reliability, and performance of communication networks have become more demanding. Furthermore, the diversity of topography and wireless spectrum conditions across regions is often difficult to address with any single wireless technology.

The MDS™ Orbit industrial wireless platform offers the security, reliability, performance, and wireless flexibility required for next-generation industrial networks. MDS Orbit enables customers to deploy advanced communications using diverse options of wireless technologies and frequencies.

MDS Orbit allows for communication over licensed spectrum, unlicensed spectrum, cellular and Wi-Fi in various form factors with single or dual radio options. Its advanced cybersecurity capabilities enable customers to secure and protect their networks and assets.

Key Benefits

- Minimize network downtime with dual-radio uplinks using fast/smart auto-failover, including dual-modem cellular or Licensed plus cellular models
- New patent-pending 3-Port Split TX/RX licensed model provides a lower cost solution with a smaller footprint for enhanced performance in environments with high interferrance
- Protect network and assets against cybersecurity attacks with powerful capabilities and electromagnetic pulse (EMP) compliance
- Whether operating a small network or hundreds of remote units per access point, MDS Orbit provides the best real-world performance in a licensed narrowband network
- Provide backwards compatibility with GE MDS SD Series or legacy GE MDS x710 radios to seamlessly expand or migrate networks

Applications

Oil & Gas
- Well Head and Production Pad Controllers & Metering Automation
- Remote Field Office Connectivity

Water & Wastewater
- Monitoring and Control
- Maintenance Workforce Mobility

Emergency & Utility Vehicles
- Law Enforcement Connectivity
- Utility Workforce Mobility

Electric Utilities
- Field Area Network
- AMI Backhaul
- Workforce Mobility

Smart Cities & Municipalities
- Traffic Signals Control
- Video Security
- Weather Monitoring Stations

Heavy Industrial
- Train Control and Machinery Monitoring
- Excavation Machine Control

Platform Flexibility

- A single platform enables networks with various radio technologies including dual radios with auto failover in a single device
- Public or Private LTE Solutions with new Dual-Active Tri-SIM Cellular routers for superior redundancy, including support for FirstNet, CBRS, Anterix, 450MHz, and more
- Licensed solutions, including new patent-pending 3-port split TX/RX technology, for improved performance in environments with high interferrance
- High-performance 900 MHz FHSS enables low latency and high-throughput unlicensed networks with multipoint and store-and-forward
- Configurable automatic over-the-air radio firmware upgrades
- Flexible interfacing options including serial, Ethernet, USB, Wi-Fi, alarm input, and SFP

Advanced Networking & Security

- Enterprise-class cybersecurity, including VPNs, key rotation, firewalling, auto-renewal certification and centralized authentication for advanced protection
- EMP hardened per MIL-STD-461G, RS105
- FIPS 140-2 (Level 2) certification*
- Dual APN, Open VPN, FlexVPN, and VRF

Industry Leading Reliability

- Superior performance in challenging environments, including adaptive power control, patented MAC, Dual-Active LTE, 3-port split TX/RX LN
- Patented Media Access Control (MAC) guarantees message delivery and eliminates collision at the access point
- Third-party certified for IEEE1613 and Class 1 Div 2 for deployment in harsh environments

MDS Orbit Platform Key Capabilities

Flexible Networking

MDS Orbit's support for dynamic and static routing, as well as managed switch capabilities, facilitate the deployment in a multitude of network architectures. To achieve maximum uplink and application uptime, MDS Orbit supports a variety of high availability mechanisms such as interface bonding, spanning tree, layer 3 failover, VRRP, as well as latency and packetloss-based failover. GRE tunneling coupled with IPSec VPNs and DMVPN further enable the establishment of secure Virtual Private Networks (VPN) across any wireless technology.

Enterprise-Class Security

The MDS Orbit platform is built on a comprehensive cybersecurity framework to enable the deployment of highly secure environments. It offers standards-based IPSec VPN and DMVPN capabilities with X.509 certificate management to allow the encryption of network paths and interoperability with non-GE devices. As an added layer of security, MDS Orbit supports the encryption of private radio links at the RF layer. RBAC and RADIUS enable local and centralized user authentication into the network. MDS Orbit's stateful firewall, as well as MAC-filtering capabilities ensure that only valid traffic is permitted through the network. Its secure boot and secure firmware protect against meddling with the hardware and software, and its magnetometer provides tamper-detection to secure against theft.

Advanced Quality of Service (QoS)

MDS Orbit supports advanced QoS functionality with fair and priority queuing to enable deterministic latency and throughput performance with up to 16 application priority queues. Its traffic shaping allows applications such as SCADA to have a dedicated throughput on the uplink for predictable performance. MDSOrbit further supports classification based on DSCP, 802.1p, and other Layer 2-4 header information.

Network Management and User Interface

The MDS Orbit platform supports standards-based SNMP and Netconf network and device management protocols for easy integration into MDS PulseNet as well as third-party network management software. It supports Command-Line Interface (CLI), an intuitive web-based Graphical User Interface (GUI) as well as wizards to simplify and speed the configuration of complex tasks. MDS Orbit's user experience is identical regardless of radio technology or form factor.

Diverse Radio Technology Options

Licensed Spectrum

MDS Orbit's licensed radio technology offers multiple narrowband spectrum options with QAM modulation that maximizes available throughput for modern IP-based applications. Performance is enhanced with raw data rates of up to 240 Kbps in a 50 kHz channel or up to 120 Kbps in a 25 kHz channel. IP header and payload compression as well as per-packet, per-remote, bi-directional adaptive modulation further optimize throughput on a pre-remote basis to ensure the network is not penalized for its lowest common denominator remote.

Backwards Compatibility

For customers looking to upgrade legacy licensed networks, the MDS Orbit licensed radio technology supports 3-FSK modulation mode, which provides backwards compatibility with legacy x710 as well as SD base stations on the A Modem. Furthermore, for those customers who desire an at-your-own-pace migration, a GE MDS Master Station equipped with MDS Orbit radio modules and an embedded evolution module allows for the coexistence of both new and legacy networks by routing the traffic over the appropriate network.

Unlicensed Spectrum

MDS Orbit's unlicensed radio offers cutting-edge performance in the 900MHz ISM spectrum with its advanced MAC technology. MDS Orbit's patented MAC prevents ingress collision at the access point by synchronizing the network and allocating time slots for one remote to transmit at a time. It enables communication at 1.25Mbps with a latency as low as 5msec for latency-sensitive automation and protection applications. MDS Orbit's unlicensed 900Mhz radio can be deployed in various topologies including point to point-to-point, point-to-multipoint, and a self-healing store-and-forward network.

Cellular

MDS Orbit supports a variety of cellular technologies, including Dual-Active Tri-SIM and Dual-SIM models with roaming and profile switching based on signal quality.

Orbit supports communication over private LTE bands including CBRS, Anterix™ 900 MHz, and 450MHz. An Orbit MCR can be configured with multiple technologies including cellular as a primary uplink or as backup for a primary licensed or unlicensed radio, or with the primary radio in an active-active configuration.

Wi-Fi

A Wi-Fi radio option can be selected as a standalone, or as a secondary radio for licensed, unlicensed, or cellular radios. MDS Orbit offers two versions of Wi-Fi to meet performance and cost requirements. A 802.11 b/g/n 2.4 GHz Wi-Fi option supports up to seven clients/hosts per AP. A 802.11 a/b/g/n 2.4/5 GHz option provides enhanced dual antenna (MIMO) performance and 32+ clients per AP.

MDS Orbit OCR
with Cellular

MDS Orbit MCR
with Cellular and 900 MHz

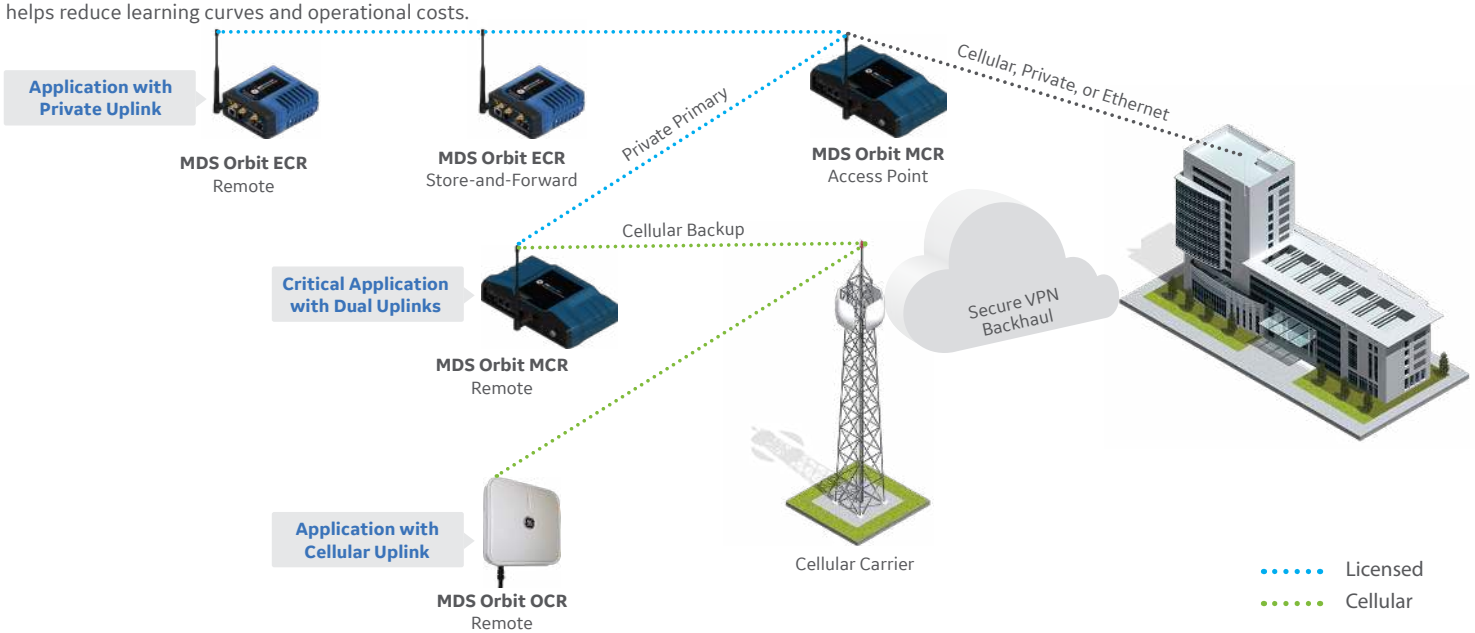
MDS Orbit ECR
with Cellular and Wi-Fi

The MDS Orbit Platform Models & Radio Support

MDS Orbit Models	MCR (Multiservice-Connect Router) Standard 	MCR (Multiservice-Connect Router) High Port Density 	ECR (Edge-Connect Router) 	OCR (Outdoor-Connect Router) 
PORT DENSITY				
Port Combination & Density Options (Factory-configured)	2 Ethernet, 1 Serial, 1 USB 1 Ethernet, 2 Serial, 1 USB	1 SFP, 2 Ethernet, 2 Serial, USB 4 Ethernet, 2 Serial, 1 USB 6 Ethernet, 1 USB	1 Ethernet, 1 Serial, 1 USB	1 PoE Ethernet 1 PoE Ethernet, 2 N-type Antenna Connectors
RADIO COMBINATIONS				
	1 WAN-Radio 1 WAN-Radio + 2.4 GHz Wi-Fi			
	2 WAN-Radios (limited options) 2 LTE WAN-Radios* 1 LN WAN-Radio with 3 port split TX/RX* 1 WAN-Radio + 2.4/5 GHz Wi-Fi			1 Unlicensed WAN-Radio + 1 LTE WAN-Radio
Cellular Radio Options	3G/4G Dual SIM LTE North America 3G/4G Dual SIM EMEA Private LTE Bands			
Unlicensed Radio Options	902-928 MHz FHSS			
Licensed Radio Band Options	135-155 MHz 150-174 MHz 216-235 MHz 330-406 MHz		406.1-470 MHz 450-520 MHz 757-758, 787-788 MHz 896-960 MHz	
Wi-Fi RADIOS				
Wi-Fi	2.4 GHz 802.11b/g/n 2.4/5 GHz MIMO 802.11a/b/g/n			

MDS Orbit Hybrid Network Example

Industrial customers depend on more than one wireless technology to extend connectivity to their field assets. The MDS Orbit platform offers a rich portfolio of wireless technologies in various form factors, as well as single or dual radio options to facilitate the deployment in various applications and scenarios. The common platform offers a seamless and unified user experience regardless of the wireless technology used. It simplifies radio operation and management, and helps reduce learning curves and operational costs.



GE MDS™ Orbit Platform Data Sheet

Unless otherwise noted, specifications listed apply to all MDS Orbit models

NETWORKING

- IPv4 Routing OSPF, EBGP, RIPv2 with performance-based route failover
- IPv6 Routing*
- Full managed switch capability, IEEE 802.3, 802.1Q/VLANs, 64 VLANs, STP
- Concurrent Bridging & Routing
- GRE Tunneling with Layer 2 (Ethernet) and Layer 3 support
- Route/path failover between any two wireless/Ethernet interfaces based on link loss, latency degradation, or packet loss thresholds
- Quality of service: 16 egress queues, priority queuing, fair queuing, traffic shaping, classification based on DSCP, 802.1p and layer 2-4 classifiers
- IP Protocols TCP, UDP, ARP, DHCP, ICMP, NTP, FTP, SFTP, TFTP, DNS, configurable HTTP and HTTPS, SSH
- Serial TCP server, Modbus/TCP, Modbus RTU, TCP client, UDP
- Unicast and Multicast, BSAP, and DNP3
- Dual APN, VRF, Open VPN, FlexVPN, and VPN DPD*

SECURITY

- IPSec VPN Server (responder) and Client (initiator) with DMVPN
- Authentication Public Key, EAPTLS, Pre-Shared, Ike 1-2
- Encryption : 3DES, AES 128/192/256, CBC, CTR, CCM, GCM, SHA 256/384/512 HMAC
- Firewalling: Stateful Layer 3-4 Firewall with MAC Filtering, NAT, Source NAT (Masquerading), Static NAT, Port Forwarding, rule violation notifications
- Device Security : Secure Boot, Secure Firmware, Digitally Signed Hardware and Software, Magnetometer Tamper Detection
- Certificate Management: X.509, SCEP, PEM, DER, RSA
- Automatic certificate renewal/re-enrollment
- User Authentication: Local RBAC, AAA/RADIUS, 802.1x

LICENSED RADIO SUMMARY

- Narrowband Frequency Bands:
  - L1B: 150 - 174 MHz
  - L1C: 135 - 156 MHz
  - L2B: 220 - 222 MHz
  - L2X: 216 - 237 MHz
  - L4A: 330 - 406 MHz
  - L4C: 450 - 520 MH
  - L4E: 406.1 - 470 MHz
  - L7A: 757 - 758 and 787 - 788 MHz
  - L9A: 800 - 870 MHz
  - L9C: 896 - 960 MHz
- Channel Size: 5, 6.25, 12.5, 25, and 50 kHz**
- Operation Modes: Access Point, Remote, Store & Forward
- Duplex Mode: Simplex, Half-Duplex
- Modulation: CPFSK, QPSK, 16QAM, 64QAM, Bi-Directional Adaptive Modulation
- Backward compatibility with MDS SD Series and x710 Master Stations using QPFSK
- Raw Data Rate: Up to 240 Kbps in 50kHz and 120 Kbps in 25kHz
- Compression: IP Header and Payload
- FEC: Dynamic, per packet
- Peak TX Power: up to +40 dBm

UNLICENSED RADIO SUMMARY

- Frequency Bands: 902-928 MHz FHSS
- Occupied Bandwidth 152 to 1320 kHz, up to 80 channels
- Modulation: 2, 4-level GFSK, Adaptive
- Raw Data Rates: 125Kbps, 250Kbps, 500 Kbps, 1000 Kbps, 1250 Kbps
- Latency of < 5 msec
- Operation Modes: Access Point, Remote, Store & Forward
- Duplex Mode: Half-Duplex
- Compression: IP Header and Payload
- TX Power: 1 watt, configurable

CELLULAR RADIO SUMMARY

Cellular Options (with Dual SIM and GPS):*

- 4GY: 4G LTE-A NAM/EMEA/LATAM - Anterix™ 900MHz, AT&T, Verizon, US Cellular*, Bell, Telus, Rogers*, Vodafone, FCC, CE, PTCRB, GCF
- 4GB: 4G LTE-A Pro FirstNet Ready™, CBRS, US - AT&T, Verizon, FCC, IC, PTCRB
- 4GA: 4G LTE-A Pro Brazil/Australia - Telstra, GCF, Anatel, RCM/ACMA
- 4GD: 4G with 2G/3G fallback EMEA/LATAM - CE, GCF, Anatel
- 4GF: 4G LTE Cat. 4 B3/7/20/31/72 - CE, Anatel, GCF*
- 4GG: 4G LTE Cat. 4 B3/20/87 - CE, Anatel, GCF*
- 4GB+4GY: Dual-Active LTE MCR

WI-FI RADIO SUMMARY

IEEE 802.11 b/g/n 2.4 GHz option:

- 1x1 SISO (single antenna/radio chain)
- Scalability up to 2 SSIDs, up to 7 clients/stations
- Max transmit power (adjustable): up to 20dBm
- Operating modes: Access Point (AP), Station, Station bridging
- Security: WPA/WPA2 PSK, Enterprise
- Applications:
  - Local configuration and management using Wi-Fi devices
  - Station/client connecting to a 2.4GHz AP in outdoor LOS environment
  - Small-scale 2.4GHz AP operating in outdoor LOS environment

IEEE 802.11 a/b/g/n Dual-Band 2.4/5 GHz option:

- 2x2 MIMO (dual antenna/radio chain)
- Scalability up to 2 SSIDs, up to 32+ clients/stations
- Max transmit power (adjustable): up to 26dBm (23dBm per antenna/chain) for 2.4GHz and 23dBm (20dBm per antenna/chain) for 5GHz
- 5GHz (U-NII-1 and U-NII-3 bands supported)
- Operating modes: Access Point, Station, Station bridging, Access-Point-Station (simultaneous AP and Station operation)
- Security: WPA/WPA2 PSK, Enterprise
- Applications:
  - Local configuration and management using Wi-Fi devices
  - Station/client connecting to a 2.4Ghz/5Ghz AP in indoor/outdoor LOS/NLOS environment
  - Large-scale AP

MANAGEMENT

- Support for MDS LaunchNET with 'Zero-touch' or 'One-touch' for easy field provisioning
- MDS PulseNET NMS Support
- Secure device management via HTTP/HTTPS, (GUI) and Juniper-style CLI via SSH or local console
- Event logging, Syslog over TLS
- Iperf throughput diagnostic
- NETCONF
- SNMPv1/v2c/v3, MIB-II, Enterprise MIB

ORBIT MODEL INTERFACES

- MCR Standard Option A
  (2) 10/100 Ethernet, RJ45
  (1) RS232/485 Serial, RJ45
  (1) mini USB 2.0
- MCR Standard Option B
  (1) 10/100 Ethernet, RJ45
  (2) RS232/485 Serial, RJ45
  (1) mini USB 2.0
- MCR SFP Option*
  (2) 10/100/1000 Ethernet, RJ45
  (2) RS232/485 Serial, RJ45
  (1) mini USB 2.0
  (1) 1000BASE-X SFP
- MCR High Density Option
  (4) 10/100 Ethernet, RJ45
  (2) RS232/485 Serial, RJ45
  (1) mini USB 2.0
- ECR
  (1) 10/100 Ethernet, RJ45
  (1) RS232/485 Serial, RJ45
  (1) mini USB 2.0
- MCR/ECR Antenna Connectors
  Licensed NB:TNC
  900Mhz Unlic: TNC
  Wi-Fi: RP-SMA
  Cellular: SMA
  GPS: SMA female
- OCR*
  (1) 10/100 PoE Ethernet, RJ45
  (2) N-Type Antenna Connectors
  (Optional)

MECHANICAL

- Case – Rugged die-cast aluminum
- Dimensions MCR – 1.75 H x 8.0 W x 4.8 D in., 4.45 x 20.32 x 12.19 cm
- Weight MCR – 2 lbs, 0.91 kg
- Dimensions ECR – 2.1 H x 4.3 W x 4.6 D in., 5.33 x 10.92 x 11.68 cm
- Weight ECR – 1.45 lbs, 0.65 kg
- Dimensions OCR: 15.59 H x 15.43 W x 3.9 D in.; 39.6 x 39.2 x 9.9 cm"
- Mounting Options Integrated DIN Rail mount and Standard Mounting bracket
- No Fans, No Moving Parts
- HALT & HASS Testing
- Case Die Cast Aluminum

ENVIRONMENTAL

- Operating Temp -40° to +70°C (-40° 158°F)
- Storage Temp -40° to +85°C (-40° 185°F)
- Humidity 95% at 60°C (140° F) non-condensing

ELECTRICAL & POWER CONSUMPTION

- Input Voltage 10 to 60 VDC
- Power Consumption Calculations with nominal 25C at 13.8V

WITH 4G LTE	POWER	13.8V
Connected (Idle)	4.0W	292mA
Typical download	4.3W	310mA
WITH 4G LTE + WI-FI	**POWER**	**13.8V**
Connected (Idle)	4.8W	350mA
Typical download	5.5W	400mA
WITH 900MHZ ISM	**AP**	**REMOTE**
Idle	293mA	235mA
50% Duty Cycle	382mA	365mA
WITH LICENSED NB	**AP**	**REMOTE**
Idle	910mA	350mA
50% Duty Cycle	950mA	780mA

AGENCY APPROVALS / STANDARDS

- FCC Part 15, 90, 80, 101, 27, 95 and IC
- ETSI / CE, EN 300.113, EN302.561
- IEEE 1613†, IEC 61850-3
- CSA Class 1, Div. 2, CSA C22.2 No. 142-M1987 & 213-M1987
- ANSI/ISA • 12.12.01 • 2015, UL 916, 5th Ed., EN60950
- EMS EN 301 489-5, EN 301 489-1
- EMP: MIL-STD-461G, RS105 Electro Magnetic Pulse
- Shock: MIL-STD-810F Method 516.5
- Vibration: MIL-STD-810F Method 514.5
- Shock and Vibration: EIA RS374A
- Storage Temp: Mil-Std 810F Section 501.4 with 1 week soak test
- IP 40/41 per IEC 60529 for Vertical Falling Water and Pollution 3 for Dust
- IEC 60068-2-1 Cold; IEC62262 & IEC60068-2-75 Shock; IEC 60068-2-2 Dry Heat; IEC 60068-2-2-38 Composite temperature/humidity cyclic
- IP67 environmental rating (OCR only)

† Requires an external DC to DC converter having floating DC inputs (neither side grounded)

WARRANTY

5-year standard manufacturer warranty on all Orbit MCR/ECR models.

* Check with local sales representative for availability.

** L1C, L2X, L4A, L4C, L7A, L9A, L9C Orbit band options support 12.5, 25, and 50 kHz. L2B supports 5 kHz only. Other band options support 6.25, 12.5, and 25 kHz.

GEGridSolutions.com/Communications

Direct: 1-844-379-9630

Email: INDC.MDSInsideSales@ge.com

GEA-12781G(E)
English
230201