
# *Jefferson County, Wisconsin*

# *Study Report (Project #: 18-0906)*

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FINAL

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# 1 Problem Statement

Jefferson County, Wisconsin retained Elert & Associates | A True North Company (Elert & Associates) to study the County's current public safety voice and paging radio communications systems and provide analysis and recommendations for enhancement. The final report will include a review of the present system followed by options for system improvement, propagation predictions, and associated budgetary estimates for conceptual designs.

# 2 Executive Summary

## 2.1 *Radio System Options and Recommendation*

Elert & Associates (E&A) finds there are multiple issues confronting the public safety users of Jefferson County land mobile radio (LMR) systems. Addressing the paging solution impacts the operation of several other elements of a new system. Each user group (Law, Fire/EMS) has specific issues requiring resolution. Overall, the coverage requirements for each sub-system and for each user are found to be unique and thus must be uniquely addressed.

The simulcast paging system must be corrected as soon as possible. Performance requirements of all sub-systems, including paging, need to be determined and specifications prepared. A key component in a vendor response will be verification and testing to ensure the performance of each of the sub-systems individually. E&A will provide additional details in a proposal to define these performance specifications as part of Phase 2 of the project. There are many details concerning the desired performance of all sub-systems that need to be determined.

Once a direction is chosen for backhaul, paging, and voice system improvements, all antenna supporting structures must be evaluated to determine if they can continue to be used, require strengthening, or if alternate structures need to be considered. If alternate structures need to be considered, the County will need to locate an alternate structure or revise the expected performance specifications allowing the use of present tower sites. Assuming no site issues once a new backhaul (microwave) system is in place, the paging system will return to its original performance.

The rest of the voice channels will be added as desired by the County. For voice systems, users have indicated portable system performance of Law Enforcement and Fire/EMS needs improvement in many areas county-wide. Countywide portable coverage cannot be attained with a single transmitter site. To improve county-wide portable coverage, additional transmitter sites are required. The next section, Budgetary Costs, provides an overview of the three improvement options for consideration by the County.

Elert & Associates recommends Option 2. Using VHF and P25 will provide enhanced portable coverage performance and should reclaim the system performance losses attributed to narrow banding of channels. The E&A coverage modeling tool indicates six sites would provide an enhanced level of coverage. LAW1, EMCOM1, and FIRE1 channels would move to P25 digital simulcast operation using six sites across the County. Each P25 channel repeater will transmit from multiple sites simultaneously and any received signals will be routed to a voting system to select the best-received signal to retransmit and send to dispatch. MARC and IFERN would continue to be voted at nine sites and transmit from the main County site only as they are primarily mobile and do not require portable coverage. Paging would continue to be tone and voice simulcast at the current nine sites. Issues with distorted paging transmission should

be corrected by updating the microwave backhaul network.

In the conceptual designs, all RF sites would be powered by a DC plant that would provide continuous power to all equipment regardless of the status of commercial power. An alarm system with sensors (power, temperature, smoke/fire, fuel level, generator run, door switch, and tower lighting) would report all applicable alarms via the microwave network. Alarms at all sites will be reported and automatically alert dispatch operations and support. A microwave network would provide redundant backhaul to all sites. Loss of a single link would not impact the operation of voice or paging systems.

For Option 2 all existing radios would be replaced with P25 VHF conventional capable units. Ten units would be multiband radios used in the system to provide direct interoperability with neighboring systems. The Mindshare console system would continue to be used. A redundant P25 system interface equipped for three channels would be used to operate the conventional P25 simulcast repeater stations.

## 2.2 *Budgetary Costs*

Three options were considered, with Option 2 being Elert & Associates' recommended solution for the public safety radio system in Jefferson County.

### 2.2.1 Budgetary Cost – Radio System Option 1

| Option | Description of Improvement | Estimated Cost | Outcome |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | Six-site VHF analog simulcast-voted design for LAW1, EMCOM1 and FIRE1 channels<br><br>Paging, MARC, IFERN, and Highway systems are replaced with new equipment.<br><br>Satellite receivers would continue to be used at nine sites for MARC and IFERN.<br><br>The current dispatch console system will remain in operation.<br><br>The microwave topology would remain as designed but replaced with 6 GHz and 10 GHz microwave radios.<br><br>All existing radios would remain in use.<br><br>All RF sites would be powered by a DC plant.<br><br>State-of-the-art grounding techniques would be implemented at all sites.<br><br>The estimate includes communications equipment shelters for three sites and two self-supporting towers.<br><br>An alarm system with sensors (power, temperature, smoke/fire, fuel level, generator run, door switch, and tower lighting) would report all applicable alarms. | $4.94M | Improved portable coverage for Law, Fire and EMS users<br><br>Limited operational changes in dispatch<br><br>New microwave radio system<br><br>New infrastructure equipment<br><br>No change to existing field radios<br><br>Additional surge protection for infrastructure equipment<br><br>New shelters at some sites<br><br>Improved alarm system |

### 2.2.2 Budgetary Cost – Radio System Option 2

**Recommended Option**

| Option | Description of Improvement | Estimated Cost | Outcome |
|---|---|---|---|
| 2 | Option 2 is a six-site VHF P25 simulcast-voted design for LAW1, EMCOM1, and FIRE1 channels.<br>Paging, MARC, IFERN, and Highway systems are replaced with new equipment.<br>Satellite receivers would continue to be used at nine sites for MARC and IFERN.<br>The Mindshare console system would continue to be used.<br>The microwave topology would be converted to a ring topology providing redundancy.<br>All microwave would be replaced with 6 GHz and 10 GHz microwave radios providing 99.999% reliability.<br>All existing radios would be replaced with P25 conventional capable units.<br>All RF sites would be powered by a DC plant.<br>State-of-the-art grounding techniques would be implemented at all sites.<br>Includes communications equipment shelters for three sites and two self-supporting towers<br>An alarm system would report all applicable alarms via the microwave network.<br>359 VHF P25 Mobiles<br>831 VHF P25 Portables<br>67 VHF P25 Control Stations | $9.73M | Improved portable digital coverage for Law, Fire, and EMS users<br>Digital operation for LAW1, EMCOM1, and FIRE1 channels<br>AES encryption for Law<br>Direct interface to digital infrastructure equipment<br>Limited operational changes in dispatch<br>New redundant Microwave radio system<br>New infrastructure equipment<br>Additional surge protection for infrastructure equipment<br>New shelters at some sites<br>Improved alarm system |

### 2.2.3 Budgetary Cost – Radio System Option 3

| Option | Description of Improvement | Estimated Cost | Outcome |
|---|---|---|---|
| 3 | 10-site, five-channel, P25 800 MHz simulcast-voted design<br>Services LAW, FIRE, EMS, Highway, and other potential County users<br>AES encryption for 531 Law radios<br>Over-the-air-Programming for 1257 radios<br>Over-the-air-Rekeying for all Law radios<br>Paging, MARC, and IFERN systems are replaced with new equipment.<br>MARC and IFERN channels would be connected to P25 talk groups.<br>The Mindshare console system would continue to be used.<br>The Mindshare console system would use the Console Sub-System Interface for direct control of trunked radio system.<br>A digital store and forward paging system with 523 digital alphanumeric display pagers is included.<br>Backhaul would be replaced with a 6 GHz and 10 GHz ring microwave network providing 99.999% reliability.<br>All RF sites would be powered by a DC plant.<br>An alarm system would report all applicable alarms via the microwave network.<br>State-of-the-art grounding techniques would be implemented at all sites.<br>Includes communications equipment shelters for four sites and five self-supporting towers<br>All existing radios would be replaced with 800 MHz P25 trunked capable units.<br>359 VHF P25 Mobiles<br>831 VHF P25 Portables<br>67 VHF P25 Control Stations | $18.16M | Improved portable digital coverage for Law, Fire and EMS users<br>Digital operation for LAW1, EMCOM1 and FIRE1 channels<br>AES encryption for Law<br>Four voice channels shared among all users of the system<br>Over the programming on all units<br>Over the air rekeying for encrypted units<br>Enables use of talk groups for special events<br>Direct interface to digital infrastructure equipment<br>Limited operational changes in dispatch<br>New redundant microwave radio system<br>New infrastructure equipment<br>Additional surge protection for infrastructure equipment<br>New shelters at some sites<br>Improved alarm system |

# 3 Findings / Issues

## 3.1 *Jefferson County Communications Systems*

### 3.1.1 Voice Radio Systems

#### 3.1.1.1 LAW1

LAW1 is an analog VHF repeated channel with a single transmitter site (Main) and nine voted receiver sites. Sites are interconnected with 960 MHz and 10 GHz licensed microwave plus fiber links, all in a star topology. Sheriff and most municipal Police departments in the County use the LAW1 channel for their primary LAW communications.

#### 3.1.1.2 EMCOM1

The EMCOM1 (Emergency Command) is an analog VHF repeated channel with a single site transmitter and nine voted receiver sites for public safety communications. Sites are interconnected with 960 MHz and 10 GHz licensed microwave plus fiber links in a star topology. EMCOM1 is designed to be a countywide repeated channel for use by any agency, sheriff, police, fire, or EMS as needed for an incident/event. The channel also serves as the primary backup channel for all agencies in case of a radio site failure at the main site with a stand-alone transmitter located at the backup site with no voting capabilities, thus it is primarily a mobile coverage channel.

#### 3.1.1.3 FIRE1

FIRE1 is an analog VHF repeated channel using two-site simulcast and nine voted receiver sites. Sites are interconnected with 960 MHz and 10 GHz licensed microwave plus fiber links in a star topology. All Fire and EMS departments use this configuration.

#### 3.1.1.4 MARC1

MARC1 (Mutual Aid Radio Channel) is an analog VHF repeated channel using a single site transmitter and nine voted receiver sites for regional communications. Sites are interconnected with 960 MHz and 10 GHz licensed microwave plus fiber links in a star topology. Public safety uses this channel for interoperability with regional and state resources.

#### 3.1.1.5 IFERN

IFERN (Interagency Fire Emergency Radio Network) is an analog VHF simplex base station channel using a single site transmitter and nine voted receiver sites for regional Fire communications. Sites are interconnected with 960 MHz and 10 GHz licensed microwave plus fiber links in a star topology. This channel is used to coordinate Fire mutual aid with local and regional departments.

### 3.1.2 Paging

#### 3.1.2.1 Fire-Rescue/EMS

The Jefferson County paging system is an analog VHF nine-site simulcast system providing countywide paging service for Fire and EMS. Sites are interconnected with 960 MHz and 10 GHz licensed microwave plus fiber links in a star topology. Currently, stability issues with the Jefferson County microwave and multiplexer network are creating issues with paging performance. This issue needs to be corrected as soon as possible.

## 3.2 *Interviews*

### 3.2.1 Users

#### 3.2.1.1 Law Enforcement

The performance of the Sheriff main channel (LAW1) for Law Enforcement users in Jefferson County appears to work well. Few issues were voiced during a scheduled meeting of their committee on October 17, 2018. Input generally consisted of what new features and functions for Law Enforcement would be available for the Law Enforcement community within Jefferson County.

#### 3.2.1.2 Fire / EMS

The performance of the Fire and paging systems are of concern to most Fire and EMS departments in Jefferson County. Paging performance issues have been traced to instability of the microwave network and are attempted to be addressed. Other issues include lack of coverage that resulted from the FCC's 2012 narrowband conversion mandate and general performance issues. Several service firms maintain Fire radios throughout the County, and there is no regularly scheduled maintenance performed on field units. Unit programming is inconsistent across the county and sometimes is performed by Fire department personnel, not service professionals. Channel naming on identical channels is also inconsistent across the County.

### 3.2.2 Service Firm

#### 3.2.2.1 General Communications (GENCOMM)

General Communications provides infrastructure maintenance for the County. This includes the VHF repeater and satellite receiver/voting system, microwave and fiber networks, and dispatch consoles for Jefferson and Watertown dispatch centers. E&A discussed the Jefferson County system with General Communications while on-site. General Communications provided documentation on Land Mobile Radio (LMR) and microwave system design, site information, and the frequencies used while on-site and via email and telephone calls as questions arose after departure.

## 3.3 *Towers/Sites*

### 3.3.1 Reviews

Elert personnel paid a visit to each County site to discover the equipment used and installation techniques employed. The antenna structures used include six self-supporting lattice towers, one monopole and three water towers. County owned antenna structures include towers at Jefferson, Palmyra and Waterloo. The antenna structures at Lake Mills, Ft. Atkinson (We Energies), City of Jefferson Water Tower, Johnson Creek and Watertown are used by the County at little or no cost to the County. Lease agreements are in place for antenna structures located at Ixonia, Sullivan and Johnson Creek. No structural analysis was conducted on antenna structures as part of this study. Structural analysis is recommended once future system improvements are determined.

# 4 Intermodulation Study

## 4.1 *Study/Review*

Whenever transmit frequencies at any one site are active they mix producing signals that could create interference to local receivers. Intermodulation studies calculate the potential mixes in the transmitter frequencies and compare results to the receive frequencies used. A mix produces a frequency that could potentially interfere with a receive frequency it is called a 'hit". Any mix of actual transmit frequencies that result in a hit may be problematic for operations.

For intermodulation any hit using three frequencies is called 'Third Order'. The intermodulation example above used three VHF frequencies, but third order hits can also be produced by two times Frequency A (second harmonic) minus Frequency B. For Jefferson County, if FIRE1, IFERN, and LAW1 transmitters channels are active at the Jefferson main site, there may be interference on the FIRE1 receiver. If the LAW1 repeater was active and dispatch was transmitting on IFERN a Fire Portable using the FIRE1 channel may have difficulty communicating while a mobile may not due its higher power. The interfering signal will be present if this condition occurs. The impact on communications will depend on the receive signal level of the inbound Fire unit.

Although higher order hits were found they are unlikely to be issues as the likelihood of all channels being in transmit is low but as effected channels use satellite receiver sites it is unlikely that either of these possibilities would impact operation unless no other satellite site received signals.

## 4.2 *Main Site*

**Intermod Checks Performed:**
Base Transmit to Base Receive

**Services Checked:**

| | Service | Tower | Tx Freq | Rx Freq | Duplex | Bandwidth |
|---|---|---|---|---|---|---|
| 001: | LAW1 | Tower 1 | 154.860000 MHz | 158.910000 MHz | Full | 12.50 kHz |
| 002: | EMCOM1 | Tower 1 | 155.775000 MHz | 158.790000 MHz | Full | 12.50 kHz |
| 003: | FIRE1 | Tower 1 | 154.370000 MHz | 153.770000 MHz | Full | 12.50 kHz |
| 004: | MARC1 | Tower 1 | 151.280000 MHz | 153.845000 MHz | Full | 12.50 kHz |
| 005: | IFERN | Tower 1 | 154.265000 MHz | 154.265000 MHz | Full | 12.50 kHz |
| 006: | HIGHWAYS | Tower 1 | 156.240000 MHz | 158.985000 MHz | Full | 12.50 kHz |
| 007: | PAGING | Tower 1 | 154.055000 MHz | 0.000000 MHz | Full | 12.50 kHz |

**Mixes Checked:**
2-Signals up to 2nd Order
3-Signals up to 3rd Order
4-Signals up to 4th Order
5-Signals up to 5th Order
6-Signals up to 6th Order
7-Signals up to 7th Order

**3-Signal 3rd Order (A±B±C):**
If transmitters are simultaneously active on FIRE1, IFERN, and LAW1 channels, there may be interference on the FIRE1 receiver.

**5-Signal 5th Order (A±B±C±D±E):**
If transmitters are simultaneously active on IFERN, HIGHWAY, PAGING, MARC1, and FIRE1, there may be interference on the LAW1 receiver.

**7-Signal 7th Order (A±B±C±D±E±F±G):**
If transmitters are simultaneously active on EMCOM1, MARC1, HIGHWAY, PAGING, IFERN, FIRE1, and LAW1, there may be interference on the MARC1 receiver.

The 3-Signal 3rd Order calculation indicates that the FIRE1 repeater receiver at the main site may be experiencing some interference if the IFERN base transmitter and LAW1 repeater is active at the same time. The interfering product is 5kHz higher than the FIRE1 receiver frequency. Today, with your voted receiver system, if other sites are receiving the FIRE1 signal from field units, other sites may be selected, and no issues would be noticed.

The 5-Signal 5th Order calculation is less likely due to the number of simultaneous transmitters; but, in a busy period, the LAW1 repeater receiver could have interference as the combination results in a direct hit on the LAW1 receiver frequency. Since this is a voted frequency, if any other site receives an acceptable signal, no issues would be noticed.

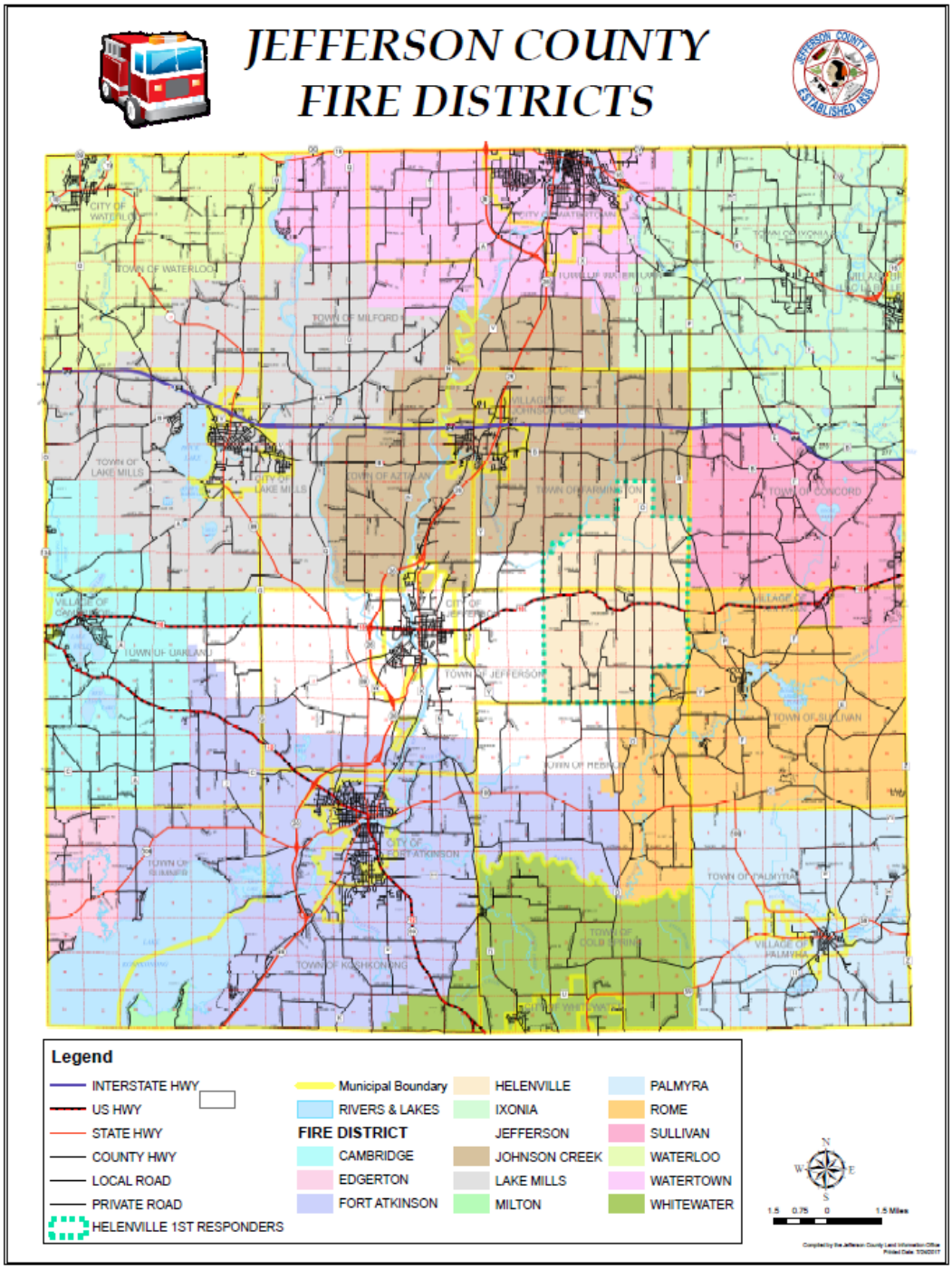
The 7-Signal 7th Order calculation is even less likely but if all stations are active an interfering signal would be generated 10kHz higher than the MARC1 receive frequency.

As IFERN is a common channel in all potential mixes, these conditions can only occur at the Main site where an IFERN station is located with this channel set. If the County chooses to implement simulcast on LAW1, EMCOM1, and FIRE1 at other County sites all other channels used at these sites should be checked with these County channels for intermodulation products.

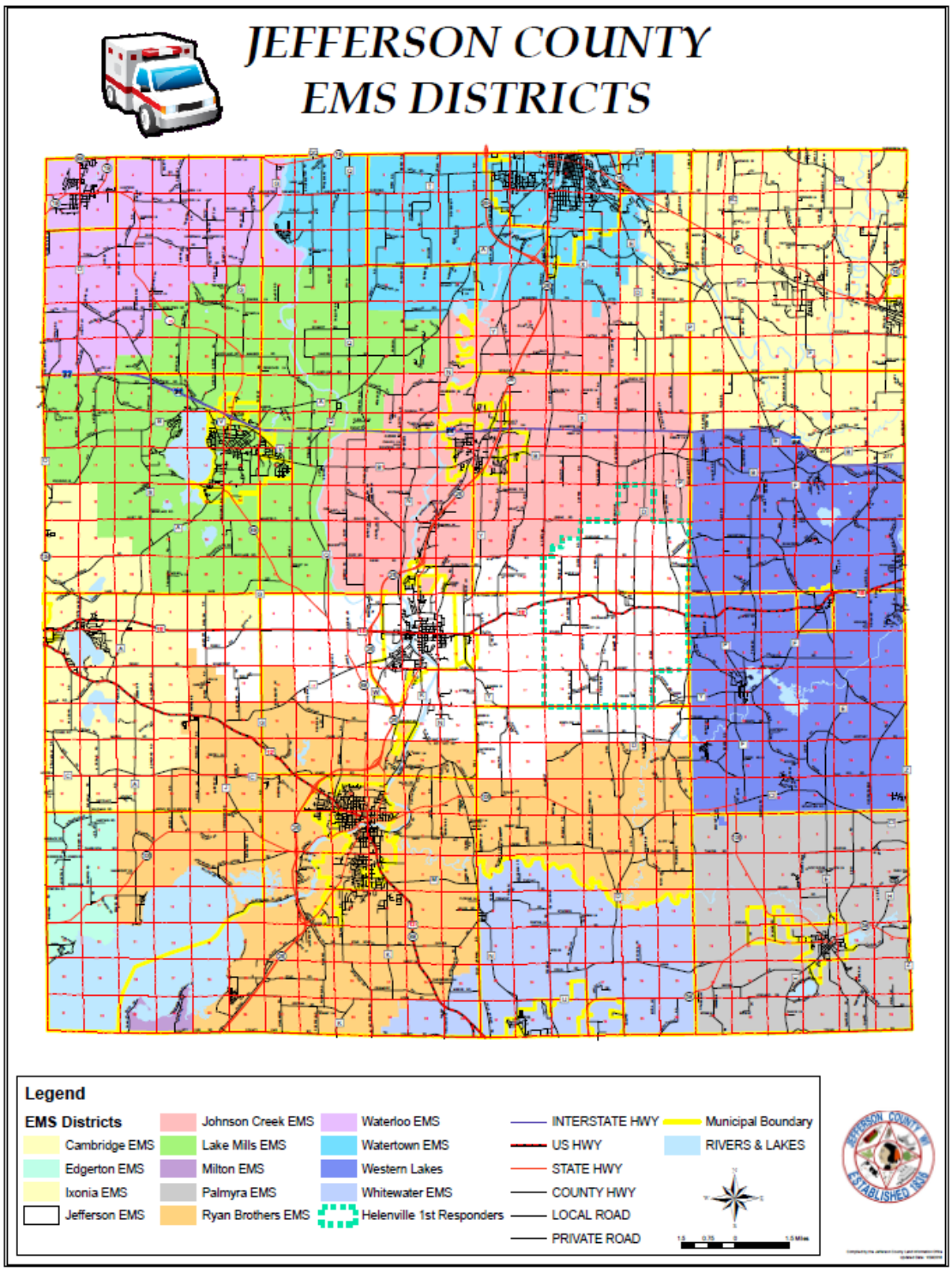
# 5 Service Areas

## 5.1 *Public Safety*

### 5.1.1 Fire



### 5.1.2 EMS


JEFFERSON COUNTY
EMS DISTRICTS
Legend
EMS Districts
Cambridge EMS
Edgerton EMS
Ixonia EMS
Jefferson EMS
Johnson Creek EMS
Lake Mills EMS
Milton EMS
Palmyra EMS
Ryan Brothers EMS
Waterloo EMS
Watertown EMS
Western Lakes
Whitewater EMS
Helenville 1st Responders
INTERSTATE HWY
US HWY
STATE HWY
COUNTY HWY
LOCAL ROAD
PRIVATE ROAD
Municipal Boundary
RIVERS & LAKES

# 6 FCC Licensing

Following are the FCC call signs held by Jefferson County and some of the agencies within the County. This list also includes the microwave link licenses used for the backhaul network.

| Item | Call Sign/Lease ID | Name | FRN | Radio Service | Status | Expiration Date |
|---|---|---|---|---|---|---|
| 1 | KSB455 | JEFFERSON, COUNTY OF | 2683225 | PW | Active | 10/8/2023 |
| 2 | KWH778 | JEFFERSON, COUNTY OF | 2683225 | PW | Active | 12/1/2025 |
| 3 | WNGN313 | JEFFERSON, COUNTY OF | 2683225 | PW | Active | 4/13/2024 |
| 4 | WQB793 | JEFFERSON, COUNTY OF | 2683225 | PW | Active | 3/31/2024 |
| 5 | WQCS368 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 5/13/2025 |
| 6 | WQCS370 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 5/13/2025 |
| 7 | WQCW818 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 6/14/2025 |
| 8 | WQCW819 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 6/14/2025 |
| 9 | WQCX645 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 6/20/2025 |
| 10 | WQHJ813 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 8/16/2027 |
| 11 | WQPP691 | JEFFERSON, COUNTY OF | 2683225 | PW | Active | 7/16/2022 |
| 12 | WQPY247 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 9/17/2022 |
| 13 | WQQE757 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 11/20/2022 |
| 14 | WQUV258 | JEFFERSON, COUNTY OF | 2683225 | MW | Active | 10/22/2024 |
| 15 | WQUW623 | JEFFERSON, COUNTY OF | 2683225 | PW | Active | 10/31/2024 |
| 16 | WQYF550 | JEFFERSON, COUNTY OF | 2683225 | SG | Active | 9/12/2026 |
| 17 | WPXP979 | JEFFERSON, CITY OF | 13592704 | PW | Active | 5/19/2023 |
| 18 | WQJL889 | LAKE MILLS EMS, INC. | 18136275 | PW | Active | 10/28/2028 |
| 19 | KRT680 | WATERLOO, CITY OF | 2689842 | PW | Active | 1/26/2023 |
| 20 | KSB464 | FORT ATKINSON, CITY OF | 2686038 | PW | Active | 10/25/2024 |
| 21 | KSL792 | LAKE MILLS, CITY OF | 2685436 | PW | Active | 10/22/2023 |

# 7 Infrastructure Equipment

## 7.1 *Repeaters / Base Stations*

Most of the VHF LMR repeater infrastructure uses Harris MASTR III stations. This model has not been in production for some time with its last date of manufacture being December 2010. The end date for repair parts from the manufacturer was December 2017. Although some parts may be available, any part that is unavailable from the manufacturer would be procured through third-party vendors or recovered from used stations. The cost for such parts would be driven by availability.

## 7.2 *Control Stations*

The Jefferson County field unit inventory reports sixty-seven (67) base stations are in use by departments across the County. These stations can be base stations for use with non-repeated channels or control stations used to communicate through a repeater. The same station can be used for either purpose or both depending on how they are programmed.

A base station (FB) or control station (FX1) both use outside antennas. Licensing of a FX1 is countywide and limits the antenna height to no more than 20 feet above surrounding structures. The RF power setting should be no more than necessary to ensure solid communications. (Note: FB and FX1 are FCC use designators.)

The equipment used for a control station is commonly a mobile radio with a power supply, but it could be any station programmed and set up appropriately. If your system is designed for portable operation, you do not need a lot of antenna height or power to communicate. If your system is simulcast, an antenna system using too much height can actually reduce performance.

A base station (FB) requires a license for each specific location, antenna height, RF power level, and a defined service area. The operation of a base station is unit to unit with no repeater. The FCC wants to ensure your signal does not interfere with co-users of the frequency. Base stations are licensed to provide communications around their location. The frequency coordinator may limit the effective radiated power and/or antenna height to minimize interference.

### 7.3 *Vehicular Repeater Systems (VRS)*

Vehicular repeaters were reported to be used by some Jefferson County agencies. Vehicular repeaters are used to enhance the performance of field units (usually portables) when a needed area of communications cannot be provided by the field unit due to terrain or obstructions thus preventing the field unit from providing acceptable performance. When a system is designed for portable operation, a mobile will usually work in most areas. If not, a vehicle can be easily moved to a location where mobile performance can be achieved. Vehicular repeaters can be self-contained or interconnect to a mobile radio to allow a portable radio to be used around the area of a vehicle repeater. Vehicle repeaters are designed for several different applications and can be simply too complex to set up and operate, especially when operating P25.

In its simplest form, a VRS system is a low powered radio device connected to a vehicle's mobile radio (usually existing) that communicates to the standard portable radio on a new (separate) channel. This allows the low powered portable radio that cannot reach the system to communicate to the VRS which is then sent to the system through the high-powered mobile radio which can reach the system. These devices add a layer of operational understanding which requires specific configuration and protocol implementation.

The use of VRS/extenders by some designers has been to implement this technology in all vehicles in a system with mobile-only coverage to then provide portable performance near the vehicle. This assumes all portable-based communications will happen within proximity of the associated VRS equipped vehicle. This concept is generally not accepted when all the protocols, operational aspects, and technical inadequacies are reviewed in detail. None of the repeater/extender manufacturers suggest this concept as the best use of their technology. In fact, some of these manufacturers have gone so far as to describe ways and means where the device will not work.

Great care must be used to reduce the impact of interference. Following protocol in their use will avoid problems and thus improve communications at critical times. Thus, buyers need to be fully aware of the limitations while understanding their capabilities. It is imperative the officer understands and correctly deploys a VRS or it may become part of the communications problem. As stated, employing P25 and VRS adds another layer of complexity to the implementation.

At VHF, use of vehicular repeaters is limited as there needs to be adequate frequency separation between the channels used. The frequencies used for portable operation cannot interfere with the existing repeater channels. In many cases, the vehicular repeater is limited in power to minimize interference. In other applications, the frequency for portable operation uses the UHF band to eliminate the potential of interference. In these cases, UHF-only portables do not serve any other purpose outside vehicular repeater operation unless dual band radios are acquired.

Most system designs never provide 100% coverage for mobile much less portable operation due to cost of the infrastructure. Modern public safety systems are designed to provide 95% portable coverage and still may have areas where mobiles cannot communicate with the infrastructure. Vehicular repeater technology can improve communications performance in the areas that do not meet the coverage goal in portable based system solutions. The conceptual designs offered by E&A and presented all assume the desire for the County to create solutions for the infrastructure to provide portable coverage to a relatively high level throughout without the use of VRS units.

Vehicular repeaters have been used to improve or provide portable communications for specific locations like schools, hospitals, or industrial parks depending on the need for such service. For locations that require routine or daily service, the infrastructure would be built to provide in-building performance or an in-building bi-directional amplifier (BDA), and a distributed antenna system (DAS) could be considered for such areas.

## 8 Dispatch

The County dispatch center is located within the Sheriff's Office at 411 South Center Avenue, Jefferson, WI. Dispatch is equipped with four dispatch positions in a space approximately 20' X 20' with the dispatch supervisor office and storage area adjacent to dispatch. The ceiling is about eight feet above the carpeted floor. Ceiling is finished with 2 X 2 ceiling tile with lighting and HVAC ducting occupying some of the ceiling tile spaces. Dispatch positions are in each corner of the room. A system for the storage of office forms and binders is in the center of the room making items accessible to all dispatch personnel. Four monitors are installed on the wall opposite the entrance to the room.

Each position is equipped with six monitors for dispatch functions. All positions are equipped with a Mindshare console along with 911, CAD, RMS, Mapping, etc. One position is also equipped with an EF Johnson Stargate console operating on the WISCOM network. The dispatch furniture is adjustable for sitting or standing.

Equipment supporting dispatch operation is in an equipment room outside of the dispatch area. The equipment room is in an elevated room and houses back-room console equipment, networking, primary and backup radio equipment, telco, and WISCOM interconnections used for communications. An Eventide logging recorder located in the dispatch area records all phone and radio traffic.

All equipment in dispatch and the equipment room is powered by redundant power systems to continue to provide short-term and long-term power in the case of commercial power failure.

# 9 Antenna Structure Sites

Jefferson County's public safety radio system infrastructure employs nine sites and a tenth site for backup. These sites use self-supporting towers and water towers for antenna structures. The County uses the Site Boss system to monitor alarms.

Each site is described below and uses diagrams as provided to generally indicate structure height and antenna location. Some of this information is not current and should be updated as changes are made to the current system.

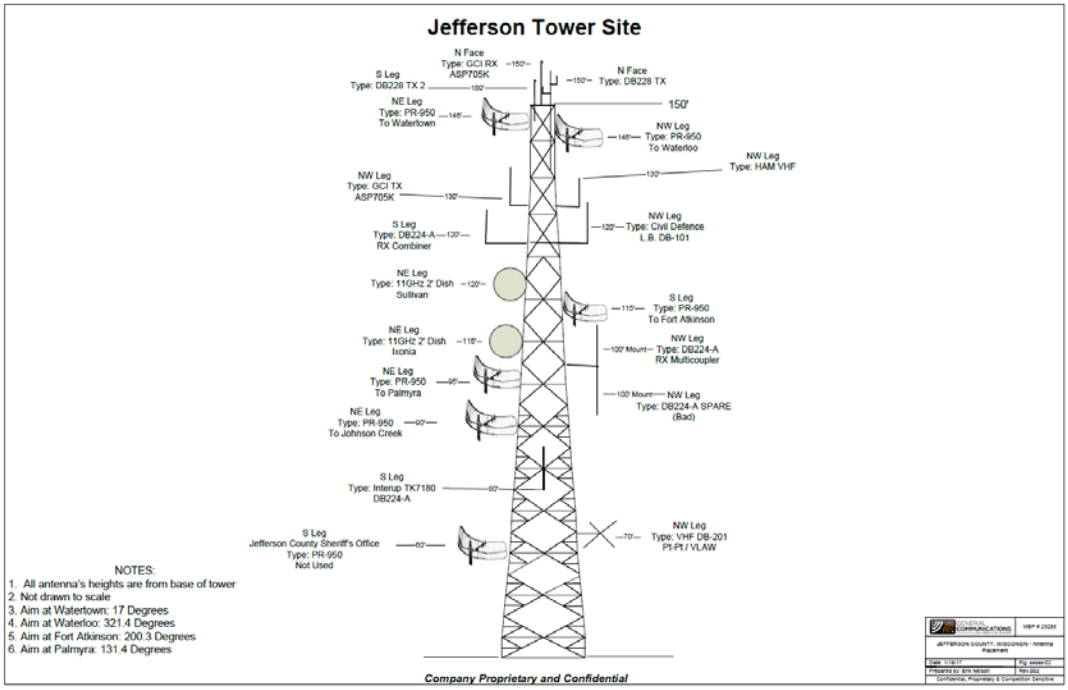
## 9.1 *Jefferson Main*

### 9.1.1 Compound

The land is owned by the City of Jefferson and leased to the County in exchange for providing dispatch services for the City. The site is named Cemetery Hill and is located at 345 E. Ogden St., Jefferson, WI 53549. The compound is fenced and encloses the tower, fuel tank, and shelter building. Tree branches are encroaching the cable entry port. A ~500-gallon propane tank is located near the southern fence-line. The tower is located between the fuel tank and the shelter.

### 9.1.2 Antenna Structure

A self-supporting tower is employed at the Jefferson County main site. The tower is owned by the Jefferson County Sheriff's Office. According to FCC license documentation, the site elevation is 271 m (889 feet), and the tower is 46 m (151 feet) above ground level. Its coordinates are 43-00-36.0 N and 088-48-05.0 W. The tower was constructed in 1981, and its FCC Antenna Structure Registration (ASR) number is 1212670.



#### 9.1.3 Shelter

The shelter is a block structure with an addition added in 2012. The equipment shelter floor dimension is estimated to be about 10 by 20 feet. The ceiling of the shelter is about 8 feet. A separate 6 by 10-foot room houses an Onan 12.5 kW generator and transfer switch.

#### 9.1.4 Installation and Grounding

The shelter houses several racks of equipment including County and commercial based systems. A 12-port cable entry panel is used to route the transmission line to the tower. A master ground bar (MGB) is located below the cable entry port. All transmission lines and outdoor CAT5 microwave cables were equipped with surge protection devices (SPDs). Transmission lines are held up by metal U-shaped supports mounted to the ceiling in several locations. Basic RF grounding techniques are employed at the site[1] but no perimeter (halo) ground system was observed or surge protection device was observed on the breaker panel. Racks are neatly arranged but not secured to the floor. Power is provided by duplex and quad outlets throughout the shelter. Each outlet is labeled with the associated breaker. Set screw couplings are used on electrical conduits. Network cables are neatly bundled using Velcro and run to several 66 blocks mounted on a board on the wall. An alarm system monitors several parameters including door, temperature, and power.

### 9.2 *Sullivan*

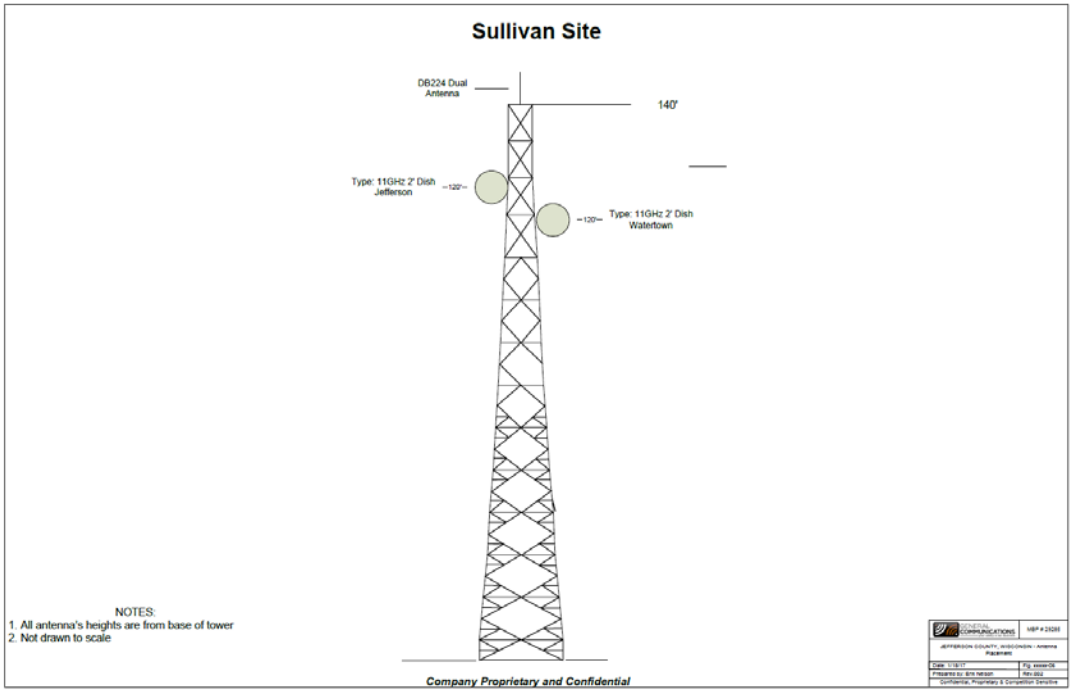
#### 9.2.1 Compound

Jefferson County rents space on a tower located at W1638 County HWY 18, Sullivan, Wisconsin and shares a driveway with W1636, a home and building site. The County is the sole occupant of the tower site. The land is in the name of Anfang Properties LLC of Sullivan, WI. The compound is approximately 20 by 20 feet with foliage surrounding the fenced area. The fence encloses the tower, shelter building, generator, and two 50-gallon propane fuel tanks. Portable 50-gallon fuel tanks located near the gate are used due to limited site accessibility. Brush and other foliage were observed within the fenced-in area, but most of the area was clear.

#### 9.2.2 Antenna Structure

It appears to be a Pyrod model self-supporting tower. According to FCC license documentation, the site elevation is 278 m (912 feet), and the tower is 36.5 m (120 feet) above ground level. (*Note the drawing on the next page indicates the above ground level (AGL) tower height is 140 feet.*) Its coordinates are 43-00-53.3 N and 088-36-52.6 W. As this tower is not registered with the FCC, it does not have an ASR number, and the date of construction is not known from FCC records.

[1] After the E&A visit, the County had an issue that caused General Communications to improve system grounding for all equipment in the shelter including adding ground rods outside.




### 9.2.3 Shelter

The shelter is a wood framed structure with a pitch roof. The floor dimensions are about 8 by 8 foot with an 8-foot ceiling. A 17 kW Honeywell residential style generator provides backup power. The generator is equipped with a cellular-base alarm system to report the current operating status and maintenance schedule.

### 9.2.4 Installation and Grounding

The shelter houses one equipment rack and a combiner rack. A three-port cable entry panel is used to route transmission line to the tower. A ground bar is located below the cable entry port both inside and outside. All transmission lines and outdoor CAT5 microwave cables were equipped with surge protection devices (SPDs). Transmission lines are held up by metal U-shaped supports mounted to the ceiling. Basic RF grounding techniques are employed at the site including a legacy perimeter ground system. Racks are secured to the floor though do not seem to be insulated from the concrete. Power is provided by duplex and quad outlets. Set screw couplings are used on electrical conduits. AC power for the equipment rack is protected with a duplex outlet surge protection device. Batteries, mounted in the bottom of the equipment rack, provide immediate backup power upon power failure. Outlets are labeled with the associated breaker. An alarm system monitors several parameters including door, temperature, and power.

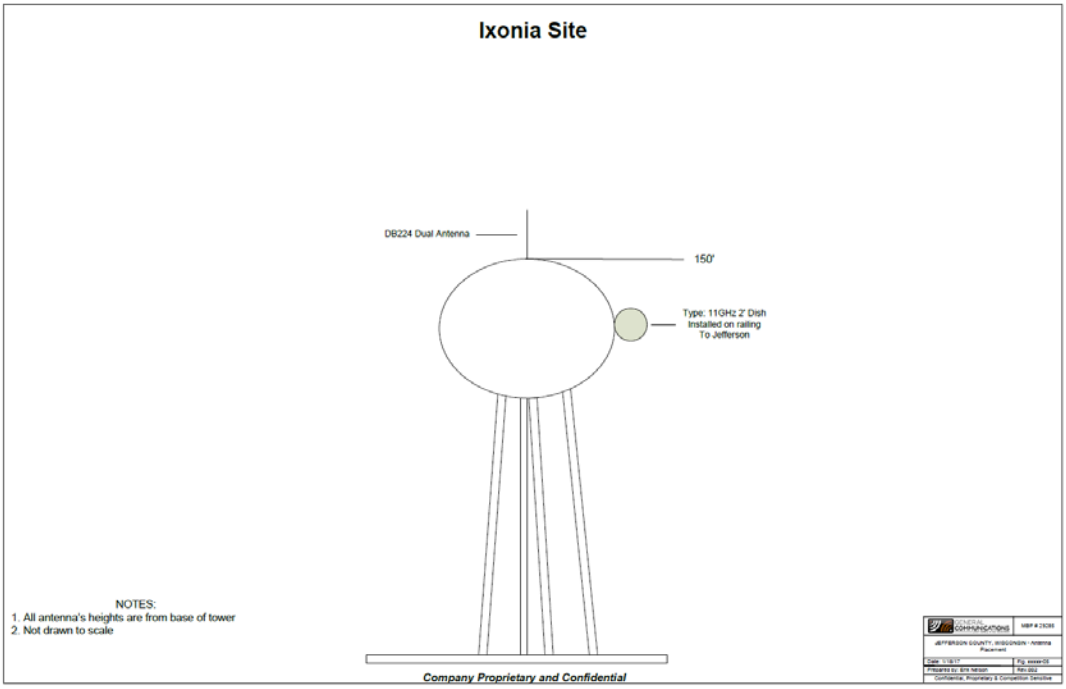
## 9.3 *Ixonia*

### 9.3.1 Compound

The Ixonia site located at N8233 County Road F, Ixonia, Wisconsin. The County rents tower space on the water tower and shares the space with a cell phone carrier. The compound area is occupied by two communications shelters – one on each side of the water tower along with several other storage trailers and other items kept in the area of the water tower. There is no fence, and a narrow ice bridge protects the County's transmission lines as they run to one leg of the water tower. A prefab communication shelter is employed at this site. There are small trees and bushes surrounding the shelter area on all sides except the entrance. There is no generator at this location.

### 9.3.2 Antenna Structure

The Ixonia water tower is used for the antenna on the County's current system. According to FCC license documentation, the site elevation is 264 m (866 feet), and the water tower height is 45.7 m (150 feet) above ground level. Its coordinates are 43-08-30.4 N and 088-35-35.9 W. There is no FCC Antenna Structure Registration (ASR) number for this site. Transmission lines for the County run up the mounts of the climbing cage installed on the ~southwest water tower leg.




### 9.3.3 Shelter

The 8 by 10-foot building is a pre-fab communications shelter secured to a concrete pad that is extended on the door side to provide a stoop. The ceiling height is about eight feet. Cable ladder is mounted at about 7.5 feet, and racks just fit underneath. The shelter has a single HVAC unit opposite the entrance door.

#### 9.3.4 Installation and Grounding

The shelter houses two equipment racks and a combiner rack. A six-port cable entry panel is used to route the transmission line to the tower. A ground bar is located below the cable entry port on the inside only. All transmission lines and outdoor CAT5 microwave cables were equipped with surge protection devices (SPDs). Transmission lines are held up by metal U-shaped supports mounted to the ceiling. Basic legacy RF grounding techniques are employed at the site including a legacy perimeter ground system. Racks are secured to the floor but not insulated from the mounts. Power is provided by duplex and quad outlets. Set screw couplings are used on electrical conduits. AC power has a surge protection device on the breaker panel. A UPS provides backup power upon commercial power failure. Outlets are labeled with the associated breaker. An alarm system monitors several parameters including door, temperature, power, etc.

### 9.4 *Waterloo*

#### 9.4.1 Compound

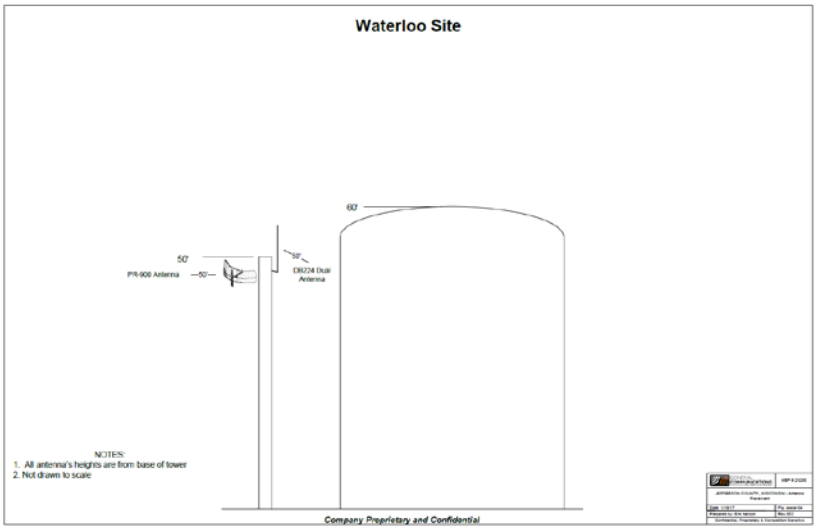
The Waterloo site is a small building and short tower near a water tank located at 733 Herron Ct., Waterloo, WI. The tower is fenced using the shelter wall as one side. There is no generator at this site[2]. The tower replaced a wood pole that remains at this location.

#### 9.4.2 Antenna Structure

A 60-foot self-supporting tower is employed at the Waterloo site[3]. The tower is owned by the Jefferson County Sheriff's Office. According to FCC license documentation, the site elevation is 283 m (928 feet), and the tower is 15.2 m (50 feet) above ground level. Its coordinates are 43-11-27.2 N and 088-59-51.9 W. The new tower replaced the wood pole in 2017 when the wooden pole no longer was able to support the antennas due to rotting. The tower has ground conductors on each leg, but these conductors are not CAD welded to the tower.

[2] A generator has been purchased and is scheduled to be installed at this site. The generator will be equipped with a cellular-base alarm system to report the current operating status and maintenance schedule.

[3] From visual inspection, the top of the tower is at or slightly above the above ground level water tower height. Assuming the highest point of the water tower is 60', the tower and the microwave antenna are slightly higher. The microwave is licensed at 40.0 feet. The tip of the paging/receive antenna is about 80 feet AGL. The paging antenna is licensed for 60 feet. The antenna structure type for WQPP691 at the Waterloo location is a pole, not a tower. It is assumed that this license was not modified when the site was updated.




,

### 9.4.3 Shelter

The shelter is a ~8 by 8 cinder-block building set next to the new tower. The building is equipped with a ventilation fan opposite the doorway and an air duct at the floor-level for inbound air. A heater unit is mounted on the wall opposite the tower side. Power enters the building on the same side as the heater unit.

### 9.4.4 Installation and Grounding

The shelter houses two equipment racks and a receive combiner rack. A two-port cable entry panel is used to route the transmission line to the tower. There is a three-port panel that remains for the wood pole. A ground bar is located below the cable entry port on the inside only. All transmission lines were equipped with surge protection devices (SPDs). Transmission lines are secured with nylon ties and standoff mounted to walls and ceiling areas. Basic legacy RF grounding techniques are employed at the site including a legacy perimeter ground system. Racks are secured to the floor. Power is provided by duplex and quad outlets. Set screw couplings are used on electrical conduits. No surge protection device was observed on the breaker panel. A UPS provides backup power upon commercial power failure. Outlets are labeled with the associated breaker.

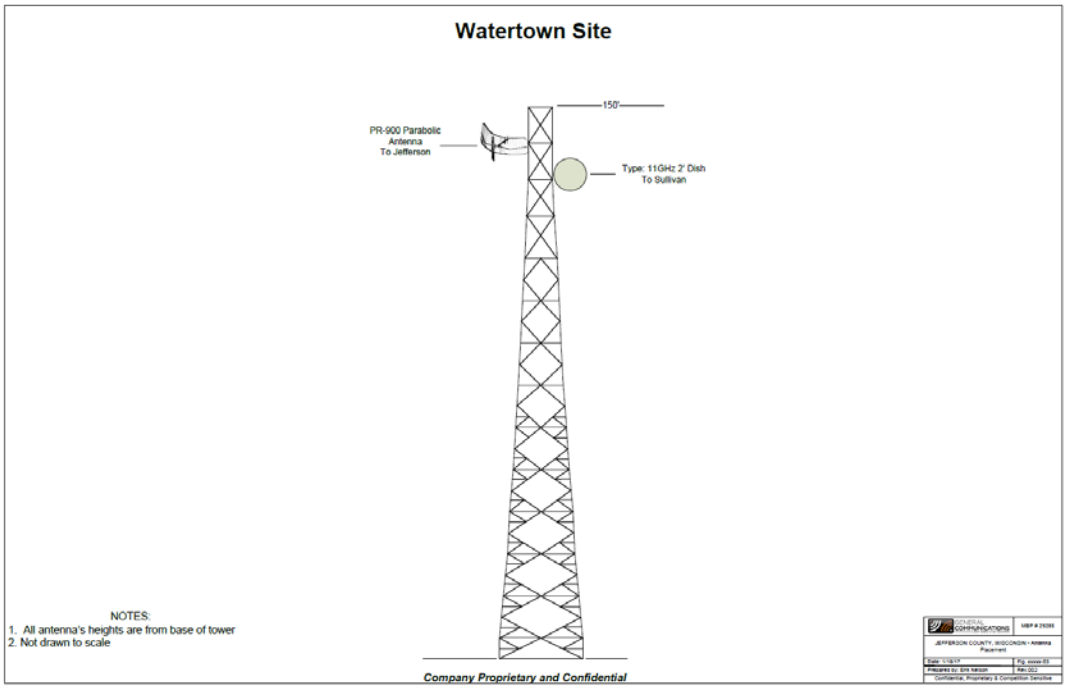
## 9.5 *Watertown*

### 9.5.1 Compound

The Watertown tower is owned by the City of Watertown site and located on the west side of the Police-Municipal-Fire Department complex at 106 Jones Street. The compound is fenced and encloses the tower and a shelter building used by a cell carrier. This is a shared public safety facility, and there is no cost to Jefferson County for use of the site. Generator power is provided by the backup for the building.

### 9.5.2 Antenna Structure

The Watertown tower is a self-supporting structure shared by several other users including a cellular carrier. The tower is owned by the City of Watertown. According to FCC license documentation, the site elevation is 250.6m (822 feet), and the tower is 45.7 m (150 feet) above ground level. Its coordinates are 43-11-45.9 N and 088-43-25.7 W. The age of the tower is unknown, and it does not have an FCC Antenna Structure Registration (ASR) number as it is not required at heights under 200 feet unless required by the FAA. The site drawing below shows microwave antenna locations on the tower but not the LMR antenna.




### 9.5.3 Shelter

The equipment shelter for the County radio system is a large room in the lower level of the Police-Municipal-Fire Department complex under the Fire Department. It has block walls and tile floor. Racks are secured to the floor. A cable support tray runs over racks. Two HERYTAGE UPS units provide continuous power upon commercial power failure.

### 9.5.4 Installation and Grounding

The equipment room houses City and County equipment. There is a Sheriff control station, Fire transmitter, and satellite receivers along the associated combining equipment at this location. A large conduit routes the transmission line to the tower through the false ceiling. The exact route to the tower was not observed. A ground bar is located below the cable entry port on the inside only. Transmission lines were equipped with surge protection devices (SPDs) upon entry to the equipment room, and a Master Ground Bar (MGB) is secured to the cable ladder. There is no perimeter (halo) ground system at this location. A ground conductor from the MGB appears to go into the ceiling back to the tower.

Transmission lines are secured with nylon ties to overhead cable ladder. Equipment racks are secured to the floor, but the combining rack was not secured. Power outlets in the cable ladder were not observed but may be wired back to the UPS units. Set screw couplings are used on electrical conduits. No surge protection device was observed on the breaker panel. A UPS provides backup power upon commercial power failure. An alarm system is in place and monitored by the City of Watertown Dispatch Center.

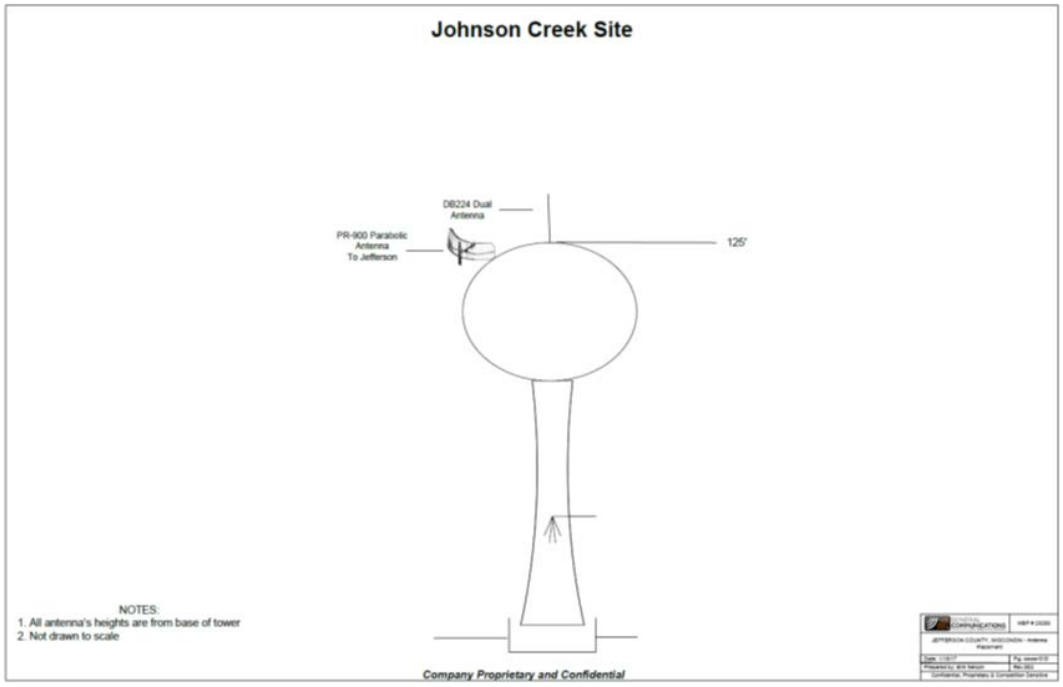
## 9.6 *Johnson Creek*

### 9.6.1 Compound

The Johnson Creek site is located at 525 Hartwig Blvd., Johnson Creek, WI. The County leases the site for $1 per year. The site is used by a cellular carrier and an Internet provider. There are two buildings at this location, but the County uses the base of the water tower for its equipment shelter. There is no generator at this location.

### 9.6.2 Antenna Structure

The antenna structure is the Johnson Creek water tower. According to FCC license documentation, the site elevation is 263 m (863 feet), and the tower is 48.7 m (160 feet) above ground level. Its coordinates are 43-04-58.2 N and 088-45-58.4 W. The water tower was constructed in 1993, and it does not have an FCC Antenna Structure Registration (ASR) number. Note that the water tower height stated in the diagram below should be corrected.



#### 9.6.3 Shelter

The County equipment is installed inside the base of the water tower. A concrete pad with a height of about six inches is used for County equipment. A small ground bar appears to be bonded to the base of the water tower.

#### 9.6.4 Installation and Grounding

One cabinet filled with equipment, a combiner rack, and three 27EV-HD deep cycle batteries are set on a concrete pad. The cabinet and combiner rack do not appear to be secured to the pad. A small ground bar is used to ground transmission line surge protection devices.

### 9.7 *Lake Mills*

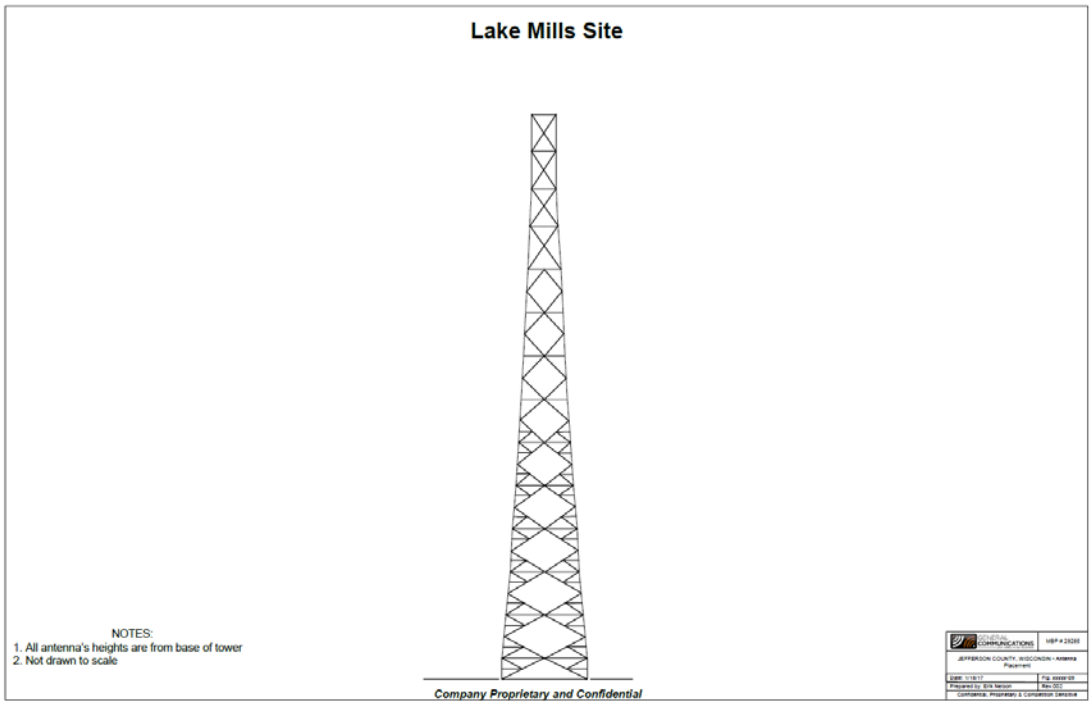
#### 9.7.1 Compound

Jefferson County shares the State-owned WISCOM facility at the eastbound rest area of I-94 for its Lake Mills site. The compound is fenced and has a backup generator. County equipment uses space in the WISCOM equipment shelter, and through an agreement, the County can use antennas already mounted on the tower at no cost.

#### 9.7.2 Antenna Structure

A 100-foot monopole is used to support antennas at the Jefferson County Lake Mills site. The monopole is owned by the State of Wisconsin also supports antennas used for the WISCOM statewide radio system. According to FCC license documentation, the site elevation is 256 m (840 feet), and the tower is 30.4 m (100 feet) above ground level. Its coordinates are 43-05-06.9 N and 088-52-23.2 W. The structure does not have an FCC Antenna Structure Registration (ASR) number.

Note that the diagram below is a lattice tower, not a monopole.



#### 9.7.3 Shelter

The building used to secure County equipment is a modern telecom communication shelter. It is equipped with cable trays near the ceiling and duplex power outlets above the cable trays. The shelter does not employ the latest grounding and surge techniques but provides protection for County equipment. Cable trays are bonded to each other, and ground conducts are available to ground racks. If WISCOM improves the level of surge protection in the future, the County will want to make similar improvements. Equipment is secured to the floor.

#### 9.7.4 Installation and Grounding

The County equipment is neatly installed in the WISCOM shelter and uses the grounding facilities provided in the shelter.

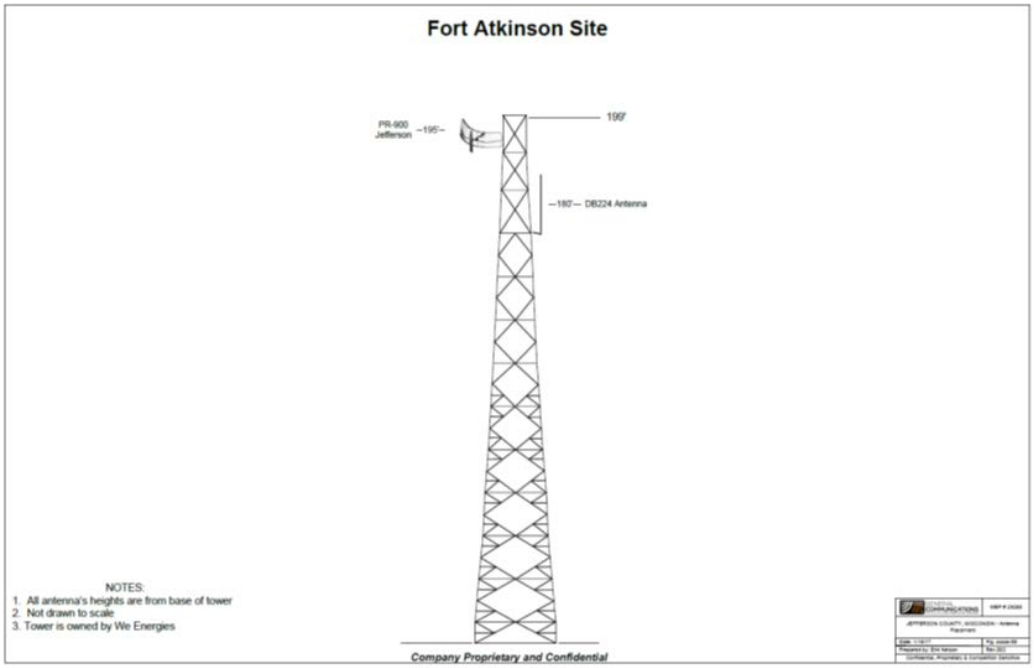
### 9.8 *Fort Atkinson*

#### 9.8.1 Compound

The location of the Fort Atkinson site is the We Energies facility at 1300 Janesville Ave., Fort Atkinson, WI 53538. There is a tower and a compound at the base of the tower adjacent to the We Energies building. The County equipment is installed on the inside wall of the building. The site is provided at no cost to the County. There are other communications services using the tower. We Energies provides generator backup power.

#### 9.8.2 Antenna Structure

A 200-foot self-supporting tower is the antenna structure at the Fort Atkinson site. The tower is owned by WE Energies. According to FCC license documentation, the site elevation is 243.2 m (798 feet), and the tower is 60.7 m (199 feet) above ground level. Its coordinates are 42-54-38.6 N and 088-51-04.8 W. The tower was constructed in 1991, and its FCC Antenna Structure Registration (ASR) number is 1050098.




### 9.8.3 Shelter

The shelter for the County equipment is along the inside wall of the We Energies building adjacent to the tower. The active equipment is mounted in locked cabinets, but the combining system is in an open rack with no fence for security; however, the area is in a fenced in, secure, and restricted area within the building. Cable entry for all (County plus We Energies indoor equipment) is provided by five, (5) ~6-inch conduits installed in the block wall. No ground bar on the inside or outside or transmission line ground kits were observed. Power for active equipment appears to be provided by a single wall outlet. Although dry during our visit, the area appears to have been flooded at some point as the bottom of the cabinet is rusted.

### 9.8.4 Installation and Grounding

The equipment cabinets are stacked, and the lower cabinet is placed on concrete blocks. Neither the cabinets or combiner racks are secured to the floor. No ground conductors were observed on combiner or cabinets. The rear door of the lower cabinet (against the wall) is not in place and rests on the floor behind the cabinet. The cables are suitably dressed and secured with nylon ties. Power outlets are marked with circuit numbers. Compression couplings are used on electrical conduits. Microwave equipment is labeled with frequency, RF power setting, and delay parameter. No grounding was observed.

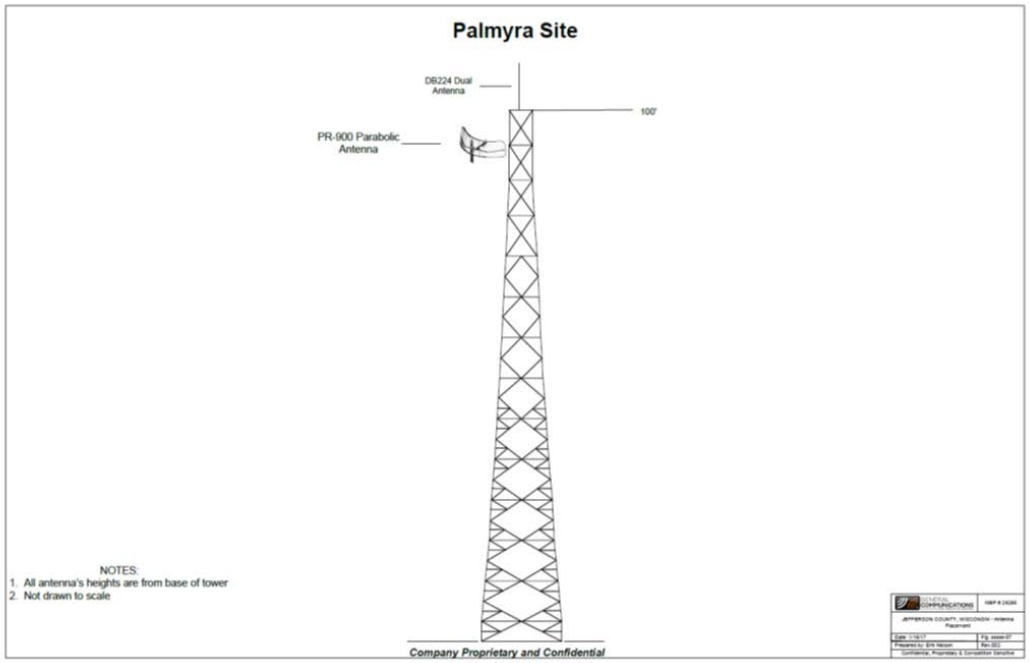
## 9.9 *Palmyra*

### 9.9.1 Compound

The Palmyra site is located inside Camp Oak Ridge at N303 Tower Rd., Palmyra, WI. The tower and associated compound are owned by Jefferson County. The County is the only user of the tower. The compound is fenced and encloses the tower, fuel tanks, and shelter building. Two portable 50-gallon propane tanks provide fuel for the 15kW generator. The generator is equipped with a cellular-based alarm system. A second concrete building occupies the site, but it is unusable due to portions of the roof that fell into the building.

### 9.9.2 Antenna Structure

A self-supporting tower is employed at the Jefferson County Palmyra site. The tower is owned by the Jefferson County Sheriff's Office. According to FCC license documentation, the site elevation is 308 m (1010 feet), and the tower is 30.5 m (100 feet) above ground level. Its coordinates are 42-51-05.1 N and 088-34-06.6 W. The tower does not have an FCC Antenna Structure Registration (ASR) number, and the age of the tower is unknown. The foundation piers are beginning to crumble.




### 9.9.3 Shelter

The Palmyra shelter is an older communication building that is failing. The floor is patched due to failure but was originally covered with vinyl floor tiles and wood paneling on the walls. The building is equipped with a two-port cable entry panel and legacy grounding system. There is a ground bar on the inside but not outside. At least three unused transmission lines and their associated antennas remain on the tower. The site is equipped with only generator fail alarms. There is an exhaust fan and residential window air-conditioner for summer and heater for winter operation.

#### 9.9.4 Installation and Grounding

The cabinet and rack are not secured to the floor, and there is a lack of grounding. A legacy grounding system is employed including a legacy perimeter ground system. The basic installation is neat and orderly. Set screw couplings are used on electrical conduits.

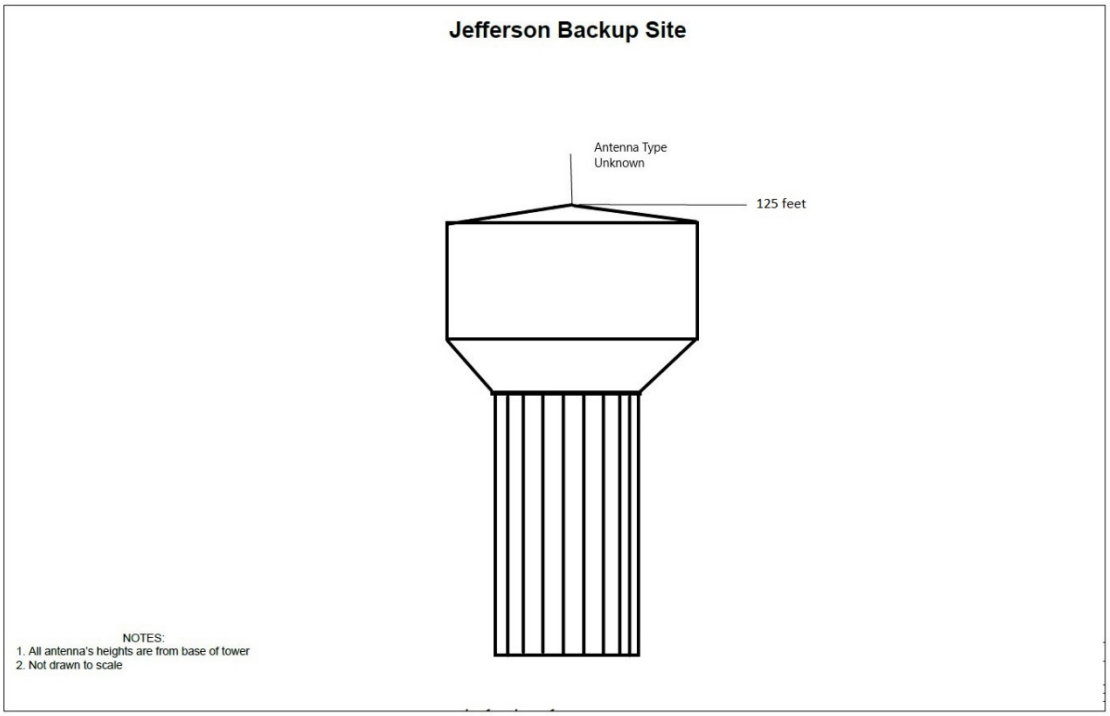
### 9.10 *Jefferson Backup*

#### 9.10.1 Compound

The back-up site for the County is the water tower on the south side of the City of Jefferson near Walmart. This site has a generator equipped with a 50-gallon propane tank; but, at the time of the visit, it was not operational[4]. The County shares space on the water tower with a cellular carrier. The County uses the site at no cost. Equipment is stored inside the base of the water tower.

#### 9.10.2 Antenna Structure

The City of Jefferson south water tower is employed for the Jefferson County back-up site. According to FCC license documentation, the site elevation is 259 m (850 feet), and the water tower is 28 m (125 feet) above ground level. Its coordinates are 42-59-10.0 N and 088-48-36.4 W. The tower does not have an FCC Antenna Structure Registration (ASR) number, and the age of the water tower is unknown.




[4] The battery was replaced on 12/20/18, and the unit was tested and found to be in working order.

### 9.10.3 Shelter

Equipment is installed in the base of the water tower. The breaker providing power to the County equipment is not marked. When conducting a generator test, it was not apparent what circuit supplied power.

### 9.10.4 Installation and Grounding

No issues were noted, although it is expected that overall improvements to bring grounding to current best practices is anticipated. Compression couplings are used on electrical conduits.

## 10 Field Terminal Summary

| JEFFERSON COUNTY UNIT INVENTORY | | | | |
|---|---|---|---|---|
| | | | | |
| | | | | |
| **UNIT TYPE** | **Moblies** | **Portables** | **Pagers** | **Base Stations** |
| **TOTAL COUNT** | **359** | **831** | **523** | **67** |
| **Village of Cambridge DPW** | 2 | 3 | 0 | 0 |
| **Fort Atkinson Fire Department** | 21 | 46 | 51 | 2 |
| **Fort Atkinson Police Department** | | | | |
| **Helenville Fire & Rescue** | 9 | 29 | 29 | 2 |
| **Ixonia DPW** | 3 | 0 | 0 | 0 |
| **Ixonia Fire & Rescue** | 31 | 52 | 68 | 2 |
| **City of Jefferson Police Department,** | 9 | 25 | 0 | 1 |
| **City of Jefferson EMS** | 12 | 35 | 65 | 1 |
| **City of Jefferson Fire Department** | 5 | 14 | 33 | 1 |
| **Jefferson County Health Department** | 2 | 0 | 0 | 0 |
| **Jefferson County Highway** | 80 | 10 | 0 | 1 |
| **Jefferson County Sheriff** | 66 | 124 | 0 | 20 |
| **Johnson Creek EMS** | | | | |
| **Johnson Creek Police Department** | 2 | 6 | 0 | 1 |
| **Lake Mills EMS** | 4 | 24 | 48 | 1 |
| **Lake Mills Fire Department** | 13 | 35 | 36 | 1 |
| **Lake Mills Police Department** | 5 | 16 | 0 | 1 |
| **Palmyra Public Safety** | 8 | 0 | 20 | 2 |
| **Rome Fire Department** | 6 | 29 | 36 | 1 |
| **RYAN BROTHERS AMBULANCE** | 22 | 10 | 23 | 1 |
| **Sullivan Fire** | 5 | 23 | 32 | 1 |
| **UW-Whitewater Police Department** | 5 | 211 | 0 | 1 |
| **Waterloo Fire & Rescue** | 16 | 40 | 46 | 2 |
| **Waterloo DPW** | 7 | 6 | 0 | 1 |
| **Waterloo Police Department** | 3 | 9 | 0 | 6 |
| **Waterloo Utility** | 0 | 7 | 0 | 1 |
| **Watertown Fire Department** | 12 | 43 | 36 | 1 |
| **Whitewater Police Department** | 13 | 37 | 0 | 16 |

# 11 Management

## 11.1 *Monitoring Tools*

Several, but not all, sites are equipped with monitoring systems that will report alarms at a site. Some sites have a cellular device attached to the generator that will report commercial power outage. Other sites are equipped with a Site Boss system that reports dry contact alarms at the site. Alarms can be power fail, temperature, and others. This system operates through the microwave network. Usually, such alarms trigger an email or page to the appropriate personnel for resolution.

## 11.2 *System Oversight/Knowledge*

Most system oversight appears to be delegated to the dispatch supervisor. In most systems, this is done by a committee. In more complex systems, governance plays a bigger role in the decisions made to ensure and maintain system performance. Although this appears to work for Jefferson County, representatives from the user community of Law, Fire, and EMS should be involved and become more familiar with the communications tools available in the industry. Local service firms and their suppliers can provide information and on-site demonstrations to increase user community knowledge.

# 12 Technical Support

General Communications provides infrastructure support for all County sites. Field units are maintained by several radio service firms. Few agencies employ maintenance contracts to ensure on-going operation. Fire and EMS agencies have radios serviced only when problems exist.

The following radio service firms were identified during E&A's on-site visit:

- Bandt Communications
- Baycom
- General Communications
- Radicom Inc.

All the above firms provide field unit maintenance and programming services for Jefferson County agencies. This methodology is easily followed with analog but there may be some difficulties in the future if the county and supported agencies move to P25 operation, especially if encryption is used.

## 13 On-going Maintenance

All systems need to be maintained on a regular basis. System infrastructure should go through a preventative maintenance check annually at a minimum. Some items should be checked multiple times per year. Data on the system performance and maintenance should be kept for future reference. Usually, a preventative maintenance agreement is established with a qualified service provider. How preventative maintenance and maintenance is done may depend on the system ultimately chosen by the County. Elert & Associates understands the County has a maintenance contract with General Communications on the current infrastructure.

Field unit maintenance of the mobile and portable radios also needs to be done on a regular basis. Preventative maintenance is recommended to be done annually. As there are multiple service firms doing the maintenance, a standard set of performance parameters may need to be established to ensure uniform operation. If existing radios are used when new system infrastructure is built, a qualification test should be completed to ensure proper operation. Again, maintenance and preventative maintenance agreements are normally used to control costs and ensure performance.

Elert & Associates finds that Fire and EMS departments do not have preventative maintenance plans in place with their service firms. Only when a field unit is determined not to function is any unit serviced. This practice can introduce several issues into the communications system that are not easily identified and commonly are blamed on the infrastructure. Again, moving to P25 makes this an even more important issue to be addressed.

# 14 Current System Issues

## 14.1 *Microwave Backhaul*

The analog microwave backhaul consists of 11GHz and 960MHz links. The multiplexer (MUX) issue with the current microwave backhaul system creates inconsistent audio levels for simulcast operation. Pagers are not able to consistently decode pages due to the instability of the simulcast transmission. Analog microwave has been replaced by digital microwave now for several years. Due to the design of the multiplexer and 960 MHz radios, these components of the current analog system must be replaced. There is also a general move to IP-based communications with digital microwave and at 960 MHz there is just insufficient bandwidth to support this protocol. The result will be to move to an IP-based microwave with greater bandwidth and IP-based multiplexers to support conventional repeaters.

The current backhaul topology uses a star and spur design. Most sites come directly into the main site in Jefferson. The Watertown connection is routed through the Sullivan site. Most links are limited in bandwidth (capacity) and are not protected with any level of redundancy if a link failure should occur. A failure of any link will result in a loss of at least one site. Losing the Sullivan link would also take out Watertown. As the microwave system supports simulcast paging and satellite receiver operation for Law, Fire, and EMS channels, any failure could severely impact operation in times of critical communications.

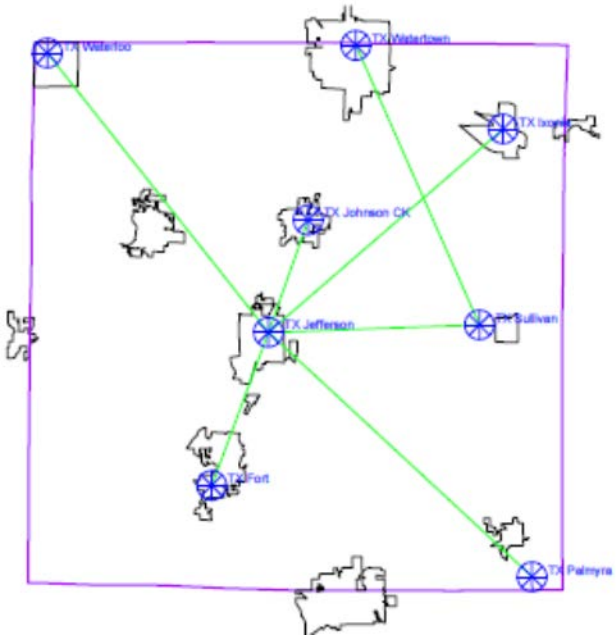



*Figure 1 - Current Microwave Topology*

The backhaul system uses two fiber links not shown on the map. The County uses a State fiber link from Lake Mills to the Jefferson County Sheriff Office and another fiber link from the Jefferson County Sheriff Office to the Main Jefferson site.

## 14.2 *Voice Systems*

### 14.2.1 Sheriff Main – (Law1)

The LAW1 channel is repeated and used by Law Enforcement throughout the County. The LAW1 repeater has a single transmitter at the Jefferson Main Site location and is licensed under call sign KSB455. The LAW1 repeater operates on a transmit frequency of 154.8600 MHz. LAW1 uses a continuous tone coded squelch system tone of 107.2 Hz for transmit and receive. The LAW1 repeater system has nine receivers operating on the frequency of 158.910 MHz at the following sites:

| | | |
|---|---|---|
| **Cemetery Hill** | **Johnson Creek** | **Sullivan** |
| **Fort Atkinson** | **Lake Mills** | **Waterloo** |
| **Ixonia** | **Palmyra** | **Watertown** |

The satellite receiver locations (all but Cemetery Hill) are backhauled via the microwave and fiber optic network to the Cemetery Hill site where any received signals are compared, and the best selected for (1) re-transmission by the repeater and (2) sent to the dispatch console system over the Cemetery Hill to Sheriff Office fiber optic link.

### 14.2.2 Emergency Command (EMCOM1)

The EMCOM1 channel is repeated and used by Law Enforcement, Fire, and EMS agencies throughout the County. The EMCOM1 repeater has a single transmitter at the Cemetery Hill location and is licensed under call sign KSB455. The EMCOM1 repeater operates on a transmit frequency of 155.7750 MHz. EMCOM1 uses a continuous tone coded squelch system tone of 103.5 Hz for transmit and receive. The EMCOM1 repeater system has nine receivers operating on the frequency of 158.790 MHz at the following sites:

| | | |
|---|---|---|
| **Cemetery Hill** | **Johnson Creek** | **Sullivan** |
| **Fort Atkinson** | **Lake Mills** | **Waterloo** |
| **Ixonia** | **Palmyra** | **Watertown** |

The satellite receiver locations (all but Cemetery Hill) are backhauled via the microwave and fiber optic network to the Cemetery Hill site where any received signals are compared, and the best selected for (1) re-transmission by the repeater and (2) sent to the dispatch console system over the Cemetery Hill to Sheriff Office fiber optic link.

EMCOM1 has a back-up repeater station at the City of Jefferson south water tower that is activated via control station from the Sheriff's Office.

### 14.2.3 Fire (FIRE1)

The FIRE1 channel is repeated and used by Fire and EMS agencies throughout the County. The FIRE1 repeater is licensed for simulcast transmitters at the Cemetery Hill and Watertown locations under call sign WQB793. The FIRE1 repeater operates on a transmit frequency of 154.3700 MHz. FIRE1 uses a continuous tone coded squelch system tone of 107.2 Hz for transmit and receive. The FIRE1 repeater system has nine receivers operating on the frequency of 153.7700 MHz at the following sites:

| | | |
|---|---|---|
| **Cemetery Hill** | **Johnson Creek** | **Sullivan** |
| **Fort Atkinson** | **Lake Mills** | **Waterloo** |
| **Ixonia** | **Palmyra** | **Watertown** |

The satellite receiver locations (all but Cemetery Hill) are backhauled via the microwave and fiber optic network to the Cemetery Hill site where any received signals are compared, and the best selected for (1) re-transmission by the simulcast repeater system and (2) sent to the dispatch console system over the Cemetery Hill to Sheriff Office fiber optic link.

### 14.2.4 IFERN (Interagency Fire Emergency Radio Network)

The IFERN channel is a simplex channel using the same transmit and receive frequency of 154.2650 MHz. Jefferson County has a base station at the Cemetery Hill location and receivers at the following sites:

| | | |
|---|---|---|
| **Cemetery Hill** | **Johnson Creek** | **Sullivan** |
| **Fort Atkinson** | **Lake Mills** | **Waterloo** |
| **Ixonia** | **Palmyra** | **Watertown** |

Received signals are backhauled via the microwave and fiber optic network to the Cemetery Hill site where any received signals are compared, and the best-selected audio is sent to the dispatch console system over the Cemetery Hill to Sheriff Office fiber optic link.

### 14.2.5 MARC1 (Mutual Aid Radio Channel)

MARC1 is a repeated channel using a transmit frequency of 151.280 MHz. The repeater is located at the Cemetery Hill location. The MARC1 repeater has a single transmitter at the Cemetery Hill location and is licensed under call sign KSB455. MARC1 uses a continuous tone coded squelch system tone of 136.5 Hz for transmit and receive. The MARC1 repeater system has nine receivers operating on the frequency of 153.845 MHz at the following sites:

| | | |
|---|---|---|
| **Cemetery Hill** | **Johnson Creek** | **Sullivan** |
| **Fort Atkinson** | **Lake Mills** | **Waterloo** |
| **Ixonia** | **Palmyra** | **Watertown** |

The satellite receiver locations (all but Cemetery Hill) are backhauled via the microwave and fiber optic network to the Cemetery Hill site where any received signals are compared, and the best selected for (1) re-transmission by the repeater and (2) sent to the dispatch console system over the Cemetery Hill to Sheriff Office fiber optic link.

#### 14.2.6 Jail

JAIL1 is a repeated channel and used by the Sheriff Office in the Jail facility. The JAIL1 repeater is licensed under call sign KSB455 and is located at the Sheriff's Office. The JAIL1 repeater operates on a transmit frequency of 155.5500 MHz and a receive frequency of 159.2100 MHz. JAIL1 uses a continuous tone coded squelch system tone of 107.2 Hz for transmit and receive.

#### 14.2.7 Highway – Public Works

The Highway channel is repeated and used by the County Highway personnel through the County. The Highway repeater is licensed under call sign KSB390 and located at the County's Main site. The Highway repeater operates on a transmit frequency of 156.2400 MHz, and a receive frequency of 158.9850 MHz and the repeater receiver system uses the receive multicoupler system at the main site. Highway uses a continuous tone coded squelch system tone of 173.8 Hz for transmit and receive.

#### 14.2.8 Simplex Channels

Jefferson County uses several simplex channels for unit to unit communications.

| Channel | TX Frequency | RX Frequency | TX CTCSS | RX CTCSS |
|---|---|---|---|---|
| **EMCOM2** | **155.775 MHz** | **155.775 MHz** | **103.5 Hz** | **103.5 Hz** |
| **FIRE2** | **154.370 MHz** | **154.370 MHz** | **107.2 Hz** | **107.2 Hz** |
| **FIRE3** | **154.415 MHz** | **154.415 MHz** | **107.2 Hz** | **107.2 Hz** |
| **LAW2** | **154.860 MHz** | **154.860 MHz** | **107.2 Hz** | **107.2 Hz** |
| **LAW3** | **155.145 MHz** | **155.145 MHz** | **107.2 Hz** | **107.2 Hz** |
| **TAC1** | **159.150 MHz** | **159.150 MHz** | **141.3 Hz** | **141.3 Hz** |
| **VLAW31** | **155.475 MHz** | **155.475 MHz** | **156.7 Hz** | **Carrier Squelch** |

### 14.3 *Paging System*

#### 14.3.1 Paging (PAGE)

The Jefferson PAGE channel is used for Fire and EMS alerting throughout the County. The PAGE channel operates on a transmit frequency of 154.055 MHz and uses a continuous tone coded squelch system tone of 107.2 Hz.

PAGE channel base stations are transmit-only and are simulcast at the following Jefferson County sites:

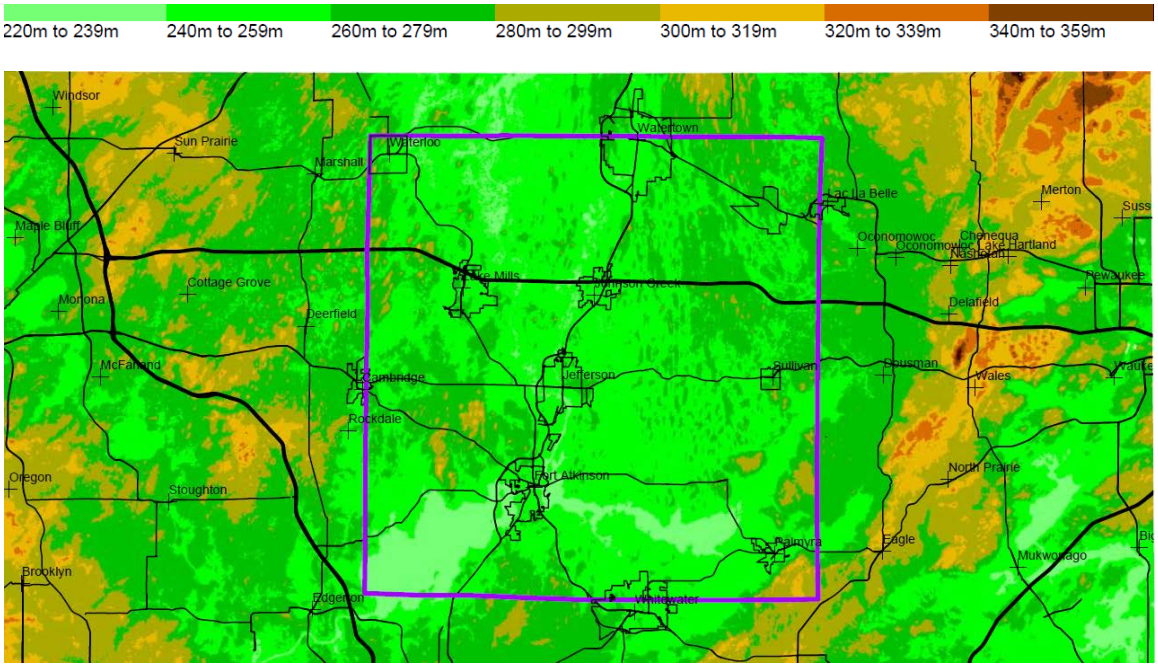
| | | |
|---|---|---|
| **Cemetery Hill** | **Johnson Creek** | **Sullivan** |
| **Fort Atkinson** | **Lake Mills** | **Waterloo** |
| **Ixonia** | **Palmyra** | **Watertown** |

The PAGE2 channel is a simplex base station at the City of Jefferson south water tower activated via wireline control from the Sheriff's Office or via control station using 155.790 using a continuous tone coded squelch system tone of 107.2 Hz.

The audio levels vary page to page due to the audio processing in the multiplexer used today in the microwave network. It was further complicated by the dynamics of satellite receiver activity. Replacement of this equipment is necessary to provide audio level stability. And with replacement there would be the strong possibility of moving to an IP-based multiplexer via IP-based microwave and fiber connectivity.

# 15 Current System Coverage Predictions

## 15.1 *Terrain*



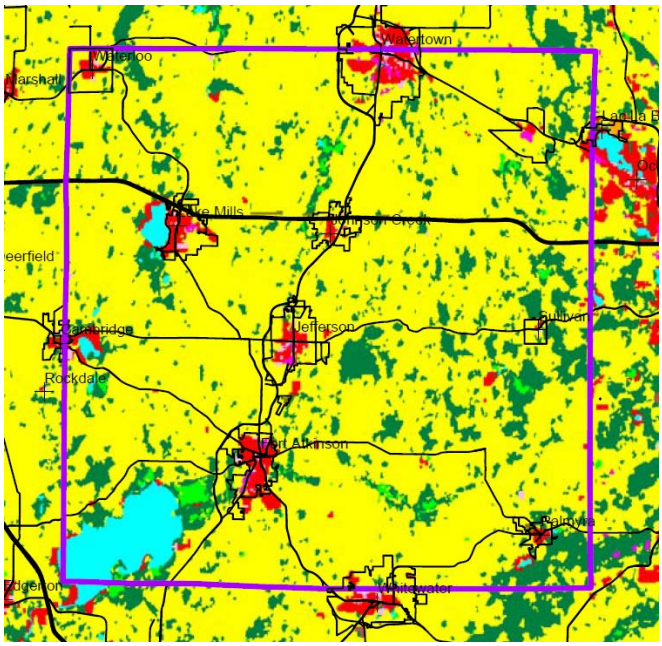

Most of Jefferson County is relatively flat with the highest and lowest terrain difference just over 200 feet. The County has a few areas in the southern portion of the county that approach 320 meters (1,046 feet). Lake Koshkonong and the Bark River Valley have the lowest elevation level of the County at less than 239 meters (784 feet). The majority of the county has an elevation of between 240 and 280 meters (787 and 918 feet).

The terrain database of the coverage modeling software contains a single figure for height above sea level for each 100 square meter tile found in the database. This height figure is used in the signal calculation between each tile and the site antenna location(s). The calculation also uses a land use attenuation parameter associated with each tile.

## 15.2 *Land Use*

The Land Use Land Clutter (LULC) database of the modeling software contains a single figure for type of land use for each 100 square meter tile that makes up the LULC database.

Land use in Jefferson County consists primarily of agricultural along with forests, wetlands, water, and residential. Each of the categories has an attenuation or clutter factor assigned to each tile LULC database. Along with terrain, it is used in each 100 square meter signal calculation.




LULC Color Customization

| Color | Description |
|---|---|
| | Water |
| | Snow Ice |
| | Wetland |
| | Open Land |
| | Rangeland |
| | Transportation |
| | Agricultural |
| | Residential |
| | Forest |
| | Mixed Urban/Buildings |
| | Commerial/Industrial |
| | High Density Urban |

## 15.3 *Predictions*

The following are predictions for the current systems using parameters found in the FCC's ULS (Universal Licensing System). Yellow indicates on-street coverage and green is residential indoor. Red is marginal and gray is unreliable. All predictions are created with 95% reliability, so predictions will be conservative and actual experience will likely be better than shown.

### 15.3.1 Law Channels

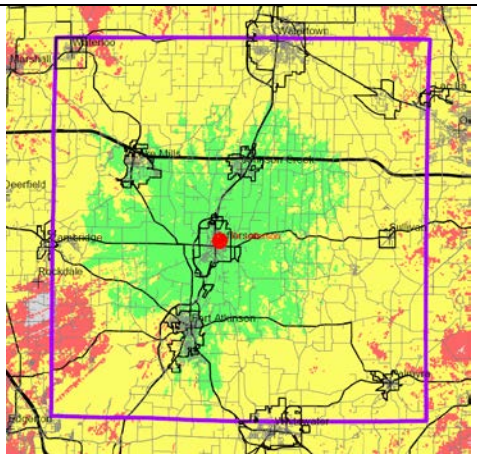


*Figure 2 - Portable Talk-Out*

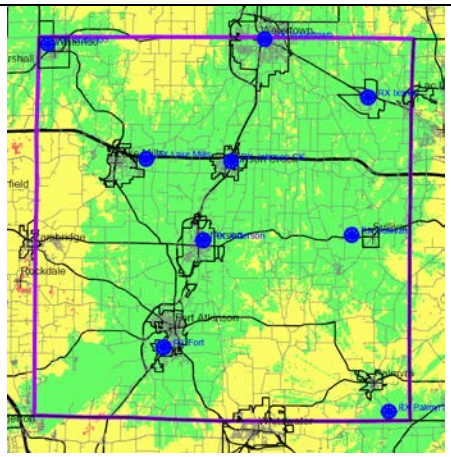


*Figure 3 - Portable Talk-Back*

The predictions above represent LAW1, EMCOM1, and MARC1 performance. As these systems employ a single site transmitter with holes shown in the portable coverage (left) near the borders of the county. The satellite receiver system improves talk-in coverage (right) and is the strongest portion of each of these channels. Predictions indicate dispatch may hear field units call-in, but it is possible field units may not hear dispatch if a field unit is within two to five miles of the border especially if inside a building.

### 15.3.2 Fire1

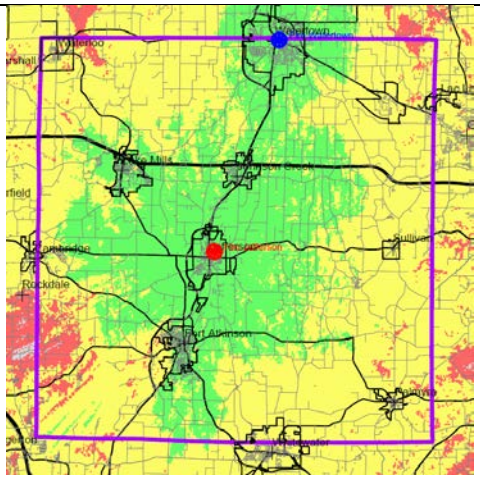


*Figure 4 - Portable Talk-Out*

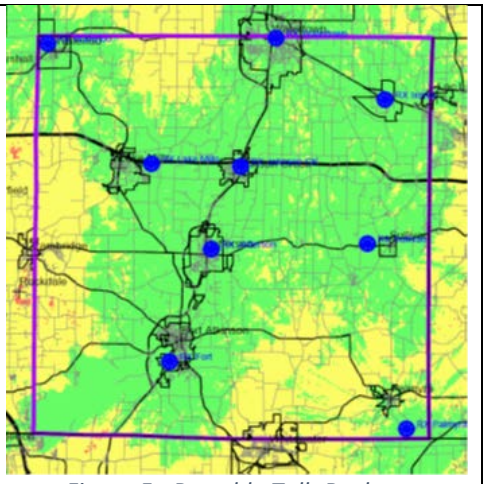


*Figure 5 - Portable Talk-Back*

The predictions above represent FIRE1 performance. The FIRE1 system employs simulcast transmitters at Cemetery Hill and Watertown sites. There are holes in the portable coverage (left) except in Watertown near the borders of the county. The satellite receiver system improves talk-in coverage (right) and is the strongest portion of system. Predictions indicate dispatch may hear field units call-in, but it is possible field units may not hear dispatch if a field unit is within two to five miles of the border especially if inside a building.

### 15.3.3 IFERN

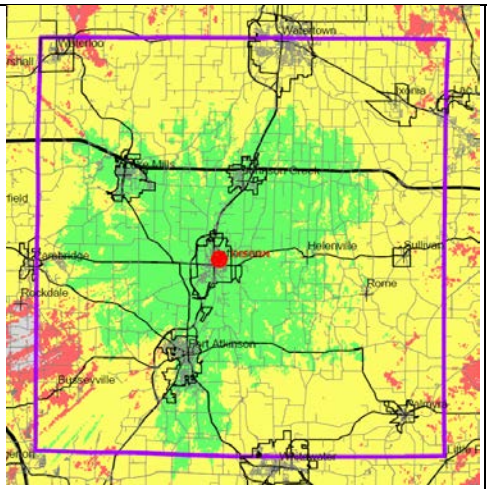


*Figure 6 - Portable Talk-Out*

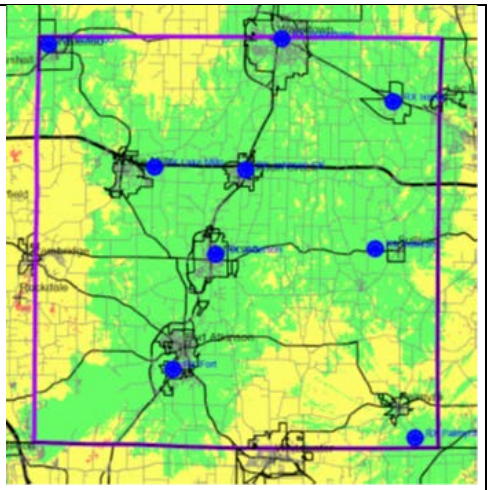


*Figure 7 - Portable Talk-Back*

The predictions above represent IFERN performance. IFERN system employs a base station transmitter at Cemetery Hill. There are holes in the portable coverage (left) near the borders of the county. The satellite receiver system improves talk-in coverage (right) and is the strongest portion of system. Predictions indicate dispatch may hear field units call-in, but it is possible field units may not hear dispatch if a field unit is within two to five miles of the border especially if inside a building.

### 15.3.4 Paging

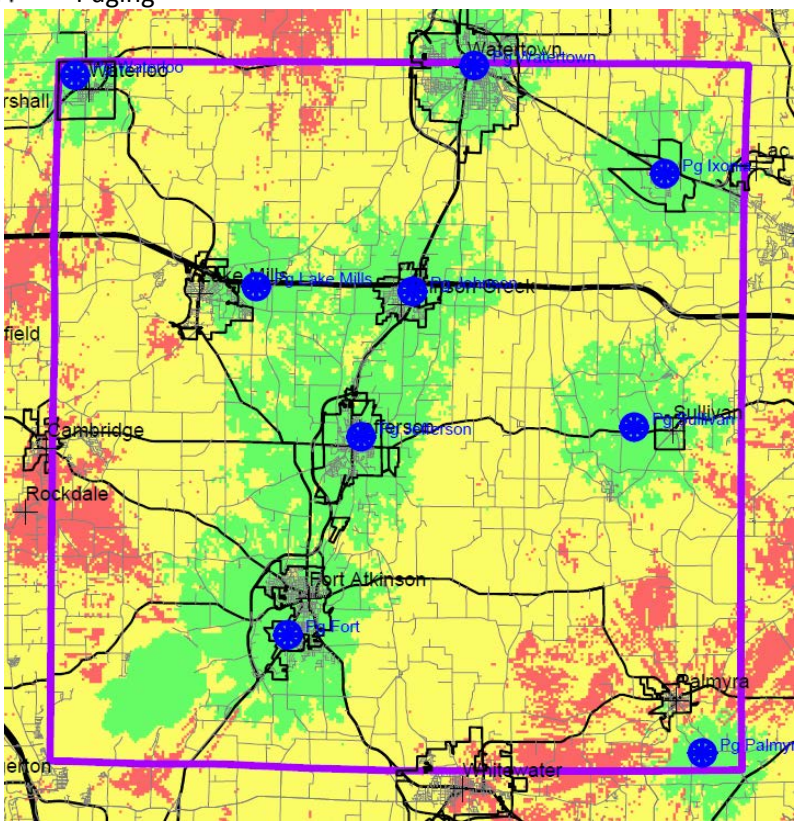



*Figure 8 - Paging Talk-Out*

Paging is simulcast, so all sites have a paging transmitter. As the microwave is creating self-interference, coverage is not optimal. The above prediction is an estimate of actual performance once the microwave and multiplexer network has been updated. As with the above predictions, the yellow indicates on-street performance and green is residential indoor. The prediction is generated with 95% reliability. This means areas may have better than the performance shown at any point in time, but overall does not statistically meet the 95% level.

# 16 Improvement Options

There are multiple possible solutions for improving the County's public safety radio system. These include simulcast and voting for the current system, use of conventional P25, and/or P25 trunking. The frequency band utilized could also change due to performance differences or to match neighboring systems. Interoperability may also impact the County's final selection.

The selection and utilization of existing sites will also need to be reviewed. A new system design will place additional antenna systems on current towers. Structural studies should be done an any existing tower to ensure the additional load can be carried. Improvements to the microwave backhaul system will likely be a major factor in structural loading studies and may require structural improvements to towers in use or possibly require new towers to be constructed. The current mounting structures on water towers may also need to be evaluated and strengthened.

As the site were previous constructed following older standards, an effort should be undertaken to make improvements in grounding, noise mitigation, power distribution and alarming. Also, at some off the sites there may be the need for actual shelter improvements and possibly replacement.

## 16.1 *Technology Overview*

Public safety radio systems in use today are generally analog conventional, P25 Conventional and P25 Trunking. P25 is the digital format adopted by public safety in the United States. P25 conventional is functionally like your current analog systems though using a digital protocol. Each channel employs a dedicated frequency pair and has a communications function (LAW1, FIRE1, EMCOM1, etc.). Users select the desired channel and communicate.

With P25 trunking, there are a number of available RF channels plus a control channel at each site all under the control of a computer who's job it is to direct the radio traffic to a virtual channel. These virtual channels are assigned by the computer control system and traffic is differentiated by what are defined as talkgroups. There are then talkgroups for Law, Fire, EMCOM, etc. and when the user selects a channel on their radio, they are really requesting a virtual talkgroup.

To the user, P25 trunking is nearly identical to conventional operation. The user selects the desired "talk group" to communicate. The licensed channels are shared among all users of the system. Trunking is much more efficient than conventional and allows many more users to use the same number of frequency pairs. Trunking is however more expensive to acquire and to operate.

Due to incentives in grant funds, many radios may have P25 conventional capability but may not be trunking capable. Depending on the age and radio model, any unit that may be P25-capable may still need an update, upgrade, or potentially would need to be replaced to operate on a P25 trunking system.

In Wisconsin, P25 systems use VHF and 700/800 frequency bands. The 700 MHz and 800 MHz bands were designed to be utilized for trunking radios systems. Waukesha trunked radio system uses 800 MHz and shares a controller with Milwaukee County. The State of Wisconsin's WISCOM P25 statewide trunked radio system and Rock County's P25 conventional system are generally VHF. The system controller of any of these systems could potentially have the excess capacity to run a Jefferson County trunked system and enjoy the interoperability that would come with such a decision. Sharing excess capacity with another

entity would also require that maintenance and upgrades would be mutually agreed to by all parties sharing the controllers. A move to P25 trunking likely would require all field units to be replaced. This assumption is made in the budgetary estimates as the price of this central controller can easily cost $500,000 if the county were to have its own.

### 16.1.1 Frequency Band

#### 16.1.1.1 VHF

The VHF band (150 MHz to 174 MHz) provides better longer-range communications but also is more susceptible to "skip" which allows signal to traverse large distances and create interference to co-channel users. There is no good way to prevent "skip" from creating potential problems as it is an atmospheric condition. If "skip" is a concern, the County could consider moving to UHF or 800 MHz bands, but doing so would create interoperability issues with neighboring VHF users. Multi-band radios are more common today and could be employed to address interoperability, but overall the costs for these units are higher.

VHF has reduced in-building penetration performance than the higher frequencies (UHF, 700 or 800 MHz). Although radio signals may pass through some building materials, any material will attenuate signals as it passes through. Steel siding or roofing will reflect radio signals and not allow them to pass through. Most residential windows offer minimal attenuation to signals, but the size of the VHF wave (~6 feet) will often be larger than typical window openings and only a portion of the wave enters a building. This results in effective attenuation of the signal power as the whole wave is not present. As low-e glass is used to improve efficiency of a building envelope, these windows generally reflect the signal and letting less of the RF energy into a structure.

At higher frequencies, more of the whole wave can get through the same size window or other physical opening. The wavefronts at higher frequencies can fully pass through openings more often than VHF and have better building penetration.

Higher frequency wavelengths behave more like light, and lower frequency wavelengths behave more like sound. A physical obstruction may block high-frequency waves, while lower frequency waves are attenuated but still are received.

VHF can be used in conventional or trunked radio systems, but when used in a trunking system, the channel used for control must be given more co-channel distance protection from other licensees as the channel is on the air 100 percent of the time. Finding a VHF channel that provides this protection can be difficult[5]. Other trunked and all conventional repeated

[5] The amount of protection for a VHF control channel will vary depending on the area but could require 160 miles or more before a co-channel user could reuse the channel without interference. Commonly more than one control channel is found in case of failure. Normal VHF repeated voice channels (trunked or conventional) are protected by about one-half that distance.

channels require about the same amount of co-channel distance protection. Thus, VHF is seldom elected for use in trunked radio systems.

16.1.1.2 UHF

The UHF band (450 MHz to 470 MHz) has a wavelength that is about 1/3 of VHF (~2 feet) and provides more building penetration than VHF. Although UHF may experience "ducting" where atmospheric conditions allow the band to propagate a few hundred miles, it is far less significant than at VHF.

UHF has improved in-building penetration performance over VHF but is not as good as higher frequencies. Steel siding or roofing will reflect radio signals. Most residential windows offer minimal attenuation to signals, and the size of the UHF wave (~2 feet) will not be a significant barrier for typical window openings. The wavefronts at higher frequencies can fully pass through openings more often than VHF and have better building penetration.

Higher frequency wavelengths behave more like light, and lower frequency wavelengths behave more like sound. A physical obstruction may block high-frequency waves, while lower frequency waves are attenuated but still are received.

UHF can be used in conventional or trunked radio systems but VHF when used in a trunking system, the channel used for control must be given more co-channel distance protection from other licensees as the channel is on the air 100 percent of the time.

Finding a UHF channel that provides this protection can be difficult in your area due to Milwaukee and Chicago which will have more users on this band. Other trunked and all conventional repeated channels require about the same amount of co-channel distance protection. UHF is elected for use in some trunked radio systems in metropolitan areas.

UHF is not utilized very often in Wisconsin for public safety and thus it also presents an interoperability challenge.

16.1.1.3 700/800

The 700/800 MHz band[6] was designed for trunking systems. This band generally provides better in-building communications due to its short wavelength. Range is limited by the radio horizon or clutter that blocks or attenuates the signal. Nearby Waukesha, Milwaukee and Walworth Counties use 800 MHz frequencies for communications.

[6] The 700 MHz band employs frequencies from 768 MHz to 775MHz for repeater transmit and 798 MHz to 805 MHz for mobile transmit. The 800 MHz band uses frequencies from 806 MHz to 825 MHz for mobile transmit and 851 MHz to 870 MHz for repeater transmit. The 700 MHz band uses 12.5 kHz channels while the 800 MHz band commonly uses 25 kHz channels. As these bands are next to each other, most mobile radios are capable of being programmed in either or both bands.

Higher frequency wavelengths behave more like light, and lower frequency wavelengths behave more like sound. A physical obstruction may block high-frequency waves, while lower frequency waves are attenuated but still are received. 800 MHz can be used in conventional or trunked radio systems, but 700 MHz is used in trunking system applications.

700 and 800 MHz bands generally have better in-building penetration performance than lower frequencies. Although radio signals may pass through most building materials, any material will attenuate signals as it passes through. Steel siding or roofing will reflect radio signals. Most residential windows offer lower attenuation to signals, and the smaller size (~1 foot) of the wavelength allows more of the wave to pass through. At these frequencies, more of the whole wave gets through the same size window or other physical opening.

### 16.1.2 Trunked Systems

There are multiple trunking formats in use today. In the United States, public safety has adopted the APCO Project 25 standard for digital communications. TETRA (Terrestrial Trunked Radio) is an ETSI standard that has been adopted by countries in other parts of the world. Only P25 and TETRA are intended for use by public safety.

P25 is a digital common air interface adopted by the United States as the standard digital protocol. Systems can be set up in a conventional mode where each user group communicates on a single channel or in trunking configurations where user groups share a set of channels. Trunking usually is chosen by those that have many user groups. Groups (talkgroups) are assigned codes acting as a communication channel. The system controller automatically selects the RF channel used for each talk group communications.

P25 costs more than an analog solution in most cases and trunking systems also require a controller thus one of the channels is used only for control. The reader should also be aware there are two forms of P25 trunking today with one defined as Phase 1 and the other is Phase 2. Neither one is better that the other and each needs to be looked at as to which makes the most sense to employ. Phase 1 generally requires more RF channels than Phase 2 and thus in some situations, Phase 2 may be the best option. Other places, Phase 1 still wins out.

Trunking systems and the associated field units will have higher prices than conventional systems and their associated field units. Under the P25 standard, all field radios can also support analog operation. The analog mode is used for interoperability across the nation through pre-assigned calling and tactical channels on VHF, UHF, 700 MHz, and 800 MHz channels. All field radios should have these channels programmed using their established naming convention for mutual aid use.

TETRA, another digital standard, uses a time division multiple access (TDMA) format with four users per 25 kHz channel. Like P25, the signaling system offers direct unit to unit and repeater operation, can provide limited data services like short message service and status messaging. The TETRA infrastructure can handoff a call from site to site like cellular.

Other common digital formats include DMR (digital mobile radio) and NXDN (Next Generation Digital Narrowband). These other formats are not compatible with P25 or with each other. NXDN was designed for commercial Private Land Mobile Radio and low-end public safety communications systems. NXDN is offered by ICOM (IDAS) and Kenwood (NEXEDGE), but each company has implemented unique versions that are not 100% compatible or interoperable. Except for NXDN, multiple vendors manufacture field radios that operate in these formats. Only ICOM and Kenwood make field units for their unique versions of NXDN. As noted earlier, digital formats are not compatible with each other. DMR on the other had has multiple manufacturers, however like NXDN, each has developed its own trunking protocols.

There are a few standalone DMR, TETRA and NXDN trunking systems serving public safety agencies in the US though as these trunking system technologies were never developed for life safety use, they do not have the inherent desired features. Using these type of trunking radio systems for general utility operations, factories and other building has been acceptable for some.

If trunking is considered, joining an existing trunking system is a possibility that could decrease the cost by eliminating the need for a system controller. Backhaul connectivity would be required, and any system updates or upgrades would not be under the County's control but rather that of the owner of the controller. However, interoperability would be about as good as can be possibly created with other users of the same controller.

### 16.1.3 FirstNet

To overcome commercial services limitations to the public safety users, the federal government introduced a dedicated solution. The First Responder Network Authority (FirstNet) of the United States was created under the Middle-Class Tax Relief and Job Creation Act of 2012 (MCTRJCA) as an independent authority within the National Telecommunications and Information Administration (NTIA). The purpose of FirstNet is to establish, operate, and maintain an interoperable public safety broadband network. To fulfill these objectives, Congress allotted $7 billion and 20 MHz of valuable radio spectrum to build the network.

The FirstNet authority then accepted a proposal from AT&T to be the contracted commercial service to provide and build out this network. This left each state to decide the option to construct their own piece of that network or allow AT&T to perform that service for them. All states ultimately approved the use of AT&T as their designated contractor. This approval process was completed in December of 2017, and AT&T's implementation plans are currently underway with 5-year contract.

FirstNet is expected to provide mission-critical, high-speed data and multi-media services to supplement the voice capabilities of today's Land Mobile Radio (LMR) networks. Initially, the FirstNet network will be used for sending data, video, images, and text. Efforts continue toward how to best also support PTT voice. The base station sites are mostly expected to be at AT&T cellular towers. Most of these sites will require improvements to make them more hardened and with greater levels of redundancy/reliability.

The FirstNet network will also carry location information and eventually support streaming video. FirstNet plans to offer cellular voice communications such as Voice over Long-Term Evolution (VoLTE) or other alternatives initially, but these are not considered mission critical voice public safety level systems. The ultimate goal of Mission Critical Voice (MCV) and Mission Critical Push-to-talk (MCPTT) over LTE does not today have an identified timeline for implementation. One of the largest obstacles is unit to unit mission-critical voice communications. Without simplex communications, it will not be a suitable platform as all calls will need to access a repeater/base station.

The job of creating a nationwide wireless network from scratch to provide the level of services identified and deliver those services with the same robust levels of coverage in all areas is considered a lengthy task. This would keep the network from being fully and completely ready for all public safety users for years. The relationship between FirstNet and AT&T is more than just a hiring of the firm to implement the network. It is the reliance on AT&T's existing network to begin delivering services, begin developing equipment, and being able to migrate user as the dedicated FirstNet frequency band is being installed. To accurately understand FirstNet's capabilities of service, it is important to understand these processes and how they apply in the area in question.

As stated, AT&T has begun the process of FirstNet implementation using the existing AT&T network as a starting point. That network will deliver services to the capabilities in place today, and as AT&T develops the future capabilities and features, those will be migrated into the platforms. At the same time, AT&T will be implementing the dedicated spectrum (Band 14) provided by FirstNet to increase coverage areas.

Ultimately, decisions of the use of FirstNet come down to the same questions of coverage, reliability, redundancy and operational features in the defined area of concern measured against costs. Jefferson County will most likely measure any migration of services to FirstNet based comparison with existing broadband (Data) services in place as those FirstNet features will most likely become available in the network.

VoLTE (Voice over LTE) is the proposed standard for the carriage of voice and the interface between a P25 trunked radio system and FirstNet. It should be noted, however, when this voice service becomes available for mass use is not yet on the timetable. FirstNet was developed first for data and video with this being the priority. Most of the leadership in the development of FirstNet suggest that even after its full deployment, VoLTE should be considered secondary and not expect this service to replace mission critical radio to radio voice communications anytime soon.

In Wisconsin, the State established the Wisconsin Public Safety Broadband (WiPSB) project to review the plans as related to the state. Critical service areas were established of which only the two primary metro areas of the county are included in Year 1 while most of the county is in Year 5 of the planned deployment.

### 16.1.4 Simulcast and Voting Technology

With simulcast, there is a common frequency set for each site. When active channels transmit from all base station sites, each site is timed to deliver its signal to the coverage area as equal as possible to all portable and mobile terminals using the same frequency set. This requires GPS timing and care in the delivery of the signals to each site. Simulcast is not perfect, though it is a feasible solution if properly designed and implemented. With P25, generally, the manufacturer is involved with the design of simulcast systems due to the knowledge and tools required to develop and optimize. Within a metropolitan area, simulcast can help improve coverage within buildings, as the signal from each repeater can deliver RF from varying sides of a structure, and when the portable talks back, voting receivers can select the best signal to be repeated. Simulcast is generally more efficient and provides better overall coverage than multi-site designs.

Increasing the signal level that reaches the portable involves more than increasing the transmitter power of the repeater. Although this could be a potential solution, in most cases, the losses to be overcome are not possible with a transmitter power increase alone. In addition, increasing power will expand the interference potential for adjacent channel users. To improve portable performance, multiple transmit and receive infrastructure locations need to be established.

Simulcasting of the repeater transmitter and voting or receivers will improve portable performance by using multiple infrastructure locations to improve the ability of receive and transmit signals thus increasing the number of potential paths. Simulcasting repeaters are used to transmit on the same frequency at multiple sites simultaneously. For receive, voting is used to choose the best-received signal from multiple sites. To use either simulcast or voting, the infrastructure sites need to be interconnected via microwave or fiber optics.

Simulcast requires repeater equipment designed to produce virtually identical modulation characteristics among stations operating at the same frequency. A backhaul system (usually microwave) distributes copies of the traffic to be transmitted to all sites. Most simulcast systems use a GPS clock to control frequency and transmitter launch times. All repeaters that transmit on the same frequency must be able to maintain identical transmitter frequency, phase, and modulation such that field units detect little difference in signals transmitted from different locations. This is more critical when implementing digital voice systems. In actual operation, the distance from the transmitter sites and receive signal levels dictates the quality of the received signal. Overall, the quality of an analog simulcast system will be less than a good signal from a single-site system. The advantage is, that to the field unit, all sites appear to be a single site.

As units traverse the service area of a simulcast system, each unit receives signal from different sites. The quality of the signal received is determined by the distance to the sites received (time) and the level of signal. With simulcast, in theory, the transmit launch time for each site is designed to provide an in-phase signal between sites.

As distance between sites varies, the launch time for each site must be set for optimum performance with all other sites around it. When a field unit is between

sites, the received signal must be nearly in-phase or the signal from one of the sites high enough to capture the receiver to decode the received signal. If these conditions are not met, the receiver may not be able to decode.

In digital simulcast, there is a hard limit to the distance between sites. In P25 and prior to LSM (linear simulcast modulation), this limit was about 6-7 miles between two repeater sites. With LSM, the limit in distance is about 13 miles. If more than two sites, the distance is less based on several factors including terrain, clutter, number of sites, site topology, site antenna elevation, and ERP levels. In the best of conditions, if the limit is exceeded, the signaling between field unit and infrastructure falls outside the maximum wait times and no longer functions. This is true regardless of the frequency band used, and nothing will be heard by the user. Since RF is more controllable at higher frequencies than lower frequencies due to its shorter wavelength, 700/800 MHz has the biggest selection of antennas thus allowing some amount of carefully creating receive areas to reduce negative self-interference.

Simulcast operation of three or more sites becomes difficult due to the factors stated above. Control of the RF signal from each site becomes very important. So even though VHF has better range than higher frequencies, with digital simulcast systems, site separation is limited by several other factors as noted.

Voting uses the receivers from the multiple sites and uses a backhaul system to aggregate these signals at a common location where they are compared, and the best signals are used for dispatch audio and retransmission. Jefferson County uses voting in its channels today. A voter for each channel selects the best mobile or portable signal multiple times per second and uses it to repeat. In digital systems an indication of bit error rate would be used to select the best-received signal, while in analog, the quality (lowest noise) of the received signal is used, thus two different kinds of voting.

With single user trunking systems, both simulcast and voting are incorporated into systems with multiple sites while with conventional systems, the voters are likely stand-alone devices. Voting and remote receive sites are common with VHF conventional systems, allowing for the lower-power portables to be received while a higher-power repeater transmitter can make up for the losses between the repeater sites and the subscriber radios. With UHF and 700/800 MHz operation, a tower top preamplifier can overcome these same losses thus pretty much doing away with the need for as many voted receivers. Tower top preamplifiers are not used in the VHF band due to excessive atmospheric noise and the lack of a band plan.

### 16.1.5 Simulcast vs. Multi-Site Systems

When multiple sites are used for trunking, there are two options: simulcast or multisite. Wide-area trunking systems are designed with many sites that use different frequency sets. Many statewide mobile-based systems are designed using multi-site. (In statewide systems, such as WISCOM, frequencies sets can be reused once outside their interference contour.) For smaller systems, like a county, obtaining additional frequencies for multisite operation is likely not very feasible as it is considered a very inefficient use of spectrum by the FCC and frequency coordinators.

In trunked, multi-site-based systems, the controller needs to keep track of the site used and a talk group selected for each active field unit. For each call, the system

needs to determine which sites have users on that selected talkgroup and deliver the associated audio to those sites. Another issue with multisite is that the only repeater receiver that can hear a unit is the one the field is associated with, which may not be the best repeater site at any one time. In the opposite direction, the field unit has only one repeater site to receive.

Simulcast is not perfect, though it is a feasible solution if properly designed and implemented. Generally, the manufacturer is involved with the design of simulcast systems due to the knowledge and tools required to develop. Within a metropolitan area, simulcast can help improve coverage within buildings, as the signal from each repeater can deliver RF from varying sides of a structure, and when the portable talks back, voting receivers can select the best signal to be repeated.

For portable based county systems, simulcast is more spectrum efficient and will provide users with better overall voice communications.

### 16.1.6 Paging

Most paging today utilizes analog with tones sent out by dispatch and pagers set up to decode the tones and to set off the receiver to allow a voice message to follow. The primary difficulties with pagers are the fact they have very poor receiver thus needing more transmitter infrastructure. And the amount of time to send a message is long.

An alternate paging system would convert the County paging channel to digital paging which would send an alphanumeric message like a text message on a cell phone. Some digital pagers allow the message to be delivered via computer-generated voice. The design and speed of the system will depend on the site used to retransmit the digital messages. Digital paging also speeds up the delivery of messages and reduces potential duplication of the message. Local Fire departments could be set up to send out their own pages with a software program on a computer via the Internet.

Digital paging could be implemented using simulcast base stations or use multiple sites with a forwarding system. P25 paging solutions are also available. The forwarding type system would send out a digital page that would be received and retransmitted across the county. All deliver alphanumeric messages. Some pager models can convert text to digital voice. A switch to digital paging would require replacement of all paging receiver units in the County and the infrastructure equipment to support it. The use of digital signaling allows pages to be sent countywide much faster than tone and voice technology.

The real gains in the use of digital paging include the lower cost of the pagers and the faster delivery of the message. It is also entirely possible to have the alpha numeric message be sent directly from the computer aided dispatch (CAD) system thus saving even more time and upping the accuracy of the message.

Another option is to utilize P25 trunking system for the paging. With this option the page signal is treated like a voice call with a talk group assigned and the pager receives the assigned talk group allowing the voice message to be delivered. The saving is there no need for separate pager transmitting infrastructure.

Some Fire and EMS departments have utilized Internet-based systems like IamResponding® which is able to send messages to smartphones and can allow for

acknowledgment of the receipt of the page. This method of page delivery can be used but, per the National Fire Protection (NFPA) standards, it is considered secondary to primary paging.

### 16.1.7 Capacity

If Jefferson County considers trunking, the number of channels to employ in such a system would need to be determined. Law, Fire, and EMS users in Jefferson County employ over 1,250 mobile and portable radio units. Early rule of thumb guidelines for SMR (trunking) systems estimates one trunking channel for every 100 field units.

For public safety systems, not all units are active 100% of the time. As Jefferson County uses about five channels for Law, Fire/EMS, Highway and Paging, 12 channels cannot be justified. If usage data is available, it can be used to determine normal levels of traffic and how this level changes during special events. If this data is not available, estimates of anticipated user levels are calculated. As trunking is more efficient than conventional operation, it is possible that as few as two to three trunked voice channels could provide the required capacity for Jefferson County's public safety users at normal traffic levels but for special events the number of voice channels must be increased.

The typical service level target for public safety systems is 99% or 0.01 grade of service (GoS) with a six-second transmission and one second wait time. E&A's estimate is based on this criterion along with the number of Law and Fire mobile radios estimated to be active during a busy hour event, the number of calls in the busy hour, and the length of each transmission as follows:

- 50 active units
- 7-9 transmissions per unit during the busy hour
- 700 to 900 transmissions during the busy hour
- 6 second transmission time

Using these parameters, the amount of air time used in the busy hour is 4,200 to 5,400 seconds. This equates to 70.0 to 90.0 minutes or 1.2 to 1.5 hours (1.2 to 1.5 Erlangs) of traffic. Using the established Erlang C calculation for trunked traffic, 5 to 6 voice channels are needed to process this traffic.

As a control channel must be added, it is anticipated the County would need at least 6 to 7 channels to support the number of county users for a trunking system. For public safety systems, a 0.01 GOS (grade of service) is generally used for the busy hour. This provides 99% availability of the system with a wait time of no longer than one second for the highest anticipated traffic level.

### 16.1.8 Coverage

Radio propagation is the description of the ability of a radio signal to travel from transmitter to receiver. The calculation considers common items such as frequency, RF power level, antenna height, antenna gain, antenna pattern, and cable losses along with loss factors. Loss factors attenuate the signal along its path to the receiver.

The loss factors for mobile operation include terrain fluctuations and ground clutter. Terrain generally blocks a radio signal and prevents it from reaching the receiver

antenna. Ground clutter includes anything above ground level including buildings and foliage. These items become barriers and attenuate or reduce the signal level.

Portable performance is impacted by all the above plus attenuation from the radio being worn close to the body and the properties of a less-than-optimal antenna which is made to be flexible. These flexible antennas become another form of attenuation from a design point of view. Since a portable is usually worn on a belt, the radio may change the orientation of the antenna depending on if the user is standing or sitting. Portables also go wherever the user goes. If users expect them to work in vehicles or buildings, the associated attenuation needs to be considered in the system design.

Coverage predictions calculate an estimated signal level to be received by a field unit from a repeater or base station antenna. Predictions use the effective radiated power level allowed by the FCC license, terrain, land use, and body losses among other attenuation factors in the calculations. Reliability and fading factors are also used in the calculation to provide a realistic map of system performance.

Portable communications are impacted even more due to characteristics discussed above. As the portable radio becomes the primary communications tool for public safety communications, the design of the infrastructure must be enhanced to support it. This requires more transmitter and receiver sites plus the ability to bring the control of the infrastructure together, so the operation of the system is transparent to the user.

### 16.1.9 Future User Technology

With the advent of FirstNet over the next 4-5 years and the subscriber radio manufacturers integrating the technology of LMR and FirstNet there is the likelihood of new user hardware. Last year, about this time, was the initial showing of possible hardware for this integration. As LMR is for voice and will be the primary method for years to come, the integration of the data capability of FirstNet will likely find user devices incorporating both.

What will this mean to the user? Public safety officers may be provided text, mapping, pictures, videos and even drawings of structures to their radio displays and being able to communicate voice via the same device using LMR. At the time, an officer will be able to send an image or video of a scene to their team and dispatch, thus sharing valuable information.

Thus, an enabling technology which was attempted years ago using LMR which failed to address most user expectations will now be possible. For now, until this new integration of technology becomes reality, it requires a radio for voice and a smart phone type device for data. Nearly every user radio vendor is working to create these tools as an integrated package. Two things to note: LMR has the proven ability to support voice communications in very difficult situations while broadband LTE data (as FirstNet uses) has a demonstrable capability of providing integrated multi-media. Now one can finally see the whole story.

## 16.2 *Operations*

### 16.2.1 Dispatch Console – Mindshare

Elert & Associates understands that the County would continue to operate using the Mindshare console system. In the conventional analog mode, our budgetary estimate assumes that no significant changes would be necessary. If the County were to decide to operate conventional P25 or P25 trunking, it is then anticipated changes to the system interface would be required. It should be noted that to use an analog console such as the Mindshare for P25 (conventional or trunking), some features of the digital technology may not be possible to incorporate.

### 16.2.2 Logging – Eventide

An Eventide NexLog 740 logs all 911, admin. phone, and selected radio traffic. The current equipment records analog inputs only. Any future P25 digital traffic would either require a digital interface or the P25 traffic would need to be decoded by a radio and recorded as analog. P25 trunking system radio traffic is recorded in an entirely different methodology than conventional radio operation.

## 16.3 *Interoperability*

Common channels are used to provide interoperability between agencies both within and outside an agency's jurisdiction. Frequency alone is not enough to ensure interoperability. In many cases where issues with interoperability have occurred, it was not due to frequency programming but the naming that created the biggest issue. Standards have been established for common interoperability channels. The National naming convention for Law Mutual Aid is VLAW31 and VFIRE21 for Fire Mutual Aid.

These naming convention**s** along with those commonly used for service in the Jefferson County area should be programmed into all radio units. Note that some of these national channel frequencies are designated for other uses in Wisconsin. IFERN and VFIRE22 uses the same frequency, but the CTCSS tones are different. They both should appear in the radio programming with their appropriate tone coded squelch tones but grouped with other similar channels.

If a standard does not exist, there should be common agreement on the channel name to minimize confusion. Adhering to the standards will benefit users when these channels are required for communications. Programming standards should be implemented, and the appropriate training provided to users. A common County channel naming convention should be discussed, adopted, and shared with neighboring counties and service firms.

All established interoperability channels should be programmed into radio units. It is recommended all radios be programmed uniformly so channels are easily found. The National Interoperability Field Operations Guide provided by the U.S. Department of Homeland Security Office of Emergency Communications provides frequency and established naming convention for these channels. The current version of the field operations guide can be downloaded at https://www.dhs.gov/publication/fog-documents.

### 16.3.1 Other Dispatch

The City of Watertown also has a dispatch center for the City. It has three positions and uses the Mindshare console system. Watertown can back-up County dispatch if that location would be become disabled.

The City dispatches Police, Fire, and EMS services for the City of Watertown only. All other locations in the County are dispatched by the County.

### 16.3.2 Medical Centers

Hospitals in Jefferson County include Ft. Atkinson Memorial and Watertown Regional Medical Center. It is common for cellphones to be used for communications.

### 16.3.3 Air Ambulance

Air Ambulance services for Jefferson County come from Madison and Milwaukee. Communications with Air Ambulance services is currently coordinated via the MARC2 channel.

### 16.3.4 Public Service

The County Highway Department has its own repeater located at the main site.

Electric utilities in Jefferson County are We Energies, Alliant Energy, and municipal utilities in Jefferson and Waterloo. Dispatch maintains contact information in case an event impacts electric utility services and public safety.

Gas utility in Jefferson County is We Energies and Alliant Energy. Dispatch maintains contact information in case an event impacts gas utility services and public safety.

There are several rail lines in Jefferson County. The Canadian Pacific tracks from Watertown to Ixonia to the Waukesha County line are also used by AMTRAK. Other rail lines in the County include the Union Pacific track from Watertown to Johnson Creek to Jefferson to Fort Atkinson, Wisconsin & Southern Railroad tracks from Waterloo to Watertown and Whitewater to Palmyra to the Waukesha County line. County dispatch maintains contact information for all railroads in case of a railway incident.

## 16.4 *System Enhancement Coverage Predictions*

The predictions that follow in this section show the various options E&A has developed for Jefferson County using the information available. In the normal acquisition process the various proposers would be expected to provide like predictions of the design they offer.

### 16.4.1 Voice System Enhancement Predictions

The predictions below are talk-out to portable from the repeater system. Yellow represents on-street coverage and green indicates residential in-building coverage. Red represents marginal coverage and gray is unreliable coverage. The predictions below represent anticipated coverage using sites, ERP levels, and antenna heights used today.

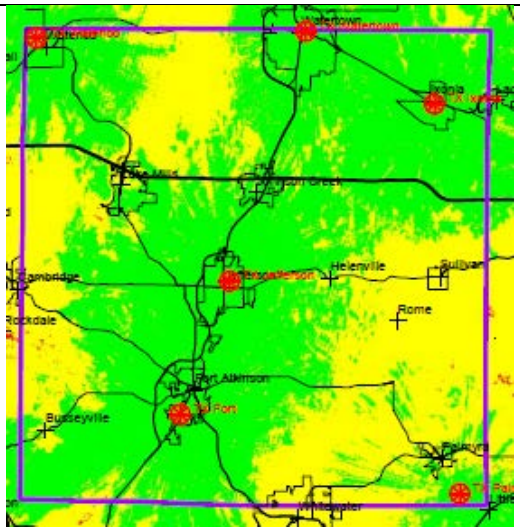



*Figure 9 - 6 Sites Analog PTO VHF*

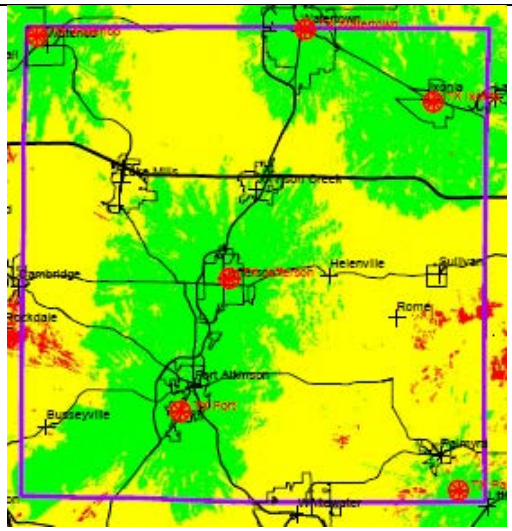



*Figure 10 - 6 Sites Analog PTB VHF*

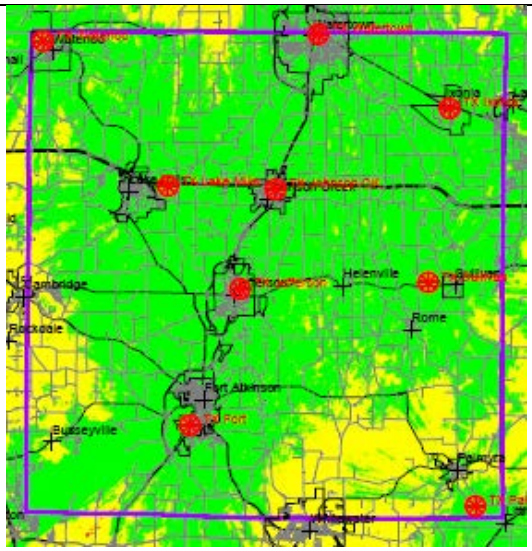



*Figure 11 - 9 Sites Analog PTO VHF*

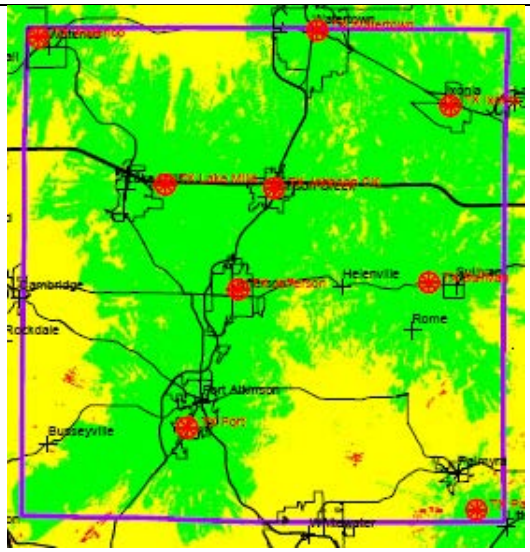



*Figure 12 - 9 Sites Analog PTB VHF*

Analog predictions include a six-site and a nine-site conceptual designs. The six-site design (Figure 9 and Figure 10) provides 43%% residential in-door coverage, and the

nine-site design (Figure 11 and Figure 12) provides 66% residential in-door coverage. An alternate Palmyra tower location could increase this to 72%.

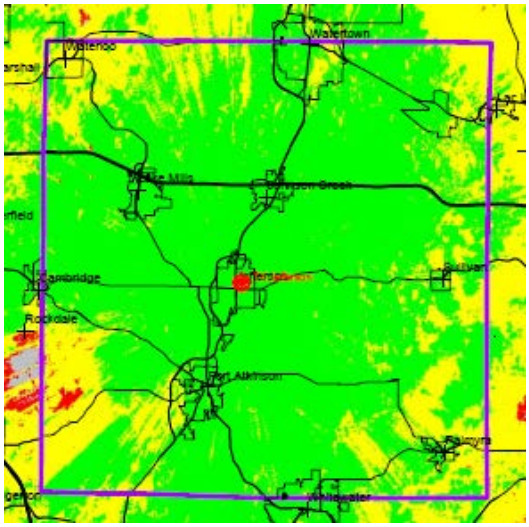



*Figure 13 – Main P25 Conventional PTO VHF*

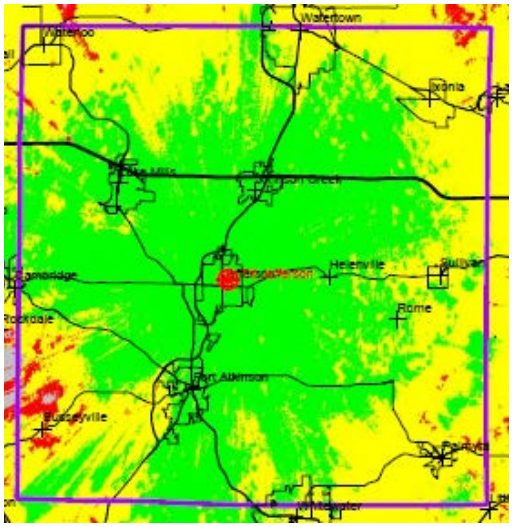



*Figure 14 - Main P25 Conventional PTB VHF*

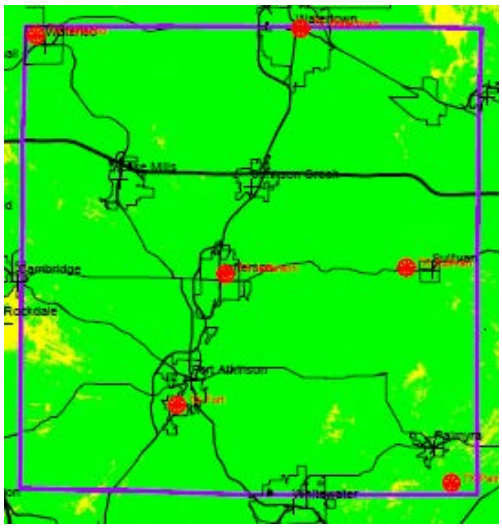



*Figure 15 - 6 Sites P25 Conventional PTO VHF*

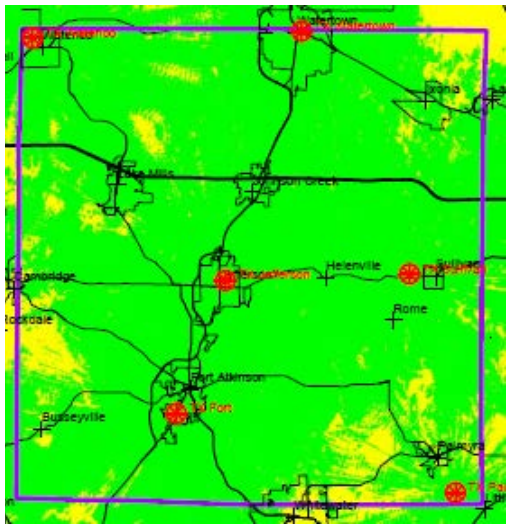



*Figure 16 - 6 Sites P25 Conventional PTB VHF*

Conceptual designs for P25 conventional are a single site (Figure 13 and Figure 14) and a six-site design (Figure 15 and Figure 16). A single site design is estimated to provide 56% residential in-door coverage, and a six-site design increases it to 90%. Existing sites are used for these predictions. Antenna system designs that use separate receive and transmit antennas would not use water tower sites. Towers with antennas at similar heights above mean sea level should be considered. Estimates for new towers at heights used for antennas today are included in the budgetary estimate for Option 2.

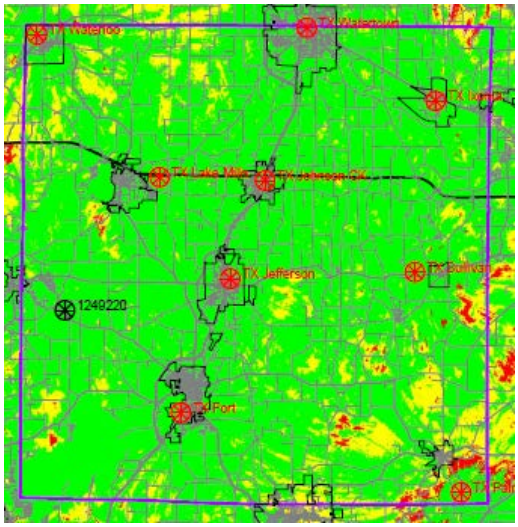



*Figure 17 - Main P25 Trunked PTO 800 MHz*

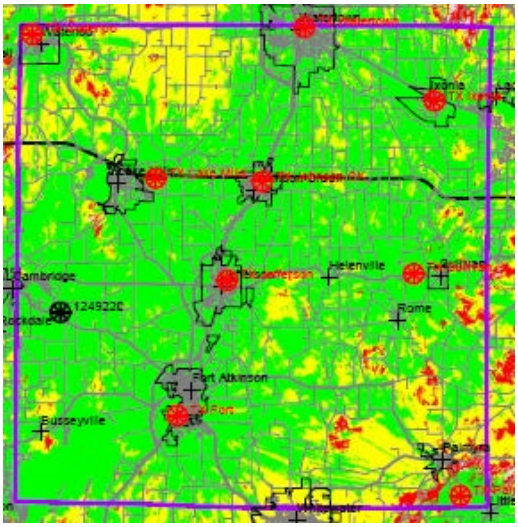



*Figure 18 - Main P25 Trunked PTB 800 MHz*

For the trunking design (Option 3), the frequency band changes to 800 MHz. Due to the properties of 800 MHz, an additional site was added near Cambridge. The 800 MHz P25 trunking predictions (*Figure 17* and Figure 18) provide about 76% residential indoor coverage. The areas between Waterloo and Watertown and north and west of Palmyra are the weaker areas. The budgetary estimate for Option 3 includes higher towers for the Palmyra, Waterloo, and Lake Mills areas plus towers for water tower sites (Ixonia and Johnson Creek).

These predictions reflect the conceptual designs for the Jefferson County report. The MARC, IFERN, and Highway systems would operate like today using a single site transmitter and satellite receiver sites. In Option 3, the Highway channel was eliminated and would become a talk group on the trunked system.

For Options 1 and 2, the paging system remains analog using all sites today. In Option 3, the budget estimate includes a nine-site digital system that uses a store and forward technology to propagate paging messages across the County. Five hundred and twenty-three (523) pagers are included providing an alphanumeric message to users.

## 16.5 *Backhaul*

There are basically two forms of acceptable backhaul technology today, microwave and fiber. The big change today is the fact nearly all communications has now moved to IP and away for linear serial circuits such as DS3 and T1s. Using IP allows for the use of off the shelf network equipment. Also, the means of interconnecting microwave and fiber become much easier and less complicated.

### 16.5.1 Conceptual Microwave Topologies

A ring topology provides the most effective redundancy in a microwave network. Two potential designs are shown below. Design #1 (Figure 19) has a potential path issue designated by the red circle on the Waterloo to Lake Mills link (see Figure 28). The terrain rises along the path, and there are trees in the area. These trees may block the Fresnel zone[7] (indicated by the lower curved line) of the microwave path. Preliminary designs are always the first step in the development of the microwave network. On-site observation of each path would also be done as part of the process.

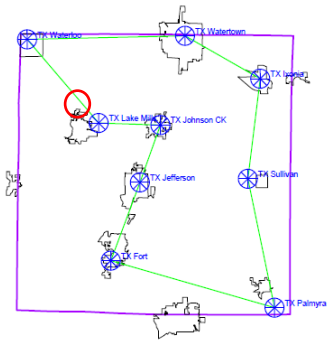



Figure 19 - Microwave Topology #1

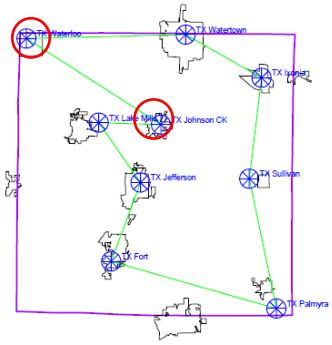



Figure 20 - Microwave Topology #2

The red circles of preliminary design #2 in Figure 20 indicate acute angles. Links with extreme acute angles could lose connectivity at the same time if the right conditions were to occur such as heavy rain and disable both links into a site. If so, the common site would be isolated and be disconnected from the remainder of the system. Simulcast and voting depend on the backhaul network to deliver control and audio information. If disconnected, the transmitters and receivers at the site would essentially shut down reducing the overall system performance in that area. Although it is possible for this to happen in design #2, it is not likely to become a performance issue.

*Figure 21 - 800 MHz P25 Microwave Topology*

The backhaul for 800 MHz required one additional site. The following is the conceptual ring topology for the 800MHz P25 trunked system.

### 16.5.2 Path Predictions

[7] The Fresnel zone is the area occupied by a microwave signal link between two antennas and it is larger than the diameter of the antennas. This zone of RF cannot be blocked by any physical elements or interference is the result.

Following is a conceptual microwave ring design along with preliminary path predictions for each path. The frequencies selected were based on the length of each path.

**Main – Fort Atkinson**

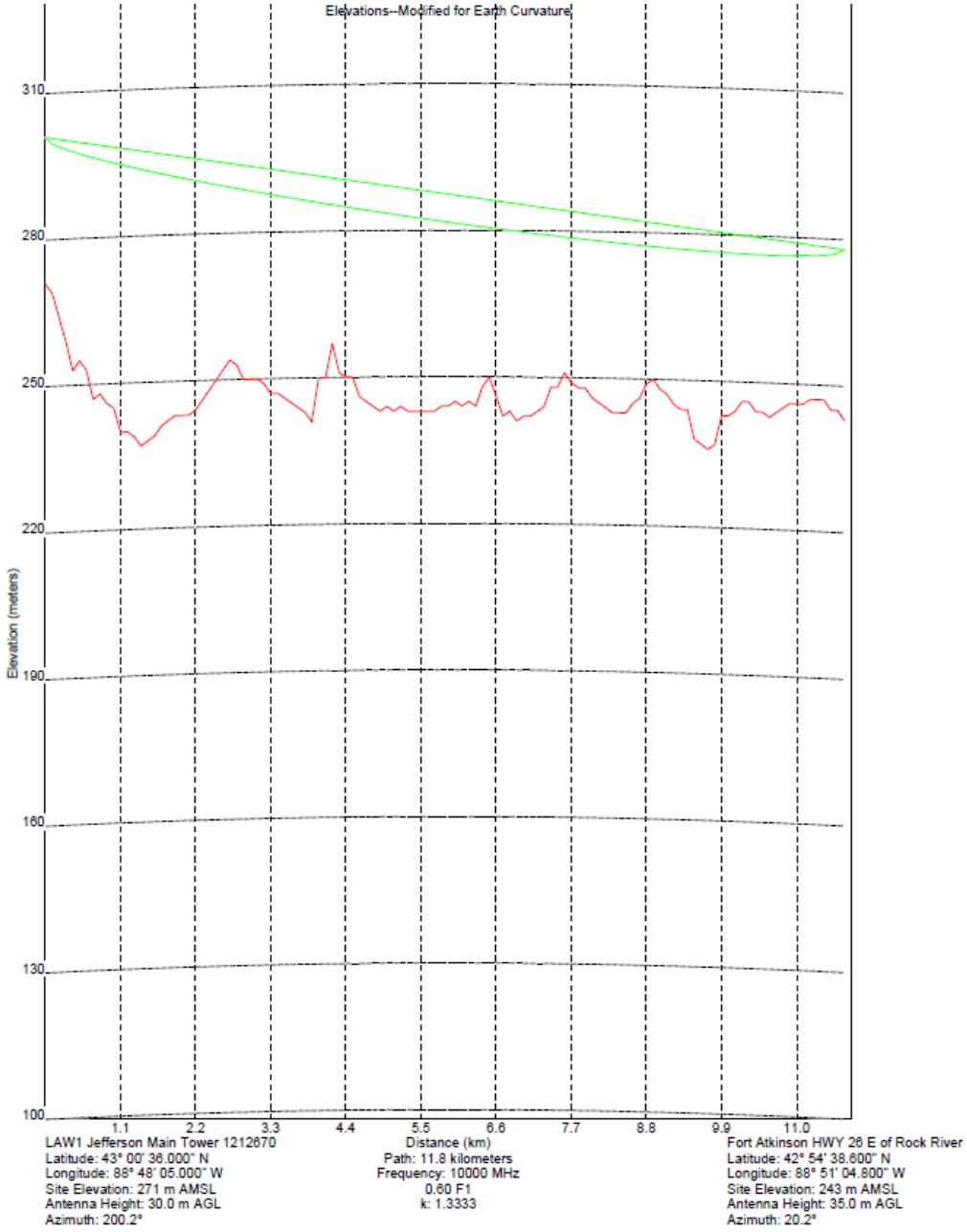



*Figure 22 - Jefferson Main / Fort Atkinson Path Detail*

**Fort Atkinson – Palmyra**

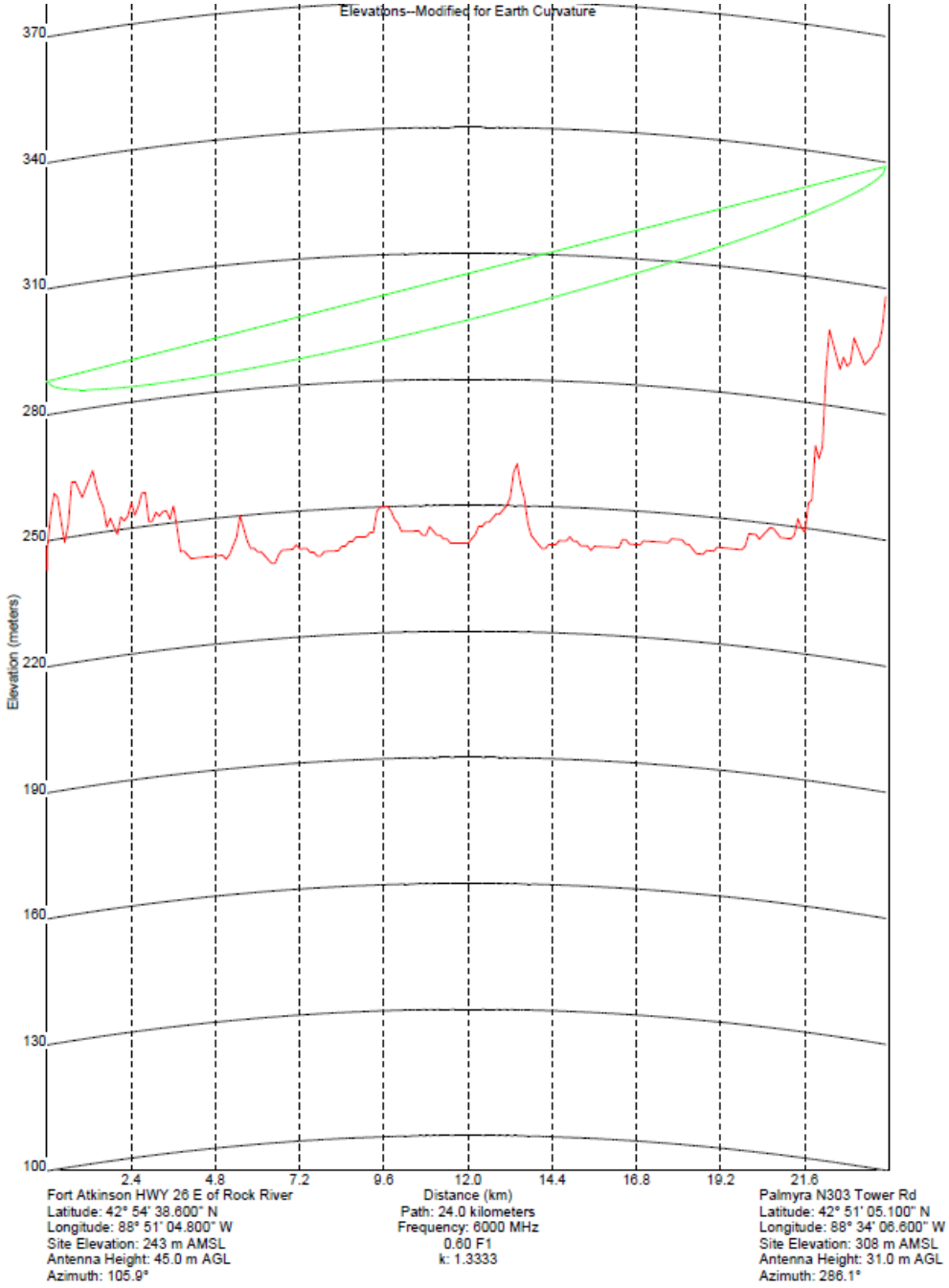



*Figure 23 - Fort Atkinson / Palmyra Path Detail*

**Palmyra – Sullivan**

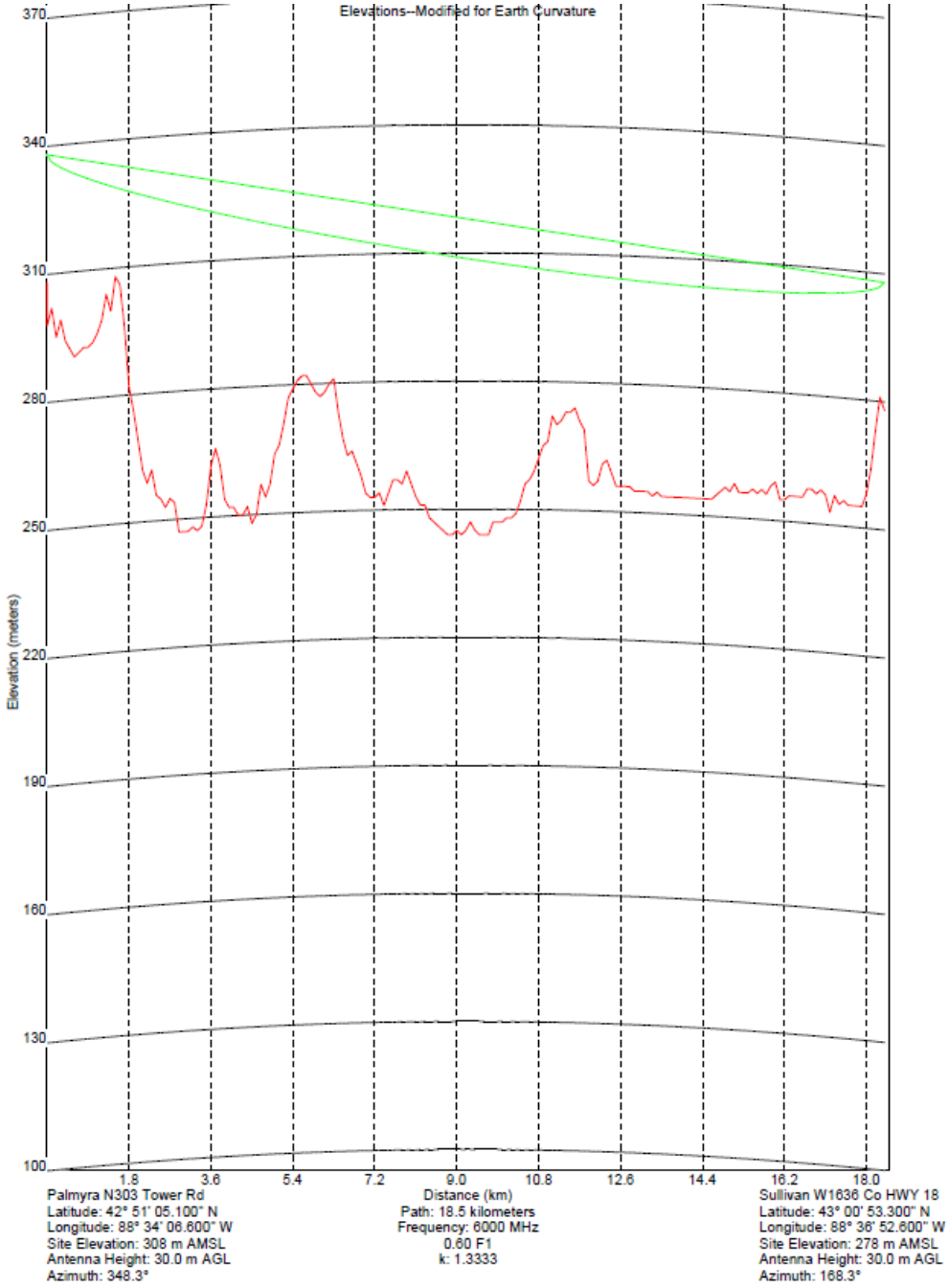



*Figure 24 - Palmyra / Sullivan Path Detail*

**Sullivan – Ixonia**

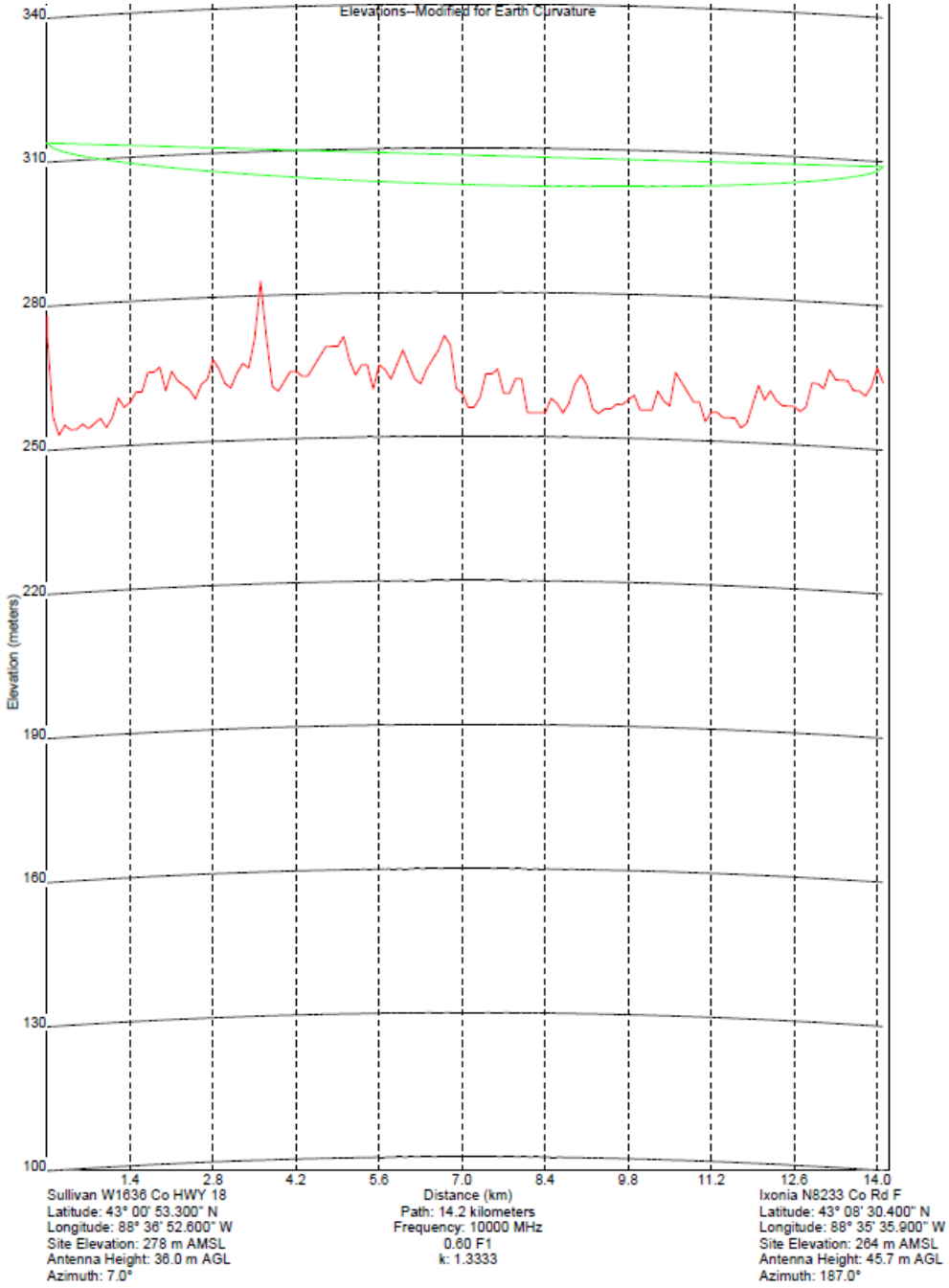



*Figure 25 - Sullivan / Ixonia Path Detail*

**Ixonia – Watertown**

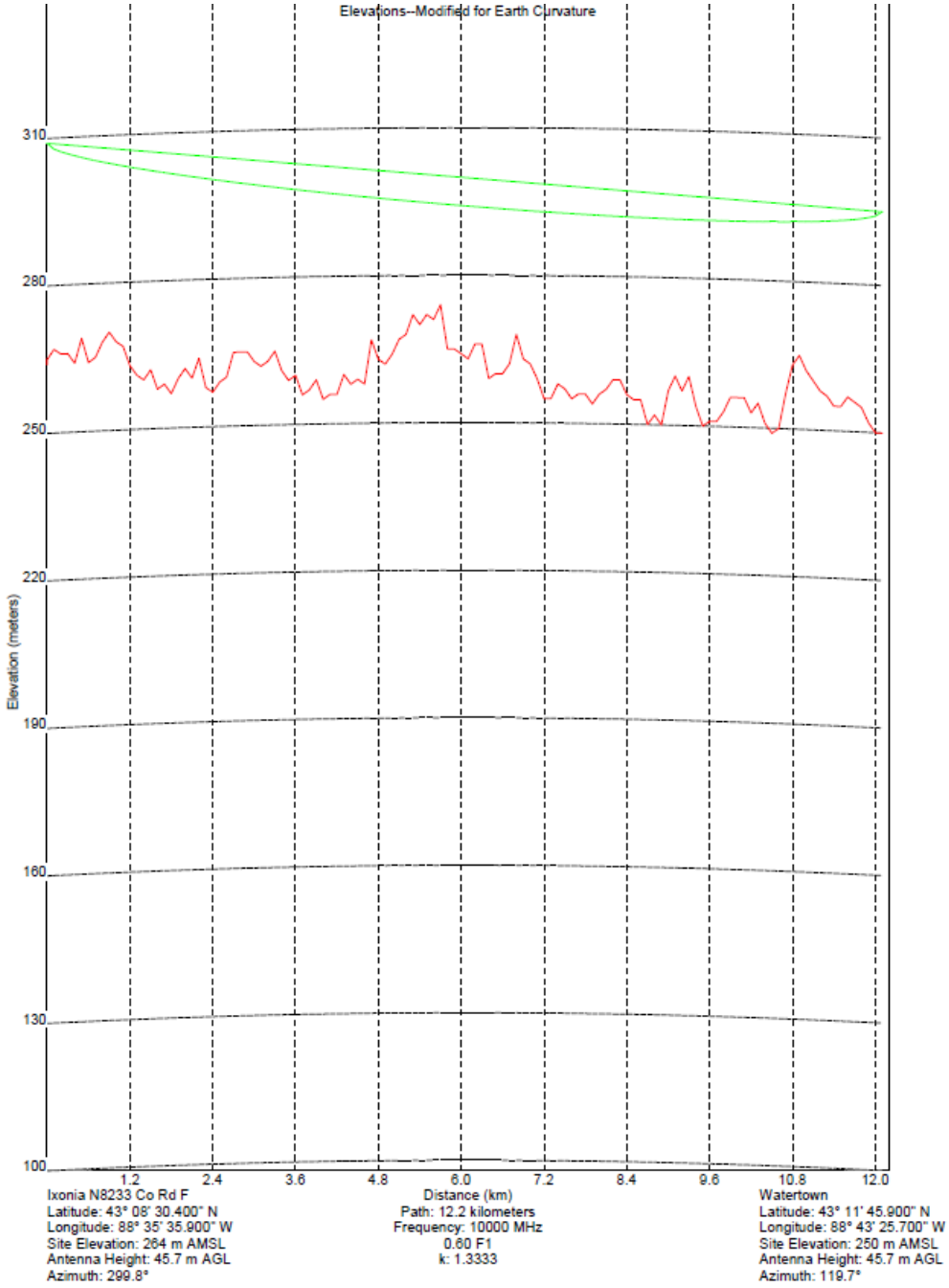



*Figure 26 - Ixonia / Watertown Path Detail*

**Watertown – Waterloo**

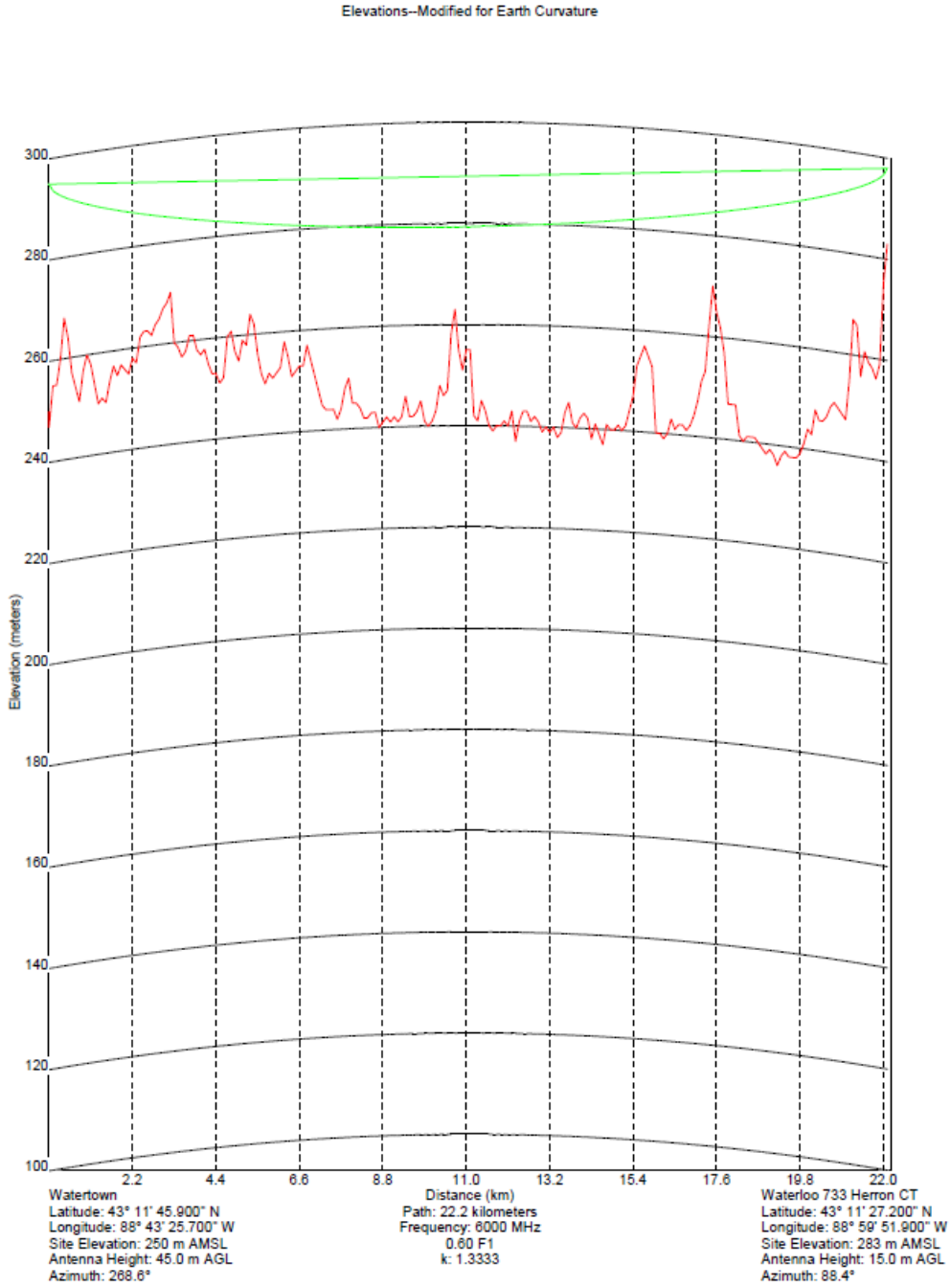



*Figure 27 - Watertown / Waterloo Path Detail*

**Waterloo - Lake Mills**

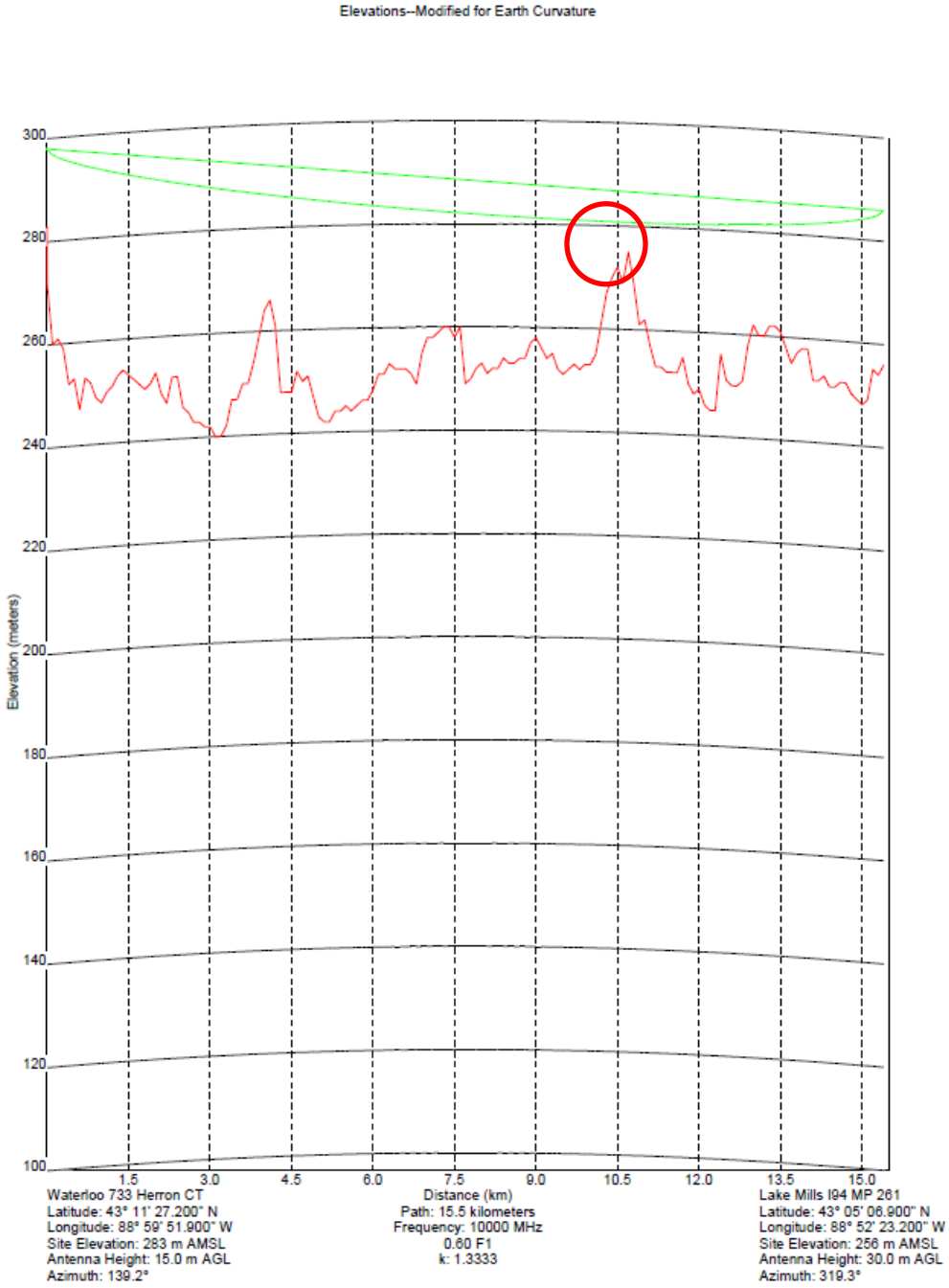



*Figure 28 - Waterloo / Lake Mills Path Detail*

**Waterloo – Johnson Creek**

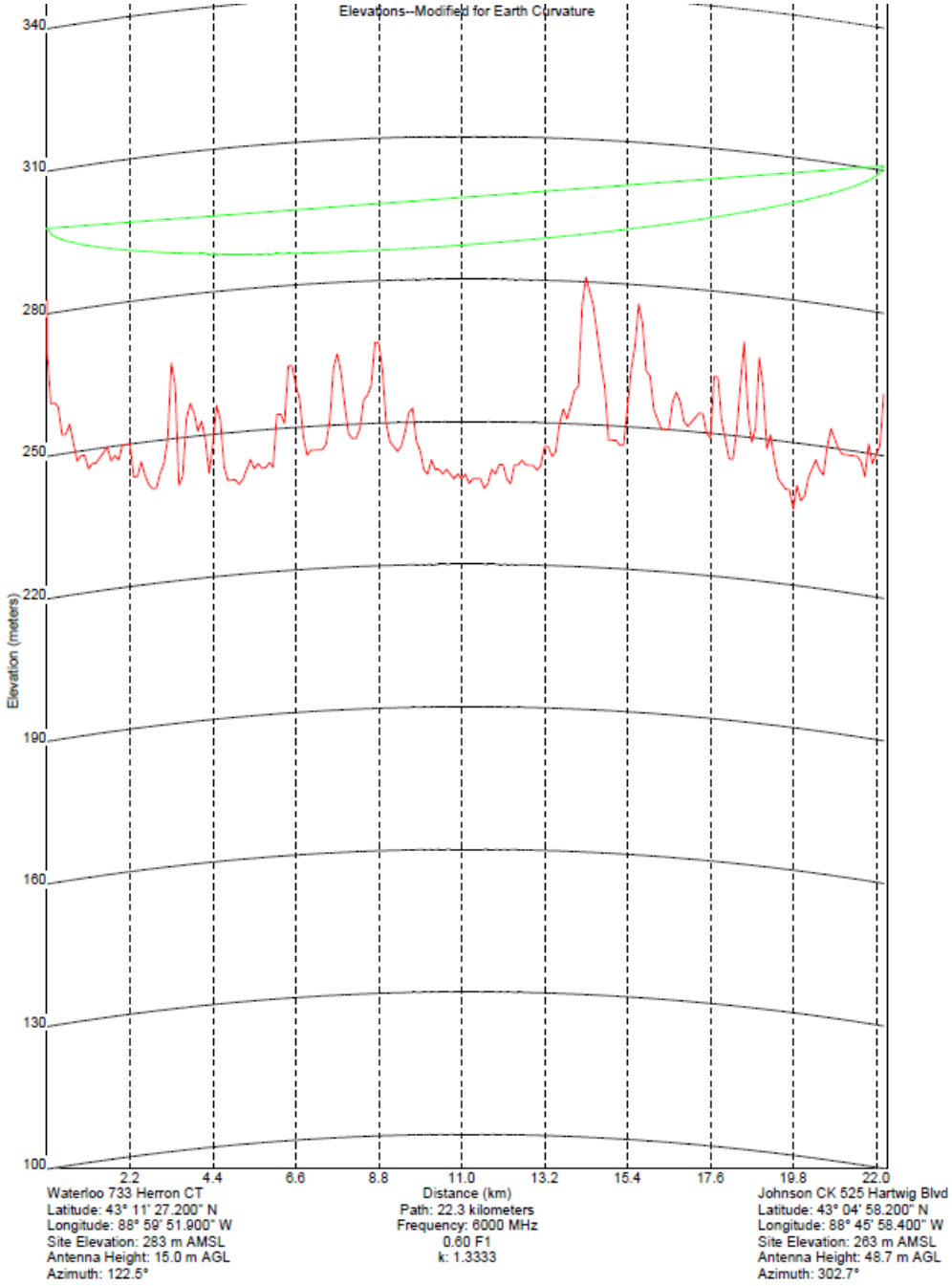



*Figure 29 - Waterloo / Johnson Creek Path Detail*

**Lake Mills - Johnson Creek**

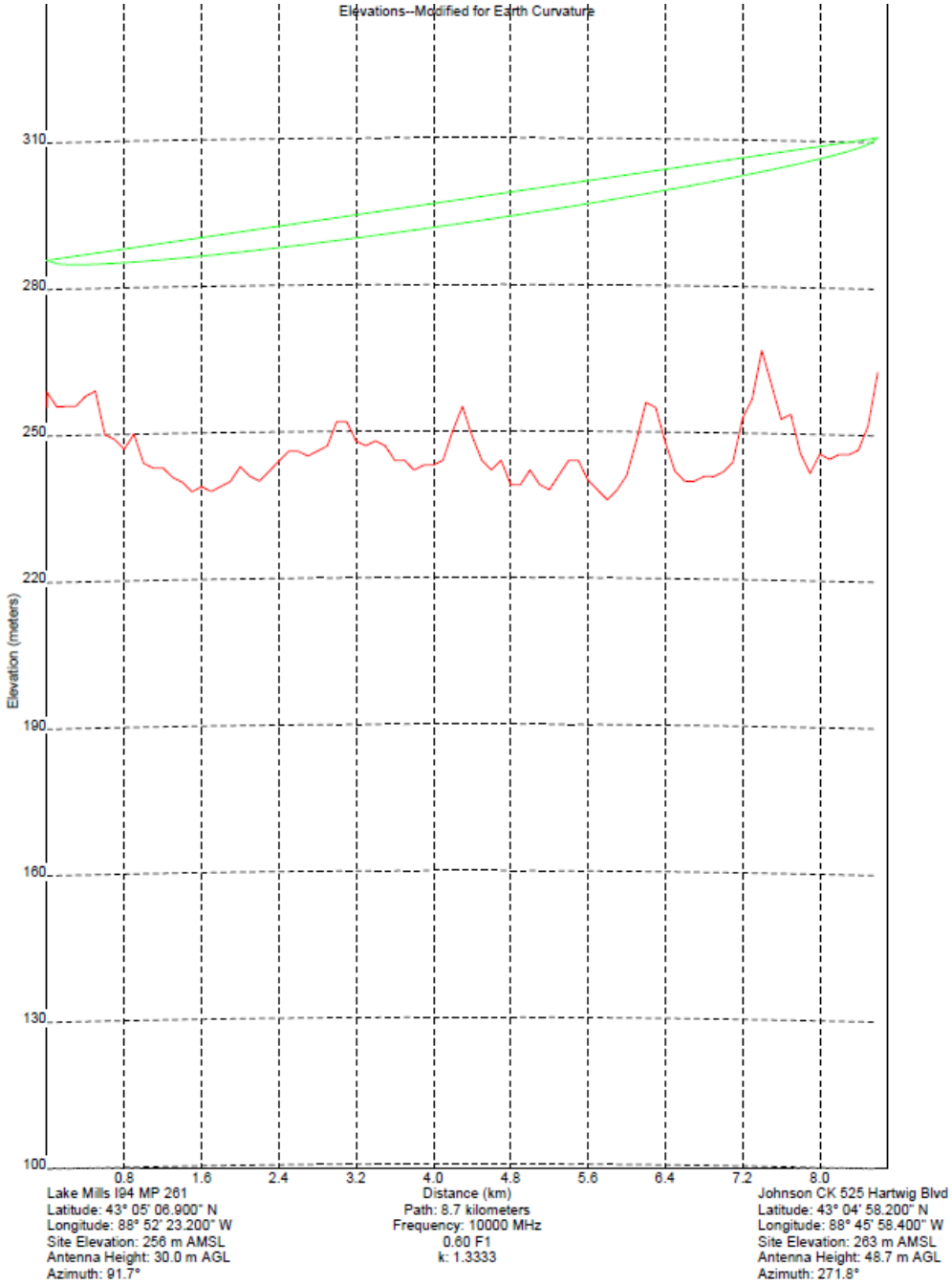



*Figure 30 - Lake Mills / Johnson Creek Path Detail*

**Johnson Creek – Main**


*Figure 31 - Johnson Creek / Jefferson Main Path Detail*

**Lake Mills – Main**

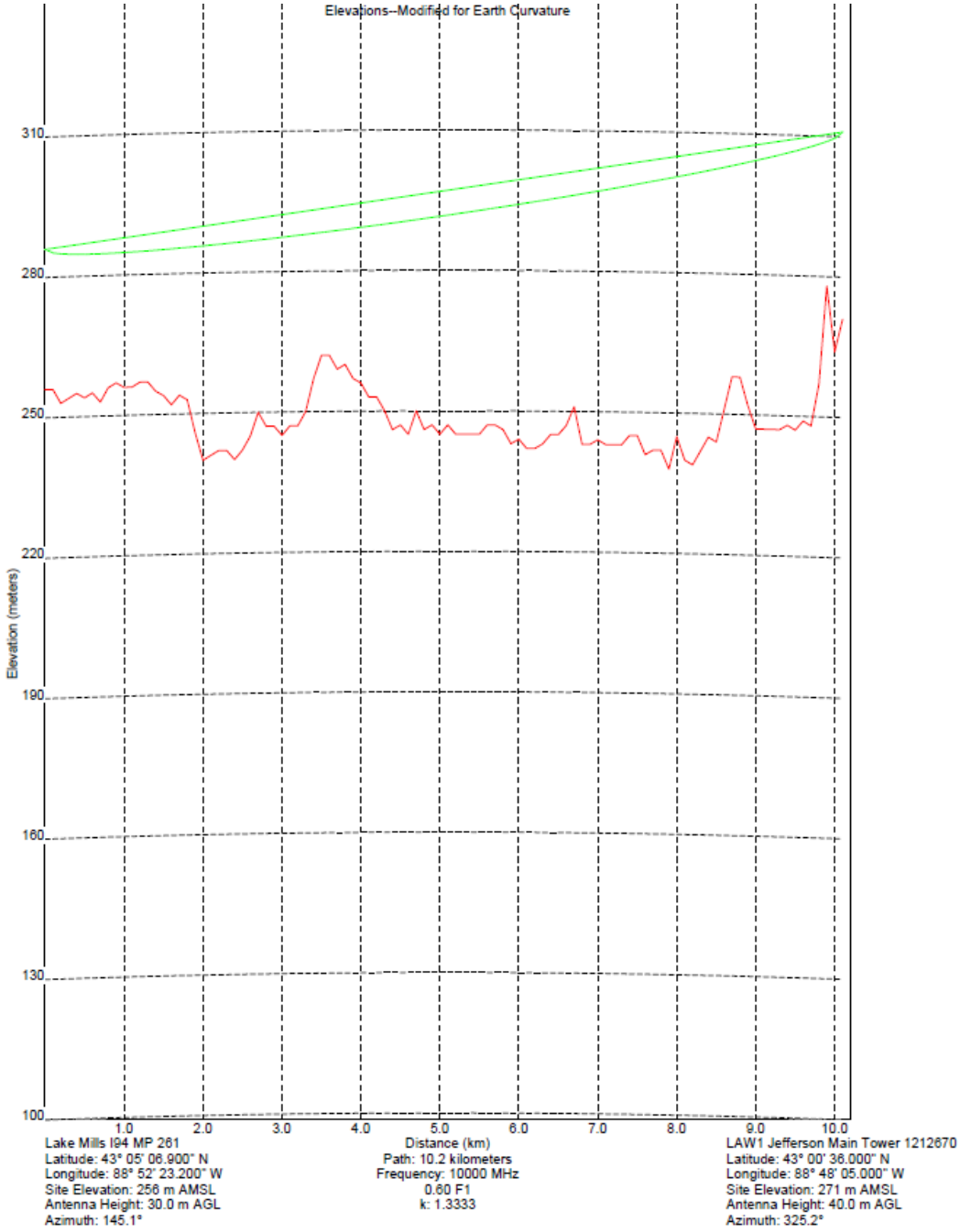



*Figure 32 - Lake Mills / Jefferson Main Path Detail*

**Main to ASR 1249220 (800 MHz P25 Trunking)**

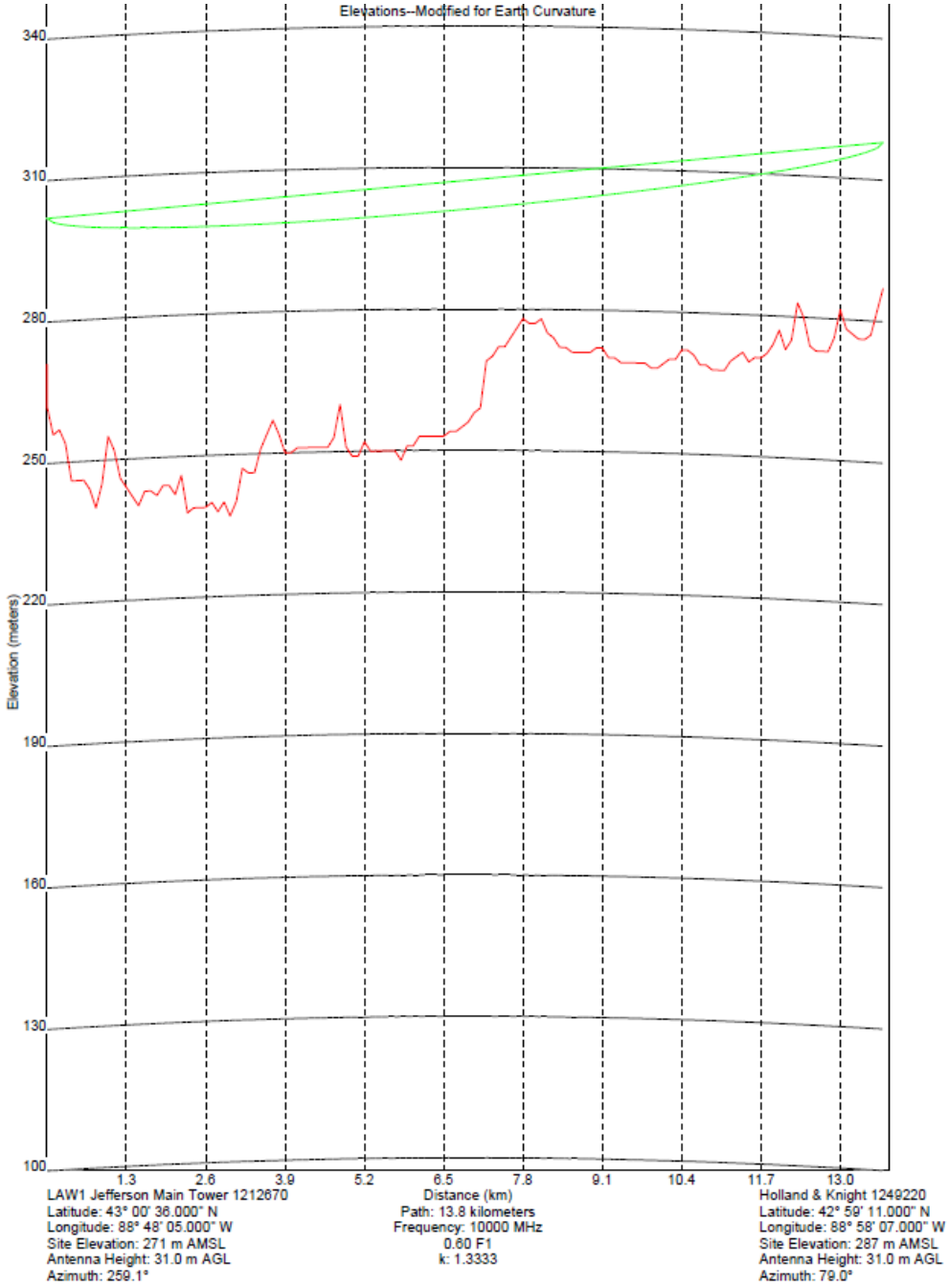



*Figure 33 - Jefferson Main / ASR 1249220 Path Detail*

**ASR 1249220 to Ft. Atkinson (800 MHz P25 Trunking)**

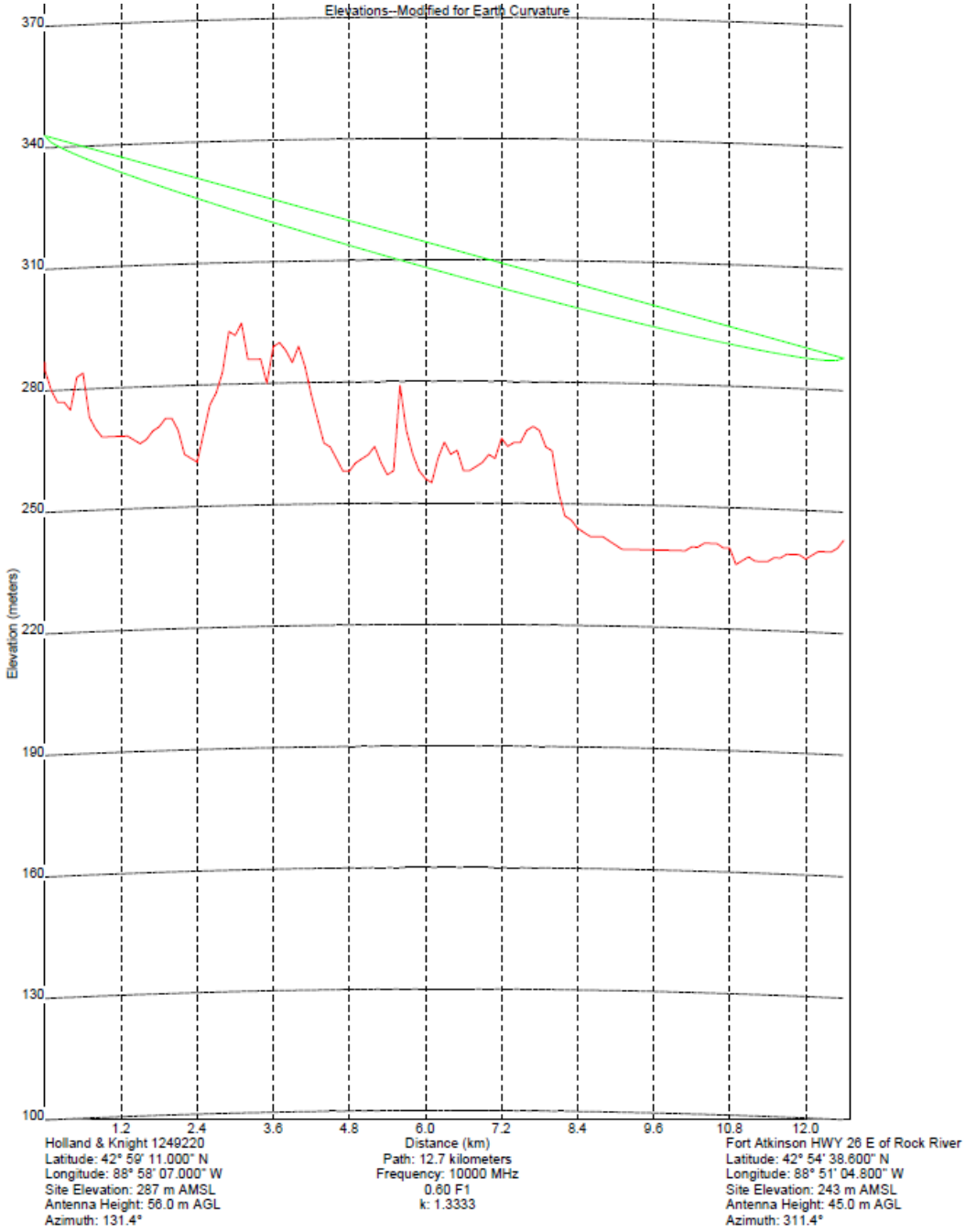



*Figure 34 - ASR 1249220 / Fort Atkinson Path Detail*

# 17 Conceptual System Options

## 17.1 *Radio System Option 1 – VHF Analog Conventional Operation*

### 17.1.1 Description

Option 1 is a six-site VHF analog simulcast-voted design for LAW1, EMCOM1, and FIRE1 channels estimated to provide 43% residential in-building portable coverage. The antenna design would use separate receive and transmit antenna systems.[8] The receive antenna would be higher than transmit antenna directly above and below each other separated by at least 20 feet. All current sites except Sullivan, Johnson Creek, and Lake Mills would be used in the design. The Ixonia water tower site may not be useable if the transmit to receive antenna separation is greater than 30 dB using the current antenna.

Water towers will not support such an antenna system, so the Ixonia water tower site is not recommended. A self-supporting tower providing equivalent transmit antenna height would be necessary. At Waterloo, the tower would be raised to 100 feet or replaced to provide the 20-foot antenna to antenna separation. For this conceptual design, it is assumed that all other towers would have the space for the antenna design. Transmit and receive combining systems would be used to minimize the number of antennas used. The budget includes an estimate for structural studies and potential strengthening based on the heights of existing towers.

Paging, MARC, IFERN, and Highway systems are replaced with new equipment, but their system design does not change. Satellite receivers would continue to be used at nine sites for MARC and IFERN. The current dispatch console system will remain in operation.

The microwave topology would remain as designed. The 960 MHz links would be replaced with 6 GHz and 10 GHz microwave radios dependent on the path. The existing 10 GHz links would remain except for Ixonia. It is anticipated an alternate antenna structure would need to be considered due to voice antenna system requirements as indicated above. No redundancy or hot standby for the microwave system is included in the budgetary estimate.

All existing radios would remain in use. All RF sites would be powered by a DC plant to provide continuous power to all equipment regardless of the status of commercial power. DC plant batteries would be charged continuously and provide surge protection from spikes on the commercial power grid. State-of-the-art grounding techniques would be implemented at all sites. All sites would need to have generator power. No generators are included in the budgetary estimate. The estimate includes communications equipment shelters for three sites (Jefferson, Fort Atkinson, and Palmyra) and two self-supporting towers (Waterloo and Ixonia).

[8] Separation is of the transmit and receive antennas can be an issue at a radio site. It is typically necessary to have vertical separation of a minimum of 20' for VHF. If this is not possible then extensive filtering is a possible alternative but it also comes at a cost of both incorporation and poorer site performance.

An alarm system with sensors (power, temperature, smoke/fire, fuel level, generator run, door switch, and tower lighting) would report all applicable alarms via the microwave network. The microwave network would also alarm any link failures.

### 17.1.2 Budgetary Costs – Option 1

| System Component | Description | Cost |
|---|---|---|
| **Vendor Infrastructure** | Repeaters, satellite receivers, voting, simulcast, antennas, microwave, power, shelter, grounding, towers, civil, dispatch equipment, and alarms | $2,772,000 |
| **Vendor Services** | Engineering, installation, testing, commissioning, and training | $474,000 |
| **Field Terminal Equipment** | Mobiles, portables, and associated accessories | $0.00 |
| **Est Civil Construction Work** | Site construction (electrical, compound, foundations, towers, fencing, etc.) | $1,074,000 |
| **Contingency** | Equipment, services, and site work | $486,000 |
| **Professional Services** | Licensing, consulting, and project management | $129,000 |
| | **Total** | $4,935,000 |

### 17.1.3 System Equipment List

| | Description | Quantity |
|---|---|---|
| **ANALOG CONVENTIONAL** | | |
| | Analog VHF Conventional Repeater / Base - LAW1, EMCOM1, FIRE1 | 18 |
| | Analog VHF Conventional Repeater / Base - Paging | 9 |
| | Analog VHF Conventional Repeater / Base - MARC, IFERN, Highway | 3 |
| **SATELLITE RECEIVERS** | | |
| | Analog VHF Receiver - MARC, IFERN | 18 |
| | Analog VHF Receiver - LAW1, EMCOM1, FIRE1 | 9 |
| **VOTING** | | |
| | ANALOG Comparator | 5 |
| **CONTROLLERS** | | |
| | Geo-Redundant Simulcast Controller | 4 |
| **ANTENNA SYSTEM** | | |
| | VHF Simulcast Repeater Antenna System | 9 |
| | VHF TX/RX 7 Ch Combining System | 1 |
| | VHF TX/RX 4 Ch Combining System | 8 |
| **LINKING & MICROWAVE** | | |
| | 6/10 GHz Link/mux /network | 2 |
| | Long Range 6 GHz Link/mux/network (diversity) | 2 |
| | Mid Range 6 GHz Link/mux /network | 3 |
| **POWER** | | |
| | 1500W Dual Conversion UPS / DC Plant System | 10 |
| **SHELTER & GROUNDING** | | |
| | Grounding System | 11 |
| | 10' X 16' Shelter | 1 |
| | 10' X 12' Shelter | 2 |
| **TOWERS** | | |
| | Self Supporting (enter height in feet) | 270 |
| | Tower Strengthening (height of structure in feet) | 1000 |
| **CIVIL ENGINEERING** | | |
| | Site Improvements (access road, etc.) | 1 |
| **ALARM SYSTEM** | | |
| | Alarms | 11 |

### 17.1.4 Coverage Predictions

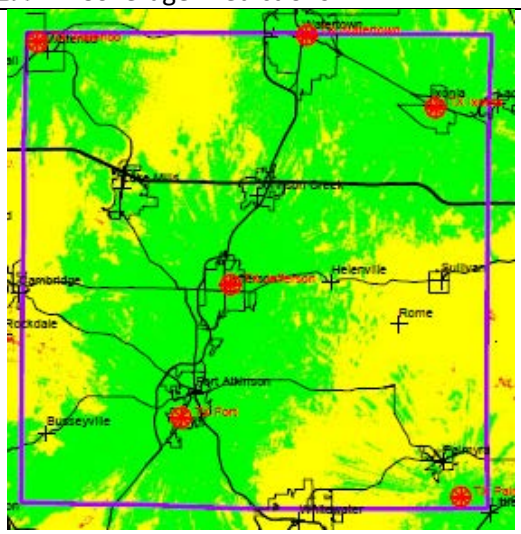



*Figure 35 - 6 Sites Analog PTO VHF*

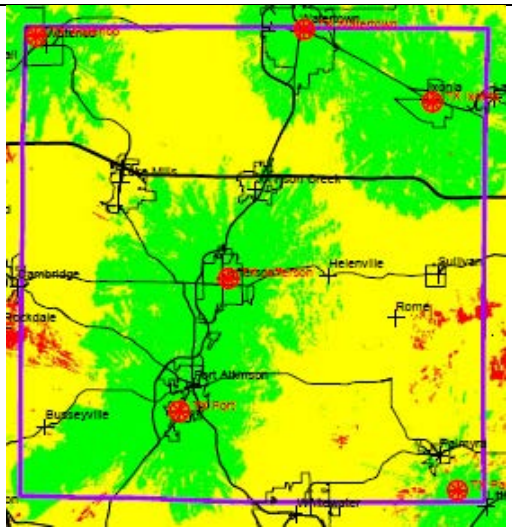



*Figure 36 - 6 Sites Analog PTB VHF*

### 17.1.5 Back Haul Topology

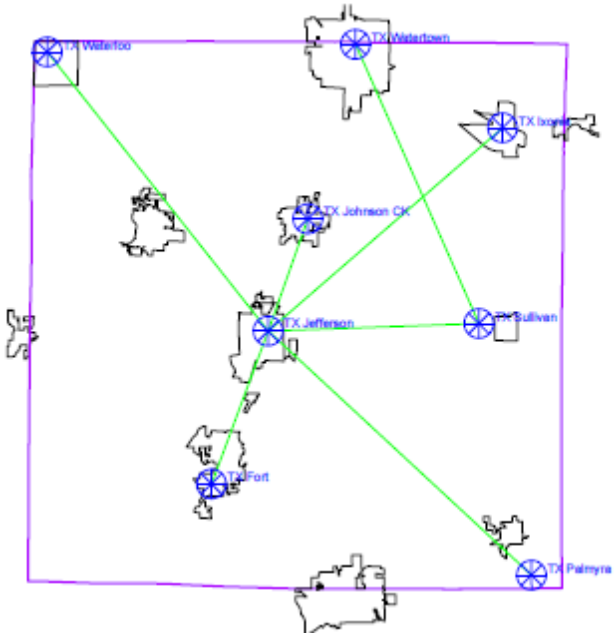



*Figure 37 - Option 1 Microwave Network Topology*

## 17.2 *Radio System Option 2 – VHF P25 Conventional Operation*

### 17.2.1 Description

Option 2 is a six-site VHF P25 simulcast-voted design for LAW1, EMCOM1 and FIRE1 channels estimated to provide 94% residential in-building portable operation. The antenna design would use separate receive and transmit antenna systems. The receive antenna would be higher than transmit antenna directly above and below each other separated by at least 20 feet. Water towers will not support such an antenna system so water tower sites would be used for analog receive systems and paging.

A higher self-supporting tower (either extended in height, replaced in the current or a nearby location) may want to be considered for the Palmyra site. Predictions indicate that terrain blocks signal to the north and west. At Waterloo, the tower would be raised to 100 feet or replaced to provide the 20-foot antenna to antenna separation. For this conceptual design, it is assumed that all other towers would have the space for the antenna design. Transmit and receive combining systems would be used to minimize the number of antennas used. The budget includes an estimate for structural studies and potential strengthening based on the heights of existing towers.

Paging, MARC, IFERN, and Highway systems are replaced with new equipment, but their system design does not change. Satellite receivers would continue to be used at nine sites for MARC and IFERN. All current sites would be used.

The Mindshare console system would continue to be used. A redundant P25 system interface equipped for three channels would be used to operate the conventional P25 simulcast repeater stations.

The microwave topology would be converted to a ring topology providing redundancy if a portion of the link would fail. All microwave would be replaced with 6 GHz and 10 GHz microwave radios dependent on the path. The existing 10 GHz link radios could potentially be reused, but the estimated budget includes all new equipment.

All existing radios would be replaced with P25 conventional capable units. Ten units would be multi-band for direct interoperability with adjacent county systems.

All RF sites would be powered by a DC plant that would provide continuous power to all equipment regardless of the status of commercial power. DC plant batteries would be charged continuously and provide surge protection from spikes on the commercial power grid. State-of-the-art grounding techniques would be implemented at all sites. All sites would need to have generator power. No generators are included in the budgetary estimate. The estimate includes communications equipment shelters for three sites (Jefferson, Fort Atkinson, and Palmyra) and two self-supporting towers (Waterloo and Ixonia).

An alarm system with sensors (power, temperature, smoke/fire, fuel level, generator run, door switch, and tower lighting) would report all applicable alarms via the microwave network. The microwave network would also alarm any link failures.

### 17.2.2 Budgetary Costs

| System Component | Description | Cost |
|---|---|---|
| **Vendor Infrastructure** | Repeaters, satellite receivers, voting, simulcast, antennas, microwave, power, shelter, grounding, towers, civil, dispatch equipment, and alarms | $3,502,000 |
| **Vendor Services** | Engineering, installation, testing, commissioning, and training | $568,000 |
| **Field Terminal Equipment** | Mobiles, portables, and associated accessories | $3,871,000 |
| **Est Civil Construction Work** | Site construction (electrical, compound, foundations, towers, fencing, etc.) | $1,074,000 |
| **Contingency** | Equipment, services, and site work | $545,000 |
| **Professional Services** | Licensing, consulting, and project management | $171,000 |
| | **Total** | $9,731,000 |

### 17.2.3 System Equipment List

| | Description | Quantity |
|---|---|---|
| **ANALOG CONVENTIONAL** | | |
| | Analog VHF Conventional Repeater / Base | 9 |
| | Analog VHF Conventional Repeater / Base | 3 |
| **DIGITAL CONVENTIONAL OPERATION** | | |
| | DIGITAL VHF Conventional Repeater | 18 |
| **SATELLITE RECEIVERS** | | |
| | Analog VHF Receiver | 18 |
| **VOTING** | | |
| | ANALOG Comparator | 2 |
| | DIGITAL Conventional Comparator | 3 |
| **CONTROLLERS** | | |
| | Geo-Redundant Simulcast Controller | 4 |
| **ANTENNA SYSTEM** | | |
| | VHF Simulcast Repeater Antenna System | 9 |
| | VHF TX/RX 7 Ch Combining System | 1 |
| | VHF TX/RX 4 Ch Combining System | 5 |
| **LINKING & MICROWAVE** | | |
| | 6/10 GHz Link/mux /network | 5 |
| | Long Range 6 GHz Link/mux/network (diversity) | 3 |
| | Mid Range 6 GHz Link/mux /network | 2 |
| **POWER** | | |
| | 1500W Dual Conversion UPS / DC Plant System | 10 |
| **SHELTER & GROUNDING** | | |
| | Grounding System | 10 |
| | 10' X 16' Shelter | 1 |
| | 10' X 12' Shelter | 2 |
| **TOWERS** | | |
| | Self Supporting (enter height in feet) | 250 |
| | Tower Strengthening (height of structure in feet) | 640 |
| **CIVIL ENGINEERING** | | |
| | Site Improvements (access road, etc.) | 2 |
| **ALARM SYSTEM** | | |
| | Alarms | 10 |
| **DISPATCH CONSOLES** | | |
| | Mindshare P25 Redundant Conventional Interface - 3 Ch | 1 |
| **FIELD EQUIPMENT** | | |
| **HIGH TIER SUBSCRIBER EQUIPMENT** | | |
| **MOBILES** | | |
| | Multi-Band Multi-Mode Mobile | 10 |
| | VHF P25 Conventional Mobile | 93 |
| **PORTABLES** | | |
| | VHF P25 Trunked Portable | 428 |
| **CONTROL STATIONS** | | |
| | VHF P25 Conventional Control Station | 46 |
| **CONTROL STATION ANTENNA SYSTEM** | | |
| | VHF Yagi (100 ft. Transmission Line) | 42 |
| **MID TIER SUBSCRIBER EQUIPMENT** | | |
| **MOBILES** | | |
| | VHF P25 Conventional Mobile | 164 |
| **PORTABLES** | | |
| | VHF P25 Conventional Portable | 380 |
| **CONTROL STATIONS** | | |
| | VHF P25 Conventional Control Station | 18 |
| **CONTROL STATION ANTENNA SYSTEM** | | |
| | VHF Omni (100 ft. Transmission Line) | 18 |
| **LOW TIER SUBSCRIBER EQUIPMENT** | | |
| **MOBILES** | | |
| | VHF P25 Conventional Mobile | 92 |
| **PORTABLES** | | |
| | VHF P25 Conventional Portable | 23 |
| **CONTROL STATIONS** | | |
| | VHF P25 Conventional Control Station | 3 |
| **CONTROL STATION ANTENNA SYSTEM** | | |
| | VHF Yagi (100 ft. Transmission Line) | 3 |
| **CONTROL STATION COMBINER** | | |
| | 8ch dbSpectra (150-174 MHz) CS Combiner | 1 |
| **FIELD UNIT OPTIONS/ACCESSORIES (HIGH TIER P25 ONLY)** | | |
| | Add AES Encryption (Single Key) | 531 |

### 17.2.4 Coverage Predictions

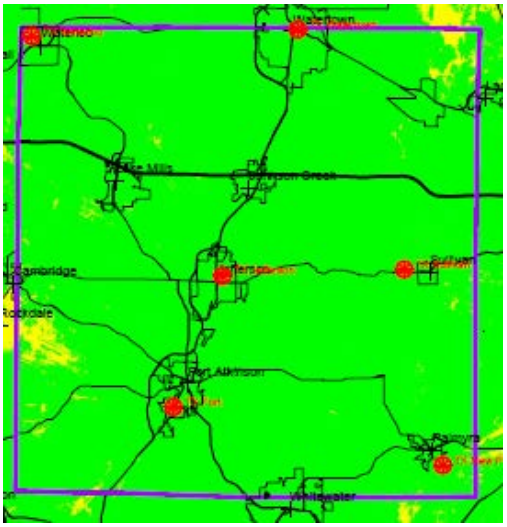


*Figure 38 - 6 Sites P25 Conventional PTO VHF*

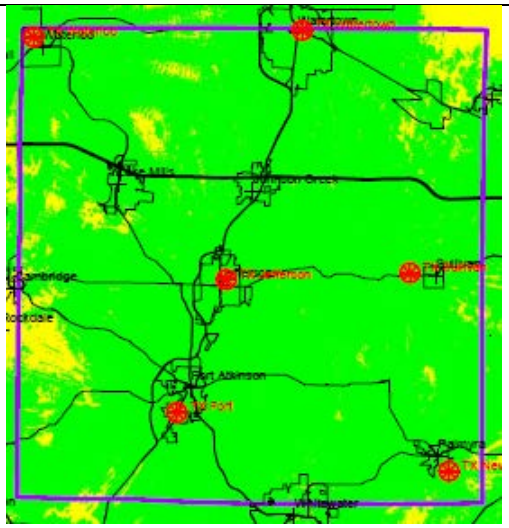


*Figure 39 - 6 Sites P25 Conventional PTB VHF*

### 17.2.5 Back Haul Topology

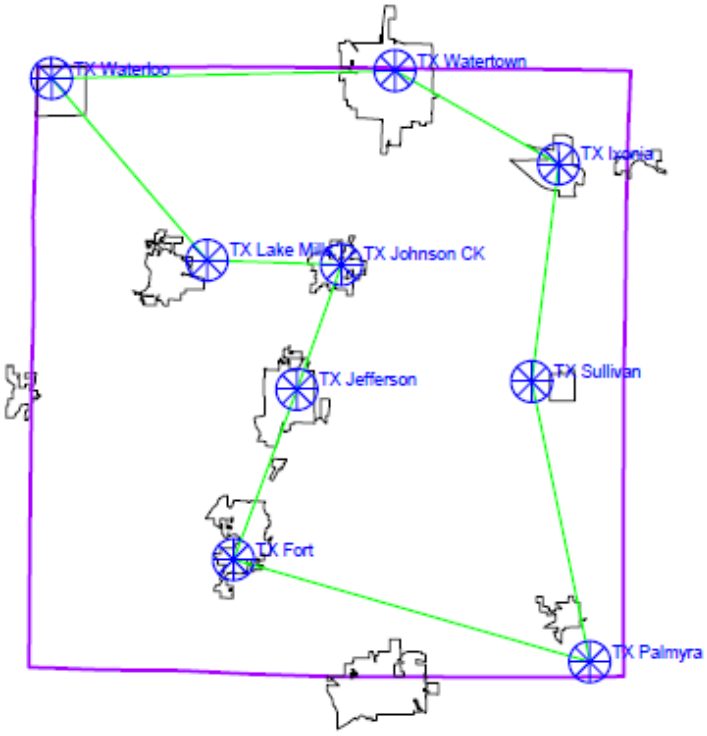



*Figure 40 - Option 2 Microwave Network Topology*

## 17.3 *Radio System Option 3 – 800 MHz P25 Trunking Operation*

### 17.3.1 Description

Option 3 employs a 10-site, five-channel, P25 Phase I 800 MHz simulcast-voted design for LAW, FIRE, EMS, Highway, and other County users. The system shares four voice channels among all users of the system. Trunking systems use “talk groups” like channels in a conventional system. Radios can be programmed with multiple talk groups to provide the communications needed. AES encryption is included in the budgetary estimate for Law units (531). Over-the-air-Programming for all units (1257) and Over-the-air-Rekeying for all Law units are included in the estimate.

This design is estimated to provide 75% portable residential in-building coverage and 98% on-street portable operation. Although the residential in-building coverage estimate is 75%, sites are located near populated areas that should provide residential in-building portable performance for most homes in Jefferson County. The antenna design would use separate receive and transmit antenna systems. The receive antenna would be higher than transmit antenna directly above and below each other separated by at least 20 feet. All current sites except Lake Mills and Ixonia would be used. As Lake Mills is a WISCOM tower, a new tower for this purpose is included in the budget.

Water towers will not support such an antenna system, so the Ixonia water tower site would not be used. A self-supporting tower providing equivalent transmit antenna height would be necessary. At Waterloo, the tower would be raised or replaced to provide the 20-foot antenna to antenna separation. For this conceptual design, it is assumed that all other towers would have the space for the antenna design and the budget includes an estimate for structural studies and potential strengthening based on the heights of existing towers. Transmit and receive combining systems would be used to minimize the number of antennas used.

Paging, MARC, and IFERN systems are replaced with new equipment. MARC and IFERN channels would be connected via a gateway to one P25 talk group each allowing a P25 user to activate either station. Once selected by a user on their P25, MARC1, or IFERN, radio activity will be routed onto the trunked system. Activity of this nature must be limited to prevent overload of the system. Only four simultaneous voice channels are available at any one time.

The Mindshare console system would continue to be used. A P25 trunked system interface would use the Console Sub-System Interface. Reprogramming of the existing console equipment would be required to set up the talk groups to be used in the system.

A digital paging system and 523 digital pagers are included in the budgetary estimate. The budgetary estimate is based on a digital store and forward design and alphanumeric display pagers.

The microwave system would use a new 10$^{th}$ site in the western portion of the County. The microwave topology would be converted to a ring topology providing redundancy if a portion of the link would fail. All microwave would be replaced with 6 GHz and 10 GHz microwave radios dependent on the path. Each link of the microwave network would be designed to provide 99.999% reliability.

The existing 10 GHz link radios could potentially be reused, but the estimated budget includes all new equipment. A single microwave link connects the main site to the Sheriff's Office and provides a redundant path for the existing fiber.

All existing radios would be replaced with P25 trunked capable units. Ten units would be multi-band for direct interoperability with adjacent county systems. For the budgetary estimate, all Law units are high-tier units.

All RF sites would be powered by a DC plant providing continuous power to all equipment regardless of the status of commercial power. DC plant batteries would be charged continuously and provide surge protection from spikes on the commercial power grid. State-of-the-art grounding techniques would be implemented at all sites. All sites would need to have generator power. No generators are included in the budgetary estimate. The estimate includes communications equipment shelters for three sites (Jefferson, Fort Atkinson, and Palmyra) and two self-supporting towers (Waterloo and Ixonia).

An alarm system with sensors (power, temperature, smoke/fire, fuel level, generator run, door switch, and tower lighting) would report all applicable alarms via the microwave network. The microwave network would also alarm any link failures.

### 17.3.2 Budgetary Costs

| System Component | Description | Cost |
|---|---|---|
| **Vendor Infrastructure** | Repeaters, satellite receivers, voting, simulcast, antennas, microwave, power, shelter, grounding, towers, civil, dispatch equipment, and alarms | $6,433,000 |
| **Vendor Services** | Engineering, installation, testing, commissioning, and training | $1,716,000 |
| **Field Terminal Equipment** | Mobiles, portables, and associated accessories | $6,839,000 |
| **Est Civil Construction Work** | Site construction (electrical, compound, foundations, towers, fencing, etc.) | $1,790,000 |
| **Contingency** | Equipment, services, and site work | $1,062,000 |
| **Professional Services** | Licensing, consulting, and project management | $322,000 |
| | **Total** | $18,162,000 |

### 17.3.3 System Equipment List

| | Description | Quantity |
|---|---|---|
| **ANALOG CONVENTIONAL** | | |
| | Analog VHF Conventional Repeater / Base | 2 |
| **P25 TRUNKED OPERATION** | | |
| | P25 800 Trunked Repeater | 50 |
| **VOTING** | | |
| | DIGITAL Trunked Comparator | 5 |
| **CONTROLLERS** | | |
| | Geo-Redundant Simulcast Controller | 5 |
| | Geo-Redundant Trunking Controller | 1 |
| **ANTENNA SYSTEM** | | |
| | 800 TX Combining System | 10 |
| | 800 RX Multicoupler System | 10 |
| | 800 BMR-10 Antenna | 20 |
| | 800 Tower Top Amplifier | 10 |
| | 800MHz Preselector | 10 |
| **LINKING & MICROWAVE** | | |
| | 6/10 GHz Link/mux /network | 4 |
| | Long Range 6 GHz Link/mux/network (diversity) | 3 |
| | Mid Range 6 GHz Link/mux /network | 4 |
| **POWER** | | |
| | 1500W Dual Conversion UPS / DC Plant System | 11 |
| | 15 kW Generator w/1X Belly Tank & Transfer Switch | 2 |
| **SHELTER & GROUNDING** | | |
| | Grounding System | 11 |
| | 10' X 16' Shelter | 1 |
| | 10' X 12' Shelter | 3 |
| **TOWERS** | | |
| | Self Supporting (enter height in feet) | 710 |
| | Tower Strengthening (height of structure in feet) | 827 |
| **CIVIL ENGINEERING** | | |
| | Site Improvements (access road, etc.) | 1 |
| **ALARM SYSTEM** | | |
| | Alarms | 11 |
| **DISPATCH CONSOLES** | | |
| | Mindshare P25 Trunking Interface CSSI - 4 Voice Ch | 1 |
| **OTHER** | | |
| | Net Clock System | 1 |
| | Audio Logging System | 1 |
| | MPLS Router | 1 |
| | MPLS Site Router | 10 |

| | Description | Quantity |
|---|---|---|
| **FIELD EQUIPMENT** | | |
| **HIGH TIER SUBSCRIBER EQUIPMENT** | | |
| **MOBILES** | | |
| | Multi-Band Multi-Mode Mobile | 10 |
| | 800 P25 Trunked Mobile | 93 |
| **PORTABLES** | | |
| | 800 P25 Trunked Portable | 428 |
| **CONTROL STATIONS** | | |
| | 800 P25 Trunked Control Station | 46 |
| **CONTROL STATION ANTENNA SYSTEM** | | |
| | 800 Yagi (100 ft. Transmission Line) | 42 |
| **MID TIER SUBSCRIBER EQUIPMENT** | | |
| **MOBILES** | | |
| | 800 P25 Trunked Mobile | 164 |
| **PORTABLES** | | |
| | 800 P25 Trunked Portable | 380 |
| **CONTROL STATIONS** | | |
| | 800 P25 Trunked Control Station | 18 |
| **CONTROL STATION ANTENNA SYSTEM** | | |
| | 800 Yagi (100 ft. Transmission Line) | 18 |
| **LOW TIER SUBSCRIBER EQUIPMENT** | | |
| **MOBILES** | | |
| | 800 P25 Trunked Mobile | 92 |
| **PORTABLES** | | |
| | 800 P25 Trunked Portable | 23 |
| **CONTROL STATIONS** | | |
| | 800 P25 Trunked Control Station | 3 |
| **CONTROL STATION ANTENNA SYSTEM** | | |
| | 800 Yagi (100 ft. Transmission Line) | 3 |
| **CONTROL STATION COMBINER** | | |
| | 8 ch dbSpectra (764-869 MHz) CS Combiner | 1 |
| **FIELD UNIT OPTIONS/ACCESSORIES (HIGH TIER P25 ONLY)** | | |
| | Add AES Encryption (Single Key) | 531 |
| | Add OTAR | 531 |
| | KVL keyloader | 1257 |
| **DIGITAL PAGING EQUIPMENT** | | |
| | Paging Controllers (primary + backup) | 1 |
| | Base Station | 9 |
| | Dispatch Equipment per positiion | 4 |
| | Pager /pairing & alerting with smartphone | 523 |
| | s.ONE - Annual SW Subscription | 1 |

### 17.3.4 Coverage Predictions

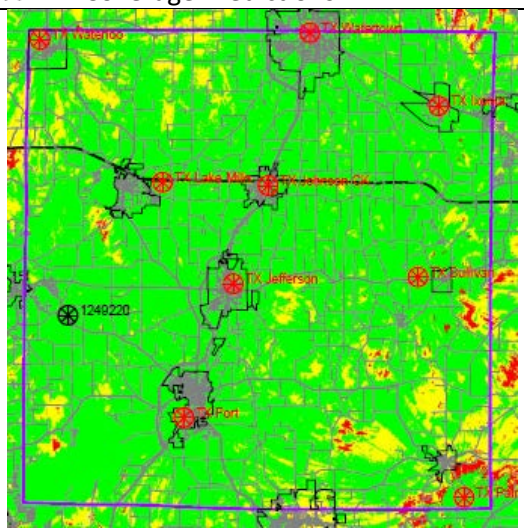



*Figure 41 – 10-Site P25 Trunked PTO 800 MHz*

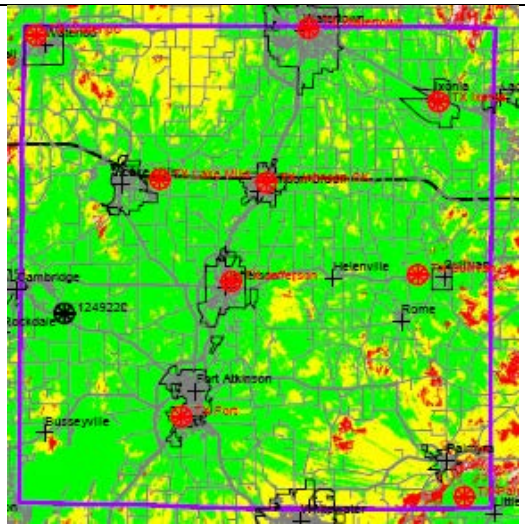


*Figure 42 – 10-Site P25 Trunked PTB 800 MHz*

### 17.3.5 Back Haul Topology

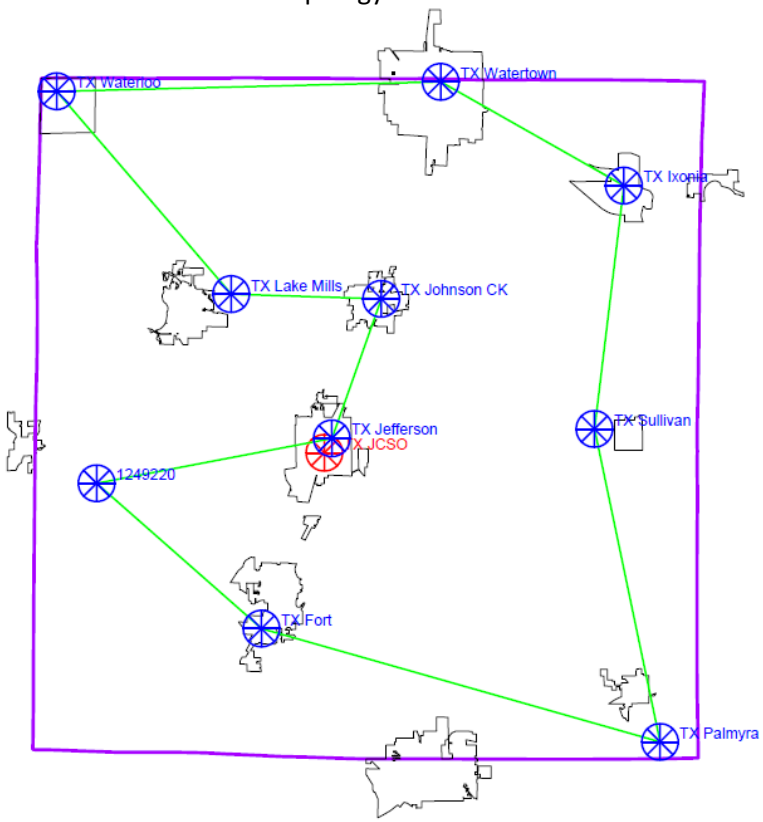



Figure 43 - Option 3 Microwave Network Topology

## 18 E&A Recommendation

Option 2 is recommended accompanied by a protected digital backhaul system to support voice and paging operation. Using VHF will provide enhanced portable coverage performance and P25 digital operation should reclaim the system performance losses attributed to narrow banding of channels on LAW1, EMCOM1, and FIRE1 channels. Simulcast will provide Law, and Fire/EMS users improved portable coverage across the County. An improved microwave network will protect the system against backhaul failures. State-of-the-art grounding techniques would be implemented at all sites.

It is anticipated repeaters could be initially programmed for analog and after all field units were P25 capable users could switch to digital operation. Although analog simulcast will improve portable coverage, the coverage improvement realized in digital would not be realized until all units were converted to digital operation.

Paging, MARC, IFERN, and Highway systems are replaced with new equipment, but their system design does not change. Satellite receivers would continue to be used at nine sites for MARC and IFERN. All current sites would be used. Paging would remain a tone-voice system using simulcast. MARC and IFERN would continue to use existing receiver site and voted.

All existing radios would be replaced with P25 VHF conventional capable units. Ten units would be multiband radios used in the system providing direct interoperability with neighboring systems.

The Mindshare console system would continue to be used. A redundant P25 system interface equipped for three channels would be used to operate the conventional P25 simulcast repeater stations.

The microwave topology would be converted to a ring topology providing redundancy if a portion of the link would fail. All microwave would be replaced with 6 GHz and 10 GHz microwave radios dependent on the path. The existing 10 GHz link radios could potentially be reused, but the estimated budget includes all new equipment.

All RF sites would be powered by a DC plant that would provide continuous power to all equipment regardless of the status of commercial power. An alarm system with sensors (power, temperature, smoke/fire, fuel level, generator run, door switch, and tower lighting) would report all applicable alarms via the microwave network.

All infrastructure and field units should be covered by a maintenance contract to ensure performance reliability. Infrastructure should undergo a performance tests twice a year and field units on an annual basis. Field testing, unit setup, and programming of all field units should be performed only by a qualified technician. All channels programmed into field units should comply with County standards to enable interoperability at local, State, and National levels using FEMA, State, and County guidelines. Channel alpha-numeric displays should use standard naming conventions and the appropriate setup for analog and digital operation when applicable. Recommendations on channel setup that follow County communications policies and procedures should be provided to each user agency and service organization.

Any civil work required to prepare sites, shelters or antenna structures for use will not be provided by the radio system vendor. A civil engineering firm is used to provide the necessary site engineering, drawings, and assist in the bidding of these products and services based on radio system vendor requirements. The civil engineer will also provide or coordinate tower analysis and strengthening activities. Examples of civil work is found in APPENDIX 10: Tower Site Overview.

## 19 Next Steps and Transition Planning

The immediate challenge for Jefferson County officials will be to choose the direction and make decisions concerning the performance levels a new system is expected to attain. This includes the performance levels for the Paging, Voice, and the backhaul systems plus all supporting infrastructure. This critical step will ultimately result in a system specification to be used to generate a system design for acquisition and to understand the costs that will be used to determine the total cost to the County. Elert & Associates is providing a proposal to assist the County in developing the performance specifications to be used in developing the procurement document. Within this proposal, we describe the course of action Elert believes the County should pursue to remedy the paging system while ensuring the desired performance of all subsystems at an acceptable cost to the County.

The vendor proposal accepted by the County via its procurement process for the radio system equipment and the support requirements would then be used to move the project forward. These support requirements must include details concerning antenna systems, power, space, and environmental requirements (HVAC). For Jefferson County, the tower structures for each site proposed need to be analyzed to determine if the proposed structures will support the proposed antenna systems. If not, additional work needs to be done to determine (1) if an antenna supporting structure can be strengthened and, if so, at what cost or (2) if the structure cannot be strengthened and may need to be replaced. If neither, another site must be identified, or modifications of the system performance be analyzed and considered. These results will drive the next set of decisions needed to move the project forward. At this point, this may include re-evaluating, balancing, and re-establishing the necessary funding requirements with minimum performance levels for the system infrastructure. The preliminary steps in system enhancement include the following:

1. Set the initial minimum system performance specifications for:
    a. Paging Coverage
    b. Voice System Coverage
    c. Microwave
        i. Reliability
        ii. Throughput
        iii. Latency
        iv. Jitter
        v. Redundancy
    d. Space, electrical power, backup power, HVAC
    e. Alarms
2. Develop a Performance Specifications Document.
3. Determine appropriate procurement vehicle.
4. Advertise and Distribute RFP specifications and if needed.
    a. Answer potential vendor questions.
    b. Familiarize potential vendors with current County assets.
5. Analyze received vendor proposal(s).
6. Prepare report and recommendation for County decision makers.
7. County to choose vendor and system design.
8. Analyze existing and/or proposed antenna structures during a detailed design process.

9. Next steps are based on results.

Once the new system is in place, a plan of action must continue to be driven by the organizations supporting it while focusing on the improvement of any identified problems. A feedback system should be implemented to allow users to report problems. Information reported should include the user, approximate location, and time of the issue. No radio system will provide 100% coverage thus large buildings, such as schools, should be tested and any areas of concern noted with plans developed to meet coverage needs.

Facilitating this change and managing the project of transitioning to a new technology will ultimately be a win-win solution and will overcome the identified barriers. The transformation will not only involve equipment and systems, but is expected to address cultural, managerial, and financial impediments that, unless addressed by the stakeholders, have the potential of impacting the success of the project.

The steps necessary to effect a successful transition include the following:

- Create a quality assurance program with a focus on problem resolution.
- Evaluate the current technology, systems, and weak points.
- Evaluate the alternatives related to operations and coverage.
- Assess each jurisdiction's business rules and related operations.
- Facilitate meetings and groups to find common ground for the design.
- Understand and assist in the development of system expectations.
- Coordinate the implementation of the new communication system.
- Create/design all necessary project management materials, tools, and documentation to effect a positive outcome.
- Prepare required reports to jurisdictional policy/decision makers.

## 20 Training

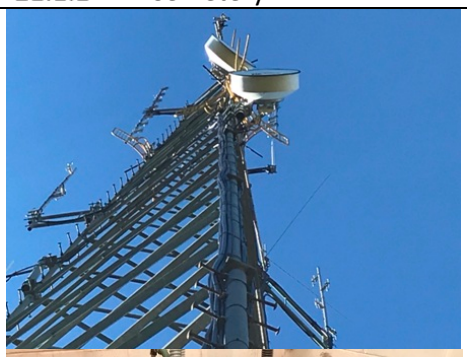
With the implications of new and enhanced technology to meet the demands of today's public safety, first responder, and EMS personnel, the need for training in the use of the new capabilities has never been greater. With the advent of these new technologies, it is possible, for the first time, to enable users to program the radio technology just the way they want. Increasingly, this integration of voice and data is having a positive impact on productivity. This change can happen only if users are trained on how to make use of the new technology and to gain access to its features.

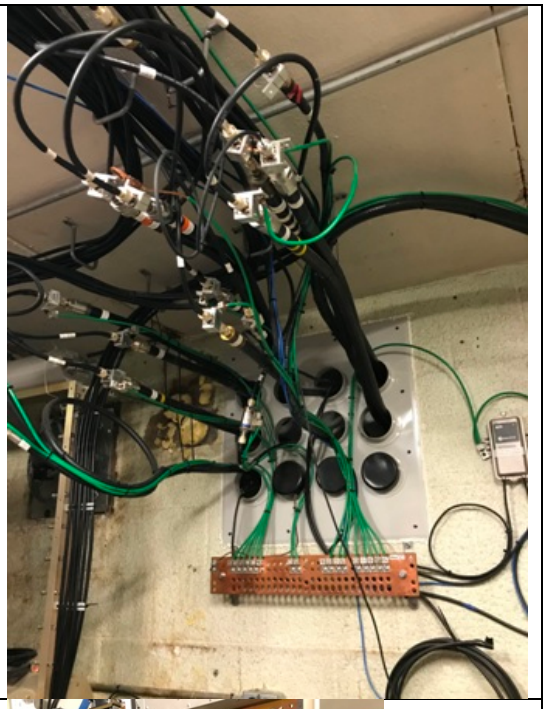
A training plan must be a part of any transition plan, as not having officers and other staff properly trained in the use will certainly doom the project or at least not allow the gains of expected productivity to be realized.

# 21 APPENDIX 1: Site Information

## 21.1 *Tower Sites*

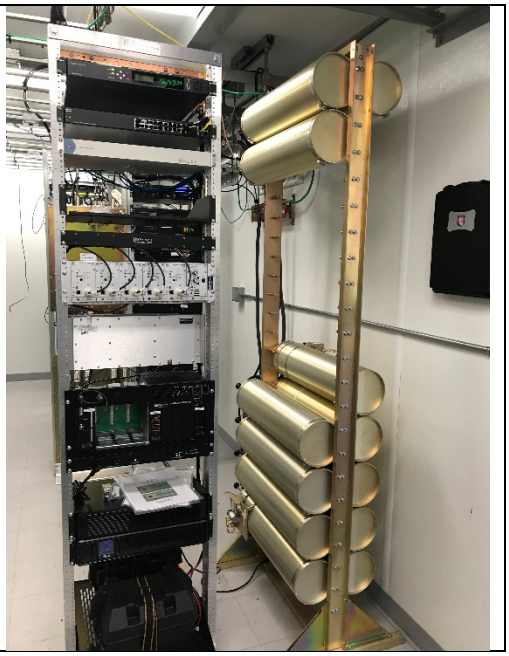
### 21.1.1 Cemetery Hill



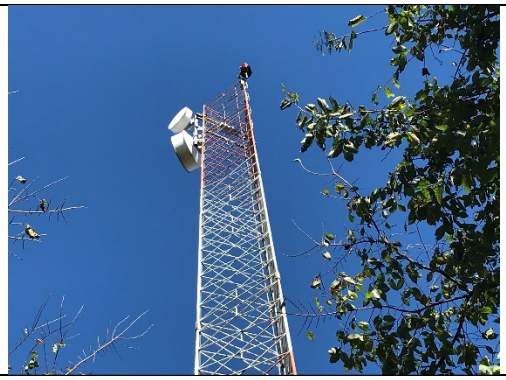


### 21.1.2 Ixonia Water Tower

### 21.1.3 Lake Mills Tower

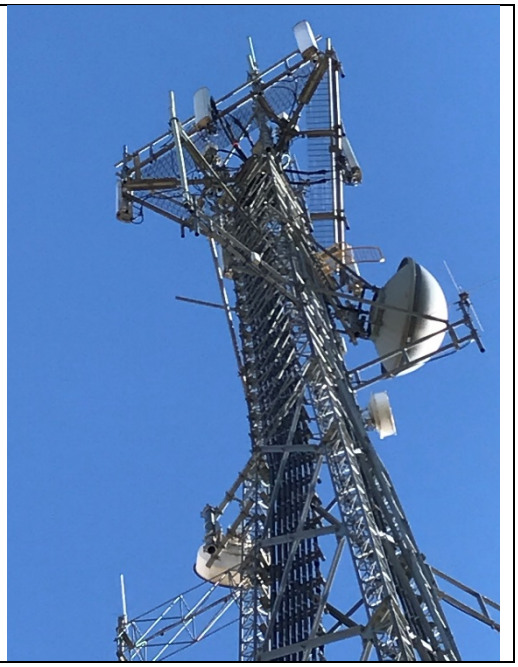


### 21.1.4 Sullivan Tower

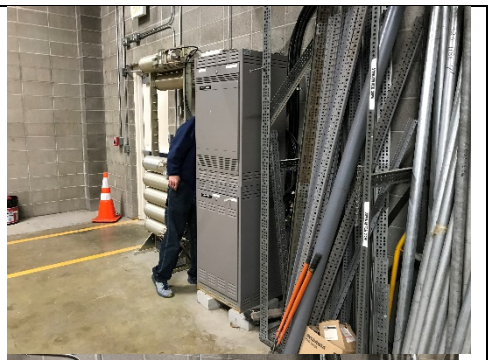


### 21.1.5 Waterloo Tower

### 21.1.6 Watertown Tower



### 21.1.7 Fort Atkinson Tower

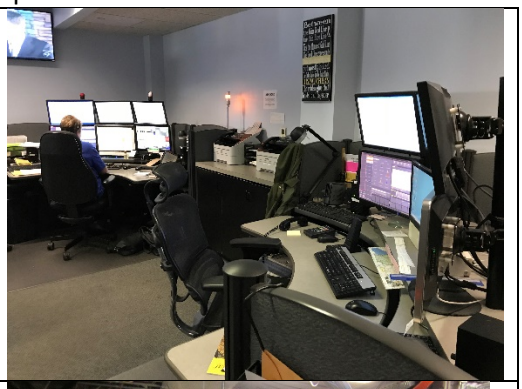


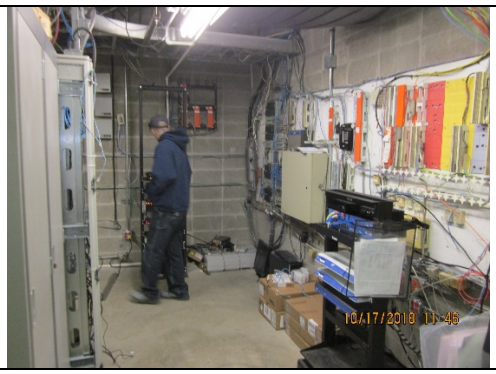
### 21.1.8 Johnson Creek Water Tower


### 21.1.9 Palmyra Tower

## 21.2 *Dispatch Center*

### 21.2.1 Jefferson County Dispatch and Equipment Room



## 22 APPENDIX 2: FCC Licenses

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# Federal Communications Commission
Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| KSB455 | 0005864061 |
| **Radio Service** PW - Public Safety Pool, Conventional | |
| **Regulatory Status** PMRS | |
| **Frequency Coordination Number** | |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 07-20-2013 | 07-20-2013 | 10-08-2023 | 07-20-2013 |

### STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Address:** 345 E OGDEN ST
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-36.0 N **Long (NAD83):** 088-48-05.0 W **ASR No.:** 1212670 **Ground Elev:** 271.0

**Loc. 2** **Address:** N3971 HWY K
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 42-59-10.0 N **Long (NAD83):** 088-48-36.4 W **ASR No.:** **Ground Elev:** 259.0

**Loc. 3** **Address:** 411 S CENTER ST
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-09.0 N **Long (NAD83):** 088-48-24.4 W **ASR No.:** N/A **Ground Elev:** 244.0

**Loc. 4** **Area of Operation**
Land Mobile Control Station meeting the 6.1 Meter Rule: WI

**Loc. 5** **Area of Operation**
Operating within a 32.0 km radius around fixed location 1

**Loc. 6** **Area of Operation**
Operating within a 32.0 km radius around fixed location 1

**Antennas**

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** KSB455 **File Number:** 0005864061 **Print Date:** 07-20-2013

| Loc. No. | Ant. No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000155.37000000 | FB | 1 | | 11K2F3E | 110.000 | 79.000 | 29.0 | 44.0 | |
| 1 | 2 | 000154.86000000 | FB2 | 1 | | 11K2F3E | 110.000 | 178.000 | 52.0 | 67.0 | |
| 1 | 2 | 000155.77500000 | FB2 | 1 | | 11K2F3E | 100.000 | 200.000 | 52.0 | 67.0 | 04-24-2004 |
| 1 | 2 | 000151.28000000 | FB2 | 1 | | 11K2F3E | 110.000 | 200.000 | 52.0 | 67.0 | 01-09-2008 |
| 1 | 2 | 000155.47500000 | FB | 1 | | 11K2F3E | 110.000 | 200.000 | 52.0 | 67.0 | 01-09-2008 |
| 2 | 1 | 000155.77500000 | FB2 | 1 | | 11K2F3E | 110.000 | 200.000 | 44.0 | 47.0 | |
| 3 | 1 | 000155.55000000 | FB2 | 1 | | 11K2F3E | 50.000 | 60.000 | 15.0 | 3.0 | |
| 4 | 1 | 000158.91000000 | FX1 | 1 | | 11K2F3E | 20.000 | | | | |
| 4 | 1 | 000158.79000000 | FX1 | 5 | | 11K2F3E | 40.000 | 40.000 | | | |
| 5 | 1 | 000154.86000000 | MO | 100 | | 11K2F3E | 110.000 | | | | |
| 5 | 1 | 000155.37000000 | MO | 100 | | 11K2F3E | 110.000 | | | | |
| 5 | 1 | 000155.47500000 | MO | 100 | | 11K2F3E | 110.000 | | | | |
| 5 | 1 | 000158.91000000 | MO | 100 | | 11K2F3E | 110.000 | | | | |
| 5 | 1 | 000159.21000000 | MO | 100 | | 11K2F3E | 40.000 | | | | |
| 5 | 1 | 000155.77500000 | MO | 250 | | 11K2F3E | 110.000 | 110.000 | | | 04-24-2004 |
| 5 | 1 | 000158.79000000 | MO | 250 | | 11K2F3E | 110.000 | 110.000 | | | 04-24-2004 |
| 6 | 1 | 000150.80500000 | MO | 25 | | 11K2F3E | 2.000 | 2.000 | | | 05-25-2005 |
| 6 | 1 | 000150.80500000 | MO3 | 25 | | 11K2F3E | 2.000 | 2.000 | | | 05-25-2005 |

**Control Points**

**Control Pt. No.** 1
**Address:** 411 S CENTER AVE
**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7346

**Associated Call Signs**

WNPG812

**Waivers/Conditions:**

NONE

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August 2007

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# Federal Communications Commission
Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| WNGN313 | 0006099917 |
| **Radio Service** | |
| PW - Public Safety Pool, Conventional | |
| **Regulatory Status** | |
| PMRS | |
| **Frequency Coordination Number** | |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 01-15-2014 | 01-15-2014 | 04-13-2024 | 01-15-2014 |

### STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Address:** CEMETERY HILL
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-36.0 N **Long (NAD83):** 088-48-05.4 W **ASR No.:** **Ground Elev:** 271.0

**Loc. 2** **Address:** 100 EDWARD ST
**City:** FORT ATKINSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 42-55-46.0 N **Long (NAD83):** 088-50-00.4 W **ASR No.:** N/A **Ground Elev:** 240.0

**Loc. 3** **Address:** 128 W MILWAUKEE ST
**City:** FORT ATKINSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 42-55-37.0 N **Long (NAD83):** 088-50-18.4 W **ASR No.:** N/A **Ground Elev:** 240.0

**Loc. 4** **Address:** N 8320 N ST
**City:** IXONIA **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-08-40.0 N **Long (NAD83):** 088-36-02.4 W **ASR No.:** N/A **Ground Elev:** 265.0

**Loc. 5** **Address:** 900 INDUSTRIAL LN
**City:** WATERLOO **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-11-14.0 N **Long (NAD83):** 088-58-52.4 W **ASR No.:** N/A **Ground Elev:** 247.0

**Loc. 6** **Address:** 126 N FIRST ST
**City:** PALMYRA **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 42-52-47.0 N **Long (NAD83):** 088-35-12.4 W **ASR No.:** **Ground Elev:** 259.0

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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**August 2007**

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**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** WNGN313 **File Number:** 0006099917 **Print Date:** 01-15-2014

**Loc. 7** **Area of Operation**
Operating within a 40.0 km radius around fixed location 1

**Antennas**

| Loc. No. | Ant. No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 100.000 | 224.000 | 46.0 | 61.0 | |
| 2 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 40.000 | 32.000 | 18.0 | 2.0 | |
| 3 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 40.000 | 30.000 | 24.0 | 8.0 | |
| 4 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 40.000 | 44.000 | 18.0 | 16.0 | |
| 5 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 40.000 | 40.000 | 15.0 | 1.0 | |
| 6 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 40.000 | 35.000 | 18.0 | 10.0 | |
| 7 | 1 | 000154.05500000 | MO | 60 | | 11K2F3E | 100.000 | | | | |

**Control Points**

**Control Pt. No.** 1
**Address:** 411 S CENTER AVE
**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7346

**Waivers/Conditions:**
NONE

**FCC 601-ULSHS1**
**August 2007**

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# Federal Communications Commission
## Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| WQUW623 | 0008099429 |

**Radio Service**
PW - Public Safety Pool, Conventional

**Regulatory Status**
PMRS

**Frequency Coordination Number**
25PWAP38024847

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 10-31-2014 | 02-21-2018 | 10-31-2024 | 02-22-2018 |

## STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Address:** W1636 COUNTY HWY 18
**City:** SULLIVAN **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-53.3 N **Long (NAD83):** 088-36-52.6 W **ASR No.:** **Ground Elev:** 278.0

**Loc. 2** **Address:** I94 MP 261 EAST OF LAKE MILLS
**City:** LAKE MILLS **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-05-06.9 N **Long (NAD83):** 088-52-23.2 W **ASR No.:** **Ground Elev:** 256.0

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000154.05500000 | FB | 1 | 300 | 11K2F3E | 110.000 | 91.400 | 42.6 | 60.9 | 10-31-2015 |
| 2 | 1 | 000154.05500000 | FB | 1 | 300 | 11K2F3E | 110.000 | 119.780 | 18.0 | 38.0 | 02-21-2019 |

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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# Federal Communications Commission
Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| WQPP691 | 0005583056 |
| **Radio Service** PW - Public Safety Pool, Conventional | |
| **Regulatory Status** PMRS | |
| **Frequency Coordination Number** | |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 07-16-2012 | 03-14-2013 | 07-16-2022 | 03-15-2013 |

### STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Address:** CEMETARY HILL
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-36.0 N **Long (NAD83):** 088-48-05.0 W **ASR No.:** 1212670 **Ground Elev:** 271.0

**Loc. 2** **Address:** N303 TOWER ROAD
**City:** PALMYRA **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 42-51-05.1 N **Long (NAD83):** 088-34-06.6 W **ASR No.:** **Ground Elev:** 308.0

**Loc. 3** **Address:** 733 HERRON CT
**City:** WATERLOO **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-11-27.2 N **Long (NAD83):** 088-59-51.9 W **ASR No.:** **Ground Elev:** 283.0

**Loc. 4** **Address:** ON HWY 26, .75 M EAST OF ROCK RIVER
**City:** FORT ATKINSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 42-54-38.6 N **Long (NAD83):** 088-51-04.8 W **ASR No.:** 1050098 **Ground Elev:** 243.2

**Loc. 5** **Address:** N8233 COUNTY ROAD F
**City:** IXONIA **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-08-30.4 N **Long (NAD83):** 088-35-35.9 W **ASR No.:** **Ground Elev:** 264.0

**Loc. 6** **Address:** 525 HARTWIG BLVD
**City:** JOHNSON CREEK **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-04-58.2 N **Long (NAD83):** 088-45-58.4 W **ASR No.:** **Ground Elev:** 263.0

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** WQPP691 **File Number:** 0005583056 **Print Date:** 03-15-2013

**Loc. 7** **Area of Operation**
Operating within a 40.0 km radius around fixed location 1

**Antennas**

| Loc. No. | Ant. No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000154.05500000 | FB2 | 1 | | 11K2F3E | 110.000 | 143.200 | 51.8 | 67.0 | 07-16-2013 |
| 2 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 110.000 | 153.500 | 36.6 | 76.0 | 07-16-2013 |
| 3 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 110.000 | 87.000 | 18.3 | 39.0 | 07-16-2013 |
| 4 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 110.000 | 149.700 | 59.4 | 47.0 | 07-16-2013 |
| 5 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 110.000 | 76.900 | 51.8 | 48.0 | 07-16-2013 |
| 6 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 110.000 | 76.900 | 51.8 | 57.0 | 07-16-2013 |
| 7 | 1 | 000159.15000000 | MO | 10 | | 11K2F3E | 50.000 | 49.000 | | | 07-16-2013 |

**Control Points**

**Control Pt. No. 1**
**Address:** 411 S CENTER AVE
**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7346

**Waivers/Conditions:**
NONE

**FCC 601-ULSHS1**
**August 2007**

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# Federal Communications Commission
## Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| WQB793 | 0006622423 |

**Radio Service**
PW - Public Safety Pool, Conventional

**Regulatory Status**
PMRS

**Frequency Coordination Number**
25PWAP35024113

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 01-03-2014 | 02-19-2015 | 03-31-2024 | 02-20-2015 |

## STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Address:** CEMETARY HILL
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-36.0 N **Long (NAD83):** 088-48-05.0 W **ASR No.:** 1212670 **Ground Elev:** 271.0

**Loc. 2** **Area of operation**
Land Mobile Control Station meeting the 6.1 Meter Rule: WI

**Loc. 3** **Area of operation**
Operating within a 32.0 km radius around fixed location 1

**Loc. 4** **Address:** 106 JONES ST.
**City:** WATERTOWN **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-11-45.9 N **Long (NAD83):** 088-43-25.7 W **ASR No.:** 1220585 **Ground Elev:** 250.6

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000154.37000000 | FB2 | 1 | | 11K2F3E | 100.000 | 224.000 | 46.0 | 60.0 | |
| 1 | 1 | 000154.26500000 | FB | 1 | | 11K2F3E | 100.000 | 224.000 | 46.0 | 60.0 | 01-09-2008 |

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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August 2007

Page 1 of 2

Licensee Name: JEFFERSON, COUNTY OF

Call Sign: WQB793 File Number: 0006622423 Print Date: 02-20-2015

Antennas

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 000153.77000000 | FXI | 15 | | 11K2F3E | 40.000 | 40.000 | | | |
| 3 | 1 | 000153.77000000 | MO | 250 | | 11K2F3E | 100.000 | 100.000 | | | |
| 3 | 1 | 000153.83000000 | MO | 250 | | 11K2F3E | 25.000 | 25.000 | | | |
| 3 | 1 | 000154.23500000 | MO | 250 | | 11K2F3E | 100.000 | 100.000 | | | |
| 3 | 1 | 000154.29500000 | MO | 250 | | 11K2F3E | 100.000 | 100.000 | | | |
| 3 | 1 | 000154.37000000 | MO | 250 | | 11K2F3E | 100.000 | 100.000 | | | |
| 3 | 1 | 000154.41500000 | MO | 250 | | 11K2F3E | 100.000 | 100.000 | | | |
| 4 | 1 | 000154.05500000 | FB | 1 | | 11K2F3E | 110.000 | 115.000 | 36.5 | 29.7 | 02-19-2016 |
| 4 | 1 | 000154.37000000 | FB2 | 1 | | 11K2F3E | 110.000 | 115.000 | 36.5 | 29.7 | 02-19-2016 |

**Control Points**

**Control Pt. No. 1**

**Address:** 411 S CENTER ST

**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7310

**Associated Call Signs**

WNGN313

**Waivers/Conditions:**

NONE



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August 2007

# Federal Communications Commission
## Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| KWH778 | 0006955160 |

**Radio Service**
PW - Public Safety Pool, Conventional

**Regulatory Status**
PMRS

**Frequency Coordination Number**

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 09-23-2015 | 09-23-2015 | 12-01-2025 | 09-23-2015 |

### STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Address:** 411 S CENTER ST
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-07.0 N **Long (NAD83):** 088-48-23.4 W **ASR No.:** N/A **Ground Elev:** 244.0

**Loc. 2** **Address:** CEMETARY HILL
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-00-36.0 N **Long (NAD83):** 088-48-05.4 W **ASR No.:** **Ground Elev:** 271.0

**Loc. 3** **Area of operation**
Operating within a 40.0 km radius around fixed location 1

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000155.14500000 | FB | 1 | | 11K2F3E | 30.000 | 50.000 | 8.0 | -5.0 | |
| 1 | 1 | 000453.82500000 | FB2 | 1 | | 11K2F3E | 20.000 | 13.000 | 8.0 | -5.0 | |
| 2 | 1 | 000045.20000000 | FB | 1 | | 20K0F3E | 100.000 | 68.000 | 37.0 | 51.0 | |

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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August 2007

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**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** KWH778 **File Number:** 0006955160 **Print Date:** 09-23-2015

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 000045.28000000 | FB | 1 | | 20K0F3E | 100.000 | 68.000 | 37.0 | 51.0 | |
| 3 | 1 | 000045.20000000 | MO | 3 | | 20K0F3E | 100.000 | | | | |
| 3 | 1 | 000045.28000000 | MO | 33 | | 20K0F3E | 100.000 | | | | |
| 3 | 1 | 000155.14500000 | MO | 30 | | 11K2F3E | 100.000 | | | | |
| 3 | 1 | 000453.82500000 | MO | 10 | | 11K2F3E | 30.000 | | | | |
| 3 | 1 | 000458.82500000 | MO | 10 | | 11K2F3E | 30.000 | | | | |

**Control Points**

**Control Pt. No. 1**

**Address:** 411 S CENTER AVE

**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7346

**Associated Call Signs**

**Waivers/Conditions:**

NONE

# Federal Communications Commission

Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION



LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR, TODD LINDERT
JEFFERSON, COUNTY OF
411 SOUTH CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQCW818 | |
| **File Number** | |
| 0006714770 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 03-19-2015 | 03-19-2015 | 06-14-2025 | 03-19-2015 |

### LOCATION

**Fixed Location Address or Area of Operation:**
Cemetary Hill
**City:** Jefferson **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | 1212670 |
| 002 | FT ATKINSON | 42-54-38.6 N | 088-51-04.8 W | 243.2 | |
| 003 | PALMYRA | 42-51-05.0 N | 088-34-06.0 W | 308.2 | |
| 004 | WATERLOO | 43-11-24.0 N | 088-59-52.0 W | 277.0 | |
| 005 | WATERTOWN | 43-11-45.9 N | 088-43-25.7 W | 250.6 | |
| 006 | SHERIFF | 43-00-09.0 N | 088-48-24.4 W | 244.0 | |
| 007 | JOHNSON CK | 43-04-58.3 N | 088-45-58.2 W | 262.0 | |
| 008 | Ixonia Water Twr | 43-08-30.0 N | 088-35-35.0 W | 264.0 | |
| 009 | SULLIVAN TWR | 43-00-53.3 N | 088-36-53.1 W | 284.5 | |

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** WQCW818 **File Number:** 0006714770 **Print Date:** 03-19-2015

FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) | Beam (deg) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Reflector Ht(m)xWd(m) | | | | | |
| 933.175 | 0.00015 | 200KD7W | 47.200 | 12-14-2006 | 001 | 1 | 001 | 39.6 | 18.2 | 12.0 | V | 200.3 | 002 | WQCW819 |
| 933.575 | 0.00015 | 200KD7W | 47.200 | 12-14-2006 | 002 | 1 | 001 | 29.0 | 18.2 | 12.0 | V | 132.7 | 003 | WQCX645 |
| 954.75 | 0.00015 | 200KD7W | 41.200 | 12-14-2006 | 003 | 1 | 001 | 45.7 | 18.2 | 12.0 | V | 321.4 | 004 | WQCS370 |
| 955.55 | 0.00015 | 200KD7W | 37.200 | 12-14-2006 | 004 | 1 | 001 | 42.7 | 18.2 | 12.0 | V | 17.0 | 005 | WQCS368 |
| 954.35 | 0.00015 | 200KD7W | 45.200 | 02-16-2009 | 005 | 1 | 001 | 27.4 | 18.2 | 12.0 | V | 207.8 | 006 | |
| 933.775 | 0.00015 | 200KD7W | 47.200 | 06-07-2014 | 006 | 1 | 001 | 41.1 | 18.2 | 12.0 | V | 19.5 | 007 | |
| 11245.0 | 0.00070 | 30M0D7W | 63.600 | 06-07-2014 | 007 | 1 | 001 | 33.5 | 37.6 | 2.2 | V | 49.2 | 008 | |
| 11365.0 | 0.00070 | 30M0W7D | 64.500 | 04-22-2016 | 008 | 1 | 001 | 39.6 | 38.5 | 2.1 | V | 87.9 | 009 | |

**Waivers/Conditions:**

NONE

# Federal Communications Commission

Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQCW819 | |
| **File Number** | |
| 0006714786 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 03-19-2015 | 03-19-2015 | 06-14-2025 | 03-19-2015 |

### LOCATION

**Fixed Location Address or Area of Operation:**
ON HWY 26, .75 M EAST OF ROCK RIVER
**City:** FORT ATKINSON **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | FT ATKINSON | 42-54-38.6 N | 088-51-04.8 W | 243.2 | 1050098 |
| 002 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) Reflector Ht(m)xWd(m) | Beam (deg) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 942.175 | 0.00015 | 200KD7W | 47.200 | 12-14-2006 | 001 | 1 | 001 | 45.7 | 18.2 | 12.0 | V | 20.3 | 002 | WQCW818 |

**Waivers/Conditions:**

NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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# Federal Communications Commission

Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR, TODD LINDERT
JEFFERSON, COUNTY OF
411 SOUTH CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQUV258 | |
| **File Number** | |
| 0007016482 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 10-22-2014 | 11-27-2015 | 10-22-2024 | 11-28-2015 |

### LOCATION

**Fixed Location Address or Area of Operation:**
Off Rt 18
**City:** Sullivan **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | SULLIVAN TWR | 43-00-53.3 N | 088-36-53.1 W | 284.5 | |
| 002 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |
| 003 | WATERTOWN | 43-11-45.9 N | 088-43-25.7 W | 250.6 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) | Beam (deg) | Reflector Ht(m)xWd(m) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10875.0 | 0.00070 | 30M0W7D | 64.500 | 04-22-2016 | 001 | 1 | 001 | 36.6 | 38.5 | 2.1 | | V | 268.1 | 002 | WQCW818 |
| 11075.0 | 0.00070 | 30M0D7D | 69.000 | 05-27-2017 | 002 | 1 | 001 | 36.6 | 41.0 | 1.7 | | V | 336.2 | 003 | WQCS368 |

**Waivers/Conditions:**

NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.



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August 2007

# Federal Communications Commission

Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQCX645 | |
| **File Number** | |
| 0006719971 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 03-24-2015 | 03-24-2015 | 06-20-2025 | 03-24-2015 |

### LOCATION

**Fixed Location Address or Area of Operation:**
N 303 Tower Road
**City:** PALMYRA **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | PALMYRA | 42-51-05.0 N | 088-34-06.0 W | 308.2 | |
| 002 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) Reflector Ht(m)xWd(m) | Beam (deg) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 942.575 | 0.00015 | 200KD7W | 47.200 | 12-20-2006 | 001 | 1 | 001 | 30.5 | 18.2 | 12.0 | V | 312.9 | 002 | WQCW818 |

**Waivers/Conditions:**

NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.



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August 2007

# Federal Communications Commission

Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQCS368 | |
| **File Number** | |
| 0007016483 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 02-13-2015 | 11-27-2015 | 05-13-2025 | 11-28-2015 |

### LOCATION

**Fixed Location Address or Area of Operation:**
106 Jones St.
**City:** Watertown **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | WATERTOWN | 43-11-45.9 N | 088-43-25.7 W | 250.6 | 1220585 |
| 002 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |
| 003 | SULLIVAN TWR | 43-00-53.3 N | 088-36-53.1 W | 284.5 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) | Beam (deg) Reflector Ht(m)xWd(m) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 959.15 | 0.00015 | 200KD7W | 37.200 | 11-13-2006 | 001 | 1 | 001 | 36.6 | 18.2 | 12.0 | V | 197.0 | 002 | WQCW818 |
| 11565.0 | 0.00070 | 30M0D7D | 66.500 | 05-27-2017 | 002 | 1 | 001 | 32.0 | 38.5 | 2.1 | V | 156.2 | 003 | WQUV258 |

**Waivers/Conditions:**

NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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August 2007

# Federal Communications Commission
Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQCS370 | |
| **File Number** | |
| 0006669004 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 02-13-2015 | 02-13-2015 | 05-13-2025 | 02-13-2015 |

### LOCATION

**Fixed Location Address or Area of Operation:**
NORTH MOST CORNER OF INDIAN HILLS DRIVE
**City:** Waterloo **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | WATERLOO | 43-11-24.0 N | 088-59-52.0 W | 277.0 | |
| 002 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) Reflector Ht(m)xWd(m) | Beam (deg) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 958.35 | 0.00015 | 200KD7W | 47.200 | 11-13-2006 | 001 | 1 | 001 | 12.2 | 18.2 | 12.0 | V | 141.3 | 002 | WQCW818 |

**Waivers/Conditions:**
NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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August 2007

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# Federal Communications Commission

**Public Safety and Homeland Security Bureau**

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR, TODD LINDERT
JEFFERSON, COUNTY OF
411 SOUTH CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQQE757 | |
| **File Number** | |
| 0005309390 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 11-20-2012 | 11-20-2012 | 11-20-2022 | 11-21-2012 |

### LOCATION

**Fixed Location Address or Area of Operation:**
525 Hartwig Blvd
**City:** Johnson Creek **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | JOHNSON CK | 43-04-58.3 N | 088-45-58.2 W | 262.0 | |
| 002 | MAIN TOWER | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) Reflector Ht(m)xWd(m) | Beam (deg) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 942.775 | 0.00015 | 200KD7W | 47.200 | 05-20-2014 | 001 | 1 | 001 | 42.7 | 18.2 | 12.0 | V | 199.5 | 002 | WQCW818 |

**Waivers/Conditions:**
NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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# Federal Communications Commission
Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COMMUNICATIONS SPVR, TODD LINDERT
JEFFERSON, COUNTY OF
411 SOUTH CENTER AVE
JEFFERSON, WI 53549

| Call Sign | |
|---|---|
| WQPY247 | |
| **File Number** | |
| 0005330888 | |
| **Radio Service** | |
| MW - Microwave Public Safety Pool | |
| **SMSA** | **Station Class** |
| | FXO |

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 09-17-2012 | 09-17-2012 | 09-17-2022 | 09-18-2012 |

### LOCATION

**Fixed Location Address or Area of Operation:**
N8233 County Road F NW of intersection of Cty F and Railroad tracks
**City:** Ixonia **County:** JEFFERSON **State:** WI

| Loc No. | Location Name | Latitude | Longitude | Elevation | Antenna Structure Registration No. |
|---|---|---|---|---|---|
| 001 | Ixonia Water Twr | 43-08-30.0 N | 088-35-35.0 W | 264.0 | |
| 002 | Jefferson Main Twr | 43-00-36.0 N | 088-48-05.0 W | 271.0 | |

### FREQUENCY PATHS

| Frequency (MHz) | Tol (%) | Emission Desig | EIRP (dBm) | Constr Date | Path No | Seg | Emit Loc No | Ant Hgt (m) | Gain (dBi) Reflector Ht(m)xWd(m) | Beam (deg) | POL | AZIM (deg) | Rec Loc No | Rec Call Sign |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10755.0 | 0.00070 | 30M0D7W | 63.600 | 03-17-2014 | 001 | 1 | 001 | 38.1 | 37.6 | 2.2 | V | 229.3 | 002 | |

**Waivers/Conditions:**
NONE

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

FCC 601-ULSHS3
August 2007

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# Federal Communications Commission
## Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: TODD LINDERT
JEFFERSON, COUNTY OF
411 S CENTER AVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| WQYF550 | 0007436891 |

**Radio Service**
SG - Conventional Public Safety 700 MHz

**Regulatory Status**
PMRS

**Frequency Coordination Number**

**FCC Registration Number (FRN):** 0002683225

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 09-12-2016 | 09-12-2016 | 09-12-2026 | 09-13-2016 |

## STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Area of operation**
Operating Nationwide including Hawaii, Alaska, and US Territories.

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000769.05625000 | MOI | 50 | | 11K2F3E<br>8K10F1E | 3.000 | 2.000 | | | |
| 1 | 1 | 000769.06875000 | MOI | 50 | | 11K2F3E<br>8K10F1E | 3.000 | 2.000 | | | |
| 1 | 1 | 000774.99375000 | MOI | 50 | | 11K2F3E<br>8K10F1E | 3.000 | 2.000 | | | |
| 1 | 1 | 000799.05625000 | MOI | 50 | | 11K2F3E<br>8K10F1E | 3.000 | 2.000 | | | |

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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August 2007

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**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** WQYF550 **File Number:** 0007436891 **Print Date:** 09-13-2016

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000804.99375000 | MO1 | 50 | | 11K2F3E<br>8K10F1E | 3.000 | 2.000 | | | |

**Control Points**

**Control Pt. No. 1**

**Address:** 411 S CENTER AVE

**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7311

**Associated Call Signs**

<NA>

**Waivers/Conditions:**

Operation in the 769 - 775 and 799 - 805 MHz frequency band at locations within 140 km of the border with Canada and within 110 km of the border with Mexico are subject to agreements between the government of the United States and the governments ofCanada and Mexico.



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August 2007

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# Federal Communications Commission
## Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: ERIK COONEN
JEFFERSON, COUNTY OF
1425 S WISCONSIN DRIVE
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| KSB390 | 0007054349 |

**Radio Service**
PW - Public Safety Pool, Conventional

**Regulatory Status**
PMRS

**Frequency Coordination Number**

**FCC Registration Number (FRN):** 0007808322

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 09-01-2012 | 12-08-2015 | 11-05-2022 | 12-08-2015 |

## STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Area of operation**
Other:20 MIRA JEFFERSON WI

**Loc. 2** **Address:** WATER TOWER HILL
**City:** JEFFERSON **County:** JEFFERSON **State:** WI
**Lat (NAD83):** 43-02-45.0 N **Long (NAD83):** 088-48-09.4 W **ASR No.:** **Ground Elev:** 271.0

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000156.24000000 | MO | 90 | | 11K2F3E | 80.000 | | | | |
| 1 | 1 | 000158.98500000 | MO | 90 | | 11K2F3E | 80.000 | | | | |
| 2 | 1 | 000156.24000000 | FB2 | 1 | | 11K2F3E | 100.000 | | 50.0 | | |

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

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**FCC 601-ULSHS1**
**August 2007**

**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** KSB390 **File Number:** 0007054349 **Print Date:** 12-08-2015

**Control Points**
**Control Pt. No. 1**
**Address:** COUNTY SHERIFF DEPT HWY 26 S
**City:** JEFFERSON **County:** **State:** WI **Telephone Number:**

**Associated Call Signs**

<NA>

**Waivers/Conditions:**
NONE

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# Federal Communications Commission
## Public Safety and Homeland Security Bureau

## RADIO STATION AUTHORIZATION

LICENSEE: JEFFERSON, COUNTY OF

ATTN: COUNTY SURVEYOR
JEFFERSON, COUNTY OF
311 S CENTER AVE, COURTHOUSE, RM 103
JEFFERSON, WI 53549

| Call Sign | File Number |
|---|---|
| WQFR875 | 0007458819 |

**Radio Service**
PW - Public Safety Pool, Conventional

**Regulatory Status**
PMRS

**Frequency Coordination Number**

**FCC Registration Number (FRN):** 0015423098

| Grant Date | Effective Date | Expiration Date | Print Date |
|---|---|---|---|
| 10-05-2016 | 10-05-2016 | 09-19-2026 | 10-06-2016 |

## STATION TECHNICAL SPECIFICATIONS

**Fixed Location Address or Mobile Area of Operation**

**Loc. 1** **Area of operation**
Countywide: JEFFERSON, WI

**Antennas**

| Loc No. | Ant No. | Frequencies (MHz) | Sta. Cls. | No. Units | No. Pagers | Emission Designator | Output Power (watts) | ERP (watts) | Ant. Ht./Tp meters | Ant. AAT meters | Construct Deadline Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 000453.75000000 | FBT | 5 | | 11K6F1D | 35.000 | 35.000 | | | |

**Control Points**

**Control Pt. No. 1**

**Address:** 311 S CENTER AVE, COURTHOUSE

**City:** JEFFERSON **County:** JEFFERSON **State:** WI **Telephone Number:** (920)674-7147

**Associated Call Signs**

<NA>

**Conditions:**
Pursuant to §309(h) of the Communications Act of 1934, as amended, 47 U.S.C. §309(h), this license is subject to the following conditions: This license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized herein. Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of the Communications Act of 1934, as amended. See 47 U.S.C. § 310(d). This license is subject in terms to the right of use or control conferred by §706 of the Communications Act of 1934, as amended. See 47 U.S.C. §606.

**FCC 601-ULSHS1**
**August 2007**

Page 1 of 2

**Licensee Name:** JEFFERSON, COUNTY OF

**Call Sign:** WQFR875 **File Number:** 0007458819 **Print Date:** 10-06-2016

**Waivers/Conditions:**

Antenna structures for land, base and fixed stations authorized for operation at temporary unspecified locations may be erected without specific prior approval of the Commission where such antenna structures do not exceed a height of 60.96 meters (200 feet) above ground level; provided that the overall height of such antennas more than 6.10 meters (20 feet) above ground, including their supporting structures (whether natural formation or man-made), do not exceed any of the slope ratios set forth in Section 17.7(b). Any antenna to be erected in excess of the foregoing limitations requires prior Commission approval. Licensees seeking such approval should file application for modification of license. In addition, notification to the Federal Aviation Administration is required whenever the antenna will exceed 60.96 meters (200 feet) above the ground and whenever notification is otherwise required by Section 17.7 of the Commission's Rules. Such notification should be given by filing FAA Form 7460-1, Notice of Proposed Construction or Alteration, in duplicate, with the nearest office of the Federal Aviation Administration, which form is available from that office.

Beginning January 1, 2013, this station must operate on channels with a bandwidth of 12.5 kHz or less, or with equivalent efficiency, regardless of the emission bandwidths set forth on this license. See Section 90.209(b)(5) of the Commission's Rules. Note, however, that the narrowbanding requirement does not apply to specific channels designated in Rule 90.20 or 90.35 for paging only.

# 23 APPENDIX 3: Mutual Aid, Adjacent County Channels

| Adjacent County, Regional, State Frequencies | | | | | | |
|---|---|---|---|---|---|---|
| | | | | R | Repeater (FB2) | |
| | | | | B | Base Station (FB) | |
| | | | | M | Mobile/Portable (M) | |
| | | | | * | Temporary Operatio | |
| | | | | | | |

| Name | Frequency (MHz) | | License | Type | Tone-DPL-NAC | |
|---|---|---|---|---|---|---|
| | Trasnmit | Receive | | | TX | RX |
| EMS Advanced Life Support (Local) | 155.4000 | 155.4000 | KH4762 | B/M | 88.5 | - |
| EMS VMED28 (Local) | 155.3400 | 155.3400 | KH4762 | B/M | 88.5 | - |
| FG BLACK / VFIRE24 | 154.2725 | 154.2725 | KO2099 | B/M | 94.8 | 94.8 |
| FG BLUE / VFIRE | 154.2950 | 154.2950 | KO2099 | B/M | 85.4 | 85.4 |
| FG GOLD | 153.8375 | 153.8375 | KO2099 | B/M | 91.5 | 91.5 |
| FG GRAY / VFIRE25 | 154.2875 | 154.2875 | KO2099 | B/M | 136.5 | 136.5 |
| FG RED | 153.8300 | 153.8300 | KO2099 | B/M | 69.3 | 69.3 |
| FG WHITE / VFIRE21 | 154.2800 | 154.2800 | KO2099 | B/M | 74.4 | 74.4 |
| IFERN | 154.2650 | 154.2650 | KO2099 | B/M | 210.7 | 210.7 |
| MARC1 | 151.2800 | 153.8450 | KSB455 | R | 136.5 | 136.5 |
| MARC2 | 152.2800 | 152.2800 | WNPG812 | M | 136.5 | 136.5 |
| POINT to POINT | 155.3700 | 155.3700 | KA6570 | M | 146.2 | 146.2 |
| Sheriff - Dane County | VHF P25 Phase II Trunked System | | | | | |
| Sheriff - Dodge County | 154.7850 | 159.0300 | KSB421 | R | 69.3 | 69.3 |
| Sheriff - Rock County | 159.0900 | 155.9850 | KSB423 | R | 540 | 540 |
| Sheriff - Walworth County | 857.4375 | 812.4375 | KNHY580 | R | 023 | 023 |
| Sheriff - Waukesha County | 851.0125 | 806.0125 | WQWN813 | R | ? | ? |
| Sheriff - Waukesha County | 852.5125 | 807.5125 | WQWN813 | R | ? | ? |
| Sheriff - Waukesha County | 800 MHz P25 Phase I Trunked System | | | | | |
| VCALL10 | 155.7525 | 155.7525 | KO2099 | B*/M | 156.7 | 156.7 |
| VLAW31 | 155.4750 | 155.475 | KA6570 | B/M | 156.7 | 156.7 |
| VTAC11 | 151.1375 | 151.1375 | KO2099 | R*/B*/M | 156.7 | 156.7 |
| VTAC12 | 154.4525 | 154.4525 | KO2099 | B*/M | 156.7 | 156.7 |
| VTAC13 / 1TAC22 | 158.7375 | 158.7375 | KO2099 | B*/M | 156.7 | 156.7 |
| VTAC14 / 1TAC23 | 159.4725 | 159.4725 | KO2099 | B*/M | 156.7 | 156.7 |
| Watertown Public Safety | 800 MHz P25 Phase I Trunked System | | | | | |
| Watertown Public Safety | 857.0125 | 812.0125 | WPFD727 | R | 156.7 | 156.7 |
| WEM Car to Car | 156.0000 | 156.0000 | KGT483 | M | 136.5 | 136.5 |

## 24 APPENDIX 4: Equipment Inventory

| JEFFERSON COUNTY UNIT INVENTORY | | | | |
|---|---|---|---|---|
| | | | | |
| | | | | |
| UNIT TYPE | Moblies | Portables | Pagers | Base Stations |
| TOTAL COUNT | 359 | 831 | 523 | 67 |
| Village of Cambridge DPW | 2 | 3 | 0 | 0 |
| Fort Atkinson Fire Department | 21 | 46 | 51 | 2 |
| Fort Atkinson Police Department | | | | |
| Helenville Fire & Rescue | 9 | 29 | 29 | 2 |
| Ixonia DPW | 3 | 0 | 0 | 0 |
| Ixonia Fire & Rescue | 31 | 52 | 68 | 2 |
| City of Jefferson Police Department, | 9 | 25 | 0 | 1 |
| City of Jefferson EMS | 12 | 35 | 65 | 1 |
| City of Jefferson Fire Department | 5 | 14 | 33 | 1 |
| Jefferson County Health Department | 2 | 0 | 0 | 0 |
| Jefferson County Highway | 80 | 10 | 0 | 1 |
| Jefferson County Sheriff | 66 | 124 | 0 | 20 |
| Johnson Creek EMS | | | | |
| Johnson Creek Police Department | 2 | 6 | 0 | 1 |
| Lake Mills EMS | 4 | 24 | 48 | 1 |
| Lake Mills Fire Department | 13 | 35 | 36 | 1 |
| Lake Mills Police Department | 5 | 16 | 0 | 1 |
| Palmyra Public Safety | 8 | 0 | 20 | 2 |
| Rome Fire Department | 6 | 29 | 36 | 1 |
| RYAN BROTHERS AMBULANCE | 22 | 10 | 23 | 1 |
| Sullivan Fire | 5 | 23 | 32 | 1 |
| UW-Whitewater Police Department | 5 | 211 | 0 | 1 |
| Waterloo Fire & Rescue | 16 | 40 | 46 | 2 |
| Waterloo DPW | 7 | 6 | 0 | 1 |
| Waterloo Police Department | 3 | 9 | 0 | 6 |
| Waterloo Utility | 0 | 7 | 0 | 1 |
| Watertown Fire Department | 12 | 43 | 36 | 1 |
| Whitewater Police Department | 13 | 37 | 0 | 16 |

# 25 APPENDIX 5: Best Practices

## 25.1 *Public Safety Communications*

Technology has changed the concept of communications for public safety communications officers just as it has changed nearly every occupation's day-to-day operations. The importance of readily available information cannot be understated as an objective of communications system designs. In addition to readily available information, officers also need a tool whereby they can communicate with whomever necessary in a secure means. Interoperability across jurisdictions and across the multiple disciplines that serve the public is an absolute requirement.

## 25.2 *Historical Technology Perspective*

Many jurisdictions began the upgrade to high band VHF FM radio technology in the 1980s as an upgrade from low band VHF. A single (or in some cases multiple) repeater(s) in support of an area offered a means of dispatch-to-car and car-to-car communications within the served area. Everyone shared the frequency in a specified area, and adjacent counties may have added neighboring counties' frequencies to their mobiles. Over time, additional repeaters were added for fire, EMS, and other needs to increase capacity and congestion. As mobile radios were replaced, these radios provided the capacity to be programmed with more frequencies, and thus, interoperability for a localized region was improved if everyone was on the same band. At the same time, some states or regions coordinated mutual aid frequencies that further enhanced interoperability at a critical incident scene. The fire departments also made dual use of their main frequency by the addition of paging to call off-duty firemen. In some cases, paging was also incorporated by other disciplines.

The problem with this expanded sharing and multiple frequencies then became how to monitor all the activities at the same time and then how to interconnect when the need occurred. The solution was that dispatchers were provided the means of interconnecting various frequencies with a "tie" or bridging device on the console, sometimes called a patch. The result allows everyone to talk to everyone if their channels are on the dispatch console. This solution has worked, and even today this capability is included in most dispatch consoles. Channel overloading has created traffic blockage, however.

## 25.3 *Radio Systems Technology Today*

As the need increased with more and more use of radio communications, adding more frequencies became the norm. Eventually, however, there were no more additional frequencies to use. Thus, the only solution at hand was to use narrower channels and thus to create new channels between the previous wider channels in the VHF and UHF bands. This process is known as narrowbanding. In some cases, narrowbanding requires an upgrade of equipment. Beyond VHF, the FCC started allocating in the higher bands of UHF and then later 800 MHz. The 700 MHz frequencies for land mobile radio use are already narrowband only. By the end of 2012, all UHF and VHF channels were required to be narrowband.

During the 1990s, several public safety jurisdictions turned to the newly allocated frequencies in the UHF and the 800 MHz band, though this move also required a change to a new technology, called trunking radio. Trunking radio allows multiple users to share a group of frequencies while establishing specific talk groups defined for each group of users. Police, fire, EMS, and Public Works could share the system infrastructure while each in effect had their own channel.

Overall, frequency loading increased with trunking, though more simultaneous paths of communications can occur as each channel is shared. Think of the checkout counter at a store, where lines form for each row, as compared to the airport, where one line of waiting customers waits for multiple representatives. The line at the airport may be longer, but it does move faster. This is the same with trunking. The users may not have to wait for their turn, as every frequency is available to every user. The hidden control frequency is used to steer the user to the unused frequency. The FCC does require enough users to make use of trunking before channels are approved.

On the positive side, interoperability was enhanced by trunking because these different disciplines could also share a common talk group where they could all communicate among each other when needed. On the negative side, however, the adjacent jurisdiction that was still on VHF could not easily communicate, thus reducing interoperability. Another positive outcome was that the higher frequency (UHF and 800 MHz) offered enhanced in-building coverage, due to the physics of radio frequency energy in these bands and the development of a frequency plan that allows for grouping of all send and receive frequencies. By this grouping of frequencies, in-building equipment can be placed to allow better coverage and to include cellular and paging.

High band VHF (150-159 MHz) offers some amount of expanded range as compared to UHF (450-512 MHz) and the newer 800 MHz bands. There was never a band plan for VHF, however, as the need was primarily to create non-interfering frequency pairs having the highest priority. This requirement was further enhanced when portables began to appear on the scene. The frequencies in use had to have enough physical separation that portables operating near one another did not interfere with each other. Radios in the 1970s and 1980s were not capable of operating with frequencies assigned with close adjacency.

Narrowbanding has created its own set of challenges, as to accomplish the use of less bandwidth means the radios must overcome the ever-increasing noise in the atmosphere, and with VHF this can mean a smaller communications range. To overcome the noise issue, digital modulation techniques were developed. APCO set out to establish a new digital standard. The outcome was Project 25, which will be discussed in further detail later in this section. For now, it should be noted that the use of P25 has shown that the combination of narrowband and this technology has extended the reach of what wideband used to offer.

### 25.4 *Conventional Radio Repeater Technology*

Land mobile radio (LMR) in its simplest form consists of two radios that make use of the same frequency and the same modulation scheme, located close enough to allow communications. In public safety, this is defined as simplex (or talk around) operation and tends to be used for close-in needs at the scene over a mile or two at best. As soon as more distance or more users are expected to share the system, communications infrastructure is needed. Namely, a repeater is generally installed at a central higher point in the geography of the area. This repeater listens to the mobile/portable units and retransmits what is heard to all other mobile units. With either scheme, the limitation is how many channels the radio has as compared to the number of talk paths and how to share these channels of communication.

Over time, repeaters were installed throughout a jurisdictional area, but this resulted in a new problem. Both the subscriber and dispatch had to know which repeater site to use, and across the coverage area, this created more interoperability issues.

Whether the system is simplex-based or a repeater system, the issue of too many users ultimately causes overload of the frequency. The answer has been to increase the number of frequencies, though the number of frequencies is limited, and hundreds of miles must separate the various users to avoid causing interference. Once users began running out of one band of frequencies, they moved to another and then another. Today, some public safety users operate in the VHF band, some in the UHF, and still others on 700/800 MHz. Due to the various bands in use, public safety organizations even within the same community may be unable to talk to each other.

### 25.5 *Simulcast Transmitters and Voting Receivers*

Simulcast has been around for a very long time, starting in the FM broadcast arena. This technology found its way into LMR thus allowing the coverage footprint of 2-way radio capability to be expanded. Early simulcast made use of the timing incorporated in the serial multiplexers and the ability to adjust the audio delays, phase and amplitude to match transmitted signals. Actually, wideband broadcast audio interfaces were used. GPS timing was used to match the transmitter RF signal phase. Today, everything has moved to the use of digital signaling and GPS timing over IP circuits.

Voting of the receiver audio from multiple receivers also has had it technology upgraded to IP. In the past the audio was sent to single location via microwave, a phone line or even a radio channel and the voter used noise gates to select the best signal to be used by the transmitter system. Today, the analog signal is converted to digital and a digital number of the signal quality is determined and sent with the digitized voice to a voter. At the voter, the signal having the best number is converted back to analog and transmitted.

In all situations today, the transport today is IP and the use of serial connectivity has pretty much disappeared as an option along with the old technology that used to support that means of connection.

### 25.6 *Trunking Radio Technology*

As the need increased for more channels than a simple repeater system could supply, a better way had to be found to make more spectrum efficiencies possible and to increase interoperability. This need has resulted in a technology defined as trunking, where subscribers to the system share the available channels via time division. Though with different technology, not everyone elects to make use of the system for various financial, political, and management reasons.

With trunking radio technology, many different types of users can share several frequencies simultaneously. To keep these users separate, talk groups are assigned, and a special control system manages the assigned frequencies or channels and what their priority of use is. Trunking, as compared to individual repeaters per user group, shows a marked improvement in spectrum efficiency while also enhancing interoperability. There is a cost to this improvement, however, in that the subscriber radios are more expensive than conventional repeater radios, and the system is much more complex to maintain and operate.

The idea of a talk group is foreign to many users of conventional repeater system technology, though once trained in its simple limitations and numerous benefits, users tend not to want to go back to the simpler life of simplex and repeaters. From the user perspective, a channel selector is used to obtain access to a talk group, just as in the past one would select a frequency to use. Once the talk group is selected, pressing the PTT button sends a request to

use, and the sender must wait 500 mS for a response to begin talking. The 500 mS is the time for the control system to connect all talk group users to the same group and allow them to hear the sender's statements.

The real power of trunked radio is the fact that all users of the system can become part of a talk group if needed and that priority messages can be sent to all system users quickly and easily. APCO Project 25 is one specialized use of trunking technology that goes to a higher level of interoperability than with the old Project 16 capability of the 1979 vintage of trunking.

VHF trunking has its own unique issues in that a frequency plan was never really developed that enables multiple frequencies to be used for trunking, as was the case for UHF and 800 MHz. With the move to narrowband assignments and the states of Wisconsin, Wyoming, and South Dakota using VHF trunking, interoperability means the use of radios that also offer trunking.

With the advent of public safety trunking operating in the VHF, UHF, 700 MHz, and 800 MHz bands, special devices called Inter-Sub-System Interface (ISSI) will allow users of these systems to bridge their system communications across operational borders and bands of operation.

## 25.7 *Fire Paging and EMS Paging*

As stated earlier, paging of part-time firefighters and EMS in most parts of the country has been and remains a utilization of the main fire/EMS repeater or base station system, as commercial paging focuses on offering coverage only in inhabited areas. With the FCC's plan to require narrowband deployment of radio systems using the VHF, UHF, and 800 MHz frequencies, this results in a problem. In addition, the paging industry is somewhat being replaced by cell phones and two-way paging/messaging devices. Paging as an industry is suffering a lowered demand. As a result, there is a lack of pager equipment availability, as the various manufacturers decide to drop their product lines. As also stated, coverage continues to be an issue in rural areas.

The solution may be to equip all part-time staff with two-way radios that have paging alert capability or to utilize an emergency notification system capable of sending short messages to multiple devices such as an office telephone, a cellular phone, an e-mail address, etc. when the need arises. One way or another, paging must be addressed as an issue. The VHF and UHF systems continue to be the choice for radio paging systems.

## 25.8 *APCO Project 25*

In the mid-1990s, the Association of Public Safety Communications Officers (APCO), in conjunction with the manufacturers of land mobile radio, created a new standard for interoperable radio communications called APCO Project 25. As had been accomplished in the 1980s with Project 16, the trunking standard, this new digital standard is hoped to be the solution for many years to come. Most federal and state agencies have adopted Project 25 as a minimum for any grant funding.

### 25.8.1 Primary Features

The primary features that ultimately have public safety excited about Project 25 technology and its merits include the following:

Voice Features

- Talk groups (preset & on the fly)
- Digital priority scan
- Private call
- Telephone interconnect
- Alert calls/paging
- Emergency alarm
- Direct radio-to-radio
- ISSI roaming

Data Features

- Continuous caller ID
- Circuit and packet data
- Encryption
- Over-the-air-rekeying
- Radio check
- Selective radio inhibit
- Direct radio-to-radio
- Silent emergency via ISSI

#### 25.8.2 Common Air Interface

The common air interface (CAI) is the most important single element of Project 25 because it is the means by which multiple manufacturers' radios can interoperate on different infrastructures.

### 25.9 *Mutual Aid Channels*

Across the country, several VHF, UHF, and 700/800 MHz frequencies have been identified as mutual aid frequencies. It is recommended that these channels or frequencies be installed in every subscriber radio and in many dispatch centers to allow for interoperability at the scene of an incident. Generally, these frequencies are simplex, where talk and listen are the same, though in some cases conventional repeaters have been established. In the 700/800 MHz bands, there are also repeater channels that have been established.

### 25.10 *Infrastructure*

Behind the scenes, connectivity of various radio base station sites, dispatch centers, and other segments of the system must have enough bandwidth and reliability to maintain system operations.

The conventional technology of single and even multiple channel repeaters has in the past been interconnected with microwave and/or leased phone lines using typically 64 kbps (DS-0) connections. In many locations, the connectivity made use of 960 MHz or 2 GHz microwave providing up to 12 or 96 analog voice channels with a multiplexer. Where geography allowed, a single repeater may have made use of multiple receivers and a voting system to select the best receiver.

Today, the interconnecting infrastructure of choice has become IP (Internet Protocol) over Ethernet utilizing microwave and/or fiber optics. With the demands of Quality of Service to carry these voice channels and in the future video, this IP transport carried over the various forms of IP services available today. The most common microwave in use today is all IP-based and typically in the licensed 6 GHz and 10 GHz bands or the 4.9 GHz band. When multiplexing of conventional repeater audio is needed there are IP-based multiplexers.

### 25.11 *Other Elements*

Beyond electronics and communications circuits, other issues also need attention. Certain questions must be answered. For example, are the buildings acceptable to house the new technology? Are the existing towers mechanically sound enough to hold the new systems while the old ones are still mounted to them? Are towers and buildings in the right locations? Does enough power and grounding exist at the sites?

Assuming microwave is utilized in support of the infrastructure requirements and assuming 2 GHz had been the link, the only option may be to move to 6 or 10 GHz systems. While the older 2 GHz distances supported 25 miles, the 6 GHz distance is only 18-19 miles, and 10 GHz supports less than 8-9 miles. The potential that a relay tower and associated equipment may be necessary is very real for many users.

With the move to narrowband operation, it is necessary to improve the power surge suppression and facility grounding to ensure the lowest possible noise at the site. This generally requires a total rework of the site infrastructure.

# 26 APPENDIX 6: Government Issues, Rules, and Grants

## 26.1 *Interoperability*

In 1995, the Public Safety Wireless Advisory Committee (PSWAC) was formed and charged with delivering a report within three years of its charter. In 1996, a series of technical, spectral, and planning recommendations were made for federal, state, and local public safety agencies. The basis of the report was to move from a group of "independent" stovepipe systems to a single "shared" utility to be used and shared by all public safety entities in a region. Three key elements were specifically addressed:

1. The lack of radio frequencies for public safety, especially in urban areas, has reached the situation where agencies are no longer able to meet communications needs.
2. Interoperability is hampered using multiple frequency bands, incompatible equipment, and a lack of standardization in repeater spacing and transmission formats. The committee's recommendation was for a minimum baseline standard, interfaces/gateways, and a fair/open method of systems acquisition. Non-technical issues must also be addressed, such as funding sources, human factors, and spectrum availability.
3. Public safety agencies have not been able to implement advanced features such as broadband data and video into their systems.

## 26.2 *Federal Communications Commission*

The FCC assigns frequencies via a license to operate over a defined property area, thus ensuring that frequency assignments are distant enough to reduce the potential for interference among users (i.e., the Property Model). With the demand for additional frequencies, the FCC has adopted a rule-making action whereby channel bandwidth must be reduced to half of what is the 25 KHz per channel norm that has been in place since VHF and UHF channels have been offered. Under the FCC rules, effective January 1, 2013, all VHF and UHF channels are reduced to 12.5 KHz. This is known as narrowbanding. The expected outcome is the doubling of available channels.

This issue of narrowbanding has resulted in another problem, however. Just making the change means the user community may well suffer a retraction of the distance a radio system covers. The single biggest issue is that noise with wideband was less of an issue than with narrowband. To overcome this issue, the choice is either to use P25 or to rebuild the system to meet tighter specifications.

# 27 APPENDIX 7: Commercial Service Options

## 27.1 *Commercial Services*

Today commercial wireless service providers are integrated into public safety systems in many aspects as an adjunct to the private-public safety systems. Those integrations are continuing to evolve with the implementation of more and more networks providing an ever-improving technology solution to the end users and improved coverages. The lack of priority and control is the mechanism for measuring the degree of reliance each agency is comfortable with using these ever-expanding networks.

Historically organizations began to rely on the use of cellular voice services to supplement radio conversations or provide enhanced communication capabilities where possible. This along with the use of add on alerting systems used by Fire and EMS services over cellular are key examples of that supplement and support users rely on in their duties. Probably the most key shift to commercial services is in the use of data connectivity services.

Many agencies implemented stand-alone data systems attempting to provide their users services for messaging, data access and digital work platforms. Most of these systems have been shelved today and have moved to commercial wireless broadband services providing a higher level of system performance at a reduced operating cost to the public safety agencies. Other limiting factors to a standalone data system also played a role in the shift and must be considered when analyzing this use of commercial data services and why it ultimately worked better for most agencies. However; current cellular commercial service options today see a public safety user no different than any other user of the services, and this can be problematic. FirstNet is hoped to fix the priority commercial services lack.

## 27.2 *FirstNet*

To overcome commercial services limitations to the public safety users, the federal government introduced a dedicated solution. The First Responder Network Authority (FirstNet) of the United States was created under the Middle-Class Tax Relief and Job Creation Act of 2012 (MCTRJCA) as an independent authority within the National Telecommunications and Information Administration (NTIA).[1] The purpose of FirstNet is to establish, operate, and maintain an interoperable public safety broadband network. To fulfill these objectives, Congress allotted $7 billion, and 20 MHz of valuable radio spectrum to build the network.

The FirstNet authority then accepted a proposal from AT&T to be the contracted commercial service to provide and build out this network. This left each state to decide the option to construct their own piece of that network or allow AT&T to perform that service for them. All states ultimately approved the use of AT&T as their designated contractor. This approval process was completed in December of 2017, and AT&T's implementation plans are currently underway.

When the FirstNet network launches, it will provide mission-critical, high-speed data services to supplement the voice capabilities of today's Land Mobile Radio (LMR) networks. Initially, the FirstNet network will be used for sending data, video, images, and text.

The FirstNet network will also carry location information and eventually support streaming video. FirstNet plans to offer cellular voice communications such as Voice over Long-Term Evolution (VoLTE) or other alternatives initially, but these are not considered public safety level systems. The ultimate goal of Mission Critical Voice (MCV) and Mission Critical Push-to-talk (MCPTT) over LTE does not have any identified timelines for these system implementations.

The job of creating a nationwide wireless network from scratch to provide the level of services identified and deliver those services with the same robust levels of coverage in all areas would be considered a lengthy task. This would keep the network from being ready for public safety users for years as implementation of most County radio systems can take up to two years. The relationship between FirstNet and AT&T is more than just a hiring of the firm to implement the network. It is the reliance on AT&T's existing network to begin delivering services, begin developing equipment, and being able to migrate user as the dedicated FirstNet frequency band is being installed. To accurately understand FirstNet's capabilities of service, it is important to understand these processes and how they apply in the area in question.

AT&T has already begun the process of FirstNet implementation using the existing AT&T network as a starting point. That network will deliver services to the capabilities in place today and as AT&T develops the capabilities and features those will be migrated into the platforms. At the same time, AT&T will be implementing the dedicated spectrum (Band 14) provided by FirstNet to increase coverage areas.

Ultimately decisions of the use of FirstNet come down to the same questions of coverage and features in the defined area of concern measured against costs. Jefferson County will most likely measure any migration of services to FirstNet based comparison with existing broadband (Data) services in place as those FirstNet features will most likely become available in the network.

VoLTE is the proposed standard for voice and the interface between a P25 trunked radio system and FirstNet. It should be noted, however, when this voice service becomes available for mass use is not yet scheduled on the timetable. FirstNet was developed first for data and video with this then being the priority. Most of the leadership in the development of FirstNet has suggested that even after its full deployment, VoLTE should be considered secondary and not expect this service to replace radio to radio voice communications any time soon.

## 28 APPENDIX 8: Delivered Audio Quality

| DAQ Delivered Audio Quality | Subjective Performance Description |
|---|---|
| 1 | Unusable; speech present but unreadable. |
| 2 | Understandable with considerable effort. Frequent repetition due to noise/distortion. |
| 3 | Speech understandable with slight effort. Occasional repetition due to noise/distortion. |
| 3.4 | Speech understandable with repetition only rarely required. Some noise/distortion. |
| 4 | Speech easily understood. Occasional noise/distortion. |
| 4.5 | Speech easily understood. Infrequent noise/distortion. |
| 5 | Speech easily understood. |

## 29 APPENDIX 9: Intermodulation Report

**Intermod Checks Performed:**
Base Transmit to Base Receive

**Services Checked:**

| | Service | Tower | Tx Freq | Rx Freq | Duplex | Bandwidth |
|---|---|---|---|---|---|---|
| 001: | LAW1 | Tower 1 | 154.860000 MHz | 158.910000 MHz | Full | 12.50 kHz |
| 002: | EMCOM1 | Tower 1 | 155.775000 MHz | 158.790000 MHz | Full | 12.50 kHz |
| 003: | FIRE1 | Tower 1 | 154.370000 MHz | 153.770000 MHz | Full | 12.50 kHz |
| 004: | MARC1 | Tower 1 | 151.280000 MHz | 153.845000 MHz | Full | 12.50 kHz |
| 005: | IFERN | Tower 1 | 154.265000 MHz | 154.265000 MHz | Full | 12.50 kHz |
| 006: | HIGHWAYS | Tower 1 | 156.240000 MHz | 158.985000 MHz | Full | 12.50 kHz |
| 007: | PAGING | Tower 1 | 154.055000 MHz | 0.000000 MHz | Full | 12.50 kHz |

**Mixes Checked:**
2-Signals up to 2nd Order
3-Signals up to 3rd Order
4-Signals up to 4th Order
5-Signals up to 5th Order
6-Signals up to 6th Order
7-Signals up to 7th Order

**3-Signal 3rd Order (A±B±C):**
1*154.370000(FIRE1)+1*154.265000(IFERN)-1*154.860000(LAW1)=153.775000(5.0)(FIRE1)

**5-Signal 5th Order (A±B±C±D±E):**
1*154.265000(IFERN)+1*156.240000(HIGHWAYS)+1*154.055000(PAGING)-1*151.280000(MARC1)-1*154.370000(FIRE1)=158.910000(0.0)(LAW1)

**7-Signal 7th Order (A±B±C±D±E±F±G):**

1*155.775000(EMCOM1)+1*151.280000(MARC1)+1*156.240000(HIGHWAYS)+1*154.055000(PAGING)-1*154.265000(IFERN)-1*154.370000(FIRE1)-1*154.860000(LAW1)=153.855000(10.0)(MARC1)

## 30 APPENDIX 10: Tower Site Overview

elert & associates
technology consultants
140 third street south, stillwater, mn 55082
phone . 651.430.2772, fax . 651.430.2661 www.elert.com

### Tower/Site Construction – 280' Greenfield site

Base Foundation Concrete Pad and Pier with Rebar Uprights – 28' x 28' x 6' with top 6' below grade Shelter to left is 12' x 6'

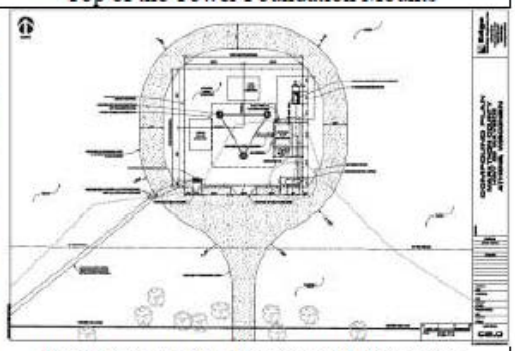
minnesota illinois south carolina florida tennessee connecticut

elert & associates technology consultants

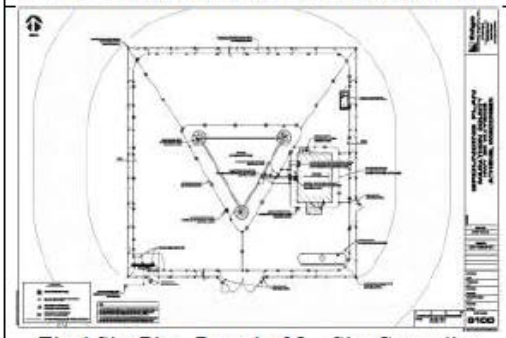
After Backfill of the Tower Foundation

Top of the Tower Foundation Mounts

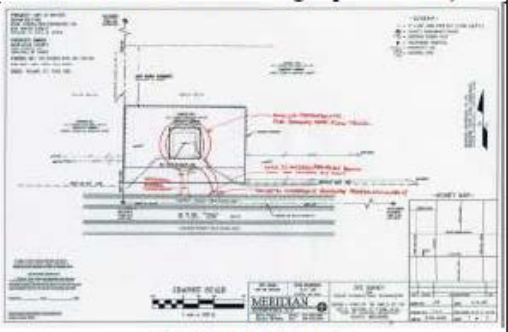
Typical Electrical Distribution
LV – AC Mains – ATS – MTS - Panel Board - SPD



Initial Site Plan for Review and Permitting
(Note, driveway around site per owner request to allow officers to access high speed Wi-Fi.)



Final Site Plan, Page 4 of 8 – Site Grounding



Official Site Survey

Note: The space around the tower in the compound was designed to allow for a second equipment shelter, the compound is 60' x 60'. There were no setback requirements thus 280' tower did not have to be located 280' from the highway which can sometimes be a requirement.